APPLICATION OF ASTER AND ETM IMAGES DATA
IN DETECTION OF GOLD-BEARING ALTERATION ZONES
IN SOUTH EASTERN DESERT OF EGYPT

Mohamed F. Sadek; Safaa M. Hasan; Safwat S. Gabr

National Authority for Remote Sensing and Space Sciences (NARSS).
23 Joseph Tito Street, El-Nozha El-Gedida, P.O. Box : 1564 Alf-Maskan, Cairo, Egypt
*Corresponding author: mfsadek@gmail.com

ABSTRACT

This study is focused on application of various remotely sensed data to reveal the spectral characterizations of some basement rocks and delineating the gold bearing alteration zones in three localities in the South Eastern Desert of Egypt namely; Wadi Beida, Wadi Defiet and Gabal Hoteib areas. In general these areas are occupied mainly by Precambrian basement rocks. The image processing of the ETM+ and ASTER data have been carried out using ERDAS Imagine 2013 and ENVI 5.0 Software. Resulted images have been used for detailed geological mapping and discrimination of the mineralized alteration zones. On the other hand, to discriminate the basement rocks forming the two areas of Wadi Beida and Wadi Defiet and detection of the gold-bearing quartz veins and the alteration zones, the data of field study and the processed data of ETM+ image have been applied. The ETM band ratioing has been applied to discriminate the gold-bearing alteration zones. The present study revealed that, the ETM band ratio image (5/1, 5/7, 5/4*3/4) show best discrimination of the gold-bearing alteration zones within the host rocks at Wadi Beida, while these zones are well discriminated using the ETM band ratio image (5/7, 5/1, 4) at Wadi Defiet area. On the other hand the processed data of ASTER image is very effective in discrimination the rock units and detection of gold-bearing alteration zones at Hoteib- Al Fawi area. This study indicates that, the gold bearing zones in the studied three localities are promising; more detailed exploration for gold mineralizations is needed to evaluate their potentiality.

Keywords: ETM+ image; ASTER; Gold; alteration zones; Eastern Desert; Egypt.

1. INTRODUCTION

The South and Central Eastern Desert of Egypt are characterized by widespread ophiolitic sequences associated with ophiolitic mélanges. Widespread brittle–ductile shear zones in the greenstone terrains across the South Eastern Desert of Egypt locally host silicification and carbonatization haloes that are commonly associated with significant Au-Cu mineralization (e.g. Nano et al., 2002; Ramadan and Konny, 2004; Gabr et al., 2010; Zoheir and Imam, 2012). Spectral identification of potential areas of hydrothermal alteration minerals is a common application of remote sensing to mineral exploration. The extraction of spectral information related to this type of target The Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) imagery has been achieved through the use of image processing techniques such as band ratio and principal component analysis (PCA). Many ore deposits are first detected in the field by the recognition of hydrothermally altered host rocks, and are typically zonally distributed. Economic mineralization is often produced by fluid processes that substantially alter the mineralogy and chemistry of the host rocks. This alteration can produce distinctive assemblages of minerals that vary according to the location and degree of those flow processes. When exposed to the surface of the Earth this alteration can sometimes be mapped at a zonal pattern. By using remote sensing techniques these zones can be detected in a regional scale. In
this study, the processed data of ETM and ASTER images have been applied to discriminate the gold-bearing alteration zones as well as the host sheared rocks.

The processed data of both Landsat and ASTER images have been used by several authors in lithological mapping for the Arabian Nubian Shield and for other areas worldwide (e.g. Sultan et al., 1986; Ramadan and kontny, 2004; Hassan, 2003; Sadek, 2004 and 2005; Gad and Kusky, 2006; Zoheir, 2004; Zoheir and Klemm, 2007; Zoheir and Imam, 2012). The main objective of the present study is application of different remotely sensed data in detection gold-bearing alteration zones and their potentialities in three localities located in South Eastern Desert of Egypt namely; Wadi Beida, Wadi Defiet and Hoteib-Al Fawi areas.

2. MATERIALS AND METHODS

The processing of digital Landsat Enhanced Thematic Mapper Plus imageries (ETM+7) data with six spectral bands (1, 2, 3, 4, 5, and 7) is carried out at the National Authority for Remote Sensing and Space Sciences, Egypt (NARSS) using different techniques. Geometric correction has been applied with sufficient number of ground control points taken from 1:50,000 scale topographic maps. Radiometric balancing has been done to achieve homogenous radiometric set of data. Mosaicing between the two scenes has been conducted to have one set of composite image that is geometrically corrected and radiometrically balanced. For multispectral data there are several computerized data processing techniques which can be applied to the problem of differentiation of the alteration zones from the country rocks. These techniques include the use of band rationing, density slices and supervised classifications. Landsat TM+7 multispectral data have been processed to discriminate the different rock types particularly the gold-bearing alteration zones within the strongly sheared metavolcanics. The selected bands include band 1 through band 5 and band 7 (Visible & Reflected Infrared “VNIR”) that characterized with 30 m spatial resolution. In addition to band 8 as the Panchromatic band (15 m).

Many band ratioing images have been tested for the best discrimination of gold-bearing alteration zones and the surrounding rock units. The band ratio ETM images (5/7, 5/1, 5/4*3/4 in RGB)(Figure 1) and (5/7, 5/1, 4, in RGB)(Figure 2) have been selected to discriminate these zones and the country rocks at Wadi Beida and Wadi Defiet areas respectively. On the other hand the Principal Components (P3, P4, P5) of ASTER data has been applied to discriminate the gold-bearing alteration zones at Gabal Hoteib-Al Fawi area (Figure 3).

ASTER data provide higher spatial, spectral, and radiometric resolutions than the Landsat 7 data. The ASTER channels are contiguous in the short wave infrared region, yielding increased accuracy in the spectral identification of minerals, rocks and soils of the Earth surface. It makes ASTER data superior over other sensors for lithological mapping (Gad and Kusky, 2006). In the present study, both ASTER Level 1B image data acquired on March 15, 2008. The data of Aster images have been used by many authors to discriminate gold-bearing alteration zones in the Eastern Desert of Egypt e.g. (Gabr and Kusky, 2006; Zoheir and Imam, 2012). The image processing of the ETM and ASTER data is carried out using ERDAS Imagine 2013 and ENVI 5.0 software. Resulted images are used for detailed geological mapping. The field check was carried out to validate and prove the interpretation of remotely sensed data.

3. GEOLOGICAL BACKGROUND

3.1. Wadi Beida Area

The Wadi Beida area is the southern part of Wadi Hodein area; it is located in the South Eastern Desert of Egypt. This area is occupied by Neoproterozoic Pan-African (Precambrian) basement rocks including metamorphic and intrusive assemblages. The metamorphic assemblage comprises
dismembered ophiolitic metamorphosed ultramafic rocks and island-arc calc-alkaline metavolcanics. On the other hand, the intrusive assemblage rocks include syn-tectonic tonalite-granodiorite (G1) and late-tectonic monzogranites-alkali feldspar granites (G2). These Precambrian basement rocks are unconformably overlain by Cretaceous sandstones and both are extruded by Tertiary basalts (Fig. 4). The NW-SE trending alteration zones at the southern western part of the mapped area were classified by Kontny et al., (1999) and Nano et al., (2002) into three types namely; quartz carbonates type, silicified type and gossans type. The gold-bearing alteration zones have been distinguished as gossans, brecciated quartz veins and quartz carbonate veins (enriched with malachite). Gold occurs within quartz veins associated with Fe-oxides (hematite and goethite) and within the metavolcanics. The average gold content reaches up to 5 g/t in the alteration zones and up to 10 g/t in the quartz veins.

3.2. Wadi Defiet Area

The study area is covered by ophiolitic ultramafics, metasediments and schistose metavolcanics intruded by syn to late tectonic intrusions of gabbro-diorite and granites. The metamorphic rocks including the ophiolitic ultramafics, metasediments and metavolcanics were affected by polyphase metamorphic events including regional, thermal and retrograde metamorphism (Fig. 5). The main structural elements affecting the rocks encountered in the study area include regional penetrative foliation, thrusting and shearing, folding (anticline, syncline and recumbent folds) and faults (normal and thrust faults).

The investigated area is recently mapped as ophiolitic serpentinites tectonically thrusted over the metasediments and metavolcanics while they are intruded by gabbro and granitic rocks (Sadek et al., 1995; EGSMA, 2003; Salem, 2003; Zoheir, 2004 and Sadek et al., 2005; Ramadan et al., 2005; Zoheir and Klemm, 2007).

Sites of Mineralization

The Um El Toyour El Fuqani old gold mine is located within the highly sheared listwaeinite and metavolcanics. Sites of mineralization include series of quartz and quartz-carbonate veins, lenses and veinlets. Salem (2003) recognized three sites located in strained, faulted and intense alteration sheared zones. These sites namely: East Gabal Um El Touyur El Fuqani listwaeinites (Site 1), Gabal Al - Adraq listwaeinites (Site 2) and west Gabal Um El Touyur El Fuqani alteration zones (Site 3) (Fig. 6). These sites are selected for detailed geological and geochemical bed rock exploration (Salem, 2003). The listwaeinite rocks in site (1) are widely distributed and occur as sheets and lenses along the thrust zone between the serpentinites and metavolcanics. They are characterized by intense alteration showing yellow colour on the Landsat ETM+ ratio image (5/1, 5/7, 4 in R, G, B).

The petrographic study indicates that, these listwaeinites are mainly composed mainly of carbonates and the main recorded ore minerals include chromite, cobaltite, pentlandite and magnetite. The geochemical analysis of 5 samples from these rocks recorded Au (0.27-0.6 g/t), Ag (<0.3 g/t), Cr (2264 to 2840 ppm), Ni (2245 to 2907 ppm) and Co (101–124 ppm).

At Gabal Al Adraq (site 2) the thickness of listwaeinites reaches up to 250 m and extends to more than 1 km with NE-SW trend, parallel to the major structure in the study area. They are enriched with mineral products of silification, pyritization, carbonatization and ferruginarion and are associated with quartz veinlets forming a stockwork. The main ore minerals are gold, chromite, cobaltite, pentlandite and magnetite. Alteration zones west of Gabal Um El Touyur El Fuqani (site 3) the metavolcanics rocks are characterized by intense gold bearing alteration zones and characterized by intense alteration features was chosen for detailed exploration work.

The thickness of these alteration zones reach up to 300 m. They extend to more than 1 km and strike NNW-SSE, parallel to the major shear zone in the study area. This is indicated by the presence of excavated gold bearing quartz veins through several vertical and horizontal shafts.

3.3. Gabal Hoteib Area

The Hoteib area is located at the extreme southeastern of Egypt directly to the north of the Egyptian Sudanese border near the border with Sudan. The area comprises two Precambrian, metamorphic and
migmat ic assemblages. The metamorphic suite is represented by ophiolitic ultramafics, while the magmatic one includes intrusive granitic rocks. The ophiolitic ultramafics are thrust ed over metavolcanic schists of andesitic basaltic composition, sometimes they are tectonically incorporated within the metavolcanic schists (Figure 3). The ophiolitic ultramafic rocks occur as elongated sheets and slices consist of serpentinite nappes, t alc carbonates, t alc graphite and listwaenite ridges (quartz-ankerite reefs). They form a NW-SE huge belt of tectonized sequence with some strained portions of highly sheared rocks along the thrust contact with the surrounded schistose metavolcanic rocks whereas the gold-bearing alteration zones with quartz veins are located.

Iqat and Al-Fawi are two ancient mines that are known in this area for their valuable gold deposits. Both mines have been exploited by ancient Egyptians and were likely to be active until the end of the early Islamic time (10th–11th century) (Zoheir and Emam, 2012). Recently, these two mines have become of a great attraction to exploration companies due to their significant gold grades (several ppms of Au) within and outside the old mining sites. The recorded Au concentrations are usually associated with a shear zones hosted auriferous quartz veins (Salem, 2007; Zoheir and Emam, 2012).

4. DISCUSSIONS AND CONCLUSIONS

The false colour composite (FCC) ETM ratio image (5/7, 5/1) and (5/4∗3/4) (RGB) was successfully used by Sultan et al., (1986) to maximize the discrimination of serpentinites and other basement rocks in the Eastern Desert of Egypt. The alteration zones and the surrounding altered metavolcanics have relatively low reflectance in band 7 due to the absorption caused by increasing the contents of carbonate or hydroxyl-bearing minerals (Sultan et al., 1986; Sabins, 1997). The ratio 5/7 is assigned in the red component and it is sensitive for these minerals. Therefore the pixel digital number value of this ratio in the alteration zones is much greater than its value in the unaltered metapyroclastics and the surrounding altered metavolcanics. The 5/1 ratio is assigned to the green component and it is sensitive for magnetite-bearing contents and the alteration zones which show lower pixel value in this ratio (0.97) than the surrounding altered metavolcanics (1.77). The (5/4∗3/4) ratio is assigned to the blue component and is sensitive to the contents of iron and aluninol-silicates bearing minerals and thereby its high pixel value in the intrusive ultramafic-mafic rocks (3.29) distinguishes these rocks from the metamorphosed ultramafic rocks (2.84).

As shown in figure (1) the FCC ratio ETM image (5/7, 5/1, 5/4∗3/4) distinguishes the altered metavolcanics exposed at Wadi Hodein-Beida showing orange colour, the hosted alteration zones show light yellow tone while the unaltered metavolcanics of belt display pinkish rose tone. The ophiolitic serpentinite-talc carbonate rocks exhibit light blue colour (Sadek, 2004).

The FCC ratio ETM image (5/7, 5/1, 4) has been applied to discriminate the gold-bearing alteration zones at Wadi Defiet area and new mineralized sites are delineated around the Um El Touyur El Fuqani old gold mine (Figure 2). On the other hand, the alteration zones at Hoteib-Al Fawi area can be detected by using the Principal Component PC3, PC4 and PC5 of ASTER images to form a false color composite image with any of the other PC images (PC3). Most of the alteration signature in the area, can be successfully discriminated as pure red colour) Spot 4 image as shown as a reference (Figure. 3). The results obtained from the remotely sensed data have been validated and checked by field studies.

5. CONCLUSIONS

The gold-bearing alteration zones exposed in Wadi Beida, Wadi Defiet and Hoteib-Al Fawi areas are generally located within the highly sheared ophiolitic ultrabasic rocks (listwaenites) and metavolcanics. Based on the applied integrated data of previous geological mapping, the FCC band ratios ETM images and principal components of ASTER images with field check, these alteration zones are accurately discriminated from the surrounding rocks. Comparing with the previous geological mapping, new gold-bearing alteration zones have been recorded in the studied areas as well as the extensions of the previously recorded mineralized zones are delineated and located on the produced geological maps.
Figure 1: False colour composite (FCC) ratio image (5/7, 5/1, 5/4*3/4) covering the Wadi Beida area showing best discrimination of the mineralized alteration zone.

Figure 3: FCC band ratio ETM image (5/7, 5/1, 4) of Wadi Defiet area.
Figure 3: (a) PCA (PC5, PC4, PC3 in RGB) image showing the proposed alteration zones (red color) (b) SPOT image (bands 4, 3, 2 in RGB) for reference showing the sampled locations (yellow stars as well as Al-Fawi/Iqat old mining locations (green circles).

Figure 4: Geological map of Wadi Beida area extracted from landsat TM image using band ratio image (5/1, 5/7, 5/4*3/4).
Figure 5: Geological map of Wadi Defeit area prepared from the interpretation of ETM Ratio image 5/7, 5/1, 4 compiled with previous maps and field work.

Figure 6: Geological map of Hoteib-Al Fawi area.
REFERENCES

EGSMA, 2003: Gological map of Marsa Shaab Quadrangle, Egypt, Scale, 1:250,000, Geol. Surv. Egypt.


