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PHYSICAL CHARACTERISTICS OF THE DIAMONDS

The general quality of Monastery diamonds is extremely poor. A size analysis based on 4600 carats of general mine production revealed the diamonds to display a gaussian size distribution with a mode in the size range -11 + 9 (-3mm). A large proportion of the diamonds are almost devoid of primary crystal form, and the majority exhibit some form of breakage surface often accompanied by the effects of severe resorption. The diamonds are colourless or shades of brown in approximately equal proportions. Yellow diamonds are conspicuously absent. A wide variety of surface features are represented, with trigons, hexagonal etch pits, corrosion sculptures and shallow depressions being the most common.

MINERAL INCLUSIONS

A sample of 131 inclusion-bearing diamonds have been categorised as eclogitic, peridotitic and miscellaneous, the latter category comprising inclusions of uncertain paragenesis as well as sulphide inclusions.

Miscellaneous Inclusions

The majority of the fifty inclusions assigned to this category are accounted for by sulphide (30) and Fe-oxide (14) inclusions. Other phases represented include plagioclase (1), zircon (1), phlogopite (1) and moissanite (3). Minerals represented under the broad term of Fe-oxide include magnetite (9), spinel (6), hematite (6), ilmenite (1) and magnesio-wustite (1). The high incidence of black spots and impurities in Monastery diamonds made correlation between the inclusions observed within the diamond with iron-oxide inclusions liberated upon diamond destruction extremely difficult. In many cases, it was not possible to claim with confidence that a particular inclusion was derived from a primary setting within the diamond. A small number of magnetite inclusions were however found in association with primary sulphide inclusions. Furthermore, the primary nature of a small proportion of monomineralic magnetite inclusions was beyond dispute. In view of the lack of any compelling evidence in support of a primary origin for the spinel, hematite and ilmenite inclusions, they are considered to be epigenetic. The plagioclase (An68.3 Ab31.0 Or0.7) and phlogopite inclusions were both recovered from diamonds hosting eclogitic inclusions but neither were observed within the diamonds prior to their destruction. A single zircon of primary nature was recovered and identified by means of qualitative microprobe techniques. The magnesio-wustite and three moissanite (SiC) inclusions are discussed in an accompanying paper (Moore et al., this volume).

Peridotitic Paragenesis

Inclusions of peridotitic affinity are poorly represented. The majority of olivines (5 out of 6) exhibit a restricted compositional range (Fog0.0 to 91.6), the sixth is Fog4.9. A single peridotitic clinopyroxene is a chrome diopside with 2.00 wt.% Cr203, 1.69 wt.% Al203 and 20.34 wt.% CaO. The one peridotitic garnet recovered coexists with an olivine (Fog1.6). Distinguishing features of the garnet composition include high levels of SiO₂ and TiO₂ (43.77 wt.% and 0.51 wt.% respectively) as well as slight enrichments in FeO and CaO (7.23 wt.% and 3.66 wt.% respectively) compared to characteristic "GIO" garnets of the harzburgitic paragenesis. The pair yields a calculated equilibration temperature (O'Neill and Wood, 1979) of 1173°C (for P = 50 kbars). A temperature estimate based on the Ca/(Ca+Mg) ratio of the Cr-diopside inclusion (Lindsley and Dixon, 1976) is 1002°C.

Eclogitic Paragenesis

Fifty-six eclogitic garnets fall into two distinct populations. One group of 10 (Group A) have compositions similar to other localities. They contain detectable

quantities of Na₂O (0.04 to 0.25 wt.%) and widely ranging concentrations of MgO, FeO and CaO. Furthermore, most are chemically indistinguishable from the garnets in Group I eclogite nodules at Monastery. The second group of 46 (Group B) form a related suite of compositions that appear to reflect the effects of pyroxene solid solution in the garnets (Moore and Gurney, 1985). Extreme concentrations of Si and Al range to as high as 47.43 wt.% SiO2 and as low as 11.29 wt.% Al2O3. Sodium is also present in extremely high concentrations, ranging to 1.03 wt.% Na20. Since the solid solution of pyroxene in garnet is a predominantly pressure dependent reaction (Ringwood, 1967), it has been suggested that the Group B garnets have an extremely deep origin (Moore and Gurney, 1985). Eclogitic clinopyroxenes (N=15) display a wide range in chemical composition. The majority are chemically indistinguishable from eclogitic clinopyroxenes included in diamond from other localities. Three have anomalously high Al203 concentrations (11.83 to 12.46 wt%) in combination with low Na₂O contents (0.78 to 2.49 wt.%) indicating the presence of the Ca-tshermakite molecule. The clinopyroxenes from eclogite nodules at Monastery exhibit restricted compositions within the range displayed by the clinopyroxene inclusions. The possibility exists that some of the diamonds hosting Group A garnets as well as a minority of clinopyroxene bearing diamonds have been derived by disaggregation of diamondiferous Type I eclogite. However, this do not represent the major source of eclogitic diamonds at Monastery. Two orthopyroxenes are highly aluminous (4.1 and 11.8 wt.% A1203) and have Mg/(Mg+Fe) ratios of 0.83 and 0.85 respectively. Both orthopyroxenes were observed to coexist with phases of eclogitic affinity indicating that the garnet websterite association reported for inclusions in diamonds from Orapa (Gurney et al. 1984) is also present at Monastery. Two inclusions of SiO2 have been recovered. Their primary nature within the host diamonds argues in favour of them being coesite rather than quartz. A single primary corundum inclusion hosting only TiO2 (3.05 wt.%) as an impurity has also been recovered.

Seven cases of individual diamonds yielding multiple inclusions of the same phase which display dramatic differences in composition have emerged in this study. In five of the diamonds, garnet is the responsible phase, while two cases involving eclogitic clinopyroxene have also been detected. The compositional discrepancies far exceed statistical analytical error, with variances of 30 relative percent being common. Episodic diamond growth (Meyer, 1985) within an environment of rapidly changing chemical composition is favoured as the most likely mechanism to account for the compositional variations.

Coexisting mineral phases useful for geothermobarometric calculations were found to be extremely rare in this study. Compounding this problem was the fact that in two of the diamonds hosting coexisting pairs, one of the phases was represented by two inclusions which displayed chemical disequilibrium. Moreover, two of the garnet-clinopyroxene pairs are represented by group B garnets. The temperatures calculated from these pairs are considered to be geologically meaningless because the presence of pyroxene in solid solution in these garnets violates the basic assumptions of the geothermometers. Two clinopyroxene-orthopyroxene pairs of eclogitic affinity yield calculated equilibration temperatures (Lindsley and Dixon, 1976; 20 kbars) in the region of 1415°C. The high Al content of the orthopyroxenes is consistent with a high temperature origin.

One diamond was found to host an olivine ($Fo_{94.9}$) and a group B eclogitic garnet. This phenomenon has now been observed by three other authors (Prinz et al., 1975; Hall and Smith, 1984 and Otter and Gurney, this volume), and it is considered that genuine cases of mixed paragenesis diamonds do occur.

The formation pressures indicated by the group B garnets are in the range 60 to approximately 140 kbars (estimated from the experimental data Akaogi and Akimoto, 1979 and Irifune et al., 1986). These diamonds thus provide an important sampling of the deep upper mantle or transition zone, the structure and composition of which is currently under debate (see review by Anderson and Bass, 1986). If the Group B diamonds were formed in a lithospheric environment then ultra-deep subcontinental root zones are implied (e.g. Jordan, 1981). However, these diamonds could have been derived from an asthenospheric source. Recent plate tectonic reconstruction models have indicated a possible correlation between South Atlantic hotspots and the Cretaceous kimberlites within southern Africa (e.g. Crough et al., 1980; Duncan, 1981). Furthermore, le Roex (Nature, submitted) has recently demonstrated chemical correlations between both Group I and II kimberlites and the South Atlantic hotspots, implying asthenospheric source regions for both groups. The possibility thus exists that Group B diamonds have formed in association with a rising diapir directly related to hotspot activity. The ultimate source of the diapir could be:

(i) a megalith of accumulated recycled (subducted) oceanic lithosphere positioned at the base of the upper mantle (Ringwood, 1982) or convectively downrafted subcontinental lithosphere as envisaged by McKenzie and O'Nions (1983).

(ii) primordial or near primordial mantle upwelled from the mesosphere (Morgan, 1971). Assuming the Monastery kimberlite (a Group I kimberlite, Smith, 1983) itself represents a product of the same hotspot, then a near primordial source would be the most applicable since it would be consistent with the geochemical characteristics of Group I kimberlite (le Roex, op cit).

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