12 IKC
12TH INTERNATIONAL
KIMBERLITE
CONFERENCE
30 YEARS OF DIAMONDS IN CANADA
8-12 July 2024 • Yellowknife

12th International Kimberlite Conference Extended Abstract No. 12IKC-158, 2024

Tales from Diamond Surface Features

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Introduction

The majority of diamonds entrained by kimberlites formed in peridotite and eclogite substrates within the sub-continental mantle lithospheric (SCML) at depths of ~120 – 200 km. Surface textures associated with diamonds recovered or eroded from these sources provide a wealth of information on crystal growth, resorption, kimberlite eruption history, conveyance in sedimentary environments, and the impact of diamond comminution processes. Pioneering research by Robinson (1979) yielded a comprehensive catalogue of diamond surface features, reflecting crystal growth, etching, resorption and transportation processes. This work also placed constraints on the sequence and causes of these events. Robinson (1979) suggested that diamond resorption and etch features developed at depths <100 km (with minor exceptions), coincident with then available experimental constraints on the exsolution of CO_2 and H_2O from kimberlite magmas. However, recent work has suggested that common etch/resorption textures (e.g. tetrahexahedroid forms) were generated by interaction with ascending kimberlite melts, whereas less common, select textures were produced by pre-kimberlite mantle metasomatism - of unspecified timing and nature (e.g. Fedortchouk and Zhang 2011; Fedortchouk 2019). In this study, I review the available evidence for the formation of various diamond surface textures, in an attempt to resolve this conundrum.

Diamond Growth and Resorption Features

Monocrystalline diamonds typically form octahedral crystals, with cubes and dodecahedra being less common/rare. Cathodoluminescence (CL) imaging of diamond plates reveals complex internal growth and resorption structures in some diamonds, particularly those of eclogitic affinity (e.g. Bulanova, 1995). Internal resorbed edges/corners vary from irregular to rounded; the latter resembling tetrahexahedroid (THH) forms. Age estimates for peridotitic diamonds are mostly >3 Ga and ~1-3 Ga for eclogitic diamonds, indicating that diamond resorption (and mantle metasomatic) events have occurred in the SCML in the past. However, it is unclear if these growth/resorption zones represent a continuum of diamond crystallisation or span longer timeframes. Another question is whether the paucity of diamonds <1 Ga reflects a lack of metasomatic events or if later metasomatic events destroyed diamonds (e.g. Giuliani et al. 2023).

Robinson (1979) identified 41 ‘pristine’ external diamond surface textures; two representing diamond growth. The most common diamond etch/resorption features are negatively oriented trigons on octahedral crystal faces and TTH (aka rounded dodecahedral) forms (Fig. 1). Other key octahedral textures include triangular growth plates, shield-shaped laminae, hexagonal pits, positively oriented trigons and serrate laminae. Cubic crystal surface textures include tetragons (positive ± negative), pointed plates and crescentic steps. THH resorption surfaces are typified by various hillock forms and several less common textures (e.g.

corrosion sculpture, shagreen texture, microdisk patterns, ribbing, rhombic serration). Non-specifc textures include lamination lines, ruts, inclusion cavities, knob-like asperities, frosted surfaces and graphite coatings.

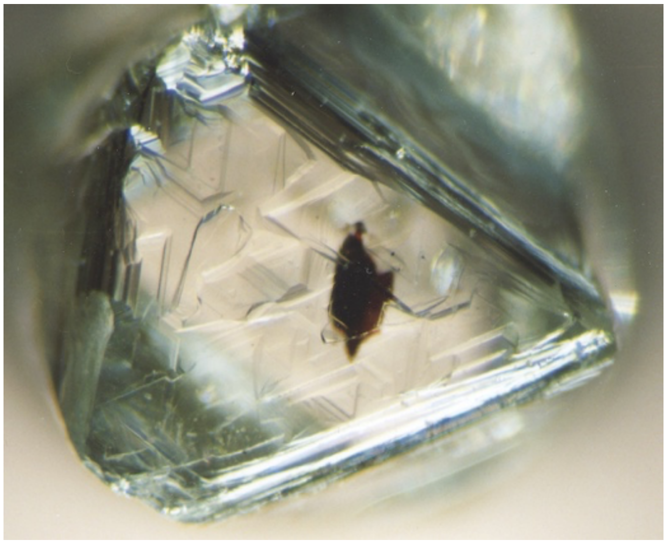

Fig. 1 Octahedral diamond (with Cr-spinel inclusion) showing etch (trigons) and partial resorption (THH) features.

Diamond Resorption Experiments

Low and high pressure experiments using a range of starting compositions (e.g. kimberlite, carbonate ±CO_2 and H_2O) have produced many of the etch/resorption features observed on natural diamonds. These experiments show that H_2O is of particular importance for the formation of negative trigons/tetragons and THH forms (Robinson, 1979). Some etch/resorption features have been produced under distinctly different conditions - for example, positively oriented trigons were observed in both high pressure-temperature experiments on carbonate melts and low pressure-temperature experiments on H_2O-bearing charges.

Diamond Transport in Kimberlite Magmas

Kimberlites are hybrid rocks that have exsolved and lost volatiles *en route* to surface. Consequently, there is significant uncertainty regarding the composition of primitive and primary kimberlite magmas, particularly with respect to volatiles (e.g. Soltys et al. 2018). Current models for kimberlite magmatism invoke a carbonate-silicate primitive magma that progressively assimilates SCLM material on ascent. Assimilation is considered to increase magma silica contents, thereby reducing CO_2 solubility and causing exsolution of CO_2-rich fluids, which facilitates eruption to surface via crack propagation. It is likely that diamonds are progressively released from entrained mantle material (xenoliths) from the time of primitive melt interaction with the SCLM to eruption at surface. At surface, many kimberlite eruption centres encompass multiple pulses of magma, potentially reworking diamond populations from earlier melts.

Surface Features attributed to Kimberlitic Melts versus ‘Pre-Kimberlite Metasomatiasm’

There is general agreement that common diamond etch/resorption features (negative trigons and THH forms) are due to interaction with kimberlite fluids. This interpretation is supported by the commonality of these features in kimberlitic diamonds, the presence of sharper edged octahedra in diamond-bearing xenoliths, observations of pseudo-hemimorphic crystals protruding from xenoliths (sharp octahedral edges within xenoliths and THH forms protruding from xenoliths) and experimental results. Disagreement exists on the development of particular, less common diamond surface textures. For example, it is suggested that features such as ‘sharp-edged’ octahedra with abundant/deep trigons and hexagonal pits, octahedra with negative trigons, ‘irregular asperities’ and ribbed dodecahedra result from pre-kimberlite metasomatism in the SCLM – based on experimental data, nitrogen aggregation results and relative abundance of these features (Fedortchouk and Zhang 2011; Fedortchouk 2019). In contrast, Robinson (1979) attributed these features to resorption by kimberlitic fluids that infiltrated mantle xenoliths prior to diamond liberation.

Discussion

The presence of resorbed internal growth layers in diamonds clearly indicates that resorption by pre-kimberlite mantle metasomatic processes occurs in the SCML. However, a key question is whether etching/resorption by kimberlitic compared to SCLM metasomatic fluids produces distinct surface textures. The rounded edges and corners of many internal resorbed growth layers appear analogous to THH forms; however, 3-D CL (or similar) imaging is required to confirm this suggestion.

There appear to be no definitive arguments for the *exclusive* formation of certain surface textures by pre-kimberlite mantle metasomatic fluids. For example, in the case of sharp-edged octahedra hosting negatively oriented trigons, the lack of overprinting THH forms favours formation by kimberlite fluids infiltrating diamond-bearing mantle xenoliths during entrainment to surface (Robinson, 1979). Similar arguments apply to (rare) knob-like asperities and associated features (e.g. ribbing on dodecahedral surfaces). These textures are found on select eclogite xenolith diamonds and their association with trigons and graphite coatings again suggests formation by infiltration of kimberlitic fluids into xenoliths (Robinson (1979).

The most compelling evidence supporting external resorption of diamonds by SCLM metasomatism comes from studies of diamonds from eclogite xenoliths (e.g. Howarth, 2023). These xenoliths contain both sharp-edged and highly resorbed (rounded) diamonds. However, even in this situation, alternative explanations are possible, including infiltration/reaction with kimberlitic fluids. Here, further work is required to characterise the material surrounding the rounded diamonds.

Acknowledgements

This article is dedicated to the memory of Derek Robinson, a venerable pioneer in diamond research.

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