THE ORIGIN OF COMPLEX "AGATE" TEXTURES IN OCTAHEDRAL DIAMONDS FROM KIMBERLITES.

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Introduction

The investigations of internal structures of octahedral macrodiamonds from kimberlites has shown the predomination of octahedral zonation and a tangential growth mechanism. Zoned, sectorial structures, resulting from mixed growth mechanisms are also occasionally present in the earliest stages of the diamond formation. More rarely, the internal zonation of diamonds may exhibit two other forms: rounded or "agate" like. The nature and mechanism of growth of the "agate" texture are uncertain. Rounded zones are considered to be either the result of growth during the change from a tangential growth mechanism to an abnormal one (Martovitsky et al, 1977), or caused by numerous slight change of conditions of resorption and regrowth (Varshavsky, 1968; Genshaft et al. 1977).

The very rare "agate" - like structure of diamonds first revealed by Seal (1965) was described by Orlov (1977) as epigenetic, having a post-growth nature. Zezin et al. (1992) have suggested that this texture is a result of a similar mechanism to that forming agate secretions, with growth from the periphery to the center of the octahedral diamond. The aim of this work is to describe two examples of of these rare complicated rounded and "agate" textures present in Yakutian macrodiamonds and evaluate the proposed origins.

Samples and analytical methods

The two unusual macrodiamonds described here are from the late Devonian Mir and the Aikhal pipes in Yakutia. The stones were sequentially sawn along the (110) plane to provide serial plates from each diamond. They were polished to reveal the inclusions and internal structure. The internal morphology of the diamonds was studied by birefringence (BR), photoluminescence (PL) and cathodoluminescence (CL). Our experience of CL imaging has shown that for correct interpretation it is necessary to have a true central section of the crystals. For complex structures (neither uniform nor isometric) it is important to have serial sections of the crystal to evaluate their three dimensional nature.

The nitrogen content and degree of aggregation have been investigated by FT-IR micro-spectroscopy; the inclusion compositions were measured by electron microprobe and the trace element compositions of the sulfide inclusions were obtained by proton microprobe.

Results

The peridotitic diamond #2016 (Aikhal) has a rounded octahedral shape and is extremely elongated on the L2 axis. It has a very complex internal morphology, indicative of a complicated growth history. Near the rim of the diamond, inclusions of olivine and Mss have been identified (Fe=40.02; Ni=21.73; S=37.1; total 98.85wt.%. Se=205; Mo=173; Te=29; Ru=55; Pd=31ppm)

At low magnification the internal structure, at first, appears to be a classical case of zonation, common to minerals grown from hydrothermal solution and very similar to those interpreted by Zezin et al. (1992) to represent rim to core, cavity fill growth. Three growth stages are recognisable from examination of the plates: (i) initial growth at two centers; forming an octahedron (bluePL) and an intergrowth of two finely layered cubooctahedrons (yellow PL), (ii) a complex rounded overgrowth associated with slight resorption, and (iii) a final octahedral growth stage followed by further resorption.

The initial cubooctahedral intergrowth consists of up to 14 growth sectors. A very fine concentric zoning is present in these sectors. At high magnification, different growth mechanisms are evident for the octahedral (massive layer by layer) and cubic (fibrous) zones, as a result of crystallographic control. The texture of the cubic zones is very similar to the spherocrystalline texture, first described in diamond by Martovitsky (1980). The first true monocrystalline zone seeded on the initial octahedron and cubooctahedral intergrowths, has a very complicated rounded shape which developed then into an elongate octahedral form. The elongation of this crystal is a consequence of the alignment of the initial growth centers creating an elongate seed for the later octahedral growth.

An unusual feature of this crystal is the presence of evidence of intense and perhaps multiple deformation. In the central zone, the fibrous cubic zones are obliquely disrupted by orthogonal conjugate sets of fine fractures, the fractures being filled by diamond of contrasting CL. These fractures are often sigmoidal in section and, across one intense yellow (CL) band are strongly refracted. These deformation effects are strongly controlled by the sectorial zoning with the massive, zoned octahedral sectors apparently unaffected. Despite the disruption of the fibrous cubic zones the primary growth zoning, seen as variable thickness pale and more intense green/yellow CL bands, is still traceable across the various sectors. Small offsets are evident along the boundaries of some sectors. Within other areas of the early cuboctahedral diamond, fibrous diamond is highly disrupted with some classical pull-apart and "feather-like" structures, again filled by diamond of contrasting CL. In the outer monocrystalline octahedral overgrowth, deformation lamellae overprint the primary growth zoning. These deformation features have two visible forms; as variations in blue CL intensity in the first overgrowth region giving an elongate tabulated appearance and as the more usual fine yellow/green lamellae in the outer overgrowth region.

FT-IR measurements have been made from each of the principal CL colour and textural variations within the central diamond plate and processed following the methods of Taylor et al. (1991). All spectra are predominantly 1aA with only minor (4-10%) 1aB. Nitrogen is low but variations generally correlate well with the recognised growth history. The initial cuboctahedral diamond has a nitrogen content around 60 ppm and the later octahedral zones contain 12-24 ppm nitrogen, excepting two rim measurements at 61 and 90 ppm. Relative hydrogen content is very distinct with moderate values in the cuboctahedral diamond and uniformly very low values in the later octahedral diamond. Assuming mantle residence around 2.9 Ga, the mean temperature is 1160+/- 17 deg.C for the 16 analyses.

The eclogitic diamond #1584 (Mir) is a colorless octahedron, elongated on L2 , with polycentrically growth layers, a blue color of PL and numerous sulfide inclusions. The very first section (not central) revealed an asymmetrical agate-like rounded zonation. A CL study of three plates made from this diamond has provided a three dimensional picture of its structure. The history of its growth is: (i) initially two centers of nucleation (fine-grained aggregate and broken octahedron), (ii) a rounded zone (oscillatory), and finally (iii) sharp edged octahedral growth. The external shape of a sharp edged octahedron elongated on the L2 axis of this diamond again results from nucleation on an elongate seed. The central part of monocrystal was formed by a mixed growth mechanism , and the periphery by a tangential growth mechanism. FT-IR spectra exhibit the 1aA nitrogen defects+small platelets peak+hydrogen in the central zone. The rim zone does not contain hydrogen and has 1aA + small content of 1aB and platelets defects. Syngenetic inclusions of omphacite, coesite and sulfides were identified in the intermediate and peripheral zones of diamond. Thus the diamond belongs to the coesite eclogite paragenesis. A few inclusions of calcite were also found in the rounded intermediate zone.

Summary and conclusions

Rounded zonation and agate-like textures in diamonds may develop in multicentered octahedral crystals under specific growth conditions. After initial growth from two or three closely located points, the aggregated or twinned centers provide a complexly shaped seed for subsequent monocrystalline octahedral growth. The mechanism of growth of the rounded zones is fine fibrous or mixed (tangential + fibrous), and may be in response to a progression towards a more viscous and carbon-supersaturated environment and away from equilibrium conditions where diamonds crystallise by a tangential growth mechanism. Such environments might be eclogitic or lhertzolitic melt (fluid).

Deformation at high temperature of such diamonds may result in an enhancement of the "agate-like" nature as, from the features present within the #2016 diamond, the octahedral and cubic sectors appear to differ in competency. Also, non-central sections of such crystals with complex rounded zonation may show an agate-like texture. No evidence has been found to support or require a rim to core, cavity-fill growth mechanism.

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