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WEBERITE FROM PIKES PEAK, COLORADO

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The mineral collection of the Cryolite Company: "Kryolitselskabet Øresund" A/S, Copenhagen, Denmark, contains two specimens labelled "Cryolite, Colorado ?, *A* and *B*." They are about 3 cm. across and consist of a grayish-white, fine-grained mass, the single grains being less than 0.3 mm. in diameter. A specimen much larger than these, about 12 cm. across, but without any label, was found together with other mineral samples, and as it is essentially of the same type as the first-mentioned specimens, it must be assumed that *A* and *B* represent fragments of the larger piece. This assumption may be considered quite safe, judging from the singular character of the specimens.

The collection of the Mineralogical Museum of the University of Copenhagen contains a specimen similar to those mentioned above. It is labelled: "Cryolite, St. Peter's Dome, Colorado, 1903, no. 1364; donated by C. F. Jarl" (former President of the Cryolite Company). Under no. 1364, the catalogue of that collection, in addition to the text on the label, bears the statement: "magnesium-containing cryolite." Even though the four specimens differ a little, their general character warrants the assumption that they all came from the same locality.

A comparison with material from the Urals did not show any such similarities. In Ivigtut no material has ever been found which showed relations or textures such as are to be seen on the Colorado material.

A. H. Nielsen, chemist at the Cryolite Company, called my attention to the unusual composition of the two specimens *A* and *B*, which he had analyzed some time ago. The results are shown in table 1.

The high content of Mg is scarcely compatable with a mineral like cryolite, and A. H. Nielsen suggested that weberite or one of the "cubic" minerals known from Ivigtut might be present. The microscopic examination clearly showed that at least three quarters of the material was weberite. The mineral has an index of refraction between 1.345 and 1.350, it is biaxial with a large axial angle and corresponds closely to the material described by R. Bøgvad (1938) from the Greenlandic occurrence at Ivigtut.

The literature was searched but nothing was found indicating earlier observations of Mg in cryolite from Pikes Peak. In order to establish the

TABLE 1

	1	2	3	4	5	6	7	8	9	10	11
Insoluble*	0.24	—	—	—	—	2.90	4.10	0.17	1.51	0.10	0.16
Al	13.45	21.03	11.92	11.71	14.3	12.97	12.94	12.23	11.77	13.55	13.25
Ca	none	—	—	—	—	1.44	1.32	5.77	6.43	0.39	0.46
Mg	10.02	5.55	10.80	10.56	8.6	7.59	6.84	8.56	8.58	9.45	9.54
Fe	none	—	—	—	—	—	—	0.26	tr.	0.27	0.25
Na	18.81	7.44	20.87	19.97	18.3	15.84	19.50	—	15.82	—	18.77
K	—	—	—	—	—	—	—	—	tr.†	—	none
F	55.07‡	46.26	56.41	57.76	(58.7)	53.43	(55.30)	ca 54.8	—	ca 56.6	—
H_2O	2.30	14.26	(none)	none	—	5.78	—	—	3.14	—	1.92
Total	99.89	—	100.00	100.00	(99.9)	99.95	—	—	—	—	—

* In 1, 8, 9, 10, 11, Ti has been determined qualitatively.
† Revealed by means of a hand-spectroscope, H. Pauly.
‡ Determined by H. Buchwald.

1. "Cryolite" from Colorado. Min. Mus. Copenhagen. Analyst A. H. Nielsen.
2. "First cubic mineral" from Ivigtut. Analyst, H. Buchwald 1935.
3. 1. recalculated after deducting 16.13% of 2.
4. Weberite theoretical.
5. "Colorado-Cryolite," analyst, C. F. Jarl 1897.
6. "Colorado-Cryolite," analysis from Pennsylvania Salt Co. 1902.
7. "Colorado-Cryolite," analysis from "Øresund" 1903.
8. Sample *B* labelled Colorado Cryolite ?, analyst, A. H. Nielsen.
9. Sample *B* labelled Colorado Cryolite ?, analyst, A. H. Nielsen.
10. Sample *A* labelled Colorado Cryolite ?, analyst, A. H. Nielsen.
11. Sample *A* labelled Colorado Cryolite ?, analyst A. H. Nielsen.

origin and the locality of the samples and the way in which the Cryolite Company had acquired them, H. Buchwald, chief chemist of the chemical laboratory of the Cryolite Company, and A. H. Nielsen searched the records of the company. It was then revealed that in 1897 C. F. Jarl made an analysis of a sample of cryolite from Colorado with the result listed under no. 5 in the table. As Jarl was on a journey to the United States in 1896, we may assume that he himself brought home the sample he examined. He gives the figures for the fluorine compounds, here recalculated to the elements (F presumably calculated as F bound to the other components). This would seem to be the first observation of Mg in "cryolite."

In the year 1902, the Cryolite Company received a letter from the Pennsylvania Salt Manufacturing Company, Philadelphia, U.S.A., containing an analysis which was said to represent the cryolite ore from the Rocky Mountains. This analysis is given under no. 6 in the table. The following year, 1903, this company received a larger sample of the ore for a closer examination. Another analysis was then made (listed under no. 7). It may be assumed that when Jarl received larger amounts of the material he decided to give part of it to the Mineralogical Museum in Copenhagen, and this is probably the specimen mentioned above.

Upon the whole it may be concluded from a study of the earlier letters that the ore body of Pikes Peak was of a relatively large size and, what seems to be essential here, the content of Mg must be rather large; in other words, the mineral weberite plays an important part in the occurrence.

From the description given by Cross and Hillebrand, these specimens may be said to have come from the socalled "Eureca" tunnel where the vein *B* of the above-mentioned authors is located. On page 290 of their paper they describe the fluorides from this place as follows:

"The greater part of the fluoride mass is now dull white and very compact, and is evidently made up of a mixture of at least two substances, neither of which has as yet been identified. Only in a single specimen is there any clue to the original mineral, but in that there is a small, solid mass of unmistakable cryolite with alteration to pachnolite (?) progressing upon its cleavage planes in the exact manner described in vein *A*, but passing into the compact white mixture already mentioned."

This may be taken to mean that Cross and Hillebrand really observed weberite and the other minerals, but were not then able to determine the new mineral.

Together with the weberite several other minerals are observed: rutile, as fine needles included in the weberite grains, and in some of the samples scattered in it as black elongated grains up to 1 mm. in length. This agrees well with the observed Ti in the analyses. Thomsenolite and/or pachnolite may be present in a few grains. In *B* which contains large amounts of Ca, fluorite occurs, and here also prosopite is present. This also points to the "Eureca" tunnel or vein *B* as the most probable place of origin for the weberite.

In this connection it may be of interest to add some information I received from H. Sørensen. During his work on systematic *x*-ray powder photography of minerals (carried out in Oslo for Dr. H. Neumann), weberite together with prosopite were found in a sample labelled Prosopite, Colorado. Dr. Neumann has kindly let me have the specimen, which belongs to the mineral collection of Oslo Mineralogical Museum, for comparison with the material discussed here. I take this occasion to express my very cordial thanks to Dr. Neumann. On one side, the sample has a coarse-grained aggregate of greenish prosopite, whereas the other side is very much like the samples found in our collections. Microscopically the sample is seen to contain the same minerals.

Among the most interesting minerals found with weberite in all the samples are three "cubic" minerals. They constitute about 15 percent of the material. The refractive indices of these minerals are near 1.365, 1.390 and 1.41. The determinations may vary about 5 in the third decimal. Judging from the refractive indices they may be compared with some minerals from Ivigtut described by O. B. Bøggild in 1913 as the third "cubic" mineral and the first "cubic" mineral.* The mineral having an index near 1.41 may be ralstonite. The third "cubic" mineral is only known from a steamboiler in Ivigtut, the second is known to occur together with thomsenolite in Ivigtut.

The term "cubic" is used in spite of the minerals being clearly but weakly anisotropic, because these minerals from Ivigtut have been classified as cubic.

The problems connected with ralstonite and the "cubic" minerals from Ivigtut have been studied for some time, and a closer examination of these relations, carried out on Ivigtut material, will be finished in the near future in this laboratory in collaboration with the staff of the Mineralogical Museum. R. Bøgvad,† late chief geologist to the Cryolite Company, started these investigations together with H. Buchwald. As it is of interest here, an analysis of the first "cubic" mineral, carried out by Buchwald, has been given here with his kind permission (no. 2 in the table). Bøgvad gives $n=1.406\pm0.001$. Bøggild (1913) for his first "cubic" mineral gives $n=1.3852$. The Colorado mineral has n about 1.390. They do not agree very closely, but the following seems to justify the similarity: Assuming that all the water in the analysis given under no. 1 represents water from a "cubic" mineral with a composition as given under no. 2 in the table, Buchwald calculated the amount of "cubic" mineral present and subtracted it in the analysis and recalculated the rest at 100 per cent with the result as listed under no. 3. As will be seen, this gives a fairly good agreement with the theoretical composition of weberite as set forth as no. 4 in the table. Accordingly the analyzed sample from the Mineralogical Museum in Copenhagen contains 84 per cent of weberite and 16 per cent of a "cubic" mineral. This is in good agreement with the microscopic results.

Analyses 8 to 11 have been included in the table just to show the variations in the material.

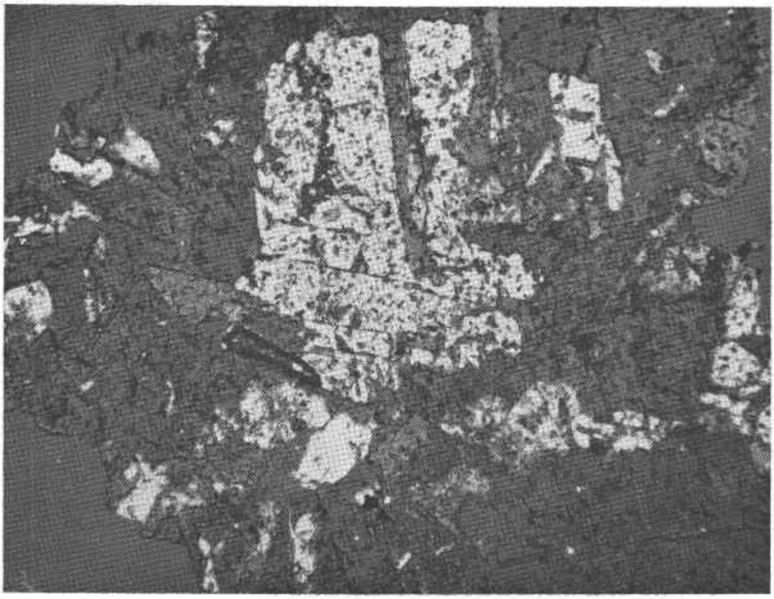
During his stay at the Oslo Mineralogical Institute, H. Sørensen was so kind as to make some x-ray powder diagrams of different types of weberite from Ivigtut and of some of the Colorado samples. The patterns are almost identical. A slight difference represented by some extra lines in the Colorado material may be due to an admixed "cubic" mineral, but this is not immediately evident. As these lines are very weak no weight has been attached to their occurrence.

From the microscopic examination of thin sections it is evident that

* By O. B. Bøggild termed "regular" minerals in "The Mineralogy of Greenland."

† He died in 1952, while working in the neighborhood of Ivigtut.

the "cubic" minerals have replaced the weberite. The texture exhibited by these minerals is seen in Fig. 1. It may perhaps constitute a valuable guide in the studies of these minerals and their relations as well as their structural behavior.



A thin section of Pikes Peak material, in liquid with $n=1.347$. Weberite crystals corroded by "cubic" minerals. Mag. 134×. Upper nicol a few degrees from crossed position in order to show the surrounding material.

It may be of interest to mention that the sections were made in the ordinary way, but afterwards the balsam was removed and pieces of a section were imbedded in a mixture of water and glycerol having an index near those of the minerals, in order to avoid too great a relief.

Summary

An examination of certain samples from the cryolite deposit, Pikes Peak, Colorado, has shown that weberite, hitherto only known from Ivigtut, is to be found among the minerals there, and that it occurs together with three different "cubic" minerals, resembling the first and third "cubic" minerals from Ivigtut, and ralstonite.

By kind permission of H. Tuxen, President of "Kryolitselskabet Øresund" A/S, I have been able to publish these investigations. For this I offer my best thanks.

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A DISCUSSION ON "ORIENTED OLIVINE INCLUSIONS IN DIAMOND"

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Recently Mitchell and Giardini (1953) reported on oriented inclusions of olivine in diamond flats. The orientation was such that (010) of olivine was parallel to (111) of the diamond and that the zone [101] of olivine was parallel to [101] of the diamond. The inclusions were elongated parallel to the [101] direction which was common to both the olivine and diamond. This is a very peculiar habit for olivine crystals as they are commonly elongated parallel to the *c*-axis. However, this habit can be understood on the basis of a newly developed theory of crystal morphology (Hartman and Perdok, 1952). According to this theory the habit of a crystal is governed by a set of chains of strong bonds running through the structure. Such a periodic bond-chain is represented by a periodic bond chain vector (P.B.C. vector) with a length equal to the period of the attachment energy of the chains.

Oriented inclusions are always connected with the pseudo-equality of parameters. In the present case the pseudo-equality concerns the direction [101] in both crystals. For the diamond the cube edge length is 3.56 Å. (Wyckoff, Chap. II, table p. 11). The parameters for olivine are: $a=4.77$ Å, $b=10.28$ Å, and $c=6.00$ Å (*Strunz, Min. Tabellen*, p. 169). The axes chosen here are the morphological ones. From these data [101] for the diamond is 5.03 Å and [101] for olivine is 7.66 Å, that is nearly $3/2\times5.03$ (misfit 1.5%). This is a good agreement. In the diamond the direction [110] makes with [101] an angle of 60°. In olivine the direction [$\bar{1}$02] makes with 101 an angle of 60°8′ and its length is 12.91 Å, that is approximately 5/2 times 5.03. The misfit is here 2.5%. According to Neuhaus (1943) oriented inclusions should have pseudo-equality of parameters in three dimensions. In this case it is found that the *b*-axis of olivine is exactly equal to $5\times d_{111}$ of the diamond.

Now it can be concluded from an inspection of the structure of olivine that there are P.B.C. vectors connected with *a.o.* [001] and [101]. The