Sr AND Nd ISOTOPIC SYSTEMATICS OF DIAMOND-BEARING ECLOGITE XENOLITHS AND ECLOGITIC INCLUSIONS IN DIAMOND FROM SOUTHERN AFRICA

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Eclogite is an important source of diamond in many southern African kimberlites as evidenced by the not uncommon occurrence of diamond-bearing eclogite xenoliths as well as the abundance of eclogite paragenesis inclusions within diamonds. Despite the importance of the eclogite association, the isotopic character of silicate minerals coexisting with diamond in xenoliths or as inclusions within individual diamonds has not previously been investigated. Here we report Sr and Nd isotopic analyses of clinopyroxene and garnet in selected diamond-bearing eclogite xenoliths from the Excelsior, Orapa, Newlands and Roberts Victor kimberlites, and of eclogitic garnet inclusions from a single Finsch diamond.

DIAMONDIFEROUS ECLOGITE XENOLITHS

Of the samples analyzed, those from Orapa and the single Roberts Victor sample have been described (Robinson et al., 1984; Shee and Gurney, 1979; Hatton and Gurney, 1979) whereas the single Newlands sample and a suite of fourteen newly collected Excelsior samples have not previously been studied. With the exceptions of samples HRV247, a type 2 calcium-rich eclogite from Roberts Victor, and diamond-free graphite eclogite XM11 from Orapa (type 2, websterite associaton) all samples are type 1 eclogites (terminology of MacGregor and Carter, 1970; Robinson et al., 1984) with garnet and clinopyroxene characterized by somewhat elevated Na_2O and K_2O respectively in comparison to non-carbonaceous eclogite, consistent with high pressure origins. All samples are kyanite-free. Garnet compositions (Fig. 1) are diverse, though still somewhat restricted compared to the full compositional range of southern African diamond eclogites (Reid et al., 1976). The distribution of Mg and Fe between clinopyroxene and garnet indicates equilibration temperatures of between 1000 and 1200°C (calculated for P=50kb). Within these limits, however, the Excelsior samples are physically and chemically distinctive compared to diamond eclogite from other localities. Garnet in the Excelsior eclogites is markedly coarse-grained (up to 3 cm), with most samples being small and consisting dominantly of single garnet crystals with accessory octahedral diamond. Clinopyroxene is present in only minor amounts in five of the fourteen specimens and in some cases is less abundant than diamond. In comparison with the compositional variability characteristic of diamond eclogite from Roberts Victor and Orapa, all but two of the Excelsior samples have restricted compositional range (Fig. 1), strongly supportive of these rocks comprising a genetically related assemblage.

Despite the small size and somewhat altered nature of most samples, isotopic results on carefully cleaned and leached mineral separates cannot be explained by kimberlite contamination or alteration effects. $^{87}Sr/^{86}Sr$ ratios in clinopyroxenes of the type 1 samples and HRV247 are highly variable, ranging from .7026 to .7067 (Fig. 2), similar to the range in the Orapa samples alone. Clinopyroxene in the type 2 graphite eclogite from Orapa has the most radiogenic Sr, with $^{87}Sr/^{86}Sr$ = .7081. Nd isotopic compositions of clinopyroxenes and garnets are correspondingly variable, with emplacement age corrected $^{143}Nd/^{144}Nd$ varying from .5117 to .5129 (Fig. 2).

With the exception of the Newlands sample, JJG144, garnet and clinopyroxene were in Nd isotopic equilibrium at the time of kimberlite emplacement, consistent with lack of petrographic or chemical disequilibrium features in all samples except HRV247. Presuming that the samples are older than pipe emplacement, internal age determinations from mineral pairs are not possible. Samples from the Excelsior suite are most likely cogenetic from chemical evidence, but between-sample ages are also equivalent (within error) to the kimberlite emplacement age. Either these rocks are young, or more likely, isotopic equilibrium was maintained on the scale of their spatial separation in the upper mantle. In JJG144, however, an apparent clinopyroxene-garnet age is 440 m.a., compared to 115 m.a. for the kimberlite. The initial $^{143}Nd/^{144}Nd$ ratio of about .5110 is extremely low, particularly in view of relatively high

$^{87}Sr/^{86}Sr$ = .7043. The eclogite (and/or the protolith) must have had a complex history, and indicates that preservation of upper mantle domains with isotopic character somewhat similar to that of peridotitic garnet inclusions in diamond (Richardson et al., 1984) need not necessarily require early encapsulation by diamond.

INCLUSIONS IN DIAMOND

Isotopic studies of silicate and sulphide inclusions in diamonds have convincingly demonstrated, with the possible exception of samples from the Premier kimberlite, that the inclusions and presumably the enclosing diamonds are much older than the host kimberlites (Kramers et al., 1979; Richardson et al., 1984). Typically small inclusion sizes and consequently low absolute trace element contents generally require that such work be performed on composite samples comprising tens to hundreds of diamonds. A potential problem with this approach is the possible presence of more than one inclusion population that may not be optically distinguishable (particularly in the case of sulphides). Through the efforts of De Beers Consolidated Mines, a collection of diamonds with uncharacteristically large inclusions has been assembled, and preliminary experiments on inclusions from a single diamond have proven successful.

A 2.3 carat yellow octahedral diamond from the Finsch kimberlite contained 35 eclogitic garnet inclusions with a total weight of 1.2 mg. The largest inclusion, about a cubic mm in size, is responsible for the greatest part of the sample weight. Inclusions were extracted by breaking the diamond in filtered air, and were rinsed with HCl prior to dissolution. Sm and Nd concentrations of 2.52 and 2.19 ppm respectively yield a high Sm/Nd ratio of 1.15 and consequently radiogenic Nd ($^{143}Nd/^{144}Nd$ = .51817 +/- 5; 2 sigma error, small blank correction applied).

Assuming a single stage history and derivation from a chondritic reservoir, the model age is 1670 +/- 40 m.a. (Fig. 3; error from analytical uncertainties). If the parent reservoir is not chondritic, but still within the compositional limits of normal depleted or enriched upper mantle, the age calculation varies little because of the highly radiogenic Nd. The age, though much older than pipe emplacement (120 m.a.), is substantially younger than sulphide inclusions (greater than 2000 m.a.; Kramers, 1979) or peridotitic garnet inclusions (3300 m.a.; Richardson et al., 1984) in Finsch diamonds. It is thus not possible to relate in a single event formation of eclogitic and peridotitic inclusion suites represented by silicate samples analyzed to date. The sulphide inclusions analyzed by Kramers (1979) may represent an additional diamond forming event. The Proterozoic model age of the eclogitic garnet is similar to some of the older ages obtained in crustal rocks of the off-craton Namaqua and Bushmanland provinces, and it is tempting to speculate that eclogitic diamond inclusions of this age could represent upper mantle event(s) related to those crustal processes.

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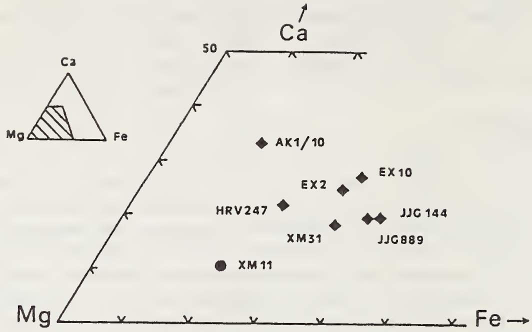

Figure 1. Garnet compositions in diamond eclogite.

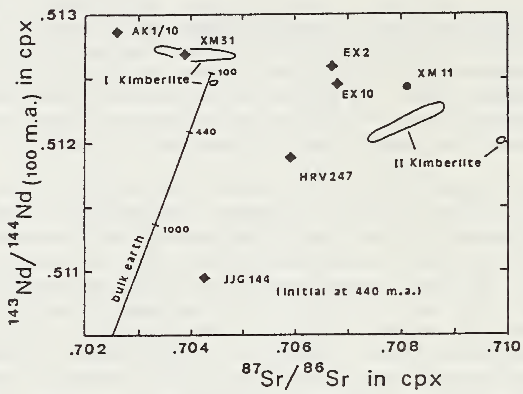

Figure 2. $^{87}Sr/^{86}Sr$ vs. initial $^{143}Nd/^{144}Nd$ in cpx from diamond eclogite.

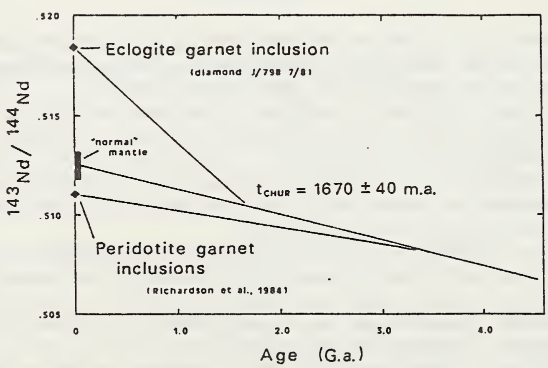

Figure 3. Model ages of Finsch diamond inclusions.