Detection of Hydrothermal potential zones using remote sensing satellite data in Ramand region, Qazvin Province, Iran

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Abstract

Ramand region is a part of Qazvin province located in South West of Buin-Zahra. In this region, hydrothermal alterations have been extended within magmatic occurrences and therefore are mostly detectable by remote sensing techniques. Altered facies could be well enhanced after applying Selective Principle Component Analysis (SPCA), Least Squares Fitting method (LS-Fit) and Spectral Angel Mapper (SAM) techniques on ASTER images. Remotely sensed photomaps can be created from such bands for detecting argillic and Fe-oxide overlapped alterations as unique but important traces of hypogenic environments. SPCA result showed that Ramand alteration spectrum reflects an orange to yellowish color that is casually indicated to mineralization potential surrounded by clayey and Fe-oxide aggregate halos. Also an advanced Silicification process has been detected within igneous units and subsequently suggested for more prospects according to satellite images. Our research has been introduced to identification of mineralization by using an expert SPCA technique issued by Crosta. Also we have verified PCA results with applying LS-Fit and SAM techniques respectively. These techniques not only realized the post-magmatic alterations but are suitable for spatial prognosis of ore-bearing mineralization respect to their paragenetic appearances. Finalized photomaps have been improved by mathematical algorithms before targeting Ramand alterations for fast field observations due to economical (minimal) sampling in performances.

Keywords: Remote sensing, Crosta, LS-Fit, SAM, Alteration, Ramand.

1– Introduction

Nowadays, producing geological maps with mineral exploration applications has been developed by satellite image processing possibilities. Remote sensing (RS) is a modern technology which without physical contacts can measure and analyze spectral characteristics of altered-mineralized regions. Remote sensing techniques also allowed identification of a large area with high accuracy and high speed productivity due to economic considerations (Beiranvand Pour *et al*., 2013). Efficiency and resolution of images increase by using satellite data processing techniques. For many years the ETM sensor images (Landset7) have been used to determine the location of hydrothermal alterations zones by applying techniques such as, "principal component analysis" (PCA) and the "least squares fitting" (Ls-fit). The emergence of ASTER sensor (Terra satellite), with 14 spectral band has a spatial resolution higher than ETM with accessibility to short wave infrared (SWIR). This accessibility provided by feasibility recognition the hydrothermal ore related minerals (Sabins, 1999). In this study, by using selective principal component analysis method, ETM spectrums used to detect epithermal alterations. Therefore an alteration photomap has been produced for investigations in Ramand mineralized regions.

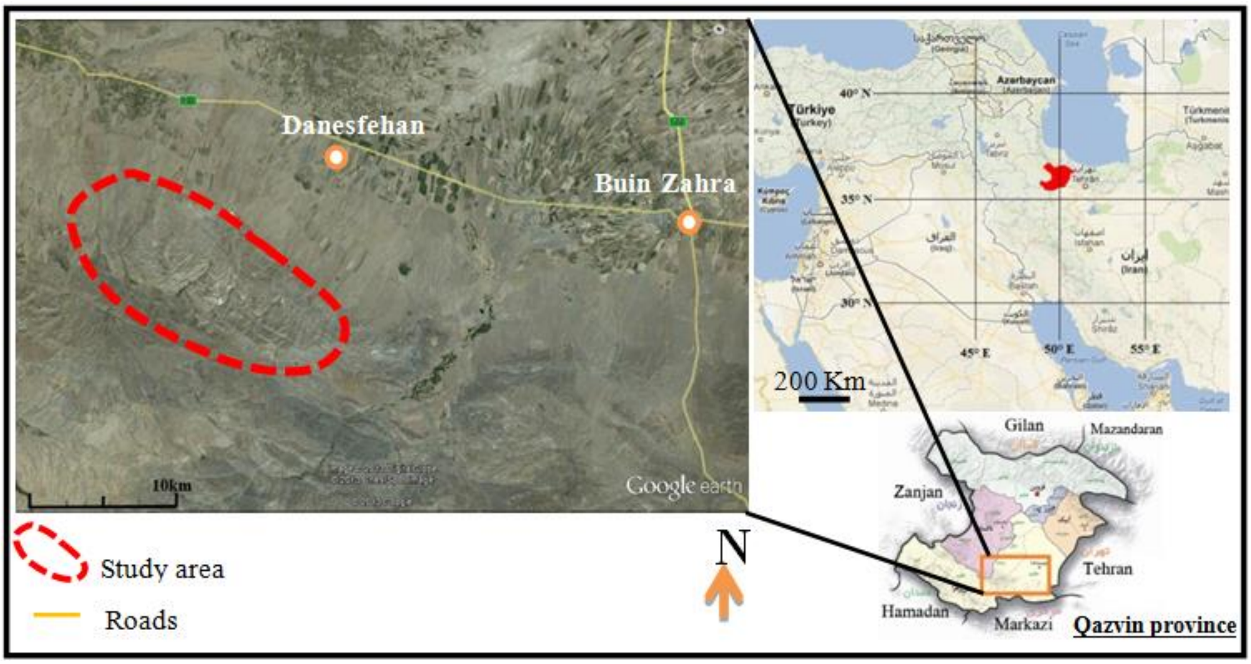

Figure 1) Ramand Study Area, SW of Buin Zahra, Qazvin, Iran.

2– Geology of the study area

According to the depositional-structural division of Iran, Ramand area is located in the northwestern margin of the Central Iran zone and from tectonical point of view, it is situated in Orumiyeh- Dokhtar zone. The Hasanabad fault is the major fault that passes through the area and Ramand Mountain is located in its northern side. As one of the old faults of the area, Hasanabad fault is the dominant active fault of the area. It has been influenced by new movements and has been active during Quaternary. The Buin Zahra earthquake of greater magnitude than 7.25 on the Richter scale (1962) that has occurred along this fault and devastated the adjacent villages confirms the activity of the fault in recent time. Hasanabad fault is the continuation of Buin Zahra fault that dominantly has compressional movements with southward dip and strike-slip inclinations. Furthermore, frequent number of faults with northwest- southeast dominant trend present in the area (Masoudi, 1989).

Ramand Mountain is located in the northwestern corner of Saveh 1:250,000 geological map and the central part of Danesfahan (Khiaraj 1:100,000) (Fig. 2).

The host rock units of the alteration mostly are comprised of rhyodacitic- rhyolitic igneous rocks and tuff. Based on the field investigations and the results of XRD analyses, acidic and intermediate volcanic rocks of Ramand Mountain area have variably undergone hydrothermal alteration, sometimes in dispersed form, under the influence of ascending hydrothermal fluids. These alterations are vastly extended in the area and mostly include argillic and silica phases' alteration. Silicified formations are the most common alteration in hydrothermal system. It is exposed in some parts of the wall rock as silicification and in some part in jasperoid form. Geochemical and petrographical characteristics of acidic volcanic rocks in the south of Danesfahan represent that they have been resulted from different petrogenesis processes. Occurrence of magmatic differentiation through fractional crystallization is the main process that have caused the generation of most of these rocks (Mansouri, 1998).

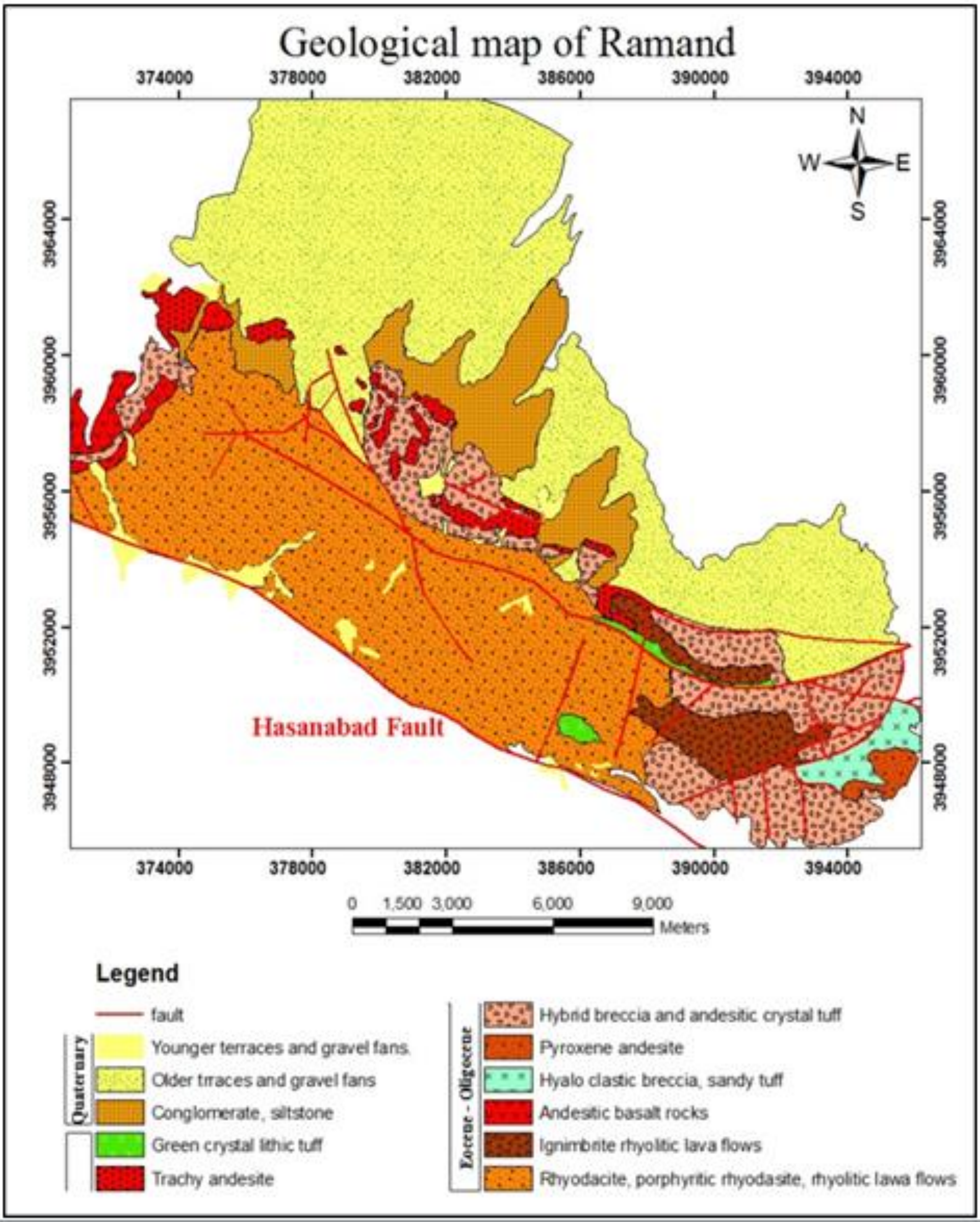

Figure 2) Ramand geological formations & structures (GSI, NJ 5961).

3– Remote sensing studies

The geology map was modified after the following image processes were made and these processes are SPCA, LS-Fit and SAM methods.

3.1- Implementation of SPCA technique for enhancement of alterations in Ramand region

In this method, reducing of the bands usually increases the probable mapping of definite processes according to discriminations between Eigen values (principal components-PC)

(Loughlin, 1992). Hydroxyl-bearing minerals are important because of their abundance in the alteration zones. Crosta technique defines the nature of alteration halos surrounding most of magmatic intrusions. Selective 7,5,4,1 ETM bands for mapping hydroxyls and selective 5,4,3,1 bands for mapping iron oxideshave been proposed.The component analysis results of the first selections known as F-series and the second known as H-series.Studying Eigenvector of F and H-Series, the PC4 values made the most differential spectrums for revealing iron oxides and clayey minerals respectively (Tables 1 and 2).

Table1) The result of PCA for Enhancing Iron oxides.

Eigenvector	Band 1	Band 3	Band 4	Band 5
PC 1	0.44759	0.597438	0.33271	0.57623
PC 2	-0.0279	0.635341	0.7262	0.261136
PC 3	-0.7294	0.045967	-0.2202	0.646037
PC 4	0.51656	0.487131	-0.5599	0.427087

Table 2)The result of PCA for Enhancing Hydroxyls.

Eigenvector	Band 1	Band 4	Band 5	Band 7
PC 1	0.47284	0.354945	0.61472	0.522072
PC 2	-0.1644	0.784691	0.07611	0.592812
PC 3	0.8517	0.270296	0.4443	-0.06449
PC 4	0.15489	0.430365	0.64726	-0.6098

Applying Band Math technique caused adding H to F components for obtaining the new H+F spectrums. RGB visible panels were constructed by these components as: R= H, G= H+F and B= F (Table 3) for mapping hydrothermal alterations within yellowish-buff to orange colors of photomap (Fig. 3).

A Selective Principle Component Analysis (SPCA) technique for identifying clay + iron oxide aggregation has been used and correlated with geochemical haloes for introducing young (Neogene) alteration facies related to epithermal mineralization processes in Ramand region.

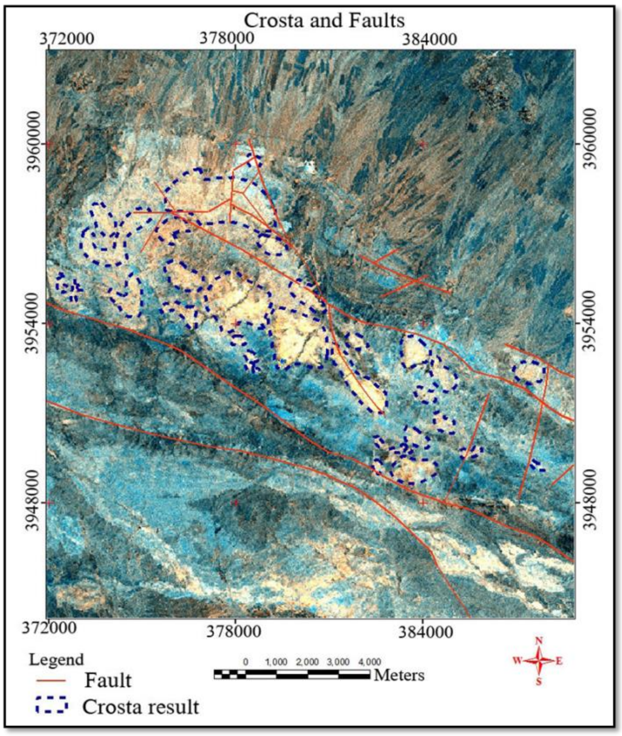

Figure 3) Hydrothermal Alterations according to Crosta PCA technique.

3.2- Detection of siliceous facies using Crosta technique

Crosta PCA is a good developed technique for identifying alteration halos in post-magmatic environments. This technique was proposed for the first time by Crosta and Moore (1989), to indicate a specific purpose as a lighter pixel than the other phenomenon, in one of the principal component images. This is an improved technique for revealing hydrothermal alterations containing iron oxides and clayey matrixes with hydroxyl ions content (Mehrnia, 2006). In practice, composite halos have geochemical association with hydrothermal systems.

Table 3) Bands Compositing components Crosta technique

R	G	B
H	H+F	F

Therefore it can be determined by Crosta technique. In addition, due to large amount of paragenesis of silica mineralization, the electromagnetic responses of Crosta photomap are coincided with clay, iron oxides and silicification aggregations in this region. Our field observations (Fig. 4) plus instrumental (X-ray) and micrographic studies (Fig. 5) confirmed that the reality of remotely sensed mineralization is in spatial relations with quartz, illite and jarosite (Table 4) (Ezzati *et al*., 2013).

It means that, for the first time in Silica-bearing facies, a Crosta based technique has been carried out for separating Si-alterations successfully. In a prone area of hydrothermal deposits with large scale amounts of siliceous and iron oxide mineralization, Crosta technique can be easily introduced these areas among the hydrothermal alteration halos.

Figure 4) Jasperoid facies in the study area(see to the South West).

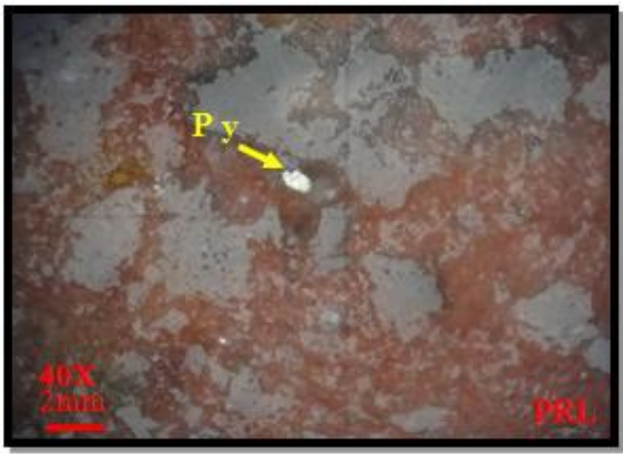

Figure 5) The higher values of iron oxides cause to red colors of matrix. (Probably presence of jasperoid).

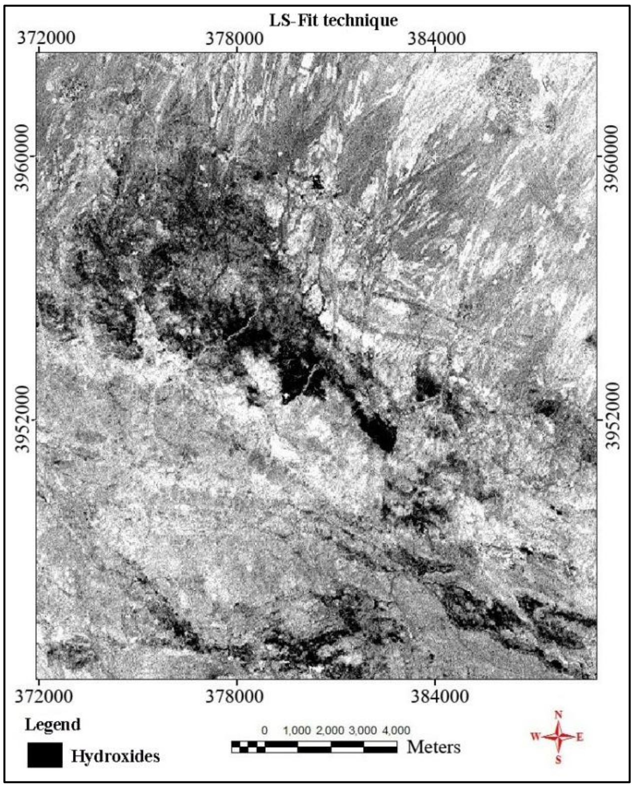

Figure 6) LS-Fit image of Ramand area (band 7 as the modelled band) showing Clay alteration as dark pixel.

3.3- Least Squares Fitting method (LS-Fit)

The technique assumes that the bands used as input values are behaving as the variables of a linear expression; and they value of the equation, namely the predicted band information, gives us a calculated output value (Fujimitsu, 2012). This predicted band is what that band should be according to the linear equation. The problem of having vegetation responsible of some reflectance in the bands that areused to map clay minerals can therefore be omitted by using this technique. The vegetation is mapped in the predicted band with the values that are calculated just by using the reflectance information in the other bands.

Table 4) The X-ray results.

Sample	Major Phase	Minor Phase	Trace Phase
M37	Quartz,Muscovite-Illite	Albite, Natrojarosite	_
M38	Quartz, Illite	Orthoclase, Jarosite	Kaolinite
M22	Quartz, Albite, Orthoclase	Montmorillonite, Kaolinite	_

The minerals which are sensitive to a specific band are thendifferentiated from the features which are reflective to the other bands as well; just by taking the difference between the predicted values and the original values (Clark *et al*., 1990). The OH-bearing minerals include an aggregate of argillic, advanced argillic and sericitic alteration minerals that could exactly represent the locations of alteration zones and hydrothermal activities. Whole bands should be modeled (differentiated) relative to one band. Because of high absorption of argillization in Band 7 of ETM image, total bands are modeled relative to this band. Subsequently, obtained dark pixels represent the targ*et al*teration. Figure No. 6 is obtained after applying a stretch and sharpening the aim pixels.

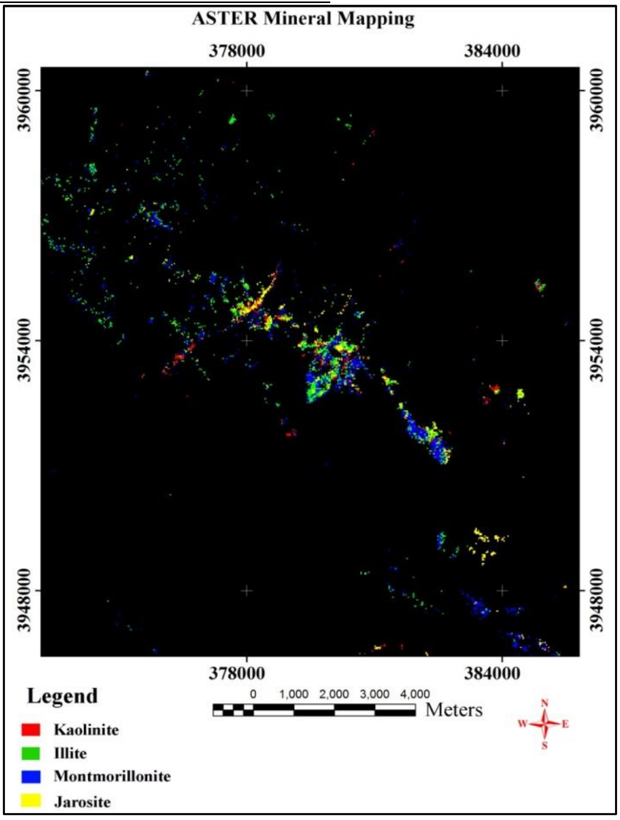

Figure 7) Final classification image map for SAM.

3.4- spectral angel mapper techniques (SAM)

The Spectral Angel Mapper (SAM) technique (Kruse *et al*., 1993) was applied to test the spectral similarity between pixel spectra and mineral reference spectra for kaolinite, illite, montmorillonite and jarosite (OH-bearing minerals).

The reference spectra were extracted from the United States Geological Survey (USGS) mineral spectral library, and were resampled to the same ASTER bands width, using filter function. Similarities between image spectra and reference spectra were calculated. Small SAM indicates better similarities between pixel spectra and references. Bands 4 to 8, around the 1400-2200 nm (Fig. 8) diagnostic hydroxyl absorption band, were used in the analysis (Fig.7).

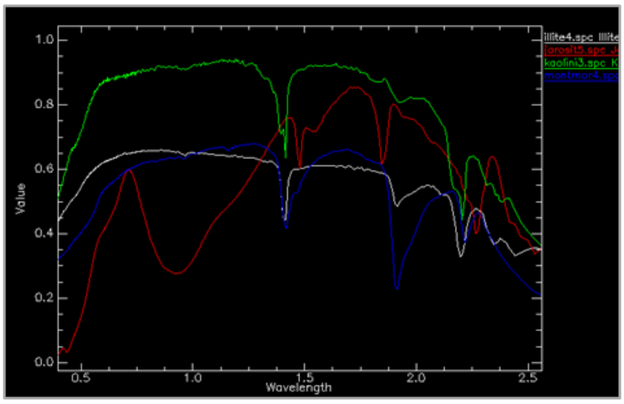

Figure 8) USGS library mineral spectra used in this study. W: Illite, R: Jarosite, B: Montmorillonite, G: Kaolinite.

4– Conclusions

After using the conventional alteration mapping methods on the ETM and ASTER image in the study area, we found that the Crosta method showed their efficiency to define the area of hydrothermal alterations. PCA illustrated the iron-oxides and hydroxyl altered minerals area of this regionvery clear. We have mapped successfully the spatial distribution of OH-bearing mineral of the study area using the LS-Fit and SAM methods. Sampling and instrumental analysis results showed that a clayey matrix within silica based mineralization is dominant in this region. Also thin section studies have been well done and confirmed the hydrothermal origination of ore bearing solutions in a post-magmatic environment. From remote sensing study, Ramand prospected regions have enough potentials for epithermal mineralization, because of extending number of solution related alterations on surfaces and paragenesis of post-magmatic mineralization in the altered regions (Kaolinite, Jasperoid, etc). It is indicated to a continuous mineralization in depth of alterations. Therefore, a comprehensive investigation on host unit features are highly recommended for further explorations with emphasizing on precious metals accumulations in the silica veinlets.

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