ABSTRACT

PhD Thesis, Degree in Geology and Mineral Exploration (Code 6D070600)

GEOLOGY AND METALLOGENY OF THE KALBA-RUDNY ALTAI JUNCTION (SOUTHERN ALTAI)

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General characteristics of the research. The thesis investigates the formation and location patterns of rocks, ore-bearing structures, and mineral deposits in the Southern Altai region, with implications for the mineral potential and exploration criteria, aiming at enhanced and sustainable use of the East Kazakhstan mineral resources. The study region is a unique natural laboratory which accommodates numerous deposits of iron, copper, lead, zinc, gold, rare metals and other mineral resources, which make basis for mining and metallurgical industry with developed infrastructure. Extended exploration for base metals, gold, and rare metals to be mined and processed at the active operations is the key prerequisite for further development of East Kazakhstan.

Keywords: Southern Altai, ore belts, deposits, iron, copper, polymetals, gold, rare metals, forecasting.

Rationale: The Southern Altai structures in Kazakhstan occur on extension of the Great Altai metallogenic belts (Kalba belt, Irtysh shear zone, and Rudny Altai) and may store yet undiscovered deposits of copper, gold, rare metals, etc.

The object of research are the Rudny Altai, Irtysh, Kalba-Narym zones, as well as the south-eastern continuation of the West Kalba zone.

The subject of research are the leading geological and industrial types of deposits of copper, polymetals, precious and rare metals (Karchiga, Maralikha, Cherdoyak, etc.).

Goal: Investigation into different tectonic settings of Southern Altai and their metallogenic prospects (copper, gold, rare metals, etc.) for improved exploration strategies.

Objectives:

1. Prioritize exploration targets for the Southern Altai region based on synthesis of previous survey and exploration data and theoretical research.
2. Relate different types of mineralization in the region to particular tectonic settings, from the Precambrian through the Cenozoic, and compare the Southern Altai tectonic and metallogenic conditions with those in the Rudny Altai, West and East Kalba areas.
3. Develop exploration criteria for different genetic types of mineralization and estimate the potential for new discoveries.
4. Identify the priority areas of exploration.

Data and methods: The work has been carried out at the D. Serikbaev East Kazakhstan Technical University, Department of Geosciences and Environment (Ust'-Kamenogorsk). The study is based on synthesized data of geological and

geophysical surveys and exploration performed previously in the Southern Altai region, with reference to the technical report *Additional 1:200,000 Geological Surveys in the Zaisan Area, AGS-200, Sheets M-45-XXV, XXXI* (2014-2016), as well as to the results obtained in Project AP08052371 *Non-Conventional Sn-Ta-Li Deposits: Formation Patterns, Exploration Criteria, and Estimation of Resources, with Implications for the Rare-Metal Potential of East Kazakhstan*. A. Bisatova, the doctoral candidate, participated in field observations and sampling of ores and rocks for laboratory analyses in the course of the Project.

The data from previous studies were synthesized from reports and publications available at the *Vostkaznedra* East Kazakhstan Interregional Geological Department of the Kazakhstan Ministry of Environment, Geology, and Natural Resources (Ust'-Kamenogorsk). Other data were provided by several institutions: K.I. Satpaev Institute of Geosciences, Kazakhstan Academy of Sciences, Altai Division (Ust'-Kamenogorsk); A.P. Karpinsky Russian Geological Research Institute (St. Petersburg); *Topaz* Exploration Company (Ust'-Kamenogorsk); etc.

The analytical techniques applied to the samples of rocks and minerals included X-ray diffraction (XRD) and X-ray fluorescence (XRF) analyses, mass spectroscopy with inductively coupled plasma (ICP-MS), and other advanced methods. The analytical work was conducted at several laboratories: *VERITAS* Advanced Laboratory, D. Serikbaev East Kazakhstan Technical University, Department of Geosciences and Environment (Ust'-Kamenogorsk); Testing Center *VK Lab Servise* (Ust'-Kamenogorsk); Analytical Center, V.S. Sobolev Institute of geology and Mineralogy (Novosibirsk); and partly at Akita University (Akita, Japan). The instruments used for the analyses were an *Agilent 7500cx* mass spectrometer (ICP-MS), a *JSM-6390LV* scanning electron microscope, and a *CPB-1M* XRD spectrometer (Analysts A.V. Rusakov, A.B. Sadibekov, and S.N. Polezhaev). The data for the Southern Altai iron, base-metal, gold, and other deposits were compared with those for their counterparts in the Rudny Altai, West Kalba, and other areas.

Study highlights:

1. The mineral deposits and occurrences of Southern Altai have been systematized with regard to the tectonic settings and geological history of the region. Mineralization types, main ore complexes, typical deposits and their host rocks have been identified correspondingly, with a focus on practical value (Table 1).

2. The Southern Altai mineral deposits and occurrences were compared with those of the West Kalba area in terms of mineralogy and chemical compositions of rocks and ores. The revealed similarity features, along with geological evidence, indicate that the Kalba gold belt extends southeastward into the territory of Southern Altai, where gold may occur as well.

3. Pegmatitic (Ta, Nb, Be), albite-greisen (Li, Ta, Sn), and greisen-quartz vein (Sn, W) mineralization types have been proven to differ in age and to be genetically related with the Kalba postcollisional granitoids (P_1). Albite-greisen (apogranitic) Ta, Sn, W, and Li mineralization was found out to be associated with the phase II Kalba granites which share temporal and compositional similarity with the Li-bearing granites of the Novo-Akhmirovo and Alakh deposits.

4. The revealed formation conditions and distribution of geological structures and mineral deposits in the active tectonic setting of Southern Altai, as well as the suggested geodynamic, geological, structural, petrological, mineralogical, and geochemical criteria for mineral exploration provide a theoretical basis for further prospecting work.

Scientific novelty:

1. On the basis of modern geotectonic concepts, the regional position of geological and ore-bearing structures of the Southern Altai, formed during the collision of the Jonggaria and Siberian cratons with an intense manifestation of folding-thrust deformations, dynamometamorphism and hydrothermal-metasomatic transformations, fixed in the form of a complex wedge-shaped virgation beam, have been clarified.

2. A complete taxonomy of deposits and ore occurrences in the Southern Altai has been developed using modern scientific concepts of geodynamic conditions and sedimentation regimes.

3. The regularities of the formation and placement of the leading types of deposits in the Southern Altai have been clarified, and they have been compared with world analogues.

4. Based on new geological data and the results of determining the absolute age, the formation of gold ore objects in a collisional geodynamic situation and spatial-genetic connection with small intrusions of plagiogranites and dikes of the Kunush complex (C_3) have been substantiated, which by a number of authors belong to adakite-type granites.

5. The main similarities and differences between the studied objects and the gold deposits of Western Kalba have been established.

6. New results were obtained on rare metal objects of the Southern Altai.

Practical value. The developed exploration criteria for the principal mineralization types (sulfides, iron, base metals, gold, and rare metals) have been used to estimate the mineral potential of the region, as well as to outline new exploration areas and prospects for 1:200,000 deep geological surveys (DGS-200). The results made basis for practical recommendations to be used in further exploration work. The candidate has got a certificate confirming the application of the results in production operations.

Application: Geology

Reports and publications: The main results of the study were reported in twenty two publications, including three papers in journals recommended by the Committee for Control in Science and Education, the KMSE; four papers in *Scopus* and *Web of Science* journals, two papers in a journal from the Russian Citation Index list; three papers in other international journals.

Publications in international peer-reviewed scientific journals included in the Scopus and Web of Science databases:

1. Bissatova A.Y., D'yachkov B.A., Mizernaya M.A., Zimanovskaya N.A. et al. Specific Features of Geotectonic Development and Ore Potential in Southern Altai (Eastern Kazakhstan) // Geology of Ore Deposits. – 2021. – Vol. 63, No. 5. – P. 383–408. https://doi.org/10.1134/S1075701521050020 **Q2**

2. Bisatova, A.E., Dyachkov, B.A., Oitseva, T.A., Kuzmina, O.N. Prospect for expansion and replenishment of rare metal resources and reserves in eastern Kazakhstan // Gornyi Zhurnal. – 2021. – №8. – P. 90-95. DOI: 10.17580/gzh.2021.08.17.

3. Bissatova A.Y., D'yachkov B.A., Mizernaya M.A. et al. Mineralogical Tracers of Gold and Rare-Metal Mineralization in Eastern Kazakhstan // Minerals. – 2021. – Vol.11 (3), 253. – P. 1-21. https://doi.org/10.3390/min11030253 **Q2**

4. Bissatova A.Y., Dyachkov B.A, Aitbayeva S.S., Mizernaya M.A., Amralinova B.B. New data on non-traditional types of East Kazakhstan rare metal ore // Naukovyi visnyk Natsionalnoho Hirnychoho Universytetu. – 2020. – №4. – P. 11-16. https://doi.org/10.33271/nvngu/2020-4/011

The research results have been tested at several republican and international scientific conferences. The conferences are namely:

1. *Metallogeny of Kazakhstan*, International R&D Conference, Almaty, 2017;

2. *Correlation of Altaids and Uralids: Deep Structure, Stratigraphy, Magmatism, Geodynamics, and Metallogeny*, IVth International Conference, Novosibirsk, 2018;

3. *Universities for Innovative Economy*, International Conference in Science and Technology, 60 years of D. Serikbaev East Kazakhstan Technical University, Ust`-Kamenogorsk, 2018;

4. *Subsoil of Kazakhstan: Basic Premise for Sustainable Development and Prosperity*, International Conference, 120th Anniversary of K. Satpaev, Ust`-Kamenogorsk, 2019;

5. *Resources of Diamond, Rare and Base Metals: from Prospecting to Mining*, First Early-Carrier Science & Education Conference, Moscow, 2020;

6. *Correlation of Altaids and Uralids: Deep Structure, Stratigraphy, Magmatism, Geodynamics, and Metallogeny*, Vth International Conference, Novosibirsk, 2020;

7. *Exploration for Diamond, Rare and Base Metals and Estimation of Resources: Theoretical and Methodological Background*, X International R&D Conference, Moscow, 2021.

Structure and volume: The thesis consists of *Introduction*, five chapters, and *Conclusions*. 166 pages, 67 illustrations, 18 tables and one appendix. The bibliography includes 107 references.

The *first section* of the dissertation is devoted to the current state of the study of the geology and metallogeny of the Southern Altai.

The *second section* discusses the features of the geological structure and metallogeny of the study area.

The *third section* describes the leading types of deposits and their assessment.

The *fourth section* is devoted to the regularities of formation and forecasting criteria of the leading geological and industrial types of deposits in the Southern Altai.

The *fifth section* provides an assessment of the prospects of the studied territory.

In *conclusion*, the main conclusions of the dissertation research and their practical significance are presented.