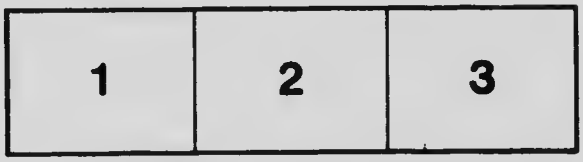
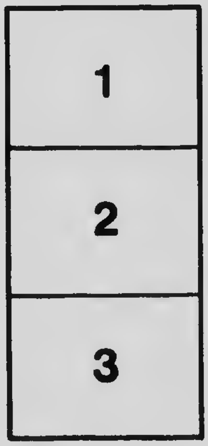
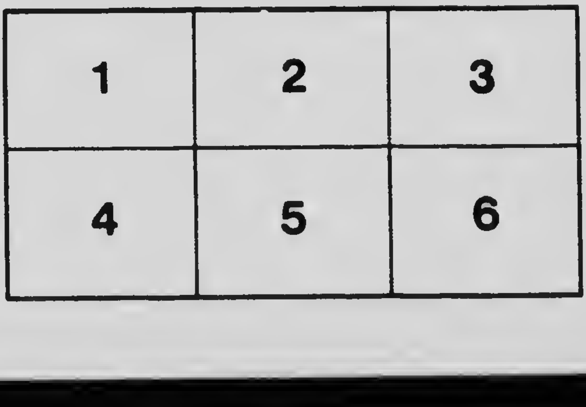

1
2
3


1
2
3


1
2
3
4
5
6

Technical and Bibliographic Notes / Notes techniques et bibliographiques

The Institute has attempted to obtain the best original copy available for filming. Features of this copy which may be bibliographically unique, which may alter any of the images in the reproduction, or which may significantly change the usual method of filming, are checked below.

L'Institut a microfilmé le meilleur exemplaire qu'il lui a été possible de se procurer. Les détails de cet exemplaire qui sont peut-être uniques du point de vue bibliographique, qui peuvent modifier une image reproduite, ou qui peuvent exiger une modification dans la méthode normale de filmage sont indiqués ci-dessous.

- ☐ Coloured covers/ Couverture de couleur
- ☐ Covers damaged/ Couverture endommagée
- ☐ Covers restored and/or laminated/ Couverture restaurée et/ou pelliculée
- ☐ Cover title missing/ Le titre de couverture manque
- ☐ Coloured maps/ Cartes géographiques en couleur
- ☐ Coloured ink (i.e. other than blue or black)/ Encre de couleur (i.e. autre que bleue ou noire)
- ☐ Coloured plates and/or illustrations/ Planches et/ou illustrations en couleur
- ☑ Bound with other material/ Relié avec d'autres documents
- ☑ Tight binding may cause shadows or distortion along interior margin/ La reliure serrée peut causer de l'ombre ou de la distorsion le long de la marge intérieure
- ☐ Blank leaves added during restoration may appear within the text. Whenever possible, these have been omitted from filming/ Il se peut que certaines pages blanches ajoutées lors d'une restauration apparaissent dans le texte, mais, lorsque cela était possible, ces pages n'ont pas été filmées.

- ☐ Coloured pages/ Pages de couleur
- ☐ Pages damaged/ Pages endommagées
- ☐ Pages restored and/or laminated/ Pages restaurées et/ou pelliculées
- ☑ Pages discoloured, stained or foxed/ Pages décolorées, tachetées ou piquées
- ☐ Pages detached/ Pages détachées
- ☑ Showthrough/ Transparence
- ☐ Quality of print varies/ Qualité inégale de l'impression
- ☐ Continuous pagination/ Pagination continue
- ☐ Includes index(es)/ Comprend un (des) index

Title on header taken from:/
Le titre de l'en-tête provient:

- ☐ Title page of issue/ Page de titre de la livraison
- ☐ Caption of issue/ Titre de départ de la livraison
- ☐ Masthead/ Générique (périodiques) de la livraison

- ☐ Additional comments:/ Commentaires supplémentaires:

This item is filmed at the reduction ratio checked below/
Ce document est filmé au taux de réduction indiqué ci-dessous.

10X	12X	14X	16X	18X	20X	22X	24X	26X	28X	30X	32X
☐	☐	☐	☐	☐	☐	☐	☑	☐	☐	☐	☐

UNIVERSITY OF TORONTO STUDIES

GEOLOGICAL SERIES

No. 10: MINERALOGY OF THE H.B. MINE, SALMO, B.C.,
BY T. L. WALKER

THE UNIVERSITY LIBRARY: PUBLISHED BY
THE LIBRARIAN, 1918

UNIVERSITY OF TORONTO STUDIES
COMMITTEE OF MANAGEMENT

MINERALOGY OF THE H. B. MINE, SALMO, B.C.

BY

T. L. WALKER.

MINERALOGY OF THE H. B. MINE, SALMO, B.C.

The H. B. Mine is situated in the Nelson mining district of British Columbia about four miles in direct line from Salmo station on the Great Northern Railway, although by wagon road it is about nine miles from the station. During 1914 and the two subsequent years it was a producer of oxidized zinc-lead ores which were shipped to smelters in the United States for treatment.

The country in the vicinity of the mines is occupied by carboniferous rocks locally known as Pend d'Oreille limestone and Pend d'Oreille schists. The limestone which is the younger, is well marmorized while the latter is composed of quartzite, mica schist and phyllite. The whole complex is intersected by numerous minette dykes. According to Galloway[1] "the 'veins' are of the bedded type and are best described as replacement ore deposits. The ore bodies are fairly regular and have been called veins but are strictly speaking, replacements. The ore bodies lie wholly within the limestone".

The oxidation of these ores has been so complete that even small specimens of sulphides are extremely rare. The chief minerals of economic value are calamine and cerussite and to a less extent the new zinc phosphate spencerite. Associated minerals are limonite, smithsonite, hydrozincite and the rare zinc phosphates hopeite and parahopeite. In 1915 and again in 1916 the writer visited the mine and collected some of the material which was later supplemented by contributions from E. W. Widdowson of Nelson, G. E. Irwin of Vancouver, and R. K. Neill of Spokane.

Calamine

This mineral is usually intimately associated with limonite and occurs commonly in mammillary masses though under exceptional conditions it is beautifully crystallized as diver-

---

[1] Report Minister of Mines, British Columbia 1915, p. 160.

gent aggregates of water clear crystals. Rarely the crystals occur as single individuals. The forms observed are (010), (001), (110), (011), (031) (101) and (301). The crystals are always attached by the lower end so that the hemimorphic character of the mineral is not apparent. The usual habit of the crystals is shown in Figures 1 and 2.

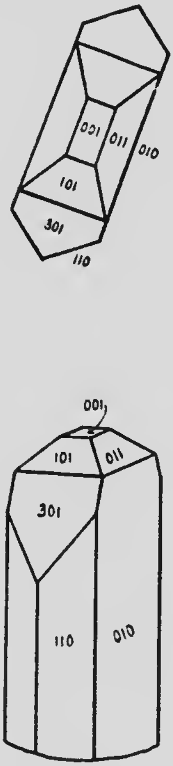


Fig. 1.

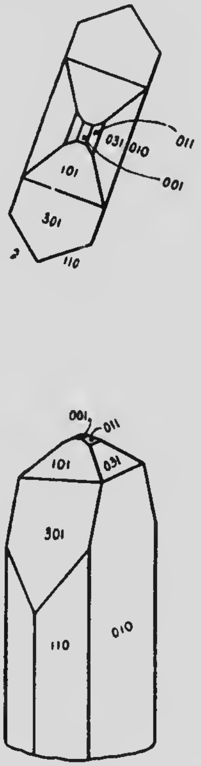


Fig. 2.

In the massive form calamine is always present in stalactitic aggregates where it always forms the outer crust of the growth, the core being sometimes spencerite, parahopeite or hopeite.

SPENCERITE

In 1915 in the H. B. Mine a cave of considerable size was discovered in which there was an unusual development of stalactitic material composed principally of the new zinc phosphate spencerite $Zn_3(PO_4)_2Zn(OH)_2.3H_2O$. Mr. Galloway who examined the mine at that time says, "The main drift in one place opened out into a large natural cave, from the roof and floor of which were hanging and extending large stalactites and stalagmites. Large botryoidal masses of the same material were scattered around".[1] Professor Phillips, referring to this cave as described by one of the miners in a letter to him, says, "We ran into this ore last October (1915) and most all of it was taken out and shipped. This ore was in a sort of cave 16′ by 24′ by 8′ high. When we broke into it there were pillars of ore reaching from the roof to the floor of the cave, also masses hanging down from the roof. . . . The main ledge of zinc carbonate passes directly over the cave. It is cut by two dykes at the cave, one dyke forming the wall and the other the roof of the cave. . . . On the floor there was a mass of very phosphatic clay which carried about twenty per cent of zinc, and buried in the clay were great chunks of this ore. About one hundred tons of ore were taken from the cave".[2]

The stalactitic masses are white or cream-coloured and are sometimes nearly a foot in diameter. The outermost zone, which is a few millimeters thick, is always calamine while the central part or core is made up entirely of zinc phosphates, principally spencerite.

The first material obtained containing spencerite shewed no crystals so that the original description was based on the cleavable material constituting the cores of the stalactitic masses.

> "Sometimes as a result of solution of the outer zone of the spencerite there is formed, between the silicate and the core of spencerite, an open space into which exceedingly delicate plates of hemimorphite project from the outer wall. This has apparently been brought about by the solution of the outer part of the

---

[1] *op. cit.*, p. 161.

[2] Am. Jour. Sc., Sept. 1916, series 4, Vol. xlii, p. 275.

spencerite, the thin plates of hemimorphite having been included in the spencerite, along cleavage-planes before the solution occurred. This type of silicate is spherulitic in structure and is found occasionally in the spencerite in minute, flat plates following the best cleavage. It is readily recognized when the mineral is examined between crossed nicols by the presence of a black cross for each spherulitic individual.

CHEMICAL PROPERTIES.

"The mineral dissolves very readily in acids. On adding ammonia to the acid solution a heavy white precipitate forms and dissolves in excess of the reagent. In this respect spencerite resembles the phosphates of zinc previously described. The quantitative analysis shows that the mineral is exceedingly pure and that it agrees very closely with the formula $Zn_3(PO_4)_2 . Zn(OH)_2 . 3H_2O$, the calculated percentage composition of which is given in column IV. Two analyses were made by the writer (I and II) and a third by Mr. E. W. Widdowson, of Nelson, B.C. (III).

	I.	II.	III.	IV.
ZnO	60.18	60.18	60.05	60.32
P_2O_5	26.14	26.23	26.74	26.32
Water at 160°	9.79	9.83	13.70	10.02
Water above 200°	3.53	3.47		3.34
MnO	—	—	0.41	—
Silica	—	—	0.40	—
	99.64	99.71	101.30	100.00

"When heated in a closed tube the mineral decrepitates and yields water in abundance. While hot the material is yellow, becoming white again on cooling; thus indicating the presence of a basic salt of zinc. The temperatures at which the water is given off are indicated in the above analyses. Between 160° C. and 200° C. there is no loss. At 400° C. the whole of the water is set free except 0.21 per cent., which appears to be still more firmly held and is set free only at a somewhat higher temperature. This difference in the attachment of the water corresponds with the formula suggested above, in which one-fourth of the water is combined to form zinc hydroxide, while the other three-fourths may be regarded as water of crystallization.

PHYSICAL PROPERTIES.

"The density of the mineral was determined as 3.145 by means of the hydrostatic balance and as 3.142 by the use of heavy solutions. The mineral is about 3 in the scale of hardness. When the powder is heated to a moderate red-heat the mineral fuses readily. It is pure white in colour. The lustre is usually pearly but occasionally vitreous. The cleavages are in three directions and of different degrees of perfection, one of them being very perfect, while the other two are slightly less so. The best cleavage lends to the mineral a somewhat scaly structure. If a small fragment be broken up and examined with a low power under the microscope it is seen that almost all the pieces lie with the best cleavage parallel to the glass support. The other cleavages as observed on these fragments appear to be at right angles to one another, so that the mineral seems to be in agreement with the rhombic system. That the plates are almost all of a common crystallographic orientation is shown by the fact that they show, when examined in convergent light, a biaxial interference-figure. Such cleavage-plates can be also readily distinguished from the small number following one of the other cleavages, because the former exhibit very low birefringence as compared with the latter.

OPTICAL PROPERTIES.

"The mineral is too cleavable to make it possible to cut prisms to determine the indices of refraction. An attempt was made to find these constants by total reflection, using thin plates parallel to the best cleavage. Since these plates give good interference-figures, the acute bisectrix is apparently normal to this cleavage. Owing to the smallness of the cleavage-plates and slight lack of parallelism of different parts of a single plate the results were very unsatisfactory. The value for β for sodium-light is about 1.6092. The optic angle for sodium-light was measured on the axial angle apparatus of Fuess, using monobromonaphthalene instead of oil: $2H_y = 46° 26'$, hence $2E_y = 81° 34'$ and $2V_y = 47° 54'$.

Fig. 3. Fig. 4.

Micro-sections of Spencerite showing lamellar twinning.

"The mineral as shown by examination of the interference-figure is negative, the optic normal being at right angles to the trace of the poorest of the three cleavages and the obtuse bisectrix at right angles to the trace of the second best cleavage. Plates parallel to the best cleavage show low birefringence, so that the difference between β and γ is not great. Such plates when examined between crossed nicols exhibit peculiar interference-colours, which suggest that the plates are not simple, but rather are composed of several very thin plates arranged so that there is a lack of parallelism. Dispersion $\rho > v$.

CRYSTALLIZATION.

"In general, the optical and physical properties above mentioned seem to suggest that the mineral is rhombic in crystallization. This is not the case however, as shown by the following:

Fig. 5.—Crystallographic scheme of Spencerite.

(*a*) A thin section cut more or less at right angles to the best cleavage shows that the mineral is polysynthetically twinned with an extinction-angle of about 6°. The plates of the twin complex are parallel to the best cleavage. (Figs. 3 and 4.)

(*b*) By etching with cold, one per cent. nitric acid for five minutes, very definite etch-figures are obtained on the best cleavage. These figures are symmetrical about only one plane (the second best cleavage), and consequently the best cleavage does not correspond to a pinacoidal cleavage in a holohedral rhombic crystal, but rather to that of a face in the orthodiagonal zone of a monoclinic crystal such as (100) or (001). (Fig. 5 shown on (100).)

"It is therefore the opinion of the writer that the mineral may be regarded as monoclinic. If we assume that the best cleavage be (100), the second cleavage (010), and the poorest cleavage (001), then the twinning-plane and composition-face is (100), and the optic axial plane lies in the orthodiagonal zone and nearly normal to the front pinacoid. In this case the optic angles measured are only approximate, being produced from a series of thin twinned plates parallel to (100), each of which, if taken apart from the others would show an angle differing slightly from that obtained on the composite plates. In the same way the value for β is not the true value.

"The writer has examined carefully the specimens from the mine for crystals of this new mineral, but without success. The stalactitic masses, which up to the present are the only form in which it has been observed, are always covered by solution surfaces, a zone between it and the covering silicate having been dissolved away. While from the optical properties the mineral appears to be monoclinic, it would be interesting to confirm this conclusion by direct geometrical measurement of crystals. In Fig. 5 the chief crystallographic observations are diagrammatically represented."[1]

The first description of spencerite having been based on an examination of specimens shewing no crystals the shipment later obtained from the same locality was carefully examined for material suitable for crystallographic measurements. In a few small cavities in the brecciated country rock associated with the stalactitic material some brilliant but small crystals were discovered. They were found to be monoclinic but always twinned with the orthorpinacoid as twinning plane and composition face as had been suggested by the optical examination of the massive material. From the crystallographic description already published[2] the following paragraphs are repeated.

"Some specimens of this mineral recently obtained from the original locality contain small druses lined with sharp crystals of spencerite, the preservation of the crystals being apparently due to the cavities having been completely sealed up by calamine.

"The crystals are very small, few exceeding 2 or 3 mm. in length. They are tabular in habit, and in colour, lustre, and habit closely resemble small, bright crystals of calamine. The crystals, though small, are admirably suited for accurate measurements. The conclusions regarding the crystal form contained in the original contribution are confirmed, since the mineral is found to be monoclinic, with polysynthetic twinning on the pinacoid (100).

---

[1] Walker, T. L., Mineralogical Magazine, Vol. xviii, 1916.

[2] Walker, T. L. (Wash. Acad. Sc., Vol. vii, No. 14, 1917).

"There are two types of crystals, the first of which is represented in Fig. 6. The peculiarity of this type is the prominence of the pyramid $(\bar{2}21)$ with relatively small terminal faces of the orthodiagonal zone. Crystals of the second type are terminated by what appears to be a large face intersecting the prism edges at 90°. A careful examination shows that this large terminal plane is striated, the faces of the striations belonging to the form $(\bar{1}02)$. (See Fig. 7.) All the crystals measured are twinned and show faces of the two constituent individuals.

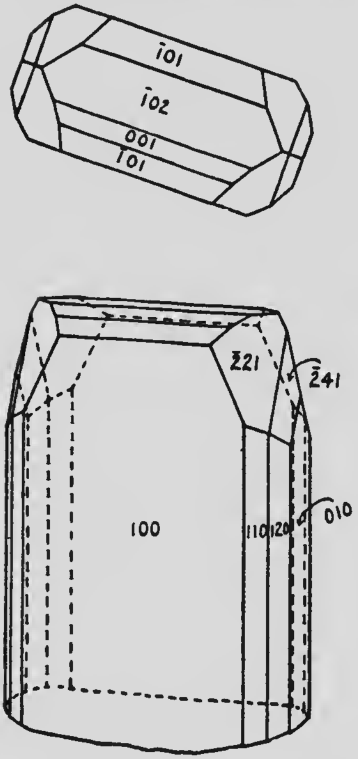


Fig. 6.—The crystal is twinned on (100) and as a result of the twinning the forms $(\bar{2}41)$ and $(\bar{2}21)$ are each represented by four faces, thus giving the crystals a rhombic appearance.

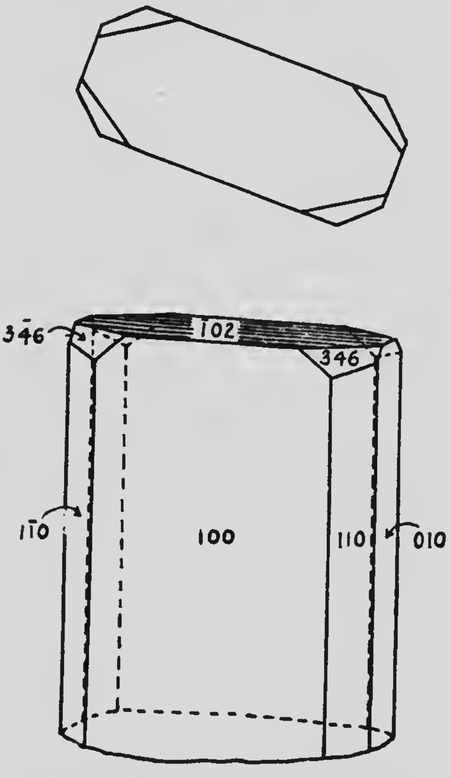


Fig. 7.—Crystals of this type exhibit twinning in the duplication of the terminal faces, (346) being represented by four faces while the two faces of $(\bar{1}02)$ occur as striations on a large plane nearly coinciding in direction with a rhombic basal pinacoid.

"The polar elements derived from the measurements are as follows:

$$p_0 = 1.0512;\ q_0 = 0.9501;\ e = 0.45071;\ \mu = 63°13'$$

corresponding to the axial ratios,

$$a : b : c :: 1.0125 : 1 : 1.0643;\ \beta = 63°13'.$$

"In Table I are indicated the forms observed and the polar angles ϕ and ρ measured and calculated for the elements indicated above. The number of faces observed for each form on the four crystals measured is shown in the second column."[1]

TABLE I

FORM.	NUMBER OF MEASUREMENTS.	ϕ		ρ	
		Measured.	Calculated.	Measured.	Calculated.
120	12	29° 34′	29° 32′	90°	90°
230	2	35° 50′	37° 04′	90°	90°
110	11	48° 32′	48° 34′	90°	90°
520	6	71° 07′	70° 34′	90°	90°
010	6	0	0	90°	90°
100	6	90°	90°	90°	90°
001	4	89° 56′	90°	26° 52′	26° 47′
$\bar{1}04$	2	90°	90°	11° 20′	11° 30′
$\bar{1}02$	3	90°	90°	5° 17′	5° 36′
$\bar{3}04$	1	89° 57′	90°	21° 07′	21° 47′
$\bar{1}01$	3	89° 53′	90°	34° 55′	35° 02′
$\bar{2}01$	1	89° 14′	90°	61° 30′	62° 20′
023	1	35° 40′	35° 26′	40° 57′	41° 03′
021	4	13° 30′	13° 21′	65° 32′	65° 25′
121	5	38° 36′	38° 48′	69° 53′	69° 53′
346	3	56° 58′	57° 22′	53° 05′	52° 46′
$\bar{1}11$	2	32° 55′	33° 23′	51° 49′	51° 53′
$\bar{1}21$	6	18° 06′	18° 14′	65° 48′	65° 57′
$\bar{2}21$	4	41° 52′	41° 52′	70° 41′	70° 43′
$\bar{2}41$	4	24° 23′	24° 08′	77° 53′	77° 51′

Recently in examining crystallized specimens of spencerite some small druses were found containing crystals of an unusual habit. They are prismatic with very sharp lance-shaped terminations. Like the crystals previously examined they are very small and bright but they differ from them in being simple individuals. The faces in the prismatic zone

---

[1] Walker, T. L., *The Crystal Form of Spincerite* (Wash. Acad. of Sciences, Vol. vii, p. 456, 1917).

are (100), (010), (110), (120) and (520), while the terminal forms in order of magnitude of the faces are $(\bar{1}21)$, $(\bar{2}20)$, $(\bar{2}41)$ and $(\bar{1}02)$ (Fig. 8). It will be observed that all the terminal faces belong to the upper negative octants so that if the clinographic drawings were made with the usual orientation the terminal faces would be scarcely seen. To obviate this the crystal is shown in Figure 8 turned 180° about the vertical axis. If these simple crystals had been available for the first crystallographic description it is probable that the orientation of spencerite crystals would have been as shown in Figure 8 but as the orientation of the crystals has already

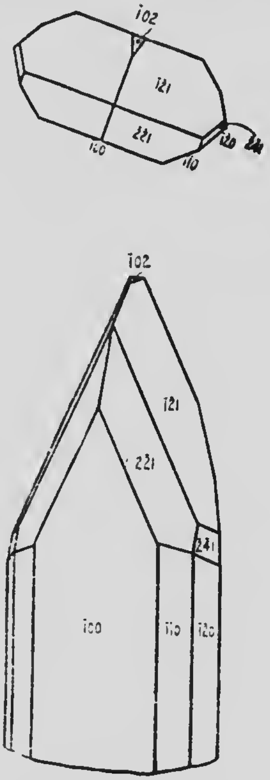


Fig. 8.

been settled it is not desirable to depart from the first orientation.

After the formation of the crystals of spencerite they were in most cases covered by a deposit of calamine as it is only in a few small cavities which had apparently been sealed up to prevent this deposition that good crystals are to be observed. In a few of these cavities the spencerite crystals are perfectly bright and free from calamine deposition. In others there are coatings of calamine, sometimes a mere frosting of the crystals while in others the crystals are completely masked. There are many examples of pseudomorphous casts of calamine where the thick-walled masses of calamine, rudely resembling the spencerite crystals in shape, are hollow. These casts are very sharp within and appear to have been formed by the deposition of the silicate on crystals of the phosphate followed, in the solution period, by the removal of the substance of the crystals. It is only where these pseudomorphs of calamine have been broken across that the interior may be observed.

As has been already stated the spencerite forms the central part of the stalactitic growths and would appear to have been sealed up by the later shell of calamine. There is frequently observed a solution cavity between the relatively insoluble calamine and the more soluble spencerite. In these cavities are found in small amounts hopeite in fine crystals, complex aggregations of parahopeite and thin-bladed projections of calamine—the adjacent plates parallel to one another suggesting that they had been present as inclusions along the best cleavage (100) of spencerite. In the microscopic examination of the latter mineral small lenticular inclusions of the same character are often noted. A small quantity of this leafy residual material was the subject of a partial analysis with the following result (I):

	I	II	II
ZnO	62.87%	67.35%	67.49%
SiO_2	23.64%	25.32%	25.01%
H_2O	6.83%	7.33%	7.50%
	93.34	100.00	100.00

Some calcite is present as the material effervesces with dilute hydrochloric acid but this was not quantitatively determined —presumably it constitutes the 6.66 per cent not accounted for in the above analysis. If this analysis be calculated on the basis of 100 the result shown in II is obtained, which agrees very closely with the theoretical composition of calamine (III)

HOPEITE

This mineral is found in the solution cavities observed on the stalactitic masses of calamine and spencerite. It appears to be a secondary mineral formed from the spencerite. The crystals are never more than three millimeters across and seldom more than one centimeter in length. Hopeite appear to be relatively insoluble as compared with spencerite as the crystals are always sharp and very brilliant. At the H. B. Mine hopeite is a rare mineral, the total amount observed being only a few grammes in weight. Only qualitative chemical tests were made. The specific gravity as determined by potassic mercuric iodide solution is 3.03. Under the microscope the crystals exhibit parallel extinction in the prismatic zone. The lustre is vitreous except on the macro-pinacoid which is pearly. There are three well marked cleavages corresponding to the three pinacoids.

CRYSTALLOGRAPHIC PROPERTIES.

Five crystals were measured. They resemble one another closely in habit (Fig. 9).

The macropinacoid is generally the predominant form. The prism (120) is usually well developed, while of the terminal faces the most prominent are the unit pyramid (111) and the unit macrodome (101). The other terminal faces are usually quite small, but, considering their size, remarkable for the accuracy with which they can be measured. The measurements on the larger crystals, while satisfactory, are somewhat less concordant than those obtained from the small crystals. The following forms were observed:

(*a*) Pyramids........................(433), (111), (133) and (163)
(*b*) Brachydomes................................(011) and (021)
(*c*) Macrodomes.........................(103), (101) and (201)
(*d*) Prisms.......(670), (120), (5.11.0), (250), (130), (3.11.0) and (160)
(*e*) Pinacoids.....................................(010) and (100)

The above list contains all the forms observed by Spencer on crystals from Rhodesia except the pyramid (233). The form (201) observed by Lévy in 1837 on material from Aix-la-Chapelle is represented by one face on one crystal. The following forms have not been previously observed:

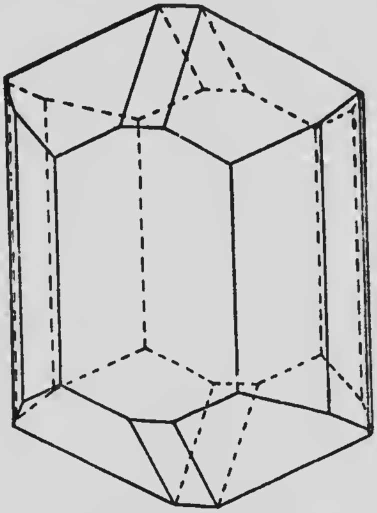


Fig. 9.—Hopeite from British Columbia.

(433) on two crystals on one of which four faces were observed. On this crystal the faces of this new form were the principal terminal faces.
(163) observed on only one crystal—faces small but with good reflections.
(021) represented by five faces out of a possible six on tl three crystals measured.
(670) observed on two crystals.
(3.11.0) shown on one crystal.
(250) three faces of this form observed on one crystal.

From crystal No. 1 the polar elements were found to be $p_0 = 0.8277$, $q_0 = 0.4720$, corresponding to the axial ratios $a : b : c : : 0.5703 : 1 : 0.4720$. These ratios are slightly lower than those obtained by previous observers, though they are very near the values of Lévy—$a : b : c : : 0.5723 : 1 : 0.4718$.

The details of the measurements given in the following table were obtained from crystals 1 and 2 except the values for the forms (103), (433), (163) and (250).

TABLE II.

NO.	FORM.	NO. 1 OBSERVED.			NO. 2 OBSERVED.			CALCULATED.	
		Faces	ϕ	ρ	Faces	ϕ	ρ	ϕ	ρ
1	111	4	60° 17′	43° 37′	4	59° 51′	43° 20	60° 18′	43° 37′
2	133	2	30° 07′	28° 35′	4	30° 22′	28° 52′	30° 19′	28° 40′
3	433	8	67° 02′	50° 10′	..	......	......	66° 51′	50° 12′
4	163	4	16° 11′	44° 36′	..	......	......	16° 17′	44° 32′
5	011	..	......	......	2	0° 35′	25° 51′	0°	25° 16′
6	021	1	0° 10′	43°	2	0° 20′	43° 28′	0°	43° 21′
7	103	2	89° 37′	15° 26′	..	.....	......	90°	15° 26′
8	101	1	89° 55′	39° 40′	1	88° 55′	39° 30′	90°	39° 36′
9	201	..	......	......	1	89° 29′	59° 04′	90°	58° 52′
10	670	..	......	......	3	56° 19′	89° 32′	56° 22′	90°
11	120	4	40° 42′	90°	4	40° 49′	89° 19′	41° 15′	90°
12	5.11.0	1	38° 44′	90°	.	......	......	38° 33′	90°
13	250	4	35°	90°	..	......	......	35° 03′	90°
14	130	3	29° 34′	90°	4	29° 13′	89° 05′	30° 53′	90°
15	3.11.0	1	25° 48′	90°	..	......	......	25° 34′	90°
16	160				1	16° 02′	89° 55′	16° 20′	90°
17	010	1	0° 05′	90°	..	..... .	......	0°	90°
18	100	2	90°	89° 42′	..	......	......	90°	90°

All the forms observed on hopeite from the H. B. Mine are shown on the gnomonic projection (Fig. 10).

PARAHOPEITE

This mineral was first observed by Spencer on specimens from North Western Rhodesia[1] where it was associated with hopeite, tarbuttite, calamine, cerussite and other lead and

---

[1] Spencer, L. J. (Min. Magazine, Vol. xv, p. 18, 1908).

zinc minerals. The mineral was found by Spencer to be triclinic though the details of its crystallography were not worked out till later.[1] The discovery of parahopeite along with the other minerals at the H. B. Mine was to be expected owing to the general similarity of the mineral association at the two localities.

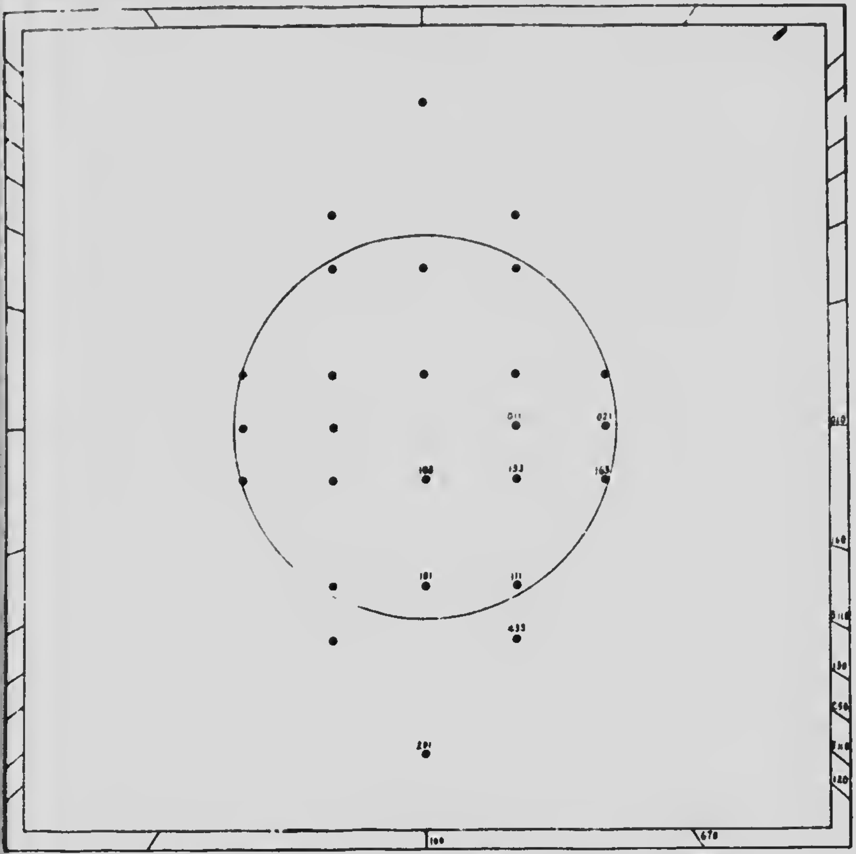


Fig. 10.—Gnomonic projection of Hopeite from British Columbia.

At the H. B. Mine parahopeite is found with hopeite in the solution cavities of the stalactitic masses between the calamine and spencerite. It is far more abundant than the

---

[1] Ledoux, Walker and Wheatley (Min. Magazine, Vol. xviii, p. 101, 1917).

hopeite but quite subordinate to the spencerite. The mineral has not been observed in good crystals but rather in fan-shaped aggregates similar to those frequently shown by calamine. These aggregates appear to be built up of crystals in which a partial parallelism of the crystals is preserved, the macropinacoids of the different individuals being more or less common to all the crystals of the aggregate. Occasionally small crystals prismatic in habit occur more or less detached, but they are valuable for measurement only, with a view to determining the mineral as parahopeite. The characteristic forms are the prisms (110) and (1$\bar{1}$0) and the macropinacoid which is usually large but corroded. The principal terminal faces are the pyramid ($\bar{1}\bar{1}$1) and the base (001) which is usually represented by a pair of faces due to the characteristic twinning which is polysynthetic with (100) as twinning plane and composition face. In general the habit of the parahopeite from British Columbia is the same as that from Rhodesia.

PHYSICAL PROPERTIES

Parahopeite has a brilliant vitreous lustre. It scratches calcite readily when the striations are made parallel to the shorter diagonal of the cleavage rhombohedron but when attempts are made to scratch calcite parallel to the longer diagonal of the rhomb the striations are very indistinct. Its hardness may therefore be regarded as about 3.5. The specific gravity was determined by means of heavy solutions and by the pycnometer. The former method gave 3.22 while the latter gave 3.236. A determination made by heavy solution on material from Rhodesia showed that the mineral from the type locality has a specific gravity of 3.21. All these values are somewhat lower than those previously published for parahopeite.

Like the mineral from Rhodesia the Canadian parahopeite shows a fect cleavage parallel to the brachypinacoid. If crystals be crushed between two glass plates a multitude of thin cleavage fragments are formed which when examined with the polarising microscope show low double refraction and polysynthetic twinning of the albite type. The extinction angle for individuals is the same as in the case of the mineral from Rhodesia. With convergent polarized light an interference figure showing a single brush may be observed, indicating that an optic axis emerges more or less at right angles to the brachypinacoid. It will be observed that in these many details the Canadian and Rhodesian minerals agree and the enumeration of these physical properties is only with a view to fixing the identity of the minerals.

CHEMICAL PROPERTIES

Some carefully selected small masses of parahopeite were ground up for chemical analysis and dried at 110°. The result of the analysis (I) may be compared with (II) the theoretical composition for parahopeite $Zn_3(PO_4)_2.4H_2O$. In view of the fact that the selected material was composed of innumerable individuals forming aggregates in which foreign matter would be expected to be present in some proportion, the agreement of the analysis with the theoretical values is remarkably close.

	I	II
ZnO	54.69	53.270
P_2O_5	30.46	31.005
H_2O	15.31	15.725
	100.46	100.000

HIBBENITE

In addition to the three zinc phosphates observed by the author on material from the H. B. Mine, Professor A. H. Phillips has described a new zinc phosphate from this mine under the name of hibbenite. It is closely associated with the spencerite in its occurrence and is apparently genetically related to it. The author unfortunately has not observed this new rare mineral on the abundant material at his disposal so that for the sake of completeness it seems desirable to repeat here some of the principal findings of Professor Phillips.[1]

"The combination of forms, the crystal angles and axial ratios are very near that of hopeite as given by J. L. Spencer[2].

"*Chemical Composition*—Several crystals were ground, combined in one sample and analyzed with the following results:

	No. 1	No. 2	Theoretical
ZnO	57.51	57.60	57.625
P_2O_5	28.77	28.88	28.721
H_2O	13.74	13.68	13.653
	100.02	100.16	99.999

"The above represents the results arrived at from the analysis of the air-dried sample. The sample dissolved readily in dilute acids to a perfectly clear solution leaving no residue and qualitative tests revealed no other elements present, except in traces. The analysis yields the ratios of $7ZnO \cdot 2P_2O_5 \cdot 7\frac{1}{2}H_2O$ or $2(Zn_3(PO_4)_2) \cdot Zn(OH)_2 \cdot 6\frac{1}{2}H_2O$, a formula which is very satisfactory, with the possible exception of the water. The water is somewhat variable with the condition of the sample. The crystals are filled with small cavities which contain water as shown under the microscope. Water was determined in another sample which had not been exposed to the air as long as the first sample, with the result that it yielded 13.90 per cent. Then a crystal was picked out of the matrix, ground, and the water determined at once with 14.8 per cent. as the result. A portion of this crystal weighing .348 gms. was then tested for loss of water at different temperatures, for comparison with that of spencerite.

"It lost at	110°	130°	210°	250°	275°	Red Heat
	5.74%	7.24%	7.93%	10.05%	11 35%	14.71

The crystals are basic, as is shown both by the high temperature at which a considerable part of the water is given off and by the yellow colour of the hot sample, due to the presence of zinc oxide.

"*Physical Properties*—There are three cleavages parallel to the three pinacoids. Of the three, the brachypinacoidal cleavage is perfect, that parallel to the macropinacoid less so, and the basal cleavage is imperfect. The specific gravity, as determined on small fragments with methylene iodide, varied but little from 3.213. It fuses easily and becomes yellow while hot: decrepitates strongly in the closed tube, yielding much water. Hardness is about 3.75, scratching calcite easily.

"*Optical Properties*—Hibbenite is a pale yellow, almost white, translucent with a vitreous, though somewhat pearly lustre. The double refraction is very weak. Extinction is parallel on all three pinacoidal sections, with the plane of the optic axis parallel to the base. The macroaxis *b* is the acute bisectrix. Optically negative."

---

[1] Phillips, A. H., *Loc. cit.*

[2] Mineralogical Magazine, Vol. xv, p. 1.

GENERAL RELATIONSHIP OF ZINC PHOSPHATES

Till recently hopeite was the only natural zinc phosphate known to mineralogists. It had been discovered at Moresnet nearly a century ago and till the discovery of this mineral in Rhodesia by Spencer in 1907 hopeite was known only from the original locality. Along with the hopeite from North-Western Rhodesia Spencer discovered two new phosphates of zinc—parahopeite and tarbuttite. The H. B. Mine is the third locality from which phosphates of zinc have been reported. All the previously known phosphates of zinc were found at this new locality except tarbuttite and in addition two new ones—spencerite, which occurs in great abundance, and hibbenite, which is described by Professor Phillips and appears to be very rare. The general chemical relationship of these minerals to one another is as follows:

Hopeite—$Zn_3(PO_4)_2 \cdot 4H_2O$.—Rhombic
Parahopeite—$Zn_3(PO_4)_2 \cdot 4H_2O$.—Triclinic
Tarbuttite—$Zn_3(PO_4)_2 \cdot Zn(OH)_2$—Triclinic
Spencerite—$Zn_3(PO_4)_2 \cdot Zn(OH)_2 \cdot 3H_2O$—Monoclinic
Hibbenite—$2Zn_3(PO_4)_2 \cdot Zn(OH)_2 \cdot 6\frac{1}{2}H_2O$—Rhombic

From the chemical point of view all these minerals are remarkable for their unusual purity and the general absence of all chemical elements not in accord with the above formulae.

THE CLAY CRUST OF STALACTITIC MASSES

Outside the calamine shell which surrounds the central core of phosphate is a deposit of clay which is grey to cream in colour. This material which is not plastic was referred to by one of the miners who wrote to Professor Phillips as "very phosphatic clay which carried 20 per cent. zinc and buried in the clay were great chunks of ore". The analysis given below (1) shows that the material examined by me is not particularly phosphatic but that in the zinc content it is comparable to the material mentioned above.

	I		II	III	
ZnO	19.99		37.98	32.48—36.00	
NiO			.24		
MgO	3.97		.54		
CaO			.76		
Al_2O_3	16.07		13.02	11.70	
Fe_2O_3	8.01	(FeO)	5.61		
SiO_2	39.49		29.36	35.64	
P_2O_5	.26				
H_2O	11.12		11.34	14.80	9.88
	98.91		98.85		

A small amount of carbon dioxide is present in the clay but this was not determined. Clays carrying considerable amounts of zinc have been frequently observed in connection with oxidized zinc ores. The analysis of such a clay from Moresnet is shown in (II) while (III) is an incomplete analysis of a zinciferous clay from Sterling Hill, N.J. These two clays have been described as distinct minerals under the names Moresnetite and Vanuxemite. They are doubtless of the same general nature as the clay from the H. B. Mine and are probably mixtures of some zinc mineral with clay.

THE ORIGIN OF THE PHOSPHATES

In the case of the deposits of zinc phosphates in Rhodesia the minerals are sometimes associated with organic remains in caves containing implements indicating that they had been occupied by men at an early period. The phosphates are sometimes deposited on bones or on bone breccias. At other times they were formed quite remote from animal phosphate deposits. The Canadian zinc phosphates as has been mentioned occur in crystalline limestone which is supposed to be carboniferous in age. The cave in the H. B. Mine had one dyke as a wall and another as roof. It was found that while the mine as a whole was unusually dry, there was an abundance of water entering the cave. The phosphoric acid necessary for the formation of the phosphates may have been derived from solution of apatite in the dykes or the source of the phosphoric acid may be in the carboniferous rocks.

It may be of interest in this connection to note that quite recently De Schmid[1] has found, in the eastern Rocky Mountains, beds of phosphates in the upper 50 feet of the Rocky Mountain quartzite which is also carboniferous. No such beds have been found in the vicinity of the H. B. Mine but it is not improbable that the phosphoric acid entering into the zinc phosphates here described may be derived from some bed of phosphate more or less equivalent to those discovered by De Schmid farther east. In the carboniferous a few miles north of the H. B. Mine, Drysdale[2] reports the occurrence of pyromorphite at the Old Timer Mine.

CERUSSITE

Cerussite has not been observed in association with the phosphates found in the cave but throughout the ore body along with calamine and limonite it is generally distributed. An account of some exceedingly beautiful specimens of cerussite from this mine was recently published.[3] The crystals are water clear with very brilliant faces and well suited for exact goniometric measurements. This is probably the finest crystallized cerussite found in Canada.

The crystals are almost invariably twinned forming six-rayed structures such as have been frequently observed for this mineral. In these complex growths the twinning ordinarily observed occurs on the face of the prism (110) but in the case of the Salmo mineral the structures are often more complex in that several of the individuals are twinned on (110) while one of these is twinned on another individual with (130) as the twinning plane. In many minerals complex twins involving more than one twinning law are common but the stellate interpenetration twins of cerussite have been regarded till recently as resulting from twinning according to one law only.

---

[1] De Schmid, H. S. (Mines Branch, [illegible] o. 12, Ottawa, [illegible]).

[2] Drysdale, C. W., *Ymir Mining Camp* (Geol. Surv. Can. Ottawa, p. 570, 1917).

[3] Ledoux, A., and Walker, T. L., *Cerussite from Salmo, B.C.* (Ottawa Nat. 1918).

On crystals measured the following forms have been observed:

(*a*) Pinacoids
  Basal pinacoid (001) usually rough and when present large.
  Brachy pinacoid (010) always the largest face so that the crystals are tabular.
  Macropinacoid (100) narrow and well defined.
(*b*) Prisms—(110) and (130).
(*c*) Brachydomes—(012), (011), (021), (052), (031), (041), (092), (051), (061), (071), (081), (091), (0.10.1), and (0.12.1).
(*d*) Macrodome—(102).
(*e*) Pyramids—(111) and rarely (112).

The domes (012) and (021) are the most prominent.

The others are present in certain crystals and give with the goniometer a long series of reflections.

The brachydomes (092) and (0.12.1) were first observed on cerussite from this locality.

BIBLIOGRAPHY ON H. B. MINE

Galloway, J. D., Report of the Minister of Mines of British Columbia, 1905, p. 160.

Ledoux, A., and Walker, T. L., Cerussite from Salmo, B.C. Ottawa Naturalist, 1918.

Phillips, A. H., New Zinc Phosphates from Salmo, British Columbia, American Journal of Science, Vol. XLII, p. 275, 1916.

Walker, T. L., Spencerite, a New Zinc Phosphate from British Columbia, Mineralogical Magazine, Vol. XVIII, p. 76, 1916. (Abstracts in Nature, June 29th, 1916, and Geological Magazine July 1916).

Walker, T. L., Hopeite from the H. B. Mine, Salmo, B.C., Journal Washington Academy of Sciences, Vol. VI, p. 685, 1916.

Walker, T. L., The Crystal Form of Spencerite, Journal Washington Academy of Sciences, Vol. VII, p. 456, 1917.