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Review

Oxygen isotopic composition as an indicator of ruby and sapphire origin: A review of Russian occurrences

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This study combines our own new and literature data on oxygen isotopic compositions of corundum from the Russian territory including deposits in Karelia, Ural, Baikal and Far East regions. Corundum and associated minerals from placer and lode deposits are discussed in this review. The oxygen isotopic compositions of the colored corundum commonly result from mixing of meteoric (including glacial), crustal (metamorphic–metasomatic), and mantle magmatic waters. The individual values closely match the oxygen isotopic values in the host rocks. This allows identification of the sources for placer corundum using the $\delta^{18}O$ value as an important component for accurate diagnostics of the gemstones. Some corundum, especially from northwestern Karelia, has extreme isotopic characteristics ($\delta^{18}O$ down to −26.3‰), which almost invariably indicate its source location.

Contents

1. Introduction

The $^{18}O/^{16}O$ ratio between stable isotopes of oxygen ($\delta^{18}O$‰) is often used in order to determine the geological origin of colored corundum (ruby and sapphire varieties). Yui et al. (2003, 2006), Giuliani et al. (2005, 2014), Sutherland et al. (2007, 2009), Vysotskii et al. (2008), Vysotsky et al. (2009), Uher et al. (2012), and Zaw et al. (2014) provided a reliable framework for the likely identification of corundum of uncertain origin, especially those from placer deposits. Commonly, geochemistry assists in distinguishing between the magmatic and metamorphic gem corundum (Giuliani et al., 2005, 2007; Sutherland et al., 2007, 2009; Uher et al., 2012). However some isotopic compositions of oxygen in corundum are quite unique that it enables to almost exclusively locate its source (Krylov, 2008; Vysotskii et al., 2008; Vysotsky et al., 2009; Vysotskiy et al., 2014; Bindeman et al., 2010; Bindeman and Serebryakov, 2011). Source identification is especially important for some gem corundum deposits where it significantly influences their market costs.

There are about 80 corundum occurrences in Russia, three of which have been explored for jewelry raw material (Lyashenko, 2011). These

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three deposits are located in the Middle Ural, where the total ruby and sapphire reserves are evaluated as highly as 8,880 and 22,985 carats respectively. Four more localities in Karelia, Baikal region, Polar and South Ural are well known sources of minerals for collectors. Most of the occurrences and deposits are poorly studied geochemically (Fig. 1).

This paper presents new and literature data on isotopic composition of oxygen for corundum and associated minerals from Russian occurrences. The geology of these localities is summarized below in order to define the mineralization origin. There is little need for detailed geological discussion, because our data are generally in a good agreement with reviews by Giuliani et al. (2005, 2014) and Sutherland et al. (2007, 2009).

2. Samples and methods

The studied corundum and associated mineral species were sampled in the Russian territory, where host deposits cover almost all the corundum genetic types (Kievlenko, 2003), and include both lode and placer deposits.

The isotopic composition of oxygen was determined at the Far East Geological Institute facilities with the help of the vacuum camera and laser isotope separation (Ignat'ev and Velivetskaya, 2004a,b). The infrared CO_2-laser (MIR-30) was used for sample heating. Its isotopic composition was then determined using the Finnigan MAT-253 mass-spectrometer. The standard gas was calibrated at the SMOW scale applying NBS-28 ($\delta^{18}O = 9.6‰$). The outer truncation error of the method was less than $\pm 0.2‰$.

3. Geological settings

The studied corundum varieties were divided into four groups according to their geological setting:

1. *Sapphire from basaltic sourced placers* was sampled from river and slope sediments in southern Far East region, where it was first discovered in gold placers in 1980s (Esin and Peretyat'ko, 1992). Later, further sapphire sites were found in the tuff of Cenozoic alkaline basalt and in modern sediments of streams draining paleovolcanic edifices (Vysotskii et al., 2002). The basalt ages range between 14.5 and 7.5 Ma (Nechaev et al., 2009). This corundum is commonly blue and green, sometimes yellow and pink in color. Its large (>1 cm) crystals are chiefly flattened, while smaller crystals are prismatic, barrel-shaped and sharp bipyramidal. They commonly have traces of magmatic dissolution on the surface (Table 1).
2. *Sapphire and ruby from syenitic pegmatite, mica- and plagioclase-dominated metasomatic rocks in middle- and high-grade metamorphic suites* are well known in Russia. They were studied at the Ilmen Mountains of South Ural, the Komarovskoye and Izumrudnye Kopi occurrences of Middle Ural, the Makar-Ruz' occurrence of Polar Ural, Tazheran Massif in the western Baikal coast, and from a xenolith site in the Tunkin-basin basalts of the southwestern Baikal region. At all these localities, magmatic rocks, namely syenite and nepheline syenite, host metamorphosed rocks of the epidote-amphibolite and amphibolite facies, and associated pegmatite and other metasomatic rocks have similar ages: Cambrian–Ordovician in the Baikal region and Permian in Urals. In addition, the magmatic rocks are completely or partly metamorphosed, especially along their margins. Consequently, distinguishing between magmatic or metamorphic origin of corundum from these rocks is very difficult.
In the Ilmen Mountains, corundum (sapphire and ruby) was found in syenite and nepheline syenite pegmatite veins with bulges or branching lenses and, less commonly, in garnet-bearing crystalline schists, amphibolites, plagioclase-dominated rocks, and metamorphosed ultramafic rocks (Nikandrov et al., 2000; Popov and Popova, 2006). The studied sapphire-bearing pegmatite forms veins 10–15 m long and 0.5–1.5 m thick among gneisses. Corundum crystals are usually enclosed within microcline-perthite aggregates and occur as clusters. The feldspathic pegmatite usually contains prismatic, barrel-shaped and sharp bipyramidal corundum crystals 2–8 cm long, rarely up to 20–39 cm long. They are bluish gray, bronze

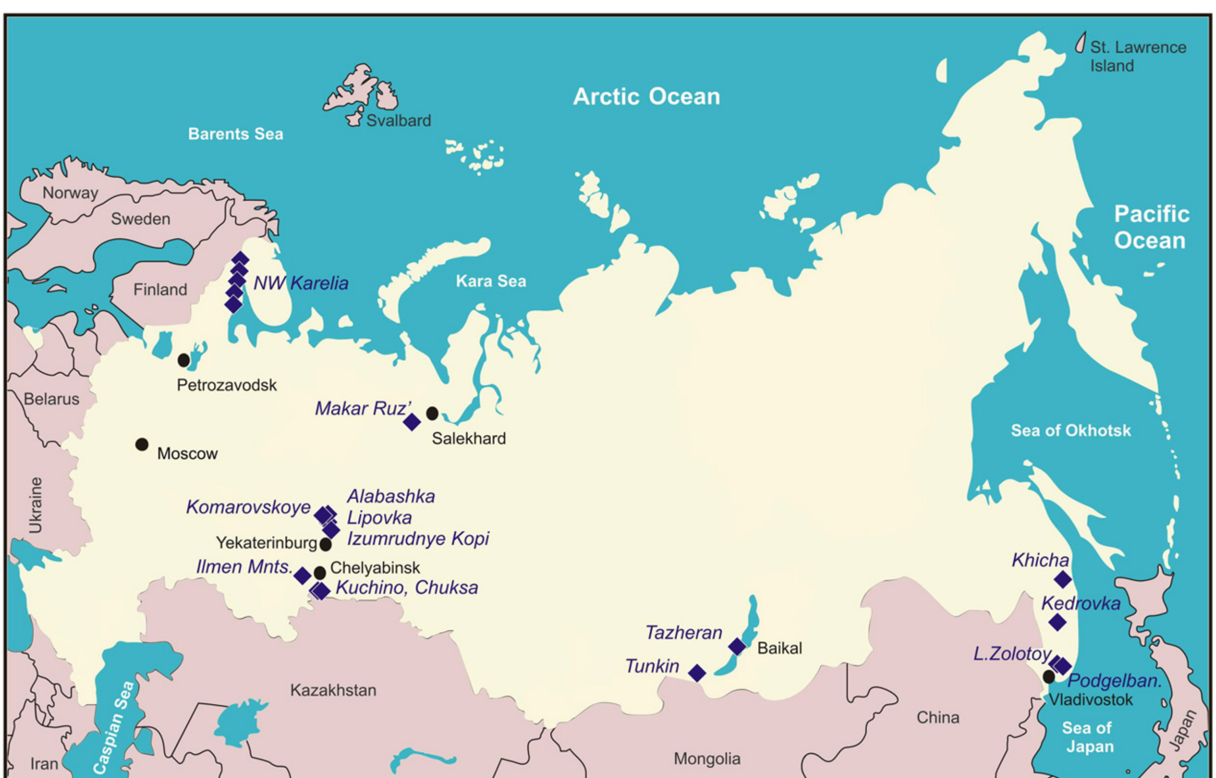

Fig. 1. Distribution of corundum occurrences in Russia.