Application of Spectral Mixture Analysis to Geological Mapping using LANDSAT 7 ETM+ and ASTER Images: Mineral Potential Mapping of Mongolian Plateau

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Abstract: Motivation of this study is based on these two aspects: geologic uses of ASTER and application scheme of Spectral Mixture Analysis. This study aims at geologic mapping for mineral exploration using ASTER and LANDSAT 7 ETM+ at Mongolian plateau region by SMA. After basic pre-processing such as the normalization, geometric corrections and calibration of reflectance, related to endmembers selection and spectral signature deviation, both methods using spectral library and using PPI(Pixel Purity Index) are performed and compared on a given task. Based on these schemes, SMA is performed using LANDSAT 7 ETM+ and ASTER image. As the results, fraction map showing geologic rock types are enough to meet purposes such as geologic mapping and mineral potential mapping in the case of both uses of these different types of remotely sensed images. It concluded that this approach based on SMA with LANDSAT and ASTER is regarded as one of effective schemes for geologic remote sensing.

Keywords: Spectral Mixture Analysis (SMA), ETM+, ASTER, Geological Mapping

1. Introduction

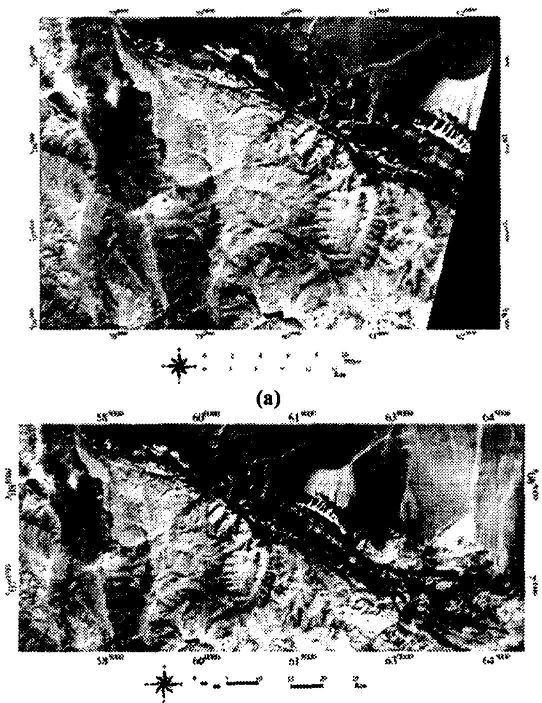
In these days, new types of remotely sensed imageries are available on target-based application, and NASA Terra ASTER image composed of 14 bands with range visible to thermal infrared wide band is regarded as one of important space-borne images for geological remote sensing. While, demands on geological application scheme with these data sets is increasing.

Study area is Gobi-Altai, southern west area of Mongolia, and both remotely sensed images are from same date on September 2002 (Fig.1). Spectral mixture analysis (SMA) classification algorithm was developed in 1986 by Adams and Smith [1] for geological mapping application. Usually SMA was designed by processing of hyperspectral (above one hundred bands) images. But, SMA allows the researcher to use more effectively the multispectral and some coarse spatial resolution data such as Landsat ETM or ASTER.

Subpixel information is vital when working at this resolution. And, by radiometrically calibrating images to surface reflectance values and applying SMA, the analyst can develop land-cover classification schemes that are more apt to be replicated and directly applied to other multi-spectral images of comparable land cover regions.

The purpose of survey is to apply for discrimination of meaningful host rock related mineralization, and results of SMA classification present a percentage fraction map. Endmembers were selected by the lithologic units of published geological maps and pre-surveyed reports.

The survey area is arid environment area so it was covered poor vegetation, desert area and relatively it is under low haze atmosphere.



(a)

(b)

Fig. 1. ASTER (RGB:B3-B2-B1) (a) and Landsat ETM+(b) false color composite image of study area (RGB Band composition is B4-B3-B2 respectively.)

Table 1. Bands characteristics of Landsat ETM+ and Terra ASTER [6]

Sub-system	LANDSAT ETM+ Band No.	LANDSAT ETM+ Spectral Range(㎛)	TERRA ASTER Band No.	TERRA ASTER Spectral Range(㎛)	Spatial Resolution	Quantization Level
VNIR	Band 1	*0.45~0.52*			15m	8 bits
	Band 2	*0.52~0.60*	1	0.52-0.60		
	Band 3	*0.63~0.69*	2	0.63-0.69		
	Band 4	*0.76-0.90*	3N	0.78-0.86		
			3B	0.78-0.86		
SWIR	Band 5	*1.55-1.75*	4	1.60-1.70	30m	8 bits
	Band 7	*2.08-2.35*	5	2.145-2.185		
			6	2.185-2.225		
			7	2.235-2.285		
			8	2.295-2.365		
			9	2.360-2.430		
TIR			10	8.125-8.475	90m	12 bits
			11	8.475-8.825		
			12	8.925-9.275		
	Band 6	*10.4-12.5*	13	10.25-10.95		
			14	10.95-11.65		

The satellite image is under excellent condition for adopting SMA algorithm and Landsat and ASTER data fusion methods[4]. That's why Terra is 30 minutes behind Landsat ETM+ it crosses the equator at about 10:30 am local solar time. Band characteristics of ETM and ASTER sensors were show in Table 1.

2. Methods

1) Spectral mixture analysis

Satellite images of ground scenes have a trade-off between and spatial and spectral resolution. With a finite amount of photons reaching a detector, there must be a practical compromise between the size of a detector and the width of its spectral bandpass, in order to keep the signal-to-noise of the sensor high.

Spectral mixture analysis is the calculation method of the abundance of various material types present within an individual pixel. In the remotely sensed image, some pixels could be clearly labeled as pure materials, but many pixels will be mixed, containing two or more material classes (endmembers). So, SMA approaches all pixels as a linear combination of pure-material spectral vectors; from this it is relatively simple to find the fractional map of each pixel [5].

In parts of geological application, hyperspectral data need to find mineralization zone or to discriminate of lithological units. But, these data have coarse spatial resolution, so it is difficult to acquire tiny materials information. That is the reason why SMA is an advantage for geological mapping application.

The Linear spectral unmixing equation is described as follows:

$$R_i = \sum_{e=1}^{N} R_{i,e} f_e + \varepsilon_i \qquad i=1...k \qquad (1)$$

R_i is the reflectance of a given spectrum in the ith spectral band, N is the number of endmembers, $R_{i,e}$ is the reflectance of reference endmember e in the ith spectral band, f_e is the unknown fraction of endmeber e in the pixel, ε_i is the error in band I for the fit of N endmembers, and k is the number of bands in the image.

2) Preprocessing

Before the SMA processing, raw image need to acquire statistics information for the pixel background characterization. And, Geometric correction and sensor calibration were processed using included GCP (Ground control point) for the stacking 14 all bands of ASTER and ETM+ respectively.

3) Selection of endmembers

Decision of the endmembers is most important SMA processing part. Normally, Spectral library such as laboratory analysis library can use as the materials of interest. But, to use spectral library information, We need to complex atmosphere correction and conversion from Digital number to reflectance value. The other method is using in-scene endmembers that were had advantages such as full scope of the materials we wanted to investigate and atmospheric correction like complicated processing do not needed.

We tried to process both using the JHU(John Hopkins University) rocks spectral library endmembers and in-cene endmembers using pre-geological survey information. Geology of study area covered by Ordovician andesitic metavolcanics, schists, limestone and Devonian sedimentary rocks, several intrusive rock such as biotite leucogranite, biotite hornblende granite and gabbrodiorite and Quaternary alluvium.

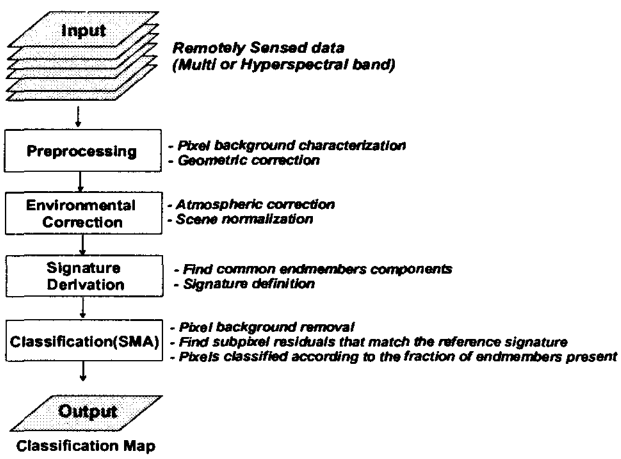


Fig. 2. Flow-chart of Spectral mixture analysis classification.

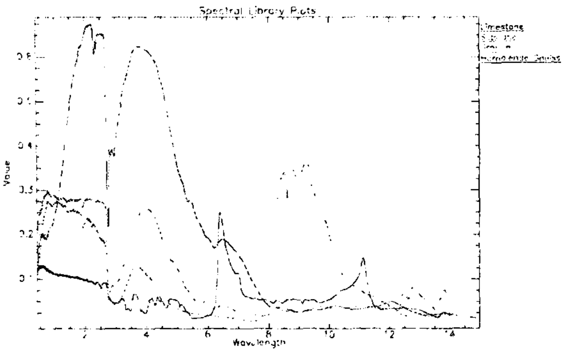


Fig. 3. **2D plots of spectral reflectance value of endmembers (referenced by JHU Spectral Library).**

Geological endmembers adopted in procedure is decided as follows:

1. Sil. Bt-Hb. Schists or Gneiss (Mineralized host rock)
2. Granites (Bt. Leucogranite or plagiogranite)
3. Limestone
4. Sedimentary rocks(Siltstone)

4) Results

Fraction map of endmembers can show the information about lithologic unit distribution and percentages to whole study area. Hb-Gneiss fraction map (Fig.4a) can shows upper-left sector and central upper area were highlighted. Granite fraction map (Fig.4b) was presented widely central area(Gr-1) relatively value high and upper portion(Gr-2). And, Fraction results map of Limestone(Fig.4c) and Siltstone(Fig.4d) can found very similar outputs results,

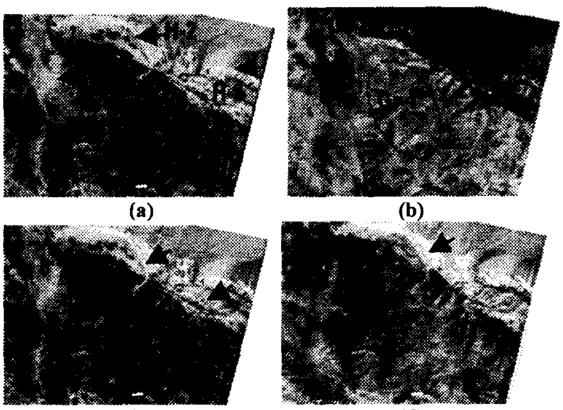


Fig. 4. The fraction result maps of four endmembers; Hb-Gneiss (metamorphics)(a), Granites(b), Limestone(c) and Siltstone(d) using ASTER data (referenced by JHU Spectral Library).

That is, the geologic distribution of limestone was reciprocate with sedimentary rocks, and geological structures such as fault and fold is complicated by the tectonic movements.

3. Conclusions and further works

The goal of this study is to find geological application using multispectral ASTER (14bands) and ETM+ (7bands) using spectral mixture analysis is one of the spectral inversion methods. ASTER data of VNIR, SWIR and TIR bands have strong points about geological application and discrimination of minerals.

In initial stage of mineral survey project, SMA mapping is one of the good assistance in planning survey strategy. Using the mineral or rocks spectral library, lithology of unconfirmed area can presume. But to apply SMA for geologic mapping, selection of endmember for SMA using statistics like PPI is very careful procedure not for bad results. The decision of number of endmembers for linear spectral unmixing analysis is theoretically unlimited but to acquire of good results prefer under five endmembers. And the endmembers should be linearly independent.

Further works for geological application of SMA are 1) to apply various endmembers selection methods for accuracy increment, 2) to assess about fraction results, and 3) to apply data fusion technique between results of ETM+ and ASTER fraction map.

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