

ANNOTATION
For the Doctor of Philosophy (PhD) degree
by specialty 6D070600 - "Geology and exploration of mineral deposits"

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Forms of occurrence of rare earths in the weathering crusts of the deposits of Northern Kazakhstan and their three-dimensional models

General description of the work

Nowadays, it is difficult to name the field of technology in which rare and rare-earth elements are not applied.

The rare-earth elements (rare earths) are yttrium, lanthanum and 13 elements of the lanthanides group (cerium, praseodymium, neodymium, samarium, europium, gadolinium, terbium, dysprosium, holmium, erbium, thulium, ytterbium, lutetium).

These elements are actively used in nuclear power engineering, radio electronics, aviation and rocket technology, machine and instrument engineering. So, neodymium is the main component of magnets used in wind turbines and hard disk drivers. Lanthanum is an important component of catalysts used in the petroleum refining industry and vehicle exhaust gas filters. Yttrium, europium and terbium are involved in the production of luminophores for computer monitors. Niobium is widely used in the production of niobium steel. The addition of even 0.5% of this metal excludes internal corrosion of oil and gas pipe joints, and they serve 4-5 times longer than usual pipes. Rare earths are also important strategic materials used in the production of precision weapons, communication systems, lasers, radars, satellites and night vision devices.

The main consumer of REE is Japan, which occupies more than 50% of the world market.

The USA, France, Germany, Belgium and India are among the major importers of REE.

According to Eurasia Capital, the demand for REE, which in 2009 was 134 thousand tons, already in 2012 increased to 180 thousand tons, and in 2014 200 thousand tons. Further stable growth of REE consumption in subsequent years is forecasted.

At present, China is the world's largest exporter of REE. United States and the countries of Southeast Asia follow further.

Kazakhstan has a chance to join the group of exporting countries of raw materials, because it possesses serious achievements in the production of rare metals and rare-earth products, as well as a number of rare-earth deposits. The production of REE depends on the increase of the investment attractiveness of the deposits, i.e. mean REE contents and their reserves.

The object of the research is the Kundybai and Talayrik fields of rare-earth elements.

The subject of the research is ore-bearing weathering crusts, productive for yttrium and rare earth elements to establish forecasting criteria for deposits of hypergenic origin in connection with the increased demand for this raw material in the world market.

The relevance of work is determined by the need to prepare a mineral-raw base of rare and rare-earth elements in Kazakhstan. Currently, the factories that produce global products (the Irtysh Chemical and Metallurgical Plant (ICMP) and the Aktau Mining and Chemical Combine) are fully operating on imported raw materials. At the global crisis conditions, it is necessary to provide the plants with Kazakhstan raw materials.

The aim of the work is to establish the forecast criteria for rare-earth deposits using three-dimensional modeling and to determine the forms of rare-earth elements in weathering crusts of hypergenic rare-earth deposits in Northern Kazakhstan.

Research objectives:

1. to analyze literary and monographic materials about the geological study of the Kundybai deposit and the rare earth site of Talayrik.
2. to determine the methodology and methods of mineralogical research and determination of rare earth elements at the deposits of Northern Kazakhstan.
3. to apply modern methods of computer modeling to create three-dimensional models of rare-earth element deposits.
4. to identify and scientifically substantiate the forecasting criteria for rare-earth element deposits.

Actual material and methods of research. The paper summarizes the materials and research results collected by the author during field and cameral work during 2012-2014 years. During the field work, the ores were documented in natural and artificial outcrops on the day surface, in underground mine workings and boreholes in the Kundybai field and the Talirayk rare earth site. In the cameral period, description of transparent (more than 800 pieces) and polished (more than 300 pieces) thin sections and the isolation of monomineral fractions for laboratory studies were performed. Analytical determination of the minerals composition, with the exception of chemical analysis (25 samples), was carried out directly by the author of the work, under the supervision of specialists from the Satpayev Geological Institute. In laboratory studies, quantitative (110 samples) and semi-quantitative (155 samples) spectral analysis methods were applied. After summarizing and analyzing the materials of previous work, three-dimensional models of the Kundybai deposit and the Talayryk site were created using the Micromine software.

Scientific novelty of the work. As a result of the application of modern methods of mineralogical research and methods of computer modeling, next can be mentioned:

1. The reliable information on analytically determinable rare-earth elements in weathering crusts and the foundation of various sections of the Kundybai deposit and

the Talayryk site was obtained for the first time. The information on REE contents in minerals that existed earlier was refined and supplemented.

2. Three-dimensional models of these objects were constructed for the first time, including skeleton models of the lithological structure of the site and ore body, block models with REE contents. The possibilities of the software allowed to interpret and visualize data on the content of REE in all exploration profiles and to establish the features in the nature of their distribution. More accurate values were obtained for the average contents of rare earths on the basis of computer calculations.

3. The forecasting criteria have been established for deposits of rare-earth elements of hypergenic origin.

The main results of the research can be presented in the form of the following main protected provisions:

Protected provisions

1. Sources of rare-earth elements of hypergenic origin are rocks of acid composition – gneiss-granites in the Talayryk section, and metamorphic rocks – gneisses, shales, amphibolites in the Kundybai deposit. Pore-forming minerals (mica, amphibolites, plagioclases) are transformed into clay minerals under conditions of chemical weathering. In this case, most of the released REE is absorbed by clay minerals, and the least part enters the solution. In this regard, clay minerals in the weathering crust of these deposits are among the main carriers of REE.

2. Establishments based on mineralogical studies on deposits of hypergenic origin: rare earths that **enter isomorphously** into the composition of relic endogenous rock-forming minerals - garnet, apatite, orthite, etc., are **concentrated** in their own newly formed hypergene minerals, chertite, ittrobrabofanite and neodymium bastnesite, and **adsorbed** by hypergenic colloidal minerals - Kaolinite, iron hydroxides, etc.

3. From the three-dimensional (skeleton and block) models of the deposit of rare earths of Northern Kazakhstan: the weathering crust controls the geometric parameters of the zones of rare-earth mineralization, and the content of rare earths depends on the type of weathering crust. On the Kundybai deposit, an increase in the content of rare earths from amphibolites to schists is observed. On the site of Talayrik, the type of weathering crust is determined only by gneiss-granites, and certain regularity in the spatial distribution of the contents of rare earths is not observed.

4. The constructed three-dimensional models of the deposit and the forms of localization of rare-earth elements in weathering crusts are the main factors for establishing general forecast criteria for the search for deposits of rare-earth elements of hypergenic origin

Practical significance. Data on the contents and forms of the presence of rare-earth elements in the weathering crust minerals can be used when performing prospecting for rare-earth elements both within the ore fields of Northern Kazakhstan and deposits of similar genesis in other regions of the world.

Approbation of research results. The main points of the thesis were discussed at the sessions of the Department of Geological Mapping and Exploration of Minerals of the Institute of geology and oil gas business after K. Turysov KazNRTU named after K.I. Satpayev. The results of the research are included in the scientific report on the project "Renewal of the evaluation works of the Kundybai deposit (Kostanai oblast), study of the material composition of ores, selection of technological samples" (2014).

Publications. According to the results of scientific research, 10 articles and reports were published, including one paper in an international scientific publication that is part of the Scopus database and has a nonzero impact factor. And four papers were published in the scientific journals recommended by the Ministry of Education and Science of the Republic of Kazakhstan. The obtained results were published in the International and Republican scientific conferences: 1-report published in the scientific collection of the International Conference of the Abroad (Bulgaria, 2015), 4 - published in the collections of International Conferences.

Scope and structure of work. The thesis consists of an introduction, four chapters and a conclusion and contains 112 pages of text, 14 tables, 41 images and photographs, as well as a list of literature from 93 titles.

List of published papers on the topic of the dissertation

1. M. Sh. Omirserikov, M. K. Kembayev, L. D. Issayeva, K. Sh. Dyussebayeva, Ewa Slaby, S. K. Assubayeva. Mineralogy and structural model of the weathering crust of Kundybay deposit (North Kazakhstan). News of National Academy of Sciences of the Republic of Kazakhstan. Series of geology and technical sciences ISSN 2224-5278, Vol.6, Number 420 (2016), 39-50.
2. L. D. Issayeva, K. Sh. Dyussebayeva, M. K. Kembayev, U. Yussupova, S. K. Assubayeva. Forms of finding of rare-earth elements in the weathering crust of the Kundybai deposit (Northern Kazakhstan). Journals of the NAS RK Geology and technical science series. Almaty, Volume 2, Number 410 (2015), 23-30.
3. L. D. Issayeva, K. Sh. Dyussebayeva, M. K. Kembayev, U. Yussupova. Rare-earth elements and their forms in the weathering crust of the ore development Talayrik (Northern Kazakhstan). Journals of the NAS RK Geology and technical science series. Almaty, Volume 6, Number 414 (2015), 57-65.
4. M. Sh. Omirserikov, L. D. Issayeva, Ewa Slaby, M. K. Kembayev. Three-dimensional frame model of the site Talayrik. Vestnik of KazNRTU Earth Sciences. Almaty, №1 2016 pp.9-14.
5. M. Sh. Omirserikov, L. D. Issayeva, K. Sh. Dyussebayeva, M. K. Kembayev, S. K. Assubayeva. Rare earth in the weathering crust of the Kundybai deposit

(Northern Kazakhstan). Bulletin of the Serikbayev East Kazakhstan State Technical University. ISSN 1561-4212. №3, 2016, 32-40.

6. Murat Omirserikov, Kulyash Dyussembayeva, Lyudmila Isayeva, Maksat Kembayev, Saltanat Assubayeva. Forms of occurrence of rare earth elements in the weathering crust of Kundybay deposit (North Kazakhstan). International Multidisciplinary Scientific GeoConferences SGEM Science and technologies in Geology, Exploration and Mining 2015, Bulgaria Volume I, pp. 159-166.

7. M. Sh. Omirserikov, L. D. Issayeva, S. K. Assubayeva, M. K. Kembayev. Study of the peculiarities of the lithological structure of the site of Talayryk. Science in the modern information society V North Charleston, USA. Vol.2 pp.12-16. 2015.

8. L. D. Issayeva, M. K. Kembayev. Rare-earth elements in the scheelite upper Kayraktinsk deposits (Central Kazakhstan). "Problems and Prospects for the Development of the Geological Cluster: Education - Science - Production". Int. Conf. Devoted to the 80th anniversary of the birth of Karatay Turysov. Satpayev KazNTU, Almaty, 2014, pp. 224-227

9. M. K. Kembayev. Construction of a three-dimensional skeleton model of the lithological structure and ore body of the rare earth site Talayryk. International Satpaev Readings - 2015 "The role and place of young scientists in the implementation of the new economic policy of Kazakhstan". Satpayev KazNTU, Almaty, 2015, pp. 182-184

10. M. K. Kembayev. Study of geological and structural features of the rare earth site of Talayrik. Proceedings of the international scientific-practical conference "Geology, metallogeny and prospects for the development of mineral resources of the Republic of Kazakhstan", devoted to the 75th anniversary of the Institute of Geological Sciences named after K.I. Satpayev.