POLYBARIC MAGMA MIXING IN ALKALIC BASALTS AND KIMBERLITES: EVIDENCE FROM CORUNDUM, ZIRCON AND ILMENITE MEGACRYSTS

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Megacryst phases enclosed in basanite, minette and kimberlite magmas provide a record of polybaric magmatic evolution during ascent of mantle-derived magmas. Evidence from trace element, isotopic and phase equilibrium data (e.g. Irving and Frey, 1984) implies that some megacrysts (e.g. Al-augite, pyropic garnet in basanites) could be cognate with the host magma, whereas others (e.g. corundum, zircon, anorthoclase in basanites) must be exotic to their hosts. One mechanism for the origin of the latter suite is precipitation from evolved magmas (e.g. nepheline benmoreites and phonolites) followed by mixing with later pulses of more primitive mafic magma. The possibility that some corundum megacrysts are xenocrysts from crustal metamorphic rocks, or are a product of desilication reactions between basanite, minette or kimberlite magmas and crustal rocks, must also be considered.

## Corundum and Zircon, Rubyvale, Queensland

A variety of megacryst species including corundum, zircon, anorthoclase, magnetite, ilmenite and pleonaste spinel occur within numerous Tertiary basaltic plugs in the Rubyvale region of central Queensland, Australia (Veevers et al., 1964; Stephenson, 1976), and adjacent alluvial deposits are actively mined for gem sapphire. The very similar geologic settings in southeast Asia (Barr and Macdonald, 1981) and Nigeria (Wright, 1970) imply that much of the world's gem sapphire forms megacrysts in alkalic basalts. The host rocks of four of the Rubyvale plugs (Mts. Leura, Pleasant, Hoy and Ball) are slightly to moderately evolved basanites ($Mg/Mg+Fe^{2+}$ 68.8-58.3). The corundum megacrysts (commonly 1-2 cm across) show multiple compositional zoning, especially in $TiO_2$ content (as reflected by zones of rutile exsolution). ICP bulk analysis of one megacryst shows minor contents of Fe, Ti (250 ppm), Mn (13 ppm), Cr (4 ppm), V (6 ppm), Sr (0.6 ppm) and Be (0.2 ppm).

Fluid inclusions within the corundums are very distinctive. They form planar arrays transverse to growth zoning, and heating-freezing studies reveal two main types. Type 1 is pure $CO_2$ (liquid + vapor). Such inclusions also occur in sapphires from minette at Yogo, Montana (Roedder, 1972). More common and associated with the first type are multi-phase inclusions composed of subequal amounts of $CO_2$ (liquid + vapor) and $H_2O$ containing halite, sylvite and other unidentified daughter minerals. Dissolution studies of the halide salts imply a high total salinity in the $H_2O$ phase ($\sim$ 35% NaCl and a similar value for KCl). These Type 2 inclusions remain unhomogenized at temperatures up to 685°C. Taken together the growth zoning, $CO_2$-rich inclusions, and high inclusion homogenization temperatures suggest a high temperature (and pressure) magmatic origin for the corundum megacrysts. The occurrences of corundum intergrown with anorthoclase at Mt. Leura (Stephenson, 1976) and with sanidine + rutile in alkalic basalt from Loch Roag, Scotland (Upton et al., 1983) support this conclusion.

Zircon megacrysts from Rubyvale lack fluid inclusions. Two crystals analyzed by INAA contain relatively low bulk Hf (0.55-0.60%), U (7-30 ppm), Ta (0.7 ppm) and REE (see Fig. 1). These minor element abundances are quite similar to those in zircons from nepheline syenite pegmatites but much lower than those in zircons from granitoids (Kapustin, 1986; Murali et al., 1983). Taken with the occurrence of corundum in miascitic nepheline syenite pegmatites and the experimental evidence for instability of anorthoclase in basalt (Chapman, 1976), these data permit the inference that the Rubyvale megacryst assemblage may have crystallized from phonolitic magma at elevated (probably deep crustal) pressures. High pressure phonolites are known in north Queensland (Irving and Price, 1981) and have been modeled as products of fractional crystallization of basanites. The mechanism by which basanite magma would evolve to a condition of alumina-saturation is not clear, but may involve crystallization under moderate $CO_2$ and/or halogen partial pressures.

## Ilmenite Megacrysts in Kimberlites

Magnesian ilmenite megacrysts are well known in kimberlites. Preliminary results from INAA of an ilmenite from Monastery Mine, Orange Free State show relatively high contents of REE (0.3-0.5 x chondrites), Ta, Hf (28 ppm) and Sc (22 ppm). Furthermore the LREE abundances in this ilmenite are enriched by an order of magnitude over those expected for equilibrium with the host kimberlite (see Fig. 2), based upon known experimental partition coefficient values (McKay and Weill, 1976; Irving et al., 1978). In contrast data for an ilmenite megacryst from Benfontein are compatible with equilibrium with its host kimberlite (Fujimaki et al., 1984). The Monastery sample apparently crystallized from a liquid (or fluid) more enriched in LREE than the present host kimberlite thus implying magma mixing at this kimberlite pipe. The possibility that zircon megacrysts in kimberlites may have crystallized from evolved liquids and are exotic to their hosts will also require testing.

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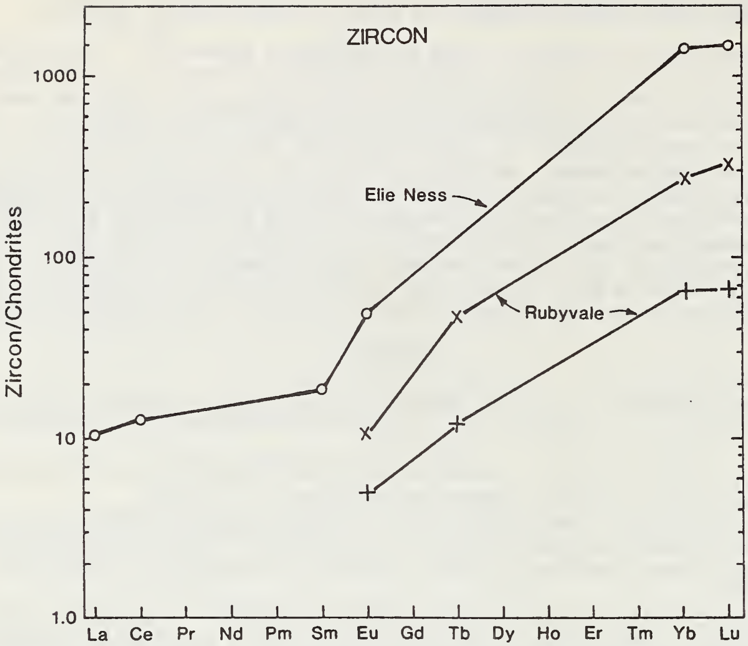


Figure 1. Chondrite-normalized REE data for zircon megacrysts from Rubyvale and Elie Ness, Scotland (Irving and Frey, 1984)

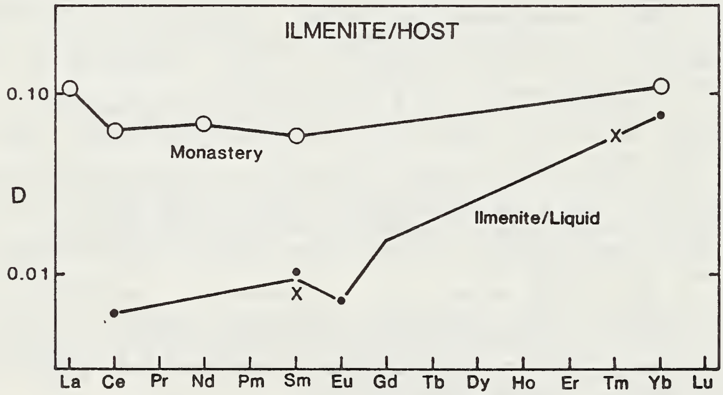


Figure 2. Comparison of ilmenite/host kimberlite REE abundance ratios (using host data from Mitchell and Brunfelt, 1975) with experimentally-determined D values.