Remote sensing abnormal extraction of hydroxyl alteration based on PCA method

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Abstract: Anomalous geological events often occur during the formation and evolution of mineral deposits. The use of remote sensing technology to extract anomalies is one of the important contents of remote sensing prospecting. The principle is to use different minerals to show differences in the responses of different bands of remote sensing images. Landsat satellite has accumulated massive amounts of remote sensing image data since its launch, providing a research foundation for geological remote sensing. This paper takes the eastern part of Tuoli County, Tacheng District, Xinjiang Uygur Autonomous Region as the research area, and selects ENVI software for remote sensing image preprocessing and remote sensing anomaly extraction. Four bands including TM1, TM4, TM5, and TM7 of Landsat5 TM image are used as the basic bands for extracting hydroxyl remote sensing anomaly information. After preprocessing, the influence of vegetation and water bodies on remote sensing prospecting is suppressed by masking method, and then the Corta method is used to delimit the threshold value to judge the degree of alteration. The PCA method is generally used to extract the remote sensing anomalies of hydroxyl alteration in the study area, and finally the thematic map visually displays the results of the remote sensing anomaly extraction, which proves that the PCA method based on Landsat5 TM images can provide a certain reference for geological work such as prospecting.

1. Introduction

Traditional geological surveys and mineral surveys consume manpower and material resources. They have disadvantages such as low work efficiency and small area coverage. With the development of remote sensing technology, geological remote sensing has been widely used in the geological industry. This technology uses remote sensing image data from land satellites, sky laboratories, and aerial platforms to conduct basic theoretical research on geological remote sensing, indoor and outdoor various rocks and minerals and spectral curve measurement[1-2]. In conclusion, geological remote sensing is a strong support for the geological industry.

Altered rock, also known as altered wall rock, is an important prospecting sign. Most porphyry copper deposits in Russia and North America, Tongguanshan copper deposit in China, Big platinum deposit in Mexico, and corundum deposit in Kazakhstan Most tin deposits in the world are deposits discovered with wall rock alteration as a sign of prospecting. Altered rocks and surrounding rocks have differences in composition, mineral structure, surface shape and color. These differences result in
different spectral characteristics. Spectral anomalies of specific altered rocks are formed in certain spectral bands. All these provide research opportunities for remote sensing. Remote sensing alteration generally refers to hydroxyl alteration and iron-staining alteration. Hydroxyl altered rocks are produced by hydroxyl, water or carbonate groups, and the hydroxyl absorption spectrum has two places of 2.2 µm and 2.3 µm. Because OH⁻ is in 2.2~2.3 µm. There are strong absorption valleys (called hydroxyl bands) nearby, which makes ETM7 produce low values and ETM5 produce high values[3]. Hydroxy minerals are mostly secondary altered minerals, such as kaolinite, muscovite, sericite, montmorillonite, green Mudstone and alunstone. From the current research at home and abroad, the more common methods for extracting remote sensing alteration are the spectral angle matching method, the band ratio method and the PCA (Principal Component Analysis) method. Among them, the PCA method is simple to operate and has good accuracy. It is one of the commonly used remote sensing prospecting methods at home and abroad.

2. Research area and data source

2.1. Study area
Tuoli County is located in the Tacheng area of the northwestern Xinjiang Autonomous Region, between 82°28’~85°20’ east longitude and 44°58’~46°24’ north latitude, with a border line of approximately 58 kilometers long. Tacheng area Tacheng is located in the northwestern part of Xinjiang, China, and has many distinctive topography. 41 kinds of metal and non-metal minerals have been discovered in Tacheng area, and the overall mineral data is relatively abundant.

According to statistics, as of 2011, 80% of Tuoli County is located in the Western Junggar metallogenic belt, with good mining conditions and obvious development advantages. This study selects the eastern part of Tuoli County, as shown in Figure 1. This area has complex topography, rich minerals, and few vegetation water bodies, which has certain research value.

2.2. Remote sensing images
The remote sensing image data used in this study is Landsat 5 satellite TM image data, which belongs to optical remote sensing data. The TM image has high spatial resolution, spectral resolution, extremely rich information and high positioning accuracy, which is widely used in various countries in the world. One of the important earth resources and environmental remote sensing data sources used. The image selected in this study is shown in Figure 2. When making the thematic map, select the area with more hydroxyl alteration distribution in the study area. Its imaging time was September 6, 2011, the row number was 145, 408, and the image location was Karamay, Xinjiang. The image data download address is: Geospatial Data Cloud (http://www.gscloud.cn/).
3. Introduction to research methods and experimental flowchart

3.1. PCA method
Principal component analysis method The principal component analysis method is based on summarizing the spectral characteristics of typical altered ores and selecting several bands to carry out principal component transformation analysis[4].
According to the magnitude and direction of the eigenvector load factor after each band transformation, the spectral corresponding characteristics of altered minerals are judged, and then the anomalous principal component images are judged, and finally the remote sensing mineralization alteration anomaly information extraction is completed.

3.2. Crosta method
The Crosta method is summarized and proposed on the basis of the PCA method. It conducts principal component analysis by selecting four characteristic remote sensing bands that reflect the change of the target ground feature better[5]. First determine the threshold, and then make different intervals according to the threshold, so as to grade the degree of alteration. This paper is based on Landsat5 TM remote sensing image to extract hydroxyl alteration. The bands selected for hydroxyl alteration are TM1, TM4, TM5, TM7, and the band information is shown in Table 1.

| Band | Wavelength range /μm | Main application areas |
|------|----------------------|-----------------------|
| TM1  | 0.45–0.52            | It can penetrate water bodies, reflect the underwater characteristics of diving, distinguish soil and vegetation. |
| TM4  | 0.76–0.90            | Measure biomass and crop growth, distinguish different types of rocks, distinguish clouds, ground ice and snow. |
| TM5  | 1.55–1.75            | Detect the self-heat radiation of different materials on the earth's surface, be used to draw map thermal of geothermal. |
| TM7  | 2.08–2.35            | Distinguish the main rock types, the degree of thermal erosion of the rock, and to detect the clay minerals. |

3.3. Research flowchart
The complete test process is shown in Figure 3, which mainly includes three parts: remote sensing image preprocessing, mask removal of vegetation water images, hydroxyl alteration abnormal extraction, and result analysis. The process is shown in Figure 3.
4. Abnormal extraction of hydroxyl alteration

4.1. Image preprocessing
When calculating the spectral reflectance or spectral radiance of the target feature, the first step is to perform radiometric calibration to convert the image brightness gray value into absolute radiance. The study area is located in a plateau area with complex terrain. Therefore, the geometric distortion of remote sensing images caused by terrain undulations and other reasons is more serious. In addition, the image must be geometrically corrected after radiometric calibration, which purpose is to eliminate or correct the geometric error of remote sensing images. Finally, atmospheric correction is carried out on the remote sensing image to eliminate the radiation error caused by the influence of the atmosphere, and invert the more accurate surface reflectivity of the ground object.

4.2. Mitigating the interference of vegetation and water bodies
In general, remote sensing prospecting research often needs to eliminate the influence of vegetation and water bodies on minerals[6]. The vegetation and water bodies are extracted by remote sensing to obtain the range of vegetation and water bodies in the study area, and the pre-processed images are masked by vegetation and water bodies through the mask tool Build Mask commonly used in ENVI. It is worth mentioning that the prerequisite for using the Build Mask tool is to have the specific range data of the mask area. For areas that are difficult to extract, you can also directly use Vegetation Suppression Tools for inhibiting the effects of vegetation.

4.3. Remote sensing extraction of hydroxyl alteration
Use the Forward PCA Rotation New Statistics and Rotate tool, select the four bands of TM1, TM4, TM5, TM7 and add the mask file obtained after the mask work, perform PCA analysis, and obtain the characteristic vector of the band matrix as shown in Table 2.
Table 2 Eigenvectors of TM 1 4 5 7.

| Eigenvectors | Band1(TM1) | Band4(TM4) | Band5(TM5) | Band6(TM7) |
|--------------|------------|------------|------------|------------|
| Band1(TM1)   | 0.1334     | 0.4525     | 0.6350     | 0.6109     |
| Band4(TM4)   | 0.4877     | 0.7276     | -1.966     | -0.4395    |
| Band5(TM5)   | 0.8425     | -0.4445    | -0.1008    | 0.2465     |
| Band6(TM7)   | -0.1307    | 0.2554     | -0.7392    | 0.6089     |

The basis for judging the main components of hydroxyl and carbonate ions is that the coefficient of TM5 is opposite to the coefficients of TM4 and TM7, and is the same as TM1[7]. According to the above basis, select the fourth component, TM7 as the discriminant band, using the Compute Statistics tool to calculate its standard deviation $\sigma$ as 0.0055. It is worth noting that due to the influence of the atmospheric correction tool, the value of $\sigma$ will fluctuate slightly in each test.

According to the multiples of $\sigma$, the abnormality levels are further classified. The classification standard of this experimental study area is I. First-level abnormality $3*\sigma=0.0165$, II. Second-level abnormality $2.5*\sigma=0.1375$, III. Third-level abnormality $2*\sigma=0.011$. Selected parts of the southwestern region where the remote sensing anomalies are concentrated in the study area to draw the thematic map (Figure 4) of hydroxyl remote sensing alteration. This experiment belongs to the extraction of the remote sensing alteration distribution range, which is carried out by comparison with the actual situation in the study area.

5. Conclusion
Based on Landsat 5 TM remote sensing images, this paper uses the PCA method to extract the hydroxyl alteration in the study area. It is mainly located in the southwest part of the study area, in this area, the vegetation coverage is low, the water area is small, and the surface types are mostly bare rock. The remote sensing anomaly distribution has a certain similarity with the actual survey situation, which proves that this method has a certain reference significance for remote sensing prospecting.

Through the PCA method of TM multi-band data, each principal component obtained often represents a certain geological significance and does not repeat each other, the geological significance of each principal component is unique. Each selects the appropriate waveband according to the specific geology of the study area to improve the general applicability of the PCA method.
The use of remote sensing technology for prospecting work is mainly to detect and identify the properties of geological bodies based on their electromagnetic wave characteristics. This technology has a wide range of research and can detect geological structures at a certain depth underground, thereby revealing the geological conditions for the formation of minerals. Provide technical support for forecasting mineral prospects and finding blind ore bodies.

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