

An occurrence of the mineral pumpellyite in the Lake Wakatipu region, western Otago, New Zealand.

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PREVIOUS accounts of pumpellyite, a blue-green hydrous silicate of calcium and aluminium, are few in number; the first record is that of Palache and Vassar,¹ who described the mineral after a study of the amygdaloidal rocks of the Keweenaw Peninsula. Later Burbank² recorded a very similar occurrence in Haiti, West Indies. Again, it was observed as a constituent of veins cutting glaucophane-schists in California by Irving, Vonsen, and Gonyer,³ and later by Waldmann⁴ at Hochlantsch Mount, Styria, in an altered diabase, and from Lake Enare, Finnish Lapland, where it occurred in altered lime-silicate rocks. Pumpellyite was found by Quitzow⁵ in diabase-porphyrates and glaucophane-rocks from the Trias of northern Calabria, Italy. The same writer⁶ later observed it in a diabase-porphyrite from Tygirsik, Altai Mts., Siberia; in the Tertiary amygdaloidal basalts at Mormanno, northern Calabria; in diabases and

¹ C. Palache and H. E. Vassar, Some minerals of the Keweenawan copper deposits: pumpellyite, a new mineral; sericite; saponite. *Amer. Min.*, 1925, vol. 10, pp. 412-418. [M.A. 3-8.]

² W. S. Burbank, Additional data on the properties of pumpellyite, and its occurrence in the Republic of Haiti, West Indies. *Amer. Min.*, 1927, vol. 12, pp. 421-424. [M.A. 3-454.]

³ J. Irving, M. Vonsen, and F. A. Gonyer, Pumpellyite from California. *Amer. Min.*, 1932, vol. 17, pp. 338-342. [M.A. 5-233.]

⁴ L. Waldmann, Pumpellyit aus Steiermark und Finnisch Lappland. *Min. Petr. Mitt. (Tschermak)*, 1934, vol. 45, pp. 92-93. [M.A. 5-479.]

⁵ H. W. Quitzow, Diabas-Porphyrite und Glaukophangesteine in der Trias von Nordkalabrien. *Nachr. Gesell. Wiss. Göttingen, math.-phys. Kl.*, 1935, N.F., vol. 1, no. 9, pp. 83-118.

⁶ H. W. Quitzow, Pumpellyit, ein häufiges Hydrothermal- und Sekundärmineral in basischen Gesteinen. *Zentr. Min., Abt. A*, 1936, pp. 39-46. [M.A. 6-429.]

diabase-tuffs from eastern Corsica; and in diabases from Braunau in Waldeck, and several other German localities. Rocks containing the 'green clinzoisite' described by G. Fischer (1929) from Wippra in the Harz, Germany, have on re-examination by Quitzow been found to contain abundant pumpellyite. Finally, Tsuboi¹ records the mineral in veins traversing the basic igneous rocks of the Mikabu system in the Titibu district, Japan.

Professor C. E. Tilley pointed out to the present writer that sections of two spilitic dolerites from Nassau, viz. nos. 19,043 (Weilburg, Lahn) and 29,657 (Sinn, south of Herborn, Westerwald), in the Harker Collection of the Department of Mineralogy and Petrology, Cambridge, contained pumpellyite, and this mineral after study has proved to be identical with the western Otago mineral described below.

Occurrence.—During the last five years the writer has been engaged in a study of the Lake Wakatipu region, in western Otago, New Zealand, composed of a varied series of sedimentary and igneous rocks which have suffered low-grade dynamothermal metamorphism on a regional scale. The rocks all belong to the zone of chlorite, but have been subdivided into four subzones according to the degree of reconstitution.² The mineral pumpellyite has been identified in schists belonging to three of these subzones, viz. Chl. 1, Chl. 2, and Chl. 3, but does not appear to be present in the more metamorphosed rocks of the Chl. 4 subzone. In addition pumpellyite is rarely an important constituent of numerous narrow quartz-albite segregation veins which cut the schists throughout this region.

Optical properties.—The mineral may occur as tiny prismatic, yellowish-green crystals (measuring up to 0.3 mm. in length) within relict clastic grains of plagioclase (now albite), or at least closely associated with this mineral. The prisms are rarely terminated, but instead often have a distinctly ragged or frayed appearance (fig. 1 B). In other slices it has a finely fibrous aspect when it builds up felt-like aggregates which appear distinctly granular under a low magnification. Such 'granules' have a most characteristic appearance due to the lack of any common orientation of the fibres, portions of the grains being green while others are yellow. In the best example

¹ S. Tsuboi, Petrological notes. Japanese Journ. Geol. Geogr., 1936, vol. 13, pp. 333-337.

² C. O. Hutton and F. J. Turner, Metamorphic zones in north-west Otago. Trans. Roy. Soc. New Zealand, 1936, vol. 65, pp. 405-406.

(no. 3471) so far examined the mineral occurs as a felt of minute prisms as well as in distinct crystals averaging 0.2 mm. in length (fig. 1 A).

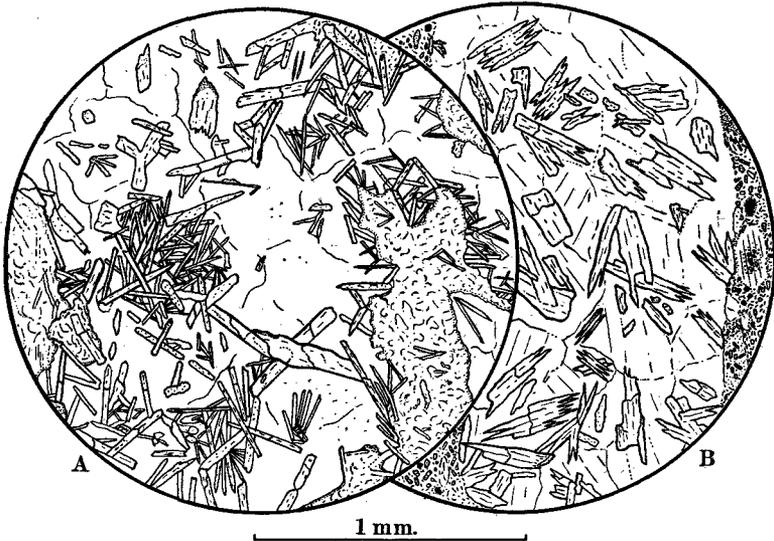


FIG. 1 A. Pumpellyite showing prismatic and 'granular' form, in quartz-albite vein, no. 3471.

FIG. 1 B. An 'auge' of crystalloblastic albite and pumpellyite in schistose greywacke, no. 3172.

Colour varies from a very pale green to a distinct bluish-green, rarely brown. Pleochroism is strong in deeply coloured varieties according to the scheme: α colourless or very pale yellow, β strong bluish-green, γ colourless or very pale yellow. The intensity of absorption being $\beta > \alpha = \gamma$. The optic axial angle is very small, possibly not exceeding 10° ,¹ while the sign is positive (determined in section no. 3172), but the determination of the sign was difficult owing to the lack of suitably oriented crystals. The refractive indices obtained by immersion in oils are as follows:

α 1.678, β 1.681, γ 1.688 ± 0.002 , $\gamma - \alpha$ 0.010. Another determination gave β 1.684. Although the birefringence in this case is approximately equal to that of quartz, brownish-purple or bluish anomalous interference-tints were detected in some instances, the result of a

¹ Not observed on specimen of determined refractive index.

combination of low birefringence and strong dispersion. The dispersion appears to be $r < v$. β is parallel to the length of the crystals, hence they may have either positive or negative elongation; the direction of maximum absorption, however, is always parallel to the long axis of the crystals. Traces of a cleavage may occasionally be

		A.	B.	C.	D.	E.
Refract. indices	α ...	1.678	1.698	1.700	1.678	1.677
	β ...	1.681	1.700	1.707	1.680	1.678
	γ ...	1.688	1.708	1.718	1.692	1.690
Optic sign ...	positive	positive	positive	positive	positive	
Dispersion	$r < v$	$r < v$	$r < v$	$r < v$	$r < v$	
2V ...	small	large	75-80°	40°	38°	
Orientation	$\beta = b$	$\beta = b$	$\beta = b$	$\beta = b$	$\beta = b$	
Colour ...	green, rarely brown	green	green	green	brown	
Pleochroism	α ...	colourless to very pale yellow	colourless	colourless	colourless	colourless
	β ...	bluish-green	bluish-green	bluish-green	pale green	brownish-yellow
	γ ...	colourless to very pale yellow	colourless	colourless	colourless	colourless
		F.	G.	H.	I.	
Refract. indices	α ...	—	—	—	1.686	
	β ...	1.69	1.68	—	1.690	
	γ ...	—	1.69	—	1.698	
Optic sign ...	positive	positive	negative	positive		
Dispersion	$r < v$	$r < v$	$r > v$	$r < v$		
2V ...	variable	40°	nearly 0°	36-40°		
Orientation	$\beta = b$	$\beta = b$	$\beta = b$	$\beta = b$		
Colour ...	bluish-green	green	green	chromium-green		
Pleochroism.	α ...	nearly colourless	colourless	usual pleochroism	almost colourless	
	β ...	bright bluish-green	green	„	light ocean-green	
	γ ...	nearly colourless	colourless	„	almost colourless	

A. Lake Wakatipu, western Otago, New Zealand.

B. Keweenaw Peninsula, Michigan. Palache and Vassar, 1925.

C. Haiti, West Indies. Burbank, 1927.

D. Mill Creek, California. Irving, Vonsen, and Gonyer, 1932.

E. Skaggs, California. Irving, Vonsen, and Gonyer, 1932.

F. Lapland. Waldmann, 1934.

G. Calabria, Italy. Quitzow, 1935.

H. Braunau, Waldeck, Germany. Quitzow, 1936.

I. Asahine, Titibu-gôri, Saitama prefecture, Japan. Tsuboi, 1936.

developed parallel to the β vibration-direction in the crystals (fig. 1 B).

A comparison of the properties of the Otago mineral with those of other occurrences is made above, and it will be seen that they do not show any great variation. The blue-green colour for the β vibration-direction appears to be characteristic of the mineral, with brown tints rare. In this connexion might be mentioned the occurrence described by Fischer (Quitow, loc. cit., pp. 41-42) of aggregates of radiating crystals with one end of the crystals red, while the other is bluish-green, and have the properties of pumpellyite.

Paragenesis and origin.—It is important to note here that Quitow has observed the following facts :

1. The close association of calcic plagioclase and pumpellyite.
2. That pumpellyite is characteristic of the first depth zone.
3. The early appearance of pumpellyite, often before epidote.

In western Otago the mineral is commonly closely associated with plagioclase in the greywackes and their sheared equivalents, or rarely in quartz-albite veins. This plagioclase was originally a calcic variety, probably andesine or labradorite, but shearing has brought about a recrystallization to albite, the anorthite molecule being represented now either by clinozoisite or epidote, or by pumpellyite. In the more highly metamorphosed rocks of this region (those belonging to the Chl. 4 subzone), where the plagioclase relicts have become completely broken down and recrystallized into a mosaic of albite grains, pumpellyite does not occur, its place being taken by epidote or clinozoisite.

The presence of pumpellyite in narrow quartz-albite veins is suggestive of a segregation by solutions of the pumpellyite molecule, as is so frequently the case with epidote.

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