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Research Article

STRUCTURAL TECTONIC FACTORS IN THE FORMATION OF MINERALIZATION ZONES IN THE SOUTHWESTERN HISSAR MOUNTAINS

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ABSTRACT
The article covers Yakkabagtag, Chakchar, Baysuntag and Surkhantag located on the territory of Southern Uzbekistan, the research work was carried out to create a map of the tectonic density of rocks in the Arc GIS program, as well as to analyze the relationship with cracks, deposits and ore manifestations identified as a result of previous geological and geophysical studies. The purpose of these works is to make it known that many solid mineral deposits and ore occurrences were formed at the intersection of earth faults and with a high density coefficient.

Keywords: *Tectonic, Faults, Zone, Crust, Earth's Crust, Southern, Relief, Landscapes, Satellite Imagery, Structural-Formation Zones, Hissar Intrusive*

INTRODUCTION

Currently, great attention is paid in our country to modern advanced areas in the field of geology. The geological industry is the basis of our country's economic growth. Thanks to modern aerial surveys and Earth sounding from space, comprehensive knowledge of the Earth's interior, forecasting of mineral deposits, studying the state and changes of the lithosphere under the influence of technogenesis, and organizing operational monitoring of the geological environment have become real. Remote sensing methods have opened up wide prospects for geological research, and in many ways predetermined the development of geology and other Earth sciences.
Modern remote sensing data are represented by multispectral and radar materials, the geological and predictive search information content of which is significantly higher than satellite images of the "visible" ranges. The processing of multispectral and radar data requires special knowledge and technology.

MATERIAL AND METHODS

The information obtained using space remote sensing sensors makes it possible to clarify existing ideas about the geological structure of the studied territory: it helps to detect previously unidentified, difficult to diagnose or "hidden" structures in the upper floors and at deeper levels of the earth's crust, which are inaccessible to generally accepted geological and geophysical methods of their recognition [3]; makes it possible to see the structure of territories in the form of an ordered system of morphostructures of various types and ranks, which is important for further structural-geomorphological and predictive prospecting studies, as well as for developing general ideas on the dynamics of metallogenic processes; helps to obtain information for hard-to-reach and poorly studied areas with a powerful cover of Mz-Kz sediments, changing climate and poor transport infrastructure.
The area of work covers the Southwestern spurs of the Hissar ridge, located on the territory of Kashkadarya and Surkhandarya regions.

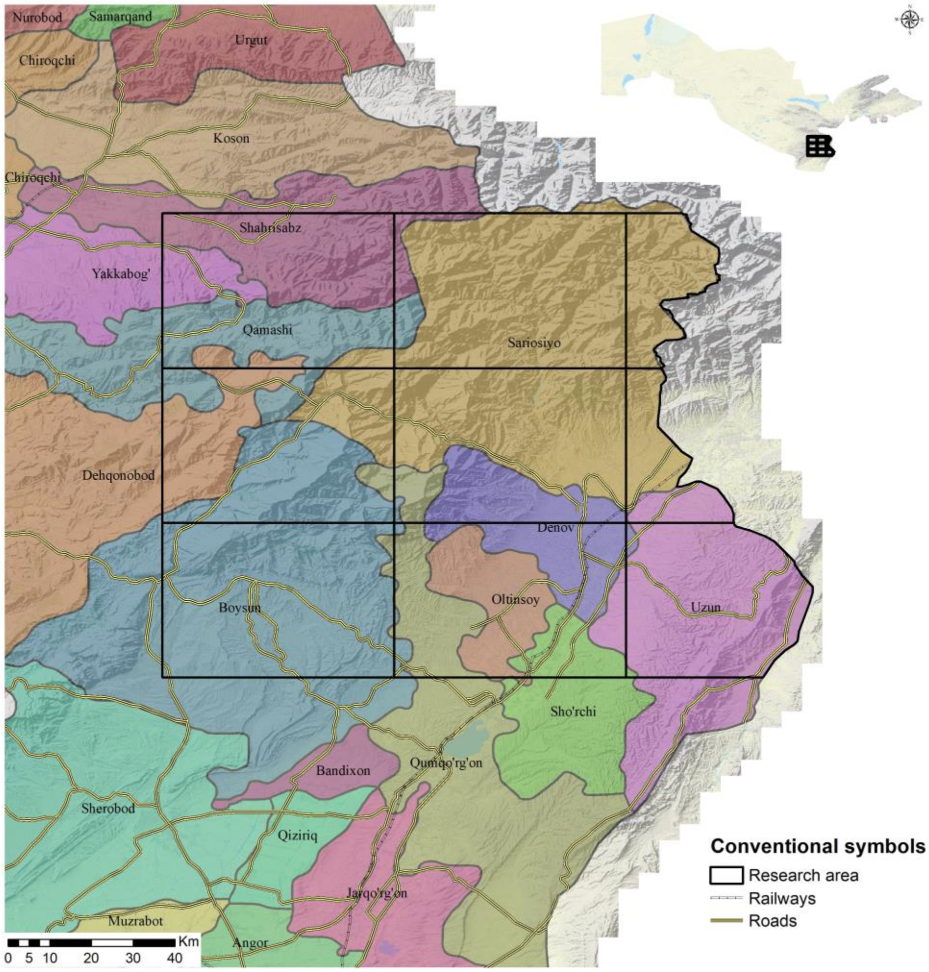

Figure 1: Overview map of the research area

The research area is divided into two structural regions based on its structural, lithological, and cosmogeological characteristics:

1. Southern-Hissar Region
2. Boysun-Kugitang Region

Southern Hissar Tectonic Region: Geographically, this corresponds to the southern slopes of the Hisor Range and is part of the Zarafshan-Oloy structural formation zone. The described tectonic area mainly consists of the granitoids of the Hisor Massif and the rocks of the adjacent southern boundary of the Orol-Yoy formation, including andesites, basaltoids, porphyrites, and others.

The area is distinguished by dense dark gray phototones and sharply inclined relief in satellite images. The phototones of both granitoids and volcanic layers are very similar, with the only distinction being the characteristic fracture pattern in the granitoids, setting them apart from volcanic rocks.

To the south, the Southern Hissar tectonic region is bordered by the Bogain fault zone along the subkenetic boundary. The fault is marked by an intensive fragmentation zone with a thickness of about 200 meters. Small serpentinite bodies (possibly a serpentinite mélange) are located along the boundary of the Bogain fault zone. The Bogain fault zone can be considered the point of intersection of the Boysun contingent and the Turkmen-Hissar ocean, forming a Silurian fracture zone (shov). The Bogain fault is clearly displayed in the western physical fields.

Boysun-Kugitang tectonic region: Geographically, this region encompasses the southern-western ranges of the Hissar Range, including the Yakkaboghtov, Chakchartov, Boysuntov, Surkhontov, and Kugitangtov mountains, as well as the adjacent desert and proluvial plains.

The described area is systematically very unique. The ranges are oriented in a submeridional direction (unlike the Hissar and Zarafshan ranges, which extend in a latitudinal direction) and converge at the ends to join the Hissar Range. Here, Meso-Cenozoic formations of significant thickness are widely distributed. The mountain ranges form horst anticlines, with Proterozoic metamorphic sequences and volcanic-sedimentary island-arc formations exposed in their cores. The anticline cores are shifted eastward to Meso-Cenozoic structures. The horst anticlines are separated by wide synclines formed from Jurassic to Upper Paleogene carbonate-terrigene deposits.

The Hissar mountain ranges are separated from the Southern Tajikistan depression by wide flat valleys along the south-western direction of the Surkhon Darya, where alluvial-proluvial and aeolian deposits have developed.

The research area, as seen in satellite images, clearly reflects its unique tectonic structures. The massive, tabular Jurassic limestone formations that cover the Kugitangtau, Chakchartau, Baysuntau, and Surkhontov ranges stand out prominently. These formations are clearly visible in satellite images across all scales.

The phototones vary from light gray to dark gray, with micro- and mesorelief forms changing across a wide range.

The described tectonic region is characterized by many photomapped horizons in the Proterozoic and Paleogene sequences. Along these horizons, various types of folded structures are reliably mapped, and the displacements along faults are clearly visible.

RESULTS AND DISCUSSION

The translation of the provided text into English with geological terminology is:

As a result of the decoding of cosmic materials in the research area, a large number of materials were obtained for linear structures identified by fault displacements. The collected materials helped identify previously mapped faults and new fractures that were previously unknown, as well as provided assistance in determining the general spatial relationships, the regularities of the fracture distribution, and their connection with folding structures.

In the decoding of lineaments and fault displacements, the following decoding markers were considered: a) the visible intersection of boundaries, b) sharp boundaries along the contact of geological formations of different ages, represented by different (phototone, photographic images) relief features such as abrupt changes, wells, straightness of valleys, fault lines, water increase, vegetation density, and others.

The clear visibility of these features in the satellite images, due to the diversity of their indicator signs, allowed for the observation of large lineaments and fractures in geological structures over long distances in various regions.

Through the analysis of satellite imagery, it became possible to identify faulted structural features in nature. The fractures appear as straight lines or slightly bent. In fragmented relief conditions, the structures of these faults and fractures are visible as sinuous curved lines.

An important part of the fault displacements becomes active during the neotectonic stage of the Earth's crust development, which allowed them to express themselves in the form of various elements of the modern relief, landscapes, and others.

In satellite images, fault displacements of the shear type were identified along the boundaries of layers with different compositions, and they appear as complex, curved lines. Frequently, continuous displacements in satellite imagery are expressed as dark or lightened, sometimes expanded to an interval, and rarely as isolated, in the form of photo-anomalies."

In geophysical fields, linear structures are identified as linear anomalies or their characteristic boundaries, while in geological fields, they are established as continuous or hidden zones of various types of one-sided structural elements (magmatic body chains, fracture zones of folds, sharp changes in orientation, and others).

The genesis of linear structures is not always clear and, most likely, they represent zones of increased conductivity in the deep horizons of the Earth's crust, reflecting heterogeneity.

As a result of the structural analysis in the research area, based on their length, straight linear structures are classified as follows:

- First-order structures extend for hundreds (up to 1000) kilometers and generally cut across various landscape zones with different decryption characteristics;
- Second-order structures are no longer than 200 km in length and can be observed in different zones with varying characteristics;
- Third-order structures span tens of kilometers, typically stand out in one landscape zone, and rarely extend into another.
- Fourth-order structures are decrypted within one landscape zone and do not exceed 5-6 km in length.

First to third-order structures likely highlight the blocky structure of the ancient basement and are primarily active during the neotectonic stage of Earth's crust development.

In the research area, fourth-order structures and shear-type structures are especially well developed in the northern part of the field.

Fourth-order structures are most clearly decrypted in cosmic imagery at the level of local generalization. In satellite imagery, they appear as straight-line relief forms (edges, extended ridges, hills, water divides), lithological boundaries, and dyke formations.

The most typical region for these structures is the north-eastern part of the area, where sub-serial linear structural formations are located; the sub-serial structure system in the Bogain fracture zone; multi-directional straight-line fracture systems observed in Paleogene-Quaternary age formations; sub-meridional structures in the Chaqchar, Boysun-Tov, and other mountains in the Surkhantau region; fault lines in the south-western areas in sub-serial zones; and the Langar shear in the northern foothills of the Yakkabog mountains.

The sub-serial structure system in the Bogaing fault zone is located in the central part of the area. The Bogain zone marks the boundary between two structural-formation zones: Zarafshan-Oloy (to the north) and South-Hissar (to the south). This structural system extends in a sub-serial direction from the middle course of the river (with a width of 4 to 7 km) from the middle course of the Tanhaz River to the middle course of the Topalang River, and is observed along the left tributary of the Khtut river, east of the studied area.

The southernmost structure of this system is the Bogain fault, which is clearly observed on the left bank of the Tanhaz River and is well decrypted along the boundary of the Cambrian-Ordovician formations with Middle-Upper Carboniferous age formations. The continuation of this fault is observed near the Chayauh village, on the left bank of the Tanhaz river. As the Cambrian-Ordovician beds approach, they are pushed over the Carboniferous.

The northern fault is a vertical fault that separates various structural and material complexes (granitoids of the Hisor Batholith and C2-3 formations) and is decrypted along the southern slopes of the Topalang river Oqsu water divide. Its northern branches intersect with granitoids, while in the south, it separates small blocks of different structural and material complexes.

To the east, this structural system is bounded by the Langar fold. It should be noted that none of the structures observed in the Bogain system belong to the Meso-Cenozoic formations.

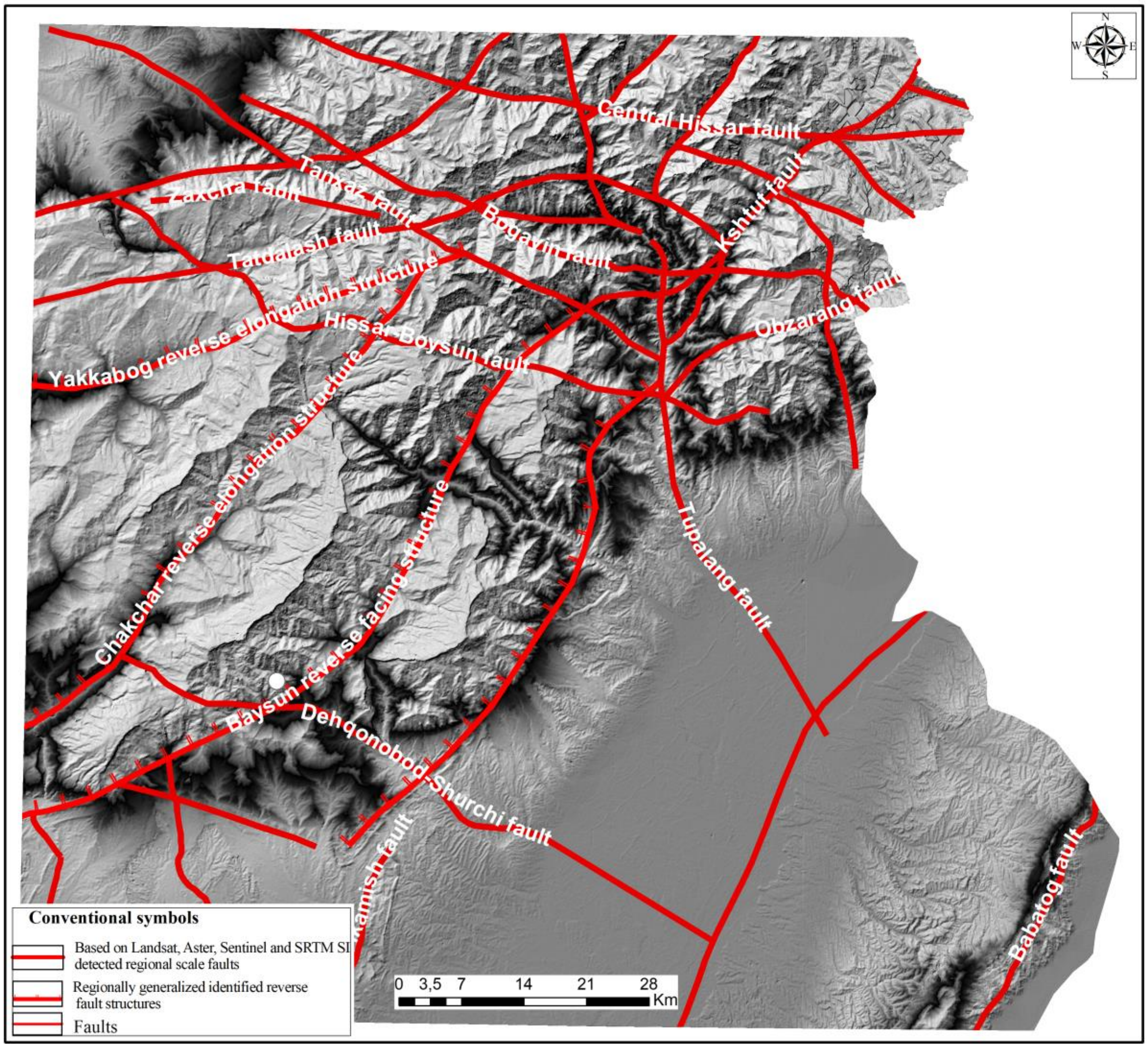

Figure 2: Main Faults Identified Through Cosmogeological and Geological Methods

The systems of equidirectional straight-line structures formed during the Paleogene-Quaternary period are most developed in the central parts of synclinal structures (Dehkanabad, Boysun, eastern part of the Kashkadarya depression) and along the left and right banks of the Surkhandarya river

In the central part of the Dehkanabad syncline, three-directional systems of straight-line small relief forms were decrypted: meridional, north-western, and north-eastern. The fractures in the north-western direction are the most widespread here, and they are concentrated within the syncline, with only a few extending outward. Meridional fractures, with an interval of approximately 16 km, divide the syncline into four parts (in the studied area). These faults extend well beyond the syncline. Among the folds, there are only two north-eastern fractures, which do not extend beyond the development of Neogene formations. These structures are typically characteristic of intersections in the extense part of the syncline.

In the northern central part of the Kofrun syncline, three directional structural systems are revealed based on small relief forms: sub-serial, north-north-east, and west-north-west. The most expanded and reliably decrypted fractures are sub-serials that are not observed outside the Neogene layer. North-east and west-north-west structures can be observed outside the fold. The decrypted structures are concentrated in the northern part of the fold.

Submeridional structures in the Chaqchar, Boysuntov, and Surkhantau mountains. These structures are located along the boundaries of various structural material complexes in the Chaqchar mountains, Chaqchar ridge, Boysun-Tov mountains—Boysun fault, and Surkhantau mountain—Surkhantau ridge. To the north, these structures are bounded by the Bogain fault (shear) zone, and to the south, these structures open in a south-western direction, transforming into vertical fractures and gradually disappearing. According to these structures, Paleozoic formations are thrust from the north-west to Meso-Cenozoic formations.

The diagonal (north-western) fault system between the Uradaryo and Kichik-Uradaryo rivers. These faults are decrypted in a range with a width of up to 20 km and typically have considerable lengths (up to 50 km). They can be traced along negative relief forms (river valleys stretching in a north-western direction) over distances of up to 70 km. These faults cut through the central part of the anticline uplift and extend beyond it, cutting through synclines.

The Langar structure extends along the northern slopes of the Yakakbogh mountains from Langar village to Qizilemchak village. The structure is well defined along the boundary of areas characteristic of the formation of Jurassic, Late Carboniferous, Cambrian-Ordovician, Middle-Upper Carboniferous formations, and granitoids of the Hisor Batholith, as well as the lower-middle Neogene complex (the underlying side of the shear). The structural line is coincident with the relief.

In addition to the regional lines and fault groups described above, numerous faults with lengths varying over several kilometers have been decrypted in the Southern Uzbekistan region. In aerial photographs, these are decrypted by specific illumination or darkening of the phototon. These faults often cross the photo field or photomarking horizons.

When identifying tectonic disruption zones, lineaments separated by remote sensing data obtained through various methods are analyzed. Today, the concept of lineament refers to the long, linear features of the relief, the axes of geophysical anomalies, and narrow line-like zonal structures with anomalous values of geophysical field gradients. The accumulated experience in lineament studies shows that they reveal directly or indirectly (partially) the features of geological structures, including fractures and tectonic disturbances that involve faults and fractures of various depths.

The term "tectonic disturbance" has a broad meaning and is used to refer to disruptions of various types, including joints, fractures, and fault zones. A fault is generally referred to as a large tectonic disturbance with a complex structure and sufficiently wide dynamic influence. Concealed faults and tectonic disruption zones, at various depths, may control the block division of the lithosphere and structural deformation, and can vary in size. These concealed faults may manifest in areas with high fracture density and low rock density, or conversely, in areas with high rock density, where the process of intrusive igneous bodies' penetration occurs, affecting the mineral deposit distribution.

Maps of the density of tectonic disruptions help justify the tectonic factors that allow the formation of mineral deposits. High values in these maps indicate a high probability of the presence of metallic ore zones. For example, in tectonic disruption zones with high density, large fold structures may form. These structures may host deposits of gold, silver, copper, and other metals.

Furthermore, the density maps of tectonic disruptions help identify areas where geological processes such as magmatic deformations, metamorphism, and changes in rock types are occurring. These processes may, in turn, be related to the formation of mineral deposits. Tectonic disruptions can lead to the redistribution and accumulation of valuable minerals, making exploration and search activities easier.

In other words, these maps help identify the most promising areas for exploring mineral deposits and assist in developing the most effective criteria and methods for exploration.

Various methods are used to create tectonic disruption density maps. In many cases, the density of linearly organized objects around a conventionally chosen cell is calculated using the Line Density and Kernel

Density commands in the ArcMap program. The following image shows the results of constructing a tectonic disruption density map of the mountains of Southern Uzbekistan based on these methods.

In the process of creating this map, linear features that closely resemble faults, as well as geological data derived from identified fault lines, served as primary data sources.

To create a tectonic disruption density map, the Kernel Density method in ArcGIS software is based on artificially enhancing the color gradients of intersecting fault zones relative to parallel fault zones. To assess the distribution density of objects in the map, the Kernel Density function in ArcGIS uses a kernel estimation method. The kernel estimation method is one of the most widely used methods for statistical analysis and evaluating the probability density of distributions, and it can be applied to various types of data, including geological information.

Thus, the line density command used in the creation of tectonic disruption density maps is based on calculating the surface area values of one of the multisegment objects within the radius of each cell. The surface area is measured in units of length. In terms of visualization, a circular area with a radius equal to the search radius is drawn around the center of each cell on the raster surface. The length value of each line segment falling within this circle is multiplied by the cell area value. These values are summed, and the result is divided by the surface area of the circle. The final result for the study area is displayed as shown (3-fig).

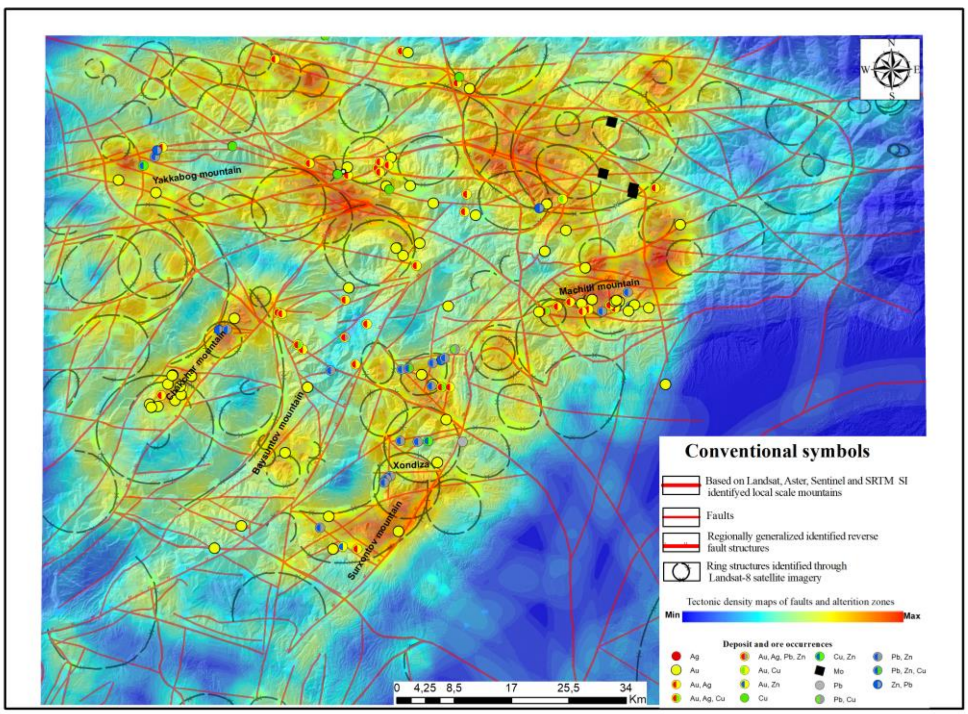

Figure 3: A fragment of minerals has been found on the map of a dense tectonic layer on the map of the sinking anomaly in the Sauthern mountains of Uzbekistan.

The methodology for creating tectonic disruption density maps, as well as the basics of numerical processing of fault networks for structural and metallogenic analysis purposes, were discussed in A.K. Glukh's dissertation (1975) and his numerous articles, as well as in several report works carried out at MRI DM (1994, 2000, 2005, 2009).

Such maps help identify tectonic zones where the likelihood of ore deposits is significantly higher. In these zones, the accumulation of mineral ores or other useful minerals can be observed, as they may be associated with tectonic disruptions. It has been confirmed that in maps created using modern software tools, ore deposits and mineral manifestations in tectonic zones with high density correspond to 70-80% of the areas. When these data were compared with geological maps, it was found that the maximum values in the tectonic disruption density map were distributed in the exocontact zones of intrusive formations.

CONCLUSION

To conclude, it can be said that the tectonic density zones for the research area were stretched mainly in the submeridional direction, which revealed anomalies in the upper mantle in the contacts of the Gissar intrusive, Bogain fault, Machitli Mountain, Kuldara-Khondiza main fault, Surkhantov fault, Machitli Mountain and Baysuntov and exactly corresponded to the mineralization zones and ore occurrences in these areas.

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