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CREATION OF A SPECTRAL LIBRARY OF ROCKS AND MINERALS OF THE BUKANTAU MOUNTAINS (CENTRAL KYZILKUM)

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Abstract

This article presents the results of spectrometric studies that made it possible to create a database of electronic spectral library of rocks and minerals on the territory of the central part of the Bukantau Mountains (Central Kyzylkum). With the verification of the obtained spectral measurements, new methods of correlation of channels of satellite images Landsat-8, Aster, Sentinel-2A for mapping lithological changes and gold mineralization have been developed.

Keywords: satellite images, Landsat, Aster, Sentinel, spectral library, lithology, mineral, rocks.

INTRODUCTION

Spectral libraries, or libraries of spectral characteristics of objects on the Earth's surface, are valuable sources of information for processing remote sensing data, they are indispensable for decoding multispectral and hyperspectral satellite images that contain information about subtle spectral differences between objects and phenomena.

Spectral libraries are sets of graphs-curves of the spectral reflectivity of objects obtained by multichannel spectrometers in the field or laboratory conditions. Due to the spectral properties of vegetation, rocks and minerals, which differ in their own light reflection and light absorption, it is possible to map the Earth's surface. To date, there are several publicly available spectral libraries that include spectral data of rocks and minerals. Below are some of them.

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1. USGS Digital Spectral Library. The library was created in the USGS Spectroscopy Lab's (current version splib07a - March, 2018). It contains data on the spectral reflectivity of minerals, rocks, soils, liquids, volatile compounds, frozen volatile compounds, vegetation, and artificial materials in the range from 0.2 to 150 micrometers. There are more than 1300 spectral curves in total [24].
2. JPL (Jet Propulsion Lab) spectral library. The library includes spectral reflectivity curves for 160 minerals ranging from 0.4 to 2.5 micrometers. For 135 minerals, measurements were made at different sizes of mineral grains (mineral particle size) – 125-500 micrometers, 45-125 micrometers and <45 micrometers. The main purpose of the library is to show the effect of grain size on the spectral reflectivity of minerals [6, 9-23].
3. ASTER spectral library. ASTER spectral library (current version 2.0 - December, 2008) was created to support the use of Terra/ASTER images and contains data from the spectral libraries listed above. In total, it contains more than 2,400 spectral curves of natural and artificial materials in the range from 0.4 to 15.4 micrometers [4].

On the basis of the spectral libraries described above, a single ECOSTRESS spectral library was compiled in 2018. Currently, the ECOSTRESS spectral library includes more than 6000 spectra of natural and artificial materials [25]. Full spectrum files, as well as auxiliary files, can be obtained on the website https://speclib.jpl.nasa.gov/download. The use of remote methods of automatic mapping of minerals and rocks, using spectral libraries of USGS, JPL, ASTER, etc., based on publicly available multispectral images such as: Landsat, Aster, Sentinel, do not always provide reliable information. The main reason for this is the spectral characteristics of rocks and minerals obtained in foreign countries with different exogenous physico-chemical conditions, age and mineralogical composition, unlike our conditions.

To solve these problems, we are faced with the task of creating a national spectral library of rocks and minerals on the example of the central part of the Bukantau Mountains (Fig. 1) in the Central Kyzylkum region, where large gold, silver and tungsten deposits of Uzbekistan are located.

With the help of multispectral satellite images, it is possible to recognize and map rocks and minerals on the Earth's surface by obtaining spectra in the invisible infrared range. The use of aerospace materials processing in geological prospecting studies is economically efficient and appropriate for mapping rocks, mineral indices and zones of secondary and hydrothermal changes, alunitization, kaolinitization, propylitization, limonitization. This is proved by the results of numerous studies conducted by foreign and domestic specialists [1, 2, 3, 8, 26-28, 30].

Over the past 15 years, new methods have been developed for processing publicly available satellite images of Landsat, Aster, and Sentinel for mapping various mineralization, lithological changes and structural-geological mapping [26-28, 30].

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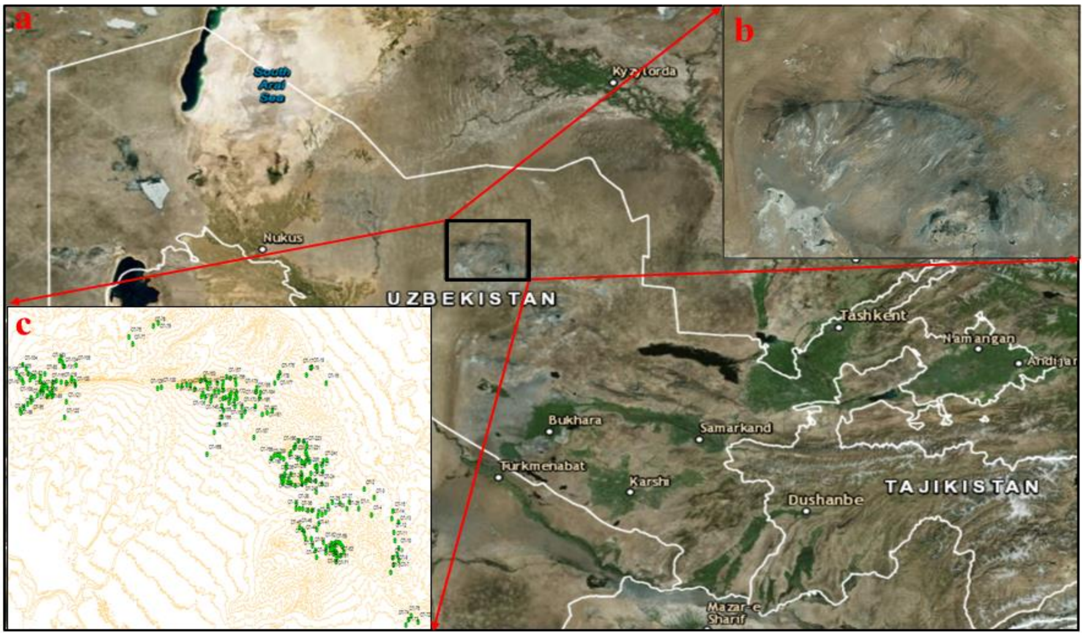
Fig 1: Overview satellite image



a - Uzbekistan and adjacent territories; b- overview of the study area of the central part of the Bukantau Mountains; c-map of the actual material (horizontal with the sampling site and spectral measurement)

METHODOLOGY

As a result of scientific research, the study of methods for creating the above spectral libraries and testing methods for processing digital satellite images, a method for creating an electronic spectral library of rocks and minerals of the Bukantau Mountains was developed (Fig. 2).

This methodology consists of five main steps, which are carried out in stages.

1. Carrying out spectral measurements. First of all, this applies to spectral measurements in the field. Because the ability of rocks and minerals to reflect light in natural conditions is very different from that obtained in laboratory conditions. In order to correct this difference, it was the rock or mineral from which the measurement was made that was taken as a sample, and spectral analysis is carried out for the second time in laboratory conditions. Thus, a spectral measurement is carried out once again by the mass of the sample taken together, and all measurements of the sample are compared.
2. Formation of the database. At this stage, spectral measurements taken from each mineral or mountain surface are compared with the results of processing satellite images, and a metadata database is created in which the light reflection coefficients of spectral measurements are concentrated.
3. Statistical data analysis. At this stage, a reference book is compiled indicating the spectral curves of mountain ranges and minerals and the maximum light reflection intervals.

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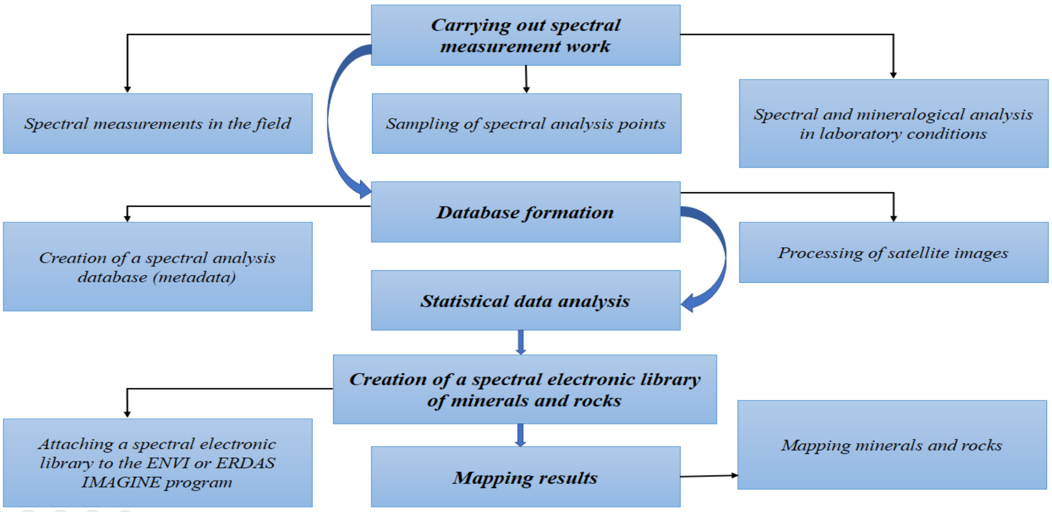
Fig.2: Scheme of methodology for creating a spectral library of rocks and minerals of the Bukantau Mountains



4. Creation of a spectral electronic library of minerals. With the help of a special program, all the spectral measurements obtained and their metadata files are collected in one application. This application is attached to the space photo processing programs ENVI or ERDAS.
5. Mapping the results. With the help of an application attached to the ENVI or ERDAS program, satellite images of the studied territory are processed and maps of minerals and rocks distributed in the territory are compiled..

Field spectrometric studies were carried out by Spectral Evolution PSM-3500, which covers measurements of the ultraviolet, optical and infrared range (350-2500 nm). When planning the routes of spectrometric studies and sampling, a geological map of the study area of a scale of 1:50,000 compiled by Ya.B. Aisanov et al. was taken into account. The routes focus on the outcrops of Paleozoic rocks and rocks that have undergone changes associated with mineralization. Measurements were made both in the field and in the laboratory. Mineralogical and petrographic descriptions were made based on the selected samples.

RESULTS

As a result of the conducted research, a spectral library of rocks and minerals was created on the territory of the Bukantau Mountains. When creating an electronic library, the main attention is paid to comparing the spectra of various rocks belonging to different ages and formations. The database characterizes the type and composition of the rock, stratigraphic confinement, color, etc. With the creation of a spectral library of rocks and minerals, publicly available multispectral satellite images were tested, the measurements obtained were imported into the program Envi-5.3. Then, an automated method was used to search for minerals of indicators of gold and other mineralization. As a result of these operations, halos of mineral changes were obtained, reflected in Fig. 3.

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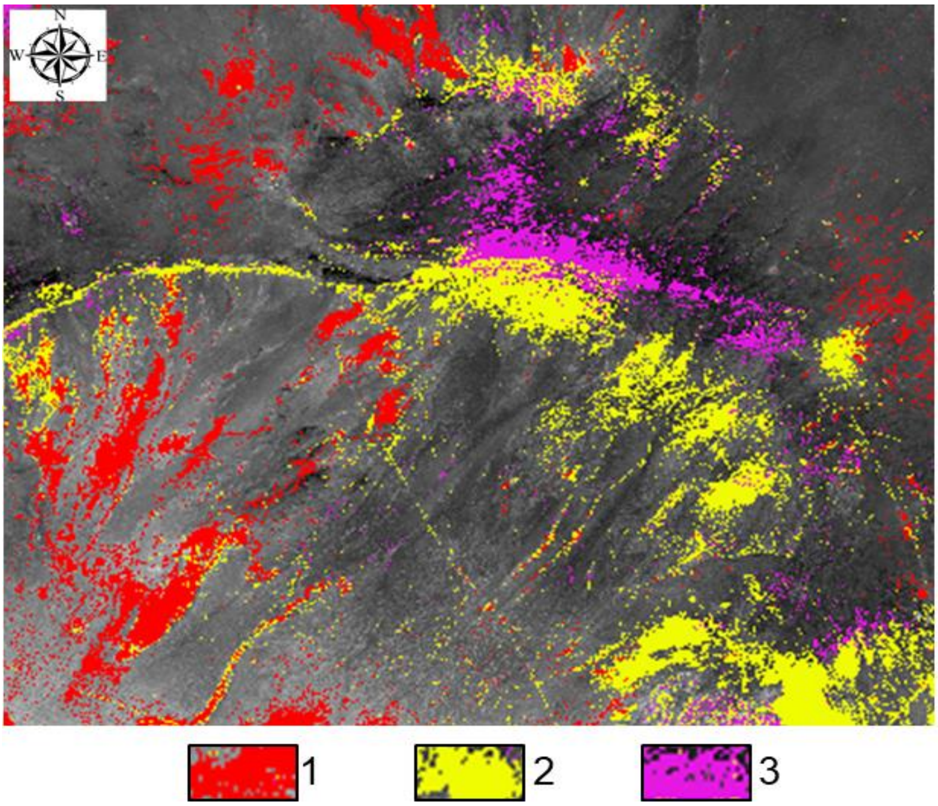
Fig 3: Map of mineral changes



1-iron oxide; 2- kaolinitization zones; 3-iron-containing rocks.

A brief geological structure of the studied territory explaining the color scheme according to the ratios of satellite image channels. In the studied area, pre-Mesozoic formations complicated by tectonic processes are exposed, in the southern part of which Cretaceous formations are represented (Fig.4a). Stratigraphically, the Pre-Mesozoic complex encompasses sedimentary, volcanogenic, metamorphic, intrusive formations that vary greatly laterally in the meridional direction in terms of material composition and genesis. On this basis, different types and subtypes of sections are distinguished, corresponding to the consedimentary structural-formation (landscape-tectonic) paleozones and subzones with varying degrees of completeness of the preserved sections. In the northwestern and northern parts of the study area, the only petrotypically large (about 150 km2. 25x6.0 km), elongated in the north-easterly direction, is represented by the same–named array - linear stock, the so-called Bokalinsky tonalite-trondyemite complex (C3b). The types of accessory mineralization of the complex are sphene-apatite-magnetite, apatite-sphene, and pyrite-apatite. Geochemical specialization – copper, gold, arsenic.

The results of processing satellite images caused for mapping the lithological heterogeneities of the study areas and identify zones of hydrothermal change. In the course of field work at this site, samples were taken for laboratory analysis. The results of laboratory studies have

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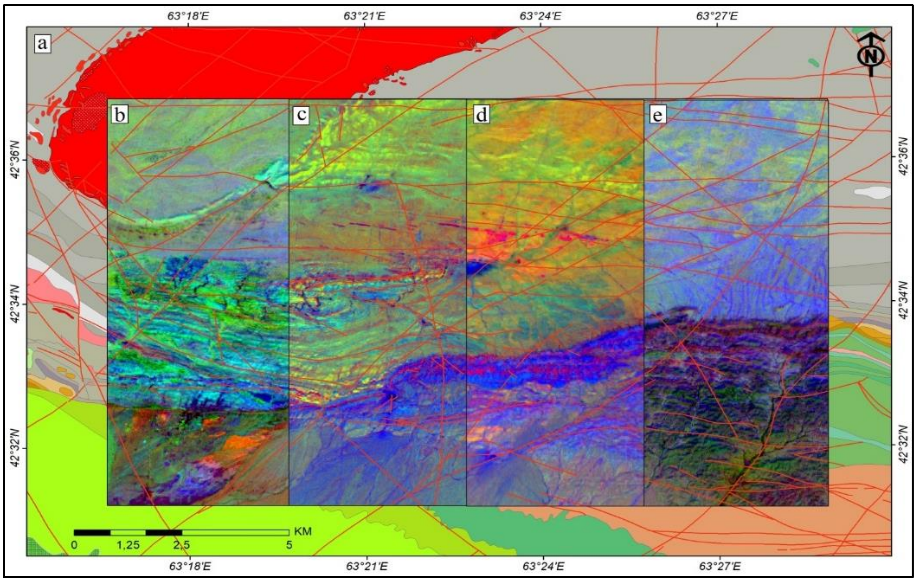
shown the industrial content of gold and related elements, molybdenum, tungsten and copper in small amounts. RGB systems use short-wave infrared (SWIR) channels in combination with the visible and near-infrared VNIR channels of Sentinel-2A satellite images, which increases the color heterogeneity, which allows to identify more polygons associated with lithology.

Fig 4: Results of processing Sentinel-2A and Landsat-8 multispectral satellite images by channel ratios compared with the geological map



a) geological map on a scale of 1:50,000 (according to Aysanov Ya.B.); b) Sentinel-2A Channels R=4/3, G=12/1, B=11/6; c) Sentinel-2A channels R=4/3, G=11/2, B=12/4; d) LC8 channels R =6/5, G=7/6, B=4/7; e) Sentinel-2A Channels R=4/3, G=12/11, B=11/6;

As a result of processing satellite images by channel ratio, various combinations have been developed that solve problems in lithological mapping. Fig.4. b, c and d are the optimal combinations obtained artificially to display lithology. In Figure 4e, the identified color anomaly limits the direction of Paleozoic sediments, and these limits correspond to geological faults.

The performed ratios of satellite image channels (Fig. 5) of Landsat-8 and Sentinel-2 in the multispectral and visible range give a false color gamut or anomaly. It is known that each narrow band of the spectrum of the electromagnetic range recorded by multispectral satellite images gives a color variety associated with lithological heterogeneities of the territory, sometimes differing in the basic composition. Figure 5 shows the results of mapping gold mineralization zones in one of the sections of the Bukantau Mountains, obtained by the ratio of channels of satellite images Landsat-8 and Sentinel-2.

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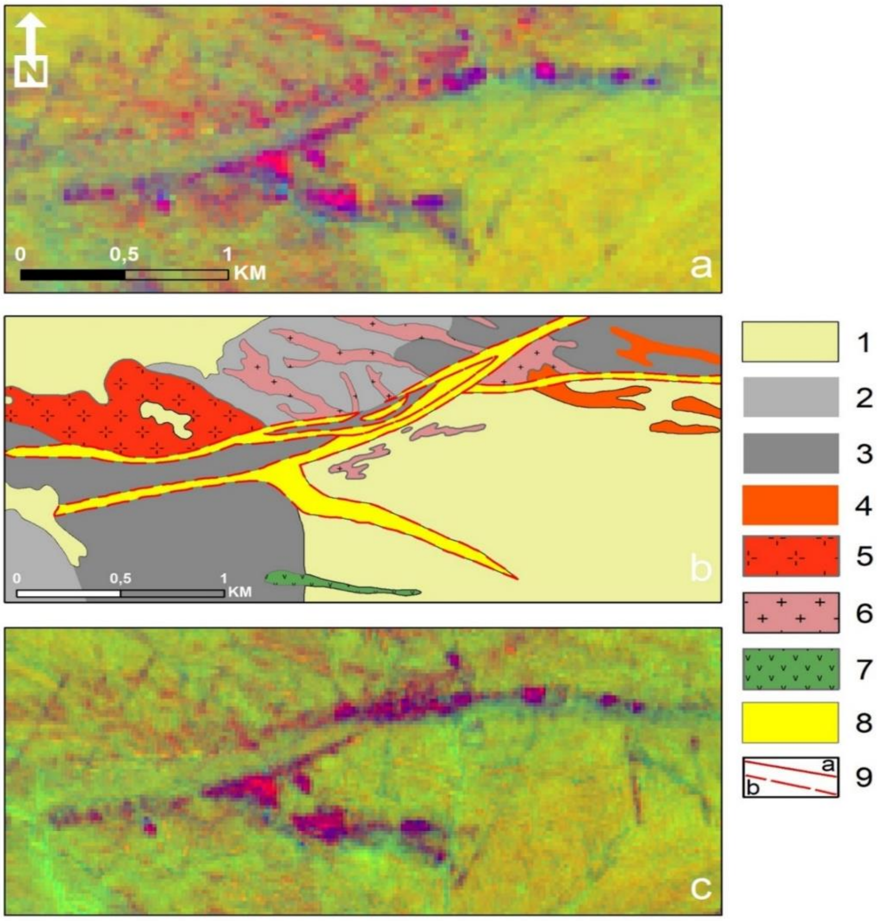
Fig 5: Processing of multispectral satellite images



a) Landsat-8 OLI; b) a fragment of a geological map on a scale of 1:25,000 c) Sentinel-2A. 1 - Meso-Cenozoic deposits overlying the foundation of Paleozoic rocks; 2- upper Carboniferous deposits; 3- lower Carboniferous deposits; 4- C2-3 kp2 (?) Volcanogenic-terrigenous-carbonate-siliceous formation, silicones, quartzites, dolomitized limestones, lenses of andesite-basalt composition. 5-Kakpatassky complex: Granodiorites, 6-Granodiorite-porphyry; 7-Diorites, quartz diorites; 8-mineralized zones established by geological data (A.P.Cheshuin, 1994). 9- Tectonic disturbances: a -traced, b -alleged.

Within the framework of this study, more than 30 combinations of Aster, Landsat-8, and Sentinel-2A satellite image channels were used and new combinations were created that made it possible to identify boundaries typical of Paleozoic formations reflected in various colors. The ratio of channels of Sentinel-2A satellite images in the short-wave infrared range allowed to identify lithological changes in the Kokpatas and Karashakh formations, in which gold mineralization was established.

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CONCLUSION

The created national spectral library of rocks and minerals provides new opportunities for automated decoding of satellite images with the allocation of promising areas, allowing to identify priority objects for searching for different types of ore minerals (gold, silver, and tungsten, copper) on the territory of the Bukantau Mountains. The results of processing Aster, Landsat-8, and Sentinel-2A satellite images with verification of spectral curves served to identify zones of hydrothermal changes associated with gold mineralization. Thanks. The article was prepared within the framework of grant No. FZ-201912109 with the financial support of the Ministry of Innovative Development of the Republic of Uzbekistan, as well as the entire staff of the Center of Remote Sensing and GIS technologies.

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