GEOLOGICAL AND STRUCTURAL SETTING OF WADI HODEIN AREA SOUTHEAST EGYPT WITH REMOTE SENSING APPLICATIONS

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ABSTRACT:

The Wadi Hodein area in the south Eastern Desert of Egypt 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. To discriminate the different basement rocks, shear zones, the data of field study together with those of false colour composite ETM ratio image (5/1, 5/7, 5/4*3/4) have been applied and the spectral signature curves of these rocks were delineated. Detailed field mapping and structural studies revealed four events of structural deformation (from oldest to youngest; D1, D2, D3 and D4) affecting the Pan-African basement rocks. D1 is represented by ENE-WSW oriented megascopic upright open folds associated with low angle thrusts as well as mesoscopic tight, overturned and recumbent folds. Kinematic indicators indicate thrusting towards the SSE. D2 is represented by NNW-SSE oriented megascopic and mesoscopic folds, which are tight, verge towards WSW. D3 includes major NNW-SSE trending sinistral shear zones that show subordinate reverse fault component and dip steeply towards the ENE. D4 is represented by NW-SE trending faults and E-W oriented dextral faults with left stepping segments.

1. INTRODUCTION

The basement rocks in the Eastern Desert of Egypt and Sinai constitute a part of the Arabian Nubian Shield that has been cratonized around the end of the Precambrian. The evolution of these rocks was conventionally interpreted on the basis of the classical geosynclinal orogenic cycle model (e.g. El-Ramly and Akaad, 1960; Sabet, 1972; Akaad and Noweir, 1980). Recent studies in the Eastern Desert indicate that, the evolution of this complex is better interpreted in terms of plate tectonic models. The south and central Eastern Desert of Egypt are characterized by widespread of ophiolitic mélange rocks, associated with extensive metasediments of oceanic character. Calc-alkaline metavolcanics characteristic of island arcs or volcanic arcs of active continental margins were also recognized. Accordingly, several plate tectonic models were proposed for the evolution of these rocks (e.g. Gass, 1981; Church, 1979; Hassan and Hashad, 1990; Kroner, 1985; Engel et al., 1980; Ries et al., 1983; Stern et al., 1984; El- Bayoumi and Greiling, 1984; Kroner et al., 1987; Greiling et al., 1994).

The investigated area is located near the Red Sea coast in the south Eastern Desert of Egypt between Latitudes 22º55´and 23º15´N and Longitudes 35º 10´ and 35º 41´ E, covering an area of about 1073 km^2 (Fig. 1). It is occupied by Precambrian basement rock assemblages unconformably overlain by Cretaceous sandstones. Both Precambrian and Cretaceous rocks are extruded by Tertiary basalts.

The main objective of this study is to discriminate the different basement rocks in the Wadi Hodein area as well as to delineate the mineralized alteration zones within the sheared metavolcanics and to investigate the structural setting of the study area.

To achieve results, the Landsat Thematic Mapper (TM) were acquired and processed. The raw data image bands 1, 2, 3, 4, 5, 7 and band ratio image (5/1, 5/7, 5/4*3/4) were applied for the geological mapping and accurate discrimination of the alteration zones. The characteristic spectral signatures for the different basement rocks in different bands and band ratios were delineated. Field work was carried out to check the interpretation of the TM images data.

2. MATERIALS AND METHODOLOGY

The study area is included in two Landsat TM scenes (Paths 172 and 173/Row 44). The processing of digital Landsat satellite imagery 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. Cubic convolution resampling technique has been used to project the image according to Universal Transverse Mercator (UTM) system with pixel size 20 m. Resampling process is carried out to determine the pixel values and to fill into the output image from the original image matrix. 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 ratios, density slices and supervised classifications. Landsat TM multispectral data have been processed to discriminate the different rock types present such as altered and unaltered rocks because different rocks have a characteristic spectral signature as a finger-print.

A band ratio image is created by dividing the digital number (DN) in one band by the corresponding DN in another band for each pixel and stretching the resulting value as an image. Each pixel in the image is processed in this way resulting in a band ratio. The use of a band ratio enhances compositional information, while the other types of information about the earth surface such as differences in topographic slope give the same appearance throughout the image (Sabins, 1997). The false colour composite ratio image (FCC) was produced by combination the three TM band ratio images 5/7, 5/1 and 5/4*3/4 in red, green and blue (RGB) in one image. The pixel digital numbers (DNs) in the three band ratios for the examined basement rock units were calculated and listed in table (1).

Figure 1: Location map for the study area

Band & Band Ratio / Rock Unit	Pixel digital numbers (DNs)		
	Ratio 5/7	**Ratio 5/1**	**Ratio 5/4*3/4**
Serpentinites	1.81	0.82	2.48
Altered metavolcanics	1.39	1.77	2.50
Unaltered metavolcanics	1.54	1.20	2.80
Alteration zones	1.73	0.97	2.29
Ultramafic-mafic intrusion	1.98	1.85	3.29
Monzogranites	1.64	1.14	2.31

Table (1): Pixel values in the applied bands ratios for the examined rock units.

3. GEOLOGICAL SETTING

The investigated area was geologically studied by some workers e.g. (Ghanem, 1972; Ramadan, 1994; Egyptian Geological Survey (EGSMA), 1992 and 2002; Sadek et al. 1996 and 2000 and Hassan, 2003; Sadek, 2004; Abdeen et al., 2008). These studies revealed that, the study area is occupied by basement (metamorphic and intrusive) and sedimentary rocks as well as Tertiary basalts (Fig. 2). The Late Proterozoic Precambrian basement rocks cover large parts of the area forming high to medium relief of weathered blocky mountains and hills. They comprise dismembered ophiolitic sequence of serpentinite-talc carbonate rocks, calc-alkaline metavolcanics, syn tectonic tonalite-granodiorite (G1), late tectonic intrusions of ultramafic-mafic rocks and monzogranite-alkali feldspar granites (G2).

Cretaceous sandstones on the other hand form small beds non-conformably overlaying the basement rocks. Both Precambrian and Cretaceous rocks are extruded by Red Sea rifting related Tertiary basalts. NW-SE strike-slip and normal faults are traced on the geological map.

The ophiolitic serpentinites associated with talc carbonate rocks are exposed either as NW-SE elongated body (Gabal Sarir) thrusted over the surrounding metavolcanics (Fig. 3) or as irregular slices tectonically emplaced within these rocks. The calc-alkaline metavolcanics which are the most predominant rocks in the study area are intruded by gabbro-diorite, tonalite-granodiorites (G1) and monzogranites (G2). They are mainly represented by meta-andesite locally associated with metadacite and metarhyolite forming Gabal Beida-Khashab mountainous belt trending NW-SE, whereas they enclose some structurally controlled gold-bearing alteration zones.

The ultramafic-mafic rocks (peridotite-gabbro) form a small circular intrusion near the southern western corner of the mapped area (Gabal Homraii) intruding the surrounding gabbro-diorite rocks. Monzogranites are exposed north of Wadi Rahaba and at Gabal Harhagit intruding the schistose metavolcanics while the alkali-feldspar granites intrude the serpentinites and tonalites.

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.

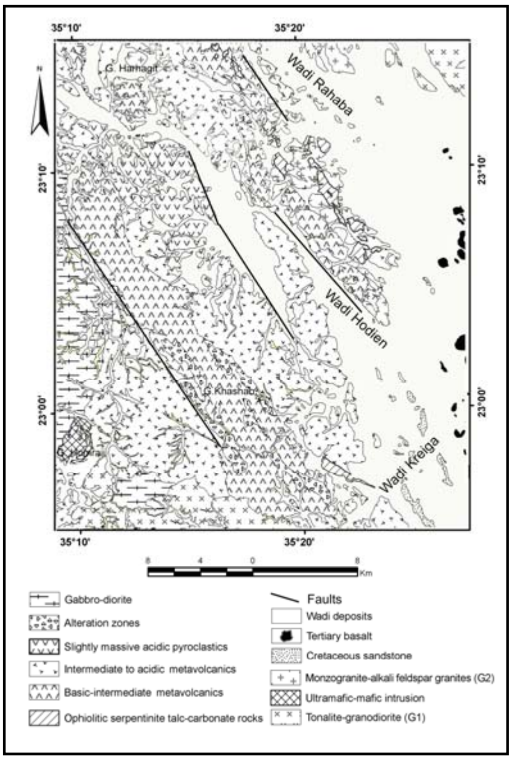

Figure 2: Geological map of Wadi Hodein area.

4. STRUCTURAL SETTING

The investigation of the structural setting of the Wadi Hodein area revealed four deformational events (D1-D4) (Abdeen et al., 2008).

The D1 deformational event is the first to affect the study area. It is responsible for the penetrative S1 schistosity with L1 stretching lineation in the metamorphic rocks (including serpentinites and metavolcanics). NE-SW oriented mesoscopic folds with SE vergence are dominated in these rocks. A major thrust at the base of the ophiolitic melange rocks overlying the island arc metavolcanics is also D1 in origin. The S1 foliation appears to be always parallel to the bedding S0.

D2 is represented by the foliation S2 and NNW-SSE trending doubly plunging macroscopic and mesoscopic folds (F2). The foliation S2 is intense crenulation cleavage in the volcano-sedimentary rocks and it often forms an axial plane cleavage to F2 folds. Interference of D1 and D2 strains also forms pencil structures. North of Wadi Hodein , the antiform extends for ~ 20 km in the NNW-SSE direction and it is asymmetric with its northeastern limb dipping at angles of 25° to 30° and its southwestern limb dipping at angles of 40° to 50°. The folded sequence is intruded by late tectonic alkali feldspar granites (G2).

The D3 deformational event is represented by two major strike-slip shear zones, named the Hodein and Khashab shear zones (Fig. 1). The Khashab shear zone is a major sinistral wrench fault subparallel to Wadi Khashab in the southwestern part of the mapped area. This shear zone strikes NNW-SSE and is steeply inclined (70°-80°) towards the ENE. It was earlier interpreted as a thrust zone (El Amawy et al., 2000b). The Hodein shear zone is an inferred strike-slip fault, which appears as a straight lineament on Landsat images of the study area.

The D4 is the youngest deformational event and it is less pronounced than the other deformational events. It is represented by NW-SE faults and E-W oriented vertical faults near the centre of the mapped area showing apparent dextral offset of the lithological units on both sides. These faults do not show a clear cross-cutting relation to any of the D1-D3 structures in the study area.

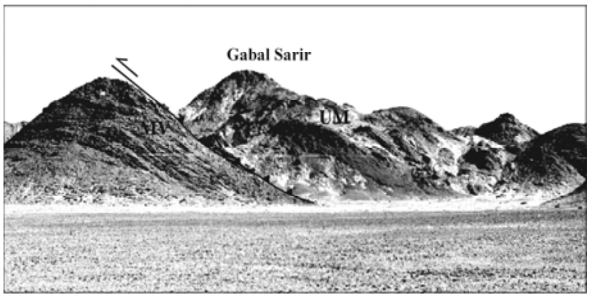

Figure 3: Gabal Sarir ophiolitic serpentinites (UM) thrusting over the calc-alkaline metavolcanics (MV).

5. RESULTS AND DISCUSSIONS

The false colour composite (FCC) ratio image 5/7, 5/1 and 5/4*3/4 (RGB) was successfully used by Sultan et al., (1986 and 1987) to maximize the discrimination of serpentinites and other basement rocks in the Eastern Desert of Egypt. As shown in table (1), 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. 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 alumino-silicates bearing minerals and thereby its high pixel value in the late tectonic ultramafic-mafic rocks (3.29) distinguishes these rocks from the metamorphosed ultramafic rocks (ophiolitic serpentinites) (2.84).

As shown in figure (4) the FCC ratio image (5/7, 5/1, 5/4*3/4) distinguishes the altered metavolcanics which show orange colour, the hosted alteration zones show light yellow tone while the unaltered metapyroclastics of Wadi Hodein display pinkish rose tone. The ophiolitic serpentinite-talc carbonate rocks exhibit light blue colour, they are discriminated from the younger ultramafic-mafic rocks which are characterized by their light magenta tone. Monzogranites appear as light green colour. These rocks can be distinguished by their variable trends of spectral signature profiles (Figures 5 and 6). Accordingly, the FCC ratio image (5/7, 5/1, 5/4*3/4) successfully discriminate the different basement rocks and the gold-bearing alteration zones encountered in the study area.

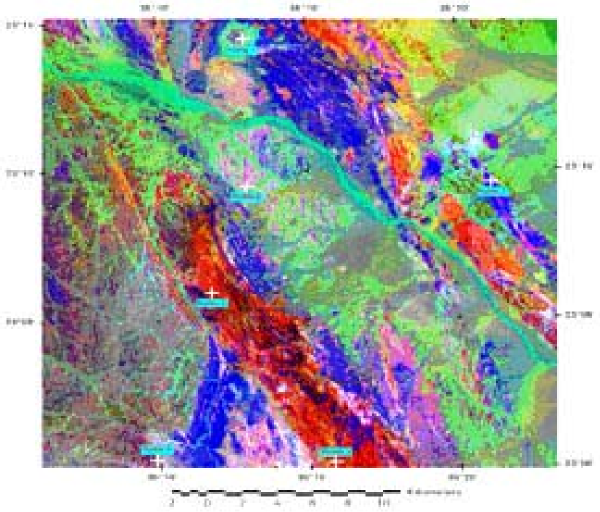

Figure 4: False colour composite (FCC) ratio image (5/7, 5/1, 5/4*3/4) covering the study area and showing the locations of spectral signature curves of the examined basement rocks.

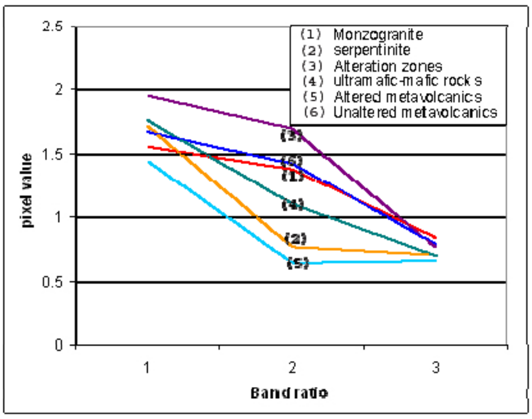

Figure 5: Discriminated spectral signature curves of the examined basement rocks (FCC ratio image data).

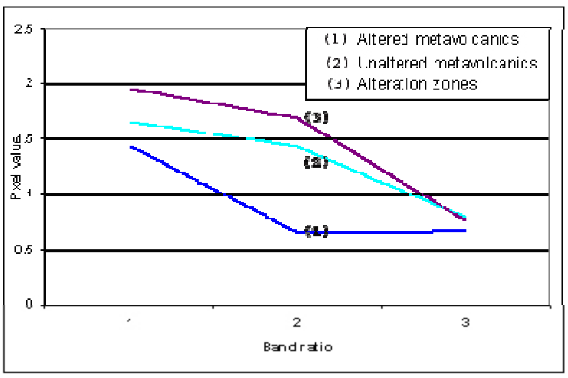

Figure 6: Spectral signature curves of alteration zones, altered and unaltered metavolcanics (FCC ratio image data).

6. CONCLUSIONS

The wadi Hodein area is occupied by Precambrian basement rocks (metamorphic and intrusive) nonconformably overlain by Cretaceous sandstones. Both Precambrian and Cretaceous rocks are extruded by Tertiary basalt. Basement rocks comprise dismembered ophiolitic sequence of serpentinites, calc-alkaline metavolcanics, syn tectonic tonalite-granitoids (G1), ultramafic-mafic intrusion and late tectonic monzogranites-alkali feldspar granites (G2). The structural study revealed four structural events affecting the basement rocks covering the study area.

For accurate discrimination of the basement rocks and the mineralized alteration zones in this area, the characteristic spectral signatures of different bands and band ratios were delineated using the data of processed raw and band ratio Landsat TM data.

In the false colour composite ratio image (FCC) (5/7, 5/1,3/4*5/4) (Fig. 4), the ophiolitic serpentinites-talc carbonate rocks of Gabal Sarir exhibit light blue colour, differing from the intrusive ultramafic-mafic rocks of Gabal Homrai intrusion which display light magenta tone. The unaltered metavolcanics of Wadi Hodein display dark orange tone while the altered metavolcanics and the enclosed alteration zones within the metavolcanics of Wadi Beida can be discriminated by their pinkish rose and light yellow tone respectively. Late tectonic monzogranites show light green tone.

The spectral signature curves show different trends using the data of the FCC ratio image (5/7, 5/1, 3/4*5/4). So, these rocks can be more accurately discriminated. This study can be applied in other areas covered by similar basement rocks particularly those which enclose mineralized alteration zones.

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