SOME MINERALS OF THE KEWEENAWAN COPPER DEPOSITS: PUMPELLYITE, A NEW MINERAL; SERICITE; SAPONITE

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In the course of the intensive geological study of the native copper deposits of the Keweenaw Peninsula carried on from 1920 to 1924 by the Calumet and Hecla Consolidated Copper Co. there came to light several minerals whose optical and physical characters did not enable them to be satisfactorily determined. As at least two of these minerals were intimately associated with the copper deposition it seemed important that their nature be established accurately by chemical analysis of purified material. The preparation of suitable material for this purpose fell to the lot of the senior author of this paper and was completed in 1921 but it was only during the past year that the chemical work was carried out in the Harvard Mineralogical Laboratory by Miss Vassar. As one of these minerals proves to be a new and distinct species, it seems well to present the results of this partial study as a contribution to our rather scanty knowledge of the exact chemical nature of the Keweenawan mineral paragenesis.

1. Pumpellyite

Early in the microscopic study of the copper ores a mineral was noted which did not agree with any known species in its optical properties. Dr. A. Wandke was the first to recognize its individuality and it was found to be widely distributed, especially in the amygdaloid ores. It was entered in our notes as "green zoisite," being optically closer to zoisite than to any other mineral. For this mineral we propose the name of *Pumpellyite* for Raphael Pumpelly, the pioneer student of the detailed paragenesis of the minerals of this region.

Pumpellyite is orthorhombic, but the determination of its symmetry rests upon its optical characters, no measurable crystals having been found. The crystals are minute fibers or narrow tables flattened parallel to a face taken as the basal pinacoid. There is an excellent cleavage in this direction. The plates are very brittle and the hardness is estimated as about 5.5. The specific gravity is slightly less than 3.2, identical with that of epidote which came down with it in the heavy solution. The color is bluish green, dark in hand specimens, rather faint in microscopic preparations and showing weak pleochroism. In Ridgeway's scale it is nearest to Russian Green, 37''' i. Where mingled with quartz or calcite, as it very often is, its color is sufficiently intense to tint the whole mass a distinct green. The optical characters were determined by Professor E. S. Larsen on the analyzed material.

Optically positive. $2V$ rather large, dispersion very strong, $\rho < \nu$; $\alpha = 1.698$; $\beta = 1.700$; $\gamma = 1.708$; all ± 0.005. Nearly colorless in the directions of α and γ; green in that of β. X is nearly normal to a perfect cleavage (basal); Y is parallel to the length of the fibers.

Larsen states: "These data are near those of zoisite but the mineral is certainly not ordinary zoisite."

The preparation of a pure sample proved to be difficult and two methods were finally used. As both involved treatment of the powder with dilute hydrocloric acid, careful tests were made which proved that pumpellyite is not attacked by this acid when the powder is boiled even to dryness.

The first method used for separation was based on the brittle nature of the mineral which caused it to crush more freely than the associated material. The sample was an amygdaloid from the Isle Royale Mine (241 E 2057) containing amygdules of pumpellyite. The rock was coarsely crushed, the powder washed in water, and after a brief time the finest powder decanted while still suspended and allowed to settle very slowly. This was found to consist essentially of pumpellyite but with a slight impurity of rock particles and epidote, with some grains of calcite. The latter was in large part removed by treatment with very dilute HCl. The material so obtained was analyzed by G. L. Heath in the C. & H. Assay office with the results stated in column 1 of the table on page 414.

The second separation was made on ore from the Kearsarge Lode in the Calumet and Hecla Mine from the crosscut from the Red Jacket Shaft on the eighty-first level. (184 G 2574.) The specimens consisted of amygdaloid with replacement areas of red feldspar, epidote, pumpellyite and calcite, the last named having been last to form and enclosing the pumpellyite. The blocks were placed in dilute HCl until the calcite was all removed. Some of the pumpellyite was set free as loose crystals but most of it remained attached to the walls of the vugs. This was broken off with a point and carefully hand-picked to remove epidote. It was then crushed to pass a 100 mesh sieve, washed to remove dust and treated in Thoulet solution in which fluorite floated, to remove quartz and calcite. The density of the solution was then increased to float the mineral and later reduced to 3.2 at which both pumpellyite and the small amount of epidote present came down together. The repeatedly washed powder was treated with the electro-magnet to remove the epidote and then hand-picked under the binocular for the same purpose. The product was substantially pure. The analysis by Miss Vassar is given in column 2; it is the average of two closely agreeing analyses made on about 2 grams of material.

Table of Analyses of Pumpellyite

	1 per cent	2 per cent	Molecular ratio of 2	
SiO_2	36.51	37.18	.616	.616=7× .088
Al_2O_3	24.11	23.50	.260	.293=3× .088
Fe_2O_3*	3.50	5.29	.033	
FeO	5.14	2.09	.029	.524=6× .087
MgO	4.70	3.18	.079	
CaO	20.16	23.08	.411	
MnO	0.15	0.13	.002	
NiO	trace	—		
CuO	0.19	—		
K_2O	1.4	trace		
Na_2O	—	0.19	.003	
H_2O+ **	3.67	6.28	.349	.349=4× .087
H_2O-	—	.06		
	99.73	100.97		

* Proportion of ferrous to ferric iron not directly determined but figured from that obtained on another purer sample.

** Loss on ignition

The molecular ratios of the second analysis lead to the formula: $6CaO.3Al_2O_3.7SiO_2.4H_2O$. The corresponding formulas of zoisite and prehnite, the two minerals nearest in chemical composition to pumpellyite, are stated for comparison.

Zoisite, $4CaO.Al_2O_3.3SiO_2.H_2O$
Prehnite, $2CaO.Al_2O_3.3SiO_2.H_2O$

OCCURRENCE. Pumpellyite appears at two periods in the complex paragenesis of the amygdaloids. It is one of the late magmatic (pneumotectic) minerals, formed before the copper began to be deposited and before the invasion of the formation by the ore-bearing solutions. Its place is after chlorite and epidote and before quartz and prehnite. This generation of pumpellyite often lines open amygdules with a velvety coating, quite alone or implanted on epidote. Again quartz is implanted on it or fills the cavity.

It was formed, and more abundantly, by the ore solutions during replacement of the amygdaloids. Bands of it are often seen following red feldspar and epidote, with or following quartz and followed by hematite, prehnite, calcite and copper. These minerals often form considerable replacement areas and where calcite followed pumpellyite without quartz, treatment with acid leaves the walls coated with a tangled mass of delicate fibrous plates of the new mineral. It is common over a long stretch of the Kearsarge amygdaloid, specimens being at hand from the Ahmeek, Centennial, Calumet and Hecla, and La Salle Mines on that lode. It is perhaps still more abundant in the Pewabic Lode, as at the Quincy Mine where, embedded in quartz, it gives a characteristic color to much of the rock. It is common in the Isle Royale and Baltic Lodes in amygdules and in bleached and highly altered areas.

In the fissure veins which cut the amygdaloids and carry copper pumpellyite is also found following chlorite and epidote, followed by quartz, calcite and prehnite, and overlapping the formation of copper.

In the felsite conglomerate lodes it is present in small amount and belongs to the early part of the ore period, following epidote and quartz and accompanying copper.

Pumpellyite was probably one of the substances known to Pumpelly and other early investigators of these minerals as "green earth"; probably also more generally mistaken for chlorite.

2. SERICITE

The form of sericite found in the Michigan amygdaloids is unlike any hitherto described and it was not recognized as such until preliminary analysis revealed the presence of large amounts of alkalies. It occurs as amygdule fillings and in large replacement areas in breccia, being especially characteristic of the leaner portions of the Isle Royale Lode.

It is massive, soft and unctuous, green to greenish yellow in color, the powder being a dull greenish white. The specific gravity is slightly more than 2.71. Under the microscope it is minutely crystalline, the scales showing an extinction angle up to 14° to the cleavage. It is optically negative with refractive index close to 1.57 and fairly strong double refraction.

Material for analysis came from the Isle Royale Mine. Selected, nearly pure, material was coarsely crushed and treated for a short time with HCl to remove calcite. It was then washed, dried and crushed to pass a 100 mesh sieve, the powder washed to remove the finest floured material and after drying passed through Thoulet solution of a specific gravity such that calcite floated in it. The first fraction was discarded and the solution slightly diluted although calcite still barely floated. The powder which came down in this second fraction was practically pure except for slight iron oxide stains on some of the grains. It was analyzed by Miss Vassar with the result shown below, the average of two series of determinations.

Sericite, Isle Royale Mine (241E 2185)

	Per cent
SiO_2	50.27
Al_2O_3	27.71
Fe_2O_3	1.87
FeO	0.53
MgO	2.39
MnO	0.03
CaO	1.06
Na_2O	0.15
K_2O	9.61
H_2O+	4.68
H_2O-	1.44
CO_2	0.76
TiO_2	trace
P_2O_5	absent
Li_2O	trace
	100.50

This analysis gives no simple ratio or formula. In this respect it is like most analyses of sericite. It conforms however to the general type of chemical composition of the listed sericites and comes very close to that of the variety listed by Dana as pycnophyllite, a sericite not optically defined.

3. Saponite

Saponite has never been well defined as a mineral species as the description given in Dana's System will clearly show. The data secured in our study seem sufficient to characterize it fairly clearly.

Saponite was found in quantity in the South Kearsarge Mine and in less abundance but better crystallized in the Ahmeek Mine. In the former it is one of the latest hydrothermal minerals to form, occurring in cavities left by excessive solution during replacement of the amygdaloid. It thus lines the walls, a last generation of adularia alone being later. In the Ahmeek Mine it was found chiefly as solid filling of replacement vugs in which it surrounded crystals of copper and quartz; it was also found with copper and epidote crystals in open cavities as minute stalactites as much as half an inch in length but less than one tenth of an inch in diameter. These were composed of spherulitic groups of fibers or plates, radiate to the axial lines.

It is white to light buff colored, 1 or less in hardness, with an unctuous feel, somewhat plastic but not adherent to the tongue. The optical characters indicate monoclinic or possibly orthorhombic crystallization. They were determined by Professor Larsen on the two analyzed samples.

1. Saponite from South Kearsarge Mine.
2. Saponite from Ahmeek Mine.

Opt. char.	2V	α	β	γ	X	Z
1. negative	small	1.479	1.510	1.511	normal to cleavage	parallel to elongation
2. negative	moderate to small	1.490	1.525	1.527	normal to cleavage	parallel to elongation

Saponite fuses before the blowpipe with difficulty to a rather porous white slag. It gives abundant water in the closed tube easily. Material which was practically pure was secured for analysis by hand picking.

Analyses of Saponite by Miss Helen E. Vassar.

1. South Kearsarge Mine (178 G 542).
2. Ahmeek Mine (166 G 908).

	1.	Molecular Ratio		2.	Molecular Ratio	
SiO_2	42.78	.709	.709 = 10 × .071	42.99	.713	.713 = 10 × .071
Al_2O_3	6.44	.063	.071 = 1 × .071	6.26	.061	.072 = 1 × .072
Fe_2O_3 FeO	1.27	.008		1.83	.011	
				2.57	.036	
MgO	24.78	.615	.671 = 9 × .0745	22.96	.570	.661 = 9 × .074
CaO	2.35	.042		2.03	.036	
MnO	0.12	.002		0.11	.002	
Na_2O	0.75	.012		1.04	.017	
K_2O	trace			trace		
H_2O+	7.90	.440	1.216 = 16 × .076	6.85	.380	1.140 = 15 × .076
H_2O-	13.96	.776		13.6[illegible]	.760	
	100.35			100.29		

Considering the highly hydrous nature of this mineral these two analyses from different localities agree remarkably closely. They yield, it is true, a formula not very simple, but the two are identical save for a difference of one molecule of water; $Al_2O_3.\ 9MgO.10SiO_2.16H_2O$ or $15H_2O$.

THE IDENTITY OF ECTROPITE AND BEMENTITE

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In 1921, Pardee, Larsen, and Steiger[1] showed the identity of bementite with caryopilite but on the basis of the chemical analysis and available crystallographic and optical data they concluded that ectropite was a distinct species.

I have since examined a specimen of ectropite in characteristic crystals from the type locality, Långban. The crystals are of the type described by Flink,[2] elongated tablets. Lying on the flat face they give parallel extinction and show that the acute bisectrix is inclined at a large angle to the normal to the plates. Broken

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[1] Pardee, J. T., Larsen, E. S., and Steiger, Geo.; Bementite and neotocite from western Washington, with conclusions as to the identity of bementite and caryopilite, *Journ. Wash. Acad. Sc.*, **11**, 25-32, 1921.

[2] Flink, Gust. Einege Neuigkeiten in schwedischer Mineralogie. *Geol. Fören. Förh., Stockholm;* **39**, 426-31, 1917.