POTASSIC RICHTERITE BEARING PERIDOTITES FROM KIMBERLITE AND THE EVIDENCE THEY PROVIDE FOR UPPER MANTLE METASOMATISM

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Introduction: The occurrence of the rare amphibole potassic richterite $KNaCaMg_5Si_8O_{22}(OH,F)_2$ in kimberlitic materials was described by Erlank (1973). The presence of this mineral has now been confirmed by microprobe analysis in 24 peridotite nodules including two samples described by Aoki (1976) and Dawson and Smith (1977), which have been made available by these authors for us to study. Apart from two samples from the De Beers and Monastery pipes all are from the Bultfontein pipe. Nodules from the latter locality have been the most intensively studied, and it is estimated that K-richterite bearing varieties comprise 5% of all nodules found at this locality. The ensuing discussion is directed to the Bultfontein nodules, unless otherwise indicated. Not all these nodules have been fully investigated, but available data indicate the following.

Bulk rock chemistry: In general, the K-richterite bearing nodules have major and minor element compositions similar to other nodules. The most obvious differences are that K-richterite bearing nodules have, on average, lower Al concentrations and higher contents of K, Na, Ti, Rb, Ba, Sr, Zr and Nb. Phlogopite bearing nodules which lack K-richterite are also somewhat enriched in the same elements but never reach the extremes of enrichment shown by those nodules containing K-richterite. Ranges found in K-richterite bearing nodules are: (%) Al_2O_3, 0.1-1.6; TiO_2, 0.04-0.4; Na_2O, 0.07-0.7; K_2O, 0.1-2.1; (ppm) Rb, 4-75; Ba, 26-149; Sr, 40-237; Zr, 12-162 ppm; Nb, 2-36.

Mineralogy: The dominant minerals in most K-richterite bearing nodules are olivine (Fo_{87-92}) and lesser amounts of enstatite (En_{90-93}, Al_2O_3 generally <0.1%) and phlogopite (2.6-5.3% FeO, 0.1-0.9% TiO_2, 0.1-0.6% Cr_2O_3, Mg/Mg+Fe = 0.90-0.95, Si+Al usually <8). K-richterite varies widely in modal abundance within and between nodules; in some cases it may comprise a quarter of a thin section, in other cases it may be necessary to cut several thin sections from a nodule before its presence is revealed. Its chemistry is marked by high K and Na, low Al, and cation proportions of Si+Al<8(Table 1). Diopside (generally 0.2-0.5% Al_2O_3, Mg/Mg+Fe=0.89-0.93, Ca/Ca+Mg=0.43-0.48) is present in about half the samples studied; it is noteworthy that it is often absent in those samples which contain the most K-richterite. Varying amounts of opaque oxides are present; generally these are Al-poor chromites. Mg-rich ilmenites are subordinate, and possibly related to kimberlite contamination. Two nodules contain an unidentified opaque mineral similar to that described by Haggerty (1975) in phlogopite from the De Beers Kimberlite. Provisional analysis of this phase yields the following data (in wt.%): TiO_2=52.5, Cr_2O_3=13.0, FeO=13.6, MgO=3.1, BaO=9.1, ZrO_2=7.4, SrO=2.4, $Nb_2O_5 \sim 0.5$. Calcite is often present as lamellae in phlogopite, and in one sample is enclosed as euhedral grains in diopside. Garnet ($Py_{73}Alm_{15}Gr_{12}$) is present only in the nodule sample from Monastery, in the form of small rounded grains armoured in olivine. The K-richterite, enstatite and diopside in this nodule have the highest Al_2O_3 contents of those analysed (4.0, 0.9 and 1.6% respectively).

Individual phases within specific nodules show no compositional variability, except in two nodules which contain K-richterite rich veins where small corroded diopsides show appreciable variation in Cr, and possibly Na and Al. Another nodule, which is altered, shows appreciable variations in Na and K between different grains of K-richterite.

Textures: All but one of the nodules have a coarse or granular texture; the exception has a porphyroclastic texture and it is significant that both phlogopite and K-richterite in this sample have been deformed. Interpretation of the origin of the K-richterite is partly dependant on the textural relationship it

exhibits with the other minerals in the nodules under consideration. The K-richterite appears to be texturally equilibrated with the other minerals and in many nodules evidence for its origin is equivocal. However, the following features are important: (a) the K-richterite is clearly a late crystallizing phase because it often poikilitically encloses the other minerals and is never itself enclosed. Several well formed K-richterite oikocrysts are of the order of 10mms in length (b) clear evidence for replacement is present in a few nodules with K-richterite corroding and embaying other minerals along grain boundaries, and enclosing optically continuous corroded grains of the same mineral (c) two nodules are traversed by more or less linear veins (one up to 3mms wide and 12 cms long) composed dominantly of K-richterite enclosing phlogopite and diopside. The K-richterite is not confined to the veins but is also present throughout these two nodules (d) there is a tendency for a close spatial association of phlogopite, diopside and K-richterite, with chromite often being enclosed in or associated with the phlogopite.

<u>Origin of K-richterite</u>: The bulk rock, mineralogical and textural evidence presented above, indicate that K-richterite is a late stage replacement mineral, and is probably the product of mantle metasomatism. This conclusion is in agreement with the preliminary reports by Erlank (1976) and Aoki (1976) which were based on studies of only a few nodules. The metasomatic process is dominated by the introduction of K (and Rb, Ba) with variable addition of Na, Ti, Sr, Zr and Nb, and occurred in or produced Al-deficient environments. Garnet (except armoured garnets as described in one nodule) or aluminous spinels could not have been present at the time of K-richterite formation, since the latter is not stable in the presence of garnet (Kushiro and Erlank, 1970). We infer that K-richterite is produced by reaction of olivine, enstatite, diopside and probably even phlogopite with a fluid phase containing K and other elements. Appropriate reactions may be written, except that we do not yet understand the role of the unidentified Ti-rich opaque minerals described above.

<u>Mantle Metasomatism</u>: We suggest that the K-richterite bearing nodules only represent the end product of the postulated upper mantle metasomatic process. A large proportion of the nodule suite at Bultfontein contains phlogopite, but no K-richterite. In these nodules there is also clear evidence of replacement textures with garnet being replaced by phlogopite and diopside. In garnet-free harzburgites enstatite is preferentially replaced by phlogopite, and in garnet-free lherzolites, diopside appears to be replaced by phlogopite. In all cases there is a strong association of phlogopite with chromite. Furthermore, these observations can be extended to nodules from Monastery and the other pipes from the Kimberley area. Thus we envisage that similar processes have produced both K-richterite and phlogopite indicating widespread upper mantle metasomatism. A generalized overall reaction could be: Olivine + Enstatite + Garnet + $Diopside_1$ + Fluid (K_2O etc, H_2O, CO_2) $\longrightarrow$ Phlogopite $\pm$ $Diopside_2$ + K-richterite $\pm$ Calcite + chromite or other opaque minerals. The sequence of change (ignoring calcite and opaque minerals) would be lherzolite or harzburgite $\pm$ garnet $\longrightarrow$ lherzolite or harzburgite $\pm$ garnet + phlogopite $\longrightarrow$ lherzolite or harzburgite + phlogopite + K-richterite. Thus we believe that K-richterite is rare because normally <u>either</u> too much Al (garnet) is present in the original nodule <u>or</u> not enough K etc <u>is</u> supplied. In either case the resultant, and more common, assemblage would include phlogopite ($\pm$ garnet) rather than phlogopite and K-richterite. Sr-isotope studies (Erlank and Shimizu, this volume) indicate that the metasomatic event pre-dates kimberlite emplacement, is isotopically unrelated to the enclosing kimberlite, and is thus of upper mantle origin. The metasomatic process described above may be only one of a series of such processes that could occur in the upper mantle leading to lithospheric differentiation and enrichment, and it should be viewed in the context of the overall history of a kimberlite peridotite nodule as depicted in Fig. 1.

Table 1. Composition of K-richterites

	Weight %					Ionic Proportions (O=23,000)		
	1	2	3			1	2	3
			Range	Ave.				
SiO_2	53.6	56.0	54.4-56.3	55.4	Si	7470	7820	7782
TiO_2	0.07	0.31	0.27-1.52	0.46	Ti	7	33	48
Al_2O_3	4.01	0.99	0.47-1.70	0.99	Al	659	163	164
Cr_2O_3	1.16	0.34	0.26-0.89	0.48	Cr	128	38	53
FeO	2.51	2.66	1.55-3.45	2.25	Fe	293	311	264
MgO	22.4	22.9	22.3-23.7	22.9	Mg	4653	4766	4797
CaO	6.98	6.83	5.09-7.65	6.74	Ca	1042	1022	1013
Na_2O	4.92	3.40	3.29-4.41	3.82	Na	1330	921	1040
K_2O	2.35	4.85	3.56-4.98	4.63	K	418	864	830
Total	98.0	98.3		97.7	Total	16,003	15,939	15,996

1 = Monastery JJG 41, 2 = De Beers 106, 3 = Bultfontein (22 samples).

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Fig. 1. Possible history of a kimberlite peridotite nodule.

Post Kimberlite: surface weathering, serpentinisation ?

Kimberlite: [Emplacement   ⌐ kelyphite formation
                                  ⌐ localized partial melting
                  Formation   - skarn type metasomatism

Pre-Kimberlite: [Metamorphic ⌐ ⌐ deformation
                                  ⌐ sub-solidus equilibration
                   Igneous   ⌐ upper mantle metasomatism
                                  - partial melting, basalt extraction

                   Original Formation   ?