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Formation of mosaic diamonds from the Zarnitsa kimberlite

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Abstract

Mosaic diamonds from the Zarnitsa kimberlite (Daldyn field, Yakutian diamondiferous province) are morphologicaly and structurally similar to dark gray mosaic diamonds of varieties V and VII found frequently in placers of the northeastern Siberian craton. However, although being similar in microstructure, the two groups of diamonds differ in formation mechanism: splitting of crystals in the case of placer diamonds (V and VII) and growth by geometric selection in the Zarnitsa kimberlite diamonds. Selective growth on originally polycrystalline substrates in the latter has produced radial microstructures with grains coarsening rimward from distinctly polycrystalline cores. Besides the formation mechanisms, diamonds of the two groups differ in origin of mineral inclusions, distribution of defects and nitrogen impurity, and carbon isotope composition. Unlike the placer diamonds of varieties V and VII, the analyzed crystals from the Zarnitsa kimberlite enclose peridotitic minerals (olivines and subcalcic Cr-bearing pyropes) and have total nitrogen contents common to natural kimberlitic diamonds (0 to 1761 ppm) and typical mantle carbon isotope compositions (–1.9 to –6.2‰ $\delta^{13}C$; –4.2‰ on average). The distribution of defect centers in the Zarnitsa diamond samples fits the annealing model implying that nitrogen aggregation decreases from core to rim.

Keywords: diamond; inclusions; peridotitic minerals; Zarnitsa kimberlite

Introduction

The Zarnitsa kimberlite is the first pipe discovered in 1954 by L. Popugaeva (Moor and Sobolev, 1957; Sarsadskikh and Popugaeva, 1955) in the Daldyn field of the Daldyn–Alakit district, Yakutian diamondiferous province, 14 km east of Udachnyi town (Fig. 1). According to U–Pb dating of zircons from kimberlites and from alluvium of the area, kimberlite magmatism in the Siberian craton had a long multistage history (Davis et al., 1980), with five distinct events of Late Ordovician, Late Silurian, Late Devonian, Late Triassic, and Late Jurassic. The Zarnitsa kimberlite emplaced in the Late Devonian. Kimberlites in the Daldyn–Alakit district are overlain by Middle Carboniferous clastic sediments and Triassic continental flood basalts, the so-called Siberian traps (Milashev and Rozenberg, 1974). The Triassic event of trap magmatism at 252 Ma lasted for a million of years (Burgess et al., 2015) and produced an igneous province occupying millions of square kilometers in the northern Siberian craton. Generally, the age range of trap magmatism in the craton can be estimated as 1500 to 252 Ma, given the existence of the Kuonamka large igneous province (Ernst et al., 2016).

The Zarnitsa kimberlite is located among Ordovician sediments on a flat divide between the Diyakha and Zagadochnyi Brooks that flow into the Daldyn River (Sobolev, 1959). With its surface area of 535×480 m^2 (about 32 ha), it is one of largest kimberlites in Yakutia, the second largest after the Yubileinaya pipe. The Zarnitsa kimberlite has a complex structure and results from several emplacement events. The kimberlite comprises species of five types that differ in color, contents of xenoliths, and postmagmatic alteration patterns. Its mineralogy (Smirnov, 1959) is generally comparable with that of other kimberlites in the Siberian craton and in South Africa. The hosted diamonds show a very uneven size distribution: small amounts of fine octahedral crystals are balanced by the presence of large gem-quality diamonds (Kharkiv et al., 1998), such as a $3.8 \times 3.7 \times 1.8$ cm, 207.3 carat crystal recovered in 2016 (called “Children of Asia”). The kimberlite deposit has been mined since 1999–2000, and open-pit mining is planned for thirty coming years.

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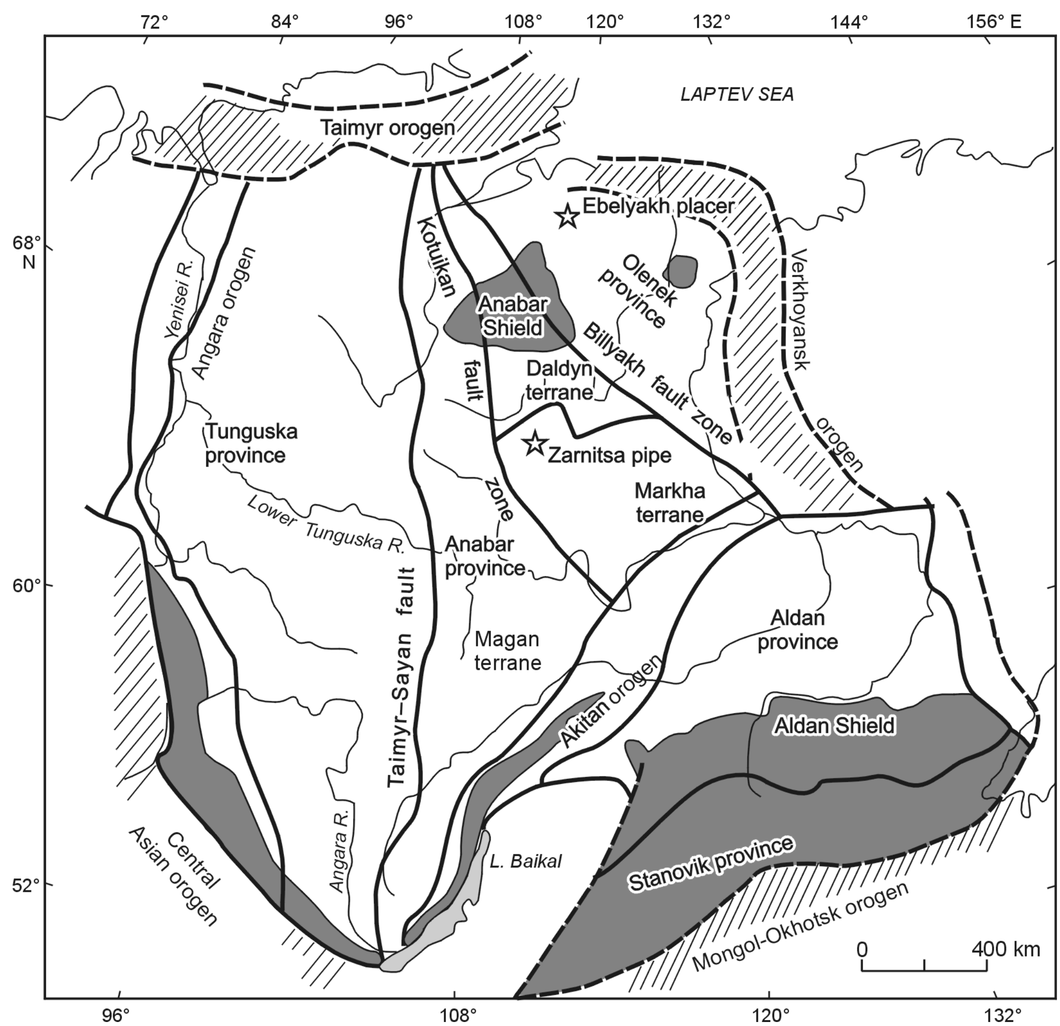

Fig. 1. Location of Zarnitsa kimberlite in simplified tectonic map of Siberian craton, after (Koreshkova et al., 2011; Rozen et al., 2006). Gray and white fields, respectively, are outcrops of Precambrian rocks and post-Riphean sediments; cross hatching shows Phanerozoic orogens; heavy lines are boundaries of provinces (suture zones); dashed lines are boundaries of orogens; asterisks mark Daldyn kimberlite field (Zarnitsa pipe) and Ebelyakh placer.

There is limited published evidence on the Zarnitsa kimberlite. Most of its diamond crystals (96%) are of variety I according to the classification of Orlov (1984); others are gray polycrystalline aggregates (variety VIII), rimmed with variety IV diamonds and cubes of variety II (Kostrovitskii et al., 2015). Among the crystals of variety I, 23% are octahedrons, 20% are rhombic dodecahedrons with laminar faces, 17% have transitional habits, and 29% are quasi-dodecahedrons. According to available data (Bulanova et al., 1999), most of the Zarnitsa diamonds enclose peridotitic minerals (23 from 30 analyzed diamonds), mainly olivines (Fo = 92–93 mol.%) and chromites (62–67 wt.% Cr_2O_3), with minor amounts of subcalcic garnets and PGE-bearing pentlandite. Inclusions in eclogitic diamonds are sulfide phases, omphacite, and pyrope-almandine-grossular garnets with the chemistry similar to that from other deposits in the Siberian craton (Bulanova et al., 1993; Sobolev, 1977). Previously determined (Klein-Ben-David et al., 2009) mineral chemistry of microinclusions in three samples of cubic diamonds from the Zarnitsa kimberlite suggests their origin from a highly magnesian carbonatite fluid/melt. Similar composition features were earlier revealed for cubic diamonds and for diamonds with cloud inclusions from the Internatsionalnaya and Yubileinaya kimberlites (Logvinova et al., 2008; Zedgenizov et al., 2009), and later for placer diamonds from the northeastern Siberian craton (Logvinova et al., 2011; Zedgenizov et al., 2011), as well as for coated diamonds from the Sytykan kimberlite (Skuzovatov et al., 2012).

The Zarnitsa diamonds share some morphological similarity with dark gray diamonds of varieties V and VII according to the classification of Orlov (1984), widespread in placers of the northeastern Siberian craton, derived from still unknown primary deposits (Afanas'ev et al., 1998, 2002, 2011; Ragozin et al., 2002, 2009, 2016a; Smith et al., 2014, 2015). The features of similarity with variety V diamonds include transitional octahedral-to-quasi-dodecahedral habits, the microtopography of grain surfaces with trigonal pits, drop-shaped hillocks, sheaf-shaped striation, etch channels, etc., and a radial mosaic microstructure uncommon to natural diamonds (Ragozin et al., 2017). Both the Zarnitsa kimberlite and placer