Identification of Burnt Rock Based on Hyperspectral Remote Sensing Data, Taking Rujigou Coal Mine in Ningxia as an Example

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ABSTRACT

The existence of burnt rock seriously affects the safety of coal mine production.In this paper, the airborne hyperspectral remote sensing image (CASI/SASI) was used as a main data resource in Rujigou Coalfield, Ningxia. Preprocesses, such as radiometric correction, radiometric calibration, atmospheric correction(spectral reconstruction) and geometric correction were carried out with ENVI5.1. Meanwhile , ASD FieldSpec® Pro FR portable spectrometer was used to test spectrum of all samples from burnt rocks, for extraction and analysis spectral characteristics. based on ground spectral data processing and comparative analysis, the Mixture Tuned Matched Filtering(MTMF) method was used to extract the boundry of the burnt rocks,and evevtually we got the distribution map of burnt rocks in the study area. After geological comprehensive analysis and field survey, the distribution of burning rocks in the field was basically consistent with the boundry extracted from hyperspectral remote sensing image. The result indicated that the CASI/SASI image had good application results and shew a promising potential in burnt rocks survey, which could provide a basic method for hyperspectral remote sensing prospecting in the same or similar unexplored areas.

Keywords: CASI / SASI aerial hyperspectral data, burnt rocks, Rujigou Coalfield,Ningxia, geological explorationthis

1. INTRODUCTION

Since the 1980s, remote sensing technology has been widely used and developed in the coal field. Guan Haiyan (1989) proposed that aerial remote sensing data could be used for coal prospecting, coal field mapping, coal mine fire area detection, and coal mine water and ground subsidence prevention investigation through aerial remote sensing experimental research in Taiyuan coal field [1]. Wan Yuqing et al. (2003) studied the reflection spectral characteristics of coal measure strata and burnt rocks in Rujigou coal field, Ningxia by using hyperspectral remote sensing technology. By sampling and analyzing the iron content of burnt rocks, they determined the quantitative relationship between the Fe^{3+} content in burnt rocks and the reflectivity of certain bands with the help of multiple regression analysis, and proposed the method of using hyperspectral remote sensing images to extract Fe^{3+} [2]. Tan Kelong et al. (2007) took the Gulaben mine fire area of Inner Mongolia Autonomous Region as an example to explore the method of monitoring underground coal seam combustion by using hyperspectral and high-resolution remote sensing technology, and realized the quantitative analysis and monitoring of combustion intensity in the fire area through hyperspectral image radiation temperature inversion combined with field geological survey and ground survey [3]. The objective of applying the quantitative survey results of remote sensing directly to the design of fire fighting engineering is realized [4]. However, there are relatively few studies on the distribution of burnt rock in coal field by using aerial hyperspectral remote sensing (CASI/SASI).

The existence of burnt rock seriously affects the safety of coal mine production.This paper takes Rujigou coal field in Ningxia as a demonstration area, takes CASI/SASI aerial hyperspectral data as the main information source, and takes FieldSpec® Pro FR portable spectrometer as the auxiliary means to collect spectra. Through the measured spectra (field and indoor) analysis, the hyperspectral research on the distribution of burned rock in the demonstration area is carried

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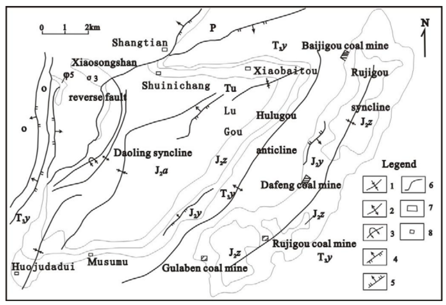
out. Combined with field investigation and sample test to verify the effect, it provides a basis for the implementation of hyperspectral remote sensing exploration in the same or similar areas.

2. GEOLOGICAL OVERVIEW OF THE STUDY AREA

Rujigou coal field is located in the Helan Mountain fault-fold belt of the platform fold belt on the western margin of Ordos Basin [5], bounded by the Alashan Shield on the west, the corridor transition belt on the south, and the Yinchuan Graben on the east, the Ordos platform fault-fold belt and the Ordos platform [6]. The coal field is represented by the NE-trending Xiaosongshan overthrust fault and the NE-axial Erdaogou syncline, Dahuolugou anticline and Rujigou syncline [7]. The outcrop strata from old to new include Ordovician, Carboniferous, Permian, Triassic, Jurassic and Quaternary, among which the Jurassic is the most widely exposed with a large number of quartz veins and occasionally carbonate veins, and the Yanan Formation of the Middle Jurassic is the main coal-bearing stratum (Figure 1).



1-Syncline; 2- Anticline; 3- steering fault; 4- reverse fault; 5- Normal fault; 6- Stratigraphic boundary; 7- Mining area; 8- Residential area

Figure 1. Geological map of the Rujigou Coalfield

3. DATA ACQUISITION AND PROCESSING

The CASI/SASI data used in this study were obtained by the CASI/SASI/TASI Airborne Imaging Spectral Measurement System (AHIS) developed by ITRES, Canada. The VIR-TIR airborne hyperspectral measurement system, It mainly consists of two sensors, the CASI-1500 and SASI-600, the ICU central controller, and a series of precise geometric correction and radiometric correction instruments (GPS device, POSAV310, ILS solar irradiance measurement instrument, three-axis stabilization platform PAV30 and IMU inertial system). Available in 380-1050 nm(CASI) and 950-2450nm(SASI), with a total of up to 388 bands and sub-meter spatial resolution. At the same time, there are three imaging modes: spatial mode spectral mode and full-frame mode (Table 1). The system is mainly used in mineral resources exploration, ecological environment monitoring, disaster detection and control, and provides technical support for the development of quantitative remote sensing technology in China.

On September 8, 2012, Y-5 small multi-purpose aircraft equipped with hyperspectral sensor carried out test data acquisition over Rujigou coal field. The flight relative altitude was 1500m, and a total of 17km2 hyperspectral data was obtained. The weather was clear and there were no (few) clouds on the day of data acquisition. Hyperspectral data. The data include CASI visible-near-infrared spectrum and SASI short-wave infrared spectrum, respectively. Among them, CASI data covers a total of 36 bands, with spectral coverage of 380-1045 nm, spectral resolution of 18 nm, and spatial resolution of 1m. SASI data consists of 101 segments with spectral coverage of 950-2450 nm, spectral resolution of 15nm, and spatial resolution of 2.25m. In the course of wave flight survey, black and white cloth measurements were also carried out simultaneously on the ground, and field spectral measurements of rocks in major mineralized areas were carried out.

The collected hyperspectral images have been corrected by flight attitude, and the spectral resolution has been processed by interval sampling, but no spectral calibration has been performed. Hyperspectral data processing first of all to browse the data check, the inspection found that the data in the 950nm-1047nm spectrum duplication, according to the principle of spectral bandwidth as small as possible, the repetition of SASI spectrum removal process; Several bands near the 1400nm and 1900nm spectra are removed because they are atmospheric Windows and are heavily affected by water vapor, which increases the amount of data computation and has no research value. Using GPS field measurement point as ground control point, geometric correction was made to the data of two hyperspectral navigation zones respectively.

The corrected results are carried out for image Mosaic. When Mosaic, the image with high resolution, new phase, less cloud and good quality is retained as much as possible. The Mosaic line meets the phenomenon of no ground object dislocation, blurring, double shadow and halo edge, and the texture and color of the Mosaic image with the same or similar time are naturally transitioned. Radiometric calibration and spectrum smoothing were performed after image Mosaic, and the processed hyperspectral image was shown in Figure 2.

Table 1. Main technical parameters of CASI/SASI airborne imaging spectrometer

Argument	Spectral range	Number of pixels per row	Spectral channel number	Spectral bandwidth	Frame rate (full band)	Total field of view Angle/(°)	Instantaneous field Angle/(°)	Signal-to-noise ratio	Absolute radiation accuracy /%
CASI-1500	380-1050nm	1470	288	2.3nm	14	40	0.028	>1100	<2%
SASI-600	950-2450nm	640	100	15nm	100	40	0.07	>1100	<2%

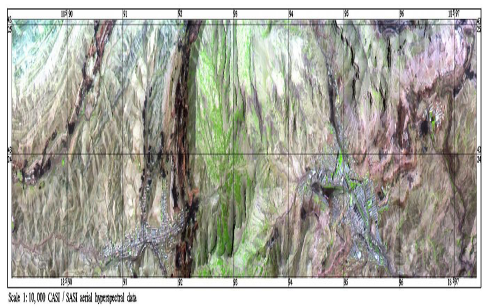


Figure 2. Hyperspectral remote sensing image of the Rujigou Coalfield（using airborne hyperspectral image CASI/SASI data，MNF transform）

4. SPECTRUM TEST

The FieldSpec® Pro FR portable spectroscopic radiation spectrometer produced by ASD was used for spectrum testing. The wavelength range was 350-2500nm and the detector was: 350-1050nm, low noise 512 array PDA, 1000-1800nm and 1800-2500nm, two INGaAs detector units, PE refrigeration constant temperature.

The purpose of spectrum testing is to find out the absorption spectrum and reflection spectrum intervals of different rocks or minerals, and to extract typical minerals and rocks through the difference, ratio, principal component, classification and other methods of different bands, so as to realize the spectral inversion research of typical rocks or minerals in high-resolution remote sensing images.

According to the geological section survey method, the location measurement. The profile survey traverses the major lithostratigraphic and mineralized alteration zones, with at least one test sample taken per typical stratigraphic unit. The rock test points on the profile should be encrypted according to the lithology changes or multiple samples should be tested at the same point, including burned rock and coal seam.

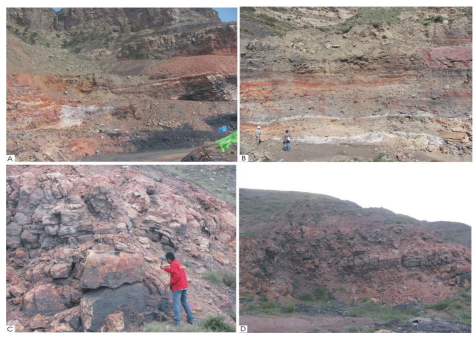
The sample size was 3cm×6cm×9cm. GPS positioning was used for each sampling point, coordinate data was collected, and field photos were taken. Each typical rock sample measured was identified and retained to verify the accuracy of the spectral test results.

At least 1 set of spectral curves are collected for each ore sample and the test parameters are recorded.

The spectral data obtained in the field were processed, and the relative abundance of minerals was determined by the ratio between the characteristic absorption peak of minerals and the characteristic absorption peak of water. The ratio calculation results were divided into six categories: absorption intensity, integral intensity, half-height width, reflectivity, intensity ratio and central wavelength. The greater the value, the higher the mineral abundance. Combined with the results of rock and mineral analysis, the spectral curves collected are compared with those of the corresponding minerals in the standard spectrum library, and the distribution rules of characteristic spectral bands of burnt rock and coal seam are summarized.

5. FORMATION AND HYPERSPECTRAL IDENTIFICATION OF BURNT ROCK IN RUJIGOU COALFIELD

Burnt rock is a kind of special rock formed by the metamorphism of surrounding rock caused by spontaneous combustion and baking of coal seam [8]. In this study, the burnt rock of No. 2 coal roof in Rujigou area is taken as the research object. According to the grain size of the original rock before burnt rock, the burnt rock can be divided into fine-medium grained sandstone burnt rock (Figure3A, C) and silt-argillaceous silt-burnt rock (Figure3B, D). According to the different degree of baking, it can be divided into two types: the layer burned rock with residual coal seam at the bottom, which is slightly baked (Figure3 A, B), and the burned rock with no residual coal seam at the bottom, and the burned rock with strong baking and collapsing or melting state (Figure3 C, D).



A-Burnt rocks with layered structure and medium-grain texture(Y003);B-Burnt rocks with layered structure and silty texture(Y010);C-Burnt rocks with collapse structure and medium-grain texture (Y048); D-Burnt rocks with collapse structure and shale-silty texture(Y011)

Figure 3. Field outcrop of burnt rock in Rujigou area

The minerals in the coal measure strata change greatly before and after burning. After burning, the carbon component disappears, the Fe^{2+} contained in it is oxidized to Fe^{3+}, and the local iron is enriched. The color is brick red and dark red , and the Fe3+ spectral characteristics are more obvious in the visible and near infrared spectral ranges. Feldspar and other minerals eventually form kaolin through the process of burning, oxidation and weathering, and the content of kaolinite in the burnt rock is generally very high according to the microscopic examination. Therefore, the burnt rock often reflects the absorption characteristics of hydroxy-containing minerals such as kaolinite in the infrared spectrum range. The reflectance of Fe3+ at 778nm is significantly higher than that at 864nm. Kaolinite contains Al-OH, and its characteristic absorption bands are located at 2205nm and 2165nm. The most significant absorption feature is the "binary structure" formed by the maximum absorption peak near 2.20μm and the secondary absorption peaks on both sides.

According to the spectral curves of multiple burned rocks collected in the field and indoor (Figure4), each spectral curve was separately filtered by mixed modulation and matching, and the filtered images were averaged to form the distribution map of burned rocks in the study area (Figure5). Through the analysis of the extracted results, it is found that there are more mining activities in the northeast of the image, with a large number of stripping faces, bright rocks and high reflection brightness. The extracted spots are clumps, which are mainly false information. The spots extracted from the central and western parts of the image are banded and blotchy, and the field verification is mainly in the distribution area of burnt rock, and the extraction effect is good (Figure 5).

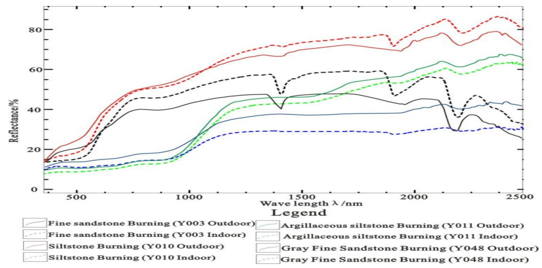


Figure 4. Field and indoor measured spectral curve of the burnt rocks in Rujigou area

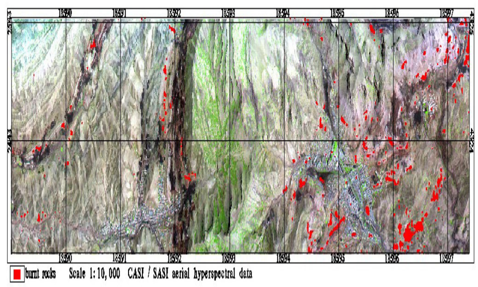


Figure 5. Distribution of the burnt rocks extracted from hyperspectral information in Rujigou area

6. CONCLUSIONS

On the basis of obtaining a large amount of geological data, aerial hyperspectral remote sensing data (CASI/SASI) and field rock and mineral spectra in Rujigou coal field, through spectral testing and rock and mineral sampling analysis, remote sensing identification of spectral characteristics of burned rocks in the study area was carried out. Combined with field investigation and verification, the following understandings were obtained:

(1) According to the spectrum library established by the field measured spectra and the reflected spectral curves of objects in the collected images, the distribution map of burnt rock is obtained by using the mixed modulation and matching filtering method, which is in good agreement with the field verification. This method can provide technical support for geological mapping in the same or similar areas.

(2) According to the spectrum curves of multiple burned rocks collected in the field and in the laboratory, it can be seen that the minerals in the coal measure strata change greatly before and after burning, and the Fe2+ contained in them is oxidized to Fe3+, and the spectral characteristics show that the reflectance at 778nm is significantly higher than that at 864nm. Feldspar and other minerals through the process of burning, oxidation, weathering and so on to form kaolin, in the infrared spectrum range to form a maximum absorption peak at 2.20 μ m and some secondary absorption peaks on both sides of the "binary structure". According to the above absorption spectrum characteristics, each spectral curve of burnt rock is filtered by mixed modulation and matching, and the filtered image is averaged to form the distribution map of burnt rock in the study area. It can be seen that the map spots of burnt rock extracted from the central and western parts of the study area are banded and speckled, and the field verification is mainly the distribution area of burnt rock, and the extraction effect is good.

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