N E W S
OF THE NATIONAL ACADEMY OF SCIENCES OF THE REPUBLIC OF KAZAKHSTAN
SERIES OF GEOLOGY AND TECHNICAL SCIENCES
ISSN 2224-5278
Volume 5, Number 437 (2019), 169 – 176 **https://doi.org/10.32014/2019.2518-170X.139**

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THE ROLE OF THREE-DIMENSIONAL MODELS OF DEPOSIT AND THERMODYNAMIC CONDITIONS OF ITS FORMATION AT SELECTING AND EVALUATING RESOURCES OF PERSPECTIVE SITES

Abstract. The state program "Digitalization of Kazakhstan" considers the accelerated introduction of modern information technology in various spheres of our life. In the geological industry, particularly in geological science, these technologies allow creating an accurate, geo-referenced spatial database of geological objects of various scales, and it represents a necessary condition for consistent, holistic, system-differentiated research of objects, which allows efficient and rational solve practical problems.

The introduction of modern digital information technology to the geological study of the bowels of Kazakhstan presents new opportunities, and the ways of solving the tasks posed require the improvement of the methodological basis of modern geological research. The basis for the improvement of this methodology is the creation of a single interconnected (with local and regional geographical coordinates) digital scientific information base of the studied mineral resources (including minerals) of Kazakhstan, regardless of the scale of geological research.

Below, the example of the Bakennoye deposit will show the creation of its scientific and information base, and on this basis, the improvement of the methodology of geological research will be shown.

Keywords: GIS-technology, *ArcGIS–10, Micromine,* 3Dmodels of deposit, ore-controlling factors, ore-bearing environment, rare metal deposits, pegmatite field, tantalum pentoxide, perspective area.

The expansion of the mineral and raw materials base of the most important stratigraphic elements such as tantalum and niobium is a topical task for the Republic of Kazakhstan, because they define innovative progress in the field of high technology.

All industrial deposits of tantalum-niobium ores are concentrated in the Eastern region of our Republic.One of the brightest representatives of such objects is the **Bakennoye deposit**, located in the ore pegmatite field Ognevsko-Bakennoye.

The deposit is located in the East Kazakhstan region. The first pegmatite veins of the deposit were discovered in 1948 by VA Filippov, subsequent - a group of geologists under the leadership of Yu.A.Sadovsky. The ore field is located on the northern flank of the central block of the Kalba-Narym zone and is confined to the Gremyachinsko-Kiinsky regional fault of the 2nd order, in the endo-exocontact of the Irtysh granite massif. The sedimentary-metamorphic deposits of the upper Devonian and the Lower Permian granitoids of the Kalbinsk complex take part in the geological structure of the deposit. The host rocks consist of siltstones, sandstones and carbonaceous shales.They are crumpled into linearly extended folds, undulating in the general structure of transverse kinks. Granitoids are represented mainly by biotite medium-coarse granites of the first phase (granite-granodioritesub formation) and their vein derivatives: aplite, aplite-pegmatites and pegmatites. With granites of the I phase, rare metal-pegmatite mineralization is genetically associated (figure 1) [1-3].

In structural terms, the Bakennoye and Ognevskoye deposits are a single whole, separated by the specificity of mineralization: the first one is complex-tantalum and the second is columbite-beryl, non-industrial [6].

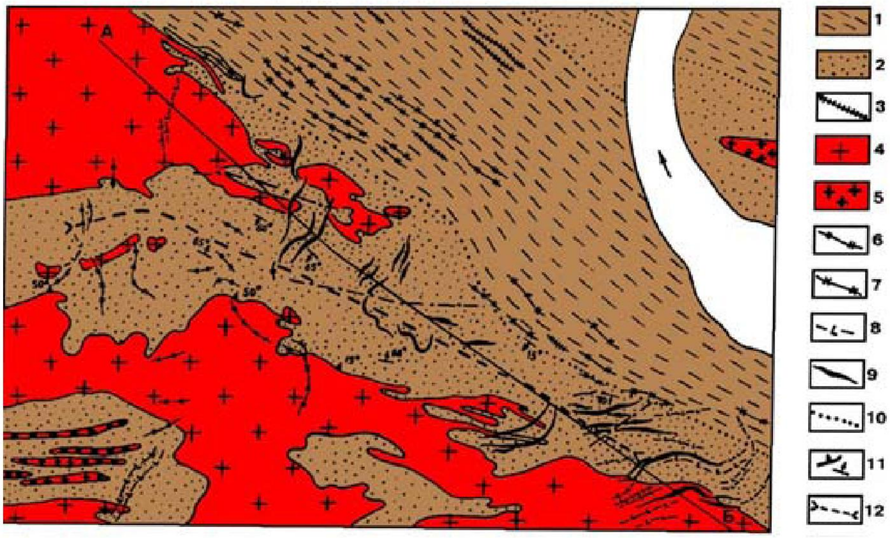

Figure 1 – Ognevsko-Bakennoyeore field. According toYu.A. Sadovskiy [7].
1 – hornfels; hornfelsed shale and 2 – magmatized rocks of the Takyr suite; 3 – granite-porphyry, plagiogranite-porphyry of the Kunushsky complex: (?); 4-9 Kalba complex: 4 – medium-coarse-grained granites of phase Iand 5 – fine-medium-grainedgranites of phase II; 6 – aplite veined granites; 7 – aplites, aplite-pegmatites; 8 – pegmatitesoligoclase-microcline non-ore; 9 – rare metal pegmatites; 10 – boundary of gradual rock transitions in the metamorphism zone; 11 – elements of occurrence of contacts of granites(a), sedimentaryrocks (б); 12 – axis of longitudinal folds.

Three-dimensional models of the Bakennoye deposit. The digital three-dimensional model of the deposit is constructed using the computer program **Micromine** [4, 5].

The geo-information database consisted of 730 pieces of information entered into the computer base for the I, II, III and VI veins[7].

Wireframe model (figure 2). The obtained skeleton model fully visualizes the structural-morphological feature of the deposit, where all the formations of the ore field have a "stepped" wedging to a depth at the horizons of 200 and 300 m, with a small approach one by one. The concentration of pegmatite veins decreases in the sections between the suites, and they themselves are insignificant in size. The predominant form of the veins is irregularly plate-shaped, in some cases plate-shaped, some lenticular. There are more than 100 pegmatite veins on the deposit, 21 of them carrying industrial mineralization. The main industrial reserves of the field are concentrated in the formations I (Spodumenovaya I vein) and II (Spodumenovaya IV vein), since they contain a high concentration of pegmatite ore veins [6].

Blockmodel (figures 3, 4). It visualizes the distribution of tantalum pentoxide contents within the deposit, since the main ore mineral is columbite-tantalite.

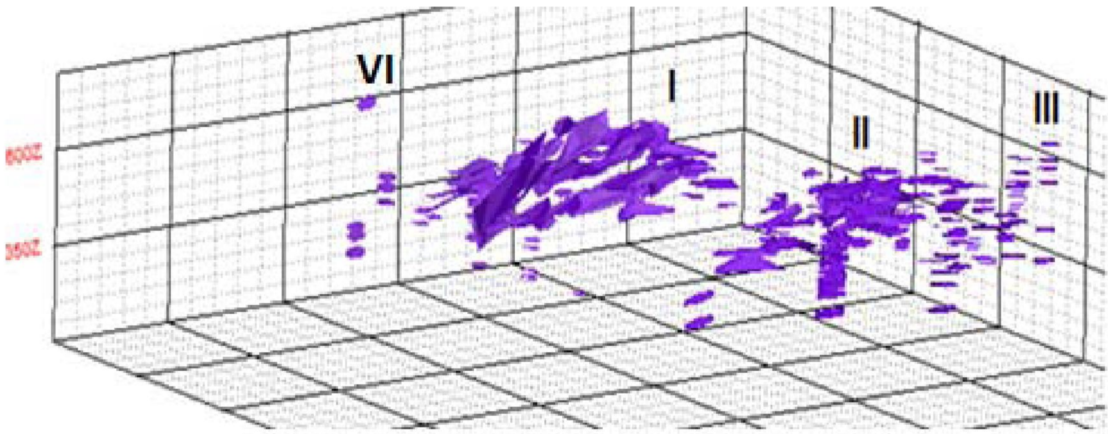

Figure 2 – Three-dimensional frame model of the deposit Bakennoye
(I, II, III, VI – numbers of suits)

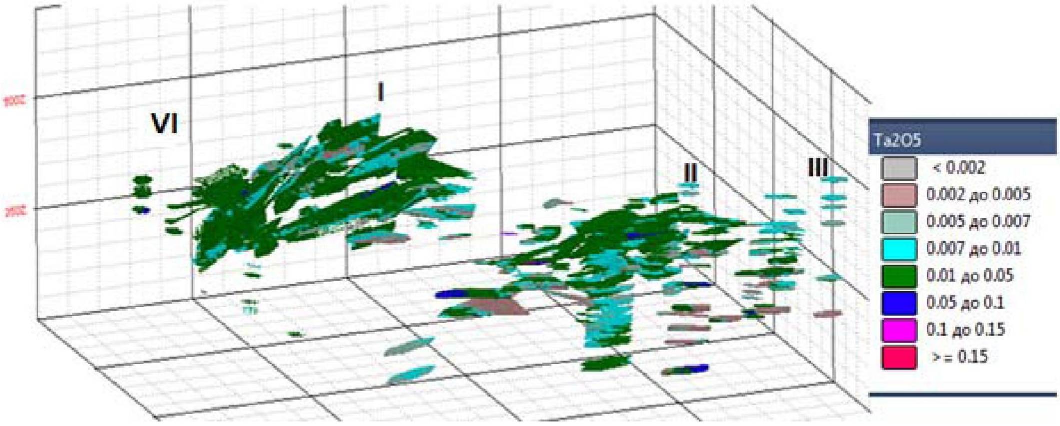

Figure 3 – Three-dimensional block model of the Bakennoye field (I, II, III, VI – numbers of suits)

In general, the following conclusions are drawn:

- the content of tantalum pentoxide varies in the range from 0.002 to 0.15%;
- the most common deposit in the deposit is tantalum pentoxide from 0.007 to 0.05%;
- a rather distinct tendency is observed for decreases in the content of tantalum pentoxide to the peripheral parts of the veins to 0.007% and lower.With the drop in the concentration of mineralization, wedging out of ores is observed, and pegmatites are almost completely transferred to non-ore veins with ore contents below them extracted;
- individual maxima of tantalum contents in the range from 0.10 to 0.15% are located both in the lower parts of the fall and in the upper parts of the I, II upwelling strata;
- areas with a low tantalum content from 0.002 to 0.005% occur in the lower horizons of the pegmatite veins of all the suites;
- especially the III suite, where in its upper part a low content of tantalum is visualized, and in the lower parts it reaches 0.10%.This is due to the fact that the upper part of this formation belongs to the Ognevskoe deposit by columbite-beryl mineralization, the lower horizons, which enter the vein after the second stage, bear the mineralization of tantalum, tin, beryllium, lithium;
- the first vein of the Kamenushinskaya (VI) suite is represented by albitizedpegmatites, the content of tantalum pentoxide reaches 0.013%.
- the average content of tantalum pentoxide according to the calculation of computer simulation was determined within0,01184%;

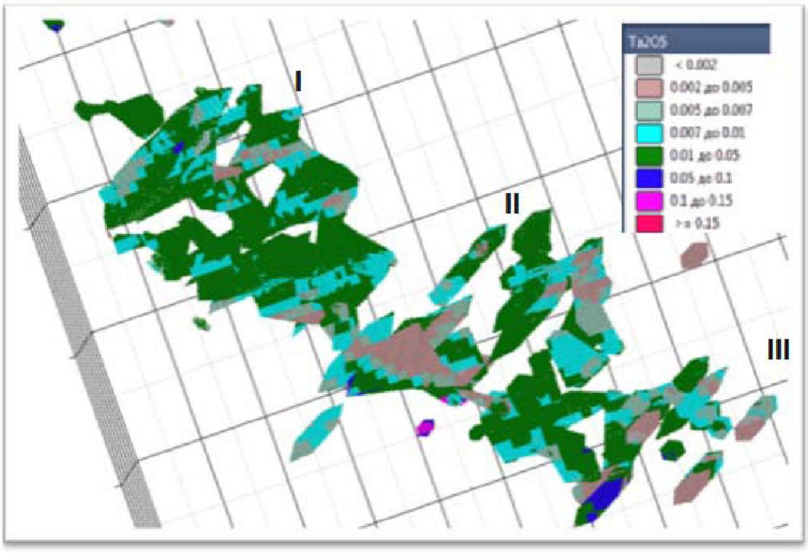

Figure 4 – Three-dimensional block model of the Bakennoye field, bottom view.

An analysis of the visualization of the distribution of tantalum mineral content resulted in a predominance of tantalum pentoxide from 0.007 to 0.05%.Its high contents (from 0.10 to 0.15%) have a limited distribution, but they can occur both in the upper and lower horizons of some deposits in the field (figure 4).

Since the actual problem is the evaluation of the prospects of the deep horizons of the deposit, the results of its three-dimensional models are compared with the data of thermometry and quantitative modeling of ore-forming systems [8].

The Bakennoye field is confined to the western part of the Irtysh pluton, which in this area is a granite plate with a thickness of more than 7 km.The introduction of an intrusive massif with a thickness of up to 6-7 km and a temperature in the range of 850-900^{0}C will lead to a redistribution of the temperature in the host environment, leading to warming of the exocontact layers of the rocks, and to a decrease in the temperature of the endocontact part of the massif [8, 9]. Therefore, a sharp decrease in temperature in the endocontact area of the ore-bearing massif contributes to the formation of structural elements, where the stage of pegmatite formation is associated with the appearance of a gently sloping fault system, and the free pegmatites (700-560°C) at the Bakennoye field were formed in this *progressive stage* of cooling the intrusion.

In addition, this stage of cooling of the intrusion is characterized by the development of contact metamorphism processes, where hornfels are formed, at temperature intervals of 640-450°C (based on the temperature of deposition of cordierite, garnet). Halo of hornfelsed rocks reaches up to 750 m vertically, and its position can contour the area of ore formation.

The thermal field of the ore-bearing massif is gradient, and it contributes to the formation of ore zoning in the deposit. According to thermometry data, ore formation occurred in the temperature ranges of 480-260°C. Not only rare and rare earth ores, but also rare metals were formed (tin, beryllium). The deposition ofrare earths, niobium and tantalum proceeded at intervals of 480-390°C, and are concentrated in the dermal contact zones, where the ore-forming and ore-localizing systems were under thermal equilibrium conditions. Rare metal ores (tin) were deposited at temperatures of 380-260°C in the above-dump zone of the ore-bearing intrusion, where the thermal nonequilibrium between ore-forming and ore-localizing systems was established.

Analysis of the thermodynamic conditions of the formation of the deposit is considered in the context of the deposit. As is known, the deposit is composed of gently sloping veins located within one hundred meter weakened zone along the contact. Raremetal pegmatites are distributed unevenly in the field and are grouped in six formations separated by sections with a much lower concentration of veins, of which three belong to the Bakennoye deposit (I, II, VI) and three to Ognevsky (III, IV, V).Stretching of veins varies from sublatitudinal (Ognevka) to submeridional (formation Kamenushinskoye Bakennoye deposit) (figure 5).

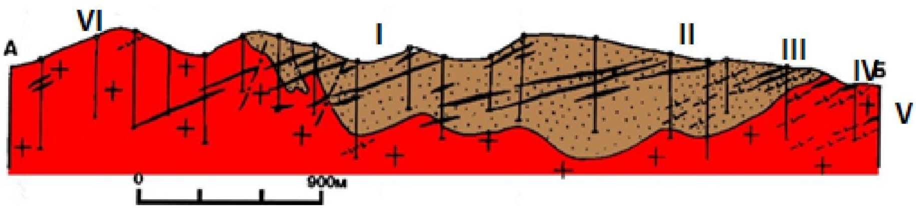

Figure 5 – Geologicalsection of Ognevsko-Bakennoyeore field (I, II, III, IV, V, VI formations)

This geological section of the Ognevsko-Bakenny ore field shows that ore pegmatite veins in some formations are localized only in the dusk, but also in the endocontact zones of the ore-bearing massif (VI, IV, V part I), and in some formations (II, III and Part I) pegmatite veins occupy only its dusk zones (figure 5).

If we take into account that the most favorable thermodynamic condition for the deposition of high-temperature ore elements is created in the endocontact region of the ore-bearing massif, the deep horizons of the suites II, III and I are of practical interest for the detection of rare metal mineralization.In addition, the deposition temperature of the main ore minerals indicates the metasomatic nature of rare metal mineralization in pegmatites, and the metasomatic nature of the formation of rare metal minerals suggests the possibility of detecting rare metal mineralization outside the pegmatite veins.

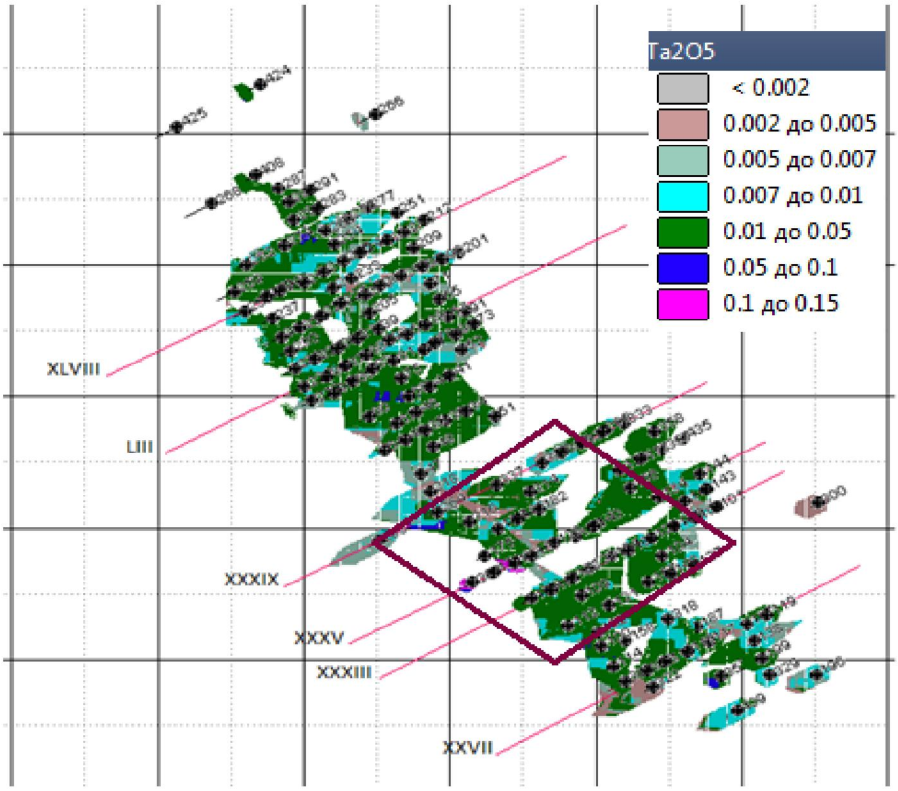

Figure 6 – Allocating a prospective site on the block model of the Bakennoye field

Thus, the analysis of the three-dimensional models of the deposit and the thermodynamic conditions of its formation make it possible to identify two prospective sites in the vicinity of the Bakennoye deposit and confirm them with geological data.

The first section is the deep horizons of the II formation between the profiles XXVIII and XXXIX, covering the veins of the deep horizons of the III formation.The parameters of the site are 500 meters long, 500 meters wide, 5 meters deep (figure 6). The allocated site corresponds to the position of the productive areas allocated on the geological and industrial model of the field [10, 11].

The second section is the deep horizons of the I formation between the LXVIII and LX profiles, it is confirmed by testing wells №283,260,254 and 245. Parameters of the site length – 500 m, width 200 m, depth 20 m (figure 7).

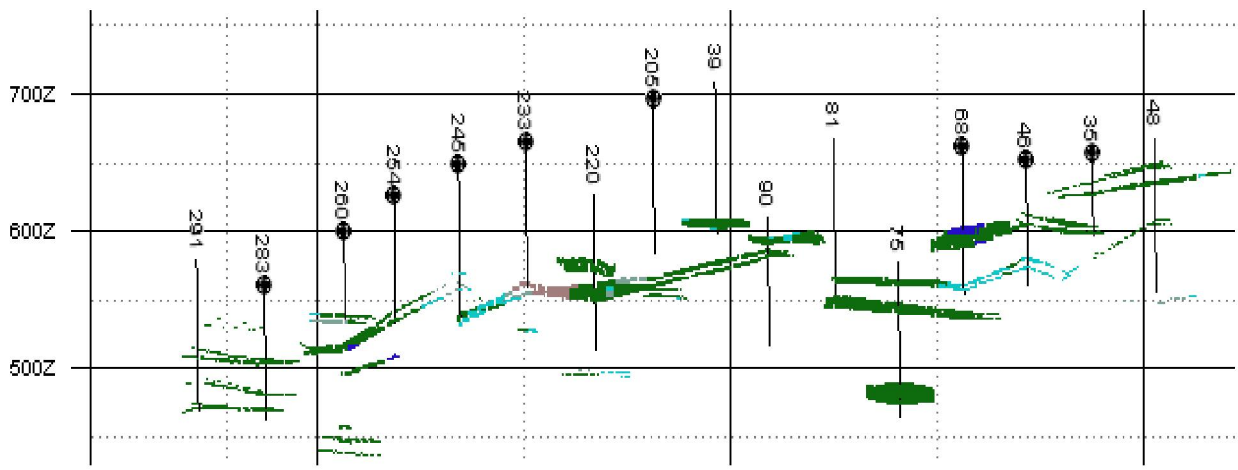

Figure 7 – Longitudinal 2D slice of the block model along the line №8 (Bakennoye deposit)

At the deep horizons of the formation, a vein№ 100is identified, which in composition refers to the lepidolite type of pegmatites, the content of tantalum pentoxide in it according to geological data is more than 200 g/t, and the stretching of veins are submeridional, which suggests that lithium pegmatites in the lower horizons are present in it (figure 8).

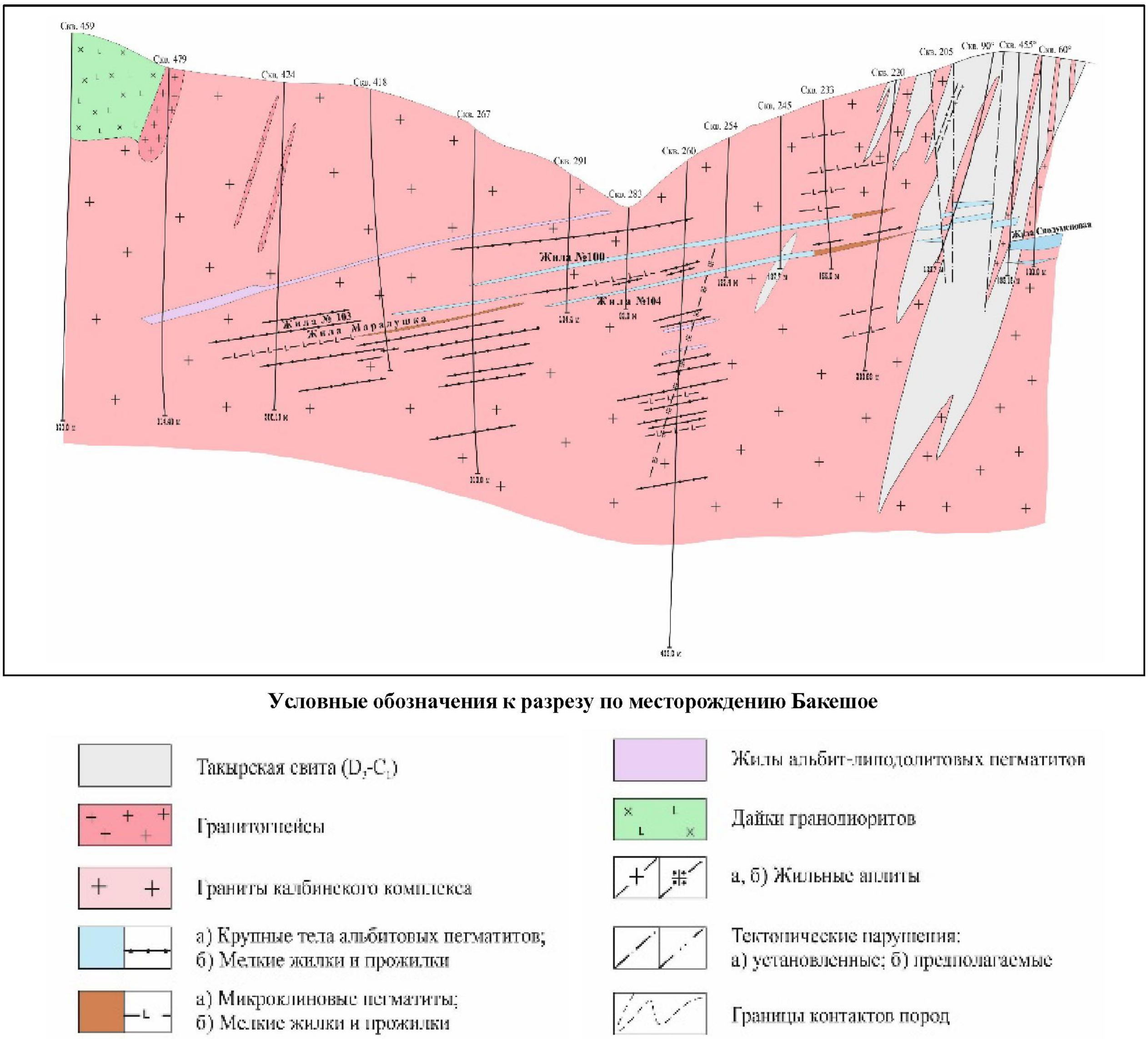

Figure 8 - Longitudinal geological section along the line№8 (Bakennoye deposit)

Reasonable views on the size and conditions of occurrence of promising areas within the Bakennoye deposit allowed quantitative assessment of their potential resources (table).

Calculation of the forecast resources of promising areas of the Bakennoye deposit

The position of ore zones, deposits, sites	The size of the forecast sites			Bort content, g/t	Resource category	Size of resources, t
	Length, m	Width, m	Depth of calculation, m			
Section Transitional between profiles XXVIII and XXXIX	500	500	5	125 g/t Ta_2O_5	P_1	284,375
First suit between profiles LVIII and LX	500	100	20	125 g/t Ta_2O_5	P_1	227,5

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ПЕРСПЕКТИВТІ УЧАСКЕЛЕРДІҢ ҚОРЫН АНЫҚТАУДА ЖӘНЕ БАҒАЛАУДА КЕНОРЫННЫҢ ТЕРМОДИНАМИКАЛЫҚ ЖАҒДАЙЛАРЫНЫҢ ҚАЛЫПТАСУЫ МЕН ҮШӨЛШЕМДІ МОДЕЛЬДЕРІНІҢ РӨЛІ

Аннотация. «Қазақстанның цифрландыру» мемлекеттік бағдарламасы біздің заманымыздың түрлі салаларында заманауи ақпараттық технологияларды жедел енгізуді қарастырады. Геологиялық салада, әсіресе геологиялық ғылымдарда, бұл технологиялар түрлі масштабтағы геологиялық объектілердің кеңістіктік, геоэкологиялық деректер базасын құруға мүмкіндік береді және бұл объектілерді дәйекті, біртұтас, жүйелік-дифференциалды зерттеуге қажетті жағдайды білдіреді, бұл тиімді тәжірибелік мәселелерді ұтымды шешу.

Қазақстанның жер қойнауын геологиялық зерттеуге заманауи цифрлық ақпараттық технологияларды енгізу жаңа мүмкіндіктерді ұсынады және қойылған міндеттерді шешу жолдары заманауи геологиялық зерттеулердің әдіснамалық негізін жетілдіруді талап етеді. Осы әдіснаманы жетілдірудің негізі геологиялық зерттеулер масштабына қарамастан зерттелетін минералды ресурстардың (соның ішінде минералдардың) сандық ғылыми-ақпараттық базасының бірыңғай өзара байланысын (жергілікті және аймақтық географиялық координаттары бар) құру болып табылады.

Төменде Бакенное кен орнының үлгісі оның ғылыми-ақпараттық базасын құруды көрсетеді және осы негізде геологиялық зерттеулер әдіснамасын жетілдіретін болады.

Түйін сөздер: ГАЖ-технологиясы, ArcGIS-10, Micromine, кенорындардың 3D моделі, кенбақылаушы факторлар, кенсиыстырушы орта, сирекметалл кенорындары, пегматитті өріс, болашағы бар аймақтар.

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РОЛЬ ТРЕХМЕРНЫХ МОДЕЛЕЙ МЕСТОРОЖДЕНИЯ И ТЕРМОДИНАМИЧЕСКИХ УСЛОВИЙ ЕГО ФОРМИРОВАНИЯ ПРИ ВЫДЕЛЕНИИ И ОЦЕНКЕ РЕСУРСОВ ПЕРСПЕКТИВНЫХ УЧАСТКОВ

Аннотация. Государственная программа «Цифровизация Казахстана» рассматривает ускоренное внедрение современной информационной технологии в различные сферы нашей жизни. В геологической отрасли, в частности в геологической науке эти технологии позволяют создать точной, привязанной к геологической среде пространственной цифровой базы данных об изучаемых геологических объектахразличных масштабов и она представляет необходимое условия для последовательного, целостного, системно-дифференцированного исследования объектов, позволяющие эффективно и рационально решать практические задачи.

Внедрение современной цифровой информационной технологии в геологическое изучение недр Казахстана представляет новые возможности, и пути решения поставленных задач требует совершенствования методологической основы современных геологических исследований. Основой совершенствования указанной методологии является создание единой взаимосвязанной (с местными и региональными географическими координатами) цифровой научно-информационной базы (основы) изучаемых объектов недр (в том числе, полезных ископаемых) Казахстана, вне зависимости от масштаба геологических исследований.

Ниже на примере месторождения Бакенное будет показано создание его научно-информационной базы, и на этой основе будет показано совершенствование методологии геологических исследований.

Ключевые слова: ГИС-технология, ArcGIS–10, Micromine, 3D модели месторождения, рудоконтролирующие факторы, рудовмещающая среда, редкометалльные месторождения, пегматитовое поле, пятиокисью тантала, перспективная площадь.

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