

Comprehensive Application on Extraction of Mineral Alteration and Mapping from ETM+ Sensors and ASTER Sensors Data in Ethiopia

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Abstract: Enhanced Thematic Mapper Plus and Advanced Spaceborne Thermal Emission and Reflection Radiometer are multi-spectral sensors on remote sensing satellites. The data of these sensors are widely used in mineral alteration and mapping. According to the different characteristics of the two sensors, they can be used to extract different mineral alteration. Enhanced Thematic Mapper Plus data can be used to extract iron-oxide and hydroxyl anomaly alteration information. Advanced Spaceborne Thermal Emission and Reflection Radiometer data have more spectral bands than Enhanced Thematic Mapper Plus data and can be used to extract more types of alteration including Mg-OH, Al-OH, alunite, illite, kaolinite etc. In this article the authors extracted mineral alteration information in Ethiopia from these sensors data on method of PCA and band ratio. The alteration information was classified into three levels and the petrochemistry components maps were completed. Practices prove that PCA and band ratio are convenient and feasible methods to extract alteration.
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Keywords: Mineral alteration, PCA, ETM+ sensors, ASTER sensors, Remote sensing.

1. Introduction

ETM+ is the Enhanced Thematic Mapper Plus onboard American satellite Landsat7 which was launched in 1999. ETM+ sensors measure reflected and emitted electromagnetic radiation from Earth's surface in 8 bands. The bands wavelengths cover the range from visible to infrared. The ETM+ bands characteristics are presented in Table 1.

ASTER is the Advanced Spaceborne Thermal Emission and Reflection Radiometer onboard American satellite Terra which was also launched in

1999. ASTER multispectral sensors have high spectral resolution than ETM+. ASTER has 14 bands divided into 3 groups including visible and near infrared radiation (VNIR), shortwave infrared radiation (SWIR) and thermal infrared radiation (TIR). The ASTER bands characteristics are presented in Table 2 [1].

ETM+ data have been successfully applied to the extraction of iron-oxide and hydroxyl mineral alteration information. ASTER. Because more of short wave infrared bands, it is possible for ASTER data to identify more mineral alteration including

alunite, carbonates, silica, iron-oxides, kaolinite, illite etc.

Table 1. Bands characteristics of ETM+.

No.	Band	Band range	Resolutions
1.	Blue-green	0.45~0.52 μm	30 m
2.	Green	0.52~0.60 μm	30 m
3.	Red	0.63~0.69 μm	30 m
4.	Near infrared	0.76~0.90 μm	30 m
5.	Hort wave infrared	1.55~1.75 μm	30 m
6.	thermal infrared	10.4~12.5 μm	60 m
7.	Short wave infrared	2.08~2.35 μm	30 m
8.	Panchromatic band	0.52~0.90 μm	15 m

Table 2. Bands characteristics of ASTER.

Group	Band	Spectral range	Resolution
VNIR	1	0.52-0.60 μm	15 m
	2	0.63-0.69 μm	
	3N	0.78-0.86 μm	
	3B	0.78-0.86 μm	
SWIR	4	1.60-1.70 μm	30 m
	5	2.145-2.185 μm	
	6	2.185-2.225 μm	
	7	2.235-2.285 μm	
	8	2.295-2.365 μm	
	9	2.36-2.43 μm	
TIR	10	8.125-8.475 μm	90 m
	11	8.475-8.825 μm	
	12	8.925-9.275 μm	
	13	10.25-10.95 μm	
	14	10.95-11.65 μm	

ETM+ swath is 185 km and ASTER swath width is 60 km and which makes it useful for regional mapping. Both of them are suitable for regional petrochemistry components mapping.

The techniques of principal components transformation technology (PCA) and band ratio are widely used in extraction of alteration information. Crosta technique is also used to judge the right anomaly alteration principal component in PCA [2, 3].

In this article, ETM+ and ASTER sensors data were used to extracted mineral alteration information in geological prospecting work in Ethiopia. The area of geological prospecting was 1012 km².

We used ETM+ data with orbiter No of 169-50 and 170-50 were selected. ASTER data with id of ASTL1A0701140802350701170270 and ASTL1A0703190802550703220192 were also selected in this work.

2. Alteration Extraction Steps

The work was divided into four steps. The first step was to get the data covering work region. The second step was data pre-processing. Then anomaly alteration were extracted by PCA, Crosta technique and band ratio. The last step was anomaly alteration

information classification and mapping. Anomaly alteration information was divided into three levels by thresholding technique. Professional software Envi 4.5 and PCI Geomatica v9.1 were selected to process data and mapping. The flow diagram is presented in Fig. 1.

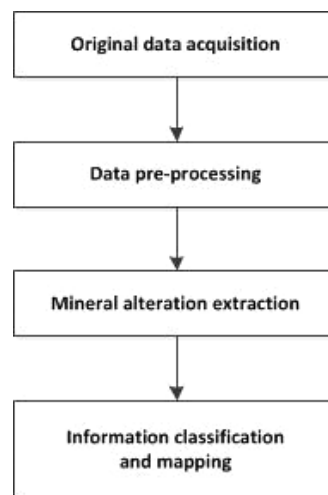


Fig. 1. Flow diagram.

3. Data Processing and Analysis

Iron-oxide and hydroxyl mineral alteration information were extracted from ETM+ data by PCA and Crosta technique. Eight types of mineral alteration information including iron-oxide, Al-OH, Mg-OH, alunite, illite, kaolinite, sericite were extracted from ASTER data by PCA and Crosta technique. Alteration of silica was extracted from ASTER data by bands ratio. Detailed analysis is following below.

3.1. Analysis of ETM+ Data PCA Eigenvector Loadings

The eigenvector loadings of iron-oxide PCA and hydroxyl PCA are presented in Table 3 and Table 4.

Table 3. ETM+ iron-oxide PCA eigenvector loadings table.

	Band 1	Band 3	Band 4	Band 5
PC1	0.188560	0.496244	0.321284	0.784196
PC2	0.099648	0.238077	-.942666	0.211592
PC3	-0.359053	-0.724284	-.090316	.581667
PC4	-0.908623	0.415301	-.001018	-.043909

In Table 3, the sign of band1 is negative and is opposite to band3 in PC4. According to Crosta rule, the Iron-oxide anomaly alteration principal component is PC4 and the bright pixels present the Iron-oxide alteration.

Table 4. ETM+ hydroxyl PCA eigenvector loadings table.

	Band 1	Band 4	Band 5	Band 7
PC1	0.171841	0.269914	0.740044	0.591568
PC2	0.030979	-0.928046	0.035981	0.369427
PC3	-0.914456	-0.078301	0.365278	-0.155598
PC4	-0.365077	0.244430	-0.563571	0.699543

In Table 4, the sign of band5 is negative and is opposite to band7 in PC4. According to Crosta rule, the hydroxyl anomaly alteration principal component is PC4 and the dark pixels present the hydroxyl alteration.

3.2. Analysis of ASTER Data PCA Eigenvector Loadings

PCA eigenvector loadings of iron-oxide, Al-OH, Mg-OH, kaolinite, illite, alunite, sericite from ASTER data are presented in tables form Table 5 to Table 11.

Table 5. ASTER Iron-oxide PCA eigenvector loadings table.

	Band 1	Band 2	Band 3	Band 4
PC1	-0.59935	-0.55893	-0.55196	-0.15399
PC2	-0.25338	-0.54144	0.795286	0.100819
PC3	-0.75874	0.617904	0.162919	0.126373
PC4	0.029888	-0.11241	-0.19058	0.974757

In Table 5, the sign of band1 and band3 are positive and they are opposite to band2 and band4 in PC4. According to Crosta rule, the Iron-oxide anomaly alteration principal component is PC4 and the bright pixels present the Iron-oxide Iron-oxide alteration.

Table 6. ASTER Al-OH PCA eigenvector loadings table.

	Band 1	Band 3	Band 4	Band 5
PC1	0.721409	0.665418	0.185386	0.049188
PC2	0.688507	-0.71727	-0.10685	0.008073
PC3	-0.07028	-0.20518	0.943457	0.250698
PC4	-0.02423	0.025341	-0.25319	0.966781

In Table 6, the sign of band4 is negative and is opposite to band5 in PC4. So the Al-OH anomaly alteration principal component is PC4 and the dark pixels present the Al-OH alteration.

Table 7. ASTER Mg-OH PCA eigenvector loadings table.

	Band 1	Band 3	Band 4	Band 8
PC1	0.720646	0.667579	0.18446	0.031336
PC2	0.691954	-0.67642	-0.25109	-0.02469
PC3	-0.04137	0.310788	-0.93491	-0.16627
PC4	-0.01256	0.014264	-0.16993	0.985274

In Table 7, the sign of band4 is negative and is opposite to band8 in PC4. So the Mg-OH anomaly alteration principal component is PC4 and the dark pixels present the Mg-OH alteration.

Table 8. ASTER kaolinite PCA eigenvector loadings table.

	Band 1	Band 4	Band 6	Band 7
PC1	-0.96548	-0.24702	-0.06158	-0.0551
PC2	-0.26036	0.924409	0.208952	0.184443
PC3	0.007545	0.288804	-0.63902	-0.71288
PC4	0.000305	0.032285	-0.7377	0.674353

In Table 8, the sign of band6 is negative and is opposite to band7 in PC4. So the kaolinite anomaly alteration principal component is PC4 and the bright pixels present the kaolinite alteration.

Table 9. ASTER illite PCA eigenvector loadings table.

	Band 1	Band 3	Band 5	Band 6
PC1	-0.73338	-0.67636	-0.04996	-0.04682
PC2	-0.67713	0.735706	-0.01349	-0.00717
PC3	0.060344	0.035552	-0.72642	-0.68368
PC4	0.00283	-0.00287	-0.6853	0.728248

In Table 9, the sign of band5 is negative and is opposite to band6 in PC4. So the kaolinite anomaly alteration principal component is PC4 and the dark pixels present the kaolinite alteration.

Table 10. ASTER alunite PCA eigenvector loadings table.

	Band 1	Band 3	Band 5	Band 7
PC1	-0.73354	-0.67651	-0.04997	-0.04188
PC2	-0.67693	0.735807	-0.01356	-0.01301
PC3	0.060662	0.030358	-0.75206	-0.65559
PC4	0.000326	0.001511	-0.65706	0.753839

In Table 10, the sign of band5 is negative and is opposite to band7 in PC4. So the alunite anomaly alteration principal component is PC4 and the bright pixels present the alunite alteration.

Table 11. ASTER sericite PCA eigenvector loadings table.

	Band1	Band 4	Band 6	Band 9
PC1	-0.96669	-0.24731	-0.06165	-0.02335
PC2	0.255752	-0.94161	-0.21154	-0.05673
PC3	-0.00847	-0.22616	0.890725	0.394194
PC4	-0.00516	0.032669	-0.39757	0.916977

In Table 11, the sign of band6 is negative and is opposite to band9 in PC4. So the alunite anomaly

alteration principal component is PC4 and the bright pixels present the alunite alteration.

3.3. Analysis of Silica Alteration Extracted from ASTER Data

Silica alteration information was extracted from ASTER thermal infrared bands data by method of bands ratio. The ratio of band 12 and band 14 is suitable for extraction of silica alteration. The statistical characteristics table of ratio imagery is presented in Table 12.

Table 12. The statistical characteristics of silica alteration ratio imagery table.

	Min	Max	Mean	Stdev
Band1 2	0	11.70088	7.521708	4.43045
Band1 4	0	10.99442	7.286081	4.28691

4. Mineral Alteration Mapping

According to technique of Deinterfered Anomalous Principal Component Thresholding Technique, each alteration information was classified into three levels [4, 5]. The standard deviation of alteration principal component imagery or band ratio imagery is presented by sign α in this technique. Iron-oxide alteration information both from ETM+ data and ASTER data were divided into low level, medium level and high level by 1.5α , 2α and 2.5α . Other types of alteration information were classified divided into low level, medium level and high level by 2α , 2.5α and 3α . The classification of mineral alteration distribution maps were presented from Fig. 2 to Fig. 11. In these figures red represents the high level, green represents the medium level and blue represents the low level.

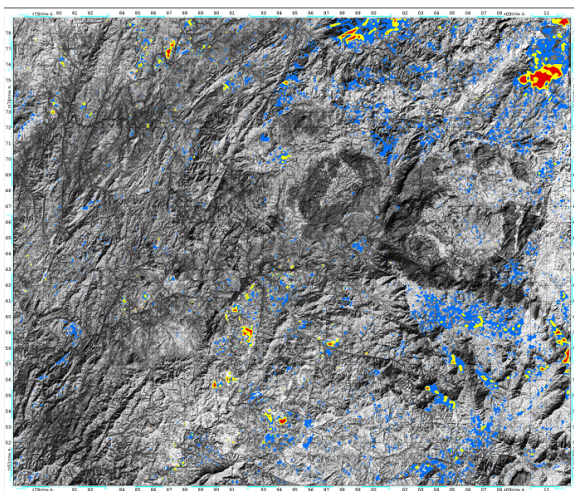


Fig. 2. ETM+ iron-oxide alteration distribution map.

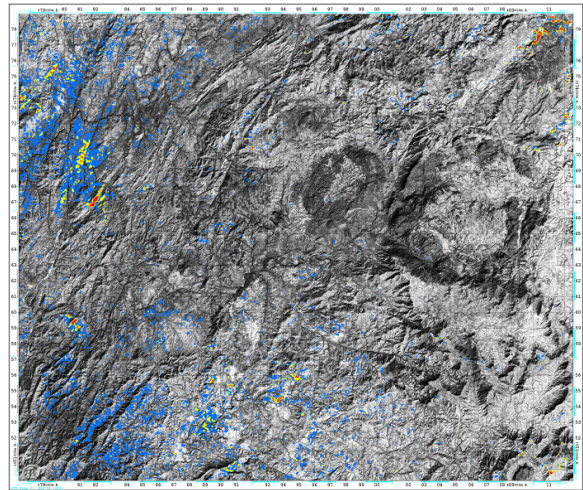


Fig. 3. ETM+ hydroxyl alteration distribution map.

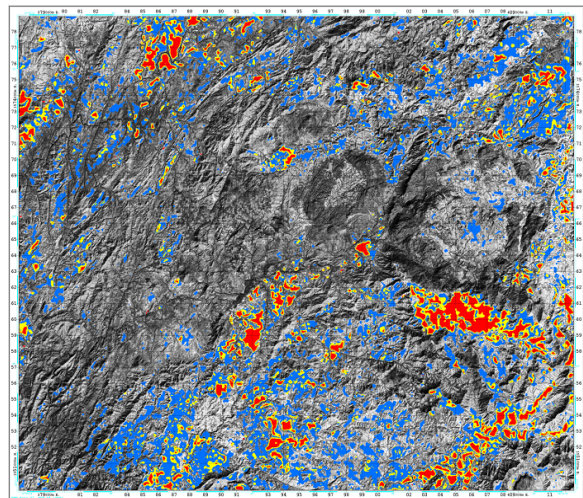


Fig. 4. ASTER iron-oxide alteration distribution map.

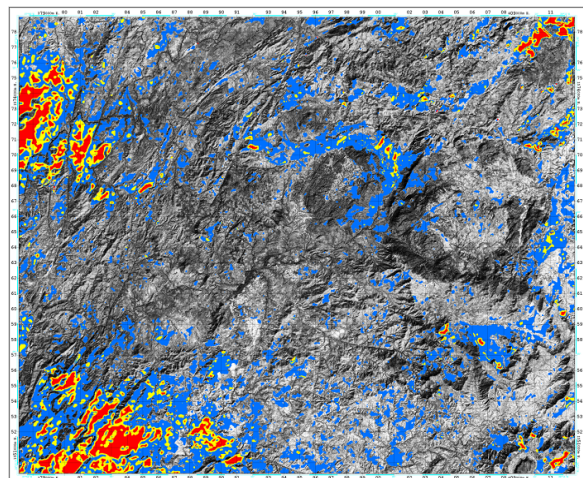


Fig. 5. ASTER Al-OH alteration distribution map.

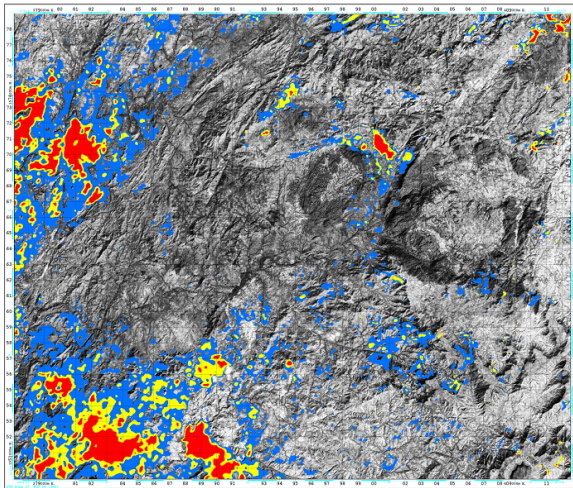


Fig. 6. ASTER Mg-OH alteration distribution map.

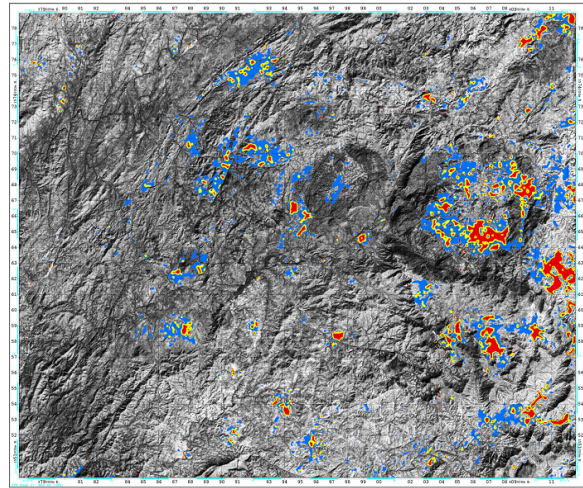


Fig. 9. ASTER alunite alteration distribution map.

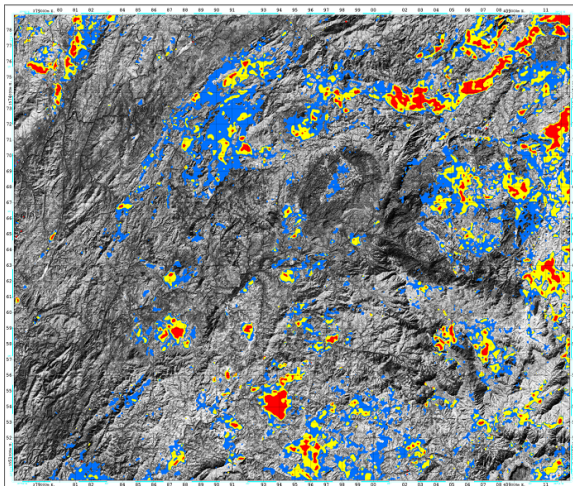


Fig. 7. ASTER kaolinite alteration distribution map.

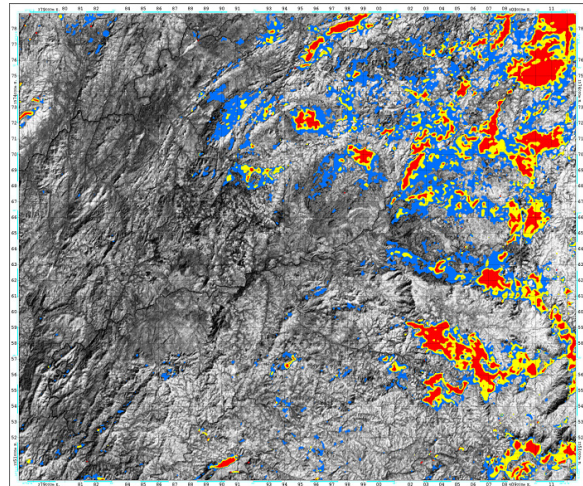


Fig. 10. ASTER sericite alteration distribution map.

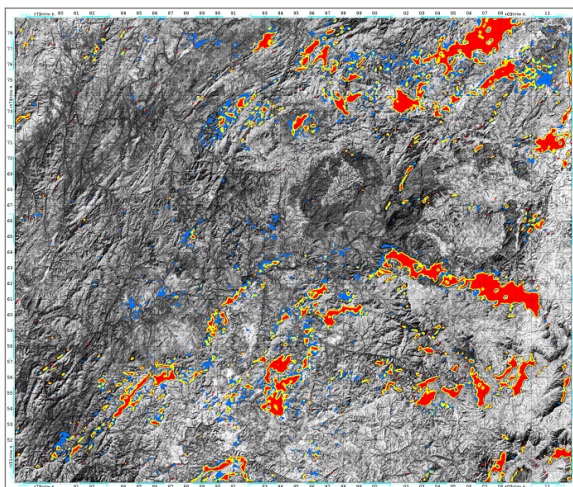


Fig. 8. ASTER illite alteration distribution map.

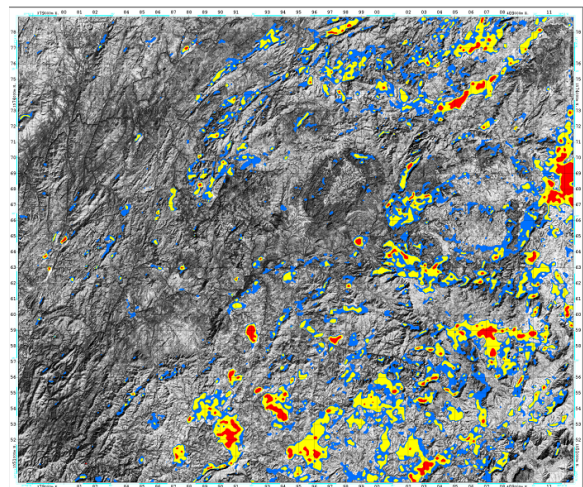


Fig. 11. ASTER silica alteration distribution map.

5. Conclusions

The ETM+ sensors data and ASTER sensors data are multispectral data from VNIR to TIR. They are very suitable for regional petrochemistry components mapping. The techniques of PCA, Corsat and band ratio are also the quickly and feasible methods to extracted mineral alteration information. Field geological work shows the correctness of alteration information extracted in this article. So remote sensing sensors can be widely used in regional mineral exploration.

References

- [1]. Aleks Kalinowski, Simon Oliver, ASTER mineral index processing manual, *Remote Sensing Applications Geoscience Australiar*, 2004.
- [2]. A. P. Crosta, C.R. De Souza Filho, F. Azevedo, C. Brodie, Targeting key alteration minerals in epithermal deposits in Patagonia, Argentina, using ASTER imagery and principal component analysis, *International Journal of Remote Sensing*, Vol. 24, Issue 21, 2003, pp. 4233-4240.
- [3]. W. P. Loughlin, Principal component analysis for alteration mapping, *Photogrammetric Engineering & Remote Sensing*, Vol. 57, No. 9, 1991, pp.1163-1169.
- [4]. Zhang Junyu, Yang Jianmin, Chen Wei, A study of the method for extraction of alteration anomalies from the ETM+(TM) Data and its application: geologic basis and spectral precondition, *Remote Sensing for Land & Resources*, Vol. 14, Issue 4, 2002, pp. 30-36.
- [5]. Zhang Junyu, Yang Jianmin, Chen Wei, A study of the method for extraction of alteration anomalies from the ETM+(TM) Data and its application: method selection and technological flow chart, *Geotectonica et Metallogenia*, Vol. 56, 2003, pp. 44-49.