THE PETROCHEMISTRY OF KIMBERLITE AUTOLITHS

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Diatreme facies of kimberlite frequently contain nucleated spheroidal bodies varying in size from a few millimetres to 70 millimetres in diameter. These autoliths consist of rock or mineral fragment nuclei which usually make up only a small volume percentage, encased in fine-grained kimberlitic material. It is thought that autoliths represent crystallisation of kimberlitic magma around a nucleus so that these bodies are more likely to reveal the matrix composition of kimberlites than the normally chaotic host kimberlite with its attendant xenolithic and xenocrystic material (Ferguson et al. in press). The nuclei of the autoliths comprise both mantle and crustal derived fragments. Olivine is the dominant mineral of the autoliths occurring as euhedral to subhedral phenocrysts 0.15 to 0.80 mm in diameter and having compositional range of Fo_{90-94}. Other possible primary phases include apatite, calcite and dolomite. Alteration reaction and minor accidental products include serpentine, ilmenite, phlogopite, spinels, perovskite and rutile.

Major element compositions were determined for a total of 26 autoliths from Wesselton Mine and various localities in Lesotho, and a cluster analysis program was used to compare the chemistry of these autoliths with 96 kimberlites and alkaline ultramafic rocks associated in space and time. It was found that the major element chemistry of the autoliths did not offer any unique composition but grouped with two of five varieties of kimberlite. Relative to the major kimberlite groups not clustering with autoliths the latter are enriched in TiO_2, P_2O_5, K_2O and MnO and impoverished in MgO. Further confirmation of the similarities between autoliths and kimberlites is given by their low K:Rb and $Sr^{87}:Sr^{86}$ values. The $Sr^{87}:Sr^{86}$ ratio for Lesotho autoliths gives values between 0.7040 and 0.7045 (Hugh Allsopp, personal communication), which are comparable to the lowest values yet recorded for kimberlites (Berg and Allsopp, 1972).

On the CMAS tetrahedron (O'Hara, 1968) kimberlites lie on a well-defined olivine control line trending sub-parallel to the CAM plane consistent with melting of a four-phase garnet lherzolite mantle rock at depths equivalent to more than 40 Kb. Autoliths have compositions which plot near the extremity of the main kimberlite trend showing no major differences to most kimberlite other than having fractionated more olivine than the more primitive varieties. This supports the contention that the autoliths represent kimberlite magma which has only undergone olivine fractionation and has erupted from depth equivalents of greater than 40Kb. The alkaline ultramafic rocks that are associated in space and time with the kimberlites plot at the extremity of the kimberlitic trend with some degree of overlap indicating possible consanguinity (Ferguson et al, in press).

PICROILMENITES IN THE AUTOLITHS

Major element compositions have been determined in the electron microprobe for a total of 70 ilmenites included in the autoliths, and five autolith nuclei. The results of these analyses are summarized in Table 1, where they are compared with other relevant ilmenite analyses from the literature.

TABLE 1

COMPOSITIONS OF MAGNESIAN ILMENITES FROM AUTOLITHS, KIMBERLITE, AND ILMENITE-SILICATE NODULES (%)

	1	2	3	4	5	6	7	8
TiO_2	52.24	53.98	50.98	47.27	52.63	56.40	56.80	53.01
Cr_2O_3	1.20	2.13	1.02	1.67	1.42	1.13	2.27	5.04
*Fe_2O_3	9.20	6.81	10.26	14.41	0.33	1.91	0.57	5.20
FeO	22.41	20.61	26.76	28.97	32.17	19.90	27.09	19.42
MgO	13.64	15.10	10.71	7.60	12.02	20.23	13.19	15.74

* Calculated from the mineral formula
1. Average Wesselton pipe and dyke ilmenite (Mitchell, 1973)
2. Average Wesselton autolith ilmenite
3. Average Lesotho autolith ilmenite
4. Average autolith nucleus
5. Primary Liqhobong ilmenite (Haggerty, In Press)
6. Secondary Liqhobong ilmenite (Haggerty, In Press)
7. Secondary ilmenite in garnet lherzolite (Boyd and Nixon)
8. Ilmenite inclusion in euhedral olivine crystal from kimberlite, Isonville, Kentucky, U.S.A. (Boyd and Nixon, In Press).

The MgO contents of the autolith ilmenites are, with few exceptions, greater than ten weight per cent, and inspection of the data in Table 1 shows that these ilmenites contain significantly more magnesia and less ferric iron than ilmenites occurring as autholith nuclei. The ilmenites from the Lesotho autoliths appear to be transitional between the nucleus ilmenites, and those from the Wesselton autoliths, both with respect to MgO and Fe^{3+}. The chrome contents of the autolith ilmenites are generally high, and values in excess of 3.0 per cent Cr_2O_3 are not uncommon. Also of interest is a fairly well developed inverse relationship between Cr and Fe^{3+}, a trend also noted by Boyd and Nixon (In Press) for ilmenites intergrown with various silicate minerals.

Of particular importance, however, is the marked similarity in composition between the autolith ilmenites and secondary ilmenites from the Lighobong kimberlite (Haggerty, In Press) and from a garnet lherzolite from Monastery Mine (Boyd and Nixon, In Press) (Table 1).

Haggerty (op. cit.) has described mantled sequences of ilmenite and spinel on picroilmenite in the Liqhobong kimberlite, and he has shown that the zoning with respect to Mg/Mg + Fe in these sequences is inverted, and that secondary ilmenites thus produced are conspicuously more magnesian than the primary ilmenites from which they were derived. Like the autolith ilmenites, these secondary ilmenites appear to be enriched in Cr, and depleted in Fe^{3+} relative to ilmenites intergrown with various silicate minerals (Boyd and Nixon, op. cit.).

These observations support Boyd and Nixon's suggestion that these magnesian ilmenites are of a later generation than the more Fe-rich variety, of which the autolith nuclei are excellent examples. From the work of Boyd and Nixon (op. cit.) and Mitchell (1973) it is evident that much of the ilmenite now found in kimberlite was formed at great depth, possibly in the low-velocity zone (Boyd and Nixon, op. cit.), and possibly also before the generation of diamond (Mitchell, op cit.).

Clearly, therefore, kimberlitic ilmenites have formed over wide ranges of pressure, temperature and oxygen fugacity. It is also evident that although the autoliths contain occasional low-magnesian ilmenites, the majority are the more magnesian variety, and the abundance of these ilmenites, together with secondary spinels in the autoliths provide strong evidence for the existence of highly reactive kimberlite liquids prior to and during kimberlite eruption.

It is concluded that autoliths represent kimberlite matrix having precipitated around solid nuclei during pipe development of kimberlite intrusions. They have only been subjected to olivine fractionation and have erupted from depths in excess of 100 km.

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