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Lithophysical characteristics of productive strata of cupriferous sandstone within Zhezkazgan ore district in the Central Kazakhstan

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Abstract

Purpose. The paper concerns additional geological appraisal and identification of extra localization criteria of cupriferous mineralization of a stratiform type. The research is intended to define physical and geological factors influencing sandstone distribution within the north-end of Zhezkazgan synclinal in the Central Kazakhstan.

Methods. A complex analysis of geological and mineralogical, geophysical, and geochemical data was carried out relying upon the information obtained from deep-hole wells. Modern methods to process and interpret the field data were applied. The analysis involved lithological dismemberment of the productive Taskuduk suite as well as determination of sulfide mineralization zone boundaries.

Findings. The research has shown that the productive levels reach down to 1500-m depth. The data interpretation has helped specify the geological structure and develop a model of ore-promising bodies of cupriferous sandstones at great depth. The applied complex data analysis has increased potential to prospect new loci of productive cupriferous sandstone deposits of Zhezkazgan type.

Originality. The research has contributed significantly to understanding of the physical and geological factors influencing the copper ore distribution in deep layers. New physical and geological criteria, determining deep copper mineralization localization, have been identified which were not considered by earlier similar studies.

Practical implications. The obtained new data as well as the developed methods are important while deep drilling planning and implementing to identify promising copper mineralization sites. The findings may be used to optimize exploration within the north-end of Zhezkazgan synclinal, and other districts having analogous geological conditions.

Keywords: *cupriferous sandstones, well logging, testing, interpretation, lithology, sulfide mineralization*

1. Introduction

Kazakhstan holds a prominent place in the world copper market owing to its rich resources and long history of copper mining [1]. Currently, copper industry is among the key branches in Kazakhstan. 6% of the explored global copper reserves are in the interior of the country. Cupriferous sandstone deposits are almost 51% of the reserves; 26.5% are concentrated in porphyry copper, and about 14.5% are in the complex ore of polymetallic sulfide deposits [2]-[4]. Nevertheless, the majority of the open-worked ore deposits of the Republic operate for several decades (for example, copper field Zhezkazgan functions more than 40 years); hence, the reserves of shallow deposits are almost depleted. A problem has been formulated for a considerable part of the region to prospect both concealed and buried deposits at more than 1000 m depths which needs use of new approaches and methods since traditional ones becomes less efficient at a great depth.

While solving the problem, direct exploration procedures are replaced with the indirect ones based upon study and use of features of 3D geological structure of ore districts, ore fields, and deposits. They involve wide application of the deep-hole well research data [5]-[10] as well as complex analysis of geophysical and geochemical statistics.

Being rich in natural resources, Kazakhstan also faces environmental and economic challenges connected with copper mining and processing [11]. The country invests actively in the technological development for more efficient and environmentally friendly use of mineral resources [12]. In recent years, attention has been paid to the search and development of new fields, which needs the use of modern techniques for exploration and assessment of the resources [13]-[15].

Within Zhezkazgan ore district in the Central Kazakhstan, copper objects, belonging to various genetic types, are known: hydrothermal plutogenic (Karaganda ore occurrence and a number of mineralization points); hydrothermal volcanogenic (6 mineralization points); contact-metasomatic

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skarn (1 mineralization point); polygenic volcanogenic-sedimentary (Akbulak Zapadny, Uytas, and Berdiken occurrences; and 2 mineralization points); polygenic sedimentary-hydrothermal-metasomatic (Zhezkazgan, Zapadnaia Saryoba, Vostochnaia Saryoba, Itauz, Kipshakpai, Karashoshak, and Dzhartas deposits; 12 occurrences, and 8 mineralization points); and sedimentary chemogenic (17 mineralization points) [16], [16]. The deposits are very important both for regional economy and the country as a whole. However, their future development needs in-depth research, and implementation of the advanced technologies. Study of geological features and factors, influencing copper mineralization distribution, is strategic for future successful progress of copper industry in Kazakhstan.

Commercial copper deposits of polygenic sedimentary-hydrothermal-metasomatic type, located within Zhezkazgan synclinal and connected with variegated deposits of Taskuduk and Zhezkazgan suites of the Middle and Upper Carboniferous, are the research subject. The copper mineralization is associated with grey-coloured cupriferous sandstone layers within the suites. According to formation conditions, it belongs to a stratiform type [18], [19] (Fig. 1).

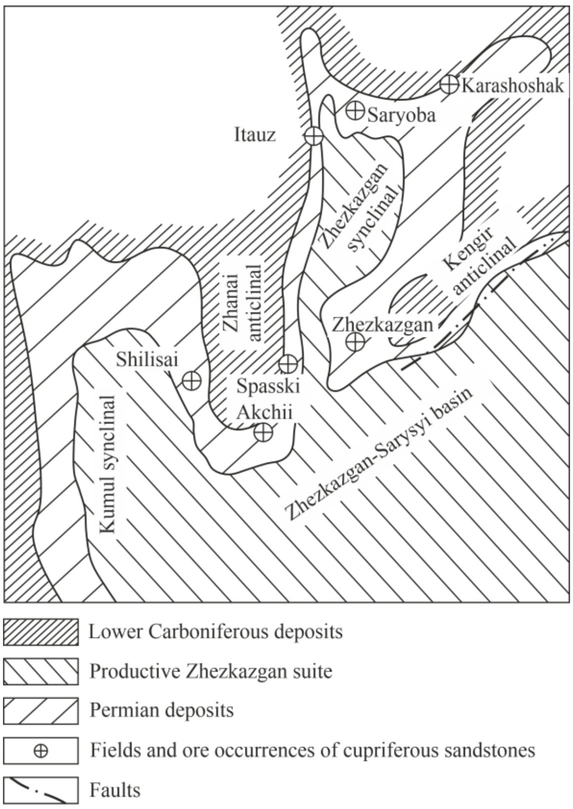

Figure 1. Structural pattern of Zhezkazgan district (according to B. Zhurbitski, Dzhezkazgan GPC)

A polygenic sedimentary-hydrothermal-metasomatic type is the most productive and distributive within the area. Following factors prove hydrothermal nature of mineralization [20]-[26]:

1. The mineralization is associated with grey-coloured sandstones; its development is limited (it does not cover the whole field of distribution).

2. Structural mineralization control is pronounced. Mainly, the mineralization is localized within small complicating folds with box section and disturbances within their flanks resulting from the graded flexures and faults. More intensive mineralization is associated with rock breaking zones within flanks of the folds and with zones of flat intra-and interstratal disturbances. Flanks of such box folds as well as flexures are followed by zones of intensive rock fragmentation.

3. The mineralization is epigenetic; it results from metasomatic substitution of carbonaceous cement and sandstone grains.

4. Rocks of Zhezkazgan and Taskuduk suites as well as Upper Beleutin subsuite are not marked by intensive regional metamorphism. At the same time, the ore levels demonstrate such hydrothermal changes in enclosing rocks as carbonatization; rock silicification; sericitization; albitization; and kaolitization of feldspars.

5. Regular and consistent ore mineralization movement from lower stratigraphic levels to upper one along with the total structure submergence. Depth isolines of intensive mineralization shape a surface cutting sidewise layers of Zhezkazgan and Taskuduk suites at an acute angle. The surface slopes are close to zones of interstratal disturbances.

6. Availability of thick Zhidelisai suite being a structural barrier for further rise of metal-saturated hydrotherms. After reaching lower levels of the formation, solutions retard. Hence, their active force was forwarded to migrate horizontally inside layers of Taskuduk and Zhezkazgan suites being the most favourable both lithologically and tectonically.

7. Confinedness of the key ore clusters (i.e. Zhezkazgan and Severnaia groups of deposits) to intersection areas of large deep faults. Epigenetic nature of the mineralization depends upon the faults being paths for the ore solution penetration from their magma chambers.

The main prospecting criteria and indicators within the area, controlling mineralization arrangement in cupriferous sandstones, are as follows [27], [28]:

– paleotectonic, i.e. the mineralization localization on the slopes of paleo-elevations and the basis flanges inside consedimental structures adjacent to source areas;

– structural and tectonic, i.e. the mineralization confinedness to the local folding elements (namely, synclinals, and wings of brachyanticlines) complicated by faults;

– stratigraphical, i.e. the copper mineralization confinedness to terrigenous sediments of Beleutin suite of the Lower-Middle Carboniferous; Taskuduk suite of the Middle Carboniferous; and Zhezkazgan suite of the Middle-Upper Carboniferous;

– paleographical, i.e. those ones characterizing facial conditions of sedimentation. Commercial copper content is defined in fluviolacustrine, lagoonal-deltoid, and coastal-marine deposits;

– lithological, i.e. the mineralization confinedness to medium-and coarse-graded grey and variegated quartzo-feldspathic and Polymistic sandstones with higher carbonate content;

– oxide mineralization zones at an outcrop of the copper containing rocks;

– geochemical, i.e. availability of primary and secondary copper dispersion halos as well as companion elements being silver, molybdenum, lead, and, zinc.

By now, potential of Zhezkazgan synclinal, with 22×12-km plan dimensions, has not been fully understood [29], [30]. First of all, it depends upon significant depth of productive levels within the synclinal down to 1600 m and deeper. Currently, prognostic are areas inside the buried share of Zhezkazgan synclinal which north-end involves Zhilandin (Severnaia) deposit group (i.e. Vostochnaia Saryoba, Zapadnaia Saryoba, Itauz, Kipshakpai etc.); its south-end involves Zhezkazgan deposit; and its periphery involves a number of small ore occurrences as well as numerous mineralization points. Flanks of the deposits and the buried sites between the fields are understudied; nevertheless, they are of practical interest as for prospecting of new ore deposits.

The research purpose is assessing the possibilities of complex analysis of deep-hole wells to identify ore zones; define and delineate the ore bodies; and evaluate their parameters, morphology, and internal structure required for estimation of the undiscovered potential resources. To solve the formulated problems, drilling results of two deep prospect wells (1800 and 1700 m) within Zhezkazgan ore district have been analyzed. Combination logging, core sampling and well testing were performed.

2. Methodology

In the prior periods, availability of deep productive levels was predicted within the area through the results of areal geophysical activities [31]-[33]. Prospecting works have helped identify that direct exploration of Zhezkazgan ore type was successful if only lithochemical survey and electromagnetics of the provoked polarization (PP) were applied. Mainly, it concerned surface areas and shallow depth (the first few hundred meters). Other geophysical exploration activities (i.e. electrical resistivity survey, gravimetric prospecting, magnetometry, seismic works) cannot solve the problem. Nevertheless, while prospecting favourable ore control structures within subsurface areas, they make it possible to perform the targeted prospect drilling [34], [35].

Following localization conditions of copper mineralization of Zhezkazgan type favoured successful use of structural geophysics approaches [36], [37]:

– stratigraphical and lithological control of mineralization, i.e. the copper mineralization confinedness to sandy formation of the Carboniferous system, and grey medium- and coarse-graded sandstones;

– confinedness of deposits to peripheral areas of large firs-order structures which plan dimensions are up to 20-30 km;

– relatively higher copper content of sites complicated by local fold and ruptural tectonics and arranged mainly along lines of the extended repeatedly regenerated tectonic wedges.

To study deep levels in the region, several prospect wells with up to 1800-m depth were drilled. They proved availability of productive levels as well as mineralization at great depth (Fig. 2).

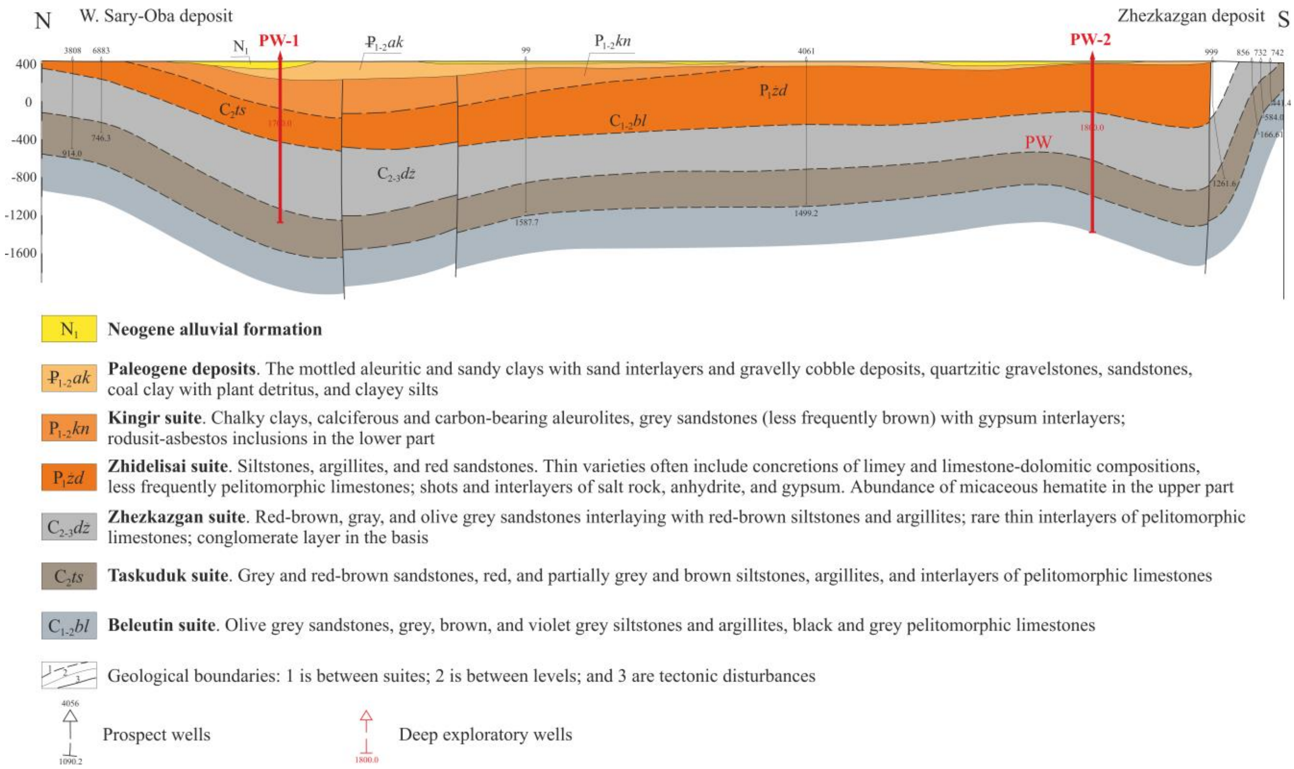

Figure 2. Geologic-geophysical profile along meridional section of Zhezkazgan district (Tsentrgeolsiomka ltd, 2017)

PW-1 well has been drilled in the northern part of Zhezkazgan synclinal 4 km south of Zapadanaia Saryoba. The well depth is 1800 m. Geological section, uncovered with the help of the well, consists of different age and polygenic deposits from Askazansor suite of the Lower Neogene clays to thin green terrigens of the Lower-Middle Carboniferous Upper Beleutin layers where fine-grained pyrite occurs, and less frequently arsenopyrite.

PW-2 well is in the central share of Zhezkazgan synclinal. Its depth is 1700 m. The geological section includes complex of rocks from the Quarternary mild clays to thin terrigens of Taskuduk suite of the Middle Carboniferous.

Geophysical survey was carried out in the wells using following complex of methods: apparent resistivity (AR); eigenpolarization potentials (Eps); gamma logging (GL); electrode potential (EP); a well alternative of the induced polarization (IP) with three-electrode configuration; a well alternative of IP with a ‘vertical profile’ configuration; inclinometry (I); temperature logging (TL); caliper logging (CL); and vertical seismic profiling (VSP).

The geological well survey was carried out to solve following problems:

– lithological dissection of logs (AR, and GL);

– identification and separation of sulfide mineralization intervals and zones within walls of the wells (AR, EPs, and IP);

– definition of intervals with high natural gamma activity, and dissection (GL);

– determination of spatial position of the well shaft (I).

The research was conducted using complex of geophysical methods and software tools for qualitative and quantitative interpretation of the information. The field data were reinterpreted in the environment of Window-based software platform Techlog (Schlumberger). The research applied all the available information on the well inclusive of logging, bore specimen, images, photographs, and thin rock sections.

Natural radioactivity diagrams (GL) for lithological dissection of the well sections were used in the logging process. Natural radioactivity of rocks was measured and analyzed over 3-15 micro roentgen per hour range depending upon the rock type. Electric log method (AR) was applied to identify ore bodies differing in the decreased resistance values. Electrical correlation has helped separate the rocks according to their granulometric composition.

Well alternatives of the induced polarization (IP) were used with three-electrode configuration and "vertical profile" configuration. The approaches have made it possible to forecast sulfide mineralization within borehole environment separating high polarizability zones which show that sulfide mineralization takes place.

Petrophysical examination helped analyze complex logging and core data to identify regularities of lithological and physical characteristics of productive layers. The examination included assessment of such secondary rock changes as carbonatization, silicification, sericitization, and chloritization.

The information were interpreted using Techlog platform which made it possible to perform both basic and extended interpretation of all data types of the well shaft.

To match geophysical and geological data, sections, developed relying upon the geophysical and geological information were compared to define correspondence between ore bodies and their accurate control. In addition, such factors, influencing the interpretation truth as availability of small tectonic disturbances, and differences in cement and organic material compositions in rocks, were taken into consideration.

Based upon the described methodological approach, the research was conducted to confirm efficiency of the complex use of geological and geophysical data while defining the nature of such geophysical anomalies, and their connection with ore-bearing levels. It is planned to apply the current data processing and interpreting procedures for geological structure specification, and development of a model for the buried ore-bearing complexes of cupriferous sandstones, which will favour the efficiency improvement as well as cost reduction for geological research.

3. Results and discussion

Qualitative and quantitative interpretation has been performed relying upon the complete GIS package. Re-interpretation of field data has helped explain both basically and extendedly all data types of the well shaft inclusive of logging, bore specimen, images, photographs, and thin rock sections (Fig. 3).

The analysis has been carried out to specify lithological composition of the well section, and compare with geological well data (core examination and testing) for determination of boundaries of sulfide mineralization zones.

The natural radioactivity diagrams (GL) were used during lithological dissection of well sections since in the majority of cases, natural rock radioactivity depends directly upon composition of the separated lithological levels [38]-[40].

It has been defined that rock colour cannot influence the natural radioactivity. 3-4 up to 10-12 micro roentgen per hour radioactivity is typical for grey and brown sandstones; more often, it is 6-9 micro roentgen per hour. Gamma activity of grey and brown siltstones is 10-15 micro roentgen per hour. Variations of gamma activity levels depends upon cement composition as well as organic material availability. Conglomerates differ in low gamma activity values being 5-7 micro roentgen per hour. Limestones demonstrate the lowest gamma activity values within well sections.

According to GL data, ore-bearing sections contain argillaceous rock; moreover, interlayers of rather thin fine- and medium-grained sandstones and conglomerates with high content of organic matter are separated steadily. Here and there, the interlayers have copper mineralization. Significant accumulations of thin-dissipated char organics are also observed in other sandstone variations owing to which the mineral becomes dark gray and sometimes black. Usually, concentration of the thin-dissipated organics is seen in rather thin interlayers having clearly defined boundaries. It is known that commercial ore tends mainly to seams of grey medium-grained sandstones and conglomerates often having high content of organic matter [41], [42].

Logging through MEP has helped identify high polarizability zones associated with sulfide mineralization areas. In this regard, enclosing rock composition did not influence heavily the polarizability. Background values of apparent polarizability are 0.5-2%. If carbonaceous matter and dissipated pyrite are available in the rocks then background values increase up to 4-7%. Taking into consideration the parameters, the apparent polarizability graphs have helped identify sulfide mineralization zones or sites enriched with carbonaceous matter.

Electric log methods (AR) have made it possible to define efficiency of electrical logging activities while defining ore bodies being rich in metallogenic minerals shown in the diagrams as those having low resistance values. The important result is the possibility to use the electrical logging data for separation of rocks in terms of their granulometric composition (i.e. fine-and coarse-grained). The matter is that copper mineralization confinedness to grey medium-and coarse-grained sandstones has been proved. Nevertheless, it is impossible to separate them depending colour. Negative results of the research, concerning certain interval in a well, depend upon low copper content in ore; availability of iron oxides in the ore-bearing suites; and drilling shot getting to enclosing rocks through fissures while boring. It especially concerns siltstones. Moreover, ore of Zhilandin (Severnaia) group deposits is of the disseminated nature. Hence, difficulty of its separation using resistivity technique is stipulated by the fact that there is no well-marked difference between resistance of enclosing rock and ore intervals.

Well alternatives of the induced polarization with three-electrode configuration and "vertical profile" configuration have helped forecast sulfide mineralization in the borehole environment. Ore zones of the deposit differ in high polarizability, which was the favourable factor to identify them within the section.

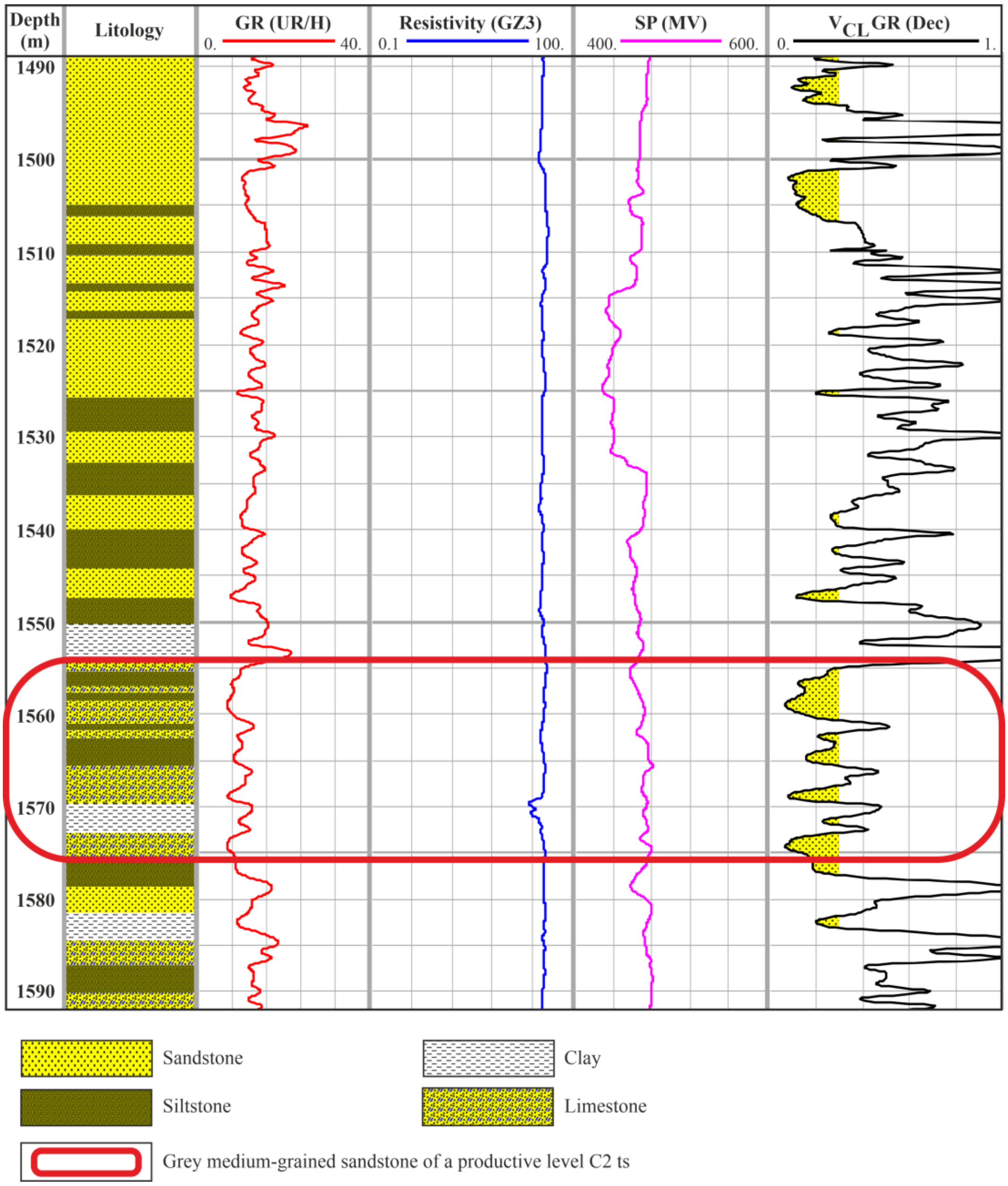

Figure 3. Logging diagrams for PW-1 well (fragment): 1 – sandstone; 2 – siltstone; 3 – clay; 4 – limestone; 5 – grey medium-grained sandstone of a productive level C2 ts.

The host medium and mineralization are rather anisotropic; consequently, while analyzing nature of current spreading for a point source, information has been got concerning spatial location of certain interlayers; textural nonuniformity has been studied; and shear zones, associated with intensive orogeny being typical for the section rocks, have been defined [43]. On the whole, the described logging techniques have helped analyze lithological heterogeneity of the geological profile; combination with testing has made it possible to define quite accurately boundaries of deep commercial accumulations of ore minerals.

Results of petrological and geochemical survey of rocks and ore, thoroughly studied within Zhezkazgan and Zapadanaia Saryoba deposits, have become the geological substantiation to interpret geophysical anomalies. Ore, occurring within the deposits, is characterized by the following:

– ore mineralization tends to gray and dark-gray medium-grained sandstones (being often enriched with the charry organics) predominantly on calciferous cement;

– within each ore-bearing level, deposits, associated with their centers, are the most persistent. Metalliferous deposits, either in upper or lower parts of the ore-bearing level, differ in extreme inconsistency, and fall into separate ore bodies;

– characteristic feature of mineralization localization within Saryoba deposits (like within Zhezkazgan field) is multilayer arrangement of predominantly agreeably deposited sheet-like ore shoots specified by extremely nonuniform distribution of ore minerals. Rich in copper interlayers alternate with poor or oreless interlayers. Such a nonuniform nature of ore mineralization distribution depends upon ingress of ore-bearing solutions to easily permeable interlayer and intrastratal sites;

– inside the ore-bearing levels, deposits are separated by waste rock interlayers. Generally, the oreless interlayers are represented by siltstones and fine-grained sandstones differing in poor fragmentation degree. The basic ore mass confinedness to gray medium-grained sandstones is explained by their brittleness as well as high porosity;

– rich sulfide mineralization is observed either along interstratal disturbances and fragmentation zones, formed within contacts of frequently alternating rocks differing in their granulometric composition, or along layer-by-layer accumulation of vegetable debris;

– more frequently, the ore mineralization nature depends upon granulometric and petrographic composition of ore-bearing rocks. Predominantly, ingrained mineralization is developed in the medium-grained sandstones. Vein mineralization is observed near interlayer disturbance and within areas with intensive fissility development. As for sandstones with eutaxitic structure, stipulated by thin lamination of sandstones differing in grain size, mineralization tends to more coarse interlayers;

– rich vein and ingrained mineralization in the enclosing rocks is shown within areas, differing in intensive fissility and high content of organic matter.

Following conclusion have been drawn relying upon the comparison of sections developed on geophysical and geological data:

a) in both cases, the basic ore bodies are viewed well, and tied up unambiguously;

b) in 15% of cases, affluent small bodies are recorded according to geophysical survey data, i.e. the research confirms partially their availability. However, considering that they have not been identified in some wells through geophysical techniques, their control is more complete according to prospecting activities;

c) it has been identified that control of small and thin ore bodies, relying upon geophysical data, is complicated by cross-bedding lenses as well as availability of insignificant layer-by-layer amplitudeless disturbances (probably, pre-ore ones);

d) the geophysical survey didn't identify ore bodies missed while drilling.

Numerous exploration wells, drilled in the southern and northern parts of Zhezkazgan synclinal, have proved availability of productive levels. Unfortunately, they could not characterize the whole structure at a depth more than 1 km. Drilling of 1800-m and 1700-m wells as well as the complex geophysical survey, followed by testing, has identified that productive levels of Taskuduk and Beleutin suites within Zhezkazgan synclinal go down to 1600 m and deeper (Fig. 4).

The detailed analysis of the core material has helped identify that within deep levels of Taskuduk productive stratum, terrigenous components of grey rocks have not any significant differences from their red analogues. Sandstone and siltstone grains are represented by differently rounded fragments of quartz, feldspar, siliceous and argillaceous-calcareous material.

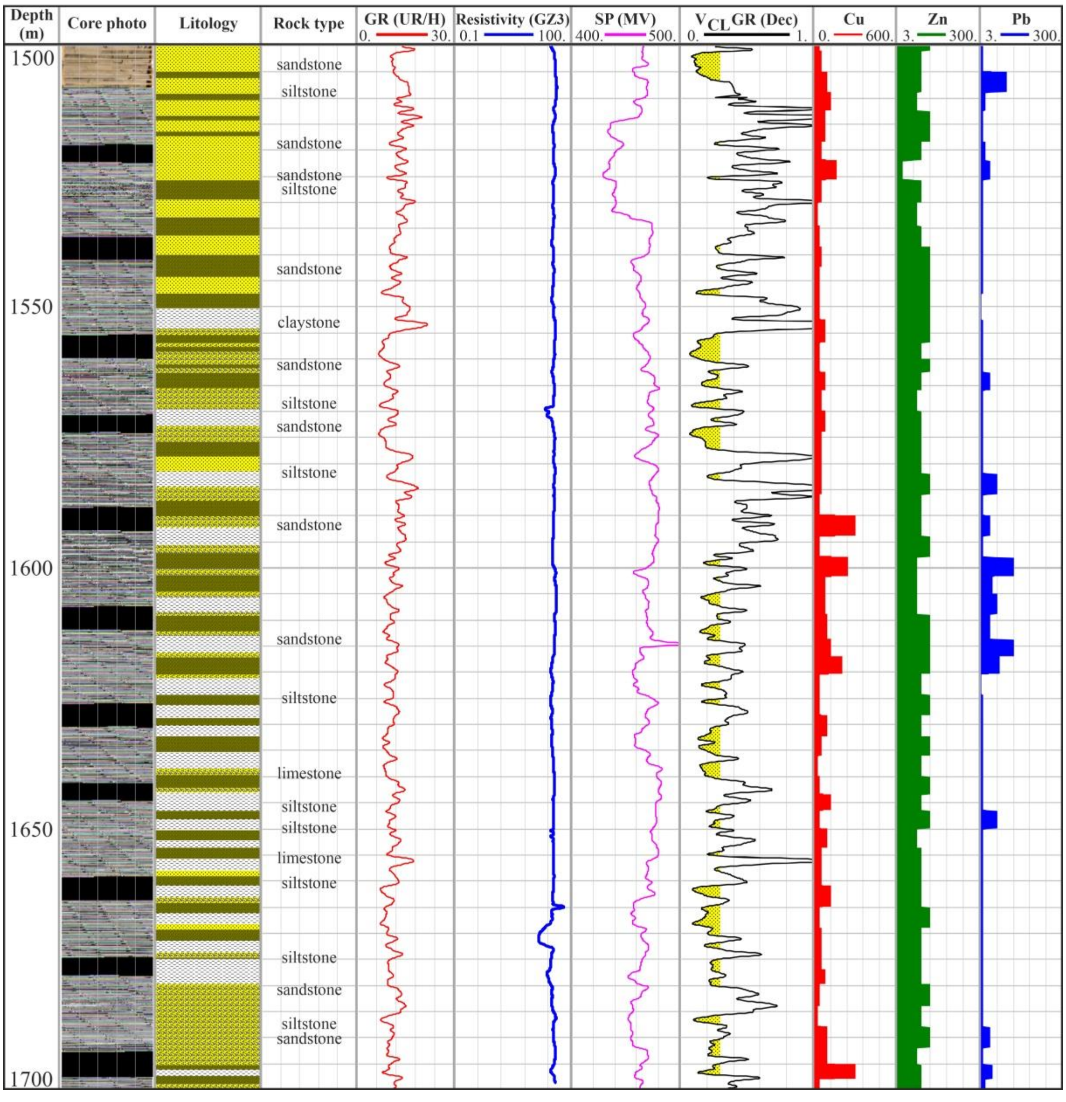

Figure 4. Fragment of complex GIS interpretation in PW-2 well (1700-m depth) with testing results (copper, zink, lead etc. content)

Cement is polymineral, mainly carbonaceous, with inclusion of epigenetic quartz; rarely, it is siliceous and chlorite-sericitic. The cement is contact, filler, and basic. Texture is massive and coarsely or finely banded. Grey rocks are carbonatized, silicified, seriticized, and chloritized. The secondary alteration degree increases along with growth in rock deformation and mineralization intensity.

Petrophysical analysis of the complex log and core data has made it possible to define a number of following new regularities of lithological and physical characteristics of the productive levels of cupriferous sandstone deposits in the context of Zhezkazgan ore district:

1. Boundary of red and brown sandstones is of a "floating" nature. It is stipulated by the fact that sometimes transition of red sandstones to grey ones is observed owing to gradual facial horizontal substitution of one sandstone type for another one.

2. Electric correlation detects two types of numerous tectonic displacements: firstly, layer-by-layer stripping within Taskuduk layer; secondly, moderate tectonic disturbance with 10-15-m displacement amplitude.

3. The ore bodies experience fragmentation, and displace by layer-by-layer stripping resulting in formation of knobs and displacements inside some ore bodies. Nevertheless, there are cases of the standard thinning by stratification of small ore bodies.

4. Gradual standard ore body thinning takes place according to stratification as well as its limitation by insignificant tectonic disturbances. Apparently, in a number of cases, ore bodies experience fragmentation, and displace in the form of layer-by-layer strippings. As a result, knobs originate in the occurrence of the ore bodies; or vice versa, their fault displacement. It is not improbable that the part of layer-by-layer disturbances, registered by geophysical survey, is a pre-ore one.

5. On the whole, the data of well geological research confirms control of ore bodies (first of all, the main ones) assumed by geologists. Consequently, the parameters to assess reserves at the stage of the detailed exploration, included in design studies, are reliable.

6. The research, carried out in a borehole, determines a number of ore body composition components as well as its thinning which should be taken into consideration while the ore body dissecting in the process of roadway development. Location of the composition components and their quantitative evaluation are among objects of operational exploration. At large, interpretation of geophysical materials confirms the data obtained as a result of drilling activities. According to all of them, the basic Taskuduk ore-bearing level is divided confidently into two parts being associated clearly in terms of the composed geological and geophysical materials. An upper share of the level is characterized by less persistent deposits. However, their control, proposed by geophysics, corresponds to drilling data. According to the geophysical survey, the number of ore layer intersections is close to the number obtained by drilling. On the whole, the well geophysical techniques confirmed borehole exploring data.

Currently, there are no direct prospecting indicator to search for mineralization in cupriferous sandstone covered with the Upper Paleozoic formations. Nevertheless, analysis of deep structures through the use of complex geological and geophysical activities may become rather helpful. Well research, included testing and geophysical survey, combined with analysis of areal geological and geophysical information, and based upon use of the current procedures for field data processing and interpreting, has made it possible to define more exactly both geological structure and represent model of the buried ore-promising complexes of cupriferous sandstones [44].

The integrated use of geological and geophysical well data helps identify more nearly nature of the geophysical anomalies, and define their association with deep ore-promising levels. At large, the findings favour the efficiency improvement as well as cost reduction for geological research.

The detailed high-resolution seismic measurements within the whole Zhezkazgan synclinal are recommended as the key trend for further exploration. The use of CMP method combined with a vertical seismic profiling method is expedient to be applied for each well to study its internal structure; identify promising flexural structures and upstanding block; and define levels with high sand fraction. Relying upon the detailed seismic works to identify new ore sites, consisting of productive deposits of Taskuduk and Zhezkazgan suites, buried under thick Upper Paleozoic formation, it is required to apply deep drilling by means of well network together with sampling and geophysical survey of the boreholes. Use of such high-resolution logging techniques (i.e. density log; lithodensity log; and acoustic logging), combined with modern modifications of a well alternative of the induced polarization approach, will help separate very definitely new deep levels consisting of productive grey medium-grained porous sandstones with high permeability and fissility, and enriched with sulfide mineralization.

4. Conclusions

The detailed lithological dissection of well section has been performed. Taking into consideration testing results, boundaries of sulfide mineralization zones have been identified. It has been defined that dissipation of productive complexes within the analyzed area is more than 1500 m.

Zhezkazgan and Taskuduk suites, being ore-bearing formation, are the integrated lithological and facial complex of terrigenous deposits with rhythmic sectional alternation of rocks differing in fragmentary material size and colour, i.e. sandstones (from fine-grained up to coarse-grained and gravelite), and siltstones with tributary participation of conglomerates and argillites, dissipating down to 1500 m and deeper. In the northern group, mineralization is associated with lower Taskuduk subsuite, and upper share of Beleutin suite which deposits within the central part of Zhezkazgan synclinal go down to 1600-1800-m depth. On the one hand, the fact is negative for geological and economic assessment of such a potential deposit since it will involve significant expenditure for underground mining.

Nevertheless, according to the results of geological and geophysical appraisal survey, prospects for Zhezkazgan ore district have been expanded within the buried share of Zhezkazgan synclinal (southward from Zapadnaia and Vostochnaia Saryoba fields) owing to prospecting of deep levels of Zhezkazgan and Taskuduk suites within which areas the detailed exploration is recommended.

Author contributions

Conceptualization: SI, KT; Data curation: ZA, ZS, AS; Formal analysis: DT, RT; Investigation: SI, KT; Methodology: ZA, DT, RT; Project administration: SI; Resources: ZA; Visualization: DT, RT; Writing – original draft: SI, KT; Writing – review & editing: ZA, ZS, AS, DT, RT. All authors have read and agreed to the published version of the manuscript.

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Conflicts of interests

The authors declare no conflict of interest.

Data availability statement

The original contributions presented in the study are included in the article, further inquiries can be directed to the corresponding author.

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Літолого-фізична характеристика продуктивних горизонтів родовищ медистих пісковиків Жезказганського рудного району в Центральному Казахстані

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Мета. Стаття присвячена геологічному довивченню та виявленню додаткових критеріїв локалізації мідного зруденення стратиформного типу. Дослідження спрямовані на визначення фізико-геологічних факторів, що впливають на розподіл медистих пісковиків у північній частині Жезказганської синкліналі Центрального Казахстану.

Методика. Комплексний аналіз геолого-мінералогічних, геофізичних та геохімічних досліджень проведено на основі даних свердловин глибокого буріння. Застосовано сучасні методи обробки й інтерпретації польових матеріалів. Аналіз включав детальне літологічне розчленування продуктивної таскудукської свити та визначення меж зон сульфідної мінералізації.

Результати. Дослідження показали, що поширення продуктивних горизонтів досягає глибин до 1500 м. Інтерпретація даних дозволила уточнити геологічну будову та створити модель рудоперспективних комплексів медистих пісковиків на великих глибинах. Застосований комплексний аналіз даних підвищив перспективи виявлення нових рудних ділянок, складених продуктивними відкладеннями медистих пісковиків Жезказганського типу.

Наукова новизна. Дослідження зробили значний внесок у розуміння фізико-геологічних факторів, що впливають на розподіл мідних руд у глибокозалягаючих горизонтах. Виявлено нові фізико-геологічні критерії, що визначають локалізацію мідного зруденення на великих глибинах, що раніше не було враховано у подібних дослідженнях.

Практична значимість. Отримані нові дані та розроблена методика мають важливе значення для планування й проведення глибокого буріння на виявлення перспективних ділянок мідного зруденення. Результати досліджень можуть бути використані для оптимізації пошуково-розвідувальних робіт у північній частині Жезказганської синкліналі та інших районах з подібними геологічними умовами.

Ключові слова: *медисті пісковики, геофізичні дослідження свердловин, випробування, інтерпретація, літологія, сульфідна мінералізація*

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