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SOME OBSERVATIONS RELEVANT TO THE FORMATION OF NATURAL DIAMONDS

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Apparent old ages for some diamonds in cretaceous kimberlite support a non-cognate diamond paragenesis. Calculated equilibrium conditions for peridotitic inclusions in diamonds closely match those for coarse peridotite xenoliths in Kimberlite, though the latter rarely contain diamonds. The P/T estimates lie close to calculated shield geotherms and the peridotite solidus. The lowest temperatures for inclusion pairs imply sub-solidus crystallisation. In contrast observations of growth spirals on octahedral diamonds and of poly crystalline nuclei inside diamonds favours metamorphic or igneous growth. He isotopic ratios favour a mantle origin and argue against subduction models.

The release of diamond into kimberlite by disaggregation of xenoliths may sometimes be important but in general neither the relative abundance nor the chemistry of diamond inclusions correlates well with mantle xenoliths found at a specific locality. Most inclusions in diamonds have a harzburgitic paragenesis with distinctive mineral chemistry compared to peridotite xenoliths. Macrocryst minerals in diamondiferous kimberlite fill the compositional gap between the inclusions and coarse grained xenoliths. This does not fit a simple disaggregation model.

Whilst the peridotitic and eclogitic inclusion parageneses have often been regarded as discrete processes their ubiquitous association and their compositional continuity at some localities suggests a related origin.

Some of these observations are irreconcilable so that neither primordial mantle, nor mantle melting nor crustal subduction models are entirely convincing, leaving the relationship of diamond to kimberlite unresolved.

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THE GENESIS OF DIAMOND

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During the last decade or so a large amount of information pertaining directly or indirectly

to the formation of diamond in nature has become available. The numerous studies of the mineral chemistry of xenoliths in kimberlite, as well as the studies of kimberlite and of inclusions in diamond provide the bulk of the information.

Early chemical analyses of inclusions in diamonds indicated the overall similarity of mineral types from worldwide localities and differing geological ages. However, the most important aspect of the early studies was the recognition that diamonds form in two geochemically distinct environments - one ultramafic and one eclogitic. This simple division although still valid in a general way, needs modification in the light of recent observations of inclusion chemistry and diamond occurrence. It appears most likely that within the upper mantle carbon is in the form of diamond and that this latter mineral can exist in several rock types within the broad subdivision of eclogite and ultramafic types.

The occurrence of diamond in kimberlite or other rock types is due to the speed and mode of transportation of the diamond to the earth's surface and thus it is highly unlikely that diamond is a phenocryst in kimberlite.

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ABUNDANCES OF CARBON IN MANTLE XENOLITHS FROM ALKALIC BASALTS

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In mantle xenoliths from volcanic rocks, C exists as CO₂ in fluid inclusions and as an elemental form in microcracks and on inclusion walls. Carbonate is usually present as well and is generally believed to have been introduced after eruption. Both absolute amounts of C and relative abundances of its various forms were determined in a suite of representative xenoliths. Interior portions of samples were crushed to coarse (<1.4 mm) fragments, washed in cold 1N HCl, and fused with a flux. Fusion in an oxidizing atmosphere liberated all elemental C and vapor as CO₂, which was then determined by titration. In contrast, only vapor was liberated from samples fused in a reducing atmosphere. A similar procedure was followed for unwashed samples.

A significant proportion of the C in nearly all samples is removed by acid-washing. The soluble fraction must reside on grain boundaries and is presumed to be carbonate. In samples collected from environments in which caliche is present, carbonate contamination from meteoric sources is suspected. In others, carbonate probably also originated by post-eruptive redistribution of C from host lavas.

Most acid-washed Cr-diopside spinel lherzolites contain 10-40 ppm (by wt.) total C. These concentrations are considerably lower than those determined from previous analyses. The range in C contents of four Al-augite pyroxenites is 40-80 ppm, and one of the amphibole-phlogopite-apatite-spinel lherzolites from Nunivak Is., Alaska contains 85 ppm C.

The average C:CO₂ ratio for all samples is 0.06. Assuming that elemental C results from the reaction $2\text{CO} \rightarrow \text{C} + \text{CO}_2$, then the vapor from which C precipitated consisted of ~30 mole % CO.

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DIAMOND CHARACTERISTICS OF THE DE BEERS POOL MINES, KIMBERLEY, SOUTH AFRICA

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Diamonds from the four operating mines at Kimberley (Bultfontein, De Beers, Dutoitspan, Wesseltown), have been examined using a classification scheme which quantifies, as a function of specific diamond size classes, such physical characteristics as crystal form, colour, ultra-violet fluorescence, and plastic deformation. In addition, from a single size class, the relative abundances of syngenetic silicate, oxide and sulphide minerals in the diamonds have been determined.

The results from the classification indicates that, in general, there is usually <10% variation in the proportion of primary crystal forms between the four mines, although secondary crystal forms show more pronounced variations. Diamond colour is broadly similar for the four mines but the proportions of the principal colours (colourless, yellow, brown) are distinctive at each mine. The numbers of fluorescent diamonds are typically low, levels varying between 5-10% in the small sizes to 20-40% among the larger stones. The principal fluorescent colour is weak blue, other minor colours being strong blue, green, orange and yellow. Blue and strong blue fluorescence are distinctive for diamonds from De Beers and Wesseltown, respectively. Plastic deformation levels for the four mines are also distinctive but levels are independent of diamond size. Inclusion studies indicate that the diamonds from all four mines have a dominant (90% plus) 'peridotitic' paragenesis, with a particularly high chromite inclusion content.

Differences in characteristics can separate diamonds from the four Kimberley mines, but those characteristics which can reasonably be associated with diamonds' formation are closely similar, which is compatible with the Kimberley diamonds being derived from a single diamond population.

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A TRANSMISSION ELECTRON MICROSCOPY STUDY OF OLIVINE INCLUSIONS IN DIAMOND

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Olivine inclusions in elasticity isotropic diamond (cubic anisotropy factor

$A = 2C_{44}/C_{11} - C_{12} = 1.54$) have been studied with a view to obtaining information about olivine dislocation substructure under mantle conditions. Olivine inclusions 0.05-0.3 mm in diameter have been extracted by combustion from a diamond from the UDACHNAYA pipe, Yakutia, USSR. Individual inclusions have been mounted on copper grids and ion thinned at 5 KV for T.E.M. examination in a JEOL microscope at 120 KV.

A low dislocation density of less than 10^4 cm^{-2} is observed. To obtain the maximum information from the few dislocations observed, the dislocation images have been recorded under diffracting conditions of $g \cdot b = 0, 1, 2$ where g is the diffracting vector and b is the Burgers vector. Straight mixed free dislocations are present with both $\{001\}$ and $\{100\}$ Burgers vectors. Heated fractures on the (010) plane are observed with $\{100\}$ loops and $\{001\}$ straight dislocations.

The above observations are consistent with the low stress and high temperatures thought to prevail in the mantle. No evidence of a subsequent high stress crustal deformation is observed.

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THE ABUNDANCE AND CHEMISTRY OF MINERALS ASSOCIATED WITH DIAMONDS AT ROBERTS VICTOR MINE

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A study of minerals in diamonds has shown that their abundance and chemistry are at gross variance with the xenolith mineralogy at the Roberts Victor Mine. The latter is >95% eclogitic.

Olivine and associated minerals predominate (~85%) in diamond. The most abundant paragenesis is harzburgitic (ol, opx, ±chr, ±gar). There is a small garnet lherzolite field (±cpx). The above minerals are similar to peridotitic inclusions world wide; (high Mg/Fe, Cr₂O₃, low CaO). An exception is that opx usually has a higher Al₂O₃ (>1wt%) and Cr₂O₃ (>0.5wt.%). Two gar/ol pairs give high equilibration temperatures >1300°C, but a cpx (Ca/(Ca+Mg)=0.45) probably equilibrated at ~1100°C.

Eclogitic gar and cpx are subordinate (~15%) to peridotitic inclusions. Sulphide occurs in both associations and a single feldspar of presumed eclogitic affinity is the only other mineral found in 166 diamonds.

There is a large compositional gap between the peridotitic and eclogitic inclusion minerals. The latter are characterised by high Fe/Mg, TiO₂, Al₂O₃, CaO, Na₂O and K₂O and by lower Cr₂O₃. The garnets are ~65% almandine, and fall outside the compositional field for Rovic eclogite (Hatton 1978). The cpx show a positive MgO/Cr₂O₃ correlation; negative for MgO/Al₂O₃, MgO/Na₂O and MgO/K₂O.