CATHODOLUMINESCENCE OF CO_2-BEARING AND CO_2-FREE DIAMONDS FROM THE GEORGE CREEK K1 KIMBERLITE DYKE, COLORADO-WYOMING STATE LINE DISTRICT.

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Cathodoluminescence (CL) provides a powerful method of investigating the complex growth and deformation history experienced by many natural diamonds. Primary growth features such as octahedral growth zonation may be recognized from CL, and in many cases this growth zonation has been repeatedly truncated by resorption surfaces. Considerable heterogeneity, for example in nitrogen content and aggregation state, exists in many diamonds. Cathodoluminescence studies may thus provide important spatial information to assist in the interpretation of Infra-red (IR) and stable isotope analyses of diamonds.

Most Type Ia diamonds exhibit variable blue CL generated by electron-donor and electron-acceptor pair recombinations (Walker, 1979). In addition, platelets (planar aggregates on cubic lattice planes) are often detected in CL photomicrographs of Type Ia diamonds with the characteristic platelet absorption in the IR region at $\sim 1365\ cm^{-1}$. CO_2-free diamond plates from George Creek exhibit the customary blue luminescence and variable platelet distribution recognized in most type Ia diamonds.

Comparison of CL photomicrographs with spectral data from IR mapping traverses suggests that large platelets develop in zones of relatively low substitutional nitrogen content, whereas smaller platelets are found in zones richer in nitrogen. This may be explained by the Woods (1985) model for platelet formation, which involves platelet formation from the aggregation of interstitial carbon atoms. These carbon atoms are ejected into the lattice by the formation of B nitrogen aggregates (which are thought to consist of four substitutional nitrogen atoms arranged around a vacancy). High nitrogen contents would promote rapid nitrogen aggregation and hence rapid nucleation of platelets, which would be of smaller size than platelets which grow in zones of lower nitrogen content and lower nucleation density.

In many George Creek diamonds yellow-green slip lines transect CO_2-free zones of blue cathodo-luminescence, indicating that these diamonds have undergone extreme plastic deformation during mantle residence. Diamonds which exhibit intensive development of plastic deformation features generally lack evidence of platelets in their IR spectra and also lack visible platelets in the CL photomicrographs. This is consistent with the proposal that platelets increase the resistance of diamonds to deformation processes by impeding the migration of dislocations (Evans, 1976).

A polished plate of a CO_2-free diamond shows a dramatic "brecciated" texture comprising irregular and curvilinear fragments delineated by subtle variations in CL colour and intensity. This diamond contains a number of rutile inclusions, and IR spectroscopy has revealed their hydrous nature. The brecciation visible in the CL photomicrograph may be the result of hydrogen loss from the rutile inclusions, or may be due to an increase in molar volume accompanying the phase transition from rutile-type structure to α-PbO_2-type structure which occurs with decreasing pressure.

Such brittle deformation in diamond has not been described before, and is particularly striking, considering that some external regions of the diamond show intense development of yellow-green slip lines indicative of plastic deformation. This disparity in deformation styles may be explained if the diamond is composed of two different growth generations which had experienced different styles of deformation before being amalgamated during a later growth episode. Alternatively disparate platelet content and inclusion content between the two zones may have caused them to behave differently during the same deformation event. The thickness and heterogeneity of the plate prevented confirmation of this proposal from IR spectra, but visual inspection proved that the "brecciated" region contains a greater concentration of rutile, garnet, sulphide and graphite inclusions.

The CO_2-bearing diamond growth generation is characterized by anomalous pink, pale purple, orange and brown luminescence. The CL colours are similar to those seen in yakutite– an impact-generated mixture of cubic diamond and hexagonal diamond (londsdaleite) found associated with the Popigai astrobleme in Russia. Absorption peaks due to the presence of CO_2 are also found in yakutite (Milledge *et al.*, 1994), and it thus appears that CO_2-bearing diamonds are characterized by anomalous CL.

Cathodoluminescence photomicrographs of polished plates reveal extremely complex intergrowth relationships between CO_2-free and CO_2-bearing components of single diamonds. The age relationship between the two diamond growth generations is often equivocal, but in no instance does the CO_2-bearing generation convincingly appear to be older than the CO_2-free generation. In diamonds which contain central regions of CO_2-bearing diamond, the morphology of the CO_2-bearing generation suggests that it represents a secondary generation which has grown in etched inclusion cavities. The CO_2-bearing diamond thus appears to be younger in age, and in many diamonds has invaded fractures and embayments of the earlier generation of CO_2-free diamond which had previously experienced severe deformation and etching.

Features analogous to those formed by annealing of fluid inclusions in quartz have been recognized within zones of anomalous CL associated with CO_2-bearing diamond (A.H. Rankin, pers. comm., 1993). Prolonged mantle residence of CO_2-bearing diamonds at elevated temperatures may have facilitated the formation of planes of smaller pseudo-secondary inclusions. A decrease in the size of the CO_2 inclusions as a result of annealing processes may have increased the potential of the inclusions to withstand decrepitation. The anomalous CL of the CO_2-bearing diamond growth generation is consistent with the location of CO_2 in sub-microscopic lattice defect sites.

References:

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