

УДК: 550.4; 55.3.4; 55 (6)

PREDICTION OF GOLD POTENTIAL AREAS BASED ON REMOTE SENSING TECHNIQUES: A CASE STUDY FROM WADI HAIMUR REGION, SOUTH-EASTERN DESERT, EGYPT

V.G. RAMAZANOV*, M.H. ALI**

Baku State University

*vramazanov@rambler.ru**,

*youssof_2008@yahoo.com***

In the recent years remote sensing was used extensively in many applications, such as geological mapping, hydrogeological investigation and prospecting for mineral deposits. Remote sensing is considered a forerunner cost effective tool which was used successfully in discovering a number of ore deposits. Thus, figuring out the regions with the potential of hydrothermal alteration could be one of the important factors in recognizing the regions of these deposits. In this study we used different image analysis methods such as Band Ratio and False Color Composite methods for detection of mineralogy and alteration on a set of ETM+ data of Allaqi district zone, south-eastern Egypt. The study area is a region of high gold and other mineral potential in Egypt. This paper shows the successful implementation of remote sensing technology for gold and non ferrous metal resource prediction in the arid climate region.

Key words: Remote sensing, ETM+ data, Band Ratio method, False Color Composite method, mineralization, gold, Egypt.

1. Introduction

A few studies have been performed on the mineral prediction in Egypt in recent years. Most of these studies done by the foreign exploration companies and their data are not available for public publications. In the recent years remote sensing was used extensively in many applications such as geological mapping, hydrogeological investigation and prospecting for mineral deposits [10, 11, 14, 15]. The increasing living standard of the underdeveloped countries entails the search for more resources to meet the demands of minerals. Therefore, new exploration techniques must be utilized to discover previously unknown reserves [6]. Remote Sensing can map and analyze rocks over hundreds of square kilometers in a single image. This geological mapping may indicate particular areas of interest that can then be investigated in detail on the ground. Improved geological understanding leads to looking for new resources in previously overlooked areas. Landsat data have been used for a

number of years in arid and semi-arid environments to locate areas of hydrothermal alteration zones [1, 12]. Since the 1970s, scientists have developed several remote sensing image processing methods, such as ratio and principal component analysis (PCA), to discriminate mineral alterations effectively [10]. This paper takes the Wadi Haimur region, southeastern desert, Egypt, as a case study area. The area of study covers an area of about 270 km², and it is a region of high gold and mineral potential, because of its unique metallogenic background, such as complex geological structures, intensive deformation and metamorphism, and strongly metallogenesis. Yet, it has a hyper arid climate, a rugged mountainous topography and these conditions led to various difficulties of mineral resource survey and prediction. In order to solve the problems, for example, interference removal, weak alteration information extraction, prospective areas localization, in the extraction of mineral alterations from remote sensing in the area, implied information of remote sensing data should be excavated deeply and comprehensively. Furthermore, remote sensing information should be combined with others multi-sources data, such as, geological and geochemical data. The study area is located in Wadi Allaqi district, about 220 km southeast Aswan City. The area is dealt by some authors. According to them, the study area structurally affected by two phases of folds. The first folds are isoclinal and have axes strike in NE-SW. These folds are superimposed by second open folds with axial traces oriented NE-SW. The faults affecting the area are thrust and strike slip faults. The thrust faults follow the NW-SE trend and separate between the upthrust ultramafic sheets and slices from the underlying metasediments. The strike slip faults cut all types of rocks, which have sinistral sense of movement that reaches 80 m in the NE-SW direction. The main elements of geology in the study area include low grade green schist island arc assemblage of metasediments, metavolcanics and ophiolitic tectonic mélanges. The layered sequences intruded by younger granites; and are separated by structural contacts. The basement rocks are blanketed by Quaternary to Recent wadi deposits.

Alteration zones were recorded associated with quartz veins and veinlets. The gold occurrences are in Quartz veins, which randomly distributed in the study area. They are cutting through all its rocks. They extend for 10 m to 200 m, their thickness varies from 0.2 to 2 m. The contact between the veins and country rocks is marked by silicification, chloritization and sericitization of the country rocks. The veins and veinlets of quartz are smoky, milky or white. The smoky veins trends NE-SW and are usually gold bearing. This study aiming usage the application of landsat image to detect new gold occurrences in the study area.

Remote sensing information extraction and image data processing

To enable visualization of different surface features from TM imagery, band ratio and false color composite images were prepared using ENVI software using bands 7, 4 and 1 in (red, green and blue) a subset image was used to

determine the study area from whole scene and also to compare it with the digital topographical and geological maps.

In the landsat TM subset, the NW-SE and NE-SW oriented Wadi Allaqi and Wadi Haimur respectively, is clearly seen. The sand sheet appears yellowish in the eastern side from the study area. The color difference between the basement and sedimentary rocks.

Remote sensing data

In this study, the author choose one scene ETM+ remote sensing image identified by path 174 and row 44 of Landsat-7 with 8 bands acquired on November 16, 2001 to extract the information related to mineral potential mapping. The image is geometrically corrected by using control points from topographic sheets and the total root mean square (RMS) error is 4.5m. The correlation matrix has been calculated and is shown in Table 1.

Table 1

Correlation matrix statistics for the study areas

Correlation	Band 1	Band 2	Band 3	Band 4	Band 5	Band 7
Band 1	1.000000	0.982736	0.945270	0.933724	0.926078	0.925294
Band 2	0.982736	1.000000	0.987902	0.981851	0.974953	0.975043
Band 3	0.945270	0.987902	1.000000	0.998575	0.992957	0.993672
Band 4	0.933724	0.981851	0.998575	1.000000	0.994409	0.995313
Band 5	0.926078	0.974953	0.992957	0.994409	1.000000	0.997928
Band 7	0.925294	0.975043	0.993672	0.995313	0.997928	1.000000

Landsat-7 was launched in April 1999, carrying the Enhanced Thematic Mapper plus (ETM+). The TM Bands 1 to 7 are in blue, green, red, near infrared and shortwave infrared, exactly the same as those in Landsat TM with 30 m ground resolution. The TM band widths are shown in Figs.2a and 2b. Bands 1, 2, 3, 4, 5, and 7 have been used for this study. The thermal infrared band (band 6) and panchromatic band (band 8) have a ground resolution of 60m and 15m respectively. However, band 6 and band 8 have not been used in this study.

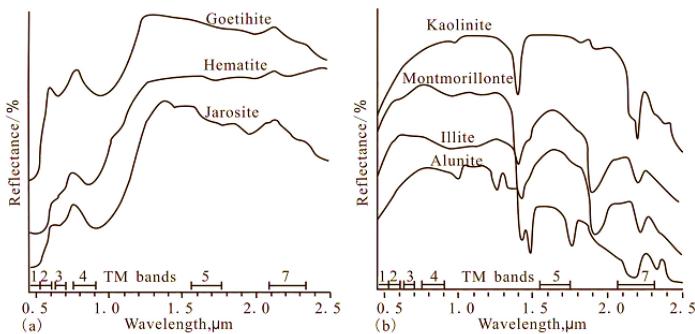


Fig.1. (a) Spectral reflectance curves for jarosite, hematite, goethite.
(b) Some common clay minerals.

IMAGE PROCESSING:

The most common type of alteration is the breakdown of feldspars and ferromagnesian minerals to a variety of clays and other hydroxyl bearing minerals. Such minerals can be detected by remote sensing techniques since the short wave infrared (SWIR) range of their spectra exhibit absorption [3]. Besides, a considerable number of ore occurrences contain sulphide minerals particularly pyrite (FeS_2) which undergo breakdown to sulphuric acid and a number of ferric hydroxides and complex sulphates which are both strongly coloured and possess crystal field absorption in the visible and near infrared range (VNIR) [3, 7]. This suite of alteration features proved to be extremely useful in delineating a variety of hydrothermal ore deposits [3].

I-The first procedure is the geometric correction of ETM+ image, where geometrically corrected and rectified to remove the geometry distortions due to sensor geometry, scanner and earth curvature. Geometric corrections has been made for the digital ETM+ bands and executed by a transformations (geo-referencing) and resampling (geo-coded) processing. Two steps of image rectifications were conducted:

1-The first step includes rectification of the scanned topographic Jabjaba map with scale 1:250000 published by (EGSMA).

2-The second step includes scanned geological map published by EGSMA. The correction is carried out by collecting well-distributed 4 ground control points from graphic tics of both topographical and geological maps. The parameters have been used in the registration procedures: UTM projection, Zone 36 N, Datum Old Egyptian 1907.

II-The second procedure is construction of false color composite image, where the geometrically corrected ETM+ image in bands (7 red, 4 Green, 1 Blue) displayed in viewer (fig. 2). It has been found that these bands where the best for visual lithologic discrimination [18, 19, 23], and also the topographic and geologic sheet visualized in 3 bands only.

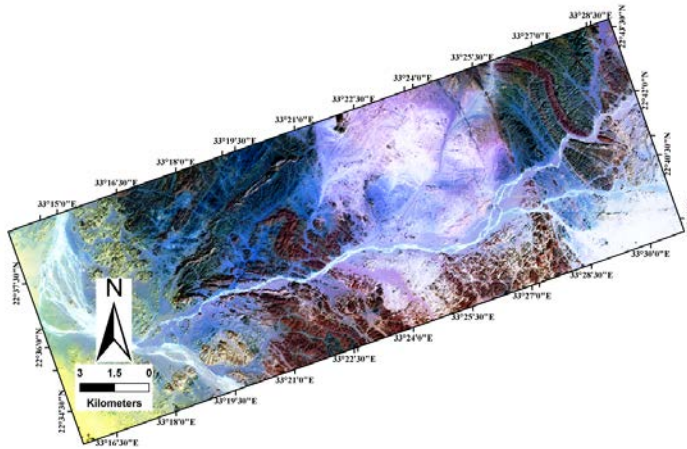


Fig. 2. Colour composite image obtained using Landsat ETM+ bands 7,4,1 in RGB, respectively.

III-The third procedure to produce the following thematic maps by using mineral composite and hydrothermal ratios and principle components analysis map for the study area to discriminate the different lithology types for geological mapping.

Alteration zone mapping using ratio image processing technique was used in the Red Sea Hills. The spectral features of ferric [bands 3/1] and hydroxyl bearing mineral [bands 5/7], in which hydrothermally altered rocks are often rich. It has been well established that ferric iron exhibits pronounced absorption features at around 0.82 μm and 0.35 μm , whereas ferrous iron has absorption at 1.0, 4.8-2.0 and 0.55-0.45. Hydroxyl – bearing minerals like clays have a major absorption feature around 1.9, 2.35 and 2.5. Detection of the above mentioned minerals has been used as prospecting guide for ore deposits. Ratio images are known for enhancement of spectral contrasts among the bands considered in the rationing and have successfully been used in mapping alteration zones. Using the theoretical knowledge about the spectral properties of most rocks and minerals, ETM+ bands 3/1 and 5/7 were selected for iron oxides and hydroxyl bearing mineral respectively. Whereas band ratio 5/4 has been computed to enhance possible ferrous oxides. These ratios of mineral bands are used to produce false colour composite images. Mineral composite ratio image obtained using the combination of bands (5/7 in red, 5/4 in Green and 3/1 in Blue) as shown in (Fig.3). Also, the hydrothermal composite ratio image are visualized in viewer, where the bands (5/7 in red, 3/1 in Green and 4/3 in Blue) as shown in (Fig. 4). Principle component analysis map also is produced. 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 [12]. Often times PCA is used to either reduce the dimensionality of the data processed in a target detection algorithm, or to reduce the noise in the hyper spectral imagery. Typically to reduce the dimensions of a data set a selection of a certain number of PCA bands is made so that certain percentage of the total variance in the data is preserved [9]. That is the dimensionality of data is reduced the bands are independent and more interpretable than the source data as shown in (Fig. 5).

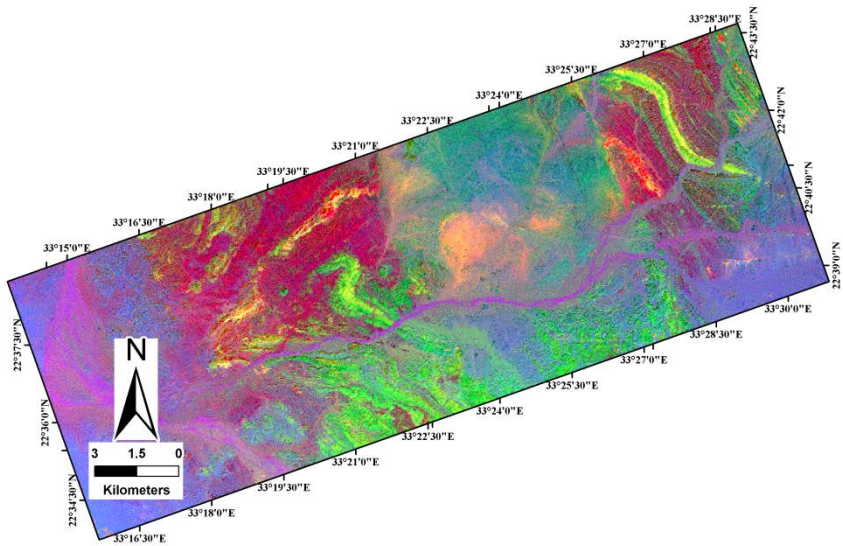


Fig. 3. Mineral composite image obtained using the combination (5/7), (5/4), (3/1) in RGB, respectively.

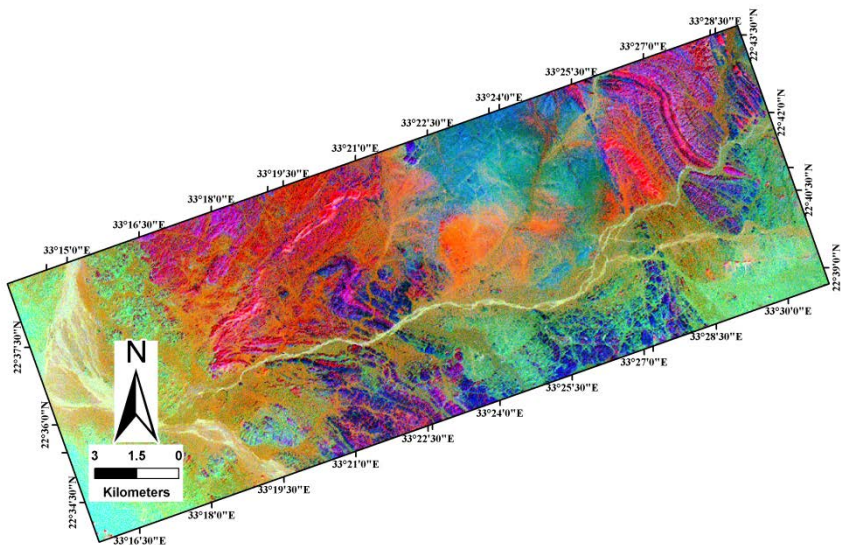


Fig. 4. Hydrothermal composite image obtained using the combination (5/7), (3/1), (4/3) in RGB, respectively.

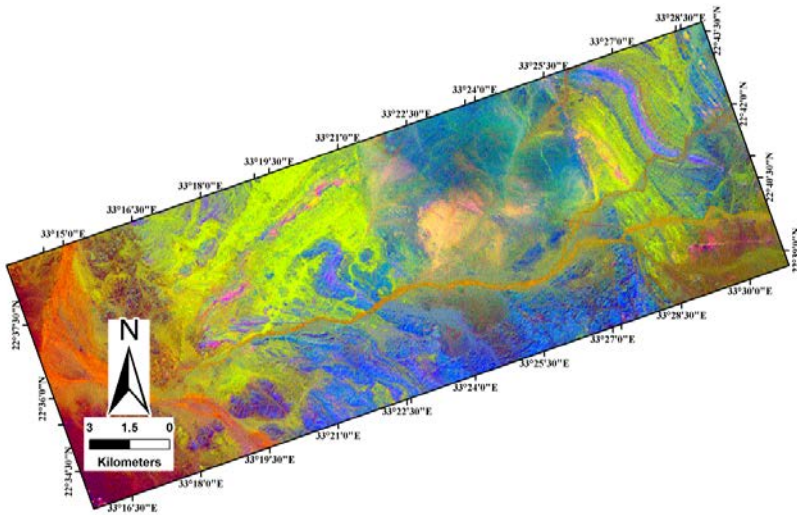


Fig. 5. PCA processed image using 423 false composite map bands in RGB, respectively

IV-The fourth procedure is carried out on the ETM data by applying the directional edge enhancement filter with kernel 5x5 using ENVI 4.4 package software to distinguished the hidden structures controlled the studied area. Then, plot and trace the lineaments, which represent the fractures (cracks and faults) that represents as straight line or somewhat curved feature in the image as shown in (Fig. 6). After measuring the structure lineaments then evaluate the structure analysis for the studied area as shown in (Tables. 2 and 3).The extracted lineaments using band 7 is recommended by authors to use for the structural lineaments interpretation in the study area [13].

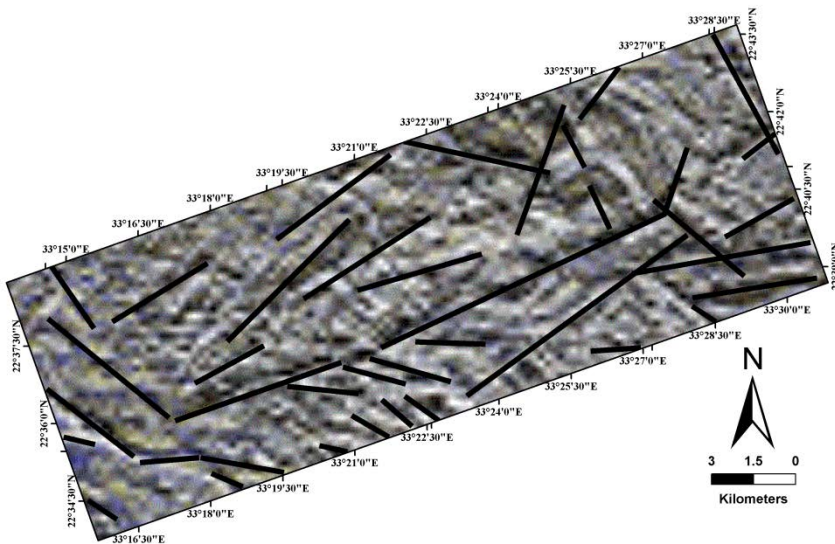


Fig. 6: Edge Enhancement image of the study area and its major lineament trends from LANDSAT-7 ETM+ data (band 7).

Table 2

Lineament orientation trends determined based on data/image source of the study area

Data Type	No. of Major Trends	Orientation Direction			Basic Relationship
		1°	2°	3°	
LANDSAT-7 ETM+	3	NE-SW	NW-SE	E-W	1° and 2° trends approximately orthogonal, 3 trend intermediate between 1 and 3 trends

Table 3

Lineament trend analysis based on data/image source of the study area

Direction	NE-SW	NW-SE	E-W
Number%	39.47	39.47	21.06
Length%	58.25	29.77	11.98

V-The last procedure is produced supervised classification technique implemented in this study to distinguish between possible gold bearings from the surrounding country rocks. This technique involves selecting a pixel, individual pixels, or a cluster of pixels with known geologic meaning (Haimur old mine site) and using then to locate regions with similar remote sensing characteristics [2, 15]. Parallelepiped supervised classification based on the seven landsat TM bands was conducted to outline areas with reflectance spectra identical to those of pixels representing the old known occurrences.

Then, extracting the promising areas for new gold occurrences and traced these areas in new coverage as shown in (Fig. 7).

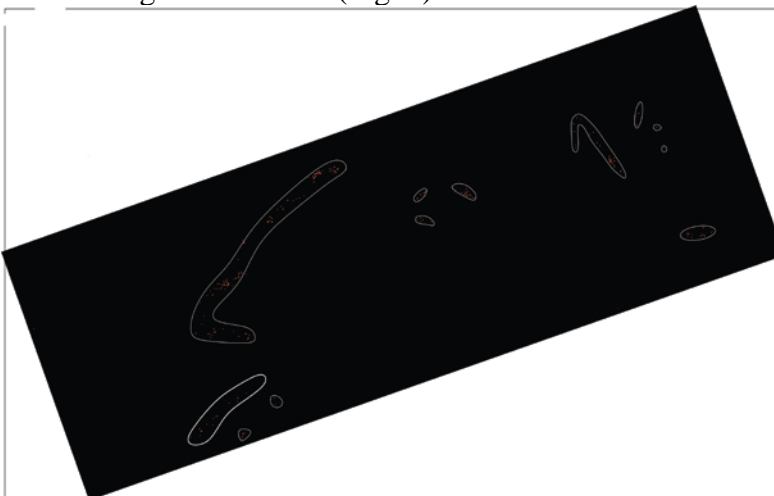


Fig.7. Gold-finding prospective areas are predicted in the study region

RESULTS AND CONCLUSION

For digital image processing of Landsat - 7 satellite data purposes, five main processing steps are following:

1. Geometric correction of ETM+ data, scanned topographic map and scanned geologic map for the study area.
2. Construction of a Band Ratio, False color composite images and principle component analysis.
3. Interpretation of a lithologic map for different type of rocks.
4. Interpretation of a structural lineament map after applying edge detection filter on the image.
5. Production of supervised classification map from selected signatures of six old known gold occurrences in the studied area.

The result leads to produce a false colour composite (FCC) image at scale 1: 100,000. This FCC image has been constructed by combinations of the ETM bands 7, 4 and 2 in red, green and blue respectively. This image helped in the identification and digitize new geological map for the study area see figure (8). Lithology discrimination of the study area was made with Landsat ETM+ data using band combinations. Almost all the lithologies could be delineated with a Landsat ETM+ false-colour composite image of bands 7, 4 and 2 in the RGB (figure 2). These results show only a little difference in location of geological boundaries for different units when compared to the geological map of EGSMA. This may be due to the topographic constraints in the field work. It is hard to determine the lithology with Landsat ETM+ false-colour composite image of bands 7, 4 and 2 in the RGB for some locations.

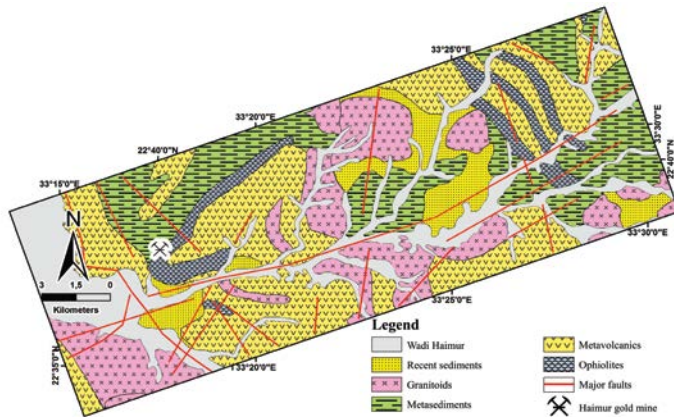


Fig 8. Lithologic unit map interpreted from Landsat ETM+ data and field observation of Wadi Haimur area, southeastern desert, Egypt. (original scale 1:100,00)

The structural analysis from lineament trends of fractures as shown in (Fig 6). The lengths and counts are measured and tabulated in Table (3). Also, the azimuths of all major and minor fractures were measured and tabulated in Table (2). These tables show the major structural lineaments are oriented NE-SW, NW-SE and E-W respectively. The first trend NE-SW represents the old

folds and the strike slip with sinistral movement. This trend parallel to the thrust contacts and the elongation of Gebel Haimur and the main trend of Wadi Haimur. The secondary trend is NW-SE, which is trend of upthrusting of ultramafic sheets (melange) over the underlying metasediments. Third trend contributed to Kalabsha and related E-W oriented faults were proved to be active and also the directions of dykes, which cut all type of rocks.

Supervised classifications enable identification of new gold occurrence with reflectance spectra similar of those of the old Haimur mine pixel location. These procedures are important in that it might lead to possible detection of new gold bearing in the study area.

REFERENCES

1. Abdelsalam, M.G., Stern, R.J., Berhane, W.G. Mapping gossans in arid regions with Landsat TM and SIR-C images: the Beddaho alteration zone in northern Eritrea. *Journal of African Earth Sciences*, 2000, v.30 (4), pp.903–916.
2. Crosta, A.P., Filho, C.R. Searching for gold with ASTER. *Earth Observation Magazine*, 2003, v.12 (5), p.38–41
3. Drury, S.A. *Image interpretation in Geology*. 3rd edition. Cheltenham, UK: Nelson Thornes. 2001, 283 p.
4. Khan, S. D., Mahmood, K., Casey, J. Mapping of Muslim Bagh Ophiolite complex (Pakistan) using remote sensing and field data *Journal of Asian Earth Sciences*, 2007, v.30 (2), 333-343.
5. Khan, S. D., Mahmood, K. The application of remote sensing techniques to the study of ophiolites. *Earth Science Reviews*, 2008, v.89, pp.135-143.
6. Kusky, T.M., Abdelsalam, M., Tucker, R., Stern, R. Evolution of the East African and Related Orogens, and the Assembly of Gondwana. *Special Issue of Precambrian Research*, 2003, v.123, pp. 81–344.
7. Lillesand, T.M., Kiefer, R.W. *Remote Sensing and Image Interpretation*, fifth ed. John Wiley and Sons, Inc., New York, 2004, 340 p.
8. Ninomiya, Y. Advanced remote lithologic mapping in ophiolite zone with ASTER multispectral thermal infrared data. *IEEE T Geosci Remote*, 2003, v.3, pp. 1561-1563.
9. Oskouei M. M, Poormirzaee R. Estimation of virtual dimensionality of hyperspectral data by principle component analysis and higher order statistical method, *Proceedings of the 5th WSEAS International Conference on REMOTE SENSING*, Genova, Italy, 2009, pp. 67-72.
10. Papp, E., Cudahy, T. *Hyperspectral remote sensing*. In: Papp, E.(Ed.), *Geophysical and Remote Sensing Methods for Regolith Exploration*. CRC LEME Open File Report, vol. 144. Canberra, Australia, 2002, pp. 13–21.
11. Qui, F., Abdelsalam, M., and Thakkar, P. Spectral analysis of ASTER data covering part of the Neoproterozoic Allaqi-Heiani suture, southern Egypt: *Journal of African Earth Sciences*, 2006, v. 44, p. 169-180.
12. Tangestani M.H., Moore F. Comparison of three principal component analysis techniques to porphyry copper alteration mapping: a case study, Meiduk area, Kerman, Iran. *Canadian Journal of remote Sensing*, 2001, v. 27, pp.176–181
13. Tombe, M. A. *Image processing techniques for geological mapping of Kurmuk-Qeissan area*. GRAS, 2006, 25 p.
14. Xiong, Y., Khan, S. D., Mahmood, K., and Sisson, J. Lithological mapping of Bela Ophiolite with remote sensing data. *International Journal of Remote Sensing*, 2011, v. 32, №. 16, pp. 4641–4658.
15. Zhang X., Pazner M., Duke N. Lithologic and mineral information extraction for gold exploration using ASTER data in the south Chocolate Mountains (California) // *ISPRS Journal of Photogrammetry and Remote Sensing*, 2007, v. 4, p. 271-282.

16. Zhang, X., Pazner, M. Comparison of Lithologic Mapping with ASTER, Hyperion and ETM Data in the southeastern Chocolate Mountains, USA. Photogrammetric Engineering and Remote Sensing, 2007, 73 (5), p.555–561.

MİSİRİN CƏNUB-ŞƏRQ SƏHRASI HAYMUR VADİSİNİN QIZIL POTENSİALININ DİSTANSİON ZONDLAŞDIRMA ÜSULLARI İLƏ PROQNOZLAŞDIRILMASI

V.G.RAMAZANOV, M.H.ƏLİ

XÜLASƏ

Son illər distansion zondlaşdırma üsullarından bir çox sahələrdə, o cümlədən geoloji planalmada hidrogeoloji tədqiqatlarda və faydalı qazıntı yataqlarının axtarışında geniş istifadə olunur. Distansion zondlaşdırma bir sıra filiz yataqlarının aşkarlanmasında iqtisadi cəhətdən ən effektiv vasitələrdən hesab olunur. Intensiv hidrotermal dəyişilmə ilə səciyyələnən regionlarda bu metodlar regionun yataqlarının öyrənilməsində ən mühüm üsullardan biri ola bilər. Bu məqalədə biz əkslərin analizinin müxtəlif üsullarından, xüsusən də Spekr nisbətləri və Süni Rənglər Kompozitiv aşkarlama metodlarından istifadə etmişik. Tədqiqat rayonu Misirdə yerləşib qızıl və digər faydalı qazıntıların yüksək potensialına malikdir. Məqalə distansion zondlaşdırma texnologiyasının quru iqlim şəraitində qızıl və əlvan metal ehtiyatlarının proqnozlaşdırılmasında müvəffəqiyyətli tətbiqini göstərir.

Açar sözlər: Distansion zondlaşdırma, ETM+ məlumatları, spektr nisbətləri üsulu, minerallaşma, Misir.

ПРОГНОЗ ЗОЛОТОГО ПОТЕНЦИАЛА ВАДИ ХАЙМУР ЮГО-ВОСТОЧНОЙ ПУСТЫНИ ЕГИПТА НА ОСНОВЕ МЕТОДОВ ДИСТАНЦИОННОГО ЗОНДИРОВАНИЯ

В.Г.РАМАЗАНОВ, М.Х.АЛИ

РЕЗЮМЕ

В последние годы методы дистанционного зондирования широко используются во многих отраслях, таких как геологическое картирование, гидрогеологические исследования и поисков месторождений полезных ископаемых. Дистанционное зондирование считается надежным экономически эффективным инструментом, которое было успешно использовано в открытии ряда рудных месторождений. В регионах с потенциальными гидротермальными изменениями оно может быть одним из важных методов в исследовании месторождений полезных ископаемых. В данной работе мы использовали различные методы анализа изображений, таких как метод Спектр отношение и Искусственные Цвета Композитных методов обнаружения минералов и изменения по ряду ETM+ данные районе Аллаги зоны юго-восточного Египта. Исследованная область является регионом с высоким потенциалом золота и других полезных ископаемых в Египте. Эта статья показывает успешное применение технологий дистанционного зондирования при прогнозировании ресурсов золота и цветных металлов в регионах засушливого климата.

Ключевые слова: дистанционное зондирование, ETM+ данные, метод спектр отношение, минерализация, золото, Египет.

Поступила в редакцию: 17.02.2012 г.

Подписано к печати: 29.03.2012 г.