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GEOLOGY AND STRUCTURAL SYNTHESIS OF PAN-AFRICAN ROCKS, GABAL EL SIBAI AREA, CENTRAL EASTERN DESERT, EGYPT

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ABSTRACT

. The NW-trending elongation of the all topographic ridges in Gabal El Sibai area draw present author's attention, as well as the differential elongation directions of the oval-shaped granitoid masses exposed in the study area trending to NNW-SSE, NW-SE and WNW-ESE directions in the eastern (as Delihimmi and Humrat Ghannam masses), central (Um Shaddad and El Sibai-Abu El Tiyur masses) and southern (Um Luseifa mass) parts of the mapped area, respectively. Field study revealed that, the area is covered by an ophiolitic melange comprising allochthonous dismembered blocks and fragments of serpentinites and related rocks, metagabbros and metavolcanics, as well as arc-metavolcanics and related volcanogenic metasediments enclosed in a melange matrix composed of metagreywackes and actinolite-biotite and graphite schists. Hammamat series, represent the extension of the known Wadi Kareim basin, unconformably overlie the ophiolitic melange along the most northwestern part of the area. The intrusive rocks are represented by syn-tectonic Um Luseifa granodiorite pluton, younger gabbros and late-tectonic granites represented by Delihimmi, Um Shaddad, El Sibai-Abu El Tiyur and Humrat Ghannam plutons.

The analysis of structural events affecting G. El Sibai area revealed the presence of at least three phases of deformations. The tectonic evolution of the area started with an early phase of collisional tectonics causing low angle thrusting and ductile type deformations comprising D1 and D2 deformations of structural elements trending NE-SW and E-W or ENE-WSW and WNW-ESE directions, respectively. The last deformation phase (D3) is dominated by a complex of subparallel and en echelon major NW-SE trending sinistral strike-slip faults. They are associated with all features and characteristics of braided fault zones similar to the NW-SE trending Najd Shear System (NSS) of the Arabian Shield. The probable extension of these NSS into the central Eastern Desert was first illustrated locally (in Hamrawin area) by Abu Zeid (1984), later confirmed in G. El Shalul area (Assran, 2000 and Abdel Monem et al., 2000) and Kadabora area (Ahmed, 2002), and its regional extension was first suggested by Stern (1985) and Sultan et al. (1988).

INTRODUCTION

The late Precambrian basement complex of Egypt forms the northwestern part of volcano-sedimentary sequence associated with scattered ophiolitic rock assemblages that evolved in back-arc/island-arc oceanic settings (Gass, 1977; Engel *et al.*, 1980; Bentor, 1985; Kroner, 1985; Kroner *et al.*, 1987; Vail, 1987 and Ragab *et al.*, 1993). These sequences were episodically deformed and intruded by syn-, late- and

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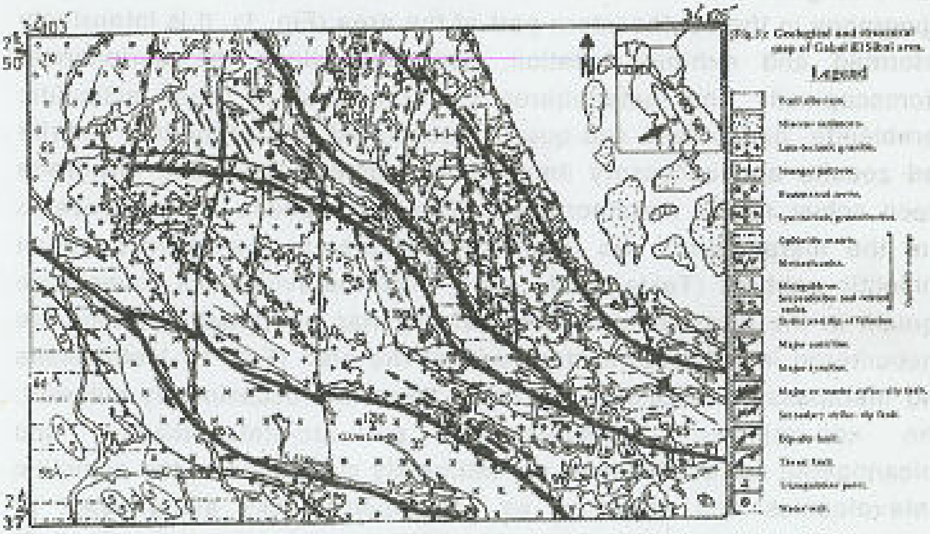
post-tectonic granitoid plutons during the Pan-African orogeny. The plutonic suites are similar to those found in the active continental margins, while most of the younger plutonic suites have A-type characteristics (Hussein *et al.*, 1982; Ries *et al.*, 1983; Stern & Hedge, 1985; El Gaby *et al.*, 1988, 1990 and Hassan & Hashad, 1990) and emplaced between 530 and 622 Ma (Hashad, 1980; Rogers & Greenberg, 1981; Hashad *et al.*, 1999 and Abdel Naby & Frisch, 2002).

The Egyptian Shield tectonic fabric was produced by several episodes of sedimentation, volcanism and intrusive activity accompanied by deformations that have predominantly N-S or NE-SW trends (Moore, 1979). This was culminated, during the late Proterozoic-early Phanerozoic, by large dislocations of these complexes by NW-trending major transcurrent sinistral strike-slip faults, first recognized in the Arabian Shield as the Najd Shear System (NSS) (Brown & Jackson, 1960) and confirmed in the central Eastern Desert of Egypt (Abu Zeid, 1984, Stern, 1985; Sultan *et al.*, 1988, Assran, 2000, Abdel Monem *et al.*, 2000 and Ahmed, 2002). The Najd Shear System (NSS) modified the earlier structures into northwesterly fabrics at about 530-630 Ma (Stacey & Agar, 1985) and may be contemporaneous with the emplacement of the younger granitoid plutons. Such shear zones are usually associated with mineralized (fluorite, barite, gold, uranium and REEs) hydrothermal activity as demonstrated by Pakiser, 1960; Hadley, 1974 and Moore, 1979. Such mineralized shear zones are proved in the northern (Shalaby, 1996), central (Abu Dief, 1992 and Ibrahim *et al.*, 2004) and southern (Ibrahim *et al.*, 2002, 2003) Eastern Desert of Egypt.

To test such hypotheses, Gabal El Sibai area, central Eastern Desert of Egypt, located between latitudes 25° 37′ and 25° 50′ N and longitudes 34° 03′ and 34° 26′ E, covering about 990 Km^2 was subjected to detailed field structural mapping (1:40.000) and petrographic investigations. It is intended to demonstrate that the area is covered by an ophiolitic melange comprising blocks and fragments of serpentinites, metagabbros and metavolcanics enclosed in a matrix composed of metagreywackes, and actinolite-biotite and graphite schists. This complex was intruded by syn-,and late-tectonic granitoids and was affected by several episodes of ductile deformations. Later, this fabric was obliterated by the effect of a NW-SE Najd shear system (NSS), which is regarded as the product of continental or plate collision.

GEOLOGIC SETTING

Gabal El Sibai area has attracted the attention of many workers, because it exhibits most of the structural and lithological aspects of the Precambrian rocks covering the central Eastern Desert of Egypt (e.g. Amin & Mohamed, 1954; Sabet, 1961; Noweir *et al.*, 1983; Kamal El Din *et al.*, 1992; Khudeir *et al.*, 1992 and 1995; Greiling *et al.*, 1993 and 1994; El Gaby *et al.*, 1994; Hamimi, 1996; Ali, 2001; Abdel Wahed *et al.*, 2002 and Ibrahim *et al.*, 2004). According to the field and structural relationships, the exposed rocks in G. El Sibai area can be classified into the following litho-tectonic unites: ophiolitic melange, Hammamat series, intrusive rocks (younger gabbros and syn-, to late-tectonic granitoids) and pegmatites, dykes and veins. These basement rocks are unconformable overlain by or faulted against Miocene sediments along the eastern side of the area (Fig. 1).



The map compiled and modified after Hamimi, 1996 and Ali, 2001

1- Ophiolitic mélange: It represents the oldest rock unite in the area and crops out in the northern, eastern and western parts of the mapped area (Fig. 1). It is composed of irregularly distributed allochthonous dismembered blocks and fragments of different sizes, ranging from pebble size to mountain size, comprising serpentinites and related rocks, metagabbros and metavolcanics, as well as non-ophiolitic blocks (arc-metavolcanics and volcanogenic metasediments) are enclosed within foliated and schistose metasediments as matrix. The matrix rocks (metagreywackes and actinolite-biotite and graphitic schists) are strongly deformed compared to the melange fragments and blocks, being well foliated, lineated and tightly folded. They are fine to very fine-grained, light greenish grey to very dark grey in colour and may attain black colour as in the graphitic schist. The ophiolitic melange rocks show tectonic contacts with each other and are intruded by younger gabbros and syn- to late-tectonic granitoids.

The serpentinites are represented by massive or sheared types and in part altered to talc-carbonate rocks. They are mostly exposed in the southwestern and eastern parts of the area as NW-trending elongated masses enclosed within ophiolitic matrix. These rocks are composed mainly of antigorite, lizardite, talc, carbonates and chromite. This might suggest that the serpentines originated from peridotites parent rocks. The metagabbros occur as a mountain-sized block of moderately topography in the southeastern part of the area (Fig. 1). It is intensively deformed and exhibits foliation, especially along the peripheries. Microscopically, the metagabbros are composed of green actinolitic hornblende, plagioclase and quartz, associated with secondary chlorite and zoesite and accessory ilmenite and sphene indicating low-grade green schist facies metamorphism. The high sphene content reveals that the metagabbros are titaniferous similar to the other Egyptian ophiolitic gabbros (Takla *et al.*, 1981). The metavolcanics cover large domain in the northwestern corner of the map and small outcrops are encountered in the southeastern part of the area (Fig. 1). Metabasalts and metabasaltic andesites represent them and occasionally pillowed. The non-ophiolitic metavolcanics, as arc-metavolcanics and volcanogenic metasediments, are intimately connected to the ophiolitic metavolcanics and crop out as unmapped blocks along Wadi El Dabbah. The banded iron formation (BIF) is observed along Wadi El Dabbah volcanogenic metasediments (Akaad and Dardir, 1983) and showing alternating iron bands of dark brown colour and lithic bands of light colour (Fig. 2a).

2- Hammamat series: They crop out in the most northwestern part of the area (Fig. 1) unconformably overlie the ophiolitic melange rocks and represent the extension of the known Wadi Kareim basin (Akaad & Noweir, 1980). The Hammamat succession are comprising thick beds of polymictic boulder-size conglomerates intercalated with minor bands and/or thin beds of greywackes, siltstones and mudstones. The rock fragments in the conglomerates are represented by basic to intermediate metavolcanics, volcanic tuffs, quartz diorite, gneissose

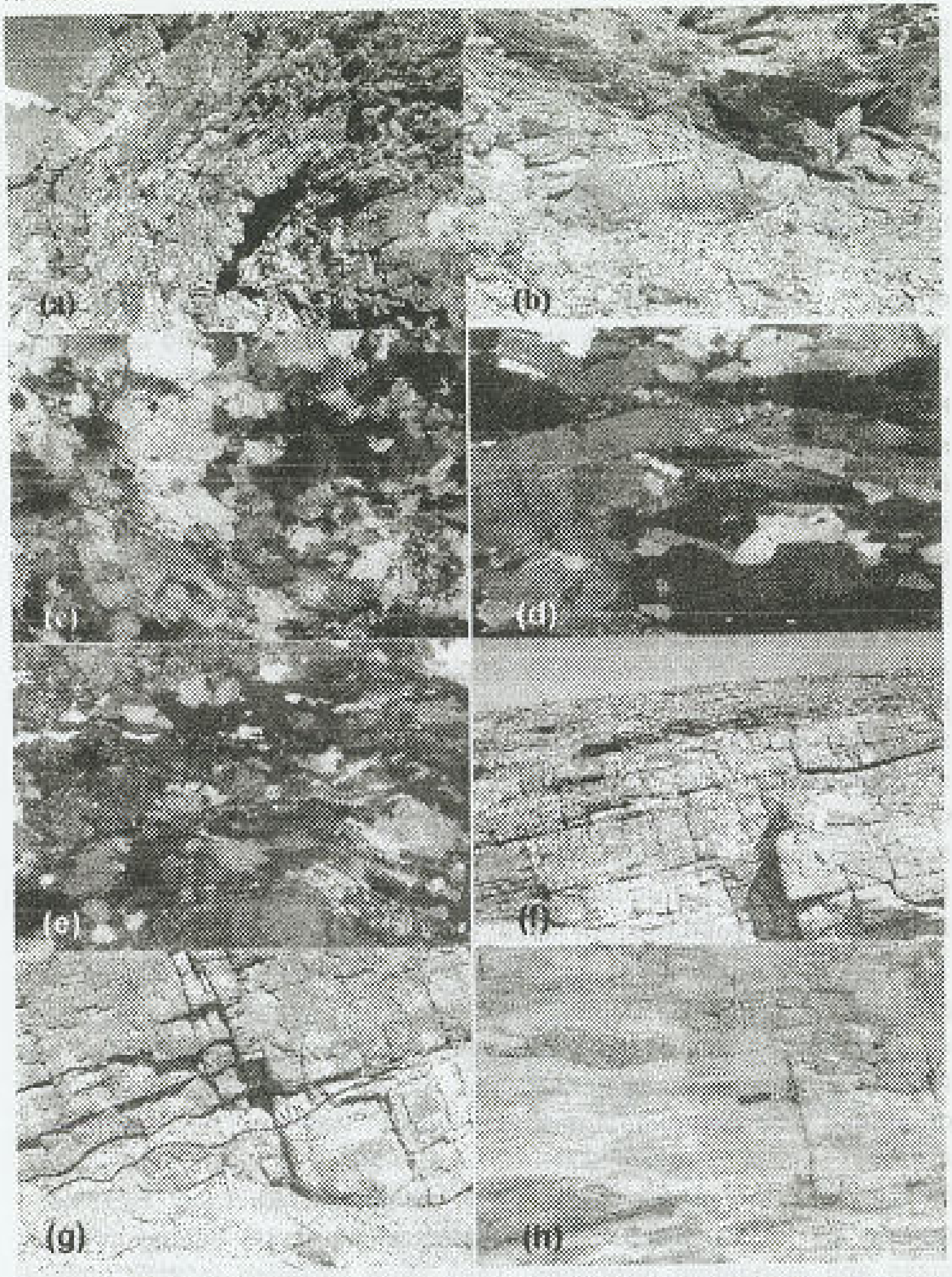


Fig. 2. **(a):** Foliated and folded volcanogenic metasediments enclosing banded iron formation (BIF) of dark brown colour, along western bank of W. El Dabbah. Looking W. **(b):** Fragment of metavolcanic boulder in foliated Hammamat series, elongated in NW-SE trend. Looking SW. **(c):** Photomicrograph of El Sibai cataclased granite showing quartz crystals with completely crushed edges due to intensive cataclastic effect. C.N.x10. **(d):** Photomicrograph of Um Shaddad gneissose granite showing mineral lineations of hornblende and biotite flakes as well as quartz and feldspar minerals. C.N.X10. **(e):** Photomicrograph of El Sibai cataclased granite showing alternating bands with slightly bending of stretched and cataclased quartz crystals and altered feldspars. C.N.X10. **(f):** Shearing criteria as banding along the most northwestern margin of El Sibai pluton. Looking SE. **(g):** Boudinaged quartz vein (still linked by necking) with axis plunging to SE, observed in highly sheared Um Shaddad granite. Looking SE. **(h):** Lenticular boudins of metavolcanics (absence of any linkage) observed in ophiolitic melange matrix. Looking SE.

granite, chert and rarely of quartzites (Akaad & Noweir, 1980 and Hamimi, 1996). These boulders have sizes range from 5-40cm length and commonly elongated (NW-trend), flattened and deformed, enclosed within foliated (NW-SE direction) and folded matrix (Fig. 2b).

3- Intrusive rocks: They are represented by younger gabbros and syn-, to late-tectonic granitoids. The younger gabbros crop out in the most northern part of the area as elongated mass trending NNW-SSE direction and intruded by Humrat Ghannam granite (Fig. 1). Microscopically, these rocks are oxyhornblende gabbros and composed of cumulus calcic plagioclase (An_{70}) and intercumulus brown hornblende, pyroxene and olivine, associated with accessory opaques, sulphides and apatite. The other intrusive granitoid rocks of sharp intrusive contacts with older country rocks are represented by five masses: G. Um Luseifa gneissose granodiorite, G. Um Shaddad gneissose granite, G. Delihimmi cataclased granite, G. El Sibai-Abu El Tiyur cataclased granite and G. Humrat Ghannam cataclased granite. They are showing elongation in different directions ranging from NNW-SSE trend along the eastern side of the map area (G. Delihimmi and G. Humrat Ghannam), NW-SE trend along the central part (G. Um Shaddad and G. El Sibai-Abu El Tiyur) and WNW-ESE trend along the southern corner of the area (G. Um Luseifa). These different elongation directions are structurally controlled by the major sinistral strike-slip faults dissecting the study area and enclosing these plutons in their fault shear zones trending NNW, NW and WNW directions from northeastern to southwestern sides, respectively (Fig. 1).

The syn-tectonic granitoid rocks is represented by G. Um Luseifa gneissose granodiorite of large size. It is grey to pinkish grey in colour, medium to coarse-grained, composed mainly of plagioclases, potash feldspars, quartz, hornblende and biotite, and showing distinct gneissose and sometimes-foliated textures. The late-tectonic granites are represented by four masses (G. Um Shaddad gneissose granite, G. Delihimmi cataclased granite, G. El Sibai-Abu El Tiyur cataclased granite and G. Humrat Ghannam cataclased granite) having different sizes and elongation directions. They show variation in their mineral compositions, where Um Shaddad gneissose granite and Delihimmi cataclased granite are richer in mafic minerals as biotite and hornblende than El Sibai-Abu El Tiyur cataclased granite and Humrat Ghannam cataclased granite, which are rich in potash feldspars. Also, plagioclases, quartz and accessory minerals (opaques, apatite and sphene) are encountered. Microscopically, all thin sections of these granitoid rock types show cataclastic effects on all their mineral components, as well as the original igneous texture is completely obliterated due to shearing (Fig. 2c). Shearing criteria, such as mineral lineations and local lithological banding are observed in all granitoid rocks, especially along their margins with trends usually parallel and/or subparallel to the major strike-slip faults (Figs. 2d, e and f).

The pegmatites, dykes and quartz veins are deleted from the mapped area, except some dyke swarms, for the sake of clarity, but they are encountered in the area. The pegmatites crop out as elongated bodies in N-S, NNE-SSW and NW-SE trends, with sizes ranging from 4-10m length and 2-6m width, and composed mainly of feldspars and quartz with small pockets of biotite. The pegmatitic bodies of El Sibai-Abu El Tiyur granitic pluton show higher radioactivity levels than others of granitic plutons, especially that encountered along the northern periphery of the pluton. The radioactivity in these pegmatitic bodies is responsible by thorianite, uranothorite and zircon in biotite mineral (Ali, 2001). The dykes of bostonite and mafic types are only encountered cutting in the older country rocks and trending, with decreasing order of abundance, NW-SE, N-S and NE-SW directions. The width of the dykes ranges from few centimeters to few meters and in length reach up to 0.5km.

TECTONIC FABRIC

The structural deformation is preserved in Gabal El Sibai area in the two stages of strain as folds and faults. These structures are developed in planar and linear structural elements and accompanied with three phases of deformations (D_1, D_2 and D_3) as presented in the following paragraphs.

1- Linear structures

1.1- Mineral lineations: A well developed mineral lineations, formed by preferably oriented feldspars, quartz and mafics, are clearly recognized in the ophiolitic metagabbros, Um Luseifa gneissose granodiorite and Um Shaddad gneissose granite, as well as in some outcrops along the peripheries of Delihimmi and El Sibai-Abu El Tiyur cataclased granites (Figs. 2d and e). The N30°-65°W trend is the dominant direction of mineral lineations and plunge mostly from 10° to 25° toward the SE direction. The trends NE-SW and E-W of early deformation phases are rarely observed, especially in ophiolitic metagabbros cropping out along the southern bank of Wadi Um Gheig, with plunge angles ranging between 15° and 35° to E and/or W.

1.2- Boudinage structures: All the boudins encountered in the area have axes trending N25°-55°W and plunging 8°-25° to SE and rarely to NW directions. Also, the Boudinage structures of small sizes, with axes trending NE-SW and plunging steeply to NE and/or SW, are observed in the ophiolitic matrix along the limbs of minor folds. Both pinch and swell structures and lenticular boudins are commonly observed in the ophiolitic melange matrix, as well as in some outcrops of highly sheared granitoid rocks as Um Luseifa gneissose granodiorite and Um Shaddad gneissose granite (Figs, 2g and h).

1.3- Pencil structures: They are developed by the intersection of the planar structures such as bedding and cleavage with irregularly polygonal cross sectional shape. These pencil structures are best developed in the fine-grained metagreywackes of ophiolitic melange matrix and siltstones of the Hammamat series, trending N30°-50°W subparallel to the major and minor fold axes in the area. Their plunge angels vary from 10° to 20° SE and/or NW directions.

1.4- Stretched rock fragments: The deformed rock fragments (boulders and cobbles) of different compositions and sizes are considered as a good strain markers (Lisle, 1985). These elongated or stretched fragments are abundant in the ophiolitic matrix and Hammamat series, and represent one of the most spectacular types where the long axes are almost parallel to the axis of last folding (F_3) phase in the area. The fragments in the area are elongated in NW-SE direction with long axes ranging between 5-40cm (Fig. 2b). This orientation may indicate that the principal stress (σ_1) is subhorizontal and normal to the fragment elongation that may be related to the direction of the shortening NE-SW direction associated with the Najd shear or fault system (Fig. 1).

2- Planar structures

2.1- Foliations: They are formed often by the combined effects of metamorphism and deformation phases. The detailed study of the overprinting relations between these foliations revealed three penetrative foliation surfaces (S_1, S_2 and S_3) which have been recorded in G. El Sibai area. The original bedding foliation (S_0) is overprinted by (S_1) foliation which is regarded as the oldest foliation direction and developed as a foliated axial planar to minor (F_1) folds in ophiolitic matrix. The S_1 foliations show variable attitude due to the effect of the succeeding phases of deformation. Generally, S_2 and S_3 foliations are dominant compared to the S_1 foliation, while the NW-SE foliation (S_3) is more dominant and easy to find in outcrops.

A sum of the 21, 40 and 123 foliation planes representing S_1, S_2 and S_3, respectively were measured in the ophiolitic melange metasediments and Hammamat series and plotted as poles to foliation strikes on equal area stereonet lower hemisphere projection (Figs, 3a, b and c). The S_1 foliations revealed tight or isoclinal fold with fold axis plunging 22° to the N46°E direction and the axial plane strikes N32°E and dips 50° to S58°E (Fig. 3a). The S_2 foliations show close or tight fold with fold axis plunging 26° to S83°E direction and the axial plane strikes N79°E and dips 60° to S11°E (Fig. 3b). The S_3 foliations show open fold with fold axis plunging 14° to the S50°E direction and the axial plane strikes N48°W and dips 80° to N42°E (Fig. 3c).

2.2- Folds: Generally, the minor folds of variable shapes and sizes are extremely developed along the main foliation and within the limbs and hinges of major folds and are being denoted to F_1 and F_2 folding phases. Three generations of folding are recognized in the highly deformed ophiolitic matrix and to some extent in the Hammamat series of G. El Sibai area as follows:

The first folding phase (F_1): The F_1 folds are isoclinal, tight, recumbent and overturned types of minor size. The axial planes of these folds strike NE-SW dipping to SE and/or NW. The fold axes of these folds plunge at low to moderate angles to NE and rarely to SW. These folds are commonly refolded by or included within the limbs of the second phase folds (Fig. 3d) and rootless due to the tectonic attenuation of limbs by effects of the later deformation phases (Abdel Khalek *et al.*, 1992).

The second folding phase (F2): Their folds are characterized by the closed to open, recumbent, inclined, symmetric and asymmetric types. The axial planes of these folds are striking variably to ENE-WSW, WNW-ESE and E-W directions and dipping to SSE, SSW and S directions, respectively. Their axes mostly trend E-W and plunge at moderate to steep angles to E and rarely to W. Also, fold axes with trends ENE-WSW and WNW-ESE and plunging to ENE and ESE are recorded.

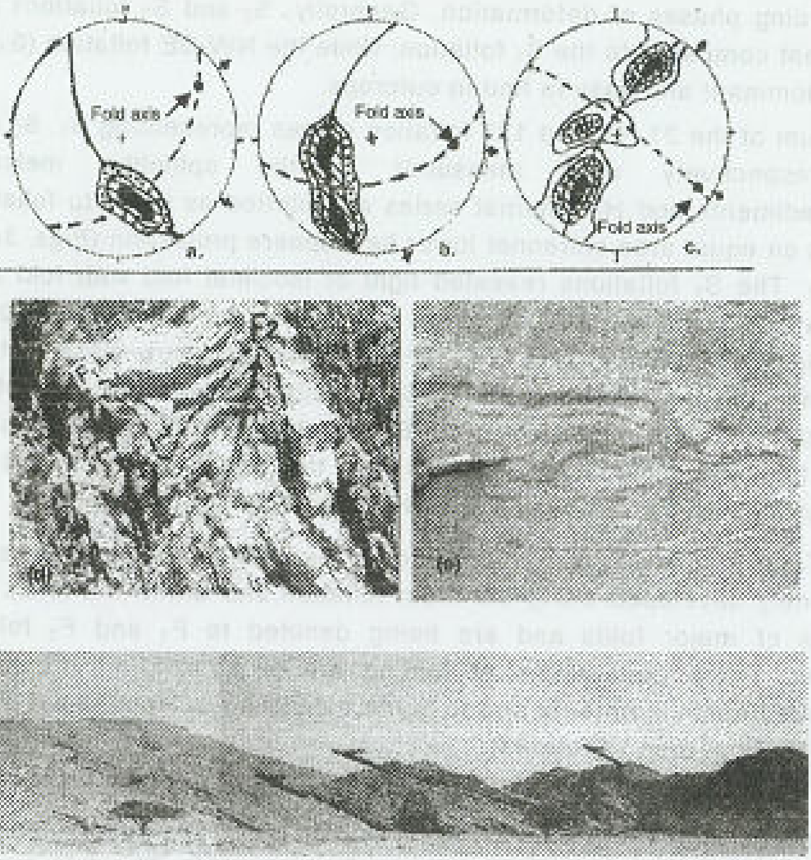


Figure 3. (a–c): Equal area lower hemisphere projections of foliations (S_1, S_2 and S_3) measured in foliated rocks. (d): Micro refolded closed or tight fold in ophiolitic matrix, north Um Shaddad granite, (F_1) fold axis trends NE-SW and (F_2) fold axis trends E-W. Looking E. (e): Micro fold related to thrust faults of last deformation phase (F_3) with fold axis trends NW-SE, northeast Abu El Tiyur granite. Looking NW. (f): Field view showing the foliated ophiolitic metasediments (right) overlying El Sibai-Abu El Tiyur pluton (left) along low angle thrust fault marked by black arrow, note decreasing of foliation dip near the contact. Looking NE.

The third folding phase (F3): The F_3 folds are represented by open folds, as deduced from the plotting of foliations (S_3) measured all over the study area on equal area net stereographic projection (Fig. 3c), with axial plane striking N48°W and dipping 80° to N42°E. The fold axis of the regional fold plunge 14° to the S50°E direction (Fig. 3c).

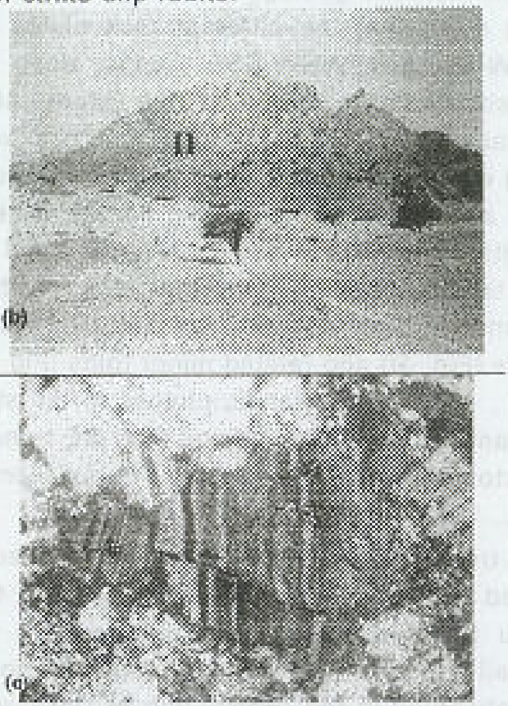
2.3- Faults

Gabal El Sibai area is traversed by different sets of faults which are represented by strike-slip fault sets striking NW-SE and N-S, thrust fault sets striking NE-SW and NW-SE and dip-slip fault sets striking NW-SE and NNW-SSE. All, these faults are traced on the aerial photographs (1: 40.000) and many of them are checked in the field.

Strike-slip faults: The present detailed geological and structural map of G. El Sibai area (Fig. 1) show that the different rock unites are elongated in NNW-SSE, NW-SE and WNW-ESE trends along the northeastern, central and southwestern parts of the study area, respectively. Tracing of aerial photographs (1:40.000) and field work confirmed that the differential elongation directions of these rock bodies are structurally controlled by a complex of subparallel and en echelon major sinistral strike-slip faults. These faults have a NW-SE trend but abruptly change strike near large bodies of competent rocks such as granitic plutons (e.g. Delihimmi, El Sibai-Abu El Tiyur and Um Luseifa plutons), then the thrust faults (Fig. 3f) and related minor folds (Fig. 3e) well developed (Sultan *et al.*, 1988). The granitic plutons in the study area are structurally concordant with the surroundings (NW-SE trending outcrops), indicating a pretectonic or syntectonic mode of emplacement (Stern, 1985 and Sultan *et al.*, 1988).

The major strike-slip NW-trending fault zones are characterized by highly sheared or mylonitized rocks as that observed along the fault zone bounding El Sibai-Abu El Tiyur pluton from the northern side (Figs. 1 and 4a). Also, small-scattered mylonite outcrops having the same trend of the fault are observed in the central part of Um Luseifa pluton along Wadi El Shush (Figs. 1 and 4b). The sense of motion along these major faults is sinistral as indicated by the directions of displacements of the geologic contacts, dykes and older faults, as well as the microscopic study of oriented samples shows a sinistral motion (Fig. 4c).

The end sections of many of the NW-SE trending fault traces are curved and intersect or join to form braided fault zones of compressional (C) or dilational (D) types in juxtaposition as shown in figures 5b and 5c. El Sibai-Abu El Tiyur pluton occurs in a dilational area within the braided fault zone. It is characterized by dense arrays of secondary N-S trending sinistral and NW trending dextral strike-slip faults (Fig. 1 and 5a), similar to R1 (synthetic) and R2 (antithetic) Riedel shears, respectively (Riedel, 1929 and Ramsay & Huber, 1987). The synthetic set (R1) making acute angles with the major faults is usually much better developed and widespread than the antithetic set (R2) making obtuse angles with the major faults directions. The other compressional braided fault zones are characterized by thrust faults striking NW-SE with low dip angle to SW or NE (Fig. 3f) and folds of minor types (Fig. 3e) with fold axes trending NW-SE subparallel to the major strike-slip faults.



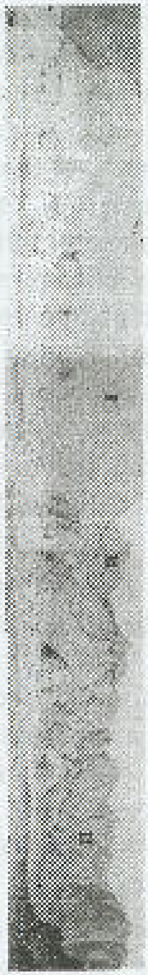


Figure 4. (a): Field panorama view showing sheared and mylonitized El Sibai granite (I) in the shearing zone of the major NW-trending sinistral strike-slip fault, along the contact between the northern periphery of El Sibai pluton (II) and ophiolitic metavolcanics (III). Along the eastern bank of W. El Dabbah. Looking E. (b): Field view along W. El Shush showing low outcrops of mylonitic rocks (I) elongated subparallel to the major WNW-ESE sinistral strike-slip fault affecting in the central part of Um Luseifa granodiorite (II). Looking NNW. (c): Photomicrograph of El Sibai cataclased granite showing sinistral motion along fractures cut in plagioclase crystals. C.N.X10.

Dip-slip faults.- Generally, these faults affecting the study area have NW-SE trend and dipping to NE and/or SW directions. The most prominent dip-slip faults are the two major faults striking NW-SE and dipping NE or SW, affecting the northeastern part of El Sibai-Abu El Tiyur pluton, forming graben shape with elevation nearly 1101m. Above sea level (Fig. 1). On the other hand, along the southwestern part of the same pluton two major dip-slip faults also striking NW-SE and dipping SW or NE form horst shape with highest elevation point 1484m. above sea level in the study area. Such dip-slip faults forming grabens and horsts may be related to the major strike-slip faults affecting the study area (Moore and Al Shanti, 1979). Also, dip-slip faults striking NNW-SSE and dipping to ENE direction, that downthrew the Miocene sediments against the basement rocks are encountered along the eastern part of the area (Fig. 1).

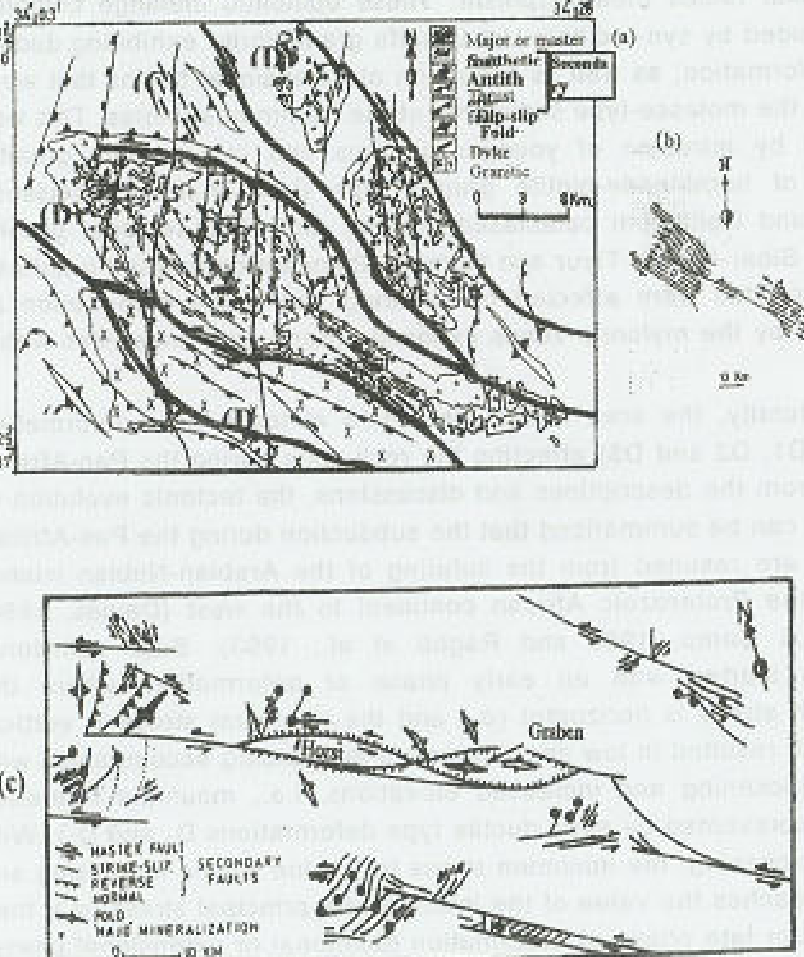


Figure 5. (a): Structural map showing traces of the secondary structures associated with the major sinistral strike-slip NW-SE trending fault system affecting in G. El Sibai area. (b): View showing local stress regime, areas characterized by compressive phenomena (C) and dilational or extensional phenomena (D), (Moore & Al Shanti, 1979). (c): Diagram showing the types and orientation of secondary structures associated with the Najd Sheart System (NSS). The tectonic setting of extensional fissure veins associated with secondary faulting is shown (Moore & Al Shanti, 1979).

DISCUSSION AND CONCLUSIONS

G. El Sibai area is covered by an ophiolitic melange comprising allochthonous dismembered blocks and fragments of serpentinites and related rocks, metagabbros and metabasalts, which are occasionally pillowed, as well as arc-metavolcanics and volcanogenic metasediments (including BIF) enclosed within a melange matrix composed of metagreywackes and actinolite-biotite and graphite schists. The mineral assemblages observed in these rock types indicate greenschist facies metamorphism. These ophiolitic melange complex was intruded by syn-tectonic Um Luseifa granodiorite exhibiting ductile style deformation, as well as formation of extensional basins that were filled by the molasse-type sediments of the Hammamat series. This was followed by intrusion of younger gabbros and late-tectonic granitic plutons of hornblende-biotite granite type (Um Shaddad gneissose granite and Delihimmi cataclased granite) and alkali-feldspar granite type (El Sibai-Abu El Tiyur and Humrat Ghannam cataclased granites). These granites were affected by shearing and brittle deformation as indicated by the mylonite zones exposed around and sometimes within them.

Structurally, the area was subjected to at least three deformation events (D1, D2 and D3) affecting the rock units during the Pan-African times. From the descriptions and discussions, the tectonic evolution of the area can be summarized that the subduction during the Pan-African orogeny are resulted from the suturing of the Arabian-Nubian island-arcs to the Proterozoic African continent to the west (Davies, 1984; Stoeser & Camp, 1985 and Ragab et al., 1993). Such collisional tectonics started with an early phase of deformation, where the maximum stress is horizontal (σ_h) and the minimum stress is vertical (σ_z) which resulted in low angle thrusting and folding accompanied with crustal thickening and increased elevations, i.e., mountain formation phase (represented by early ductile type deformations D_1 and D_2). With crustal thickening, the minimum stress (σ_z) value will be increasing and when it reaches the value of the intermediate principal stress (σ_y), then a second or late phase of deformation (dilational or extensional phase) caused by the same collisional event proceeds by predominantly strike-slip faulting (represented by D_3 of brittle type deformations). Such two-phases patterns of intraplate deformation have been recognized in most ancient orogenic belts (Mattauer, 1973).

Therefore, the ductile type deformation comprising D_1 and D_2 deformations are all related to the early phase of deformation of the collisional event of the Pan-African orogeny. The structure style and orientation of thrusting and folding of these early deformation phases indicate a general E-W crustal shortening of the Arabian-Nubian Shield. Also, the tectonic transport in the central Eastern Desert of Egypt was suggested to be towards the NW-direction, i.e., the compressive forces were directed from the SE (Shackleton *et al.*, 1980; Ries *et al.*, 1983; Greiling, 1987; El Nady, 1994 and Assran, 2000). This is consistent with the measured orientations of the structural elements in the studied area pertaining to this deformation phases including foliations (S_1 and S_2), mineral lineations and fold axes (F_1 and F_2).

The major or long sinistral strike-slip or wrench faults trending approximately NW-SE, secondary synthetic (R1) and antithetic (R2) Riedel shears, thrust faults (NW-SE), open folds (F_3), foliation (S_3), mineral lineations (NW-SE) and probably the graben and horst formation described under D_3-deformation are related to the second or late phase of deformation of the same collisional event. An analysis of the configuration of the long distance major wrench or strike-slip faults and adjacent ones in the studied area suggests that these structures resulted from a collision between a rigid-plastic body (central Eastern Desert) and a rigid indenter from the SE-direction, as predicted from slip-line field theory (Molnar & Tapponnier, 1975 and Tapponnier & Molnar, 1976). All such features indicate that this fault system belongs to the Najd shear system (NSS), which originated as a consequence of continental collision from the eastern or southeastern direction (Moore, 1979 and Davies, 1984) and might represent the late phase of deformation in the area.

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جيولوجية و تركيبة صخور البان-أفريكان في منطقة جبل السباعي بوسط الصحراء الشرقية-مصر

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تعتبر أهمية هذا البحث في إيجاد تفسير للامتداد الطولي (stretching or elongation) للظواهر الطبوغرافية بمنطقة البحث حيث جميعها تأخذ اتجاه شمال غرب-جنوب شرق مع التغير الطفيف في الأتجاه أما شمال شمال غرب-جنوب جنوب شرق كما هو الحال في أقصى شمال شرق المنطقة وأما غرب شمال غرب-شرق جنوب شرق كما هو الحال في أقصى جنوب غرب المنطقة وذلك بالطبع له علاقة بتكوينية المنطقة. تغطى منطقة السباعي بصخور تجمعات الميلانج الأفيولت و التي تعتبر من أقدم صخور المنطقة و تحتوى على كتل و حصى صخرية ذات أحجام مختلفة تصل إلى حجم الجبال من صخور السربنتين و متغيراتها و الجابرو المتحول و الصخور البركانية المتحولة بعضها ممثل بالبازلت الوسائدى، وكذلك تجمعات الأقواس الجزيرية البركانية المتحولة وما يصاحبها من صخور فتاتية بركانية جميعها موجودة فى صخور الميتاجرايواكي و الهورنبلند-أكتينوليت و

الجرافيت شيست بالإضافة إلى صخور رواسب الحمامات. أقتحمت هذه الصخور القديمة بصخور الجرانوديورايت الممثلة بجبل أم لصيفه وصخور الجرانيت الحديثة مثل جبل السباعى-أبو الطيور و الديلهمى و حمرة غنام.

أثبتت الدراسة التركيبية التفصيلية بمنطقة البحث أن هناك ثلاث مراحل تهشم. فالمرحلة الأولى (D1) تميزت بطيات شديدة الضيق و تنساب محاورها في أتجاه شمال شرق-جنوب غرب وكان أتجاه القوة الضاغطة والمؤدية لهذه المرحلة من جنوب شرق إلى شمال غرب و تميزت المرحلة الثانية (D2) بطيات مفتوحة و مقلوبة و مضطجعة بمحاور في أتجاه شرق-غرب وما صاحبها من صدوع أدت إلى تكوين أحواض بين جبلية ترسبت فيها رواسب الحمامات وكان أتجاه القوة الضاغطة والمؤدية لهذه المرحلة من الجنوب إلى الشمال. أما المرحلة الثالثة و الأخيرة (D3) تميزت بصدوع شبه متوازية ولها أطوال تصل إلى عدة كيلومترات و لها حركة أفقية يسارية (sinistral) تتقابل مع بعضها البعض مكونة نطاقات تأخذ الشكل الضفيرة (braided zones) منها نطاقات الضغط (compressive zones) ولها تراكيبها المميزة و الأخرى نطاقات المد (extensional zone) ولها تراكيبها المميزة و في هذه المرحلة من التهشم حدثت الأستطالة لجميع صخور المنطقة بما فيها الكتل الجرانيتية المتزامن تداخلها مع هذه المرحلة من التهشم.