GROWTH HISTORY OF AN ECLOGITIC DIAMOND FROM THE KAAL VALLEI KIMBERLITE, SOUTH AFRICA - AN INFRARED, CATHODOLUMINESCENCE AND CARBON ISOTOPE STUDY.

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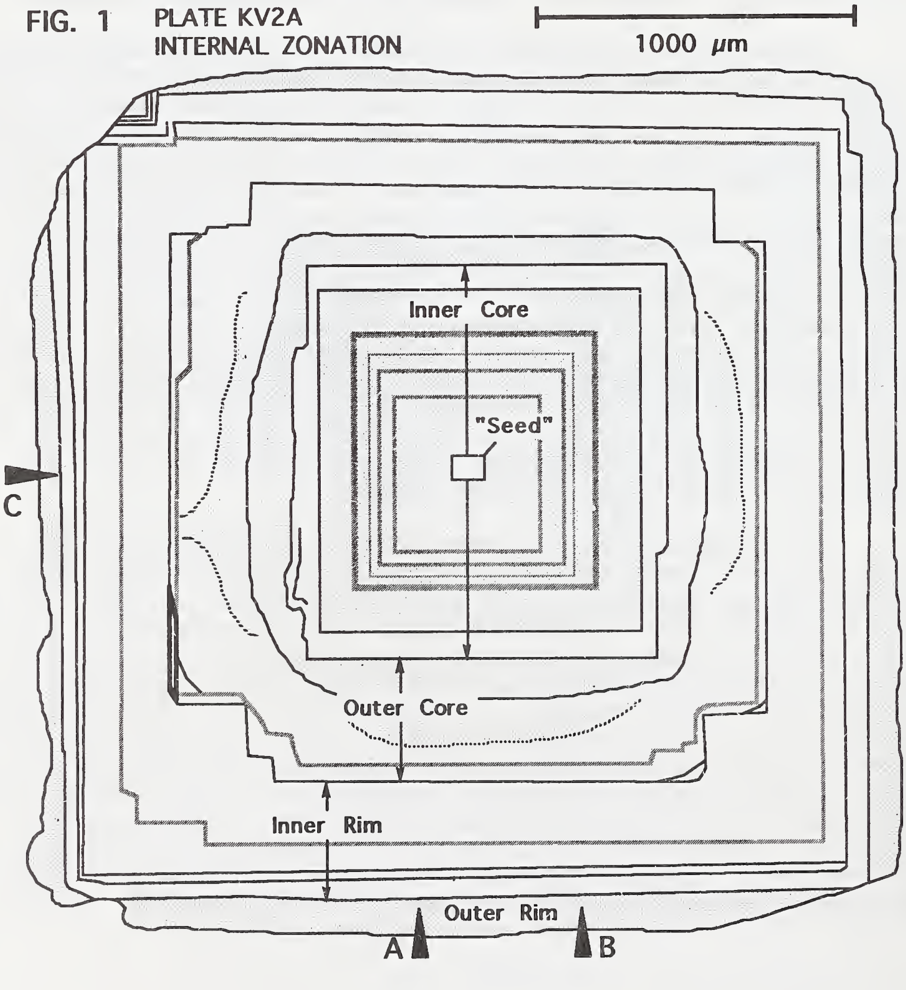
Introduction: A (100) polished section was prepared through an octahedral diamond (KV2A) extracted from an eclogite xenolith from the Kaal Vallei kimberlite, South Africa. The internal structure of the diamond was examined by cathodoluminescence at low and high resolutions. The diamond platė was mapped for hydrogen and nitrogen using a infrared (IR) microscope and several IR traverses across the specimen were undertaken. An ion microprobe carbon isotope study is currently in progress.

Cathodoluminescence Results: The diamond has a complex internal structure that may be roughly divided into four zones (Fig. 1). Located in the growth centre of the crystal is a small ~100 μm diameter "seed" diamond. It has a curious structure comprising deep tetragonal and trigonal etch features now apparently infilled with later diamond. The external shape of the seed is consistent with a resorbed and etched microdiamond which acted as the nucleus for growth of later diamond. An inner core region surrounds the seed and comprises a set of nested octahedra that represent a period of regular octahedral growth. This growth period ends in a phase of platy growth which was followed by a period of cuboid growth in the outer core which lacked strong crystallographic control. The cuboid growth is characterized by fine oscillatory zonation, and development of curious tubercular structures and mismatch features that seem to have developed around original surface imperfections. Towards the end of this growth period the cuboid zones were selectively resorbed and truncated, particularly on the corners, where deep etch pits developed. This was followed by a further thin layer of oscillatory growth which infilled some etch pits. The final growth periods were of regular octahedral diamond and added the inner and outer rims. Minor late stage etching resulted in truncation of corners, development of surface pits, and growth of graphite.

Infrared Results: Results of mapping the hydrogen defect peak (3107 cm-1) show that the inner core is enriched in hydrogen distributed in the form of a central-cross structure. Nitrogen varies from ~1400 atomic ppm in the core to ~500 atomic ppm in the outer rim (Fig. 2). There is a significant drop in nitrogen concentration across the inner core-outer core boundary where the growth mechanism changes from octahedral to cuboid. The aggregation state of nitrogen defects varies smoothly from about 50-55% in the inner core to ~20% in the inner rim, and there is a jump to about 5-10% aggregation in the outer rim. On a total nitrogen versus aggregation state plot, the spectral data from the growth zones define a mixing line rather than a set of discrete isotherms suggesting that most of the diamond grew over a relatively continuous period without a significant hiatus. Assuming an Archean age for the diamond (residence time of 2.7 Ga), aggregation temperatures vary from 1110°C in the inner core, through 1107-1102°C in the outer core and inner rim, to ~1056°C in the outer rim. Platelet indices (see Taylor and Milledge, 1995) increase from core to rim indicating growth occurred in a regime of falling T.

Discussion: A simple, though non-unique, thermal model can be devised to explain the growth and thermal history of diamond KV2A using constraints provided by the nitrogen aggregation data. Assume the host eclogite was intruded at 2.7 Ga as a ~1500°C melt into the cratonic lithosphere at ~5 GPa and this melt crystallized as a 10km thick eclogite "sill". Assume further that the diamond began to crystallize from an initial nucleus during the latter stages of crystallization and cooling of this eclogite body and that the eclogite eventually cooled to the ambient cratonic geotherm. Under such conditions using standard thermal equations for cooling of an igneous body (e.g Spear, 1993, p.44), the inner core of the diamond would have grown at 2.65Ga, 1184°C and inner rim would have completed growth 70Ma later at 1154°C. The cuboid outer core, developed at an intermediate stage, may have been a consequence of the temperature reduction combined with an increase in the amount of carbon available, and/or conditions under which growth on octahedral faces was "poisoned" by influx of some trace component. In this model, the outer rim would have grown much later during the Proterozoic at ~1.6 Ga and a final heating event late in the history of the eclogite body (at <200 Ma) is required to explain the appearance of graphite. A final heating is consistent with high observed xenolith temperatures (~1120°C) and the fact that the eclogite was completely isotopically re-equilibrated during the Cretaceous.

FIG. 1 PLATE KV2A INTERNAL ZONATION



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References:

Spear, F.S. (1993) Metamorphic phase equilibria and pressure-temperature-time paths. Mineralogical Society of America, Washington D.C.

Taylor, W.R. and Milledge, H.J. (1995) Nitrogen aggregation character, thermal history, and stable isotope composition of some xenolith-derived diamonds from Roberts Victor and Finsch. 6th IKC Abstracts (this volume).

FIG. 2 KV2A Nitrogen Variation: Traverses A, B and C