

## Deep diamonds and inferences on the role of aluminium in the transition zone and lower mantle.

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The São Luiz alluvial deposit of Mato Grosso State, Brazil, contains diamonds whose syngenetic inclusions of 50 - 400  $\mu\text{m}$  diameter, not only exhibit shallow upper mantle mineralogies, but also reveal mineral parageneses only stable at pressures corresponding to depths of >300 km within the earth (Harte and Harris, 1994; Harte *et al.* 1994). These diamonds, therefore, provide a unique opportunity to glean information on the stable phases and the compositional characteristics of areas of the earth normally inaccessible for direct measurement. Many of the inclusion phases correspond to those obtained as run products from high pressure and high temperature experiments appropriate to the deep earth. For example, majorite (Si-rich, Al-deficient garnet), which is an experimentally determined transition zone mineral (eg. Akaogi *et al.* 1987), has been found; whilst the assemblage of (Mg,Fe)O ferropericlaise in association with (Mg,Fe)SiO<sub>3</sub> and CaSiO<sub>3</sub>, as observed in experimental work on lower mantle conditions (eg. Irifune and Ringwood, 1987), has also been recovered. In addition it is apparent that some of the assemblages appear to be sourced around the boundary between these two regions approximating to a depth of 670 km. For example one diamond yielded a ferropericlaise in addition to an Fe-rich olivine, and another a ferropericlaise in association with a quartz composition. If the SiO<sub>2</sub>, (Mg,Fe)<sub>2</sub>SiO<sub>4</sub> and (Mg,Fe)O are all in equilibrium, then they correspond to a pressure range of 16-20 GPa at 1273K within the (Mg,Fe)SiO<sub>3</sub> system and in the range of 17-20 GPa at 1273K within (Mg,Fe)<sub>2</sub>SiO<sub>4</sub> system (Yagi *et al.* 1978; Jeanloz and Thompson, 1983).

One of the main debates relating to lower mantle mineralogy is the nature of the phase carrying aluminium. Does Al stabilise its own phase or is Al incorporated into other phases? Early experimental work on pyrolite and MORB starting compositions (Irifune and Ringwood, 1987; Ito and Takahashi, 1987) constrained an Al-rich phase which could not be identified. More recently, Al has been shown experimentally to be incorporated into perovskite structured (Mg,Fe)SiO<sub>3</sub> (Irifune, 1994; Kesson *et al.* 1995) although other workers (O'Neill and Jeanloz, 1994; Ahmed-Zaid and Madon, 1995; Yagi *et al.* 1996) suggest that a separate Al-rich phase coexists with a mildly aluminous perovskite structured (Mg,Fe)SiO<sub>3</sub>. All these experiments involve some degree of uncertainty, whether in the measurement of run conditions of pressure or temperature or the relevance of bulk composition employed to those of mantle regions. Clearly there is still much controversy over the role of Al and, although pressures and temperatures cannot explicitly be constrained at this stage, the São Luiz diamonds provide an opportunity to shed light on some of this controversy.

Al is found here in three different phases; dominantly orthopyroxene or clinopyroxene compositions with amounts of Al<sub>2</sub>O<sub>3</sub> up to 12.6 wt %; corundums of both sapphire and ruby varieties and a new tetragonal mineral of pyrope-almandine composition, particularly distinguished by a lack of Ca and majorite substitution. This new phase has provisionally been called haitchite (Harris *et al.* 1996). The Al-bearing phases occur in three distinct associations; Group 1, ferropericlaise + CaSiO<sub>3</sub> + type I pyroxene + haitchite; Group 2, ferropericlaise + type II pyroxene + ruby; Group 3, ferropericlaise + type III pyroxene + haitchite.

Within Group 1, Al<sub>2</sub>O<sub>3</sub> appears as up to 2.7 wt % in the essentially (Mg,Fe)SiO<sub>3</sub> composition type I pyroxene and 20-24 wt % in haitchite. Experimentally, there has been evidence based on pyrolite to suggest that majorite starts to lose its majoritic component at pressures greater than 19 GPa and remains stable with ferropericlaise (Mg,Fe)SiO<sub>3</sub> + CaSiO<sub>3</sub> partly into the lower mantle (Irifune and Ringwood 1987). As yet, however, haitchite has not been observed.

Groups 2 and 3 involve grains of Al-rich pyroxenes. These grains lie on a trend of increasing Al content with increasing Ca, Cr and Na and decreasing Mg and Fe.

In Group 2, type II pyroxene consists of 10 wt% Al<sub>2</sub>O<sub>3</sub>, 1 wt% Na<sub>2</sub>O and 0.7 wt% CaO. Of the inclusions recovered, one is a composite grain of type II pyroxene and ruby. Yagi *et al.* (1996),

Ahmed-Zaid and Madon (1995) and O'Neill and Jeanloz (1994) allude to similar associations.

In Group 3, type III pyroxene involves 11 wt %  $\text{Al}_2\text{O}_3$ , 4.5 wt%  $\text{Na}_2\text{O}$  and 4.5 wt%  $\text{CaO}$ . Of the inclusions recovered, one is a composite grain of type III pyroxene and haitchite.

In addition, a sapphire inclusion has been recovered which is the first example of this variety of corundum to be found in a diamond. Its lack of association with another phase, however, makes its position of origin in the mantle unclear.

From the parageneses obtained from São Luiz diamonds it is clear that both régimes involving a separate Al phase and régimes involving Al incorporation into predominantly ferro-magnesian minerals are present; their relative stability is probably depth-related.

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