ANNOTATION

Theses for the PhD degree in specialty:
6D070600- "Geology and exploration of mineral deposits"of

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RESEARCH OF ORE CONTROL FACTORS OF SYRYMBET ORE FIELD IN DIGITAL 3D FORMAT AND EVALUATION OF ITS POTENTIAL RESOURCES (USING GIS TECHNOLOGIES AND REMOTE SENSING DATA)

The thesis is devoted to the actual topic at the present time, the creation of the own resource base of rare earths in Kazakhstan, which have a high price in the world market and are the basis for the development of innovative technologies. In the context of the goals set by the President of the Republic for innovative development of Kazakhstan, scientific research is timely.

1. Actuality. In Kazakhstan, as a result of the work of several geological researchers' generations, a large number of geological, geophysical, geochemical and other materials with various content and scale have been accumulated. Dissemination of information on ore objects in different stock, literature sources and maps of different scale makes it difficult to compile a holistic view of ore control factors, their general and particular characteristics.

This factor complicates the establishment of effective forecasting and prospecting criteria for mineral deposits and the allocation of structures or sites favorable for the search of ore-rich objects. And thereby makes it difficult to assess their potential resources, including the Syrymbet ore field located in the north-western part of Kokchetav median massif. Deposits and ore occurrences of rare metals and rare earth elements are concentrated in the Syrymbet ore field.

Today it is difficult to name the field of technology in which rare metals and rare earth elements would not be used. They are actively used in nuclear power engineering, radio electronics, aviation and rocketry, machine and instrumentation engineering. The main consumer of REE is Japan, which occupies more than 50% of the world market. Among the major importers of REE are also the USA, France, Germany, Belgium and India.

2. The object of the study is the exogenous rare-earth Shok-Karagai deposit of the Syrymbet ore field (Northern Kazakhstan).

3. The subject of the study are granitoids, linear weathering crusts with rare earth mineralization to identify ore-controlling factors.

4. The aim of the study is to improve the scientific and methodological basis for the allocation of ore-controlling factors of rare-earth mineral deposits and build their 3D model by creating a digital geo database.

5. Research objectives:

1) To study the geological and genetic features of the deposits and ore occurrences of the Syrymbet ore field;

2) On the core of boreholes at the Shok-Karagai field, to study the mineral composition of the bedrock, the weathering crust, and the material composition of the ores, as well as to isolate the main minerals bearing rare earth mineralization;

3) To create a digital geo informative system of the Shok-Karagai deposit on the basis of complex geological, geophysical, mineralogical and space (RSE) data on the basis of GIS technology and build its three-dimensional geological and petrophysical models;

4) In the 3D model format, to conduct a system analysis of the main ore control factors, forecasting and search criteria of the exogenous Shok-Karagai field. To identify promising areas for rare earths within and on the flanks of the field.

6. The research method is to carry out predictions, in 3D format, on the basis of geological and geophysical materials for the ore region and the deposit.

7. The solution of the above mentioned tasks as a result of the research allowed the candidate to defend the following main protected positions:

1) In the Syrymbet ore field rare-metal and rare-earth deposits of endogenous and exogenous origin are genetically and spatially related to intrusive massifs, where endogenous deposits are localized in their apical parts, and exogenous deposits are situated in their weathering crusts;

2) On the exogenous rare-earth deposits (Shok-Karagai type) of the Syrymbet ore field, REE carriers are their own rare-earth minerals - monazite, silicorabdophanite, parisite, and also isomorphous impurities of rock-forming and accessory minerals of the weathering crust;

3) In the 3D model of the exogenous rare-earth Shok-Karagai deposit, it is established that the distribution of REE on its boundaries has a certain regularity, where their content increases with depth;

4) The digital geo-information system and the 3D model of the Shok-Karagai deposit make it possible to identify ore control factors and prospective areas for rare earths within the area of the field.

The protected provisions are formulated on the basis of the carried out studies.

8. The main results of the work include the following:

1) *Results of mineralogical studies:*

In bedrock from rare earth minerals on a microprobe are found:

✓ phosphates of rare earths of the cerium group - a) ***monazite*** is found in granite-porphyry in the form of a crust in the void. In the mineral elements of the lanthanides group are established: *cerium* - La, Ce, Pr, Nd, Sm, Eu and *yttrium* - Gd, Dy. In addition, radioactive elements - Th and U; b) ***silicorabdophanite*** (a kind of mineral rhabdophanite) - found in the explosive-hydrothermal breccia in the siliceous mass in the form of rare fine micron grains. In the mineral, only the elements of the *cerium series* La, Ce, Pr, Nd and radioactive element Th are installed;

✓ calcium fluorocarbonate and rare earths of the cerium group is ***parisite***. The mineral is found in granite-porphyry, sericitized, containing fluorite. In the mineral elements of the group of lanthanides are established - *cerium* - La,

Ce, Pr, Nd, Sm, Eu and *yttrium* - Y, Gd, Tb, Dy. Of the radioactive elements Th. Parisite is found in the form of small grains of 1-10 microns in size, which are represented as a cluster.

In weathering crusts with rare earth mineralization:

- ✓ According to the data of spectral semi-quantitative analysis, on the average in the Shok-Karagai section, the sum of the cerium series predominates over yttrium approximately 4-fold;
- ✓ actually rare-earth minerals in the weathering crust are monazite and parasite;
- ✓ the main ones are cassiterite, wolframite and secondary ilmenorutil, as well as other rock-forming and accessory minerals (kaolinite, mica, zoisite, zircon, sphene, fluorite) among the minerals in the weathering crust where isomorphic REE impurities may be present. They were installed as impurity elements in zircons with different color Y in the amount of 70-75 g / t; La - from 0 to 500 g / t; U - from 50 to 350 g / t; in one case Th – to 30 g / t; Nb - from 30 to 100 g / t. In mica Y and La, 350 g / t. Nb is much (10,000 g / t) in mica and orthite.

2) *Results of model constructions:*

When constructing a ***three-dimensional model of the deposit***, the following results were obtained:

- ✓ forms of ore bodies are not complex, simple, in the form of an elongated formation. Geometrical parameters of the site are 1000×350 m. Such simple forms of ore bodies are predetermined by the development of the linear weathering crust, where tectonic disturbances are developed in the zone of crushing;
- ✓ delineation in the boundary of ore bodies on the content of the ore component makes it possible to establish the regularity in the allocation of its contents. Visualization of the boundary of ore bodies at the Shok-Karagai deposit shows that the content of rare-earth elements increases with depth, since the reservoir with a rare earth content in the range of 0,10% is lower than that with a rare earth content of 0,07%. Zoning occurs in the distribution of the contents of rare-earth elements.

This is due to the fact that the source of rare earth elements are the albitized and greisenized granites and granite-porphyry of the Dalnensky complex. Therefore, the closer to the source, the higher in the weathering crusts the content of rare-earth elements in the Shok-Karagai deposit.

When constructing ***the petro-physical model of the deposit***, the following features are distinguished:

- ✓ The zoning according to the petro-physical properties of rocks is observed in the area of the deposit, where the density increases with depth. A fairly high density is observed in granitoids (2,62 g / cm^3) and a clayey-crushed zone (2,45 g / cm^3), the lowest one is in the zones of the soil-vegetation layer (2,25 g / cm^3);
- ✓ high values of magnetic susceptibility are observed in granitoids (121 * 10^{-6} CGS), the others have low values of magnetic susceptibility in the range from 15 * 10^{-6} CGS to 30 * 10^{-6} CGS.

3) ***Results of the geo-database for the geo-informative system:***

A *geo-informative system* of the geo-database for the Shok-Karagai field was created for a detailed and consistent study of its ore control factors, such as:

Structural-tectonic: Large multi-seam violations of the northeastern direction (Shokkaragai, Valikhanovsky zones, etc.) and minor violations of the northwestern, sub-meridional and sub-latitudinal directions;

Magmatic: Sub-alkaline granites, granite-porphyry, granophyres and quartz porphyry of the sub-volcanic complex;

Lithological: weathering crust for granitoids;

Meta-somatic: Hydrothermal changes;

Geophysical: Increased magnetic field values of porphyry granite caused by hydrothermal rock changes. The gamma activity value reaches up to 300 micro R / h;

Geochemical: High contents of rare earth elements.

Material: The presence of mineral-carriers of rare-earth elements.

The level of rare-earth element concentrations in the Shok-Karagai field ores allows one to compare it with the large deposits of Kazakhstan (Kundybai, Akbulak and others).

Analyzed and systematized ore-controlling factors allowed extending ***the forecast-search criteria in rare-earth deposits of exogenous genesis:***

1. Regional faults of the north-eastern strike, feathering their violations with the zones of fragmentation;
2. Intrusive formation of acidic and sub-alkaline composition;
3. Linear crust of weathering by intrusive formations;
4. Hematitized, sericified, chloritized, silicified and fluoridized granitoids;
5. Positive magnetic anomalies over hydrothermally reformed granitoids and gamma activity of enclosing rocks;
6. High clarke contents of REE, thorium, lead, tin, zinc, niobium, zirconium, uranium;
7. cassiterite, wolframite, ilmenorutil, kaolinite, mica, zoisite, zircon, sphene, fluorite.

Estimation of forecast resources for rare earths in the Shok-Karagai field.

17 ore bodies of rare-earth mineralization are allocated on the area of the Shok-Karagai deposit. The investigation of the core in the boreholes with numbers 7001, 7003, 7006, determined by the strike of known ore bodies and model constructions of the ore body showed that the content of the rare earths on the continuations of the main ore body (up to 2 km) is also kept at the 0,07% onboard side. Promising areas are the sections, which are the continuation of the main ore bodies of the deposit.

Then the total area of ore mineralization to the rare earths of the Shok-Karagai deposit is approximately 7 square kilometers, where the geometric parameters with the change of its boundary has got the following values: 2000 × 350 m. The thickness of ore bodies is from 2 to 25 m, the average thickness of ore bodies is 5 m. The volume weight of the ore mass is close to 2,0 t / m^3.

Forecast resources of this field for category P_1 on REE are estimated in the range of 70000 tons.

The conducted research has a scientific and practical significance.

8. The scientific novelty of the study is determined by the fact that **for the first time a systematic scientific and information base has been created for the Shok-Karagai deposit**, which allows to carry out a detailed study and analysis; to recognize ore control factors and allocate some perspective sites of rare earths within and on the flanks of the field that is under study.

9. Practical significance. Within and on the flanks of the Shok-Karagai field, promising areas for rare earths have been identified and their resources have been estimated. They can be recommended to authorize state bodies and geological exploration companies for carrying out some prospecting and evaluative works.

10. Actual material. The author of the thesis participated in the development of the Scientific and Technical Program: "Scientific and Technological Substantiation for the Development of the Rare Metal Sector in Kazakhstan for 2012 -2014" on the topic: "Exploration and Evaluation Work at the Shok-Karagai Field (North-Kazakhstan Region)". The actual material was selected by the dissertator in performing field geological studies, outline observation of outcrops and core documentation of exploratory wells, and geological materials of other researchers published in print both in Kazakhstan and abroad.

In the office period, the analysis and description of transparent (more than 500 items.) and polished (more 300 items.) were conducted. The polished sections were made at the University of Adam Mickiewicz (Poland), the Institute of Geological Sciences named after K.I. Satpayev and in the inter-departmental grinding laboratory of the Institute of Geology, Oil and Gas Sciences called after K.Turysov at Satpayev's University. Quantitative (180 samples) and semi-quantitative (120 samples) spectral analyzes of samples of stone materials were carried out on the laboratory basis of the IGS named after K.I. Satpayev.

Petro-physical models of the ore field and deposits of the studied region are made.

Based on the complex of geological, geophysical, analytical and remote (RS) data, a digital database (geo-informative system) was created and a three-dimensional model of Shok-Karagai deposit was built, using some computer programs as ArcGIS, Micromine.

12. Approbation of research results. The main theses of the dissertation were discussed at the sessions of GSP and EOMD Department at the Institute of Geology, Oil and Gas Business named after K.Turysov of the University of K.I.Satpayev. The results of the research are reflected in the scientific report of the project: "Exploration and evaluation works of the Shok-Karagai field, study of the material composition of ores, isolation of industrial ore bodies, evaluation of rare-earth mineralization in categories P_1 and P_2" (2014).

13. Publications. Based on the results of the scientific research, 9 articles and reports were published, including 3 works in the international scientific publication included in the Scopus database and having a nonzero impact factor and 3 articles in scientific publications recommended by the Ministry of Education

and Science of the Republic of Kazakhstan. The results are widely approved at international and republican scientific conferences, such as "Resource-reproducing, low-waste and environmental technologies for subsoil development" (Moscow (Russia) – Zanjan (Iran), 2013), International Multidisciplinary Scientific GeoConference SGEM-2015 (Albena, Bulgaria, 2015), Izvestiya Series of Geology and Technical Sciences (Almaty, 2015-2017), International Scientific and Practical Conference "Scientific and Personnel Support of Innovative Development of the Mining and Metallurgical Complex" (Almaty, 2017).

14. Scope and structure of work. The thesis consists of an introduction, five chapters and a conclusion and contains 104 pages of printed text, 21 tables, 48 drawings and photographs, as well as a list of literature from 88 titles.