

Carbon Isotope Mapping and Diffusion in Diamond

B. Harte and J. Craven

Grant Institute of Earth Science, School of GeoSciences, University of Edinburgh.

Background and Objectives

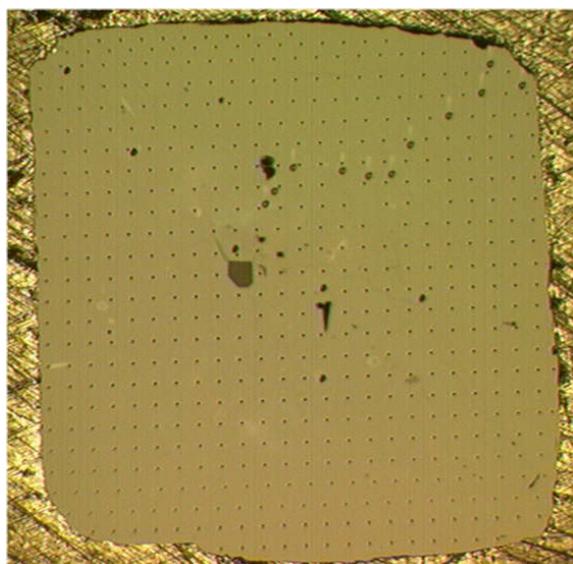
The carbon isotope composition of natural diamonds is widely used as an indicator of their conditions of formation and the source of the fluid/melt from which they precipitate in the Earth's mantle [1, 2]. Given that estimates of the ages of natural diamonds are commonly more than 1000 million years [3], and that mantle residence temperatures are widely expected to be between 1200-1400°C, the possibility arises that the initial carbon isotope composition of the diamond may be modified by diffusion while at depth in the mantle [4].



Up to the present, ion microprobe determinations of carbon isotope ratio in diamonds have been done by a few analyses at selected points across the crystals [4, 5] and these point analyses are then compared with the growth zones in the diamond revealed by cathodoluminescence (CL). Studies of different diamonds show both the absence and presence of variations in carbon isotopes in conjunction with growth zones [4, 6], but the detail of isotope ratio variation in relation to growth zone structure has not been determined. Clearly, the extent of detailed correspondence of carbon isotope compositions with the original growth zone structure across a whole crystal would provide a test of whether extensive diffusive modification had occurred subsequent to crystal growth. The purpose of the measurements reported here was to map carbon isotope compositions in sufficient detail to examine this correspondence.

Method

The new Cameca ims 1270 ion microprobe enables rapid, high precision analyses to be performed automatically over long periods of time so it is now possible to map minerals for minor variations in isotopic ratios.



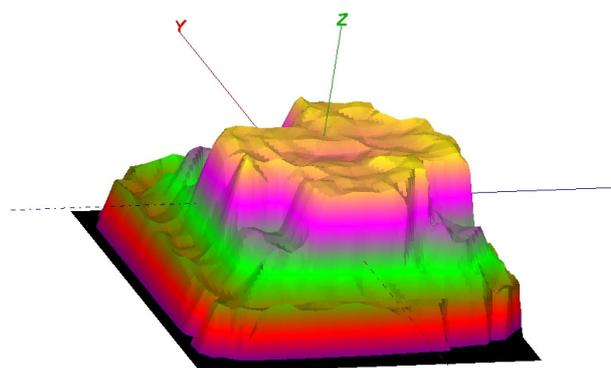
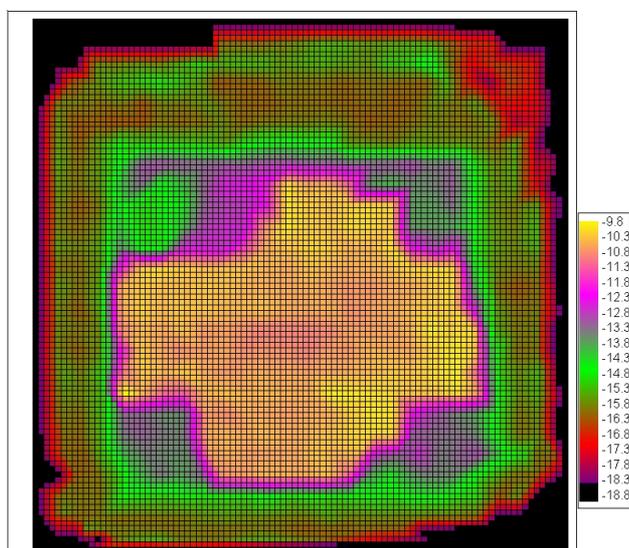
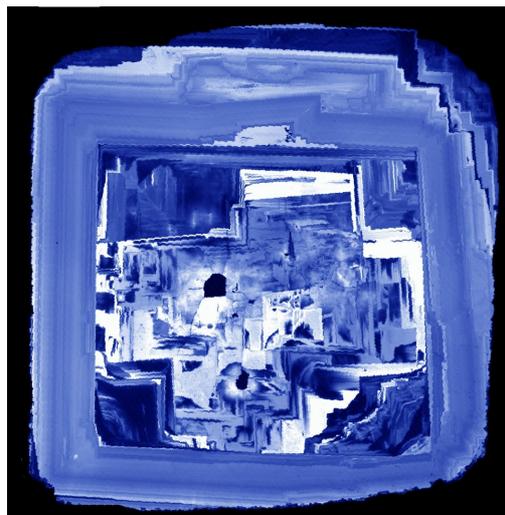
The diamond crystal selected for measurement was mounted in indium between two standards of known isotopic composition. The reflected light photograph shows the array of ion probe pits that were used to create the contour plots of $\delta^{13}\text{C}$. Larger pits used for Nitrogen analysis can also be seen together with less reflective silicate inclusions of coesite and clinopyroxene.

Point determinations on the sample were made at 100 μm intervals along line transects which were themselves 100 μm apart – making a grid of 26 lines with up to 24 points per line. Five measurements were made on the standard crystals at the start and end of each line – thus enabling calibration of the sample measurements for each line against 10 standard measurements.

Results

The diamond selected for study is part of the collection from Guaniamo, Venezuela, investigated by Schulze et al. [7], and is notable for its complex CL pattern, which has led to it being referred to as the 'Picasso' diamond and figured in *Nature* (volume 423, page 24) and on the cover of the 8th International Kimberlite Conference Hawthorne volume (2004). The CL image is shown opposite.

The collected carbon isotope data, forming a grid of points at 100 μ m intervals, have been contoured to yield a map of carbon isotope variation across the whole crystal.



Contour Plot showing the range in $\delta^{13}\text{C}$ from -9.8 (yellows) to -17.8 (reds)

3-D construction of the contoured $\delta^{13}\text{C}$

Discussion

As may be seen the growth pattern of the CL image is matched exceptionally closely by the carbon isotope map. This matching includes details of the four corners of the inner areas as well as the overall growth patterns. Clearly, there is no evidence of disturbance of carbon isotope compositions subsequent to growth by diffusive equilibration across the growth zones. This result strongly supports the view that the $\delta^{13}\text{C}$ values measured on natural diamonds are directly related to the $\delta^{13}\text{C}$ composition of the mantle fluid reservoir from which the diamond grew.

References

- [1] Galimov, E.M. *Geochim. Cosmochim. Acta*, 55 (1991) 1697–1708.
- [2] Kirkley, M.B., Gurney, J.J., Otter, M.L., Hill, S.J. and Daniel, L.R. *Appl. Geochem.*, 6 (1991) 477-494.
- [3] Harris, J.W. In Nixon, P.H.(ed.) *Mantle Xenoliths*, Wiley & Sons, (1987) 478-500.
- [4] Harte, B., Fitzsimons, I.C.W., Harris, J.W. and Otter, M.L. *Min. Mag.* 63 (1999) 829-856.
- [5] Hauri E.H., Wang J., Pearson D.G., Bulanova G.P. *Chem Geology* 185 (2002) 149-163.
- [6] Fitzsimons ICW, Harte B, Chinn IJ, Gurney JJ, Taylor WR *Mineral Magazine* 63 (1999) 857-878
- [7] Schulze, D.J., Harte, B., Valley, J.W., Brenans, J.M., & Channer, D.M.De R. *Nature*, 423 (2003) 68-70.

