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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. Discussed the future of using GIS in different spheres. GIS gives possibilities to collect the data, renew it or use new information in the analysis. It requires a quick change of GIS information about Earth because procedures on the Earth are dynamically changeable. Periodically changing information in GIS allows us to get new information and analyze it. GIS technologies and techniques started using widely in all spheres of humanity. It is important to know its properties.

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. In the eastern part of it, gold-copper-porphyry deposits and ore occurrences have been established [Khalilov et al. 2016] [7].

The Almalyk ore field is located in the eastern part of the Beltau-Kuraminsky volcano-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

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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.

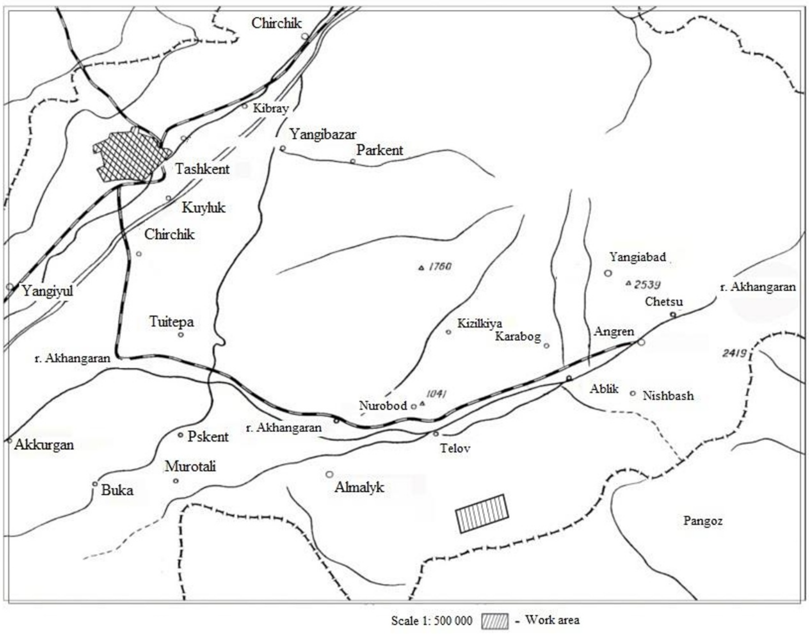

Fig. 1. Overview map

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 prospecting 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] [6].

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] [2]. 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].

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 ore fields; Moiseeva M.I. - on the Shenibek ore field and in the eastern part of the region, Zavyalov G.E. - in the interfluve Urgaz-Kandyr. As a result of performing special work in compiling a predictive map of the Almalyk region for copper and lead at a scale of 1:25000 (1963), the first summary map of hydrothermally altered rocks in the Almalyk region (Kulakov A.A.) was compiled, which, together with other maps, served as the basis for compiling a metallogenic map.

The Almalyk ore region, where several deposits of copper, gold, and polymetallic ores are concentrated, is located in the Middle Tian Shan in the Kuraminsky metallogenic zone of the Beltau-Kuraminsky VPP, formed in the Middle Carboniferous - Early Permian on the southern margin of the North Kyzylkum microcontinent.

The substratum of the belt is composed of terrigenous flyschoid sequences (O–S), volcanic rocks (D_1), and terrigenous–carbonate deposits (D_3–C_1).

The ore region, which is equivalent to a large porphyry-type 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.

3 System analysis

More than half of the area, estimated at 850 km^2, is occupied by a large polychronic (C_1–C_3) Almalyk pluton, composed of phaneritic gabbroids, sodium and potassium profile granitoids, syenites, syenitediorites, as well as rocks of the final phases - granodiorite-porphyries, quartz monzonite porphyries, and diorite porphyrites. (Fig. 2) [Zvezdov et al 2018] [3].

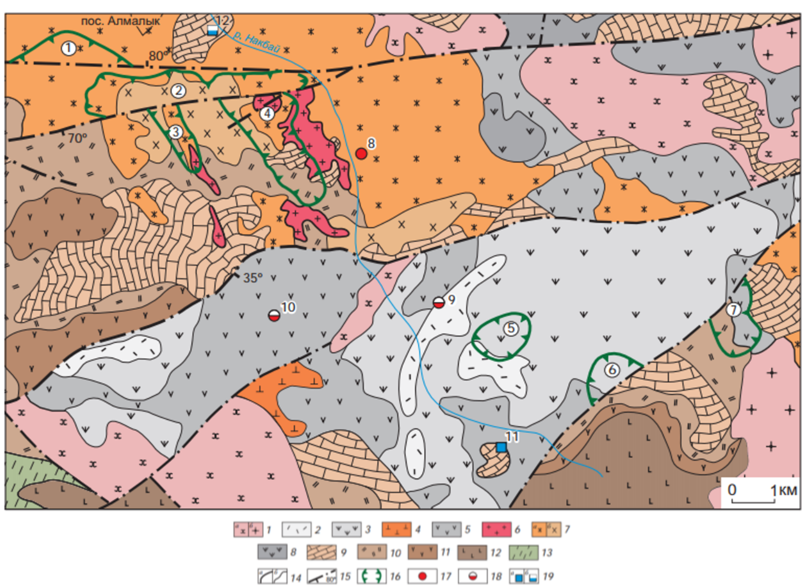

Fig 2. Scheme of the geological structure of the Almalyk ore region with the position of deposits of different ore-formational types (compiled using materials from the Almalyk Geological Survey and SAIGIMS).

Formations of the Beltau-Kurama volcano-plutonic belt: 1 is late stage, C_3–P_1 (a-gabbro-monzonite-monzodiorite, b-granodiorite-adamellitic), 2–7 are early stage (2–5 are andesite-dacitic, productive on gold-hydromica-quartz mineralization, C_2m1– C_3: 2 is Nadak andesite-dacitic lava-pyroclastic complex, 3–5 are Akchinsky andesite-andesidacite extrusive-lava-subvolcanic complex: 3 is supra-ore andesidacite sequence undivided, 4 is extrusive domes of early generation andesidacites, 5 is sub-ore andesitic strata; 6, 7 are gabbro-diorite-monzodiorite-granodiorite formation (Almalyk complex), productive for porphyry copper mineralization: 6 is ore-bearing granodiorite porphyry and quartz monzonite porphyry, 7 is rocks of the main phase (a is syenite-diorite, b is diorite)); VPP basement: 8 is Minbulak trachybasalt–trachyandesite–dacite–rhyolite complex (C_2b), 9 is limestone and dolomite (D3–C1), 10–12 are andesite–basalt–andesite–rhyodacite formation (D_1): 10 is rhyodacites (quartz porphyries), 11 is andesites, 12 is basaltic andesites; 13 is dislocated terrigenous and volcanogenic-terrigenous deposits (O–S); 14 is geological boundaries (a is ore-bearing porphyry intrusions, b is enclosing rocks); 15 is basic discontinuous violations; 16 is horizontal projections of shtockwerk ore bodies of gold-molybdenum-copper-porphyry deposits, their numbers: Karabulak (1), Dalni (2), North-West Balykty (3), Kalmakyr (4), Under kauldinskoye (5), Kyzata (6), Sary-Cheku (7); deposits and occurrences of other ore formation types, their numbers: 17 is gold-quartz vein Akturpak (8), 18 is gold-hydromica-quartz Kauldi (9), Bichanzor (10), 19 is stratiform sulfide-polymetallic in carbonate rocks (but not transformed Kulchulak (11), b is skarnirovannoe and partially regenerated Kurgashinkan (12)).

Post-magmatic alterations cover rocks in a wide range: from rocks of the Caledonian complex to young intrusions of granodiorite-porphyries of the post-Nadakian age. The following groups of metasomatites of a regional scale are distinguished: contact hornfelses, greisens, propylites, secondary quartzites, and secondary abilities, divided into mineral facies.

Here we restrict ourselves to consideration of hydrothermally altered rocks associated with mineralization. All large zones of altered rocks are controlled by tectonic disturbances and crushing zones along the Bashtavak, Burgundin, Miskan, Kolbulak, Zhelezny, Lashkerek, and other faults, as well as by the development of stocks of young intrusions and a series of dikes. All the deposits and ore occurrences of copper, polymetals, and gold known in the region are located in these zones [Kulakov et al. 1972-75] [5].

As a result of summarizing the data of V.F.Viktorov and R.A.Musin on the relationship of each stage of the hydrothermal process with ore deposition in space and time, processes of hypogene origin characteristic of copper-molybdenum deposits are distinguished: veinlet silicification with hematite; medium sericitization and medium silicification with biotitization and chloritization; strong sericitization; zones of secondary quartzites.

Veinlet silicification with hematite is characterized by the development of a series of quartz veinlets with a thickness of fractions of an mm to several cm (rarely 2-3 m) 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. Quartz is the main vein mineral in the Kalmakyr and Sary-cheku deposits and is often associated with pyrite and chalcopyrite.

Zones and areas of this type of silicification occur at the Shaugaz molybdenum deposit, the Yangokly, Kyrkkyz, Myndjilki, Arbat, and Kandyr ore occurrences and are associated with rocks of acidic and intermediate composition: granodiorite-porphyry of the Gushsay type, syenite-diorite of the Almalyk type, effusive formations of the Akchinskaya suite, quartz porphyry, and syenite porphyry. The most widely and intensively manifested silicification is along regional faults, where conjugation of veinlets of different directions is observed [Kulakov et al. 1972-75] [5].

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, Sary-cheku 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] [5].

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] [5].

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 SiO_2, 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, skarning, ankeritization, chloritization, and silicification, epidotization [Kulakov et al. 1972-75] [5].

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.

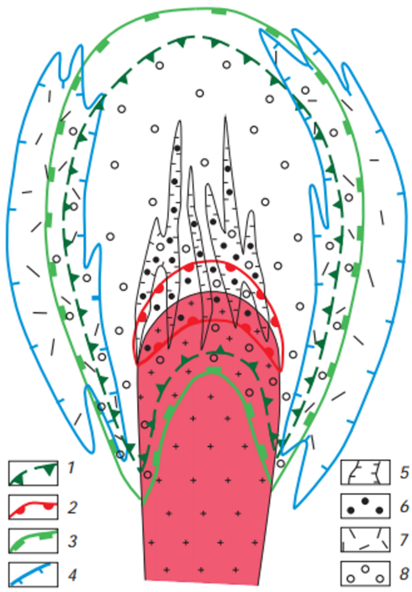

Fig 3. Generalized model of zoning of porphyry copper stockworks of Almalyk ore field: 1 is contour of industrial molybdenum-copper with gold mineralization; areas of development of veinlets of ore-forming mineral associations of various stages of stockwork formation: 2 is early (I), 3 is middle (II), 4 is late (III), 5 is final (IV); average statistical volumes of ore veinlets of different stages (in % of the volume of host rocks): 6 is 0.2–0.4 (I, IV), 7 is 1.0–1.2 (III), 8 is 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] [3].

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 [Badalov et al 1971] [2].

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] [1].

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] [4].

Their spatial combination forms complex clarkes ominous plutonogenic (intrusive) ore-magmatic systems of various facies (depths). The researchers of the Almalyk region established the zoning of ore formation: in the upper parts – Pb – Zn; at medium depths Cu + Mo (the main industrial ore bodies), in the deep parts – Mo + W, in the root (lower) – rare metal – rare earth accessory mineralization [Akhundjanov et al. 2021] [1].

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] [8] (Table 1).

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

Breeds	Number of samples	Clark (according to A.P. Vinogradov)	Clark concentration of copper
Metasomatites	198	47	10.30
Granodiorites	86	20	50.66
Granodiorite porphyry	6	20	16.25
Quartz porphyry	4	47	13.94
Diorites	6	35	17.48
andesites	5	35	40.74

The Shaugaz-Kandyr 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] [9]

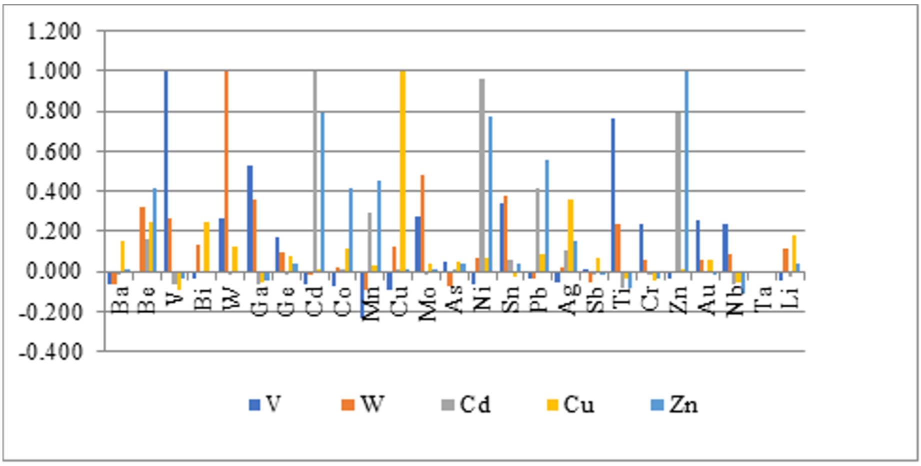

Fig 4. Ratios of chemical elements in rocks of Shaugaz-Kandyr River within area

Corresponding schemes show ratios of clarkes and clarke element concentrations in various rocks.

In metasomatites, it can be seen that the clarke concentrations of the elements Mo-Au-Sb-As-Pb-W-Ta-Ag-Cd have higher values than the clarke contents. It is also seen that the clarke concentrations of Cu-V-Ga-Sn-Zn-Nb elements are slightly lower than the clarke values (Fig. 5).

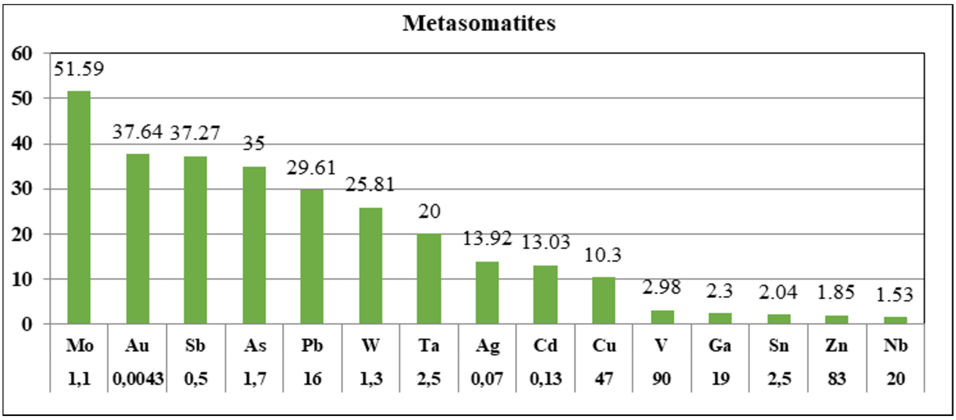

Fig. 5. Ratios of clarkes and clarke concentrations of elements in metasomatites of Shaugaz-Kandyrsai interfluve (198 samples)

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

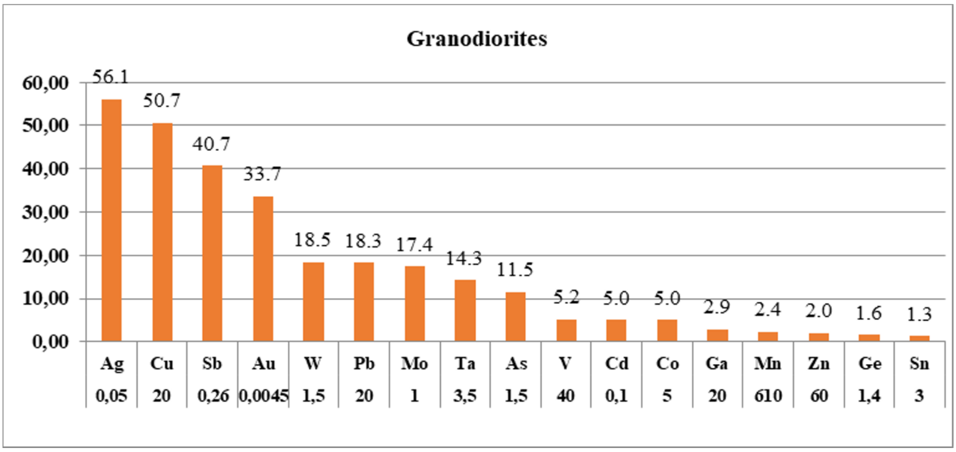

Fig. 6. Ratios of clarkes and clarke concentrations of elements in granodiorites of Shaugaz-Kandyrsai interfluve (86 samples)

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

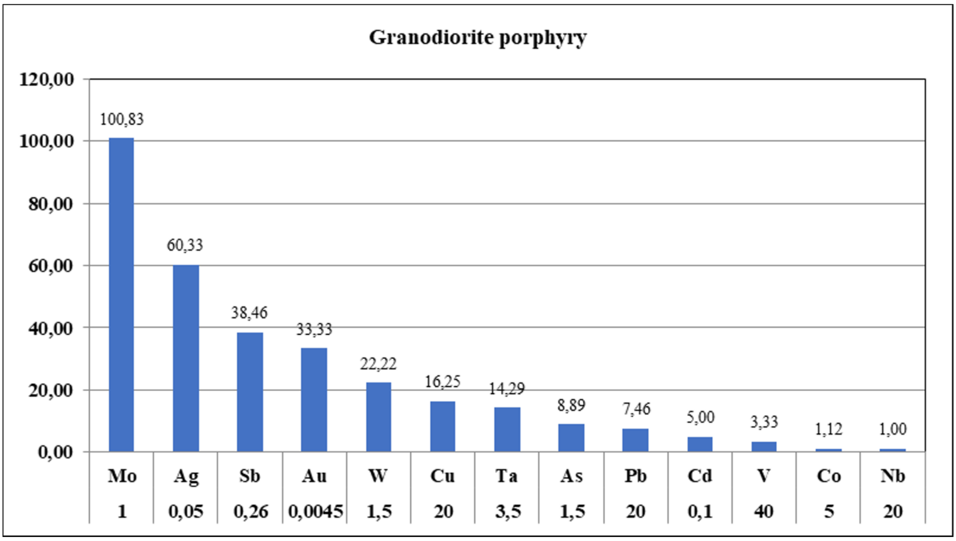

Fig. 7. Ratios of clarke concentrations and clarke elements in granodiorite porphyry of the Shaugaz-Kandyrsay interfluve (6 samples)

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).

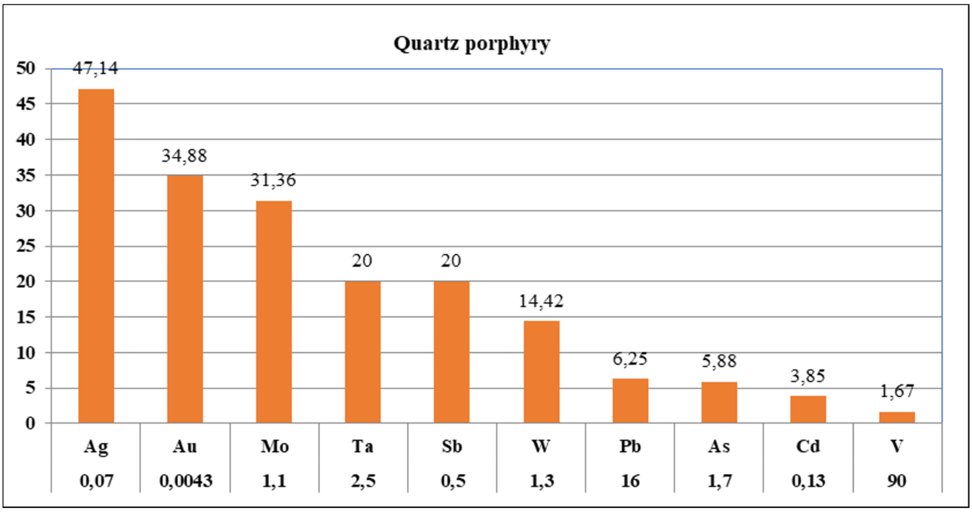

Fig. 8. Ratios of clarke concentrations and clarke elements in quartz porphyry of the Shaugaz-Kandyrsay interfluve (4 samples)

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.).

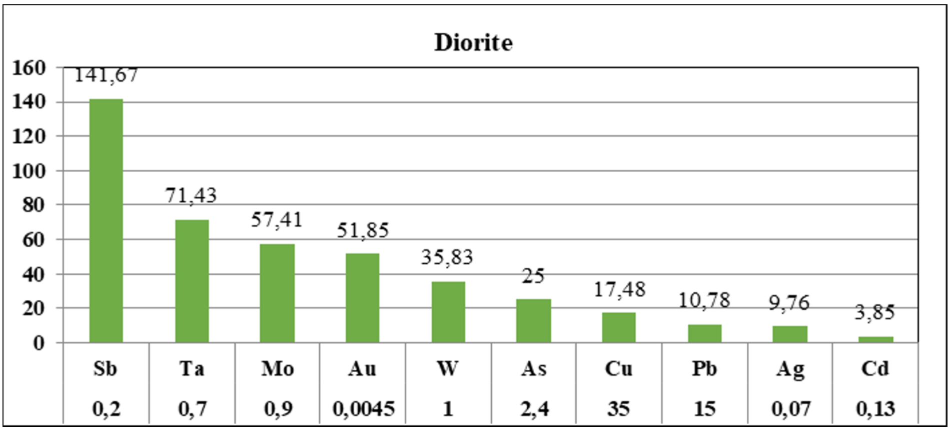

Fig. 9. Ratios of 10larke concentrations and 10larke elements in diorites of the Shaugaz-Kandyrsay interfluve (6 samples)

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

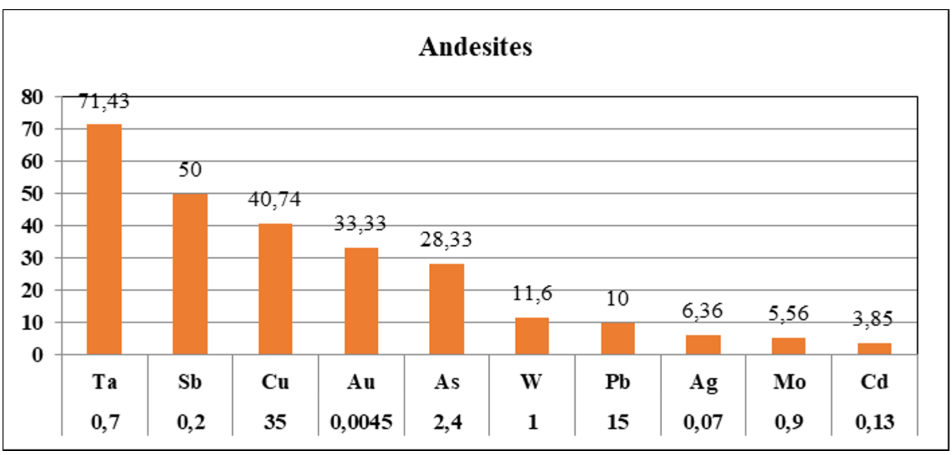

Fig. 10. Ratios of clarke concentrations and clarke elements in diorites of the Shaugaz-Kandyrsay interfluve (5 samples)

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 clarke concentrations of chemical elements in igneous and metasomatic rocks relative to their clarke 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.

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