THE COMPOSITION OF MANTLE XENOLITHS IN THE MATSOKU KIMBERLITE PIPE

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The ultramafic xenoliths of mantle origin (Group 1 of Cox, Gurney and Harte 1973) from the Matsoku Pipe consist essentially of olivine, opx, cpx and garnet. The megascopic and microscopic features of the rocks have been described in detail (Cox, Gurney and Harte 1973, Harte, Cox and Gurney 1973).

The bulk chemistry of selected samples and the major element chemistry of the constituent minerals have been determined and show a wide spread but a largely continuous series of compositions (See Fig.1). End members show the following range in Mg/Mg+Fe ratio (at%): bulk 80.8-92.8, gt 69.8 -85.2, cpx 84.2-94.7, opx 85.6-93.8, ol. 83.4-94.8. Equilibrium between co-existing minerals is indicated by the regular sympathetic variation in Mg/Mg+Fe (Fig.2) and the consistent partitioning of elements such as Cr, Ti & Na. The clinopyroxene compositions show a restricted Ca/Ca+Mg in the range of 0.440-0.453 for 14 xenoliths indicating a temperature of equilibrium of approximately 1050°C on the 30kb solvus (Boyd 1970). The orthopyroxene Al_2O_3 content lies in the restricted range 0.71-0.87 which is identical to the range in Al_2O_3 as shown by 6 xenoliths of garnet lherzolite from Kimberley. Taken as a whole the above shows the rocks to have come from a restricted mantle location and to have equilibrated under sub-solidus conditions, and is further shown by their petrography (Harte, Cox, and Gurney 1973). In the following discussion in which selected groups of rocks are discussed and compared, it is assumed that relative compositions of minerals (in particular Fe/Mg ratios) in different rocks have not been changed from their values at above solidus temperatures.

1. The Common Peridotites (e.g. LBM9, LBM11 and BD1355) are coarse granular rocks similar in the modal proportions of minerals present and in chemistry to the common garnet lherzolite found in other Kimberlite Pipes in South Africa. The Mg/Mg+Fe (at%) is: bulk (5) 92.0-93.0, gt (3) 83.4-85.2, cpx (3) 92.3-94.7, opx (3) 93.1-93.8, ol. (3) 92.3-92.5. Even if only the garnet of these rocks is the major contributor to a partial melt it is not possible to generate a magma with as high an iron content or as low a bulk Mg/Mg+Fe ratio as those reported for LBM12, 18 or 11102. The Common Peridotites are therefore thought to be residua.

2. The Coarse Granular Banded Rocks (e.g. LBM33, LBM36, LBM37) show a range in Mg/Mg+Fe within the range for coarse granular unbanded rocks (See Section 3). The banded rocks are enriched in clinopyroxene and this is reflected in a high CaO content (CaO/Al_2O_3 generally $>$ 1). No differences in chemical composition have been noted between the minerals of separate bands but the bulk composition of the bands varies widely because of the differences in mineral proportions. The occurrence of constant mineral compositions in bands of widely different mineral proportions and bulk composition, and the presence of a continuous spectrum of modal and chemical compositions unaligned to normal differentiation trends suggests the banding to be cumulitic in origin. The presence of cumulates is also confirmed by dunite LBM20 (See Section 4).

3. The Coarse Granular Unbanded Rocks (e.g. LBM6, LBM12, LBM18 and 11102), have lower whole rock and mineral Mg/Mg+Fe ratios that the Common Peridotites (bulk (3) 80.8-89.0, gt (4) 69.8-79.2, cpx (4) 84.2-90.7, opx (4) 85.6-90.8, ol. (4) 83.4-89.5 (at %). These rocks, like the banded rocks do not show marked enrichment of titanium or potassium, have very high chromium and nickel contents relative to basalts and do not contain any

primary hydrous mineral phases. The unbanded rocks could possibly represent liquids formed during an igneous event in the mantle, but on the basis of their chemistry are more likely to be cumulates closely related to the banded rocks discussed above. It is noticeable that these rocks and the banded rocks do not plot on a single line of liquid evolution in Fig.1.

4. The Dunites (e.g. LBM20, LBM39) are not all the same composition. LBM39, a coarse grained olivine rock has an olivine of composition Fo 94.8, LBM20, a recrystallised and finer grained dunite with $<$ 2%opx, and minor cpx, has an olivine of Fo 90. This is less magnesian than the olivines in the Common Peridotites whilst LBM39 is more magnesian than these.

In addition the opx and olivine of LBM20 is more magnesian than the olivines in all the coarse granular rocks other than C.P. LBM39 is thought to represent residual material and LBM20 is interpreted as a cumulate.

5. The Recrystallised Rocks have been subdivided into two types, those with flaser structure (e.g. LBM16 and LBM32), and those with more uniform grain size (e.g. LBM20, LBM38B). The recrystallisation which has taken place has not obviously affected the composition of the constituent mineral assemblages except where the rock has also been metasomatised. The minerals in the recrystallised rock remain in equilibrium with each other and have compositions within the series mentioned earlier and represented in Fig.2.

6. The Metasomatised Rocks (e.g. LBM32 and LBM38B) have been affected by a metasomatic event which has altered the bulk and mineral compositions and led to the development of ore minerals and phlogopite in the rock. Only recrystallised rocks have been extensively metasomatised. The bulk composition of LBM32 and LBM38B shows enrichment of TiO_2, K_2O, $S^=$ and some trace elements (e.g. Cu). Nevertheless the gt, cpx, opx and olivine compositions also conform to the series outlined earlier and reflected in Fig.2.

7. LBM38 is a unique rock in the suite studied because it consists of two parts separated by a sharp, at least partly metasomatic contact. LBM 38A is a common peridotite, close in mineral compositions to LBM11. In comparison LBM38B is a recrystallised metasomatised rock with minerals of lower Mg/Mg+Fe ratio, and lower chrome content, though remaining similar to the general span of mineral compositions described above.

8. General The coarse granular rocks contain no primary hydrous phase. Phlogopite, where present, appears secondary and is a minor phase. Potassium was not detected in the major phases of the coarse granular rocks (detection limit 100 ppm) and the bulk analyses show low potassium contents.

These rocks also contain little titanium although small concentrations were detected in all the major minerals. The iron-rich rocks (e.g. LBM12, LBM18) appear to be slightly enriched in titanium and this is reflected in the bulk and mineral analyses.

The P_2O_5 content of all the xenoliths except LBM41 is on the detection limit of the method used and extremely low in concentration.

The Nickel content of the Group 1 xenoliths studied ranges from 0.45% NiO in LBM20 (approximately 98% olivine) to 0.11% NiO in LBM18 (no olivine). The NiO contents of other xenoliths lie between these two extremes and appear to be closely related to the olivine content of the particular rock.

The Cr_2O_3 content of the bulk samples ranges from 0.05% Cr_2O_3 in LBM20 to 0.93% in LBM32. The range for four phase xenoliths is from 0.34% in LBM10 and LBM16 to 0.93%. Chrome is consistently distributed amongst the major mineral phases of the four phase xenoliths being concentrated in the garnet followed by clinopyroxene, orthopyroxene and finally olivine in which the Cr_2O_3 content is never greater than 0.05%. With the exception of LBM12 and 11102 there is a tendency for the chrome content of the minerals to increase with increasing $\frac{Mg}{Mg+Fe}$.

The garnet analyses indicate on inspection that the trivalent lattice site in the garnet is predominantly occupied by chromium and aluminium, the combined total of chromium plus aluminium in atomic proportions indicating a 99.3 average occupancy of the trivalent site. It is possible that there is no ferric iron present in these garnets. In addition the only significant variations noted in the divalent lattice site involve the elements calcium, magnesium and iron.

A good correlation has been noted between the sodium content of the clinopyroxene and its Al + Cr content.

Conclusions: The Group 1 xenoliths are considered to be a closely related suite of rocks derived from a restricted mantle location, and to have formed during a single partial melting event which predates kimberlite emplacement. They have subsequently re-equilibrated under sub-solidus conditions but it is considered that their relative compositions have not changed.

LBM39 is a sample of residual mantle as are the Common Peridotites, though these latter rocks have not contributed as fully to the partial melt as the coarse grained dunite.

The coarse grained granular banded rocks are interpreted as cumulates from the melt from which the above rocks are residua. LBM12, LBM18 and 11102 which are coarse grained unbanded rocks are also considered to be cumulates, as is LBM20.

Some of the Group 1 rocks have subsequently been recrystallised and metasomatised by fluids enriched in K, Ti, Si and other elements, and where this latter has occurred the bulk chemistry, mineralogy and mineral compositions have been affected.

The xenoliths have finally been rapidly transported to the surface in the kimberlite magma, to which they are unrelated in origin.

References

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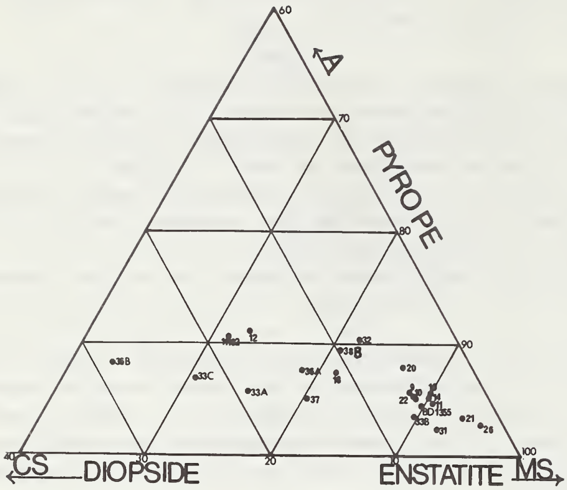

FIG. 1 Bulk compositions of Matsoku xenoliths (Group 1) projected from olivine into the plane CS-MS-A, within the CMAS tetrahedron (see O'Hara, 1968, Fig.4).

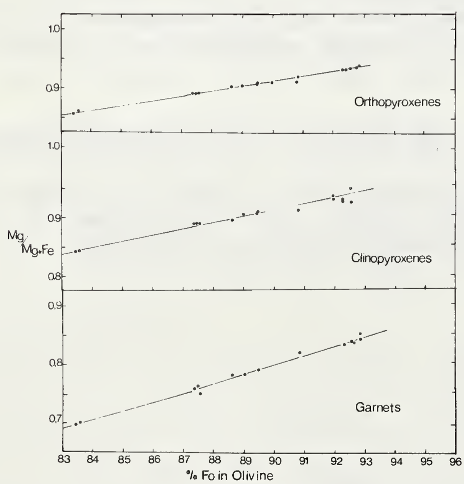

FIG. 2 Mineral atomic Mg/Mg+Fe plotted against % Forsterite in co-existing olivine. Matsoku xenoliths.