

PUMPELLYITE FROM CALIFORNIA

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ABSTRACT

Two varieties of pumpellyite, differing slightly in optical properties from the mineral as originally described, but chemically like it are described from near Petaluma, California, where they occur associated with lawsonite in glaucophane schists. Analyses of these two varieties, one green in color, one brown, are given and their optical properties are tabulated. A new formula for the mineral is suggested. No material was obtained on which crystal measurements, other than the cleavage angle, could be made.

The mineral pumpellyite was originally described in 1925 by C. Palache and H. E. Vassar¹ as occurring along with epidote in amygdaloidal cavities in a lava from Lake Superior. It is, essentially, a hydrated calcium aluminum silicate, with minor amounts of iron, magnesium and manganese. It has since been recorded from Haiti, again from an amygdaloidal lava, a description of which, by Burbank,² gave slight variations in some of the optical constants from those of the original material. No chemical analysis of the mineral from Haiti has been made.

The material to be described in this communication was collected by Mr. M. Vonsen of Petaluma, California. It occurs in a glaucophane schist and is of two varieties. One of these is dull green in color and forms, along with lawsonite, veins in glaucophane schist at Mill Creek. At this locality the schist is cut by two sets of veins, one consisting of lawsonite and pumpellyite, the other of lawsonite alone. The latter are cut sharply by the former, so that there appear to be two ages of lawsonite in the veins. In the lawsonite-pumpellyite veins, the pumpellyite is seen to be replacing the lawsonite. The second variety of pumpellyite is brown in color, fibrous, and occurs as tufts or radiating aggregates in the glaucophane schist itself. This material was collected from near Skaggs.

Little difficulty was encountered in separating the mineral. The specific gravity of the green variety was found to be 3.18 while the brown gave a result of 3.22. Until the analyses were known they were considered to be new minerals as there is variation in appearance and occurrence in the two varieties, nor does either coin-

¹ Palache, Charles and Vassar, Helen E., Some minerals of the Keweenaw copper deposits, *Amer. Mineralogist*, vol. x, p. 412, 1925.

² Burbank, W. S., Additional data on the properties of Pumpellyite, *Amer. Mineralogist*, vol. xii, p. 421, 1927.

cide with the properties of the previously described pumpellyites.

The properties of pumpellyite from the different localities are given in tabular form below for comparison.

TABLE OF OPTICAL PROPERTIES OF PUMPELLYITE

	Pumpellyite from Lake Superior	Pumpellyite from Haiti	Pumpellyite, green from Mill Creek	Pumpellyite, brown from Skaggs
Indices of Refraction	$\alpha=1.698$ $\beta=1.700$ $\gamma=1.708$	1.700 1.707 1.718	$1.679 \pm .003$ 1.680 1.692	$1.677 \pm .003$ 1.678 1.690
Optical Character	+	+	+	+
Dispersion 2V	$\rho < \nu$ strong large	$\rho < \nu$ strong large $75^\circ-80^\circ$	$\rho < \nu$ strong $40^\circ \pm 2^\circ$	$\rho < \nu$ strong $38^\circ \pm 2^\circ$
Optical Orientation	Y = elong.	Y = elong. = b? Z \wedge cleavage (001) = 31°	Y = elong. = b X \wedge a = 12°	Y = elong. = b X \wedge a = 12°
Form	Fibrous	Prismatic parallel to Y	Fibrous, twinned; twin plane and composition plane = (001)	Fibrous, occa- sional twins; twin and comp. plane = (001)
Cleavage	Perfect nearly normal to x (basal)	Basal well de- veloped	Basal almost normal to Z. (100) im- perfect	Basal almost normal to Z. (100) im- perfect
Color	green	bluish green	green	brown
Pleochroism	X = colorless Y = bluish green Z = colorless	colorless bluish green colorless	colorless pale green colorless	colorless brownish yellow colorless

The best cleavage of the pumpellyite *i.e.* the face on which the majority of fragments in an immersion lie, gave an off-centered acute bisectrix figure, but in thin sections of the mineral no very pronounced cleavage could be identified. Several fibres, measured on a goniometer showed two faces at 45° to one another and these were thought to be cleavage faces. In thin sections, however, no such cleavage could be made out. It is possible that the measurement was made on crystal faces, but no reflections other than these two were obtained, nor did any of the fibres show crystal terminations.

With the green variety twinning is visible in thin sections cut across the fibres, and the optical orientation in relation to the composition plane was determined by use of the Fedorov stage. Such sections are shaped like oak leaves with the composition plane down the center. The composition plane was found to be the twin plane also, and is oriented parallel to $Y = b$ and almost perpendicular to Z . The angle between X and the twin plane is 12° . The cleavage is parallel to the twin plane, and if we consider it as basal, the twin plane is (001) and $X \wedge a = 12^\circ$.

In sections parallel to (100) the twinning is liable to escape notice as both individuals show parallel extinction and differ only slightly in birefringence.

Twinning is less common in the brown variety, but the orientation in relation to the elongation is identical.

Analyses of the two varieties by F. A. Gonyer are quoted below along with that of the Lake Superior material.

Comparing the analyses we see that going from A to C we have a

TABLE OF CHEMICAL ANALYSES OF PUMPELLYITE

- A. Pumpellyite from Lake Superior, analyzed by H. E. Vassar³
 B. Pumpellyite from Mill Creek, green, analyzed by F. A. Gonyer
 C. Pumpellyite from Skaggs, brown, analyzed by F. A. Gonyer
 D. Composition of Pumpellyite calculated from the formula $6\text{CaO} \cdot 3\text{Al}_2\text{O}_3 \cdot 7\text{SiO}_2 \cdot 4\text{H}_2\text{O}$.
 E. Composition of Pumpellyite calculated from the formula $\text{Ca}_4(\text{Al}, \text{Mg})_6\text{Si}_6\text{O}_{23}(\text{OH})_3 \cdot 2\text{H}_2\text{O}$.

	A.	B.	C.	D.	E.
SiO ₂	37.18	38.01	37.63	37.0	38.2
TiO ₂		0.21	0.41		
Al ₂ O ₃	23.50	25.88	27.14	27.0	27.3
Fe ₂ O ₃	5.29	1.11	—		
FeO	2.09	2.90	3.25		
MnO	0.13	0.17	1.03		
MgO	3.18	1.81	1.47		4.4
CaO	23.08	22.70	21.49	29.6	23.8
Na ₂ O	0.19		0.46		
		0.46			
K ₂ O	tr		0.08		
H ₂ O+	6.28	6.64	7.27	6.3	6.7
H ₂ O-	0.06		0.12		
	<u>100.97</u>	<u>99.89</u>	<u>100.35</u>	<u>99.9</u>	<u>100.4</u>

³ *Loc. cit.*, p. 414.

series in which the aluminum content increases, showing less replacement by ferrous and ferric iron, manganese and magnesium, while more lime is replaced by alkalis. Both these progressive changes would lead to a lowering of the indices of refraction, which is in accord with the observations.

The increase in titanium which offsets these variations is too slight to have any material effect. The brown variety probably owes its color to its content of manganese as it is free from ferric iron and on heating turns a bluish color. The green material on heating turns brown.

The atomic proportions derived from these analyses as shown in the table following would lead to the formula $\text{Ca}_4\text{R}_6\text{Si}_6\text{O}_{23}(\text{OH})_3 \cdot 2\text{H}_2\text{O}$, where $R = (\text{Al} : \text{Mg} + \text{Fe}) = 5 : 1$.

CALCULATION OF FORMULA

A.	B.	C.
Atomic proportions of:		
Si 616 = 6×103	Si 633 = 6×106	Si 627 = 6×105 .
Al 460	Ti 3	Ti 5
Fe 66 } 526	Al 506 } 523	Al 532 } 537
Fe 29 } 636 = 6×106	Fe 14 } 610 = 6×102	Fe 45 } 634 = 6×106
Mn 2 } 110	Fe 40 } 87	Fe 45 } 97
Mg 79	Mn 2 } 87	Mn 15 } 97
Ca 411	Mg 45	Mg 37
Na } 417 = 4×104	Ca 405	Ca 383
K 6	Na } 14 } 419 = 4×105	Na } 16 } 399 = 4×100
H 704 = 7×101	K } 14	K } 16
O 2897 = 28×103	H 738 = 7×105	H 820 = 7×117
	O 2920 = 28×104	O 2959 = 28×106

- A. Pumpellyite from Lake Superior.
- B. Pumpellyite from California, green.
- C. Pumpellyite from California, brown.

In the formula given to the original pumpellyite, $6\text{CaO} \cdot 3\text{Al}_2\text{O}_3 \cdot 7\text{SiO}_2 \cdot 4\text{H}_2\text{O}$ the ferric iron was calculated in with the alumina and the ferrous iron, magnesia, manganese, and alkalis taken along with the lime. The analyses of both varieties of the Californian pumpellyite fit this formula moderately well, but it was found that by calculating the alumina with the ferric and ferrous iron, magnesium and manganese, and only the alkalis with the lime,

as x -ray analysis has shown to be the more natural substitution,⁴ we obtain the formula given above which is in closer agreement with the three analyses. In this form the relation with zoisite, $\text{Ca}_4\text{Al}_6\text{Si}_6\text{O}_{24}(\text{OH})_2$, is brought out. The pumpellyite might be considered as zoisite with (MgH) replacing aluminum and with the addition of two molecules of water. This close relation is reflected in the similarity of their crystallographic and optical properties. The main difference is in indices of refraction which are lower in the case of the pumpellyite, a result which might be expected from the increase in water content.

Professor Palache has requested the writers to point out that in the 1925 paper on pumpellyite,⁵ the formula for zoisite was inadvertently misquoted. The accepted formula is, as given above, $4\text{CaO} \cdot 3\text{Al}_2\text{O}_3 \cdot 6\text{SiO}_2 \cdot \text{H}_2\text{O}$.

The hydration curve of pumpellyite would throw much light on the role played by the water in its composition, but the apparatus necessary to make this determination was not available.

In conclusion, the writers wish to express their indebtedness to Professor E. S. Larsen and to Mr. Berman for checking the determinations of optical constants.

⁴ Wherry, E. T., Volume isomorphism in the silicates, *Amer. Min.*, vol. 8, 1923, p. 2.

⁵ *Loc. cit.*, p. 414.