isotopic composition of barite from the Saf'yanovka ores is a consequence of bacterial reduction that is in accordance with abundant fauna relics in the deposit. Barite from the Saf'yanovka ores was formed under more reducing conditions that is evident from the higher CO and CH_4 contents in gaseous composition of fluid inclusions. High Cu content, higher homogenization temperatures of fluid inclusions and higher salinity of the fluid in barite from the Semenov-3 clastic ores are related to its precipitation from the high-temperature hydrothermal fluid in assemblage with late Cu-Fe-sulfides.

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FORMATION CONDITIONS OF THE RIDDER-SOKOLNOE DEPOSIT, RUDNYI ALTAI, KAZAKHSTAN

Риддер-Сокольное золото-полиметаллическое месторождение является крупнейшим на Рудном Алтае. Формирование оруденения связано с раннедевонским (эмс) вулканизмом. Оруденение локализовано в депрессионной палеоструктуре, возникшей на склоне или подножье подводной вулканической гряды. Его размещение контролировалось зонами трещиноватости, служившими проводниками гидротермальных рудоносных растворов, отлагавших оруденение в придонной части морского бассейна и на путях их следования. Отчетливо проявлены признаки выноса рудного материала из подрудных пород месторождения.

The Ridder-Sokolnoe gold-polymetallic deposit is the largest deposit in the Rudny Altai. It is located in the Leninogorsk-Zyryanovsk subzone of the Rudny Altai metallogenic zone within the Leninogorsk graben bounded by the Ivanovsky (Obruchevsky) reversed fault in the south and Severny thrust in the west, north and northeast, which is alternated by the Bosyakovsky reversed fault in the southeast. The territory of the graben hosts the Leninogorsk ore field with Ridder-Sokolnoe and similar Kryukovskoe, Novo-Leninogorskoe, Obruchevskoe, and Dolinnoe deposits.

The polymetallic massive sulfide volcano-sedimentary deposits of the Rudny Altai are related to the Emsian-Frasnian basalt-rhyolite volcanism. The mineralization in the ore zones is concentrated at the different stratigraphic levels. In particularly, mineralization of the reviewed ore field is hosted in the Emsian rocks including Leninogorsk, Kryukovskaya, and Il'inskaya formations and Eifel Sokolnaya Formation.

The lower part of the volcanic-sedimentary Leninogorsk Formation consists of hydrothermally altered rhyolite and dacite lavas and lavabreccias and the upper part is composed of various kinds of tuffs, volcanomictic gravelstones, sandstones, and siltstones. The thickness of the formation is 50–350 m.

The Kryukovskaya Formation is subdivided into three members. In the northern part of the deposit, the lower member is composed of sedimentary breccias with angular and semirounded fragments of felsic volcanic rocks, rarely, sedimentary and metamorphic rocks and granites, which are cemented by aleuropelitic material. Occasional pyrite and pyrite-polymetallic ore clasts and interlayers of sandstones and siltstones may be found in the lower member. The thickness of the lower member reaches up to 350 m. These rocks facially transit to siltstones and silty sandstones with rare sandstones 120 m thick.

The intermediate member is composed of siliceous, carbonaceous-clayey, and calcareous claystones and siltstones with interlayers of sandstones. The siliceous rocks are often transformed into microquartzites and sericite microquartzites. The sericite-chlorite-quartz rocks are probably volcanic in origin. The thickness of members varies from 300–400 m in the western part of the ore field up to 50 m and complete pinching out at the northeastern part. In area of the Kryukovkoe orebody, this member is completely replaced by lava-extrusive bodies transformed into quartzites and sericite-quartz altered rocks. Some areas (Ridder, Central, and Northeastern orebodies) host andesitic sills.

The upper member with thickness varying from 10 m up to the first hundred meters includes calcareous siltstones (shists of the hanging wall). The member completely pinches out in the arches of some cupola structures and in these areas the rocks of the Il'inskaya Formation lie over this intermediate member of the Kruykovskaya Formation.

The boundary with Il'inskaya Formation is characterized by appearance of the mafic and intermediate volcanic rocks. The formation is composed of tuffs, tuffaceous and volcanomictic gravelstones and sandstones with interlayers of lavas of andesites, basaltic andesites, and basalts. The red and lilac colors of the rocks are the typical features of the Il'inskaya Formation. The thickness of the formation varies from 20–30 m in the northern part of the ore field up to 200–250 m in its southern part.

The Late Devonian dolerite dikes crosscut the entire Devonian structure of the deposit.

The Ridder-Sokolnoe deposit is located within the Severnaya (North) anticline, the near-latitudinal axis of which is close to the Severny thrust in the northern part of the deposit. Within the deposit, the Severnaya anticline is complicated by the Ridder-Sokolnaya and Kryukovskaya brachianticlines. The Ridder-Sokolnaya brachyanticline, hosting the major orebodies, is transversely oriented to the axis of the Severnaya anticline, is 2.5–3 km wide, and is traced for 50 m. The dip angles of its wings are usually 3–5? to 10–15?, locally, up to 60? in the western wing with flexural folds (the western flank of the Rudder orebody and Zavodskaya orebody). The wings are gradually flattened and beyond its limits become slightly inclined or horizontal. Uplifting again, the northeastern wing forms the Kryukovskaya brachianticline.

In addition to the above-mentioned Severny thrust and Ivanovsky (Obruchevsky) reversed faults, the ore field is cut through by NW- and NE-trending faults, which displace the structure for more than tens and hundreds of meters. These displacements probably reflect the weakened fracture zones resulted from the scattered spreading that is confirmed by the coinciding orientation of fractures developed in the rocks and above mentioned faults.

The polymetallic massive sulfide ores from the Ridder-Sokolnoe deposit are characterized by increased Au and Ag contents. Currently, it is accepted that formation of precious metal mineralization is closely related to that of polymetallic massive sulfide ores in contrast to the previous point of view.

The total area of sulfide mineralization exceeds 20 km^2. The mineralization occurs in the rocks from the upper member of the Kryukovskaya Formation up to the green shists of the Zavodskaya Formation and is traced for 800 m to the depth. It is subdivided into four horizons. The main volume of economic mineralization is concentrated in the intermediate member of the Kryukovskaya Formation.

Gold-polymetallic mineralization is related to the first horizon and concentrated in the intermediate member of the Kryukovskaya Formation under the hanging wall shists of the upper member. Below, in microquartzite, it is replaced by network stockwork, transiting into the vein bodies to the depth, which host gold-polymetallic mineralization in the transiting and upper parts and copper-zinc ores in the deeper levels. The layered polymetallic ores of the second Ridder orebody are also related to the first horizon. These ores are hosted by the member of intercalating carbonaceous siltstones and claystones.

The second horizon includes the mineralization at the contact zone of intermediate siltstone and lower gravelite-agglomerate member of the Kryukovskaya Formation. The roots of the above mentioned veins with zinc-copper and copper ores are also related to this horizon. The boundary between the first and second horizons is either conditional or clear in different areas. For example, quartz-sulfide veins of the second horizon in the Central orebody forms subconformable body of copper ores, which are separated by the barren sericitized quartzites and sericite-quartz rocks from the overlying ores of the first horizon. In some areas, the mineralization of the second horizon is characterized by the absence of ores of the first horizon. The Au content of ores from the second horizon is lower in contrast to the first one.

The third ore horizon is confined to the contact of the Kryukovskaya and Leninogorsk formations and represents the pocket and stringer-disseminated polymetallic mineralization. It is possible that Zavodskaya orebody is located at this level.

The fourth ore horizon is hosted in the green shists of the Zavodskaya Formation at the contact with the Leninogorsk Formation. The mineralization represents the subconformable lens-shaped bodies of stringer-disseminated polymetallic and copper-zinc ores combined in the footwall with crosscutting bodies, intruding the green schists to the depth of 100 m and more. The content of precious metals is the lowest. At present, it is not mined. The relation of this mineralization and mineralization at other horizons is not identified. Probably, this mineralization is early, because ore clasts similar in composition were found in the clastic sediments of the lower member of the Kryukovskaya Formation.

On the basis of the above mentioned data, the generalized geological-genetic model of the formation of the deposit (mineralization of the first and second horizons) is as follows.

The Emsian depression on the slope or at the foot of the submarine volcanic ridge characterized by the high degree of fracturing of the seafloor was a place of discharge of the hydrothermal fluids, ascending through the fracture zones. The latters were probably related to the magma chamber, which has produced the volcanic rocks of the bottoms of the ore-bearing section. In the initial stages, the fluids were relatively low-temperature, depleted in metals, and enriched in Si. Mixing with cold bottom waters, they deposited siliceous hydrogel admixed with dispersed sulfides. The rate of accumulation of these sediments exceeded the rate of sedimentation outside the fracture zones that caused the formation of arched uplifts composed mostly of siliceous sediments along the fracture zones.

The main stage of ore formation is related to the high-temperature fluids enriched in metals, which were the products of the developed hydrothermal system affected deeper zones. At this stage, the hydrothermal vents were concentrated at the local areas of fracture zones, leading to the formation of the cupola structures.

The mineralization of the first and second horizons was deposited simultaneously that is evident from zonation typical of sulfide deposits. We suppose that copper and copper-zinc ores were deposited at the depth of 150–400 m from the seafloor surface and polymetallic veins were formed at the depth of 150 m under the boundary between the rocks and unlithified sediments. In initial stages, the polymetallic massive sulfide bodies were separated by areas of hydrothermal-sedimentary rocks with disseminated ore mineralization. In some areas, the formation of such orebodies is ended by formation of quartz-barite cupolas with size of 500 ? 200 m in the lower part of the cupola and more than 100 m along the vertical from the base. The basement and periphery of the cupolas contain individual massive sulfide bodies, locally, with clastic structure and cemented by quartz-barite or carbonate-quartz aggregates with disseminated sulfides. In the top areas of the cupolas, quartz-barite rocks may be alternated by hematite-barite-quartz rocks. The boulders and blocks of ores and quartz-barite rock buried in the sedimentary rocks of the hanging wall are often found in the cupola slopes. The quartz-barite bodies in the lower part of the cupolas transit into the underlying microquartzites through the stockwork zone, where the brecciated microquarzites are cemented by barite. The hematite-bearing rocks in the top of the cupolas indicate change of the reduced conditions into the oxidized ones.

At the final stages, the hydrothermal activity exhausted and orebodies were buried by the sediments. However, some areas show the traces of the late hydrothermal activity, manifesting in the small zones of hydrothermally altered rocks with stringer-disseminated polymetallic mineralization in the schists of the hanging wall.