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AN IMPORTANT RESERVE OF IMPROVING THE ASSESSMENT AND INDUSTRIAL DEVELOPMENT OF LARGE COMPLEX ORE DEPOSITS OF NON-FERROUS, NOBLE AND RARE METALS (UZBEKISTAN)

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Abstract:
The article discusses the issues of increasing the efficiency of geological and economic assessment and development of large complex fields in floating conditions on the example of the Almalyk group of fields. It is shown that the application of a fundamentally new optimized complex-system-dynamic and situational approach to the assessment of deposits increases the commercial, open-pit mined reserves of complex noble-color-rare-metal-porphyry ores of the Almalyk group deposits by four times. These results made it possible to substantiate the construction of a new processing complex, additional to the existing mining and processing plant (AGMK), based on the development for the Dalneye (Yoshlik-1) development.

Keywords: Geological and economic assessment, complex ore deposits, porphyry copper ores, integrated geological and economic assessment, Kalmakyr, Kurgashinkan, Almalyk, Uzbekistan

Analysis of the current state of large explored and exploited ore deposits in Uzbekistan and other countries shows that traditionally, to establish the industrial value of deposits, a single cut-off grade of the useful component is used (the cut-off grade is calculated based on the average parameters of the deposits).

At the same time, almost all deposits of non-ferrous, rare, noble metals are represented by ore bodies with a complex inner structure that do not have clear contacts with accommodating rocks, variable morphology and are distinguished by the multicomponance of ores. Under such conditions, averaged characteristic of deposits and feasibility and technical and economic indicators of production in the establishment of edges becomes ambiguous and reduces the value of the object [5].

Until recently, in Uzbekistan, the geological and economic assessment of large complex deposits of non-ferrous, noble and rare metals and the rationale for them of industrial designs was made, in most cases, on the basis of a rational static approach, based on unchanged technical and economic indicators of production [1, 11]. The useful components of the ores were divided into 2 parts: one main and the rest on passing. Often, the complex nature of ores, systemic communications and features of mining and processing, time factor, as well as the specificity of each specific situation [6, 12] were not fully taken into account.

With the advent of computer technologies in mining and geological studies, the large amount of computation and multivariate calculations began to ensure the high performance and quality of the received control decisions [3, 4, 15].

This created a real possibility of replacing a widespreadly used rational static approach to the assessment of large complex ore deposits and the rationale for them of industrial condizations, to an optimized comprehensive-dynamic and situational principal approach to the assessment of the deposits under consideration [7].

High mineral resource potential of the Republic of Uzbekistan [13] and the use of certified mining and geological programs in industrial assessment of mineral resources and stocks of Uzbekistan deposits made it possible to make geological and economic information about objects more informed, reliable and transparent [9, 10]. This undoubtedly makes the mineral resource potential of Uzbek deposits even more attractive to invest. The effectiveness of this method is shown on the example of the estimation and development of the Almalyk deposit (Tashkent region, the Republic of Uzbekistan).

THE DISCUSSION OF THE RESULTS

Ore occurrences of copper and lead on the right bank of the Almalyksai were identified by geologist S.F. Mashkovtsev in 1925, the ore occurrence of copper was named Kalmakyr, the ore occurrence of lead (and zinc) – Kurgashinkan.

As they were studied and explored further, it became clear that these ore occurrences are actually deposits. Kalmakyr and Kurgashinkan immediately began to be studied and developed as independent deposits of various types, each in its own ore field (Kurgashinkan - in the Kurgashinkan ore field, Kalmakyr - in the Almalyk ore field) (Fig. 1).

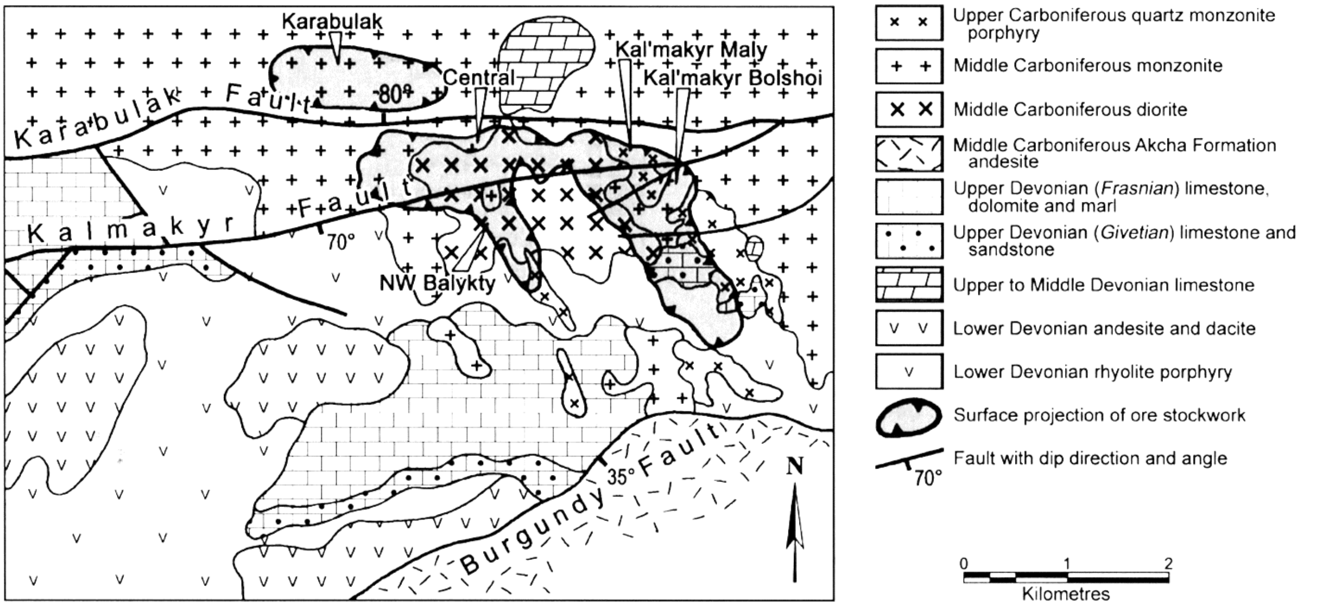

Fig. 1 The geological scheme of Almalyk ore field (after Golovanov et al., 2005)

The Kurgashinkan deposit was transferred for development to the Altyntopkan lead-zinc plant. On the basis of the development of the Kalmakyr deposit, the Almalyk copper-molybdenum combine was created.

Active exploration work at these fields began in 1931. The Kalmakyr deposit was classified as a copper-porphyry type, which is simultaneously classified by most geologists as a copper-molybdenum type. True, at Kalmakyr, the content of molybdenum in the ore is mainly thousandths of a percent, i.e. almost an order of magnitude lower than the average for porphyry copper deposits, but this is more than offset by the fact that the Kalmakyrskaya ore contains tenths of grams of gold and the first grams of silver per ton of ore, on average. Until 1950, at the Kalmakyr deposit, only the zone of oxidized copper ores and the zone of secondary sulfide concentration (chalcocite ores) were studied, explored and evaluated. Based on the calculation of reserves of these ores in 1950.

LenGiprorud Institute has completed a project for the development of a deposit, open-pit to a depth of 200 m. Annual production capacity in terms of rock mass is 8 million cubic meters. m, for ore - 8 million tons. Stripping work at the Kalmakyr open pit, with associated ore mining, began in 1954. In the same year, the Kurgashinkan mine (open pit) began shipping lead-zinc ore to the Almalyk dressing plant.

In 1959, both combines were merged into one Almalyk mining and metallurgical plant (AGMK).

Further exploration of sulfide ores at Kalmakyr, lying below the oxidation zone, showed that they represent the main value of the deposit (over 90%). On the basis of their calculation, in 1960, Giprotsvetmet (Moscow Institute of Design of Nonferrous Metallurgy Objects) drew up a second project for the development of the Kalmakyr deposit, which provides for the development of not only oxidized and secondary sulfide ores, with an increased copper content, but also poorer in terms of the content copper, primary sulphide ores. The parameters of the Kalmakyr open pit and its annual production capacity for ore and rock mass in the new project have increased several times.

In parallel with the development of the Kalmakyr deposit and its detailed additional exploration, at the beginning of the sixties of the last century, on the left bank of the Almalyksai, in the area adjacent directly to the western flank of the Kalmakyr deposit, three new porphyry copper deposits were identified, similar in composition and nature of mineralization to the Kalmakyr deposit. These three new deposits are: Dalneye deposit (located to the west of the Maly Kalmakyr site practically on its immediate continuation and in the same tectonic wedge, between the Karabulak and Kalmakyr faults); North-West Balykty deposit, adjacent to the southwestern flank of the Dalneye deposit, located south of the Kalmakyr fault, stretched parallel to Almalyksai and the Bolshoi Kalmakyr area, and the Karabulak deposit - located north-west of the Dalneye deposit, north of the Karabulak fault, adjacent this fault (Fig. 2).

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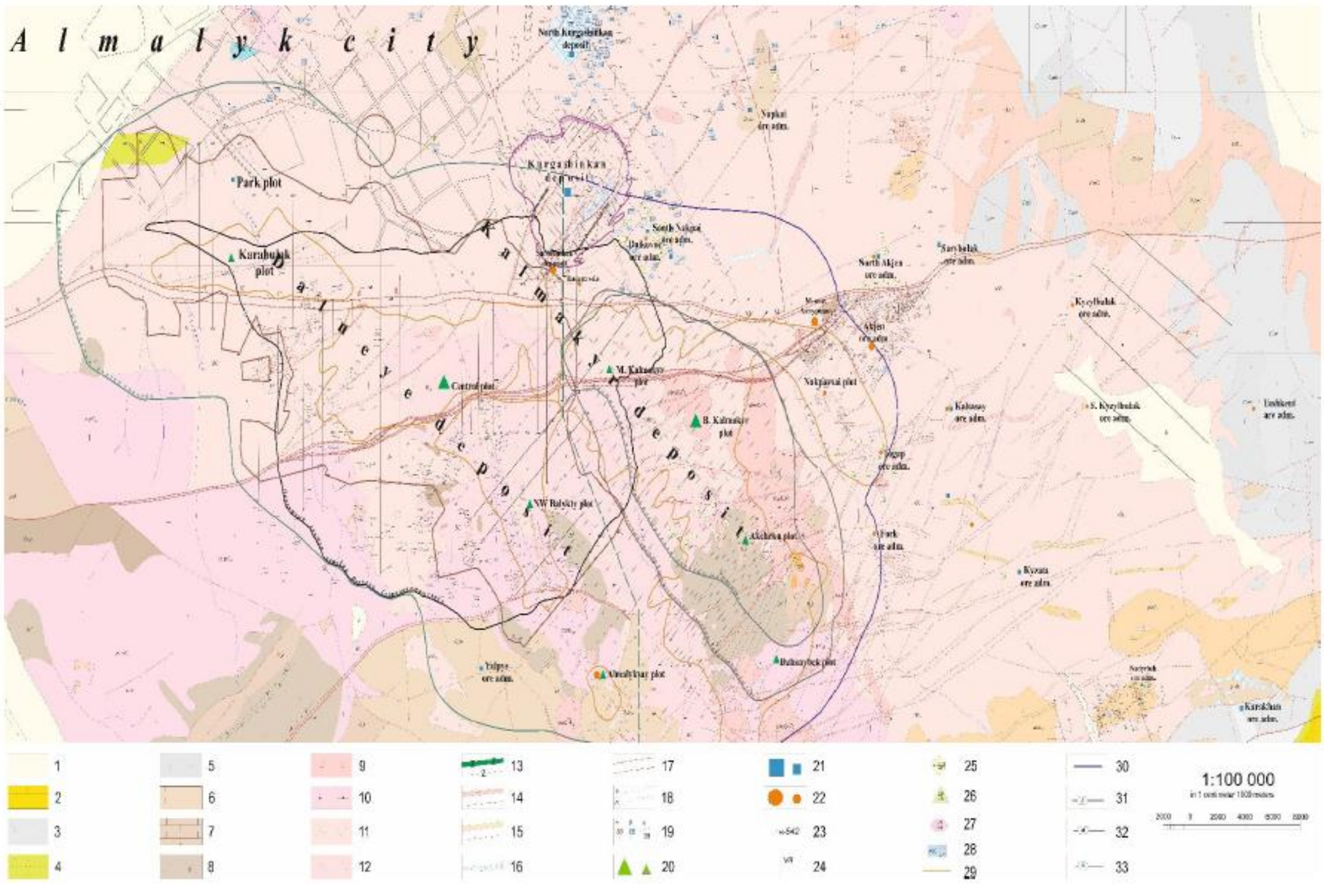

Fig. 2. Almalyk ore field. Prospects for open-pit mining of the Kalmakyr and Dalneye deposits

Legend: 1 - loess and deluvial-alluvial deposits Q; 2 - shell limestones, quartz sandstones Pg; 3 - sandstones with intercalation of interstitial clays K; 4 - andesitic porphyrites and their tuffs, lower subformation C22ac1; 5 - pyroxene-andesite porphyrites and their tuffs C2mb; 6 - gray, light gray thin-bedded dolomites D3fm; 7 - gray, black dolomites with interlayers of sandstones and mudstones D3fr; 8 - andesidacite porphyry D13. Intrusive formations: 9 - granodiorite-porphyry of the Almalyk type γδп pC3-P1; 10 - granite-porphyry γп prC2-3; 11 - syenodiorites εδC2; 12 - diorites δC2. Dikes: 13 - diabases,14 - granodiorite-porphyry, 15 - syenodiorite-porphyry. 16 - quartz veins; 17 - large tectonic faults; 18 - contacts of rocks: a - reliable, b - assumed; 19 - elements of occurrence: a - faults, b - veins. Deposits, sites and ore occurrences: 20 - copper, 21 - polymetals (lead and zinc), 22 - gold; 23 - well and its number; 24 - section and its number. Testing results: 25 - for gold: sampling interval, m, numerator - gold content, g / t, denominator - silver content, g / t; 26 - for copper: numerator - copper content,%, denominator - tested thickness, m; 27 - for molybdenum: the numerator is the content of molybdenum,%, the denominator is the tested thickness, m; 28 - for lead and zinc: sampling interval, m, numerator - lead content,%, denominator - zinc content,%. 29 - contours of ore stockworks recommended by Almalyk geological exploration, 1983: areas Karabulaksky, Central, North-West Balykty and Amalyksaysky; 1995 - Kalmakyr deposit. The limiting contours of the quarries recommended by Giprotsvetmet: 30 - the Dalny 1 and Dalniy 2 quarries (1970), 31 - the Dalny quarry (1983), 32 - the Kalmakyr quarry (1995), 33 - the limiting contour of the united Almalyk quarry (Thematic part of the State Enterprise SPC "GBiTSM").

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Preliminary exploration of the Dalnee deposit was completed in 1964 and detailed exploration began. However, in 1967, due to slightly lower average copper and gold grades in the Dalnee ore, compared to Kalmakyr, the Dalnee deposit was mothballed.

1969, Giprotsvetmet, who was the general designer of AGMK, based on new data from the Almalyk geological survey (geological expedition) on additional exploration of the Kalmakyr and Dalneye deposits, developed a new project of conditions, and in 1970 made a feasibility study (feasibility study) for the expansion of the copper production of AGMK. In the draft conditions and feasibility study, it was recommended:

expand the contour of the Kalmakyr quarry by cutting the Akcheku section and deepening the quarry: according to option 1 - up to the level of +390 m, according to option 2 - up to the mark of +330 m.;

to reduce the cut-off content of copper in the ore: in the open pit - from 0.4 to 0.3%, outside the open pit - from 0.5 to 0.4%;

the Dzhanybek area, the Kalmakyr deposit, adjacent to the southeastern flank of the Akcheku area, should not be included in the contour of the Kalmakyr open pit;

the Dalneye deposit will be developed in two relatively small open pits 300 and 200 m deep.

The annual productivity of the Kalmakyr quarry, in comparison with the 1960 project, was increased by 1.35 times; completion of the development of the Kalmakyr deposit should come: according to the first option - in 1997, according to the second option - in 2005.

The above recommendations of Giprotsvetmet (adopted on the basis of a static approach to the assessment of deposits) led to the following poor and in some cases even unsatisfactory management decisions:

underestimation of the entire ore potential of the Almalyk ore field, especially on the left bank of the Almalyksai, i.e. the Dalneye, North-West Balykty and Karabulak deposits, which delayed their discovery by 35 years and the start of industrial development for another 30 years;

allotment of the area of the Dalneye deposit for the dumps of the Kalmakyr quarry in 1952;

construction on this area of two capital railway stations (Kalmakyr and Porodnaya) and construction through it of a major double-track railway line Kalmakyr mine - Almalyk MPF (copper-processing plant)

development of a technology for enrichment of ores and production of concentrates at AGMK, aimed at maximum extraction of chalcopyrite into copper concentrate, and the extraction of other useful components was not evaluated (it was extracted as it was possible). The consequence of this is that at the Almalyk MPF, a significant part of free gold, most of pyrite and molybdenite, all magnetite, galena, sphalerite and other valuable minerals (the total value of losses of useful components makes up from one third to one half of the total value of deposits).

In 1969, the Sredazniprotsvetmet Institute (Central Asian Institute for the Design of Non-Ferrous Metallurgy Objects) joined the assessment of the deposits of the Almalyk ore field. By 1970, he developed the optimized limiting boundaries of the united Almalyk quarry and completed a design for the porphyry copper deposits Kalmakyr and Dalnee, an alternative to the design of Giprotsvetmet. When developing these documents, Sredazniprotsvetmet, as part of the first stage of assessing the Almalyk ore field, applied a number of elements of an optimized complex-system-dynamic and situational approach to assessing deposits and justifying conditions for them. This allowed Sredazniprotsvetmet, in comparison with the Giprotsvetmet project, to detail a number of issues of the geology of deposits and their mineralogical and geochemical features, and also to take into account:

especially favorable economic and geographical position of the deposits of the Almalyk ore field;

high complexity of the elemental and mineral composition of ores, as well as favorable geochemical forms of the presence of components in the analyzed ores (especially in poor ones, in terms of copper content;

favorable conditions for the occurrence and development of deposits;

high intermittency of industrial and poor copper ores, as well as waste rocks;

lack of natural geological boundaries between deposits and ore bodies;

that the estimated deposits of the Almalyk ore field, Kalmakyr, Dalnee and others, are in fact large areas of a single especially large stockwork complex Almalyk deposit (it is named Bolshoi Almalyk);

scientific and technological progress in geology, mining, beneficiation, metallurgy, transport and other industries.

Taking into account, eliminating and reducing the above and remaining outside the scope of this article, the shortcomings of the static approach to assessing the deposits under consideration allowed Sredazniprotsvetmet, in comparison with the Giprotsvetmet project, to draw the following scientifically grounded conclusions:

a significant part of poor copper ores in the Almalyk ore field, with an average copper content of more than 0.2%, (not taken into account by the Almalyk geological survey and therefore not assessed by Giprotsvetmet); in fact, they are industrial ores, their reserves must be calculated, put on the state balance sheet and can be economically mined in an open pit;

to reduce the cut-off grade of copper in the ore, not to 0.3-0.4%, as recommended by Giprotsvetmet, but to 0.2%;

on the right bank of the Almalyksai, include in the development of the Kalmakyr open pit the Dzhanybek area, the Kalmakyr deposits (located to the southeast of the Akcheku area, not included by Giprotsvetmet in the contour of the open pit), on the left bank of the Almalyksai, can be economically mined by the open pit of the Dalneye, NZ Balykty and Karabulak deposits, which must first be re-preserved and further explored;

with the inclusion in the mining of poor copper ores, delineated according to the cut-off copper grade of 0.2% recommended by Sredazniprotsvetmet, almost all the deposits of the Almalyk ore field are combined into one single deposit Bolshoy Almalyk [2], completely underexplored not only on the left bank of Almalyksai, but also on its right bank, including Kalmakyr area;

increase the depth of the Kalmakyr open pit by almost 300 m (in relation to option 2 of Giprotsvetmet in the feasibility study of 1970) and, accordingly, expand the parameters of this open pit in the plan (Fig. 3);

to develop the Dalneye deposit in a single open pit, up to a depth of 600 m.;

The above scientifically grounded conclusions and recommendations made it possible to increase the total potential of industrial reserves of non-ferrous, noble and rare metals of the Almalyk ore field more than twofold, including those mined by the open pit more than threefold.

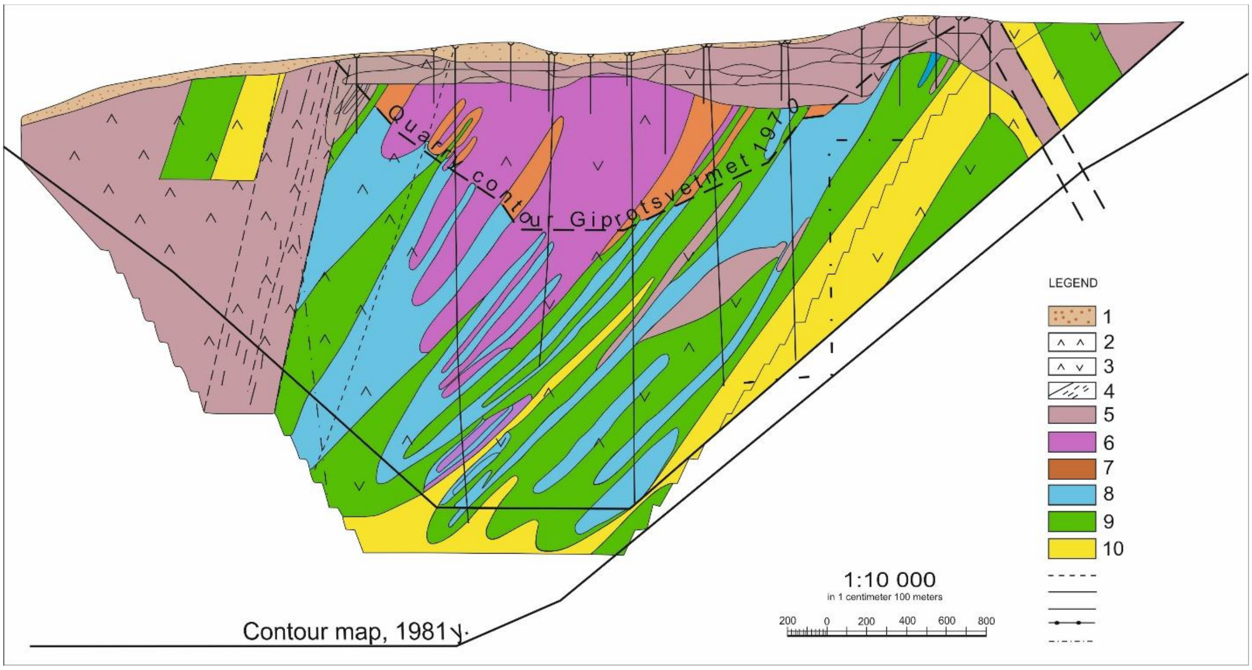

Fig. 3. The Kalmakyr deposit. Cross section.

1 - quaternary sediments; 2 - diorites; 3 - syenodiorites; 4 - faults with friction clays and intensive crushing of rocks; 5 - oxidized, mixed and secondary sulfide ores. Balance sulphide ores with copper content: 6 - high, 7 - low; poor sulphide ores with copper content: 8 - relatively high, 9 - relatively low; 10 - poor sulphide ores (in terms of copper content).

Both draft conditions for the deposits of the Almalyk ore field (Giprotsvetmet and Sredazniprotsvetmet) were considered at a meeting of the GKZ (State Committee for Reserves) of the former Soviet Union. Preference was given to the Sredazniprotsvetmet project. Exploration of the Dalneye deposit was reactivated and funds were allocated for the continuation of exploration work.

In accordance with the recommendations, the depth of calculating the reserves of the Kalmakyr deposit and developing them in a quarry was increased by 300 m, up to a mark of +25 m.

Almalyk exploration department performed work on delineation and calculation of balance ores in the open pit contour at a cut-off copper grade of 0.2%, as well as off-balance (outside the open pit) reserves of poor high-grade copper ores, which significantly increased the potential of Almalyk.

In 1978, detailed exploration was completed, the reserves of the Central area of the Dalneye deposit were calculated and approved by the State Reserves Committee, outlined by a cut-off copper grade of 0.2% (recommended by Sredazniprotsvetmet). In addition to this, the Almalyk geological survey in 1979-1983. carried out a detailed additional exploration of the flanks and the deep part of the Dalneye deposit, including the areas) NW Balykty and Karabulak, performed a reserve estimate and approved them in the State Reserves Committee. As a result, the reserves of the Dalneye deposit, explored for a cut-off copper grade of 0.2%, significantly exceeded the reserves of the Kalmakyr deposit, explored mainly for a cut-off copper grade of 0.3-0.4%. To eliminate this discrepancy, Almalyk geological exploration, in 1981-1993, carried out additional exploration of the flanks and deep part of the Kalmakyr deposit, according to the cut-off copper content of 0.2% and the calculation of reserves in 1996. As a result, the reserves of the Kalmakyr and Dalnee deposits were practically equal. Thus, the first stage of the comparative assessment of porphyry copper deposits of the Almalyk ore field was completed, on the basis of two fundamentally different approaches: Giprotsvetmet (rational static) and the authors of this article (optimized complex-system-dynamic and situational), the beginning of the development of methodological foundations and implementation in the production of which was started by the authors as part of Sredazniprotsvetmet [8]. It was convincingly proved the advantage of the optimized complex-system-dynamic and situational approach to their assessment recommended by Sredazniprotsvetmet (even with its partial use) over the rational static approach used by Giprotsvetmet to the assessment of the deposits under consideration. The proposed approach to the assessment of the deposits under consideration made it possible to more than double the reserves of copper, gold, silver, molybdenum, sulfur, selenium, tellurium, rhenium in the Almalyk ore field and to prove the possibility of working out almost all of them by open pit mining and the good washability of the ores representing them. At the same time, the unit costs for the identification, exploration and calculation of the identified additional reserves of metals turned out to be very low. Geologists of the Almalyk Geological Survey and the Ministry of Geology of Uzbekistan, who participated in this work, were awarded the honorary title of laureates of the State Prize of the Former Union.

Further studies aimed at increasing the completeness of the assessment of ore reserves in the subsoil, improving their quality and increasing the efficiency of their extraction and development, it was found that most of the deposits (Kalmakyr deposit, including the areas: Maly and Bolshoi Kalmakyr, Akcheku, Dzhanybek and Nakpaysay; Dalneye , including the areas: Central, NW Balykty, Karabulak and Almalyksai; the Kurgashinkan deposit with its flank areas, as well as the small gold deposits Sartabutkan, Golduran and Akturpak) are actually areas of a single especially large Almalyk deposit [2, 14].

As the study of the composition and nature of its mineralization became more detailed, it became increasingly clear that its type is especially highly complex, that gold (together with its accompanying silver) and molybdenum (in molybdenite, together with rhenium and osmium-187 present) in these ores, despite their relatively low average grades are practically equivalent to copper, the grades of which in the ore are also low. In this regard, further assessment of the ores of the deposits under consideration as porphyry copper and their delineation only by the cut-off grade of copper (almost like copper), as is done by Moskovsky Giprotsvetmet to this day, is irrational, since gold is relatively often present in the poor copper ores of Almalyk. in industrially interesting quantities, and molybdenum in them, in molybdenite, together with very expensive osmium-187 and rhenium, are present even in increased amounts compared to ordinary and rich copper ores. Consequently, the delineation of the industrial ore stockwork by

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cut-off grade of copper leads to a very high level of losses in the depths of gold and, especially, molybdenum, together with osmium and rhenium. According to the published data of the Oak Ridge Laboratory of the USA, the price of the isotope osmium-187, for the period 1970-2005. rose from 10,000 to 150-200 thousand dollars per gram. the need to take into account and evaluate the osmium-187 isotope in the ores of Almalyk, as well as its further extraction during the processing of molybdenum concentrates at the Almalyk MMC, are quite obvious. Due to its consistently high price on the world market, the isotope osmium-187, along with gold and copper, is actually the third main useful component in the complex noble-color-rare-metal-porphyry ores of the Almalyk ore field [14].

Taking into account the above, since 2005, the authors have carried out a new optimized systematic integrated assessment of the Almalyk ore field deposits, including: delineation of an industrial ore stockwork by the cut-off grade of all useful components contained in the ore, expressed in terms of the conditional main useful component. For this, an LBD was compiled for the fields, including all wells drilled at the fields and mined workings, as well as all testing results for each of the selected samples; justification of the optimized conditions has been carried out; in the LBD data, for each sample, all useful components are converted into a conditional main component, using justified, in the conditions section, optimized conversion factors; as well as the calculation of ore and metal reserves by areas, deposits and by a single, uniting all industrial areas of the ore field, Almalyk deposit. The optimized limiting contour of the combined Almalyk open pit was rebuilt, and the reserves were calculated along the horizons in this limiting open pit contour.

The assessment of the Bolshoi Almalyk field carried out in 2012 in the above sequence for its two especially large components, the Kalmakyr and Dalnee (Eshlik-1) areas, based on an optimized complex-system-dynamic and situational approach and adjusted in 2019, made it possible, quickly, by a small (3-5 people) research group, without additional prospecting and exploration work, without attracting expensive mining and drilling and transport equipment, without its maintenance and repair personnel, without the consumption of spare parts, materials, energy, etc., t .e. with practically no cost to identify in the Almalyk ore field (in extremely favorable economic and geographical conditions, where the climate allows almost all year round to carry out mining in an economical, relatively safe, open way; where there is an abundance of competent skilled labor, there is drinking and industrial water, electricity, natural gas, there are roads and access roads to the deposits, etc.) very significant additional reserves of ore and metals (exceeding the currently approved ones), evaluate them in an optimized way, calculate and prove the possibility of their almost complete development in an open way (by rebuilding the optimized limit unified Almalyk career).

Thus, the overall (for the I and II stages of research) result of replacing the rational static approach to the assessment of the Almalyk deposit with an optimized complex-system-dynamic and situational approach to its assessment made it possible to increase the industrial, open-pit mined reserves of complex noble-color-rare-metal porphyry ores of the Almalyk deposit four times.

CONCLUSIONS

The above results of improving the assessment and increasing the efficiency of the industrial development of Almalyk deposits allowed the AMMC, in 2017, to begin, in addition to the existing copper mining and processing complex, on the basis of the development of the Kalmakyr deposit (a section of the Almalyk giant deposit), the construction of a new, even more powerful , copper mining and processing complex AGMK, on the basis of the development of another (a site of the giant Almalyk deposit) Dalneye deposit (Yoshlik-1).

In 2019-2020 AGMK carried out revision additional exploration of the Almalyk deposit areas, during which it was confirmed the presence of significant additional reserves of ore and metals in comparison with the reserves approved in 1983 for the Yeshlik-1 (Dalneye) deposit and for the Kalmakyr deposit in 1996.

These results confirm the correctness of the principled approach of the authors of this article to the assessment of large ore complex deposits of Almalyk and other regions, and also create favorable prerequisites for further significant expansion of the production capacity of the Almalyk MMC.

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