ABSTRACT

Dissertation for the degree of Doctor of Philosophy,
Specialty: 6D070600 – «Geology and exploration of mineral deposits»

Baisalova Akmaral Omarkhanovna

«THE AKZHAYLAUTAS GRANITE MASSIF AND ADJACENT REGIONS: FEATURES OF METASOMATIC PROCESSES OF RARE METAL MANIFESTATIONS»

The main study object is the Verkhnee Espe deposit with main ore elements comprised of: zirconium, niobium, tantalum, yttrium and rare earths elements. In small quantities are also present: lithium, beryllium, thorium, tin, lead, etc. The main concentrations of rare metals of the Verkhnee Espe deposit are associated with contact metasomatites, albite granites and, to a lesser extent, pegmatites with rare-metal replacement.

1. Relevance. So far, no alternative materials have been found for rare-earth elements, so the demand for them increases year by year, and without them the development of modern electronics is not possible. In the message of Nursultan Nazarbayev, the Head of our Republic of Kazakhstan on *"The Kazakhstan way - 2050: common goal, common interests, common future"* states that "it is important to increase the development of rare earth metals, given their importance for science-intensive industries – electronics, laser technology, communication and medical equipment".

Researchers of the study region (A.V. Stepanov, A.A. Beus, and others) previously noted that the most important task for further research of the Verkhnee Espe deposit is to conduct a detailed mineralogical-geochemical investigation. Integrated development of natural resources demands studying the material composition of the deposit as follows: to determine the mineral composition of ores; to identify typomorphic features of minerals in ores; to determine impurity elements in minerals and the forms of their entry; and to establish the sequence of formation of minerals and zoning in their distribution.

2. The objects of the study are the rare-metal occurrences of the Akzhaylautas granite massif and adjacent areas of Verkhnee Espe and Iysor (East Kazakhstan).

3. The aim of the dissertation is the detailed petrographic, mineralogical and geochemical study of the Akzhaylautas massif (Iysor and Verkhnee Espe) apogranites by modern analytical methods to define the practical significance of these deposits in particular and of the ore field as a whole, as well as to reveal the sequence of mineral formation in granites and metasomatites and to determine the absolute age of the mineralization related to the alkaline granites of Verkhnee Espe.

4. Objectives of the study:

1) to study the rocks and ores of the Akzhaylautas granite complex by modern methods (optical microscopy, X-ray phase analysis, electron microscopy, spectral analysis, etc.);

2) to study the metasomatites of the massif and to determine the main stages of mineral formation in them;

3) to study the distribution of rare elements in rocks and individual minerals (zircon, gagarinite, gadolinite, pyrochlore, etc.) in granites;

4) to determine the absolute age of alkaline granites in the Verknee Espe deposit; this data can contribute to the successful forecasting of rare earth deposits in other regions of the Republic.

Resolving the above tasks as a result of the conducted research allowed the candidate to defend the following main protected positions:

First protected position. Mineralogical studies of ore-bearing granites of the Akzhaylautas massif with the use of a complex of modern analytical methods made it possible to elucidate the most important questions in determining the sequence of mineral formation and the character of the distribution of rare-earth mineralization in metasomatites.

The second protected position. There were established the main element-carriers of rare earths mineralization, including narsarsukite, zircon and gagarinite, which contain genetic information of the sequence and intensity of the metasomatic processes that played a role in the REE concentration.

Third protected position. There was determined the absolute age of rare earth mineralization of alkaline granites of the Verkhnee Espe deposit, using zircon that is the most stable and informative mineral to constrain the age relationships. This data can assist in the successful forecasting of similar rare-earth deposits of the post-collisional stage.

5. Scientific novelty of the work:

1) the sequence of the stage of mineral formation in the fenitized rocks of the deposit is specified;

2) the character of occurrence of rare-earth elements in zircon crystals of hydrothermally altered alkaline granites was studied.

3) the geochronological age of mineralization related to the alkaline granites of the Verkhnee-Espe deposit is determined and specified using modern analytical research methods.

6. Practical significance

It is known that the results of mineralogical research provide significant assistance to ore enrichment specialists and technologists. Determination of mineral composition of ores at the macro level and micro level, including: the identification of typomorphic features of minerals, determination of element-impurities in minerals and the forms of their occurrence, establishing the sequence of formation of minerals and the character of zoning in their distribution; the identification of physico-chemical conditions for the formation of minerals, and the establishment of indicator minerals, make it easier to solve the most important issues in determining the genesis and age of the formation of the deposit, and also in developing new prospecting criteria. At present, no explored deposit can

progress into an operation without a detailed study of the mineral composition and identification of industrial types of the ores that make up the deposit. The study of the mineral composition of ores at the macro and micro levels allow the development of new modern methods of enrichment and rational schemes for extracting a useful component. In the proposed thesis, the above-mentioned range of topics is investigated, which determines its practical significance.

7. Main results of the study:

Research and analytical work were carried out in the LLP laboratories at the "IGS after. K.I. Satpayev", Core Research Facilities at the Natural History Museum (London, U.K.) and at the Satpayev University. The executed work concerned geochronological, petrochemical, mineralogical and geochemical (including isotope) studies.

An optical-microscopic study of more than 100 polished thin sections (PTS) of the investigated objects (Polam - MCP300 ZEISS-Axio Scope A1) has been carried out; semi-quantitative data (including graphs, diagrams and images) were obtained on a low-vacuum scanning electron microscope "Zeiss EVO-15LS" (about 200 analysis) at the Core Research Facilities at the Natural History Museum (London, U.K.).

In a number of cases, the diagnosis of minerals has been refined by the method of powder X-ray diffraction using an automated diffractometer DRON-3.0 (CuKα-radiation). Conditions for shooting the diffractogram: accelerating voltage 35 kV; anode current 20 mA; shooting detector 2 deg/min.

More than 45 complete silicate analyzes (by wet chemistry) were conducted at the Core Research Facilities at the Natural History Museum (London, U.K.) that allow the study of petrochemical features of the massifs.

A study of the chemical composition of 50 samples was carried out using an electron-probe microanalyzer JCXA 733 using an INCA ENERGY energy dispersive spectrometer at an accelerating voltage of 25 kV, a probe current of 25 nA and a focused (1-2 μm diameter) or defocused (10 μm) probe. As comparison samples were used: albite (Na), MgO (Mg); Al_2O_3 (Al); SiO_2 (Si); adularia (K); CaF_2 (F, Ca); TiO2 (Ti); Pb (PbS); Fe_2O_3·MnO (Fe, Mn), metallic Sn (Sn); V (V); Zn (Zn), U (U); Nb (Nb); Ta (Ta); ZrO_2 (Zr); x (PO_4) (x - REE); P (GaP) [1].

Diagnostics and detailed investigation of the chemical composition of ore and rare earth minerals were performed using Cameca SX100, a dedicated wavelength-dispersive X-ray electron microprobe (more than 60 analyses) at the Core Research Facilities of the Natural History Museum (London, U.K.).

The valence of iron in arfvedsonite and minerals of the astrophyllite group was determined by the Mossbauer spectroscopy method.

A cathodoluminescence analysis of 125 zircon crystals on an electron scanning microscope (Zeiss EVO 15LS) with a cathodoluminescent attachment at the Core Research Facilities of the Natural History Museum (London, U.K.) was carried out.

The absolute age of rare metal mineralization related to alkaline granite (using zircon that formed during hydrothermal mineralization) was determined using the modern highly sensitive inductively coupled plasma laser ablation mass

spectrometry method (ICP-MS-LA) at the Core Research Facilities of the Natural History Museum (London, U.K.).

During 2016 the author successfully passed two foreign scientific internships at the Department of Earth Sciences, the Natural History Museum in London (UK). This professional training was of great importance to carry out analytical studies using state-of-the-art analytical equipment in the world-class laboratory.

8. Factual material and personal contribution of the author

The thesis is based on field materials (more than 120 rock samples) and analytical study carried out by the PhD student during her doctoral studies in the period 2014-2017 at KazNITU after. K.I. Satpayev, as well as on the study of collection samples of rocks and minerals of A.V. Stepanov – the discoverer of the Verkhnee Espe deposit. The work was carried during the implementation of state budget research commissioned by the Science Committee of the Ministry of Education and Science of the Republic of Kazakhstan on the topics: "The discovery of new minerals in Kazakhstan for the deep processing of natural raw materials" (№ state. reg. 0000000 head of the project Bekenova G.K.), "Creation of a database on unique, rare and insufficiently studied minerals of deposits of noble and rare elements of Kazakhstan for complex development of mineral raw materials" (№ state. reg. 00000 head of the project Bekenova G.K.). In addition to the author's own materials, research results of A.V. Stepanov and the scientific leader G.K. Bekenova were also utilized. A number of the previous research works were also used, including: Korzhinsky D.S., Mineev D.A., Beus A.A., Balashov Yu.A., Belova N.A., Stepanov A.V., Kosals Ya. A., and others, as well as groups of foreign authors whose publications are listed in the list of sources.

Approbation of work. The results of the research and the main conclusions of the thesis were reported at the international scientific and practical conference dedicated to the 100th anniversary of academicians of the Academy of Sciences of the Kazakh SSR Kayupov A.K., Shcherba G.N., Corresponding Member of the Academy of Sciences of the KazSSR Zhilinsky G.B., and the 90th anniversary of the academician of the Academy of Sciences of the Kazakh SSR Abdulin A.A., on the theme of "*Geological science and development of Kazakhstan's mineral resources in the framework of the 2050 development strategy"* at the IGS after K.I. Satpaev (Almaty, December 18-19, 2014), international conference of "Satpaev Readings" on the theme of *"The role and place of young scientists in realizing the new economic policy of Kazakhstan"* (Almaty, KazNTU, April 11-13, 2015), and international conference on the topic of *"Ontogeny, phylogeny and the system of minerals"* (Miass, Russia, 05-09 October 2015). The main findings of the study were reported at the 15th international multidisciplinary scientific geoconference SGEM 2015 (Albena, Bulgaria, June 13-20, 2015), the international scientific and practical conference on *"Sustainable scientific and technological development of trends and technologies"* devoted to the 25th anniversary of the National Engineering Academy of the Republic of Kazakhstan (Almaty, October 10-11, 2016), the 39th international annual winter conference *"Mineral deposits studies group-MDSG"* University College Dublin (Ireland, January 4-7, 2016), and at the 40th Annual International Winter Conference *"Mineral deposits studies group-*

MDSG", University College Bristol (Bristol, United Kingdom, December 19-21, 2016).

Publications. 15 works were published on the topic of the thesis, including 3 articles in journals recommended by CCSS of the Ministry of Education and Science of the Republic of Kazakhstan (Izvestiya NAS RK (series of geology and engineering sciences), Vestnik of EKSTU, Vestnik of KazNITU); 2 articles in the journal included in the Scopus database; 2 abstracts in the journal of Applied Earth Science, part of Thomson Reuters; 8 articles in the materials of international scientific conferences of the far and near abroad.

Structure and amount of work. The thesis consists of an introduction, seven chapters, a conclusion, an appendix and a list of cited literature (103 titles). The total amount of work is 148 pages, including 93 figures and 21 tables.