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Positively oriented trigons on diamonds from the Snap Lake kimberlite dike, Canada: Implications for fluids and kimberlite cooling rates

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Abstract

The role of fluid(s) in the formation of different lithological facies of kimberlites is still poorly understood. The uncertainty in the composition of kimberlite melts hampers understanding the composition of volatiles, the depth of exsolution, and the effect on magma ascent and fragmentation. Recent estimates of H_2O and CO_2 solubility in kimberlite-like magmas suggest very shallow exsolution of fluid, while many features of kimberlites indicate the presence of significant fluid fraction at depth. Deep magmatic fluid produces negative trigonal etch pits on natural diamonds, the characteristics of which depend on the temperature and composition of the fluid. Positively oriented trigonal etch pits are very rare on natural diamonds and are likely a feature of resorption events unique to only some kimberlite magmas. Here we present the first systematic study of positively oriented trigonal etch pits on natural diamonds from Snap Lake kimberlite dike, Northwest Territories, Canada. The study used 91 micro-diamonds selected from a population of 251 diamonds representative of all six kimberlite litho-facies identified in the Snap Lake dike. We established that unlike the majority of diamonds from kimberlite pipes in the Northwest Territories, every studied Snap Lake diamond shows positively oriented trigons. These trigons cover the whole diamond surface starting from the {111} faces and continuing over the resorbed edges. They overprint negatively oriented trigons and modify them into hexagons. Atomic force microscopy obtained detailed geometry of 154 positive trigons on 14 diamonds. Three distinct trigon morphologies dependent on the type of the crystal lattice defect were recognized. The point-bottomed shape and positive correlation between the depth and diameter of the individual pits suggest a high CO_2 content in the fluid. Comparison with the existing experimental data on positive trigons implies resorption at low-pressure conditions in the 800–1000 °C temperature range by trapped magmatic fluid after the dike emplacement. The intensity of this late resorption event (and the size of the positive trigons) increases from the dike contact with the country rock into the interior of the dike. Such a late resorption event is absent in the majority of kimberlites, which form pipes, and might be a specific feature of hypabyssal kimberlite bodies (dikes). The absence of positive trigons on diamonds from the majority of kimberlites suggests very quick magma cooling below ~800 °C after the pipe emplacement, precluding the development of any late resorption features. Our study shows that for kimberlitic magmas, for which mineral chemistry is unable to provide a robust record of magmatic fluid, morphological details of dissolution features on the surface of diamond and other mantle-derived minerals can serve as a fluid proxy. Better constraints of the pressure, temperature, and oxygen fugacity of the reversal in the trigon orientation on diamond may help to reconstruct the emplacement path of geologically diverse kimberlite bodies.

Keywords: Diamond resorption, kimberlitic fluid, Snap Lake kimberlite, trigonal etch pits, atomic force microscope