Using ASTER Image Processing for Hydrothermal Alteration and Key Alteration Minerals Mapping in Siyahrud area, IRAN

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Abstract: - Many ore deposits are first detected in the field by the recognition of hydrothermally altered host rocks, and are typically zonally distributed. Ore deposits are often produced by fluid flow processes that alter the mineralogy and chemistry of the country rock. One of the main reason for extention using a multi-spectral and hyperspectral sensor is due to detect the optical characteristics of the Earth's surface using several of spectral bands. All previous studies show that remote sensing has a important impress to detection alteration zones. The Advanced Spaceborne Thermal Emission and Reflection Radimeter (ASTER) sensor measures reflected radiation in VNIR, SWIR and TIR electromagnetic energies. It is cheap and easily available. The alteration minerals in Siyahrud area have been successfully investigated in the field and have been successfully detected by processing of Aster data. The finding shows hydrothermal alteration, which can be a model in indicating the productive units in this region. This Alteration mapping have been used by principal component analysis method , band ratio and False Color Composit method. this study and field investigation shows the hydrothermal alteration zone related to: iron oxide-bearing & hydroxide-bearing minerals and mineral endmembers related to epithermal gold include phyllosilicates minerals (Kaolinite,Illite, Alunite minerals). Results indicates ASTER's capability to provide information on alteration minerals which are importance for mineral exploration activatites.

Key-Words: - Siyahrud, Alteration mapping , Epithermal Mineralization, ASTER, band ratio, False Color Composite .

1 Introduction

Spectral identification of potential areas of hydrothermal alteration minerals is a common application of remote sensing to mineral exploration. The extraction of spectral information related to this type of target The Advanced Spaceborne Thermal Emission and Reflection Radimeter (ASTER) imagery has been achieved through the use of image processing techniques such as band ratio and principal component analysis(PCA) [1]. Ore deposits are often produced by fluid flow processes that alter the mineralogy and chemistry of the country rock. A diversity of previous researches has proved the reliability of multispectral data analysis in the field of alteration detection[2]. Many ore deposits are first detected in the field by the recognition of hydrothermally altered host rocks, and are typically zonally distributed. Economic mineralization is often produced by fluid processes that substantially alter the mineralogy and chemistry of the host rocks. This alteration can produce distinctive assemblages of minerals that vary according to the location, degree, and longevity of those flow processes. When exposed to the surface of the Earth this alteration can sometimes be mapped at a zonal pattern [3]. By using remote sensing techniques these zones can be detected in a regional scale.In this research , processing was performed on the ASTER satellite imagery data of the Siyahrud area to map spectral signatures associated with the hydrothermal alterations. Siyahrud region in North-West of Iran is an importance region for presence of good mineralization of sulfo deposits, copper and iron carbonate in igneous rocks in west part of Nuce village and valuable metals such as Gold, Sb, Mo, and other metals that have been composed in the form of vein , veinlet and Skarn deposits. Different image processing technique such as Crosta methods and band ratio and false Color composits methods have been used to analysis the data set. Finally the results cheked by Field study. at the end of this research alteration zones and epithermal gold index minerals have been recorded. The results shows hydrothermal alteration, which can be a model in indicating the productive units in this region.explorationary targets.maps, in a way that these alteration could be used for base metal and evaporate minerals coparative exploration surveying.

1.1 Geology of Study Area

The Siyahrud area, is located in 70 km in the west of Ahar in north-west of Iran. The area is comprises of Eocene volcanic rocks as andesit, dasite, volcanic breccia, basic tuff and synsedimentary volcanics. Post Eocene magmatism had been played important roles in Siyahrud area, which results of these processes had caused Oligocene plutonism and volcanic activities.The intrusion of Oligocene parts in various faces caused to the alteration and mineralization such as cupper, molybdenum, gold and iron in the Siyahrud area.Granitoidic rocks with component of Granodiorite to alkali that has been influenced of hydrothermal fluids

2 Methodology

The ASTER spectral range was selected for detecting the main alteration mineral spectral features. The instrument consists of three separate subsystems with a total of 14 bands. The VNIR subsystem obtains optical images , with a spatial resolution of 15 m. The shortwave infrared (SWIR) subsystem also scans optical images of six band, with a spatial resolution of 30 m. The TIR subsystem obtains optical images of five bands with a spatial resolution of 90 m Images with SWIR and high resolution are very important[4]. In this study we tried to detect the alteration zones and targeting key alteration minerals in Siyahrud area by different image processing methods on Aster imagery data such as false colore composite, band ratio methods and Crosta method.During the study,data analyses were carried out using ENVI4.2 software . At the end of processing data, validity of mentioned methods have been proved by field study.

2-1 Band combination and band ratio transformation analysis

Since, most satellite images are available in multiband formats, so review of a single band in a period of time does not give much information. Knowing the interactions between different wavelengths is very important to identify features and different types of land cover and representing the more than one band simultaneously on image processing system and preparing multiband version will be useful and effective. This is almost available through using color composite images. Despite the ASTER bandwidth, the instrument is useful in predicting mineral suites[5]. A color composite of separate multispectral bands with blue, green, red, (RGB) colors is the most often shown form. Although this approach may seem simple, but in choosing the bands and displaying colors we should be careful in a way that the events be displayed correctly and with colors which are understandable for the user. Figure 1 is an false Colore Composite (SWIR468) image of the Siyehroud area showing a general sight of alteration in it. These bands are highly sensitive to lithological and alteration variations and are in a region of the electromagnetic spectrum that the eye cannot perceive. This is therefore the recommended image for geological/alteration interpretation[6]. Based on this images magenta tones represent hydrothermal and phropilitic alterations respectively. Also in the Figure 2 showing image of compound band ratio of RGB (2/1, 4/9, 3/2) that yellow color represents the presence of hydrothermal alteration in this region (Fig.2).

2-2 Crosta method

The principal component transformation is a multivariate statistical technique that selects uncorrelated linear combinations (eigenvector loadings) of variables in such a way that each successively extracted linear combination or principal component (PC) has a smaller variance [7]. The main aim of PC analysis is to remove redundancy in multispectral data.Principal component analysis is widely used for mapping of alteration in metallogenic provinces ([8]; [9]; [10]; [11]; [12]). Crosta technique is also known as feature oriented principal component selection. Through the analysis of the eigenvector values it allows identification of the principal components that contain spectral information about specific minerals, as well as the contribution of each of the original bands to the components in relation to the spectral response of the materials of interest. According to present experiences and previous studies and also geological structure of region, appropriate bands for PCA analysis can be recognized.

For example, following band compositions can be used as a good material in Croasta method for discriminating phyllosilicates which are the main features of alteration. Alonite (bands 1, 3, 5, and 7), Ilit (bands 1, 3, 5, and 6), Kaolinte and Smektit (bands 1, 4, 6, and 9),Kaolinte

(bands 1, 4, 6, and 7) [13].
It should be mentioned that the main reason for selected band set, comprising 1, 4, 6 and 7, is that the Kaolinite has highest reflectance values in bands 4 and 7 and high absorbs in bands 1 and 6 (Fig. 3).

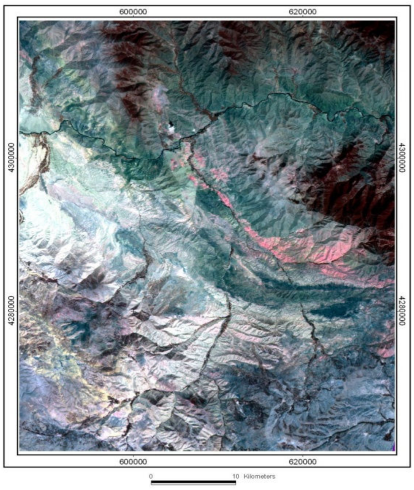

Figure 1 Red-Green-Blue Color Composite of Bands 4, 6 and 8.

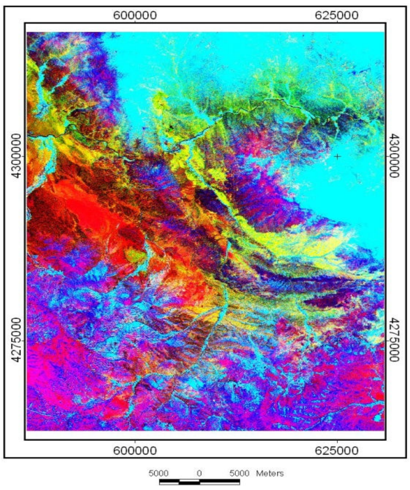

Figure 2 Red-Green-Blues Color composite of Ratio 2/1, 4/9, 3/2. Yellow color showing the Hydrothermal Regions.

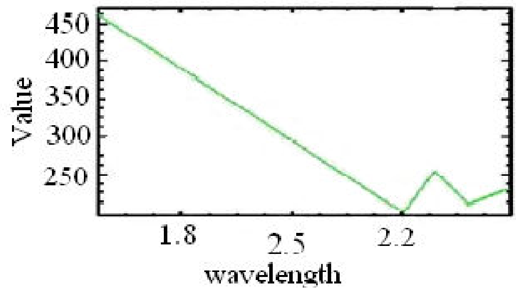

Figure 3 Kaolinite's spectral absorption pattern

PCA was applied to subsets of four ASTER bands, using an adaptation of the Crosta technique proposed by Loughlin (1991). The subsets were selected according to the position of characteristic spectral features of key alteration mineral endmembers in the VNIR and SWIR portions of the spectrum.
For mapping Hydrothermal alteration zones, First determined zones include iron oxide and hydroxyl minerals by PCA methods . For recording Iron oxides bearing minerals in Siyehroud region by Crosta method comprising bands 1, 2, 3 and 4 have been used. Table 1 shows the results of Principal Component Analysis for recording Iron-oxide

Table 1 results of principal component analysis of bands 1,2,3and 4

PCA	Band1	Band2	Band3	Band4
Pc1	0.64	0.69	0.08	0.33
Pc2	0.08	0.14	-0.96	-0.22
Pc3	-0.31	-0.12	-0.25	0.91
Pc4	0.70	-0.70	-0.07	0.12

bearing minerals with the mentioned bands.In according to results, inverse of PC4's image showing presence of Iron-oxide bearing minerals in the Siyahrud area (e.g. Red pixels in Fig.4).

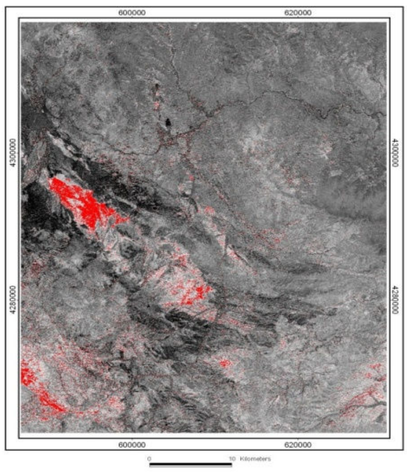

Figure 4. Image of inverse of PC4(1,2,3,4) which red pixels showing Iron-oxide-bearing minerals in Siyehroud area

Also for recording hydroxyl-bearing minerals in study area by Crosta method comprising bands 1, 3, 4 and 6 have been used. Table 2 shows the results of principal Component Analysis for recording hydroxyl-bearing minerals. In according to the results, image related to PC4 shows the presence of hydroxyl-bearing minerals in the study area (e.g. Green pixels in Fig. 5).

Table 2 results of principal component analysis of bands sets, comprising 1,3,4 and 6

PCA	Band1	Band3	Band4	Band6
Pc1	0.74	0.12	0.42	0.51
Pc2	0.18	-0.97	-0.14	0.09
Pc3	0.64	0.15	-0.53	-0.54
Pc4	0.07	-0.15	0.73	-0.67

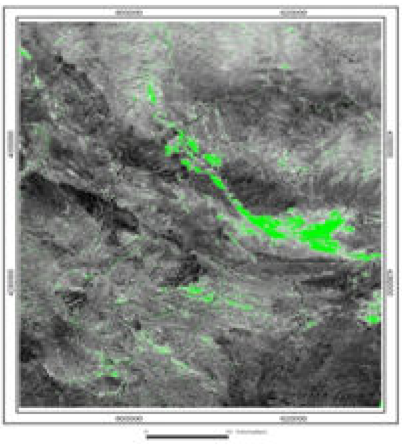

Figure 5 Image of PC4 (1, 3, 4, 6) that green pixels are related to hydroxile bearing minerals in Siyehroud area.

At the end for hydrothermal alteration mapping a RGB composite images (e.g. -PC4 (1234), PC4 (1346), 3/2) was used (Fig.6). that green and yellow color show hydrothermal alteration and the red color shows Iron-oxide-bearing minerals in Siyehroud area.

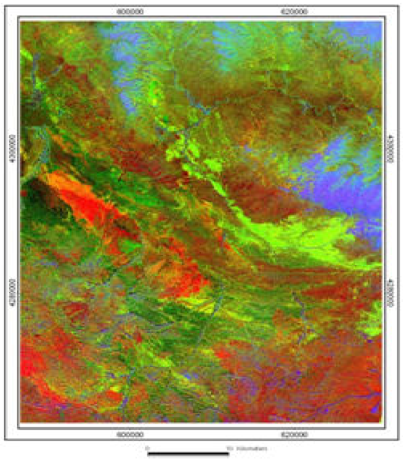

Figure 6 Color composite (RGB) showing abundance of hydrothermal alteration that is presented with yellow and greenish yellow in Siyehroud area.

2-4 Targeting key alteration minerals using PCA of ASTER data

PCA was applied to subset of four ASTER bands, using an adaptation of the Crosta technique proposed by Loughlin (1991). The subset were selected according to the position of characteristic spectral features of key alteration mineral endmembers (Table 3) in the VNIR and SWIR portion of the spectrum.After applying PCA, the eigenvector matrix used to calculate PCA for each subset was examined, to identify which PC contained the target (mineral) information. The criterion for the identification is the same proposed by Laughlin (1991): the PC that contains the target spectral information shows the highest eigenvector loadings from the ASTER bands, coinciding whit the target's most features, but with opposite signs (+ or -) [13].

Table 3 Aster bsnds (VNIR+SWIR) used to generate mineral abundance maps by PCA

	Alteration Minerals		
	Alunite	Ilite	Kaolinite
ASTER bands	1	1	1
	3	3	4
	5	5	6
	7	6	7

2-4-1 kaolinite

Recording Kaolinit for detection of advanced Argillic alteration in the study area is important. for this comprising bands 1, 4, 6 and 7 have been processed by Crosta method. Table 3 shows principal component analysis results for recording kaolinite by applying bands set, comprising bands 1, 4, 6 and 7. The fourth component has been choosen due to maximum difference between bands 6 and 7 in table 4 . Green color in figure 7 showing kaolinite regions[13].

Table 4 results of principal component analysis of comprising bands 1, 4, 6 and7.

PCA	Band1	Band4	Band6	Ban7
Pc1	0.66	0.38	0.47	0.45
Pc2	0.74	-0.45	-0.37	-0.33
Pc3	-0.10	-0.18	0.45	0.37
Pc4	-0.02	-0.03	-0.66	0.75

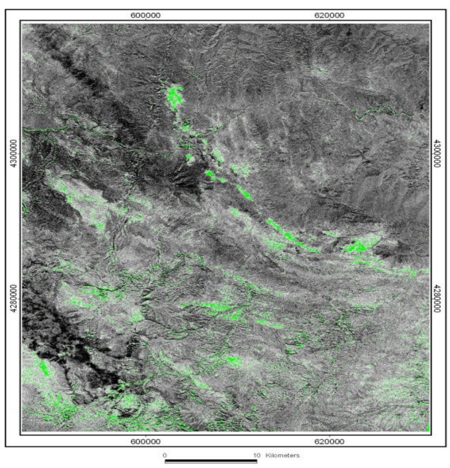

Figure 7 image of PC4 (1467) in which green pixels are related to presence of Kaolinite in Siyehroud district.

2-4-2 Alunite

For recognition of alunite which is the index mineral of alunitization alteration, bands 1, 3, 5 and7 have been choosen to take part in principal component analysis. Table 5 showing principal component analysis for the mentioned bands set. The bands 5 and 7 has been selscted for the maximum reflectance of Alunite in the band 7 and minimum reflectance in the band 5 that the most difference in the PC4 has been seen.

Because of negative and high loading of PC4 from band 7, PC4 image is negated (by multiplying all pixels by -1) so that target material is displayed as purple color in the respective abundance image (Fig.8)[13].

Table 5 results of principal component analysis of bands sets, comprising bands 1, 3, 5 and 7.

PCA	**B1**	**B3**	**B5**	**B7**
pc1	0.73	0.09	0.46	0.48
pc2	0.07	-0.99	0.04	0.04
pc3	0.67	0.002	-0.51	-0.52
pc4	-0.00	0.00	0.71	-0.69

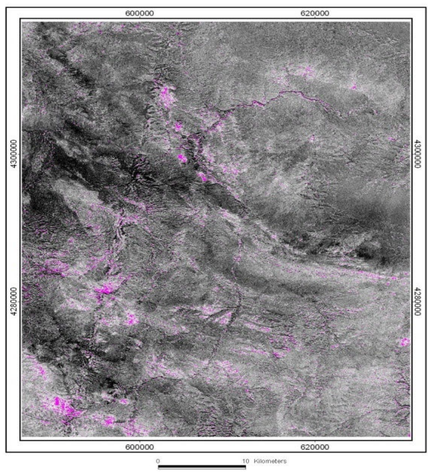

Figure 8 image of PC4 (1357) in which purple pixels are related to presence of Alunite in Siyehroud district.

2-4-3 Illite

Illite is one of the important Argillic alteration. For recording this mineral, applied Croasta method by using the bands 1, 3, 5 and 6 (Table 6).

Table 6 results of principal component analysis of bands sets, comprising bands 1, 3, 5 and 6.

PCA	Band1	Band3	Band5	Band6
Pc1	0.72	0.09	0.47	0.50
Pc2	0.06	-1.00	0.05	0.05
Pc3	0.69	-0.01	-0.47	-0.55
Pc4	-0.02	0.00	0.75	-0.67

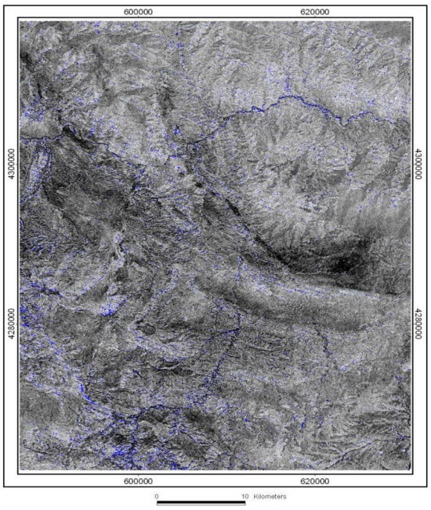

Figure 8 image of PC4 (1356) in which blue pixels are related to presence of Illite in Siyehroud district**.**

4 conclusion

Analysis of ASTER spectral reflectance data of Siyahrud area provides promising finding. The results obtained for study area prove that the using PCA tecnique as a simple and fast method , on ASTER data can extract subtle mineralogy information in study areas. That using these information can be useful in exploration base-metal and Gold mineralization in Siyahrud region.Other methods that used in this research such as band ratio and false color composition can use for improve accuracy of study and give a general sight of areas. At the end of this study finding was checked with field study that saw good correlation between anomalies such as Cu, Iron, Mo, Au and Sb with the detected alteration zones by ASTER imagery processing.

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