

DEPARTMENT OF THE INTERIOR

BULLETIN

OF THE

UNITED STATES

GEOLOGICAL SURVEY

No. 20

---

CONTRIBUTIONS TO THE MINERALOGY OF THE  
ROCKY MOUNTAINS

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WASHINGTON  
GOVERNMENT PRINTING OFFICE  
1885



## ADVERTISEMENT.

[Bulletin No. 20.]

The publications of the United States Geological Survey are issued in accordance with the statute, approved March 3, 1879, which declares that—

"The publications of the Geological Survey shall consist of the annual report of operations, geological and economic maps illustrating the resources and classification of the lands, and reports upon general and economic geology and paleontology: The annual report of operations of the Geological Survey shall accompany the annual report of the Secretary of the Interior. All special memoirs and reports of said Survey shall be issued in uniform quarto series if deemed necessary by the Director, but otherwise in ordinary octavos. Three thousand copies of each shall be published for scientific exchanges and for sale at the price of publication; and all literary and cartographic materials received in exchange shall be the property of the United States and form a part of the library of the organization: And the money resulting from the sale of such publications shall be covered into the Treasury of the United States."

On July 7, 1882, the following joint resolution, referring to all Government publications, was passed by Congress:

"That whenever any document or report shall be ordered printed by Congress, there shall be printed in addition to the number in each case stated, the 'usual number' (1,900) of copies for binding and distribution among those entitled to receive them."

Under these general laws it will be seen that none of the Survey publications are furnished to it for gratuitous distribution. The 3,000 copies of the Annual Report are distributed through the document rooms of Congress. The 1,900 copies of each of the publications are distributed to the officers of the legislative and executive departments and to stated depositories throughout the United States.

Except, therefore, in those cases where an extra number of any publication is supplied to this office by special resolution of Congress, as has been done in the case of the Second, Third, Fourth, and Fifth Annual Reports, or where a number has been ordered for its use by the Secretary of the Interior, as in the case of Mineral Resources and Dictionary of Altitudes, the Survey has no copies of any of its publications for gratuitous distribution.

### ANNUAL REPORTS.

Of the Annual Reports there have been already published:

I. First Annual Report to the Hon. Carl Schurz, by Clarence King. 1880. 8°. 79 pp., 1 map.—A preliminary report describing plan of organization and publications.

II. Report of the Director of the United States Geological Survey for 1880-'81, by J. W. Powell. 1882. 8°. lv, 588 pp. 61 pl. 1 map.

III. Third Annual Report of the United States Geological Survey, 1881-'82, by J. W. Powell. 1883. 8°. xviii, 564 pp. 67 pl. and maps.

IV. Fourth Annual Report of the United States Geological Survey, 1882-'83, by J. W. Powell. 1884. 8°. xii, 473 pp. 85 pl. and maps.

The Fifth Annual Report is in press.

### MONOGRAPHS.

Of the Monographs, Nos. II, III, IV, V, VI, VII, and VIII are now published, viz:

II. Tertiary History of the Grand Cañon District, with atlas, by Clarence E. Dutton, Capt., U. S. A. 1882. 4°. xiv, 264 pp. 42 pl. and atlas of 24 sheets folio. Price \$10.12.

III. Geology of the Comstock Lode and the Washoe District, with atlas, by George F. Becker. 1882. 4°. xv, 422 pp. 7 pl. and atlas of 21 sheets folio. Price \$11.

IV. Comstock Mining and Miners, by Eliot Lord. 1883. 4°. xiv, 451 pp. 3 pl. Price \$1.50.

V. Copper-bearing Rocks of Lake Superior, by Roland D. Irving. 1883. 4°. xvi, 464 pp. 15 l. 29 pl. Price \$1.85.

VI. Contributions to the Knowledge of the Older Mesozoic Flora of Virginia, by Wm. M. Fontaine. 1883. 4°. xi, 144 pp. 54 l. 54 pl. Price \$1.05.

VII. Silver-lead Deposits of Eureka, Nevada, by Joseph S. Curtis. 1884. 4°. xiii, 200 pp. 16 pl. Price \$1.20.

VIII. Paleontology of the Eureka District, by Charles D. Walcott. 1884. 4°. xiii, 298 pp. 24 l. 24 pl. Price \$1.10.

## ADVERTISEMENT.

The following are in press, viz:

IX. Brachiopoda and Lamellibranchiata of the Raritan Clays and Greensand Marls of New Jersey, by Robert P. Whitfield. 1885. 4°. ix, 338 pp. 35 pl.

X. Dinocerata. A Monograph of an Extinct Order of Gigantic Mammals, by Othniel Charles Marsh. 1885. 4°. —, — pp. 56 pl.

XI. Geological History of Lake Lahontan, a Quaternary Lake of Northwestern Nevada, by Israel Cook Russell. 1885. 4°. —, — pp. 46 pl.

The following are in preparation, viz:

I. The Precious Metals, by Clarence King.

Geology and Mining Industry of Leadville, with atlas, by S. F. Emmons.

Geology of the Eureka Mining District, Nevada, with atlas, by Arnold Hague.

Lake Bonneville, by G. K. Gilbert.

Sauropoda, by Prof. O. C. Marsh.

Stegosauria, by Prof. O. C. Marsh.

### BULLETINS.

The Bulletins of the Survey will contain such papers relating to the general purpose of its work as do not properly come under the heads of ANNUAL REPORTS or MONOGRAPHS.

Each of these Bulletins will contain but one paper and will be complete in itself. They will, however, be numbered in a continuous series, and will in time be united into volumes of convenient size. To facilitate this each Bulletin will have two paginations, one proper to itself and another which belongs to it as part of the volume.

Of this series of Bulletins Nos. 1 to 20 are already published, viz:

1. On Hypersthene-Andesite and on Triclinic Pyroxene in Augitic Rocks, by Whitman Cross, with a Geological Sketch of Buffalo Peaks, Colorado, by S. F. Emmons. 1883. 8°. 42 pp. 2 pl. Price 10 cents.

2. Gold and Silver Conversion Tables, giving the coining value of Troy ounces of fine metal, etc., by Albert Williams, jr. 1883. 8°. ii, 8 pp. Price 5 cents.

3. On the Fossil Faunas of the Upper Devonian, along the meridian of 76° 30', from Tompkins County, New York, to Bradford County, Pennsylvania, by Henry S. Williams. 1884. 8°. 36 pp. Price 5 cents.

4. On Mesozoic Fossils, by Charles A. White. 1884. 8°. 36 pp. 9 pl. Price 5 cents.

5. A Dictionary of Altitudes in the United States, compiled by Henry Gannett. 1884. 8°. 325 pp. Price 20 cents.

6. Elevations in the Dominion of Canada, by J. W. Spencer. 1884. 8°. 43 pp. Price 5 cents.

7. *Mapoteca Geologica Americana*. A catalogue of geological maps of America (North and South), 1752-1881, by Jules Marcou and John Belknap Marcou. 1884. 8°. 184 pp. Price 10 cents.

8. On Secondary Enlargements of Mineral Fragments in Certain Rocks, by R. D. Irving and C. R. Vanhise. 1884. 8°. 56 pp. 6 pl. Price 10 cents.

9. A Report of work done in the Washington Laboratory during the fiscal year 1883-'84. F. W. Clarke, chief chemist; T. M. Chatard, assistant. 1884. 8°. 40 pp. Price 5 cents.

10. On the Cambrian Faunas of North America. Preliminary studies by Charles Doolittle Walcott. 1884. 8°. 74 pp. 10 pl. Price 5 cents.

11. On the Quaternary and Recent Mollusca of the Great Basin; with Descriptions of New Forms, by R. Ellsworth Call; introduced by a sketch of the Quaternary Lakes of the Great Basin, by G. K. Gilbert. 1884. 8°. 66 pp. 6 pl. Price 5 cents.

12. A Crystallographic Study of the Thionite of Lake Lahontan, by Edward S. Dana. 1884. 8°, 34 pp. 3 pl. Price 5 cents.

13. Boundaries of the United States and of the several States and Territories, by Henry Gannett. 1885. 8°. 135 pp. Price 10 cents.

14. The Electrical and Magnetic Properties of the Iron-Carburets, by Carl Barus and Vincent Strouhal. 1885. 8°. 238 pp. Price 15 cents.

15. On the Mesozoic and Cenozoic Paleontology of California, by Dr. C. A. White. 1885. 8°. 33 pp. Price 5 cents.

16. On the higher Devonian Faunas of Ontario County, New York, by J. M. Clarke. 1885. 8°. 86 pp. 3 pl. Price 10 cents.

17. On the Development of Crystallization, etc., by Arnold Hague and J. P. Iddings. 1885. 8°. 44 pp. Price 5 cents.

18. On Marine Eocene, Fresh-water Miocene, and other Fossil Mollusca of Western North America, by Dr. C. A. White. 1885. 8°. 26 pp. 3 pl. Price 5 cents.

19. Notes on the Stratigraphy of California, by George F. Becker. 1885. 8°. 28 pp. Price 5 cents.

20. Contributions to the Mineralogy of the Rocky Mountains, by Whitman Cross and W. F. Hillebrand. 1885. 8°. 114 pp. 1 pl. Price 10 cents.

Numbers 1 to 6 of the Bulletins form Volume I, and numbers 7 to 14 Volume II. Volume III is not yet complete.

The following are in press, viz:

21. The Lignites of the Great Sioux Reservation, by Bailey Willis. 1885. 8°. — pp. 5 pl. Price — cents.

## ADVERTISEMENT.

22. On New Cretaceous Fossils from California, by Charles A. White, M. D. 1885. 8°. — pp. 5 pl. Price — cents.

### STATISTICAL PAPERS.

A fourth series of publications having special reference to the mineral resources of the United States is contemplated.

Of that series the first has been published, viz:

Mineral Resources of the United States, by Albert Williams, Jr. 1883. 8°. xvii, 813 pp. Price 50 cents.

The second volume of this series, Mineral Resources 1883 and 1884, is in preparation and will soon be put to press.

Correspondence relating to the publications of the Survey, and all remittances, which must be by POSTAL NOTE or MONEY ORDER, should be addressed

TO THE DIRECTOR OF THE

UNITED STATES GEOLOGICAL SURVEY,

*Washington, D. C.*

WASHINGTON, D. C., *May* 25, 1885.

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J. W. POWELL DIRECTOR

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BY

WHITMAN CROSS and W. F. HILLEBRAND



WASHINGTON  
GOVERNMENT PRINTING OFFICE  
1885



LETTER OF TRANSMITTAL.

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UNITED STATES GEOLOGICAL SURVEY,  
DIVISION OF THE ROCKY MOUNTAINS,  
*Denver, Colo., March 1, 1885.*

SIR: I have the honor to transmit herewith a paper by Messrs. W. Cross, assistant geologist, and W. F. Hillebrand, chemist, representing work that has been done by them in the office and laboratory of this division, at intervals of leisure from their regular duties, during the past three years. Believing that the results of their investigations form a valuable contribution to the mineralogy of the Rocky Mountains, I would respectfully suggest that they be published in the form of a bulletin, so that they may be made immediately available to those interested in this science.

Very respectfully, your obedient servant,

S. F. EMMONS,  
*Geologist in Charge.*

Hon. J. W. POWELL,  
*Director United States Geological Survey.*



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# CONTRIBUTIONS TO THE MINERALOGY OF THE ROCKY MOUNTAINS.

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By WHITMAN CROSS and W. F. HILLEBRAND.

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## INTRODUCTORY REMARKS.

A large part of the subject-matter contained in the following pages has already appeared in print, at various times during the past four years, in the *American Journal of Science* or the *Proceedings of the Colorado Scientific Society*. As opportunity has offered, the studies have been extended upon the old or upon new and better material, so that much of that which has been previously published is here presented in a revised or enlarged form. The desirability of collecting in one place the notices of minerals from the same general region has led to the reproduction of some descriptions unaltered.

The more purely mineralogical parts of Sections I and II, for which the first-named author is chiefly responsible, does not claim to be so thorough and exact in many cases as the nature of the material may render desirable. This is partially explained by a want of the proper instruments for use in determining certain optical and physical properties of the minerals, but still more fully by the fact that the geological investigations in progress have left but little time for pure mineralogy.

In regard to the chemical part of the work a few remarks are necessary. From the first establishment of a laboratory in Denver a special aim has been to make the analytical work as thoroughly accurate as possible even though the amount accomplished should in consequence be lessened. As the main part of the laboratory work consists in investigations upon eruptive rocks, an exact knowledge of whose composition is at present deemed of great importance, it was sought to reduce the errors ordinarily incident to analyses of such rocks to the smallest possible limits. To this end none of the ordinary reagents employed in any quantity are used without being first subjected to careful analysis. If they are found to contain sufficient impurity to influence even to a slight extent the result of an analysis, they are either rejected altogether or purified, or the percentages of impurities present are estimated and deducted from each analysis, for which weighed or measured quantities of these reagents are employed. Thus the very small quantities of

silica, ferric oxide, alumina, and lime, almost invariably to be found in the purest of sodium carbonate, in a measure due to dust that has collected in the process of manufacture and packing, and which will generally influence the result of an analysis from 0.1 to 0.2 per cent., are allowed for. Ammonia, which, after being kept in carboy for some length of time, often contains large amounts of silica and other foreign matter, is redistilled and collected in pure water every few weeks.

By taking such precautions and using wherever possible platinum vessels, with proper care a high degree of accuracy is attainable. Especially is this so when no solid reagents enter into an analysis, as in the case of zeolites, of which a large number of analyses appear on subsequent pages and in few of which the sum total of percentages exceeds 100.1. A long series of analyses of eruptive rocks has been made in which, during the past two years, it has been the rare exception for an analysis to foot up over 100.2.

Without these explanatory remarks the close approximation to 100 per cent. shown by so many analyses might rather inspire distrust than confidence.



## I.—MINERALS FROM THE BASALT OF TABLE MOUNTAIN, GOLDEN, COLORADO.

By WHITMAN CROSS and W. F. HILLEBRAND.

### DESCRIPTION OF TABLE MOUNTAIN.

Table Mountain is a plateau or *mesa* with an area of from 4 to 5 square miles, situated upon the border of the great plains, 12 miles west of Denver, approaching so closely to the abruptly rising foot-hills, composed of Archæan rocks, that the intervening space is not more than 1 mile in width. Within this space, however, are exposed the upturned edges of strata of the Triassic, Jurassic, and Cretaceous ages, including in the latter the coal-bearing Laramie formation, all dipping steeply eastward. The mountain owes its existence to a sheet, or rather, in most places, to two sheets of basalt, which have in a measure protected the underlying soft Tertiary beds from erosion, which has removed the upturned Mesozoic strata to the west, until a valley several hundred feet deep has resulted, separating Table Mountain from the foot-hills. The Tertiary strata below the basalt are horizontal, and seem at first glance unconformable with the Mesozoic, but this is largely due to the location of the valley of erosion in a sharp fold; in other places apparent conformability is shown.

Clear Creek issues from the foot-hills opposite the mountain, and has cut a gorge directly through it, dividing it into what are known as North and South Table Mountains, which have an average elevation above the creek bed of about 700 feet. On the banks of the creek behind the mountain is situated the town of Golden.

The source of the basalt is in certain dikes situated to the north and northwest, whence the lava spread out in sheets and flowed to the south-southeast. The lower sheet averages 100 to 115 feet in thickness and possesses the structure of a stream which has flowed upon the surface. Adjacent to the underlying strata is a layer of a very porous structure about 1 foot in thickness, then follows massive compact rock for 70 feet, while the upper 40 to 50 feet show many cavities, large and small, more or less flattened and drawn out, and the surface is rough and jagged. The first sheet was covered by a second, of identical composition, before erosion or decomposition had produced noticeable effects.

Of the second sheet only the massive lower part remains, and its thickness, as well as the lateral extension of both sheets, can only be a matter of conjecture. The rock is a feldspar basalt of very simple composition, rather coarsely crystalline in its massive parts, and in the porous part with a groundmass which becomes finer grained as it approaches the contact or the surface. A glassy base, now much devitrified, was formerly present in the porous parts.

In the cavities of the upper portion of the lower sheet are many beautifully crystallized zeolites, associated with calcite and aragonite. The mode of occurrence varies somewhat in different parts of the mountain, and a few species seem to be locally restricted, but most of those to be described can be found in abundance and well developed.

At a point on the southern face of North Table Mountain, where the greatest number of species occur together, the students in the School of Mines at Golden began blasting for specimens several years ago. During the present investigations the locality was still further opened and absolutely fresh and clear material was obtained.

The only previous notice of this mountain is embodied in the report of Arch. R. Marvine, in the Annual Report of the United States Geological and Geographical Survey of the Territories for the year 1873, pp. 129-131, but the information given is exceedingly meager and in part incorrect.

The Survey is indebted to Prof. A. Lakes, of the School of Mines, for calling special attention to Table Mountain.

**MANNER OF OCCURRENCE OF THE MINERALS.**—The following mineral species have been identified in the cavities of the basaltic sheet, viz.: analcite, apophyllite, chabazite, levynite, thomsonite, mesolite, natrolite, scolecite, stilbite, laumontite, calcite, and bole. Of the occurrence of these species a few remarks will be in place before proceeding to detailed descriptions.

Primarily one can distinguish between the minerals occurring in fissures and those in the roundish cavities of the amygdaloidal zone. On both mountains are many fissures and irregular cavities having outward communication, in which calcite, bole, and reddish zeolites are almost always deposited. Occasionally colorless zeolites (analcite or natrolite) appear in fissures, but it is much more characteristic to find them in the closed cavities. On the other hand a reddish, horizontally stratified zeolitic deposit is found in many amygdaloidal cavities, filling the smaller ones completely or forming a floor in the larger ones. As the minerals developed here are in part the same as those found in adjacent fissures, and as these reddish deposits always precede in time the formation of the colorless zeolites, it seems probable that all the cavities containing the minerals in question were formerly penetrated by fissures. Some such explanation is necessary, for cavities containing the reddish zeolites occur side by side with those in which only members of the other group are present. In some few cases, small fis-

tures, now filled, were found leading into cavities containing the stratified deposits.

The zeolites are then naturally divisible into two groups, according to mode and time of formation, the first containing laumontite, stilbite, and thomsonite; the second, stilbite and thomsonite, with all the other species of the above list. They will be thus considered in the following description.

ORDER OF DEPOSITION.—Considering all the species which occur in associations allowing inferences as to relative age, the following may be given as the order observed, beginning with the oldest:

1. Laumontite.
  2. Stilbite.
  3. Thomsonite.
  4. Calcite (yellow).
  5. Stilbite.
  6. Chabazite.
  7. Thomsonite.
  8. Analcite.
  9. Apophyllite.
  10. Calcite (colorless).
  11. Mesolite.
- } Red or yellowish.

Chabazite and thomsonite were also formed again in very small quantity, probably between 9 and 10. Natrolite, scolecite, and levynite do not occur in direct association with most of the above, so that their places in the series are unknown.

#### ZEOLITES. FIRST GROUP.

GENERAL.—The minerals of this group are best developed in the stratified deposits of the amygdaloidal cavities, where also the order and manner of deposition can most clearly be seen.

In a large cavity containing a floor of the reddish-yellow mixture of the minerals of this group, it is at once noticed that the roof and sides above the level of the stratified mass show no trace of any one of these species. From this fact and from the structure of the mass the inference is warranted that the formation began at the bottom and proceeded very rapidly to its close. Usually the lower portion of such masses is composed of a reddish-yellow mineral in irregular grains, forming a compact aggregate in which lie isolated spherules of a similarly colored radiate mineral. These spherules are seldom more than 2<sup>mm</sup> in diameter and are very perfect spheres. They increase in number upward and finally compose the greater part of the deposit.

In one cavity, 6 to 8 feet in horizontal diameter and about 2 feet in height, the deposit is quite different. Here the main mass is loosely granular, and is formed chiefly by a bright greenish-yellow mineral, while a stratified appearance is produced by layers of a white or colorless substance.

Some of the light layers are chiefly made up of easily recognizable stilbite, and the same mineral in distinct tablets forms the upper layer of the whole deposit. There are also irregular seams of white running through the yellow material.

#### LAUMONTITE.

**DESCRIPTION.**—If the loose sand from the above-mentioned cavity be placed under the microscope with a power of about 15 diameters, it is seen to consist of prismatic grains, mostly with broken terminations. Many of the grains are clear and transparent, with the greenish-yellow color mentioned, while others are dull. The clear prisms polarize strongly, and extinction upon a prismatic plane takes place at an angle of  $35^\circ$  to  $40^\circ$  with the vertical axis.

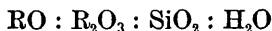
On splitting open some of the white layers, surfaces are obtained showing minute stout prismatic crystals, which seen under the microscope present the same habit as the yellow grains. The prism angles are nearly  $86^\circ$  and  $94^\circ$ , and the termination is usually formed by an oblique plane, like a hemidome of the monoclinic system. The optical orientation is the same as in the yellow crystals and corresponds also to the requirements of the monoclinic system so far as can be determined. The properties given agree with those of laumontite, and in the light of the chemical analyses the identification of both yellow and white crystals with that mineral seems entirely justifiable.

**CHEMICAL COMPOSITION.**—The analysis gives the following results:

	I.—Yellow grains.	II.—White crystals.
SiO <sub>2</sub> .....	51.43	52.07
Al <sub>2</sub> O <sub>3</sub> .....	21.52	21.30
Fe <sub>2</sub> O <sub>3</sub> .....	0.94	.....
CaO.....	11.88	11.24
K <sub>2</sub> O.....	0.35	0.42
Na <sub>2</sub> O.....	0.19	0.48
H <sub>2</sub> O.....	13.81	14.58
	100.12	100.09

(W. F. Hillebrand.)

Oxygen ratios:



I. 1 : 2.97 : 7.83 : 3.50

II. 1 : 2.94 : 8.15 : 3.81

(In all calculations of ratios 27 is taken as atomic weight of Al.)

These analyses represent the composition of air-dried material, and the percentages were calculated from the analyses published in the

American Journal of Science.<sup>1</sup> The latter were made after drying over sulphuric acid, it having been observed that at 100° C. an unexpectedly large loss took place, steadily increasing as the temperature rose above 100°. Even when simply dried over sulphuric acid the loss in the case of I was 0.60 per cent., and in the case of II was 1.45 per cent. These abnormally large losses, coupled with still larger ones observed subsequently in analyzing other zeolites, seemed to indicate that all, or at any rate nearly all, the water removed by sulphuric acid should be counted with the water of crystallization, especially as when this was done the oxygen ratios generally more nearly approached that required by theory; for example, in II the ratio for material dried over sulphuric acid is only 1 : 2.94 : 8.15 : 3.42, instead of 1 : 2.94 : 8.15 : 3.81 as above given. Recent investigations by Jannasch<sup>2</sup> on heulandite and epistilbite tend to confirm us in this opinion.

The ratio of II agrees fairly well with the theoretical requirements of laumontite, 1 : 3 : 8 : 4, especially as it can hardly be supposed that the material was absolutely pure. It is quite probable that a small amount of stilbite was included with the material analyzed, which would explain the rather high value for SiO<sub>2</sub>.

In regard to the amount of water found it is only necessary to suppose that the dull particles have lost a part of their water while the transparent grains are entirely fresh in order to explain the relation of water to the other constituents as shown in the above ratios, a supposition in full accord with the characteristic tendency of laumontite to lose its water on exposure.

The mineral is not quite so easily fusible before the blow-pipe as typical laumontite should be according to the text-books, but the difference is not sufficiently pronounced to be considered abnormal.

#### MIXED ZEOLITES.

GENERAL DESCRIPTION.—Turning now to the more compact reddish-yellow deposits, which correspond so closely to the one described above, the same constituent minerals were sought for. Some small cracks or fissures were noticed, usually ending blindly in the yellow mass, some of which were only partially filled with minute white crystals. On splitting the mass open along such a half-filled crack two surfaces were obtained, coated with minute but exceedingly perfect clear crystals, easily recognizable under the microscope as laumontite and stilbite. The little crystals of the former show occasionally the clinopinacoid and a steep positive orthodome in addition to the prism and base.

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<sup>1</sup> III, Vol. XXIII, p. 135.

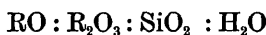
<sup>2</sup> Neues Jahrbuch für Mineralogie, etc., 1884, II, 206.

The sand obtained by simple fracture of the yellow massive portion on being placed under the microscope is seen to consist largely of fragments of tabular crystals, the angles of which, so far as they are determinable, correspond to stilbite. The grains which are not evident fragments of tablets are in part roughly prismatic, though seldom showing definite faces; neither could the optical action be satisfactorily determined.

**CHEMICAL COMPOSITION.**—Chemical analyses were made from two different specimens of the yellow granular mass, care being taken to exclude all reddish spherules. The results are given under III and IV below.

	III.	IV.
SiO <sub>2</sub> .....	54.20	53.87
Al <sub>2</sub> O <sub>3</sub> .....	17.26	17.26
Fe <sub>2</sub> O <sub>3</sub> .....	0.77	0.74
CaO.....	8.35	8.27
K <sub>2</sub> O.....	0.17	0.07
Na <sub>2</sub> O.....	1.38	1.48
H <sub>2</sub> O.....	18.09	18.44
(W. F. Hillebrand.)	100.22	100.13

Oxygen ratios:



III. 1 : 3.01 : 10.43 : 5.80

IV. 1 : 3.03 : 10.42 : 5.95

Analyses III and IV were published in the *American Journal of Science*, with this difference, that they represented the composition of dried material. Inasmuch as III lost 2.14 per cent. of moisture in two days over sulphuric acid (no further loss in three days) and IV 1.69 per cent. under similar conditions, the whole is counted as water of crystallization for the reasons given in discussing the analyses of laumontite.

As will be seen later, pure crystals of colorless stilbite from Table Mountain do not possess, as regards SiO<sub>2</sub> and H<sub>2</sub>O, quite the theoretical composition of that mineral (see analysis VI, p. —). If, however, that analysis represents the composition of all stilbite from this locality, these analyses III and IV correspond remarkably well to mixtures of much stilbite with a little laumontite, as was surmised from microscopical examination of the material.

It seems remarkable that the material from two different cavities should contain the two minerals in so nearly the same proportions as is indicated by the analyses.

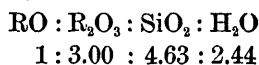
#### THOMSONITE SPHERULES.

**CHEMICAL IDENTIFICATION.**—Concerning the reddish spherules no data of importance could be obtained except by chemical analysis,

Under V is given the composition found for this substance in material which was apparently very pure.

	V.
SiO <sub>2</sub> .....	40.52
Al <sub>2</sub> O <sub>3</sub> .....	29.22
Fe <sub>2</sub> O <sub>3</sub> .....	0.79
CaO.....	12.43
Na <sub>2</sub> O.....	4.31
H <sub>2</sub> O.....	12.79
	100.06
(W. F. Hillebrand.)	

The oxygen ratio for this is:



These figures agree so well with those obtained for the colorless thomsonite (see page 25) that in the absence of anything to the contrary the identity of the two substances can scarcely be doubted. It was noticed here, as in the other thomsonite, that about 2 per cent. of the water could be expelled only at a very high temperature. The ferric oxide in all these minerals seems to replace a portion of the alumina.

Thomsonite in the form of these reddish spherules has been deposited locally in great abundance in irregular cavities on the upper surface of the lower sheet of basalt and also in the angular spaces formed where the scoriaceous crust of the flow has been broken or crumpled. It is here deposited alone, free from stilbite and laumontite, but the spherules are exactly similar in size and appearance to those formed in the cavities below.

## ZEOLITES. SECOND GROUP.

### STILBITE ("DESMIN" GERMAN).

GENERAL.—As has been already mentioned, stilbite occurs occasionally in clear, colorless crystals, as well as in the manner characteristic of the first series. It is noteworthy that in all such cases as yet observed the clear stilbite is either deposited upon the colored zeolites of the group described, or in close proximity to them, although it may be associated with chabazite or clear thomsonite, species having no such limitation. When these three minerals are associated it is sometimes difficult to assign an order of deposition, as they seem to have been nearly contemporaneous. The tablets of stilbite are usually attached by an edge, projecting at various angles from the underlying surface, and rarely appear so abundantly as to form a crust.

CRYSTAL FORM AND OPTICAL PROPERTIES.—The largest crystals seen measure about 1.5<sup>cm</sup> in longest diameter and 2.3<sup>mm</sup> in thickness.

These crystals, however, are made up of several plates, which are not in exactly coincident orientation, and their surfaces are not very smooth or glistening, from which causes they are not available for either crystallographical or optical studies. For these purposes only the minute transparent tablets which are occasionally found intermingled with the others could be used.

These tablets have the usual rhombic symmetry which has been explained by von Lasaulx as the result of a double twinning of a monoclinic groundform isomorphous with those of harmotome and phillipsite, and according to the laws observed in those species. The isomorphism thus pointed out has been advocated from the chemical side by Fresenius.<sup>3</sup> The Table Mountain stilbite presents some structural and optical properties not fully in accord with the statements of von Lasaulx, and yet the material is not perfect enough to show the full significance of the disagreement. A description of the observed variation may lead to an explanation based upon the study of other and better material.

Assuming the isomorphism stated, the predominant face is  $\infty P \infty$ , while  $\infty P$  and  $0 P$  are always present, and  $+ P \infty$  occasionally. The front prism angle was measured at  $118^\circ 22'$ , by attaching small flakes of mica to the dull surfaces of a large crystal, while approximate measurements in the orthodiagonal zone could be made under the microscope.

For optical examination a number of small tablets were mounted in balsam, lying upon the predominant pinacoidal face; others were mounted in the same position after a little grinding, which was intended simply to remove impurities from the surface. All exhibit the same optical action. The larger crystals could not be used for the reasons stated above.

Fig. 1 of the plate represents the structure described by von Lasaulx<sup>4</sup> in crystals examined by him, the figure being copied from his article, with a simple inversion to correspond with Figs. 2 and 3. On examining a crystal of tabular form, mounted as above described, between crossed nicols, there appears a division into four quadrants,  $a a$  and  $b b$ , by lines passing through the centre parallel and normal to the clino-axis. By parallel position of these lines with the principal sections of the nicols all four portions appear equally dark, but the maximum of extinction is only obtained by a revolution of about  $5^\circ$  from this position, for two diagonally opposite quadrants when the revolution is to the right, for the other two when to the left. There is therefore a difference of about  $10^\circ$  in extinction of adjoining quadrants. According to von Lasaulx the bisectrix is inclined  $5^\circ$  to the clino axis, while the optical normal makes an angle of  $34^\circ$  with the vertical axis. Reference will be made to this point later. A distinct zonal structure parallel to the outlines of  $0 P$ , and  $\infty P$  is described, and a very faint subdivision of

<sup>3</sup>Zeitschrift für Krystallographie, III, 42, 1878.

<sup>4</sup>"Ueber den Desmin." Zeitschrift für Krystallographie, II, 576, 1878.



each quadrant by this zonal structure is mentioned, but it is distinctly stated that no corresponding optical division exists. It is noted, however, that in a given quadrant the extinction adjoining  $d$  may be slightly less than that near  $c$ . Aside from this division into quadrants, which is in agreement with the supposed symmetry and twinning of the mineral as isomorphous with harmotome and phillipsite, there are often four other fields,  $c\ c$  and  $d\ d$ . The portions  $c\ c$  are diverging bundles of a somewhat fibrous, colorless mass, producing in all positions brilliant aggregate polarization. The parts  $d\ d$  are made up of bars placed perpendicularly to the line of  $0\ P$ , the area thinning out wedge-like toward the centre. Sections situated in the orthozone show coincident extinction throughout, so that these irregular aggregates ( $c$  and  $d$ ) seem to consist of stilbite substance having at least the orthoaxis in common with the rest. In all the many occurrences examined by von Lasaulx this division is more or less distinct. The portions  $c$  and  $d$ , termed by him "inverse substance," in contrast to the normal quadrants  $a$  and  $b$ , sometimes predominate largely, while  $d$  at least is occasionally very subordinate. With this action as given by von Lasaulx will now be compared that exhibited by the Table Mountain stilbite.

Fig. 2 represents the optical behavior of a crystal from Table Mountain, and is typical of that in all examined. It is in parallel position with Fig. 1, the dome  $+P\infty$  being added while at one end is a repetition of  $\infty P$  and  $P\infty$ . The same primary divisions are here seen as in Fig. 1, but each quadrant,  $a$ , is clearly subdivided when seen in polarized light by the zonal structure, which in the octants  $a$  and  $b$  runs parallel to the outline of  $\infty P$ , in  $a'$  and  $b'$  parallel to  $0\ P$ . The two systems meet in an irregular line which usually runs from the angle between  $0\ P$  and  $\infty P$  to the centre of the crystal. The bands of the two systems do not cross each other, as represented in Fig. 1, and a very small but appreciable variation in optical orientation may be seen. The direction of extinction in  $a'$  and  $b'$  measures about  $4^\circ 15'$  from the edge of  $0\ P$ , while in  $a$  and  $b$  it is  $5^\circ$ – $5^\circ 30'$  from the same direction. This corresponds to the statement of von Lasaulx that there seemed to be in some cases a difference between the extinction of  $a$  near the space  $d$  and that near  $c$ , the latter being greater. So far the action might be considered as slightly more intense than usual, whereby the subdivision of the quadrants is plainer. However, the position of the optical normal as given by von Lasaulx demands that the bisectrix should cut the clino axis, *i. e.*, the line of  $0\ P$  in the figure, at an angle of about  $5^\circ$  and the vertical axis at about  $56^\circ$ , while the bisectrix in the present case is inclined  $5^\circ$  to the clino axis and about  $46^\circ$  to the vertical axis, the normal consequently intersecting the latter at about  $44^\circ$ . In all crystals and in each quadrant the bisectrix lies in a dome which is steeper than the basal plane by about  $5^\circ$ , and hence truncates the angle between  $0\ P$  and  $\infty P$ , bringing the optical normal to an inclination of about  $44^\circ$  with the vertical axis. The close

agreement in other respects suggests the possibility that the position of the bisectrix relative to the clino axis may have been transposed by von Lasaulx.

The portions lettered *c* in Fig. 2 correspond in position and character to those of Fig. 1. An attempt has been made to indicate their irregular form and their relation to other parts. Usually based upon the outline of  $P\infty$ , they may spring from any part of the line of  $\infty P$ , and universally run toward the centre, often wedging out before reaching it and never penetrating segments *a'* or *b'*. Parts corresponding to *d d* in the Fig. 1 are here represented by a few bars at right angles to  $OP$ , but, although most numerous near the sharp line between *a'* and *b'*, they do not appear in sufficient quantity to form a distinct field, as *d* in Fig. 1. These interpositions seem most probably to be portions of *a'* included in *b'* and *vice versa*. The lower part of Fig. 2 shows the irregular relation of *b'* to *a'* in some cases, the dividing line being sharp while very much broken. In *b'*, which is thus enlarged, are numerous interpositions which are most sharply defined and apparently thickest on the side opposite *a'*, while thinning out toward that area. Some bars in *b'* seem to have a thin wing-like appendage on the side next *a'*. The orientation of these interposed bodies cannot be definitely ascertained, but they seem to correspond closely to the adjacent division of the next quadrant.

The areas *c c* often contain stripes corresponding to *a* and *b* and also more rarely of *b'* or *a'*. Fig. 2 shows how each repetition of  $\infty P$  is accompanied by portions which are banded parallel to its outline and correspond optically to all other parts of the same position. In some crystals a close examination shows a delicate zonal structure, parallel to that of *a* or *b*, in small irregularly shaped parts of *c*, and as these are almost always thin and overlaid by substance of other orientation, so that a uniform extinction does not take place, it seems quite probable that these portions showing aggregate polarization are made up of an intergrowth of thin flakes of *a* and *b* with the ortho axis in common, but not in fully coincident position otherwise; corresponding thus to the known tendency of the mineral in larger crystals and which is characteristic of those from this locality. Von Lasaulx also suggests this explanation, but thinks the brilliant and strongly contrasted polarization of parts whose extinction angles should so nearly coincide is antagonistic. The interference of light in passing numerous laminae and possible tension arising from the manner of intergrowth assumed seem, however, sufficient to account for this strong action.

During the study of the twin structure in phillipsite, Trippke<sup>5</sup> made a section through the centre of a double twin crystal, parallel to the clinopinacoid of one of the simple twins and obtained thus a form cor-

<sup>5</sup> P. Trippke. "Beiträge zur Kenntniss der schlesischen Basalte und ihrer Mineralien." Breslau, 1878. (Dissertation.)

responding to the crystals of stilbite. Fig. 3 is a reproduction from his work showing the optical division of the section. Its formal correspondence with that described for stilbite is noteworthy. The segments *a* and *b* correspond to *a'* and *b'* of Fig. 2, even to the interposed bars at right angles to 0 P, which are interpreted by Trippke as inclusions of a substance in *b*, and the reverse (loc. cit., p. 39). The areas *c*, *d'*, *f*, *e'* represent, however, four distinct individuals which do not correspond to *a* and *b* of Fig. 2, except in form. Likewise the wedge-shaped portions *a'* and *b'* do not correspond to *c* of the stilbite, for they represent substance whose basal plane falls parallel to  $\infty P\infty$  of *a* and *b*. If the various parts of the stilbite crystals do possess the ortho axis in common, as indicated by the observations of von Lasaulx and by a single section secured parallel to 0 P in a Table Mountain crystal, then the structural correspondence between Figs. 2 and 3 is meaningless except for the segments based upon 0 P. These are actual equivalents.

The material thus far obtained from Table Mountain does not permit of crystallographic measurements of sufficient accuracy to determine definitely whether the division into octants, indicated by the optical behavior, can be traced in the outer form or not. The incomplete results obtained have been given in detail because it seems probable that the material examined by von Lasaulx does exhibit in less distinct form the same action. It is hoped that an attempt to secure better specimens from Golden may be successful, so that further examination may be made.

ANALYSIS.—Pure crystals gave on analysis the following:

	VI.
SiO <sub>2</sub> .....	54.67
Al <sub>2</sub> O <sub>3</sub> .....	16.78
CaO .....	7.98
Na <sub>2</sub> O .....	1.47
H <sub>2</sub> O .....	19.16
(W. F. Hillebrand.)	100.06

Oxygen ratio:

RO : R<sub>2</sub>O<sub>3</sub> : SiO<sub>2</sub> : H<sub>2</sub>O

1 : 2.97 : 10.97 : 6.41, instead of

1 : 3.00 : 12.00 : 6.00, as required by the ordinarily accepted formula.

#### CHABAZITE.

GENERAL.—With the exception of stilbite this is the oldest of the colorless zeolites. In most cases where several zeolites occur together chabazite forms the lining of the cavity and the others are deposited upon it. It is often found alone, however, and excellent specimens are abundant.

The glassy white, or rarely pinkish, crystals have the usual rhombohedral form and the faces are occasionally as much as 1<sup>cm</sup> in diameter.

The crystals are usually twins of interpenetration. In some of the smaller cavities are subdividing walls of chabazite or miniature columns composed of many small crystals. A second generation of chabazite came after thomsonite and analcite, but the crystals are few and very minute.

**CHEMICAL COMPOSITION.**—Chemical analysis of clear crystals gave as follows:

	VII.	VIII.
SiO <sub>2</sub> .....	47.86	47.18
Al <sub>2</sub> O <sub>3</sub> .....	19.30	19.67
Fe <sub>2</sub> O <sub>3</sub> .....	*0.12	
CaO .....	9.94	9.74
SrO .....		0.43
K <sub>2</sub> O .....	0.35	0.37
Na <sub>2</sub> O .....	0.52	0.51
H <sub>2</sub> O .....	22.07	22.15
(W. F. Hillebrand.)	100.16	100.05

\* From attached limonite.

	Per cent.
Loss on drying over sulphuric acid .....	2.66
Total loss at 100° C. ....	4.76
Total loss at about 300° C. ....	18.45
Loss above 300° C. ....	3.70

From the above analyses it is impossible to deduce a formula strictly in accordance with that of Rammelsberg<sup>6</sup> or that of Streng.<sup>7</sup> Assuming part of the alkaline earths to be replaced by alkalies, the following oxygen ratios are obtained:

	RO : Al <sub>2</sub> O <sub>3</sub> : SiO <sub>2</sub> : H <sub>2</sub> O
VII.	1 : 3.05 : 8.57 : 6.59
VIII.	1 : 3.04 : 8.27 : 6.47

It is highly probable that a part of the water is basic. The presence of strontia in such quantity is noteworthy.

The material was not examined microscopically.

#### THOMSONITE.

**OCCURRENCE AND GENERAL DESCRIPTION.**—This zeolite followed closely upon the chabazite; indeed its earliest aggregates are so intimately associated with that mineral as to make it evident that the deposition of the one had begun before that of the other had ended. The mineral occurs in very minute rectangular blades, which are placed upon each other like the leaves of a closed fan, and the very compact combinations of such aggregates are usually arranged in a more or less distinct radiate manner. Sometimes spherical forms result, in other cases columns, by radiation from an axis, or, less frequently, walls, the blades standing at right angles to the central plane. Where crystals of yellow

<sup>6</sup> Zeitschrift d. D. geol. Ges., XXXVI, 220, 1884.

<sup>7</sup> Berichte d. oberhess. Ges., etc., XVI, 74, 1877.

calcite were not covered by chabazite the thomsonite has never failed to coat them, the blades being approximately perpendicular to the crystal faces. When a large surface of chabazite has been completely coated by the more or less radiate aggregates of thomsonite, forming an undulating surface, the whole has a most delicate silken lustre, while that on a fractured surface of a spherical mass is more satin-like. The aggregates are white when pure and single blades are transparent.

It is difficult to obtain isolated leaves, and they are then so thin as to affect polarized light but slightly, still it was definitely determined that the direction of total extinction between crossed nicols is parallel to the longitudinal axis. By examination of the ends of the blades under the microscope with a power of 90 diameters, it could be seen that the vertical edges were formed in many cases by a plane at right angles to the dominant surface. Occasionally a prism was found with angle very near  $90^\circ$ , and in a few cases both forms together were seen. These planes correspond to the macropinacoid (dominant) prism and brachypinacoid of thomsonite, as given by all authorities. The termination seems to be the basal plane. The average thickness of these blades is about  $0.01\text{ mm}$ . Toward the close of the zeolitic formation a second generation of thomsonite was deposited. The blades are in this case longer than in those of the first while the other dimensions remain about the same. In combination with the base upon the crystals of this latter growth are apparent brachydomes, whose angles with the base were most frequently measured at about  $145^\circ$  or  $135^\circ$ .

The blades of the second generation, when deposited upon those of the first, have the same crystallographic orientation and serve simply as prolongations of the latter. Through the usual slight yellow tinge of the recent growth, the line between the two is clear. The long blades of the second growth of thomsonite often form bundles resembling rough prismatic crystals, and these bundles arranged in a loosely and irregularly radiate manner form bunches an inch or more in diameter upon which the delicate needles of mesolite have a special tendency to deposit themselves.

The thomsonite of Table Mountain was first identified through a quantitative analysis by Carlton H. Hand, at the time a student in the School of Mines at Golden. The analysis was not published and has been lost.

**CHEMICAL COMPOSITION.**—The following results were obtained by the analysis of different specimens of thomsonite from Table Mountain:

	IX.	X.		XI.		XII.		XIII.
		<i>a</i>	<i>b</i>	<i>a</i>	<i>b</i>	<i>a</i>	<i>b</i>	
SiO <sub>2</sub> .....	40.88	40.68	40.70	41.21	41.17	42.66	.....	41.63
Al <sub>2</sub> O <sub>3</sub> .....	29.68	30.12	29.75	29.71	.....	29.25	29.29	.....
CaO .....	11.88	11.92	11.89	11.34	11.38	10.90	10.90	.....
Na <sub>2</sub> O .....	4.72	4.44	.....	5.62	.....	4.92	.....	.....
H <sub>2</sub> O .....	12.91	12.86	.....	12.20	.....	12.28	12.34	.....
(W. F. Hillebrand.)	100.07	100.02	.....	100.08	.....	100.01	.....	.....

Oxygen ratios: •

	RO : R <sub>2</sub> O <sub>3</sub> : SiO <sub>2</sub> : H <sub>2</sub> O			
IX .....	1	: 3.03	: 4.73	: 2.49
X, mean of <i>a</i> and <i>b</i> .....	1	: 3.09	: 4.77	: 2.51
XI, mean of <i>a</i> and <i>b</i> .....	1	: 2.98	: 4.68	: 2.31
XII, mean of <i>a</i> and <i>b</i> .....	1	: 3.14	: 5.19	: 2.50

DISCUSSION OF ANALYSES.—In all of these analyses the figures under *b* denote repeated determinations. Analysis IX was made upon material taken from the purest and finest specimen of thomsonite as yet obtained. Separation from the underlying thin layer of chabazite was complete. The material for X was also selected with the greatest care from a very pure specimen. Imperfectly spherical aggregates were broken up quite finely, and each particle appropriated for analysis was first closely examined with a strong lens in order to detect any trace of chabazite. Thinking it possible that a small amount of chabazite might have escaped notice, a second portion of thomsonite from the same specimen was procured by breaking off the ends of the blades, and this was found to contain 41.63 per cent. of SiO<sub>2</sub> (XIII). A microscopical examination of this material showed that these blades of thomsonite contained very small, irregularly rounded particles imbedded in the outer surfaces. These particles, which are clear or slightly yellowish, do not affect polarized light perceptibly and are not crystalline in form. They are present in varying quantity toward the termination of nearly all blades, but are usually entirely wanting in the lower portions of all aggregates. In the material yielding IX they were present in less quantity than usual, and even if they consisted of pure silica could have affected the result but slightly.

Analyses XI and XII were made upon substance known to be slightly contaminated by delicate hairs of mesolite which could not be fully removed. Both represent thomsonite from bunches of the kind mentioned above.

RELATION TO "MESOLE."—In the hope of throwing some light upon the cause of the difference between the composition of normal thomsonite (oxygen ratio 1 : 3 : 4 : 2½) and the variety sometimes called "mesole" (oxygen ratio well represented by those of the foregoing analyses); the ratios for all the analyses of mesole given in Dana's System of Mineralogy, and of such others as could be obtained, were calculated and the results examined.

Intermixture of free silica or of mesolite has been generally considered the cause of the excess of silica in mesole. While the presence of either or both of these substances may be a sufficient explanation in some instances, and in two of the above analyses (IX and X) undoubtedly is, to some extent at least, a true one, it will not answer for a majority of the published analyses examined. Only one of these, on

Nova Scotia material, by How, affords a ratio very near that furnished by IX and X above.

While positive proof is wanting of the total absence of free silica in the purest of the Golden thomsonite analyzed, the most thorough microscopical examination failed to reveal its presence or that of any other foreign matter.

Mesolite cannot be the disturbing element here, because in order to raise the silica 3 per cent. above that of normal thomsonite there would be required an admixture of not far from 50 per cent. of mesolite, which amount would also have raised the oxygen value for water. It seems indispensable to a solution of this question that numerous and accurate analyses should be made of this variety of thomsonite from as many localities as possible, and that careful microscopical examination should in every case furnish as far as possible a guarantee of the purity of all material taken for analysis.

#### ANALCITE.

GENERAL DESCRIPTION.—Analcite follows thomsonite in time of deposition. At the locality mentioned on North Table Mountain its crystals are pure white or transparent and vary in size from very small ones to those nearly an inch in diameter. The predominating form is the common trapezohedron 202 having its octahedral edges evenly truncated by  $\frac{3}{10}$ . The appearance of  $\frac{3}{10}$  is very characteristic of the Table Mountain analcite, though the form is never prominent and is usually represented by an exceedingly narrow line. According to Zirkel<sup>8</sup> the form  $\frac{3}{10}$  has been observed but once on analcite, viz., by Laspeyres on that from the Kerguelen Islands. A second generation of analcite was observed, analogous to that of chabazite, the crystals being very small and clear. They were deposited upon apophyllite.

On the eastern side of North Table Mountain analcite is often present alone, filling small cavities completely and developed in immense crystals in the larger ones, some being nearly 2 inches in diameter. The faces of such large crystals are often uneven through depressions or other irregularities bounded by faces of 202.

On South Table Mountain analcite is more abundant than any other zeolite. Large cavities have a floor of analcite but always in quite small crystals. Natrolite is almost invariably deposited upon it and frequently small cracks are filled with the same mineral associated with calcite or natrolite. Analcite was also found in spaces between the pebbles of a conglomerate bed, not far below the basalt, the pebbles being of basic eruptive rocks.

OPTICAL BEHAVIOR.—The anomalous optical properties of much analcite have been the subject of careful investigation by numerous able mineralogists, some of whom have sought the explanation in a complicated twin structure by which a substance of lower degree of sym-

<sup>8</sup>Naumann-Zirkel, "Elemente der Mineralogie." Leipzig, 1881.

metry may imitate a higher, while others have referred the phenomenon to double refraction arising from inner tension. Since the exhaustive researches of Ben-Saude<sup>9</sup> few have opposed the latter view, according to which all optical action in analcite, which is abnormal for a mineral crystallizing in the regular system, is regarded as secondary and produced by molecular disturbances due to changes of temperature. The mode of formation of the mineral and the crystal forms developed determine the character of the anomalous action.

In the preliminary description of the Golden zeolites<sup>10</sup> it was stated that the analcite of Table Mountain "is doubly refractive, but so irregularly that it cannot be well used in confirmation of the interesting observations of Ben-Saude." At about the time of this publication a suite of the Golden zeolites was sent to Professor Carl Klein, of Göttingen, the foremost in the group of those who have sought to explain many optical anomalies in crystallized minerals by the theory of inner molecular tension due to secondary causes. The thorough examination of the Table Mountain analcite by Professor Klein, the results of which were published in the *Neues Jahrbuch für Mineralogie*, etc. (1884, I, 250), shows that the above statement is correct only for the larger crystals, while the smaller and most perfect ones agree entirely with the observations and conclusions of Ben-Saude. Renewed examination by us upon minute and carefully-selected crystals fully confirms this testimony.

Professor Klein also subjected our material to investigation in a direction recently followed by him in regard to many minerals with eminent success, particularly in the cases of boracite<sup>11</sup> and leucite.<sup>12</sup> By means of an apparatus devised for the purpose the effect of heat upon the optical properties of a given mineral can be observed under the microscope. The application of this method of research to the Table Mountain analcite enables Professor Klein to state that in sections parallel to  $\infty 0 \infty$  and  $\infty 0$  the doubly refractive action of the various segments into which the crystal is divided becomes less and less, and finally disappears entirely, leaving an isotropic field. By thin sections this change is effected rapidly, while in the thicker ones it is retarded, and in some cases was not wholly successful. These investigations seem to demonstrate clearly that analcite is a regular mineral, whose anomalous optical properties are due to molecular disturbances produced by a decrease in temperature from that prevailing at the time of formation of the mineral.

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<sup>9</sup> "Ueber den Analcim." *Neues Jahrbuch für Mineralogie*, etc., 1882, I, 41.

<sup>10</sup> *Am. Jour. Sci.*, III, XXIII, p. 452, 1882.

<sup>11</sup> *Neues Jahrbuch für Mineralogie*, etc., 1882, I, 235.

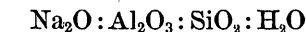
<sup>12</sup> *Ibid.*, 1884, II, 49.



CHEMICAL COMPOSITION.—Analyses of crystals, apparently pure, which were, however, not examined microscopically, gave as follows:

	XIV.	XV.
SiO <sub>2</sub> .....	55.82	55.80
Al <sub>2</sub> O <sub>3</sub> .....	22.42	22.45
Na <sub>2</sub> O .....	13.48	13.45
H <sub>2</sub> O .....	8.88	8.35
(W. F. Hillebrand.)	100.10	100.05

Oxygen ratios:



XIV. 1 : 3.03 : 8.56 : 2.14

XV. 1 : 3.04 : 8.57 : 2.14

The excess in silica and water is most probably due to presence of hydrated silica.

#### APOPHYLLITE.

GENERAL DESCRIPTION.—This mineral occurs in well-developed crystals of prismatic habit with  $\infty P \infty$  and P predominating, while 0P is in most cases quite subordinate or wanting entirely. The larger crystals which are occasionally half an inch in diameter, are often of a greenish tinge, sometimes quite pronounced, and possess more or less uneven surfaces produced by a repetition of the crystal faces, so that the termination is made up of a large number of small pyramids.

The prismatic surfaces are roughened by depressions or elevations bounded by prism and pyramid planes. This feature is very prominent in all large crystals, while the smaller ones are in contrast sharp and clear with smooth, brilliant faces. Especially noticeable on these small and clear crystals, though not peculiar to them, is a replacement of the pole edge of the pyramid by a small re-entering angle formed by pyramid faces. This angle is nowhere prominent, yet may be easily identified on all clear crystals, both large and small. No corresponding irregularity of any kind could be detected on the dimetric prism of these crystals.

As a rule the largest crystals occur in the small cavities, and their growth has been more or less hemmed by the walls, while the more perfect crystals are present in the large cavities, and are usually small and numerous.

OPTICAL PROPERTIES.—Apophyllite is another of the group of minerals exhibiting in many cases an optical behavior not in accordance with the outward symmetry, and the mineral from Table Mountain shows this anomalous action in typical form. The thorough investigation of such minerals having become within the past few years a work for the specialist, with appliances not at our disposal, we shall confine ourselves to a simple statement of observed facts. We are able, however, to refer to the published results obtained by Professor Klein from an examination of material from Table Mountain. Unfortunately but a

few small crystals of this locality are suitable for such study, owing to the irregularities of form common to the larger ones, so that a satisfactory suite of specimens could not be placed at Professor Klein's disposal. His results are contained in the same article with those upon analcite.<sup>13</sup>

The mere observation of the optical anomalies of apophyllite is no difficult matter, provided good crystals are available, for the easily-obtained sections parallel to the perfect basal cleavage planes are most suitable for the purpose. It is, however, a significant fact that only the most perfect and symmetrically developed crystals exhibit the peculiar action in sufficiently simple form to permit a satisfactory description. With all apparent, and sometimes, it must be confessed, without visible irregularities in form, there appear variations and distortions of the more regular action about to be described.

The Table Mountain apophyllite crystals are bounded by  $\infty P \infty$  and P with 0 P as a frequent addition. If a regular crystal of this form be divided into a number of sections parallel to the basal cleavage plane, there will be small ones of square outline, situated in the pyramid near the apex; larger ones of octagonal form through the intersection of both pyramid and prism; and still lower, square ones again from the prism alone. Such sections, ground to the desired thinness and mounted in Canada balsam, show the following peculiarities when examined in parallel polarized light. Unless otherwise stated the examination takes place between crossed nicols, and the position in which the diagonals of the pyramidal section are parallel to the planes of vibration in the nicols is designated as position A, that produced by revolving the crystal section through  $45^\circ$ , as position B.

Figs. 4, 5, and 6, represent the relation in a crystal examined and described by Professor Klein,<sup>14</sup> all of them in position A. Fig. 4 illustrates the appearance in a section near the apex of a crystal having 0 P and showing the small re-entering angles above mentioned. In the centre is a dark field, whose outlines are only approximately parallel to those of the pyramid. The outer zone is then divided in segments based upon the four sides, the opposite pairs having the same optical orientation. Fig. 5 represents the division in the octagonal section cutting  $\infty P \infty$  and P. The central field is here much smaller and the segments upon P consequently larger. Based upon  $\infty P \infty$  are low triangular spaces of still different optical action. Fig. 6 shows the relations in a section of the same crystal taken in the prism. The central field is here very small, while those areas corresponding to the outlines of  $\infty P \infty$  have increased very markedly. The optical behavior of these divisions in position A is usually as follows: The central field is nearly or quite dark, the sectors based on outlines of P are light and equal,

<sup>13</sup> Neues Jahrbuch für Mineralogie, etc., 1884, I, 253.

<sup>14</sup> These figures taken from the cited article.

while those upon  $\infty P \infty$  are not homogeneous in action. The areas based upon  $P$  are optically biaxial, the plane of the axes lying normal to the outline of  $P$  adjoining. When a gypsum plate producing red light of higher order is inserted, and so situated that the lesser axis of elasticity runs from the upper left-hand to the lower right-hand quadrant, the blank sectors appear yellow, the dotted ones blue, while the inner field has more or less perfectly the red color of the outer field of vision. The sectors based upon  $\infty P \infty$  are usually variegated in color, red, blue, or yellow, as will be described further on. In position  $B$  the whole becomes dark except the irregular sectors adjacent to  $\infty P \infty$ .

The statements of Professor Klein are chiefly directed to show that the optical properties observed are, to a very large degree, dependent upon the crystal faces developed. Thus the crystal whose sections are figured had a well-developed basal plane, to which fact is attributed the presence of the central field, while the decrease in size, as the sections are taken deeper in the crystal, corresponds to the distance from  $O P$ . He states that in a crystal without a basal plane the central field is wanting. The appearance of the prism  $\infty P \infty$  as a boundary of a section is accompanied by the appearance of the low triangular spaces of irregular optical behavior. The biaxial fields seem definitely related to the outlines of  $P$ .

The examination of several crystals with reference to this relationship between outer form and optical action has shown us that any generalization with regard to  $O P$  and the central field is impracticable. In several crystals showing no base at all the dark central field is present, in one case being large near the apex and very small in the prism; in another case the reverse; also in crystals with  $O P$  developed this field is sometimes smallest near that plane, and again it does not vary materially in size from the pyramid to the prism. In no case, however, has the prism  $\infty P \infty$  appeared as a boundary of a section, without an adjacent field in which the action is often complex, the complexity increasing as the section is taken lower in the crystal. No sector in this position has ever been seen independent of the development of  $\infty P \infty$ .

The figures of Professor Klein are intended to illustrate the most regular action observed, and it is quite natural to assume that this simple relation of optically different parts is largely dependent upon the regularity in the development of the crystal form. The deviations from this simple relation and action of individual parts have never been fully described, but in the series of sections we have examined these variations are very numerous and seem quite as important in considering the cause of the optical phenomena as the more regular condition occasionally seen.

The central core is very variable in form. Within a given crystal it often changes perceptibly from section to section either in size or in outline. As has been stated, it may be largest near the apex of the

crystal (whether  $0\ P$  is developed or not) and steadily decrease in size downwards, or its apex may be in that of the pyramid, and in some cases it runs as an inner prism through the whole observed part of the crystal. Its section is but rarely square, although rectangular in many cases, and this variation has no observable relation with the prominence of adjacent pyramid faces. The more perfectly rectangular its outline the sharper its boundaries are, and the more homogeneous its optical action. Variations from the rectangle are produced by broken side-lines, by the deviation of its angles from  $90^\circ$ , and by an increase in size until it can no longer be inscribed within the prism  $\infty\ P\ \infty$ . With all such irregularities are combined disturbances in the optical action of the centre. In the simpler instances, by position A the field is not wholly dark and several faint black crosses are seen whose arms are parallel to the diagonals of the pyramid, and revolve with the section, disappearing more or less completely in position B. These arms rarely cross each other at exactly  $90^\circ$ , and especially where the side lines of the rectangle are broken the field is divided into numerous irregular areas, each having by position A a black cross whose arms may join at any angle. These revolve with the section and either disappear or become less distinct by position B. In one section the optical division is quite regular, in that by position A the field is composed of a mosaic of light and dark squares or rectangular blocks, whose sides are parallel to the outlines of the prism  $\infty\ P\ \infty$ . In position B the same structure is visible with the dark squares as the light ones. The lighter areas are very faint and shade off into the darker ones. With the insertion of the gypsum plate the place of the black cross is sometimes indicated by bushy indistinct blue and yellow arms, normal respectively to the adjacent blue and yellow segments on the outlines of  $P$ . In two or three cases one side of the central field is absent, and there is a gradual shading from the adjoining sector into the area of the centre. The opposite side of the field is very sharp and clear in such instances. By using the gypsum plate the change is very distinct, from the normal red next to the sharp outline, by transition shades out to the distinct yellow or blue of the sector.

The segments based upon  $P$  are much less subject to variation than the central field. They are always present and usually prominent. Normally they appear equally light in position A, but opposite pairs differ in intensity upon a slight revolution, and are wholly dark in position B. On insertion of the gypsum plate, in position A, one pair appears blue, the other orange-yellow. In regular crystals the dark lines which separate them run from the angles of the pyramid, or normal to  $\infty\ P\ \infty$  if its faces are developed, to the angles of the central field, as in Figs. 4, 5, and 6. If the inner field is not regular, these lines must bend to meet the angles, and in fact they are often wholly irregular curved or broken lines, neither normal to each other nor to the outline of  $\infty\ P\ \infty$ . An optical variation of these segments is frequent, in that the outer

portions or a broad band through the centre, parallel to the outline of P, is much lighter than that portion near the central field. If the gypsum plate is inserted the color of the lighter parts is purer blue or yellow, and shades off into reddish hues toward the red centre. In position A indistinct dark figures are sometimes seen, and these usually spring from a point on the surface or from the angles of the central field. Fissures when present commonly furnish a number of centres for such disturbances.

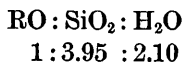
Finally, the areas based upon  $\infty$  P  $\infty$  are quite variable both in form and behavior. They are sometimes very low, perfect triangles, and in such cases their action is often simple. In position A they are dark, in B light. With the gypsum plate inserted they are red in position A, while in B opposite pairs are respectively blue or yellow, as with the pyramidal segments in the former position. When complex they consist chiefly of laminæ parallel to  $\infty$  P  $\infty$ . In position B, with gypsum plate, a part of these laminæ appear red, the remainder blue or yellow.

The simple recital of the optical variations observed seems sufficient to deter any one from an attempt to explain the anomalous action of apophyllite on a theory of complex twinning. The insensible gradations and shadings between all structures and optical conditions seen, are much more characteristic of the phenomena due to unequal tension or pressure in glass and colloidal substances, than of any complex twinning definitely known in a mineral.

**CHEMICAL COMPOSITION.**—In chemical composition this apophyllite is quite normal, the fresh substance yielding the following:

	XVI.
SiO <sub>2</sub> .....	51.89
Al <sub>2</sub> O <sub>3</sub> .....	1.54
Fe <sub>2</sub> O <sub>3</sub> .....	0.13
CaO .....	24.51
K <sub>2</sub> O .....	3.81
Na <sub>2</sub> O .....	0.59
H <sub>2</sub> O .....	16.52
F .....	1.70
O for F .....	100.69
	0.72
	99.97
(W. F. Hillebrand.)	

Considering all potassium and sodium as combined with fluorine, the following oxygen ratio is afforded:



The theoretical ratio 1:4:2 would be still nearer approached were it not for a probable slight loss of silica and excess of water, scarcely to be avoided in analyses of silicates containing fluorine. The Fe<sub>2</sub>O<sub>3</sub> is undoubtedly owing to minute particles of limonite which could not be completely removed. The Al<sub>2</sub>O<sub>3</sub> is much higher than in most

analyses, and the condition in which it is present seems undeterminable.

**ALTERATION.**—The Table Mountain apophyllite is frequently subject to alteration in a peculiar manner, which is, so far as we can ascertain, different from anything previously observed for that mineral. By this alteration a pearly-white, very finely-foliate substance is produced in the basal cleavage fissures of the apophyllite. The decomposition begins at the surface and progresses inward, the flakes of the newly-formed substance lying parallel to the cleavage planes. Some crystals which are outwardly snowy white, show perfectly fresh substance within. When the outer surface of an altered crystal is dull the resemblance to albine is marked, but on fracturing such a crystal the distinct foliation and lustre show the different nature of this substance.

As more or less apophyllite is usually mixed with the alteration product it was quite difficult to ascertain its chemical composition. Material apparently very pure was finally obtained from the specimen in which the decomposition was most advanced, by treatment in the following manner: The finely-powdered substance was stirred up in water, and the finer portions were poured off from the heavier impurities; the material suspended in the water was allowed to settle, the clear liquid was decanted, and the residue evaporated, accidentally *quite* to dryness. It having been found that the air-dried material lost several per cent. of water over sulphuric acid, it was certain that some loss had been occasioned by drying on the bath; hence the drying was completed at 100° C., and the following analysis was then made:

	XVII.
SiO <sub>2</sub> .....	67.96
Al <sub>2</sub> O <sub>3</sub> .....	8.48
Fe <sub>2</sub> O <sub>3</sub> .....	1.04
CaO .....	5.47
MgO .....	0.53
K <sub>2</sub> O .....	1.23
Na <sub>2</sub> O* .....	0.74
H <sub>2</sub> O .....	14.55
F .....	none
(W. F. Hillebrand.)	100.00

\* By difference.

The Fe<sub>2</sub>O<sub>3</sub> comes from certain reddish flakes which could not be separated. The H<sub>2</sub>O is, from reasons above given, much too low, and the other figures are consequently too high.

Neglecting Fe<sub>2</sub>O<sub>3</sub> and H<sub>2</sub>O the following oxygen ratio is obtained:

$$\begin{array}{l} \text{RO} : \text{Al}_2\text{O}_3 : \text{SiO}_2 \\ 1 : 1.86 : 16.66 \end{array}$$

from which no satisfactory formula is deducible.

It is plain that this alteration product has nothing in common with albine except the color, Knop<sup>15</sup> having proved, for many cases at least, that the latter substance is chiefly calcite.

## MESOLITE.

**GENERAL DESCRIPTION.**—Mesolite is the last of the minerals deposited at the locality on North Table Mountain where all of the species thus far described occur so often together that their order of succession is plain. The mineral appears uniformly in masses composed of exceedingly delicate needles loosely grouped together, very much like the spicules of a fine sponge. Such light aggregates frequently fill the smaller cavities entirely. In the larger ones the bases of the rounded bunches, 1 to 2 inches in diameter, often touch each other. The very latest deposition, the finishing touch so to speak, is a thin film coating the whole mass. This is sometimes a continuous membrane, and in other cases more like a thick cobweb. The exquisite delicacy of some of these films is quite wonderful. In rare cases bunches on the upper and lower walls of a cavity are united by such a membrane. Single needles are clear, but the aggregate appears pure white.

As was mentioned under thomsonite, the loose aggregates of the second generation of that mineral seem specially suited to attract the deposition of mesolite.

None of the mesolite needles are large enough to allow any determination of their crystal form, even under the microscope at a high power. They seem simply like very fine transparent hairs.

**CHEMICAL COMPOSITION.**—The identification as mesolite rests upon the following chemical analysis:

	XVIII.			Mean.
	a.	b.	c.	
SiO <sub>2</sub> .....	46.14	46.02	46.33	46.17
Al <sub>2</sub> O <sub>3</sub> .....	26.88	26.87	.....	26.88
CaO.....	8.77	.....	.....	8.77
Na <sub>2</sub> O.....	6.19	.....	.....	6.19
H <sub>2</sub> O.....	12.17	12.17	12.13	12.16
(W. F. Hillebrand.)	100.15	.....	.....	100.17

Oxygen ratio :

$$\text{RO} : \text{R}_2\text{O}_3 : \text{SiO}_2 : \text{H}_2\text{O} \\ 1 : 3.08 : 6.00 : 2.63$$

If mesolite be considered as a mixture of the isomorphous silicates contained in scolecite ( $\text{CaAl}_2\text{Si}_3\text{O}_{10} + 3 \text{ aq}$ ) and natrolite ( $\text{Na}_2\text{Al}_2\text{Si}_3\text{O}_{10} + 2 \text{ aq}$ ), the present occurrence would answer very nearly to the requirements of the combination of 2 of scolecite + 1 of natrolite, the percentage of which would be: SiO<sub>2</sub> 46.32, Al<sub>2</sub>O<sub>3</sub> 26.40, CaO 9.61, Na<sub>2</sub>O 5.32, H<sub>2</sub>O 12.35=100.00.

<sup>15</sup> In Blum, Die Pseudomorphosen, etc.; Dritter Nachtrag, 1863, p. 41.

## NATROLITE.

DESCRIPTION AND ANALYSIS.—Natrolite occurs much less abundantly than any of the species thus far described, and seems to be restricted locally to the northern part of South Table Mountain. It usually appears in delicate prisms sparingly deposited upon analcite or associated with that mineral in fissures. It has also been observed upon yellow calcite, chabazite, and thomsonite.

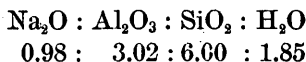
The crystals show only  $\infty$  P and P; they extinguish light exactly parallel to the prism, and are therefore of the normal rhombic type. The microscope shows many crystals to be partially coated with calcite, which explains the presence of  $\text{CaCO}_3$  in the following analysis of the needles:

	XIX.
$\text{SiO}_2$ .....	43.66
$\text{Al}_2\text{O}_3$ .....	24.89
$\text{CaO}$ .....	4.87
$\text{Na}_2\text{O}$ .....	14.66
$\text{H}_2\text{O}$ .....	*8.09
$\text{CO}_2$ .....	†3.83
(W. F. Hillebrand.)	100.00

\* By difference. † Calculated for total  $\text{CaO}$ .

There being much less than half a gram of material at disposal for analysis, no attempt at a direct water determination was made. On treating with acid there was a strong effervescence of  $\text{CO}_2$ ; therefore in calculating the following oxygen ratio the  $\text{CaO}$  was assumed to be present entirely as  $\text{CaCO}_3$ .

Oxygen ratio:



A study of the ratio time thus obtained, however, renders it probable that a small part of the  $\text{CaO}$  was combined with silica, in which case the  $\text{CO}_2$  would be less and the  $\text{H}_2\text{O}$  consequently higher, bringing the ratio still nearer to the theoretical 1 : 3 : 6 : 2.

## SCOLECITE.

DESCRIPTION AND ANALYSIS.—Scolecite occurs sparingly in a zone just above that containing a great number of the zeolites. It appears in small spheres or segments of spheres with a radiate structure, and greatly resembles thomsonite, though easily distinguished by the brilliant white color and satin-like lustre. Toward the centre of the aggregates there is often a greenish color.

The mineral only occurs in very small cavities, which are often entirely filled by it and seldom contain any other zeolite. Minute tablets of brown mica which are coated, as are the walls of the cavity, by a lavender-colored material, usually appear as the only associates of the scolecite. It occurs also in some cases with the next species to be described. Chabazite and thomsonite may occur in larger cavities directly



adjacent to smaller ones containing scolecite, but they have never been found with the latter.

The mineral gelatinizes on treatment with hydrochloric acid and was found to have the following composition :

	XX.
SiO <sub>2</sub> .....	46.03
Al <sub>2</sub> O <sub>3</sub> .....	25.28
Fe <sub>2</sub> O <sub>3</sub> .....	0.27
CaO .....	12.77
Na <sub>2</sub> O .....	1.04
K <sub>2</sub> O .....	0.13
H <sub>2</sub> O .....	*14.48
(W. F. Hillebrand.)	100.00

\* Difference.

No attempt at a direct water determination was made, owing to the small amount of pure material available.

Oxygen ratio :

RO : Al<sub>2</sub>O<sub>3</sub> : SiO<sub>2</sub> : H<sub>2</sub>O

1 : 3.02 : 6.23 : 3.26

It was impossible to free the mineral entirely from attached limonite and an insoluble silicate, which probably accounts for the high values for SiO<sub>2</sub> and H<sub>2</sub>O in the oxygen ratio. The agreement with the theoretical ratio 1 : 3 : 6 : 3, is, in any case, close enough to establish the identity of the mineral as scolecite.

#### LEVYNITE.

GENERAL DESCRIPTION.—To the species levynite is referred a mineral occurring very sparingly in small cavities side by side with those containing scolecite, although the two have never been observed together. When but partially filling the cavity, white or colorless tabular crystals are developed, which resemble very closely the form usually given as characteristic of levynite. Referring to the figures of Dana or Naumann-Zirkel, and adopting the ground form of the latter, the Table Mountain crystals are formed of twins of interpenetration producing hexagonal tablets with 0 R and R as the chief faces, the re-entering angle formed by  $-\frac{1}{2}$  R being seldom distinct. R is always striated, often coarsely, parallel to the combination edge with  $-\frac{1}{2}$  R.

The faces of R and 0 R are not smooth enough to allow of good reflections, hence the following measurements are not very exact, although sufficiently so to prove the identity in crystal form with levynite :

	Measured.*	Theoretical.
R $\wedge$ R (hor.) .....	125° 10'	125° 14'
OR $\wedge$ R .....	117° 38'	117° 23'
R $\wedge$ $-\frac{1}{2}$ R .....	130° 22'	129° 45'

\* Average.

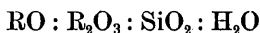
The crystals are attached by an edge, about half of the full crystal being developed free. They are extremely brittle, and fracture very easily at right angles to the horizontal edge of R, *i. e.*, parallel to  $\infty$  P 2, so that material suitable for optical observation could not be obtained.

Associated with the levynite in some cavities or appearing independently in adjoining ones, is a fibrous mineral, dull white in color and never showing crystal faces. As seen below it is practically identical with the levynite in composition, although so different in formal development. It cannot be referred to any definite species from present data.

**CHEMICAL COMPOSITION.**—Analysis of the pure crystals of levynite gave XXI, while the allied substance has the composition XXII:

	XXI.	XXII.
SiO <sub>2</sub> .....	46.76	46.97
Al <sub>2</sub> O <sub>3</sub> .....	21.91	22.39
CaO .....	11.12	10.85
K <sub>2</sub> O .....	0.21	1.17
Na <sub>2</sub> O .....	1.34	0.79
H <sub>2</sub> O .....	18.65	18.03
	99.99	100.20
(W. F. Hillebrand.)		

Oxygen ratios:



XXI. 1 : 2.90 : 7.01 : 4.66

XXII. 1 : 3.01 : 7.15 : 4.58

The water lost in drying has been included in the oxygen ratios, for the reasons given under laumontite. The ratios for dried material are:

XXI. 1 : 2.90 : 7.01 : 4.03

XXII. 1 : 3.01 : 7.15 : 3.94

#### OTHER MINERALS.

##### BOLE.

**DESCRIPTION AND ANALYSIS.**—In many irregular cavities in the scoriaceous crust of the lower sheet, and especially noticeable at about the centre of the northern face of South Table Mountain, is a dark brown clay which probably comes under the above head. It is very dense and apparently homogeneous, and has the peculiar fracture characteristic of such masses. Placed in water it falls apart without decrepitation. It is often associated intimately with a brown massive calcite, and in other cases it alone fills cavities completely. Two specimens, one of a light (XXIV), the other of a dark brown color (XXIII), were subjected to analysis.

	XXIII.	XXIV.
SiO <sub>2</sub> .....	42.63	46.17
Al <sub>2</sub> O <sub>3</sub> .....	18.76	22.03
Fe <sub>2</sub> O <sub>3</sub> .....	11.88	4.64
CaO .....	2.59	2.30
MgO .....	3.39	2.42
K <sub>2</sub> O .....	0.35	} *2.06
Na <sub>2</sub> O .....	0.24	
H <sub>2</sub> O .....	20.21	20.38
	100.05	100.00

(W. F. Hillebrand.)

\* By difference.

From these results no satisfactory ratio or formula can be deduced. They probably represent mixtures of different hydrous silicates.

### CALCITE.

**OCCURRENCE AND DESCRIPTION.**—The carbonate of calcium has had three periods of deposition in the basaltic cavities of Table Mountain, two as calcite and one as aragonite. In the form of wine-yellow crystals it preceded even chabazite, being in all observed cases deposited directly on the basalt and coated usually by chabazite or thomsonite. It is rarely found in those cavities to which water has had access through fissures, having been dissolved. The second deposit of calcite came after apophyllite. These crystals are colorless or slightly straw-yellow, and the form of both varieties is commonly that of a sharp scalenohedron terminated by a low rhombohedron.

The aragonite is present only as a snow-white incrustation, apparently with a special tendency to deposition upon chabazite, though often noticed upon apophyllite and thomsonite. It was next to the last mineral deposited, only mesolite having been observed upon it.

The brown calcite mentioned as associated with bole is never present in the zeolitic cavities.

## II.—MINERALS FROM THE NEIGHBORHOOD OF PIKE'S PEAK.

By WHITMAN CROSS and W. F. HILLEBRAND.

### GENERAL.

The name of Pike's Peak has become well known the world over in connection with the large and perfect crystals of Amazon stone (microcline) which have found their way into almost every mineral collection of importance, and yet the stranger who ascends the mountain from Manitou may see no sign of that or of any other of the numerous species accredited in a general way to the region. It may be well, therefore, to preface this description with a few remarks concerning the mode of occurrence and the distribution of the Pike's Peak minerals.

The mountain proper rises to a height of 14,147 feet, and is surrounded by many lesser peaks which reach 10,000 feet. The same coarse reddish granite which forms the greater part of all these points extends in a northerly direction for at least 35 miles. Owing to a lack of gold and silver bearing ores the granitic formation has not been thoroughly explored, the region is uninhabited, excepting on certain routes of travel, and the great majority of the mountains and streams are unnamed. Hence it is that minerals found in many remote spots are afterwards labelled simply as from Pike's Peak. For many of the species the inaccuracy is unimportant, as throughout the entire granitic area some of them are surely to be found upon search.

LIST OF SPECIES KNOWN.—Up to the year 1882 the following minerals had been identified with certainty, viz.: Microcline, albite, biotite, muscovite, quartz (smoky and clear), fluorite, columbite, göthite, hematite and limonite (pseudomorph after siderite), arfvedsonite, astrophyllite, zircon, bastnäsite, and tysonite. The species described in this article have been identified by us since that time, viz: topaz, phenacite, kaolinite, cryolite, pachnolite, thomsenolite, gearksutite, ralstonite (?), prosopite, and elpasolite.

Another series of minerals now in the course of investigation embraces several salts of cerium, yttrium, etc., belonging to species not as yet fully determined, although xenotime and ytrotantalite are probably present. Cassiterite also occurs in small quantity. (See p. 74.)

**MODE OF OCCURRENCE.**—The reddish granite of the region belongs to a type common in the Colorado range of the Rocky Mountains, and is supposed to be a part of the Archæan formation. It consists of a largely predominant reddish feldspar, to which are added brilliant black biotite and quartz, the latter subordinate, and occurring in small grains. The feldspar consists largely of an intergrowth of orthoclase and albite, somewhat after the manner of perthite.

Throughout the granite body, though much more abundant in some places than in others, are drusy cavities or "pockets" of very variable size, and often distorted by movements of the rock mass. Lining these druses, or entirely filling them in some cases, are crystals of feldspar and smoky quartz, in the first degree, with fluorite, topaz, phenacite, zircon, göthite, hematite, and limonite, as more or less constant companions.

The granite disintegrates rapidly through the action of the weather into a coarse, gravel-like mass, and many of the mountain slopes are covered by such material, with solid rock appearing here and there. On finding fragments of crystal in the *débris* the prospector for minerals, with pick and shovel in hand, endeavors to find the original cavity from which the fragments came. One of these druses has been known to yield more than a ton of crystallized specimens of Amazon stone, smoky quartz, etc.

Vein-like masses, composed chiefly of white quartz and reddish microcline, are also locally abundant, and in these are sometimes found small masses of cryolite and its alteration products, with zircon, astrophyllite, and columbite as observed associates.

#### CRYOLITE.

**LOCALITY.**—The point at which cryolite and its alteration products have been found is at the northeastern base of Saint Peter's Dome, a minor peak due west of Cheyenne Mountain and near the toll-road from Colorado Springs to the Seven Lakes, at the southern base of Pike's Peak. The spot lies nearly on the southeastern border of the extensive region within which Amazon stone and its associates occur, and may be thus considered within the "Pike's Peak region," although several miles distant from the mountain proper. The fluorides were first shown in a prospect shaft and in a neighboring tunnel, but visits made to the locality since the first publication have proven the presence of cryolite masses in several of the small irregular veins north and west of Saint Peter's Dome.

**OCCURRENCE AND ASSOCIATION.**—The manner of occurrence and the relationship of the fluoride masses can now be stated much more clearly than was possible in our first notice. Cryolite, in the massive form to be described, was deposited in the veins of secretion which are

so abundant in the granite country rock, in small but pure and homogeneous masses. Some of these veins have certainly had two periods of secretion, as is shown in the Eureka tunnel, Saint Peter's Dome. This tunnel penetrates for about 200 feet an irregular mass, consisting largely of white quartz and reddish microcline. The greater part of the quartz is the common white vein material containing no included minerals, but a portion of it, appearing in sharply defined angular blocks, is full of the transparent zircon to be hereafter described. Small particles of microcline are also disseminated through this quartz, while in the body of the vein it presents huge individuals, sometimes several feet in diameter. An examination of the tunnel walls shows here and there faces of pure massive fluorides 5 or 6 feet across and sharply defined against both pure and zircon-bearing quartz, the spaces filled being very irregular and angular. No contemporaneous minerals of importance accompany the zircon and cryolite in this vein.

The purity or homogeneity of the white quartz, zircon-bearing quartz, and fluoride masses, together with their irregular forms, seems to indicate different periods of development, and it seems further probable that a time of disturbance, in which the original quartz and feldspar vein was much fractured, produced the irregular spaces subsequently filled by different deposition. The cryolite may have been formed here during the time in which fluorite and topaz were deposited in the cavities of the region to the northwest.

The only mineral observed to be undoubtedly contemporaneous with the cryolite is columbite, which has been seen in small crystals embedded directly in fresh cryolite. At one place as trophyllite blades penetrate cryolite, but these are implanted directly upon the granite wall, and are probably an earlier formation, as are the zircon crystals at their base, and impregnating the granite itself. In the immediate neighborhood arfvedsonite and astrophyllite are quite abundant, both occurring most frequently embedded in white massive quartz. The original locality of tysonite and bastnäsite is not far from Saint Peter's Dome, but little is known to us concerning the manner of occurrence of these minerals.

**PURELY SCIENTIFIC VALUE OF THE DISCOVERY.**—As numerous inquiries concerning the probable commercial value of this new cryolite locality have been received since the published description, it may be well to emphasize the conclusion which is clearly suggested by the description of the occurrence of the mineral. All the cryolite as yet known occurs in the form of subordinate masses in the veins of secretion which appear here and there throughout the granitic formation, and there is no reason to suppose that masses of economic importance can occur in the region.

**RECENT LITERATURE OF CRYOLITE AND ITS ALTERATION PRODUCTS.**—The minerals of this group, of which so little was known a few years ago, are now among the best known. As most of the recent pub-

lications are of direct interest to us in describing the material of the new find, a brief mention of the leading articles is in place.

The earliest contribution to be mentioned is that of Prof. P. Groth, then in Strassburg, who instituted a careful investigation of cryolite and its alteration products, several of which had received names without satisfactory proof of their homogeneity, while more or less doubt was justifiable in regard to the chemical composition of all of them. Similar rare minerals of other occurrence were also studied. The purely mineralogical part of this investigation was conducted by Professor Groth personally, while material selected by him was subjected to chemical analysis by Dr. J. Brandl, in Munich. To the papers by Messrs. Groth<sup>16</sup> and Brandl<sup>17</sup> we shall refer frequently in the course of the following description. Owing to better material we are able to supplement in some particulars the results of these gentlemen, and in but a single case, namely, in regard to the composition of pachnolite, is there any discrepancy between our conclusions and theirs.

Concerning the crystallography of the group, Krenner<sup>18</sup> and Des Cloizeaux<sup>19</sup> have made important contributions while the laws of twinning in massive cryolite have been investigated by Mügge.<sup>20</sup>

**GENERAL DESCRIPTION.**—The pure cryolite appears in massive aggregates of large individuals, quite like that from Greenland. The three prominent cleavage surfaces are often continuous for two or three inches, indicating the size of the individuals present. A delicate pink or even decidedly rosy hue is characteristic of the freshest substance found, but the greater part is either of a faint greenish tinge or dull white, and none so far obtained has the snowy whiteness or the clearness of the Greenland mineral. The color disappears on heating, leaving the cryolite pure white.

The three marked cleavage directions are situated nearly at right angles to each other and one seems slightly more perfect than the other. A parting parallel to these planes is by no means so easily effected as one would expect from the distinctness with which they are seen, a fact explained by the complicated polysynthetic structure to be described.

**TWIN STRUCTURE.**—As no crystals of cryolite have been found in this locality, the study of the complicated twin structure exhibited by the massive material is no easy matter. The recent investigations of

<sup>16</sup> P. Groth. "Beiträge zur Kenntniss der natürlichen Fluorverbindungen," *Zeitschrift für Krystallographie*, VII, pp. 375-388 and 457-493, 1883.

<sup>17</sup> J. Brandl. *Sitzungsbericht der königl.-bayr. Akademie der Wissenschaften zu München*, 1882, p. 118, and *Annalen der Chemie*, CCXIII, p. 1.

<sup>18</sup> J. A. Krenner. "Die grönländischen Minerale der Kryolith Gruppe." Budapest, 1883.

<sup>19</sup> A. Des Cloizeaux. "Nouvelles observations sur le type cristallin auquel doit être rapportée la cryolite." *Bull. Soc. Min. d. Fr.*, 1883.

<sup>20</sup> O. Mügge. "Über die Zwillingsbildung des Kryolith." *Jahrbuch d. wiss. Anstalten zu Hamburg*, 1883, p. 67.

Krenner, and especially those of Mügge upon the massive mineral from Greenland, have, however, done much to make the relations clear.

Dana<sup>21</sup> mentions  $\infty$  P, Websky<sup>22</sup> 0 P and  $\infty$  P  $\infty$ , and Krenner<sup>23</sup>  $\infty$  P and  $\frac{1}{2}$  P as twinning planes identified upon crystals of cryolite. Mügge<sup>24</sup> seems to have identified  $\pm \frac{1}{2}$  P as a twinning plane in the massive material, independently of Krenner's determination. In all the above-mentioned laws the axis of revolution is the normal to the twinning plane, which is usually the composition face. The polysynthetic development of various laws was briefly alluded to in the first notice of the Colorado cryolite, and the descriptions of Mügge show that a similar, although by no means equally complicated, structure exists in the Greenland mineral.

The well known pseudo-symmetry of cryolite is illustrated by the following values, taken from Krenner:  $\beta = 89^\circ 49'$ ; the prism angles are  $88^\circ 2'$  and  $91^\circ 58'$ , the angles between 0 P and opposite prism faces are  $90^\circ 8'$  and  $89^\circ 52'$ . The axes of elasticity are also situated in peculiar agreement with this symmetry, the bisectrix lying in the clinodiagonal section, inclined  $43^\circ 54'$  to the vertical axis and  $45^\circ 55'$  to the clino axis. It is to be noticed that by all the above-mentioned laws of twinning the planes of 0 P and  $\infty$  P are brought in so nearly coincident positions that the deviations are unnoticeable upon the cleavage surfaces of the massive substance.

The examinations of Mügge were conducted upon thin sections lying in water, the index of refraction of the liquid being almost equal to that of cryolite. Our observations were made upon sections prepared in the usual manner. As none of them exhibit anything corresponding to the results obtained by Mügge on heating to a temperature of over  $400^\circ$  C., it is assumed that no change in the optical properties was produced by the temperature necessary in mounting these sections in balsam.

Although we cannot in the cleavage material distinguish with certainty between  $\infty$  P and 0 P, or between the positive and negative quadrants, still, if from a given cube, sections be prepared parallel to each of the three cleavage faces, we should be able to observe the relations of all twinning laws seen to each other and to a ground form which can be assumed. For a clear distinction of all the individual parts it is necessary to examine the thin sections between crossed nicols and with an inserted gypsum plate giving the field of vision a red color of the higher order. As nearly all the twinned parts are symmetrically related to  $\infty$  P or 0 P, the first position in which their relations can be seen to advantage is secured by placing the cleavage lines in each section  $\pm$  to the principal sections of the crossed nicols. This position is hereafter designated as position I. It is evident that the extinction in the basal section takes place parallel to the diagonals of the prism, as indicated

<sup>21</sup> System of Mineralogy, 5th ed., p. 127.

<sup>22</sup> Neues Jahrbuch für Mineralogie, etc., 1867, p. 810.

<sup>23</sup> *Loc. cit.*

<sup>24</sup> *Loc. cit.*



by the cleavage lines, *i. e.*, about  $45^\circ$  from each. The theoretical extinction parallel to a face of  $\infty P$  is  $31^\circ 15'$  from the vertical axis (Groth), which direction lies parallel to one set of cleavage lines.

The various laws of twinning observed will now be taken up and the resulting structure parallel to each of the cleavage faces described.

*Law a.*—Twinning plane and composition face  $\infty P$ , axis the normal upon it.

One of the three sections shows a fine banded structure parallel to one set of cleavage lines; this resembles plagioclase twinned according to the albite law, but the boundaries are less clearly defined. In position I alternate bands are blue, the remainder yellow; reversed colors are produced by a revolution of  $90^\circ$ ; extinction occurs at about  $31^\circ$  from the twinning plane, right or left according to color. The second section shows no such banded structure, but extinction takes place at  $31^\circ$  from either cleavage system. The third section exhibits a banded structure with blue and yellow colors, but with nearly coincident extinction at  $45^\circ$  from the twinning line, which is parallel to one cleavage direction.

As experience shows this twinning to be always parallel to one pair of prism faces and there is evidently a definite relation between the other laws and the present, we will assume the left-hand front prism-face as the twinning plane,  $\infty P (l)$ . The first section was therefore parallel to  $\infty P (r)$ , the second to  $\infty P (l)$ , and the third to  $0 P$ . This assumption is made in all subsequent discussion, so that the relations of the different laws may be correctly expressed.

The laminae are sometimes broad, but more frequently narrow, measuring 0.01 to 0.10<sup>mm</sup> in thickness. It is therefore difficult to prepare a section so nearly parallel to  $\infty P (l)$  that it shall not cut obliquely several of the laminae, producing a broad irregular banding, as represented in Fig. 7. The four vertical bands with irregular boundaries are alternately blue or yellow in position I, and extinguish at  $31^\circ$  right or left.

*Law b.*—Twinning plane and composition face  $\frac{1}{2} P (r)$ , axis the normal upon it.

Sections parallel to  $\infty P (r)$  usually show in each lamina produced by the first law a structure illustrated by the lower left-hand portion of Fig. 8. The parts of new orientation are represented by the small rectangular or graphic forms lying parallel to the diagonals of the square, right or left as the case may be, and however zigzag the shape the bounding lines are almost always parallel to the diagonals mentioned. These forms are apparently identical with those described by Mügge as twinned parallel to  $\pm \frac{1}{2} P$ , and they appear in the other two sections in a manner agreeing with this supposition. In Fig. 7 they are represented by the smaller horizontal lamellae which do not cross the boundaries of the broad bands, and in Fig. 9 by the vertical lamellae included in the larger ones. They are therefore cut by the plane  $\infty P (r)$  nearly or

quite at right angles, and their inclination is that of the plane  $\pm \frac{1}{2} P$ , according to which they are intergrown.

The explanation above given is, however, insufficient, as there are particles of three distinct optical orientations among these formally indistinguishable portions. If a lamina cut parallel to  $\infty P (r)$  be placed in position I, and then shows a blue color, the visible included parts of the form in question will appear yellow. On revolving the lamina  $31^\circ$ , to its position of extinction, it is found that some of those diagonally-situated particles have the same extinction as the lamina containing them, while the others become still brighter yellow and are found to extinguish simultaneously with the adjacent yellow lamina. On moving the section out of position I diagonal parts of the third orientation appear. These were blue in position I, but do not extinguish with the substance surrounding them; on the contrary, they correspond in this particular with the neighboring yellow lamina. It is impossible to definitely determine the laws according to which the substances are twinned, but in Fig. 10 the observed relations are explained in one way. The larger arrows indicate the normal directions of extinction parallel to  $\infty P (r)$ , with reference to the vertical axis. The area  $x$  represents the position of the corresponding directions of extinction in a lamella twinned parallel to the upper right-hand face of the positive hemipyramid,  $\frac{1}{2} P (r)$ . This will extinguish at  $31^\circ$  to the right from the vertical axis, while corresponding very nearly in color with the inclosing substance in position I. This is considered the equivalent of the law identified by Krenner. The lamella  $y$  is related to  $x$  as if twinned according to law  $a$ , and thus will exhibit parallel extinction with the inclosing substance but the opposite color in position I. The part  $z$  corresponds in color and extinction to the adjacent lamina, twinned after law  $a$ , and intergrown parallel to  $\frac{1}{2} P (r)$  or  $-\frac{1}{2} P (l)$ .

Careful study of a number of sections has failed to show any method of distinguishing between these various parts aside from their optical orientation. Now one, now another, seems to predominate, and often all three are to be seen in a single lamina.

The sections parallel to  $\infty P (l)$  and  $0 P$  cut these thin particles at an oblique angle, and their proper optical action is thus so obscured that they cannot be used to test the accuracy of the relation represented by Fig. 10.

*Law c.*—Twinning plane  $\infty P \bar{\alpha}$ , axis the normal upon it, composition face  $\infty P$ , or an irregular surface near it.

Sections parallel to  $0 P$  never show a twinning plane running parallel to either pinacoid, and yet substance is found whose orientation corresponds to the requirements of the above law. This is shown upon  $0 P$  by polysynthetic twin structure parallel to the second prism plane,  $\infty P (r)$ , the laminae extinguishing at  $45^\circ$  and hence presenting  $0 P$ . (See Fig. 9.) This might be considered as twinning after the prism plane  $\infty P (r)$  except that a corresponding structure upon  $\infty P (l)$  does

not appear. There is, it is true, a vertical lamellar twinning sometimes seen, but accompanied by the substances intergrown as described under law *b*. This is represented in Fig. 7, and is the natural result of law *c*, which brings  $\infty P (r)$  with its twinning after laws *a* and *b* into parallel position with  $\infty P (l)$ , produces a crossing of the laminae upon  $0 P$ , and, lastly, brings  $\infty P (l)$  parallel to  $\infty P (r)$ . This latter position is naturally seldom seen in sections, as the part thus twinned is usually a rather thin plate parallel to  $\infty P (r)$ , of the chief individual. In one case, however, a section parallel to  $\infty P (r)$  which exhibits the usual complicated structure over the greater part, passes by an irregular indistinct line into substance of more simple action, like that represented for  $\infty P (l)$  in Fig. 7, as if the slightly oblique section plane had cut into the plate twinned after this law *c*. Websky describes the composition face, in the case noticed by him, as irregular, although lying approximately parallel to  $\infty P \infty$ .

*Law d.*—Twinning plane  $\frac{1}{2} P (l)$ , axis the normal upon it, composition face  $\infty P (l)$ , or an irregular surface near it.

By this law  $\infty P (r)$  and  $0 P$  are interchanged. It seems required to explain the appearance in the section parallel to  $\infty P (r)$  of laminae parallel to those of *a*, but with extinction of  $45^\circ$  (see Fig. 8), and the similar laminae on  $0 P$  with extinction of  $31^\circ$ , and including parts twinned after the law *b*. Upon  $\infty P (l)$ , the composition face, this law cannot be identified.

*Law e.*—Twinning plane— $\frac{1}{2} P (l)$ , axis the normal upon it, composition face irregular.

This law seems required to account for certain relations frequently seen upon  $\infty P (r)$  and  $\infty P (l)$ . Upon the former the usual structure of this face appears at right angles to its proper position, while upon  $\infty P (l)$  horizontal bands may be seen which are polysynthetic, and give extinction at  $45^\circ$  from position I. This would be explained by the law above given, and is illustrated by Figs. 7 and 8.

Of the above laws the first seems to be identifiable in all portions not parallel to the twinning plane, and the second is nearly as persistent. Law *d* affects substance already twinned after laws *a* and *b*, while *c* and *e* produce a twinning of matter showing *a*, *b*, and *d*. Laws *c*, *d*, and *e* are thought to be justified, for however irregular their composition face, the position of the parts twinned after *a* and *b* is always a very definite and regular one with reference to corresponding parts in the primary individual.

Whether the prismatic twinning plane is right or left, it is clear that the planes of laws *b* and *e* and the composition face of *c* lie in the zone between the prismatic twinning plane and  $0 P$ , and that the plane of *d* is in the zone of  $0 P$  to the other prism plane.

No twinning parallel to  $0 P$  was noticed, unless a horizontal division of a few laminae twinned after *a* be thus interpreted (Fig. 8).

**CHEMICAL COMPOSITION.**—For all analyses of this and the following minerals the greatest care was taken to have the purest of reagents. The fluorine was in all cases determined by the Wöhler-Fresenius method, with the slight modifications introduced by Brandl,<sup>25</sup> except that the iron plate instead of the oil-bath was used for heating. The sulphuric acid was obtained of the highest degree of concentration and purity by distillation from a platinum retort. The water was determined by absorption in a chloride of calcium tube, the mineral having been heated in a tube with either oxide of lead or carbonate of sodium, the results being the same whether one or the other was used.

The cryolite, of which the analysis is here given, possessed the specific gravity 2.972 at 24° C., was faintly pink in color, and contained as a visible impurity the oxide of iron represented in the analysis:

	XXV.
FerO <sub>3</sub> .....	0.40
Al.....	<sup>26</sup> 12.81
Ca.....	0.28
Na.....	32.40
H <sub>2</sub> O.....	0.30
F.....	<sup>a</sup> 53.55
	99.74
(W. F. Hillebrand.)	

<sup>a</sup> As the mean of 53.35, 53.46, 53.55, and 53.85.

The presence of a slight amount of water indicates incipient alteration, but although purer and fresher material was subsequently obtained, a second analysis seems unnecessary.

**ALTERATION OF CRYOLITE.**—Although pure and fresh cryolite is common, the greater part of masses so near the surface is naturally changed. In the Eureka tunnel the surfaces seen upon the walls exhibit plainly the three cleavage directions of cryolite, especially when moistened. The material is chiefly massive pachnolite, however, as can be distinctly seen in thin sections, while fresh cryolite is still visible in small patches. Alteration of the cryolite proceeds in two ways, producing the same minerals in the end. By one process the principal cleavage fissures are utilized by the solutions which effect the change, and thin walls are formed of a white crystalline substance. The next step seems to be the bodily removal of the cryolite matter between these walls, leaving a network of partitions in the three directions of the chief cleavages of the original cryolite. These partitions or walls are lined by minute crystals. The second mode of alteration proceeds from the neighboring quartz and from the boundaries of the different crystalline individuals of the cryolite, the result being a compact crystalline mass of a faint bluish tinge. The material at hand illustrates the two processes and their products about equally well, and they are often combined.

<sup>25</sup> Annalen der Chemie und Pharmacie, CCXIII, p. 1.

<sup>26</sup> If Al=27. In this and all subsequent analyses, percentages of aluminium are calculated with the assumption of 27 as its atomic weight.

A large part of the material in the Eureka tunnel is a massive mixture of indistinguishable compounds, probably derived from the alteration of pachnolitë. Fluorite is one of the further products, but never appears prominently.

The small mass of fluorides struck in the incline near the Eureka tunnel is remarkable for the purity of a number of further products. Near the quartz and granite walls decomposition has progressed until a pure white substance has been formed, which, when dry, is a kaolin-like powder of extreme fineness. It resembles plaster of Paris when wet, as it invariably is in the vein. This is the geadsudit to be described further on. From this same small mass were obtained most of the specimens utilized in the determinations of the species whose consideration follows.

#### PACHNOLITE.

FROM THE THIN WALLS.—The microscopical examination of the walls and membranes produced by the first mode of alteration of the cryolite, shows them to be coated by many minute but perfect, colorless, and transparent prismatic crystals, which are usually placed at right angles to the central plane of the wall, though sometimes in an irregular manner. They reach a maximum length of  $2^{\text{mm}}$  by a thickness of  $0.2$  to  $0.4^{\text{mm}}$ . The crystals are occasionally yellow in color while retaining their transparency, the color being doubtless owing to some matter derived from the alteration of the astrophyllite which penetrates all such specimens. The crystallographical identification of these crystals with pachnolite is quite certain, for upon placing them in vertical position under the microscope the prism angles can readily be measured, and correspond closely to  $81^{\circ} 24'$  and  $98^{\circ} 36'$ , the theoretical angles of pachnolite (see Groth, l. c., p. 463). The prism  $\infty P$  and base  $OP$  are in all cases the chief faces, accompanied frequently by a hemi-orthodome and very rarely by a clinodome, both very slightly developed. The former is considered to be  $-P \infty$ , from data given below. Pyramid faces have not been seen upon crystals of this growth. Although all detached crystals show, when examined in polarized light as lying upon a prism face, an oblique twinning plane in the prismatic zone,<sup>27</sup> still a projecting angle upon the base can but rarely be seen. The reflecting surfaces of the thinnest walls are composed of innumerable small facets of rhombic outline,—the basal planes of the very low prisms. In fragments from some of the thinnest walls, placed horizontally under the microscope and observed in polarized light, twinning parallel to the shorter (ortho-) diagonal can easily be seen. The crystals are usually quite equally bisected by the twinning line. The central portion of these walls is rather dull white, and probably represents the alteration product on cleavage planes of the original cryolite, while the crystals

<sup>27</sup> Groth, l. c., p. 464.

themselves were formed during or after the removal of the intermediate cryolite substance. Material from a network of thin walls covered by pachnolite crystals was subjected to chemical analysis, yielding the result under XXVII, p. 54.

FROM THE BLUISH MASSIVE ALTERATION PRODUCT.—The pale bluish mass formed by the second mode of decomposition has, in great part, a regular crystalline structure produced by a more or less perfect intergrowth of pachnolite individuals in three directions approximately at right angles to each other. Nearly simultaneous reflection over the greater part of certain irregular surfaces make this relation plain. By the examination of such a surface with a lens one can usually identify a number of rhombic facets which are nearly or quite coincident in position with striated planes, the two corresponding to  $OP$  and  $\infty P$  of different individuals. Such a structure is also illustrated by the crystals in the numerous small cavities occurring in the massive material.

These cavities are wholly of irregular shape and reach a maximum observed diameter of 3 to 4<sup>mm</sup>. The crystals lining them are often very perfect, and are occasionally 2 to 3<sup>mm</sup> in length, with a thickness of 1<sup>mm</sup> or less. The study of these crystals proves that, as in the preceding case, most of them must be referred to pachnolite, although thomsonolite is sparingly present. These pachnolite crystals differ in habit from those already described in that the pyramid is usually prominent, being, however, in nearly every case truncated by the basal plane; in fact, crystals without  $OP$  are very rare. The rhombic section of the prism is everywhere plain. Although every prism on being optically tested shows a twinning plane in the prismatic zone, the low projecting angle of  $179^{\circ} 20'$  upon  $OP$  can seldom be distinctly seen. Many crystals are somewhat extended parallel to one pair of prism faces. A hemi-orthodome of the same order as the pyramid is sometimes developed, and probably corresponds to that noticed upon the crystals of the foregoing type. Most of the crystals of these cavities, while very perfect and distinctly recognizable as pachnolite, are too small and their surfaces are too frequently covered by minute crystals of a later growth to be available for measurements with the goniometer. Two specimens, however, of the bluish massive material, when carefully examined, proved to contain pachnolite in a form allowing of more exact crystallographical, optical, and chemical investigation.

CRYSTALLOGRAPHICAL DETERMINATIONS.—The first of the specimens above mentioned, which we will designate specimen A, is about  $8 \times 5 \times 2$ <sup>cm</sup> in size, is somewhat more coarsely granular than the variety just described, and possesses in an eminent degree the regular structure there observed. While compact in the greater part of the specimen, there are portions in which the grains are more loosely aggregated together, and parts of individuals have perfectly developed crystal faces. In some minute cavities a few crystals with quite perfect terminations

were found, and upon these some faces were sufficiently large and polished to admit of measurements with a Fuess reflection goniometer. These crystals are about 1<sup>mm</sup> long and nearly the same in thickness. They show  $\infty P$ ,  $0P$ , with subordinate  $-P$ , and a negative pyramid determined, as  $-3P\bar{3}$ . They are all twinned parallel to  $\infty P\bar{\infty}$ , and the low projecting angle upon  $0P$  is sometimes distinctly visible.

The angles given in the following table are all means of numerous closely agreeing measurements and demonstrate the crystallographical identity of the mineral under discussion with pachnolite:

Angle.	Crystal a.	Crystal b.	Other crystals.	Calculated.
	$\circ$ /	$\circ$ /	$\circ$ /	$\circ$ / "
$\infty P \wedge \infty P$ .....	81 19	81 22	81 18	81 24
$\infty P \wedge 0P$ .....	.....	90 21	90 21	90 20
$-P \wedge 0P$ .....	.....	116 39	116 30	116 30
$-3P\bar{3} \wedge -3P\bar{3}$ .....	138 45	.....	138 45	138 52 14
$-3P\bar{3} \wedge \infty P$ .....	149 03	.....	.....	149 07 19
$0P \wedge 0P$ (twin) .....	.....	179 21	.....	179 20

The face  $-3P\bar{3}$  was observed on a number of distinct twin crystals, with projecting angle on  $0P$ , and in several cases on both of the negative angles.

Upon one side of specimen A are a few thomsenolite crystals, distinguishable by their prism angle of nearly  $90^\circ$ . They lie irregularly, and seem to be later in formation than the pachnolite. Upon them are deposited minute prosopite crystals and indistinct alteration products. In the mass of this specimen no thomsenolite can be detected, while all individuals with partially free development are plainly pachnolite. Analysis XXVIII of the table (p. 54) was made upon material obtained from the clear loosely granular portions of specimen A, and although it was necessary to include many transparent grains of irregular shape, in order to obtain a desirable amount of substance, there is no doubt in our own minds that thomsenolite was wholly absent from the material analyzed.

The second specimen, B, from which especially good material was obtained, had a seam 2<sup>cm</sup> thick of coarse granular structure running through it, and upon splitting it open along this seam two surfaces of water-clear loosely adhering crystalline grains of pachnolite were exposed with the regular arrangement described. Actual development of crystal faces other than the prism is rarer than in specimen A, but the size of the grains, reaching 5<sup>mm</sup> in length by 1—3<sup>mm</sup> in thickness, is such as to admit of the preparation of thin sections for optical examination, and also gave absolutely pure material for chemical analysis. None of the crystals upon which the faces were well formed were superior to those of specimen A, and only measurements of the prism angles were made. The face  $-3P\bar{3}$  was not observed at all.

The optical properties of these pachnolite crystals are such as to leave no doubt concerning their crystallographical identity with the

mineral described by Professor Groth as pachnolite. Several sections were prepared as nearly parallel to the clinopinacoid as possible. These exhibit in all cases a twin structure, and this is frequently polysynthetic. The twinning lines are straight and lie parallel to the vertical axis. Extinction takes place at  $21^{\circ} 30'$  to  $22^{\circ}$ ; or  $68^{\circ}$  to  $68^{\circ} 30'$  from the twinning line, in opposed directions in alternate laminae. According to Groth the bisectrix is in the plane of symmetry, and inclined  $68^{\circ} 5'$  forward from the vertical axis. Sections parallel to the base also show the twinning structure, the line lying parallel to the orthodiagonal.

A large part of the purest crystals and fragments from this specimen were used for chemical analysis and repeated water determinations, the results of which are given below (XXIX, p. 54).

**CHEMICAL INVESTIGATION.**—Previous to the analysis by Brandl<sup>28</sup> of pachnolite carefully selected by Groth, pachnolite and thomsenolite were considered to possess the same chemical composition. The results of all earlier analyses, excluding such as referred to manifestly very impure material, while frequently deviating materially from the figures required by theory for the formula  $\text{NaF}$ ,  $\text{CaF}_2$ ,  $\text{AlF}_3$ ,  $\text{H}_2\text{O}$ , still agree on the whole very well, as shown in the accompanying table, and fully justified the belief in the chemical identity of the two species.

	Thomsenolite.		Pachnolite.					
	Wöhler. <sup>29</sup>	König. <sup>30</sup>	Knop. <sup>31</sup>	König. <sup>30</sup>	Vom Rath. <sup>22</sup>		Hagemann. <sup>33</sup>	Calculated for $\text{NaF}$ , $\text{CaF}_2$ , $\text{AlF}_3$ , $\text{H}_2\text{O}$ .
Al.....	13.43	13.74	13.14	12.50	13.46	12.93	10.37	12.32
Ca.....	17.84	16.79	17.25	18.17	18.10	17.99	17.44	17.98
Na.....	10.75	10.10	*12.16	10.23	10.63	12.06	12.04	10.34
H <sub>2</sub> O.....	8.20	9.00	9.60	8.19	.....	.....	8.63	8.10
F.....	49.78	50.37	50.79	51.54	.....	.....	51.15	51.26
	100.00	100.00	102.94	100.63	.....	.....	99.63	100.00

\* Also, 10.80 and 10.81.

Wöhler's analysis was entirely confirmed some years subsequently by Jannasch,<sup>34</sup> in Göttingen, who analyzed pure thomsenolite selected by Klein.

In view of the above, the analysis of pachnolite by Brandl, showing results agreeing well with those required by the formula  $\text{NaF}$ ,  $\text{CaF}_2$ ,  $\text{AlF}_3$ , was calculated to cause no little surprise. Groth accepts without question the anhydrous nature of pachnolite, and endeavors to explain

<sup>28</sup> Annalen der Chemie und Pharmacie, CCXIII, p. 6.

<sup>29</sup> Neues Jahrbuch für Mineralogie, etc., 1876, p. 851.

<sup>30</sup> Proceedings Acad. Sci. of Phila., 1876, p. 42.

<sup>31</sup> Annalen der Chemie und Pharmacie, CXXVII, p. 61.

<sup>32</sup> Sitzungsbericht d. niederrhein. Ges. für Natur- und Heilkunde, 1860, XX, p. 141.

<sup>33</sup> Am. Jour. Sci., 1866, II, XLI, p. 119.

<sup>34</sup> Neues Jahrbuch für Mineralogie, etc., 1877, p. 808.



away the opposing evidence, shown in the foregoing table, by assuming that the supposed homogeneous material analyzed was contaminated largely with thomsenolite. As in no published analysis does the percentage of water fall below 7 per cent., this assumption necessitates a most improbable admixture of thomsenolite. In those cases where the percentage of water equals or exceeds that required for thomsenolite the presence of gearsutite is suggested by Groth as a possible explanation. Even on this supposition the percentage of foreign admixture could not fall below 50 per cent., in which extreme case the whole of the impurity must be gearsutite, an amount which it is difficult to conceive should have escaped the notice of such observers as König, vom Rath, and Knop, the latter of whom expressly says that his analysis was made upon material identified as pachnolite.<sup>35</sup> Notwithstanding the difficulty of explaining the agreement between the previous analyses of pachnolite and thomsenolite, on the assumption of the anhydrous nature of the former, the correctness of Brandl's analysis was not at first questioned by us.

In the course of the present investigation the compact bluish material (see page 50), having the specific gravity 2.980 at 22° C., was first analyzed, the crystalline pachnolite not having yet been observed. The results of analysis as given under XXVI, below, agree in the main so well with the figures required for the formula  $\text{NaF}$ ,  $\text{CaF}_2$ ,  $\text{AlF}_3$ ,  $\text{H}_2\text{O}$ , that no hesitation was felt in considering the mineral to be thomsenolite, probably slightly contaminated with fluorite. Later, the crystalline coating on the thin walls produced by the first mode of alteration of the cryolite, the crystals forming which had not yet been identified crystallographically as pachnolite, were subjected to analysis with the results given under XXVII. Here again the identity with thomsenolite seemed clear. It was not until the analysis of perfectly transparent fresh crystals and crystal fragments, all taken from specimen A, above described, gave the results shown under XXVIII, that the possibility of the first analyses having been also made upon pachnolite was suggested. That this was, however, so in the case of No. XXVII, subsequent careful examination fully revealed, though the crystals analyzed were not entirely free from foreign admixture. It seems certain, also, that the compact bluish portions (XXVI) consist almost entirely of pachnolite, although it cannot be positively asserted that some thomsenolite may not be intergrown with it. That no possible doubt might exist in the mind of any one as to the homogeneity of the material used for analysis XXVIII, a further analysis was made upon crystals from specimen B, above described, particular care being taken to identify each as pachnolite by the rhombic section. The results of this analysis appear under XXIX.

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<sup>35</sup>Neues Jahrbuch für Mineralogie, etc., 1876, p. 850.

	Hillebrand.						Brandl. <sup>36</sup>	Calculated for NaF, CaF <sub>2</sub> , AlF <sub>3</sub> , H <sub>2</sub> O.	
	XXVI.		XXVII.		XXVIII.				XXIX.
Al.....	11.94		12.93	12.92	12.14		12.27	13.51	12.16
Ca.....	19.32		15.27	15.17	18.06		18.04	18.83	18.12
Mg.....	0.13		1.53						
Na.....	10.43		10.28		10.23		10.25	11.73	10.36
K.....			0.13						
H <sub>2</sub> O.....	7.87	7.95	8.64	8.79	8.10	8.11	8.05		8.11
F.....					51.33	51.28	*51.39	55.69	51.35
					99.88		100.00	99.76	100.00

\*By difference.

Further determinations of water, on material from specimen B, gave 7.95, 7.99, 8.14, and 8.15 per cent. Still other determinations, some on material every fragment of which showed the rhombic section, others on material taken at random from the crystalline mass, gave results between 7.90 and 8.20 per cent. The specific gravity at 17°C. of the perfectly pure material, as the mean of four determinations varying between 2.963 and 2.968, was 2.965. A single determination on another portion, equally pure, at 22°C. gave 2.962. The transparent crystals, as well as all the other portions analyzed decrepitated violently on heating in a test tube, the walls became lined with the white deposit so characteristic of thomsenolite and pachnolite, and much water was given off. Hence it appears that the pachnolite from Pike's Peak and thomsenolite are identical in composition, unless the fact of all analyses of thomsenolite showing slightly more water than required for the formula NaF, CaF<sub>2</sub>, AlF<sub>3</sub>, H<sub>2</sub>O may indicate, as suggested by Groth, a partial replacement of fluorine by hydroxyl in that mineral. Should this prove to be the case, a plausible explanation of the difference in crystallization of the two minerals is offered without recourse to the theory of dimorphism.

A satisfactory explanation of Brandl's results, so opposed to those presented by all earlier analyses and the ones above given, is impossible, but it may be well to call attention to the fact that Brandl was obliged to make his determinations of fluorine and the metals upon quantities of 0.1106 gr. and 0.1430 gr. weight respectively, whereas material was not wanting for the present analyses, the determinations having been made upon weights of from 0.3 gr. to 0.75 gr. It nowhere appears that a direct test for water was made upon the material furnished by Groth. The latter, it is true, remarks (*l. c. p. 461*): "*Ausserdem bildet sich bei letzterem (Thomsenolite) in den kälteren Theilen des Rohres ein Wasserbeschlag, welcher beim Erhitzen reinen Pachnolithes natürlich ausbleibt.*" The absence of water does not, however, seem to be hereby proven, but simply to be assumed from the close approximation to 100 of Brandl's results, exclusive of water. Brandl himself says water is wanting, but does not mention whether this was ascertained

<sup>36</sup> Annalen der Chemie und Pharmacie, CCXIII, p. 6. The percentage of Al is calculated to correspond with the other analyses (Al=27).

by direct experiment. The small amount of material at his disposal renders it not improbable that no direct test was made.

Since the conclusion of the above investigations, through the kindness of Mr. Albert F. Damon, president of the Pennsylvania Salt Manufacturing Company, we have obtained specimens of Greenland cryolite and its alteration products. From one of these specimens was removed a large number of small, needle-like, pyramidally terminated, twinned crystals with a rhombic prismatic section, showing in fact precisely the common occurrence<sup>37</sup> and ordinary habit of pachnolite<sup>38</sup> as described by Groth. These crystals, slightly yellowish in color, but quite transparent, were individually examined under the microscope, all such as did not show beyond a doubt the above described habit being excluded. They were then tested in a small glass tube for water. Decrepitation ensued on heating and the walls of the tube became lined with a white powder, and also with a deposit of water, in such quantity as to preclude the possibility of its having been derived from but a small portion of the material experimented upon.

**OTHER FORMS OF PACHNOLITE.**—In some very cellular specimens, whose walls run irregularly and seemingly without reference to the cleavage of the original cryolite, are crystals of pachnolite of different habit from that so far described.

One or two of these cavities show crystals corresponding in size to those upon the thin walls, but exhibiting each and every one a re-entering angle on the free termination. In such little crystals the basal planes are prominent, and they are bounded on the inside by a pyramid and dome, doubtless  $-P$  and  $-P\bar{\infty}$ . Outward there sometimes appears another pyramid ( $+P?$ ), though the prismatic faces themselves usually form a sharp edge with  $OP$ . All these crystals are too small for measurement, but as the appearance described is such as would be normal for the termination by which the twin crystals are commonly attached, it seems admissible to consider the faces as  $OP$ ,  $-P$ ,  $-P\bar{\infty}$  and probably  $+P$ . On many twins of this kind the outer or positive angles between  $\infty P$  and  $OP$  are replaced by two faces greatly resembling those of  $-3P\bar{3}$ , and although entirely too minute for measurement it is probable that this form  $-3P\bar{3}$  is here represented. The crystals of Greenland pachnolite are always attached by the end with the re-entering angle, according to Groth.

#### THOMSENOLITE.

**OCCURRENCE AND DESCRIPTION.**—While it is quite certain that thomsenolite is present in small quantity with the pachnolite, it has been impossible to obtain any quantity of it for examination. The microscopical study of the minute crystals lining the thin walls described, shows a few of nearly square section with sharp pyramidal form and destitute

<sup>37</sup> P. Groth, *l. c.*, p. 461.

<sup>38</sup> P. Groth, *l. c.*, p. 462.

of a twin structure. These are usually deposited with corresponding ones of pachnolite in a wholly irregular manner upon the low crystals of pachnolite forming the main portion of the walls. The reflecting surfaces of the massive product show under the lens distinctly rhombic facets or striated planes; and thin sections, which reveal the characteristic twinning of pachnolite, afford no reason for suspecting the presence of thomsenolite here in any considerable quantity.

The statement already made for a single case (p. 51) is probably true for all cases where thomsenolite has been noticed, viz., that it is later in formation than the greater part of the pachnolite, although the latter mineral is usually present in a second generation, as contemporary with the thomsenolite. No chemical identification has been possible, but the nearly square section, perfect basal cleavage, and absence of twinning are under the circumstances quite sufficient proofs.

In many cavities, arising from both modes of decomposition of the cryolite, a second series of minerals has been deposited, chiefly as a whitish, easily crumbling aggregate of minute crystalline grains, which are recognizable under the microscope as thomsenolite, pachnolite, and a mineral of the isometric system. The difference in habit of the former two species is here quite plain, for some of the little crystals of thomsenolite are doubly terminated and show distinct monoclinic symmetry in spite of the square section, through the more prominent development of the negative pyramid, while pachnolite seems perfectly rhombic in form, through its twinning.

#### RALSTONITE.

PROBABLE IDENTIFICATION.—This rare species, originally described by Brush,<sup>39</sup> from microscopic crystals, has been more definitely determined by Groth and Brandl. Its chemical composition is, according to Brandl, expressed by the formula  $3\text{NaF}$ ,  $4\text{AlF}_3$ ,  $\text{H}_2\text{O}$ , a small part of the sodium being replaced by calcium. The crystals are of the isometric system, and represent the cube modified by the octahedron.

Groth's description of the occurrence of the mineral agrees very closely with that of the isometric mineral mentioned above as appearing with a recent generation of thomsenolite and pachnolite. The crystals here found are transparent cubes whose corners are replaced by small octahedron faces and seldom reach a diameter of  $1^{\text{mm}}$ , while sinking to microscopic size. Some crystals of pachnolite seem by a low magnifying power to be coated by a crystalline dust whose particles are found, by applying a high power, to be most perfect little crystals of the form just mentioned. These sometimes unite to form a crust. No material for a chemical test could be secured, but the analogy in form and occurrence is so complete that scarcely a doubt can exist of the identity of these beautiful little crystals with the species ralstonite, although another mineral of the same crystal system is now to be described.

<sup>39</sup> G. J. Brush, *Am. Jour. Sci.*, III, II, 30, 1871.

## ELPASOLITE, A NEW MINERAL.

Just at the close of our investigations a mineral was found, occurring sparingly in a few specimens, which seems to be very different from any known species. It was found in small cavities in the massive pachnolite as a compact irregular mass, colorless but not perfectly clear, and exhibiting but seldom traces of crystalline form. In one specimen, however, the mass of the mineral was covered by small rounded crystal-like projections, which seemed like crystals of the isometric system. An examination with a loupe showed the absence of recognizable faces, but such particles when broken off and tested under the microscope proved to be fully isotropic. A few faces found on one crystal seemed to belong to cube and octahedron, and particles detached from the same are isotropic in action in polarized light. Supposing that this substance must be ralstonite in exceptional development, enough material for the following partial chemical analysis was selected, being carefully freed from attached particles of pachnolite and other anisotropic minerals by microscopical examination. The Al, Ca, and Mg were accurately determined, the K and Na, owing to an unfortunate mishap, only approximately. No water could be detected by direct test upon a small portion. Fluorine was present in quantity, and the percentage given below is calculated on the assumption that the metals are fully combined with it:

	XXX.
Al .....	11.32
Ca .....	0.72
Mg .....	0.22
K .....	23.94
Na .....	9.90
F .....	46.98
	98.08
(W. F. Hillebrand.)	

From this analysis may be derived a formula analogous to that of cryolite, in which about two-thirds of the sodium is replaced by potassium.

The imperfections of the above analysis do not allow of definite conclusions as to the composition of the mineral, but it is nevertheless widely different from any known mineral species, while the purity of the substance is shown by its isotropic action in polarized light. Since the original description of the mineral<sup>40</sup> the locality has been revisited in the hope of obtaining more material, but the spot was at the time inaccessible, so that we can offer no further data concerning this interesting new species. We wish to propose the name *elpasolite* for it, from the county El Paso, which embraces the greater part of the Pike's Peak region. Further investigations as to the properties of the mineral will be made as soon as material can be procured.

<sup>40</sup> Am. Jour. Sci., III, XXVI, 283, 1883.

## GEARKSUTITE.

**GENERAL DESCRIPTION.**—This mineral, first observed by Hageman<sup>41</sup> on compact thomsenolite, and described as earthy and kaolin-like in aspect, dull white, opaque, and of hardness 2, seems to be so rare in connection with the Greenland fluorides that no one has had material for further examination. Groth<sup>42</sup> found it in very small quantity among the minerals at his disposal, but could not obtain enough for analysis. He found, however, that it consisted of very minute microscopic needles, with oblique extinction, and considers it as undoubtedly a definite species.

Among the minerals from St. Peter's Dome gearksutite is quite abundant. It is not formed from other minerals by molecular replacement, but is deposited from solution in cavities upon fresh crystals of pachnolite, etc. The smaller cavities are sometimes filled by it, and on the contact with the quartz it is specially developed.

In appearance it corresponds closely to the description of the Greenland mineral as given by Dana, the resemblance to the purest, finest kaolin being especially remarkable. Examined microscopically, gearksutite is seen to consist, as stated by Groth, of exceedingly minute colorless needles, the average length of which is less than 0.02<sup>mm</sup> and the thickness less than 0.002<sup>mm</sup>, and apparently possessing oblique extinction.

**CHEMICAL INVESTIGATION.**—Gearksutite was found by Hagemann (*l. c.*) to possess the following composition :

Al.....	15.52
Ca.....	19.25
Na.....	2.46
H <sub>2</sub> O.....	26.22
F.....	41.18
	<hr/>
	98.63

An examination of the above results shows that the atomic ratio of Al:Ca+Na<sub>2</sub>:F is 1:1:4, instead of 1:1:5, which would represent complete saturation and require about 12 per cent. more fluorine than was found. On the assumption that the missing fluorine is replaced in the mineral by oxygen or hydroxyl, there should appear a much greater loss than the analysis indicates. An error is therefore evident, probably in connection with the determination of the fluorine or of the water, or both, in consequence of which the construction of a satisfactory formula has heretofore been impossible.

The material for the following analyses was first partially crushed, then freed from admixed heavier particles of foreign matter by triturating in a beaker with water, the impurities falling to the bottom of the vessel, while the light gearksutite remained suspended in the liquid

<sup>41</sup> Dana, System of Mineralogy, 5th ed., p. 130.

<sup>42</sup> Groth, *l. c.*, pp. 460, 481.

and was removed by decantation. By repeating this operation a great many times a product was finally obtained entirely free from all foreign admixture. It was allowed to settle completely, the supernatant liquid poured off and the residue dried first on the water bath, then at 100° C. Thorough pulverization of this residue is a difficult matter, as it flattens out under the pestle, forming flakes which strongly resist the pulverizing action. This is of little moment, however, since the flakes are so spongy as to offer no hindrance to attack by sulphuric acid. Two analyses were made from the same sample, with the results tabulated below. In *b* sodium and potassium were not determined:

	XXXI.		
	<i>a.</i>	<i>b.</i>	Mean.
Al.....	15.22	15.19	15.20
Ca.....	22.29	22.32	22.30
Na.....	0.10	.....	0.10
K.....	0.04	.....	0.04
H <sub>2</sub> O.....	15.54	15.39	15.46
F.....	42.14	42.01	42.07
	95.33	.....	95.17
Loss as O.....	4.67	.....	4.83
	100.00	.....	100.00
(W. F. Hillebrand.)			

Taking the figures in the third column and combining the fluorine with the calcium, sodium, potassium, and, as far as possible, with the aluminium, there remains of the latter 5.35 per cent., requiring 4.76 per cent. of oxygen, an amount agreeing very well with that obtained above by difference and making the sum total almost exactly 100:

22.30 Ca	requires 21.18 F.
0.10 Na	requires 0.08 F.
0.04 K	requires 0.02 F.
9.85 Al	requires 20.79 F.
10.11 Al <sub>2</sub> O <sub>3</sub>	————
15.46 H <sub>2</sub> O	42.07
42.07 F	
————	
99.93	

The agreement of the above analysis with that of Hagemann, after substituting in the latter for the sodium its equivalent in calcium, is very close, with the single exception of the water. As his analysis was manifestly erroneous in some particular, the assumption of the identity of gearksutite with the mineral here discussed is fully justified, supported as it is by the similarity in occurrence, appearance, and physical characteristics. His error would then consist in having obtained from 4 to 5 per cent. too much water, a result not difficult of explanation, in

the case of a hydrated fluoride, if no precaution was taken to prevent the escape of fluorine.

Substituting in the mean of analyses *a* and *b* for sodium and potassium their equivalent of calcium, and dividing the percentages by the atomic weights, the atomic ratio is found to be as given below:

Al .....	$15.20 \div 27 = 0.563$
Ca .....	$22.41 \div 40 = 0.560$
H <sub>2</sub> O ....	$15.46 \div 18 = 0.859$
O .....	$4.76 \div 16 = 0.297$
F .....	$42.07 \div 19 = 2.214$

The ratio of Al : Ca : F is here nearly as 1 : 1 : 4, the same as found by Hagemann. Subtracting from the atomic value for water an amount 0.297 equal to that for oxygen, in order to form with the latter hydroxyl, the result is as given in the first column below, while in the second appears the ratio referred to calcium as unity.

Al.....	0.563	1.005
Ca.....	0.560	1.000
H <sub>2</sub> O .....	0.562	1.004
HO.....	0.594	1.061
F.....	2.214	3.954
		} 5.015

It will be seen that by combining hydroxyl and fluorine the ratio Al:Ca:H<sub>2</sub>O:(F,OH) is 1:1:1:5, and the formula for the mineral becomes CaF<sub>2</sub>, Al(F, OH)<sub>3</sub>, H<sub>2</sub>O, in which the fluorine and hydroxyl combined with the aluminium, stand nearly as 2:1. Were the latter proportion exactly fulfilled, the formula might be written 3CaF<sub>2</sub>, 2AlF<sub>3</sub>, Al(OH)<sub>3</sub>, 3H<sub>2</sub>O, requiring the percentages: Al 15.17, Ca 22.47, F 42.69, O 4.50, H<sub>2</sub>O 15.17=100.00.

Of the 15.46 per cent. of water found by analysis, 5.35 per cent. has been considered in the foregoing as basic. While this amount may, on theoretical grounds alone, enter into the inner constitution of the mineral as basic water, the remainder cannot, but must be water of crystallization. That a portion of the water is basic is rendered more than probable by the fact that at 300° C. some is still retained. In this connection the following experiments were made: 0.5677 gram of the mineral, not, however, from the same sample as that used for analysis, dried first at 100° C. and contained in a platinum crucible, was exposed in an air bath during 145 hours to temperatures ranging from 100° C. to 300° C., the weight being taken at intervals averaging 10 hours each. The results in brief showed that at 145° C. the loss was but 0.35 per cent., at 230° C. only 0.92 per cent., at 250° C. 7.02 per cent., after prolonged heating at 265°-270° C. 9.49 per cent., and at 295° C. 13.92 per cent. As no further loss occurred after six hours heating at 295°-300° C., a portion of the residue which still retained its original appearance was subjected to a quantitative test for water, of which 1.76 per cent. was found.



This added to the 13.92 per cent. driven off below  $300^{\circ}$  C. made the total 15.68 per cent. Since this is slightly higher than the mean of the previous results, it seemed possible that some fluorine might have escaped. The remainder of the residue was therefore tested quantitatively for fluorine, of which was found 40.60 per cent., thus apparently proving the correctness of the surmise. A similar experiment with the same general results was made upon a smaller portion of another sample. A comparison of the full results of both experiments showed that by sufficiently prolonged heating at approximately  $270^{\circ}$  C. all the water of crystallization could be driven off; also that by still further heating at little if any higher temperature the basic water began to escape, but was not entirely expelled even after many hours exposure to a temperature of  $295^{\circ}$ – $300^{\circ}$  C.

While these experiments cannot be considered as affording any conclusive proof that the water in this mineral is to be reckoned as water of crystallization and basic water in the above given proportions, since at the point when the last of the former is driven off by heat some of the latter appears also to escape, still the belief that this should be done is a natural one and is supported by the fact (which may possibly, however, be merely the result of accident) that by so doing the ratio of calcium to water of crystallization is exactly 1:1, while if all the water is assumed to be water of crystallization the ratio is 1:1.534 or 2:3.068.

EVIGTOKITE.—In the Journal of the Chemical Society for 1883, p. 140, Walter Flight describes a mineral obtained from the cryolite bed of Greenland. "It is made up of a congeries of minute white transparent crystals, mostly broken up and lying entangled among each other in every sort of direction, which gives the mass an appearance of opacity much resembling that of kaolin or chalk."

Chemical analysis showed it to consist of—

	Equivalents.
Al.....16.23 with F 33.64 = 49.87	0.59
Ca.....22.39 with F 21.27 = 43.66	1.12
Na.....0.43 with F 0.33 = 0.76	
	94.29
Water.....5.71	0.63
	100.00

The fluorine seems to have been calculated for the metals, and the water was found by difference.

From the above data the author obtains the formula  $2\text{CaF}_2$ ,  $\text{Al}_2\text{F}_6$ ,  $2\text{H}_2\text{O}$ ,<sup>43</sup> and, considering the mineral new, names it evigtokite.

Mr. Flight seems to have overlooked the description of gearksutite in Dana's System of Mineralogy and Professor Groth's remarks upon the same (l. c., pp. 481 and 493), else the very fair agreement of his analytical data for the metals with those of Hagemann, and the similarity of oc-

<sup>43</sup> Probably a printer's error. It should read  $2\text{CaF}_2$ ,  $\text{Al}_2\text{F}_6$ ,  $\text{H}_2\text{O}$ .

currence, appearance, and physical characteristics of the two minerals, must have led to at least a suspicion of their identity. There can hardly exist a doubt that Flight has analyzed gearsutite and that the name evigtokite is therefore to be dropped.

#### PROSOPITE.

**OCCURRENCE.**—This rare species, hitherto unobserved in association with the cryolite minerals and known only in connection with the tin-bearing veins of Altenberg in Saxony, has been identified at St. Peter's Dome.

Both of the coarsely crystalline specimens of pachnolite, above described as A and B, have prosopite upon them. Specimen B is in parts in process of alteration to a dull white substance with little cavities in which are minute crystals of prosopite. These are colorless, transparent, tabular in shape, agreeing exactly in form and optical behavior with those determined as prosopite by chemical analysis. In two other specimens of pachnolite prosopite tablets may be seen upon certain granular surfaces when decomposition of the pachnolite has already begun. The crystals are usually attached by the prismatic edges, although free and perfect terminations are to be found. Gearsutite was noticed upon them in one specimen and the position of prosopite in the series of hydrous fluorides is doubtless between thomsenolite and gearsutite. No material for chemical tests could be procured from the specimens described.

The penetration of the fluoride mass by astrophyllite blades springing from the side of the vein has been mentioned (p. 42). Here the cryolite has been altered to cellular pachnolite, according to the first mode described, and this has for the greater part given way to other products and been dissolved and carried away, leaving the astrophyllite blades more or less free or imbedded in gearsutite and other soft, crumbling material. The free blades usually have a coating composed of a little purplish fluorite, and over this a nearly colorless or slightly yellowish substance. At and toward the base of the astrophyllite blades the latter is present in roundish aggregates made up, as shown by the lens, of clear tablets, in more or less radiate arrangement. The crystal form is here quite obscure, but the general appearance was so suggestive of prosopite that by sacrificing the best specimen enough material was obtained for determination of the bases and of fluorine, with the result given below, XXXVI, p. 64.

Adjoining the quartz in the Eureka mine is usually an irregular zone of purplish or greenish fluorite, and next to this a rather coarsely granular mass of a colorless mineral, with two distinct cleavage planes, which passes gradually into the compact white substance beyond. This zonal arrangement is not without exceptions, for both granular and compact masses come directly in contact with the quartz in some specimens, and fluorite is more or less abundantly sprinkled through the

other substances; in fact, the relation of the minerals to each other is such as to indicate that they are but different phases of alteration from a common source. The granular mineral occurs in sufficient purity to afford material for chemical analysis, and its individuals are large enough to admit of the preparation of thin sections, with definite relations to the cleavage planes. The analysis first proved the identity of this mineral with prosopite, the optical properties shown by the thin section confirmed this determination, and a few minute crystals were found in one specimen, which agree with the published data on the Saxon mineral. As the identification of this rare species, particularly in its present association, is a matter of considerable interest, we will describe it somewhat in detail.

**CRYSTALLINE FORM AND PHYSICAL PROPERTIES.**—The minute crystals observed are all of the habit shown in Fig. 11 of the plate. This is from a camera lucida drawing of a crystal measuring 0.5<sup>mm</sup> normal to the edge of the prism, and can therefore make no pretensions to crystallographic accuracy. The crystals are colorless and transparent, have uniformly a tabular form through the development of  $\infty P \infty$ , and show painfully the prism and two pyramids, which may be considered as  $P$  and  $-2P\bar{2}$ , for extinction takes place nearly or quite parallel to the edge of  $-2P\bar{2}$ , which is, according to Des Cloizeaux<sup>44</sup> and Groth,<sup>45</sup> the position of the bisectrix.

Thin sections prepared as nearly as possible perpendicular to the edge of the two cleavage faces in the irregular granular individuals, show that the angle of the cleavage planes is very nearly 135°, and that extinction takes place parallel to the direction bisecting that angle. This behavior agrees perfectly with the statements concerning prosopite, according to which the chief cleavage is parallel to  $-2P\bar{2}$ , the angle of which is about 134°. The present material does not allow of a definite settlement of the question of the crystalline form of prosopite, but nothing observed is in conflict with the reference to the monoclinic system.

**CHEMICAL INVESTIGATION.**—The formula deduced by Brandl<sup>46</sup> for prosopite, from the results of his analysis as here given—

		Atomic values.
F .....	35.01	1.842
Al .....	23.37	0.853
Ca .....	16.19	0.405
Mg .....	0.11	0.004
Na .....	0.33	0.014
H <sub>2</sub> O .....	12.41	0.689
Loss as oxygen .....	12.58	0.786
	100.00	

<sup>44</sup> Bull. Soc. Min. de Fr., V, 317.

<sup>45</sup> *l. c.*, p. 290.

<sup>46</sup> Annalen der Chemie und Pharmacie, CCXIII, p. 13.

is  $\text{Ca F}_2, 2\text{Al (F,OH)}_3$ . The whole of the water is assumed to be basic, entering with oxygen into the constitution of the mineral as hydroxyl, the latter replacing an equivalent amount of fluorine. In support of this assumption Brandl mentions that no loss is perceptible below  $260^\circ \text{C}$ .

In an earlier partial analysis Scheerer (Pogg. Ann., CI, p. 361) found Al 22.77, Ca 16.41,  $\text{H}_2\text{O}$  15.50.

Of the analyses tabulated below, those under XXXII, XXXIII, XXXIV, and XXXV were made upon material from vein B. That analyzed under XXXII, *a* and *b*, was composed of comparatively large irregular crystalline pieces showing no visible impurity whatever, having a specific gravity at  $23^\circ \text{C}$ . of 2.880 and a hardness of about 4.5. As the ratio Al: Ca differed materially from that of 2:1, required by Brandl's formula, it appeared that some foreign matter must be present, consequently no further determinations were made, as it was hoped better material might be obtained.

Analysis XXXIII was made upon material separated from quartz, zircon, fluorite, and other accompanying minerals, by a solution of iodide of mercury in iodide of potassium. The result was a slight improvement, and the analysis was completed. The material for XXXIV was picked out carefully by hand with the aid of a lens; but as the result was still unsatisfactory, a further portion (XXXV), aggregating, however, only 0.1022 gram, was selected with the greatest possible care, every particle being distinctly crystalline, and showing under the microscope no trace of impurity. Here a slight improvement becomes evident in the ratio, but as the amount taken for analysis was so extremely small, it cannot be asserted that the better results may not be due to unavoidable errors of analysis. The material for analysis XXXVI was derived from the crystals occurring on astrophyllite. This material was, however, evidently not quite pure, being opaque and very slightly colored in part by oxide of iron. The analysis was made merely to prove its identity with the prosopite of the other occurrence.

	XXXII.		XXXIII.	XXXIV.	XXXV.	XXXVI.
	<i>a.</i>	<i>b.</i>				
Al .....	21.94	21.68	21.88	22.13	22.49	21.64
Ca .....	17.67	17.87	16.92	17.14	16.80	16.84
Mg .....			0.20		0.15	0.35
Na .....			0.48		0.48	0.79
K .....						0.11
$\text{H}_2\text{O}$ .....			*13.54			
F .....			33.14	33.22		32.30
Loss as oxygen .....			86.16			
			13.84			
(W. F. Hillebrand.)			100.00			

\* And 13.37.

The mean of analyses XXXII-XXXV is as follows:

Al.....	22.02
Ca.....	17.28
Mg.....	0.17
Na.....	0.48
H <sub>2</sub> O.....	13.46
F.....	33.18
<hr/>	
Loss as oxygen.....	86.59
	13.41
	<hr/>
	100.00

After subtracting from the fluorine an equivalent for the calcium, magnesium, and sodium, and combining the remainder with aluminium, there remains of the latter 14.39 per cent., requiring 12.79 per cent. of oxygen, instead of 13.41 per cent. found by difference. The atomic values appear as follows, after substituting for magnesium and sodium an equivalent of calcium:

$$\begin{array}{rcl}
 \text{Al} & \dots\dots & 22.02 \div 27 = 0.815 \\
 \text{Ca} & \dots\dots & 17.98 \div 40 = 0.449 \\
 \text{F} & \dots\dots & 33.18 \div 19 = 1.746 \\
 \text{H}_2\text{O} & \dots\dots & 13.46 \div 18 = 0.748 \\
 \text{O} & \dots\dots & 12.79 \div 16 = 0.799
 \end{array}
 \left. \begin{array}{l} \\ \\ \\ \end{array} \right\} 1.547 \left\} 3.293$$

The result is unsatisfactory, the ratio of Ca: Al being 1:1.81 instead of 1:2. In none of the material analyzed was the slightest trace of kaolinization to be observed, nor any other foreign matter. It therefore becomes impossible to explain with any degree of certainty the above abnormal results.

The general agreement of all the analyses, the aluminium being found too low and the calcium too high in each case, shows pretty conclusively that an explanation cannot be sought for in analytical errors.

As fluorite occurs here always in most intimate association with prosopite, and the possibility suggested itself that some of this might be so intergrown with the latter as to escape the closest scrutiny, it became desirable to ascertain what change would be effected in the ratio above given by subtracting enough calcium to make the ratio Ca: Al as 1:2, and an equivalent amount of fluorine. The atomic values then become:

$$\begin{array}{rcl}
 \text{Al} & \dots\dots & 0.815 \\
 \text{Ca} & \dots\dots & 0.408 \\
 \text{F} & \dots\dots & 1.664 \\
 \text{HO} & \dots\dots & 1.547
 \end{array}
 \left. \begin{array}{l} \\ \\ \end{array} \right\} 3.211 \left\} 7.87$$

which agree nearly as well for the formula  $\text{Ca}, \text{Al}_2 (\text{F}, \text{OH})_8$  as those obtained by Brandl.

If, instead of the mean of all the analyses, the figures of XXXIII alone

are taken for calculations similar to the above, the result is the same, even a little more closely approximating to the ratio 2:1:8.

The prosopite is much less readily attacked by sulphuric acid than the other fluorides described, and unless the pulverization is very thorough a small portion is generally left undecomposed even by boiling acid. To this fact may possibly be due the deficit of nearly 2 per cent. in fluorine, as compared with Brandl's results. On the assumption that 35 represents more nearly than 33.18 the true percentage of fluorine in the mineral analyzed, the ratio of water to required oxygen after combining all fluorine is 1:1.005, instead of 1.068. Allowing, then, for possible admixture of fluorite as above, the ratio Al:Ca:F+OH is 2.00:1.00:7.99, almost exactly 2:1:8.

The observation made by Brandl that below 260° C. no loss in weight occurs, was found to apply here, provided the exposure to this degree of temperature is short. If continued for many hours a slight but sensible loss is observed.

#### ZIRCON.

**GENERAL OCCURRENCE.**—Zircon is one of the most widely distributed minerals of the region, occurring as an associate of nearly all other species in veins and druses and also impregnating the granite itself. König<sup>47</sup> has described it as an associate of astrophyllite and as intergrown with microcline. In its usual form it is brown or nearly black in color, and has only the ground pyramid and corresponding prism, the latter quite subordinate. König identified the basal plane 0P, and it seems to appear in very minute form upon crystals of all modes of occurrence though on comparatively few from each place. Sometimes the zircon crystals are more than an inch in diameter, sacrificing perfection to size, as there is commonly more or less distortion of angles and unevenness of surfaces in such individuals.

**ZIRCON FROM THE EUREKA TUNNEL.**—Reference has already been made in describing the occurrence of cryolite to the mutual relations of the different parts of the irregular vein into which the Eureka tunnel has been driven. The part containing zircon is but small, comparatively, and is sharply defined. It evidently represents a contemporaneous formation of quartz, zircon, and microcline. Zircon crystals varying in size from less than 1<sup>mm</sup> to 1<sup>cm</sup> are very plentifully and uniformly scattered throughout, while small patches of reddish microcline were also included in the more abundant quartz and themselves inclosed numerous small zircons. The occurrence is noteworthy from the perfection in form and the transparency of the zircon.

The zircon crystals imbedded in quartz are sometimes perfect, but in most cases the formal development has been hindered by the surrounding mineral, producing striated or distorted faces. These crystals,

<sup>47</sup> G. A. König, *Zeitschrift für Krystallographie*, I, 423, 1877.

too, are much shattered by the jars of the blasting and the blows necessary in breaking up the larger pieces. Those smaller crystals deposited in the microcline were able to develop freely and they are now found imbedded in pure white kaolinite or a compact yellowish mica—the alteration products of the original microcline, some of which is yet visible. The nature of the surrounding material has protected these crystals from jars and also makes it possible to isolate single ones, absolutely unharmed, for examination. The color varies from a rich reddish brown to a light wine or honey yellow shade. A few minute crystals are of a deep emerald green and spots of similar color were noticed in some pinkish crystals. While a few are really gems in clearness and color, they are usually of the smallest size, and are those found in the kaolinite or mica.

The common habit of all crystals is pyramidal, the prisms being always subordinate when they appear. The forms determined with certainty are  $P$ ,  $3P$ ,  $0P$ ,  $3P3$ ,  $\infty P$  and  $\infty P\infty$ . The rare face  $0P$  is much less frequently developed than any of the others, but it was observed distinctly on at least twenty-five crystals. Repeated measurements on different crystals of the angle  $0P \wedge P$  give results varying less than  $3'$  from the calculated value ( $137^{\circ}50'$ ). Between  $0P$  and  $P$  is a low pyramid appearing quite constantly with  $0P$ , which forms an angle of  $164^{\circ}46'$  with  $P$ . This corresponds very nearly to  $\frac{1}{2}P$ . The angle between this form and  $P$  is replaced by a curved surface giving an almost continuous reflection, but the angle with  $0P$  is distinct.  $0P$  is often visible on but one termination, but it is by no means rare to find it upon both.

Chemical analysis shows this zircon to be exceedingly pure and the specific gravity of transparent crystals is 4.709 at  $21^{\circ}C$ .

#### KAOLINITE.

The chief alteration product of microcline in the Eureka vein proves to be a very pure kaolinite. Some of the large individuals are changed into a compact white foliate kaolinite in the mass of which the cleavage planes of the microcline are still indicated. In other cases a more coarsely foliate aggregate is formed, the single leaves of which are beautiful transparent crystals.

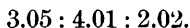
The smaller patches of microcline deposited in the zircon-bearing quartz are also changed into kaolinite or a yellow micaceous mineral whose analysis accompanies that of the kaolinite below. Sometimes small cavities in the quartz contain single projecting crystals. These are exceedingly thin, colorless, transparent, rhombic leaves, the acute angle being usually evenly truncated, producing sometimes an almost perfect hexagon. The result of many measurements under the microscope seems to indicate that the obtuse angle of the rhomb is slightly less than

120°, the best results varying from 118° 30' to 119° 30'. The thinnest leaves show distinct action on polarized light and extinguish parallel to the diagonals of the rhomb. The thicker crystals are made up of many tablets which are usually not perfectly coincident in position and sometimes form more or less perfect rosettes. The kaolinite possesses the composition XXXVII, and the mica XXXVIII, as given below. The kaolinite contained a small amount of fluorite in almost microscopic crystals, the quantity being calculated from the Ca found.

	XXXVII.				XXXVIII.
	a.	b.	Mean.		
SiO <sub>2</sub> .....	45.91	46.22	46.06	SiO <sub>2</sub> .....	52.59
Al <sub>2</sub> O <sub>3</sub> .....	39.65	39.62	39.63	Al <sub>2</sub> O <sub>3</sub> .....	29.72
H <sub>2</sub> O .....	13.77		13.77	Fe <sub>2</sub> O <sub>3</sub> .....	1.40
CaF <sub>2</sub> .....	0.68		0.68	CaO .....	0.26
	100.01		100.14	MgO .....	2.12
				K <sub>2</sub> O .....	8.33
				Na <sub>2</sub> O .....	0.50
				H <sub>2</sub> O .....	4.39
(W. F. Hillebrand.)				(W. F. Hillebrand.)	*99.31

\*The presence or absence of fluorine was not ascertained.

Oxygen ratio of XXXVII:



The kaolinite has nearly the theoretical composition, while the mica is probably a variety of muscovite.

#### PHENACITE.

FROM CRYSTAL PARK.—This mineral was first identified from two crystals found in association with topaz in Crystal Park, near Manitou. Subsequent search revealed a number of others at the same place, but as they are inferior to those originally described<sup>48</sup> no new data can be given of this occurrence. The crystals found are but fragments, representing in each case somewhat less than half of the complete crystal. Fig. 12 of the plate represents one crystal in about the natural size; another measures nearly 7<sup>cm</sup> in longest diameter, and has the same faces developed in similar manner. In no crystal do any faces of the vertical zone appear, thus producing a flat lenticular habitus. The forms appearing have been identified as R,  $-\frac{1}{2}$ R,  $-R$  and  $\frac{3}{2}$ P2, and although the faces are too rough to admit of exact measurements with the reflection-goniometer, the size of the faces and their simple devel-

<sup>48</sup>Am. Jour. Sci., III, XXIV, p. 282, October, 1882.



opment render sufficiently accurate results with the hand instrument possible. The angles obtained as means of several measurements are:

	Crystal <i>a</i> (Fig.)	Crystal <i>b</i> .	Authorities.
	° /	° /	° / "
R $\wedge$ R (terminal) .....	.....	116 20	116 36 (D)
R $\wedge$ R (lateral) .....	.....	63 00	63 24 (S)
R $\wedge$ $\frac{1}{2}$ R (over $\frac{2}{3}$ P2) .....	148 30	148 50	148 18 (D)
R $\wedge$ $\frac{2}{3}$ P2 .....	159 45	159 58	159 56 (D&S)
R $\wedge$ -R .....	74 30	74 40	74 42 45 (S)
- $\frac{1}{2}$ R $\wedge$ - $\frac{1}{2}$ R .....	143-144 00	.....	144 1 26
- $\frac{1}{2}$ R $\wedge$ -R .....	.....	163 43	163 32 2
$\frac{2}{3}$ P2 $\wedge$ - $\frac{1}{2}$ R .....	168 11	168 50	168 22 (S)
$\frac{2}{3}$ P2 $\wedge$ $\frac{2}{3}$ P2 .....	150 40	156 00	156 44 (D&S)

The figures of the third column are the calculated angles given for phenacite by Dana<sup>49</sup> or Seligmann,<sup>50</sup> or else our own calculations based on the theoretical values given by them. The agreement between the angles measured on these crystals and the theoretical ones is sufficiently close to justify the signs given to the faces of the figures. In the development of the different forms R and  $-\frac{1}{2}$ R are always prominent, while the faces of  $\frac{2}{3}$ P2 are variable. One face of  $\frac{2}{3}$ P2 on crystal *b* is 2.5<sup>mm</sup> broad, although usually each face of  $-\frac{1}{2}$ R is broader than both adjoining faces of  $\frac{2}{3}$ P2; -R is subordinate and the faces are quite rough;  $\frac{2}{3}$ P2 appears with its full complement of faces. The roughness of the faces is in part caused by striæ, which on  $-\frac{1}{2}$ R and  $\frac{2}{3}$ P2 run parallel to the terminal edge of R replaced by those faces. On R the markings are less distinct. These striæ and partially regular depressions seem like natural etching figures, and bring out the rhombohedral symmetry of the mineral very plainly.

The crystallographical determination of these minerals as phenacite is confirmed by all the physical characteristics as far as observed and by the chemical composition. There is an imperfect cleavage parallel to  $\infty$  P2. Both crystals are clear and colorless, resembling quartz, and the hardness is nearly or quite 8. The specific gravity of the crystal figured, though containing some impurities, is 2.967 at 23° C.

PHENACITE FROM NEAR FLORISSANT.—Another occurrence of phenacite was discovered during the summer of 1884, near Florissant, in association with the topaz crystals described later on. The crystals here are small, colorless, of lenticular form, and are deposited upon or slightly embedded in amazon stone crystals, in the same manner as the topaz, which is often present side by side with the phenacite. None seen exceed 5<sup>mm</sup> in diameter, and crystals of this size in one case form an almost continuous crust upon the surface of a feldspar crystal. More commonly they are attached by an edge, although occasionally in all other positions.

<sup>49</sup> Dana, System of Mineralogy, 5th ed., p. 263.

<sup>50</sup> G. Seligmann, in Neues Jahrbuch für Mineralogie, etc., 1880, I, 129.

These small crystals, while preserving the lenticular form of those from the first locality, exhibit a development of several new faces. These can be determined with considerable certainty by a reference to the article by Seligmann, reviewing the crystallography of the species.<sup>51</sup> All the present forms are mentioned by him as occurring with very nearly the same relative development upon the phenacite from the Ilmen Mountains, in the Urals. The zonal relations are almost sufficient to determine the new faces, although measurements were made to insure accuracy.

The new forms observed are:  $-2R$ , seen in a few crystals in good development;  $-\frac{1}{2}R3$ , which appears prominently with six nearly equal faces;  $R3$ , of which only three faces were found on any crystal, and which is often not developed at all;  $\infty R$  and  $\infty P2$ , appearing as very narrow faces, which do not produce a prismatic habit in any case and are often wanting. A narrow face sometimes seen between  $R$  and  $-\frac{1}{2}R3$  is probably  $\frac{1}{3}P2$ .<sup>52</sup>

#### TOPAZ.

Within the past two years topaz has been found in several places within the Pike's Peak region, and we can supplement our original notice<sup>53</sup> of the mineral quite materially.

Topaz has been found in Crystal Park, south of Manitou, in a cavity containing feldspars, smoky quartz, zircon, and phenacite; at the main amazon stone locality near Florissant, about 12 miles northwest from Pike's Peak; and, more plentifully and in better form than elsewhere, on Devil's Head Mountain (Platte Mountain), north of Pike's Peak about 30 miles.

CRYSTAL PARK.—Of the few crystals found in this locality the most perfect one measures 2.5<sup>cm.</sup> parallel to the vertical axis, 3.3<sup>cm.</sup> parallel to the brachy axis, and 2.8<sup>cm.</sup> parallel to the macro axis. It is colorless and some parts of the crystal are very clear. The prisms  $\infty P$  and  $\infty P2$  are well developed. The terminations are drusy, although many of the prominences are large enough to admit of the determination of some of the faces which bound them. The pyramid  $2P$  has been recognized with certainty, while a form between  $\frac{2}{3}P$  and  $P$ , which is probably  $\frac{4}{3}P$ , and another pyramid near  $2\check{P}4$  are also present. Measurements of sufficient accuracy for the calculation of these latter forms could not be obtained. The lateral edges of these pyramidal prominences lie in a plane corresponding to the brachydome  $2\check{P}\infty$ , and although that form does not actually appear, the crystal has a domatic habit. A rough face of  $4\check{P}\infty$  is present quite distinctly. While one termination is more perfect

<sup>51</sup>G. Seligmann. "Krystallographische Notizen, I," Neues Jahrbuch für Mineralogie, etc., 1830, I, 129.

<sup>52</sup>An announcement of this locality was made by W. E. Hidden, Am. Jour. Sci., March, 1885, received after this article was written.

<sup>53</sup>Am. Jour. Sci., III, XXIV, p. 282, 1882.

than the other, both are alike. Not more than a dozen crystals have been found in this locality.

**FLORISSANT.**—The first specimen identified from Florissant is mainly noteworthy on account of the enormous size of the original crystal from which it came. This specimen is but a corner of a large crystal, the forms appearing being two faces of  $\infty \text{P}2$ , one of  $\infty \text{P}$ , and one each of  $2\text{P} \infty$  and  $4\text{P} \infty$ . The fragment is about 9<sup>cm</sup> ( $3\frac{1}{2}$  in.) in its longest diameter, and if the other faces were developed to correspond to those here seen, the complete crystal must have been nearly or quite one foot in diameter parallel to the brachy diagonal. It is clear in parts and has a decided greenish tinge. It was supposed to be fluor spar by the original collectors, and the other pieces of the crystal are undoubtedly lost.

The specific gravity of this fragment is 3.578 at 22° C. and it has the following composition:

	XXXIX.
SiO <sub>2</sub> .....	33.15
Al <sub>2</sub> O <sub>3</sub> .....	57.01
F .....	16.04
	106.20
O for F .....	6.75
	99.45
(W. F. Hillebrand.)	

Atomic ratio:

$$\text{Si} : \text{Al}_2 \\ 1.025 : 1.000.$$

Within a few months a further discovery of topaz has been made near Florissant. In this case the crystals were found deposited upon or partially imbedded in amazon stone, albite, or limonite (pseudomorph after siderite). The crystals seen by us are deposited upon different faces of the microcline and so seldom with any parallelism in position that any such coincidence must be considered accidental. In size the crystals vary from a length of nearly two inches to those which are almost microscopic. They are deposited singly or in groups and are attached in all positions, so that many of them are quite well terminated at both ends. The forms observed are as follows:  $\infty \text{P}$  and  $\infty \text{P}2$ , both polished and striated;  $4\text{P} \infty$ ,  $2\text{P} \infty$ , and  $\frac{4}{3}\text{P} \infty$ ;  $0\text{P}$ ;  $2\text{P} \infty$ ;  $\text{P}$  and  $\frac{2}{3}\text{P}$ ;  $\infty \text{P} \infty$ .

Quite characteristic is the prominent development of the brachydomes  $4\text{P} \infty$  and  $2\text{P} \infty$ , the former in particular, the faces of opposite terminations often meeting.  $4\text{P} \infty$  is almost uniformly dull, like ground glass, while  $2\text{P} \infty$  is smooth and brilliant, passing into  $\frac{4}{3}\text{P} \infty$  or  $0\text{P}$  by a roughened line.  $\frac{4}{3}\text{P} \infty$  and  $0\text{P}$  are usually rough through minute irregularities bounded by crystal planes. The base is usually very narrow through the predominance of the brachydomes, the pyramidal planes and the macrodome are quite insignificant when present at all, and  $\infty \text{P} \infty$  is occasionally present as a small, smooth face. No indications of hemi-

morphism are noticeable, although the faces of opposite ends are seldom symmetrically developed.

Some of the crystals have a decided greenish tinge, although many are colorless.

**TOPAZ FROM DEVIL'S HEAD MOUNTAIN.**—The country embracing Devil's Head Mountain is composed chiefly of the same granite which has been described in its occurrence near Pike's Peak, and it contains similar druses of microcline, smoky quartz, and other minerals. The topaz found here is the most noteworthy crystallized species, some of the specimens found being probably the best yet discovered in the United States. The discoverer, Mr. W. B. Smith, now assistant in the Rocky Mountain division of the Survey, has given us a few notes on the manner of occurrence and associations of the topaz, which are appended to this description, p. 73.

In the American Journal of Science for December, 1883, Rev. R. T. Cross, of Denver, published a note announcing the discovery of this locality by Mr. Smith. The specimens obtained since that time are much superior to those first found, though comparatively few in number.

Specimens from Devil's Head have found their way into various mineral collections of the country, and as the most noteworthy crystals passed through our hands we are able to give some details. All are colorless or faintly wine-colored and very clear within, though marred by more or less roughened surfaces, often stained by oxide of iron which penetrates fissures. Many fragments are sufficiently clear for cutting.

Three especially fine crystals have been obtained. Of these the one with the most polished surfaces, and hence the clearest, weighs 3.5 ounces, measuring  $\tilde{a}:\tilde{b}:\tilde{c}=4.4:4.9:3^{\text{cm}}$ . The faces  $\infty P$ ,  $\infty \tilde{P}2$ ,  $4\tilde{P} \infty$ ,  $\frac{4}{3}\tilde{P} \infty$ ,  $0P$ ,  $\frac{2}{3}\tilde{P} \infty$ ,  $P$ , and  $2P$  are quite well developed, while  $\alpha \tilde{P}3$ ,  $\infty \tilde{P} \infty$ ,  $2\tilde{P} \infty$ , and  $\frac{2}{3}P$  are less prominent or not present in full quota. But one termination has definite faces.

The second crystal weighs 5.5 ounces, and measures  $\tilde{a}:\tilde{b}:\tilde{c}=3.7:5.5:4.6^{\text{cm}}$ . Clear with dull surfaces. One termination has large  $0P$ , with a very symmetrical development of the faces mentioned above and  $2\tilde{P} \infty$ . A second termination is formed by one large undulating face, corresponding to  $\frac{2}{3}P$ , with  $0P$  and single faces of  $4\tilde{P} \infty$  and  $2P$ .

A third crystal weighs  $6\frac{3}{4}$  ounces and measures  $\tilde{a}:\tilde{b}:\tilde{c}=4.2:5.3:4.5^{\text{cm}}$ . It has rather dull surfaces but is clear within, and has a distinct wine color. One termination is quite symmetrical, showing the planes named.

A number of the smaller crystals are very clear and transparent, with beautifully polished surfaces, although it is seldom that all are smooth.

Nearly all crystals from Devil's Head, Crystal Park, and many from Florissant, have been found detached, some being badly broken. The same is true of a large portion of the crystals of the accompanying

minerals. Movements of the whole mountain mass, as in folding or faulting, have probably caused this detachment and fracture of the crystals. Particularly noticeable with the topaz, though also observed on smoky quartz, is the fact that all these old fracture planes are healed over, so to speak, and are now covered by drusy surfaces caused by little prominences which are bounded by glistening crystal faces. An examination shows that pyramidal planes of both orders are the most common, the little elevations resembling those upon  $2P_{\infty}$  above described. When the fractured plane is parallel  $OP$  there are usually a great number of the pits or etching figures also previously noticed.

#### APPENDIX.

##### NOTES UPON THE OCCURRENCE OF TOPAZ AT DEVIL'S HEAD MOUNTAIN, BY W. B. SMITH.

The name "Devil's Head" was applied many years since to a jagged and precipitous mass of granite, rising to a height of 9,348 feet, in the Colorado range, some 30 miles north of Pike's Peak. This is the name by which it is still known locally, though upon Hayden's Atlas it is called "Platte Mountain."

The granite forming the mountain is similar to that near Pike's Peak, and the minerals found occur in cavities or pockets as in the latter region. No extensive pockets of amazon stone, smoky quartz, etc., have been found, but a few smaller ones contain a noteworthy association of species.

**TOPAZ.**—The pocket in which the topaz was found is of irregular shape, being about 50 feet long, from 2 to 15 feet wide, and averaging 4 feet in depth. Owing to the disintegration of the rock at the surface many of the crystals had been carried in the *débris* to a considerable distance down the mountain side, and were badly worn and broken.

The topaz occurs in isolated and usually loose crystals, surrounded by distorted quartz crystals, of smoky and reddish shades—frequently the exact color of the topaz—light green microcline, mamellary radiations of albite, cleavage masses and compact nodules of mica—probably muscovite, although sometimes much altered from the original substance. Also, more rarely, cassiterite, goethite, orthite?, fluorite and kaolinite occur. Much of the topaz is reddish, though wine-yellow, milky blue, and colorless crystals were found.

All the crystals attached to the gangue were more or less decomposed, a kaolin-like substance being the result. Frequently the terminal planes and a part of the prism would be found protruding from the rock unaltered, while the remainder of the crystal, running into the

albite, would be composed of alternate layers of topaz and kaolin. More frequently, however, the kaolin, instead of being parallel to the cleavage planes, occupied curved fissures running irregularly through the topaz.

**MICROCLINE.**—This mineral in simple crystals was the common species in the pocket. Some were very large, measuring 18 inches across. They were usually badly fractured and fell in pieces on being removed. The base, 0 P, of each crystal has a curious appearance, owing to the angular elevations and depressions that compose the surface, looking not unlike oriental characters cut in relief.

**CASSITERITE.**—Twenty-five or thirty small, irregularly-shaped masses of this mineral were found embedded in massive albite or quartz. A few rude crystals were obtained, one being a little less than an inch in diameter. Only the pyramid is developed. No cassiterite was found outside of the topaz-bearing cavity.

**FLUORITE.**—In the adjacent region a number of interesting crystals of the chlorophane variety of fluorite were found in a small pocket of microcline and smoky quartz. The most perfect crystal is a cubo-octahedron, with every face well developed. It was found lying loose in the cavity and the surface is rough. The color is of a greenish tinge outwardly, with an included cube of dark purple.

### III.—ON THE LUSTRE EXHIBITED BY SANIDINE IN CERTAIN RHYOLITES.

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By WHITMAN CROSS.

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The sanidines of two rhyolites in Colorado, examined by the writer, possess a remarkable lustre which is, as far as he can ascertain, unlike anything previously described by any other observer. One of these cases has already been briefly noticed in the *American Journal of Science* for February, 1884. The discovery of a second instance of this same lustre, and the results of a comparison with earlier descriptions of lustre and color in feldspar, render a fuller treatment in this place desirable.

**SANIDINE IN RHYOLITE FROM CHALK MOUNTAIN.**—The rhyolite containing the lustrous sanidine occurs in a massive body forming the greater part of Chalk Mountain, situated upon the continental divide at the headwaters of the Arkansas, Ten Mile, and Eagle Rivers, in central Colorado. It is of the type recently defined as nevadite by Messrs. Hague and Iddings,<sup>54</sup> and may be characterized as a porphyritic rock, showing large glassy sanidine and many smoky quartz crystals embedded in a grayish ground mass, which appears under the lens to be evenly granular, and is really so, with the exception of isolated glass particles revealed by the microscope. Biotite is but sparingly present. This nevadite is one of the most beautiful of rocks, owing to its abundant smoky quartz crystals and to the lustrous sanidines about to be described. Chalk Mountain lies upon the boundary between the geological maps of the Mosquito range and of the Ten-Mile mining district, which are soon to be published, with monographic reports, by the U. S. Geological Survey. In both of these works the manner of occurrence and the characteristics of the rock will be fully given.

Many crystals of sanidine in the nevadite exhibit in certain positions a delicate or brilliant satin-like lustre. If examined with the aid of a lens a faint play of very delicate colors is seen, while the crystal seems white and opaque when looking down upon the lustrous surface in such a direction that the lustre itself does not appear. The position of the lustrous plane is readily seen to be near that of the orthopinacoid, and the extent of the deviation from it is plain when a crystal twinned ac-

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<sup>54</sup> *Am. Jour. Sci.*, III, XXVII, 461, 1884.

according to the Carlsbad law is observed. By facing the light and revolving such a crystal about its orthoaxis it is found that the lustrous planes of the two halves are not coincident, but are inclined at approximately  $20^\circ$  to each other, while evidently lying in or very near the orthodiagonal zone.

On examining the larger crystals a cleavage parallel to the plane of lustre is evident, and if an isolated fragment be fractured by a sharp blow upon the predominant brachypinacoid many flakes are produced, some of which are parallel to  $OP$ , while others are parallel to the lustrous surface. Those parallel to  $OP$  exhibit under the microscope a very fine striation at right angles to the trace of  $\infty P \infty$ , while optical action is normal. The flakes parallel to the plane of lustre are found to be made up of extremely thin plates, usually rectangular through the development of cleavages parallel to  $OP$  and  $\infty P \infty$ . If but a few of these plates overlies each other, delicate variegated colors appear in ordinary light. By increase in the number of plates the flake becomes dull white and opaque. The phenomena are very plainly the familiar ones produced by polarization and interference of light in traversing a series of thin plates. Transmitted light is soon wholly extinguished by a sufficient increase in the number of plates, and reflected light produces the lustre seen.

A parting parallel to this plane can be easily produced with a knife-blade in those crystals having a very bright lustre. The separation is as sharp and perfect as that parallel to any cleavage plane of the crystal. By sections parallel to  $\infty P \infty$  the position of the plane with reference to the axes  $a$  and  $c$  is readily determined with approximate correctness; but the most satisfactory, and probably the most accurate, measurements were obtained in the following manner:

At one point in the mountain the nevadite, here unusually coarse-grained, was found to contain many small round or irregular druses lined by minute but perfect transparent crystals, chiefly of sanidine and quartz. The quartz crystals are for the most part simple dihexahedrons; the sanidines thin tablets, which are almost invariably Carlsbad twins, with prominent development of the clinopinacoid. Such crystals examined under the microscope, as they lie upon the predominant pinacoidal face, afford a means of determining approximately the position of the plane parallel to which the parting referred to takes place.

Fig. 13 of the plate represents one of these crystals, a normal Carlsbad twin, with a third and smaller plate, also in twin position. The faces shown in profile are  $\infty P$ ,  $OP$ ,  $P\infty$ , and  $2P\infty$ . From all the outlines and from basal cleavage or irregular fissures run very fine dark lines, in uniform direction for each individual of the twin, and penetrating varying distances into the crystal. This undoubtedly represents an incipient stage of that parting which, in some crystals of the rock, occasions the brilliant lustre, for these dark lines do not represent needles of



any mineral substance, but air films, upon the fissures, showing the extent to which actual parting has taken place in the direction indicated in the remainder of the crystal by the fine, clear striation. As seen from the figure, the position of the surface is that of a positive hemi-orthodome, for the cleavage plates of large crystals show the plane to be at right angles to the clinopinacoid. The mean of a number of measurements in different parts of the crystal places the inclination of the plane thus indicated to the vertical axis at  $8^{\circ} 40'$ . Assuming the axial ratio—

$$a:b:c = 0.653:1:0.552 \text{ and } \beta = 64.$$

—as determined by Strüver<sup>55</sup>, for free crystals of sanidine, the face corresponds closely to  $\frac{1}{2}P \infty$ . This would require an angle of  $72^{\circ} 40'$  with the basal plane, while that measured in the crystal figured was  $72^{\circ} 53'$ . Of course this cannot be regarded, under the circumstances, as anything more than an approximate determination.

The lustre as thus far described is found chiefly in the sanidines of the coarser-grained modifications of the rock. Some of the crystals do not exhibit the phenomenon distinctly, and in those of the finer-grained portions of the mass it is commonly not visible at all. Yet, thin sections of such varieties do sometimes show a pale, delicate, bluish color in the sanidines, which is like that often seen in labradorite. By close examination of sections parallel to the plane of the satiny lustre it is frequently found that there are clear and transparent portions which do not exhibit the bright lustre, but if the light be properly guarded a faint bluish color is seen in these clear portions simultaneously with the satin-like lustre in the remainder. After the connection has thus been established it becomes easy to see, in most cases, that the blue color, seen only in clear and transparent crystals, appears upon the same plane which in other cases shows the satiny lustre.

**SANIDINE IN RHYOLITE FROM RAGGED MOUNTAIN.**—Since the appearance of the article describing the lustre of the Chalk Mountain sanidine, another and even more striking instance has been brought to the notice of the writer, through his friend Mr. R. C. Hills, of Denver, who presented him with a sanidine crystal from the rhyolite of Ragged Mountain, Gunnison County, Colorado, in which the satiny lustre is very marked. The crystal in question was several inches in length parallel to the clinoaxis, and has a square prismatic form in that direction, through the predominant and equal development of  $\infty P\Delta$  and  $0P$ . The brilliant, satiny lustre is exhibited in all its beauty when these elongated crystals are fractured transversely, and in the crystal seen the fracture is parallel to the lustrous plane itself. According to Mr. Hills, this is commonly the case, and large masses of the rock often show numerous square sections, reaching 2–3 inches in diameter, each possessing the lustre very distinctly.

<sup>55</sup> Cited by Tschermak, *Lehrbuch der Mineralogie*, 1883, p. 455.

From the crystal mentioned thin sections were prepared parallel to  $OP$ ,  $\infty P \infty$  and the plane of the lustre. That parallel to  $OP$  shows under the microscope uniform extinction  $\pm$  to the edge of  $\infty P \infty$ . The lustrous plane is indicated in the pure and transparent portions by a very fine clear striation lying, so far as determinable, exactly at right angles to the trace of  $\infty P \infty$ . This striation is exceedingly delicate, and appears most distinctly when directed from the observer toward the source of light. Through a large part of the section, however, the clear striation is replaced by dark lines, easily seen to be sections of parallel planes, upon which are many dark bodies like gas cavities or empty spaces. These are zigzag in shape, but bounded chiefly by lines seemingly parallel to  $OP$  and  $\infty P \infty$ . The plane holding these bodies is steeply inclined to  $OP$ .

The section parallel to  $\infty P \infty$  shows a clear striation where parting has not taken place, and dark lines representing the sections of planes containing air or empty cavities where the separation has begun. The situation of the lustrous plane with reference to the axes  $a$  and  $c$  is here plain. The angle susceptible of most accurate measurement is that between the basal cleavage fracture ( $a$ ) and the clear striation. Repeated determinations show this angle to be between  $72^\circ 30'$  and  $73^\circ$ . This corresponds closely to the results obtained from the crystal in the Chalk Mountain rock, and shows conclusively that the lustrous planes in the two cases may be considered identical.

The thin section parallel to the lustrous plane brings out still more distinctly a zonal structure which was visible in the crystal. The outer zone has a much more brilliant lustre than the interior, and certain parts of the latter are quite transparent. In these portions, when the satiny lustre of the outer zone is at its maximum of brightness, a delicate pale blue color is visible, like that noticed in the Chalk Mountain sanidine. Under the microscope the appearance is similar to that already described for cleavage flakes. Where the lustre is brightest the parting is apparently complete, with continuous air films between plates. Where the sanidine exhibits the blue color there is either no indication of the laminated structure, or the beginnings of the parting are represented by the same dark zigzag cavities or air pores seen in the basal section. These are now clearly seen to be bounded for the most part by lines parallel to  $OP$  and  $\infty P \infty$ .

Although no alteration in the ordinary sense is visible, the section is opaque where the number of plates overlying each other is great.

PREVIOUS DESCRIPTIONS OF LUSTRE IN FELDSPAR.—The bluish color sometimes seen in adularia, albite, or oligoclase and the play of colors so beautifully exhibited by labradorite have been the subjects of study on the part of various mineralogists. Sir David Brewster ascribed the phenomenon to the action of certain flat rectangular bodies observed with the microscope, and which he considered as filled by air, or,

at least, by some matter of much lower refractive power than the feldspar.

The first satisfactory investigation of this subject was, however, by E. Reusch,<sup>56</sup> who made (1862-'63), a careful study of the bright lustres and chatoyant colors exhibited by various minerals.

The results of Reusch's study of the feldspars are of particular interest in connection with the foregoing, and although the original has been consulted, the writer wishes to quote the concise *résumé* given by Dana in his System of Mineralogy, 5th edition, p. 336: "The play of colors, especially remarkable in much labradorite, and occurring also in some adularia, albite, and oligoclase, indicates, according to Reusch, the existence of a cleavage structure of extreme delicacy transverse to the median or brachydiagonal section. In adularia the plane of this cleavage is perpendicular to this section (or that of the clino-diagonal); in labradorite it is in general more or less inclined, and differently in different specimens. The play of colors, Reusch observes, appears therefore to be that of thin plates; yet the lining of what he regards as a cleavage system appears to be of indistinguishable minuteness; and although the existence of thin plates can hardly be established by the microscope, it is proved by their effects in the play of colors, nebulous images within, and the phenomena of inflection or diffraction which result from their regular grouping." By preparing a polished surface parallel to the orthopinacoid, Reusch determined, for adularia, the inclination of the plane producing the nebulous images to the vertical axis, at  $11^{\circ} 38'$ , as a mean of many careful observations. The angle with the clinoaxis is given at  $74^{\circ} 18'$ . The corresponding measurements of the cleavage inclinations in the Chalk Mountain sanidine given above are  $8^{\circ} 40'$  and  $72^{\circ} 53'$ . If we assume  $\beta = 63^{\circ} 53'$  for adularia, as is commonly given, the latter measurement of Reusch would require the former angle to be  $10^{\circ} 25'$ , and as the value  $11^{\circ} 38'$  was obtained from an artificially-prepared surface we may perhaps be justified in considering the measurement  $74^{\circ} 18'$  the more correct, in view of the nearer agreement thus shown with the results on sanidine where the direction of the new cleavage plane is more distinctly indicated.

It seems almost unnecessary to point out any more clearly that the actual parting observed in the sanidines of these rhyolites is a beautiful natural proof of the correctness of the conclusion drawn by Reusch from his admirable investigation. The satiny lustre is caused by the fuller development of that internal lamellar structure which produces the beautiful delicate blue color in clear adularia or sanidine in the manner explained by Reusch.

Vogelsang, who made a study of the play of color in labradorite,<sup>57</sup> ex-

<sup>56</sup>E. Reusch, "Ueber das Schillern gewisser Krystalle," in Pogg. Ann., CXVI, 392; CXVIII, 256; CXX, 95.

<sup>57</sup>Cited by Naumann-Zirkel. Mineralogie, p. 158, 11th Ed., Original in "Archives Néerlandaises," Tome III, 1868.

plained the blue color as due to polarization from thin plates, the yellow and red as caused by numerous included lamellæ and microlites of mineral substances, while the green and violet shades are thought to be the result of a combination of the blue with the yellow or the red. Reusch states, as mentioned above, that the undeveloped cleavage in labradorite does not correspond in position to that in adularia, being near the brachypinacoid and variable in different specimens.

From the above it seems quite possible that the rectangular bodies thought by Brewster to be the cause of the bluish color may have been the equivalent of those seen in the sanidine, which indicate the beginning of the actual parting in the direction of the latent cleavage.

LUSTRE UPON OTHER SANIDINES.—In the Microscopical Petrography of the Fortieth Parallel (p. 83), Professor Zirkel mentions a "superb blue color" as characteristic of the small sanidines in a rhyolite from Chataya Peak, Pah Ute Mountains, Nevada. It is also visible in various rhyolites east of the point named. The cause of the color is thought unexplainable, for "no strange particles can be detected, neither needles, nor plates, nor grains, nor a dust-like powder, nor glass or fluid inclusions."

An examination of these rhyolites by the writer indicates clearly that this phenomenon is simply another instance of that which has been described. The intensity or brilliancy of the color exhibited in some of these rocks is quite striking.

CONCLUSION.—The phenomenon which has been described does not seem comparable with any hitherto recognized property of crystals. It seems incorrect to speak of it as "cleavage," for that internal structure manifested by the fine basal cleavage of this same species is accompanied by no such optical action; nor can the writer recall any such combination in any other mineral. This lamellar structure is to be considered as another of those physical characteristics of minerals, such as cleavage, fracture-figures, "*gleitflächen*," etching-figures, twinning produced by pressure, etc., which will doubtless remain unexplained until the molecular constitution of crystallized bodies is made clear.

#### IV.—AN UNUSUAL OCCURRENCE OF TOPAZ.

By WHITMAN CROSS.

The nevadite of Chalk Mountain, which was described in the preceding section, contains in its small drusy cavities another mineral of decided interest besides the sanidine. Accompanying the quartz and sanidine in the cavities are minute leaflets of biotite, a few ore grains, and, in a few druses only, very perfect crystals of colorless transparent topaz. Usually but a single crystal of topaz is present in one of the druses; and that is larger and more perfect in development than any other. The topaz is attached directly to the walls of the cavity and often bears small tablets of sanidine upon it. The crystals which can be recognized as topaz vary from 0.5<sup>mm</sup> to 3<sup>mm</sup> in length, but it seems quite probable that there are some smaller ones indistinguishable from quartz.

The determination as topaz rests upon the crystalline form which is very distinct and is that of common topaz. One crystal measuring 3<sup>mm</sup> in length and 1<sup>mm</sup> in thickness was removed from the rock and its angles measured with a Fuess reflection goniometer. This crystal presents  $\infty P$ ,  $\infty \bar{P}2$ , and  $2\bar{P} \infty$  as the dominant forms;  $0P$  is a narrow face and  $4\bar{P} \infty$ ,  $2\bar{P} \infty$ ,  $2P$ , and  $P$  are minute, but very distinct. The angles measured are as follows:

	$\infty$	$\infty$
$\infty P \wedge \infty P$ .....	124	16
$\infty \bar{P}2$ over $\infty \bar{P} \infty$ .....	93	7
$0P \wedge 2\bar{P} \infty$ .....	136	30
$0P \wedge P$ .....	134	11
$0P \wedge 2P$ .....	115	55

$2\bar{P} \infty$  appears as a very narrow face in the zone of  $2P$  to  $2P$ . This is the usual habit, with the occasional addition of  $\infty \bar{P} \infty$  and a more prominent development of  $0P$ . This crystal is also imperfectly terminated at the attached end, showing  $2\bar{P} \infty$  most prominently, with  $4\bar{P} \infty$  and  $2P$  also recognizable, and there are no signs of hemimorphism.

In some druses all crystals are thinly coated by a black incrustation which seems to be pyrolusite.

So far as I can ascertain, all previously known and described occur-

rences of topaz are in granite, gneiss, or some other member of the series of metamorphic or crystalline schists. In the present case topaz is found in an eruptive rock, probably of early tertiary age, while the appearance of the associated minerals certainly suggests that they may all be sublimation products, though it is not capable of direct proof. The sanidine crystals from the druses, examined microscopically, contain gas inclusions, while neither fluid nor glass inclusions were seen.

## V.—ASSOCIATED RARE MINERALS FROM UTAH.

BY W. F. HILLEBRAND.

In the American Eagle mine, Tintic mining district, Utah, occur, in intimate association, several minerals, the majority of which, it is believed, are new to the American continent. All the specimens examined were obtained from an ore-heap at the works of the Boston and Colorado Smelting Company, near Denver, where they were first observed and their probable identity established by Mr. Richard Pearce, metallurgist to the above company. More detailed examinations were made in the laboratory of the Survey at Denver, as opportunity offered, in compliance with a desire expressed by Mr. Pearce.

### OLIVENTITE.

Recognizable by its dark olive-green and wood-brown color, and by its crystal form, is olivenite, occurring in a mixture of various brown and yellow oxygen salts of iron, copper and calcium. The only planes observed, according to Mr. Whitman Cross, belong to the prism and brachydome. While fine crystals are not of infrequent occurrence, the major part of the mineral appears in that characteristic brown, compact, fibrous state to which it owes its old name of wood-copper. The amount of crystallized material available sufficiently pure for a satisfactory analysis was very limited on account of the firm adherence of small green hemispheres of conichalcite on many of the crystals. Analysis gave the following results:

	XL.
CuO .....	55.40
As <sub>2</sub> O <sub>5</sub> .....	40.05
P <sub>2</sub> O <sub>5</sub> .....	0.06
H <sub>2</sub> O .....	3.39
Fe <sub>2</sub> O <sub>3</sub> .....	0.25
CaO .....	0.16
ZnO .....	Trace.
Quartz .....	0.40
	99.71

The ferric oxide of the analysis was derived from a little adhering hydrated cupri-ferric arseniate and the calcium and zinc oxides from attached conichalcite. The oxygen ratio for CuO : As<sub>2</sub>O<sub>5</sub> (P<sub>2</sub>O<sub>5</sub>) : H<sub>2</sub>O is

4.00 : 5.00 : 1.08, instead of 4 : 5 : 1 required by the formula  $\text{Cu}_3\text{As}_2\text{O}_8 + \text{H}_2\text{CuO}_2$ .

#### CONICALCALCITE.

Covering the surface of often large pieces of more or less soft and friable mixed arseniates, sometimes uniting to form a complete coating, are innumerable beautiful emerald-green semi-translucent globules, averaging three-fourths of a millimeter in diameter and showing distinct radiate structure when broken. Notwithstanding the considerable amount of material from which to select, the obtaining of perfectly pure material in sufficient quantity for analysis was impossible without devoting several days to the work, in consequence of the firm adherence of gangue to the flattened base of the globules and of the fact that the nucleus of each globule usually consisted of some of the same soft gangue matter. The material analyzed was so small in quantity, therefore, that the analytical results can lay no claim to the highest degree of accuracy, especially as all estimations had to be made upon the same portion. No specific gravity determination was attempted for this reason, and also because there were no means of determining the corrections to be made for small amounts of impurities other than quartz.

	XLI.	Conicalcalcite from Spain.
CuO .....	28.68	31.76
CaO .....	19.79	21.26
MgO .....	0.54	
ZnO .....	2.86	
Ag .....	0.30	
As <sub>2</sub> O <sub>5</sub> .....	39.94	39.68
P <sub>2</sub> O <sub>5</sub> .....	0.14	8.81
V <sub>2</sub> O <sub>5</sub> .....		1.78
H <sub>2</sub> O .....	5.52	5.61
Fe <sub>2</sub> O <sub>3</sub> .....	0.36	
CO <sub>2</sub> .....	*0.97	
Quartz .....	0.90	
	100.00	100.00

\* By difference.

The ferric oxide was derived from attached gangue. The carbon dioxide was probably combined with lime, since a temperature was required for its expulsion higher than that at which all the water escaped, the latter having been estimated by direct weight. Part of the water seemed to escape at a much lower temperature than the remainder. The silver is not a constituent of the gangue, since none could be found in the latter underlying the green coating. It is not present as chloride, for nitric acid readily takes it all into solution; nor could any native silver or sulphide be detected. The only conclusion to be drawn is that it exists in the mineral in an oxidized state, presumably as silver arseniate.

In appearance and composition this mineral resembles no other than conicalcalcite, found hitherto only in Andalusia, Spain, and represented by a single analysis in Dana's System of Mineralogy, p. 563 (quoted above



for the sake of comparison). It will be noticed that vanadium is wanting (it was specially looked for) in the mineral from Utah, and phosphorus nearly so; while zinc, which was not a constituent of the Spanish mineral, here replaces apparently some copper.

Allowing for the  $\text{CO}_2$  its equivalent of  $\text{CaO}$ , the oxygen ratio is as follows:

$$\begin{array}{l} \text{RO} : \text{As}_2\text{O}_5 (\text{P}_2\text{O}_5) : \text{H}_2\text{O}. \\ 1.00 : 1.18 \quad : 0.41. \text{ or} \\ 4.00 : 4.72 \quad : 1.64. \end{array}$$

instead of 4:5:1.5 required by the supposed formula  $(\text{Cu}, \text{Ca})_3 \text{As}_2\text{O}_8 + \text{H}_2\text{CuO}_2 + \frac{1}{2}\text{H}_2\text{O}$ .

Heated in any manner before the blow-pipe most violent decrepitation ensues, the entire fragment flying into fine powder. In a closed tube, after decrepitation has ceased, the particles by gentle tapping may be made to collect at the bottom as a brown-black spongy mass of great volume. This collected on a loop of platinum wire fuses before the blow-pipe, at first with a pale bluish coloration of the flame. This behavior accords in a measure with that mentioned in Dana's System of Mineralogy (*loc. cit.*).

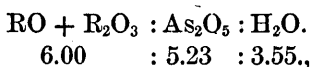
#### CHENEVIXITE.

Thickly scattered in irregular patches throughout some portions of such ore as occurs in hard lumps, giving to a broken surface a mottled appearance, is a compact greenish opaque body, with little or no lustre, which corresponds in composition very well with chenevixite from Cornwall, as represented by one of the two analyses in Dana's System of Mineralogy, p. 583. The hardness, however, is lower, being 3.5 instead of 4.5, as there given. The color is an olive-green, sometimes shading away into a greenish yellow after exposure. The fracture is subconchoidal.

	XLII.			Chenevixite from Cornwall.
	a.	b.	Mean.	
CuO ...	26.41	26.21	26.31	31.70
CaO ...	0.44	.....	0.44	0.34
MgO ...	0.16	.....	0.16	.....
Fe <sub>2</sub> O <sub>3</sub> ...	27.37	.....	27.37	25.10
Al <sub>2</sub> O <sub>3</sub> ...	0.66	.....	0.66	.....
As <sub>2</sub> O <sub>5</sub> ...	35.08	35.20	35.14	32.20
P <sub>2</sub> O <sub>5</sub> ...	.....	.....	.....	2.30
H <sub>2</sub> O ...	9.41	9.25	9.33	8.66
Quartz	0.40	.....	0.40	.....
	99.93	.....	99.81	100.30

The analysis was made upon air-dried powder, since the latter loses about 0.75 per cent. of water even over sulphuric acid, which loss be-

comes slightly greater at 100° C., and continually increases as the temperature rises. The oxygen ratio is—



while that of the above-quoted analysis of the Cornwall mineral is 6:5.35:3.30 instead of 6:5:3, as assumed most probable. The material now analyzed cannot with any certainty be regarded as pure, hence the deviation from this theoretical ratio is not of great importance.

Before the blow-pipe the mineral from Utah differs from that from Cornwall, in that it does not usually decrepitate, while in other respects the behavior is identical; it fuses readily, gives off arsenical fumes, and leaves a black magnetic scoria.

Both chenevixite and conichalcite appear to be generally regarded as doubtful species, for their names do not figure at all in some of the best mineralogical works, but it can hardly be questioned now that they represent definite species whose precise nature, however, is yet a matter for further investigation to reveal.

#### A HYDROUS CUPRI-CALCIUM ARSENIATE.

In rare instances, fine silky white needles have been observed, chiefly on conichalcite, but in such small quantity that the only data as to their composition are the following determinations made by Mr. Pearce on less than a centigram of material:

CaO .....	31.5
As <sub>2</sub> O <sub>5</sub> .....	38.6
CuO and H <sub>2</sub> O* .....	29.9
	100.0

\* By difference.

The copper estimation was a failure, but the percentage of CuO was judged to be fully 20 per cent. The composition would then seem to be near that of conichalcite with the proportions of CuO and CaO reversed, but in view of the wide limits to be allowed for possible error in the analysis, further comment is useless.

#### JAROSITE.

Jarosite in fine transparent brown crystals was observed by Mr. Pearce on a few specimens of ore. The identification rests upon partial chemical analysis, and more fully upon angle measurements by Mr. Whitman Cross.

#### THE MASSIVE ORE.

With jarosite is completed the list of probably distinct species, as far as observed, with the exception of one or two others present in too small quantity for even qualitative identification. There are, however, cer-

tain characteristic components of the ore which seemed to merit examination.

A portion of the ore is a brown substance, showing nodular forms and a granular surface when broken and of considerable hardness owing to disseminated quartz. Analysis furnished the following results:

	XLIII.
Fe <sub>2</sub> O <sub>3</sub> .....	44.22
Al <sub>2</sub> O <sub>3</sub> .....	0.48
CuO .....	1.30
CaO .....	1.33
MgO .....	0.10
K <sub>2</sub> O .....	1.72
Na <sub>2</sub> O .....	0.40
As <sub>2</sub> O <sub>5</sub> .....	20.01
S O <sub>3</sub> .....	6.66
H <sub>2</sub> O .....	11.02
Quartz .....	12.00
	99.30

These figures probably represent a mixture of a hydrated ferric-alkali sulphate (perhaps jarosite), and one or more hydrated arseniates.

In places it passes gradually into a brilliant black substance, closely resembling jet, and possessing conchoidal fracture, difficult to extract even in very small quantity, but having, according to Mr. Pearce, the following composition:

Fe <sub>2</sub> O <sub>3</sub> .....	41.47
CuO .....	4.88
CaO .....	7.27
As <sub>2</sub> O <sub>5</sub> .....	27.65
Ign .....	18.49
	99.76

It was subsequently ascertained that the loss on ignition represents SO<sub>3</sub> as well as H<sub>2</sub>O, hence it is useless to attempt the construction of a formula.

Filling interstices between the nodular forms of the brown mixture above described and occurring as an irregular coating on much of the ore, there is a soft powder of a bright straw color of which the average composition is as follows:

	XLIV.
Fe <sub>2</sub> O <sub>3</sub> .....	37.84
PbO .....	13.74
CuO .....	2.33
K <sub>2</sub> O } .....	*3.03
Na <sub>2</sub> O } .....	
As <sub>2</sub> O <sub>5</sub> .....	12.22
P <sub>2</sub> O <sub>5</sub> .....	0.40
SO <sub>3</sub> .....	16.85
H <sub>2</sub> O .....	9.39
Quartz .....	3.30
	100.00

\* By difference.

The resemblance to certain alteration products of galena and pyrite found in several of the Leadville mines is striking, and, like some of these, it seems to be a mixture of lead sulphate, jarosite, and hydrated ferric arseniate.

All of the above-described minerals and mixtures, with exception of crystallized jarosite, may sometimes be observed on one and the same piece of ore. It is not improbable that further investigation at the mine itself might bring to light still other minerals belonging to the group of hydrous arseniates.

In this connection it may be mentioned that Mr. Pearce has identified pseudomalachite occurring with hübnerite (see p. 96) from near Phillipsburg, Montana Territory. According to Mr. Pearce's analysis it contains CuO 62.56,  $P_2O_5$  20.10,  $H_2O$  17.34 (by difference).

## VI.—MISCELLANEOUS MINERAL NOTES.

By W. F. HILLEBRAND.

### LÖLLINGITE.

**OCCURRENCE.**—The cobaltiferous and nickeliferous variety of löllingite which is to be described occurs at the head of Brush Creek, Gunnison County, Colorado. It has been found in the Luona mine at the western base of Teocalli Mountain, and in the American Eagle and Horace Porter mines on White Rock Mountain. The peculiar ore bodies of which the löllingite forms a part are irregular masses, the relations of which are not yet understood. The investigations of the United States Geological Survey, now in progress in Gunnison County, include the area of Brush Creek, and these interesting bodies will be carefully studied.

At the Luona mine, according to Mr. J. G. Ridgley, of Denver, the löllingite is associated with native silver, proustite, argentite, pyrrhite, chalcopyrite, galena, siderite, barite, and calcite, the last three composing the gangue. Much of it is decomposed, forming secondary oxidized products, most conspicuous among which is erythrite. At the other localities smaltite is a common associate. The smaltite analyzed by Dr. W. M. Iles (*Am. Jour. of Sci.*, III, XXIII, 380, 1882) was probably from one of the mines on White Rock Mountain.

**DESCRIPTION.**—The löllingite occurs in compact, massive form, and also embedded in barite or siderite, and presents a very striking appearance on fresh or newly fractured surfaces. There are seen embedded in the siderite and barite gangue, steely white forms, about one-eighth of an inch in diameter, of pronounced radiate structure, the longer radii protruding from the mass and giving the whole a beautiful stellate appearance. The star forms occur sometimes single, but more frequently joined together in greater or less number without losing in any marked degree the peculiar character of the individual. In some specimens the appearance approaches that of a dense, homogeneous mass, several inches in diameter, but even in the densest portions the radiate structure is generally distinctly discernible.

In order to discover, if possible, a clue to the crystallographic structure, and also to obtain material for analysis, specimens were treated with hydrochloric acid without previous crushing, whereby the siderite

and the arseniates of iron, cobalt, and nickel were entirely dissolved. The löllingite remained quite black on all parts where the gangue had been eaten away, but surfaces of previous fracture retained their white color. The star like forms were then seen to be composed of a considerable number of long flattened ellipsoids, interpenetrating at a common centre in every direction. When one of these clusters was broken through, the star form appeared on the surface of fracture. The aggregates were joined together loosely, now that the cementing material had been removed, though frequently in large clusters of many hundreds of all sizes, from those visible only with the aid of a microscope to others an eighth of an inch or more in diameter.

A microscopical study of the finer part of the material liberated from its imprisonment in the gangue, and broken off from the larger pieces during the treatment with acid and subsequent washing, furnished the solution to the question as to what was the crystallographic form of the flattened ellipsoids composing the aggregates, and the law of the twinning. The fundamental form is that of löllingite, showing only the prism and macrodome, as in Fig. 14.<sup>58</sup> Frequently these two forms are equally developed, producing a resemblance to a low pyramid of the tetragonal system. Very few even of the most minute crystals are perfect in form, and possessed of sufficiently smooth surfaces to allow of even approximate measurement under the microscope. Repeated attempts were made to get these in proper position under the instrument, but in only one case with comparative success, owing to their microscopic size. The angle of the prism was then found to be very nearly  $122^{\circ}$ , that given for löllingite being  $122^{\circ} 26'$ .

Parallel to the combination edge of the prism and macrodome there is almost always on the prism a striation (more coarsely marked the larger the crystal), caused by the alternate reproduction of the prismatic and domatic faces. Approaching the combination edge the reproduced dome face becomes relatively larger than that of the prism, the consequence of which is a gradual rounding of the corners and a contraction, and eventual disappearance of a distinct terminal dome, the result being, as represented in Fig. 15, an elipsoidal form with a slight ridge through the center representing a prism edge. Frequently the corners of a crystal, occupying the position of Fig. 14, appear as if modified by a brachydome, but no such form has been observed, the replacement being a straight serrated edge, caused by the same alternation of faces as in the case of rounded corners. Even where the macrodome is well developed it generally shows a continuation in some degree of the prismatic striation parallel to the same combination edge.

The first step toward the complex twin structure is the formation of

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<sup>58</sup> All the accompanying figures, with the exception of Fig. 14, were drawn by the aid of a camera lucida, and therefore make no pretensions to crystallographic accuracy. Fig. 17 is magnified about 15 diameters, the others from 40 to 150 diameters.

a single twiu, or, rather, trilling, by interpenetration of three single crystals having the basal section in common, and a face of the prism as composition face (Fig. 16). A basal section shows a six-rayed star, with angles of very nearly  $60^\circ$ , by microscopical measurement, between the axes of the rays. In the microscopic trillings one individual frequently predominates greatly in size over the other two, these appearing often as thin leaves, projecting but a short way out of the larger crystal. These trillings are finally found again interpenetrating, not according to any recognizable law, but seemingly in every direction, and in indefinite numbers, forming thus the complex aggregates first spoken of. All these stages of changes in form may be observed with great ease under the microscope, the very smallest crystals alone showing crystallographic faces well defined. As the crystals, single or twin, increase in size, the faces gradually grow more and more indistinct, and finally disappear entirely in consequence of increasing striation.

Notwithstanding repeated attempts, the basal cleavage mentioned in text-books as characteristic of löllingite could rarely be produced, and no cleavage in any other direction except in the case of the trillings. Here an individual frequently broke off at the line of union of the three; that is, in a plane parallel to the brachypinacoid.

Aside from the forms distinctly recognizable as löllingite are, however, others belonging apparently to two different minerals. The first of these became visible on dissolving the gangue, when there came to the surface of the acid and the water used for washing out the latter a great number of minute but brilliant metallic particles, which resolved themselves, under the loupe, but still better under the microscope, into thin leaves or blades, of which Fig. 17 represents one of the more perfect examples. Its forms appear to consist of two pinacoids of the rhombic system, one very broad, the other very narrow, and a terminal dome having an angle of almost exactly  $90^\circ$  by microscopical measurement. The faces are most brilliantly reflecting. Distinct cleavage was not observable. The second mineral, which is almost always microscopic in size, is represented in Figs. 18, 19, and 20. The prominent form is that of a lengthened prism with an angle of very nearly if not quite  $90^\circ$ . Repeated measurements gave values fluctuating between  $88^\circ$  and  $92^\circ$  as the extremes. It is terminated at right angles by a basal plane, the four corners of which are frequently replaced by faces which may be those of a pyramid or two domes, according as the habit is pinacoidal or prismatic. The cleavage is parallel to the base. Single crystals are rare, two or more being generally seen interpenetrating, as in Figs. 18 and 19, generally at an angle of  $90^\circ$ , or united, as in Fig. 20. In the latter figure only the outlines, not the faces, of the different horizontal individuals are shown; nor do the numerous vertical attachments present appear. Occasional instances of three prisms crossing at right angles like the axes of a rectangular system were observed, and also a single instance of the form represented in Fig. 21, where

each of the arms showed a domatic face. The most striking feature of all but the last of these different forms is the invariable widening at the point of union or intersection, as shown in the figures.

**CHEMICAL COMPOSITION.**—Even an approximate separation of the last two minerals described, from each other and from the smallest löllingite crystals, was impossible, hence no conclusion could be reached as to their quantitative composition. Qualitative tests proved them both to be arseniates of cobalt, the square prismatic forms containing also iron and nickel. An incomplete quantitative test upon a mixture of these three minerals showed a much higher percentage of cobalt and nickel than the analysis of the pure löllingite.

Before the blow-pipe the löllingite furnished the reactions mentioned in the text-books, the residue after treatment with charcoal being infusible, strongly magnetic, and, furthermore, giving the characteristic reaction for cobalt with fluxes; soluble in nitric acid, giving a pink solution.

Of the analyses given below, XLV was made upon clusters of löllingite trillings, free, so far as could be determined by the loupe, from attached or penetrating blades or prisms of the other two minerals described. As a check a small quantity of the single crystals and trillings was picked out with the utmost care under the microscope and subjected to partial analysis (XLVI), no trace of foreign adherent matter being visible. The specific gravity of the material used for the first analysis was 7.335 at  $14\frac{1}{2}^{\circ}$  C. Correcting for one half per cent. of siliceous gangue of assumed specific gravity 2.65, the true specific gravity of the mineral becomes 7.400.

	XLV	XLVI
As.....○.....	71.18	.....
S.....	0.56	.....
Bi.....	0.08	.....
Cu.....	0.39	.....
Fe.....	22.96	22.69
Co.....	4.37	4.20
Ni.....	0.21	0.19
	99.75	

The first of these analyses leads closely to the formula  $\text{Fe}(\text{Co}, \text{Ni}) \text{As}(\text{S})_2$ , while XLVI shows beyond a doubt that both cobalt and nickel are constituents of the löllingite and not derived from attached crystals of either of the other minerals. The presence of cobalt recalls the glaucopyrite of Sandberger, though the antimony found in that mineral is here wanting. The peculiar comb-like excrescences described by him, indicating rhombic twinning by interpenetration, may be analogous in some degree to the twinned structure of the present mineral.

Some varieties of rhombic  $\text{CoAs}_2$ , all of which, according to Leroy W. McCay,<sup>59</sup> should be united under the name safflorite, present features

<sup>59</sup>Inaugural Dissertation, Freiberg, 1883.



remarkably like some of those herein described, notably as regards the tendency to form twins of interpenetration; and from the presence of cobalt it might be suspected that this mineral was rather to be considered as safflorite than löllingite. Its exceedingly high percentage of iron and high specific gravity, both greater than that of any safflorite yet examined, are not unimportant objections to this conclusion.

In the description of this mineral in the American Journal of Science, Vol XXVII, p. 354, through a misapprehension not to be explained in a few words, Sandberger is wrongly quoted as authority for the statement that the brachydome is characteristic of rhombic  $\text{CoAs}_2$ . Attention was called to this error by Mr. Leroy W. McCay, who is inclined to consider the above-described mineral as safflorite. While acknowledging that through the elimination of the statement referred to, the main point there brought forward in favor of identity with löllingite was taken away, the evidence is by no means conclusive that the mineral should be classed with safflorite. Further examination, especially of a crystallographical nature, on both löllingite and safflorite, are necessary in order to settle this question. The mineral having been already described as löllingite, this name is here retained.

#### ZINCKENITE.

In the Brobdignag mine, Red Mountain, San Juan County, Colorado, occurs a massive gray mineral showing greasy metallic lustre, without apparent crystalline structure, but to all appearances of complete homogeneity; of specific gravity 5.21 at 18° C. and hardness 3–3.5, which upon analysis was found to be an arseniferous zinckenite, this being, it is believed, the first observed occurrence of the mineral in the United States. Besides the usual blow-pipe reactions for zinckenite, including violent decrepitation, there appear those for arsenic, preceded in the closed tube by a light sublimate of sulphur. The results of analysis are:

	XLVII.	
	a.	b.
Sb.....	35.00	.....
As.....	5.64	5.59
Pb.....	32.77	32.79
Cu.....	1.20	.....
Ag.....	0.23	.....
Fe.....	0.02	.....
CaO.....	0.31	.....
K <sub>2</sub> O }	0.45	.....
Na <sub>2</sub> O }		
S.....	22.50	22.50
Gangue.....	0.59	.....
	98.71	

The atomic ratio is, for

$$(\text{PbCu}_2\text{Ag}_2) : (\text{Sb}_2\text{As}_2) : \text{S} \\ 1.00 : 1.09 : 4.11.$$

While this is close enough to the theoretical ratio 1:1:4 to establish the probable formula  $\text{PbS}, \text{Sb}_2\text{S}_3$ , the result was not such as the care expended on the analysis warranted, supposing that no impurities were present. Calculation shows that while the antimony and arsenic taken together are in excess of the amount required for lead, copper, and silver, the sulphur falls short by half of one per cent. The actual deficit in the latter amounts, however, to about one per cent., for it was found that about half of one per cent. existed in the free state and could be extracted by carbon-disulphide. The only explanation of these contradictory circumstances was to be sought in the presence of oxygen salts, which would at the same time account for the difference between the sum total of the analysis and 100.

Ammonium acetate failed to extract any lead sulphate, but nevertheless pure water extracted a not inconsiderable quantity of soluble matter, even when the digestion was carried on in an atmosphere of carbonic acid. The filtrate showed neither acid nor alkaline reaction toward litmus paper. Silver nitrate produced no precipitate whatever, thus showing the absence of soluble chlorides or sulphides; but hydrogen sulphide threw down a copious orange colored precipitate of antimony trisulphide and the corresponding arsenic compound, entirely free from lead. Barium chloride produced a slight precipitate of barium sulphate. The antimony consequently existed in solution in an oxidized state—that of trioxide—as shown by evaporating some of the original solution with hydrochloric acid and adding potassium iodide. The manner of combination was not ascertained, but from the presence of alkalies this seems pretty certainly indicated. The salts, whatever they may be, are not very readily soluble, for six digestions with warm water in an atmosphere of carbonic acid were insufficient to complete the extraction. The sulphur trioxide found was probably combined with lime.

These experiments show that a large part of the apparent loss in the analysis is to be made up by oxygen, which, by requiring a considerable proportion of antimony, arsenic, and sulphur for combination, brings the ratio of the elements actually constituting the zinckenite very near that required by theory. They also show that the specific gravity given above, even were it corrected for quartz, is too low. Suitable corrections for quartz, free sulphur, and soluble salts would undoubtedly increase the specific gravity to the figure given in textbooks, *i. e.*, 5.3–5.35.

The above method of examination and its results have been dwelt upon somewhat in detail, because they show so clearly that apparent homogeneity in the case of non-crystallized metallic sulphides is no criterion of their purity, and also because thereby is indicated a possible way of reconciling with some definite formula the results of many analyses, especially of massive uncrystallized metallic sulphides, like the one here de-

scribed, whose position in a system of classification might otherwise be impossible of precise determination. (See also Guitermanite, p. 106.)

## COSALITE.

In the collection of the Colorado Scientific Society are a few specimens of a mineral from the Comstock mine, near Parrott City, La Plata County, Colorado, presented by Mr. R. C. Hills, according to whom it occurs in a quartz vein associated with pyrite, sphalerite, a telluride of unknown composition, though probably sylvanite, and native gold. In the specimens examined it appears in irregular masses of small size, rarely an inch in length, and generally much smaller, without cleavage or recognizable crystalline structure except for an occasional faint indication of fibrous texture on fractured surface. The fracture is irregular; color, grayish white, but pale yellow on exposed surfaces; hardness, about 3.5; specific gravity undetermined.

The outer zone of the small bodies spoken of is found on close examination to be a mixture of two or more minerals, among which minute grains of pyrite were alone recognizable. Sufficient material was, however, obtained for analysis, free from all impurity, except a little pyrite and 1.29 per cent. of insoluble gangue. This afforded the following reactions: In closed tube, sublimate of sulphur; in open tube, formation of sulphur dioxide; on charcoal, fusible, giving reactions for lead, bismuth, silver, and copper; soluble in chlorhydric and nitric acids, in the former with precipitation of silver chloride.

The analysis, after deduction of the gangue, gave these results:

	XLVIII.*
Bi .....	42.93
Ag .....	8.43
Cu .....	7.50
Pb .....	22.49
Fe .....	9.70
Zn .....	Trace.
S .....	17.11
	99.16

\* The following atomic weights are used: Bi. 208, Ag. 108, Cu. 63.4, Pb. 207, Fe. 56, S. 32.

Allowing for the iron and a proportionate amount of sulphur as pyrite, the atomic ratio deduced from the above is:

$$\begin{array}{l} R : Bi_2 : S \\ 2.00 : 1.00 : 4.94 \end{array}$$

showing the general formula for the mineral to be  $2RS + Bi_2S_3$ , wherein R represents Pb and the double atoms  $Ag_2$  and  $Cu_2$ . The ratio of  $Ag_2 + Cu_2 : Pb$  is 1 : 1.11.

Although copper was absent, and but 2 per cent. of silver present in the mineral originally described by Genth as cosalite, it does not appear

advisable, in the absence of any data as to the crystallographic form, to consider this a distinct species, but to class it, as has been done with tselkite, under cosalite.

#### HÜBNERITE.

In the collection of the Colorado Scientific Society are specimens of hübnerite from the Royal Albert vein, Uncompahgre district, Ouray County, Colorado.

The mineral occurs in long flattened crystals vertically striated; imbedded in quartz, but none sufficiently well formed for measurement could be extracted; in fact, definite faces are rarely visible, though two prisms and the orthopinacoid have been observed. The lustre is sub-vitreous to resinous, and the color brownish black to pale yellow in very thin crystals. In transmitted light the color is ruby red to yellow, slightly tinged with green when the thickness is not too great. Extinction takes place parallel to the vertical axis in a plate parallel to the orthopinacoid, and at an angle of  $19^{\circ}$  to  $20^{\circ}$  to the same axis in a cleavage section parallel to the clinopinacoid, as observed by Des Cloizeaux for wolframite. In the plates parallel to the orthopinacoid a tendency to cleave at right angles to the clinopinacoid and also at angles approximating  $61^{\circ}$  and  $68^{\circ}$  to the same face was observed. The specific gravity at  $24^{\circ}$  C. is 7.177, and the composition as follows:

	XLIX.
SiO <sub>2</sub> .....	0.62
Nb <sub>2</sub> O <sub>5</sub> (?) .....	0.05
WO <sub>3</sub> .....	75.58
MnO .....	23.40
FeO .....	0.24
CaO .....	0.13
	100.02

Which agrees very closely with that required by theory for the formula MnWO<sub>4</sub>.

This mineral is also found in a mine near Phillipsburg, Montana, according to Mr. Richard Pearce. The specimens in the collection of the Colorado Scientific Society show large flattened crystals of imperfect form in quartz. Mr. A. H. Low, chemist at the Boston and Colorado Smelting Works, has analyzed the mineral approximately and found:

WO <sub>3</sub> .....	74.82
MnO .....	25.00
FeO .....	0.06
	99.88

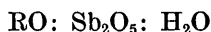
Other localities of occurrence in Colorado are Jamestown, in Boulder County, and near Silverton, in San Juan County.

## BINDHEIMITE.

A specimen of bindheimite from a claim near the Bertrand mine, Secret Cañon, Nevada, came into possession of the Colorado Scientific Society, and was analyzed in the laboratory of the Survey. The specimen was compact and devoid of crystal form, except for a few minute crystals impossible of identification. The color, in general a yellowish green, was in places lemon yellow. The specific gravity at 19° C. was 5.01, after allowing for 4.59 per cent. of quartz of 2.65 specific gravity, and 20.33 per cent. of cerussite of specific gravity 6.5. The following are the results of analysis :

	L.		
	a.	b.	Mean.
PbO .....	49.68	49.92	49.50
CuO .....	0.58	0.59	0.58
ZnO .....	0.17	0.19	0.18
CaO .....	0.66	.....	0.66
MgO .....	0.03	.....	0.03
K <sub>2</sub> O .....	0.14	.....	0.14
Na <sub>2</sub> O .....	0.21	.....	0.21
H <sub>2</sub> O .....	5.86	5.87	5.86
Sb <sub>2</sub> O <sub>5</sub> .....	35.18	35.21	35.20
Fe <sub>2</sub> O <sub>3</sub> .....	0.09	.....	0.09
Ag .....	0.29	.....	0.29
CO <sub>2</sub> .....	3.35	3.36	3.35
Quartz .....	4.59	.....	4.59
	100.83		100.68

Of the water 1.95 per cent. escaped over sulphuric acid, and a further 0.70 per cent. at 100° C. The oxygen ratio derived from the above, excluding PbCO<sub>3</sub>, Ag, and Fe<sub>2</sub>O<sub>3</sub>, is:



$$3.14: 10.00: 5.92$$

If that water which escapes over sulphuric acid be considered true hygroscopic water, the ratio becomes 3.14:10.00:3.98. The first of these ratios corresponds to the formula 3 PbO, 2 Sb<sub>2</sub>O<sub>5</sub>, 6 H<sub>2</sub>O, while the second is represented by 3 PbO, 2 Sb<sub>2</sub>O<sub>5</sub>, 4 H<sub>2</sub>O.

## KAOLINITE.

In the American Journal of Science, Vol. XXVII, 1884, p. 472, Mr. R. C. Hills gave a short description of the material whose chemical composition is discussed below. The mineral appears as a white or straw-colored powder, composed of minute scales, and occurs in certain vugs or cavities in a quartz vein material, inclosed in a large mass of eruptive rock, of which it is an alteration product. Barite, galena, and occasionally other ore minerals are associated with the kaolinite. The National Belle mine, on Red Mountain, near Silverton, San Juan County, Colorado, is the original and principal locality for this mineral.

Under the microscope the powder resolves into a multitude of most perfect transparent crystals of hexagonal form, but evidently of the rhombic system, as shown by the optical action. They present a predominant basal plane, but also very distinctly a rhombic pyramid and a brachydome of very similar development, thus maintaining the resemblance to a hexagonal form. Figures illustrating these crystals accompanied Mr. Hill's description.

**CHEMICAL COMPOSITION.**—The material examined contained a number of black grains as an impurity, and was of a very faint straw-yellow color, from a thin coating of limonite. The latter was mostly removed by hydrochloric acid and the former by stirring up with water in a beaker, allowing the glass to stand for a moment and then pouring off what had not yet settled. The residue was again treated in a similar manner. From the decanted portion a very pure product was obtained, of brilliant whiteness.

The fine flakes, when suspended in quantity in water, impart to the latter a most beautiful satiny appearance.

At  $18\frac{1}{2}^{\circ}$  C. the specific gravity of the purified substance is 2.611. Before the blow-pipe intumescence takes place, but no fusion whatever. Strong boiling hydrochloric and sulphuric acids exercise little solvent action. The following are the results of analysis:

	LI.
SiO <sub>2</sub> .....	46.35
Al <sub>2</sub> O <sub>3</sub> .....	39.59
Fe <sub>2</sub> O <sub>3</sub> .....	0.11
H <sub>2</sub> O .....	13.93
F .....	*0.15
Less O for F. ....	100.13
	.06
	100.07

\*As mean of 0.17, 0.14, and 0.14.

The Fe<sub>2</sub>O<sub>3</sub> comes undoubtedly from limonite which had not been entirely removed by hydrochloric acid.

None of the water escapes at a temperature of  $330^{\circ}$  C.; it is therefore probably all basic water. The text-books mention half the water of kaolinite as probably basic. If this is true, a marked distinction, aside from that occasioned by the presence of fluorine, exists between this mineral and kaolinite. Frenzel has described a variety of kaolin (myelin),<sup>60</sup> which loses none of its water until a very high temperature is reached.

This point should be carefully observed in future examinations of similar minerals, for upon the confirmation of such a difference as that mentioned, coupled, perhaps, with the presence of fluorine, there would

<sup>60</sup>Naumann-Zirkel, Mineralogie, 11th ed., p. 676.

be necessitated the separation of such minerals as the present one and myelin from kaolinite.

#### A CHROMIFEROUS PSEUDOMORPH.

From the Rochelle mine, on Running Water River, Wyoming Territory, there was obtained a single fragment of a dark green mineral, apparently a pseudomorph. Although crystal planes were visible, as well as more than one direction of cleavage, the identity of the original mineral could not be ascertained, partly owing to the cutting of artificial faces. In one direction, parallel to one of pronounced cleavage, a distinct lamination was observable. Edges and thin flakes were translucent. The lustre was greasy, and the color of the powder apple-green. Specific gravity at  $12\frac{1}{2}^{\circ}$  C., 2.831. Hardness about 3. Analysis gave:

	LII.	
SiO <sub>2</sub> .....	45.54	45.24
Al <sub>2</sub> O <sub>3</sub> .....	37.15	} 88.07
Cr <sub>2</sub> O <sub>3</sub> .....	0.79	
MgO .....	0.38	0.34
K <sub>2</sub> O .....	10.70	
Na <sub>2</sub> O .....	0.90	
H <sub>2</sub> O .....	4.80	
	100.26	

It is evident from the analysis that the product of alteration is allied to muscovite. With substitution of Fe<sub>2</sub>O<sub>3</sub> for Cr<sub>2</sub>O<sub>3</sub> the composition agrees almost exactly with that of the pseudomorph liebennerite.

#### NATIVE LEAD.

W. P. Blake describes in the American Journal of Science, Vol. XXV, p. 161, native lead occurring on galena, from the Jay Gould mine, Wood River district, Idaho Territory. A specimen of this occurrence in the collection of the Survey shows metallic lead, without any galena, running through a mass of quartz rock (the latter stained reddish, perhaps from minium). The quartz is somewhat cracked, and the several pieces are held in place by filaments of lead. A white coating of lead carbonate appears in a few small cavities. The lead is argentiferous.

## VII.—NEW MINERAL SPECIES FROM COLORADO.

By W. F. HILLEBRAND.

### ZUNYITE.

The Zuñi mine on Anvil Mountain, near Silverton, San Juan County, Colorado, has furnished to science two new minerals, one of them being of a remarkably interesting nature.

A portion of the ore from this mine, as represented by two specimens, for the use of which I am indebted to Mr. Franklin Guiterman, consists, when unaltered, of an uncrystallized sulphide of lead and arsenic, upon broken surfaces of which appear numberless projecting glassy faces of tetrahedra of the regular system. On destroying the sulphide by nitric or nitro-hydrochloric acid, washing thoroughly by decantation, and finally employing a solution of high specific gravity to effect separation from a very small amount of barite and whatever other lighter or heavier impurities may be present, a product is obtained consisting of fine crystals on which the predominant form is  $\frac{0}{2}$ , generally modified by

$-\frac{0}{2}$ , and frequently also by  $\propto 0 \infty$  and  $\frac{m0m}{2}$  (Whitman Cross). While goniometric measurements of the tetrahedral angles by Mr. Cross varied frequently within a degree from the normal, this must have been owing to surface irregularities, for generally the crystals are entirely without action on polarized light, and can therefore belong to none but the regular system, although a few show very faint polarization due to interior tension (Cross).

Their size varies from that of extreme minuteness to a diameter, in rare instances, of 5 millimeters. The smallest of the crystals are generally quite clear and transparent, but the vast majority carry more or less uncrystallized, unmagnetic, black inclusions, the nature of which the microscope does not reveal. Repeated preliminary tests showed that these were in no respect similar to the sulphide in which the crystals had been imbedded, being practically insoluble in the strongest acids, with the exception of hydrofluoric acid. The tetrahedra themselves, even in fine powder, are also unaffected by any acids other than hydrofluoric, and even with this acid the action is very slow. Fusion with potassium hydrosulphate effects decomposition in time, and with alkaline carbonates quite readily.

The lustre is glassy, cleavage octahedral, hardness about 7, and the specific gravity in the case of two different lots, carrying in so far as could be judged the same amount of inclusions, was 2.906 and 2.894, at  $18\frac{1}{2}^{\circ}$  C. and  $20^{\circ}$  C., respectively. By diluting a portion of the Thoulet



solution until a few minute crystals free from black specks remained suspended in the liquid, and then taking the density of the latter by a Mohr balance, the specific gravity of the pure mineral was found to be 2.875 at 15° C.

The influence of the inclusions upon the specific gravity was not sufficient to allow of effecting anything like a complete separation, by the employment of a solution of high density, of pure matter from that carrying inclusions, even when finely powdered. For although the portions first falling consisted of the largest and blackest crystals or fragments, and each succeeding precipitate was of a slightly lighter shade, the last was still noticeably dark and by no means pure. The difficulty of separation in this manner was further enhanced by the fact that much of the material from which the portions taken for final analysis were obtained was more or less altered and consequently of lower specific gravity, the result being that the pure crystals and slightly altered ones containing many inclusions fell together. After very great labor, however, enough material for final tests was obtained by hand-picking under the loupe. This showed no signs of alteration and but here and there a minute black speck.

Qualitative analysis of less pure material showed the presence of silica, titanic oxide, alumina, ferric oxide, soda, potassa, lithia, fluorine, chlorine, phosphorus pentoxide, and water. When heated in a tube acid water which attacked glass was given off. Whole crystals when heated sometimes decrepitated, and always became opaque and porcelain-like, but showed no sign of fusion in the hottest blow-pipe flame.

On account of the hardness, which rendered grinding in an agate mortar unadvisable, the sample was crushed in a steel mortar, the metal from the latter extracted by hydrochloric acid, and, after washing thoroughly by filtration, the finest portions were separated from the coarse by levigating with water. The most impalpable powder was reserved for alkali tests.

In these, decomposition was effected by igniting with three parts of bismuth oxide for half an hour at a dull red heat. Treatment with hydrofluoric acid would have required several days for the decomposition alone, and it is improbable that the Lawrence Smith method would have succeeded well. Lithia could not be quantitatively estimated, although the spectroscopic evidence of its presence was strong.

Silica, alumina, ferric oxide, titanic oxide, and fluorine were generally estimated in the same portion, and, in one instance, also chlorine and phosphorus pentoxide. Fusion was made with potassium carbonate. After separation of silica, alumina, etc., in the usual manner, the phosphoric acid remaining in solution was removed by silver nitrate. The fluorine was not calculated from the weight of calcium fluoride obtained, but from the difference between this weight and that after conversion into sulphate. In one instance (analysis LV, below) a considerable amount of pure silica was added before fusion with alkaline carbonate,

and here somewhat more fluorine was found than when no silica was added. Silica was always examined for phosphoric as well as for titanio acid when the latter was known to be present.

The solution containing ferric (titanic) and phosphoric oxides and alumina was divided into two parts, in the one of which the phosphorus was determined, in the other the weight of the combined oxides. The latter were brought into solution by fusion with potassium hydro-sulphate; the titanic oxide if present was then thrown down by boiling in presence of sulphurous acid, and the iron was precipitated as sulphide from a tartaric acid solution and subsequently weighed as oxide. The alumina was found by difference.

Beryllia was carefully tested for by digesting the alumina and ferric oxide (introduced as chlorides) for several days with ammonium carbonate in excess. The very slight amount of matter found then in solution proved to be alumina.

Chlorine was estimated in a separate portion by precipitating as silver chloride in a platinum dish, after leaching the alkaline carbonate fusion and acidifying the filtrate with nitric acid. As a precautionary measure the chloride was then dissolved on the filter with ammonia and reprecipitated by nitric acid, after which it was collected and weighed in a Gooch crucible. In one instance the silver chloride thrown down before precipitating the fluorine as calcium fluoride was weighed and found to tally very closely with the results obtained on separate portions.

Water was estimated by heating the mineral with dry sodium carbonate in a glass tube and collecting in a weighed calcium chloride tube.

The results upon the purest material were as follows:

- LIII.—0.9055 gram gave 0.2200  $\text{SiO}_2$ , 0.0018  $\text{Fe}_2\text{O}_3$ , 0.5230  $\text{Al}_2\text{O}_3$ , and 0.0466 F.  
 LIV.—1.1568 gram gave 0.2817  $\text{SiO}_2$ , 0.0022  $\text{Fe}_2\text{O}_3$ , 0.6710  $\text{Al}_2\text{O}_3$  and 0.0613 F.  
 LV.—0.8436 gram gave 0.4882  $\text{Al}_2\text{O}_3$ , 0.0018  $\text{Fe}_2\text{O}_3$ , 0.0054  $\text{P}_2\text{O}_5$ , 0.0244 Cl and 0.0473 F.  
 LVI.—0.6512 gram gave 0.0058  $\text{Mg}_2\text{P}_2\text{O}_7$ , hence 0.0037  $\text{P}_2\text{O}_5$ .  
 LVII.—1.0039 gram gave 0.0060 KCl, NaCl and trace LiCl, 0.0052  $\text{K}_2\text{PtCl}_6$ , whence 0.0016 KCl and 0.0044 NaCl, LiCl, or 0.0010  $\text{K}_2\text{O}$  and 0.0023  $\text{Na}_2\text{O}$ ,  $\text{Li}_2\text{O}$ .  
 LVIII.—1.0042 gram gave 0.0064 KCl, NaCl, LiCl, 0.0052  $\text{K}_2\text{PtCl}_6$ , whence 0.0016 KCl and 0.0048 NaCl, LiCl, or 0.0010  $\text{K}_2\text{O}$  and 0.0025  $\text{Na}_2\text{O}$ ,  $\text{Li}_2\text{O}$ .  
 LIX.—0.7022 gram gave 0.0824 AgCl, whence 0.0204 Cl.  
 LX.—0.7505 gram gave 0.0891 AgCl, whence 0.0220 Cl.  
 LXI.—0.5073 gram gave 0.0552  $\text{H}_2\text{O}$ .  
 LXII.—0.4021 gram gave 0.0439  $\text{H}_2\text{O}$ .  
 LXIII.—0.3502 gram gave 0.0381  $\text{H}_2\text{O}$ .

	LIII.	LIV.	LV.	LVI.	LVII.	LVIII.	LIX.	LX.	LXI.	LXII.	LXIII.	Mean.
$\text{SiO}_2$ .....	24.30	24.36	.....	.....	.....	.....	.....	.....	.....	.....	.....	24.33
$\text{Fe}_2\text{O}_3$ .....	0.20	0.20	0.21	.....	.....	.....	.....	.....	.....	.....	.....	0.20
$\text{Al}_2\text{O}_3$ .....	57.76	58.00	57.87	.....	.....	.....	.....	.....	.....	.....	.....	57.88
$\text{K}_2\text{O}$ .....	.....	.....	.....	.....	0.10	0.10	.....	.....	.....	.....	.....	0.10
$\text{Na}_2\text{O}$ .....	.....	.....	.....	.....	0.23	0.25	.....	.....	.....	.....	.....	0.24
$\text{Li}_2\text{O}$ .....	.....	.....	.....	.....	trace.	trace.	.....	.....	.....	.....	.....	trace.
$\text{H}_2\text{O}$ .....	.....	.....	.....	.....	.....	.....	.....	.....	10.88	10.92	10.88	10.89
$\text{P}_2\text{O}_5$ .....	.....	.....	0.64	0.57	.....	.....	.....	.....	.....	.....	.....	0.60
F .....	5.15	5.30	5.61	.....	.....	.....	.....	.....	.....	.....	.....	*5.61
Cl .....	.....	.....	2.89	.....	.....	.....	2.90.	2.93	.....	.....	.....	2.91
Less O for F and Cl .....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	102.76 3.02
	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	99.74

\* The highest figure for fluorine is here taken as probably nearer correct than the others, because of a possible analytical error in the latter having in this case been lessened by the addition of silica before making the alkaline fusion.

In deducing a formula from these data the  $\text{Fe}_2\text{O}_3$  and  $\text{P}_2\text{O}_5$  may for reasons subsequently mentioned be neglected. Since none of the water escapes at  $270^\circ\text{C}$ , it may be assumed that it exists as water of constitution, or basic water, and it is perhaps to be reckoned with the small quantities of alkalis. The atomic ratio is then found to be:

$$\begin{array}{cccc} (\text{H}, \text{K}, \text{Na}) & : & \text{Si} & : (\text{Al}_2) & : (\text{O}, \text{F}_2, \text{Cl}_2) \\ 1.2208 & : & 0.4055 & : 0.5674 & : 3.1232 \end{array}$$

or

$$18.00 : 6.00 : 8.39 : 46.21$$

which is not far from

$$18.00 : 6.00 : 8.00 : 45.00$$

giving the formula  $\text{R}_{18}\text{Si}_6(\text{Al}_2)_8(\text{O}, \text{F}_2, \text{Cl}_2)_{45}$  or  $9 \text{R}_2\text{O}$ ,  $6 \text{SiO}_2$ ,  $8 \text{Al}_2\text{O}_3$ , with part of the oxygen replaced by fluorine and chlorine.

The  $\text{Fe}_2\text{O}_3$  of the above analyses came undoubtedly from a thin film of ferric oxide on the tetrahedral crystals which had not been entirely removed by the various treatments with acids to which they had been subjected.

The  $\text{P}_2\text{O}_5$  cannot well be a constituent of the tetrahedra and is probably derived from a small proportion of an admixed aluminium phosphate. The excess of alumina constantly found over that required for the above formula renders this the more likely. Evidence of the presence of an admixed phosphate was also obtained by direct experiment. In material not specially purified there were observed a few irregular and generally dull grains which at first were supposed to be fragments of tetrahedra, perhaps slightly altered. Half a dozen of these, weighing in all less than 1 milligram, were picked out, crushed, fused with sodium carbonate, the fusion dissolved in nitric acid, and a few drops of molybdate solution added. A distinct yellow precipitate formed in a short time. Yet while the presence of an aluminium phosphate would, by lowering the aluminium of the above analyses, make the ratio  $\text{Si}:\text{Al}_2$  nearer 6:8 than it has been shown to be, I am not at all certain that the discrepancy is hereby entirely to be explained. For the given amount of  $\text{SiO}_2$  only 55.19 per cent. of  $\text{Al}_2\text{O}_3$  is required, leaving 2.69 per cent. for combination with only 0.60 per cent. of  $\text{P}_2\text{O}_5$ . Moreover, the above given ratio between  $\text{SiO}_2$  and  $\text{Al}_2\text{O}_3$  has been found by repeated careful analyses not included in the above, made on entirely different samples, to be practically constant. It is therefore possible that the true formula is more complex than that given above, or that some source of contamination exists which has as yet escaped detection.<sup>61</sup>

<sup>61</sup>After the above was ready for the press Mr. Cross communicated to me the following facts as the results of further microscopical examination:

"The zunyite has a polarizing inclusion, quite plentiful in a few crystals, but lacking entirely in most of them. When mounted in balsam the dark impurities stand out very plainly, causing the crystals to seem much more impure than they really are. The polarizing substance cannot be identified, but it is too brilliant for apatite. It has no good crystal form." This polarization, he further says, is distinct from that mentioned on p. 100, as occasionally shown by the zunyite itself. Hereby the opinion expressed above, that some foreign admixture was present, is confirmed.

As a name for the mineral, *Zunyite* is proposed, after the mine from which it was obtained.

The black inclusions in the zunyite were shown to contain titanic oxide by the following partial analyses of dark crystals:

SiO <sub>2</sub> .....	23.93	23.66
TiO <sub>2</sub> .....	0.75	0.84
Al <sub>2</sub> O <sub>3</sub> .....	*58.30	*58.45

\*Not freed from Fe<sub>2</sub>O<sub>3</sub> and P<sub>2</sub>O<sub>5</sub>.

In order to ascertain whether they consisted only of titanic oxide or of some titanate, an attempt was made to separate from the zunyite a quantity sufficient for analysis. It was soon found that this could be but very imperfectly accomplished and only by reducing large quantities of zunyite crystals to fine powder and then effecting the separation by means of the Thoulet solution. In this manner a mixture of barite, black particles, and attached zunyite was obtained, weighing, after thorough washing, but 0.5528 gram, which furnished the following results on analysis:

	LXIV.
BaSO <sub>4</sub> .....	83.90
SiO <sub>2</sub> .....	1.50
TiO <sub>2</sub> .....	8.60
Al <sub>2</sub> O <sub>3</sub> .....	3.33
Fe <sub>2</sub> O <sub>3</sub> .....	0.20
P <sub>2</sub> O <sub>5</sub> .....	Trace.
H <sub>2</sub> O, F, Cl, and loss .....	2.47
	100.00

Since the silica and alumina bear to each other nearly the same ratio as in zunyite, and since both fluorine and water were found to be present in small quantity, it is probable that all these were derived from attached zunyite, the perfect separation of which from the inclusions is practically impossible even with the comparatively large amounts operated upon. There remains then only titanic and a little ferric oxide, showing that the inclusions consist, in all probability, of titanic oxide alone.

By far the greater part of the zunyite-bearing ore seems to be in an advanced stage of decomposition. Through the kindness of Mr. J. A. Porter, of Durango, Colorado, the Colorado Scientific Society is the possessor of about fifty pounds of this altered ore completely filled with zunyite. The original double sulphide has almost disappeared, being changed into lead sulphate and other less well-defined compounds. While the zunyite is here in great measure still perfectly fresh, a considerable portion has been more or less altered, incipient change being indicated by a faint cloudiness through the crystals which, beginning apparently at the centre, spreads outward and increases in degree until, as a final product, there ensues a dull white opaque substance retaining in a measure the outlines of the original crystal and showing here and there a black grain of titanic oxide.

It was from this partially-altered ore that the material for the complete analysis above given and for the investigation of the inclusions was obtained, as the specimens of unaltered sulphide were too small to afford sufficient material by hand-picking.

A knowledge of the composition of the result of alteration of zunyite seemed desirable; hence the lightest of all portions separated by the Thoulet solution, of specific gravity 2.45, was partially analyzed. The result was unsatisfactory, indicating a mixture of probably several substances, of which a little undecomposed zunyite is known to be one, but the general character of the chemical change is in a measure shown.

	LXV.
SiO <sub>2</sub> .....	58.47
Al <sub>2</sub> O <sub>3</sub> .....	22.03
Fe <sub>2</sub> O <sub>3</sub> .....	0.27
CaO(SrO?) .....	1.70
ZnO .....	0.20
K <sub>2</sub> O .....	0.53
Na <sub>2</sub> O(Li <sub>2</sub> O) .....	1.29
P <sub>2</sub> O <sub>5</sub> .....	2.21
As <sub>2</sub> O <sub>5</sub> .....	0.40
SO <sub>3</sub> .....	4.52
F .....	0.91
Cl .....	0.15
H <sub>2</sub> O and loss .....	9.32
	100.00

Some of the constituents, as the As<sub>2</sub>O<sub>5</sub> and ZnO, have evidently been derived from the sulphide ore in which the mineral was imbedded.

#### GUITERMANITE.

The metallic sulphide forming the matrix of the zunyite, of which in a fresh state, as before observed, but two specimens were at disposal, is of a bluish-gray color, possesses light metallic lustre, and a hardness of about 3 on places free from included zunyite. A small amount of pyrite is visible in spots.

Heated in the closed tube it fuses readily and there appears a slight sublimate of sulphur followed by a heavy one of arsenic sulphide; while on charcoal the usual reactions for sulphur, arsenic, and lead may be observed.

The following analyses were made:

	LXVI.			LXVII.		
	a.	b.	Mean.	a.	b.	Mean.
Zunyite .....	1.77	.....	1.77	3.81	3.82	3.82
As .....	13.50	13.30	13.40	13.00	.....	13.00
Pb .....	63.40	63.80	63.60	61.65	61.62	61.63
Cu .....	0.17	0.18	0.17	0.17	0.17	0.17
Ag .....	0.02	.....	0.02	0.02	.....	0.02
Fe .....	0.42	0.43	0.43	0.87	0.89	0.88
S .....	19.65	19.70	19.67	19.67	19.45	19.56
O .....	.....	.....	.....	0.55	.....	0.55
Total .....	98.93	.....	99.06	99.74	.....	99.63

Analyses LXVI *a* and *b* were first made, on material which had a specific gravity of 5.828 at  $17\frac{1}{2}^{\circ}$  C. Corrected for admixed zunyite of specific gravity 2.9, this becomes 5.94. As the total could hardly be brought above 99 per cent., in spite of great care in analyzing, the cause of this was sought for and found as will be subsequently explained.

In the experiments (not of a quantitative nature) having this end in view the sample was exhausted, therefore fresh material was used for two subsequent analyses, LXVII *a* and *b*.

In both these and the previous ones the sulphur was found in excess of that required for the metals, on the assumption that all the arsenic was present as trisulphide and the iron as disulphide. This was due to the presence of free sulphur, which was estimated quantitatively by extracting with carbon disulphide and carefully evaporating the filtrate to dryness in a weighed crucible. After three extractions no more sulphur was dissolved. The amount thus obtained represented 0.59 per cent. of the material used for analyses, LXVII, *a* and *b*.

While accounting completely and satisfactorily for the excess of sulphur, this did not explain the low summation shown in the first analyses. It was found, however, that notwithstanding the apparent purity of the mineral, lead sulphate was present in some quantity.

The sulphur trioxide of this was estimated by extracting the sulphate from the mineral by digestion with warm dilute hydrochloric acid in an atmosphere of carbonic acid, three or four digestions being sufficient for complete extraction, and, after partial neutralization of the filtrate, precipitating as barium sulphate. The result was 0.69 per cent.  $\text{SO}_3$ . The lead oxide of the sulphate could not be estimated in this extract, because even the dilute acid slightly decomposed the sulphide, taking lead but no arsenic into solution. Under the conditions of the experiment practically no hydrogen-sulphide could be oxidized in the short time required for making the extraction.

As a check, the lead oxide of the sulphate was estimated quantitatively by extracting the sulphate with neutral ammonium acetate in a closed flask, three or four digestions with fresh solution being sufficient, throwing down the lead as sulphide, and converting into sulphate before weighing. The percentage of lead oxide thus found was 2.70, instead 2.61 required by the 0.69 of  $\text{SO}_3$  found. 2.61 of  $\text{PbSO}_4$  contains 1.78 of lead, 0.28 of sulphur, and 0.55 of oxygen. Thus the sum total was brought much nearer to 100.

Excluding now the lead sulphate, free sulphur, and pyrite, the following atomic values are obtained:

Pb.....	$59.85 \div 207. = 0.2891$	} 0.2904	3.35	10.05
$\text{Cu}_2$ .....	$0.17 \div 126.8 = 0.0013$			
$\text{As}_2$ .....	$13.00 \div 150. = 0.0866$			
S .....	$17.68 \div 32. = 0.5525$			
			6.38	19.14

These lead to the formula  $10 \text{ PbS}, 3 \text{ As}_2\text{S}_3$ . A simpler formula, and one not far removed from the above, is  $3 \text{ PbS}, \text{ As}_2\text{S}_3$ . If a small quan-

tity of galena was present, of which, however, there was no evidence, other than that afforded by the decomposition of some lead sulphide by dilute hydrochloric acid without simultaneous solution of arsenic, the latter formula is probably the correct one. But this evidence is of little value, for any arsenic dissolved from the double sulphide would probably be immediately thrown down again by the hydrogen sulphide evolved. Whichever formula may be the true one, the mineral appears to be new to science, and a name, *Guitermanite*, is proposed, in honor of Mr. Franklin Guiterman, who first called attention to this and the associated zunyite.

In conclusion, a few words will be in place respecting the occurrence of these two new minerals. According to Mr. Guiterman there appears to be no decided indication of a fissure vein in the Zuñi mine, but the minerals occur in what seem to be pipe veins enlarged in places, the surrounding rock being probably andesite. In this and other mines of the region kaolinization of the country rock is a marked feature.

#### A PROBABLY NEW MINERAL.

A portion of the ore from the Missouri mine, Hall's Valley, Park County, Colorado, is composed largely of a sulpho-bismuthide of copper and silver. It occurs in a quartz gangue associated with chalcopyrite and wolframite, and although the latter is only visible on close examination, it comprises from 1 to 2 per cent. of the whole, as found by special tests. A considerable quantity was extracted by chemical and mechanical means, free from all foreign matter except a little attached quartz, and was proven to be wolframite by qualitative chemical tests and by a determination of the specific gravity.

The mass of the sulpho-bismuthide appears throughout the quartz as a dark, bluish-gray substance without distinct forms of crystallization. In numerous cavities appear small slender crystals, generally bronzed by oxidation and so deeply striated as sometimes to present the appearance under the loupe of bunches of needles. Occasionally they seem to be joined together laterally forming thin corrugated plates. Owing to this deep striation no crystal faces can be detected either on the sides or the free terminations. The habit is strikingly like that of bismuthinite, for which the crystals were, indeed, at first taken.

After several days labor enough material was removed from the cavities for the determination of the metals. It could not, however, be freed altogether from quartz and chalcopyrite. The specific gravity at 17° C. was 5.75. Making correction for 4.43 per cent. of quartz and 6.98 per cent. of chalcopyrite of assumed specific gravities 2.65 and 4.2, this becomes 6.31. The analysis appears under LXVIII below.

The more compact material, excluding as far as possible the needles, gave, after deducting 59.75 per cent. of gangue, the results under LXIX.

LXX is the analysis of a mineral presented by Mr. William McCree as coming probably from the Missouri mine. In appearance it differs in no respect from the compact material already described, except that no chalcopyrite is distinctly visible in the small specimens at my disposal, and the quartz grains are less firmly cemented together. It contains, however, some lead, which is entirely wanting in the other specimens analyzed, although the general formula is the same; hence I am led to believe that it came from some other portion of the workings or from an adjacent mine where ore like that from the Missouri mine is reported to occur. The specific gravity was 3,869 at 15° C., which becomes 6.680 on making correction for 47.57 per cent. of gangue of ascertained specific gravity 2.643.

The most marked blow-pipe reactions for LXVIII, LXIX, and LXX, were entirely similar, a sublimate of sulphur appearing in the closed tube, sulphur dioxide escaping in the open tube, and the fused fragment or powder on charcoal affording the bismuth reactions with great intensity. All were soluble in nitric and hydrochloric acids, in the latter with precipitation of silver chloride.

	LXVIII.	LXIX.	LXX.
Bi .....	60.74	63.36	62.45
Ag .....	0.89	4.09	9.89
Cu .....	15.96	12.65	6.68
Pb .....			2.74
Fe .....	2.13	0.59	0.10
Zn .....	0.10	0.07	0.07
S .....	*19.94	*18.83	17.90
	99.76	99.59	99.83

\*Calculated.

After subtracting from LXVIII 6.97 per cent.; from LXIX, 1.91 per cent., and from LXX, 0.33 per cent. of chalcopyrite, with the proportions of sphalerite represented by the zinc, the atomic ratios become:

	R	:	Bi <sub>2</sub>	:	S.
LXVIII.	3.00	:	3.95	:	14.75.
LXIX.	3.00	:	4.03	:	14.98.
LXX.	3.00	:	4.10	:	15.15.

where R represents Pb and the double atoms Ag<sub>2</sub> and Cu<sub>2</sub>. In each case the ratio is nearly 3:4:15, which leads to the general formula 3RS + 4Bi<sub>2</sub>S<sub>3</sub>.

It seems probable that the needle-like crystals are a pure sulphobismuthide of copper, and that in the more compact portions silver replaces a part of the copper, and in some cases a further replacement of copper by lead takes place.



This ore from the Missouri mine is auriferous. The material used for analysis LXIX, gangue and sulphide together, assayed 1.85 ounces gold to the ton. According to Mr. Pearce, of the Boston and Colorado Smelting Works, it was frequently much richer, running as high as 40 ounces to the ton.

Before conferring a name upon this mineral, or even definitely claiming it as a new species, further investigation is advisable. A personal visit to the Missouri and other neighboring mines in October, 1884, in the hope of obtaining better material, was not rewarded with success.



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## EXPLANATION OF PLATE.

- Fig. 1 illustrates the twin structure and optical properties of stilbite, seen in clinopinacoidal section, as described by von Lasaulx. See text, p. 20.
- Fig. 2 illustrates the twin structure and optical properties of stilbite from Table Mountain, in corresponding position to that of Fig. 1. See text, p. 21.
- Fig. 3 illustrates the twin structure and optical properties of phillipsite, as described by Trippke. See text, p. 23.
- Figs. 4, 5, and 6 show the optical anomalies observed in the apophyllite of Table Mountain, by C. Klein. See text, p. 30.
- Figs. 7, 8, 9, and 10 illustrate the polysynthetic twin structure observed in the cryolite of Saint Peter's Dome. See text, pp. 43-47.
- Fig. 11 represents the crystal form of prosopite from Saint Peter's Dome. See text, p. 63.
- Fig. 12 represents a crystal of phenacite from Crystal Park, natural size. See text, p. 68.
- Fig. 13 shows the position of the parting which produces the lustre of the sanidine in the nevadite of Chalk Mountain. See text, p. 76.
- Fig. 14 the fundamental form of löllingite. See text, p. 90.
- Figs. 15 and 16, forms of löllingite, observed in the material from Gunnison County, Colorado. See text, p. 90-91.
- Figs. 17, 18, 19, 20, and 21 represent different forms of a rhombic arsenide of iron, cobalt, and nickel, observed in association with löllingite, Gunnison County, Colorado. See text, p. 91.

