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Exploration and historic estimate calculation

REPORT ON RESULTS

on the uranium deposit of “Jusandalin”

(as of January 01, 1991)

Volume I

Geological Structure and Methodology of

Geological Exploration

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INTRODUCTION

JUSANDALIN (ULYTAU) uranium deposit was developed in 1982, 15 km south of the operating mining enterprise on the basis of the well-known uranium-molybdenum deposit Botaburum.

This report is a summary of the deposit Jusandalin, which summarizes the results of prospecting, preliminary and detailed explorations performed during the period from 1981 to 1990 by the Eastern Mine. The completed amount of work is given below, in Reference.

This report consists of two volumes.

The volume I of the report contains data on the geology of the deposit, morphology and conditions of occurrence of mineralisation.

The methodology of the performed work is described in detail.

The second volume of the report provides the methodology for the calculation of historic estimates.

The authors of the report are given on the title pages of the corresponding volumes.

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At different times and at different stages of work teams of different research institutes took part on the Jusandalin deposit: Leading Research Institute of Chemical Technology (V.I. Konstantinov), Russian Geological Research Institute (A.V. Bulychev), Russian University of Geological Exploration (V.N. Tyutin), Russian Institute of Mineral Stock (G.I. Frolov) and others, the results of which are given in the corresponding reports of research institutes.

The material composition of mineralisation and the mineralogical and geochemical characteristics of the deposit based on detailed exploration data were mainly performed by Leading Research Institute of Chemical Technology staff and were used by us in separate sections, with reference to the respective authors.

INFORMATION ABOUT THE DISCOVERY AND EXPLORATION OF

THE DEPOSIT OF "JUSANDALIN"

As a result of geological and prospecting works there were obtained convincing facts about the presence of these disturbances, hydrothermal changes of berezitization, albitization, etc., which are favorable for the localization of uranium mineralization. - The geological and prospecting works resulted in convincing evidence of the presence of these disturbances and hydrothermal changes such as berezitization, albitization, etc. A radiometric anomaly was delineated, which served as the object for further detailing, which gave mineralisation holes at the end of 1981.

Drilling of appraisal holes in 1982 under these anomalies, commercial mineralisation were uncovered (holes Nos. 1376,1357).

Thus, the discovery of the uranium deposit Jusandalin dates back to 1982.

On April 22, 1982 there was approved a technical meeting on selection of major trends of preliminary exploration of Jusandalin deposit; the scope of drillholes drilling was determined in order to define structure and scale of the deposit.

Identified mineralisation deposits were delineated from the surface by a 50 x 50 m grid, sections between them by a 200 x 100 and 100 x 100 m grid; flanks of the deposit were intersected by drillholes by a 400 x 200 m grid.

In addition, deep horizons of the field were intersected in profiles 123, 131 - 135 by drillholes up to 1100 m deep.

Preliminary exploration of the deposit from the surface was pursued in 1982-1984.

The scope of uranium emplacement was determined as a result of the exploration work, mineralisation deposits were outlined and the geological and structural position of the deposit was researched.

For this purpose, at the end of 1984, sinking an exploration and production shaft of the "D-1" mine was started 600 meters deep in the lying of the Dyke Fault, 400 m to the south-west (Stretch 123 degrees) of the mineralisation-bearing zone.

A commercial evaluation of the upper horizons of the deposit was conducted in 1985 simultaneously with the sinking of the shaft of mine "D-1" by exploratory drillholes to a depth of 200-250 m in order to substantiate the optimal depth of the upper exploration horizon. Drilling data confirmed the presence of known uranium emplacement in this interval and allowed to justify the establishment of the upper exploration horizon at a depth of 200 m from the surface (absolute mark. + 258m).

There was defined a place of a laying of production and exploration shaft "D-2" of 500 meters in depth on the south-western flank of the deposit in the profile 140 in order to involve the deposit Jusandalin in mining in this year.

Exploration and production shaft of "D-1" mine was intersected in the field with a depth of 613.5m by the beginning of 1987 as well as industrial waste was carried out on the production and exploration shaft of mine "D-2" with a depth of 31m.

However, "The Protocol of the technical meeting on the development of the deposit of Jusandalin" dated March 12, 1987, approved by P.N. Verkhovyh decided to conduct exploration with a minimum amount of mining and drilling operations from one exploration horizon from the shaft of mine "D-1".

For this purpose, a horizon of 40m (500m from the surface) was selected, where the most valuable mineralisation of body 4 were intersected by drillholes from the surface.

Sinking of mine workings and underground drilling in the northern part of the deposit were completed by July 01, 1990.

The morphology of mineralisation bodies, internal structure of mineralisation-bearing zone were specified and material composition and technological properties of mineralisation were researched as a result of mining exploration.

Historic estimate of the deposit Jusandalin were calculated as of 01.01.1991 and submitted for consideration of the Scientific and Technical Council of Yuzhpolymetal.

GEOLOGICAL STRUCTURE OF THE MINERALISATION FIELD AND THE JUSANDALIN DEPOSIT

The mineralisation field Jusandalin is located in the western endocontact part of the cognominal massif, adjacent to Botaburum mineralisation field from the east, covers the area of the deposit itself and adjacent areas (southwestern flank of Botaburum deposit, mineralisation occurrence drillholes 34, areas No. 2, felsite, Granite, anomaly 38.

Geologically the area is composed mainly by volcanogenic sedimentary formations of Devonian and breakthrough granitoids of Jusandalin granite massif.

Among Devonian formations sedimentary-volcanogenic deposits of lower Devonian (Kaidaulsk formation) and mainly volcanogenic rocks of middle-upper Devonian (Karasai formation) are distinguished.

The Kaidaulsk Formation spreads over a small area in the northern and southeastern parts of the mineralisation field and is represented by red-colored sandstones with horizons of siltstones, mudstones, conglomerates, andesite porphyrites, medium and acidic lavas and their pyroclastic varieties.

Deposits of the Karasai Formation are spread in the central and southern part of the mineralisation field and lie mainly as remnants.

They are represented by conglomerates of mixed composition, red-colored sandstones and tuffleschones, andesite porphyrites and their tuffbreccias, felsites and their analogs.

The Jusandalin mineralisation knot, as well as the Botaburum, is characterized by a wide manifestation of magmatic formations associated with repeated pulsation volcanic activity synchronous with the formation of strata and formations and introduction of hypabyssal intrusions.

Two volcano-intrusive formations are distinguished within the mineralisation knot. Andesite-diorite, represented by volcanic and sedimentary-volcanogenic rocks.

The sedimentary-volcanogenic part of the formation is united in the Koktas (Kaidaul) Formation, and the intrusive part makes up the first Devonian complex.

The second formation is the Liparite-Granite Formation, formed by effusives of mainly acidic composition and their pyroclastic analogues, and large intrusives of granite composition.

The sedimentary-volcanogenic part of the formation combines two formations: The Karasai and the Kiyakhty (the latest is outside the mineralisation knot).

Granitoids form the second Devonian complex, of which the Jusandalin massif in particular is composed.

Sub volcanic intrusions of predominantly acidic composition are distributed in the mineralisation field area, within the strata of each of the distinguished formations, which have both consonant and secant occurrences. The intrusion of extrusive rocks is synchronous with the formation of the rock formations. Some extrusions represent a vent by volcanic edifice of the central and linear types. The largest volcanic edifices are the Botaburum edifice and edifices in section No. 2 and Drillholes 24. Magma feeder channels were deep faults of northwestern and near meridional strike.

Rocks of the second Devonian intrusive complex compose in the area, as indicated above, Jusandalin granite massif, which occupies more than half of the mineralisation field. The age and conditions of formation of the massif are considered differently by various researches.

The formation of the massif took place in a single Upper Devonian cycle, divided into three phases: in the first (main) formed the normal and leucocratic, plagioclase with biotite and hornblende medium-coarse granites, in the second - alaskite granites and alaskites, in the third - the rocks of the vein series.

Vital series (aplites, granite-aplites, granite-porphyries) are closely associated with granites as well as detached from them, forming dike belts of diorite porphyries, micro-diorites, quartz porphyries and dikes of complex composition.

Dike belts generally run along the main fault structures, the most widely developed northeastern, sublatitudinal, and meridional.

In the area of the mineralisation field is mainly distributed alaskitic (leucocratic) granites and alaskites, represented by fine-medium-grained varieties and porphyritic granites of fine-medium-grained structure.

Other intrusive rocks within the mineralisation field include andesite porphyrates, which are widespread in the southern part, gabbro-diabases - in the area of the Botaburum deposit.

Felsites and felsite-porphyries in the form of schistose and elongated bodies with crushing in volcanogenic-sedimentary rocks are quite widely developed. Felsite bodies of fluidal felsites are less common, as well as dyke-shaped bodies of near-latitudinal and northeastern strike.

Quartz porphyries in the form of small elongated bodies of various orientations are noted in the southern part of the area. Lava-breccia of quartz porphyries are often developed along these bodies. A northwesterly elongated granodiorite body is also identified here.

In the area of the Botaburum deposit, a body of granodiorite porphyries has intruded along the Dyke fault zone.

Faults of various scales and ages are widespread in the area of the mineralisation field.

Most of them were laid, and the initial stages of geosyncline formation have a long history of development. As for the entire area, we can distinguish:

Sub meridional, northwestern, northeastern, and sub-latitudinal.

Sub meridional strike-slip faults (Jusandalin zone) are the oldest.

Faults of northwestern direction are regional (seams of the Tulkuly fault zone).

The most widely developed faults of northeastern strike (Az.40° and Az.60°).

Faults of this direction form extended zones, often healed by dykes of different composition, are interblock and mainly contain emplacement.

Sub latitudinal faults are zones of increased fracturing, along which observed dyke belts of different compositions.

All types of metasomatic changes are developed within the Jusandalin mineralisation field, as well as in the mineralisation cluster. Depending on the importance given to them in the search for uranium deposits, the degree of their research is different, and they are presented in detail in the reports of the exploration party of PA “Yuzhpolymetall”, as well as in the reports of scientific organizations (Leading Research Institute of Chemical Technology, Russian University of Geological Exploration, Russian Institute of Mineral Stock, etc.).

Hydrothermal-metasomatic changes for the Jusandalin deposit and their connection with uranium emplacement are described in detail in the lithological and petrographic article.

THE DEPOSIT OF “JUSANDALIN”

The deposit is located in southern Balkhash region within the sheet L-43-125-B-g of the State topographic map, in the area bounded by coordinates $44° 32^{1} 20^{11}$ -$44° 34^{1} 00^{11}$ northern latitude and $74° 26^{1}$ – $74^{0} 26^{1}$ -$74^{0} 26^{1}$ eastern longitude.

Geologically, the deposit is confined to the endocontact part of the cognominal granite massif, 1 km from its contact with the surrounding effusive-sedimentary formations of middle-upper Devonian.

The massif is represented by rather monotonous leucocratic (alaskite) granites of Upper Devonian, containing in the endocontact part big (up to 100-1500 m across) relics of Devonian xenoliths. Only insignificant part of these xenoliths is exposed on the surface (about 5% of endocontact area).

The leucocratic (alaskite) granites are medium-grained pinkish-red rocks composed of crystals of microcline-perthite - 50%, quartz - 35-50%, plagioclase - up to 10%, biotite and hornblende - 1-3%, magnetite - 1-3%.

The rocks usually lack plagioclase, and the amount of perthite increases up to 70%. Sometimes small prismatic plagioclase grains are included in the potassium feldspar aggregate.

In the core of prospecting and appraisal drillholes observed phenomena of migmatization and granitization of the host rocks, up to the formation of metasomatic granites on sandstones and andesite porphyrites with gradual transitions of one to the other. On the other hand, during the contact impact on sandstones and especially on felsite porphyries (in the remains-xenoliths), the latter acquired a macro granitic structure with porphyraceous exudations of secondary quartz.

Hornification of the sequence is also widespread. It follows that along with the clearly magmatic genesis of biotite granites composing the Jusandalin massif, a major role in the formation and formation of the intrusion was played by transmagmatic granitizing solutions.

At the deposit was established a wide development of rocks of dyke complex, in particular bundles of dioritic porphyries and a fairly long (about 20 km long) dyke of quartz porphyries, traced from the southern flank of the Botaburum deposit to the southwestern flank of the Jusandalin single field.

In general, the deposit is characterized by a wide range of metasomatic and contact changes in rocks. Exocontact part of the massif and xenolith remains of Devonian effusive-sedimentary rocks are intensively hornfelsed in order to formation of quartz-biotic hornblende. Greisenization of rocks expressed by the formation of a new quartz-tourmaline-muscovite aggregate in the form of nests and inclusions in garnets was noted in various parts of the deposit.

Within the main mineralisation-bearing zone, located in the lying side of the quartz porphyry dyke along the leading seam of the Dyke fracture zone - intensively manifested albitization of granites, which is associated mainly with uranium emplacement.

Albitization at the deposit can be represented as the following metasomatic column:

1. The external zone is represented in varying degrees sericitized, less often - silicified leucocratic granites, developed in areas of increased fracturing and crushing rocks, with sericite or sericite-pyrite cement. In areas of crushing granite fragments are often silicified. The external zone of the column is an area of accumulation of silica and potassium components, displaced from the inner and central zones.

2. The internal zone of albitization is represented by pinkish-brown albitized leucocratic granites. Individual feldspar crystals are selectively hydrohematized, partially replaced by albite and clayey-hydrosludite aggregate. In cracks and micro cracks, an abundance of greenish-gray chlorite and iron hydroxides, less often clay mineral and carbonates is noted. In areas with high uranium concentration, quartz grains are dark gray to black in color.

3. The central zone of albitization is represented by brown, pinkish-brown or chocolate-surgundy varieties of intensely albitized florigated granites. The rocks are colored by iron hydroxides, intensively developed by feldspars together with albite.

In the interstices of minerals and in micro cracks there are isolations of iron hydroxides, chlorite, carbonates and clay-hydrosludite minerals, quartz is replaced by carbonate, chlorite and albite, less often - clay-hydrosludite aggregate.

Often uranium mineralization is associated with rocks in the central albitization zone, ranging from thinly dispersed to visually distinguishable vein-deposited black mineralization. Quartz in this case has a black or anomalous dark gray coloration.

4. Nuclear parts of the central albitization zones are characterized by the maximum degree of chlorite-albite (with carbonate) changes up to complete replacement of quartz and displacement of silica in the external zone. The so-called "quartz-free granites," i.e. apogranitic albitites are formed, among the latter there are four varieties:

(a) Porous albitites, composed of microcline-albitite aggregate with nasturan, coffinite, carbonates, clay minerals and ferrum oxides, filling only partially the voids of leaching quartz. Uranium minerals are surrounded by rims of clay minerals of the illite-montmorillonite type, especially clearly visible on chipping fractures.

b) Albitites, which have a similar petrographic composition, but differ from the first in the fact that the pores are filled with carbonates (calcite and greenish dolomite), as well as an aggregate of mineralisation and circum-mineralisation minerals.

c) Albitites developed on cataclased rocks with unclear initial petrochemical composition; probably, some of them were represented by syenitic schliere segregation of magmatic or autometasomatic origin, bearing no traces of quartz leaching. The petrochemical composition of albitite is similar to the previous ones.

d) Microcline-chlorite-albite rocks, usually without uranium-mineralisation minerals and located either in deep parts of mineralisation-bearing zones (drillhole No. M-1377) or on the flanks of the deposit (drillhole No.1475). Relicts of quartz, almost entirely replaced by albite and chlorite, are established in thin sections. Chlorite is sometimes associated with a rash of finely crystalline pyrite and leucoxene.

Albitites form lens-shaped bodies within the central zone of albitization.

Sub-meridional lenses are also mapped along with the bodies of albitites coinciding in orientation with the mineralisation-bearing zone of the Dyke fault. All of them are linked to specific tectonic seams.

In some cases manifestations of uranium mineralization associated with hydro-mica-sulfide changes were noted besides to the usual adherence of uranium mineralization to albitized rocks.

In general, this type of changes in the deposit is developed quite widely and is confined mainly to a system of tectonic fractures of submeridional direction.

TECTONICS

There are widely developed faults in the area of the deposit. The most widespread of them form three main systems along the strike: north-eastern, east-northeastern (60-70°) sub meridional. Less widespread are disturbances of northwestern (290x310) and sub-latitudinal directions.

The thickness of disturbances varies from the first centimeters at individual fractures with friction clay to 10-15 m at the crushing zones formed by systems of convergent fractures.

The most clearly expressed on the surface of the deposit are north-east-trending fracture zones, which form a belt about 1 km wide, which has a north-east (.20-30) strike and general south-east at an angle of 75-80° dip (Dyke Fault Zone) in total with dykes of quartz porphyries, diorite porphyrites, and zones of intense fracturing, 8 to 25i thick.

Sub meridional faults are tectonic seams from 2 to 10 m thick, dipping often westward at an angle of about 70° (Jusandalin Zone).

East-northeast-trending faults are represented by tectonic seams with friction clay up to 15 m thick, dipping southeastward at angles up to 80°.

According to the time of deposition, sub meridional strike-slip faults are the earliest, although movements along some of them were also present during the period of mineralisation formation.

The east-northeast strike-slip faults are distinguished by the intensity of later movements, as they usually displace both sub meridional and northeast-trending faults, as well as dykes of dioritic and quartz porphyries.

In the northeastern disturbances, which are pre-diked in time of deposition, intensive displacements probably occurred during the period of mineralisation formation, making them the most mineralisation-bearing compared to disturbances of other directions.

MORPHOLOGY AND CONDITIONS OF OCCURRENCE OF MINERALISATION BODIES

As noted above, the uranium deposit of Jusandalin is confined to the corner of the intersection of powerful tectonic fault zones of meridional strike and Dyke fault zone of northeastern strike. According to the preliminary exploration data, the deposit is represented by two pendularly located South and North deposits. Each mineralisation deposit is represented by a series of separate mineralisation bodies confined to tectonic faults within the mineralisation-bearing zones and located at different hypsometric levels.

According to representations obtained as a result of preliminary exploration, all mineralisation bodies are confined to tectonic disturbances of the Dyke fault zone and have a well-defined narrow-linear orientation with a steep (70-85°) dip to the southeast. The emplacement almost extends from the surface to a depth of 660 m, with isolated undercutting at a depth of 1,000 m.

It should be noted that the emplacement interval to a depth of 300 m is characterized mainly by redeposited low grade mineralisation. The high grade in content and significant thickness mineralisation bodies are concentrated in the interval of 350-600 m from the surface.

A set of mine workings was sold from the shaft of “D-1” mine at a depth of 500 m from the surface, for the purpose of detailed exploration of body 4 of the Northern deposit.

Mineralisation drifts 1 and 2 were passed along the strike of the body, and were passed cross-strike drifts. In addition, the mineralisation-bearing zone was drilled on the horizon by separate holes, and the body 4 by air-impact drilling in 50-25m between profiles. The results of detailed exploration showed that the mineralisation deposits have a more complex structure.

The mineralization is localized in both northeastern and meridional fault zones.

The mineralisation-bearing meridional tectonic zones are characterized by a narrowly stretched along tectonic seams shape of mineralisation bodies, small thicknesses, and a series of uranium content. This mineralisation bodies are not contoured by the dip and rise. The most explored of them is body 5, intersected by a number of holes, which is not delineated by underground drilling along the dip and rise, other mineralisation bodies (6,7,8) of this type were intersected by 5-7 holes within the horizon (drawing No.9).

Mineralisation bodies 2_b, 3_b and 4 are confined to the northeastern tectonic fault zones.

The presence of mineralization, within the exploration horizon, on body 2b is confirmed in the profiles II+V drillholes 154, 156, 158, 160 and is not contoured on the dip and rise. Barrel thickness of mineralization in these drillholes ranges from 0.6m to 24.4m, and uranium content from 0.51 to 0.180%. The mineralisation are contrasting and only in drillhole 15B a rim of off-balance mineralisation is noted.

Body 3b on the horizon was uncovered by cross measure drift 123 and drillholes in profiles VI+VI. Outlined by descending and uprising. The mineralisation are low grade, ordinary and off-balance mineralisation in terms of content. Industrial mineralisation in the thick off-balance contour are allocated according to the conditions. Only its northeastern closure was uncovered within the exploration horizon, at the down dip of the body. The main historic estimate of body 36 are located in the southwestern direction of the above-exploration horizon (drawing No. 24).
The main mineralisation and uranium historic estimate of the Northern deposit are concentrated in body 4, which was the main object of underground mining and drilling exploration. It was intersected along the strike by mineralisation drifts 1 and in the cross strike by cuts. It was drilled by fans of holes’ in 50-25m intervals within the exploration horizon.
If the body is outlined by core drilling drillholes from the surface, then it is not outlined by dip. Core drilling drillholes Core drilling machine-4, drilled from drillholes 1, 2, 3 below the exploration horizon, noted the presence of commercial mineralization to a depth of 357m

As noted above body 4 is confined to a thick (up to 50m) zone of tectonic disturbances of north-eastern strike, represented by zones of crushing, intense fracturing, numerous tectonic seams made by friction clay are noted. Dioritic porphyrite dykes which are frequently mineralized are also noted here.

The body has a steep slope within the zone in the northeastern direction, in its lying side there is an mineralisation pillar of the same slope, which has considerable (30-40m) thickness and high grade mineralization. In the hanging side the mineralization is represented by a series of small en echelon bodies with rank and low grade mineralisation.

The tectonic fault zone hosting the mineralization of body 4, like all northeastern zones, has a fairly steep (70-80°) dip to the south-east.
A characteristic feature of the mineralisation column within this zone is as follows. Mineralization is contrasting on the hanging side of this zone, there is almost no off-balance rim, and the mineralisation are mostly high grade. While in the lying side, especially in the bridges of articulation with mineralization confined to meridional disturbances, the mineralisation are low grade, there is an alternation of balance and off-balance mineralisation mineralization with powerful off-balance halos.

High grade mineralization (0.3 to 1.4%) is quite clearly marked in the horizontal section of the mineralisation column in the exploratory horizon in the form of thin 0.3 to 0.5m, but quite numerous narrow elongated strips along tectonic seams or confined to dykes of porphyritic diorites and very rarely in the form of individual local spots.

We can assume that the Southern and Northern deposits of the Jusandalin deposit, despite the low grade exploration of the mineralisation-bearing zone as a whole, represent a fairly large stockwork, confined to the intersection of powerful tectonic zones of the Jusandalin and Dyke faults. Uranium mineralization is confined to separate tectonic seams of both meridional directions, as well as to numerous smaller disturbances and fractures of plumage of different directions.

GENESIS OF THE DEPOSIT

The material composition of mineralisation and the sequence of mineral formation processes allow to conclude about hydrothermal and hypergenic conditions of commercial mineralisation formation.

1. Deposition of uranium-mineralisation paragenesis with coffinite, uranium oxides of several generations, brannerite. The mineralization age is obviously ~ 360 - 380 million years.

2. Manifestation of Hercynian hydrothermal process, alteration of primary mineralisation, uranium regeneration in the form of late oxides, new formation of calcite-hydro silicate association of minerals with iron, lead, zinc and copper sulfides. Approximately 250-260 million years old.

3. Hypergenic process of the formation of the linear weathering crust with oxidation of primary mineralisation and redeposition of uranium minerals (up to industrial concentrations).

Hypergenic alteration of primary mineralisation, apparently, was carried out over a long period of time, and continues to the present, as evidenced by the data of their age determination by neuron induction method (XeS/XeN) and a sharp violation of the isotope system in the minerals of primary uranium mineralisation.

METHODOLOGY OF GEOLOGICAL EXPLORATION

Exploration of the deposit of Jusandalin was mainly carried out in three stages:

I - stage. PROSPECTING WORK

Stage I exploration work consisted of the uranium specialized geological surveys at the scale of 1:10000 and 1:2000, using the complex of geophysical methods.

At the end of the stage, the identified anomalies were evaluated by individual core drilling drillholes. Mineralisation-bearing zones with commercial mineralization were identified.

II - stage. PRELIMINARY EXPLORATION

Preliminary exploration was performed by drilling of inclined (76-80°) drillholes from the surface along the exploration profiles, in order to isolate mineralisation-bearing zones and trace them on the dip.

In addition, several structural prospecting drillholes were drilled to a depth of up to 1100 m in order to study and assess the mineralisation-bearing capacity of deep horizons of the deposit.

uranium historic estimate were calculated according to the results of preliminary exploration

III - stage. DETAILED EXPLORATION.

Detailed exploration was carried out in the deposit only within the limits of the Northern Deposit, mainly within body 4, where the biggest part of deposit historic estimate is concentrated.

For this purpose, the production and exploration shaft of the “D-1” mine and a set of mine workings and drill holes were intersected on the mountain -38 m. Explored by underground mining and drilling works and part of mineralisation bodies 3b and 4 were attributed to the historic estimate.

DEGREE OF EXPLORATION OF THE DEPOSIT

The Jusandalin mineralisation field is covered by a specialized geological survey at a scale of 1:10000 on an area of 19 sq.km. Prospecting works were carried out by the method of geological exploration adopted by PA “Yuzhpolymetal”. They include a complex of ground geophysical works: gravity surveying, magnetic surveying, electrical surveying, emanation surveying by method of charged plate (MCP).

Mapping drilling was carried out to a depth of 35m by the network of 400-200 x 200-100m with obligatory gamma-ray logging of drillholes.

The detected radioactivity anomalies were detailed by mapping drilling with network densification to 100-50 x 30-10 m and, if possible, were intersected by trenches.

The area of the deposit of Jusandalin (1, 2 sq. km) was covered by geological survey of 1+2000 scale.

For detailed mapping, as a rule, main ditches of 200-400m length were used, passed in the field every 20-100m.

The network of mapping drillholes was brought to 50x20-10m.

Preliminary exploration of the field was carried out by drilling inclined (76-80°) drillholes from the surface along exploration profiles. The network of exploratory drillholes from the surface was 100 x 40-50m. At the same time mineralisation-bearing zones along the dip were intersected by drillholes in 80-100m at the top of the deposit (0-300m from the surface) and in 100-200m at the lower horizons.

Exploratory horizon - 38mRL. passed at a depth of 500m from the surface of the exploration and production shaft of the mine “D-1”.

Crescent tube 123 was passed from the mine shaft along the profile 123, which crosses the entire mineralisation-bearing zone to body 4. Body 4 is intersected along strike by mineralisation drifts 1 and 2 and cross-cut by cuts.

From the dissections and mineralisation drifts, the pit-bearing zone as a whole was evaluated by pneumatic impact drilling drillholes to a depth of 200m.

Drillholes were drilled in the plane of the horizon across the strike of the north-eastern mineralisation-bearing zones in 40-40m intervals.

Mineralisation-bearing zone, which contains body 4, was explored by means of 50-25 x 25m network of holes with depth of 40-80m.

Mineralisation content of the north-eastern tectonic zones containing mineralisation bodies 2b, 3b, 4 was estimated by drilling inclined drillholes from drillholes 1, 2, 3 using Core drilling machine -4 machine. Drillholes were drilled in sections 120, II and III, 231 to 350 m below horizon-38 mRL.

The results of underground mining exploration confirmed the presence of mineralization in the horizon of body 2b, established mineralization confined to tectonic zones of meridional direction, and calculated historic estimate for mineralisation bodies 3b and 4 within the exploration horizon, limited by +12mRL and -88mRL.

GEOLOGICAL SURVEY WORK

The methodology of the geological survey was determined by its scale, the terrain relief, the number of natural rock outcrops and the complexity of the geological structure.

The thickness of the cover of loose sediments in the field varies between 0.5-2m. Natural outcrops are rare and confined to the beds of temporary watercourses or uplands.

In order to tie in the field geological objects, a parallel network of profiles and pickets, fixed on the ground with wooden stakes, was laid out. The distance between the profiles is 100 m, with pickets in them every 40 m. The profiles are oriented in the north-west direction (307°), crossing the strike of the mineralisation-controlling structure (Dike fault).

In order to tie in the field geological objects, the reference network of parallel profiles and pickets, fixed on the ground with wooden stakes, was made. The distance between the profiles is

100 m, with pickets in them every 40 m. The profiles are oriented in the north-west direction (307°), crossing the strike of the mineralisation-controlling structure (Dike fault).

Before and during the geological survey, geological walking routes were taken to verify and study tectonic faults, dikes and lithological rock varieties, and trenches and mapping drillholes were drilled.

The density of the network of workings in the area is uneven and depends on the complexity of the geological structure, sediment thickness, as well as on the degree of geophysical study.

Geological documentation of all natural and artificial outcrops was made in accordance with the requirements of the "Instruction of the Ministry of Geology and Subsoil Protection on Primary Geological Documentation of Field Geological Exploration Work".

The results were recorded in field logs and picket books.

DRILLING WORK.

The methodology of drilling works in the field was determined by the design and target tasks of the geological service of PA “Yuzhpolymetal” and depended on the scale of their conduct, the degree and quality of the previous research and technical capabilities of the geological prospecting party.

Surface (mapping, prospecting and exploratory) and underground drilling were used at the deposit.

Mapping drilling was carried out by self-propelled drilling rigs. Data of profile geological traverses, electrical and magnetic survey data were used for selection of mapping drillhole locations.

The drillholes were drilled with a continuous bottom hole, and as they emerged from the weathering crust, they were drilled with diamond core bits. A considerable part of the drillholes (-80%) was drilled by pneumatic impact with cuttings sampling.

Gamma-ray logging was carried out in all drillholes.

Geological documentation and sampling was performed on a daily basis, and the results were entered into the drillhole logs. Schematic geological maps of scale 1:2000, 1:10000 were made based on drilling results.

Prospecting and exploratory drilling was done with core drilling machines. The average depth of the drillholes was 610m.

The locations of the drillholes and the orientation of the drillholes were determined in accordance with the annual geological exploration projects and local projects. The drillholes were drilled by instrumental means.

Drillholes were drilled with roller cone bits of 112mm diameter and P-105K blowpipes with cuttings withdrawal and the following casing with pipes of 89-108m diameter. The average casing depth was 30 m. Further drillhole sinking to its design depth was carried out with diamond crowns with a diameter of 59mm.

Multilateral directional drilling was used in evaluating deep horizons. For this purpose, the main drillhole was passed to the design depth, then an additional drillhole was drilled with the help of whip stock Core drilling machine. Orientation of whip stocks was carried out with a universal pin orienting device.

Geological logging and sampling was carried out as the drillholes were deepened by 40-50 m.

Transitional gamma-ray logging and inclinometry were carried out every 100 m of drillhole deepening, and full complex of geophysical surveys: gamma-ray logging, electrical logging and inclinometry were carried out upon completion of drillhole drilling.

Geological sections of scale 1:2000 with consideration of azimuthal and zenith curvature were made according to the drilling results; logs of holes of scale 1:500 with detailing of mineralisation intervals of scale 1:50 were prepared. With the help of petrographic study of thin sections lithological and metasomatic features of the section were established.

Underground drilling works were carried out from the passed mine workings and were carried out by the NKR-100M, NKR-100MPV and Core Drilling machine -4 rigs.

The main volume of drilling was carried out with NKR-100M rigs, depth of the drillholes is up to 70m, location of the drillholes is fan in the vertical plane.

Drilling of deep (up to 200m) holes was carried out with the NKR-100MPV with a four-cylinder engine.

For inclined (70-85°) core-drilling drillholes orts were previously passed, from which drilling chambers were knocked out.

Concrete foundations were built in the chambers, on which the Core Drilling machine -4 rig was mounted. Drilling was carried out both with drill bits and diamond core bits.

Sludge was taken from the holes with a blowhole, and core and cuttings were taken from core holes with a roller cone drill.

Gamma-ray logging was obligatory for all drillholes. The results of core drilling were recorded in the drillhole logs, and pneumatic drilling - in the documentation logs.

Geological sections of 1:1000 and 1:200 scales were made according to the results of drilling works.

MINING OPERATIONS

Mining operations at the deposit consisted of tunneling on the surface of the deposit, as well as tunneling of the exploration and production shaft of the "D-1" mine and a set of mine workings.

Ditches on the surface of the field were passed by mechanical means, by excavators.The length of the ditches chosen on the basis of the solution of a particular geological problem, and ranged from 20 to 400 m. Depending on the thickness of soft deposits, the depth of the ditches was 1.5-2.5 m, deepening in the rocks reached 0.5-1.5 m depending on the hardness of the primary rocks and the excavator capacity.

An exploration and production shaft "D-1" was drilled on the profile 123, 70 m to the north-west of the drillhole No. 1397 (d. 600m) for underground survey of the Northern deposit. The diameter of the drillhole in the rough - 5.6 m, in the light - 5.0 m, cross-section - 24.63 sq. m and 19.63 sq. m respectively. The shaft is fastened with M-200 concrete, the thickness of the fastener is 0.3 m.

The method of shaft sinking from top to bottom by drilling and blasting, with the blasting charges 40mm in diameter to the depth of 4, 2 m.

The drillholehead part of the shaft was intersected by deep (15m) 105mm diameter holes drilled by self-propelled unit URB-2A-2.

Blasted rock was unloaded with the help of the grader from the loader KS-3 with the capacity of 0.22 cube m. and attached to the truck-mounted crane. Bulk metal frameworks were used to secure the shaft collar and the drillholehead part which simultaneously served as temporary shoring and were subsequently poured with 300 grade concrete.

Sinking of the shaft was realized by blasting of a set of blast-holes 40-43mm in diameter and 4.2m in depth which were driven by hand-operated hammers PP-65s.

Shipment of rock mass was carried out by clamshell loader KS-3 in a bucket of 2.0 cubic meters.

The tunneling was carried out from the tunneling headframe equipped with all the necessary tunneling and shaft equipment. Stabilization of the shaft was carried out using 4.2-meter high sectional self-opening formwork OSS-5.0 with quick-setting monolithic concrete. Concrete was delivered to the shaft by concrete mixers.

Reinforcement of the shaft was carried out after sinking the shaft and cutting of the near-drillholebore pits.

Reinforcement was carried out from bottom to top with simultaneous installation of shoots and installation of ladder sections and communications. There was no drainage - the shaft was flooded.

Reinforcement was carried out using a two-story reinforcing shelf with a four-story cradle suspended below for hanging conductors.

One firing pin was installed in the section of the trunk, carrying two strings of paired conductors and attached to the barrel wall with tubular anchors.

The tunneling header was dismantled and a metal bench header was installed at the end of tunneling.

The shaft was equipped with a single-end hoist by means of the tunneling machine.

Mechanical equipment of the car exchange complex was mounted in the shaft building. A one-story cage of I NOV-400-90 type was hinged in the shaft.

The exploration project for the deposit of Jusandalin, submitted by PA "Yuzhpolimetal", provided for exploration of the mineralisation-bearing zone on two horizons + 50m and - 50m, by a system of drifts, cross ditches and rising between the horizons, with subsequent drilling of exploration drillholes from them.

It was decided to carry out mining exploration on one horizon after reviewing the project

Firstly, to open the body 4 with the quadrupole 123, and then to pass exploratory drifts and orbits to explore the body along the strike and across it. From the traversed mine workings to carry out exploration drilling drillholes.

An exploration horizon of -38mRL was selected based on the results of drilling from the surface.

After the installation in the barrow courtyard of the mountains. -38m of mechanical equipment of the car exchange complex, drilling of horizontal mine workings began.

Boring of the mine face was carried out by using portable drilling rigs LKR-IU. Shipment of rock mass from the working face of the mine was carried out by loading machines PPN-3 and MPDN-1.

Delivery of cars to the shaft was carried out by contact electric locomotive K-10.

Based on the sizes of the used equipment the cross-section of mine workings by cross-slope 123 and mineralisation drifts 1 and 2 - 9.5 sq. m (with the laying of the rails), and on the orts and cuts - 8.1 sq. m.

The excavations were mainly passed without fastening; the interfaces of the excavations were fastened with rod support and shotcrete. The intersections of powerful tectonic faults (drift 1) were secured with metal fasteners and solid wood.

DOCUMENTATION

Geological documentation of all mine workings and drillholes passed in the field during exploration work was carried out in accordance with the instructions of the Ministry of Geology and Subsoil Protection Requirements "On conducting geological documentation of mine workings".

The ditches were documented at a scale of 1:100 along one of the walls and the bottom. All ditches were examined with a radiometer. The obtained data were recorded in the gamma profiling log and then transferred to tracing paper, which was an overlay on the geological sketch of the ditch. The ditch was documented at a scale of 1:50 in places where gamma activity anomalies were detected.

Documentation of the shaft was performed as it was deepened to the formwork height (4 m), immediately after sinking. It included sketching the walls as a reamer, detailed geological description, sampling and radiometer listening on 1x1 m grid.

The primary documentation was maintained at a scale of 1:100 in special picket sheets, sewn from alternating sheets of tracing and millimeter paper, where detailed sketches and descriptions of exposed rocks were made on the millimeter paper, and the data of gamma activity measurement in the form of isolines were displayed on tracing paper.

Two walls and the roof were sketched in horizontal mine workings during the driving of mineralisation and mine face. The documentation was maintained on a scale of 1:100, in places with increased gamma-activity - 1:50, on millimeter paper, and subsequently redrawn in the same scale on the worksheets.

Special attention was paid to lithological rock varieties, dykes, and tectonic disturbances during the documentation. The reddening spots of rocks were particularly carefully sketched within the mineralisation intervals, the role of tectonic fractures in the localization of mineralization was elucidated. The documentation also noted accumulations and disseminations of sulfides, secondary uranium mineralization, rock alteration zones.

Core drilling drillholes from the surface were documented as they were deepened by 40-50 m in a special log.

Each drillhole was issued by log, which included: a geological column, detailed geological description of rocks, refined data after the study of thin sections, data from gamma-ray logs, and for deep drillholes - the entire set of geophysical studies (drillhole logs, electrical logs and inclinometry). The data of spectral and chemical analyses and data of measurements of physical properties of rocks were also recorded in the log of the drillhole, besides the acts of laying and closing, with the data of controlling depths were made for each drillhole.

All documentation was maintained at a scale of 1:500, mineralisation intervals were drawn up at a scale of 1:50, with calculations of thickness and content of mineralisation intervals, the results of core sampling were also taken here.

Based on the drillhole logs, geological sections were constructed, mainly on a scale of 1:2000, taking into account the azimuthal and zenith curvature. Geological maps of 1:2000 - 1:10000 scale were constructed prior to the mapping drilling data.

All underground drilling drillholes were carefully documented, descriptions of cuttings and core samples were made in documentation logs, and the sampling locations were tied in.

In addition, drillhole logs with the results of gamma log interpretation, geological description of rocks, sampling data, etc. prepared for core drilling drillholes by the SKB-4 machine.

The horizontal plan and geological sections of scale 1:1000, 1:500 and 1:200 were made based on the documentation of the drillholes and workings.

The sampling plan of the mine workings is drawn at a scale of 1:100.

Block diagrams in axonometric projection and planned axonometry of body 4 were built at a scale of 1:1000 for a complete idea of the morphology of the mineralisation-bearing zone and mineralisation bodies.

TESTING (SAMPLING)

Sampling was carried out systematically from all mine workings.

The core (cuttings) of drillholes was subjected to geochemical sampling. The sampling intervals corresponded to the thickness of individual rock varieties or the length of 1-3 trips, but did not exceed 10 km. Core pieces were sampled, equally beaten off from the sampled interval every 10-15 cm or 15-20 g of cuttings per 1 m of drillhole penetration (method of dotted line). The initial weight of samples was 250-300 g.

Core samples were taken in the intervals with gamma-activity by caratage above 100 mcr/h. Core sampling was performed by manually splitting the core along the axis into two parts, one of which was taken as a sample. The length of the sample was tied to the tunneling flight and was 1-2 m.

Underground mine workings were subjected to lithogeochemical sampling by the method of dotted line. The sampling interval varies from 2 to 5 m, depending on the complexity of the geological structure.

The back-balance and mineralisation intervals were subjected to trench sampling. Trench sampling was carried out manually, trench cross-section 5x3 cm, length varies from 0.6 to 1.5 m.

In addition, samples, specimens and thin sections were taken in the most geologically interesting places, characterized by different degrees of hydrothermal-metasomatic changes, manifestation of mineralisation mineralization, etc.

Surface mine workings (trenches) were sampled by the method of dotted line in the planned intervals, which consists in manual sampling of equal-sized pieces of rock, sampling interval is 0.5 - 1.0 m.

TOPOGRAPHIC SURVEYING WORKS

Topographic support of geological prospecting works consisted in breaking and referencing of profiles, transfer of mine workings and drillholes location project, topographic referencing of mapping and core-drilling drillholes.

A network of 100x40m profiles with a relative misalignment of not less than 1:300 was created for these purposes. There were laid the main lines between the profile lines with accuracy not less than 1:1500. A 50x20 m grid with the accuracy of line breakdown not less than 1:500 was laid out for detailed geological survey of the field surface at the scale of 1:2000, and the main lines - not less than 1:1000.

Line pegging was carried out by theodolites T-15 and measuring steel ties.

The state geodetic network served as the basis for the planning reference, from which a network of survey points was developed using forward and backward sights, both single and networks of microtriangulation. Observations were carried out with 2T5K theodolites in one complete reception with divergences of horizontal angles in semi-receptions not more than 10 seconds. The discrepancies in the values of coordinates calculated from the two surveying points did not exceed 0.4 m. The mapped drillholes, ditches, deep drillholes, and profile network were tied back from the survey points. Technical leveling was used to determine the height position of deep drillholeheads. X; Y and H coordinates of deep drillholes were entered into the "Drilling Drillhole Catalog", survey points - into the "Catalog of coordinates of analytical points".

Triangulation network of the 2nd order with the inclusion of the sides of the analytical network was built on the mine site "D-1" for surveying of mining works, made in 1984-1985 by the enterprise m/y A-3159. The approach point is remote from the shaft D-1 at 205m.

The marks in the shaft and on the exploration horizon were transferred as the shaft was intersected. The marks in the shaft and on the exploration horizon were transferred as the shaft was intersected. References were placed in the shaft wall. The mark was transferred to the exploration horizon from the XU reference, which has an absolute mark of -25, 26m.

Mine workings are oriented geometrically through the shaft D-1, by means of a connecting triangle of advantageous form with two offsets plumb.

Theodolite way of increased accuracy was laid along the horizon. Mine surveying points were concreted in drillholes on the roof of the workings. Angles were measured with theodolite "Wild T2", with measurement on each stand of the right and left angles.

Lengths were measured by steel 50-meter tape measure on the balance.

Survey theodolites were made by theodolite 2T30. Angles at the points were measured by one complete reception. Survey of excavation contours was carried out by polar and ordinate methods.

Technical leveling of mine workings on the horizon performed by leveling N-3.

Parameters of exploratory drillholes were determined from the survey points of the survey network by polar method, with the transfer of absolute marks to the drillholeheads.

The results of surveying of the mining works are given in the log of coordinates calculation for mine D-1.

GEOPHYSICAL RESEARCHES

GEOPHYSICAL FIELD WORKS

The following field geophysical works were conducted within the boundaries of the deposit of Jusandalin during 1981-1984:

a) gamma-ray surveying of surface mine workings (ditches, pits, clearings);

b) gamma logging of mapping drillholes;

c) emanation track survey;

d) electrical surveying;

e) magnetic survey;

f) Atmogeochemical survey;

g) gravity survey

GEOPHYSICAL DRILLHOLE LOGGING

(a) Gamma-ray logging of surface drillholes.

Gamma-ray logging of surface drillholes (as a complex with electric logging and inclinometry) was carried out in accordance with gamma-ray logging Instruction (5), whereby AEX-1500 type logging station with PKS-1000 type radiometer and “Almaz” scintillation detection units were used based on Na J /Tl/ monocrystal screened with 1.34*1.50 mm thick lead filter (sheet lead as per GOST 9559-60).

The result was recorded on a PASK type logger.

The energy threshold of registration was set up at the level of 20+5 kV with the help of the source Thallium-204. The gradation of the device and stability control were carried out similarly to Scintillation Radiometers Search -68 device (see Section 1, item a of this chapter).

The control source KO was a cylindrical tin vessel with a hole along its axis. The external diameter and length of the cylinder is 100 mm. The vessel was filled with mineralisation material with a binder (epoxy compound).

The results of calibration and control measurements were recorded on the diagram chart. The stability diagrams of the device operation were plotted in the logbook according to the results of measurements with KO.

Marking of the cable was conducted with a 20-meter tape measure with the distance between the marks equal to 10 m.

The drillhole logging data were bound to the depths by the marks. The depth of the marks was calculated by the formula:

$$M=(N-1)\,L+l+m$$

Where N - number of drillhole logging tool marks;

L - distance between the marks, m;

l - the price of the first mark, m;

m - distance from marking point to drillholehead, m.

Gamma drillhole logging was conducted at a depth scale of 1:500 + 1:200; detailing of anomalous intervals + at a scale of 1:50 or 1:20 (depending on the thickness of mineralisation intervals). The detailing of the anomalies was conducted, starting with a count rate corresponding to 50µR/h gamma radiation; detailed recording of the gamma anomaly captured the host rocks at least 1 meter on each side of the mineralisation interval.

The ascent rate of the drillhole instrument did not exceed 500m/h at a time constant of 0.1 to 2.5 s. When detailing anomalies, the logging speed was reduced to 60 m/h (at a constant time of 2 s).

To assess the level of random measurement errors, a control mineralisation interval logging was carried out at the rate of:

- 10 % of the main logging volume, but not less than 30 mineralisation or anomalous intervals during the reporting period (year);

- control intervals were distributed equally over the area of the site and at equal intervals.

The criterion of standard determination of mineralisation intervals depths was considered to be the deviation according to the main and control logs by not more than 0.5 for depths from 0 to 500 m and by not more than 1.0 m for depths from 500 to 1000 m.

The criterion of the normal level of random errors was considered to be the mean square error not exceeding 7% (when comparing the anomaly areas on the logging plots during the main and control measurements).

Quantitative interpretation of the gamma-ray logging data was performed graphically using the formula:

$Q=S/kh$, where

q - uranium content in percent;

S - gamma-anomaly area;

k- recalculation coefficient, numerically equal to the count rate of 0.01% uranium;

h- the thickness of the mineralisation intersection in units of length along the drillholebore.

The thickness of the mineralisation intersection was determined by one of the methods:

- method Z½ (J 1/2) based on finding the position of the points where the gamma ray intensity is equal to half the maximum;

- the method Z_0, based on measuring the steepness of the wings of the anomaly;

- method J posterior, based on finding the position of points in which the intensity is equal to a given one (the method of a given intensity).

The conversion factor K was assumed to be 115mcr/h per 0.01% uranium, based on the assumption that the mineralisation of the Jusandalin deposit are identical in elemental composition to the mineralisation of the Botaburum deposit (silicate mineralisation with an effective atomic number Z eff from 10 to 18 and a normal environment conversion factor N= 1±0.03). The validity of this assumption was confirmed by the results of the full chemical analysis of samples taken during underground exploration of the horizon - 38m; see Table No. 17, Volume 2.

Gamma anomaly area was calculated using a planimeter and was expressed taking into account the scales on the depth axis and count rate axis in units of cm.mcr/h. The value of the area measured by the planimeter and taken into calculation was not less than 5 cm2; at smaller sizes of the area gamma-ray logging diagrams were recalculated in a larger scale.

Corrections for violation of radioactive equilibrium F_{re}, for the equivalent contribution of thorium and potassium in the measurement results, as well as corrections for mineralisation moisture and mineralisation density, were not entered into the interpretation results, because during drilling of drillholes there was extremely low core recovery, which did not allow a reliable laboratory analysis of the distribution of these parameters.

Correction for gamma ray absorption by drilling fluid was introduced into the results of quantitative interpretation in accordance with the requirements of Gamma Logging Instruction (5); table 4.1; item 4.47.

At the same time, the equivalent thickness of the severe solution layer was calculated according to the formula:

$$T_{our}=P_0\ (r_0-R)$$

where: P_0- density of drilling mud, g/cm^3

$2r_0$- drillhole diameter, cm

2 R, - drillhole device diameter, cm

For the drillhole tool, “Almaz” (3.8 cm) and 5.9 cm drillholes, the equivalent thickness of sour mud-water layer was 0.9, and the value of correction for sour mud absorption P_{bur} was 0.97.

Correction for gamma-radiation absorption by casing was not introduced (drillholes were passed without casing).

The error of the gamma-ray logging results was assessed by comparing the areas of the drillhole logs during the main (S_0) and control (S_R) measurements.

The random error of determining the area was found by the formula

$$\pi = \sqrt{\frac{1}{n-1}\left(\sum_{1}^{n} Zi^2\right)}, \text{ where}$$

n is the number of measurements, and Zi= [2 $(S_0$-$S_k)/(S_0$-$S_k)$]

The error of the equipment during the period between neighboring calibrations was determined by the value of the standard deviation

$$\pi = \sqrt{\frac{1}{n-1}\sum_{1}^{n} (R_i - \overline{R})^2}$$

Where:

π - number of measurements

R_i - results of separate measurements

R - mean value

to the coefficient of variation: V= π /R

Actual values of the indicated errors were as follows:

- random error + ± 4.5% (standard + not more than ± 7%)

- coefficient of variation of normally working radiometers + ± 6% (standard + not more than ± 7%) The number of control measurements was 85 mineralisation intervals equally distributed over the deposit area (standard + not less than 20 mineralisation intervals); in relative terms, the volume of control was more than 11% of the main logging volume (standard - not less than 10%).

The depths of mineralisation intervals determined by the main and control logs diverged from each other not more than:

- 0.20 m for depths from 0 to 500m;

(standard + no more than 0.5 m);

- 0.40 m for depths from 500 to 1,000 m;

(standard + not more than 1.0 m);

(b) Electrical logging of surface drillholes

The apparent resistivity (AR) and spontaneous polarization (SP) electric drillhole logging were conducted for the purpose of lithological partitioning of the section.

The works were conducted in complex with gamma ray logging (see Section 2, point a). The KS was recorded with a 0.5 m 8, 0 No. potential probe at a scale of 50+250 mV/cm. The PS was recorded at a scale of 2.5 + 12.5 mV/cm. Along the depth axis, the scale was chosen depending on the depth scale selected during gamma-ray logging; the rate of electric logging was determined by the rate of drillhole device elevation during gamma-ray logging.

The section was subdivided into lithological horizons based on a set of electric and gamma-ray logging data and the lithological characteristics of individual horizons based on core data.

The quality of the electrical logging was assessed by the results of the main and control logs. The mean square discrepancy between the main and control logging results did not exceed + 3% (standard + no more than +10%).

The volume of the control electric logging was determined by the volume of the control gamma-ray logging. The discrepancy between the depths of extreme points on the CS and PS plots according to the main and control logs did not exceed the values:

+0.10 m in drillholes up to 500 m depth,

(standard + no more than 0.5 m);

+0.0 m in drillholes to a depth of 1000 m,

(standard + not more than 1.0 m);

(c) Hole deviation measurements

Measurements of zenith and azimuth angles were made by inclinometers type MI-30, MIR-36. Measurement points were taken every 20 m of the drillhole depth. The inclinometers were adjusted and calibrated using a USK-2 inclinometer.

The quality control of the drillhole deviation elements determination was conducted by carrying out repeated measurements.

The volume of control was 450 0 m or 11% of the total gamma-ray logging volume.

Actual discrepancies were:

by the zenith angle 4 +_ 0.4° 30 (standard + no more than + 0.5);

on the azimuth +4° (standard + not more than + 5°).

RADIOMETRIC WORKS IN UNDERGROUND MINE WORKINGS

During the underground exploration of the deposit (horizon - 38l) the following radiometric works were carried out:

a) gamma profiling and detailed gamma survey of all underground workings;

b) gamma-testing of mineralisation intersections;

c) gamma logging of underground drillholes;

d) express analysis of mineralisation in wagons.

Work on the above complex of radiometric studies was conducted in order to obtain information on the parameters of mineralisation bodies, thickness of mineralisation intersections and uranium content in them.

a) Gamma profiling and detailed gamma survey.

Gamma profiling of mine workings was conducted in accordance with the requirements of the section “Radiometric studies in mine workings” set out in the book “Guidelines for the application and combination of methods of mass prospecting of uranium deposits” (3)

Whereby were used radiometers of RPR-1 and Scintillation Radiometers Search -68-01 types; the detector unit of the latter was screened by a lead filter with thickness of 1.35 ÷ 1.50 mm.

Tuning, calibration and stability control of the radiometers were performed according to the procedure described above (Section 1, point a).

The works were conducted as excavations, gamma profiling was conducted by spiral-axial method with aural indication of activity and fixing of gamma-radiation after 1 m (by the maximum count rate, in mcr/h). The results were recorded on the geological sketch of the excavation. Abnormal areas subject to detailed gamma survey and gamma-testing were identified according to the data of gamma profiling. Anomalous were considered to be the areas with activity over 50 μR/h.

Detailed surveying was conducted in order to study the distribution patterns of mineralization and to clarify its boundaries, the survey was conducted along both walls with vertical profiles every 1.0 m (the step of observations along the profile was 10 cm).

Gamma and drillhole sampling profiles were outlined based on the results of gamma profiling and detailed gamma survey.

b) Gamma sampling

Gamma sampling was conducted along the mine workings, uncovered uranium mineralization.

Both walls were sampled using a system of horizontal profiles at 1.0+1.2 m from the bottom of the excavation, as well as vertical profiles with a measurement step of 0.1 m. Horizontal sampling profiles were divided into one-meter intervals and then into 0.1-meter intervals, corresponding to the measurement step.

The walls of workings were thoroughly washed with water current before sampling in order to exclude the influence of radon decay products and radioactive dust. The intensity of interfering radiation was periodically controlled in the process of sampling.

Sampling was conducted with radiometers of directional reception of RGN-1 "Fon" (fon-background) type (with metrological verification in the Central Laboratory of Measurement and Control in PA “Yuzhpolymetal”).

Adjustment of radiometers was conducted in accordance with its Operation Manual (9) calibration and stability control were carried out according to the procedure described above (Section 4, item a).

A working conversion factor F_{re} was determined to switch from radiometer readings to uranium content by comparing the results of gamma and drillhole sampling (in accordance with the requirements of the Instructions on gamma sampling (13); p.4.b. The comparison was made for 32 mineralisation intervals of meter length (total length 32 m). The average intensity of gamma-radiation Δ J (µh/h) was calculated and the working factor Frb was found by the formula for each mineralisation interval.

$$F_{re} = \Delta J/q,$$ where

q- uranium content in the drillhole sample.

The average value of F_{re} was calculated using the obtained partial values of F_{re}.

In this case obtained: F_{re} =35±0.082 (r.u.-relative units); MCR/h per 0.01% uranium. The value of F_{re} =35 mcR/h at 0,01 % of uranium was taken for quantitative interpretation of the gamma-sampling data because its mean square deviation (+0,082) is less than the standard limit (± 0,10) (13), p.26, p.4,6). The calculation of F_{re} is given in Table 19, Vol.2.

Reliability of gamma-sampling was assessed according to the results of control measurements of mineralisation intervals of sampling and by comparing the results of gamma-and-furrow sampling (the results of reliability assessment are given below). The volume of control gamma sampling was more than 10% of the number of mineralisation intersections in the sampling.

Quantitative interpretation of gamma-sampling data was conducted as follows:

- if the thickness of the mineralisation interval was more than 1 m, then the average value of J was calculated within the meter interval, and the uranium content in it was determined by the formula

$$q = \Delta J/Kg;$$

- if the thickness of the mineralisation interval h was less than 1 m, then, its thickness was determined by one of the ways depending on the anomaly standard and the nature of mineralization:

$$q = S/Fre * h,$$ where

S- is the area of gamma anomaly in the sampling, obtained by graphical way.

The value of the given intensity was found by the formula

$$J_{pre}=Fre*Q_{pre}$$

Q_{pre} - preset cutoff grade of uranium in mineralisation (0*030%).

It was 105 mcr/h.

Assessment of reliability of gamma-sampling data was conducted by determining the systematic and random errors.

Assessment of systematic error was carried out by comparing the results of drillhole and gamma-sampling. In this case, the results were compared, equally distributed over mineralisation intersections of the horizon - 38m. They are grouped into three content classes:

- ordinary mineralisation with uranium content of 0.101% or more;

- low grade mineralisation with a grade of 0.031 to 0.100%;

- off-balance mineralisation with a grade of 0.010 to 0.030%.

The grouping is based on the values obtained by trenching.

The value of the systematic difference in the contents was estimated by the difference of the average values in each of the allocated classes:

$$\bar{Z} = (\textstyle\sum_1^n x_i - y_i) \,/\, n = \bar{x} - \bar{y}, \text{ where}$$

x_i-y_i- results of the main and control measurements;

n- the number of pairs to be compared;

$\bar{x} - \bar{y}$- mean values of the main and control measurements.

Statistical significance of the obtained mean difference is estimated according to t-statistics

$$t = |z|\sqrt{n} \,/\, \sqrt{\sum_1^n (z - \tilde{z})^2 \,/\, n - 1}$$

The belonging of the outermost members of the set Zi to the sample is estimated according to Smirnov's statistics.

$$E = \max|z_i - \tilde{z}| \cdot \sqrt{\textstyle\sum_1^n \quad (Z_i - Z)^{2}/_{n}} \qquad \text{, where}$$

Z is the mean value

As a result, we found that the systematic error in the gamma sampling was not statistically significant and its magnitude can be neglected.

Calculation of a random error of definition of a metrological percent at gamma-sampling was made by results of the basic and control sampling of the same mineralisation intervals. Calculation was made by the formula

$$Smp = \sqrt{\sum_{1}^{n} \frac{\overline{mp_0 - mp_k}}{mp_0 + mp_k} \cdot \frac{2}{N}}$$

Where mp_o: mp_k - metric percent by the results of the main and control tests.

The error of determining the metroproportion was + 5, 3% (with the standard being - 10%).

The results of error assessment are given in Tables 20; 21, Volume 2.

Stability of radiometers operation during testing was evaluated by the value of relative standard deviation.

$$S_R = \sqrt{\frac{1}{n}\sum_{1}^{n} [R_i - R]^2} \,/\, R$$

R_i- the average of the control observations before and after the work shift;

R - reference observations (at calibration).

Actual values of S_R for normally working equipment did not exceed the standard value (7%; see (13) p.b.2.2).

Furrow sampling (mainly, samples of meter length) was carried out after conducting gamma-sampling along the horizontal profiles.

c) Gamma Ray Logging of Underground Drilling Drillholes

Gamma Ray Logging of Underground Drilling Drillholes was conducted in accordance with the requirements of the Gamma Ray Logging Instruction, 1987 edition (10).

Serial radiometers PRIII4-01 and PRII-01 (with or without M index) were used for logging. Radiometers have passed metrological check in I&C CPU of PA “Yuzhpolymetal”; their adjustment, calibration and stability control in operation were carried out similarly to SRP-68-01 + Scintillation Radiometers Search -68-03 devices (see Section 1, item a). The energy threshold of the radiometer registration was set at the level of 20+5 keV.

A tape measure of PC-10 type was used for cable marking, the marks were applied every 1 meter, the setting error did not exceed ± 0.5 cm.

Gamma-ray logging of the drillholes was conducted by the point method with a measurement step of 1.0 m in the host rocks and with a measurement step of 0.1 m during detailing of mineralisation intervals.

The drillholes were flushed with water for 3 hours to exclude the influence of radon release on the logging results; they were purged with compression air in a continuous mode during dry drillhole logging. Flushing and purging of the drillholes made it possible to reduce the influence of radon on the instrument indications to the level not exceeding twice the background gamma-radiation of the host rocks.

Assessment of gamma-ray logging reliability was conducted according to the results of control measurements of mineralisation holes; the volume of control was more than 10% of the number of mineralisation holes (the result of the assessment is shown below).

Quantitative interpretation of the gamma-ray logging data was performed graphically by plotting on millimeter paper at a scale of 1:50 along the distance axis; the scale along the intensity axis was chosen with the expectation that the anomaly spread did not exceed 20 cm. The thickness of the mineralisation interval h was determined according to the shape of the anomaly and the nature of mineralization using one of the following methods: Z½; J½; Z_o; J_{pre}

The value of the present intensity was determined by the formula

$$J_{pre} = K^* \, Frb \, ^*Q_{pre},$$ where:

K is a conversion factor numerically equal to 115 μR/h per 0.01 of uranium.

The choice of the numerical value of K (115 micr/hr for 0,01 % of uranium) is proved by the results of the full chemical analysis of 30 mineralisation drillhole samples, evenly selected along the mineralisation intersections of -38m horizon (the core from underground drilling holes was not studied because of its low yield). As a result, it was established that mineralisation of the deposit have silicate composition at Z ef. = 12 and No. = 0.975 (without taking into account losses during calcination). Calculation of parameters Z eff. and N are given in tables 17, 18, volume 2.

Following formula was used to determine the uranium content within the allocated mineralisation interval:

$$Q=S/K^*Fre^*h,$$ where

- the area of the anomaly within the perimeter of the closed contour, bounded by the anomaly chart and the distance axis. The area was calculated by trapezoidal method with a quantization step equal to 2 mm (10 cm at a scale of 1:50 along the distance axis).

Coefficient of radioactive equilibrium Radioactive Balance Factor was taken equal to 0.645 (see Section 4, point a).

In addition to the correction for violation of radioactive equilibrium in the results of quantitative interpretation entered correction for gamma-radiation absorption by flushing fluid Pb. Correction Pb was found from Table 5 of Gamma Logging Instruction (40) by the equivalent thickness of flushing fluid layer Tb; the value of Tb was determined by the formula

$$Tb=p_o(r_0-R) \quad , g/cm2,$$ where

p_0 - density of flushing liquid;

r_0 -radius of the drillhole

R- radius of drillhole cross-section

Correction for gamma radiation of thorium and potassium in mineralisation was not introduced due to its negligibly small value (see Section 4, p.e).

Correction for mineralisation moisture was also not introduced, since the actual moisture of mineralisation is less than 3%; see table No.____ volume 2.

The reliability of gamma ray logging data from underground drillholes was assessed by calculating the random error from the main and control logs of the same mineralisation intervals.

At the same time:

- the error in determining the thickness of mineralisation intervals h calculated by the formula was ±6.3 cm, (the standard is 7 cm);

$$S_m = \sqrt{\frac{1}{2n}\sum_{1}^{n}\left(hi_0 - h_k^i\right)^2}$$

- the error in determining the metroproportion calculated by the formula was + 5.3%, (standard + 7%).

$$S_{mp} = \sqrt{\frac{2}{n}\sum_{1}^{n}\left(\frac{mp_0^{i-}}{mp_0^i}\frac{mp_R^i}{-Mp_k^i}\right)^2}$$

Stability of operation of radiometers used during logging was evaluated by the value of relative standard deviation Cp (similarly to the directional reception radiometer RGN I "background".

In this case, the actual values of C did not exceed the standard value see (7%; see (10), p.5.1.2).

Estimation of the value of systematic error was not made due to the lack of results of core analysis due to its low yield.

d) Express analysis of mineralisation in the carts

All the rock mass, issued in the trolleys from the mine during sinking of the horizon - 38m, was analyzed at the mineralisation monitoring station (OMS), equipped with a radiometer type PCR-b "Stand". Adjustment, calibration and stability control of the radiometer was carried out in accordance with the technical description of the radiometer (11).

At the same time, were used radiation sources from radium of RA type.

The OMS conversion coefficient for transition from radiometer readings to uranium content in the railcar was assumed to be equal to the OMS conversion coefficient in effect at the “Kapitalnaya” mine (Botaburum mine) based on the identical geometry of measurements; a correction was introduced into the OMS conversion coefficient to account for a shift in the radioactive equilibrium toward uranium.

The OMS recalculation factor at the “Kapitalnaya” mine was established empirically.

Transition from the radiometer readings to the uranium content in the rail car was carried out by the formula:

$$q=N\,K/\,Frb,$$ where

N - count rate, imp/m;

K - OMS conversion coefficient, numerically equal to 4.10^{-6} % of uranium per 1 ppm.