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Mineralogical criteria for the diamond potential of Upper Triassic placers on the northeastern margin of the Siberian Platform

N.V. Sobolev *, A.M. Logvinova, E.I. Nikolenko, S.S. Lobanov

V.S. Sobolev Institute of Geology and Mineralogy, Siberian Branch of the Russian Academy of Sciences, pr. Akademika Koptyuga 3, Novosibirsk, 630090, Russia

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Abstract

Representative sampling of a diamond-bearing basal horizon in the Carnian Stage (Upper Triassic) on the northeastern margin of the Siberian Platform revealed a wide spectrum of indicator minerals, first of all, garnets, whose compositions are the same as in the inclusions in the regional diamonds. Of special interest are garnets of potential eclogite paragenesis with an abnormally high impurity of MnO (0.5–3.2 wt.%), which was earlier detected in more than 20% of garnets present as inclusions in diamonds of northern Quaternary placers and recommended as a new mineralogical criterion for diamond presence. Subcalcic Cr-pyropes of dunite–harzburgite paragenesis were also found in variable amounts, from 0.7 to 3.9 rel.%, in the sample of 973 grains of pyropes of lherzolite and websterite parageneses. Three grains contain 11.9, 12.6, and 16 wt.% Cr_2O_3, which corresponds to the presence of 30–34% of Mg–Cr-knorringite component. Such pyropes have been revealed for the first time in the study region. Cr-spinels are a mixture of compositions typical of kimberlites and the regional alkali-ultrabasic rocks. All studied samples contain picroilmenites with a variable content of Cr_2O_3 impurity. Since Mg–Fe–Ca-garnets with Mg# < 35 can be partly hosted in metamorphic rocks of the Anabar Shield, the elevated content of Na_2O impurity (>0.09 wt.%) was also taken into account. The different contents of indicator minerals in the samples might be due to the variable composition of the diamond orebodies. The Carnian placers call for new systematic sampling. Special attention should be given to estimation of the composition of garnets of presumably eclogite paragenesis with elevated contents of TiO_2, MnO, CaO, and Na_2O and to search for perovskite and Nb-containing rutile. These minerals, together with zircons, are of interest for determining the U–Pb isotopic age of probable diamond orebodies—kimberlites.

Keywords: diamond; eclogitic garnet; pyrope, Cr-spinel; picroilmenite; mineralogical criteria for diamond potential

Introduction

The Yakutian diamondiferous province includes 25 kimberlite fields with about 1000 kimberlite bodies (Fig. 1). Its northeastern part, located in the least accessible and unexplored area of the Siberian Platform, is of special interest. It is bounded by the coast of the Laptev Sea in the north and the Lena River in the east and extends into the Anabar Shield, up to the administrative boundary with the Krasnoyarsk Territory, in the west. About 70% of all proved and predicted resources of placer diamonds of the Russian Federation are localized in this vast area of the Yakutian diamondiferous province (Grakhanov et al., 2007; Zinchuk and Koptil', 2003). Exploration of these Arctic areas is an urgent problem (Dobretsov and Pokhilenko, 2010).

In the mentioned part of the diamondiferous province, called the Lena–Anabar subprovince and occupying about 400,000 km^2, the repeatedly redeposited Quaternary diamond placers occur at hundreds of kilometers from each other. The repeated mixing of diamonds in all placers is evidenced by their similar typomorphic features. The largest placers are in the Anabar diamondiferous region (Zinchuk and Koptil', 2003).

In contrast to the more southern regions and kimberlite fields (Arctic Circle and zones south of it) of Paleozoic age, which include all known mined primary diamond deposits (Agashev et al., 2004; Davis et al., 1980; Kinny et al., 1997), the northeastern area of the province has weakly diamond-bearing or barren kimberlite pipes of Mesozoic age (Agashev et al., 2004; Davis et al., 1980). The only exclusion is the Triassic Malokuonapskaya kimberlite pipe (Khar'kiv et al., 1998) with the near-commercial content of diamonds. A classical example of a barren kimberlite pipe is the Obnazhennaya pipe, whose Mesozoic (Jurassic) age was established at the beginning of study of Yakutian kimberlites (Milashev and

* Corresponding author.
E-mail address: sobolev@igm.nsc.ru (N.V. Sobolev)

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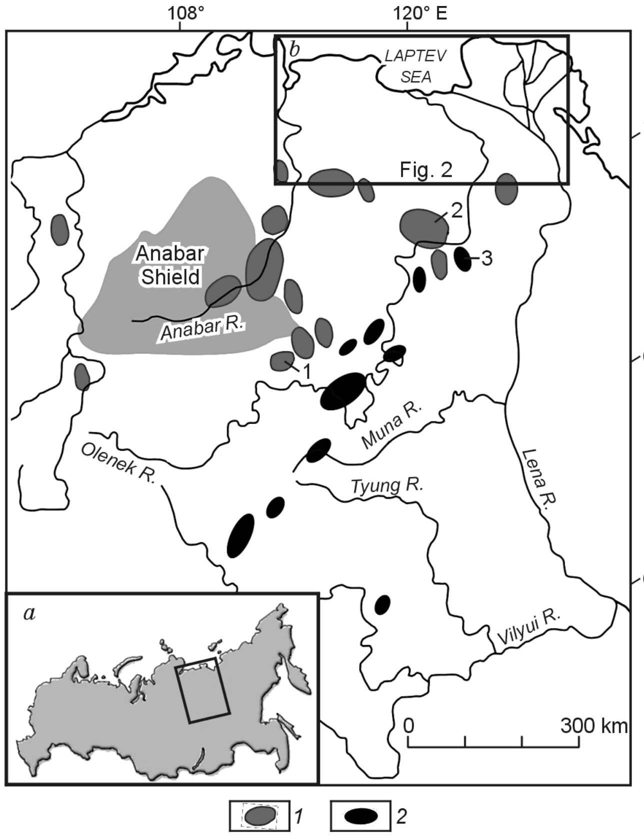

Fig. 1. Schematic occurrence of Mesozoic (*1*) and Paleozoic (*2*) kimberlite fields within the Siberian Platform, after Sobolev et al. (1999). 1–3, Approximate location of the Malokuonapskaya kimberlite pipe (1) in the Kuranakh kimberlite field, Obnazhennaya pipe (2) in the Kuoik kimberlite field, and the Ivushka pipe (3) in the Toluop kimberlite field. *a*, Location of the study area on the map of Russia; *b*, area shown in Fig. 2.

Shul'gina, 1959). Its comprehensive mineralogical investigations did not reveal indicators of diamonds (Sobolev, 1974). The Ivushka pipe, one of the oldest (Paleozoic) diamond-bearing pipes in the same region, overlain by Permian deposits, was discovered by the Amaka expedition in 1991, based on the scientific prediction substantiated earlier by the research works performed by the Institute of Geology and Geophysics, Novosibirsk, and by the proof of the diamond potential of the Lower Carboniferous gravelstones in the Kyutyungde trough (Sobolev et al., 1981).

The goal of this work was to generalize the results of sampling of the basal horizon in the Carnian Stage (Upper Triassic) on the Laptev Sea coast and to compare the compositions of garnets, Cr-spinels, and ilmenites from the samples with the compositions of the same minerals from diamonds of the Quaternary regional placers.

Specifics of placer diamonds

Diamonds from northern placers are highly diverse and were used for the general classification of diamonds (Orlov, 1973). This classification includes diamonds of types V and VII, not found in kimberlites yet and widespread only in northern placers (Afanas'ev et al., 2011). Rounded cryptolaminar dodecahedra are also abundant. They are usually called diamonds of the Uralian and Brazil type (type I, after Orlov (1973)), since such diamonds are typical of placers in the Urals and Brazil (Kukharenko, 1955). Diamonds of these types occur approximately in equal proportions in the considered placers.

Morphologic specific features are a crucial identification sign of the presence of kimberlite and placer diamonds, which makes it possible to distinguish between diamonds from different kimberlite fields and pipes (Orlov, 1973). Study of the physical properties of diamond, especially the carbon isotope composition (Sobolev et al., 1979), assessment of the abundance of various mineral inclusions in diamonds (Efimova and Sobolev, 1977), and analysis of their chemical composition are also of exceptional significance. Early investigations already led to the conclusion about the obvious genetic relationship of kimberlite and placer diamonds to two main geochemical (geologic) types of upper-mantle substratum (depths greater than 120–150 km): ultramafic (peridotitic) (U(P)-type) and eclogite (E-type) (Meyer and Boyd, 1972; Sobolev, 1974; Sobolev et al., 1969a). The validity of this type division was confirmed by the numerous findings of both xenoliths of diamond-bearing peridotites and eclogites in kimberlites from different Earth's regions, including the earliest findings within the Yakutian kimberlite province (Bobrievich et al., 1959; Sobolev, 1960; Sobolev et al., 1969b, 1972), and primary (syngenetic) inclusions in diamonds. The U-type parageneses include high-Mg minerals, such as olivine, enstatite, Cr-diopside, high-Cr pyrope and Cr-spinel, and phlogopite (Sobolev et al., 2009b). The E-type parageneses include Fe–Mg-garnets with variable contents of Ca and a Na impurity being an indicator of ultrahigh pressures (Sobolev and Lavrent'ev, 1971), omphacite, rutile, ilmenite, coesite, sanidine, corundum, disthene, and biotite. There is also an intermediate websterite (pyroxenite) type of paragenesis. Classification of the main types of parageneses in natural diamonds was supported by prolonged research and is almost generally accepted today (Shirey et al., 2013, Table 1).

The ratio of the recognized types of parageneses varies in diamonds of kimberlite fields and pipes of different world diamondiferous provinces, but in general, the U-type paragenesis significantly dominates over the E-type one, especially in Yakutian kimberlites (Efimova and Sobolev, 1977; Meyer, 1987). In Yakutian primary deposits, U-type paragenesis was revealed in almost 99% of all diamonds measuring 1–4 mm and containing syngenetic inclusions; such diamonds are the most abundant and typical of kimberlites. The same ratio is confirmed by study of the carbon isotope composition of diamonds, which showed "heavy" $\delta^{13}C$ values (from 2 to 8‰) in most of diamonds with U-type paragenesis and "light" values (from 8 to 34‰) in most of diamonds with E-type paragenesis (Cartigny, 2005; Shirey et al., 2013; Sobolev et al., 1979). This method is of crucial significance for identifying a probable U- or E-type paragenesis in diamonds lacking mineral inclusions (Galimov, 1984; Sobolev et al., 1979) and