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MASTER DISSERTATION

«Matching of geophysical data interpretation of logging and core material of uranium deposits»

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АҢДАТПА

Диссертациялық жұмыс кіріспе, әдеби шолу, қолданылған әдебиеттер тізімі және 3 тараудан тұрады. Жұмыс 37 беттен және 23 суреттен 4 кестеден және тұрады. Қолданылған әдебиеттер тізімі 7 атаудан тұрады.

Осы жобаның мақсаты Керн негізінде су өткізбейтін аралықтардың жүріс-тұрыс заңдылықтарын зерттеу және көрінетін меншікті кедергінің қисықтарын түсіндіру бойынша әдістер мен ұсыныстарды әзірлеу.

Түйінді сөздер:жерасты ұңғымалық сілтілеу, уран өндіру, каротаж, Геовиста.

Зерттеу нысаны:Геовиста маркалы каротаждық станциясы.

Зерттеу әдісі:эксперименталды әдіс.

РЕФЕРАТ

Настоящая диссертационная работа включает в себя введение, литературный обзор, заключение, список использованных источников и состоит из 3 разделов. Работа состоит из 37 страниц, 23 иллюстрации, 4 таблиц. Список использованных источников содержит 7 наименований.

Целью данного проекта было изучение закономерностей поведения непроницаемых интервалов на основе керна и разработка методов или рекомендаций по интерпретации кривых кажущегося удельного сопротивления.

Ключевые слова: топливный элемент, мембранно-электродный блок, слой катализатора, газодиффузионные слои, электроды свободные от платинума.

Объект исследования: каротажная станция марки Геовиста.

Метод исследования:экспериментальный метод.

ABSTRACT

This dissertation work divides for introduction, conclusion, list of references and the main three sections. The work consists of 37 pages and 23 illustrations and 4 tables. The list of references includes 7 titles.

The aim of this project was to study the regularities of behavior of impermeable intervals based on the core and development of methods or recommendations for the interpretation of the curves of apparent resistivity.

Keywords: in-situ leaching,uranium mining,logging, Intymak1.

Object of research: Geovista logging station.

Method of researching: experimental method

NOMENCLATURE AND ABBREVIATIONS

ISR	In situ recovery
Geovista	Geophysical station to carry out well logging.
RLLD	Resistivity lateral log deep. Geovista probe for majoring resistivity.
KS(AR)	Apparent resistivity. The most widely used method of electric logging of wells, which is based on the difference in specific resistivity of different types of sedimentary rocks.
Kobra	Geophysical station to carry out well logging.
Intymak	Stratigraphic and geological horizons of Kazakhstan
Uyuk	
Ikansk	
Kanjugan	
Phase1	Primary logging (resistivity, gamma ray, deviation)

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INTRODUCTION

At the moment, the economy of the most countries depends on mineral resources, including uranium. One of the leading countries in uranium mining is Kazakhstan. The uranium reserves and resources in Kazakhstan actually amount to 1.7 million tons or about 12% of the total volume of the world uranium reserves and resources. 1.1 million tons out of it are extracted by in-situ leaching method.

In Kazakhstan, acid leaching agents are used for uranium extraction. Extraction of uranium by the in-situ leaching method is made by the company Katco, which contributes to the reduction of environmental footprint. Kazakh-French joint venture JV LLP KATCO was established in 1996. The company is engaged in geological exploration, production, design and construction of facilities for the extraction and uranium ores processing, as well as the operation of these facilities at the fields, in particular at the Muyunkum and Tortkuduk fields in the South Kazakhstan region.

Overlying Palaeogene strata are divided into three horizons, from oldest to youngest: the Kanjugan horizon (Palaeocene), the Uyuk-Ikansk horizon (Lower-Middle Eocene), the Intymak horizon (Middle Eocene). Palynological data constrain more precisely the age range for these three horizons from Thanetian to lower Lutetian. Uranium deposits in the region are located within Cretaceous-Paleogene permeable sandy formations, within a 200 to 500 meters thick artesian multi-layered aquifer complex. This aquifer is confined between a thick impermeable cover of upper Eocene to Miocene formations and low permeability Paleozoic formations. [6]

The pilot was started in 2004 and the drilling technological wells in 2005. Local production began in 2006 with an annual production capacity of 700 tons of uranium.The logging in the field first was made with Geovista station. Geovista is a geophysical complex of the Geovista brand, which was produced in London. It is designed for geophysical exploration of a well on a cable. The geophysical complex includes geophysical well measurement instruments, geophysical descent mechanism with geophysical cable, and ground control and conversion unit for signal transmission and laptop to control the process and data registration. [1]

8500 destructive wells were logged on Phase 1 by Geovistanow the company is faced with the fact that they need to over calculate the reserves of uranium on these destructive wells. However due to the absence of interpretation methods of diagrams made by Geovista station, currently, there are some difficulties with developing 3D models and 2D interpretations in KATCO. Indeed, if there are, some errors in interpretation they can greatly affect the estimation of reserves (over or under). Therefore, we decided to develop interpretations methods of diagrams made by Geovista for the destructive well on the basis of interpretation of diagrams made by Geovista on core wells. The **purpose** of this project is to analyze the process of data interpretation of the recorded by geophysical complex Geovista. Consequently, our **objectives** are to:

- collect the data;
- validate the interpreted data;
- define delta % which will help to find threshold for impermeable rocks;
- find the peak of resistivity in the beginning of horizon Intymak 1 in order to define the threshold for impermeable intervals.

In order to obtain the objectives we used data collection and interpretation methods.

Several methods were used to determine the permeability in the rocks. One of these methods was measured by Geovista probe (and data of resistivity is named RLLD) considered the thickness lower than 1 m. It means intervals (impermeable) greater than 1 meter can't be measured and aren't taken into account while analysis. In other words, thicknesses are greater than 1 m are easy to interpret without core wells. Is this case, core interpretation is fundamental to indicate thin impermeable intervals. The purpose of this method is to calculate

the average delta using low and high resistivity values. The graph of this delta ratios and impermeable rock thickness can provide a help to define impermeable intervals.

The second method based on the study of the peak of Intymak 1. This peak is available in all wells and where the peak begins to decrease sharply there is a chance that it is a threshold for impermeable rocks. The goal of this project is to collect peak statistics and make a template. For statistics will be used wells of all 7 deposits and if statistics show above 80% then this peak can be used as a boundary to identify impermeable rocks in destructive wells.

KATCO - WORLD'S LARGEST ISR OPERATOR

KATCO is a joint venture for uranium mining established in 1996, with uranium reserves of 1.7 million tons. KATCO successful industrial partnership between France's ORANO, a uranium mining expert and world leader in nuclear energy, and Kazakhstan's Kazatomprom, the national nuclear operator. ORANO owns 51% of the joint venture and Kazatomprom 49%. The partnership has enabled KATCO's processing plants to become the largest and most technically advanced in situ recovery (ISR) production facilities in the world.

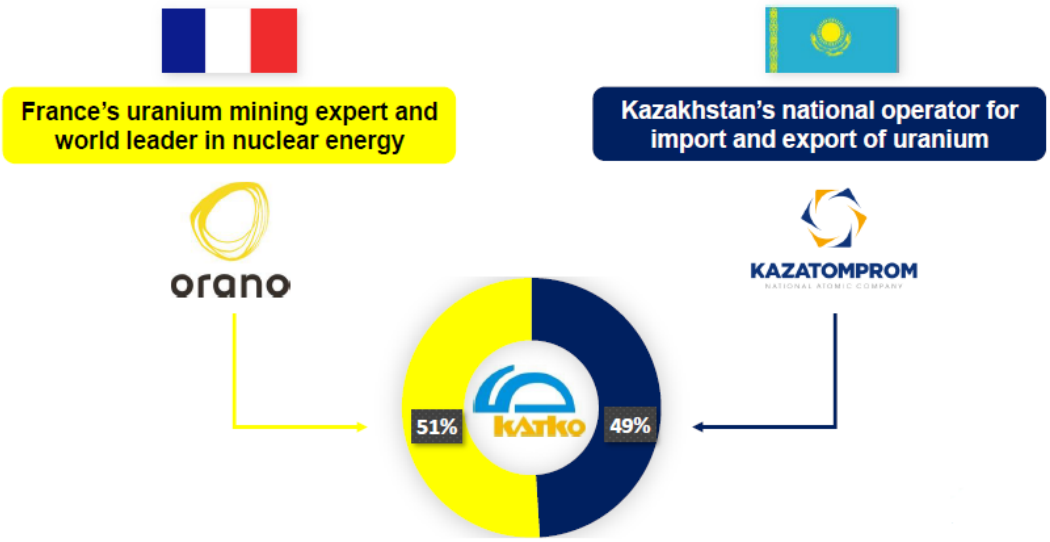

Figure 1. Ownership percentage of KATCO (Corporate social responsibility report, 2016, KATCO)

ORANO transforms nuclear materials so that they can be used to support the development of society, first and foremost in the field of energy. The group offers products, technologies and services with high added value throughout the entire nuclear fuel cycle, with activities encompassing mining, uranium chemistry, enrichment, fuel recycling, logistics, dismantling and engineering. As the first link in the nuclear fuel cycle, AREVA's mining activities prospect for, produce and sell uranium worldwide. The group is one of the world's leading uranium producers and operates mines in Canada, Kazakhstan and Niger. Because it adopts a responsible approach to mining, ORANO performs its extractive operations in a manner that respects both people and the environment. The group also supports sustainable economic development in the regions where it operates.

Kazatomprom is the national nuclear operator of Kazakhstan and is fully owned by the Samruk-Kazyna sovereign wealth fund. Kazatomprom is strategically focused on maintaining key positions in the world nuclear power market, diversifying its activity into the front end of the nuclear fuel cycle, participating in the development of foreign assets and moving into allied high-technology fields. Today, it is the largest uranium producer in the world, accounting for 21% of global output. KATCO is managed by a 10-member Committee of Directors (CODIR) and a "Supervisory Board", which has seven members: four representatives from ORANO and three from Kazatomprom. The partnership follows its compliance policy.

KATCO's primary objective is to explore and develop the Tortkuduk North, Tortkuduk South and Muyunkum South uranium fields in South Kazakhstan to produce and sell uranium oxide (U3O8).

After signing a Subsoil Use Contract in 1999, which initiated the exploration, development and production of uranium resources from the Muyunkum deposits, KATCO began building a pilot ISR mine and uranium processing plant. Once it was complete, in 2004, the Company embarked on the full industrial development of its mining and processing activities. In 2006, the Muyunkum South processing plant went into full operation. In 2007, the processing complex at Tortkuduk was commissioned.

Following a 2008 agreement between AREVA and Kazatomprom to increase uranium production, KATCO became the world's largest ISR mining operator. In 2009, its annual output exceeded 3,000 tons. In 2010, the "Fast Track" project was initiated to accelerate the development of the Tortkuduk processing complex. In 2013, annual output reached 4,000 tons. Since then, it has exceeded that level for four years in a row.

In April 2016, KATCO produced its 30,000th ton of uranium and accounted for around 7% of annual global output.

In 2014 and 2015, the Business Quarterly magazine ranked KATCO 48th among the 500 largest companies in Kazakhstan.In 2015, it was the 26th largest taxpayer and the number one tax contributor among uranium miners in the country.

Of the workforce of 1,266 employees at the end of 2016, more than 51% come from the Sozak district, where KATCO's mining sites are located. More than 98% of employees are Kazakh nationals: over 70% are from South Kazakhstan, 17% from Almaty and 11% from other regions of the country. Less than 1.5% of employees are expatriates, primarily French nationals.

KATCO manages its talent pipeline by developing partnerships between Kazakhstan's technical schools and universities and higher education institutions in France, as well as internally through ORANO's corporate university program [1].

LITERATURE REVIEW

Study of lithology in wells with core was done by geologists and by geophysics of geophysical stations Kobra and Geovista as well.

Figure 2. Geophysical logging station mark Geovista

In 2017, statistics were made to determine the permeability of thin intervals made by geophysical complex of logging mark Kobra. The work was carried out by Chingiz IRKITBAYEV - Expert of reserves and geological control.

Statistics were made by 859 exploratory wells with coring. The analysis was carried out to study the behavior of resistivity in thin impermeable intervals. This analysis included statistics on the average value of high and low values of resistivity.

Delta was defined and the average delta was calculated for each thickness. Then, data for statistics were collected and the correlation between the delta and thickness (0.2-1m) was determined for each interval. And a mathematical function was selected for it.

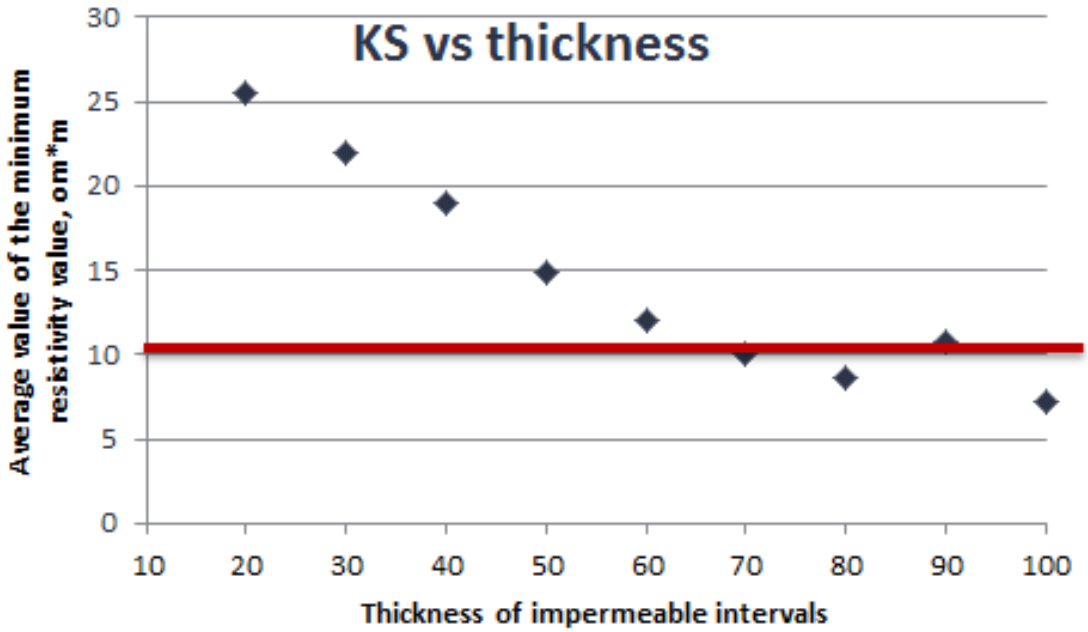

Figure 3.The ratio of the average value of the minimum resistivity value of KS and the thickness of impermeable rocks.

On the figure, the threshold 10 Om*m which is used to determine impermeable intervals, according to the core material can be used only for intervals of 70cm and above.

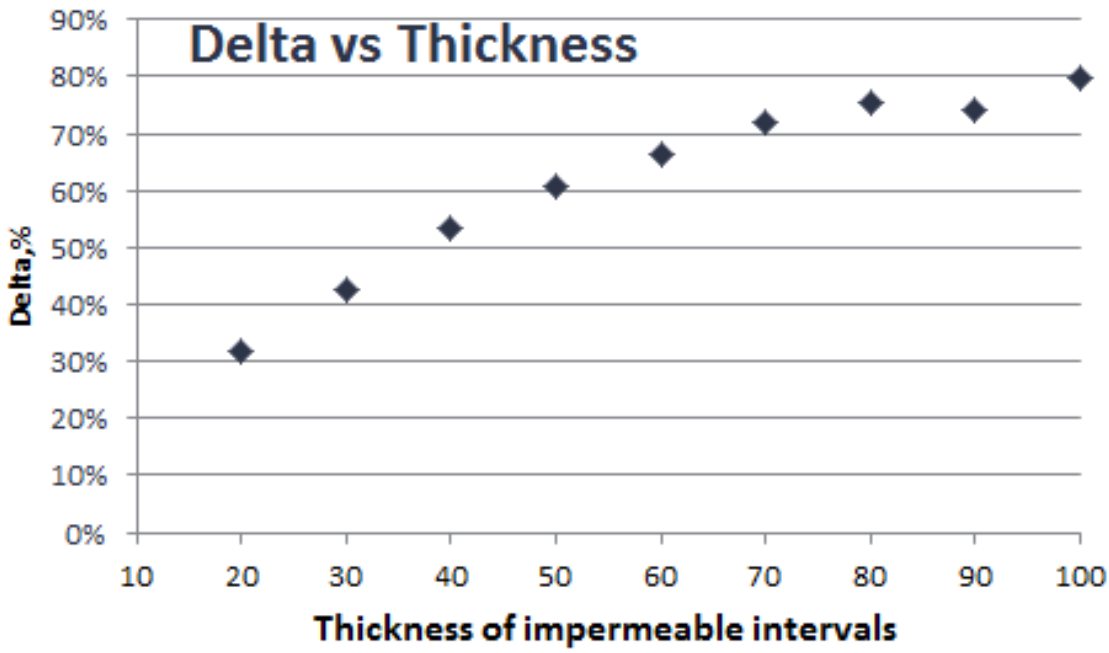

Figure 4. The ratio of the delta,% and the thickness of impermeable rocks.

As shown in the Figure 4, for impermeable intervals from 20 to 60 cm, you can navigate the delta, i.e. how quickly the KS falls in the interval.

As a result, all these data analysis helps geologists of KATCO in interpreting the lithology for destructive wells (exploratory and technological wells). [5]

1. GENERAL INFORMATION ABOUT TORTKUDUK DEPOSIT

1.1 Summary

Pilot production at KATCO began with 100 t of uranium capacity used to confirm the technical and economic feasibility of the industrial operation. In April 2004, AREVA and KAZATOMPROM agreed to launch the industrial KATCO operation. A satellite production site was built at Muyunkum South and the main processing plant, with a production capacity of 3,000 metric tons of uranium oxide per year, was constructed at Tortkuduk. The first industrial production tests began on March 30th, 2007.

1.2 Location

The Tortkuduk project is located in Suzak district, Southern Kazakhstan province, in the Republic of Kazakhstan (Figure 5). The Republic of Kazakhstan borders with Russia in the north, and China, Kirghizstan, Uzbekistan and Turkmenistan in the south. The Tortkuduk section is located 650 km west from Almaty, 330 km north from the province administrative center Chimkent, and 85 km north from the district administrative center of Chulakkurgan. The operation area is accessible by road. The main processing plant is located at Tortkuduk and a satellite plant is located at Muyunkum South. The two plants have a combined capacity of 6,000 m^3/h and include ion exchange resinadsorption columns. In addition to the front end circuits (i.e. ion exchange and elution circuits) the Tortkuduk processing plant includes back end circuits, where the eluate is purified and uranium is precipitated and conditioned for shipment. There is no back end circuit at Muyunkum. The satellite plant produces an eluate solution which is taken to the Tortkuduk plant for further purification and uranium precipitation. [4]

Figure 5. General Location Map

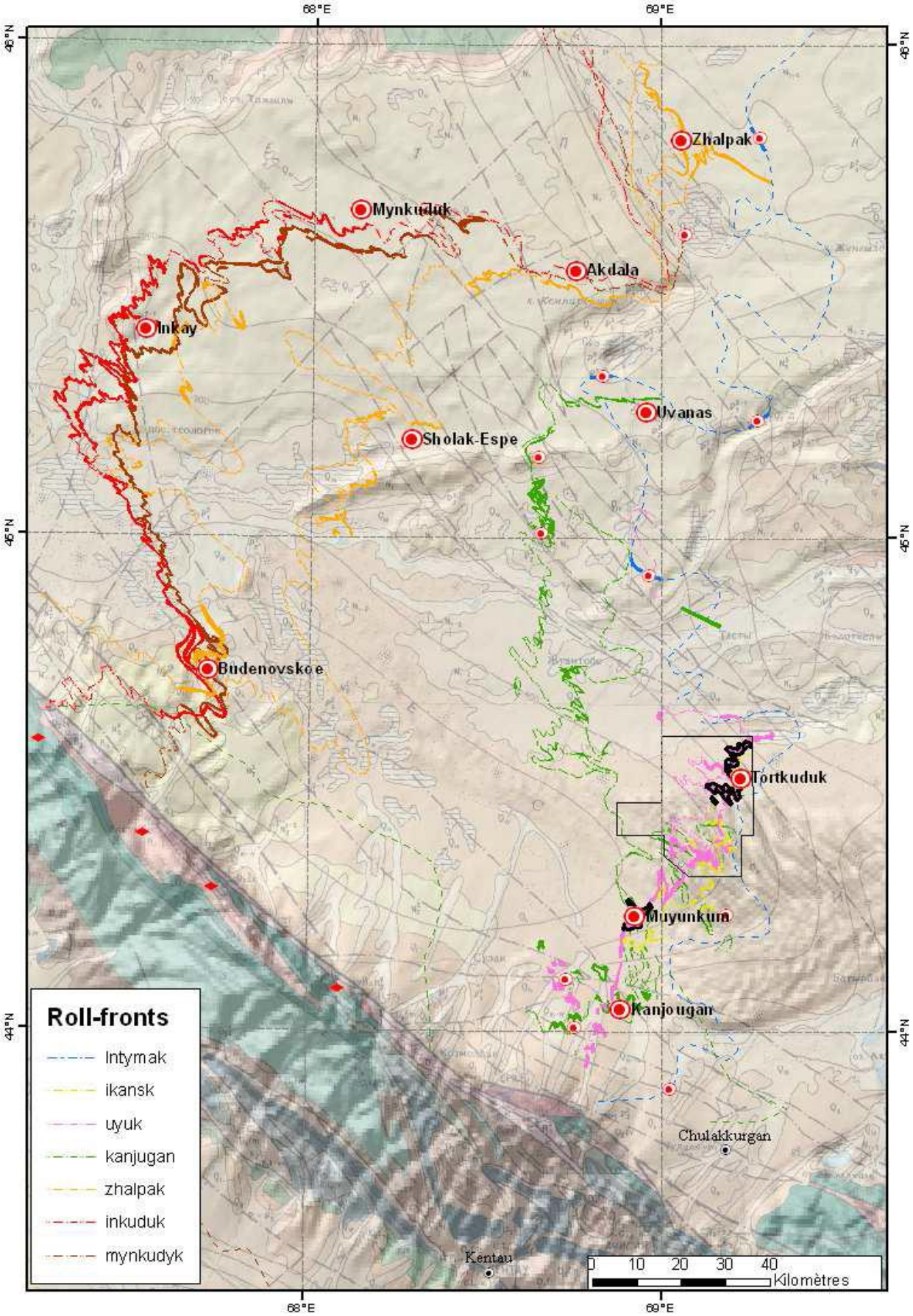

Figure 6. Geological map of the Shu-Saryssu basin

1.3 Geology

The Tortkuduk deposit belongs to the Mesozoic-Cenozoic Shu-Saryssu basin. The Shu-Saryssu basin is 800 km long, and up to 250 km wide, limited by the Karatau Mountains to the south and Chuskoa uplift to the north.

Uranium deposits in the region are located within Cretaceous-Paleogene permeable sandy formations, within a 200 to 500 meters thick artesian multi-layered aquifer complex. This aquifer is confined between a thick impermeable cover of upper Eocene to Miocene formations and low permeability Paleozoic formations. The Tortkuduk uranium deposit is a roll front type deposit. Roll front deposits are characterized by epigenetic uranium mineralization at an oxidation-reduction (redox) interface within a permeable sandstone formation.

The Mesozoic-Cenozoic formations in the Tortkuduk area range from upper Cretaceous to Quaternary sediments. The upper Cretaceous formations are directly overlying the folded Permian red sandstones formations at a depth ranging from 550m in the south of Tortkuduk to 350m depth in the north. The upper Cretaceous sedimentary rocks are composed of sandstone with gravels and pebbles and interbedded layers of conglomerates, clays and siltstones. The thickness of the upper Cretaceous sediments is approximately 110-120 m.

Overlying Palaeogene strata are divided into three horizons, from oldest to youngest: the Kanjugan horizon (Palaeocene), the Uyuk-Ikansk horizon (Lower-Middle Eocene), the Intymak horizon (Middle Eocene). Palynological data constrain more precisely the age range for these three horizons from Thanetian to lower Lutetian.

The Kanjugan is the oldest and deepest front system. It is made of marine coastal delta type sediments. The inferior zone (productive zone) is formed of sandy delta sediments as the superior part is mainly made up of clays and silts. The productive zone is 10-15m thick in average but can be up to 30 m in some regions and has a horizontal extension of 4-5km. [6]

The Kanjugan horizon is mainly composed of a 50-70m thick accumulation of clays deposited in floodplain environment, interbedded with isolated sand channels. In the area of the Tortkuduk deposit, the Kanjugan sand bodies are commonly completely oxidized. No significant uranium mineralization has been identified to date in the Kanjugan horizon. The Uyuk – Kanjugan contact is erosive.

The Uyuk formation is composed of shallow marine and deltaic sediments. It can be divided into 2 main horizons: the productive horizon (inferior sandy horizon) and the impermeable horizon. The base of the Uyuk is erosive. The inferior zone is made of sands, in which can be found lenses of clay, and silt. These can represent up to 10% of the horizon in some parts. The transition to the impermeable superior zone is irregular. The productive zone is 10-30m thick. [6]

The Ikansk formation is similar to the Uyuk in terms of composition and structure. This formation is beveled and disappears almost completely towards the North. The inferior unit is made of submarine type delta sediments, defined by fine to medium grain sands. The superior unit is described as a coastal deltaic with poorly sorted sands and gravels. Intervals of clay, silt and organic matter are frequent.

These two horizons are separated by an impermeable dark clay layer of 0.5 to 5m in thickness.Sands formations make up 60% of the Ikansk. The max thickness can attain 55-60 m but only represents a few meters in thickness in Tortkuduk. [6]

Uranium mineralization in the Tortkuduk deposit is located in the Uyuk-Ikansk formation. The Uyuk horizon consists of a widespread 20-40m thick sand layer, composed of sand channel accumulations in a coastal environment. The sedimentary rocks are composed of well-sorted medium grain sandstones, rich in organic matter fragments.

The sedimentary rocks of the Ikansk horizon are composed of inequigranular sandstone with abundant interbedded layers of siltstones and clays. The Uyuk and Ikansk

formations are separated in the south of the Tortkuduk deposit by a 2-5m clay layer. In the north of the deposit, Uyuk and Ikansk sandstones are generally connected.

The Intymak formation covers the Ikansk series with transgressive marine marls (superior Eocene). The base of the Intymak in erosive and the inferior part is rich is phosphate. The basal part of the Intymak is composed of polygenic sands, gravels, and clays. Lots of fossil debris, such a gastropods, shark teeth, and fish remains can be found. [6]

The Intymak formation is composed of 30-60m thick marine green clays and marl, including 2-4 m thick green sandstone and phosphated gravels at the base of the formation. The base of these marine clays represents a Maximum Flooding Surface at regional scale and is used as reference level for stratigraphic correlations and deformations mapping (Figure 7).

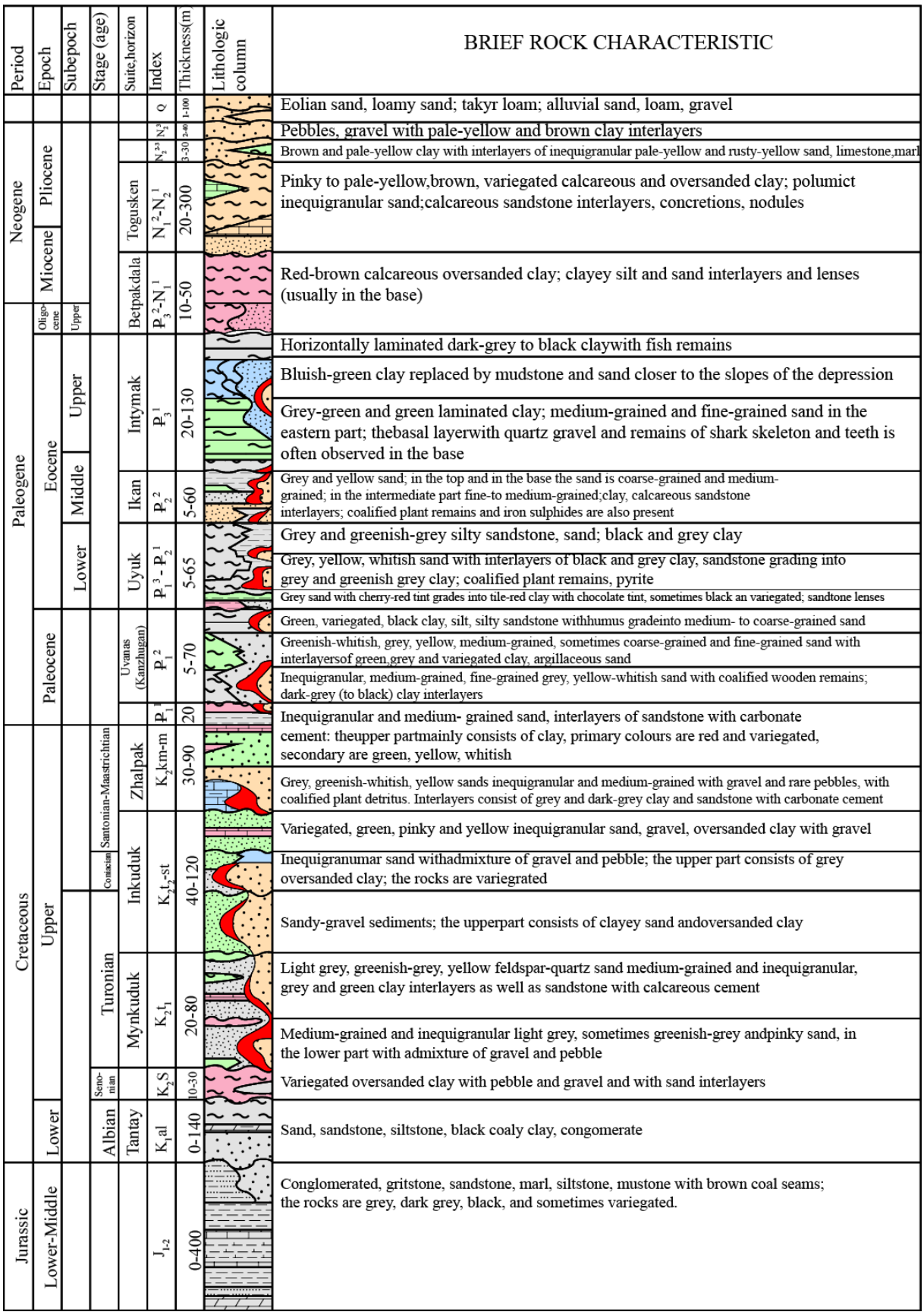

Figure 7. Stratigraphy of the Chu Saryssu basin in Tortkuduk/Muyunkum deposit (modified from [6])

1.4 Mining

The Tortkuduk uranium deposit is a roll front type deposit. Roll front deposits are characterized by epigenetic uranium mineralization at a redox interface within a permeable sandstone formation. Uranium is transported by oxidized groundwater within confined aquifers and is precipitated where the fluid encounters a reduced environment, forming typically a crescent-shaped ore body that crosscuts the sandstone bedding. An active roll front deposit slowly migrates in the aquifer following the hydraulic gradient due to the oxidation of reduced sandstones. The thickness of a roll front generally ranges from 3 to 15 m.

Pathfinder elements include V, Mo, Se, locally Cu, and Ag. Some vanadium deposits are intimately associated with roll front uranium deposits.

Favorable factors for ore deposition include:

- Low dip of sandstone formations;
- Lateral variations of permeability within sandstone formations;
- Abundance of organic matter and/or sulphides (pyrite, marcasite).

1.5 Uranium mineralization

The Tortkuduk area is characterized by a complex-shaped double roll front within the Uyuk-Ikansk undivided formation (Figure 8). The “nose” of the roll is almost 20m thick and flanks are up to several meters thick. Mineralization continuity can be observed on the km scale. Sectioned, the mineralization is crescent- shaped with nose along the reduced area and wings in the oxidation area.

An important feature of uranium-mineralized bodies is changes in the proportion of uranium and radium throughout these bodies. Uranium dominates in the nose parts and decreases in the wings, and radium dominates in the residual bodies and forms radium halos (which are shown as anomalies despite containing no uranium by gamma-ray logging results). Uranium and radium correlation is described by the radioactive equilibrium factor (“REF”). [2]

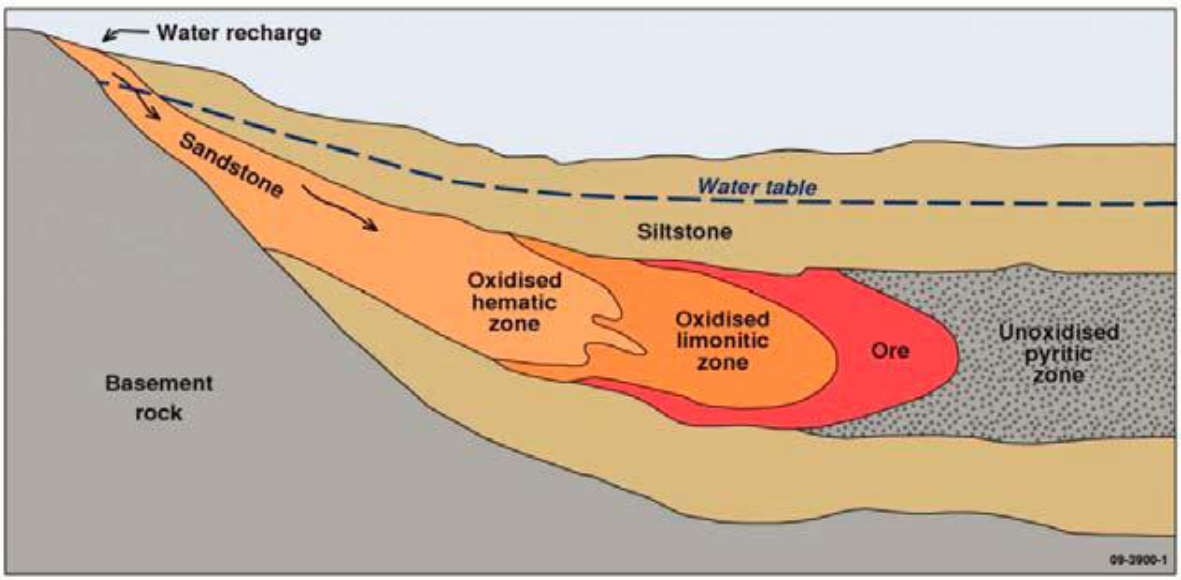

Figure 8. Roll-front schematic cross-section

Mineralization comprises mainly coffinite, more rarely coaly-coffinite, coaly-sulphide-coffinite and very rarely pitchblende-coffinite. The Tortkuduk area is characterized by a relatively low ratio of coffinite to pitchblende (35% coffinite and 65% pitchblende).

Uranium minerals are commonly associated with pyrite.The clayey-siltstone part of the sandstone contains up to 50-70% of the uranium mineralization.

Most of the time, the high grades are associated with the nose.The wings are more or less present. The roll front is ribbon-shaped bordering the reduction front. [3]

1.6 In-Situ Recovery process

Mining at Tortkuduk is based on the In-Situ Recovery (ISR) process. The permeability and confinement of the Uyuk aquifer at Tortkuduk is favourable to ISR extraction. In addition, the ore grade, the deposit depth and the geotechnical parameters of upper formations preclude from open pit or underground mining economically.

The uranium ISR process at Tortkuduk starts with the injection of a solution of sulphuric acid and water into the deposits through injection wells. The acidic solution creates a chemical environment that dissolves sandstone-hosted uranium. Uranium-rich pregnant solutions are pumped to surface through production wells and are transferred to settling ponds and a processing plant through pipe lines (Figure 9). The solutions are further processed in the plant in order to extract uranium. The treated solutions are recycled by re-injection in the well field, following an acid concentration re-adjustment. [7]

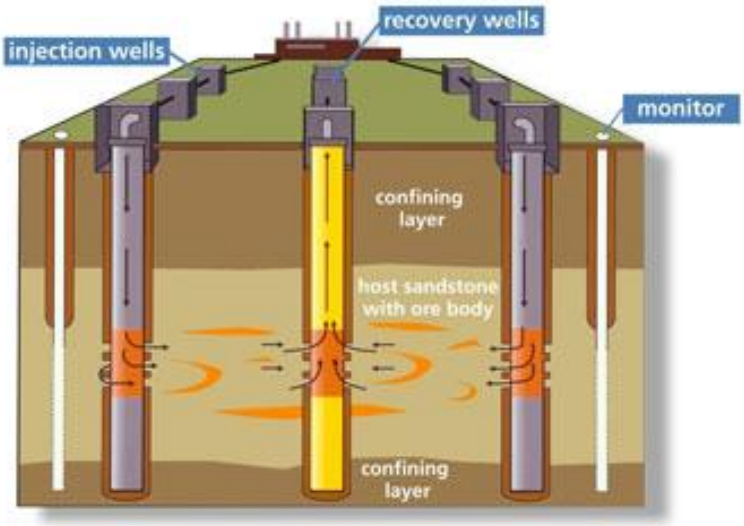

Figure 9. In-situ leaching process

Advantages of in-situ leaching: include minimal environmental impacts, protects water, land and wildlife. The industry has exceptional worker safety and in-situ leaching (allows for) a very economical recovery of low grade uranium. Thus, the ISL method is the environmentally safest method among all known mining methods.

Disadvantages:

- Permeability problems:
- If ore body is impermeable it must be cracked by explosions
- Precipitation of secondary minerals might cause permeability problems
- The leaching liquid may stream downwards without percolating the ore body entirely
- Risk of contamination of ground water (compare acid rock generation) because of poor solution control.

1.7 Structural model

Several models have been interpreted for the formation of this sedimentary basin. Russian geologists first interpreted the Chu Saryssu basin as a dissymmetric graben with the Karatau horst separating it from the Syr Daria basin. This interpretation would include a normal faulting system on the eastern border of the Karatau with a vertical movement of over a kilometer (Figure 10). The India-Asia collision, which began in the Oligocene, was then responsible for the N-S compressive system that affects the foreland basins like the Chu Syrasu.

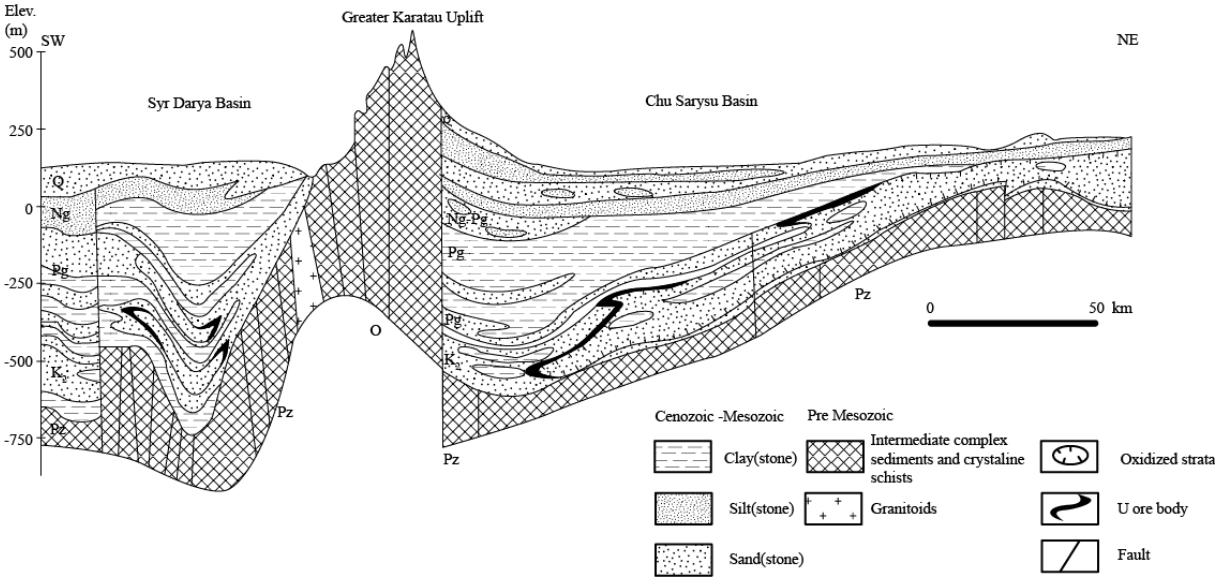

Figure 10. Cross-section through the Chu Saryssu basin (Modified from Petrov et al., 1995)

2 WORKING METHODOLOGY

2.1 Study of thin impermeable intervals.

From 2005 to 2009, KATCO performed 8500 logging with the Geovista station for destructive technology wells. Then, starting in 2010, the company switched to another mark, the Kobra geophysical complex, to perform logging for Phase1. Now, Katco is faced with the fact that they will have to recalculate the reserves to build 3D models and 2D interpretation. Due to the lack of core data, the interpretation of lithology is performed by apparent resistivity. Since KATCO engineers are used to working with the Kobra station, the Geovista interpretation is difficult at the moment.

To understand how to perform the correct interpretation with the Geovista station, it was suggested to collect statistics of the behavior of the RLLD in impermeable intervals: clays, siltstones and etc. In the analysis, the attention was paid to lithological types of rocks and thickness of impermeable intervals.

As it is known, resistivity always falls in impermeable intervals and the higher the starting resistivity value and the more thickness of impermeable interval, there will be the more difference between the start (high resistivity value) and the end (low resistivity value) of impermeable interval.

The final outcome was to study this regularity and develop function of dependence resistivity change (delta) and thickness of impermeable intervals.

22 historical wells with core were used for analysis, where the logging was carried out with Geovista station. Only 18 wells were taken from them, as in 4 wells the probe was not calibrated and as a result these wells did not correspond to the test. Also, during the internship new 12 core wells were drilled and logging was made with Geovista station.

So, in total, there were 30 wells, which were, first of all, checked for correctness of all interpretation was checked.

Secondly, the interval of impermeable rocks was determined.

Thin impermeable intervals from 0.2 to 1.2m thickness were considered in the study out of 30 available drill holes.

Third, for each impermeable interval where core material was available, the behavior of the resistivity signal was determined. Statistics was collected for the high and low resistivity values (Om*m) for each impermeable interval.

Fourth, all impermeable intervals were divided by its thickness and an average low and high resistivity was calculated. An example of finding a low and high resistivity value for an impermeable interval is presented in Figure 11.

Fifth, an analysis was done when all data was compiled in one table. A graph of correlation between the average low resistivity value and the impermeable interval thickness was built. Using the graph, we identified a threshold for impermeable rocks that were made by the Geovista station. The threshold for impermeable intervals, with thickness equal or greater than 0.5m., was 8 Om*m.

According to the graph based on core data, all intervals where the low resistivity signal is equal or lower than 8 Om*m can be regarded as impermeable intervals. This can help to make decision on destructive drill holes where there is no any core data (Figure *15*).

Therefore, it makes difficult to interpret thin impermeable intervals.

Sixth, the only one tip that can help to make good decision on lithology interpretation is calculation of delta between high and low resistivity values. This can be applied on the function determined for relationship between delta and impermeable thickness (Figure 16).

Seventh, we transferred the delta to percentage. Delta was transferred to percentage, because it is convenient to use to avoid problems when we have uncalibrated logging. Table 1 shows the results of delta and delta percentage.

And at the end after the delta calculation, we built the graph of the ratio between thickness and RLLD delta, %.

A table with the following fields was drawn up with the following fields.

- Thickness
- RLLD value for Intymak2;
- The average high RLLD for each interval
- The average low RLLD for each interval
- Delta value;
- Delta as a percentage.

Table 1.The results of the resistivity and calculation of the delta.

Thickness, m	Intymak2, RLLD	HighRLLDvalue	LowRLLDvalue	Delta	Delta, %
0.2	4.4	18.3	14.3	4	21
0.3	4.4	29	14.8	14.2	31.5
0.4	4.3	29.4	12.8	16.5	47.6
0.5	4.7	13.9	7.3	6.6	47.5
0.7	3.9	13.8	5.6	8.2	58.9
0.8	2.8	11.5	7.2	4.3	37.3
0.9	4.5	17.8	7.7	10.1	50.7
1.2	3.8	16.2	4.8	11.4	70.3

According the results, graphs were drawn up:

- the ratio of the minimum value of RLLD and the thickness of impermeable rocks (*Figure 15*);
- the ratio of the delta(%) and the thickness of impermeable rocks (*Figure 16*).

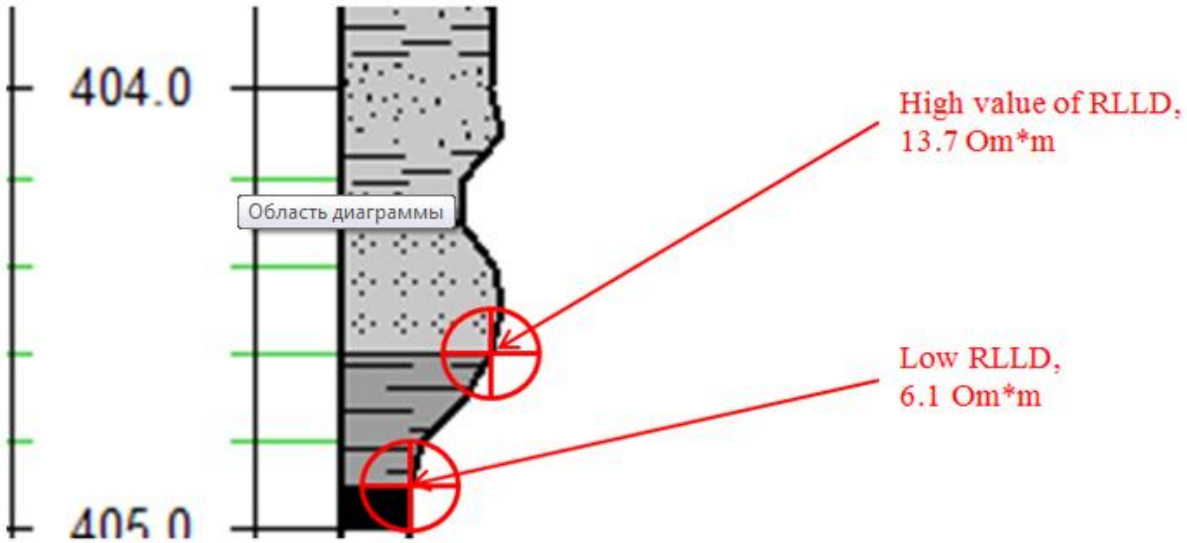

Figure 11. Example of define high and low resistivity.

2.3 The study of peak Intymak1.

This project was based on the study of the peak Intymak1. This peak is available in all wells. This can be seen in the figure 14. There was an assumption that this peak could be a threshold for determining impermeable intervals. In the logging data where the decline of the resistivity begins sharply it can be used as a boundary of the definition of impermeable intervals. And this regularity would be used for destructive wells to determine the permeability. This regularity was discovered by geologists, but it was not tested on the basis of permeability analysis.

This project was based on the study of this regularity and in this project we proved statistically that this theory is correct.

The analysis was carried out with core wells. The peaks of 697 wells were studied at this project.

At first, the resistivity data was taken by each of all 697 wells and checked for correct interpretation.

Secondly, the peak was determined.

Thirdly, in the figures of logging data where the decline of the resistivity begins sharply we considered it as a boundary of the definition of impermeable interval. There are some examples of the peak in the Figure 12.

Fourth, using lithology, for statistics, we selected all the intervals that have crossed threshold.

Finally, we did statistics on these intervals. According to the project, if 75% or more of the interval that crossed the threshold is impermeable, this method will be used for destructive drill holes for both stations. In destructive wells, if the resistivity of intervals crosses this boundary when there is signal depletion, then we can say that this interval is impermeable.

A template for statistics built for each deposit and shown in the figures (Figure 17; Figure 18; Figure 19; Figure 20; Figure 21; Figure 22; Figure 23).

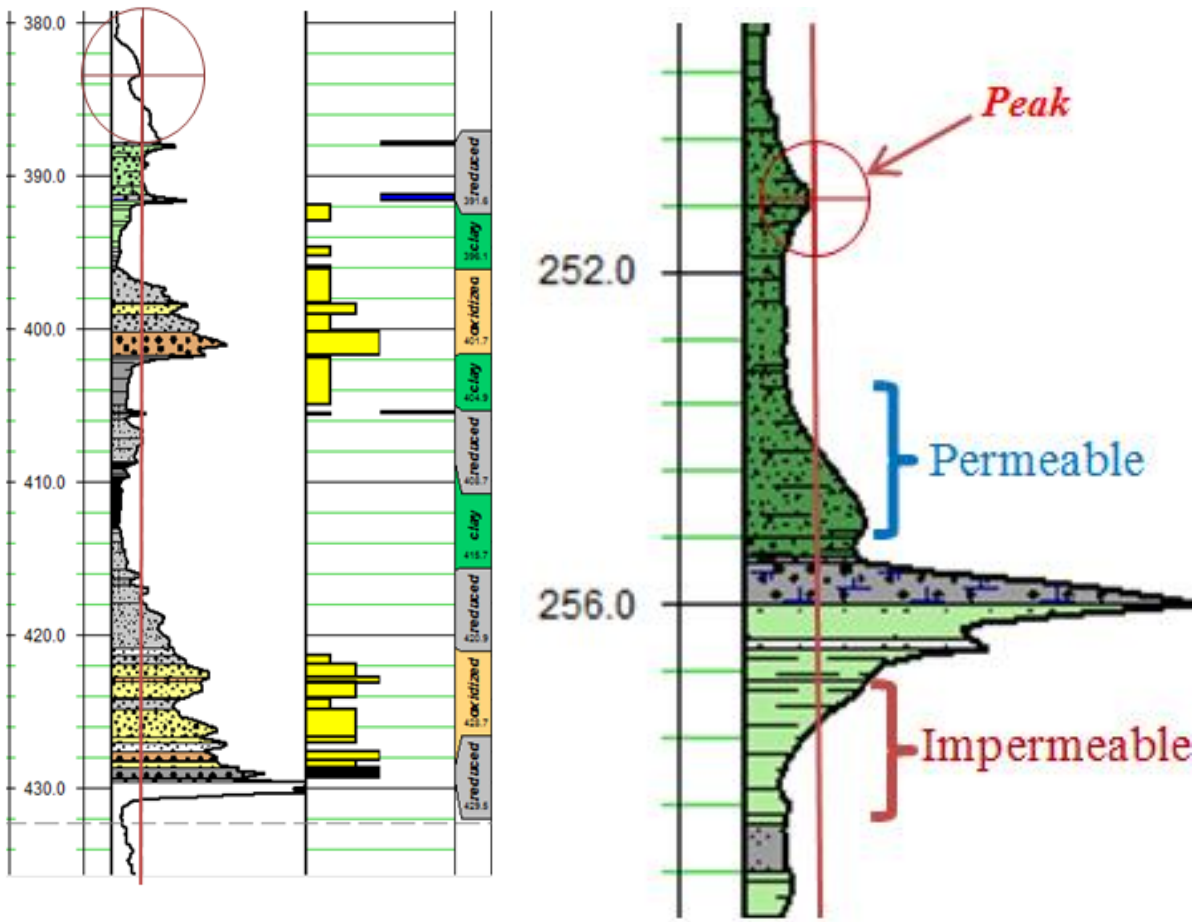

Figure 12. Examples of the definition of the Intymak1 threshold line for impermeable intervals.

The company KATCO, there are two productive areas. They are Tortkuduk and Muyunkum. There are 14 deposits in this 2 sections and the analysis was conducted on 7 deposits. The statistics were made for each deposit separately. Below is a table (Table 2) of deposits with the number of wells.

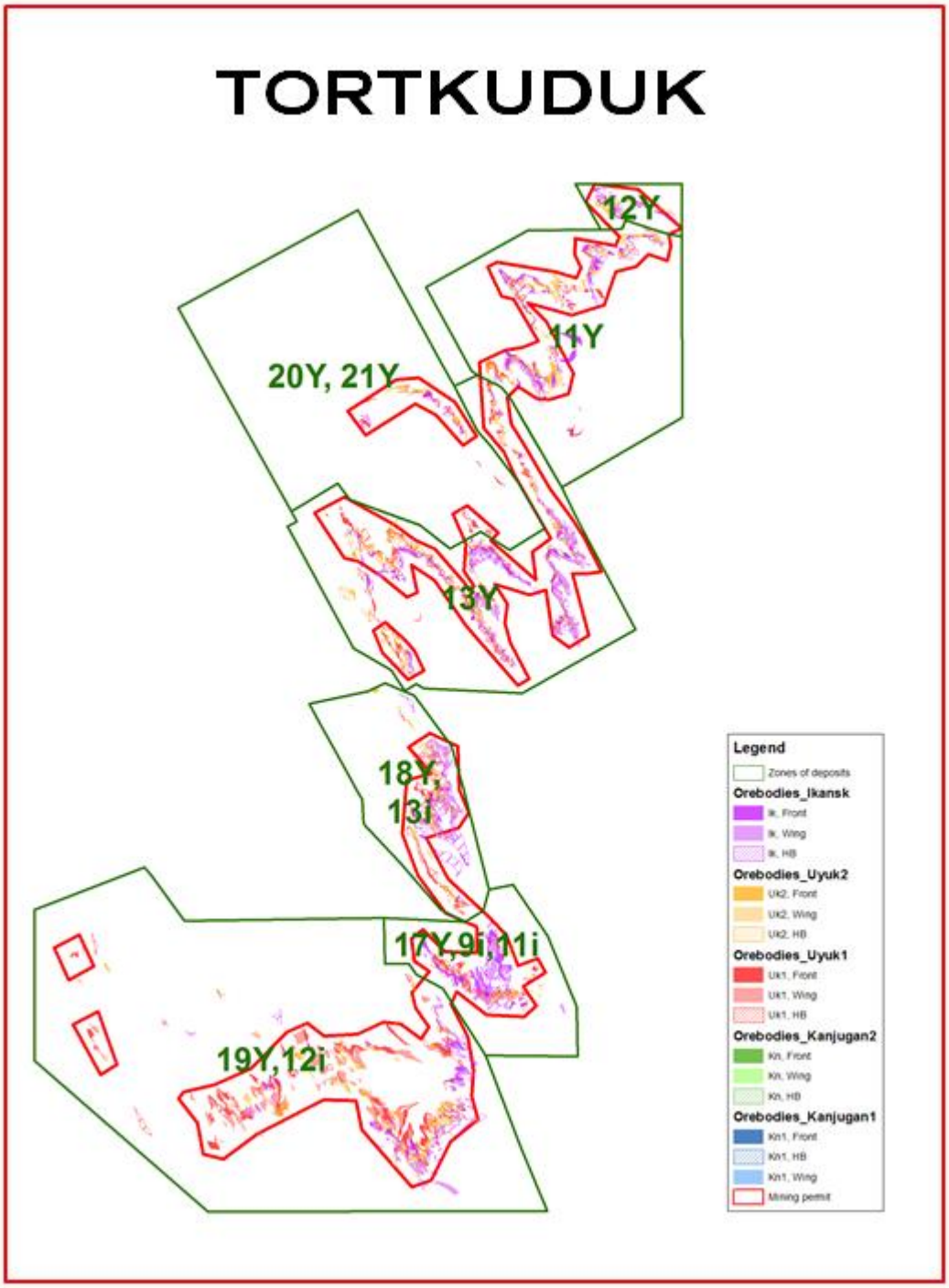

Figure 13.Map of Tortkuduk deposits.

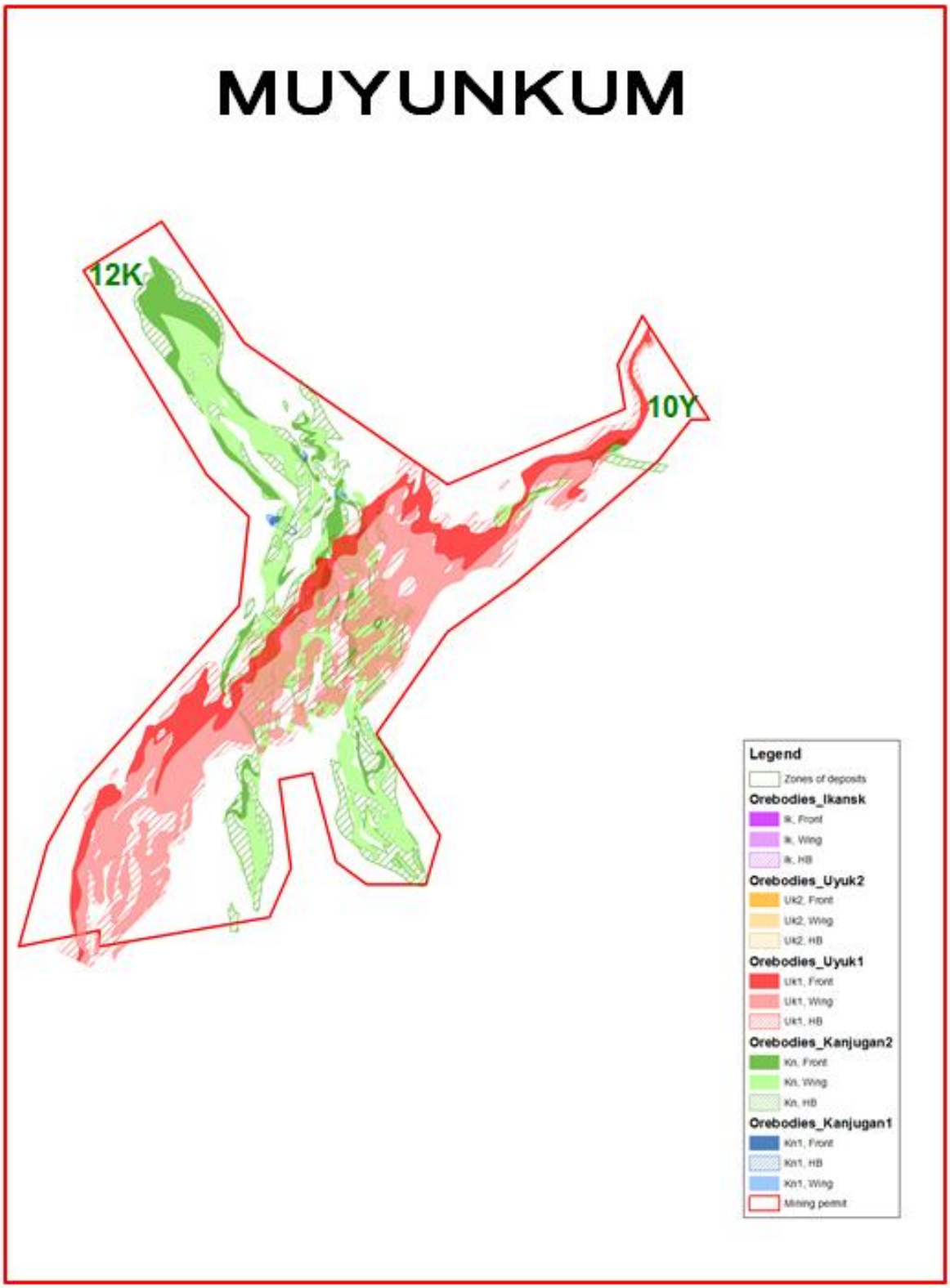

Figure 14.Map of Muyunkum deposits.

Table 2. Number of drill holes used for each deposit

Deposit name	Number of drill holes
12к	100
13y	100
19y	100
10y	100
18y	100
11y	99
17y	98

According to the results of analysis made on wells in 7 deposits, we found out that among intervals interpreted by geologists big percentage was impermeable and small percentage was permeable interval.

3. RESULTS OF PROJECT

3.1 Results study of thin impermeable intervals.

Based on the below statistics, we can say that 8 Om*m, this is the threshold of the resistivity value for impermeable intervals with the thickness of 50 cm and above. That is, all intervals with a lower resistivity value of less than 8 Om*m can be considered impermeable according to statistics.

But for intervals of impermeable rocks with the thickness of 0.4 m and below this threshold can't be used, as the resistivity does not have time to fall to the threshold of 8 Om*m and therefore these intervals are difficult to determine by the resistivity.

As a hint when interpreting without core wells, you can use a function from the graph (Figure 11), where delta of resistivity is the average difference between high and low resistivity values in %.

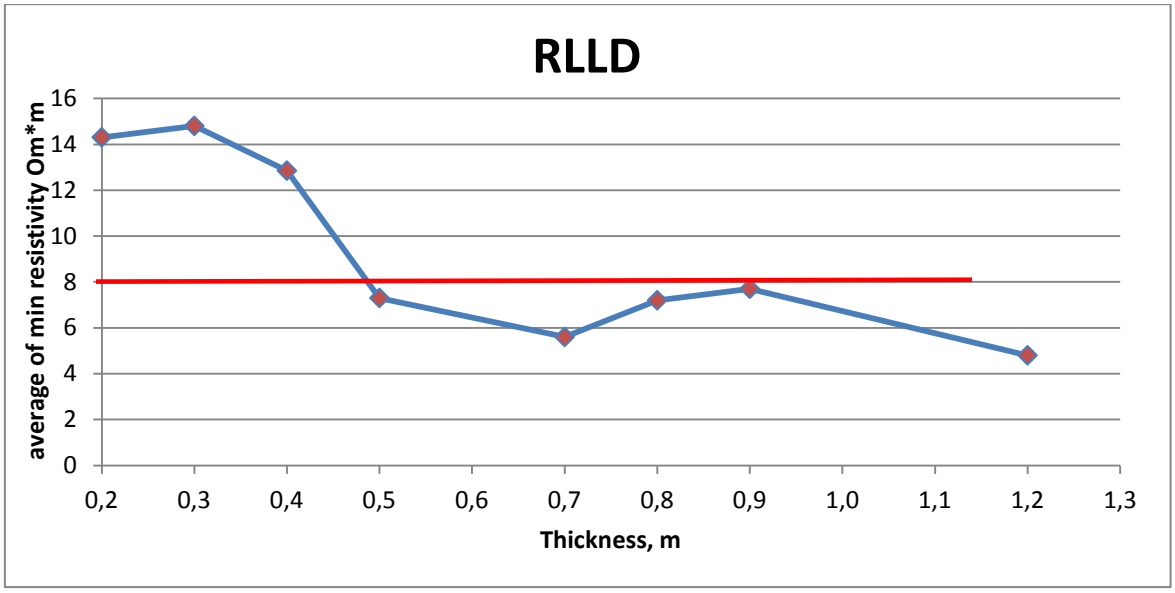

Figure 15.The ratio of the average value of the minimum resistivity value of RLLD and the thickness of impermeable rocks.

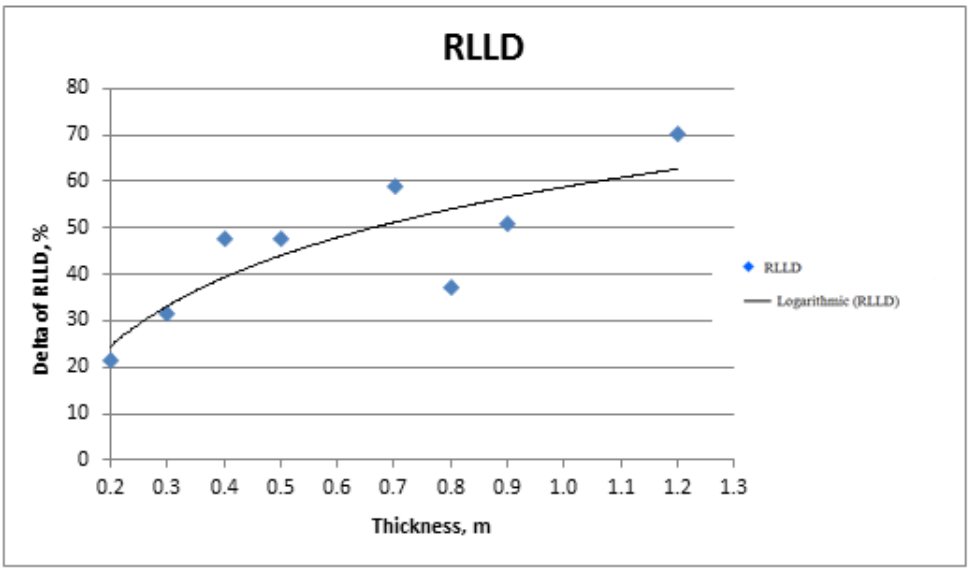

Figure 16. The ratio of the delta,% and the thickness of impermeable rocks.

According to the graph, you can see the trend, with the increase of impermeable intervals in the thickness, the delta increases.

As you see, for each thickness of impermeable rocks the delta value threshold varies:

- for 20 cm of impermeable rocks the delta value threshold is 21%;
- for 30 cm of impermeable rocks the delta value threshold is 31%;
- for 40 cm of impermeable rocks the delta value threshold is 49%;

An average delta was calculated for each thickness. If individual lithological interval delta of particular thickness is greater than experimental delta on the graph (Figure 16), these intervals can be considered as impermeable.

Due to the fact that there is little data in KATCO database, we see that the location of the points on the graphs does not form a smooth function. More data is needed to determine a more accurate curve.

Table 2 shows the average resistivity value for maximum and minimum values for different lithological classes.

Table 3.Average value of KS for grain size for maximum and minimum value.

Grain	Average high RLLD value	Average low RLLD value
course sand	26.1	22.3
course sand clay	22.6	16.8
find sand clay	18.1	14.2
fine sand	20.7	17.1
medium sand	21.6	17.3
mediumsandclay	19.2	16.2
silts	18.8	14.2
very fine sand	19.4	15.4
veryfinesandclay	16.9	15.0

3.2 Results the study of peak Intymak1

The analysis showed the good result and showed the minimum value – 75% of the impermeable intervals, that crossed this treshold. The results are shown in the figures below:

Deposit 12k:
Number of drillholes: 100
Average value of KS by Intimak1: 9,94Om*m

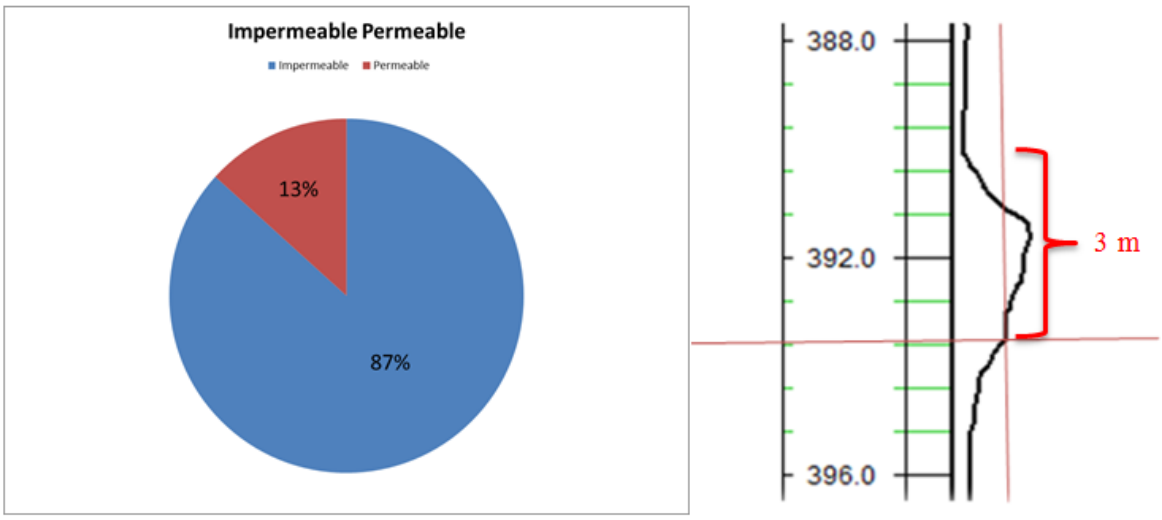

Figure 17. Statistics on permeability by deposit 12к.

The Figure 17 shows that of the 100% intervals that crossed the theshold 87% was impermeable and 13% was permeable interval.

Deposit 13y:
Number of drillholes: 100
Average value of KS by Intimak1: 8,66Om*m

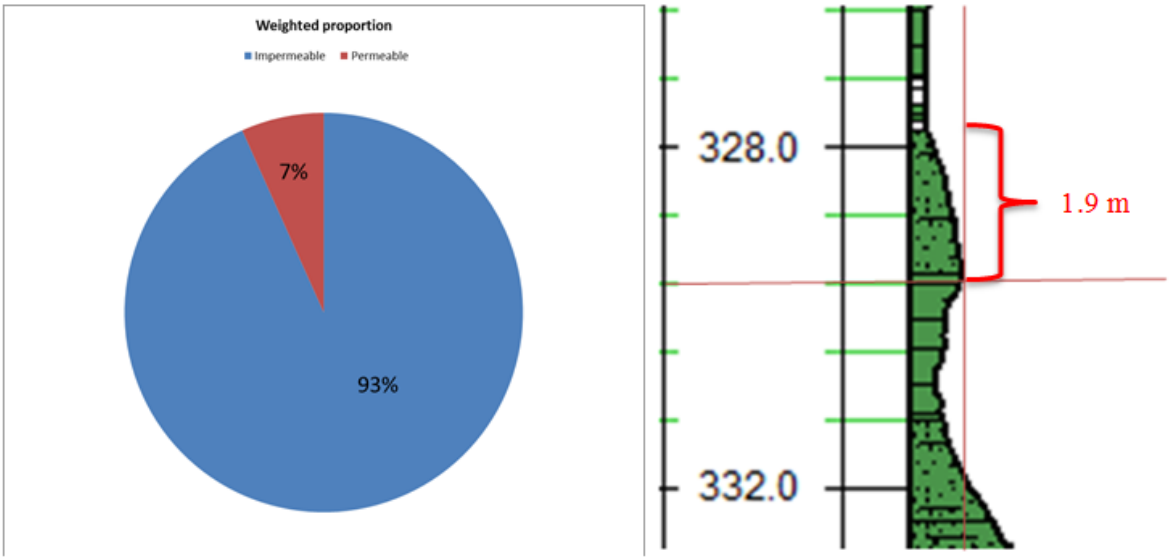

Figure 18. Statistics on permeability by deposit 13y.

The Figure 18 shows that of the 100% intervals that crossed the theshold 93% was impermeable and 7% was permeable interval.

Deposit 19y:
Number of drillholes: 100
Average value of KS by Intimak1: 6,07Om*m

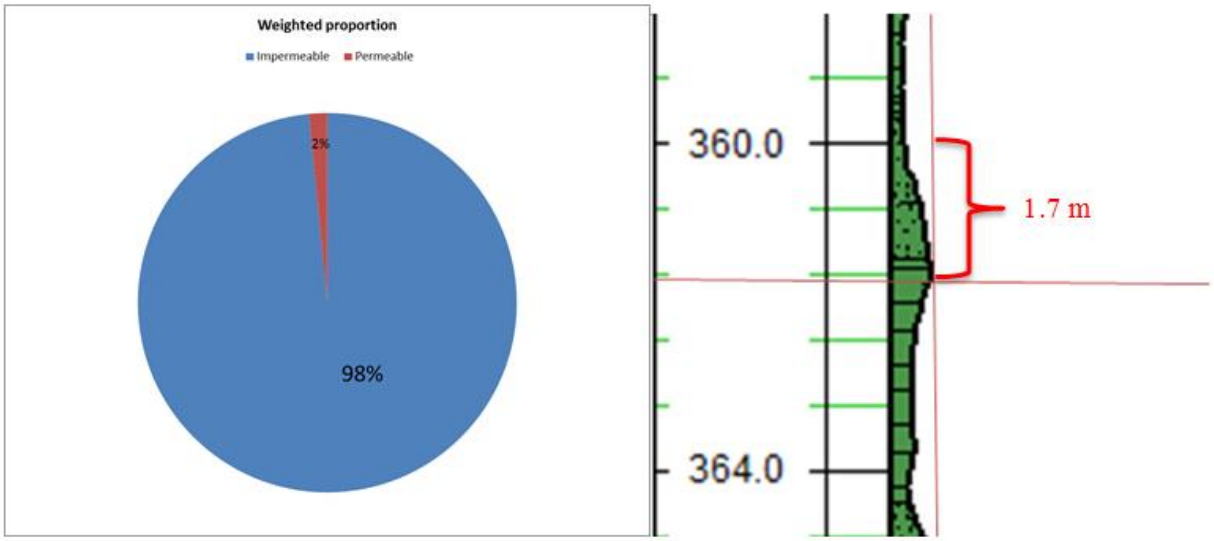

Figure 19. Statistics on permeability by deposit 19y.

The Figure 19 shows that of the 100% intervals that crossed the theshold 98% was impermeable and 2% was permeable interval.

Deposit 10y:
Number of drillholes: 100
Average value of KS by Intimak1: 10,5Om*m

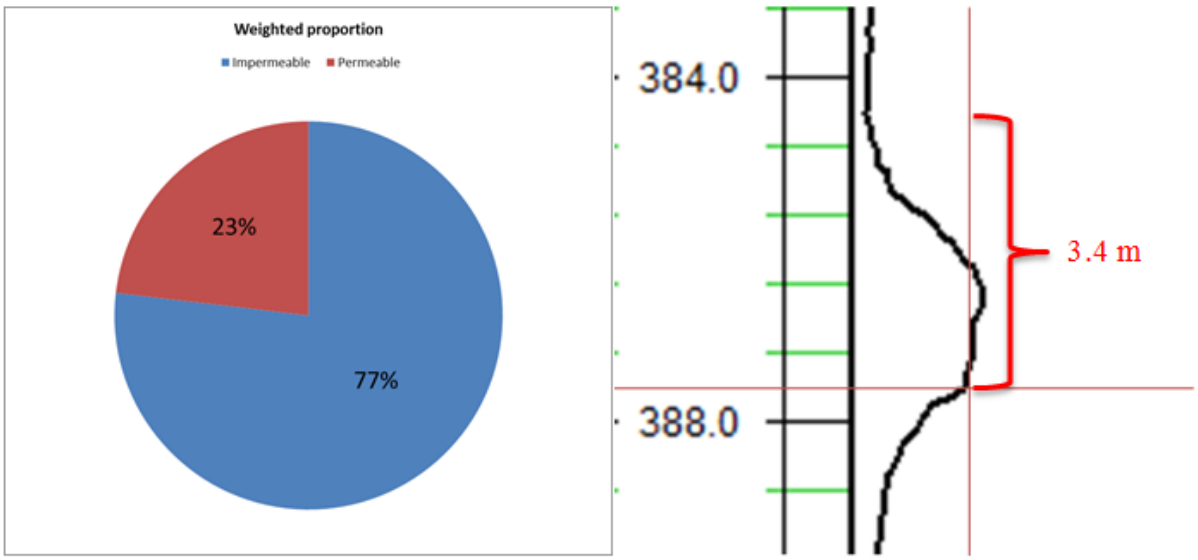

Figure 20. Statistics on permeability by deposit 10y.

The Figure 20 shows that of the 100% intervals that crossed the theshold 77% was impermeable and 23% was permeable interval.
Deposit 18y:
Number of drillholes: 100
Average value of KS by Intimak1: 8,47Om*m

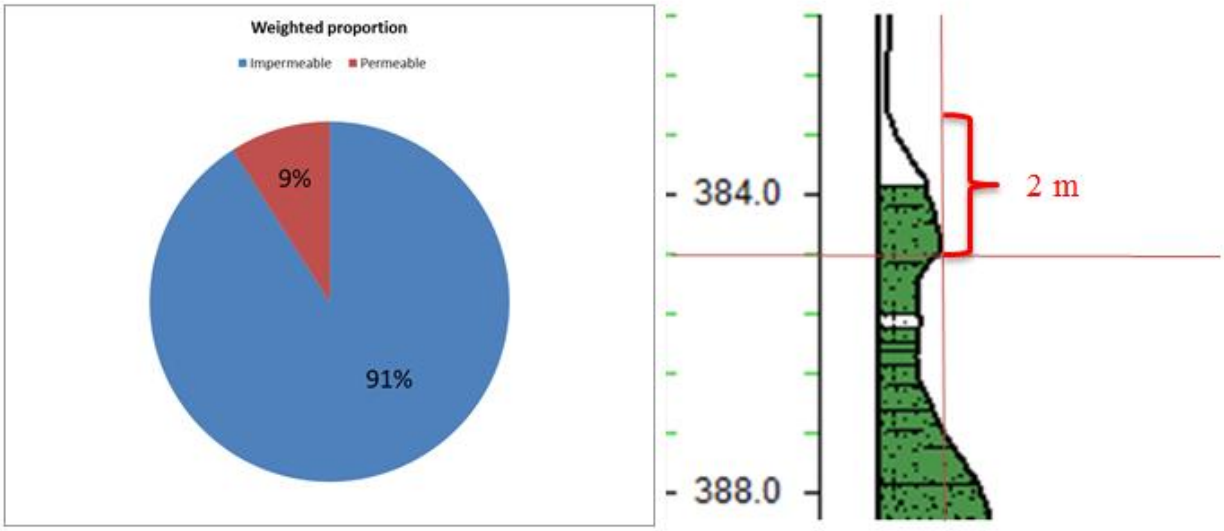

Figure 21. Statistics on permeability by deposit 18y.

The Figure 21 shows that of the 100% intervals that crossed the theshold 91% was impermeable and 9% was permeable interval.

Deposit 17y:
Number of drillholes: 98
Average value of KS by Intimak1: 10,67Om*m

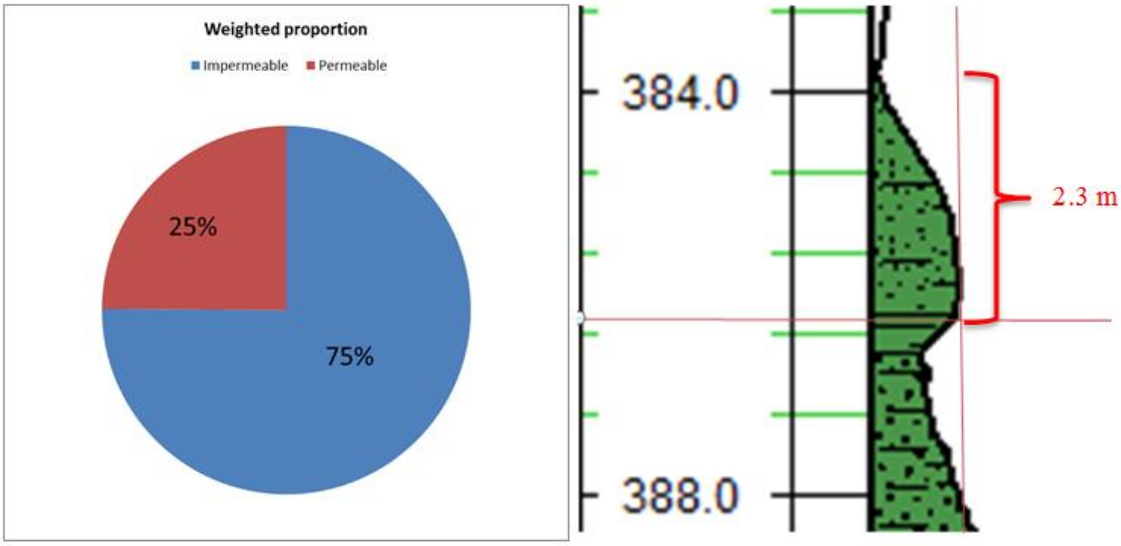

Figure 22. Statistics on permeability by deposit 17y.

The Figure 22 shows that of the 100% intervals that crossed the theshold 75% was impermeable and 25% was permeable interval.

Deposit 11y:
Number of drillholes: 99
Average value of KS by Intimak1: 9,17Om*m

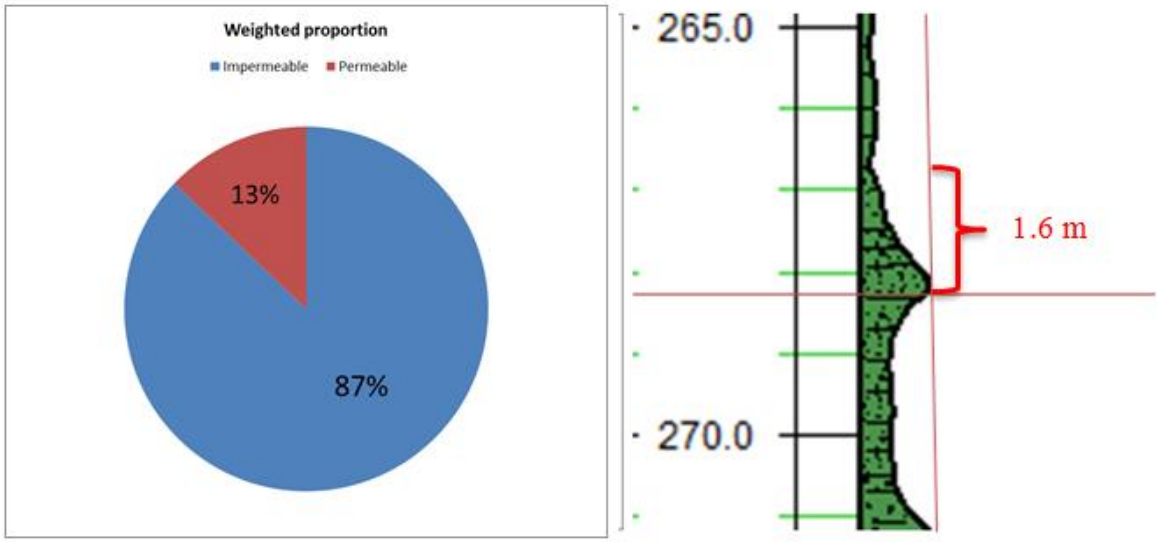

Figure 23. Statistics on permeability by deposit 11y.

The Figure 23 shows that of the 100% intervals that crossed the theshold 87% was impermeable and 13% was permeable interval. All seven diagrams prove our theory that it is possible to define impermeable and permeable intervals with this method in destructive wells.

Data for statistics were collected to find the peak position in Intymak1. You can use the average distance between the bottom of Intymak2 and peak of Intymak1. The analysis was carried out on seven deposits, for each separately. For statistics, 20 core wells were needed from each deposit. Below are deposits with average capacity. As we can see for each deposit there is an average distance for finding the peak. And we can use these distances as a standard for these below-represented deposits by definition of peak point.

Table 4.Proportion of permeable and impermeable intervals on deposits and the average distance between Intymak2 and the reference peak in Intymak1.

Deposit name	Proportion of permeable and impermeable intervals,%		Average distance between Int2 and reference peak in Int1.
17Y	75	25	2.3
19Y	98	2	1.7
10Y	77	23	3.4
18Y	91	9	2.0
11Y	87	13	1.6
13Y	93	7	1.9
12k	87	13	3.0

The table shows the average distance between Intymak2 and the main peak in Intymak1. Above, in the figures (Figure 17; Figure 18; Figure 19; Figure 20; Figure 21; Figure 22; Figure 23) shows examples of representative forms of resistivity curves for clay sand in Intymak1. To facilitate the search, the table shows the average distance from the sole of Intymak2 and the peak.

CONCLUSION

Using data of core interpretation and logging stations, two methods were developed to help interpret the data and these methods were tested for correctness.

The analysis showed that these methods could be used, firstly, to determine permeability of thin intervals in wells without core using the ratio of delta between the interval thicknesses. This statistic defined the behavior of KS logging in impermeable rocks and produced graphs that can be used to make a decision when interpreting thin impermeable intervals of destructive wells.

Secondly, the limit of permeability intervals was defined with the help of the peak which is at the beginning of the Intymak1 horizon. This technique is universal as it does not depend on the calibration of logging. The result of analysis is based on relative data and can be used on any logging.

In future, these methods help interpret the lithology of technological drill holes fast and qualitatively, therefore it can help to make sound decision.

And also, it is necessary to develop a tool that will perform an automatic interpretation of lithology according to the data of the logging in KATCO, as the interpretation of lithology is a very important stage in the assessment of the reserve. If to interpret the data manually, it will take a very long time, but with these tools you can save time.

It can be developed using machine learning or any other algorithms. The methods we have identified to interpret logging data can be used as functions in these algorithms for interpretation accuracy, because in case of an error, there may be an underestimation of reserves or a revaluation of reserves.

BIBLIOGRAPHIC REFERENCES

1. LLP JV KATCO, (2016). *Corporatesocial responsibility report*, KAZAKHSTAN: KATCO
2. Mathieu R, Deschamps Y, Selezneva V, Pouradier A. (2015). *Key MineralogicalCharacteristics of the new South TortkudukUranium Roll-Front Deposits*, Kazakhstan, 13th SGA Biennial Meeting, 1835 – 1838.
3. Fiet, N. 2012. *Stratigraphicalanalysis of geologicaluranium-bearingformations (Central-Muyunkum).*Kazakhstan: KATCO.
4. AREVA. (2014, May). *AREVA: World Wide Presence. AREVA IN KAZAKHSTAN*. Retrieved 092014, from AREVA: http://www.areva.com/
5. IRKITBAYEV C (2018). *Behavior of resistivity signal (KS) in impermeablefacies.* KAZAKHSTAN: KATCO
6. JSC Volkov Geology, (2004, 2008). *Uranium deposits of KAZAKHSTAN*, KAZAKHSTAN: Almaty
7. Demehova I, Ibrayeva M. (2017). *Repair work on geotechnical wells enterprises ISL uranium*. KAZAKHSTAN: Almaty