Geodynamic issues of ore deposits in Central Asia

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Abstract

The focus of this study is on a pressing issue in ore geology, specifically the geodynamics of ore formation. The paper delineates a comprehensive methodology for examining the geodynamic context in regions hosting endogenous mineralization. The foundation for reconstructing geodynamics lies in geological and structural investigations into the circumstances surrounding mineralization, complemented by outcomes from physical modeling. Tectonic tension and deformation analyses of ore fields and deposits further contribute crucial insights.

The study underscores that understanding the geodynamic setting is paramount for elucidating the processes leading to ore formation. This involves a detailed examination of geological structures, conditions of mineralization, and physical modeling results. By adopting this approach, the research provides a robust framework for reconstructing the geodynamic conditions prevalent during the period of ore formation.

As a practical application of this methodology, the paper presents results from the reconstruction of the geodynamic situation during the ore formation period in a gold deposit situated in Western Uzbekistan. These findings contribute to a deeper comprehension of the geodynamic processes associated with the formation of valuable mineral deposits, thereby enhancing our ability to interpret and potentially predict similar occurrences in ore geology.

1 Introduction

The era of discovery of near-surface deposits and those reaching the surface is gradually ending. For many states whose subsoil is rich in mineral resources, there are certain expansion problems. As we know, solutions to problems largely depend on the effectiveness of the results of prospecting and exploration work, the discovery of new mineral deposits, as well as on the introduction into production of new methods of geological research and technology for processing geological data.$^1$-$^3$
of these phenomena is that ore formation processes accompanied them in all eras of Earth's tectogenesis.

Ore formation processes occur against the background of activity of the earth's crust and are characterized by heterogeneity in the geological structure and set of tectonic elements. The activity of the earth's crust is caused by the movement of blocks and discontinuous structures and at the same time forming new elements of tectonics.

The study of the dynamics that determined the movements of a section of the earth's crust and the activity of its structural elements, against the background of tectonic tension and deformation during the period of ore formation, makes it possible to decipher the geodynamic situation of the area where mineralization occurs, as well as to determine the mechanism of development of ore-controlling structures.

The results of these studies will make it possible to identify new favorable structural positions, the mechanism of their formation similar to the studied adequate reference objects, as well as the geodynamic situation against which these processes occurred.

2 Materials and methods

The methodology for studying the geodynamics of ore formation of deposits is aimed at reconstructing the geodynamic situation of the area where mineralization occurs before and during the occurrence of mineral formation processes. At the same time, the main attention is paid to the geological and structural elements that controlled the placement of mineralization. The problem is solved using a complex of geological research methods, where an important place is occupied by the method of geological-structural analysis of the conditions of mineralization placement with the determination of the factors of its control, the founders of which are A.V. Korolev, P.A. Shekhtman, F.I. Volfson, E. N. Nekrasov.

No less important in all its levels of studying geodynamics are studies of tectonic tension and deformation of the earth's crust. The study is carried out within the framework of experimental tectonics, using the method of physical modeling of the structures of ore fields and deposits developed by M.V. Gzovsky (1975) and D.N. and improved V.A. Koralev, I.D. Fathuyalaev, M.K. Turapov. The importance of studying these features lies in the fact that all geological processes of the Earth are closely interrelated with its tension and deformation.

Studying the tension of the area where mineralization is manifested and its structures, as well as deformation and dynamics, makes it possible to establish the mechanism of formation and development of ore-controlling structures; in addition, the relationship between the activity of tension structures and deformation with ore formation is determined.

Thus, the basis of the methodology for studying the geodynamic situation of ore formation, within ore fields and deposits, is the results of studying the geological and structural conditions of the formation and placement of endogenous mineralization, as well as data from modeling tectonic stresses and deformations in the structures of ore fields and deposits.

3 Results and discussion

To date, methods for studying the geodynamics of local ore-bearing areas, developed at the Institute of Mineral Resources at the University of Geological Sciences of the State Committee for Geology of the Republic of Uzbekistan, have reconstructed the geodynamic situation of gold ore fields and deposits of Chatkal-Kuraminsky (Chadak, Kyzylalmasay, Kauldy, Kochbulak) and Kyzylkum (Muruntau, Kokpatas, Turbay, Daugyztau, etc.) regions. The main reasons that determined the geodynamic situation at the sites, as well as the severity of geodynamics before and during ore formation, were determined.
Research by Kh.M.Abdullaev, A.V.Korolev, P.A.Shekhtman, F.I.Volfson, E.N.Nekrasov, V.A.Nevsky, V.F.Chernyshev, V.P.Fedorchuk, Kh. A. Akbarova, M.K. Turapova, N. Asanalieva, etc., on ore fields and deposits of Central Asia with endogenous mineralization, made it possible to identify the main factors controlling mineralization, where the main factor is the structural factor. This ore-controlling factor includes: folded, faulty, contact, volcanotectonic structures. Among them, a special place is occupied by discontinuous structures that develop as ore-bearing structures, in folds, at the contact of intrusive formations in a system of volcanotectonic interfaces. However, the mechanism of their formation and development before and during ore formation have not been sufficiently studied. The solution to this urgent problem would largely allow for the purposeful and effective implementation of forecasting and prospecting work on the flanks and deep horizons of known and developed deposits [7-9].

The formation and development of ore-controlling structures occurs against the background of tension and deformation of the earth's crust, which are closely interrelated. The manifestation and combined influence of the internal and external forces of the Earth change the structure, structure and composition of the earth's crust, which is always in motion. In addition, they influence tectonic tension and deformation, activate previously laid structures and can form new ones, which in the future can become the main cause of the manifestation of various geological phenomena, including ore ones. These processes together determine geodynamics, that is, the geodynamic situation of the earth's crust.

Research by Kh.A.Abdullaeva, I.Kh.Khamrabaev, A.V. Korolev, F.I. Volfson, E.N. Nekrasov, V.P. Fedorchuk, V.A. Nevsky, V.F. Chernyshev, V.A. Korolev, Kh.A. Akbarov, P.V. Pankratov, M.U. Umarkhojaev and other geological and structural conditions for the placement of endogenous mineralization, in various geological and industrial types, gold-silver, lead-zinc and other deposits, make it possible to clearly identify the structures that controlled the placement of mineralization, as well as determine the time of their formation, in relation to ore processes [1, 2, 3, 4, 5, 6].

Considering that one of the supporting elements of the developed methodology for studying the geodynamics of ore fields and deposits is data on the geological and structural conditions of the formation and placement of mineralization.

Deciphering the geodynamic situation of ore formation is primarily based on data from the study of regional geological processes that determined this geodynamics, making it possible to determine and clarify the direction of regional tectonic forces acting on the studied ore-bearing ore formations.

The study of the geodynamics of ore fields and deposits consists in determining active structures, the influence of their activity on tension and deformation, on the movement of tectonic blocks and ore-controlling structures, in a certain complex relationship between the processes of activity of blocks, discontinuous structures, tension and deformation, with the manifestation of ore mineralization. The main thing is to decipher the kinematics of the formation and development of ore-controlling structures, to determine their physical state before and during ore formation. In addition, the reason why endogenous mineralization is localized in certain local areas (structural positions) of ore-controlling structures is established, despite the fact that the structures are often many kilometers long. Within the framework of the above-mentioned methodology, below we will consider the results of the work carried out to study the geodynamic situation of one of the gold mining objects of Western Uzbekistan during the period of ore formation and development.

As is known, the geological and structural position of the studied ore field is determined by its location at the intersection of the Daugyztau dislocation zone with the Beltau-Daugyztau fold-fault structure [10]. One of its main objects is a gold deposit, confined to a structural position caused by the intersection of the Daugyztau and Asaukak faults. In the geological structure, two structural floors are distinguished: the lower Paleozoic structural floor,
composed of metaterrigenous formations and the Rakhats suite, and the upper Mesozoic-Neogene structural floor. The ore-bearing formations are the formations of the lower structural floor. The spatial distribution of ribbon-shaped and lens-shaped ore bodies is controlled by northwestern and northeastern, submeridional faults. Before proceeding with the reconstruction of the geodynamics of ore formation of the ore field, it is first necessary to determine the geodynamic position of the territory in the central part of which the ore field is located in the regional geodynamics of Central Kyzylkum.

Central Kyzylkum is characterized by a complex geological structure, a variety of fold-fault faults and a block structure. The study of the geodynamics of the region (Fig 1), the Hercynian stage of its development, made it possible to establish that under the influence of regional tectonic forces in the northeastern direction, primarily northeastern, submeridional faults, which are the boundary elements of large tectonic blocks, became active.

The activity of the faults caused the movement of the blocks, which was reflected in the internal structure and stress-strain state of each block. Beltau is one of such elongated blocks, where the western and eastern boundaries are anti-Tienshan transverse deep faults, which also began to move when the region was exposed to regional tectonic compression forces (the impact of microplates according to L.P. Zonanshain, T.N. Dalimov, Yu.S. Savchuk, R.Kh. Mirkamalov, etc.). The movement along the boundary faults occurred counterclockwise, and therefore the eastern part of Beltau is relatively displaced to the northeast, and the western part to the southwest. The impact of multidirectional forces on the Beltau area led to the formation of northeastern fault systems, while tectonic tension drops to a minimum, with a weakening of the general deformation of Beltau.
As a result of the formation of new fault structures, their activity, as well as the activity of earlier formed faults, fragmentation of the Paleozoic foundation occurred, with the formation of block structures.

It was in such a geodynamic environment, determined by the influence of regional tectonic forces, as well as magmatic processes, that the formation of gold ore objects took place, including the studied and other gold deposits and numerous ore occurrences.

A study of the geodynamics of the ore field during the period of gold mineralization (Fig. 2), based on a comprehensive analysis of geological, structural and tectonophysical data, shows that by the stage of ore formation, with the object, there were faults of the northeastern and latitudinal systems, transverse anti-Tien Shan deep faults. The gradual formation of these fault systems divided the area of the ore field into a number of small tectonic blocks. The block structure and system of discontinuous structures determined the structural framework of the ore field.

**Fig. 2.** Scheme of geodynamic settings of the period of ore formation of the studied ore field (option III): 1 - faults; 2 - local compression zone; 3 - estimated compression zone; 4 - zone of all-round compression; 5 - local tension zone; 6 - estimated stretch zone; 7 - zone of all-round tension; 8 - stretching; 9 - direction of regional compression forces; 10 - directions of displacement of local sections; 11 - ore occurrences; 12 - boundary of the Paleozoic basement.
Transverse deep and latitudinal structures have been established. Their activity caused the displacement of tectonic blocks, which was the main reason for the tectonic activity of intra-block structures, changes in tension and deformation of the blocks. These changes are especially clearly observed along the ore-controlling structures, as well as in the zones of their junction and intersection with other faults. The dominance of horizontal tectonic forces in the geodynamics of ore formation led to increased activity of northeastern structures, along the horizontal plane, in the form of shear. Movements along faults caused displacements of tectonic blocks. The blocks along which the Daugyztau, Asaukak, and Vysokovoltnoe fields are located experienced displacement in the southwestern direction. Despite the slight displacement of the blocks, it was reflected in their stress-strain state. The joint manifestation of the activity of boundary structures, tectonic blocks, the displacement of the blocks themselves and their stress-strain determined the internal geodynamics of the blocks, where renewal of intra-block structures and new structure formation are observed. In addition, these processes contributed to the formation of opening cavities along the northeastern ore-controlling structures, in the zones of their interface with the Daugyztau deep fault, creating structural positions favorable for the placement of endogenous gold mineralization. It was in these structural positions that the Daugyztau and Asaukak fields were subsequently formed. Their structural position is confined to a block with a wedge-shaped shape formed due to the conjugation of northeastern faults with the Daugyztau fault at depth. The geodynamic setting of the areas of these deposits is determined by the horizontal displacement of tectonic blocks. The displacement of blocks and wedge-shaped morphology, under the influence of regional tectonic compression forces, contributed to the formation of opening cavities and synchronously with these processes, new detachment structures were formed, complicating the internal structure of the ore-controlling structures and their near-fault space, which led to decompression of the host environment, which was one of the reasons for the influx of ore-bearing solutions from the depths of the Earth and, subsequently, the formation of gold deposits.

The conducted mathematical and statistical analysis of data on the pattern of distribution of gold ore occurrences in Western Uzbekistan (Table 1) shows that about 33% of all gold deposits and ore occurrences in the region are located in the zones of regional northwestern faults.

Table 1. The relationship between gold ore objects and regional faults of Western Uzbekistan

<table>
<thead>
<tr>
<th>Name of the regional structure (numbers on the map) &quot;Regional faults of Central Asia&quot;</th>
<th>Genetic type (according to M.A. Akhmadzhanovich, O.M. Borisov, Zh. Yakubov, A.K. Bukharin and others)</th>
<th>Distribution of gold occurrences in fracture zones in %</th>
</tr>
</thead>
<tbody>
<tr>
<td>North-Kyzylkum (42)</td>
<td></td>
<td>0</td>
</tr>
<tr>
<td>Bukantau (46) rise</td>
<td></td>
<td>0.6</td>
</tr>
<tr>
<td>Central Kyzylkum (47) rise</td>
<td></td>
<td>0</td>
</tr>
<tr>
<td>Tamdy-Karatyr (66)</td>
<td></td>
<td>0</td>
</tr>
<tr>
<td>Besapan-South Fergana (67)</td>
<td></td>
<td>3.4</td>
</tr>
<tr>
<td>South Tamdy-Katran (68)</td>
<td></td>
<td>5.1</td>
</tr>
<tr>
<td>Aristantau-Taldyk (69)</td>
<td></td>
<td>2.3</td>
</tr>
<tr>
<td>Auminzatau-Surmetash (70)</td>
<td></td>
<td>≈8</td>
</tr>
<tr>
<td>Aktau-Turkestan (71)</td>
<td></td>
<td>0.6</td>
</tr>
<tr>
<td>Karatau-Zarafshan (72)</td>
<td></td>
<td>4.5</td>
</tr>
<tr>
<td>Kulzhuktau-Zarafshan (73)</td>
<td></td>
<td>0</td>
</tr>
<tr>
<td>Zirabulak-Dukdan (74)</td>
<td></td>
<td>1.7</td>
</tr>
<tr>
<td>Zirabulak-Magian (75)</td>
<td></td>
<td>3.4</td>
</tr>
<tr>
<td>South Tien Shan (76)</td>
<td></td>
<td>≈3.0</td>
</tr>
<tr>
<td>Utegen (112)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Number of objects 176

≈33%
4 Conclusions

In conclusion, we note that the geodynamic situation of the area of the studied ore field with gold mineralization, manifested in the Hercynian metallogenic era, is determined by the regional tectonic regime, where horizontal movements occupy a dominant position. Horizontal forces caused activity (shift) of the northeastern, latitudinal ore-controlling faults, and they, in turn, caused tectonic blocks. These tectonic phenomena affected tension and deformation, and a redistribution of tectonic stresses occurred both along fault zones and within tectonic blocks. Zones of local compression and tension deformation were formed. The latter is characterized by a drop in tectonic tension, which was a favorable environment for the manifestation of gold mineralization. Geodynamic processes observed along ore-controlling faults and tectonic blocks contributed to the formation of cavities, the opening of cavities, and the formation of new structures, which also provided a favorable environment for the formation of gold ore objects.

References