

Pumpellyite-bearing basic igneous rocks from the Lower Ordovician of North Pembrokeshire, Wales

R. E. BEVINS

Department of Geology, The University, Keele, Staffs. ST5 5BG

SUMMARY. The first occurrence of pumpellyite in the Lower Ordovician volcanic rocks of North Pembrokeshire is reported and its form and chemistry are described. The significance of pumpellyite in relation to the grade of metamorphism attained during the Caledonian orogenic episode is discussed.

THE Lower Ordovician of North Pembrokeshire comprises a succession of shales, siltstones, and sandstones, with sporadically associated volcanic rocks. The Fishguard Volcanic Group (Lower Llanvirn) represents the thickest volcanic horizon and is best developed between Strumble Head and Fishguard (fig. 1). This succession is composed largely of basic lavas and high-level intrusives, although there is also an extensive development of rhyolitic lava with associated autoclastic and pyroclastic rocks. Lava of intermediate composition is present only in minor amounts. Volcanic rocks of Arenig age are found at Trefgarne where basic to intermediate lavas and pyroclastics make up the Trefgarne Volcanic Series.

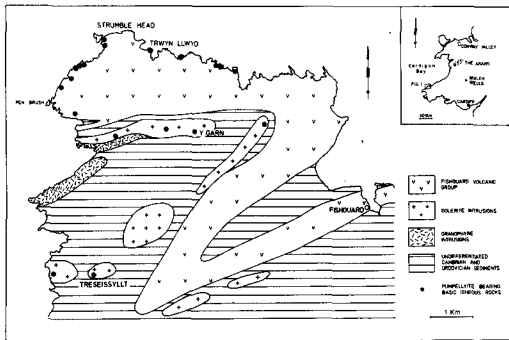


FIG. 1. Location of pumpellyite-bearing basic igneous rocks in the Fishguard Volcanic Group and associated intrusions.

The whole region was affected by the Caledonian orogenic episode, which folded the strata and produced an axial planar cleavage in the least competent beds. Contemporaneously with this

deformation, the rocks suffered metamorphism at a low grade with a new mineral assemblage being produced, which has replaced the original igneous assemblage. Evidence shows the grade of metamorphism to be in the prehnite-pumpellyite facies with a mineral assemblage that includes prehnite, pumpellyite, chlorite, epidote, calcite, stilpnomelane, sphene, and actinolite. Plagioclase is commonly albitized and pyroxene is sometimes pseudomorphed by chlorite, especially in the Trefgarne Volcanic Series, although in the Fishguard Volcanic Group pyroxene is largely a metastable relict phase. Prehnite-stilpnomelane assemblages have been reported by Roach (1969) from the Ordovician intrusions of the North Pembrokeshire coast. These were ascribed to deuteric alteration within the intrusions but are now recognized as metamorphic assemblages (Roach and Floyd, pers. comm.).

Previous descriptions of pumpellyite from Wales. Pumpellyite has only been described from a limited number of localities in Wales (fig. 1). Nicholls (1959) described pumpellyite from Builth Wells, suggesting it to be of autometamorphic origin, occurring in the margins of 'sacs', which formed due to the concentration of a volatile-rich immiscible liquid rich in Ca, Mg, and Fe. This hypothesis was later questioned by several authors, including Raam *et al.* (1969) and Coombs (1974), who ascribed the mineral to a metamorphic origin, having found pumpellyite also in the associated sediments. Ridgeway (1971) noted the presence of pumpellyite in altered dolerites from the Aran Mountains of Mid Wales and suggested that it was metamorphic in origin. Jenkins and Ball (1964) identified pumpellyite in soil samples from the Conway Valley area in North Wales. This they traced back to local doleritic and gabbroic intrusions.

Locations of pumpellyite in North Pembrokeshire. In the Lower Ordovician of North Pembrokeshire, pumpellyite has been identified from a number of localities within the Fishguard Volcanic Group, where it occurs within both the pillow lavas and the

associated intrusive rocks. These localities are shown in fig. 1. It has also been identified by X-ray diffractometry from the Trefgarne Volcanic Series, further south. However, this note will be limited

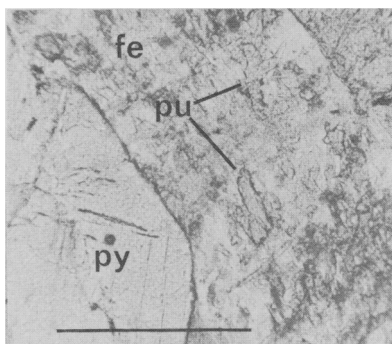
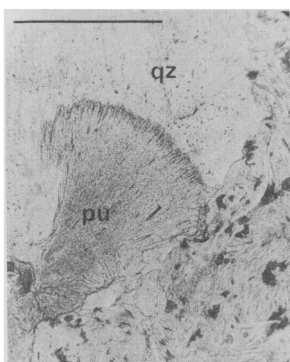
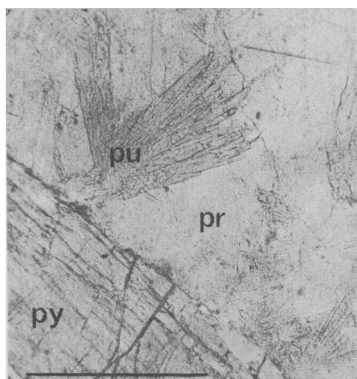


FIG. 2. Photomicrographs of Fishguard Volcanic Group basic rocks and associated intrusions containing pumpellyite. Scale bars represent 0.25 mm. *a* (top), well-formed pumpellyite (pu) crystals in prehnite (pr) alteration vein. Relict clinopyroxene (py) also present. In dolerite (YG54) from Y Garn. *b* (middle), radiating pumpellyite (pu) needles associated with quartz (qz) occurring as amygdule infilling. From pillow lava sample (SBR11) Trwyn Llwyd. *c* (bottom), small pumpellyite (pu) masses in altered feldspar (fe) crystal. Relict clinopyroxene (py) also present. Dolerite from Garn Fawr (GF51).

to a description of the form and chemistry of pumpellyite found within the Fishguard Volcanic Group and associated intrusions.

Pumpellyite form and chemistry. Pumpellyite shows a variety of form within the basalts, dolerites, and gabbros: in alteration veins it occurs as stout, prismatic crystals (up to 0.4 mm long) and is frequently associated with prehnite (fig. 2*a*); as amygdule fillings where it consists of long, thin crystals, arranged in a radial form (fig. 2*b*); in the matrix of the rock as small prismatic crystals scattered throughout the matrix; replacing plagioclase (fig. 2*c*) and in rare cases replacing pyroxene.

Crystals show low birefringence, generally of first-order colours and often anomalous. All of the forms show a marked pleochroism, which is generally blue-green (β) to colourless (α and γ), although from one locality, Trwyn Llwyd (fig. 1), it shows a greenish-brown to colourless pleochroism. Zen (1974) noted a similar pleochroic scheme in iron-rich pumpellyites from Jonestown, Pennsylvania. The Trwyn Llwyd sample has not yet been analysed.

TABLE I. Analyses of pumpellyite from North Pembrokeshire

	1	2	3	4
SiO ₂	36.95	36.33	35.79	37.08
TiO ₂	n.d.	n.d.	n.d.	n.d.
Al ₂ O ₃	20.76	19.35	22.35	22.55
FeO*	9.97	11.16	9.65	8.31
MnO	n.d.	n.d.	n.d.	n.d.
MgO	1.88	1.43	1.31	1.52
CaO	23.33	23.00	22.34	23.28
Na ₂ O	n.d.	n.d.	n.d.	n.d.
K ₂ O	n.d.	n.d.	n.d.	n.d.
Total	92.89	91.27	91.44	92.74

FeO* = Total Fe as FeO.

n.d. = Not detected.

1, 2. Dolerite from Treseissyllt. Grid ref. SM916392. Pumpellyite occurs in rock matrix.

3, 4. Dolerite from Y Garn. Grid ref. SM893356. Pumpellyite occurs in alteration veins with prehnite.

Pumpellyite crystals in dolerites from Y Garn and Treseissyllt (fig. 1) were analysed on a Geoscan Mark II microprobe. It was operated at an accelerating voltage of 15 kV and a current of 3.5×10^{-8} amps. An energy dispersive system was used for detection and measurement, with calibration against metals, oxides, and silicate standards. The results are shown in Table I. For comparison, pumpellyites from other low-grade metamorphic

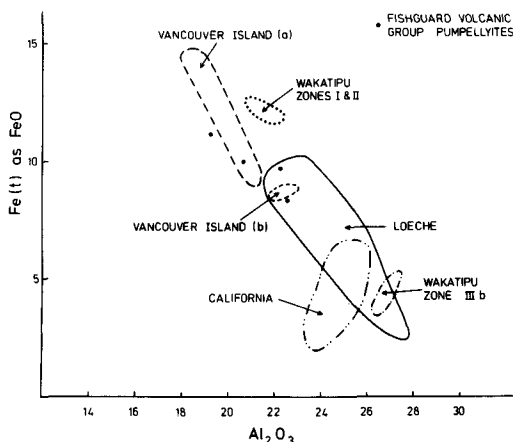


FIG. 3. FeO versus Al_2O_3 (wt%) plot of pumpellyites from North Pembrokeshire intrusions and other areas. Vancouver Island (a) after Surdam (1969); Wakatipu (Kawachi 1975); Vancouver Island (b) (Kuniyoshi and Liou); Loèche (Coombs *et al.*, 1976); California (Ernst *et al.*, 1970).

areas are plotted in fig. 3, which shows the variation of Al_2O_3 and total iron as FeO. The Fishguard pumpellyites appear similar to pumpellyites from the Triassic Karmutsen Volcanic Group, Vancouver Island (Surdam, 1969; Kuniyoshi and Liou, 1975) with comparatively low Al_2O_3 . Low Al_2O_3 and high total iron appear to be typical of the lower grades of metamorphism. An example of this chemical variation may be found in the pumpellyites from the Wakatipu District, New Zealand (Kawachi, 1975). Pumpellyites in Kawachi's Zones I and II, which belong to the prehnite-pumpellyite facies, have comparatively low Al_2O_3 and high total iron, whereas in Zones IIIa and IIIb, which are in the pumpellyite-actinolite facies, higher Al_2O_3 and lower total iron are seen. Thus the grade of Caledonian metamorphism in this area is now much more precisely known.

Pumpellyite occurring as inclusions in albite crystals has not yet been analysed from the Fishguard Volcanic Group. Very low MgO has been reported in pumpellyites of similar form from Loèche, Switzerland by Coombs *et al.* (1976).

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