Distribution of copper in intermediate rocks of Shaugaz-Kandyrsay interfluve (Eastern Almalyk)

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Abstract. The chemical composition of metasomatites and igneous rocks of the Almalyk ore area (Basin of Shaugaz-Kandir Rivers) and general statistical parameters of the distribution of chemical elements in the ore zones and upper rocks are given. High and low Clark concentrations of the elements in the study area were calculated.

1 Introduction

The Almalyk ore region is one of Central Asia's largest mining and industrial regions. The presence here of large exploited deposits of copper, lead, and gold, which are in favorable economic conditions, was the reason for conducting a significant amount of prospecting and exploration work in the area, aimed at its detailed study and identification of new industrial facilities.

Geographically, the Almalyk ore region belongs to the western part of the Kuraminsky range's northern slope and occupies the Akhangaran River's left side. The region's eastern part is cut by the Saukbulak, Urgaz, Shaugaz, Abjaz, and Kandir rivers. The area has been considered a promising target for discovering porphyry copper, polymetallic, and gold-silver mineralization for many years [Khalilov et al. 2016].

The Almalyk ore field is located in the eastern part of the Beltau-Kuraminsky plutonic belt, in the Tashkent region, on the northern slope of the Kuraminsky ridge. The area borders the Republic of Tajikistan in the west, bounded by the Akhangaran River in...
the north, the Kandyr and Gushsay Rivers in the east, and the Kurama Ridge in the south (Fig. 1). Sedimentary, volcanogenic, and intrusive formations are widely developed in the region.

A systematic study of the northern slopes of the Kuraminsky Range began in 1925-26 when S.F. Mashkovtsev carried out a geological survey at a scale of 1:420000. Mashkovtsev published the first data on the results of the work. In 1935 he completed a report on a ten verst shooting, which by that time had covered the entire area of the eastern part of the Tashkent sheet. Geological and prospection works on a scale of 1:200000, carried out in 1927-29, B.N. Nasledov clarified the details of the geological structure and ore content of the northern Karamazar [Nasledov 1938].

From 1964 to 1970, within the limits of the Almalyk ore region, under the direction of I.F. Gaidamak and Yu.S. Shmanko, gravimetric surveys were carried out at scales of 1:50000 and 1:100000. In 1975, A.A. Kulakov and V.V. Neverov carried out generalizations on the study of geology, structure, and conditions for the placement of minerals in the Almalyk region. Promising areas for copper, polymetals, and gold have been identified [Badalov et al. 1971]. In 1975, E.D. Molchanov carried out prospecting and exploration work with an assessment of the prospects for the Kyrkkyz, Yangokly ore occurrences. 11 wells were drilled, and one adit was passed. The predicted resources at the Kyrkkyz ore occurrence have been calculated [Badalov et al. 1971].

2 Methods and Materials

In the Almalyk region, the processes of post-magmatic alteration of rocks manifested themselves with exceptional intensity and diversity. The complete material on their study was collected by Musin R.A., Zakirov T.Z., Viktorov V.F. on the Almalyk and Saukbulak...
3 System analysis

The ore region, which is equivalent to a large porphyry-RMS with complex metallogeny, gravitates towards the eastern flank of a significant basement protrusion, which bears the features of a long-term (from the Silurian to the Permian) uplift with a corresponding reduction in the thickness of the overlying stratified complexes and a change in their facies composition, as well as with a wide development of intrusive formations of the same age range.

Fig 2. Scheme of the geological structure of the Almalyk ore region with the position of deposits of different ore-formational types (compiled using materials from the Almalyk Geological Survey and SAIGIMS).
2. Turbulences cover rocks in a wide range: from rocks of the Caledonian Kuchinsky andesite–dacitic lava and gold–copper mineralization sequences. The most widely and intensively manifested are:

- Biotitization and chloritization
- Strong sericitization
- Zones of secondarily formed quartzites
- Medium sericitization and medium silicification with hematite
- Zones of hypogene origin characteristic of copper–molybdenum deposits

As a result of summarizing the data of V.F. Viktorov and R.A. Musin on the relationship between the generation of magmatic-hydrothermal deposits and the geological structure of the region, the following groups of metasomatites of a regional scale are distinguished: contact hornfelses, porphyry deposits, their numbers: Karabulak (1), Dalni (2), North Karabulak (3), Kalmakyr (4), Under kauldinskoye (5), Kyzata (6), Sary Tash (7), Akturpak (8), 18

Quartz is the main vein mineral in the 

- Veinlet silicification with hematite is characterized by the development of a series of quartz veinlets with a thickness of fractions of a meter that develop along the periphery of the zone of quartzites that do not contain industrial mineralization. It is closely related to the ore process spatially and genetically. Outside the zone of industrial mineralization at the Kalmakyr deposit, silicification becomes weak, and ore mineralization disappears along with it.

Post supra–plutonic belts: 1

- Subvolcanic complexes: 3
- Extrusive domes of early generation andesidacites: 5
- Extrusive dacitic lava: 7
- Basalt: 8
- Granodiorite formation (Almalyk complex): productive for copper–molybdenum deposits are distinguished: veinlet bearing granodiorite porphyry and quartz greisens, prophyry copper mineralization: 6

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C1), 10
Medium sericitization and medium silicification with biotitization and chloritization. This complex of processes manifests itself much more widely and, as a rule, accompanies copper ore bodies located near veinlet silicification areas. A large field of manifestation of these processes is located at the Kalmakyr, Sarychek deposits, in the area of the Dalnee and Yuzhnoye deposits. They are widespread among the effusive of the Central Block, where they are controlled by contacts of intrusions of quartz porphyritic syenite-diorites and tectonic contacts of limestones with effusive (Katrangi). These processes have a significant development among the effusive in the upper reaches of the Karakiya, say in the South Saukbulak area along the Kolbulak and Iron faults.

To a lesser extent, they are developed in effusive formations of the Akcha Formation, granodiorite porphyries of the Gushsay type, syenite porphyries, syenite diorites, and quartz porphyries; in rocks of different petrographic composition [Kulakov et al. 1972-75].

Strong sericitization, in contrast to the average, indicates a weak development of ore minerals, the intensity of the pre-ore hydrothermal process, and significant fracturing of the rocks. In general, it is unfavorable for ore deposition, which is established at the Kalmakyr deposit; however, outside the zones of its development—near them, ore mineralization of industrial significance is possible. Zones of intense sericitization occur mainly along regional faults in Gushsay-type granodiorite porphyries, andesitic and andesite-dacitic porphyries, syenite porphyries, Almalyk-type syenite-diorites, quartz porphyries. They are easily subjected to supergene change processes and, from the surface, are represented by sericite-kaolin rocks [Kulakov et al. 1972-75].

Secondary quartzites develop during intense sericitization when metasomatic quartz begins to stand out. These rocks are products of the initial stage of the hydrothermal process, are rich in SiO₂, and are usually barren. They are characterized by silicification throughout the rock mass in association with finely scaly sericite and finely crystalline pyrite. Sometimes these zones are superimposed by weak ore mineralization (Arbat I ore occurrence). This is the first type of secondary quartzite. It is distributed in the deposits of Kalmakyr, Dzhanybek, and Sarychek along the Kuntushmes say and in the east of the region along the Shaugaz, Yakkabag, etc. Quartzites of the second type were formed according to lithological differences of effusive rocks favorable for replacement. The available material on the study of hydrothermally altered rocks makes it possible to identify the processes of near-ore changes characteristic of polymetallic deposits: serpentinization, skarnig, ankeritization, chloritization, and silicification, epidotization [Kulakov et al. 1972-75].

Molybdenum-copper with gold ores are formed by dissemination and clusters of sulfides, sulfide-quartz veinlets, and rarer veins. Poor disseminated ores prevailing in the inner parts of metasomatic columns vertically and laterally are replaced by industrial disseminated-veinlet and then vein-disseminated essentially pyrite ("pyrite" aureole) with separate thick veins with Au-Ag-polymetallic mineralization.
Fig 3. Generalized model of zoning of porphyry copper stocks of Almalyk ore field: 1 - contour of industrial molybdenum-copper with gold mineralization; areas of development of veinlets of ore-forming mineral associations of various stages of stockwork formation: 2 - early (I), 3 - middle (II), 4 - late (III), 5 - final (IV); average statistical volumes of ore veinlets of different stages (in % of the volume of host rocks): 6 - 0.2–0.4 (I, IV), 7 - 1.0–1.2 (III), 8 - 1.9–4.1 (II); other conv. designation see Fig. 1.

In the same direction, early mineral associations (quartz-potassium feldspar with molybdenite, quartz-magnetite, and quartz-molybdenite-pyrite) are replaced by the main productive quartz-molybdenite-chalcopyrite-pyrite with gold and further on the flanks of the MPS-late quartz-polysulfide with gold and silver.

The latest of the ore-forming (quartz-chalcopyrite-pyrite and quartz-pyrite) associations (the so-called "dry veinlets" without vein accompaniment) gravitate towards the axial zone of the stockwork. The volumes of the vein mass (in the volume of host rocks) are tenths of a percent for the earliest and latest associations, up to 8–10% or more (on average from 2 to 4–5%) for the main productive (Fig. 3) [Zvezdov et al. 2018].

4 Results

The distribution of copper in the sedimentary rocks of the Chatkal-Kurama mountains is discussed in the works of V.I. Rekharsky (1965), D.M. Surgutanova, M.D. Troyanov (1966), L.M. and others [Badaev et al. 1971].

Researchers of porphyry copper deposits of the Almalyk mining region seem to have a commonality in their geological structure, tectonics, magmatism, material composition, and genesis of industrial mineralization. Ores of Kalmakyr, Dalnee (Yoshlik), Karabulak, Northwestern Balikly deposits of disseminated, vein-disseminated and vein type contain Cu (0.4%), Mo (0.005%), Au (0.59 g/t), Ag (2.6 g/t), which are concentrated in chalcopyrite, molybdenite, pyrite. In terms of reserves, the Almalyk deposits are super-giant and unique.

Of particular industrial importance are rhenium (3016 g/t), osmium–187 (4.6 g/t), and selenium (2016 g/t) in molybdenites.
Attention is drawn to the elevated contents of nickel (180 ppm) and cobalt (565 ppm) in pyrites, as well as the presence of platinum and palladium in sulfide minerals [Akhundjanov et al. 2021].

With a decrease in the thickness of the granite layer of the Chatkal-Kurama block from north to south, in the same direction, the lithophilic metallogenic specialization of the Chatkal subzone (Li, Be, W, U, Bi, Sn, TR) changes to chalcophile in the Kurama subzone (Cu, Pb, Zn, Au, Ag, Tl). The main ore objects are located in the Kurama subzone. They are represented by porphyry copper and lead-zinc deposits of the Almalyk group and near-surface gold-silver deposits in volcanic rocks [Kremnev et al. 2016].

Their spatial combination forms complex clark concentrations of copper in metasomatites and igneous rocks of the Shaugaz-Kandyrsai interfluve are metasomatite 10.30, granodiorite 50.66, granodiorite-porphyry 16.25, quartz porphyry 13.94, diorite 17.48, andesite 40.74 [Khaliyorov et al. 2022] (Table 1).

Table 1. Clark concentrations of copper in rocks of interfluve Shaugaz-Kandyrsai.

<table>
<thead>
<tr>
<th>Breeds</th>
<th>Number of samples</th>
<th>Clark (according to A.P. Vinogradov)</th>
<th>Clark concentration of copper</th>
</tr>
</thead>
<tbody>
<tr>
<td>Metasomatites</td>
<td>198</td>
<td>47</td>
<td>10.30</td>
</tr>
<tr>
<td>Granodiorites</td>
<td>86</td>
<td>20</td>
<td>50.66</td>
</tr>
<tr>
<td>Granodiorite porphyry</td>
<td>6</td>
<td>20</td>
<td>16.25</td>
</tr>
<tr>
<td>Quartz porphyry</td>
<td>4</td>
<td>47</td>
<td>13.94</td>
</tr>
<tr>
<td>Diorites</td>
<td>6</td>
<td>35</td>
<td>17.48</td>
</tr>
<tr>
<td>Andesites</td>
<td>5</td>
<td>35</td>
<td>40.74</td>
</tr>
</tbody>
</table>

The Shaugaz-Kandyrsai area of the Almalyk ore field is located in the Beltau-Kuraminsky volcano-plutonic belt on the northern slope of the Kuraminsky ridge. In the course of geochemical studies (316 samples), a correlation of chemical products and their ratios was compiled [Khaliyorov et al. 2022].

Fig 4. Ratios of chemical elements in rocks of Shaugaz-Kandyr River within area.
Corresponding schemes show ratios of clarkes and clark concentrations in various rocks. In metasomatites, it can be seen that the clark concentrations of the elements Mo - Au - Sb - As - Pb - W - Ta - Ag - Cd have higher values than the clark values. It is also seen that the clark concentrations of Cu - V - Ga - Sn - Zn - Nb elements are slightly lower than the clark values (Fig. 5).

Fig. 5. Ratios of clarkes and clark concentrations of elements in metasomatites of Shaugaz-Kandyrsai interfluve (198 samples)

It can be seen in granodiorites that the clark concentrations of the Ag - Cu - Sb - Au - W - Pb - Mo - Ta - As - Pb - Cd elements are higher than the clark values. It can also be seen that the clark concentrations of V - Cd - Co - Ga - Mn - Zn - Ge - Sn elements are somewhat lower than the clark values (Fig. 6).

Fig. 6. Ratios of clarkes and clark concentrations of elements in granodiorites of Shaugaz-Kandyrsai interfluve (86 samples)

In granodiorite porphyries, it can be seen that the clark concentrations of the elements Mo - Ag - Sb - Au - W - Cu - Ta - As - Pb - Cd elements have higher values than the clark values. It is also seen that the clark concentrations of the V - Co - Nb elements are somewhat lower than the clark values (Fig. 7).

Fig. 7. Ratios of clarkes and clark concentrations of elements in granodiorite porphyries (30 samples)
In porphyry quartz rocks, it can be seen that the Clarke concentrations of the Ag-Au-Mo-Ta-Sb-W elements are higher than the Clarke contents. It is also seen that the Clarke concentrations of the Pb-As-Cd-V elements are somewhat lower than the Clarke values (Fig. 8).

In diorite rocks, the Clarke concentrations of the Sb-Ta-Mo-Au-W elements are higher than the Clarke contents. It can also be seen that the Clarke concentrations of As-Cu-Pb-Ag-Cd are somewhat lower than the Clarke values (Fig. 9).
Fig. 9. Ratios of clark concentrations and clark elements in diorites of the Shaugaz-Kandyrsay interfluve (6 samples).

In andesites, it can be seen that the clark concentrations of Ta-Sb-Cu-Au-As-W are higher than the clark values, and it can also be seen that the clark concentration of Pb-Ag-Mo-Cd is slightly lower than the clark values of these elements (Fig. 10).

Fig. 10. Ratios of clark concentrations and clark elements in diorites of the Shaugaz-Kandyrsay interfluve (5 samples).

5 Conclusions

As a result of the research, 316 samples of 0.5 kg were taken from rocks such as granodiorites, diorites, metasomatites, diorite-porphyries, quartz porphyries, and andesites. Based on the results of the spectral-chemical analysis of these samples, the clark concentrations of chemical elements in igneous and metasomatic rocks relative to their clark were calculated.

A common reason for the region's wide distribution of copper and copper-bearing products is the widespread development of the hydrothermal process in the area. The analysis results show that copper-bearing granodiorites, diorites, and andesites developed in the Shaugaz-Kandyrsay interfluve have significantly higher clarks of copper concentration than the clarks of this element in the corresponding rock types.
References


