The evolution of diamond morphology in the process of dissolution: Experimental data

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ABSTRACT

In this paper, we report results of experiments on the dissolution of octahedral, pseudo-dodecahedral, and cubic natural diamond crystals in water-containing carbonate and silicate systems at high-pressure and high-temperature conditions in the diamond stability field. The dissolution agents used include CaCO₃, CaMg(CO₃)₂, CaMgSi₂O₆, and kimberlite from the Udachnaya pipe, Yakutia, with addition of distilled water. The obtained diamond dissolution forms were studied using scanning electron microscopy and double-beam interferometry. A quantitative analysis of rounded diamonds was carried out by the photogoniometry method. The experimental data show that diamonds change their morphology from octahedrons, dodecahedrons, and cubes to tetrahexahedroids when dissolved in water-containing systems. Octahedron transforms into tetrahexahedroid when the weight loss is 20–25%; cube, when the loss is >50%; and pseudo-dodecahedron passes into tetrahexahedroid when the weight loss is as low as 10%. Comparison of crystal morphology, surface features, and goniometric data of diamond dissolution forms produced in water-containing systems and of rounded natural diamonds showed their complete identity. It has been established that the morphological variations of rounded natural diamonds depend on the initial habit of the crystals and the degree of their dissolution. With the significant dissipation of the starting crystals the dissolution forms of initial octahedrons, pseudo-dodecahedron, and cubes are similar. The evolution of the diamond crystals morphology is terminated with the formation of tetrahexahedroid with curvature parameters AB = 36°07', CD = 13°15', and DD = 13°15'. The obtained quantitative data allowed us to construct a scheme for the morphological evolution of natural diamond crystals during their dissolution.

Keywords: Diamond, morphology, dissolution, HPHT experiment

INTRODUCTION

A characteristic feature of natural diamond morphology is the widespread occurrence of rounded crystals. Because they appear similar to flat-faced crystals, these are called rounded dodecahedrons or dodecahedroids (Fersman and Goldschmidt 1911; Kukharev 1955; Orlov 1977; Sunagawa 1984). From a strictly crystallographic viewpoint, with regard to the presence of edges and corners, these diamonds are rounded tetrahexahedrons or tetrahexahedroids (Moore and Lang 1974; Robinson 1978). It was reported (Orlov 1977) that tetrahexahedroids differ from each other in the curvature of rounded surfaces and angles between adjacent surfaces.

The most common opinion is that the morphology of these crystals is a result of dissolution of diamond in kimberlitic and lamproitic magmas (Moore and Lang 1974; Orlov 1977; Robinson 1978; Sunagawa 1984; Gurney et al. 2004). Investigations into the morphology of natural diamonds suggest that, during dissolution, octahedra gradually transformed into transitional forms and, thereafter, into tetrahexahedroids (Sunagawa 1984; Robinson et al. 1989; Otter and Gurney 1989; McCallum et al. 1994). In experiments on diamond dissolution in different media at atmospheric pressure, it was not possible to produce rounded crystals morphologically similar to natural diamonds (Frank and Puttick 1958; Evans and Sauter 1961; Harris and Vanse 1974; Mendelssohn and Milledge 1995). Such rounded diamond crystals were produced only at high pressures and temperatures (Khokhryakov and Pal’yanov 1990, 2004; Arima 1998; Khokhryakov et al. 2001; Kozai and Arima 2005). The experiments showed the important role of water (Kanda et al. 1977; Pal’yanov et al. 1995), CO₂ (Kozai and Arima 2005) and redox conditions (Yamaoka et al. 1980; Arima 1998; Khokhryakov et al. 2002; Kozai and Arima 2005) during the natural dissolution of diamond. However, the variation of diamond morphology upon dissolution has not been studied extensively. Kozai and Arima (Kozai and Arima 2005) studied the morphological evolution for only natural diamond octahedrons. The authors described the morphological characteristics based on a classification scheme where all tetrahexahedroids belong to the same class. However, as we already noted natural diamond tetrahexahedroids have different morphologies and curvature of their rounded surfaces (Kukharev 1955; Orlov 1977).

In the present work, we report the results of experiments on dissolution of octahedral, pseudo-dodecahedral, and cubic crystals of natural diamonds in water-containing carbonate and silicate systems under the mantle P-T conditions and present data on the produced dissolution forms. A quantitative analysis of rounded diamonds was carried out by the photogoniometry method. The change of the morphology of initial octahedrons, pseudo-dodecahedrons, and cubes was traced to 85% initial weight loss. The morphology of produced dissolution forms was compared with that of rounded natural crystals. The data obtained allowed construction of a scheme for the morphological evolution of natural diamond crystals during their dissolution.

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