Results of $^{40}$Ar/$^{39}$Ar Dating of Ores of the Ermakovo F–Be Deposit, West Transbaikalia, Russia

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Abstract—The Ermakovo F–Be deposit, the largest Be deposit in Russia and one of the world’s largest deposits, is located in West Transbaikalia. The ores of the deposit are diverse in their morphology and composition; mostly there are phenakite–bertrandite–fluorite metasomatites after limestones. The origin of Be mineralization is related to the stock of leucocratic subalkali aegirine-bearing granites, the age of which corresponds to 224–226 Ma. The available age of ores of 225.5–219 Ma is close to the age of ore-generating granites. To specify the age of the ores, we determined the $^{40}$Ar/$^{39}$Ar age of K-feldspar and, for the first time, of the Be mineral milarite, a K- and H$_2$O-bearing Be silicate (KCa$_2$(Be$_2$Al$_4$Si$_{12}$O$_{30}$)·H$_2$O), from different ore bodies of the Ermakovo deposit. The age spectrum of milarite (sample Er-17) has a stable plateau in the high-temperature part, which consists of four consecutive steps composing ~50% of the released $^{39}$Ar with an age of 182.5 ± 3.0 Ma. The age of K-feldspars is similar (169.8–170.6 Ma). The results of $^{40}$Ar/$^{39}$Ar dating of minerals from ores of the Ermakovo F–Be deposit indicate that the processes of mineral formation occurred over a long period from 225 to 170 Ma.

Keywords: Ermakovka F–Be deposit, $^{40}$Ar/$^{39}$Ar dating, ores, milarite

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The Ermakovo F–Be deposit, the largest Be deposit in Russia and one of the world’s largest deposits, is located in West Transbaikalia, 140 km to the east of the town of Ulan-Ude. The geological structure of the deposit, the composition of ores, and their genesis have been studied by many researchers including A.I. Ginzburg, V.I. Gal’chenko, Ya.A. Kosals, N.P. Zabolotnaya, M.I. Novikova, I.I. Kupriyanova, F.G. Reif, and others. The later works characterize in detail the formation sequence of intrusive rocks of the ore field [5–7], the crystallization conditions and degassing of a stock of ore-bearing aegirine granites and the composition of magmatic fluids [8], the peculiarities of the structure of veined Be ores, and the metal potential of ore-forming fluids [2, 3, 9].

The Ermakovo deposit occurs in a near–wall part of the Mesozoic Kizhinga riftogenic depression and is localized in a carbonate-terrigenous sequence, which is preserved as a relatively large pendant in the area of the Paleozoic granitoids (Fig. 1). The host sequence is a latitudinal asymmetric syncline. The metamorphosed sandstones occur in its core, and a sequence of intercalated dolomites, limestones, and amphibole–pyroxene–biotite schists form the wings. The mafic, intermediate, and felsic dikes are widely abundant within the ore field of the deposit (Fig. 1). The hydrothermally altered rocks include (i) albite and quartz–albite–microcline metasomatites after pre-Mesozoic granites and pegmatites, (ii) garnet–pyroxene and pyroxene–vesuvianite skarns after carbonate and silicate rocks including some igneous rocks, (iii) microclinites, which replace both metasedimentary and effusive rocks, and (iv) veined zones of fluoritization typical of all rocks within the ore field, which are controlled by faults.

The origin of Be mineralization is related to the stock of leucocratic aegirine-bearing subalkali granites [8]. The ores are diverse in morphology and composition; mostly they include phenakite–bertrandite–fluorite metasomatites after limestones. Much of the ores includes veins in zones of coarse–clastic breccias (zones II, XII) and veinlets (zones I, I1). According to geologists, bertrandite was dominant in the upper horizons of the deposit, which have already been mined, whereas the lower horizons of the main open pit are dominated by phenakite ores.

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GEOLOGY OF ORE DEPOSITS
RESULTS OF $^{40}$Ar/$^{39}$Ar DATING AND DISCUSSION

To specify the age of the ores, we determined the $^{40}$Ar/$^{39}$Ar age of K-feldspar and, for the first time, of the Be mineral milarite, a K- and H$_2$O-bearing Be silicate (KCa$_2$(Be$_2$Al$_{12}$O$_{30}$)·H$_2$O). From different ore-bodies of the Ermakovo deposit. The minerals were...
sampled from ore zones I (K-feldspar), II (K-feldspar), XII (K-feldspar), and XVII (milarite) of the deposit (Fig. 1). The 40Ar/39Ar age was analyzed at the Center for Multielemental and Isotopic Studies, Siberian Branch, Russian Academy of Sciences, Institute of Geology and Mineralogy, Siberian Branch, Russian Academy of Sciences (IGM SB RAS, Novosibirsk) following the method of [10].

As a result of dating, two groups of age values are calculated: 169.8–170.6 and 182.5 Ma (Fig. 2). The 40Ar/39Ar age is first determined for the Be mineral milarite. The sample for dating was taken from a large radial crystal without visible inclusions of other minerals and secondary alterations. The age spectrum of milarite (sample Er-17) has a stable plateau in the high-temperature part, which consists of four consecutive steps composing ~50% of the released 39Ar with an age of 182.5 ± 3.0 Ma.

Dating of K-feldspar from different ore zones of the Ermakovo deposit showed consistent values of the isotopic age in the range of 169.8–170.6 Ma (Fig. 2). The age plateau, however, could not be distinguished in the age spectrum of K-feldspar from sample E-5-6 according to the criteria [11, 12]. At the same time, the average age value by two steps in the high-temperature part of the age spectrum of sample E-5-6 coincides with those for the age plateau of K-feldspar of samples Er-2-37 and Er-12-1 and is 170.4 ± 2.8 Ma.

The presence of steps with older age values in the low-temperature part of the age spectrum of K-feldspar of ore zone I (sample E-5-6) indicates a younger age of their formation with further re-equilibration of the K–Ar isotopic system at the boundary of 170.4 Ma. K-feldspar, which could have undergone secondary alterations, can reflect the age of superimposed geological processes. The age of ~170 Ma probably reflects the epigenetic processes (dike magmatism) that affected the K–Ar isotopic system of K-feldspar.

The 40Ar/39Ar age of milarite (182.5 ± 3 Ma) is younger than the previously published age of ore-generating alkali granites and Be ores (226–219 Ma). The results of 40Ar/39Ar dating were verified using isochrones showing complete coincidence with the data on the age of the plateau. This fact increases the reliability of our results; thus, this age difference is most likely caused by geological reasons.

The igneous rocks of this age (~180 Ma) are unknown in the ore field of the Ermakovo deposit, although it is well studied. Thus, one of the reasons for the large difference between the age of ore-bearing alkali granites and mineralization can be related to the longer cooling of the ore-generating granitoid pluton. Actually, the thermochronological data on the Angara–Vitim batholite shows that the origination and crystallization of large granitoid plutons is a long process, which lasts more than 100 million years [10]. Reif (2008) showed that the Stok ore-generating alkali-

Fig. 2. 40Ar/39Ar spectra of minerals of ores from the Ermakovo F–Be deposit: (a) K-feldspar from ore zone I (sample E-5-6); (b) K-feldspar from ore zone II (sample E-2-37); (c) K-feldspar from ore zone XII (sample E-12-1); (d) milarite from ore zone XVII (sample E-17).
granitic pluton at the Ermakovo deposit and a similar pluton at the Orot Be deposit at a distance of 30 km from the Ermakovo deposit are the inliers of one large magmatic reservoir. Thus, it could have formed over a long period.

Thermobarogeochemical studies of ores of ore zone XVIII showed that they formed in relatively high-pressure (thus, deep) conditions [1]. They were responsible for slow cooling of the parental intrusive, which could yield several pulses of ore-forming fluids. At the same time, no products of these consecutive pulses of ore formation, which reflect the different stages of cooling of an ore-magmatic system, have been established reliably. This is probably related to the limited age values of different types of Be mineralization, although this large deposit with a unique amount of Be mineral species and a large amount of spatially unrelated ore zones distinct in the composition of Be minerals should have formed during the long evolution of the ore-forming system.

Another reason for the origination of late stages of ore formation could be related to a later magmatic stage that resulted in the formation of the post-ore felsite dike, the Rb–Sr age of which is 184–161 Ma [5, 6]. The spatial link of mineralization with dikes of syenites is identified in ore zone XVIII, where Be mineralization includes an assemblage of Ca—Na berillosilicates (leucophanite—meliphanite—eudidymite), which replaces the early phenakite. The age of these dikes is unknown; however, the fluids responsible for the formation of ores from ore zone XVIII are higher alkaline suggesting a genetic link between Ca—Na berillosilicates and alkaline dike magmatism [1].

Phenakite BeSiO₄ is a major Be mineral in ores of the Ermakovo deposit, which was deposited at the early stage of ore formation, whereas the milarite—bavenite mineralization formed at the latest sulfide–carbonate stage [4]. No clear structural gap between the stages is identified, but the early phenakite is replaced by milarite, bavenite, and calcite aggregates. The time range between the ore formation stages is unknown, but the interrelations of Be minerals show that milarite formed after the main fluorite—phenakite ores, almost at the final pulse (stage) of ore formation of the deposit. This pulse was probably related to the dike magmatism, which requires additional geochronological studies of post-ore dikes.

Thus, the results of ⁴⁰Ar/³⁹Ar dating of minerals from ores of the Ermakovo F—Be deposit indicate that the processes of mineral formation occurred over a long period from 225 to 170 Ma.

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CONFLICT OF INTEREST

The authors declare that they have no conflicts of interest.

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