

FIG. 1. Variation in unit-cell dimension and refraction index with composition.

11.621 Å found by Skinner (1956) for synthetic anhydrous material; optically, however, the sample ranged from  $n$  1.800, corresponding to his value, down to about  $n$  1.792 with the bulk near  $n$  1.796.

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#### SOME EXPERIMENTAL DATA ON THE STABILITY OF PUMPELLYITE

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The hydrothermal stability of pumpellyite, Ca<sup>4</sup>(Mg, Fe<sup>+2</sup>, Mn) (Al, Fe<sup>+3</sup>, Ti)<sub>5</sub>O(OH)<sub>3</sub>[Si<sub>2</sub>O<sub>7</sub>]<sub>2</sub>[SiO<sub>4</sub>]<sub>2</sub>·2H<sub>2</sub>O, a common mineral of low grade

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metamorphic rocks (Coombs, 1953; Seki, 1961), has been investigated. Concentrates (<0.045 mm.) were obtained from three New Zealand pumpellyite-bearing rocks: pumpellyite in O.U. 15265,<sup>2</sup> from the Haast Schist Group, Henley, South Otago, is bluish green ( $\alpha$ ,  $\gamma$  colorless to very pale green;  $\beta$  bluish green) and fairly homogeneous ( $\beta = 1.686 \pm 0.005$ ); 16654 and 22300, both from the Maitai Group (Permian), Nelson, contain inhomogeneous pumpellyite which ranges from a colorless, low-iron variety to a pleochroic rich bluish green ferriferous type. In the latter, crystal cores tend to be more highly colored than crystal margins. All samples are biaxial positive. In addition to pumpellyite, all samples contained approximately 25 percent quartz. Sample 22300 contained epidote. Other impurities—sericite, chlorite, sphene, and albite—occurred in trace amounts in some concentrates.

Samples were heated in sealed and unsealed silver tubes within cone seal hydrothermal pressure vessels. Temperature was controlled to  $\pm 5^\circ\text{C}$  with Pt-PtRh(13%) thermocouple and a "Transitrol." Water pressure was measured on a calibrated Bourdon gauge. Partial pressure of oxygen was not controlled. The bombs were cooled rapidly in air under pressure. Duration of runs varied from 7–47 days. Products were identified with petrographic microscope and by X-ray diffraction.<sup>3</sup>

These data indicate that the assemblage pumpellyite + quartz decomposes under the conditions of the experiments between 500 and 550°C in the pressure range 500–3000 atmospheres; the decomposition curve (Fig. 1) shows a very steep positive slope. At water pressures less than 500 atmospheres, the reaction is sluggish with pumpellyite remaining unaltered after periods up to 14 days at temperatures above 500°C.

Owing to fine grain size of the reaction products, optical studies are not precise and X-ray diffraction patterns diffuse. Therefore, the pumpellyite decomposition reaction could not be determined in detail. Certainly anorthite and a pale green clinopyroxene (probably salite:  $\alpha = 1.708$ ,  $\gamma = 1.732 \pm 0.005$ ;  $Z\Delta c = \text{ca. } 45^\circ$ ) form the predominant reaction products; remnant quartz is usually present, though much less abundant than in starting material. Occasional crystals of unidentified phases have been noted optically, but they have not been successfully identified or recognized in the X-ray pattern.

Numerous attempts to reverse this reaction were made using seeded and unseeded mixtures of the pumpellyite decomposition products; re-

<sup>2</sup> Specimens kept in the Geology Museum, University of Otago.

<sup>3</sup> A table listing experimental results has been deposited as Document No. 9898 with the American Documentation Institute, Auxiliary Publications Project, Photoduplication Service, Library of Congress, Washington, D.C., 20540. Copies may be secured by citing the document number, and remitting in advance \$1.25 for photoprints or \$1.25 for 35 mm. microfilm.

sults were all negative or indecisive. Likewise, synthesis experiments using oxide mixtures of pumpellyite composition yielded indecisive results. Anorthite, wairakite, montmorillonite and other phases crystallized readily and persisted for periods as long as 28 days. In some unseeded runs with the oxide mixture, occasional grains of a tiny (up to 0.01 mm) pleochroic green mineral with high relief appear to have partially replaced the core of anorthite crystal groups. Although this phase clearly resembles pumpellyite, a positive identification was not achieved. This

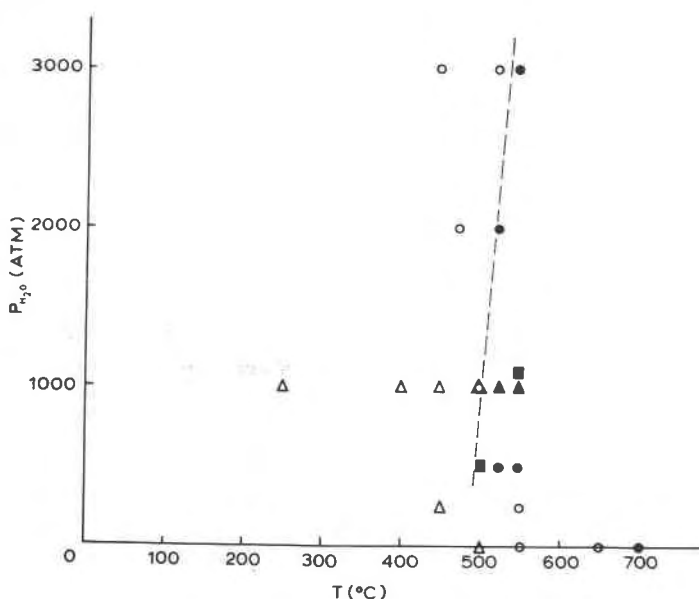


FIG. 1. Stability field of pumpellyite+quartz under the described experimental conditions. 16654 = circle; 15265 = triangle; 22300 = square; open symbol = pumpellyite+quartz; closed symbol = anorthite+clinopyroxene.

material formed in experiments of seven days' duration at 375°C–1000 atm and 400°C–3000 atm.

Recent data on the hydrothermal stability of epidote (Holdaway, 1966) indicate that clinozoisite ( $Cz_{87}$ - $Ps_{13}$ ) plus quartz reacts to form anorthite plus grossularite along a slightly less steep curve than that presented here, and at somewhat higher temperatures: 1000 atm at 575°C, 2000 atm at 609°C, 3000 atm at 671°C. Iron-rich epidote persists to slightly higher temperatures. Thus epidote in the starting material in two of our experiments (22300) remained unchanged above the temperature where pumpellyite has begun to decompose.

## DISCUSSION

Pumpellyite plus quartz reacts to form anorthite plus clinopyroxene at temperatures slightly above 500°C at 1000 atmospheres and 530°C at 3000 atmospheres. The decomposition curve for this dehydration reaction appears to have a very steep, positive slope. These  $p$ - $T$  conditions may vary with different oxidation conditions, or with starting material of a different composition. In natural rock systems, it is unlikely that pumpellyite persists to temperatures as high as 500°C; in nature it is replaced by other lime-bearing minerals (e.g., epidote and ca-amphibole) long before the appearance of metamorphic ca-plagioclase.

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MICA PERIDOTITE, WYOMINGITE, AND ASSOCIATED POTASSIC  
IGNEOUS ROCKS IN NORTHEASTERN UTAH

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An association of highly potassic, silica-poor igneous rocks has been discovered east of Salt Lake City, Utah, near the junction of the east-west trending Uinta Arch and the north-south trending Wasatch Mountains, both uplifted during the Cretaceous-Tertiary Laramide Orogeny. The occurrence of mid-Tertiary granitic plutons and extrusive andesitic rocks, mostly pyroclastic, in this same area has been known for several decades, but the potassic rocks have been discovered only in recent years, in part through areal mapping by students of the University of Utah. The rather widely scattered (Fig. 1) potassic rocks range in age from Upper Eocene to Lower Pliocene. They comprise two small plugs or dikes of mica peridotite and two centers of minor intrusions and flows of phlogopite-diopside-analcime or sanidine rocks similar to those found in the Leucite Hills of Wyoming, about 150 miles to the northeast and in the Fitzroy Basin of northwestern Australia.