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MÉTODOS COSMOGEOLÓGICOS PARA IDENTIFICAR DEPÓSITOS MINERÁIS

REMOTE SENSING TECHNIQUES FOR IDENTIFICATION OF MINERAL DEPOSIT

КОСМОГЕОЛОГИЧЕСКИЕ МЕТОДЫ ДЛЯ ВЫЯВЛЕНИЯ ПЕРСПЕКТИВНЫХ МЕСТОРОЖДЕНИЙ ИСКОПАЕМЫХ

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RESUMO

Foram realizados os estudos sobre o uso de sensoriamento remoto da Terra para detectar estruturas geológicas de controle de minério. Os resultados da pesquisa foram obtidos usando um banco de dados de sensoriamento remoto baseado em imagens de satélites Landsat e ASTER. Como resultado deste trabalho, foram construídos esquemas de estrutura espacial de regiões individuais do Cazaquistão, determinados os principais fatores de controle de minério e determinadas as áreas de detecção de mineralização endógena. As imagens de satélite digitais selecionadas fornecem uma determinada escala de pesquisa e têm a resolução espectral máxima; portanto, cobrem a área de pesquisa em todas as faixas espectrais possíveis. Os diagramas de estrutura espacial mostram que de acordo com a morfologia as estruturas lineares são falhas, zonas de maior perturbação, limites geológicos, elementos de folheações, corpos de diques e outros elementos de natureza geológica. Sob condições de um relevo fracamente dissecado, métodos de gradiente multidirecional e vários métodos de filtragem provaram ser eficazes na interpretação de estruturas lineares. Ao identificar estruturas de anéis e arcos dentro das áreas estudadas, foram utilizadas as seguintes características: os limites de arcos e anéis entre blocos com diferentes texturas de materiais espaciais; limites da heterogeneidade da paisagem, morfologia de arcos e anéis. Em termos de escala, as estruturas de anel são subdivididas condicionalmente em estruturas de segunda ordem e pequenas. Estruturas com um raio de 3 a 50 km pertencem às estruturas de anel de segunda ordem, e estruturas com um raio inferior a 3 km pertencem a estruturas pequenas. Os complexos estratificados nas áreas estudadas são claramente divididos em cominuídos e litificados. Depósitos de neogeno quaternários, proluviais e aluviais, aluviais, eólicos e depósitos de origem indiferenciada são interpretados como cominuídos. Os complexos em camadas litificadas são dobrados e têm proliferação predominantemente noroeste. Na identificação de corpos de rochas intrusivas, foram utilizadas bibliotecas espectrais, características de textura das imagens de satélite e a experiência dos autores.

Palavras-chave: *sensoriamento remoto, interpretação digital de imagens de satélite, fatores de controle de minério, esquemas cosmogeológicos, áreas prospectiva.*

ABSTRACT

Studies on the use of Remote Sensing to highlight ore-controlling geological structures were performed. The research findings were obtained using a remote sensing database created from Landsat and ASTER data. As a result of this work, space-structural schemes of individual regions of Kazakhstan were built, and the main ore-controlling factors were determined. Besides, the areas for the detection of endogenous mineralization were identified accordingly. The selected digital satellite imageries provide a given research scale and have the maximum spectral resolution; therefore, they covered the research area in all possible spectral ranges. In space-structural diagrams, the lineament morphology represents the faults, areas of increased fracture, geological

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boundaries, litter elements, dam bodies, and other elements of a geological nature. Under conditions of a weakly dissected relief, the multidirectional gradient methods and various filtering methods proved to be useful for distinguishing linear structures. When identifying ring and arc structures within the study area, the following functions were used: the boundaries of arcs and rings between blocks with different textures of space materials, boundaries of landscape heterogeneity, the morphology of arcs and rings. According to the scale, ring structures are conventionally divided into second-order and small structures. Structures with radius from 3 to 50 km belong to second-order ring structures, and small structures with a radius less than 3 km belong to small structures. Stratified complexes in the studied areas are divided into loose and lithified. Neogene-Quaternary proluvial, alluvial-proluvial, alluvial, aeolian and undifferentiated sediments are classified as loose. The lithified layered complexes fold into folds with a predominance of the northwestern strike. When identifying bodies of intrusive rocks, spectral libraries, texture features of satellite images, and the experience of the authors were used.

Keywords: *digital image interpretation, ore-controlling factors, cosmogeological schemes, promising areas.*

АННОТАЦИЯ

Проведены исследования по использованию дистанционного зондирования Земли для выделения рудоконтролирующих геологических структур. Результаты исследований получены с использованием базы данных дистанционного зондирования, созданной на основе космических снимков Landsat и ASTER. В результате этой работы были построены космоструктурные схемы отдельных регионов Казахстана и определены основные рудоконтролирующие факторы, а также определены площади обнаружения эндогенной минерализации. Выбранные цифровые спутниковые изображения обеспечивают заданный масштаб исследования и имеют максимальное спектральное разрешение, поэтому они охватывают область исследования во всех возможных спектральных диапазонах. На космоструктурных схемах линейные структуры по морфологии представляют собой разломы, зоны повышенной нарушенности, геологические границы, элементы слоистости, дайковые тела и другие элементы геологического характера. В условиях слабо рассеченного рельефа для интерпретации линейных структур оказались эффективными методы разнонаправленного градиента и различные методы фильтрации. При идентификации кольцевых и дуговых структур в пределах исследованных областей использовались следующие признаки: границы дуг и колец между блоками с различными текстурами космических материалов; границы ландшафтной неоднородности, морфология дуг и колец. По масштабам кольцевые структуры условно подразделяются на второго порядка и малые. Структуры с радиусом от 3 до 50 км относятся к кольцевым структурам второго порядка, а небольшие структуры с радиусом менее 3 км - к малым. Стратифицированные комплексы на изучаемых участках четко делятся на рыхлые и литифицированные. Неоген-четвертичные пролювиальные, аллювиально-пролювиальные, аллювиальные, эоловые и отложения недифференцированного происхождения интерпретируются как рыхлые. Литифицированные слоистые комплексы сложены в складки и имеют преимущественно северо-западные простирания. При идентификации тел интрузивных пород использовались спектральные библиотеки, текстурные особенности космоснимков и опыт авторов.

Ключевые слова: *дистанционное зондирование, цифровая интерпретация космоснимков, рудоконтролирующие факторы, космогеологические схемы, перспективные площади.*

1. INTRODUCTION

Existing traditional technologies for targeting and detecting minerals is limited by depth, visibility, and heterogeneity. The work is mainly carried out on the Earth surface and is characterized by discrete data. Deeply occurring geological structures often remain uncharacteristic and undervalued. The underestimation of the phenomena associated with the profound effects of space sounding reduces the effectiveness of the completeness of research and the discovery of deep minerals. Geological studies using remote sensing data provide new material for developing science and practice in this area. The study attempts to develop a method of analyzing ore-controlling geological structures in exploration areas based on Remote sensing data. The described technology was tested in practice for mineral exploration in Kazakhstan (Galvão *et al.*, 2008; Blaschke, 2010; Mars and Rowan, 2010; Chemin and Ducati, 2011; Khorram *et al.*, 2013; Barrachina *et al.*, 2015; Khorram *et al.*, 2016).

Along with the advances in technology, there has been a rapid and growing social acceptance of remote sensing. At first, remote sensing was a concern to the public with the “eye in the sky” and “Big Brother” concept. This perception, however, has eroded to a considerable extent (but may be returning). Today, many sensors are deployed on numerous satellites and airborne platforms that collect vast amounts of remotely sensed data around the globe and around the clock. These data of various characteristics in spectral, spatial, radiometric, and temporal resolutions are commonly utilized in environmental and natural resource management, climate change, disaster management, law enforcement, military, and military intelligence gathering. Remote sensing has permeated daily human lives through Google Earth; global positioning systems (GPS); weather forecasting, wildland fire, hurricane, and disaster management; precision agriculture; and natural resources inventory and monitoring. People cannot live without it (Khorram *et al.*, 2016).

2. MATERIALS AND METHODS

2.1. Selection of Satellite Imageries

The possibilities of using Remote Sensing were not limited to those listed. The article used data Remote Sensing data for targeting and determination of minerals. In this study, Landsat ETM+ and ASTER (the Advanced Spaceborne Thermal Emission and Reflection Radiometer), Digital Elevation Models (DEM) – data from SRTM (Shuttle Radar Topographic Mission) and AsterGDEM (Aster Global Digital Elevation Model) were used Landsat ETM+ archival data were obtained from the satellite imagery library of the University of Maryland (USA) (Galvão *et al.*, 2008). The data of this space system were characterized by the following spectral ranges for multispectral channels: 1) 450-515 nm; 2) 525-605 nm; 3) 630-690 nm; 4) 750-900 nm; 5) 1550-1750 nm; 6) 10400-12500 nm; 7) 2090-2350 nm; 8) PAN channel – 520-900 nm. The spatial resolution of the images was: for 1, 2, 3, 4, 5, and 7 channels – 30 m for six channels – 60 m for the PAN channel – 14.25 m (Figure 1). Two Landsat scenes were used – p147r028_7dk19990826 and p148r028_7dk19990817.

ASTER data were obtained from the satellite imagery library of the American Geological Society (USGS) (EarthExplorer, 2020). The spectral and spatial resolutions of Aster data are shown in Tables 1 and 2. The spectral characteristics of the images of this space system are 1-3 channels (VNIR range) 520-860 nm, 4-9 channels (SWIR range) 1600-2430 nm, 10-14 channels (TIR range) 8125-11650 nm. The spatial resolution of images: 1-3 channels – 15 m, 4-9 channels – 30 m, 10-14 channels – 90 m. DEM (Digital Elevation Model) of AsterGDEM was obtained from the same library. These data have a spatial resolution of 25 m. Preprocessing digital satellite images, preparation of distance bases and space-structural schemes were performed using licensed software ERDAS Imagine 10.0 and ArcGIS 9.3 in the Scientific-Innovative and geological Remote sensing research Center "Cosmogeology" at the Tomsk Polytechnical University, Russia.

Upon the completion of Landsat and ASTER, data space-structured schemes were obtained for the targeted area. In these areas, the main ore-controlling factors were identified, and the promising areas for detection of mineralization were identified relatively. The general scheme of the study includes the following main stages:

1) Selection of Remote Sensing data.'

2) Preprocessing and processing of digital satellite images;

3) Preparation of distance basics based on Landsat and ASTER data;

4) Interpretation and compilation of space-structural schemes in the study area.

To support the work stipulated by the research plan (which was presented in the four paragraphs above), medium spatial resolution imageries, including Landsat ETM+ and ASTER, were selected, as well as Digital Elevation Models (DEM) of SRTM and AsterGDEM data were targeted for structure analysis. The selected digital satellite images provided the specified research scale and the maximum spectral resolution, i.e., they made it possible to cover the research area in all possible spectral ranges. The images were selected considering the climate during the period of vegetation cover, lack of snow cover, and minimal humidity. These conditions met the requirements for research of the selected objects (Akoveckij, 1983; Beloborodov and Kogen, 1984; Poceluev *et al.*, 2007; Poceluev *et al.*, 2010; Poceluev *et al.*, 2012; Baibatsha, 2018).

2.2. Data analysis and interpretation

The processing of remotely sensed data for geological interpretation was divided into two main stages. The first stage was preprocessing. It is intended to calibrate and atmospherically correct the satellite data and was mainly required for further interpretation. The preprocessing stage includes the following types of transformations: 1) geometric correction of satellite images; 2) radiometric calibration of images; 3) correction of the influence of the atmosphere; 4) recovery of missing pixels; 5) contrasting; 6) filtration;

7) recalibration of the multispectral image to a higher spatial resolution. The second stage was processing carried out for the purpose of geological interpretation. In this regard, the main point of the procedures of the second processing unit was to identify the features of the earth's surface that have a direct or indirect geological nature (Mamanov *et al.*, 2016).

Details of the and interpretation and modeling of geological and ore systems were considered in works of Akoveckij (1983); Beloborodov and Kogen (1984); Poceluev *et al.* (2007); Poceluev *et al.* (2010); Poceluev *et al.* (2012), and Gohman (2015). The most acceptable can be recognized as the technological scheme for deciphering digital satellite imagery data, Figure 2, (Kalmykov and Serokurov, 1991). In the given scheme, the more traditional approach in geology was visual interpretation. The classification of methods for visual interpretation of Remote Sensing data was generally based on the two approaches: direct (direct interpretation) – a geologist carried out recognition of target objects; preprocessing and processing; and formal (indirect interpretation)was conducted with the allocation of point, linear, arc, ring and plane elements on the earth's surface according to color, texture, brightness and other characteristics, followed by their sorting, statistical processing, qualitative and quantitative assessment, related to geological structures and objects. Direct interpretation involved knowledge of the geology of the studied area by the specialist-interpreter. It often came down to clarifying the boundaries of geological objects mapped by other methods (mainly ground-based) (Lyubimova and Spiridonov, 1999).

Formal visual interpretation of the first stage was limited to recognition and fixation of landscape or thermal heterogeneities. It thus freed the operator from the ideological framework of geological models adopted in the area or its organization. However, as a rule, formal interpretation in its pure form did not occur (it seems that the rule is known to many geologists: “see what you know” worked here), the experience and knowledge of a specialist played a decisive role(Lyubimova and Spiridonov, 1999). In this regard, the possibility of fully formal interpretation in the computer version raises great doubts, although this direction looks attractive since it allows us to exclude the subjective factor.

In interpretation, as a rule, both approaches were used. In addition to this, the interpretation of the source and derivative data was usually made by highly qualified geologists with approximately the same level of training and experience. In this case, the focus was not on finding out the percentage of integration of the interpretation results but on the possibility of obtaining additional information. The assessment of integration in percentages or points, the results of which are often given in the literature devoted to this topic, in the authors’ opinion, was either formal-statistical or subjective. Especially in cases where lineament interpretation was performed, since the lineament could reflect an area object, for example, a straightened section of a river valley and a dividing ridge along with it. Identifying geological structures as lineaments in the processing stage revealed more essential to make sense for achieving g of maximum integration of results (Mamanov *et al.*, 2016).

As practice shows, the analysis of satellite images and digital elevation models revealed many differently oriented lineaments, which were a dense network and numerous ring structures of different sizes. Provided mapped showing lineaments can be generated by various factors, including layering, streakiness, the fracturing of rocks, facies of igneous and metamorphic rocks, fault zones, which are reflected in the features of the soil and vegetation cover, temperature fields, and relief. In some cases, ring and arc structures were directly related to the deep origin rocks or have a deep source, such as bodies of intrusive and volcanic rocks, over-intrusive domes. However, often such a relationship was not detected or was very indirect. The discussion was the nature of large ring structures with a diameter of tens and hundreds of kilometers (Poceluev *et al.*, 2010).

Since the grid of lineaments and ring structures is currently mapped to one degree or another and is confused with line structures on the earth surface, it identified specific structures. It established their relative age and metallogenic value, additional processing of primary data was required. To solve these problems, there were qualitative and quantitative methods for the analysis of primary data (Poceluev *et al.*, 2012).

Qualitative methods for analyzing the lineaments were widely described in the literature and were quite useful in the metallogenic analysis (Crowley *et al.*, 1989; Dolivo-Dobrovol'skij *et al.*, 1980; Kac *et al.*, 1986; Kac *et al.*, 1989; Kalmykov and Serokurov, 1991; Percov, 2000). Specialists carried them out and, together with the data of direct interpretation, allowed revealing structure-forming elements. Quantitative methods for analyzing the spatial relationships of lineaments, arc, and ring structures made it possible to obtain digital estimates, establish correlation dependencies, and filter information.

Various techniques and methods for preliminary processing of raster images were used to identify mineralization control factors and create predictive-search models. Raster image analyzes were based on the next features: direct interpretations of heterogeneous objects to define its type and scale; qualitative and quantitative analyses of data; interpretation of data, and its correlation with available geological and geophysical data.

The use of digital processing of imagery data with formal interpretation at the first stage, followed by deciphering the data, made it possible to recognize weakly anomalous objects of both linear and arc and ring morphology and elements of a geological character – intrusive formations, paleo-valleys. The results of the interpretation of raster images at the last stage were filtered out based on available geological and geophysical data. The set of reporting information included layers of decryption results containing the entire set of linear, circular, and areal elements of the geological structure. The geological nature of some of them can be clarified if complete information was available on the geology of the area (Mars and Rowan, 2010).

2.3. Indicators of identification and interpretation of linear structures

Traditionally, linear morphology objects on space structural diagrams show intermittent faults, zones of increased fracturing, various cleats, geological boundaries, bedding elements, dike bodies, and other elements of a geological nature. The entire complex of initial and derivative space data was used to identify linear structures in the studied areas. In poorly divided relief conditions, methods of differently oriented gradients and various filtering methods have proven to be especially useful for emphasizing linear structures. In some cases (for example, in the southern part of the Usharal site), linear structures were distinguished due to directed differentiation of digital relief models. The followings are used as indicators of linear structure in this study (Poceluev *et al.*, 2007; Poceluev *et al.*, 2010; Poceluev *et al.*, 2012):

– gradient areas of the filtered image;

– rectilinear fragments of the boundaries between blocks with different image texture;

– linear boundaries underlined by oppressed vegetation;

– straight sections of the elements of river valleys of a high order;

– landscape heterogeneities of linear morphology;

– gradient sections of the first derivative of a digital elevation model.

During the interpretation and processing of space-structural schemes, lineaments having a geological nature were distinguished. Their interpretation was carried out using open geological information. Linear structures were discontinuous disturbances, geological boundaries; bedding elements of sedimentary rocks; dikes of various composition. Indicators of revealing ring and arc structures and their interpretation Ring and arc structures were traditionally distinguished during the visual interpretation of aerial and satellite imageries. The literature noted the spatial relationship of ring structures and mineral deposits (Lyubimova and Spiridonov, 1999; Percov, 2001; Labutina, 2004; Baibatsha *et al.,* 2016). Simultaneously, various mechanisms of the formation of ring structures (endogenous, exogenous, cosmogenic) were discussed. When highlighting the ring and arc structures in the study area, the following features were used:

– arc and annular boundaries between blocks and different texture of space materials;

– boundaries of landscape heterogeneities of arc and ring morphology.

To identify ring and arc structures, the entire complex of primary and secondary satellite imageries was used. For instance, in East Balkhash and Usharal areas, more than 30 ring and arc structures with a radius of the hundred meters to 48 km were mapped. The radius of the ring structure is conditionally divided into structures of the second-order and small. The second-order ring structures include structures with radius from 4 to 48 km and small ones with a radius of less than 4 km.

It is assumed that all structures were associated with endogenous processes and magmatism. In particular, for the Yenisei Ridge, it was shown (Anan'ev *et al.*, 2012) that first-order ring structures reflect deep facies of granitization during the continental crust formation. Ring structures of the second-order were associated with intermediate intrusive bodies, both blind and exposed by erosion. Higher-order structures can record traces of the interaction of hydrothermal fluid systems with host rocks. According to possible formation mechanisms, all mapped structures were divided into magmatogenic, hydrothermal-metasomatic, and unknown origins.

2.4. Features (Extraction) of planar bodies and Paleovalleys

An analysis of the entire complex of primary and secondary satellite imageries made it possible to distinguish stratified complexes and bodies of intrusive rocks of various compositions and forms of occurrence (Mamanov *et al.*, 2016). Stratified complexes in the studied areas were divided into loose and lithified. Neogene-Quaternary proluvial, alluvial proluvial, alluvial, aeolian and undivided sediments were classified as loose. The lithified Paleozoic stratified complexes occupy a significant part of the area plots. They were wrinkled in folds with a predominant northwestern strike of the axes.

To extract the bodies of intrusive rocks, the authors used the Johns Hopkins University Rock Library (2020) and the USGS Spectroscopy Laboratory (2020), texture features of satellite images. ASTER satellite images distinguish the vast majority of the bodies of intrusive rocks. Based on mineralogical composition, intrusive rocks were divided into ultrabasic, essential, and intermediate following spectral characteristics. Areas with traces of hydrothermal-metasomatic changes, which possibly control the position of ore mineralization, were also classified as planar bodies.

In the exocontact parts of acidic intrusions, thermal exposure traces are often found, which can be represented by keratinization, skarning. Such traces indicate active intrusive contact and can be considered as a criterion for mineralization. In some local areas of the studied areas, similar exocontact changes were also established by spectral characteristics without a visible connection with magmatism. This may indicate the presence of blind acidic intrusions that do not reach the surface (Barrachina *et al.*, 2015).

3. RESULTS AND DISCUSSION:

The geological remote sensing for detection and exploring of minerals has been tested in various structural and geological zones and areas of Kazakhstan (Baibatsha, 2018): Torgai district, Karsakpai-Ulytau zone, Shu-Ile belt, North Balkhash, East Balkhash, and Usharal (Figure 3). Ore areas were characterized by varying degrees of knowledge. It should be noted that all the covered areas were poorly studied to depth, especially the territories covered by sediments. The tested techniques are effective for areas such as separate sections of the Valeryanov structural-formation zone, characterized by difficult natural conditions for work – extremely low exposure, poorly divided relief, significant areas of allochthonous deposits, very high agronomic “noisiness” and wide development of hydrological objects (Figure 4) It should be noted that the research area is geologically quite well studied and explored. Therefore, ore mineralization could be explored mainly in considerable depth and buried by loose deposits. This requires the use of new technologies to determine and explore mineral deposits, which allow, at the initial stage, to optimize the size of promising areas for setting up exploratory work in a short time at a minimum cost.

An analysis of Landsat satellite images of the near-IR and thermal channels reveals extended ribbon-like bodies interpreted as buried paleo-valleys (Figure 5). When interpreting satellite images, especially their infrared and thermal channels were found useful for distinguishing buried paleo-valleys and planar bodies of acidic intrusions. Their total length is 228 linear kilometers. According to the manifestation of remotely sensed data, the paleo-valleys are divided into two types: the first type is quite wide (600-3500 m) fragmentary-ribbon-like, read-only in satellite imagery; the second type is narrow (300-900 m), long ribbon-like ones are read in satellite imagery and are emphasized by a network of small lakes (Figure 6). By the nature of the relationship, it was found that the second type of river paleo-valleys crosses the first. Based on this, it is proposed to distinguish two different-age river paleo systems (Poceluev *et al.*, 2010).

Within the area described above, two systems of buried paleo-valleys of the pre-Paleogene age are distinguished. The most ancient paleovalleys are believed to be erosion-karst erosive from Cretaceous and Carboniferous deposits. By age, they are closest to the time of the formation of the Shaimerden and Krasnooktyabrsk deposits, the position of which is controlled by one of these valleys. The direction of the paleo-valleys is variable, but in general, they have a north-northeast orientation. Thus, they can be considered as a search criterion.

The position of mineralization is controlled on the one hand by the development of these valleys, and on the other hand, by tectonic zones of the basement. These zones determine both the location of the paleodolines themselves and the position of the Karst cavities in the interface with structures of a different orientation. The confinement of mineralization to Karst cavities in the paleo-valleys channels makes it possible to generally represent the conditions for the formation of mineralization and classify it as the “Niagara” type. The term, obviously, most fully reflects the formation mechanism of these ores.

At the same time, deposits of paleo-valleys may include mineralization of a different composition. They may be associated with infiltration-type uranium mineralization in the Upper Jurassic-Lower Cretaceous paleo stream deposits, known in the depressive structures of the northern slope of the Kostanai rampart. There, the paleo-valleys also have a north-north-east direction and merge to the north.

It is possible to identify buried gold placers in the Paleostream deposits, which is indicated by the presence of high metal concentrations (0.2-0.7 to 5 g / t) in deposits 6a of the Aiat deposit and sub-bauxite “clay” clays of the East Aiat deposit. Similar placers in ancient (buried) valleys are known in the Jitigara district of the Kostanai region. In the paleo-valleys, it is also possible to identify zircon-ilmenite placers.

Prospects for the Arganaty area. According to the methodology described above, space-structural schemes of the Arganaty area (East Balkhash) were compiled due to the work. The diagrams show the whole complex of selected elements. The scheme of covering the area of the work with space materials is shown in Figure 7. On the area, linear, ring, and planar space geological structures are distinguished. More than 900 linear structures were identified, among which about 640 received geological interpretation. Discontinuous disturbances, geological boundaries, and layering elements of lithified stratified complexes were attributed to such structures.

Faults on the Arganaty area are predominantly northwestern and sub-latitudinal strikes. The primary fault violation is a right-shift displacement located at the northeast border of the area. It has a north-eastern strike, and it is not possible to determine the amplitude of the displacement due to the wide development of modern sediments and the laid-out relief near the area. Sublatitudinal faults associated with the main structure are classified as second-order faults disturbances. The amplitudes of right-and-right strike-slip faults in such structures reach 16 km. Other faults have a predominantly north-eastern strike.

Ring structures with a radius of 0.13 to 48 km were mapped in the Arganaty area and its immediate vicinity. It should be noted right away that the site is located in the central part of the second-order magmatogenic ring structure with a radius of 48 km. Ring structures with a smaller radius are “embedded” in this ring structure. The presence of such a complex of ring structures usually indicates the multi-tiered position of the intermediate magma foci.

According to possible formation mechanisms, all annular sections are conditionally divided into magmatogenic and hydrothermal-metasomatic. The reasons for this separation were the spatial combination of ring structures with single manifestations of intrusive magmatism, signs of thermal effects on the host rocks in the north-eastern part of the area, and traces of metasomatic changes. All these facts suggest the presence of a not deeply lying blind magmatic body of considerable size, with which the manifestations of minerals are possibly associated.

Aeolian and undivided Neogene-Quaternary sediments, lithified complexes, an erosion-exposed intrusive body of the presumably medium composition, and a blind intrusive body presumably acidic composition, areas with traces of thermal effects and hydrothermal-metasomatic changes in the host rocks were identified as areal bodies in the area. Stratified formations occupy almost the entire area. Modern aeolian sediments occupy depression in the central part of the area, and undivided Neogene-Quaternary formations are located in the north-eastern, central, and southern parts of the site. The lithified complexes of the presumably Middle Paleozoic age are exposed to elevations in the eastern, northern, and western parts of the area. A single stock of intrusions of presumably medium composition is mapped in the eastern part of the area. Its size is 1.8x0.67 km. Traces of thermal effects are found in his exocontact – contact hornfelses are assumed here. The same hornfelses are recorded in the northern and eastern parts of the area.

A blind intrusive body, presumably of an acidic composition, is mapped in the central part of the area. Signs of its isolation were traces of weak thermal effects on the host rocks and a system of telescopic ring structures. Such systems of ring structures not only indicate the position of the magma chamber but can also indicate its formation and occurrence conditions. Based on the experience gained, it can be argued that the blind acidic intrusive body in the central part of the site has a southeastern declination.

Of particular interest are traces of hydrothermal-metasomatic changes. Spectral analysis of the ASTER data in these areas indicates mineralization of muscovite, chlorite, carbonate, and epidote. All these areas of hydrothermally altered rocks gravitate toward discontinuous disturbances in the northwestern and sublatitudinal orientations.

The prospects of the Arganaty area are associated with the manifestation of endogenous mineralization and the possible detection of groundwater. Endogenous mineralization can be associated with the manifestation of intrusive magmatism. The signs of which (a single stock, thermal action areas on the host rocks, magmatogenic ring structures) are found within the area. Au, Cu, Mo, Pb, Zn, Sn, W are expected in the area. It is proposed to consider the following mineralization factors within the area:

– ring structures, or rather their arc segments and especially the conjugation sections of such arc segments with multidirectional discontinuous faults;

– multidirectional discontinuous violations;

– intrusive body;

– the blind intrusive body;

– areas with traces of thermal effects on the host rocks;

– areas with signs of hydrothermal-metasomatic changes.

Based on the mineralization factors within the Arganaty area and its immediate vicinity, new promising areas for detecting endogenous mineralization were identified (Figure 8).

4. CONCLUSIONS:

The results of this study are the collection and analysis of a remote sensing database and diagrams for the area of interest. The main cosmogeological factors of mineralization were revealed. Directions for organizing a complex of prospecting work in promising areas were determined. The prospects for the studied territories are related to the possibility of detecting endogenous mineralization (mainly gold, copper, PGM, nickel, lead, zinc, tin, tungsten, chrysotile asbestos) and groundwater. The application of space geological studies results is informative for new or poorly studied territories and geologically concerning fairly well-studied areas. In this regard, in such areas, one can identify mainly hidden and unconventional mineralization, which requires new forecasting and prospecting technologies. This is also true for an area characterized by a significant development of unconsolidated loose sediments, many hydrological objects, a poorly divided relief, a multi-storey geological structure with access to the day surface, and the identification of paleo-valleys where potential placers can develop.

In buried paleo-valleys, the position of mineralization is controlled on the one hand by the development of these valleys, and on the other, by tectonic zones of the basement. These zones are defined as the location of the paleo-valleys themselves and the position of the Karst cavities in the mating areas of multidirectional structures. The paleo-valleys position can control the mineralization of the area, and alluvial deposits of the valleys include uranium mineralization of the infiltration type and placers of gold. Paleo-valleys may include significant groundwater resources for both drinking and technical purposes.

Currently, a draft of prospecting works has been drawn upon selected prospective sites. Geological and geophysical works have been planned to select the location of the prospecting boreholes, conduct testing, and a complex of laboratory studies of the selected samples.

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Table 1. *Aster satellite image characteristics*

Survey regime	VNIR	SWIR	TIR
Channel number and spectral range, nm	1: 520-600 2: 630-690 3: 760-860	4: 1600-1700 5: 2145-2185 6: 2185-2225 7: 2235-2285 8: 22- 95-2365 9: 2360-2430	10: 8125-8475 11: 8475-8825 12: 8925-9275 13: 10250-10950 14: 10950-11650
Spatial Resolution, m	15	30	90

Note: VNIR – visible-to-near-infrared, SWIR – short-wave infrared, TIR – the thermal infrared.

Table 2. *Used Aster Images*

Image Nomenclature	Survey date
AST_L1T_00304162005060149_20150509025419_21847	16.04.2005
AST_L1T_00304222007060222_20150519050231_7719	22.04.2007
AST_L1T_00304242007054959_20150519054503_44651	24.04.2007
AST_L1T_00306092007060200_20150519203835_40386	09.06.2007
AST_L1T_00311182007054930_20150522024610_15537	18.11.2007
AST_L1T_00304132007060828_20150519021401_31111	13.04.2007
AST_L1T_00304132007060837_20150519021405_34433	13.04.2007
AST_L1T_00306242001061013_20150417225959_93408	24.06.2001
AST_L1T_00306252007060215_20150520011602_22932	25.06.2007

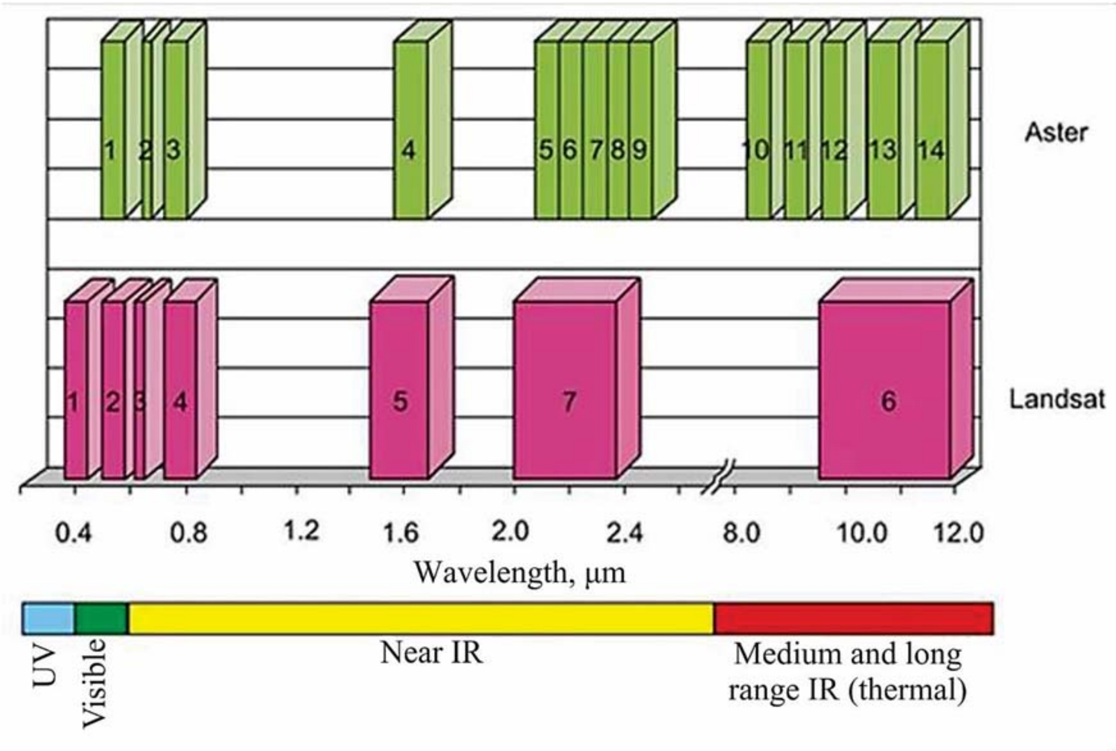

Figure 1. *Spectral characteristics of the Landsat and ASTER (the Advanced Spaceborne Thermal Emission and Reflection Radiometer) space systems*

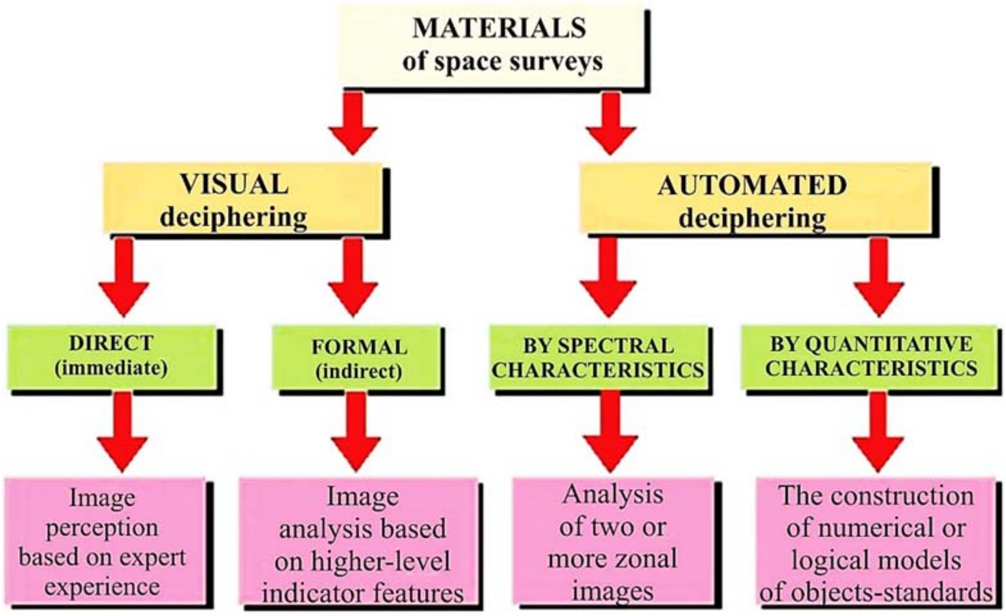

Figure 2. *Technological scheme for Deciphering digital satellite images*

Source: Kalmykov and Serokurov (1991).

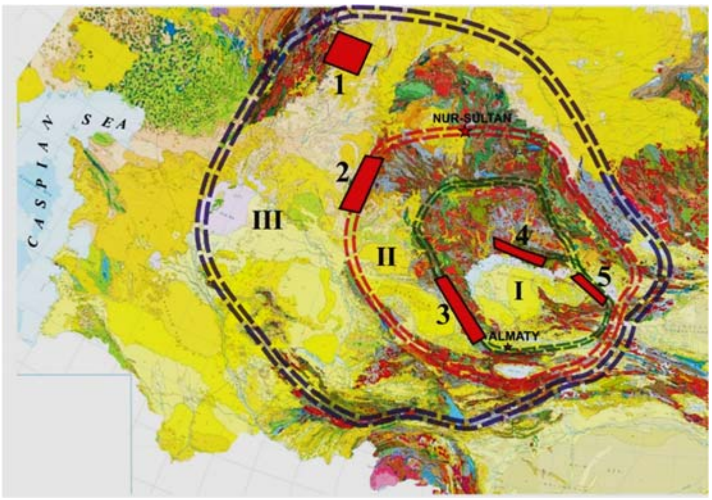

Figure 3. *Space geological exploration areas on the tectonic scheme of Kazakhstan: 1 – Torgai; 2 – Karsakpay-Ulytau; 3 – Shu-Ile; 4-5 – North (4) and East (5) Balkhash*

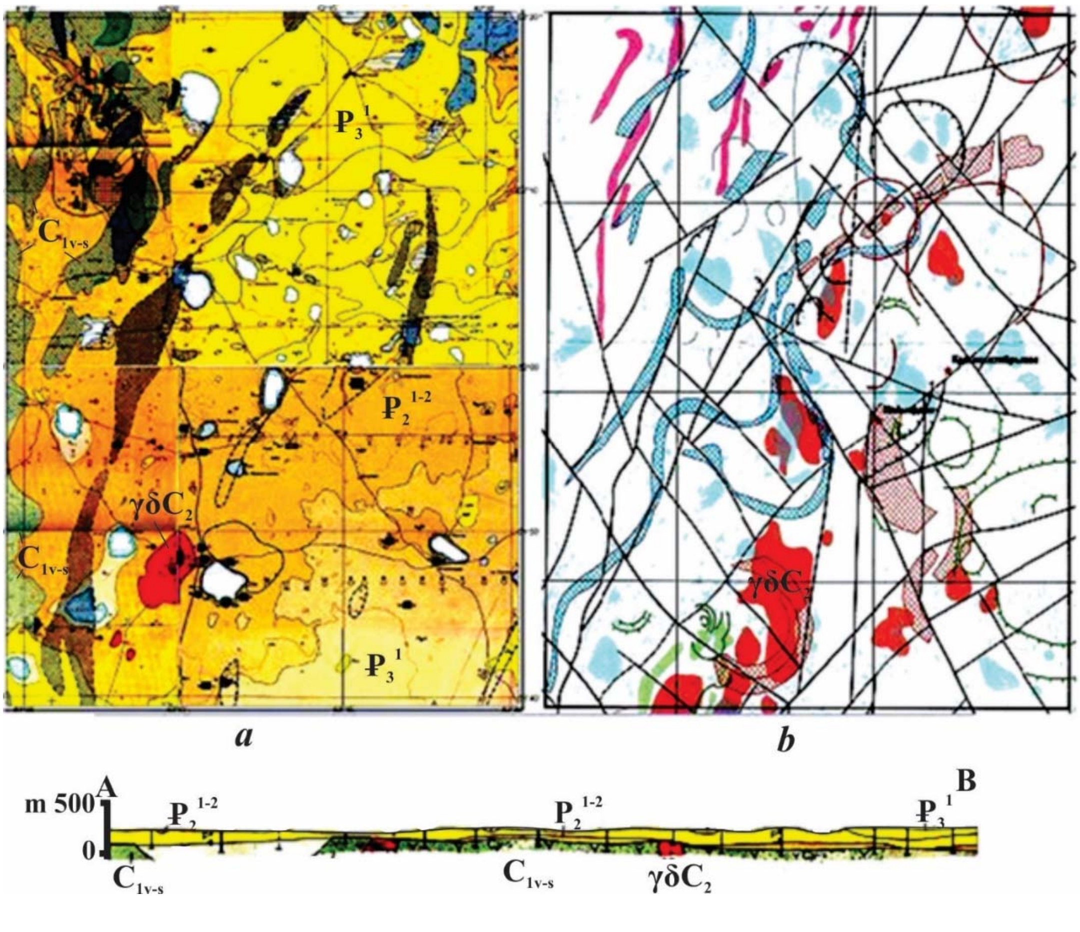

Figure 4. *Geological map of the Valeryanov zone closed by sediments (a) and its cosmostructural diagram with the interpretation of hidden structures, areal bodies, and paleodolines at a depth of 40-60 m (b)*

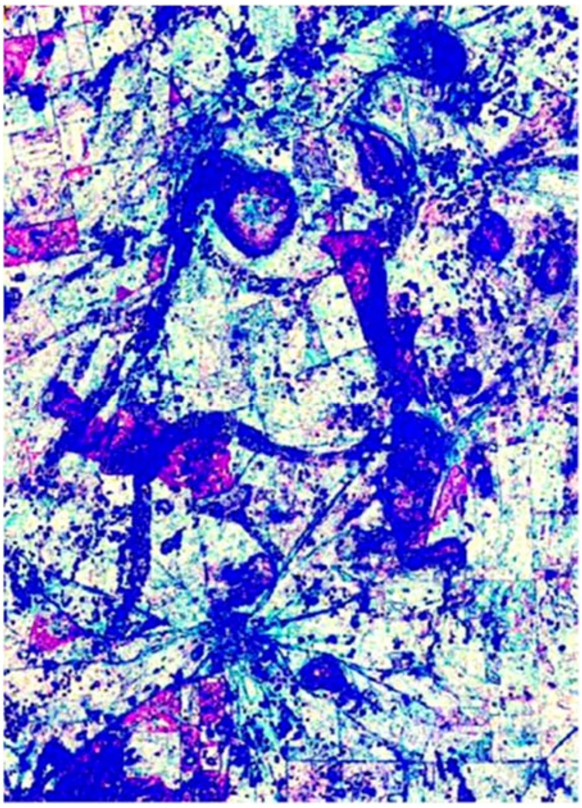

Figure 5. *An example of the selection of paleovalleys. The raster is obtained as a result of thematic filtering with subsequent indexing of infrared and thermal channels*

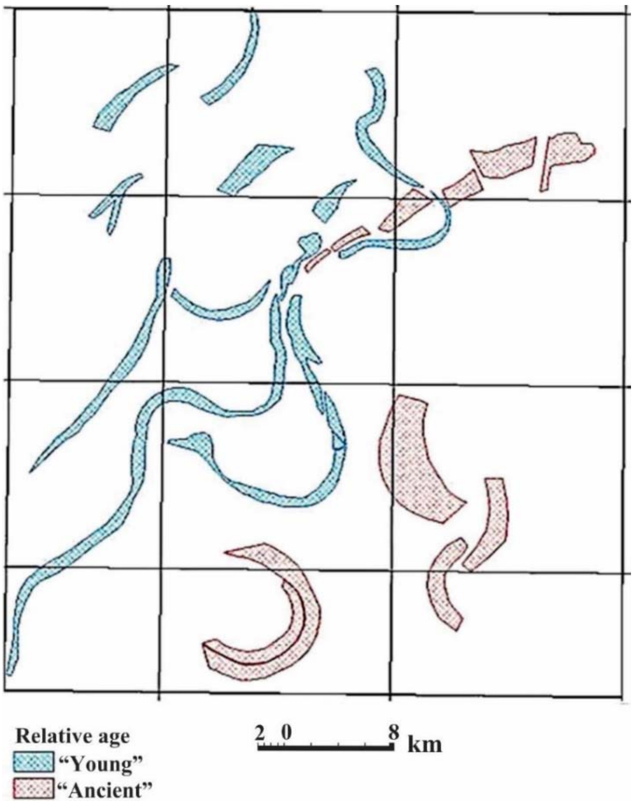

Figure 6. *The development pattern of buried Cenozoic paleo-valleys of the Torgai area*

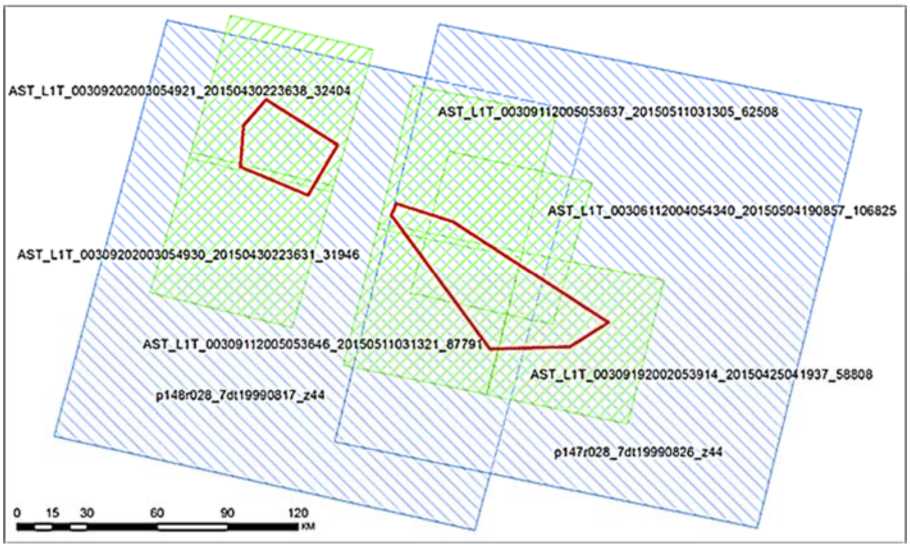

Figure 7. *The scheme of covering the work area with space materials*

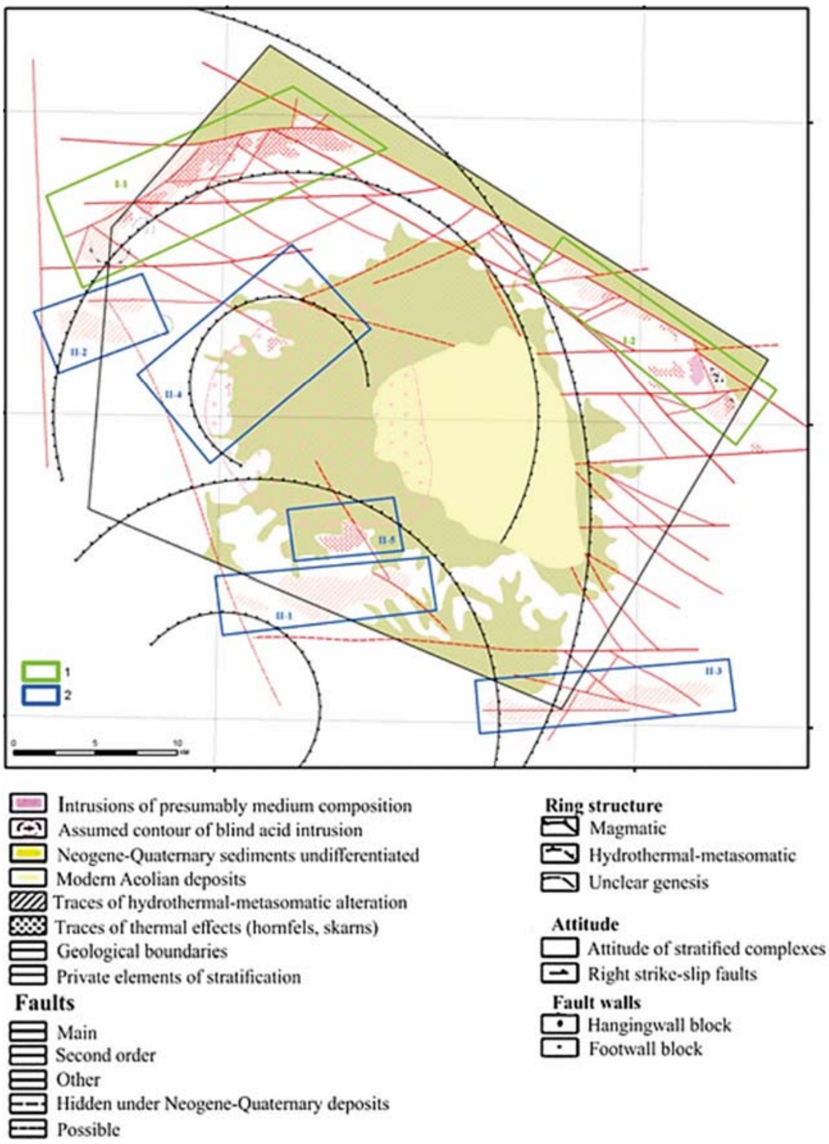

Figure 8. *Prospective blocks of the Arganaty area (East Balkhash) for the detection of endogenous mineralization: 1 – blocks of the first stage; 2 – blocks of the second stage*