THE GEOCHEMISTRY OF ULTRAMAFIC NODULES FROM PIPE 200 AND THEIR BEARING ON THE NATURE OF THE UPPER MANTLE BENEATH LESOTHO.

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The following types have been recognised in a suite of 33 ultramafic nodules:

A. Garnet Lherzolites (15 samples) - no primary spinel phase
B. Garnet Chromite Lherzolites (8 samples) - primary chromite and garnet
C. Chromite Lherzolites (4 samples) - garnet now absent but originally present.
D. Chromite Harzburgites/Lherzolite (5 samples) - primary chromite only
E. Spinel Harzburgite (1 sample) - primary aluminous spinel and enstatite.

The majority of nodules are termed lherzolites, despite the fact that amounts of bright green chrome diopside are always small (<5 vol%, more typically only 1-2 vol%). When present purple chrome pyrope garnets and dark red brown chromites occur in similar small amounts. Garnets commonly have kelyphite alteration coronas and in some instances (Type C nodules) only kelyphite or coarser clusters of secondary spinels with phlogopites and clinopyroxenes remain to indicate the likely original presence of garnet.

Olivines are significantly more fosteritic (Fa 4.9-5.0) in the chromite harzburgites/lherzolite (Type D nodules) than in the lherzolite nodules (Fa 7.0-8.6) which contain or originally contained garnet (Types A, B and C). As in other aspects of its mineral chemistry, the spinel harzburgite (Type E) is exceptional in that it contains olivine Fa_7 yet lacks evidence to indicate that it ever contained garnet.

Orthopyroxenes in all nodules are enstatites but more magnesian in Type D nodules (Fs4.1-4.3) than in Types A, B and C (Fs6.3-7.7). In the latter nodule types they have mean values of 0.83 wt% Al_2O_3 (range 0.54-1.04), 0.45 wt% CaO (range 0.29-0.53) and 0.40 wt% Cr_2O_3 (range 0.18-0.50), in comparison with mean values of 0.65 Al_2O_3 (range 0.36-0.95), 0.25 wt% CaO (range 0.18-0.41) and 0.48 wt% Cr_2O_3 (range 0.23-0.76) in the Type D nodules. Orthopyroxene in the spinel harzburgite (Type E) has a significantly higher Al_2O_3 content (1.45 wt%).

Clinopyroxenes in all nodules have similar 100 Ca/Ca+Mg ratios (46.0-48.4) but quite variable contents of Al_2O_3 (1.64-3.99 wt%), Cr_2O_3 (1.59-4.25 wt%) and Na_2O (0.81-3.14 wt%). Al_2O_3 and Na_2O vary sympathetically (Fig.1) reflecting variable jadeite contents. In two nodules clinopyroxene grains have cloudy rims with lower jadeite than the clear cores. We attribute this jadeite depletion, and likewise the associated kelyphitic alteration of garnets, to the combined effects of metasomatism and decompression resulting from incorporation in kimberlite and subsequent diatreme emplacement. Nevertheless, much of the compositional variation between clinopyroxenes in different nodules, especially in Cr_2O_3, is thought to be a primary feature controlled by rock chemistry and the pressure/temperature conditions during equilibration.

Garnets in most nodules have higher Cr_2O_3 and CaO contents (14.3-18.6% uvarovite, 3.4-5.8% knorringite) than the garnets in the common lherzolite nodules in many other kimberlites and trend in composition towards the extreme chrome rich green garnets found as xenocrysts in the nearby Kao kimberlite (Fig.2).

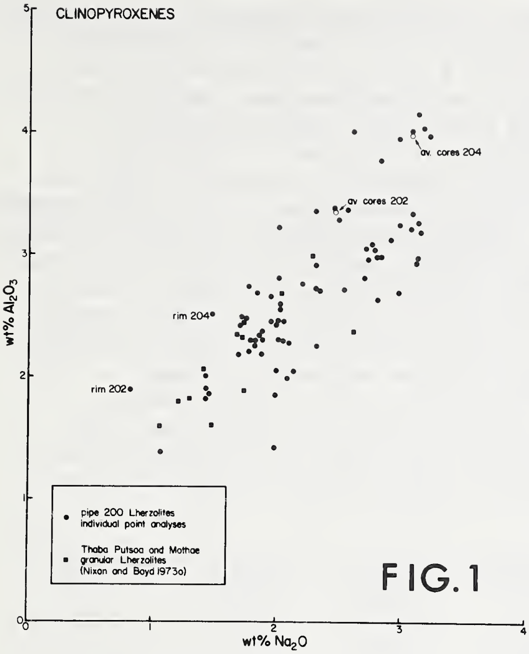

FIG.1

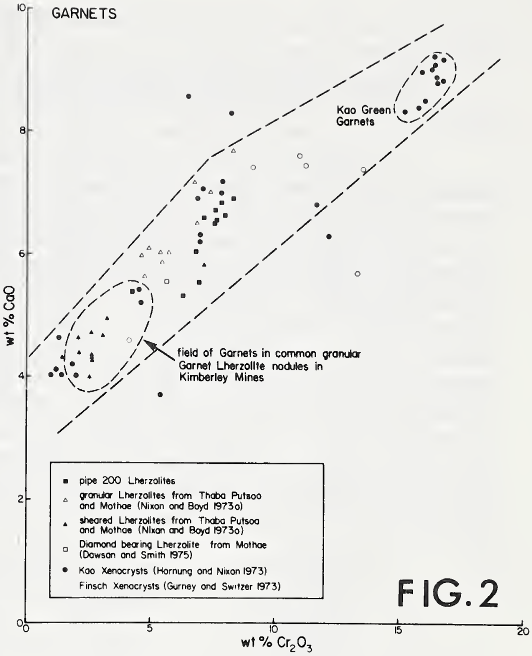

FIG.2

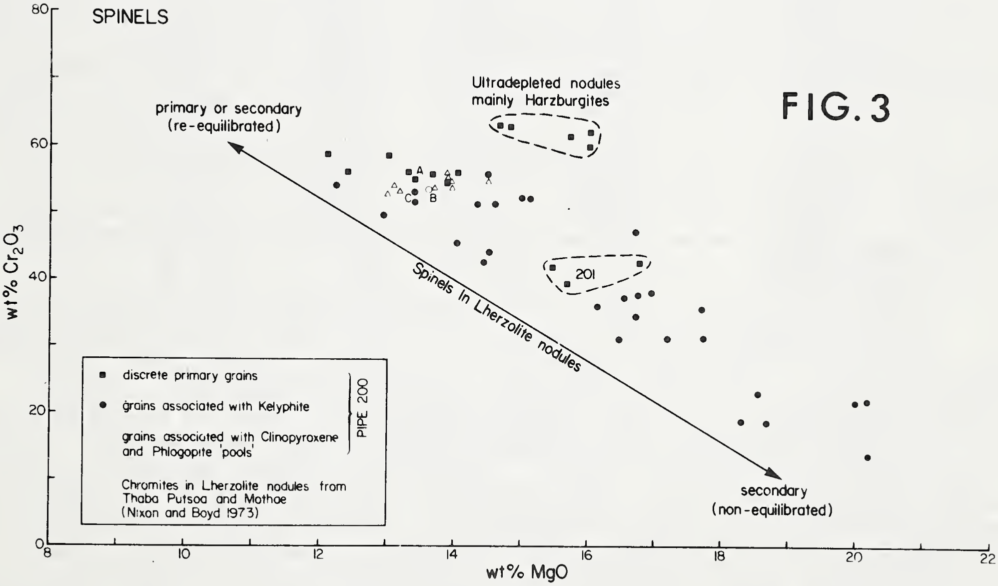

FIG.3

Spinels of the primary type are low Al magnesiochromites, except in the spinel harzburgite (labelled 201) where they are aluminous chrome spinels with an appreciably lower Cr/Cr+Al ratio. Primary spinels in Type D nodules have highest absolute Cr_2O_3 contents. Spinels associated with kelyphite show a wide range of compositions (Fig.3). Undoubted secondary spinels from the innermost parts of kelyphites are high Al chrome spinels. However, other spinel grains from the outer parts of kelyphites or occurring in 'pools' of phlogopite and clinopyroxene grains have compositions more akin to the primary spinels. Thus if they do represent a secondary generation derived from garnet breakdown, it would appear that they have re-equilibrated with the lherzolite assemblage.

Average Whole Rock Compositions for the 5 ultramafic nodule types are given below. For comparative purposes the analyses have been recalculated to 100% on a H_2O and CO_2 free basis and with total iron expressed as FeO.

It is apparent that there are consistent differences in whole rock chemistry between the garnet only lherzolites (Type A), chromite lherzolites which either contain or originally contained garnet (Types B & C), and chromite only harzburgites/lherzolite (Type D). Mg/Mg+Fe and Cr/Cr+Al ratios increase and Al_2O_3, CaO and Na_2O contents decrease for the nodule types in that order reflecting their increasingly 'depleted' chemical nature in terms of their 'basalt' yielding potential. Thus primary mineralogical variations between these nodules seem likely to have been largely controlled by rock chemistry. However, such an explanation is inadequate in the case of the spinel harzburgite (Type E) which has a composition most comparable to nodule Types B and C. The absence of petrographic evidence to indicate it ever contained garnet, combined with the notably more aluminous character of its primary spinels and orthopyroxenes, point to lower pressure equilibration conditions for this particular nodule.

TYPE	A	B	C	D	E
SiO_2	46.85	46.78	46.35	44.06	45.30
TiO_2	00.06	0.12	0.09	0.18	0.17
Al_2O_3	1.07	0.55	0.40	0.20	0.48
Cr_2O_3	0.32	0.26	0.22	0.16	0.21
FeO	6.63	5.95	6.40	4.52	5.80
MnO	0.11	0.10	0.11	0.06	0.10
NiO	0.29	0.31	0.33	0.32	0.30
MgO	43.44	45.21	45.44	50.25	46.90
CaO	0.97	0.53	0.45	0.14	0.61
Na_2O	0.13	0.08	0.09	0.04	0.03
K_2O	0.09	0.06	0.08	0.03	0.07
P_2O_5	0.04	0.04	0.04	0.22	0.02
100Mg/Mg+Fe	92. 1	93. 1	92. 7	95. 2	93. 5
100Cr/Cr+Al	17. 4	24. 1	28. 4	40. 0	22. 2

Calculated equilibration conditions for the garnet bearing lherzolites are 1025-1080°C, (Wood and Banno 1973) and 38-42kbs, (Wood 1974), implying derivation from a restricted depth zone some 120-130 kms down. With the obvious exception of the Type 3 spinel harzburgite, there is no evidence to indicate that the garnet free ultramafic nodules have been derived from substantially shallower mantle depths. Indeed those garnet free nodules with chrome diopside give similar Wood and Banno (1973) equilibration temperatures. The apparent rarity of nodules recognised as likely to have been derived from the uppermost 85-95 kms of the mantle beneath Lesotho may result either from their generally highly depleted chemical character which renders the employed geothermometers/geobarometers inapplicable or perhaps more likely from the inaccuracy of the latter over the appropriate pressure/temperature range.

Mineralogical and chemical comparison between the common Pipe 200 ultramafic nodules and those from other pipes in northern Lesotho and in the Kimberley area, as well as in the Lashaine volcano, indicates that the mantle beneath Pipe 200 and most of northern Lesotho is exceptionally depleted down to depths of the order of 130-150 kms.