# THE UTILITY OF HYPERSPECTRAL DATA ON EXPLORATION OF SANDSTONE-HOSTED URANIUM DEPOSITS*

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## ABSTRACT

Based on hyperspectral data mining techniques and characteristics of imaging spectrum, Hyperion satellite hyperspectral data are used to study the diagnosable spectral signatures and quantitatively extract the absorption spectral features of sandstone-hosted uranium deposits in northern China. In terms of information extraction approach and the processing method of extra-abundance data, we have adopted the quantitative method of radiance calibration, geometric correction and spectral mapping to study the geological features of uranium deposits. The prospect of hyperspectral data mining techniques for exploration and evaluation of uranium deposits has been discussed in the paper. Good results have been achieved in the practical application.
**Keywords**. Hyperspectral data mining, Uranium deposits, Mineral mapping

## INTRODUCTION

Recently, the exploration of sandstone-hosted uranium deposits has been greatly promoted in order to meet the need of rapid development of atomic energy in China, and the new technologies have played on important role in the exploration of uranium resource (ZHANG J-L et al., 2003). Data mining and knowledge discovery from database(DM&KDD) of hyperspectral remote sensing(HRS) as an advanced earth observation technology has provided a technological basis for the exploration of uranium deposits. HRS has the unique feature of images and spectrum integration. It synthesizes the spectrum defining the quality of object and the image showing object location(PU R-L and GONG P. 2000, ZHANG J-L and CAO D-Y,2005), so using this approach the uranium mineralization zone can be identified from the satellite hyperspectral image.

EO-1 Hyperion image and field spectra data are utilized to study the hyperspectral data mining technologies of uranium deposits which include ore bearing bed identification, hydrocarbon micro-leakage discrimination, and spectral feature extraction of ore-controlling fault.

## HYPERION DATA CALIBRATION

Hyperion is the advanced hyperspectral remote sensing sensor developed by National Aeronautics and Space Administration (NASA). It was launched by Earth Observing-1 (EO-1) satellite in November 2000(Liao, Jarecke P., and Gleichauf D. 2000). In this study, four scenes images have been acquired, the mode of sensor is Nadir Only, the overlap between lines is larger than 20%.

Hyperion data calibration technologies include atmospheric rectification, geometric correction and mosaic imaging. Concerning atmospheric rectification, the FLAASH algorithm and ground calibration are used to convert Hyperion data from radiance to reflectance, and several sandy riverbeds having fairly large and homogenous properties are selected as ground calibration sites. Utilizing above methods, the surface reflectance of each pixel of Hyperion data is derived(Figure 1 and Figure 2).

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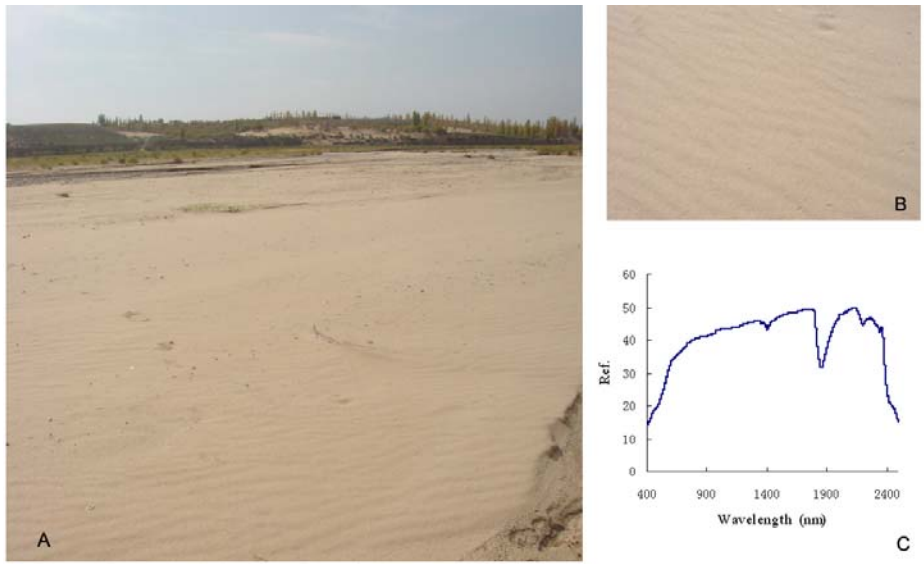


**Figure 1.** Sketch map showing field photo and spectral curve of ground calibration site A-field photo of riverbed, B-zoom photo, C-field spectral curve.

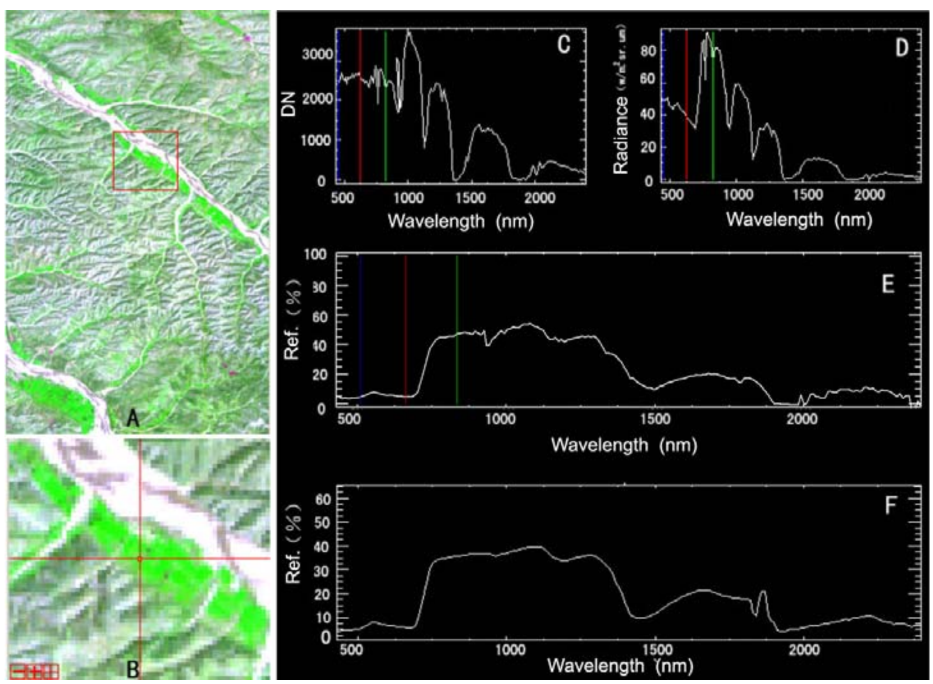


**Figure 2.** Contrast map of spectral data before and after atmosphere rectification. A-Hyperion image, B-local zoom image, C-raw gray curve, D-radiance curve, E-calculated reflectance data from image, F-field spectral curve.

Furthermore, relating to geometric correction and mosaic imaging, we use large scale topographic map and ground control points to build geometric correction models of Hyperion images, and the precise spatial feature of each scene Hyperion image is retrieved. Finally, adopting mosaicking module of ENVI, the mosaic image of study area has been achieved (Figure 3).

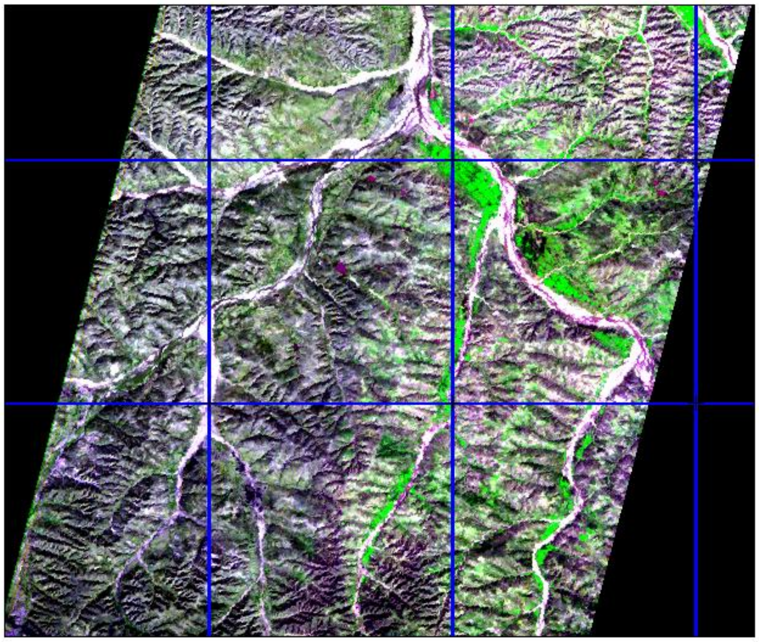

**Figure 3** Mosaic image of study area (local).

## HYPERSPECTRAL MINERAL MAPPING

The green-grey sandstone of middle Jurassic Zhiluo Group is main ore-bearing bed in the study area, underlying stratum is kaolinitic sandstone of middle Jurassic Yanan group, and the latter widely outcrops on the surface. Applying hyperspectral mineral mapping technology, the spatial distribution of kaolinitic sandstone can be delineated, and the thematic map is helpful for us to research on the development and distribution of ore-bearing bed, and it is also useful to identify uranium mineralization zone.

Hyperspectral mineral mapping is carried out using the Spectral Angle Mapper (SAM) approach to compare image spectra to reference spectra (field spectra or pure pixel spectra) in n-dimensional space(WANG Jin-nian,1999). Through calculating the angle between the reference spectra and each pixel vector, the smaller angles represent closer matches to the reference spectra, so the pixel having an angle less than the specified threshold value will be classified as the same type as the reference material. In this study, integrating with the field spectra and geological setting, the hyperspectral mineral mapping of kaolinitic sandstone of the Jurassic system was developed, and the optimal results have been achieved(Figure 4). The spatial distribution identified by the hyperspectral mineral mapping has been confirmed by ground validation.

## HYDROCARBON MICROSEEPAGE CHARACTERIZING

That uranium deposits have closely relationship with hydrocarbon microseepage (petroleum or natural gas) is due to the fact that the reducing environment is created by migrating hydrocarbons and reducing fluids and is favorable for precipitation of uranium (Schumacher, D., 1996,). In other words, the hydrocarbon microseepage provides the reducer for uranium precipitation. Utilizing hyperspectral remote sensing technology, the hydrocarbon-induced alterations can be detected, such as clay alteration, carbonatization, pyritization, bleached red beds, geothermal anomaly, etc.

In this study, we use field spectra measurement and spectral index of ETM to extract diagenetic alterations anomaly information of hydrocarbon microseepage. Research shows $Fe^{2+}$(1-1.5um), $OH^{-1}$(2.2um) and $CO_3^{2-}$(2.34um) related to natural gas leakage are extracted in the study site(Figure 5), and the anomalous area has been located in term of spectral index image and thermal infrared image of ETM. The corresponding results are important to us for analyzing the prospect of uranium exploration in this study area.

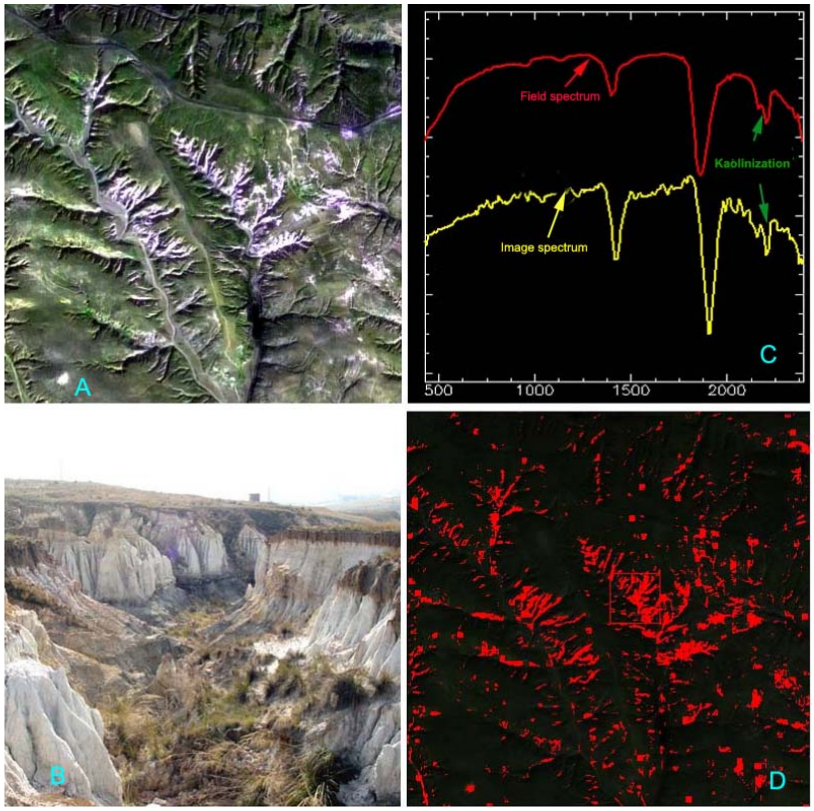


**Figure 4.** Hyperion hyperspectral mineral mapping of kaolinitic sandstone
A-hyperspectral image, B-field photo, C-field and image spectra, D-result image.

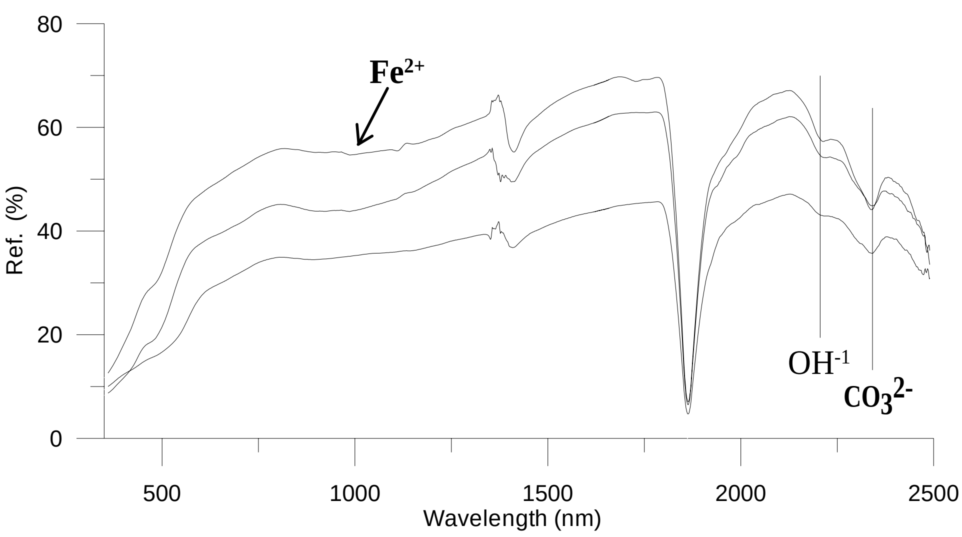


**Figure 5.** Field spectra of hydrocarbon induced diagenetic alterations.

## OPTICAL FEATURES OF ORE-CONTROLLING FAULT

Lots of remote sensing and geological studies have revealed the uranium deposits are controlled not only by ore-hosting layer, but also by ore-controlling fault in the study area, and this ore-controlling fault is not only the conduit for deep petroleum and natural gas migrating upwards, but also the depressurization and local discharge zone, so the water was driven to the fault(LIU De-chang, 2005). Studies include analysis of diagnosable absorption spectra, interpretation of hyperspectral image, statistics of dominant orientation of lineation and the geothermal anomaly along the fault. The ore-controlling fault is rested on the boundary of different hues in the composite image of Hyperion, and the north side is uplifting area where has clear texture, the south side is down throw block where has hazy hue. Because the fault influents the spatial distribution of lineation, we have conducted the statistics of dominant orientation of lineation, and discovered that a set of E-W striking lineation whose direction is the same as the strike of ore-controlling fault. Furthermore, according to thermal image analyzing and field spectral measurement, it is found that fault located in the boundary of different temperature fields, and the diagnosable absorption spectra of both sides of fault is obviously different.

## CONCLUSIONS

Hyperspectral remote sensing is one of the frontier technologies in optical remote sensing, and with the development of aerial and satellite remote sensing sensors, it has been widely used in many fields, including mineral exploration, natural disaster prediction, environmental protection, zoology survey, and so on. This paper uses atmospheric rectification, geometric correction and mosaic imaging, SAM geological mapping and spectral index approach to analyze the characteristics of uranium deposits in Hyperion hyperspectral image, and the optimal results have been achieved in the practical application.

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