MINISTRY OF EDUCATION AND SCIENCE OF THE REPUBLIC OF KAZAKHSTAN

SATBAYEV UNIVERSITY

Geology and Oil-gas bussines institute n/a K. Turyssov

Department of Geophysics

Bektursynova Diana

«Interpretation of geophysical well logging data for calculating uranium reserves using the example of the Budenovskoye deposit»

EXPLANATORY NOTE
to the graduation work

Specialization 6B07201 -"Oil and Gas and Ore Geophysics"

Almaty 2022

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ADMITTED TO DEFENSE
The Head Of the Department Of Geophysics, Doctor of Geologicaland Mineralogical Sciences, Professor
__________________A. E. Abetov"19" May 2022g.

Graduate work

On the topic: «Interpretation of geophysical well logging data for calculating uraniumreserves using the example of the Budenovskoye deposit»

Specialization 6B07201 - "Oil and gas and ore geophysics"

Completed by:D.M.Bektursynova
Scientific supervisor
_____________Aliakbar M.M.

"19" May 2022g

Almaty 2022

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Department of Geophysics

APPROVED
by Head of the Department of Geophysics, Doctor of Geological and Mineralogical Sciences, Professor
______________A. E. Abetov

"19" May 2022g.

TASK
to complete the graduate work

The student: Diana Bektursynova (Maksatovna)
Тема: «Interpretation of geophysical well logging data for calculating uranium reserves using the example of the Budenovskoye deposit»
Approved *by the order of the Rector of the University No.* 2131-Б dated "24November 2021".

The deadline for delivery of the completed work is "20" May 2022.
Initial data for the work: «Report on the results of exploration of the Budenovskoyefield with a sub-account of uranium reserves «Akbastau JV JSC»»
Summary of the thesis:
a) Geological structure of the Budyonovskoye field. Uranium mineralization
b) Geophysical well logging in the field
d) Uranium reserves estimation
List of graphic materials: applications
Recommended main literature: from sources

SCHEDULE
of preparation of the graduation work

Name of sections, list of issues to be developed	Deadline for submission to the supervisor	Note
Geological structure of the Budenovskoye field. Uranium mineralization	28.02.2022	Done
Geophysical well logging in the field	12.04.2022	Done
Uranium reserves estimation	06.05.2022	Done

SIGNATRUES
consultants and a standard controller for the completed thesis with an indication ofthe relevant sections of the work

Section names	Research supervisor, consultants, Full name (academic degree, title)	Date of signing	Signature
Geological structureof the Budennovskoye field. Uranium mineralization	M. M. Aliakbar	19.05.2022	
Geophysical well logging in the field	M. M. Aliakbar	19.05.2022	
Uranium reserves estimation	M. M. Aliakbar	19.05.2022	
Normocontroller	Sh. O. Kiseyeva	19.05.2022	

Scientific Supervisor_____________ Aliakbar M. M..
The task was accepted by the student____________Bektursynova D. M.Date "19" May 2022g.

ANNOTATION

The thesis isdevoted to the study of the methodology for calculating stocks in mestrogeny Budenovskoe, as well as evaluating the effectiveness of the methodology used. In addition, suggestions were made to optimize the calculation based on geological modeling.

Problems: technology for calculating reserves at the Budenovskoye field, and ways to optimize it.

The purpose of the work: to study the geological and geophysical foundations of the field study, with the aim of subsequent calculation of reserves. Justify the proposed optimization option.

АННОТАЦИЯ

Дипломная работа посвящена исследованию методики подсчета запасов на месторождении Буденовское, а также оценки эффективности используемой методики. Помимо этого, внесены предложения по оптимизации подсчета, на основе геологического моделирования.

Основная задача: исследование технологии подсчета запасов на месторождении Буденовское, и способы ее оптимизации.

Цель работы: изучить геолого-геофизические основы изучения месторождений урана, с целью последующего подсчета запасов. Обосновать предложенный вариант оптимизации.

АННОТАЦИЯ

Дипломдық жұмыс Буденовское кен орнындағы қорларды есептеу әдістемесін зерттеуге, сондай-ақ қолданылатын әдістеменің тиімділігін бағалауға арналған. Сонымен қатар, геологиялық модельдеу негізінде қор есептеуді оңтайландыру бойынша ұсыныстар енгізілді. Негізгі мәселелер: Буденовское кен орнындағы қорларды есептеу технологиясын және оны оңтайландыру әдістерін қарастыру. Жұмыс мақсаты: қорларды есептеу мақсатында кен орынды зерттеудің геологиялық-геофизикалық негіздерін қарастыру. Ұсынылған оңтайландыру нұсқасына негіздеме жасау.

Contents

INTRODUCTION

Uranium is a special wealth of Kazakhstan. Rare States are lucky to have reserves of this strategically important element. Kazakhstan is the first in the world in terms of uranium production and the second in terms of proven reserves (after Australia). Kazakhstan's uranium concentrate provides about 40% of the needs of peaceful nuclear energy and is supplied to almost all countries of the world where nuclear power plants are operated.

The object of research is a method for calculating uranium reserves at the Budennovskoye field.

The aim of the work is to study the methodology of inventory calculation based on the analysis of available materials

The purpose of this paper is to describe the geophysical study of the Budenovskoye field, describe the conducted geophysical studies on the territory on the basis of which the calculation of uranium reserves is carried out, as well as a detailed study and analysis of the technology and results of the calculation of reserves.

The relevance of the work lies in the economic benefits of uranium mining, due to its extreme demand on the world market in the form of energy raw materials. In addition, the efficiency of energy production and consumption significantly determines the level of development of the country. Uranium mining in general is of the greatest relevance in the territory of Kazakhstan, as the most economical and environmentally friendly method is available-ISL. In addition, the method of calculating reserves used in the field is outdated and requires significant optimization.

The methodological basis of the work is materials on calculating uranium reserves, as well as materials obtained during practical training. Information about the geological and geophysical study of the area, the work carried out on the calculation of reserves.

1 Geological structure of the Budennovskoye field. Uranium mineralization

1.1 General information about the Budyonovskoye field

Administratively, the work site is the Sozak district of the South Kazakhstan region.

Site 1 of the Budennovskoye field is in the southwestern part of the Shu-Sarysu depression. Orographically, the territory is a gently sloping foothill accumulative plain, adjacent from the north to the Big Karatau ridge. The relief is characterized by alternating hills, gentle hills, and river valleys, elongated in the north and south directions. In the north, there are hilly and cellular sands of the Moinkum massif, which are stretched in a strip from 20 km to 30 km wide from west to east. The sands are alluvial-Aeolian, covered with sparse desert vegetation. Absolute marks of the flat part plus 125 m, sandy massif plus 310 m.

In the transition part to the desert, there is an intermittent band of salt marshes and sores of the NW strike; the largest salt marshes lakes (Aizhaikyn, Ashchikol) are in the lower reaches of the Shu River in the northern part of the area and to the NW from it.

The hydrographic network is poorly developed. The Shu River flows in winter and spring, and in summer it turns into a chain of ples with bitter-salty water. Small mountain rivers from the Karatau Basin are lost in the loose sediments of the outflow cones.

The climate is sharply continental with cold, low-snow winters (up to minus 30 °C) and hot (up to 40 °C) dry summers. The amount of precipitation in the flat parts of the territory does not exceed 190 mm per year (in the mountainous parts from 300 m to 400 m). Their maximum (up to 85 %) occurs in the winter-spring period. The heating season is from October 15 to April 15. The freezing depth of the soil is from 50 cm to 60 cm.

The population in the district is unevenly distributed and concentrated mainly near the mountains and the Shu River.

The main industrial enterprises of the district are connected with the uranium mining industry. The Uvanas, Mynkuduk, Inkai, Budennovskoye, Kanjugan, Moinkum, and Akdala fields are already being developed in the region; the base city of Taukent has been built.

Since the object of interest is in the Upper Cretaceous aquifers, this chapter focuses on this part of the Mesozoic section.

The field area is in the southwestern part of the Shu-Sarysu depression, which is a large Epicaledonian depression characterized by a three-tiered structure. In its vertical section, the following are highlighted: 1. A folded basement composed of dislocated Proterozoic and Early Paleozoic formations; 2. An intermediate structural floor or lithified sedimentary layer; 3.A platform cover consisting of weakly lithified Mesozoic-Cenozoic deposits containing industrial uranium mineralization.

Within the ore field of the deposit, the folded foundation lies at depths of more than 2 km. The Middle-Upper Paleozoic sedimentary deposits of the intermediate floor reach the daytime surface within the northwestern tip of the Big Karatau ridge, and in the field itself they are opened by a number of wells at depths from 540 m to 750 m with a regular gentle dip in the direction of the Main Karatau Fault. They include complexes of the Early carboniferous marine terrigenous-carbonate formation overlain by a continental series of sediments up to 1500 m thick: the Dzhezkazgan *($C_{2-3}dz$)* and Zhidelisai *($P_1\check{z}d$)* formations. The latter are dominated by red-colored siltstones with sandstone interlayers.

1.2 Stratigraphy of the Mesozoic-Cenozoic cover

Lower Mesozoic formations in the area of the deposit are practically unknown. The most ancient of them, presumably Jurassic *(J_{1-2})*, were found in single wells on the Aksumbinsky ledge at a depth of 580 m. This is a typical continental terrigenous molass composed of gray siltstones and sandstones with abundant carboniferous plant remains. Within the Leontief graben (Karatau basin), this complex is coal-bearing.

1.2.1 Cretaceous-Paleogene platform complex

Lower Cretaceous (K_1). Deposits of this age were discovered by wells in the western part of profile I on the Aksumbinsky uplift at depths of 490-540 m. These are cherry-red clays with interlayers of clay siltstones up to 22 m thick. The age (Aptian-Albian-Cenomanian) is given conventionally by analogy with the Lower Cretaceous of the Syrdarya depression.

Upper Cretaceous (K_2). Upper Cretaceous deposits occur in the southwestern part of the Shu-Sarysu depression at depths from 250 m to 670 m and deeper and are represented by non-lithified rocks formed in the conditions of lacustrine-alluvial and foothill-alluvial plains. On the Paleozoic roof, they occur almost horizontally or with very gentle (up to 1-2°) angles of incidence.

The stratigraphic division of the section is based on the principles of cyclicity and rhythmostratigraphy using logging data, as well as paleontological age determination and analysis of the material composition of clays and sands. There are three Upper Cretaceous horizons (from bottom to top) in the Budyonovsky field area: Mynkuduk, Inkuduk and Zhalpak.

In the Paleogene section, the following horizons are distinguished: Uvanas (Kanzhugan), Uyuk, Ikan, and Intymak.

1.2.2 Late Alpine activation complex

Neogene deposits of the region form the main component of this complex of sediments. Its formation is associated with the latest stage of tectonic activation. The main content and essence of the neotectonic stage is determined by the increasing intensity of tectonic movements. The Neogene part of the upper floor consists of the Betpakdala formation and the Toguzken formation.

Quaternary deposits *(Q)* in the deposit are represented by all divisions and links (from the lower to the modern one). They are widely developed in flat areas and form modern river valleys, dry channels, takyr and salt marsh basins, and sandy massifs. The thickness of sandy precipitation does not exceed 10 m, increasing to several tens of meters in the cones of the outflow of the foothill part of Big Karatau and within the Moinkum sand massifs.

1.3 Tectonics

The field area is the western part of the Suzak depression. The central structure of the district is the Aksumbinskaya basin, 80×40 km in size, which stretches along the Karatau Ridge in the NW direction with Paleozoic roof markings of up to 600 m. The basin is bounded to the south by the gorst anticline of B. Karatau, to the west by the Daut-Bugudzhil saddle, and to the north by the Bugudzhil uplift. The southwestern side is complicated by the Aksumbinsky protrusion measuring 6 × 2 km, which can be traced under the cover in the South direction for 20 km.

The Daut-Bugudzhil saddle, which closes the Suzak Depression from the west, is a submeridional elevated structure with an absolute Paleozoic roof elevation of 350 m.

A characteristic feature of modern structures is the conformality of the folds of the platform cover and the relief of the Paleozoic base.

The structural and tectonic structure of the southern flank of the Budenovskoye ore field is rather complex and is determined by its position on the NW dipof the gorstanticline uplift of the Big Karatau. The influence of block structures of the northwestern ("Karatau") orientation, limited by long-lived fault-shear disturbances laid down in the Upper Paleozoic (possibly earlier), on the paleomorphology of the ancient surface of the pre-Upper Cretaceous alignment is manifested differentially, increasing in the Southwesterly direction as it approaches the BKF.

Fault tectonics in the area is quite widely developed. The most pronounced are the deep-laid faults of the NW (Karatau) direction: BKF, Aksumbinsky and others. The activation of faults in this direction with vertical and horizontal displacements of hundreds of meters is associated with the uplift of the horst anticline in the Neogene-Quaternary period.

1.4 Characteristics of uranium mineralization

The Budenovskoye deposit, together with its northern extension, Inkai, is controlled by the leading part of the giant arc, which is formed by regional ore – forming fronts of reservoir oxidation in permeable horizons of the Upper Cretaceous. The ore-bearing zones of the deposit are traced from North to South at a distance of about 51 km from profile 0 (north) border) to the Zhabakol profile (in the south).

In the most drilled northwestern part of the geological allotment of the site (200×50 m network), the width of the wing rectilinear elements of deposits in the Low

Inkuduk subhorizon ranges from 400 m to 500 m (normal). The bag part, according to available data, has a width of 150 m to 200 m.

1.5 Lithologicaland facies characteristics of productive horizons. Control of uranium mineralization

The position of the deposit in the frontal part of the regional reservoir water flow, significant thickness and high permeability of productive horizons determined a number of mineralization features at this site. These include:

- a very complex morphology of mineralization in terms of, which is expressed in the tortuosity, deep and frequent "corrugation" of ore belts, repeating the very whimsical outlines of the ore-controlling boundaries of the PO,
- a large scale of mineralization along the vertical with its clearly manifested multi-tiered nature,
- very complex and diverse forms of ore deposits in vertical sections,
- significant scale of ore production,
- high productivity of deposits and
- certain features of the material composition of ores.

Unlike the Mynkuduk deposit, where the main ore-bearing horizon is the Mynkuduk horizon, and Inkai, where both horizons are approximately equivalent in their ore content, the main uranium reserves at the Budyonovsky deposit are concentrated in the Inkuduk horizon.

1.6 Morphology of uranium mineralization

The Inkuduk horizon contains the main uranium reserves in the field, and in the detailed explored part of site 3, almost all of them are located. According to the data obtained during exploration work, uranium mineralization with industrial parameters in the underlying Mynkuduk horizon is currently underexplored in the eastern half of the geological allotment. The Inkuduk horizon is characterized by the greatest thickness of water-permeable sediments, relatively low reduction, and high filtration properties, which is why the ore-controlling geochemical boundary in it is located to the west of the others. In the plan, ore deposits are sinuous belts of complex corrugation. With the general general meridian direction of the ore-bearing strip, which reaches about 6.75 km in section 3, the direction of complicating the morphology of bays and festoons is NW, almost at 45^0 to the general one.

The forms of deposits in transverse vertical sections are extremely diverse. Among them, the following stand out:

- a large group of monorolls of various modifications with different ratios of the sac and wing parts of ore bodies.
- a group of so-called "cascade" rolls formed when two or more monorolls merge vertically.

- a group of "conjugated" rolls controlled by the borders of adjacent oxidation zones that are laterally close together, resulting in the merging of the bag parts of the roll bodies associated with them.

The castle parts of the rolls have a width of several tens to 100, rarely more than meters with a thickness of up to 20 m, and its wedging occurs bluntly, sharply, without ore leaks into the gray-colored part of the section. The wings of the rolls are developed everywhere, and the lower one is most pronounced; the mineralization thickness in the wing parts does not exceed the first meters, rarely up to 5m. Separate ore bodies, remnants, occur in the rear zone of oxidation in the central parts of the horizon, which is explained by the heterogeneity of the section, the abundance of small lenses of clay-silty water-resistant rocks in the horizon.

The depths of balance ores in the Low Inkuduk subhorizon in site 1 gradually increase from north to south from 680 m to 705m and deeper.

2 Geophysical well logging

2.1 Geological tasks

The value of the geophysical parameter measured during logging is influenced not only by many geological, continuously changing characteristics, which are complexly interrelated and have random variability, but also by the conditions for performing measurements, so the geological characteristics obtained through empirical connections in each individual case can significantly differ from the actual values.

The optimal ratio of geophysical methods and modifications in the general complex of well logging was determined from geological problems. When performing geophysical work in wells, the following main tasks were solved:

1. Detection of radioactive anomalies in wells.
2. Determination of the depth, boundaries and thickness of ore intervals and their uranium content for calculating reserves.
3. Litho-stratigraphic division of the borehole section.
4. Identification of permeable and impermeable rocks in the section of the ore-bearing horizon with a breakdown of permeable rocks by litho-filtration types, as well as determination of layer-by-layer Kf values$_ф$ in the section of wells.
5. Evaluation of the quality of core material and completeness of its extraction during well drilling.
6. Monitoring of the technical condition of wells.

2.2 Complex of methods

To solve the above-mentioned geological problems, a complex of geophysical well research methods was applied, including:

- gamma logging (Gl);
- electric logging in modifications of apparent resistivity logging (RL)and spontaneous potential logging (SP);
- inclinometry (IN);
-instantaneous fission neutron logging (NL);
- cavernometry (CM).
- thermometry (TM);
- induction logging (IR);
- current logging (CL).

At the same time, the first three methods from the complex (gamma logging, electric logging of RL, SP, inclinometry) were performed in all wells, regardless of their goals, tasks and purpose. Therefore, this complex is called "Standard". Without performing all the methods included in its composition, the well could not be accepted for activation as having completed the geological task. The remaining logging methods are additional, aimed at solving individual specific problems of a geological, technical and technological nature and were carried out in hydrogeological wells.

2.3 Gamma logging

Measuring the Ig intensity of natural g radiation from rocks along the wellbore is called gamma logging (GL).

It is conventionally assumed that the effective range of the gamma – ray logging facility (the radius of the sphere from which 90% of the radiation perceived by the indicator originates) corresponds to approximately 30 cm; radiation from more remote rock areas is absorbed by the environment before reaching the indicator. An increase in ds due to well wall erosion and cavern formation (usually in clayey rocks) is accompanied by a decrease in gamma – ray logging readings. In most cases, the cement ring also affects the value of the detected g-radiation, reducing it. To determine the g-activity of the reservoir, the gamma – ray logging data is interpreted quantitatively to standard conditions.

The intensity of radioactive radiation from rocks in the well is measured using a g-radiation indicator located in the depth device. Registration is carried out during the interaction of gamma radiation with the atoms and molecules of the substance filling the indicator. Geiger – Muller counters or more efficient scintillation counters that better dissect the section are used as indicators.

As is known, radium halos are formed at the boundaries of uranium ore bodies during ore formation. Residual radium halos are one of the most characteristic features of the radiology of exogenous reservoir-infiltration uranium deposits.

According to current concepts, they are formed due to differences in the migration capacity of uranium and radium in the hypergenesis zone. Uranium is a more mobile chemical element in an oxidizing environment than radium. When the reservoir oxidation zone moves, the contour of uranium deposits moves along the groundwater flow faster than the contour of radium deposits. Therefore, in the sections, we observe that the contours of radium and uranium deposits do not coincide, radium is shifted towards the oxidation zone, and in the parts of ore deposits adjacent to the it, there are so-called residual radium halos.

The radioactive equilibrium between uranium and radium in uranium ores is determined by the radioactive equilibrium coefficient (Crc), which is calculated by the formula:

$$Crc = qRa/qU, \quad (1)$$

where qRa and qU are the mass fractions of radium in units, respectively equilibrium uranium (1 g U = 3.4×10-7 G Ra) and uranium.

2.4 Instantaneous fission neutron logging

The method is based on the registration of instantaneous fission neutrons of uranium-235 nuclei that occur when uranium ores are irradiated with a fast neutron flux from a pulsed neutron generator. Consequently, the NL data do not depend on the contents of radium, thorium, and potassium radioisotope in ores. In contrast to the interpretation of gamma-ray logging data, the results of the uranium content interpretation do not require corrections for the radioactive equilibrium between the elements of the uranium-radium series.

At the stage of search and evaluation, exploration works, the NL method is used as a control method, which allows to study and evaluate the reliability of correction coefficients for gamma-ray logging in the most complete way.

The use of the NL method at the search and exploration stage makes it possible to quickly make a decision on the further direction of drilling operations, assess the detected radioactive anomalies, identify Ra halos, and clarify the presence and position of it for interpreting GL data. In the future, obtaining quantitative mineralization parameters (thickness of the ore interval and mass fraction of uranium) using NL will reduce the volume of drilling with core sampling along the ore-containing horizon, and accordingly reduce the volume of testing and analytical laboratory work.

The NL method is necessary for sites with a complex geological situation, where it is almost impossible to obtain representative core material for testing, for example, when the ore-bearing rocks are represented by boulder and pebble deposits.

Most effectively, the NL method can be used to determine the parameters of uranium mineralization in cases where the radioactive equilibrium between uranium and radium is shifted in one direction or another due to various reasons as in the Figure 1 below and Appendix A.

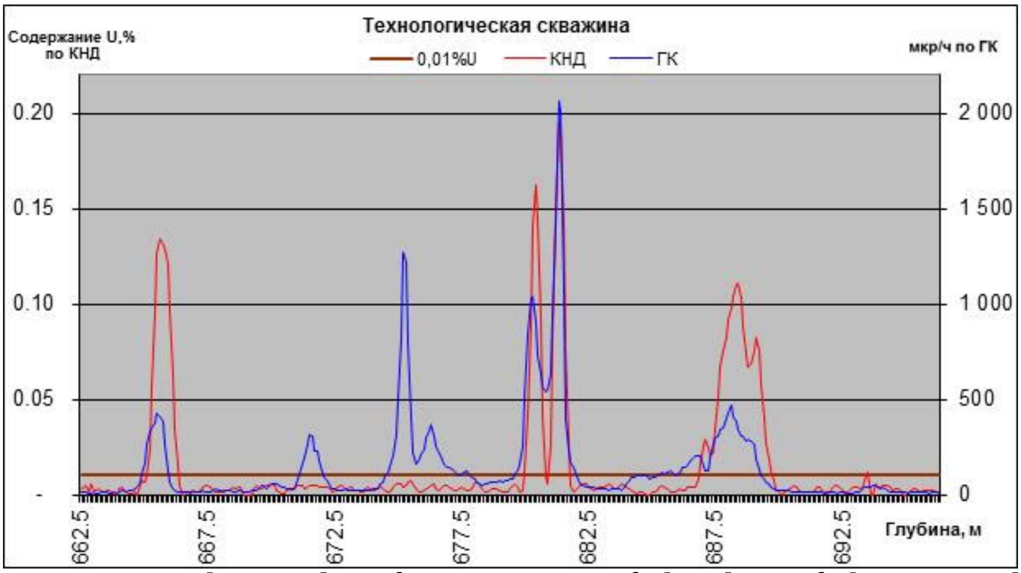

Fig.1 The results of comparison of the data of the GL and NL showing the differences in the halo distribution of uranium and radium within the well

As practice shows, this situation inevitably occurs during the industrial development of reservoir-infiltration deposits by the ISL method. This is because only uranium passes into productive solutions during leaching. Radium remains in its place of occurrence. Naturally, this leads to a sharp shift in the radioactive equilibrium between uranium and radium, which, ultimately, may differ from the equilibrium by two or more orders of magnitude.

Thus, the use of NL data in conducting technological experience, in preparing for operation and operation of reservoir-infiltration uranium deposits allows us to obtain reliable and very useful information necessary for solving a whole range of problems.

2.5 Standard electric logging (RL, SP)

The purpose and objectives of the method are to perform a lithological and stratigraphic division of rocks in the borehole section, estimate the permeability of rocks in the ore-bearing horizon, and divide it into lithological and filtration types, with the assignment of the uranium mineralization localized in them to one or another lithological and filtration type to take these factors into account when calculating uranium reserves.

Survey electric logging was performed on a scale of 1:200 and 1:1000, while detailed electric logging was performed on a scale of 1:50 within the ore-bearing horizon. The speed of electrical logging was determined and limited by the speed of the borehole device during gamma logging.

Considering that the electric logging materials were used for quantitative interpretation, special attention was paid to the quality of electric logging works, as well as to gamma-ray logging.

During search and exploration operations, control measurements of apparent resistances were constantly carried out. According to the main and control logging data, the error in determining the values of apparent resistances was estimated. Based on these measurements, the presence or absence of systematic discrepancies was determined and, if any, the value of the correction factor for a particular logging station was estimated.

Earlier relative discrepancies were calculated using the formula:

$$\overline{\Theta} = \frac{x_i^o - x_i^k}{x_i^o + x_i^k} 200\% , \qquad (2)$$

where: x_i^o - the average value of the monitored parameter (pk$_к$) in the i-th interval according to the main logging data.

x_i^k - the same according to the control (repeated) logging data.

Summary data on the results of control electric logging of CS, PS at site 1 of the Budenovskoye field are shown in Table 1.

Table 1

Summary results of the main and control RL logging

Operating period K-number of drilled wells.	Number of drilled wells.	Numberof counter points. Loggingdata(sle.)	Counter volume logging rate(%)	Average relative differences, in %
1	2	3	4	5
1985-86	26	12	46,2	3,7
1988-89	21	15	71,4	4,9
2008	114	16	14,0	5,2
2009	45	3	6,7	5,6
2011	150	15	10,0	4,8
2012	20	7	35,0	4,6
Total	**331**	**66**	**19.9**	

Table 1 shows that in general, the volume of control logging for all periods of operation is 19.9 %. This indicates that the volume of control logging is quite representative, the quality of primary materials is high, and thus, all of the above indicates that the electrical logging data is reliable and can be used to solve the tasks assigned to the method.

2.5.1 Geoelectric characteristics of rocks

Electric logging of wells in the modification of apparent resistances and natural polarization is one of the main methods for performing lithological and stratigraphic dissection of a section with an assessment of the technological and filtration properties of ore-bearing horizons. In most cases, geophysical information is the only one that allows us to obtain information about the geological and technological properties of the well section, so the geoelectric properties of the section, which determine the capabilities of the method, were studied, and analyzed in detail.

The geoelectric parameters of the rocks forming the lithological section of site 1 were determined based on the results of interpretation of the data of electric logging of CS, PS, performed with the use of granulometric analysis data.

Conditions for measuring electrical properties are sandy-clayey rocks watered almost throughout the section, mainly represented by alluvial and proluvial-alluvial deposits.

The mineralization of reservoir waters within the ore band of the deposit varies slightly, from 3.5 g / l in the Inkuduk ore-bearing horizon of the deposit to 5.5 g / l in the Mynkuduk ore-bearing horizon. When drilling wells, in the vast majority, drilling mud was used, which has a mineralization close to that of reservoir water. This factor significantly reduces the informative value of the PS method, so this method has a subordinate, secondary character. The increased salinity of the reservoir waters of the Mynkuduk horizon reduces the level of CS recording relative to the reservoir waters of the Inkuduk horizon, which allows us to confidently separate these two horizons.

The results of geological and geophysical studies of the Mesozoic-Cenozoic rocks show that the lithological section is mainly represented by loose sandy-clay deposits.

Appendix A provides data describing the electrical resistances of rocks in the Inkuduk horizon. It is on the knowledge of these geoelectric properties of the section that the interpretation of the CS electric logging data is based, performed at both quantitative and qualitative levels of interpretation.

The data presented in the table on the values of apparent rock resistances for clarity and convenience of analysis are presented in the form of a variational graph (Fig.2).

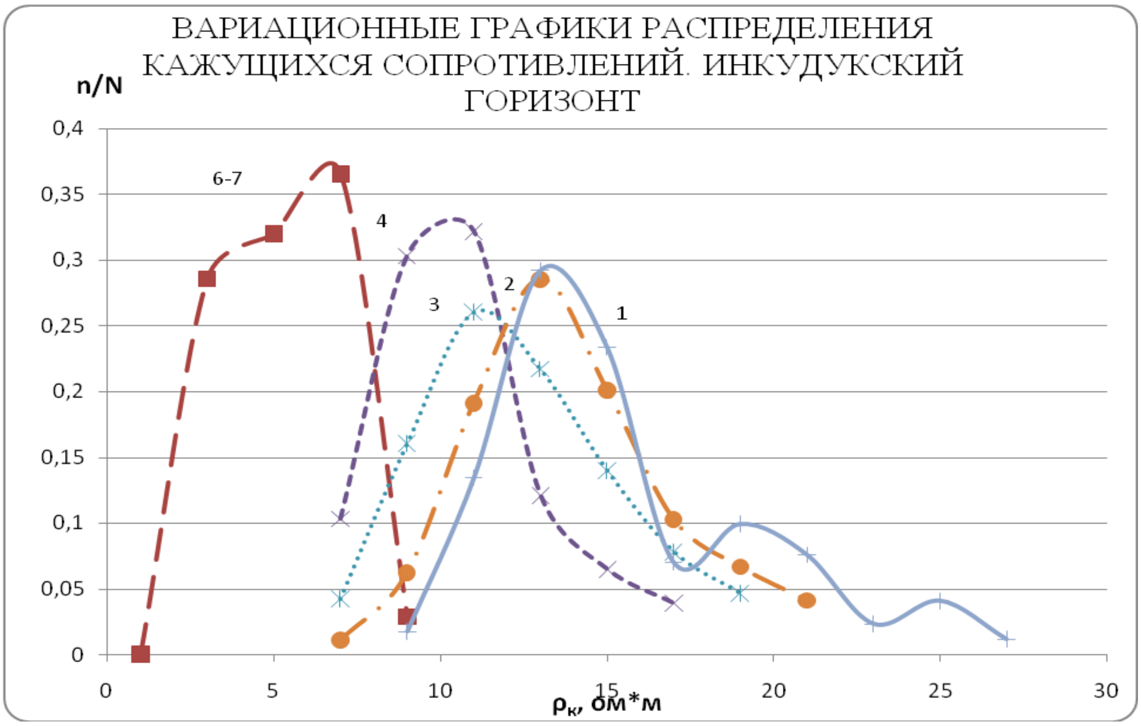

Fig.2 - Variational graph of distribution of RL on Inkuduk horizon

From the variational graphs presented in Figure 1, it can be seen that modal values of apparent electrical resistances of lithological varieties of rocks within the ore-bearing horizon confidently and unambiguously distinguish three groups of rocks:

- clay rocks are clays, siltstones, clay siltstones, and silty clays.
- sand rocks are fine-grained, mixed - and medium-grained sands.
- rocks of gravel composition – sand-gravel and gravel-pebble formations.

Sands of different grains with gravel, which occupy$_к$ an intermediate position in terms of p k values, can be distinguished the least reliably and with a greater error.

The most important thing, from the point of view of studying technological properties, is the fact that impermeable rocks (clays, siltstones) can be separated from permeable rocks (sands of varying degrees of granularity and sorting) reliably and unambiguously.

The proximity of reservoir water and drilling mud mineralization significantly reduces the informative value of the PS method for lithological section dissection, and this method in the complex is subordinate in nature and is used as an auxiliary method for qualitative interpretation of electric logging.

3 Calculation of uranium reserves

3.1 Conditions adopted for calculating uranium reserves at mestorodeniand Budenovskoye fields

The following industrial standards were approved for calculating uranium reserves in the field: Budennovskoe with the following parameters:

- on-board uranium content in the extraction of ore intervals in terms of thickness – 0.01%;
- the minimum total metric percentage for the well included in the contour of the ore body or block – 0.0400;
- the maximum thickness of ore-free zones and substandard interlayers included in the ore interval is 1.0 m;
- maximum capacity of non-ore intervals and substandard ores included in one counting block for reserves:

categories C_1 – 6.0 m.

categories C_2 – no limit.

- the minimum area coefficient of ore content (the ratio of the number of wells with balance mineralization to the total number of wells within the area of the counting block) - 0.75;
- minimum size of an isolated counting block of the category From$_2$ – 40 thousand m2^2.
- the maximum size of a counting block of category$_{C1}$ is 300 thousand^{m2}.
- the maximum content of silt-clay particles less than 0.05 mm in size in ore intervals is 30%;
- minimum permeability of the ore-bearing aquifer (filtration coefficient) - 1.0 m / day;
- delineation of counting blocks should be carried out within single aquifers (sub-horizons), taking into account local water closures;
- off-balance reserves of blocks in permeable sediments, delineated according to the minimum metric percentage for the well 0.0200, without limiting the average metric percentage for the block and the thickness of empty rocks between intervals of 6 m, adjacent in plan to the contours of blocks of balance reserves of category C_1, and also statistically take into account uranium reserves in clays and clay interlayers (siltstone content- clay particles more than 30 %) with an on-board content of 0.01 % and an on-board metric percentage of 0.035, off-balance reserves of both types should be taken into account separately;
- calculate uranium reserves in individual ore bodies that meet the conditions of balance ores and are located outside the contours of blocks with reserves of category C_1, but are projected on their area at an on-board metric percentage of 0.0200;
- reserves of associated components within the contours of blocks of balance reserves of uranium: rhenium, scandium, rare earth elements, yttrium – take into account as off-balance.

3.2 Calculation of balance reserves of uranium

3.2.1 Inventory calculation methodology

Reserves of categories$_{C1}$ and$_{C2}$ are calculated using the geological block method. The choice of the calculation method is determined by the peculiarities of the exploration technique carried out by vertical drilling wells along a rectangular network, subhorizontal occurrence and reservoir-lenticular morphology of ore deposits, the linear dimensions of which in terms of many times exceed the ore capacity. Combined with the variability of mineralization morphology within the productive horizon, all this makes it impractical to use other methods of counting. The use of the geological blocks method made it possible to output average parameters for counting blocks using data not only for network wells, but also for wells drilled on additional profiles, hydrogeological and other wells for various purposes.

Inventory is calculated using the formula:

$P=S \cdot Kr \cdot p$ (3)

where:	P	–	metal reserves in tons;
	S	–	area of blocks in plan in thousand m2$^{\text{of m2}}$;
	Kr	–	area coefficient of ore content;
	p	–	specific productivity for the block in kg/^{m2}, defined as the product of the average metric percentage for the block by the volume weight of ore: $p = m^* c \cdot d \cdot 10$, (4where: where: m is the average ore thickness in the block, m c is the average ore content in the block, % d-is the volume weight of the ore, t/m3^3

In addition to metal reserves, the following are estimated during the calculation::

Mo	–	total thickness of permeable deposits of the block in m;
m	–	average ore thickness of the block, m;
C	is	the average uranium content in the ore mass, separated by 0.01%;
Vp	–	vp is the volume of ore mass included in the block in thousand^{m3};
Q_{Qp} is the	ore	mass of the block in thousand tons;
V	is	the volume of permeable deposits of the productive pack to be treated with solutions, thousand m3^3

In accordance with the conditions, the calculation was carried out for ore bodies. The calculated ore body was assumed to be a reservoir-like volume of permeable ores and rocks, in which uranium mineralization is contained either in the form of a monolithic ore layer, or in the form of a series of ore layers separated by empty rocks, the thickness of which, in general, does not exceed 6 m (for blocks of category C_1).

The calculation of reserves with the allocation of an ore-saturated pack as a counting ore body is most consistent with the projected extraction method, which involves working out the extracted ore body with a single system of wells.

Ore reserves are considered as balance reserves only in permeable deposits characterized by a silt-clay particle content of less than 30 % and filtration coefficients of morethan 1 m/day. The content of silt-clay particles (clay content) was determined according to granulometric analysis, and the values of filtration coefficients (permeability) were determined according to the results of quantitative interpretation of electric logging data based on experimental hydrogeological works.

The C1 and C2 inventory counting blocks$_1$ and C_2 are shown on 1:2,000 scale plans and presented on Figure 3.

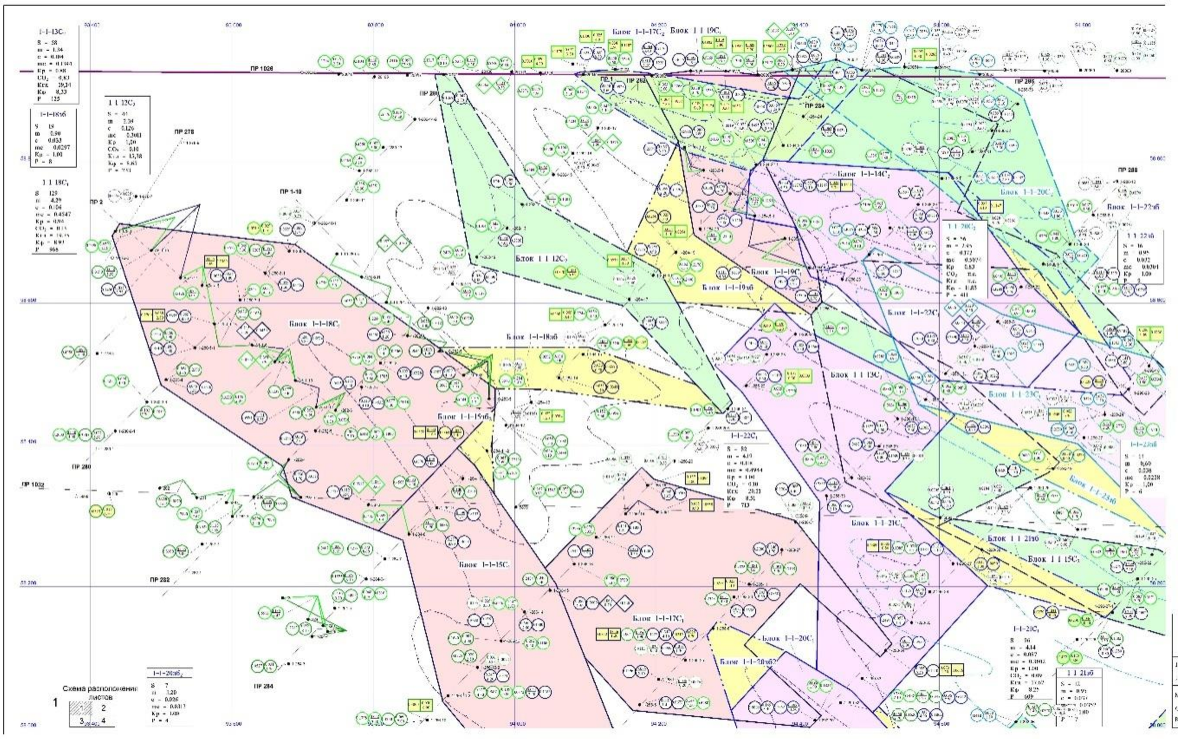

Fig.3 – Technological blocks (plan delineating)

The relative position of block polygons and the overview plan for blocking the site's inventory are shown in the consolidated inventory calculation plan on a scale of 1: 10,000. Due to the multi - tiered mineralization and excessive workload of the reserve calculation plans, separate 1:2,000 scale plans show the geometrization of ore bodies in the Lower and Middle Chuduk subhorizons separately.

In addition to the standard metric percentage parameter, the calculation plans show the thickness of the ore body and the uranium content at each intersection, which makes it possible to really judge the ore volume in each well.

The plans are accompanied by cross-sections of productive horizons along exploration profiles along a network of 200×50-25 m. We also present sections along short profiles (sections) perpendicular to the profiles of the main network in areas of complex configuration of ore objects. The given set of sections is essentially a graphical representation of a three-dimensional model of the site structure and allows us to assess the validity of one or another method of linking and interpolating ore deposits between exploration profiles.

The calculated sections are shown in detailed scales (horizontal -1:1000, vertical – 1:200), which allowed us to apply the necessary geological, technological, geochemical and other information elements to them with the required accuracy and detail (Figure 4).

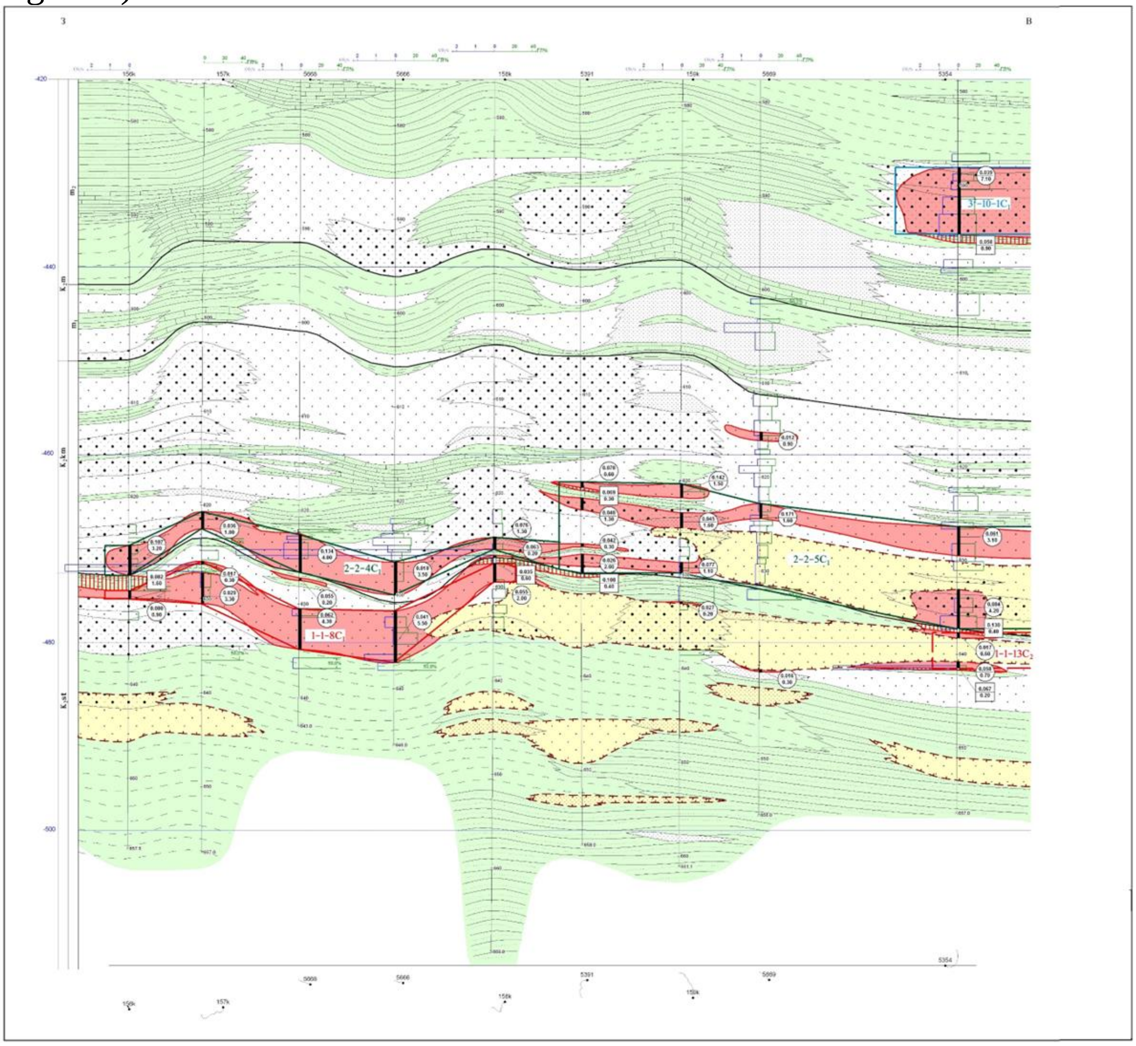

Fig.4 – Technological blocks (cross-section delineating)

Permeable deposits of ore – bearing horizons are characterized by high values of filtration coefficients (from moderately permeable-Kf=2-3 m/day to highly permeable-Kf>10 m/day), often significantly exceeding the limit value (1 m/day) established by the conditions. Thus, all ore bodies located in permeable deposits are very favorable objects for underground leaching.

The contours and parameters of ore deposits are displayed on the sections of the productive horizon with the allocation of intervals of permeable and impermeable ores, represented by the corresponding conventional signs. In addition, histograms of clay content and carbonate content in ore and ore-bearing rocks are presented. All this data additionally characterizes the selected counting blocks.

3.2.2 Drawing polygons of counting blocks in a cross-section and in a plan

The explored balance reserves of categories$_{C1}$ and$_{C2}$ of site 1 are located within the Lower and Middle Chuduk subhorizons, which are characterized over the entire area by common structural-tectonic, facies-lithological, hydrogeological and geotechnological features. The ores of the Mynkuduksky horizon are sporadically developed in the southern part of the site and are not of industrial significance.

Based on this, the construction of counting blocks is based on the following principles:

- the same type of structural and morphological features of mineralization within the block.
- uniformity of mineralization content to certain vertical sections of the horizon section and to wedging elements in the section of the reservoir oxidation zone;
- proximity of average values of lithological and filtration properties of ore rocks included in the block;
- uniformity of the exploration network within each block.

When constructing counting blocks, the principle of their uniformity in structural and morphological features was adopted as the main one. In ore deposits, bag, wing, and remnant parts were identified, within which counting blocks were delineated with a fairly definite spatial correlation along parallel sections. As a rule, the correlation of ore bodies based on these features in the formation of blocks is quite reliable. However, in some areas, the correlation turned out to be possible if the six-meter thickness of non-ore rocks determined by the conditions between the ore intervals included in the counting block was exceeded.

Due to the absence of a lower regional water barrier, the division of deposit 1 of the Inkuduk horizon into morphological elements was carried out with an assessment of their hypsometric position relative to the upper boundary of the Mynkuduk horizon.

Special attention was paid to the uniformity of the lithological and filtration properties of the ore rocks included in the block. The complex distribution of litho-filtration types in the alluvial section does not allow for their geometrization and allocation of blocks entirely composed of one type. Therefore, the filtration uniformity of the block was achieved by including rocks with close average permeability values in the block.

In addition to the basic principles listed above, when constructing blocks, in order to ensure the greatest possible simplicity of their configuration, the authors tried to avoid including in a single block ore bodies with large fluctuations in thickness and width, or areas with sharp bends in ore deposits in the section or plan. If ore bodies with abrupt changes in the above parameters were included in a single block, a more rigid extrapolation was carried out between wells and profiles, taking into account the lithological and structural features of mineralization localization and morphostructural elements of ore bodies.

Delineation of ore deposits and allocation of counting blocks were carried out on 1:2,000 scale plans and on sections of productive horizons with a horizontal scale of 1:1,000 and a vertical scale of 1:200, i.e. on horizontal and vertical projections of ore bodies.

In the absence of natural mineralization restrictions, the lower and upper boundaries of the blocks were drawn along the bottom and roof of the ore bodies (the onboard uranium content of 0.01% established by the conditions).

If the contours of conditioned mineralization were significantly complicated due to individual wells with sharply reduced ore capacity, the upper and lower boundaries of blocks were drawn along neighboring wells with the inclusion of non-ore, substandard or off-balance intervals for a well with an abnormally low ore capacity for this block. In such cases, the total block capacity for a well with a small ore capacity was determined graphically on the section.

When determining ore intervals at intersections exceeding the six-meter thickness of empty rocks, the ore intersection was considered conditioned only when both intervals (or, as an extreme case, one of them) were themselves conditioned. Otherwise, this intersection was considered off-balance despite the fact that the total metric percentage for it could exceed the boundary conditional values.

The blocks were bounded by vertical lines along the width of the ore deposits.

In the plan, the delineation of blocks was also carried out by straight lines connecting the boundary points obtained during interpolation between the conditioned and substandard or non-ore wells along the profile. The position of wells on the plan is defined as the projection of the point of intersection of the wellbore with the base of the ore deposit. The boundary points (as well as the wellbore) were projected on a vertical plane (along the profile line) and determined the position of the vertical boundaries of the counting block in the section.

Determination of boundary points or interpolation between ore and non-ore or off-balance wells along the profile was carried out on the plan, taking into account the morphological features of ore deposits.

Baggy parts of ore deposits in most cases wedge out sharply, at short distances, so the interpolation was carried out in a single way – by 1/4 of the accepted (or actual, if it is less than the accepted) distance.

From the side of the wing parts of the deposits, the interpolation was carried out by 1/4 of the accepted (or actual, if it is less than accepted) distance between the ore and non-ore wells, and by ½ - between the ore and off-balance wells. If the mineralization capacity of an ore well significantly exceeds (at least 3 times) the mineralization capacity in an off-balance well, then, in order to avoid possible overestimation of the block area, interpolation was carried out by 1/4 of the accepted (or actual, if it is less than the accepted) distance.

Interpolation between the profiles was carried out by half the distance of the accepted network, if there are wells with off - balance mineralization corresponding to the position in the plan and section of the mineralization of the ore profile on the adjacent profile, and by 1/4-if there are no such wells.

If only one well with balanced mineralization is installed on the extreme profile in the block, then extrapolation was not carried out and the block was limited to this profile, and interpolation between wells along the profile was carried out in the same way as indicated above.

With a sharp change in the width of the deposit between adjacent profiles and in the absence of off-balance wells on the profile with a smaller deposit width corresponding to the position in the plan and section of the balance wells on the profile with a larger deposit width, the delineation of the ore deposit was carried out with an interpolation of the larger deposit width by using the interpolation method. This technique was mainly applied from the wing parts of deposits, the morphology of which is more whimsical.

3.3 Method for calculating average parameters

3.3.1 Determination of uranium capacities and contents by intersections and blocks

The determination of the thickness of ore intervals and their uranium content at the deposit was carried out based on the results of interpretation of gamma-ray logging. The possibility of using and reliability of the gamma-logging interpretation data for calculating reserves at the Budennovskoye field is justified by the large volume of comparison of the results of testing and gamma-logging. Discrepancies in power, metric percentage, and content do not exceed acceptable limits.

Internal and external controls were performed evenly over time and by grade of uranium content. The results of the control indicate that there are no random and systematic discrepancies that exceed the permissible limits.

The thicknesses of ore intervals were determined by a given on-board content with the inclusion of permeable interbeds of non-ore rocks or rocks with substandard content with a thickness of up to 1 m in the ore interval. At the same time, the uranium content in the subdivided interval, together with the interlayer with substandard content, was not less than 0.01 %. The formation of ore intervals was carried out taking into account the location of each jointed interval to the same element of the ore deposit.

Layers of impermeable rocks with a thickness of more than 0.1m were excluded from the total thickness of the ore interval. The value of 0.1m is determined based on the ability of uranium to leach from low-thickness (10-15cm) clay interlayers and the capabilities of machine processing of logging data.

No correction was made to the power value for the angle of meeting of the well with ore bodies, since with the near-horizontal (0-1°) occurrence of ore bodies and the deviation of the wellbore from the vertical, which does not exceed, on average, 3-5°, the value of this correction is within the accuracy of graphical constructions.

The ore capacity at the intersection included in the counting block was determined by summing the capacities of individual ore intervals in the block contours.

The average ore capacity of the block (m) was defined as the arithmetic mean of the ore capacities of all intersections included in the counting block.

The average uranium content for block (c)was defined as the weighted average of the contents at intersections for their thickness.

To calculate the volume of rock mass of the block, the total thickness of permeable deposits of the block was determined with the inclusion of interbeds of non-ore rocks or substandard ores. In this case, the total crossing capacity was defined as the sum of the capacities of all permeable rocks from the upper to lower boundaries of the block, and the average permeable capacity of the block was defined as the arithmetic mean of the total capacities of all intersections included in the block.

3.3.2 Identification and accounting of outstanding (hurricane) intersections

Detection and limitation of outstanding uranium contents were carried out using the maximum permissible content (according to the method of I. L. Kogan). Outstanding intersections were those where the average uranium content in the block decreased by more than 10 %.

All blocks of categories$_{C1}$ and$_{C2}$ were checked for identifying and limiting outstanding content. When the number of ore intersections in a block is small, to increase the reliability of the hurricane analysis, data from neighboring blocks were combined, provided that they are homogeneous and belong to a single ore body. When checking each subsequent intersection, all detected previous outstanding intersections were counted with their true values.

In isolated blocks of category$_{C2}$ with a small number of ore intersections in the block (less than 10), hurricane analysis was not performed, provided that the uranium contents for ore intersections are close to the average uranium contents for this deposit.

3.3.3 Determination of the area coefficient of ore content

When identifying and delineating counting blocks, except for ore wells, the block contours included non-ore or off-balance wells located inside the block. Delineating them without distorting the morphology of ore deposits is not always possible. Therefore, the size of the block area was supplemented with the coefficient of ore-bearing capacity by area, which makes it possible to statistically take into account the influence of non-ore and off-balance wells included in the block contour. The ore-bearing coefficient was determined individually for each block as the ratio of the number of ore wells to the total number of wells.

Blocks of category$_{C1}$ are characterized by high values of the ore-bearing coefficient from 0.88 to 1.00, with an average value of 0.96. For blocks of category$_{C2}$ Krr varies from 0.80 to 1.00 with an average value of 0.91.

3.3.4 Measuring the area of counting blocks

The areas of counting blocks were measured using the Mapinfo program (version 10.0) on a personal computer at the specified points. In order to avoid possible errors and as a control, the areas were measured graphically directly on the original plans on a scale of 1: 2000 with the division of complex areas into elementary figures.

3.3.5 Determination of the volume weight of ores

The volume weight and moisture content of ores were determined from monoliths taken from the core of wells.

The volume weight was determined by the method of cutting rings and hydrostatic weighing of waxed samples, and the humidity was determined by the weight method according to the existing method. Reserves were calculated for absolutely dry ore.

Monoliths were selected from ore and non-ore rocks immediately after core lifting and radiometric listening. Distribution of monolith sampling points over the area is relatively uniform The selection of monoliths was carried out in such a way as to characterize all rock varieties. In total, 107 monoliths were selected from the ores at site 1 along the Inkuduk horizon. To calculate the volume weight and humidity, we also used the results of studies of monoliths throughout deposit 1, including sections 1 and 3. There are 191 monoliths in total.

To calculate uranium reserves, the volume weight of ores from the Inkuduk horizon is assumed to be 1.76 g /^{cm3}.

3.4 Principles of inventory qualification

According to morphological features, the ore bodies of site 1 are divided into roll and lenticular ones. In the most studied western part of the site, the width of wing rectilinear deposits in the Inkuduk horizon ranges from 400 m to 500 m. The bag part has a width of 150 - 200 m. The length of the deposit within the site is the first kilometers.

Uranium reserves were calculated in the Inkuduk horizon within deposit 1 within the boundaries of the geological allotment.

Exploration of deposits of the second group for working out by the PV method with the identification of reserves of category C_1 is carried out by drilling operations with a distance between wells along the length of the ore deposit of 400×100 m and in width - 100×25 m.

During the search and evaluation stage of work on the Southern flank of the field, experimental work was not carried out to select the most optimal network density at the exploration site. However, given that the Budennovskoye field is a natural extension to the south of the Inkai field, the exploration network can be adopted by analogy. Analysis of the results obtained at the exploration sites of section 1 of the Inkai field showed that$_1$ the following exploration networks are reliable for identifying C-1 reserves (Table 2).

Table 2

Exploration network density for identifying C_{-1} reserves

Width of the deposit (or part of it)	Morphology of ore bodies in plan	Exploration network density
up to 150 m	simple linear shapes	100 × 25 m
more than 150 m	simple and fancy shapes	200×50 m

The Budennovskoye field site, where detailed exploration was carried out in 2008-2012 and where C_{-1} reserves are calculated, was drilled in a 200x50 m network, but the variety of morphological features of mineralization in terms of plan (which especially affects the determination of ore areas) sometimes forced us to deviate from the direction and density of the network. Three profiles (incisions) perpendicular to the main network were made in the bag part of the deposit. When calculating reserves, wells drilled off-grid (prospecting, hydrogeological, etc.) were also taken into account. They were counted as independent intersections if they were separated from the exploration wells by at least the accepted distance between the network wells. In cases where the distance between wells is less than the accepted distance, data for such wells were averaged with data for the nearest network wells.

An exploration network of 400 × 100–50 m was used to identify C-2 reserves.

All geological and industrial parameters of mineralization were studied at the site: the size of deposits, their morphology, lithological and material composition of ores, geochemical and lithological filtration types, thickness of ore bodies and uranium content, technological properties of ores, hydrogeological and engineering-geological conditions of deposits in the ore, under-ore and over-ore parts of the section. Field technological tests were carried out.

Based on the above and based on the requirements of the " Instructions..."[1], uranium reserves are classified as category C 1:

- with an exploration network density of at least 200 × 50 m;
- with a relatively identical and correlated geological and structural-morphological structure of ore deposits;
- with the completeness of the study of the hydrogeological conditions of the productive horizon, characterized by pumping from cluster and single hydrogeological wells;
- with the study of engineering and geological features and water-physical properties of rocks and ores, provided by the selection and analysis of samples for granule composition and carbonate content;
- determination of rock filtration coefficients based on the interpretation of well logging over a network of at least 200 × 50 m;
- with data from laboratory studies of monoliths selected from representative areas of deposits;
- with the study of the geotechnological properties of ores, provided by the results of a multi-well experience of PV and data from laboratory studies of

technological samples, which allow extrapolating the results of OPV to the entire area of explored reserves.

Category C_2 includes stocks in blocks:

- with an exploration network density of 400 × 100-50 m.

- with relatively homogeneous structural and morphological features of ore bodies;

- with the study of hydrogeological features based on pumping data from cluster and single wells;

- with the study of the engineering and geological features of rocks and ores, provided by the selection and analysis of samples for granulation and determination of filtration coefficients based on the interpretation of electric logging over the 400×100 m network;

- with the study of geotechnological properties of ores based on laboratory tests of technological samples and definitions of clay content and carbonate content.

The study of the balance reserves of categories$_1$ and C_2 C1 and C2 is provided by the results of 1 cluster and 2 single hydrogeological pumping, analysis of samples for granule composition, samples for carbonate content, technological samples, determination of moisture and volume weight of ores by monoliths.

These surveys cover the entire area of the site in accordance with the exploration and qualification of reserves.

As a result of the calculation of balance reserves in the ore deposits of the site, 23 blocks of category C_1 and 21 blocks of category C_2were identified. The ratio of $_{C1}$ and C2 reserves was 79.50% and 20.50%, respectively.

3.5 Inventory calculation using Petrel software

Based on the above, it is obvious that the process of calculating reserves at the studied field, performed manually, requires optimization. One of the possible options is to use geological modeling for the purpose of subsequent calculation of reserves. Further, using the example of the “Petrel” software, the sequence of actions required to perform this task is shown.

1. Importing data into Petrel project. Below are the basic data that will be required for 3D geological model building:

- collar table (well positions);
- trajectory deviation (trace);
- electrical logs;
- radiometric logs;
- equivalent radium;
- ore intervals from;
- stratigraphic markers (if exist);
- core data (lithology, redox);
- geochemical assays (uranium / radium assays, gran-size, CO2).

2. Building stratigraphic model. Stratigraphic model is the basis of 3D grid in the whole project. The main source of structural carcass of the model is stratigraphic markers of formations in the drill holes interpreted by geophysical logging data. Stratigraphic model starts from creation of reference surface and ends with the bottom of the last production horizon.

3. Building 3D grid. 3D grid sizes will depend on the purpose of the project.
For reserves estimation the length and width of the drilling grid usually correspond to drilling mesh: (Appendix C. Fig. 1,2)
Exploration phase and development phase: for example, a x b and cxd.
Technological drilling phase: usually average distance between technological wells is about vm and taking into consideration grid of exploration and development wells, the recommended grid will be approximately equal to a x b and cxd.
The height of the cell will also depend on the project purpose:
For reserves estimation – xm
3D grid border will be as following:
For reserves estimation and potential zones assessment a wide region must be chosen which covers all existing wells to assess any potential mineralization near the projecting block;

4. Litho Facies modelling. It is done using simple permeable/impermeable lithological model.(Appendix C. Fig.3)

5. Upscaling and variogram study. Building a variogram according to lithological permeability.

6. Kriging. Indicator Kriging method is used to interpolate lithological permeability variable in the grid.

7. Redox modelling. Reduction-Oxidation environment modelling is based on named variable.

8. Mineralization modelling. Variogram analysis and model fitting, kriging, and mineralization domain control. (Appendix C. Fig.4)

9. Equivalent radium interpolation with kriging. Cell selection, variogram analysis and model fitting, and kriging of eRa.

10. Selection of blocks. Horizontal and vertical selection. (Apendix C. Fig.5)
Horizontally: by contours of geological and technological blocks or cells;
Vertically: by reservoir limits or effective thickness of leaching/active zone.

11. Uranium reserves estimation.

Petrel model can be a good tool:

- to assess geological risks;
- to project technological wells;
- to control technological levels and validate vertical position of screens. This will be especially relevant for areas with 2 or more productive horizons.
- to calculate rock mass parameters;
- to forecast block behavior;
- to estimate reserves.

CONCLUSION

The calculation of reserves is the most important stage of uranium mining, determining the economic feasibility and future direction of work. Geological and geophysical studies were carried out at the Budennovskoye field, which made it possible to estimate the reserves, and subsequently start uranium production through the ISL. However, in the course of the work, we identified ways to optimize this work using software.

Final work results: Based on the materials provided, conclusions were drawn about the state of geological and geophysical exploration of the Budennovskoye field. Based on these data, conclusions were also drawn about the methodology and technology for calculating uranium reserves. A new technology for calculating stocks is proposed.

Completed works: Description of geological and geophysical study based on the analysis of data on geophysical studies conducted on the territory of the field.

Description of the method for calculating uranium reserves, taking into account the construction of the contours of counting blocks in the section and in the plan, the method for calculating average parameters for subsequent calculation (including determining the capacity and content of uranium by intersections and blocks, identifying and accounting for outstanding (hurricane) intersections, determining the area coefficient of ore content, measuring the areas of counting blocks, determining the volume weight ore), principles of reserve qualification.

An alternative technology for calculating reserves is studied and described using the example of other deposits.

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Appendix A

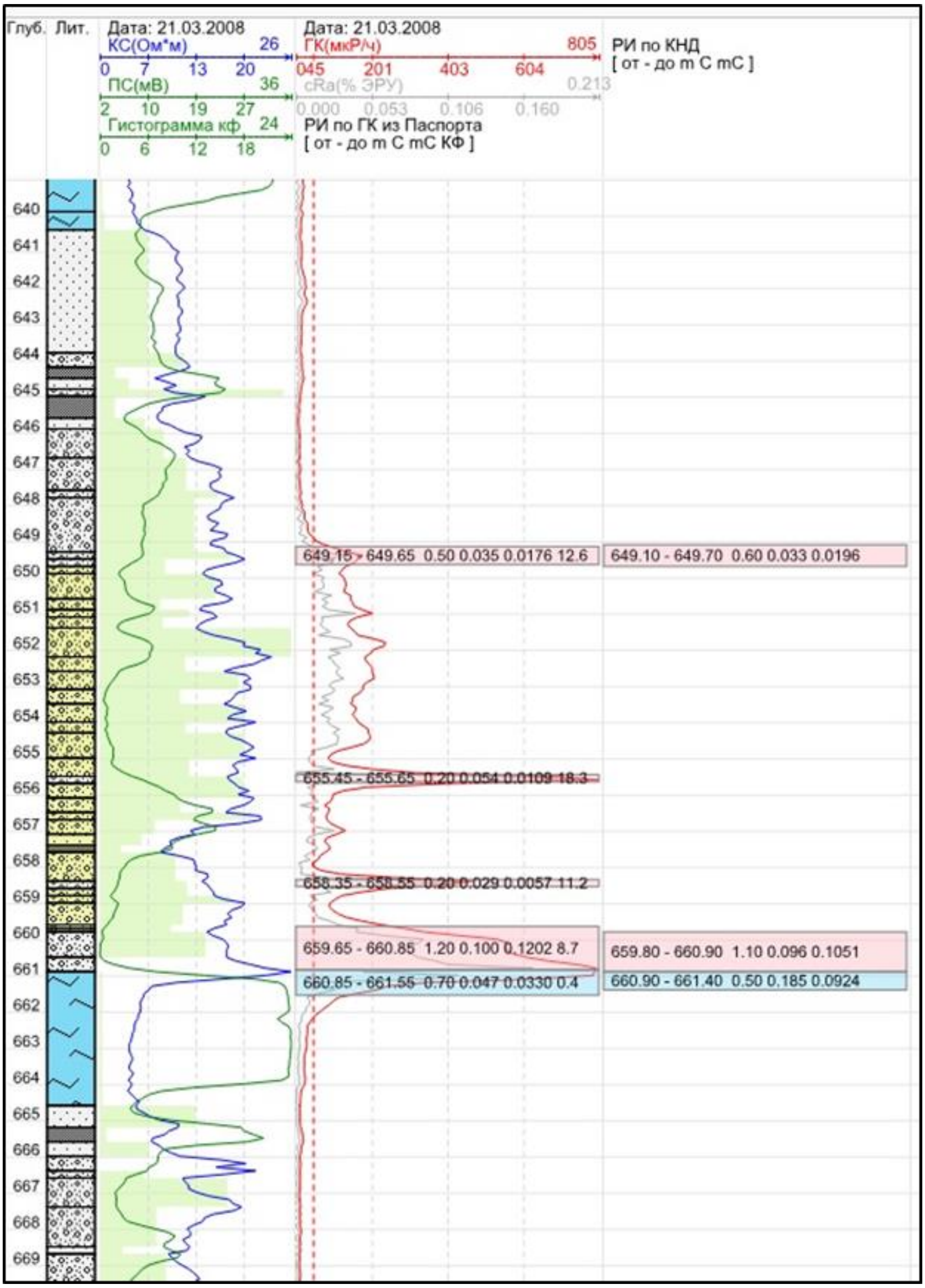

Fig.1 - Comparison between GL and NL

Appendix B

Name of breeds	Lithological difference code	Filtration characteristics of rocks*	Number of definitions	p_k, Om*m	S p_k
1	2	3	4	5	6
Gravel and pebble deposits	1	P	249	17.71	0.27
Mixed-grained sands, mixed-grained sands with gravel	2	P	1691	15.43	0.08
Medium-grained sands	3	P	765	12.15	0.09
Fine-grained sands	4	P	338	10.60	0.09
Clays, siltstones	6-7	N	175	5.48	0.17

Table 1 - Values of apparent electrical resistances of rocks ore-bearing horizon

* Note:
H – watertight rocks
P – water-permeable rocks.

Appendix C

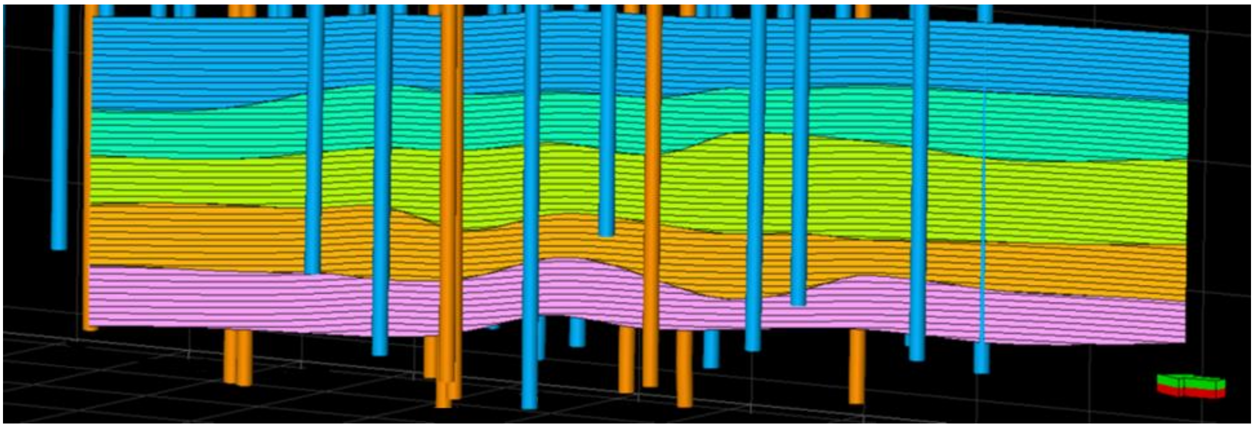

Figure 1 - Cross section of 3D grid

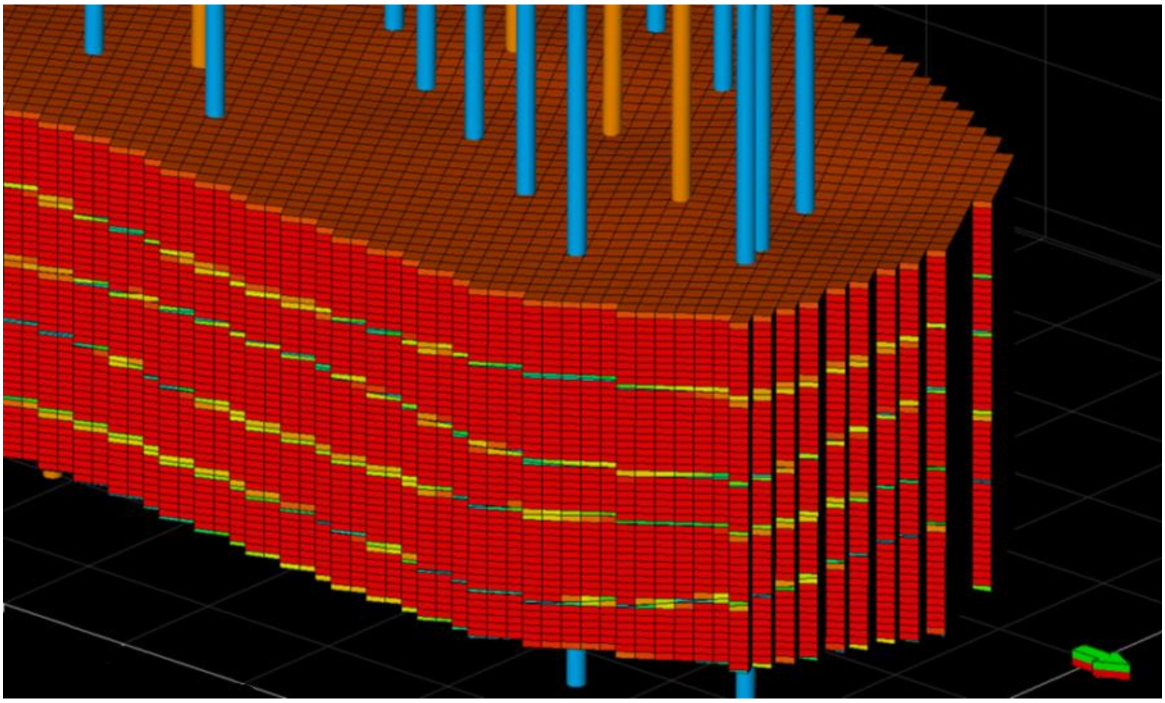

Figure 2 – Example of 3D grid in Petrel

Appendix C (continuation)

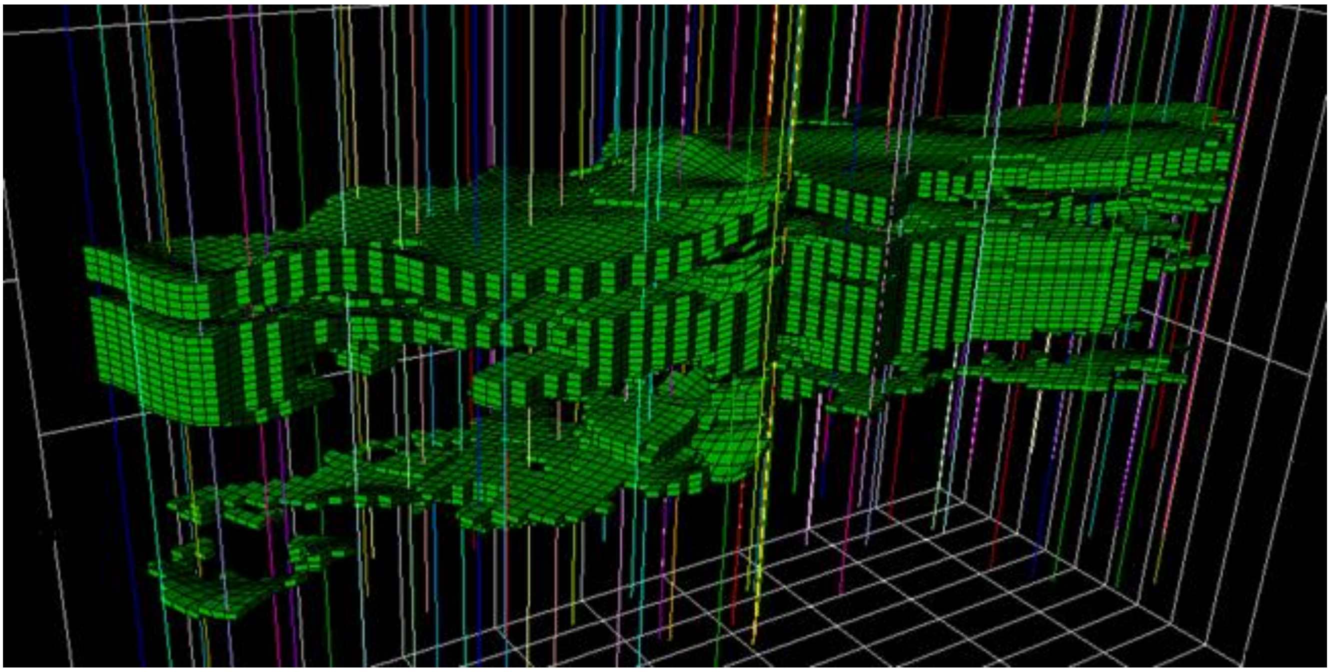

Fig.3 - Example of lithological model

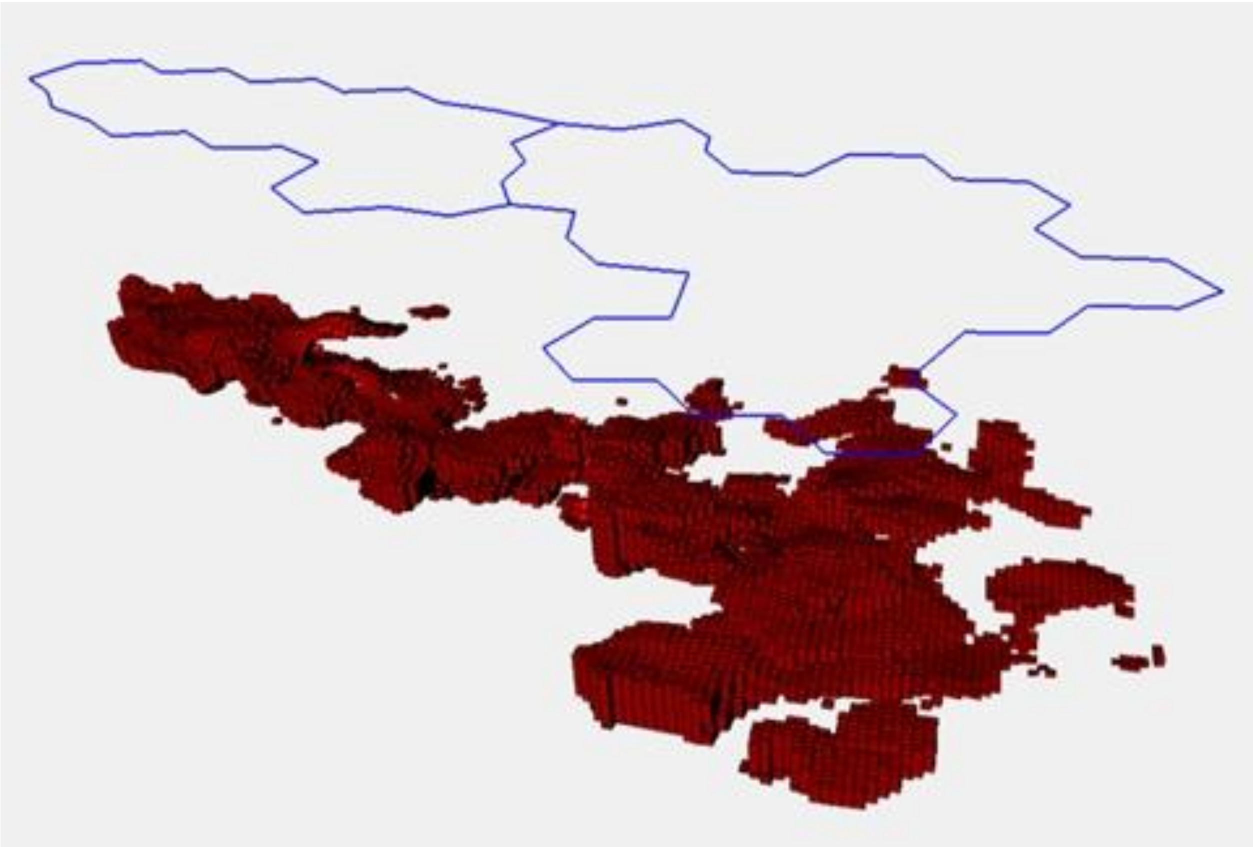

Fig. 4 - Example of mineralized domain

Appendix C (continuation)

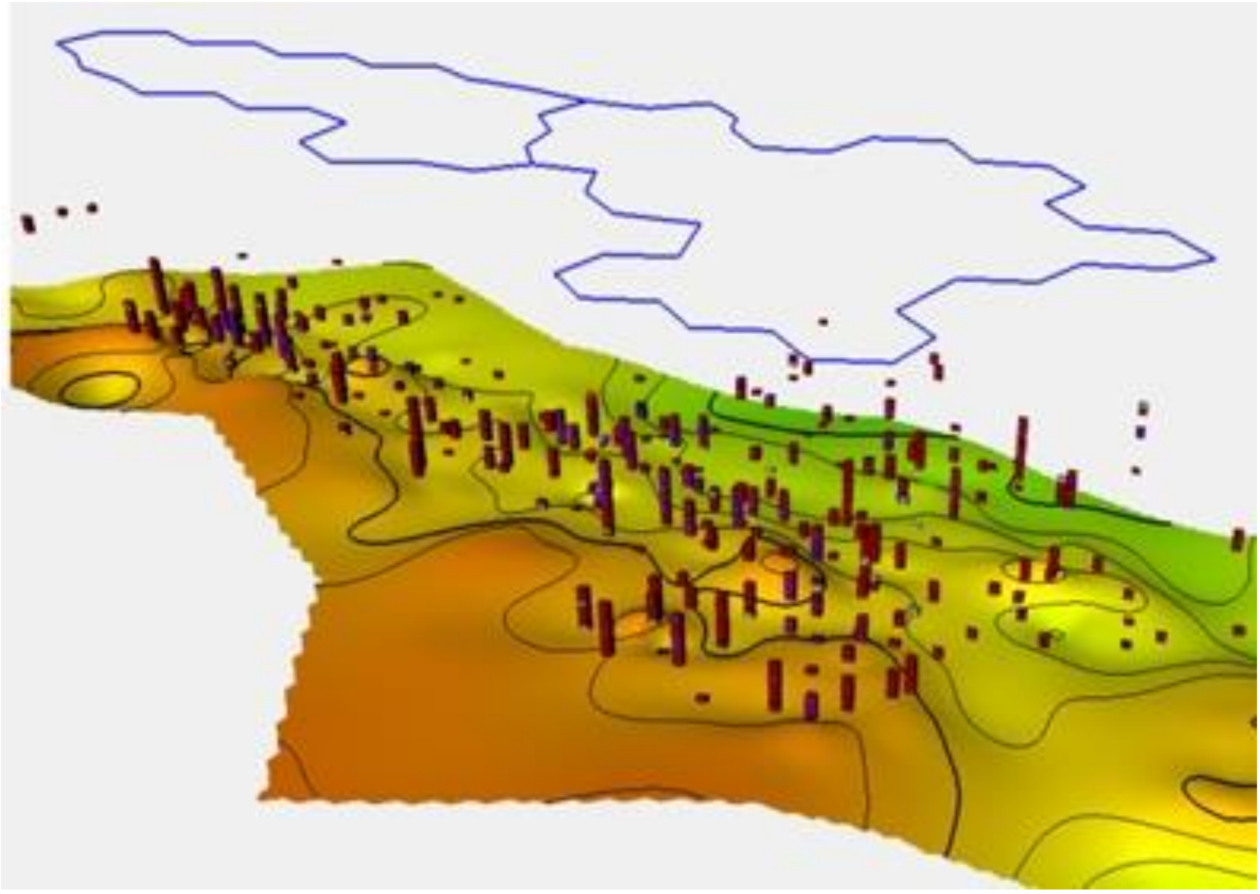

Fig.5 - Cell selection by mineralized domains

Протокол

о проверке на наличие неавторизованных заимствований (плагиата)

Автор: Бектұрсынова Диана Мақсатқызы

Соавтор (если имеется):

Тип работы: Дипломная работа

Название работы: «Interpretation of geophysical well logging data for calculating uranium reservesusing the example of the Budenovskoye deposit».docx

Научный руководитель: Мадияр Әлиакбар

Коэффициент Подобия 1: 3.8

Коэффициент Подобия 2: 1.4

Микропробелы: 2

Знаки из здругих алфавитов: 3

Интервалы: 0

Белые Знаки: 0

После проверки Отчета Подобия было сделано следующее заключение:

Заимствования, выявленные в работе, является законным и не является плагиатом. Уровень подобия не превышает допустимого предела. Таким образом работа независима и принимается.

Заимствование не является плагиатом, но превышено пороговое значение уровня подобия. Таким образом работа возвращается на доработку.

Выявлены заимствования и плагиат или преднамеренные текстовые искажения (манипуляции), как предполагаемые попытки укрытия плагиата, которые делают работу противоречащей требованиям приложения 5 приказа 595 МОН РК, закону об авторских и смежных правах РК, а также кодексу этики и процедурам. Таким образом работа не принимается.
Обоснование:

Дата 18 мая 2022г. *проверяющий эксперт*

Протокол

о проверке на наличие неавторизованных заимствований (плагиата)

Автор: Бектұрсынова Диана Мақсатқызы

Соавтор (если имеется):

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Обоснование:

Дата 18 мая 2022г. *Заведующий кафедрой Геофизики*

Допущена к защите

РЕЦЕНЗИЯ

на дипломную работу бакалавра специальности «6В07201 – Нефтегазовая и рудная геофизика» на тему: «Интерпретация данных ГИС для подсчета запасов на примере месторождения Буденовское» Бектурсыновой Д.М.

Актуальность работы заключается в экономической выгоде добычи урана, в связи с его крайней востребованностью на мировом рынке в виде энергетического сырья. Добыча урана в целом имеет наибольшую актуальность на территории Казахстана, так как доступен наиболее экономный и экологически безопасный способ добычи – ПСВ. Геофизические исследования скважин являются ключевым элементом исследования для последующего подсчета запасов. Помимо этого, используемый на месторождении метод подсчета запасов является устаревшим и требует значительной оптимизации. Поэтому целью исследования является изучение применения методов ГИС для подсчета запасов и изучении методики в целом, а также предложение более актуальных вариантов работы над подсчетом запасов.

На основе изучения уже представленной методики были сделаны выводы об ее эффективности, был проведен сравнительный анализ и были отмечены преимущества предлагаемого программного обеспечения.

Список использованной литературы содержит 17 наименований. Дипломная работа была выполнена на основе фактического материала, собранного в период прохождения производственной практики в НАК «Казатомпром», АО СП «Акбастау».

Оценка работы. Работа является законченным научно - исследовательским трудом, выполненным автором самостоятельно на соответствующем уровне. Работа написана доходчиво. Предложенные автором дополнения являются достаточно новыми, обоснованными и достоверными.

Бектурсынова Д.М. заслуживает присвоения степени бакалавра по специальности «6В07201 – Нефтегазовая и рудная геофизика».

Рецензент

Главный менеджер геофизического
управления филиала АО «Волковгеология»
-«Геотехноцентр»
Баясилов Рауан Абдикаримович

«18» мая 2022 г.

ОТЗЫВ РУКОВОДИТЕЛЯ

Алиакбар М.М. на дипломную работу бакалавра специальности «6В07201 – Нефтегазовая и рудная геофизика» на тему: «Интерпретация данных ГИС для подсчета запасов на примере месторождения Буденовское» Бектурсыновой Д.М.

Дипломная работа посвящена актуальному вопросу – оптимизации подсчета запасов урана на основе данных ГИС. Данные исследования помогут повысить геологическую эффективность геофизических работ, проводимых на урановых месторождениях инфильтрационного типа на территории Республики Казахстан.

Методология исследований определялась поставленными задачами, которая включает анализ существующих методик подсчета запасов на основе данных ГИС. Применяемый на практике метод подсчета запасов имеет ряд недостатков, в связи с этим, в данной работе предложена методика подсчета запасов урана в программе Petrel. Данная программа позволяет наиболее достоверно посчитать запасы урановой руды, так как перед подсчетом запасов в программе строится 3D-геологическая модель рудного тела. К тому же надо отметить, что подсчет запасов в ПО позволит существенно сэкономить время и минимизировать погрешности, имеющие место при подсчете запасов традиционным методом.

Личный вклад Бектурсыновой Д. состоит в сборе, обобщении и критическом анализе геолого-геофизических данных по месторождению Буденновское, проверке адекватности применяемой методики подсчета запасов урана, на основе сопоставления двух методик подсчета запасов.

Фактический материал был собран в период прохождения производственной практики в АО «СП Акбастау».

В целом, Бектурсынова Диана подготовила дипломную работу на должном научном уровне. Полученные результаты практически обоснованы.

Бектурсынова Д.М. заслуживает присвоения степени бакалавра по специальности «6В07201 – Нефтегазовая и рудная геофизика».

Лектор
кафедры «Геофизика»
КазНИТУ им. К.И. Сатпаева
Алиакбар М.М.