First Data on Isotropy and Mineralogical Features Ores Kumirnogo Silver Deposit (Russia, Primorsky Region)

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Abstract. Located in the north part of Primorsky region, the Kumirnoe silver deposit is very interesting object from a geological point of view. Data about isotopic mineralogical characteristics of its ore mineralization was first presented in this essay. More than 80 ore bodies are known at the deposit. They mostly contain quartz, hydromica, sericite, adularia, chlorite, montmorillonite and kaolinite. Ore mineralization is represented by silver-bearing minerals: acanthite, pyrirargyrite, polybasite, stephanite, freibergite, selenium-containing aguilarite and eletrum. The obtained isotope data indicate that sulfur composition is close to meteorite standard, this is indicated by the narrow positive interval of its sulfur ratios (2,0-2,8‰). It gives the reason to assume that homogeneous hydrothermal ore-forming solutions participated in its formation. Its comparison with isotopic data of gold-silver deposits located in the continental marginal volcano-plutonic belts (Ducat, Mnogovershinnoe, Sergeevskoye) shows that the formation of the Kumirnoe deposit was at the same time: Cretaceous-Paleogene, it’s possible it was under similar geological conditions. This is confirmed by the age data obtained by us earlier for Kumirnoe deposit (it matches Cretaceous- Paleogene).

1. Introduction
The Kumirnnoe silver deposit is one of the most perspective deposits of Primorsky Region. It is located within the Nizhne-taezhyi ore cluster which, in turn, is a part of the East Sikhote-Alin volcano-plutonic belt (ESAVPB). The remoteness of its location from the developed infrastructure affected good study of the object. This paper contributes to the knowledge of the deposit by presenting new isotopic and mineralogical data.

Geological background of the deposit is rather complicated, characterized by differently-oriented faults, large magmatic centers and extensive silver, lead, zinc, tin, copper, and gold leakage fluxes [5, 6, 9]. Country rocks stratigraphically are divided into lower terrigenous and upper volcanogenic units. The Early Cretaceous rocks of the lower one are crumpled up into NE-trending folds which are overlaid by stratified pyroclastic deposits of the Primorskaya (Turonian-Campanian), Samarginskaya (Maastrichtian) and Bogopolskaya (Danian) formations constituting the upper unit. These pyroclastics are comagmatic with the Late Cretaceous granitic plutons found within the ore field and the surrounding territory.

Multi-metal-silver (Sn-Cu-Pb-Zn-Au-Ag) mineralization of the Kumirnnoe deposits is localized in about 80 ore bodies oriented predominantly in the northwestern, rarely submeridional, sublatitudinal, and northeastern directions. Three mineral assemblages: pyrite-arsenopyrite, polymetal, and silver-acanthite-sulfosalt, are recognized. They correspond with formation of buck of pyrite and arsenopyrite...
(1), sphalerite, galena, and chalcopyrite (2), acanthite, pyrrygrite, polybasite, freibergite, stephanite, matildite, argyrodite, native gold as well as indium-bearing sphalerite (3), respectively.

2. Analytical technique
Mineralogical studies of ores were carried out at the Center of collective use of the Far East Geological Institute FEB RAS by the JXA-8100 electron probe micro analyzer, and the Zeiss AxioPlan 2, AxioImager D, and Nikon Eclipse LV100 Pol. imaging microscopes. This has enabled mineral composition, intermineral relationships and order of mineral formation to be revealed.

Sulfur isotope data were obtained using a Flash EA-1112 Elemental Analyzer (Thermo Scientific, Germany) set to S configuration of a standard protocol converting the sulfides’ sulfur into sulfur dioxide gas. $^{34}$S/$^{32}$S isotope ratios were measured on a MAT-253 (Thermo Scientific, Germany) mass-spectrometer under a continuous flow of helium. The measurements were performed with regard to SO$_2$ laboratory standard calibrated against IAEA-1, IAEA-S-2, IAEA-S-3, and NBS-127 reference materials. The formers were also used for standardizing the analytical system while running the analyses. Measurement results are presented in common form: $\delta^{34}$S = (R$_{\text{sample}}$/R$_{\text{standard}}$ - 1) and reported in ‰, where R$_{\text{sample}}$/R$_{\text{standard}}$ indicates $^{34}$S/$^{32}$S in a sample and in VCDT standard, respectively. $\delta^{34}$S measurement precision (σ1) constitutes ±0.1‰ for the standard (n=5) and for samples.

3. Isotopic and mineralogical characteristics of ores
Ore minerals at the Kumirnoe deposit occur as impregnations, aggregates and streaks of sulfides – pyrite, arsenopyrite, sphalerite, galena, and chalcopyrite, silver minerals – acanthite, pyrrygrite, polybasite, stephanite, freibergite, as well as electrum and native silver. Main gangue mineral is quartz; there are also hydromica, sericite, adularia, chlorite, and to a lesser extent montmorillonite and kaolinite. Quartz is found in two generations: coarse-medium-grained druses strongly developed on flanks of ore bodies, and subordinate vein quartz in association with adularia, sericite and chlorite.

The following is the more detailed description of the most common ore minerals of the deposit: arsenopyrite, pyrite and sphalerite. Arsenopyrite occurs in two varieties. One of two represents crystalline aggregates densely disseminated within rock mass. Crystals of mainly rhombic and slender-prismatic habit form twins or more complicated intergrowths with the grainsize from thousandth to first millimeter fractions. This variety of arsenopyrite is the earliest sulfide, which follows from its relationship with pyrite, Zn, Pb, and Cu sulfides, and silver minerals. In some ore bodies there are found zoned arsenopyrite crystals with antimony-enriched cores. Average microhardness of arsenopyrite-I constitutes 750 kgf/mm$^2$, which is slightly lower than standard values. Perhaps this is due to the antimony included in its crystal lattice. Arsenopyrite underwent partial substitution by acanthite and scorodite. Another variety of arsenopyrite occurs as small idiomorphic crystals in quartz matrix in close proximity to silver-containing minerals, inferring it may have formed during the deposition of silver-acanthite-sulfosalt aggregates [10, 12].

Pyrite is widespread in nested sulfide minerals, though in differing proportion to arsenopyrite. Two generations are distinguished. The first one represents impregnations of cubic-shaped crystals of thousandth to tenth of millimeter size, mostly abundant in zones close to veins’ selvage. Pyrite accumulations often contain the finest (no more than one μm) inclusions of acanthite, pyrrygrite, polybasite, and freibergite, and such rare mineral as aguilarite [11]. Average microhardness of pyrite equals 1373 kgf/mm$^2$. Its chemical composition corresponds to stoichiometric ratio; of the trace elements, only arsenic is present in minor (0.45 mas%) amounts. The second generation of pyrite is rarely found as submicron-sized inclusions in the silver-antimony sulfosalt associations.

Sphalerite occurs as reticula in quartz matrix and as fine vein lets in the pyrite of first generation, as well as in chalcopyrite and galena. Average microhardness is 246 kgf/mm$^2$.

The isotopic analysis of sulfur from sulfides of the Kumirnoe silver deposit has been carried out for the first time. The measurements yielded values close to meteoritic sulfur −2.0-2.8‰. This demonstrates the high homogeneity of ore-forming hydrothermal fluids participated in the formation of silver-containing mineralization zones.
The obtained sulfur isotopic values well correspond to those for gold-silver deposits located in continent-marginal volcanoplutonic belts (VPB) of the Russian Far East. Such, for example, as deposits Dukat (-11 – 12‰) and Sergeevskoe (-5 - 9‰) of the Okhotsk-Chukchi VPB, and deposit Mngovershinnoe (-6 - 2‰) of the Sikhote-Alin VPB [1, 4, 7, 8]. As can be seen, the range of values is rather wide, allowing 2.0-2.8‰ of the Kumirnoe deposits to get into this interval. According to [2, 3, 8], all of these three deposits were formed in the Cretaceous-Paleogene. The age of the Kumirnoe is 47-64 Ma that also falls on the Late-Cretaceous-Paleogene.

4. Conclusions
The ore bodies of the deposit under study are made up of quartz, hydromica, serisite, adularia, chlorite, montmorillonite, and kaolinite. Ore minerals occur as impregnations and streaks of pyrite, arsenopyrite, sphalerite, galena, chalcopyrite, silver minerals, such as: acanthite, pyrargyrite, polybasite, stephanite, freibergite, selenium-containing aguilarite, and electrum. Isotopic values of sulfur from the mineralized zones are close to VCDT reference values suggesting that the deposit formed with the participation of deep fluids likely related to a mantle source.

5. References
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