ISSN (e): 2689-0992
DOI: https://doi.org/10.37547/tajas/Volume02Issue07-16

Application Of Ratio Bands Of Space Images For Mapping Minerals On The Example Of Kokpatas-Okzhetpes Trend In Mountain Bukantau (South Tien Shan)

OPEN ACCESS
The American Journal of Applied Sciences
July 2020
Page No.: 94-103
Volume-II Issue-VII
PUBLISHED: 31 JULY 2020
www.usajournalshub.com/index.php/tajas

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Abstract
This article presents the results of processing Earth remote sensing materials using the ASTER satellite image ratio bands. On the territory of Bukantau-Kokpatas-Okzhetpes trend, mineral changes are mapped: iron, kaolinite and quartz indices. The relationship of mineral metasomatic changes with zones of ore mineralization, ore occurrences and deposits and fault zones that control metasomatic mineral changes is established. The structural, magmatic and lithological factors of mineralization are substantiated.

Keywords: ASTER, Bukantau-Kokpatas-Okzhetpes trend, gold deposits, mineralized zone, Ore Controlling Factors, lithology, kaolinite index, iron index, quartz, sulfides, carbonates.

Introduction
Recently, the international experience of foreign countries with advanced space technologies has shown that the results of remote sensing methods in geology are the

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most reliable and cost-effective. When performing work on remote sensing, a special role is played by automated methods for processing satellite images of different multispectral ranges. Unlike multispectral sensors installed in remote sensing devices, human eyes are not able to see all the radiation from the electromagnetic ranges of nature's spectra.

The territory of the South Tien Shan, known in the geological literature of the South Tien Shan folded system, occupies an intermediate position between two rigid massifs - the Syr-Darya in the north and the Karakum-Tajik in the south.

The South Tien Shan fold system extends through Uzbekistan, Tajikistan, Kazakhstan, Kyrgyzstan and Northern China and is one of the most important gold belts in which several world-class deposits, super-large and large, have been identified. These include Muruntau and Kalmakyr (Uzbekistan), Kumtor (Kyrgyzstan), Daugiztau (Uzbekistan) and Jilau (Tajikistan) [1]. Figure 1 shows parts of Central Asia on the territory of the South Tien Shan.

The semi-closed and closed territories of the South Tien Shan include the Central Kyzylkum area, which is located in Uzbekistan, where the ore deposits of the Paleozoic structural floor are exposed in the mountains of Bukantau, Tamdytau Kuldzhuktau, Beltau, Aristantau, etc., where gold, silver, tungsten and other metals.

The object of research is the territory of the Kokpatas-Okzhetpes trend with gold deposits and ore occurrences which is located in the Bukantau mountains, Western Tien Shan (Fig. 1)

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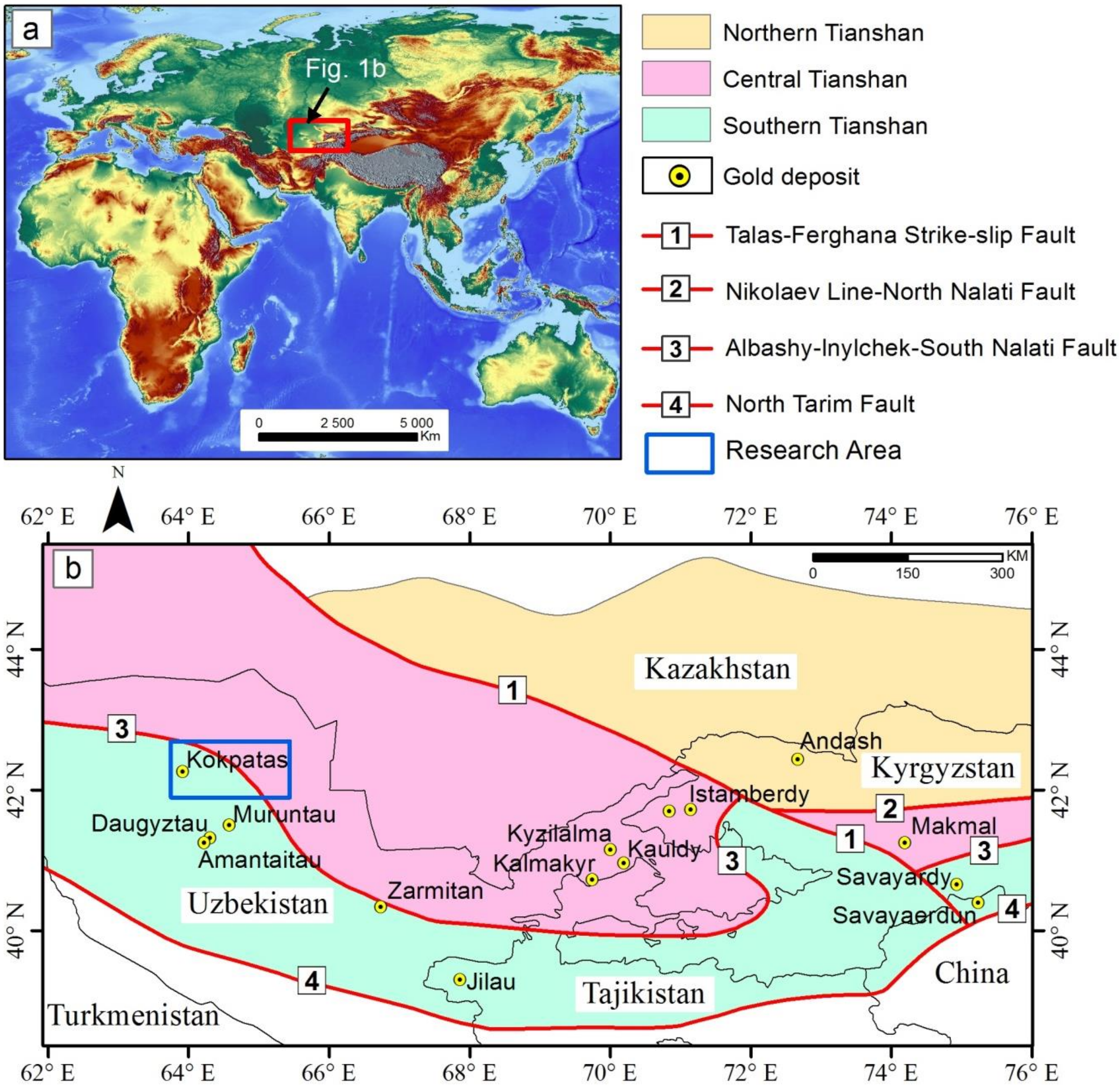

Fig. 1. (a) Map of digital elevation model of the world (b) Geological map of part of the territory of the South Tien Shan orogen in Central Asia (modified after Lei et al., 2018[1].; Mirkamalov et al., 2019[2]).

In terms of spatial distribution, in relation to tectonic structures, genetic features and patterns of formation and distribution, they are divided into Boztauskoye, Kokpatassky and Okzhetpesky ore fields, which are antiforms that can be traced in a chain in the central part of the Bukantau mountains. According to I.Kh. Khamrabaev, Kh.R. Rakhmatullaev, M.M. Mansurov, V.A. Korolev, Yu.I. Paramonov, R.Kh. Mirkamalov, Yu.S. Savchuk and other Hercynian thrust structures control gold - sulfide interspersed and gold-sulfide-quartz vein-vein mineralization of many deposits.

The presence of gold mineralization within the Kokpatassky ore field was first established by Yu.V. Finkelshtein in 1960. Kh. R. Rakhmatullaev discovered native gold here in the same year. In 1963, L.Z. Paley proved the industrial importance of gold mineralization, and a significant area at the border of limestone and overlapping shales was evaluated as promising for gold [3].

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On the Kokpatassky gold ore field, 21 sites with 79 industrial ore deposits have been explored, for which gold reserves have been approved. In essence, each site is an independent field. They belong to the gold-sulfide ore formation (T.V. Nosenko, 2003).

The Okzhetpes ore field is confined to the southeast submergence of the Bukantau anticlinorium and is controlled by faults of the deep-seated northwest direction [3]. The Okzhetpes silver ore deposit is located near the tectonic contact of carbonate and terrigenous rocks of the Middle Carboniferous of the Murun complex [4]. The field was discovered in 1974 by A.S. Aristov and V.I.Zonov as a result of a general search within the Okzhetpes Upland. From 1974 to 1978 within the Okzhetpes ore field, prospecting and prospecting and evaluation work was carried out [3].

Silver mineralization is a system of rock-shaped quartz veins and vein silicification sites in the northeast fault, at the contact of carbonate and terrigenous strata. Ore quartz crystalline. Of ore minerals, pyrite prevails (90%), the accumulations of which in places reach 25-30% of the mass of rocks [3, 4].

Materials and Methods.

For remote determination of mineral formations in the relief, from a wide range of the electromagnetic range, a wavelength of 0.4-2.5 microns is usually used. Especially important is the near infrared range (SWIR) in the range of 2.0-2.5 microns. It is in this interval that the main spectra of hydroxides, sulfates, carbonates, which are characteristic of various types of rocks and secondary hydrothermal changes, are recorded. In thermal and other infrared channels at different intervals of the spectrum, zones of silicification, sulfidization, argillization, propylization, etc. are recorded.

Given that the gold deposits of the Central Kyzylkum region have hydrothermal genesis, the use of remote sensing methods becomes appropriate.

ASTER is the first multispectral space sensor to distinguish and identify minerals of hydrothermal changes in the short-wave infrared range (SWIR) of the electromagnetic spectrum [5] for lithological mapping, detection of changes in minerals associated with gold [6] and mapping of mineral zones of hydrothermal change [7].

As is known, the Kokpatas deposit belongs to the gold-arsenopyrite-pyrite (sulphide, arsenic) mineral type [3], and for mapping mineral changes here the ratio bands of satellite imagery are used. The algorithms developed by foreign researchers Rowan et al. [8], Yamaguchi and Naito [9], Mars and Rowan [10] - determination of the mineral index by the ratio of the spectral bands ASTER VNIR, SWIR and TIR.

$$\text{OH bearing altered minerals Index (OHI)} = \left[\frac{\text{канал7}}{\text{канал6}}\right]\left[\frac{\text{канал4}}{\text{канал6}}\right] \quad \text{Kaolinite Index (KLI)} = \left[\frac{\text{канал4}}{\text{канал5}}\right]\left[\frac{\text{канал8}}{\text{канал6}}\right]$$

$$\text{Alunite Index (ALI)} = \left[\frac{\text{канал7}}{\text{канал5}}\right]\left[\frac{\text{канал7}}{\text{канал8}}\right]$$

$$\text{Calcite Index (CLI)} = \left[\frac{\text{канал6}}{\text{канал8}}\right]\left[\frac{\text{канал9}}{\text{канал8}}\right]$$

$$\text{Quartz Index (QI)} = \frac{(\text{канал11} * \text{канал11})}{\text{канал10} * \text{канал12}}$$

$$\text{Carbonate Index (CI)} = \frac{\text{канал13}}{\text{канал14}}$$

$$\text{Mafic Index (MI)} = \frac{\text{канал12}}{\text{канал13}}$$

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$$\text{Ferrum Index (FI)} = \frac{\text{канал5}}{\text{канал3}} + \frac{\text{канал1}}{\text{канал2}}$$

Results and Discussion

The use of the ASTER satellite imagery ratio bands method when studying the Kokpatassky ore field made it possible to obtain new data on sulfides and carbonates substituted with iron hydroxides and partially leached [3]. The data obtained, using this method for the territories of the Kokpatassky ore field and the Altyntau field, allow us to recommend them for mapping the iron index over the entire territory of the Bukantau mountains (Fig. 2).

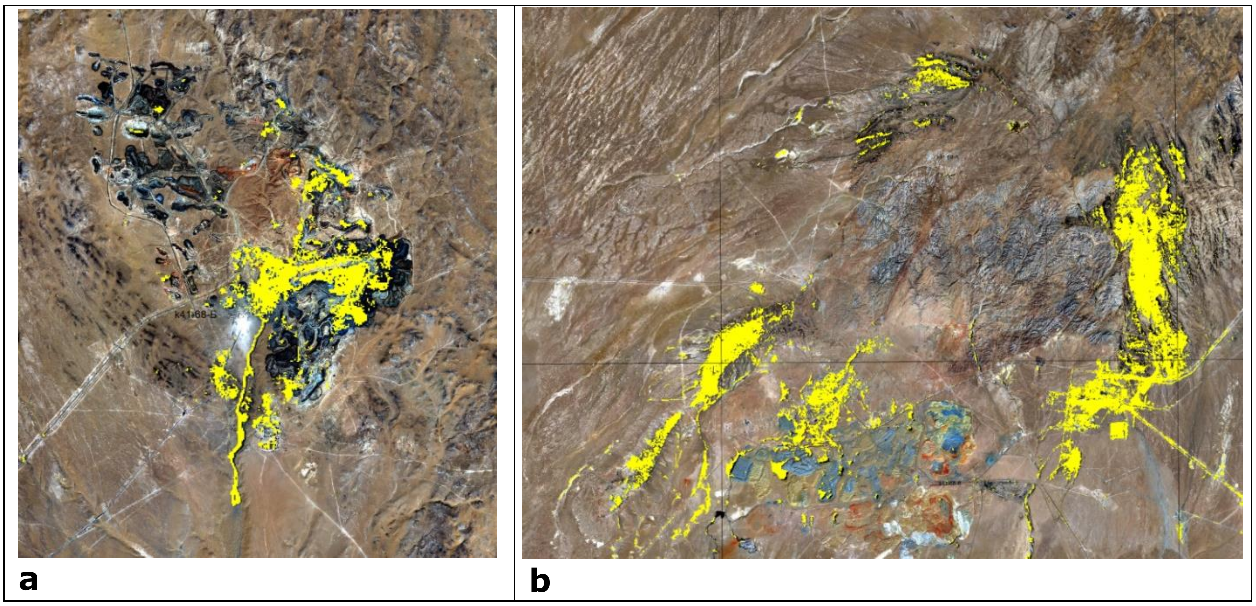

Fig. 2. Manifestation of the iron index (yellow light). a - Kokpatas quarry contour; b - southwestern flank of the Altyntau igneous intrusive.

Researchers found that the appearance of native gold film or tear-shaped in the size of about mm, which indicates the enlargement of gold in the oxidation zone [2, 3], is observed in the Kokpatassky ore field in dense and loose iron hydromica. The content of iron hydroxides reaches 5.2%. They are represented by goethite, hydrogetite, jarosite, scorodite, pittitis, psilomelan. For the oxidation zone of hydromica, kaolinite is very characteristic. Proceeding from this, an automated interpretation was carried out according to the ratio bands of satellite images to the kaolinite index (Fig. 3).

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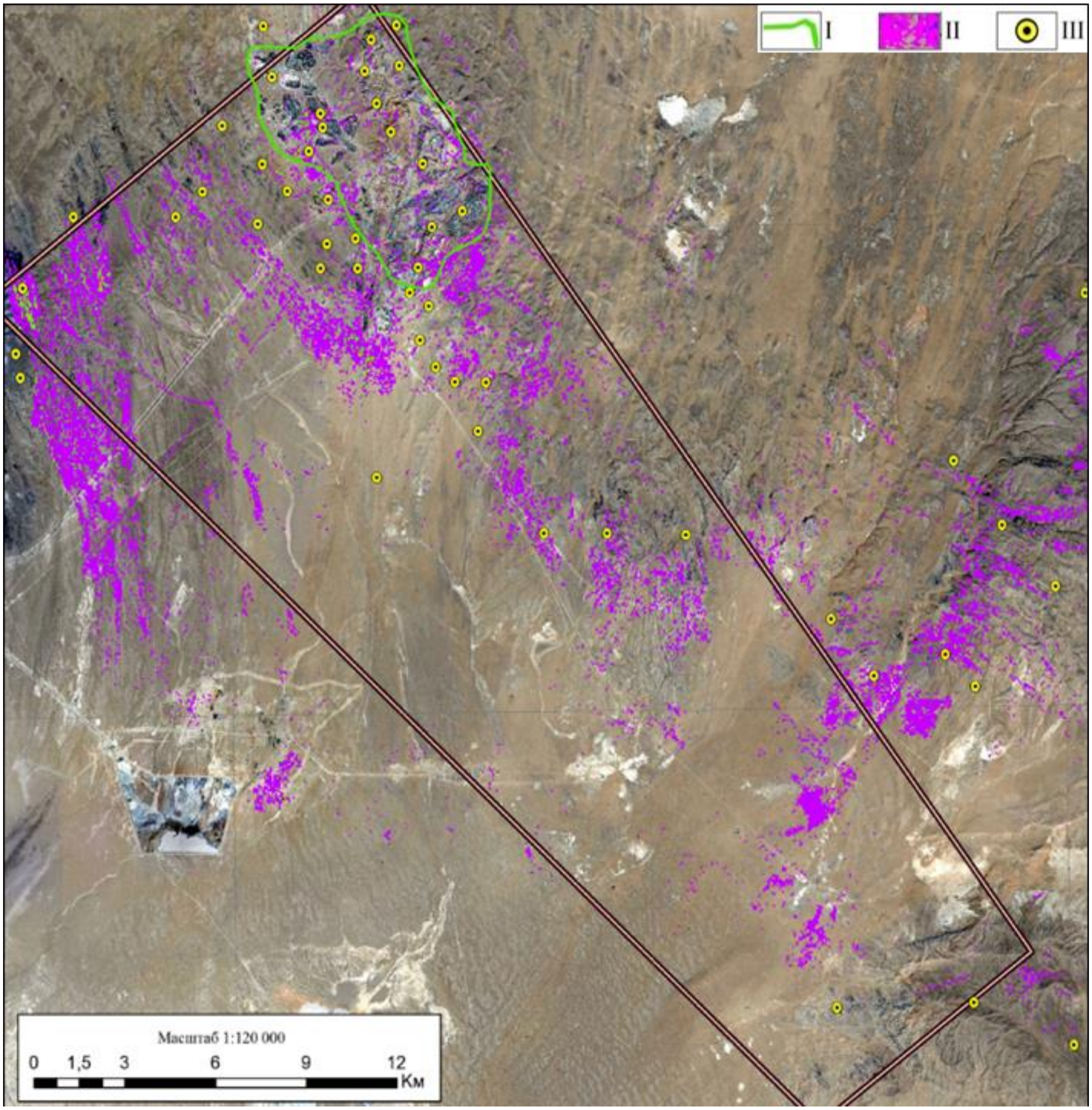

Fig. 3. Results of processing satellite images ASTER in the territory of Bukantau-Kokpatas-Okzhetpes trend. I - the boundary of the Kokpatas deposit; II - distribution zone of kaolinite minerals; III - deposits and ore occurrences.

For processing materials of remote sensing of the earth, geological and geophysical data and the main factors of localization of gold ore occurrences are used. According to geophysical data, zones of increased permeability in East Bukantau play an ore-controlling role.

All deposits and occurrences of Bukantau gold are located within extended intra-block crushing and crushing zones, usually sub-consonant with the enclosing strata. Thus, these zones play an ore-controlling role and can be compared by typification of V.A. Korlev and P.A. Shekhtman (1965) with ore-bearing faults.

In addition to crushing and crushing, the zones are also characterized by small

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stocks and igneous body of the formation of small bodies of motley composition, often forming belts and bundles; sometimes an increased number of quartz veins and veins is noted [11].

According to L.I. Dementeyenko, one of the main structures in the south of Bukantau is the Kokpatassky fault zone with a width of about 10-13 km, which includes the mountains Okzhetpes, Kokpatas and Boztau. The Kokpatassky fault stretches along the southwestern wing of the Dzhelsai-Okzhetpes anticline and forms flexural bends along the strike. According to the results of geophysical work, several small faults of this direction were established.

They extend subparallel to the contact line of the intrusion and are almost parallel to each other. Their length reaches up to 3-5 km, thickness - up to 8-10 m, and they are accompanied by zones of intense fracturing, formed during cooling of the intrusive body (Fig. 4).

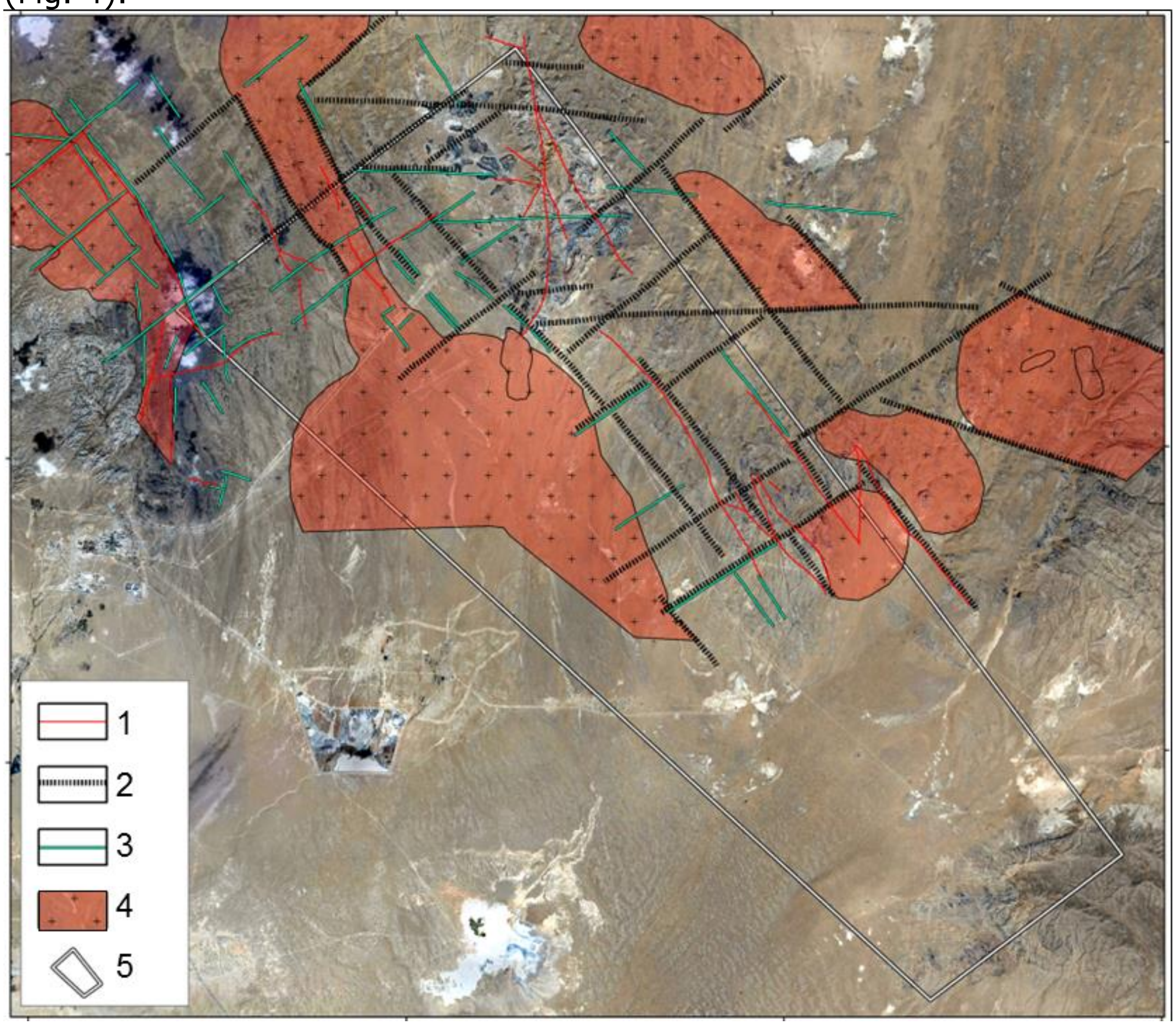

Fig. 4. Deep tectonics and magmatism of the Kokpatassky ore region according to gravity and magnetic exploration data (compiled by Goipov A.B., using materials from N. I. Oransky [11]). Tectonic disturbances established by: 1 - geological data; 2 - data of gravity exploration, 3 - data of magnetic exploration; 4 - granites and granodiorites; 5 - contour of the area of work of the Kokpatas-Okzhetpes

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trend.

In the Kokpatassky ore field, a wide distribution of diorite and lamprophyre dikes has been established. Sites of their maximum manifestation are located outside the Kokpatassky intrusion. As T.V. Nosenko notes, such dikes are rare in the intrusive body itself, while in other intrusive massifs that are accompanied by their own dyke series, their greatest concentration is observed precisely within the massifs themselves.

The dikes compose the Kokpatassky dyke belt, elongated in the sub-latitudinal direction by almost 60 km with an average width of 10-15 km (Yudalevich, 1983). The most saturated dikes are the Kokpatassky ore field, where individual dikes have a thickness of 0.4-5 m and a length of several tens to first hundreds of meters.

Spatially and in time, gold mineralization is close to the formation of the described dyke complex.

An analysis of geological and geophysical materials in combination with satellite image interpretation data allowed us to establish the deep tectonic structure and location of intrusive formations of the Kokpatassky ore field (see Fig. 3).

According to these data, the ore field area is located in the intrusive space and it is assumed that this is a zone with a negative surface shape of the intrusion.

According to V.S. Korsakova et al. (1997), the Kokpatassky ore field is confined to deposits of the Kirkkuduksky and Kokpatassky suites, thrust over the carbonate core of the Kokpatassky antiform. Metavolcanogenic-carbonate-siliceous-terrigenous deposits of both suites are broken through by a large number of diorite dikes and disturbed by numerous faults.

According to H.R. Rakhmatullaev, V.S. Korsakov, T.M. Khon, A.D. Shvetsov, Yu.S. Savchuk, Yu.I. Paramonov [13], N. Yu. is a structural factor in the control of gold mineralization of the Kokpatassky ore field, where the Kokpatassky deep fault plays ore-bearing and ore-distributing roles.

The rocks in the fault zone are brecciated, fragmented, pierced by quartz veins and mineralized by sulfides.

Ore deposits are stratiform, lenticular and irregular in shape. The majority of ore bodies associated with reverse faults and overthrusts have a stratiform shape. Often they are dipping. According to the degree of favorable ore localization for the objects of each gold ore formation, the lithological mineralization factor is established.

L.I. Dementeyenko in the study of gold deposits in the region in 2005-2007 He noted that for the manifestations of gold-sulfide mineralization, sandstones and siltstones of the flyschoid and olistostromic formations (Kokpatassky type), as well as porphyry-porphyritic dikes of formations of small bodies of motley composition are favorable.

Along with the structural, lithological, and magmatic factors of controlling gold ore mineralization, the results of interpretion satellite images of a new generation are important in studying the patterns of formation and placement of mineralization, their prediction and search.

The mineral indices (halos) revealed during the interpretation of the ring and linear structure made it possible to clarify:

- geological and structural position of the manifestations of gold Kokpatassky ore field;
- the relationship of mineralization with fault structures;

ISSN (e): 2689-0992 DOI: https://doi.org/10.37547/tajas/Volume02Issue07-16

- relationships and spatial distribution of gold mineralization with magmatic formations.

Conclusions

Based on the results of processing of remote sensing materials and the ratio bands of satellite images ASTER, the distribution zones of the Kokpatas-Okzhetpes trend mineral index were mapped. The main mapped zones of the distribution of kaolinite minerals, quartz and iron indices are observed near ore deposits and occurrences.

As a result of a comprehensive analysis of geological and geophysical information and comparison of the processing of Earth remote sensing materials, two new forecast areas have been identified prospectively for gold mineralization located along the western submersion of the Kokpatassky deep fault. The compiled structural maps reflecting the search features of gold deposits localized within the mineralized zones, lithological formations, and secondary change zones identified by automated decryption can serve as the basis for forecasting and exploration within the Kokpatas-Okzhetpes trend.

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