International Journal of Geology, Earth & Environmental Sciences ISSN: 2277-2081
An Open Access, Online International Journal Available at http://www.cibtech.org/jgee.htm
2025 Vol. 15, pp. 313-317/Khasanov and Ruziyev
Research Article

THE ROLE OF RING STRUCTURES IN PROSPECTING FOR MINERAL DEPOSITS: A CASE STUDY OF THE BUKANTAU AREA

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ABSTRACT
The article evaluated the significance of ring structures in the search for mineral resources in the Bokantog area based on remote sensing. Landsat-8 imagery was used to identify circular and arcuate geological structures, and their morphology and relation to lineaments were analyzed. The study results indicated a close association between ring structures and mineralization, particularly gold-sulfide mineralization. Multispectral processing and hydrothermal alteration zone detection algorithms were tested on the Derbez ring structure as a case study. The findings confirm the importance of integrating satellite imagery with geological and geophysical data to enhance exploration efficiency.

Keywords: *Ring Structures, Bukantau Area, Mineral Resources, Satellite Imagery, Remote Sensing, Lineaments, Hydrothermal Zones, Mineralization, Multispectral Processing, Exploration*

INTRODUCTION
Global practice over the last 30 years demonstrates that the use of digital satellite imagery is becoming increasingly vital in ensuring the growth and replenishment of mineral resource reserves, as well as in the effective planning of geological exploration. The sharp rise in demand for precious, rare, and strategic mineral raw materials in developed countries necessitates the rapid and cost-effective identification of structures promising for mineralization in specific regions. Consequently, integrating digital satellite imagery with geological, geophysical, and geochemical data is becoming a matter of paramount importance.
By processing such integrated datasets using statistical, structural, algorithmic, and metallogenic analysis methods, it becomes possible to conduct a deeper study of the internal structures of areas associated with mineralization processes, identify their spatial characteristics, and reliably delineate prospective zones. The application of modern digital analysis technologies-including remote sensing, artificial intelligence, clustering, and regression models-significantly accelerates the exploration process and helps provide more accurate predictions. As a result, the efficiency of geological exploration increases, resources are optimized, and the process of discovering new ore sites is elevated to a qualitatively new level. In particular, identifying structures and exploration indicators intrinsically linked to mineral deposits requires the utilization of these advanced analytical methods for the effective delineation of prospective areas.

MATERIALS AND METHODS
Ring structures are geological objects identified in aerospace imagery through color disparities, characterized by isometric, concentric, or centrally oriented shapes. They manifest as geological bodies with a clearly defined center of symmetry, possessing diverse genetic origins and ages. The term 'ring structure' was first introduced in 1904 by A. Harker to describe structures formed as a result of volcanic eruptions in Scotland. In fact, morphostructures of rounded shapes were identified in 1931 by N.P. Gerasimov and P.K. Chikhachev through geomorphological analysis [Gerasimov N.P. *et al.,* 1931]. Furthermore, they established the correlation between ring structures and their geological composition, classifying them as neotectonically rejuvenated regions of the Earth's crust.
Remote sensing data serves as a crucial tool for identifying these ring-shaped formations. Similar to systems of arcuate anticlines and synclines, brachyanticlinal uplifts, and volcanic formations, ring structures are typically reflected in the geomorphological framework of a region [Borisov O.M. *et al.,* 1977].

Regarding the specific study area, S.S. Shultz [Shultz S.S. 1973] was the first to identify ring structures in the Bukantau Mountains using satellite television imagery, referring to them as the 'arch uplifts of Central Kyzylkum' (Bukantau, Tubabergen, Irlir, etc.). This scientific problem was most comprehensively and detailedly investigated by O.M. Borisov and A.K. Glukh [Borisov O.M. *et al.,* 1982]. The authors characterized the morphological composition and geological features of ring structures in Central Asia, providing substantiation for structures located in Bukantau and adjacent areas, such as Irlir, Eastern Bukantau, Dzhetymtau, Takhtatau, and Tulkitau.

Image decoding (interpretation) of remote sensing satellite imagery provides thematic (primarily qualitative) information about the object or process under study and its relationship with the surrounding environment. In visual decoding, objects are identified and interpreted based on the reading of the photographic data.

Each interpreter (decoding specialist) inevitably brings a certain degree of subjective judgment when delineating observed formations, objects, and geological structures reflected on a geological map [P.P. Nagevich *et al.,* 2015]. This inherent subjectivity in visual interpretation results is not always a negative attribute; rather, it is analogous to the subjectivity found in cartography. During the interpretation process, the specialist performs cartographic generalization based on personal expertise: simplifying boundaries and disregarding minor or insignificant objects [Labutina I.A. *et al.,* 2011].

While methods for distinguishing regional and local tectonic structures based on brightness (color), contrast, and image texture have been automated, this chapter specifically examines the analysis of satellite image texture—namely, the directional characteristics of objects within the image. The primary focus is not merely on where and which directions are clearly manifested, but on the extent to which these directions predominate—for instance, whether orthogonal, meridional, or other orientations are prevalent.

The proposed approach is similar to the traditional photolineament analysis most commonly used in geology, where a specialist identifies linear segments of an image associated with tectonics and subsequently performs a statistical analysis of the directional distribution of these minor lineaments within a sliding window or delineates elongated lineaments. Various software packages exist to automate the analysis of manually drawn lineaments (for instance, statistical analysis in Erdas Mapper and Lessa packages; elongated lineaments can also be tracked [Koike K. 1995]).

Arcuate structures observed in satellite imagery are generally characterized as ring structures. Structural analysis of satellite images obtained through infrared and radar methods was conducted using **WinLessa** and **PCI Geomatica** software. In satellite imagery, these structures are manifested by spectrometric anomalies and image patterns, often defined by systems of concentric and arcuate tectonic elements. While ring structures have been known for a long time, the advent of satellite imagery has made them a subject of particular focus for geologists. The significant interest in them arises not only from their identification across almost all global regions via satellite data but also from the fact that more than 50% of them are associated with various mineral deposits. In certain cases, ring structures form at the intersection nodes of Earth's crustal fractures (Figure 1).

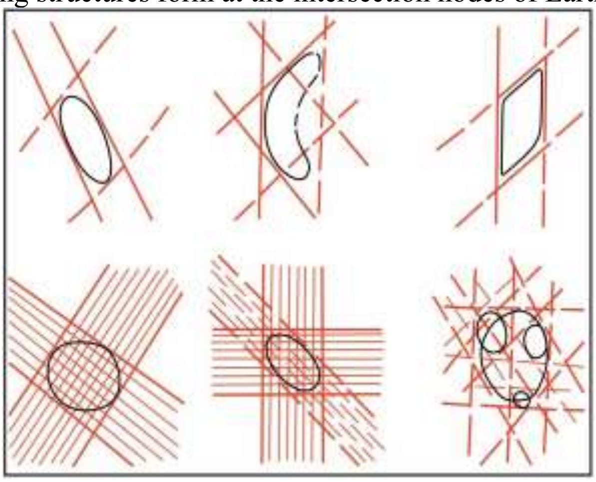

Figure 1. Schematic diagram illustrating the dependence of ring structure configurations on the characteristics of intersecting lineaments (based on data from V.I. Makarov and L.I. Solovyeva).

The generally accepted genetic classification includes **monogenic ring structures**, formed under the influence of a single primary geological process, and complex **polygenic ring formations**. Among monogenic structures, endogenous, exogenous, and cosmogenic types are distinguished. Endogenous structures may arise through various internal processes, including tectonic movements (tectonogenic), magmatic activity (magmatogenic), and the transformation of pre-existing rocks alongside the formation of new ones (metamorphogenic) [Nurkhodjaev A.K. *et al.,* 2017; Goipov A.V. *et al.,* 2021].

In the process of studying (identifying) ring structures, a consistent sequential approach must be implemented. This is a fundamental two-stage framework:

1. Detection (Manifestation) Stage;
2. Identification (Correlation) Stage.

The first stage concludes with the interpretation of remote sensing materials using topographic maps, as well as geological and geophysical data. The second stage involves determining the age, formation mechanism, and genetic origin of the geological body and tectonic structure. At this stage, standard geological and geophysical research methods are applied.

Ring structures can be delineated using various methods:

- Geological (through mapping/imaging);
- Geomorphological (through analysis of relief structures);
- Geophysical (through analysis of magnetic and gravity anomalies).

However, the primary and most essential method remains the interpretation of satellite imagery [Nurkhodjaev A.K. *et al.,* 2017; Goipov A.V. *et al.,* 2021]."

In the interpretation of ring structures, the primary indicators include the arcuate bending of river networks and mountain ranges, arc-shaped crustal fractures, and the arcuate boundaries of cosmogeological complexes. Furthermore, rounded positive or negative morphostructures, along with photographic and photometric features, serve as key diagnostic signs that reflect the internal configuration of the structure. The ring and linear structures delineated through both automated and visual decoding of remote sensing data are subsequently verified during the field validation phase. By correlating these findings with data from other geological research methods, a strategic pathway for targeted mineral exploration is established.

RESULTS AND DISCUSSION.

The advancement of satellite observation technologies has enabled the identification of numerous circular formations on the Earth's surface, ranging in diameter from several hundred meters to thousands of kilometers. Research indicates that 70-80% of these structures are intrinsically linked to various geological processes.

The primary essence of utilizing Earth remote sensing materials for geological purposes lies in optimizing the mineral exploration process and reliably delineating prospective areas. Satellite imagery allows for the remote identification of a region's general geological framework, tectonic elements, geomorphological features, and structural hallmarks of the Earth's crust, thereby significantly enhancing the efficiency of exploration activities. In metallogenic studies, satellite images are primarily analyzed using indirect criteria. These criteria help identify key structural factors controlling mineralization processes—such as lineaments, ring structures, tectonic faults, rift zones, geodynamic centers, and other geological indicators. The identification of these factors, in turn, provides a robust scientific basis for isolating regions with a high probability of ore formation. Consequently, integrating remote sensing data with geological, geophysical, and geochemical information increases exploration efficiency, leads to significant time and cost savings, and serves as one of the most advanced modern methods for identifying prospective areas.

As part of the cosmogeological research conducted in the central part of the Bukantau Mountains, data obtained from the automated processing of multispectral satellite images were analyzed. In this process, the characteristics of the spectral algorithm specific to the **Kokpatas gold deposit**, used as a reference for delineating hydrothermally altered zones, were correlated with the geological conditions of the study area (Figure 2) [Khasanov N.R. 2024]. The results obtained from applying the algorithm for identifying hydrothermally altered zones demonstrated a distinct correlation with sulfide mineralization and gold-bearing zones [Nurkhodjaev A.K. *et al.,* 2017].

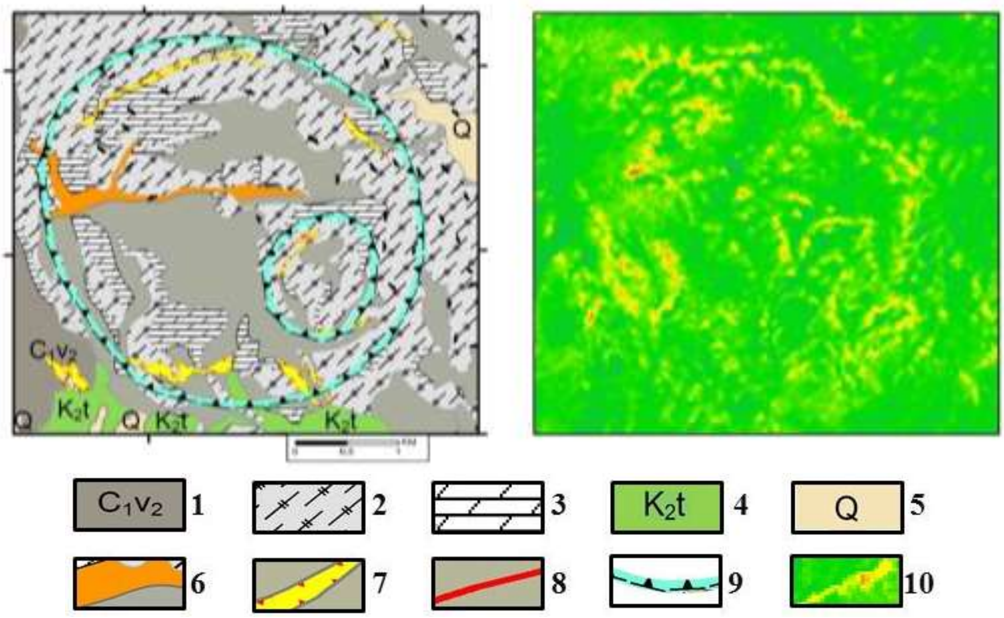

Figure 2. Correlation between the geological map and remote sensing data: (Left) Fragments of the geological map of the Kokpatas ore field (after Marchenko, 1982); (Right) Results of hydrothermally altered zones, mineralization, and gold-bearing zones identified through the multispectral processing of Landsat-8 OLI satellite imagery. Legend: *1-Lower Carboniferous undifferentiated deposits, volcanogenic and terrigenous facies (Korashokha formation); 2-Upper Riphean, Kokpatas formation: Silicified rocks; 3-Kokpatas formation: Carbonate rocks; 4-Upper Cretaceous, Turonian stage deposits; 5-Quaternary deposits; 6- Gold mineralization zones; 7-Mineralization zones; 8- Geological faults (fractures); 9- Ring structures; 10-Hydrothermally altered zones identified through satellite imagery processing.*

As a result of the research, a close correlation between several ring structures and mineral deposits within the study area was established. Through visual and software-based decoding, the Derbez ring structure was identified in the Bukantau region. Multispectral processing of this structure led to the delineation of a prospective gold-sulfide mineralization zone (Figure 3) [Khasanov N.R. 2021].

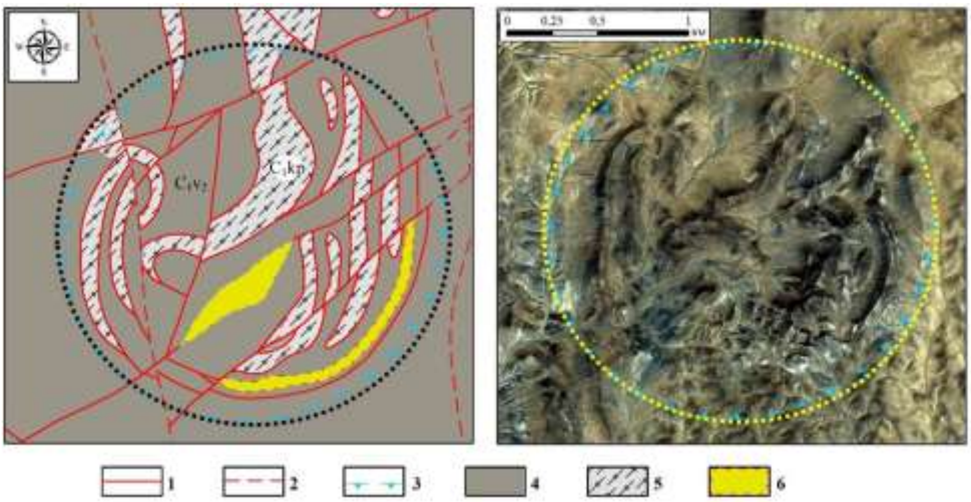

Figure 3. Geological and satellite imagery representation of the Derbez ring structure. *Legend: 1-Geological faults and tectonic contacts (confirmed);2-Geological faults and tectonic contacts (inferred/tentative); 3-Ring structures; 4-Undifferentiated Lower Carboniferous deposits, volcanogenic and terrigenous facies (Korashokha formation); 5-Lower Carboniferous, Kokpatas formation: Siliceous rocks; 6-Mineralization zone.*

The morphological characteristics of the geological formations distributed throughout the region-specifically their circular and arcuate shapes—evoke significant interest in the decoding of ring structures and the evaluation of their metallogenic importance [Nurkhodjaev A.K. 2017]. It is widely recognized that the application of modern remote sensing materials and various spectral channels within the electromagnetic spectrum represents one of the most innovative approaches for identifying and analyzing geological objects, particularly ring structures. The algorithms utilized within these technologies have undergone extensive testing over many years and have yielded positive results in global studies concerning the formation characteristics of circular structures, their correlation with tectonic factors, and their intrinsic relationship with mineralization processes.

CONCLUSION

The research conducted in the Bukantau region clearly confirms the strategic importance of ring structures in mineral exploration. Through both visual and automated decoding methods applied to remote sensing data and Landsat-8 satellite imagery, arcuate and circular geological structures were identified, and their morphological characteristics, relationship with lineaments, and geological ages were studied in detail. The results indicate that ring structures are intrinsically linked to mineralization zones, particularly gold-sulfide mineralization, providing a reliable scientific basis for delineating prospective areas. Algorithms for processing multispectral satellite imagery and isolating hydrothermally altered zones were successfully applied, as demonstrated by the case study of the Derbez ring structure. Furthermore, integrating remote sensing results with geological, geophysical, and geochemical data significantly enhances exploration efficiency, allows for the optimization of time and resources, and serves as an advanced modern methodology for identifying new ore-bearing sites.

REFERENCES

Borisov O.M., Glukh A.K [1977]. Materials on the tectonic terminology of endogenous ring structures // Principles of tectonic zoning of Central Asia. T, Vip. 28. - p. 203-213.

Borisov O.M., Glukh A.K [1982]. Ring structures and lineaments of Central Asia. T.: Fan,. - 122 p.

Gerasimov N.P., Chikhachev P.K [1931]. Geological sketch of the Kyzylkums - M.: Tr. GGRU, Vip. 32. 126 p.

Goipov A.V., Asadov A.R [2021]. Remote sensing in geology. Teaching aids. Tashkent: UGS. 275 p.

Khasanov N.R [2021]. Results of cosmogeological studies in the Derbez-Kokpatos foothills. Journal of the National University of Uzbekistan, Natural Sciences.[3/2/1]. 215-218 p.

Khasanov N.R [2024]. Cosmostructural and spectral factors of remote sensing materials in the search for mining zones (on the example of the Derbez - Kokpatos fields): Abstract of dissertation for the degree of Doctor of Philosophy (PhD) in Geology and Mineralogy. T.,22 p.

Koike K [1995]. Hepatitis B virus HBx gene and hepatocarcinogenesis. *Intervirology*. 38. p. 134-142.

Labutina I.A., Baldina E.A [2011]. Using remote sensing data for monitoring ecosystems of protected areas. Methodological manual M. p.28.

Nurkhodjaev A.K., Togaev I.S., Shamsiyev R.Z [2017]. Methodological guide for compiling a space-geological map of the Republic of Uzbekistan based on digital space images. Tashkent. IMR.. 200 p.

P.P. Nagevich, V.S. Shein [2015]. Universal grid of planetary faults and distribution of hydrocarbon deposits. // Geology of oil and gas. № 4. p.69-77

Shultz S.S. (Jr.) **[1973].** Concentric arca structures of the eastern part of the Turan plate in space images News of Universities. Geology and Exploration. № 7. - S. 182-184.