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Research Article

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Application on extraction of iron-oxide and hydroxyl anomaly alteration information from the TM data in Ethiopia's Halmo region

Ming Tao*[1,2], Zhang Wenshan[3] and Peng Guangxiong[3]

[1]*College of Civil Engineering & Architecture, China Three Gorges University, Daxue Street, Xiling District, Yichang City, Hubei Province, China, China*
[2]*National Field Observation and Research Station of Landslides in Three Gorges of Yangtze River, China Three Gorges University, Daxue Street, Xiling District, Yichang City, Hubei Province, China*
[3]*Central South University, Lu Shan Nan Street, Yuelu District, Changsha City, Hunan Province, China*

ABSTRACT

The authors firstly reviewed and discussed the extraction method of alteration anomalies from TM remote sensing data. TM remote sensing data in Ethiopia's Halmo were processed. The iron-oxide and hydroxyl anomaly alteration information were extracted and analyzed based on the processed TM data. Anomaly alteration area was divided into three levels including high level, medium level and low level. The alteration anomalies distribution maps were completed to guide the further work.

Key words: Iron-oxide, Hydroxyl, Anomaly alteration, TM data

INTRODUCTION

Remote sensing anomaly alteration information is the spectral information of surrounding rock alteration that reflected in remote sensing imagery. Anomaly alteration information is import ore prospecting indicators. The iron-oxide and hydroxyl anomaly alteration are closely related with metal ore. Iron-oxide anomaly alteration reflects the iron bearing minerals including pyrite, siderite, limonite, hematite etc. Hydroxyl anomaly alteration reflects the host-rock alteration including kaolinite, montmorillonite, chlorite ,carbonate, calcite etc. Different anomaly alteration has different reflection characteristics in reflection band. So remote sensing data are used to extract anomaly alteration information by those different reflection characteristics.[1-4].

TM remote sensing data are often used to extract iron-oxide and hydroxyl anomaly alteration information.TM remote sensing data are multispectral imagery acquired by thematic mapper in No4 and No5 Landsat Satellite of American. Thematic mapper has seven bands named from Band 1 to Band 7. The parameters of each band is presented in Table 1.

Table1. The parameters of each band of thematic mapper

No	Band	Spectrum range(μm)	Resolution(m)
Band1	Blue	0.45-0.52	30
Band2	Green	0.52-0.60	30
Band3	Red	0.63-0.69	30
Band4	Near IR	0.76-0.90	30
Band5	SWIR	1.55-1.75	30
Band6	LWIR	10.40-12.5	120
Band7	SWIR	2.08-2.35	30

Visible light and near infrared in spectrum range is from 0.4μm to 2.5μm.In this spectrum range, the alteration minerals in the rock present spectrum absorption valley. These alteration minerals contain ions or ionic groups of Fe^{2+},Fe^{3+},OH^-,CO_3^{2-} etc. The absorption spectrum range of Fe^{2+} is from 1.1μm to 2.4μm. The absorption spectrum range of Fe^{3+} is from 0.45μm to 0.94μm with the corresponding TM band1,band2 and band3. The absorption spectrum range of OH^- is from 2.2μm to 2.3μm with the corresponding TM band7. The absorption spectrum range of CO_3^{2-} is from 1.9μm to 2.55μm with the corresponding TM band7. The alteration minerals present bimodal spectrum feature of relatively high value in band3 and band5 because they contain Fe^{2+},Fe^{3+},OH^- and CO_3^{2-} .This is the reason we can extract anomaly alteration information from the TM data. Those minerals containing very little Fe^{2+},Fe^{3+},OH^- or CO_3^{2-}have no bimodal spectrum feature[5][6].

The principal components transformation technology is widely used to reduce correlation between each band in multispectral remote sensing data processing. It is a multivariate statistical technique which 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].So it is also often used to extract anomaly alteration information.

Crosta rule was developed to extract iron-oxide and hydroxyl anomaly alteration information based on the principal components transformation technology. It is a methodology called Feature Oriented Principal Components Selection[8]. A rule is built to select the principal components analysis(PCA) eigenvector loadings. And the corresponding principal component images are considered contain the largest amount of information directly related to the theoretical spectral signatures of specific targets. It is also can indicate whether the target is presented by dark or bright pixels in the relevant principal component image.

According to Crosta rule, anomaly alteration information could be extracted by PCA on TM band combination[9][10]. Iron-oxide anomaly alteration can be extracted by PCA on TM band1,band3,band4 and band5.The eigenvector loadings should be examined to decide whether PC3 or PC4 is the principle component which present iron-oxide anomaly alteration. The judgment criteria is that the coefficient sign of band3 is opposite to band1 and band4. And coefficient sign of band3 is often as same as band5.The PC which fits the criteria is the principle component contain iron-oxide anomaly alteration. Hydroxyl anomaly alteration can be extracted by PCA on TM band1, band4, band5 and band7. The judgment criteria which decide whether PC3 or PC4 is the principle component is that the coefficient sign of band5 is opposite to band4 and band7. And coefficient sign of band1 is often as same as band5.The PC which fits the criteria is the principle component contain hydroxyl anomaly alteration.

The anomaly alteration can be divided into three levels by standard deviation of principal component image. If the standard deviation is presented by sign α, then iron-oxide anomaly alteration can be divided into low level, medium level and high level by 1.5α,2α and 2.5α. Hydroxyl anomaly alteration can be divided into low level, medium level and high level by 2α,2.5α and 3α. This technique is called Deinterfered Anomalous Principal Component Thresolding Technique[10].

Ethiopia is a country located in the northeast of Africa with rich metallic mineral resources. Halmo region have good metallogenic geological conditions with many outcrops were discovered in the previous geological work. TM data were selected to get more anomaly alteration information for further geological prospecting work.

EXPERIMENTAL SECTION

The experiment was divided into four steps. The first step was to get the experimental data. The main experimental data was TM data covering Halmo region. The second step was data pre-processing. TM data become more accurate than the original data after pre-processing. Then iron-oxide anomaly alteration and hydroxyl anomaly alteration were extracted by PCA and Crosta rule. The last step was anomaly alteration information classification. Anomaly alteration information were divided into three levels by thresolding technique. Professional software Envi 4.5 and PCI Geomatica v9.1 were selected to process data and mapping. The flow diagram is presented in Figure 1.

TM original data acquisition and data pre-processing

TM original data are provided free of charge by USGS(U.S. Geological Survey) for scientific research. So a scene of TM data with ID of p169r50_5t841122 in this experiment was acquisited from USGS website. Data pre-processing includes data cropping and geometric correction. After pre-processing, we got TM data covering Halmo region and match well with Halmo region topography.

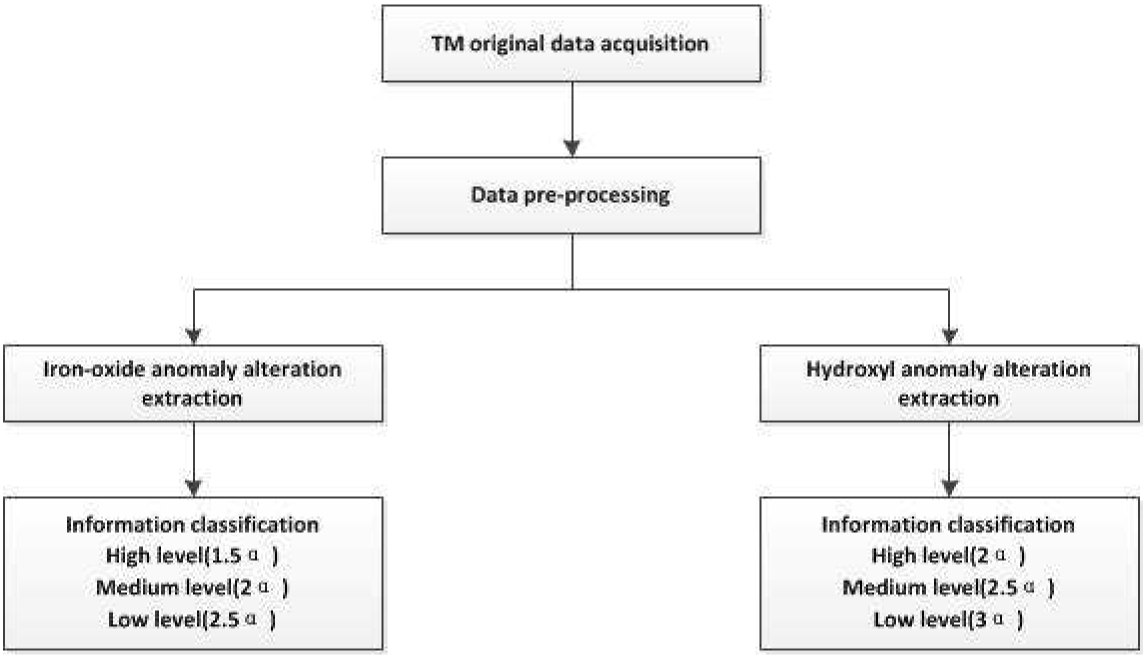

Figure 1: Flow Diagram of Experiment

Iron-oxide anomaly alteration extraction

Iron-oxide anomaly alteration can be extracted by PCA on TM band1, band3, band4 and band5. The mean and standard deviation of each band were calculated. The eigenvector loadings from PC1 to PC4 were also calculated. The statistical table is presented in Table 2.

Table2. Iron-oxide alteration extraction PCA statistical table

	Band1	Band3	Band4	Band5
Mean	77.527165	89.936316	107.980714	125.252782
Standard deviation	10.209996	25.939397	20.626582	36.024455
Eigenvector loadings				
PC1	0.189191	0.518167	0.356208	0.754205
PC2	-0.237561	-0.498343	0.833758	0.008192
PC3	0.258955	0.570467	0.421199	-0.655821
PC4	0.916905	-0.397146	0.023563	0.031721

Hydroxyl anomaly alteration extraction

Hydroxyl anomaly alteration can be extracted by PCA on TM band1, band4, band5 and band7. The mean and standard deviation of each band were calculated. The eigenvector loadings from PC1 to PC4 were also calculated. The statistical table is presented in Table 3.

Table3. Hydroxyl anomaly alteration extraction PCA statistical table

	Band1	Band4	Band5	Band7
Mean	101.057246	66.982122	131.138966	98.214408
Standard deviation	28.096275	15.263393	39.792671	32.732515
Eigenvector loadings				
PC1	0.411070	0.234331	0.682904	0.556554
PC2	0.909540	-0.051631	-0.342181	-0.230183
PC3	0.017295	-0.747423	-0.254029	0.613620
PC4	0.058820	-0.619502	0.593316	-0.510621

Information classification

Anomaly alteration information was divided into three levels by the multiple of standard deviation of principal component image. Standard deviation of Iron-oxide anomaly alteration principal component image and Hydroxyl anomaly alteration principal component image were calculated. The classification indexes table is presented in Table 4.

Table4. Classification indexes of anomaly alteration

Iron-oxide anomaly alteration		Hydroxyl anomaly alteration	
α	6.298401	α	4.356471
1.5α	9.447602	2α	8.712942
2α	12.5968	2.5α	10.89118
2.5α	15.746	3α	13.06941

RESULTS AND DISCUSSION

Analysis of Iron-oxide anomaly alteration PCA eigenvector loadings

As shown in Table2, the eigenvector loading of band3 is -0.397146. The sign of band3 is opposite to band1 and band4. According to Crosta rule, the iron-oxide anomaly alteration principal component is PC4. Because of the sign of band3 is negative, the dark pixels in PC4 image present the iron-oxide anomaly alteration. As shown in Table4, iron-oxide anomaly alteration was divided into three levels by 1.5α, 2α and 2.5α.The finally iron-oxide anomaly alteration distribution is presented in Figure 2.

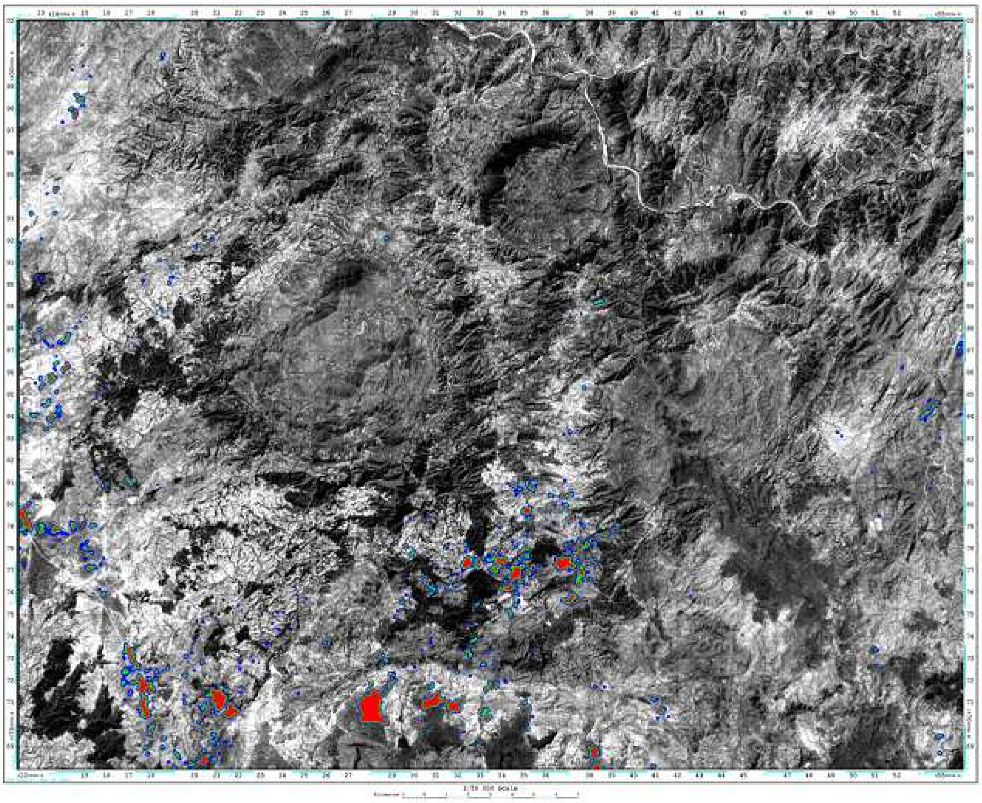

Figure 2: Iron-oxide anomaly alteration distribution map

In Figure2,red represents the high level, green represents the medium level and blue represents the low level

Analysis of hydroxyl anomaly alteration PCA eigenvector loadings

As shown in Table3, the eigenvector loading of band5 is 0.593316. The sign of band5 is opposite to band4 and band7. According to Crosta rule, the hydroxyl anomaly alteration principal component is PC4. Because of the sign of band5 is positive, the bright pixels in PC4 image present the hydroxyl anomaly alteration. As shown in Table4, hydroxyl anomaly alteration was divided into three levels by 2α, 2.5α and 3α.The finally hydroxyl anomaly alteration distribution is presented in Figure 3.

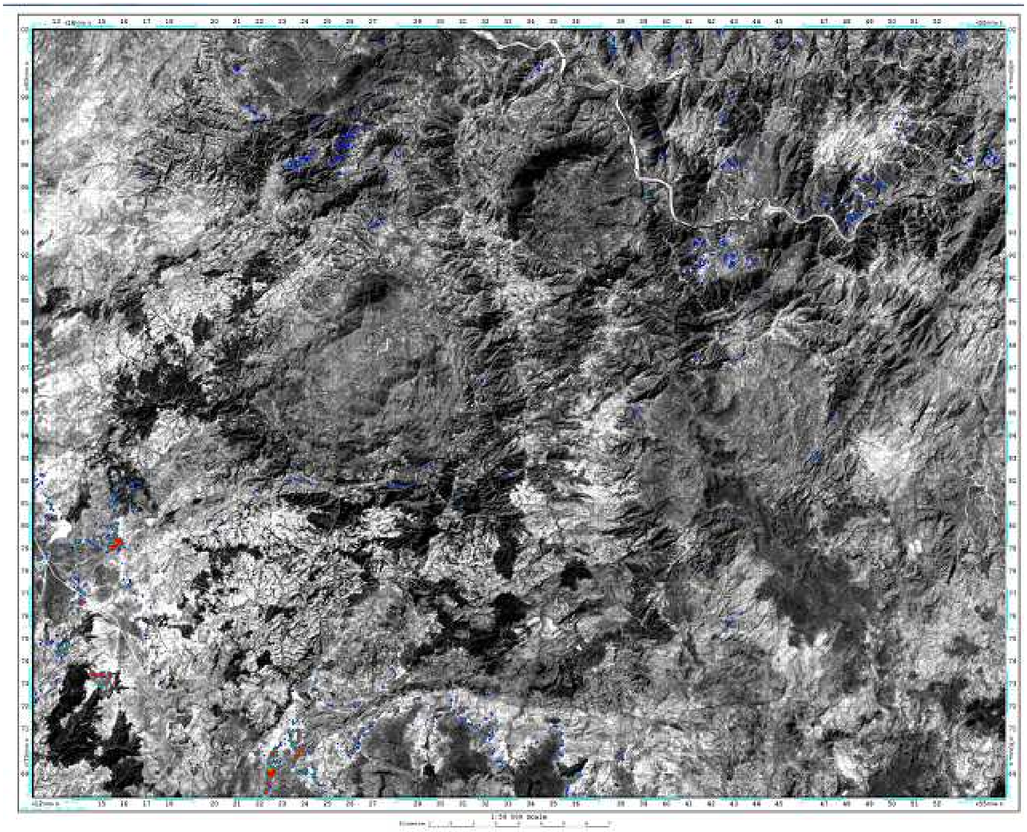

Figure 3: Hydroxyl anomaly alteration distribution map

As the same to Figure2, red represents the high level, green represents the medium level and blue represents the low level In Figure3

CONCLUSION

The surface of the bare area in Halmo is large and vegetation is few, so the exaction of mineral anomaly alteration from TM data is feasible. The minerals containing Fe^{2+},Fe^{3+},$OH^-$and CO_3^{2-} in Halmo region can be identified by PCA technique and Crosta rule. The morphology and distribution of anomaly alteration can be used as important ore prospecting indicators in future geological investigation work.

Because the anomaly alteration principal component still contain few other non-alteration information, so new technology should be developed to get rid of unnecessary noise information and further improve the anomaly alteration extraction accuracy.

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