Aerial visible-thermal infrared hyperspectral feature extraction technology and its application to object identification

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Abstract. Based on aerial visible-thermal infrared hyperspectral imaging system (CASI/SASI/TASI) data, field spectrometer data and multi-source geological information, this paper utilizes the hyperspectral data processing and feature extraction technology to identify uranium mineralization factors, the spectral features of typical tetravalent, hexavalent uranium minerals and mineralization factors are established, and hyperspectral logging technology for drill cores and trench also are developed, the relationships between radioactive intensity and spectral characteristics are built. Above methods have been applied to characterize uranium mineralization setting of granite-type and sandstone-type uranium deposits in south and northwest China, the successful outcomes of uranium prospecting have been achieved.

1. Introduction
Aerial hyperspectral remote sensing is an important parts of high resolution remote sensing technologies and has been used to geological survey, environment research, agriculture and forest investigation and so on [1]. Recently, the uranium geological exploration is promoted in order to meet the demand of development of atomic energy in China [2]. As one of the new earth observation technologies aerial hyperspectral remote sensing plays an important role in extracting and identifying the geological features of hydrothermal alterations, mineralization controlling faults, ore bearing strata and complex multi-stage plutons. This paper uses aerial visible-thermal infrared hyperspectral imaging system and the data mining methods to analyze uranium mineralization setting and predict the prospective areas in China.

2. Aerial visible-thermal infrared hyperspectral imaging system
Aerial visible-thermal infrared hyperspectral imaging system includes three sensors, visible-near infrared Compact Airborne Spectrographic Imager (CASI), Short-wave-infrared Airborne Spectrographic Imager (SASI) and Thermal-infrared Airborne Spectrographic Imager(TASI), an Instrument Control Unit (ICU) and a series of precision geometric correction and radiometric calibration apparatus, such as PAV30 Gyro-stabilized platform, POS AV, IMU, ILS, etc (figure 1). The technical performances of this system are listed as following (table 1). Moreover, field visible-thermal infrared spectrometers are also used to acquire the reference spectra and verify the remote sensing interpretation results.
Figure 1. Aerial visible-thermal infrared hyperspectral imaging system components.

Table 1. The technical performances of Aerial visible-thermal infrared hyperspectral imaging system.

| Items               | CASI       | SASI       | TASI       |
|---------------------|------------|------------|------------|
| Spectral range      | 380-1050nm | 950-2450nm | 8000-11500nm |
| Image pixels        | 1470       | 640        | 600        |
| Spectral bands      | 288        | 100        | 32         |
| Spectral bandwidth  | 2.3 nm     | 15 nm      | 125 nm     |
| Frame rate          | 14         | 100        | 200        |
| FOV                 | 40°        | 40°        | 40°        |
| IFOV                | 0.028°     | 0.07°      | 0.068°     |
| SNR                 | >1000      | >1000      | >1000      |

3. Hyperspectral data processing and feature extraction technology

Aerial visible-thermal infrared hyperspectral data processing technology includes atmospheric rectification, geometric correction, temperature/emissivity separation and object spectral mapping. The atmosphere rectification method mainly uses modern atmospheric radiation transfer models and field measurement spectral data to calculate the image reflectance. Geometric correction method utilizes six orientation elements (three dimensional space and three axis attitude parameters provided by GPS/IMU) to recover the spatial feature of hyperspectral image. The temperature/emissivity separation algorithm uses Normalized Emissivity Method (NEM) to calculate the temperatures and band emissivities [3]. The feature extraction technology includes a series of object spectral mapping methods, such as spectral match, anomaly finder, constrained energy minimization and so on.

Above aerial visible-thermal infrared hyperspectral data processing methods integrated with field spectral data processing technology and multi-source geological data mining (geophysical, geochemical and geological information) compose the hyperspectral data processing and feature extraction technologies for object identification (figure 2).
4. Applications to uranium geological exploration

Based on hyperspectral data processing and feature extraction technology, the spectral characteristic of typical tetravalent and hexavalent uranium minerals, metallogenic factors including hydrothermal alterations, plutons and ore-bearing strata has been identified, and uranium mineralization setting has been evaluated.

4.1. Spectral identification of uranium minerals and metallogenic factors

The diagnosable absorption spectral features of typical tetravalent and hexavalent uranium minerals mainly focuses on 400-540 nm, 2.1-2.5 um and 9-14 um, the absorption spectra of 400-540 nm wavelength are caused by charge transfer, and absorption spectra of 8-14 um wavelength are caused by symmetric stretching vibration, asymmetric stretching vibration and bending vibration of uranium oxygen ion, silicic acid radical, phosphate radical and sulfate radical. The absorption spectra of 2.1-2.5 um are caused by double frequency and composing frequency of hydroxyl, water molecule and some metal-hydroxyl fundamental frequency [4].

Figure 2. Flow chart of hyperspectral data processing and feature extraction technology.

Figure 3. Spectral features of tetravalent uranium minerals.
Hydrothermal alterations are the important uranium mineralization factors and have indication function for uranium deposits. For the granite-type uranium geological exploration in study area, typical hydrothermal alterations include alkali metasomatism, hematitization, chloritization, silication, fluoritization and hydromicazation, and research shows that the diagnosable absorption spectral features of above alterations regularly change with the alteration strength, for instance, with the increase of alteration degree, the absorption spectral intensity of alkali metasomatism gradually enlarges at 855nm, the absorption slope increases at 550nm and the absorption wavelength in thermal band shifts to long wave from 9.27um to 9.47um (figure 4).

![Figure 4. Spectral features of alkali metasomatism.](image)

Spectral feature extract and identification technology also has been used in hyperspectral logging for drill cores and trench, lots of spectral and geological information of drill cores and trench have been acquired, the relationships between radioactive intensity and spectral characteristics are established, the spectral diversification of geological body in vertical and horizontal orientation are analyzed (figure 5).

![Figure 5. Comparison of hyperspectral, radioactive and geological logging.](image)
4.2. Mineral spectral mapping and geological interpretation for uranium mineralization
Using hyperspectral imaging system, field spectral measurement and its data processing methods, the
mineral spectral mapping for hydrothermal alterations and ore-bearing plutons have been carried out
(figure 6), the metallogenic potential of uranium deposits has been evaluated, and the prospective
areas have been located.

Figure 6. Hyperspectral mineral mapping for uranium deposits.

5. Conclusions
Aerial hyperspectral remote sensing technology and field spectral measurement are vital to identify
spectral characteristic of uranium mineralization factors, its mineral spectral mapping and geological
interpretation results integrated with geological analysis, geophysical and geochemical survey provide
technical support for metallogenic prognosis. Furthermore, thermal infrared hyperspectral technology
and its data processing approaches including temperature/emissivity separation, emissivity anomaly
detecting and mineral identification also provide new information for uranium geological exploration.

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