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Research Article

SPECTRAL ANALYSIS OF THE LANDSAT 8 IMAGE OF THE NURATA MOUNTAINS BY THE PCA METHOD

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ABSTRACT
The article presents the essence of the principal components analysis method and the results of processing and analysis of the Landsat 8 satellite image of the Nurata Mountains. The results of the study confirmed that when selecting and mapping rocks of different types and ages, the image processed by the Principal Component Analysis (PCA) method is the most informative. Taking into account the geological features and numerous intrusions of the Nurata Mountains, RGB combinations of the principal components make it easy to distinguish intrusive rocks of different composition. At the same time, intrusive rocks are separated by their color phototone and patterns.

Keywords: *Landsat, Spectral Channels, Multispectral Images, Processing, Covariance, Correlation, Decryption, Rocks*

INTRODUCTION
In recent years, large volumes of Earth remote sensing materials have been accumulated in the form of digital satellite images of various resolutions and spectral ranges, specialized software products have been developed for their processing and analysis. The use of remote materials in geology made it possible to study the geological structure of the studied territory in a new way, geological and material complexes, structural heterogeneities in both open and closed territories. They are also widely used in the isolation of hydrothermally altered rocks and minerals. This is proved by the results of research conducted by foreign and domestic specialists (Ergashev *et al.*, 2001; Kashkin *et al.*, 2001).

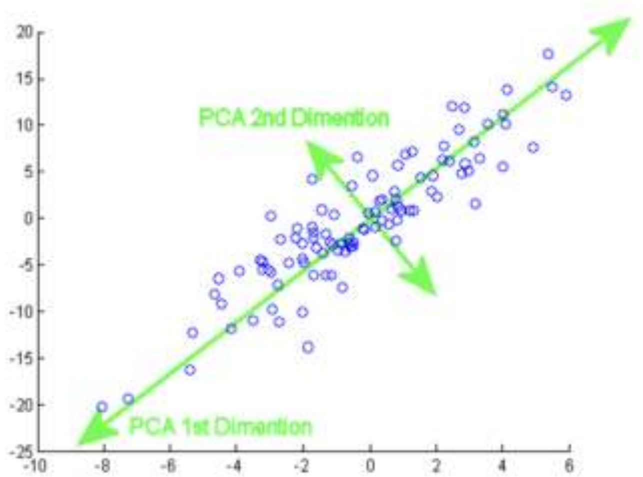

Figure 1: Distribution of spectral features by main components
To date, multispectral data are optimal for solving problems related to both decoding and determining the material composition of rocks. Moreover, well-proven methods of statistical processing are applicable when processing data of this type. One of such methods is the Principal Component Analysis (PCA) method (Kegl, 2008; Karpenko, 2016). Processing of a multi-zone image based on the principal

component method allows you to obtain a new image for which the first component has the greatest spectral contrast and is therefore the most informative. In the following components, the meaningful information decreases, and the older components contain only information about various noises and systematic errors of the shooting system.

MATERIALS AND METHODS

The work used multispectral images of the Nuratinsky Mountains (flight 155_32, 156_32) obtained from Landsat 8 satellites, the date of shooting September-October 2013. Preliminary processing of these images, including radiometric calibration, has been carried out. Further processed by the RSA method using the ENVI software product.

Principal Component Analysis (PCA) is a reliable statistical method that is used to suppress the effects of radiation dominating in all ranges, resulting in improved spectral reflectivity and enhanced mapping of geological features. The principal components method is designed to isolate uncorrelated combinations of features among correlated data, including in multispectral image processing tasks. The result of the tool is a multi-channel raster, where the number of channels is equal to a given number of components (one channel per axis or component in a new multidimensional space).

Figure 1 shows an example of a two-dimensional space of spectral features, as the value in the first channel increases, the value in the second increases, which means a high correlation between these channels. It can be seen that the area of distribution of values is located at an angle to the axes of the graph, so none of these axes shows the entire range of values of the object. This means that when synthesizing a color image, the image will be deprived of colors. For example, all types of vegetation will be depicted with close indistinguishable shades of color. This arrangement of brightness values is typical for most natural objects (vegetation, soils, rocks). If the coordinate axes are expanded so that one of them runs parallel to the field of distribution of values, and the second is located orthogonally, then along each of the axes the range of values will be maximum, which will increase the possibilities of decrypting the image.

The algorithm of the PCA method consists of the following sequential steps:

1. At the first stage, the vector of average values is calculated. These data are necessary for calculating the covariance matrix (Table.1);
2. The covariance matrix of the original matrix is calculated (Table 2);
3. The calculation of the eigenvectors and the corresponding eigenvalues of the vectors is performed (Table.3);
4. A transformation matrix is formed, for this the eigenvectors are ordered by their eigenvalues, and m eigenvectors with the largest eigenvalues are selected;
5. The initial matrix of features is transformed into the matrix of the main components using the transformation matrix obtained at the previous stage.

As a result of calculations, 8 matrices of the main components were obtained, combining 3 of them in the RGB system, which are color images of the main components.

Table 1: Calculation of the vector of average values

Channel statistics	Min	Max	Average	Eigenvalue
Band 1	-481.868347	144.518600	50.305887	2530.682294
Band 2	-66.193298	103.479179	9.532319	90.865102
Band 3	-46.925396	74.396782	5.404705	29.210833
Band 4	-29.334808	18.939598	1.418199	2.011287
Band 5	-23.785469	56.170132	0.623541	0.388803
Band 6	-28.712248	29.075560	0.402912	0.162338
Band 7	-10.194331	3.574791	0.154528	0.023879
Band 8	-0.228874	0.717786	0.024541	0.000602

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Table 2: Covariance matrix

Ковариация	1	2	3	4	5	6	7	8
PC1	2530	0.00	-0.00	-0.00	-0.00	0.00	-0.00	0.00
PC2	0.00	90.86	-0.00	-0.00	-0.00	0.00	-0.00	-0.00
PC3	-0.00	-0.00	29.21	0.0000	0.00	-0.00	0.00	-0.00
PC4	-0.00	-0.00	0.00	2.01	0.00	-0.00	0.00	-0.00
PC5	-0.00	-0.00	0.00	0.00	0.39	0.00	0.00	-0.00
PC6	0.00	0.00	-0.00	-0.00	0.00	0.16	0.00	0.00
PC7	-0.00	-0.00	0.00	0.00	0.00	0.00	0.024	0.00
PC8	0.00	-0.00	-0.00	-0.00	-0.00	0.00	0.000	0.001

Table 3: Calculation of eigenvectors

Eigenvektor каналы	1	2	3	4	5	6	7	8
PC1	0.647	0.626	-0.384	-0.059	-0.084	0.0319	-0.169	0.006
PC2	-0.006	-0.009	0.021	0.290	-0.311	-0.707	-0.206	-0.525
PC3	0.006	0.016	-0.032	0.266	0.199	0.568	0.033	-0.751
PC4	0.0003	0.002	-0.011	0.749	-0.505	0.258	0.084	0.332
PC5	-0.045	-0.031	0.091	-0.526	-0.772	0.245	0.116	-0.205
PC6	-0.055	-0.077	0.228	-0.033	-0.039	0.219	-0.938	0.090
PC7	-0.232	-0.360	-0.885	-0.048	-0.061	0.027	-0.162	0.009
PC8	0.722	-0.686	0.083	0.003	0.002	0.003	0.0374	-0.009

The first main component (PC1) will have the maximum amount of independent information, the second main component (PC2) will have the second largest amount of independent information not contained in the first main component, etc. Figure 2 shows images of the Main Components (RS) obtained as a result of processing the Landsat 8 satellite image using the PCA method.

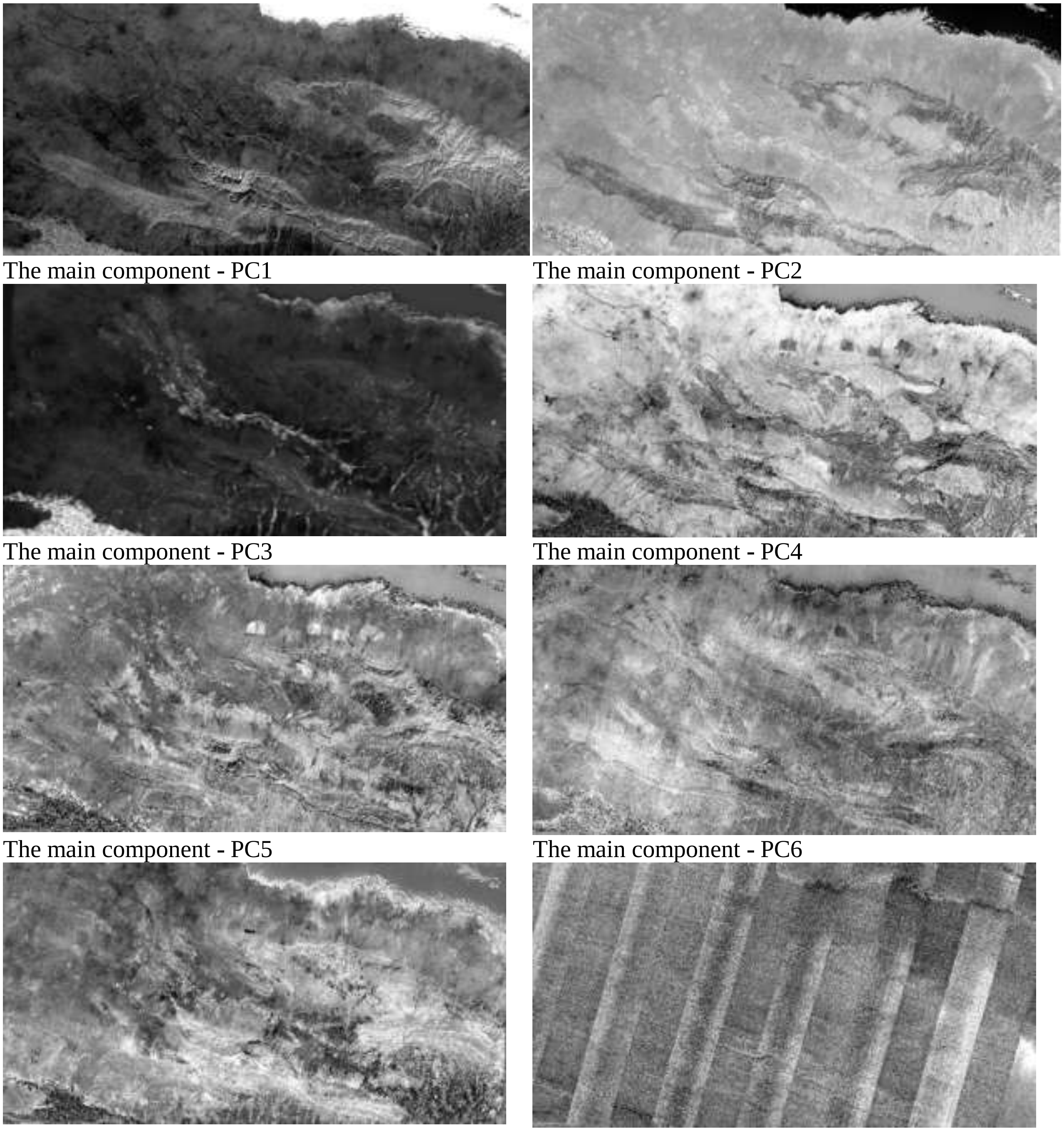
RESULTS AND DISCUSSION

Nurata mountains are a system of elevations and deflections, plunging from the SE to the NW. The geological structure of Nuratau is determined by intensively dislocated rocks of the Paleozoic basement, which are represented by carbonate-terrigenous strata of the Cambrian-Devonian and intrusive formations of the Carboniferous-Permian age.

The analysis of the main components by separability is very time-consuming. Therefore, to evaluate and further analyze the geological informativeness of the new channels of the main components, a color combination in the RGB system was performed. The number of RGB combinations depends on the number of main components (the total number is 8 factorial). Experimentally selected more than 20 combinations using the first three components, which are the most informative.

Figure 3 shows the combinations of the first three main components (PC3, PC2, PC1) in the RGB system. As a result of the analysis, different types of rocks of the studied territory were identified. In the folded basement, metamorphogenic formations of the Lower Paleozoic are revealed by violet - reddish and purple colors. Carbonate-terrigenous rocks are purple-greenish-yellowish in color.

Intrusive formations of the Nuratinsky Mountains stand out well in RGB combinations with channels containing less variable information (PC3-PC8). Figure 4 shows the combinations of the first three main components (PC5, PC4, PC3) in the RGB system (Fig.4). As a result of the analysis, all intrusive formations of the studied territory were identified. Intrusive formations of the Carboniferous-Permian age



The main component - PC1

The main component - PC2

The main component - PC3

The main component - PC4

The main component - PC5

The main component - PC6

The main component - PC7

The main component - PC8

Figure 2: The main components obtained as a result of processing by the RSA method.

are mainly composed of gabbro, syenite, diorite and granodiorite rocks. They differ markedly from metamorphosed and carbonate rocks in bluish-green phototones with white spots.

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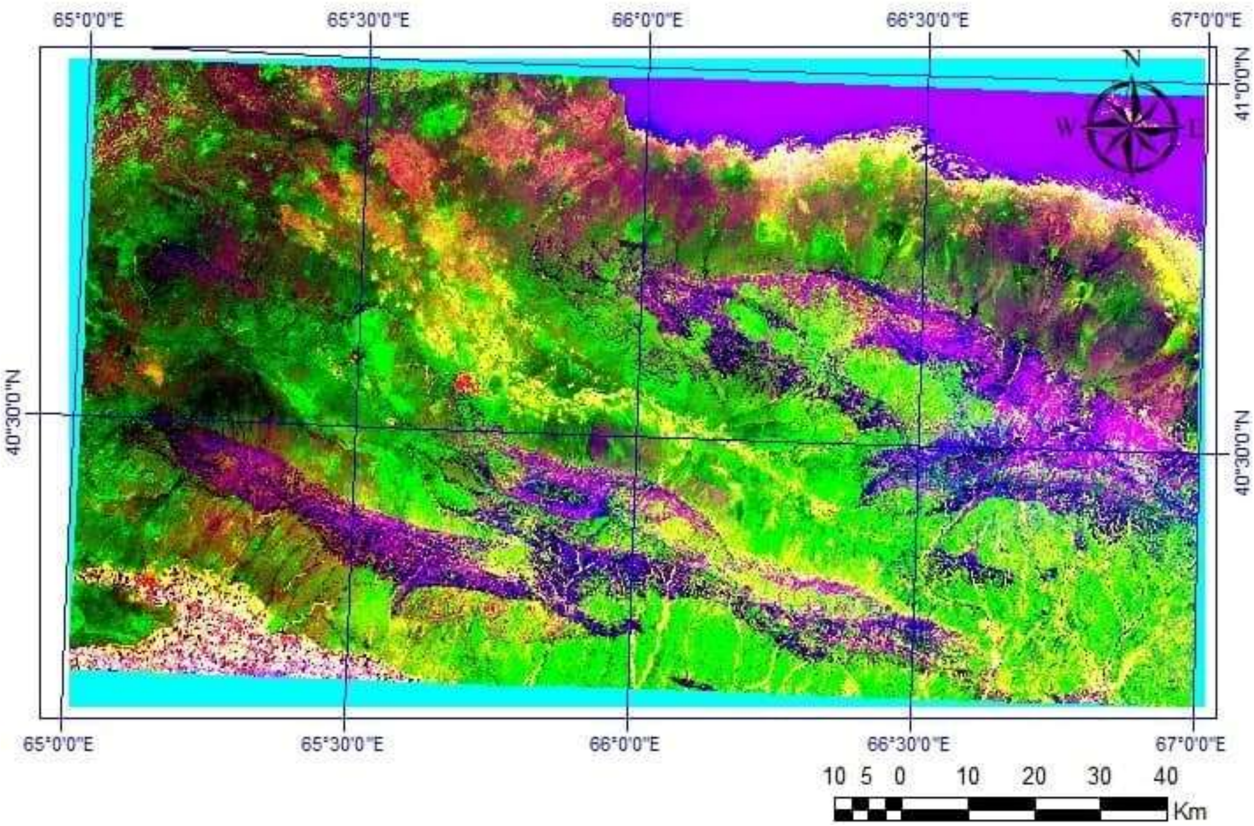

Figure 3: The combination of the main components (PC3, PC2, PC1) in the RGB system

Igneous rocks of various composition and age are widely distributed within the Nurata Mountains. The composition of intrusive formations has been studied in detail by geologists, the age of these formations is from the Proterozoic to the Late Paleozoic. The volcanogenic complexes of the Nurata region include the following: Majerum metabasalt (PR1?), Silurian (?) metabasalt-metandesite, Malguzar diabase-granitoid (S), metadacite-rhyolite Tangin formations, Chimkurgan trachybasalt-trachyandesite-trachyte complex, carboniferous volcanogenic formations of Nuratinsky mining district. The intrusive complexes of the Nuratinsky mining district include the following: Nuratinsky hyperbasite-gabbro (PP1?), Koshrabad gabbro (essexite)-syenite-granosienite, Kattaichi gabbro-diorite-granodiorite, Shurak granodiorite-adamellite-granite, Chagatai carbonatite.

CONCLUSIONS

Thus, this method of processing satellite images "sifts" different, smaller information contained in images and color combinations in the RGB system, the main components that make it possible to map different types and different ages of rocks painted in different tones, including quaternary and modern formations that differ in age and composition.

Assessing the geological informativeness of various combinations of RSA results, we can conclude that this processing method allows us to obtain remote materials on which the greatest geological and material information is integrated in the conditions of the Nuratinsky Mountains. Such images are recommended as a basis for geological survey, thematic and other works, as well as for targeted lithological and petrographic studies.

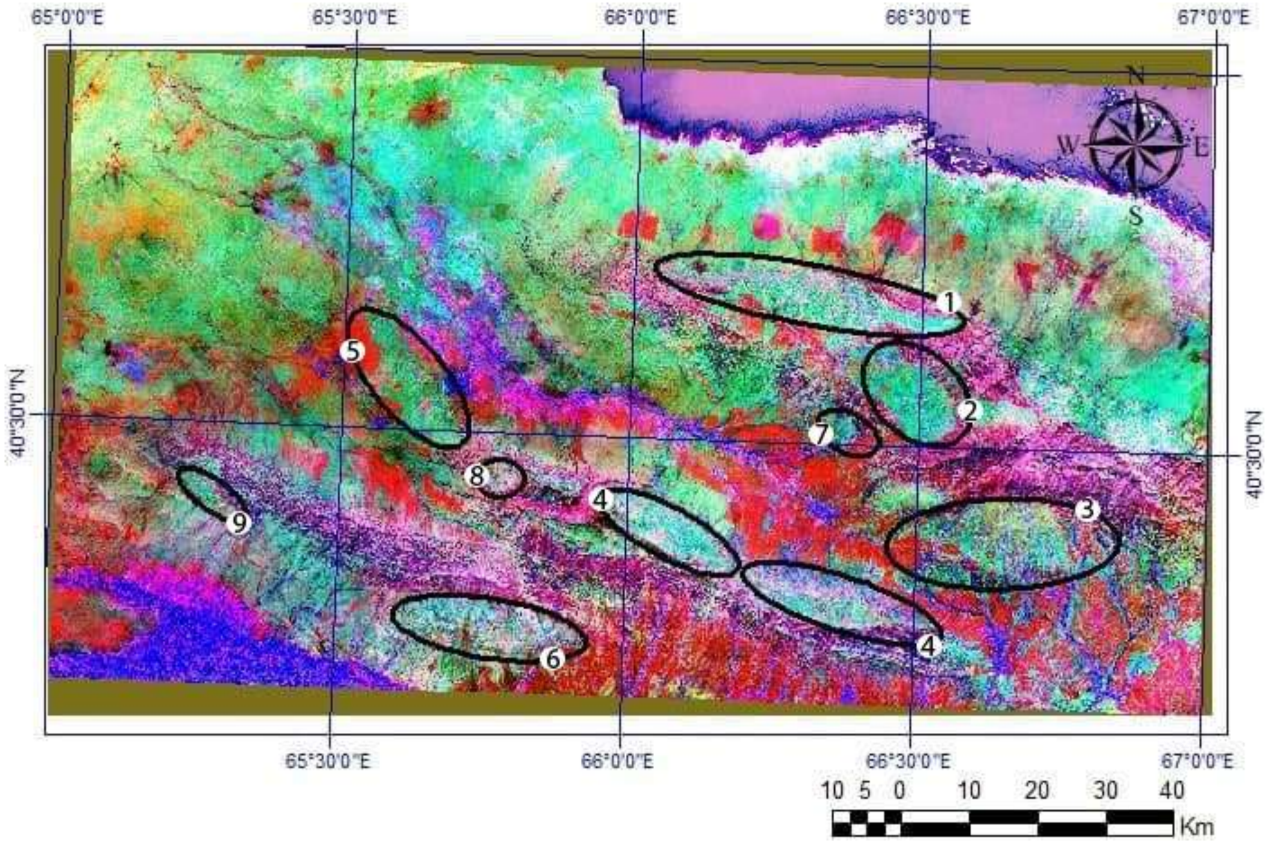

Figure 4: The combination of the main components (PC5, PC4, PC3) in the RGB system
Intrusive: 1-Temirkabuksky, 2-Ustyugsky, 3-Koshrabatsky, 4- Aktau, 5- Nuratinsky, 6-Karatau, 7-Akchopsky, 8-Bitabsky, 9-Chettiksky.

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