



# Cyclic growth conditions for Diavik diamonds? Insights from carbon isotopes

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## Introduction

The A154 South Pipe of Diavik Diamond Mine is known for producing exceptionally high quality stones. However, the existence of millions of sub-micron inclusions gives diamond a creamy white to opaque grey colour (Tomlinson, 2005). Such opaque diamond commonly occurs as “coats” surrounding clear diamond, while clear coats on opaque cores are rare. A secondary ion mass spectrometry (SIMS) study has been carried out in order to investigate  $\delta^{13}\text{C}$  variations at scales of tens of microns in clear and opaque diamond.



Figure 1: Bisected and polished diamonds showing typical opaque coats surrounding clear cores.

## Motivation

It is clear that different processes are responsible for the formation of clear and opaque diamond. While it is generally accepted that diamond forms by precipitation from a C-rich fluid (e.g. Stachel et al., 2006, Klein-BenDavid et al., 2007), the mechanisms governing the formation of opaque diamond are poorly understood.

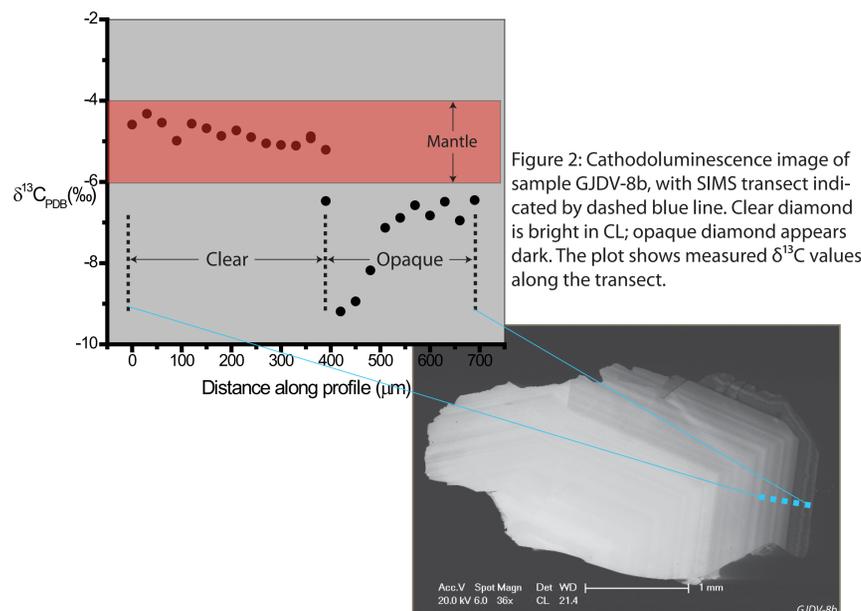


Figure 2: Cathodoluminescence image of sample GJDV-8b, with SIMS transect indicated by dashed blue line. Clear diamond is bright in CL; opaque diamond appears dark. The plot shows measured  $\delta^{13}\text{C}$  values along the transect.

## Carbon Isotopes

- $^{13}\text{C}$  and  $^{12}\text{C}$  partition variably into different mineral and fluid phases
- Stable isotopes of carbon can serve as valuable geochemical tracers



## Growth by Fluid Pulses

Core-coat boundaries are commonly marked by abrupt ( $<100\ \mu\text{m}$ ) decreases in  $\delta^{13}\text{C}$  (Fig. 2), suggesting a similarly abrupt change in geochemical conditions during growth. Following this decrease,  $\delta^{13}\text{C}$  values tend to increase gradually towards more “normal” mantle values.

- Abrupt decrease may be due to influx of low  $\delta^{13}\text{C}$  fluid
- High carbon activity in the new fluid would cause rapid growth of diamond on existing “seed” crystals
- New fluid gradually equilibrates with surroundings, causing the observed gradational return to higher  $\delta^{13}\text{C}$  values

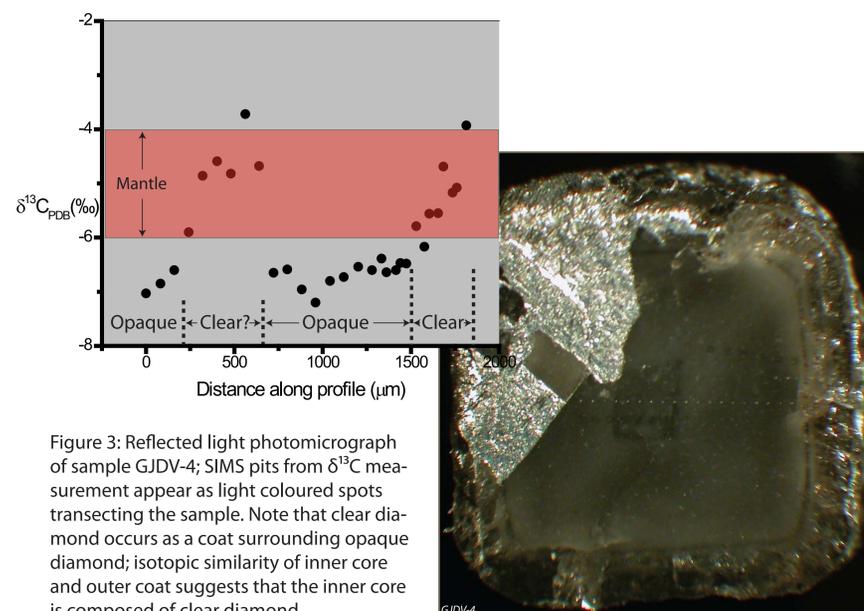


Figure 3: Reflected light photomicrograph of sample GJDV-4; SIMS pits from  $\delta^{13}\text{C}$  measurement appear as light coloured spots transecting the sample. Note that clear diamond occurs as a coat surrounding opaque diamond; isotopic similarity of inner core and outer coat suggests that the inner core is composed of clear diamond.

## Diffusional relaxation of $\delta^{13}\text{C}$ homogeneity

Not all core-coat boundaries show abrupt changes in  $\delta^{13}\text{C}$ , suggesting that diffusion of carbon may have obscured an initially sharp contact. In order to investigate the magnitude of this effect, diffusion of  $^{13}\text{C}$  was modelled using a numerical solution to the continuity equation:

$$\frac{\partial C}{\partial t} = \kappa \frac{\partial^2 C}{\partial x^2}$$

where the proportionality constant  $\kappa$  is the self-diffusion coefficient of carbon and has been determined as a function of temperature by Koga et al. (2003)

After 1 Ga at 1400K, an initially very abrupt ( $0.1\ \mu\text{m}$ ) change from  $-5$  to  $-9\text{‰}$  will be gradational over a length of  $1\text{-}3\ \mu\text{m}$ , while 1 Ma at 2000K will cause the same initial contrast to grade over  $100\ \mu\text{m}$ . A  $3\text{‰}$  change over  $\sim 400\ \mu\text{m}$  similar to that shown in Figure 3 would take approximately 4.5Ga at 1750K, or 17Ma at 2000K.

## Conclusions

- Injection of C-supersaturated, low  $\delta^{13}\text{C}$  fluid is consistent with measured profiles
- Abundant inclusions are also explained by rapid growth due to diamond precipitation from a C-supersaturated fluid
- Diffusion at normal lithospheric mantle temperatures cannot account for the gradational changes in  $\delta^{13}\text{C}$  across clear-opaque boundaries

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