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Research Paper

Application of Concentration-Area Fractal Model for Separating Hydrothermal Alteration Zones of Kerman Cenozoic Magmatic Arc (KCMA) Using ASTER Images Data

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Abstract: Separating hydrothermal alteration zones is a main challenge in remote sensing science. The results showed that application of conventional methods based on spectral properties could not exactly separate hydrothermal alterations. Therefore, this research attempted to identify hydrothermal alteration zones in the study area by combining principal component analysis and concentration-area fractal model. The developed model was evaluated by confusion matrix, commission and omission error and total accuracy. The commission and omission error of phyllic zone is 4.51 and 9.13 percent, respectively, and the omission error of argillic zone is equal to 54.16 percent. The results indicated that concentration-area fractal model is able to identify phyllic, argillic and propylitic zones in the study area. Because of the same spectral signature of phyllic and argillic minerals, the concentration-area fractal model could not exactly discriminate these two alteration zones.

Keywords: Hydrothermal alteration, Principal component analysis, Concentration area.

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INTRODUCTION

Separation of hydrothermal alteration zones is the main challenge of remote sensing science [1-5]. Various researches showed that the conventional image processing methods based on the spectral properties of pixels cannot easily separate hydrothermal alterations in the region. Therefore, other techniques should be used to identify alteration zones from each other. Some methods based on fractal geometry have been widely used in various sciences, especially geochemistry. These methods are one of the best methods in separating altered zones from each other. The present research aims to identify hydrothermal alteration zones in the study area by combination of principal component analysis and concentration-area model as a fractal technique.

METHOD

Concentration- Area fractal model

The fractal concentration-area model is used to provide a better view of the changes and differences in the image based on the values of the pixels, the frequency distribution of the pixels, as well as the spatial and geometric characteristics of the image patterns [6]. In this model, the goal is to establish a relationship between the area and the threshold of the reflection percentage. This relationship is described below:

$$A(PR \geq S) \propto PR^{-\alpha} \tag{1}$$

Where:
A(PR): the cumulative area enclosed by pixels whose reflection percentage is greater than or equal to S.
S: the threshold in the log-log concentration- area plot.
α: is the fractal dimension [7].

FINDINGS AND ARGUMENT

The results of principal components analysis for SWIR bands of ASTER and also for bands 4, 5 and 7 are presented in Table 1 and Table 2.

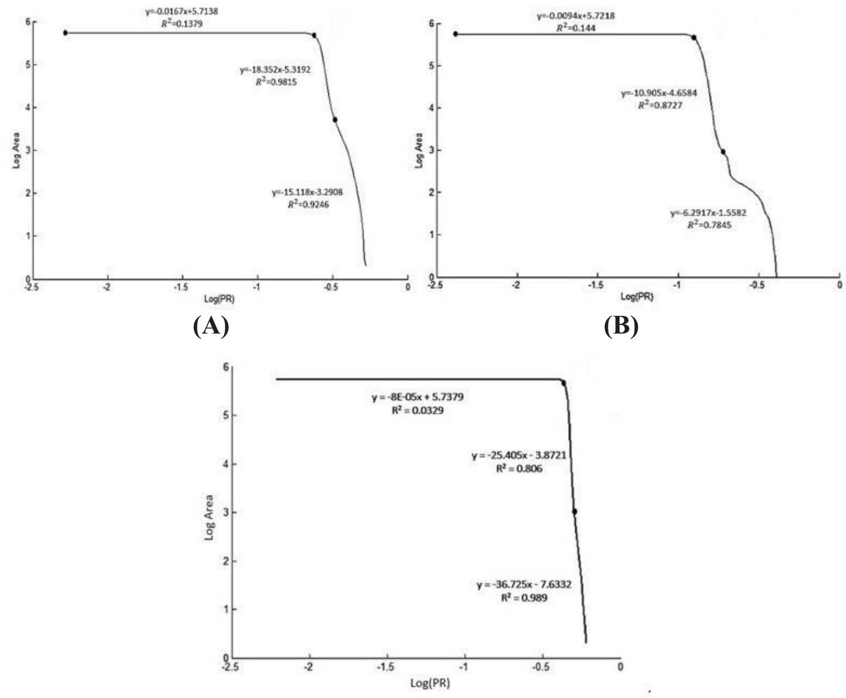
Table 1. Results from the principal components analysis of the SWIR bands

Eigen vector	Band 4	Band 5	Band 6	Band 7	Band 8	Band 9
PC1	-0.427598	-0.400889	-0.426348	-0.386474	-0.417658	-0.388427
PC2	-0.725287	-0.188249	-0.066972	0.113997	0.476143	0.440827
PC3	0.505706	-0.548788	-0.524832	0.094679	0.392172	0.069873
PC4	-0.185023	0.098481	-0.172764	0.788370	0.052759	-0.549463
PC5	-0.029049	-0.000579	0.299476	-0.394490	0.637657	-0.589272
PC6	0.017410	0.702128	0.647117	0.227000	-0.188843	-0.27608

Table 2. Results from the principal components analysis of bands 4, 5 and 7

Eigen vector	Band 4	Bnad 5	Band 7
PC1	0.617593	0.568517	0.543476
PC2	0.776463	-0.330699	-0.536417
PC3	0.125235	-0.753277	0.645670

According to Table 1, the principal component analysis is suitable to detect Phyllic alteration based on the PC3. PC5 also presents the propylitic alteration minerals. According to Table 2, the PC3 image is introduced as the most suitable image to highlight the argillic alteration. To provide the pure pixels of alteration, the fractal model of concentration-area was used to determine the new classification. The results of the used fractal model are illustrated in Fig. 1 and the images are extracted based on the threshold of log-log plot of concentration-area model in Figures 2-4.



(C)

Figure 1. The log-log plot of percent reflection versus area, **A:** phillic alteration, **B:** propylitic alteration, **C:** argillic alteration

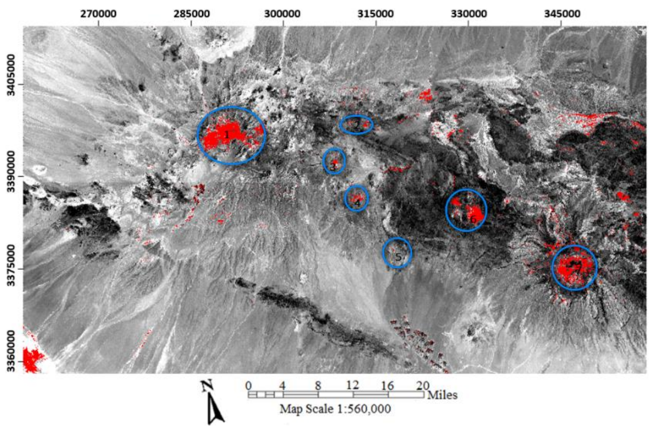


Figure 2. Image PC3 from 6 SWIR ASTER analysis for detecting Phyllic alteration using power-low formula

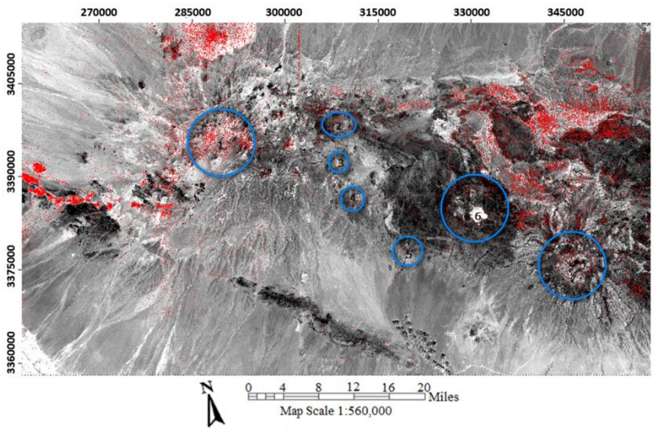


Figure 3. Image PC5 from 6 SWIR ASTER analysis for detecting Propylitic alteration using power-low formula

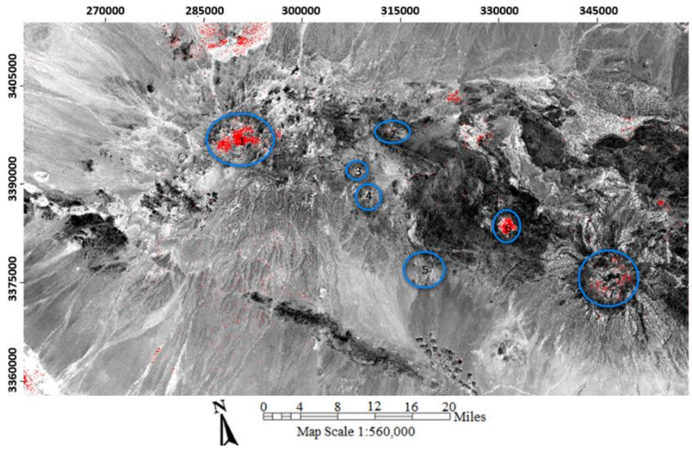


Figure 4. Image PC3 from 4, 5 and 7 ASTER bands for detecting argillic alteration using power-low formula

In order to evaluate the quality of the classification, the C-A fractal model is quantified in the form of a confusion matrix. According to Table 3, the error of removing the argillic zone is found to be 54.16%, which means that 54.16% of the pixels that belonged to the argillic zone, have classified in other zones mistakenly. The reason of this high error can be attributed to the lower number of training pixels compared to other zones. Also, due to the large number of training pixels in the Phyllic zone, the C-A model has been able to identify this type of alteration.

Table 3. The confusion matrix of classification results for Concentration-Area Fractal model

Confusion matrix	Phyllic (field)	Argillic (field)	Propylitic (field)	Total	Error of commission (%)
Phyllic (FIK)	507	51	0	558	9.13
argillic (FIK)	0	66	0	66	0
propylitic (FIK)	24	27	279	330	15.45
No alteration	60	0	213	273	
total	591	144	492	1227	
Error of omission (%)	4.51	54.16	0		Total accuracy: 89.30%

CONCLUSIONS

The results showed that the hybrid model of PCA and fractal model could be an effective tool to identify the phyllic, argillic, and propylitic pixels. The results of the confusion matrix indicated that the error of classification of the argillic zone is 54.16%. This high error is due to the lower number of training pixels in this zone compared to other zones. Also, due to the large number of training pixels in the phillic zone, the proposed algorithm is able to identify this type of alteration. Also, because of the same spectral signature of phillic and argillic minerals, the concentration-area fractal model could not exactly discriminate these two alterations.

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