

# A SUGGESTED ORIGIN OF MARID NODULES IN KIMBERLITES BY HIGH PRESSURE CRYSTALLIZATION OF LAMPROITIC MAGMA.

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Chemical, mineralogical and isotopic studies have been made on the nodules of the MARID (Mica-Amphibole-Rutile-Ilmenite-Diopside) suite in southern African kimberlites. Dawson and Smith (1977) proposed that MARID rocks represent crystallization products of magmas in the higher parts of the upper mantle. With the underlying assumption that the MARID suite is indeed igneous in origin, this abstract discusses the possible relationships between MARID rocks and other ultrapotassic ultrabasic rocks.

Patchy, inhomogeneous distribution of all minerals and variable grainsize within and between nodules is characteristic of MARID rocks. Phlogopite usually dominates with diopside and K-richterite being the other major minerals. All contain varying amounts of ilmenite, rutile and a variety of accessory minerals including apatite, which are usually only present as a few modal percent or are absent. Olivine is absent from these rocks and enstatite is found only in rare samples (one in this study). Many of the textures seen in MARID rocks are broadly analagous to those in the coarse pyroxenite body of the plutonic alkaline Phalaborwa Igneous Complex in South Africa.

MARID nodules have been analysed by XRF for major and trace elements. The textural characteristics already discussed and the small size of samples (long axis typically 10-15 cm) contribute towards the problem that individual bulk compositions cannot be representative of potential precursor melt compositions. Notwithstanding this limitation, the analyses obtained do provide an indication of the compositions and compositional ranges to be found in MARID rocks. Table 1 and Fig.1 present the compositions of four nodules which represent two common types of assemblage. AJE137 and BF05 have phlogopite >> diopside > K-richterite >>> ilmenite ~ rutile. AJE214 and 5 have > 70% K-richterite, with phlogopite > ilmenite, and minor rutile. AJE214 has ~ 15% ilmenite which is untypically high. The MARID rock analyses bear a striking resemblance to Mg-rich ultrapotassic rocks from various localities. In particular as shown in Table 1, the range of compositions exhibited by the lamproites from W. Australia that Jaques et al (1984) defined as ultrabasic (MgO>18%), is remarkably

Table 1. Whole rock analyses of MARID nodules and of selected rocks from the literature.

	AJE137	AJE214	BF05	5	ol-lamproites		bt.
					min	max	maf.
SiO <sub>2</sub>	45.57	42.65	44.28	45.94	40.10	42.80	42.6
TiO <sub>2</sub>	3.03	10.71	2.88	4.80	2.64	5.77	5.3
Al <sub>2</sub> O <sub>3</sub>	6.55	1.32	7.13	1.51	3.30	4.51	8.3
Cr <sub>2</sub> O <sub>3</sub>	0.15	0.17	0.15	0.09	0.08	0.25	0.2
Fe <sub>2</sub> O <sub>3</sub>	7.53	11.59	7.29	7.56	7.57	9.34	8.9
MnO	0.06	0.10	0.06	0.07	0.11	0.14	-
MgO	21.08	20.24	20.91	20.52	19.04	26.90	15.8
CaO	5.74	6.11	5.37	6.24	4.06	5.61	10.7
Na <sub>2</sub> O	0.91	2.01	0.62	2.22	0.36	0.63	0.8
K <sub>2</sub> O	6.95	4.09	7.68	4.16	3.46	5.11	7.1
P <sub>2</sub> O <sub>5</sub>	0.07	0.01	0.06	0.03	0.62	1.48	-
NiO	0.08	0.08	0.10	0.09	0.09	0.19	-
L.O.I.	3.09	1.71	3.99	3.87	5.90	8.72	-
H <sub>2</sub> O-	0.14	0.16	0.18	0.19	0.95	2.32	-
Total	100.94	100.95	100.70	97.30	98.70	101.13	98.8

AJE137, BF05, AJE214 and 5 are MARID rocks.  
Olivine-lamproites: range of 6 analyses with MgO>18 %  
from W.Australia, Jaques et al (1984).  
Synthetic biotite mafurite used by Edgar et al (1976).

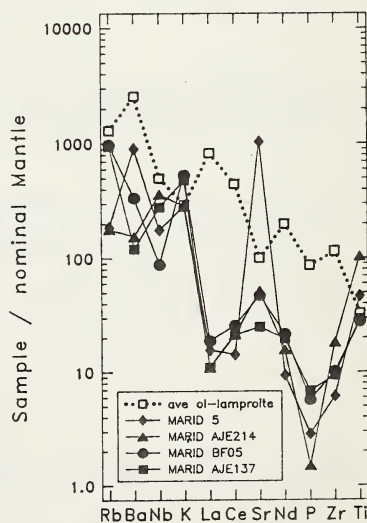


Fig.1 "Spidergram" comparing the compositions of MARID rocks with that of average olivine-lamproite for the same samples as reported in Table 1.

close to those of MARID samples. It is proposed that the compositional similarities and the textural appearance of MARID rocks strongly suggest that they represent the plutonic compositional equivalents of highly potassic volcanics of lamproite-type, crystallized at depth.

There have been a number of experimental studies on a variety of ultrapotassic rocks at a range of high temperatures, and pressures up to 40 kbar, in the presence of  $H_2O (+CO_2)$ . Of them, the synthetic biotite mafurite used by Edgar *et al* (1976) shown in Table 1, is most similar to MARID rock compositions. At 30 kbar (likely maximum pressure of formation of MARID rocks), and 15% added  $H_2O$ , phlogopite, diopside and ilmenite crystallized. The compositions of these phases compare well for most elements with those in MARID rocks (see Fig.2). K-richterite was absent in this study but was present in other similar experiments, eg. on a melilite-nepheline leucite by Gupta *et al* (1976).

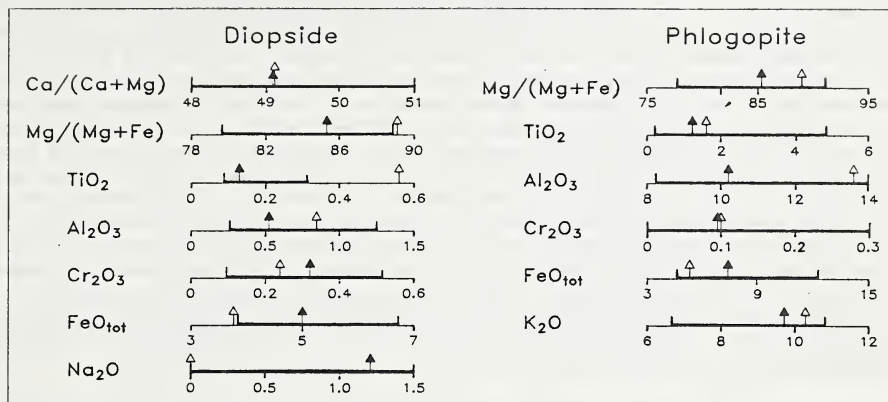


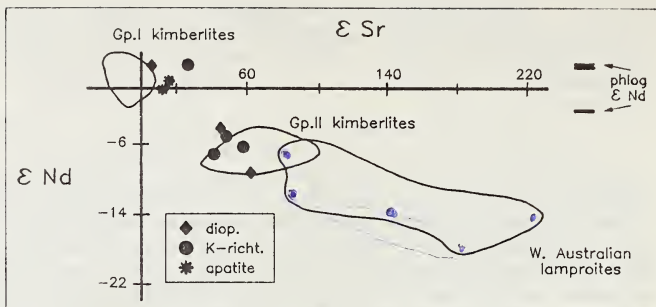
Fig.2 Comparison of average mineral compositions produced by Edgar *et al* (1976) at 30 kbar, 1100° C (open arrows), to those in MARID rocks (filled arrows). The range in MARID rocks is also shown (thick horizontal bars).

It is suggested that the principal differences in mineral assemblage and composition between MARID and lamproitic rocks result from crystallization of the latter at lower pressures. Experimental work on  $TiO_2$  solubility in phlogopite (Tronnes *et al* 1985) for example, supports this view. They found that with increasing pressure, high Ti-phlogopite broke down to low Ti-phlogopite + rutile. Lamproitic phlogopite is  $TiO_2$ -rich (up to 10%), whereas primary MARID phlogopite in this study has an average concentration of 1.2%  $TiO_2$ , with rutile present in the rocks.

Incompatible trace element concentrations in MARID rocks are high. While lamproites have higher average concentrations of these elements, some MARID rocks have comparable concentrations, as shown in Fig.1. Very high REE concentrations are found in relatively rare apatite-rich MARID rocks, (not shown), but generally the REE and Zr contents are distinctly lower in MARID nodules. It is speculated that late stage aqueous fluids may have escaped from the crystallizing MARID magma carrying the bulk of the REE and the complement of other incompatible elements that had not been accommodated in MARID phases, metasomatising the surrounding peridotite mantle. Faster crystallization under volcanic or hypabyssal lower temperature conditions would have prevented similar losses in lamproitic rocks. High (50 ppm) concentrations of Nd in diopsides indicate that MARID melts must originally have had high REE concentrations; using a  $K_d$  of 0.22, a parent melt of ~200 ppm Nd is indicated.

In Fig.3, Nd and Sr isotopic ratios on minerals separated from MARID rocks from this study and Kramers *et al* (1983) are compared to fields for W. Australian lamproites and southern African kimberlites (after Fraser *et al* 1985). There is a range in isotopic composition from mildly depleted to fairly enriched in the minerals, which lie along this shallow trend. It is suggested that this array in MARID minerals reflects a mixing process between original melt compositions with relatively depleted signatures like those of Group I kimberlites, and ancient enriched subcontinental lithosphere.

Fig.3  $\epsilon$ Sr- $\epsilon$ Nd correlation diagram for MARID minerals as compared to W. Australian lamproites and S. African kimberlites. Sources of data given in the text.  $\epsilon$ Nd values of phlogopites shown on the right of diagram as  $\epsilon$ Sr values not determined or out of range.



Although MARID-type rocks (mica-pyroxenites + amphibole) have been invoked as a source material for various ultrapotassic rocks in studies that have recognised their genetic connection, an alternative explanation which fits observations is that they are plutonic equivalents of these volcanics, and are regional parallels of MARID rocks. Gupta and Yagi (1976) reviewed a range of theories on the origin of highly potassic magmas, and concluded that they are most likely to be derived by partial melting of phlogopite-rich peridotite. While this may be in part correct as a source of lamproitic magmas in general, as well as MARID magmas, it is considered likely that the scavenging of incompatible elements from the surrounding enriched subcontinental lithosphere by the rising melts may play a further role in creating the extremely enriched nature of these rocks. Thus their compositional characteristics may not solely reflect those of their source material. It is also considered feasible that MARID melts could have originated as small volume asthenospheric melts which were substantially modified by scavenging as they rose, in the manner described above. The isotopic evidence for a mixing relationship with one end-member having a relatively depleted isotopic signature is more readily reconcilable with an ultimate source in the asthenosphere than in previously enriched peridotitic lithosphere.

MARID rocks may be the unique result of conditions prevailing beneath southern Africa. The stable cratonic setting in which they are found contrasts with the mobile belt/rift related settings in which most ultrapotassic rocks of similar composition occur. This may be why MARID magmas were less likely than equivalent magmas in other areas to have succeeded in penetrating the lithosphere to appear as lamproitic rocks, but crystallized at high pressures at depth instead, probably resorbing any diamonds that may accidentally have been incorporated.

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