# Mineral mapping using ETM⁺, ASTER and Hyperion imagery in Honghai area of Hami in Xinjiang, China

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*Abstract*—**Utilizing remote sensing technology to explore mineral resources with multi- and hyperspectral geologic, which is adopted to extract alteration anomaly and mineral mapping, can detect mineral information directly and be used for prognosis possible exploration target areas.Choosing Honghai area of Hami in Xinjiang as example, the authors adopt ETM+,ASTER and Hyperion imagery to extract the hydroxyl and iron stain alteration information. Combining geological setting and mines, previous research, specially about ore bearing stratum, forecast other favourable target area using alteration distribution map, Mineralization alteration map with the ETM+,ASTER and Hyperion imagery are analyzed. The result reveals that extraction of anomalies agree with the ore-bearing strata, formation as well as ore deposit, and the integrated information can be used to the next exploration for the mineral resource decision-making.**

*Keywords:* **mineral mapping; ETM+; ASTER; Hyperion; Honghai, Xinjiang**

## I. INTRODUCTION

Utilizing remote sensing technology to explore mineral resources with multiple source data ,which is adopted to extract alteration anomaly, can detect mineral information directly and is used for prognosis possible exploration target areas[1] The geologic remote sensing community can bridge the gap with the geosciences community.[2]Since 80 times, the combination of multi-source information, is the inevitable trend and the main means of prediction of mineral resources. Hyperion data also can be used to help evaluate the accuracy of spectral mapping results obtained from the multispectral ETM+ and ASTER images. This capabilityis especially important for areas where ground truth information is limited or unavailable.[3]

In the paper, Choosing Honghai area in Hami of Xinjiang as example, the authors utilized  ETM+, ASTER, Hyperion imagery to the extraction of mineralized alteration anomalies and mineral mapping, based on the GIS platform, associated with geological setting and mines, previous research, the mineralization alteration map with the ETM+,ASTER and Hyperion imagery are analyzed.

## II. GEOLOGIC SETTING

The study area is located in Eastern Tianshan, which belongs to Carlatagg porphyry copper-gold mineralization subzones, Xinjiang Hami Honghai area, among 91°11′~93°10′E,42°30′~42°50′N, and the exposed strata are mainly for coal-bearing clastic rocks of Late Paleozoic and volcanic sedimentary formations of Mesozoic. [4]That regional volcanic institutional development and magmatic activity with multi-stage and multi-cycle characteristics, indicate that it is located in the long-term geothermal activity center, with the formation of porphyry copper-gold ore, veins like copper-gold (silver) polymetallic ore, epithermal gold ore favorable geological conditions of the mine. [5]The abundant intrusive rocks are mainly late Paleozoic times in Carlatagg, then in abyssal facies, shallow as followed. The rock types are complex, such as gabbro, diabase, diorite, plagioclase granite and monzonitic granite, etc. Mines (Ore deposits ) in the area are abundant, such as multi-metal minerals like gold, copper, nickel etc. Besides, Host-rock alteration are mainly pyrite, limonite, chloritization, chalcopyrite, peacock petrochemical, lithification and carbonatization etc.(Fig.1.)
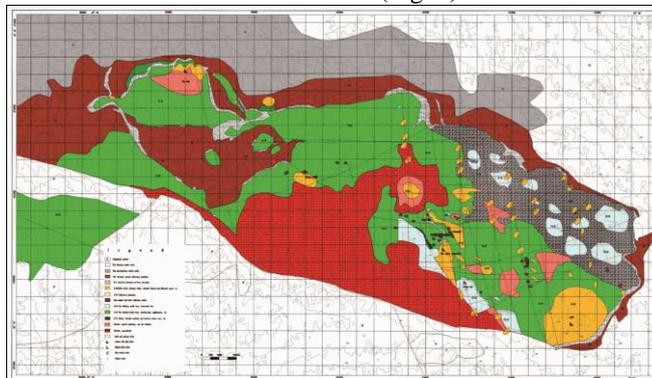


Fig. 1.  Geological map of Honghai area in Hami of Xinjiang at 1:50,000 scale(according to the overall design of the investigation and evaluation of Copper and Zinc polymetallic ore in the Red Sea area of Hami in Xinjiang, 2010)

## III. METHODOLOGY

### A. *Extraction of mineralized alteration anomalies using ETM⁺*

1) *pro-processing:* In the research, in order to extract effective spectral and favorable prospecting information,

pretreatment of the image including radiometric correction, geometric correction, mosaic, resize ,removal of the interference information, et al, is indispensable.

ETM$^+$ image covering all the study area is relatively clear, and little of water, vegetation snow et al, but some cloud. With the method of high-end or low-end cutting to remove the interference information of cloud, , the alteration information of images is extracted. Mask processing of interference information, has important significance on removal of false alteration information.

2) *Enhancement processing of the images;* Based on the analysis of ETM$^+$ spectral information, hydroxyl and iron staining alteration information was respectively obtained by (TM1, TM4, TM5, TM7) and (TM1, TM3, TM4, TM5) bands. TM1, TM4, TM5, TM7, the four bands were analyzed by the principal component analysis (PCA), criteria principal of identifying hydroxylate component is: for the syndrome vector of the principal components, the signs of TM5 coefficient is contrast with coefficient signs of TM7 and TM4,TM1 and TM5 coefficients are of the same sign. TM1, TM3, TM4, TM5, the four bands were analyzed by principal component analysis. The criterion principal of contamination of iron component is: for the syndrome vector of the principal components, the TM3 coefficient sign is contrast with coefficient signs of TM1 and TM4, TM3 and TM5 coefficients are of the same sign."Mean value + N times of standard deviation" method was adopted to the classification of the alteration anomalies. For hydroxyl alteration anomalies, N usually takes 2-3; for iron staining alteration anomalies, N usually takes 1.5-2.5[6]. Through the threshold segmentation of iron staining, hydroxyl component, alteration information is graded and is generally divided into three grades.

3) *Analysis of Results:* The distribution map of hydroxyl and iron staining alteration anomalies shows, block aggregation alteration information and some stripped distribution is found ,which is related to regional alteration information of the local area. Among the 8 known deposits in this area , almost all have the corresponding alteration anomalies. The coincidence coefficient is relatively high (Fig.2)
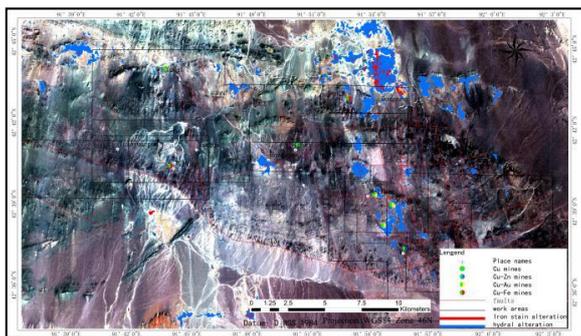


Fig.2.Distribution map of iron staining alteration anomalies and the hydroxyl alteration anomalies of Honghai (ETM+742)

## B. Mineral mapping using ASTER

Alteration extraction process can be divided into three parts: remote sensing image pre-processing; remote sensing image mask; principal component analysis to extract alteration.

1) *Pre-processing:*Remote sensing image pre-processing includes atmospheric correction, geometric correction, image cropping of the study area, in addition, the combination of bands 1-3 whose resampling is 30m resolution and bands 4~9, prepared for the subsequent processing.

2) *Mask:* As for the interference to the alteration extraction result, the cloud, shadow, water, vegetation, is needed to be removed through the mask. It is found that there is little interference information about vegetation, water and shadow except cloud in the experimental area. Therefore, the ninth band of high-end cutting was used to mask the cloud of the remote sensing data in this experiment.

3) *Principal component analysis to extract alteration:* Principal component analysis in this experiment is commonly used to extract alteration information from remote sensing images and ferritization,Kaolin, Chloritized mineralization alteration are mapped.

The Ferritization mineralization alteration information in ASTER bands 1,3 is the absorption valley, in bands 2, 4 is the reflection peak, and its feature in the feature vectors is constrast between bands1, 3 and bands 2, 4, so we select ASTER bands 1, 2, 3, 4 to mask analysis principal component, getting 4 feature vectors,as shown in Table I.PC4 meets the characteristics of limonitization, on the PC4 stretching after using thresholding method by the mean value +2 times, 2.5 times or 3 times the standard deviation as the threshold value, and the alteration is divided into three levels.

TABLE I.  THE FOUR FEATURE VECTORS OF THE FERRITIZATION ALTERATION

| Eigenvector | Band1 | Band2 | Band3 | Band4 |
|---|---|---|---|---|
| PC1 | -0.712370 | -0.568757 | -0.400735 | -0.091954 |
| PC2 | 0.682137 | -0.455839 | -0.571232 | 0.024366 |
| PC3 | 0.115625 | -0.669587 | 0.683747 | 0.266033 |
| PC4 | -0.117681 | 0.142755 | -0.213529 | 0.959259 |

The Kaolin alteration information absorption peak at ASTER bands 3, 6, a reflection peak at the fourth band, and the feature vector is constrast between bands 3, 6 and band 4, to mask analysis principal components using bands1, 3, 4, 6, getting from the feature vector (Table II) the PC4 inversion, extracting alteration information extraction method, using the same threshold of 3 levels of alteration.

TABLE II.  THE FOUR FEATURE VECTORS OF THE KAOLIN ALTERATION

| Eigenvector | Band1 | Band3 | Band4 | Band6 |
|---|---|---|---|---|
| PC1 | -0.865669 | -0.486731 | -0.111731 | -0.035017 |
| PC2 | 0.491268 | -0.870761 | -0.016790 | 0.012194 |
| PC3 | -0.095692 | -0.068610 | 0.955300 | 0.271178 |
| PC4 | -0.010765 | 0.012664 | -0.273196 | 0.961815 |

The Chloritized alteration information has absorption valley in the ASTER band 4, and band 8 appears the reflection peaks, which should be expressed as the characteristic value in band 4 is negative, and the band 8 is positive in the feature vector. So we select bands 1, 3, 4, 8 to mask analysis principal components, and get the feature vector shown in Table III that

PC4 fits with the features of the alteration, and divide the alteration into three levels by thresholding method.

TABLE III. THE FOUR FEATURE VECTORS OF THE CHLORITIZED ALTERATION

| Eigenvector | Band1 | Band3 | Band4 | Band8 |
|---|---|---|---|---|
| PC1 | -0.866003 | -0.486919 | -0.111773 | -0.021314 |
| PC2 | -0.491908 | 0.870434 | 0.018109 | 0.006521 |
| PC3 | 0.089766 | 0.072249 | -0.983057 | -0.142555 |
| PC4 | -0.002480 | -0.005816 | -0.144148 | 0.989536 |

The silicification alteration is obtained through the method of the band ratio algorithm: $(13 \times 14)/(10 \times 12)$, according to the ASTER band characteristic. Then the appropriate threshold is selected to mapping the silicification alteration.

*4) Analysis of Results:* The distribution map of the Chloritized alteration and the Kaolin alteration information ,the Ferritization mineralization alteration and the silicification alteration in the local area ia as following. Among the 8 known deposits in this area ,seven have the corresponding alteration anomalies.There is a close correlation between alteration and the corresponding stratum,lithology in the geological map.(Fig.3)
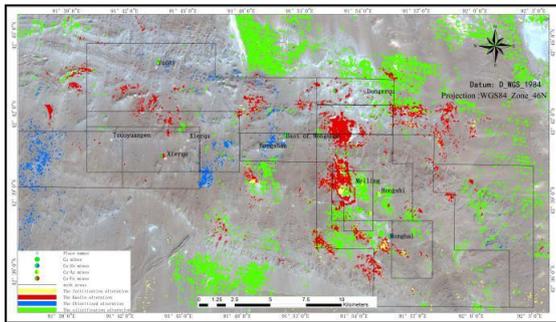


Fig.3.Distribution map of ferritization alteration,Kaolin alteration, Chloritized alterationof Honghai (ASTER)

## C. Mineral mapping using Hyperion

Alteration information extraction of Hyperion data is mainly divided into two parts: data pre-processing and mineral mapping.

The 1GST data EO1H1390302002238110PZ and EO1H1400302010099110Pv are applied in this project, which have been made radiometric correction, geometric correction, image registration, topographic projection.

*1) Pre-processing of Hyperion imagery*

*a) Data format conversion:* with the hyperion tools, an ENVI plug-in, original file with radiation data is converted to a new one in ENVI BIL format, which include the average wavelength and FWHM value.

*b) Removal of uncalibrated bands and moisture affected bands:* in the 242 bands of hyperion image, radiometric calibration bands are at VNIR8~57, SWIR 77~224; no scaling bands are the bands 1~7, 58~76, 225~242,which are set to 0. Bands with a spectral range of 1 356~1 1 417nm, 820~1 932nm and more than 2,395nm that are seriously effected by water vapor. These bands contain rarely contain information of the ground. So we speak them out.[7]

*c) Conversion from pixel values to the absolute value of radiation :* the product is generated with the expansion factor, the factors of VNIR and SWIR were respectively 40 and 80, the pixel value of the Hyperion data must be converted to absolute radiance values.

*d) Repair bad line:*bad lines of the band are picked out and recorded, then the average value of adjacent rows or columnsis of the band lines are used to repair .

*e) The removal of vertical stripes:* removal of low-pass filtering method.

*f) The atmospheric correction, correction is performed using ENVI FLASH correction function.*

*g) The study area is getted by cutting.*

*2) Mineralmapping*

*a) Minimum noise fraction (Minimum Noise Fraction, MNF):* used to determine the distribution of the inherent characteristics of image, noise separation and balance in the image data, calculation of reduce subsequent processing. We select 20 bands of MNF to perform the step according to the data .

*b) Pixel purity index (PPI):* The pixel purity index method of iteration for each pixel in the image is to get the pixel relatively pure image (as image spectrum analysis of 3 terminal unit).And we select 20 bands of MNF to perform the step according to the pixel purity index plot picture.(Fig.4.)
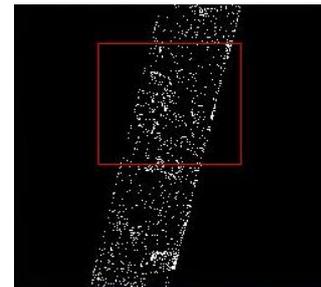


Fig.4.The PPI result of the Hyperion image EO1H1400302010099110Pv

*c) N dispersion (n-D):* In order to improve the accuracy of ENVI samples, N dimension dispersion method is utilized to get the more purified samples.

*d) Spectral analysis (ID):* Spectrum analyzer in ENVI, is performed and through the contrastive analysis of spectral curve and ENVI classification results of interested objects with USGS mineral spectral library(Fig.5.), the unknown object are identified to achieve the purpose of target detection and recognition.
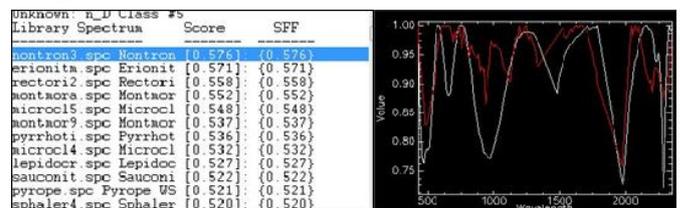


Fig.5.Spectral analysis of Nontron mineral with *USGS mineral spectral library (the white Curve is USGS mineral spectral library of* Nontron mineral)

Seven kinds of mineral in EO1H1390302002238110PZ are identified: Recogni, Hedenbe, Rectori, Goethit, Magneti, Desertv, Bronzite. Eleven kinds of mineral in EO1H1400302010099110Pv are identified: Pyrite, Galena, Ilmenit, Jarosit, Quartz, Nontron, Cassiter, Erionit, Mascagn, Montmora, Axinite. There is a close correlation between mineral and the corresponding stratum, lithology in the geological map.

*e) Spectral Angle Mapping (SAM, Spectral Angle Mapper):SAM* is a spectral angle matching method to get mineral mapping with the appropriate threshold, and seven kinds of mineral are mapped in the paper using hyperion data. And the threshold we selected during mapping is as shown in the Fig.6-7.
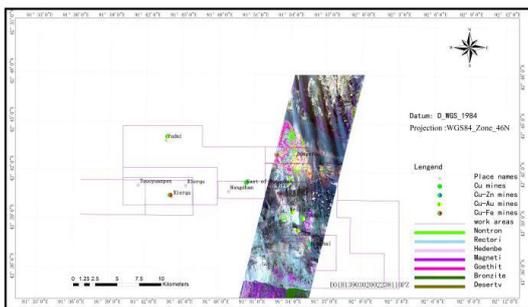


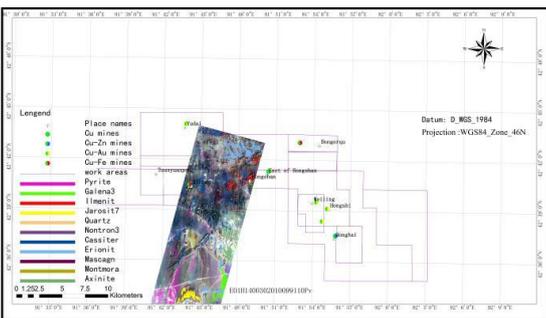Fig.6.Mineral mapping of EO1H1390302002238110PZ Hyperion image of Honghai



Fig.7.Mineral mapping of EO1H1400302010099110Pv Hyperion image of Honghai

## IV. RESULTS AND DISCUSSION

According to the comparison of mineral mapping using different imagery, combining geological setting and mines, previous research, specially about ore bearing stratum, forecast other favourable target area using alteration distribution map, Mineralization alteration map with the ETM$^+$,ASTER and Hyperion imagery are analyzed. The result reveals that extraction of anomalies agree with the ore-bearing strata, formation as well as ore deposits.

## V. SUMMARY AND CONCLUSION

1) The retrieval of hyperspectral Hyperion data, reflectance image pretreatment is generated by pretreatment steps which includes: removal of the bad lines, strip noise; the atmospheric correction based on ENVI FLAASH module.

2) Three different levels of mineral mapping are obtained from Multispectral and hyperspectral extraction,the coincidence coefficient of the corresponding anomalies of multispectral images and hyperspectral image are high.

3) Combined with the geological map application analysis and interpretation of the anomalies,the coincidence coefficient is high between the anomalies and the appropriate ore-bearing strata, formation as well as ore deposit.The integrated information can be used to the next exploration for the mineral resource decision-making.

Many problems also exist in the study, the next step of research can be further strengthened, which can be summarized as follows:

1)No time for field verification, can only be compared to each other through both, as well as the analysis and geological map of ore-bearing strata superposed, can't field verification anomaly distribution information, and types;

2)The extraction of anomolies information based on hyperspectral data is lack of the measured spectral data.

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