

THE AMERICAN MINERALOGIST

JOURNAL OF THE MINERALOGICAL SOCIETY OF AMERICA

VOL. 14

MAY, 1929

No. 5

MOOREITE, A NEW MINERAL, AND FLUOBORITE FROM STERLING HILL, NEW JERSEY

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The minerals here described occur in intimate association with altered pyrochroite, rhodochrosite and zincite, in a vein in normal calcite-franklinite-willemite ore from the Sterling Hill Zinc mines. The willemite in one of the specimens examined, is replaced, near the vein, by brown serpentine ($n=1.56$). The cavities in the pyrochroite are lined, and some of the crevices are filled, with glassy white tabular crystals which, upon investigation, proved to be a new mineral, for which the name mooreite is here proposed, in honor of Dr. Gideon E. Moore*, an early investigator of Sterling Hill and Franklin minerals. A closely related bluish-white mineral filling some of the crevices in the pyrochroite is termed here δ -mooreite. The other mineral occurring in the veins is a hair-like material in fluffy aggregates very loosely bound together, filling cavities in the pyrochroite, and covering the crystals of mooreite. Analyses of this material indicate that it is essentially a basic borate of magnesium, identical with the new mineral fluoborite, recently described by Geijer.¹ On one specimen were found some fibrous white rosettes of willemite which resemble the fluoborite and are easily confused with it.

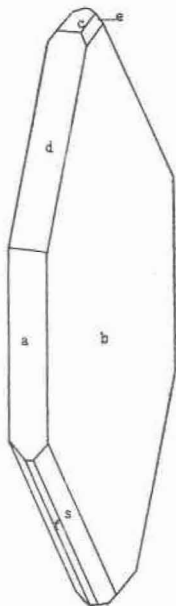
* Gideon E. Moore, chemist of the Passaic Zinc Company in 1872 and of its successors until 1895. He described the minerals brushite, chalcophanite and hetaerolite, the two latter first found at Sterling Hill. Moore was born in New York in 1842 and died there in 1895. He was a graduate of Yale and took his Ph.D. in Heidelberg in 1869. His first professional work was as chemist for the Gould & Curry Mine on the Comstock from 1863 to 1867 and he then studied the minerals of that famous lode but did not publish his results. In later years he took out several patents in connection with the metallurgical treatment of Franklin zinc ores and others relating to organic chemistry. We are indebted for these facts to the Librarian of the New Jersey Zinc Company.

¹ *Geol. För. Förh.*, Stockholm, Jan.-Feb. 1926, p. 85, Vol. 48, pt. 1. *Sveriges Geol. Undersökning*, Ser. C., No. 343, Årsbok 20 (1926), No. 4.

MOOREITE

CRYSTALLOGRAPHY

Mooreite is monoclinic. The crystals are tabular and generally in subparallel aggregates grouped on the clinopinacoid. Of the many crystals studied, only a few were of a quality sufficiently good to yield moderately accurate measurements, the remainder were etched, striated, or distorted by subparallel growth. The angle table gives the measured angles together with the elements and angles calculated from them. The elements have been calculated from weighted averages in the making of which single good readings have been given preference over many rather poor ones, so that the elements are probably more accurate than an inspection of the measured angles would indicate. The principal forms of the crystal (fig. 1.) are b (010), always the largest faces on the crystal, d (101) present as long narrow faces usually having mediocre reflection surfaces and r ($\bar{1}11$) as long narrow line faces with good reflections. The other forms occurred on most crystals but were not used in the calculations because of their inferior quality. There



Mooreite, Franklin, New Jersey

were a few occurrences of c (001) which gave fairly good direct measurements of the inclination of the axes, and these were used in preference to indirect methods of computing the inclination.

A number of small doubly terminated crystals were found almost ideal in development.

No crystals of δ -mooreite were found, but it is thought to be monoclinic also, from its optical properties.

TABLE I
ANGLE TABLE—MOOREITE

$p_0 = 1.743$	$a = .553$
$q_0 = .813$	$c = .963$
$e = .537$	$\beta = 142^\circ 27'$
$\mu = 57^\circ 33'$	

Letter	Symbol	Calculated		Observed maximum		Observed minimum		Average	
		ϕ	ρ	ϕ	ρ	ϕ	ρ	ϕ	ρ
c	001	90° 00'	32° 27'		32° 42'		32° 16'		32° 27'
b	010	0°	90° 00'						
a	100	90° 00'	90° 00'						
d	101	90° 00'	69° 41'		70° 23'		69° 34'		69° 54'
e	$\bar{1}01$	90° 00'	55° 01'						55° 00'
f	$\bar{1}02$	90° 00'	21° 39'						21° 29'
g	011	33° 27'	49° 06'	32° 02'	49° 06'	33° 15'	49° 14'	33° 11'	49° 09'
p	121	54° 30'	73° 13'	55° 01'	73° 18'	54° 23'	73° 06'	54° 42'	73° 12'
r	$\bar{1}11$	56° 01'	59° 52'	56° 15'	59° 51'	55° 56'	59° 48'	56° 03'	59° 50'
i	$\bar{1}13$	9° 12'	18° 01'	— 9° 24'	18° 05'	9° 22'	17° 57'	9° 23'	18° 01'
v	$\bar{1}15$	49° 07'	16° 26'	49° 11'	16° 18'	48° 51'	16° 15'	49° 01'	16° 17'

CHEMICAL COMPOSITION

Mooreite is a very basic, hydrous sulphate of magnesium, manganese and zinc. The two types differ principally in the relative proportions of these three bases.

TABLE II
TABLE OF ANALYSES OF MOOREITE AND δ -MOOREITE

1. and 2. Separate complete analyses of mooreite.
3. Average of 1 and 2 omitting unessentials and recalculated to 100 per cent.
4. Molecular ratios of 3.

5. Analysis of δ -Mooreite.

6. Molecular ratios of 5.

1	2	3	4	5	6
MgO 25.41	24.98	25.38	.629	17.27	.427
MnO 11.46	12.24	11.93	.167	17.98	.253
ZnO 24.57	24.24	24.58	.300	26.30	.323
SO ₃ 11.11	10.73	10.99	.136 = $1 \times .136$	11.64	.145 = $1 \times .145$
H ₂ O 27.20	26.67	27.12	$1.506 = 11 \times .137$	26.39	$1.466 = 10 \times .146$
B ₂ O ₃ Present				Present	
SiO ₂ 0.06				0.08	
CaCO ₃	0.89				
99.81	99.75	100.00		99.66	

The formulas to which these analyses lead are:

Mooreite $8 \text{ RO} \cdot \text{SO}_3 \cdot 11\text{H}_2\text{O}$ where $\text{R is Mg : Mn : Zn} = 4 : 1 : 2$.

δ -Mooreite $7 \text{ RO} \cdot \text{SO}_3 \cdot 10\text{H}_2\text{O}$ where $\text{R is Mg : Mn : Zn} = 5 : 3 : 4$.

or they may be written:

Mooreite $7\text{R}(\text{OH})_2 \cdot \text{RSO}_4 \cdot 4\text{H}_2\text{O}$

δ -Mooreite $6\text{R}(\text{OH})_2 \cdot \text{RSO}_4 \cdot 4\text{H}_2\text{O}$

There are no known minerals to which mooreite is closely related. Nor can it be said which of the two varieties is the more typical chemically for it could not be determined whether or not one of them was forming at the expense of the other. δ -mooreite appeared to be replacing pyrochroite in one place which might be interpreted as meaning that it was first to form and was intermediate between the manganese hydrate, pyrochroite, and the magnesium-rich mooreite.

PHYSICAL AND OPTICAL PROPERTIES

Mooreite is clear, glassy white in color, with a perfect cleavage parallel to b (010). δ -mooreite is bluish white, granular, and has a less perfect pinacoidal cleavage. The hardness of both varieties is about 3. The specific gravity was determined by the pycnometer method:

Mooreite = 2.470

δ -Mooreite = 2.665

The optical characters, determined by the immersion method are compared below:

MOOREITE	δ -MOOREITE
Biaxial negative, $2V=50^\circ \pm$	Biaxial negative, $2V=40^\circ \pm$
$X=b$; $Z \wedge c=44^\circ$	
$\rho > \nu$ perceptible	
$\alpha=1.533$	$\alpha=1.570$
$\beta=1.545$	$\beta=1.584$
$\gamma=1.547$	$\gamma=1.585$

FLUOBORITE

On the previous page mention was made of the occurrence, with mooreite, of fluoborite. The material in most specimens consists of a fluff of loosely felted fibers unattached in the cavity and later in origin than all of the associated minerals. It was found, however, that the borate had begun to be deposited at least as early as the mooreite which contains fibers of it. This fluffy material is so light in weight that difficulty was experienced in obtaining a sufficient amount for analysis, and, as a matter of fact, the unusual difficulty of this particular analysis made necessary much preliminary work, so that a scarcity of material was encountered. In the course of the investigation new material was obtained consisting in part of fluoborite in a compact finely fibrous form intimately mixed with a hydrous carbonate probably closely related to hydrozincite, and in part as veinlets in an especially pure zincite from Sterling Hill. A specimen of the latter in the Harvard Museum had long been labelled hydrozincite. Upon closer examination it was found to contain veinlets of fluoborite comparatively free from impurities. The main mass of the specimen is the pure zincite referred to above, penetrating which are irregular areas of carbonates. The carbonates have been partially altered to a dull granular mass showing slickensided surfaces upon which the fluoborite veinlets are found. In a few instances the veins are fluorite. The analysis in Table III is of the fluoborite in this specimen. It is considered the best of the analyses made because the sample was practically free from impurities. Many difficulties were encountered in the preparation of a sample and in devising a satisfactory method of analysis. Fortunately the best sample was analyzed after considerable work had already been done on inferior material and the method, outlined in Table III had been devised.

TABLE III

ANALYSIS OF FLUOBORITE; L. H. BAUER, ANALYST

1. Fluorite, analysis of material associated with zincite. 1.28 grams, about 97 per cent pure. (Cat. number 89379).
2. Molecular ratio of 1.
3. Carbonate impurity deducted as calcite (some MnCO_3).
4. Molecular ratio of 1 after deducting impurity.
5. Calculated composition for $6\text{RO} \cdot \text{B}_2\text{O}_3 \cdot 3(\text{F}_2, \text{H}_2\text{O})$.

PROCEDURE IN ANALYSIS

1.28+grams were used for analysis.

0.1512 gram was taken for determination of H_2O .

Ref. *Am. Jour. of Sci.*, V, 48, 3rd Series, 1894.

Freshly ignited C.P. CaO equivalent to $2\frac{1}{2}$ times the weight of the sample was taken as a retainer for the fluorine. C.P. anhydrous PbO as recommended by Penfield was found unsatisfactory.

0.1873 gram was taken for determination of CO_2 .

0.202 gram was taken for MgO , ZnO , MnO , and CaO ; these were determined by well known standard methods.

0.1918 gram was taken for determination of B_2O_3 . Distillation Method as Modified by Chapin. Ref. *Scott's Standard Methods of Chemical Analysis*, 4th Ed., Vol. I, page 87.

The sample was fused with twice its weight of C.P. SiO_2 and eight times an equal mixture of Na_2CO_3 and K_2CO_3 . Strict precautions as outlined by Chapin were observed in dissolving and transferring the HCl solution of the sample into the distillation flask.

This procedure was first tried with synthetic mixtures of C.P. CaF_2 and B_2O_3 .

0.1502 gram was taken for determination of fluorine. Ref. *Fresenius, Quant. Chem. Analysis*, Vol. II, page 1182. *Treadwell and Hall, Analytical Chemistry*, Vol. II, 7th ed., page 407. In the absence of silica the sample was fused as in the boron determination with twice its weight of C.P. SiO_2 and eight times an equal mixture of Na_2CO_3 and K_2CO_3 . The fusion was not blasted and all subsequent operations where possible were performed in platinum ware.

	1	2	3	4	5
MgO	60.07	1.487	.007	$1.538 = 6 \times .256$	67.38
ZnO	2.41	.030			
MnO	1.93	.028			
CaO	1.19	.021	.021		
B_2O_3	17.25	.246		$.246 = 1 \times .246$	17.40
F_2	17.60	.463	.028	$.753 = 3 \times .251$	17.00
H_2O	5.22	.290			
CO_2	1.23	.028			
	106.90				107.15
	7.41				7.15
	99.49				100.00

In Table IV are some of the analyses made on other samples. Analyses 3 and 4 of this table are on impure material before and after the easily soluble portion was removed. The fluorborite is difficultly soluble in acid. In analysis 4 of the acid treated portion, the fluorine and boric acid are found in amount, demanded by the fluorborite formula. There is, however, a deficiency in water, which may account for the low total. Analyses 1 and 2 of Table IV are of fluorborite with varying amounts of impurities.

TABLE IV
ANALYSES OF FLUORBORITE

1. Fluorborite from Sterling Hill, analysis of material associated with zincite. 85 per cent pure. Impurity calcite. L. H. Bauer, analyst.
2. Fluorborite from Sterling Hill, analysis of material associated with zincite. (Cat. No. 89345). Large impurity of hydrous carbonate probably $4\text{RO} \cdot \text{CO}_2 \cdot 3\text{H}_2\text{O}$.
3. Fluorborite from Sterling Hill, associated with mooreite. Large impurity of hydrous carbonate.
4. Fluorborite. Sample 3 after treatment with HCl (1:1) until effervescence ceased. The low total may be accounted for by the deficiency in the water as given.
5. Fluorborite from Norberg, Sweden. Analyst Dr. Bygden. $\text{*SiO}_2, \text{Al}_2\text{O}_3, \text{Fe}_2\text{O}_3$.

	1.	2.	3.	4.	5.
MgO	48.00	29.16	46.33	62.07	61.65
ZnO	3.69	30.06	15.00	2.05	
MnO	6.10	8.55	4.13	2.09	0.05
CaO	7.36	0.17			
B ₂ O ₃	14.40	2.57	10.87	18.68	17.90
F	14.16	1.55	9.83	17.14	9.30
H ₂ O	4.55	16.13	10.62	1.29	10.78
CO ₂	6.87	11.64	5.22		1.36
SO ₃	0.45	0.14	0.27		2.16*
	<hr/>	<hr/>	<hr/>	<hr/>	<hr/>
	105.58	99.97	102.27	103.32	103.20
Less O for F ₂	5.96	.65	4.14	7.22	3.92
	<hr/>	<hr/>	<hr/>	<hr/>	<hr/>
	99.62	99.32	98.13	96.10	99.28

The best analysis leads to the formula: $6\text{MgO} \cdot \text{B}_2\text{O}_3 \cdot 3(\text{F}_2, \text{H}_2\text{O})$ in which the ratio of water to fluorine is as 2:3. The ratio in fluorborite from Norberg is approximately as 12:5; the Sterling Hill occurrence is thus much richer in fluorine although the molec-

ular percentage of the two constituents combined remains the same in both occurrences. This seems to add weight to the assumption that the water and fluorine are mutually replaceable in this mineral and under suitable conditions we might reasonably expect a fluorine free "fluoborite." In this connection it is interesting to note that sussexite, the mineral which is probably most closely related to fluoborite, as was pointed out by Geiger, is free from fluorine.

PHYSICAL PROPERTIES OF FLUOBORITE

The fluoborite, associated with mooreite, from Sterling Hill is uniaxial negative (-), with $\omega=1.548$ and $\epsilon=1.518$. The specific gravity, determined by floating a loosely matted aggregate in clerici solution is 2.88. The fluoborite associated with zincite had the following properties. Uniaxial negative (-), $\omega=1.547$; $\epsilon=1.522$, and a specific gravity, determined on compact fibrous aggregates, of $2.92 \pm .01$. This value for the specific gravity is probably more accurate than the one given for the fluoborite associated with mooreite because the material used was more suited to such a determination.

It was not possible to determine the crystallographic nature of the material directly, as was the case with the type material, since fibers showed no hexagonal outline under the microscope and were far too small for goniometric study. Indirectly, however, by comparison of X-ray powder spectrographs of the type material and the Sterling Hill fluoborite, it was found that the structures of the two give essentially the same spectral lines.