Enigmatic diamonds from the Tolbachik volcano, Kamchatka

ERIK M. GALIMOV1, FELIX V. KAMINSKY1,*, SVETLANA N. SHILOBREEVA1, 
VYACHESLAV S. SEVASTYANOVI, SERGEI A. VOROPEV1, GALINA K. KHACHATRYAN2, 
RICHARD WIRTH3, ANJA SCHREIBER3, VLADIMIR V. SARAYKIN4, GENNADY A. KARPOV5, 
AND LEONID P. ANIKIN5

1Vernadsky Institute of Geochemistry and Analytical Chemistry, Russian Academy of Sciences, Kosygin Street 19, Moscow 119334, Russian Federation 
2Central Research Institute of Geological Prospecting for Base and Precious Metals, Varshavskoye Shosse 129, Moscow 117545, Russian Federation 
3Helmholtz Centre Potsdam, GFZ German Research Center for Geosciences, 3.5 Surface Geochemistry, Telegrafenberg, C120, D-14473 Potsdam, Germany 
4Institute of Physical Problems, Zelenograd 124460, Russian Federation 
5Institute of Volcanology and Seismology, Russian Academy of Sciences, Petropavlovsk–Kamchatskii 683006, Russian Federation

ABSTRACT

Approximately 700 diamond crystals were identified in volcanic (mainly pyroclastic) rocks of the Tolbachik volcano, Kamchatka, Russia. They were studied with the use of SIMS, scanning and transmission electron microscopy, and utilization of electron energy loss spectroscopy and electron diffraction. Diamonds have cube-octahedral shape and extremely homogeneous internal structure. Two groups of impurity elements are distinguished by their distribution within the diamond. First group, N and H, the most common structural impurities in diamond, are distributed homogeneously. All other elements observed (Cl, F, O, S, Si, Al, Ca, and K) form local concentrations, implying the existence of inclusions, causing high concentrations of these elements. Most elements have concentrations 3–4 orders of magnitude less than chondritic values. Besides N and H, Si, F, Cl, and Na are relatively enriched because they are concentrated in micro- and nano-inclusions in diamond. Mineral inclusions in the studied diamonds are 70–450 nm in size, round- or oval-shaped. They are represented by two mineral groups: Mn-Ni alloys and silicides, with a wide range of concentrations for each group. Alloys vary in stoichiometry from MnNi to Mn5Ni, with a minor admixture of Si from 0 to 5.20–5.60 at%. Silicides, usually coexisting with alloys, vary in composition from (Mn,Ni)5Si to (Mn,Ni)2NiS1 and Mn2Si2, and further to MnSi, forming pure Mn-silicides. Mineral inclusions have nanometer-sized bubbles that contain a fluid or a gas phase (F and O). Carbon isotopic compositions in diamonds vary from –21 to –29‰ δ13CVPDB (avg. = –25.4). Nitrogen isotopic compositions in diamond from Tolbachik volcano are from –2.32 to –2.58‰ δ15NAP. Geological, geochemical, and mineralogical data confirm the natural origin of studied Tolbachik diamonds from volcanic gases during the explosive stage of the eruption.

Keywords: Diamond, Kamchatka, caviatation, silicide, carbon isotope, nitrogen isotope, volcanic gases, volatiles

INTRODUCTION

Numerous finds of diamonds in products of an eruption from six volcanoes in Kamchatka and Kuril Islands are known to date. They extend from the Atlasov Island, northern Kuril Islands (the Alaid volcano) in the south up to Koryakia in northern Kamchatka (Kutyev and Kutyeva 1975; Kaminskyy et al. 1979; Baidakov et al. 1995; Seliverstov 2009; Kaminsky et al. 2016, 2019). In 2013–2014, a series of diamonds was identified in volcanic rocks of recent (2012–2013) fissure eruption of the Tolbachik volcano (Anikin et al. 2014). They are considered as a phase formed from volcanic fluids (Gordee et al. 2014; Karpov et al. 2014; Silaev et al. 2015; Galimov et al. 2016a, 2016b). The existence of diamonds in conditions that do not carry out any evidence of the presence of high pressure in their medium raises discussions about the origin of these diamonds. Suggestions about their origin as the result of cavitation, CVD mechanism, and even that they are the result of technical contamination were expressed (Litasov et al. 2017). Therefore, we performed an additional, more detailed study of the Tolbachik diamonds that may enlighten the origin of these enigmatic diamonds.

SAMPLES AND METHODS

Geological setting

The Plosky (Flat) Tolbachik volcano, 3085 m high, is located at 55°50.0’ N and 160°22.5’ E within Eastern Kamchatka approximately 340 km northeast of Petropavlovsk-Kamchatsky. It is a Hawaiian type volcano, belonging to the southern part of the Klyuchevskaya volcano group, which is one of the world-known volcanic areas with recent volcanic activity. It has some features, which discriminate it from typical subduction-zone volcanoes, first of all by high alkali contents (up to 7 wt% Na2O + K2O) and great depth (180–190 km) of the subducting slab beneath the volcano (Gorbakov et al. 1997). The age of the Tolbachik volcano is 10000 yr (Brautseva et al. 1995). From July 1975 to December 1976, a fissure eruption took place in the southern part of the Plosky Tolbachik, which was called “the Great Tolbachik Fissure Eruption” and studied in detail (e.g., Fedotov and Markhinin 1983).

The volcanic activity in this area resumed on November 27, 2012, and continued