

EVIDENCE FOR A DEEP ORIGIN FOR SÃO LUIZ DIAMONDS.

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The diamonds recovered from the Sao Luiz river in northern Mato Grosso state, in Brazil, are believed to be derived from nearby kimberlites related to the Cretaceous Aripuena Kimberlite province. These kimberlites are intruded into the Rio Negro-Juruena belt, a possible island arc terrane, which yields Proterozoic metamorphic ages and lies between partly remobilised Archaean belts of the Guyana-Guapore craton. The particular importance of the Sao Luiz diamonds lies in the unusual characteristics of the diamonds themselves, and, as outlined in this study, their syngenetic inclusion content, which extensively shows mineralogical and geochemical features indicative of deep (sub-lithospheric) origins. The majority of inclusions fall into two groups, one containing garnet-rich inclusions and the other consisting largely of oxide, colourless silicate and rare carbide inclusions.

The Garnet-rich Inclusions Suite.

Petrographically most of these inclusions have the appearance of orange to pale orange garnets of eclogitic inclusion paragenesis. Back scattered electron (BSE) images and electron microprobe analysis shows that in detail, whilst some inclusions consist of garnet alone, most inclusions contain a minor phase of clinopyroxene chemical composition in addition to a garnet-like phase. Rarely, other uncertain phases and possible alteration products are also present.

Two groups of these apparently garnetiferous inclusions have been established on the basis of their silicon content. The first group is indistinguishable in major-minor element chemistry from typical garnets of eclogite paragenesis and shows normal silicon contents. In the second group the silicon values are higher than the three cations (per 12 oxygens) expected in a normal garnet structure and range up to 3.3. The aluminium concentrations in the high-silicon garnets are lower than those of normal garnets presumably partly because the excess silicon atoms occupy octahedral sites in the garnet structure. However, the decrease in Al is greater than that equivalent to the increase in Si, and there is no further compensation by increase in typical octahedral site cations such as Ti and Cr (Fig. 1a). However, the high-silicon garnets commonly show divalent cations + Na in excess of the 3 (per 12 oxygens) needed to fill the cubic site (Fig. 1b). Thus some divalent cation substitution in the octahedral site is suggested, which would also help to maintain charge balance as a result of the Si for Al substitution. Na contents up to 0.08 cations in the high-silicon garnets also adjust charge balance.

The cation substitutions shown by the high-silicon garnets suggest high-pressure pyroxene solid solution in the garnet structure (Moore & Gurney, 1985; Irifune et al., 1989). Overall the Sao Luis garnets suggest depths of formation from around 180 km, near the expected base of the lithosphere, to around 400 km. Temperature estimates for coexisting garnet-clinopyroxene pairs with normal-silicon garnet range from 1281 to 1665°. For the high-silicon garnet parageneses, temperature estimates are even higher and are considered unreliable because of the unusual garnet-chemistry and, in some cases, a lack of equilibrium as shown by variable mineral chemical compositions.

Textural relationships between garnet and clinopyroxene vary considerably, though the clinopyroxene is usually concentrated at the margins of the inclusions. In association with the normal-silicon garnets, clinopyroxene is usually in a small number of grains with clear indications of faceted boundaries. The clinopyroxene associated with high-silicon garnets has more irregular, often curving, boundaries and may occur as numerous scattered small 'blebs' as well as larger and more discrete clinopyroxene grains. In one instance the clinopyroxene has the form of possible exsolution lamellae within the garnet. However, the chemical compositions show that the clinopyroxenes commonly seen, could not be produced along with normal-silicon garnets as a result of decomposition of the high-silicon garnets. The textures and the occasional variability of mineral compositions in the case of the high-silicon garnets, suggest a frozen reaction history, perhaps involving melt.

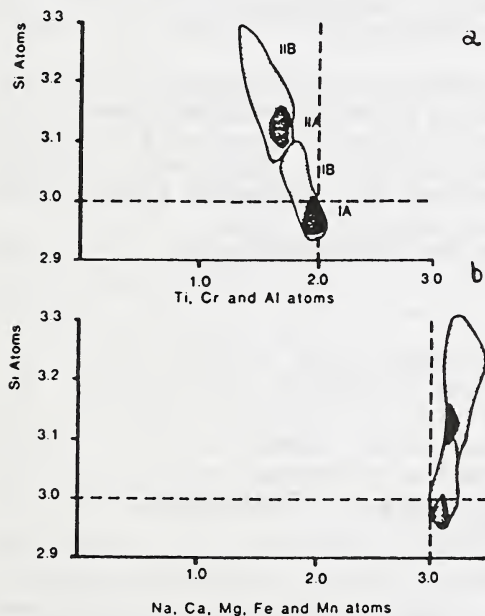


Fig. 1 Plots of normal Octahedral site cations and Cubic site cations against Si Content. Increasing Si is associated with decreasing Al+Ti+Cr and increasing Na+Ca+Mg+Fe+Mn, as one goes through the sequence from normal-silicon garnet without clinopyroxene (IA), to normal silicon garnet with clinopyroxene (IB), to high-silicon garnet without clinopyroxene (IIA), to high-silicon garnet with clinopyroxene (IIB).

Ion microprobe analyses of the garnets also show evidence of complex relationships, particularly for the more incompatible elements. Each garnet analysed shows moderately constant relative abundance of Y and the HREE (Sm to Lu). Between garnets these HREE concentrations vary largely from 8x to 60x chondrite, with a tendency for the high-silicon garnets to be in the lower part of this range. The LREE are progressively depleted with decreasing mass relative to HREE, but variations in concentrations are very large and such variations are seen in garnets of normal and high-silicon content. La varies from 5x

to $<0.01x$ chondrite. A similar range of variations is seen in Nb, and concentrations up to $15x$ chondrite show that garnet may carry substantial Nb. Melts in equilibrium with the inclusions could vary from OIB-like to MORB-like. The commoner trace element compositions are similar to those of normal eclogitic inclusions in diamonds and thus do not preclude an original sublithosphere origin for these normal eclogitic inclusions.

The oxide, colourless silicate and carbide inclusions suite.

The non-garnetiferous inclusions from Sao Luiz diamonds are varied, but many show distinctive features indicating a very high pressure origin. The oxides are MgO-FeO (periclase-wustite) solid solutions, which show a range of Fe/Fe+Mg values from 0.16 to iron-rich values of 0.61. In addition to Fe and Mg there are variable small amounts (usually <1 wt%) of Cr, Al and Ni in the oxide phases. Some of the Ni may be present as metal rather than oxide and there are also small inclusions ($<2\mu\text{m}$) of iron-nickel alloy, with a composition Fe:Ni = 70:30, in many of the oxides.

The colourless group of inclusions includes silicates with the compositions of wollastonite, silica (SiO_2), and diopside, all of exceptional purity. The remaining two silicates are an unidentified alumino-silicate phase close to $\text{Ca}_2\text{Al}_2\text{SiO}_7$ and an olivine (Fo=85). In one case SiO_2 co-exists with a ferripericlase of Fe/Fe+Mg 0.30. In addition to the silicates, two colourless to pale blue crystals of SiC composition (moissanite) have been recovered from 2 diamonds.

Experimental evidence shows that below 650 km in the mantle, olivine and pyroxene should be represented by ferripericlase and perovskite-structured pyroxene (including a possible phase of wollastonite composition and perovskite structure). SiO_2 may occur as stishovite. The Sao Luiz inclusions may represent this sub-650km mineralogy. The position of moissanite in this mineralogy is uncertain, but it implies reduced conditions.

References.

- Moore, R. O. & Gurney, J. J. (1985) "Pyroxene solid solution in garnets included in diamond." *Nature*, 318, 553-555
- Irifune, T., Hibberson, W. O. & Ringwood, A. E. (1986) "Eclogite-garnet transformations in basaltic and pyrolite compositions at high pressure and temperature." *Geological Society of Australia Abstracts*, 16, 259-263.