

# BEARING OF THE SUBCALCIC, Cr-POOR MEGACRYST SUITE ON KIMBERLITE PETROGENESIS AND LITHOSPHERIC STRUCTURE

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Radiogenic isotope systematics of igneous rocks provide important constraints as to the character and evolution of melt sources, and is consequently an essential tool in petrology. Even given the problems imposed by severe contamination with mantle and crustal material not generally encountered in most mantle-derived melts, a range of isotopic compositions in kimberlite and related rocks demonstrates the involvement of time-averaged enriched to slightly depleted upper mantle sources worldwide (e.g. Smith, 1983; McCulloch et al., 1983; Weiss and Demaiffe, 1985). Broadly speaking the various isotopic components have been generally attributed to either of two general types of mantle reservoir. One is characterized by radiogenic Sr and comparatively non-radiogenic Nd and Pb (Group II kimberlites and most potassic lamproites), indicative of ancient enriched sources and probably isolated within subcontinental lithosphere. Kimberlites and related rocks with slightly 'depleted' isotopic character (e.g. Group I) are worldwide the dominant type of kimberlite, and typically have a range of Sr isotopic compositions clustered around bulk earth values, but with Nd isotope compositions consistently higher than bulk earth. It is notable that these types of kimberlites tend to define horizontal arrays that crosscut the general trend of the mantle array as defined by OIB (ocean island basalt) compositions, at least where enough data are available (Fig. 1). The 'true' compositions of the ultimate sources of kimberlite are obscured to greater or lesser degrees by contamination and admixture of lithospheric components. Such mixing can be viewed as an essential part of the kimberlite production process; certainly so from an economic point of view.

The isotopic compositions of minerals of the subcalcic, Cr-poor megacryst suite may reflect source character better than the kimberlites if it can be unequivocally shown that they are related to their hosts. Diopside is generally the mineral analyzed for Sr, Nd and Pb isotopes given the greater abundances of those elements in cpx compared to other coexisting minerals, although Nd in garnet may be useful, and Os tests on opx are underway. Overlapping but generally lower Sr isotope ratios and slightly higher Nd isotope ratios for most cpx samples compared to their host kimberlites suggest xenolithic origins (Fig. 1), although crystallization from a parent melt prior to evolution and lithospheric contamination of the melt could result in the observed relationships (see Nixon et al., 1981; Jones, 1987; Smith, 1983) provided isotopic re-equilibration with the host does not occur during transport to the surface. The results have not been straightforward to interpret, mainly because of the notably limited isotopic variation in megacrysts from kimberlites throughout southern Africa, lack of detailed studies at single localities, and the general absence of the suite (along with high-temperature peridotites) in compositionally distinctive Group II kimberlites or lamproites. Moreover, in the one assemblage so far studied in detail, De Bruin (1991) demonstrated that several subtly distinct megacryst 'packages' with respect to isotopic and chemical character are present, and this is probably true of most localities. Hence, simple correlations between isotopic and chemical composition may not occur for small numbers of samples selected largely on the basis of size and freshness (to give the easiest and best isotopic analyses). Six samples from the Kaalvallei kimberlite yield equivocal results, although the most calcic megacryst does have a significantly higher Sr isotopic character than the main group, suggestive of operation of some type of AFC process.

The Frank Smith and Lace kimberlites are, respectively, 114 and 142 Ma Group I and II bodies with distinctive isotopic character compared to most southern African Group I occurrences (Fig. 1). Abundant megacrysts occur at Frank Smith, and Lace represents one of the few Group II kimberlites with garnet megacrysts of unequivocal subcalcic affinity. Two Cr-poor diopside megacrysts from Lace represent the only subcalcic cpx megacryst samples so far known from Group II kimberlites. There is a clear correspondence in isotopic character between megacrysts and host kimberlites in the main Group I cluster, Frank Smith and Lace. As with the kimberlite, the Frank Smith megacrysts have somewhat higher <sup>143</sup>Nd/<sup>144</sup>Nd and lower

$^{87}\text{Sr}/^{86}\text{Sr}$  than those of the main group (Fig. 1). The Lacey diopsides vary similarly to their host kimberlites, their Group II character differing considerably from the main group of megacrysts. Isotopic compositions therefore strongly indicate a relationship between the megacryst suite and their host kimberlites. Either the megacrysts are cognate to 'proto-kimberlite' melt at high pressure prior to modification of the kimberlite on ascent, or they are xenocrysts that crystallized from basic melts derived from the same source as the kimberlites. In either case the megacryst isotopic compositions represent unmodified kimberlite source compositions.

The Group I source composition is identical to the HIMU compositional reservoir throughout southern Africa (Fig. 1), and is dissimilar to any known plume compositions in the South Atlantic except for St. Helena. The few available comparatively radiogenic Pb isotope analyses of megacrysts reinforce the HIMU character. Group I kimberlites therefore do not contain a material component derived from hotspots currently active in the South Atlantic. Moreover, this composition is not restricted to southern African kimberlites of Cretaceous age. Both Venetia (about 500 Ma in age) and the Premier cluster (1200 Ma) have similar source compositions, as do the 400 Ma Colorado-Wyoming kimberlites. In the latter case, however, there are compositional variations with position along the Front Range, a feature not seen in southern Africa but which also constitutes important evidence against incorporation of a material component from sublithospheric hotspots into kimberlite. (An important experiment will be to determine if the Colorado-Wyoming megacryst suites vary sympathetically in isotopic character.) High temperature-peridotite xenoliths, many type I eclogites and other alkaline, intraplate continental rocks have similar compositions, or compositions that range to higher and lower Sr and Nd isotopic character, including Minas Gerais kimberlites and related rocks (Fig. 1, Bizzi et al., 1994) and African carbonatites (Bell and Blenkinsop, 1989). Ringwood et al. (1992) recognized the HIMU character of the source for Group I rocks, and Hart et al. (1986) originally proposed that the full array of compositions occurred within continental lithosphere. Geophysical evidence as well as petrologic requirements for (Group I) kimberlite production at depths considerably in excess of 200 km indicate that HIMU-like material is an important component in deepest continental lithosphere, and it could have been produced by post-Archean subduction related processes. By implication, HIMU and DUPAL signatures in the oceanic regime may be a result of delamination during plate migration, rather than transfer of a plume component from the core-mantle boundary or the transition zone.

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