Study oxidation zone of Naymanzhal gold deposit (central Kazakhstan) the purpose of it develop with methods of heap leaching

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Abstract. We studied the mineral composition of the oxidation zone of ore deposits, ore types are marked, which define the vertical and lateral zonation in the distribution. For presentation ore body in the mineralized areas were built in three-dimensional space. For this purpose was created analytical database on the results of sampling wells and ditches. There was set sufficiently complex morphology of the ore bodies, with their variability along strike and dip, the nonuniform distribution of the contents of the gold and silver. The results of mineralogical studies of gold ore oxidation zone, their technological and physical-mechanical properties were favorable for heap leaching.

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Introduction

Administratively Naymanzhal deposit is 300 km east of the city of Karaganda. Long-term practice of foreign companies of using heap leaching confirms their high technical and economic efficiency. Compared with traditional factory technologies, heap leaching is characterized by low capital investment and operating costs, lower energy and water consumption, high productivity. Using this method there is no need to fine grinding ore before removing, which is quite energy consuming process. Currently heap leaching method used in almost half of the world's leading countries in the production of gold, so its implementation is very fast [1-4]. This economically advantageous method of mining of precious metal deposits in recent years is widely used in Kazakhstan [5, 6]. Large volumes of ores with low gold content, favorable climatic conditions, large thickness and extent of the ore bodies, low sulfide content were the reason for the study of these oxidized zones Naymanzhal deposit and prepare a proposal for the exploitation ores with open method using heap leaching.

Methods

There were examined under binocular microscope schlich geochemical samples. The densest types of ores from the oxidation zone were studied by mineragraphy. Made various analytical determinations: chemical and spectral analyzes, X-ray diffraction study of clay minerals and loose powdery ores oxidation zone. Composition of gold and rare minerals determined microanalyzer JCXA-733. We studied physical and mechanical properties of ores from the oxidation zone. Geological maps and sections are made using the Mapinfo - version 8. The program Micromine - version constructed three-dimensional models of ore bodies with the distribution of concentrations of gold in them.

Research

In the scheme of structural and metallogenic zoning of Central Kazakhstan Naymanzhalskaya area occupies a special place. This area, lying within *Tarbagatai-Chingis-Maykainskaya metallogenic zone*, located between the two traditional areas of ore - Maykainsky the north-west and Akbastau-Kosmurunsky the south.

Geological and structural characteristics of Naymanzhal deposit

Modern structure of Naymanzhalsky ore field formed in two main stages. In the first stage, in the lower Paleozoic island arc was laid on a large stretching area north-east direction, which resulted in a large northwestern tensile crack, which caused the formation and accumulation of arc volcaniclastic products. Hydrothermal-metasomatic alteration of basic rocks developed along weakened zones: silicification, sericitization with deposition of volcanic-hydrothermal pyrite ores. Later, when the so-called "closing" arc" is compressed transversely northwestern faults, which to form Naymanzhalskaya anticline complicated series of the faults and reversed faults. Base of the anticline composed of basalts, basaltic conglomerate (lower bundle). Higher in the section they overlap purple aleurolites interbedded with jasper, which in the central part of the field are replaced by jasperoids (aleurolites with an admixture of silica up to 90-95%). This is explained by the formation of siliceous ridge. Formation of jasperoids obviously related to the deep part of the ocean floor, i.e. local narrow trough.

In the second stage, in Permian-Triassic time, as a result of tectonic and magmatic activity appeared latitudinal faults along which there was a partial redistribution of gold and additional silicification rocks. Then there was breaking tectonics having northeasterly direction, led to the formation of flexure shifts (Figure 1). Flexure divided the single ore zone in the central part into two parts, provided redeposition mineralization. Because of it were introduced extra portions of gold mineralization in the Permian-Triassic time.

The geological structure of the deposit Naymanzhal

Features of localization of "naymanzhalsky" type mineralization (pyrite-gold-arsenic-polymetallic) are theirs affinity to strata of the Ordovician basalt-siliceous-terrigenous formation rocks. This type are formed in a marine environment for a long period - from the Upper Cambrian to Carboniferous and experienced the impact of tectonic and magmatic activity processes in the Permian - Triassic time.

Lower-Middle Ordovician volcanic, volcano-sedimentary, less terrigenous rocks and beds take part in the geological structure of the deposit. Subvolcanic and intrusive formations are less developed. Lower Ordovician ore-bearing sediments are conditionally divided into three parts: Lower - underlying, Middle - ore-bearing and Upper - overlap (Figure 2).

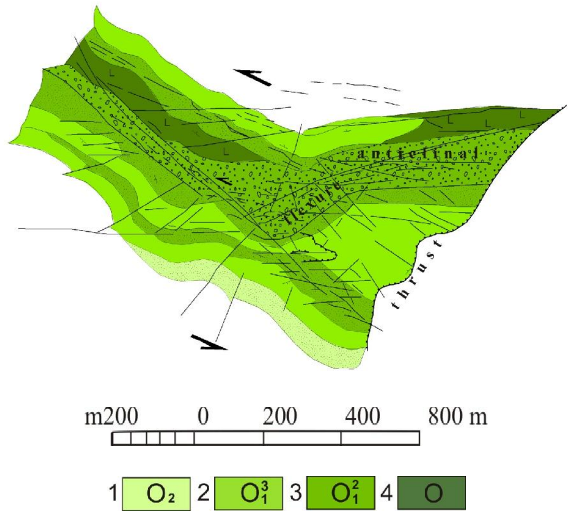

Figure 1 - Schematic structural model of the deposit Naymanzhal

1 - Polymictic sandstones; 2 - Upper packet. Pink silicon with siltstone interbeds; 3 - Middle packet. Mineralized zone. Volcaniclastic sandstones, siltstones, grits; 4 - Lower packet. Basalts.

Lower green-colored tutu (O_1^1) is mainly composed of basalt, andesite, rarely basaltic andesites, subvolcanic dykes and small bodies of pyroxenite, dolerite and products of their destruction and rewashing - volcaniclastic conglomerates, grits, sandstones.

Middle ore-bearing variegated pack (O_1^2) mainly composed of siliceous rock - sericite - chlorite composition with lenses interbedded massive, banded gold - pyrite - arsenic - polymetallic ores, with socket and vein - disseminated sulphide mineralization, as well as lenses, boudins, interbedded volcaniclastic siltstones, sandstones, grits rarely interspersed with abundant sulphides - pyrite and arsenopyrite (5-10%). Siliceous sedimentary formation (jasper, ferruginous mudstones) constitute a small part in the structure of the section. Thickness of variegated packs within the deposit varies from 40 to 120 m.

Upper packet (O_1^3) composed more coarse sediments and greywacke - lilac colored grained sandstones, interbedded sandstones and gray-green siltstones. Thickness terrigenous-siliceous packs vary from 70 to 120 m.

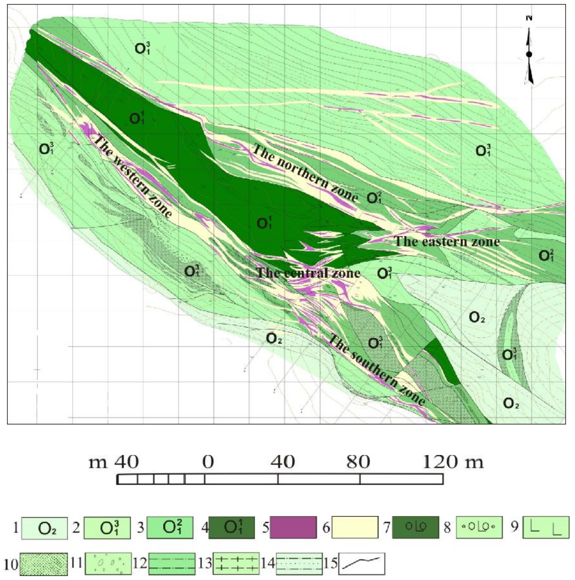

Figure 2 - Geological map of the deposit Naymanzhal

1-4-Ordovician formation: 1 polymictic sandstones, tobacco-yellow siltstones; 2-mauve jasper silicons interbedded with lilac siltstone, purple siltstone interbedded with greenish-gray sandstone impregnated with pyrite; 3-siliceous-sericite-chlorite rocks with lenses and interbedded of massive, banded sulphides, vein-disseminated sulphide mineralization, volcaniclastic siltstones, sandstones, grits impregnated with sulphides; 4-basalts with pyroxenite segregations of dark green color, volcaniclastic conglomerates, grits, sandstones; 5 orebodies (cutoff grade Au> 0,5 g / t); 6 - zones of hydrothermal and later hypergenic changes, ferrugination, kaolinization, silicification, formation of gypsum; 7-volcaniclastic conglomerates; 8-volcaniclastic grits; 9-basalts; 10-silica, jasper; 11 conglomerates with fragments of chert; 12-siltstones; 13-siliceous siltstone; 14 interbedded sandstones and siltstones; 15 faults.

Morphology of ore zones and ore bodies

As a result of conducting a detailed search, appraisal and exploration have been studied all the major aspects of the geological structure of the deposit Naymanzhal, the principal of which are mineralized zones and within ore bodies. Mineralized areas are well mapped in ditches and boreholes on the typical real and structural-textural features, but the ore bodies with a fixed cut-off grade of gold 0.5 g/t are distinguished only by the results of chemical testing. This provision likewise applies to both oxidized and semioxidized and primary unoxidized gold ores.

Spatial position and morphology of the mineralized zones is totally controlled by lithological, structural and tectonically features of the deposit structure. Spatial position and their morphological features of the internal structure at the deposit Naymanzhal allocated 5 mineralized zones: Western, Central, Southern, Northern and Eastern.

The mineral composition of the ore oxidation zone in the deposit Naymanzhal

Ore oxidation zone at the deposit all over the place developed to a depth of 20-60 m, and in "pockets" reach 80-120 m from the surface. Among the dense varieties are the following types: 1) significantly jarosite and scorodite; 2) jarosite, scorodite and jarosite-arsenite-siderite; 3) jarosite-scorodite-arsenite-siderite-ironstone; 4) ironstone, iron-manganese and manganese. All these types of ores have mainly vein-disseminated and vein textures, rarely nest-interspersed. Mainly it is thin veinlets with a thickness of 5 mm and smaller separation up to 3-5 mm within kaolin mass. Banded and massive textures are less common.

The main ore minerals of the oxidized zone are iron hydroxides (goethite and hydrogoethite), scorodite and jarosite. Valuable minerals are gold and silver. Among the secondary attributed hematite, manganese minerals, arseniosiderite. The remaining minerals are rarely seen and very rare (chalcophanite, coronado, bixbyite, etc.).

Research data schlich geochemical samples from oxidized ores of this deposit showed a great variety of gold forms. These crystals are irregularly shaped, isometric, lumpy, and lamellar. There were grains, similar to dendrites and spongiosum. Finely dispersed gold is into them. In the oxidation zone there is "residual" gold or hypogene in which the silver content reaches 20-25%, and secondary - high fineness (982-999) [3]. Sponge gold and gold foil with iron hydroxides refers to the secondary gold. Ennoblement of gold occurs in the oxidation zone by reducing the amount therein Ag, Cu and Fe [7, 8]. Iron and copper impurities in low concentrations are typical for gold.

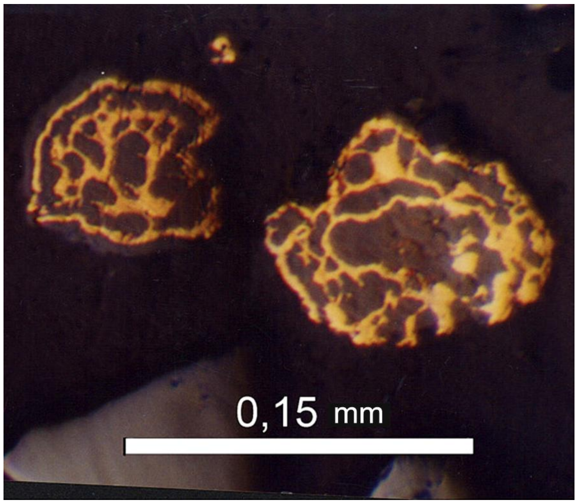

Figure 3 - Gold distributed by zones in the goethite-hydrogoethite aggregate

Vertical and lateral zonation of hypergenesis zone

In the supergene zone location of various types of ores in different directions obeys different rules. So weakly manifested vertical zoning and clearly expressed in the lateral zonation.

Vertical zonation in the distribution of types of oxidized ore is extremely ambiguous. However, overall, to a first approximation, zoning regularities are identified. Should indicate, an extremely high degree of variability is in vertical zonation within the deposit area. In one exploration well can be watch different subzones (surface caving, jarosite, pyrite, ironstone loose subzones). However, in another well - the number and order of appearance of each of the subzones can be totally different, or may be marked by a sharp change their bedding depths. At the same time, in areas of deep penetration of the oxidation zone, in particular in the central part of the deposit identified definite zoning. In the top, to a depth of

4.0-5.0 m below the surface is subzone "surface caving": clay, sandy, fragments of rocks, ores. Typically, they are depleted by the presence of gold, silver. Below, to a depth of 12 - 25 m from the surface developed subzone ironstone: brown sandy loam, gravel, pieces of iron ores. However, the thickness is different, until complete disappearance. Often this subzone interbedded with unconsolidated, porous or loose formations of jarosite subzone. Jarosite subzone widely developed on the surface of the deposit, i.e. where ironstone area eroded (or preserved in the form of supergene chert). Obviously, jarosite subzone lies below ironstone subzone and underlain with rare interbedded carbonaceous pyritic or sulfur unconsolidated sediments. Loose deposits, as revealed by the results of drilling, belong to the boundary transition mixed ores into oxide. Here marked secondary sulfide enrichment zone having a thickness from 1 to 8 meters. Ore in this zone are represented by gray, black shales with abundant impregnation newly sulphides (up to 60% of total weight) - pyrite and arsenopyrite. There are fragments of quartz-pyrite, quartz-arsenopyrite, quartz-galena-sphalerite primary ore. Worldwide secondary sulfide enrichment zone overlaps interbedded brown clay having a thickness of several meters, which also carry impregnations of secondary pyrite and arsenopyrite. Found that the upper limit of the zone of secondary sulfide enrichment hypsometrically strictly confined to the level of +320 m. The lower edge of the zone reaches a depth of 313 m. Ore of secondary sulfide enrichment zone sometimes carry higher concentrations of gold and silver.

Lateral zonation of the oxidation zone deposits precisely identified and recorded in the patterns of ore type's distribution in the plan (Figure 4).

West ore zone consists predominantly jarosite-scorodite-arsenite siderite ores with small admixture of iron ore. White, unpainted colors kaolin component increase marked at the extreme north-western flank. For this part of the field is characterized by the predominance of the spectra of illites and highly ordered illites with small admixture of smectite, chlorite, jarosite. To the south-eastern end of the ore zone, noted the appearance of iron ore with brown color of the surrounding rock matrix.

Central ore zone is characterized by the development of jarosite, scorodite, jarosite-arsenite-siderite, significantly scorodite and jarosite ores. Kaolin matrix here brightly colored bright yellow, brown tones. Within it are rare iron ore. Textural features of ores are widespread development of breccia textures, where fragments of kaolin rocks cemented jarosite - arsenite siderite aggregates. Rock matrix is characterized by increase of kaolin and smectite components over illite.

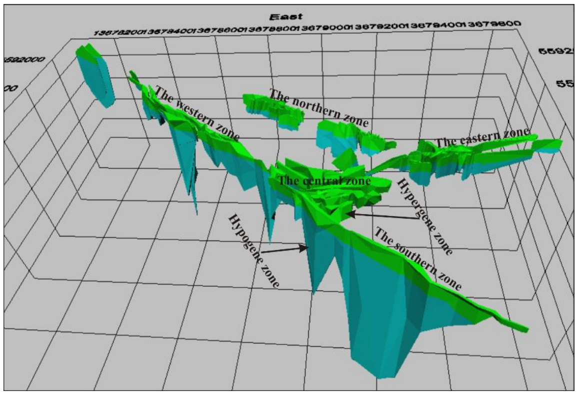

Figure 4 - The lateral zonation in the distribution of ore types in 3-D

South ore zone is represented in most iron, iron-manganese and manganese ores. The highest silver content of the deposit (up to several hundred grams per ton) are marked here. Manganese ores are often presented powdery and granular varieties. Infrared spectroscopy reveals the prevalence of spectra of highly ordered illites and kaolinite over illites.

North ore zone for today poorly understood, it can be noted visually predominant development of iron ore in white kaolin matrix.

East ore zone differs from the North that kaolin matrix has an intense brown, yellow. The primary type of ore is iron, jarosite-scorodite.

Regularities of the spatial distribution of gold concentrations in the ore bodies

For presentation ore bodies in three-dimensional space was used solid modeling. Available materials showed that wells were crossed orebodies unequally. However, the scales of the field, the density of exploration network are sufficient to obtain reliable information about the morphology and distribution of the mineralization bodies to the full depth of the oxidation zone development. Production experience of individual ore beds, large and small clusters of ore bodies allowed revealing intermittence existing ore material in geological space [9, 10]. The distribution of ore bodies in the geological space and their morphological characteristics typically depend on the structural elements, in particular of intersecting fractures escaping to depth. Ore bodies in the mineralized zones on the results of testing and three-dimensional models of Naymanzhal ore bodies have rather complex morphology. They are caused by the variability of strike and dip, uneven distribution of the contents of the gold and silver.

To determine the spatial heterogeneity of mineralization and calculate the input parameters for the evaluation of gold grades Naymanzhal field mineralization interpretation was carried out using the following methods and techniques: 1. every geological section displayed individually and interactively interpreted; 2. main sections have been limited in size + / -25 meters and the intermediate + / -12 or 6 meters. In ditches with career assaying used limits + / -1.5 meters; 3. interpret all string were tied to the appropriate sampling intervals and composite intervals, that is, the interpretation was carried out in a three-dimensional environment (Figure 5); 4. internal dilution within the mineralized bodies are not interpreted and not modeled. Internal dilution has been included in the case when, as a whole, its thickness was less than 2 m and not diluting the total content of the average content lower than the selected board content; 5. interpretation was extended to 12.5 meters to the east or west (along the strike and dip of the ore body) from the corresponding first or last section (12.5 meters is half the distance between the profiles of exploratory wells and ditches); 6. if the mineralized body is not fed to the nearby drilling section, it was projected on half the distance to the next section and broke off (typically 12.5 meters). The total strike and dip direction of the ore bodies were left unchanged.

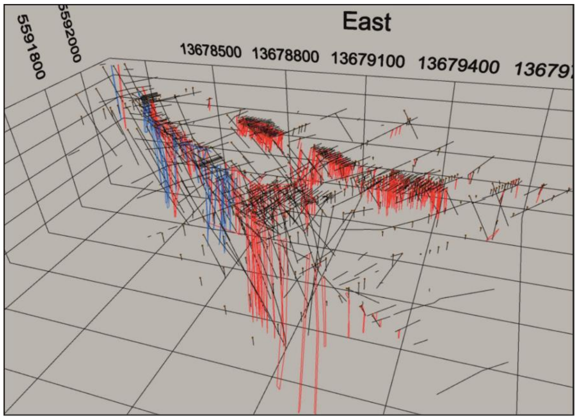

Figure 5 - Interpretation of mineralized zones of gold deposits

Geostatistical analysis was performed for the ore bodies from the oxidation zone and the elements studied in three orthogonal directions to evaluate the spatial variability of the mineralization in each direction.

Gold content distribution showed that in direction azimuth 132°, dip 6° at a distance of 98 m; azimuth 252°, dip 78° at a distance of 52 m mineralization changes slightly and convergence is good. The vertical direction in azimuth of 221° and dip 10° mineralization varies abruptly from 0.3 to 5 g/m [11].

Thus, the data of a study of the spatial variability of gold grades within the ore bodies show its highly unequal distribution of the ore bodies (Figure 6).

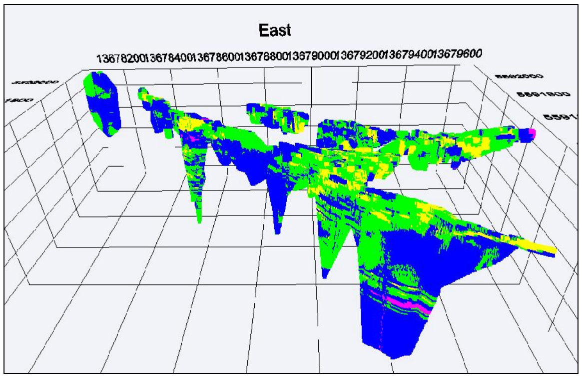

Figure 6 - Distribution of gold in ore bodies: values <0.3 (yellow); 0.3 to 1 (green); 1 to 5 (blue); > 5 g/t (purple)

Findings

Within the field area in placing ore types in the supergene zone established the following regularities: high degree of variability of different subzones in vertically and quite distinct zonal location of various types of ore in the plan. In general, for the North and East ore zones are more typical kaolinite with iron ores; for Western jarosite-scorodite-arsenite-siderite varieties; for South - iron combined with iron-manganese and manganese ores; for Central - a mixture of all of the above.

The main part of the gold in the oxidation zone is freely finely dispersed pure form, easily extractable by cyanidation. Oxidized ores contain "residual" hypogene gold, with reliability determined by the relationship with relict sulphides and quartz, and secondary, which is determined by association with hypergenic minerals. Dominated by idiomorphic and lumpy grains, for the most part are "residual" or relict primary ore gold particles. Spongy gold is hypergene newly created. Was established and shown spatial variability of gold grades within all ore bodies in three-dimensional model.

Conclusions

Mineralogical and geochemical study of ores from the oxidation zone, high porosity and permeability of the rocks enclosing the mineralization, as well as the data to assess the technological properties of oxidized ores are favorable to mining by cyanide solution heap leaching method.

Results of research can be used when mining this method other deposits with similar geological position and similar mineral composition of ores. Naymanzhal deposit can be taken as the standard by the results of a comprehensive study of the upper oxidized parts. Therefore, based on these data is taken positive or negative decision for testing object.

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