

Further indirect confirmation of the accuracy of the gel technique came from weight-loss studies of magnesium iron silicate melts in platinum containers. For samples weighing about 100 mg, the actual loss in weight due to reduction of Fe_2O_3 to FeO and Fe (the latter dissolves in the platinum) agreed within ± 2 mg with a value calculated from an analysis of the final ferric: ferrous ratio of the silicate and the assumed composition of the starting material. In a few cases where agreement was not obtained, there was reason to suspect the accuracy of the iron analysis.

The X-ray diffraction pattern of the starting material is that of ferric oxide, and shows no lines for silica or magnesia, which evidently are not present in a very crystalline form. The Mössbauer spectrum of the material consists of the six-line pattern characteristic of ferric oxide.

No attempt was made to prepare gels yielding ferric oxide and silica together with the oxides of calcium, aluminum, sodium or potassium. It appears to be difficult, if not impossible, to prepare gels yielding only Fe_2O_3 and SiO_2 . The problem is to find a solvent system which will keep the ferric benzoate in solution until the gel has time to form.

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PUMPELLYITE OF DEUTERIC ORIGIN

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ABSTRACT

Pumpellyite occurs as radiating crystals in cavities in altered syenite from the Prospect Intrusion near Sydney, New South Wales, with a variety of other minerals. Optically positive and negative pumpellyite coexist, and the optical properties show no correlation with mineral association. The cavity-filling minerals grew at low temperature and confining pressure.

INTRODUCTION

During recent years, many occurrences of pumpellyite have been described from low-grade, regional metamorphic terrains. The present paper records an occurrence of pumpellyite in a completely different geological environment.

OCCURRENCE

In the differentiated Prospect teschenite-picrite intrusion, west of Sydney, New South Wales, pumpellyite is abundant (up to 10 percent by volume of the rock) in deuterically altered syenite differentiates, and also occurs in teschenite, teschenite-pegmatite and analcime syenite. The petrology of the intrusion has been described in detail by Wilshire (1967).

The syenites and microsyenites consist of a framework of anorthoclase, minor plagioclase, subordinate clinopyroxene and opaque minerals, together with interstitial material. In the unaltered syenites, the interstices contain small grains of aegirine, aegirine-augite, alkali feldspar, plagioclase, apatite, biotite, sphene, and fluorite, set in a base of coarse-grained primary analcime. The altered syenites were originally rich in analcime (Wilshire, 1967) but have since been extensively replaced by secondary minerals.

In the most altered syenitic rocks (*e.g.* 10952, 39776)¹ pumpellyite is observable in hand specimens as clusters of prismatic crystals (over 1 mm in length) lining and partly filling numerous cavities. The pumpellyite is intergrown with a variety of secondary minerals in these cavities and also replaces some of the primary minerals. The secondary minerals include albite, chlorite, prehnite, biotite, sphene, apatite, fluorite, analcime, carbonate, pyrite, and unidentified clay minerals.

The interstices in altered syenite range from 0.5 mm to over 10 mm across. They may be partly rimmed by clear albite, optically continuous with the partly kaolinized framework feldspar, and are commonly zoned with chlorite-pumpellyite rims and extensive carbonate centers (Fig. 1). Biotite may appear with chlorite in this zonal sequence. Locally, minor prehnite is intergrown with the pumpellyite, albite and chlorite. In addition, pumpellyite may be associated with small grains of fluorite, apatite, analcime, sphene, and rarely an unidentified clay mineral. The pumpellyite occurs as subradiating aggregates of prismatic crystals.

The framework plagioclase and alkali feldspar show minor replace-

¹ Specimen numbers refer to catalogued rocks in the Department of Geology and Geophysics, University of Sydney.

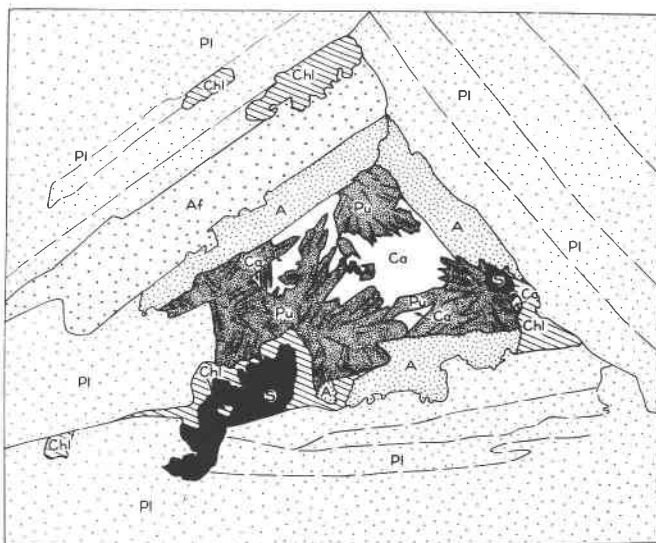


FIG. 1. Typical aggregate of prismatic pumpellyite crystals partly lining an interstitial site in altered syenite. Abbreviations: Pu=pumpellyite, Chl=chlorite, Ca=calcite, A=albite, Af=alkali feldspar, Pl=plagioclase, S=sphene. $\times 75$.

ment by pumpellyite occurring with sphene in small irregular clusters. Feldspars are also replaced by carbonate and rarely by chlorite and biotite. Clinopyroxene is commonly replaced by carbonate, rarely associated with pumpellyite and biotite.

In one microsyenite specimen (29481) an irregular, ramifying replacement vein, averaging 0.5 mm across, consists mainly of carbonate with marginal clear albite, chlorite, pumpellyite, and rare prehnite. The common centrally occurring minerals are apatite, fluorite and analcime.

In altered teschenite (29492, 29494), pumpellyite occurs in partly filled, sub-spherical cavities, some over one foot across. These contain marginal layers of prehnite and/or pumpellyite with chlorite, passing into zones (one or two inches thick) of coarse-grained, columnar prehnite, succeeded by central zones of carbonate.

OPTICAL AND X-RAY DATA

The identification of pumpellyite was confirmed by an X-ray powder photograph using a 114.6-mm diameter camera, comparing the measured spacings with the data of Coombs (1953).

For optical study, pumpellyite grains were extracted from interstices in the various rock types. Of twenty grains measured, one was found to be optically negative with $\beta=1.711$, $\gamma=1.718 (\pm 0.003)$, $2V=ca 85^\circ$,

$Z \wedge c = 27^\circ$. The remainder are positive with β ranging from 1.690 to 1.700 and $2V = 60-80^\circ$; dispersion is strong $r < v$, and $Z \wedge c = 20-25^\circ$. The pumpellyite is pleochroic from colorless or very pale bluish green ($X = Z$) to blue-green (Y). No golden-brown colored varieties were observed. At Prospect there appears to be no systematic relationship between the optical properties of the pumpellyite and any specific mineral association. Both negative and positive pumpellyites coexist in the same rock and exhibit the same blue-green absorption. However, previous work (Coombs, 1953; Deer *et al.*, 1963) implies that optically positive pumpellyite is green, whereas brown varieties are negative. Extrapolating the data of Coombs (1953), a change in optic sign (without change in orientation) would be expected at a β refractive index of about 1.710. This is confirmed by the Prospect material. The negative pumpellyite would be expected to have about 9 percent by weight of total iron (as Fe_2O_3) according to the determinative chart of Coombs (1953, p. 131, Fig. 8).

DISCUSSION

The occurrence of pumpellyite at Prospect is important because the teschenite-picrite body is intrusive into unmetamorphosed shales under a cover of about 600 feet (Wilshire, 1967). This implies that the pumpellyite (and associated prehnite) can be only of deuteric origin, and hence grew in an environment characterized by a low confining pressure.

Previously, pumpellyite has been reported from deeply buried sedimentary-volcanic sequences (*e.g.* Coombs, 1954, 1961; Smith, 1968), low-grade metamorphic terrains (Seki, 1961) or, rarely, from cavities (Meixner, 1965) and replacing biotite (Struwe, 1958) in granitic rocks. It also occurs as a secondary mineral in interglacial sediments and Tertiary basalts at depths of less than 100 feet in geothermal areas in Iceland (Sigvaldason, 1963).

Donnelly (1966) observed rare pumpellyite in andesitic fragments and spilitic flows from the U.S. Virgin Islands and invoked an autometasomatic origin. However, these rocks have been buried to depths in excess of 17,000 feet and the interbedded sediments have suffered mineralogical adjustments similar to those in the volcanics (Donnelly, 1966), so that an origin due to burial metamorphism cannot be excluded.

Nicholls (1959) recorded abundant pumpellyite in the margins of immiscible magma "sacs" in the Lower Spilites of the Builth Volcanic Series, Wales. He explained this as being an autometasomatic alteration product caused by a concentration in the "sac" margins of a volatile-rich immiscible liquid rich in Ca, Mg and Fe. Such a liquid is unlikely as a late magmatic residuum. Moreover, this concentration mechanism seems improbable because of the small size (approximately 6 inches in

diameter) of the "sacs" and the presence of fine-grained margins which could represent chilled selvages in pillow lavas (see also Vallance, 1965, p. 474). In addition, we have observed authigenic pumpellyite in specimens of the sedimentary and fragmental spilitic rocks (collected by T. G. Vallance in 1961), associated with the Bultih Volcanics.

We are unaware of any previously published account of pumpellyite occurring in a high-level intrusive or volcanic rock that has not been subjected to deep burial or geothermal activity. However, the Prospect occurrence appears to represent a clear example of deuteric pumpellyite.

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