source is also believed to be a metasomatized mantle.

In contrast to jadeite and omphacitic pyroxenes, all the phases with low densities stable at lower pressures including quartz, albite, sanidine, and phlogopite exhibit solubilities increasing with rising pressure, fig. 3 (Kennedy, 1950; Clark, 1966; Ryabchikov and Boettcher, 1980). In comparison with the results of the present work for jadeite, it implies that for the isochemical phase assemblage a maximum should exist on the sodium concentration in the fluid-pressure curve in the pressure range where the plagioclase-clinopyroxene reaction takes place. For mantle lherzolites such boundary pressures lie between 10 and 15 kbar, and corresponding depth levels may be most favourable for the precipitation of sodium from ascending fluids.

It can also be hypothesized that a similar maximum solubility for potassium may exist but at much higher pressures (50-80 kbar) where the traces of potassium present in mantle lherzolite at shallower depths in the form of small amounts of phlogopite or sanidine are transferred into clinopyroxene solid solution.

If the appearance of the zones of anomalous mantle enriched in alkalis is due to metasomatism caused by ascending fluids, then Na-rich zones should be confined to shallower depths than K-rich zones. Subsequent involvement of such zones in the processes of partial melting may explain the appearance of alkali-rich primary magmas. The confinement of the sources of K-rich basic magmas (including kimberlites) to depths greater than that of Na-rich basalts is in accord with the model outlined which is partly based on the results of our experiments.

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[*Manuscript received 2 July 1984*]

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MINERALOGICAL MAGAZINE, SEPTEMBER 1985, VOL. 49, PP. 603-606

Priderite stability in the system $K_2MgTi_7O_{16}$–$BaMgTi_7O_{16}$

MAFIC and ultramafic magmas anomalously enriched in K, Ba, Ti, Zr, and other incompatible and LIL elements are probably direct partial melts of mantle sources which are also enriched in these elements. Potential mineral reservoirs for these elements obviously must be stable under the *P,T* conditions of the mantle source. The commoner reservoirs for K and, to a lesser extent, Ti are phlogopite and K-rich amphibole, both of which are stable up to 30 kbar and at temperatures in excess of continental mantle geotherms (Modreski and Boettcher, 1972; Kushiro and Erlank, 1970). Much less common minerals containing these elements are wadeite ($Zr_2K_4Si_6O_{18}$) and priderite, of approximate composition $(K,Ba)_{1.33}(Fe,Mg,Ti)_{8-x}O_{16}$, where x is very small and is dependent on the amounts of Ba and Fe^{+3} in the formula, as given by Norrish (1951). These minerals occur in the lamproites of the West Kimberley region, Western Australia (Prider, 1939; Jacques *et al.*, 1984) and in the high potash lavas of the Leucite Hills, Wyoming (Carmichael, 1967; Kuehner *et al.*, 1981). The occurrence of both of these minerals as microphenocrysts, associated with diopside, phlogopite, and K-richterite phenocrysts, suggests wadeite and priderite may be early formed phases in the evolution of these highly unusual magmas. Wadeite is stable up to 25 kbar and 1250 °C (Arima and Edgar, 1980) and is thus a potential reservoir for K and Zr. In this note we report the results of experiments on Fe-free priderite in the system $K_2MgTi_7O_{16}$-$BaMgTi_7O_{16}$ from atmospheric pressure to 30 kbar at 1200–1400 °C to assess the potential of this mineral as a reservoir for K, Ba, and Ti in the mantle.

Starting materials for all experiments consisted of oxide mixes of compositions $K_2MgTi_7O_{16}$ (KP_{100}) and $BaMgTi_7O_{16}$(BP_{100}) initially heated in a quench furnace to 1000 °C for 20 hours followed by further heating at 1200 ± 10 °C for 4 days and quenching. Intermediate compounds (KP_{75}-BP_{25}, KP_{50}, BP_{50}, KP_{25}-BP_{75}) were made by mixing KP_{100} and BP_{100} by weight. High-pressure experiments were done in a single-stage, 1.27 cm diameter piston cylinder apparatus (Boyd and England, 1960) calibrated at the kyanite-sillimanite transition at 22 kbar and 1300 °C (Richardson *et al.*, 1968). No frictional correction was made for pressure and no temperature correction for the effect of pressure on the e.m.f. of the Pt-$Pt_{90}Rh_{10}$ thermocouples used to record temperature. Pressures are believed to be precise to ±0.5 kbar and temperatures to ±5 °C.

Products of the experiments consisted either of priderite or priderite + rutile which were identified optically or by X-ray diffraction methods. Optical distinction between priderite and rutile was unreliable because of the close similarities in their optical properties but they could be distinguished on X-ray powder diffraction patterns. Comparison of the *d*-spacings of the products of the experimental runs with those of natural priderite and of a synthetic Ba-priderite (Norrish, 1951) showed close agreement. Cell parameters of the KP_{100} priderite composition synthesized at 1200 °C at atmospheric pressure ($a = 10.13 \pm 0.03$, $c = 2.97 \pm 0.02$ Å) are very similar to those of natural priderite determined by Norrish (1951) who gives $a = 10.11 \pm 0.02$, $c = 2.96 \pm 0.004$ Å. The cell parameters of our products were confirmed using the LCREF computer program (Applied Mathematics Division, Argonne National Laboratory, 1965, unpublished) which calculates the crystal lattice by a method of least squares analysis.

Results of the experiments at atmospheric pressure and 1200 °C (Table I) indicate that rutile is an additional phase in compositions between KP_{50} and KP_0 but is not detected in compositions more K-rich than KP_{50}. For runs with rutile and priderite, the relative proportions of priderite to rutile, as determined by the intensities of the most prominent priderite (310) and the adjacent rutile (110) peaks, decrease with increasing Ba in the bulk compositions. Cell parameters from priderites crystallized throughout the entire range of compositions at 1200 °C (Table I) are probably constant within the limits of precision of the method. In Ba-rich priderites crystallized from KP_{25} and KP_0 the strong (110) and weak (400), (510), and (002) peaks are absent. These peaks are also either absent or of much lower intensity in the Ba-priderite synthesized by Norrish (1951). A run at 1300 °C using KP_{25} showed rutile was still present but in slightly lower amounts than in the 1200 °C experiment. Cell parameters of priderite in this experiment were comparable with those at the lower temperature but no peaks were missing. Results of high-pressure experiments on compositions KP_{75}-KP_0 (Table II) under mantle conditions are virtually identical with those at atmospheric pressure except that there appears to be an increase in rutile relative to priderite in the more Ba-rich priderite compositions. Additionally the (110), (400), (510), and (002) peaks are present in the KP_{50} composi-

Table I. Results of experiments at atmospheric pressure.

Bulk Composition	Cell parameters(Å)		Cell volume(Å^3)	Priderite:Rutile	Missing Peaks
wt. %	a	c			
At 1200°C					
$KP_{100}BP_0$	10.13	2.97	89.36	- (1)	none
$KP_{75}BP_{25}$	10.16	2.97	89.62	- (1)	none
$KP_{50}BP_{50}$	10.16	2.97	89.62	6:1	none
$KP_{25}BP_{75}$	10.12	2.97	89.27	3:1	(110),(400),(510),(002)
KP_0BP_{100}	10.07	2.96	88.23	2:1	(110),(400),(510),(002)
At 1300°C					
$KP_{25}BP_{75}$	10.09	2.97	89.00	4:1	none

(1)- rutile absent

Table II. Results of experiments at high pressures.

Bulk Composition wt. %	P(kb)	T(°C)	Cell Parameters(Å) a	c	Cell volume(Å^3)	Priderite: Rutile	Missing Peaks
$KP_{75}BP_{25}$	15	1300	10.12	2.97	89.27	-$^{(1)}$	none
$KP_{75}BP_{25}$	25	1300	10.20	2.98	90.58	-$^{(1)}$	none
$KP_{75}BP_{25}$	25	1200	10.13	2.98	89.96	-$^{(1)}$	none
$KP_{50}BP_{50}$	30	1300	10.13	2.98	89.96	2:1	none
$KP_{25}BP_{75}$	30	1300	10.11	2.99	90.38	2.2:1	(110),(400),(510),(002)
$KP_{25}BP_{75}$	30	1400	10.12	2.99	90.47	2.7:1	(110),(400),(510),(002)

$^{(1)}$- rutile absent

tion in contrast to the results at atmospheric pressure.

This study suggests two priderite solid solutions approximately represented by the formulae (K,Ba) $MgTi_7O_{16}$ (K-rich priderite) and (Ba,K)$MgTi_{7-x}O_{16-x}$ (Ba-rich priderite) where x represents the possible deficiency in Ti and O as indicated by the systematic increase in rutile coexisting with increasing Ba contents. The values of x cannot be accurately assessed on the basis of this study and the formula for the Ba-rich priderite has no crystallographic justification. Other explanations for the presence of rutile along with Ba-rich priderite include lack of stoichiometry, as suggested by Bayer and Hoffman (1966) who could not prepare Ba–Ti oxide compounds of the α-MnO_2 (hollandite) structural type, and the presence of vacant (K and Ba) tunnel sites in the structure (Pring and Jefferson, 1983). According to Post *et al.* (1982), tunnel cavities may remain vacant. Oxygen deficiency has been demonstrated in the Al-rich mullite structure (Cameron, 1977; Nakajima and Ribbe, 1981).

At one atmosphere and 1200 °C and in the high-pressure experiments, the limit of solid solution of priderite occurs at approximately 50 wt. % of the end member compositions (Tables I, II). The *a* parameter and cell volumes of the Ba-rich variety may be slightly less than those of K-rich priderites. If this conclusion is correct and not due merely to analytical uncertainty, it may lend support to either Ti and O deficiency or non-stoichiometry in the Ba-rich priderite structure. Pring and Jefferson (1983) showed that natural priderite has an open-packed tetragonal, hollandite-type structure in which the large cations (K and Ba) are in eightfold sites (tunnel cavities) whereas the Mg, Ti, and Fe are in octahedral co-ordination. Based on the results obtained by the LCREF program, all priderites in this study are tetragonal. Hence any distortions in the Ba-rich priderite structure produced by non-stoichiometry caused by Ti and O deficiency, or vacant tunnel sites, must be slight but might explain the absence of certain planes in these priderites.

We conclude that both K and Ba-rich priderite solid solutions have a wide stability range and are thus potential reservoirs for K, Ba, and Ti in the mantle. The absence of Ba-rich priderites in nature, analogous to the compositions KP_{50}-KP_0, is probably due to lack of magmas or source regions for such magmas with sufficient Ba relative to K. Natural priderites also contain Fe which may lower their stability temperatures. However, this is unlikely to be sufficient to substantially alter our conclusions.

Acknowledgements. We thank M. Arima for his guidance and interest during the course of this study and P. Thelin for running the LCREF program. Financial support was provided by a grant from the Natural Science and Engineering Research Council of Canada to ADE.

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[Manuscript received 31 October 1984; revised 28 December 1984]

KEYWORDS: priderite, system $K_2MgTi_7O_{16}$-$BaMgTi_7O_{16}$, wadeite.

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MINERALOGICAL MAGAZINE, SEPTEMBER 1985, VOL. 49, PP. 606-610

A contact-metamorphic occurrence of the assemblage nepheline-scapolite-diopside in a metabasic flow breccia from Bergslagen, Sweden

THE 1.9-1.8 Ga-old volcanic-sedimentary sequence in the Saxå sedimentary rift basin, 8 km SW of Hällefors, Western Bergslagen, Sweden (fig. 1) comprises (from old to young) acid metapyroclastics and marbles of the Middle Leptite Group, and metatuffites with metabasic sills, dykes and flows, overlain by phyllites, all of the Upper Leptite-hälleflinta and Slate Group (Oen *et al.*, 1982). Rifting, block faulting and compressive deformation resulted in the present symmetrical configuration of the area with generally westerly dipping strata. Intrusion of the 1694 ± 191 Ma Filipstad granite (Rb-Sr whole rock; Oen, 1983) truncated the folded Saxå rift basin to the south (fig. 1).

Nepheline associated with scapolite, diopside, andesine, biotite, and calcite has been observed in a metabasic flow breccia of the Upper Leptite-hälleflinta and Slate Group, at a distance of 150 m from the Filipstad granite. Metabasic flows and flow breccias from the same stratigraphic level, but further away from the granite, contain hornblende-andesine-biotite-calcite-quartz-sphene. In this paper evidence is presented supporting a contact metamorphic origin for the nepheline-scapolite-diopside assemblage, caused by the intrusion of the Filipstad granite.

The metatuffites belonging to the Upper Leptite-hälleflinta and Slate Group contain the assemblages hypersthene-andalusite-biotite-quartz and corundum-microcline-sericite-scapolite-andalusite-biotite-sphene adjacent to the granite instead of the assemblages hornblende-biotite-quartz-plagioclase and microcline-diopside-scapolite-biotite-sphene further away from the granite. The temperature, estimated from these assemblages, lies roughly between 500 and 700 °C (Hellingwerf, 1981), based on data of Evans (1965), Turner (1968), Haas (1972), and Sobolev (1972).

The temperature of the country rock adjacent to the solidifying Filipstad granite has been calculated to be roughly 500 °C (Hellingwerf, unpubl. data), using the equations of Jaeger (1957, 1959).

The nepheline-bearing metabasic flow breccia consists of small (< 2 cm), angular metabasic fragments, cemented by calcite. The fragments show relict vesicular textures with calcite-filled amygdules (fig. 2). Crystallization of (calc-) silicates has obliterated most of the original pilotaxitic, glomeroporphyritic, and intersertal textures (Hellingwerf, 1981). The present texture is characterized by poikiloblastic nepheline and scapolite, and granoblastic diopside and calcite. Minor but conspicuous quantities of pyrrhotite are present in the diopside-rich aggregates. The fragments also contain minor hornblende, poikiloblastic brown biotite, anhedral andesine, and accessory ilmenite rimmed by sphene, apatite, cubanite, chalcopyrite and hematite (Table I).

Electron microprobe analyses of nepheline, scapolite, and andesine were made on a Cambridge