Structural evolution of Wadi Road El-Sayalla area, Eastern Desert, Egypt

Khaled Gamal ALI1, Hassan Ali ELIWA2, Masoud Salah MASOUD1, Mamoru MURATA1, Ahmed El Sayed ABDEL GAWAD1

1Nuclear Materials Authority, Cairo, Egypt 2 Minoufiya University, Cairo, Egypt 3 Naruto University of Education, National University Corporation, Naruto, Japan

Wadi Road El-Sayalla area is a part of the south Eastern Desert of Egypt. It comprises two plutons, Nikeiba basement rock complexes and Fileita Nubian sandstone. It is composed of metavolcanics, syenogranite, alkali feldspar granite and quartz syenite intruded by felsite and dolerite dikes and quartz veins at Nikeiba plutons which non-conformable overlain by Nubian sandstones at Fileita area.

Purpose of the work. The present work of this paper is to elucidate the interaction between inherited ductile fabrics and overprinting brittle structures. It is important to reconstruct the tectonic evolution of Wadi Road El-Sayalla area which help in constraining the mineralization trends in the study area.

Research methods. The folding related to ductile structures were analyzed using stereographic projection software packages GE Orient version 9.4.5. The fracture analyses related to brittle structures were carried out quantitatively using the paleostress analyses of the different sets to calculate the tensors related to the different compressional and extensional events using Tensor program.

Results. Structural evolution in the investigated area enabled the separation of five structural episodes: E1: syn-tectonic granite (tonalite-granodiorite); folding-thrusting episode associated with the cratonization of the arc-inter-arc rocks association. E2: Late-tectonic granite; upright folding episode associated with compression and shortening to the NE-SW direction. E3: Post-tectonic granite intrusion episode produced syenogranite and alkali feldspar granite of Nikeiba. E4 and E5: Early Cretaceous to Post Pleistocene episode is manifested by syncline folding along ENE-WSW detected in the Nubian sandstone of Fileita (E4). On the other hand, E5: Fracturing, faulting episode is characterized by multi-trends of fault populations (E-W strike slip (right); oldest), N-S strike slip (left), E-W dip slip, NE-SW strike slip (right) and NE-SW dip slip (youngest). Accessories as thorite, uranothorite, monazite, zircon, allanite, yttrocolombite and fluorite appear to be structurally controlled by the interaction between inherited ductile fabrics and overprinting brittle structures. The NE-SW, NW-SE, E-W, NNW- SSE and N-S normal faults are considered to be important deep seated structure trends which controlled many injections of felsite and dolerite dikes and alteration features that could have acted as good pathways for mineralization.

Keywords: Wadi Road El-Sayalla, Nikeiba, Fileita, Egypt, folding-thrusting, cratonization, folding episode, faulting episode.

Introduction

The studied area is a part of the basement complex in the Eastern Desert of Egypt; passed through several structural events since the early cratonization episode of the arc-inter-arc associations. So, the structural analyses of it enabled the separation of successive structural events including ductile and brittle deformations. Many researchers have extensively studied structure evolution of the basement complexes and associated rocks in the Eastern desert of Egypt [1–7]. The structural field measurements were carried out on scattered pattern making use of the wadis in the area. They include primary structure measurements as bedding, secondary structures like foliation, deformed pebbles, faults, joints, minor and meso-scale folds. All the measurements were analyzed using different proper techniques “GE Orient version 9.4.5 and Tensor program according to [8–10]” to characterize the different structure that affected the area through out its geologic history.

Geologic setting

The exposed rock types at Wadi Road El-Sayalla are located between Latitudes 23°44'18"–23°54'36" N and longitudes 34°10'48"–34°24'36" E, in the Eastern Desert of Egypt (Fig. 1). Field studies indicate the presence of metavolcanics, tonalite-granodiorite, syenogranite, alkali feldspar granite and quartz syenite non-comfortably overlain by Nubian sandstone. Metavolcanics form a thick sequence of stratified lava flows interbedded with their pyroclastics. They are represented by ash and lithic lapilli metatuffs of basaltic, andesitic and dacitic composition. These rocks are intruded by tonalite-granodiorite, syenogranite, alkali feldspar granite and quartz syenite as well as by felsite dikes and quartz veins. Tonalite-granodiorite forms low relief masses and is non-comfortably overlain by Nubian sandstones at Fileita area. Tonalite-granodiorite consists of plagioclase, K-feldspar, quartz, hornblende and biotite. Syenogranite is to moderate relief and is composed of K-feldspar, quartz, biotite, plagioclase and iron oxides. Alkali feldspar granite is the last phase at Nikeiba plutons. It is characterized by moderate relief and is composed of K-feldspar, plagioclase, quartz, and biotite. Quartz syenite forms high relief hills and is composed of K-feldspar, quartz, plagioclase, amphibole and biotite. Syenogranite and quartz syenite are highly albitized, hematitized and kaolinitized. Syenogranite, alkali feldspar granite and quartz syenite intrude the metavolcanics with well exposed intrusive contact. Felsite dikes cut the syenogranite, alkali feldspar granite and quartz syenite in the northeastern part of the mapped area. They are brecciated along the contact with metavolcanics and syenogranite. They are composed essentially of K-feldspar quartz and plagioclase together with subordinate biotite.
Nubian sandstones include two Formations: lower Timsah Formation and upper Um Baramil Formation (Fig. 2). Timsah Formation attains 7.5 m thick, and comprises different types of cross-bedding, pebbly ferruginous, gradded bedding and clayey sandstones. Gradded- and cross-bedding features are observed as primary sedimentary structure in some sandstone beds. Um Baramil Formation is the most extensive exposure of Nubian sandstone in the investigated Fileita area. It overlies Timsah Formation and in other parts overlies the tonalite-granodiorite with non-conformity surface. This formation attains 70 m in thickness and comprises yellowish to dark grey sandstone, kaolinitic sandstone and pebbly ferruginous sandstone. Timsah and Um Baramil formations are traversed by N-S strike slip sinstral faults (Fig. 1).

Structural analyses

The studied area is an object of an intensive detailed systematic analysis of the structural fabrics (bedding, foliation, fold axes, fault populations, joints and liniments) collected from different sites distributed all the outcropping rock types (Fig. 1). During the detailed field study, the chronological criteria (cross-cut relationships, overprinting relations, overprinting of marks, reactivation geometries as well as fold-fault relationships) have been carefully documented in order to define the succession of the deformational events. A fundamental concept in structural analysis is the proposition that the small-scale structures in the field can act as a guide to the large-scale regional features that are not visible to the field observer.

Ductile fabrics

Field observations indicate that the ductile deformation was restricted only to highly sheared metavolcanics as regional isoclinal and upright folds with pervasive NW-SE and ENE-WSW foliations. Ductile deformation is studied by analyzing the measured structural elements represented by foliations and minor fold axes, using the lower hemisphere stereographic projection. Based on measurements of foliation, lineaments and fold axes have been collected from different sites distributed along the metavolcanics exposures. These measurements have been categorized and analyzed according to its trend distribution. Each system of foliation has been analyzed to deduce its principal compression direction as well as their corresponding inferred tectonic regime.
Bedding

Bedding planes are locally preserved in the metavolcanics and measured whenever possible; they are frequently transposed by foliation and later deformation. So, the earlier ductile deformation episode can depict from the foliation. Bedding surfaces in the metavolcanics strike NW-SE and dipping generally range between 50º to 80º SW. On the lower hemisphere equal area has graphical analysis; (Fig. 3, a) indicates a great circle with fold axis plunging (82º/N-234º). This fold trend represents the third folding generation F3.

Foliation

Foliation planes resulted from deformation which flattened the embedded clasts. One distinctive
On the other hand, strike slip faults have NE-SW and NNE-SSW trends from an aeromagnetic map of normal faults are the same trends of different types of alteration processes including albitization, hematization, kaolinitization and dissilicification affecting syenogranite, alkali feldspar granite and quartz syenite.

NW-SE to NNW-SSE with minor trends NE-SW , E-W and N-S.

The platform regime began in Paleozoic through northern Africa. Regional deformation observed in the area is represented by a compressional regime with major strike-slip faults. This regime continued throughout the Cenozoic following a late Mesozoic (Triassic) compressional regime that initiated the development of the Red Sea [6, 11, 12]. The NE-SW strike-slip faults arepull-apart faults associated with the opening of the Red Sea. The Red Sea opening continued later in the Cenozoic following a NE-SW to NW-SE direction. The study area is located along the NW-SE Nubian sandstone trend. The Red Sea opening related to the NE-SW compression and shortening trend during E2 is to the NE-SW direction, i.e., quite different from the NW-SE shortening direction during E1. This means that crustal shortening directions flipped through about 90°

The fourth folding generation F4 is manifested by syncline folding that existed in Nubian sandstone at Fileita area (Fig. 5, a). The F4 axes are 75°/027° and 63°/122° (Fig. 5, b, c). The F4 fold is nearly coaxial with the F1 folds indicating that the compression during this episode (E1) continued in the same direction.

The age of E1 episode can be estimated to be between the formation of the arc-inter-arc rock association and the intrusions of the syntectonic granites. These granites have an age (660–730 Ma) [13]. They are considered as emplaced at the culmination of the low angle shearing tectonic event.

The fourth generation F4 is manifested by syncline folding that existed in Nubian sandstone at Fileita area (Fig. 5, a, b). The bedding planes are plotted on an equal area projection to show the trend and dip of the regional fold axis F4 plunging (12°/N-83°) along the axial plane (N84°E/84°S) that existed after the intrusion of younger granites and the deposition of Nubian sandstone Post-Cretaceous.

Brittle deformation and paleostress analyses

Tectonic analyses based on the aeromagnetic survey data

Wadi Kharit/Wadi Jararah basin may be explained in terms of a pull a part wrench with right-lateral motion (Fig. 6). In pre-Jurassic time, the main trend of the basement rocks was composed mainly of NW-SE system. Tectonic analyses explain the geometric configuration and orientation of a pull a part movement which governed the sedimentation history of the area; the platform regime began in Paleozoic through northern Africa [14].

A rose diagram (Fig. 6) represents the main faults trends from an aeromagnetic map. The main trends of normal faults are NW-SE to NNW-SSE with minor trends NE-SW, E-W and N-S. On the other hand, strike slip faults have NE-SW and NNE-SWW trends. These trends can be considered as deep seated trends in the study area. From the present study; alteration processes including albitionization, hematization, kaolinization and dissilicification affecting syenogranite, alkali feldspar granite and quartz syenite are mainly associated with the NW-SE to NNW-SSE, NE-SW, E-W and N-S deep seated normal fault trends. This means that the deep seated trends from an aeromagnetic map of normal faults are the same trends of different types of alterations delineated the granitoids at Wadi Road El-Sayalla area.

Paleostress analyses

The (INVD) direct inversion [8–10, 16] used to determine paleostress tensors from fault-slip data sets. This method is based on some hypotheses which can be verified on the basis of data consistency after computations and geological observation at data collection sites: 1) The stress field was homogeneous within the site studied for the tectonic event considered. 2) Slip occurred in
Figure 5. Folding in Nubian sandstone. a – false colored photo showing synclinal fold comprising Timsah Formation and bedding in Um Baramil Formation, photo looking to north; b – graphical solution of contoured poles to bedding associated in Nubian sandstone at Fileita area, contours at 2, 4, 8, 16 and 32% for 81 bedding.

Рисунок 5. Складчатость в нубийских песчаниках. a – цветная фотография, показывает синклинальную складку, состоящую из отложений Тимсахской свиты и слоев в Ум-Барамильской свите, объектив фотоаппарата направлен на север; b – графическое решение оконтуренных полюсов к осадочным слоям в нубийских песчаниках в районе Филейты, контуры 2, 4, 8, 16 и 32 % для 81 наслоений.

Figure 6. Interpreted tectonic map and rose diagram showing faults trends based on aeromagnetic data for Wadi Kharit / Wadi Jararah area, Eastern Desert, Egypt, after [15].

Рисунок 6. Интерпретированная тектоническая карта и роза-диаграмма, показывающие направления разломов на основе аэромагнитных данных для района Вади-Харит/Вади-Джарара, Восточная пустыня (Египет), по [15].
the direction of the maximum resolved shear stress should parallel the fault plane and corresponds to the measured striae. 3) Faults moved independently but consistently with a single and common stress tensor during the tectonic event. 4) Fault displacement is small relative to the fault surface area [16, 17]. Paleostress reconstruction of brittle deformation is based on the analysis of fault slip data using computer programs of tensor [8–10, 16]. These methods depend on determining the best fitting reduced paleostress tensor for a given fault slip data set. The direction of slip on a fault plane depends on the orientation of the maximum (σ1) and minimum (σ3) principal stress axes and on the ratio Φ = (σ2 – σ3)/(σ1 – σ3). This ratio provides a convenient index to characterize the relationship between the principal stress magnitudes. It ranges from 0 (meaning that σ2 = σ3) to 1 (meaning that σ2 = σ1). Whereas simple extension generally corresponds to high values of Φ (e.g., > 0.5), multidirectional extension is characterized by low values that make σ2/σ1 stress permutation easier. In compressional tectonics, changes between reverse and strike-slip faulting modes often correspond to situations with low values of Φ, down to about zero [18]. A quality estimator of data dispersion is the average “ratio epsilon” of RUP. Possible value of estimator RUP ranges from 0% (maximum shear stress parallel to slip with the same sense) to 200% (maximum shear stress parallel to slip with opposite sense). The average ratio of the direct inversion method (RUP) in percent (100) value < 75% = good consistency [19] as, it generally corresponds to good fits between actual fault slip data distribution and computed shear stress distribution. Another quality estimator is calculated, ANG as to the average angle (in degrees) between the measured lineation and the computed slip lineation. The results are acceptable for values between 1° to 25° [19] which are the case of the present analyses.

In the present study, paleostress tensor analyses have been conducted in the studied area based on crosscutting and geometrical relationships between faults and dikes. Twenty-one stations have been studied in which 166 fault slip data were used in calculation. Their analyses allow the calculation of 21 paleostress tensors. There are 29 faults characterizing extension, 132 faults characterizing simple shear (compressional) regime and 5 faults characterizing pure shear regime.

A - Extensional stress regime
It has been defined fault-slip data sets of system in 5 sites (Table 1) and (Fig. 7). These systems are gathered into different extensional regimes NW-SE, NNW-SSE, NE-SW and NNE-SSW. The faults recording NW-SE to NNW-SSE striking extension are found in two sites of the area (sites 104A and 109B). While the faults recording nearly NE-SW and NNE-SSW-striking extensions are recorded in three sites (111N, 3/6C and 91A). The average orientations of σ1 axes are N-315° and N-170° for NW-SE and NNW-SSE-striking extension, N-226° and N-45° for NE-SW extension and N-196° for NNE-SSW extension. The different alteration processes encompass albitization, hematitization, kaolinitization and dissilicification affected Wadi Road El-Sayalla granitoid plutons are similar to those trends of normal deep seated faults resulted from an aeromagnetic map. These fault trends are NW-SE to NNW-SSE, NE-SW, E-W and N-S in which reveal NE-SW to ENE-WSW, NW-SE, N-S, and E-W extensional trending minimum stress (σ3). These extensional trends considered the most important trends for higher radioactive zones at Nikeba area as reported by [20].

B - Compressional stress regime
It has been defined using 137 faults from simple shear system and 5 faults from pure reverse compression system in 16 sites (Table 1) and (Fig. 7). These systems are gathered into five events of different compressional regimes N-S, NNW-SSE, NE-SW, E-W and NE-SW. The strike-slip regime (σ1 with horizontal σ3 and σ2) occurs in 15 sites. The compressional event is detected from strike-slip systems (sites 91, 3/6D for N-S while 109 and 3/6 for NNW). The computed σ2 for this system plunges 14°, 39°, 4° and 15° in 187°, 172°, 156° and 337° directions. The NW-SE compressional event represents strike-slip phases (sites 92, 101A, 102, 104, 109A and 111). The computed σ2 for these systems are 327°, 326°, 165°, 129°, 304° and 313° with plunges from 27°, 18°, 74°, 8°, 1° and 16°. From (Fig. 7) the alkali feldspar granite take an oval shape along the NW-SE direction as the same direction of the foliation planes in the metavolcanics in which their strike ranges between 120° to 160°. Quartz syenite affected by the N-S strike slip left lateral compression causing the displacement of their plutons (Fig. 7).

The faults recording E-W-striking compression is detected from two conjugate strike-slip fault systems (93 and 101). The orientations of σ1 axis are 104° and 276° respectively with plunges 17° and 14°. The NE-SW compressional event (sites 109C, 3/6A and 3/6B, have orientation of σ2 in 251°, 46° and 72° directions with plunges 21°, 4° and 2° respectively. The pure compressional regime (σ1 vertical with horizontal σ3 and σ2) is only detected in the NW-SE compression (reverse) (site 92A). The computed σ2 for this system plunges 8° in 152° direction. This regime characterized by reverse fault causing highly sheared zone between syenogranite and quartz syenite. Also, the major synclinal folding (F4 generation), associated with Nubian sandstone basin at Fileita (Post-Cretaceous) and formed by pure compressional regime in NW-SE direction.

The geometry of fault populations is complex and varies from site to site. Oblique faulting is common where slip movements were initiated along pre-existing fault planes. For instance, some E-W and NW-SE trending oblique-slip faults have been reactivated into strike-slip sinistral faults (sites 102 and 92). This indicates that this event is younger than the N-S and NW-SE extensional events. Also, E-W trending oblique-slip faults have been reactivated into strike-slip dextral faults (sites 109C). This indicates that this event is younger than the N-S extensional event.

The ratio of stress differences Φ has very high value (0.5) in sites 92, 102, 104 and 111 i.e. σ3 is very close to σ1 so, changing between dip-slip faulting and strike-slip faulting modes can took place [18]. Conversely, where the tectonic regime is dominated by extension, a decrease in the ratio Φ results in more irregular trajectories of σ2 and local permutations of σ2/σ1 [18] (site 104A and 109B).

Tectonic evolution of Road El-Sayalla area
The following geological and tectonic episodes were inferred from the present study and the geochronological data for the surrounding areas were published (Fig. 8).

Syen-tectonic granite; folding-thrusting episode (E1)
It was associated with the crystalization of the arc-inter-arc rock association. Low angle thrusting, tight and isoclinal folds of (F1) were formed during this stage (E1). Sol Hamed-Onib and Allaqi-Heiani suture were formed due to the collision between Gerf and Gabgaba-Gebeit terrains (> 715 Ma [13]). Also, the metavolcanics are similar expressions of the ~ 750 Ma crust-forming events [21]. The compression during early folding-thrusting episode (E1) continued in the same direction to generate nearly coaxial folds (F2) with (F1). The F2 folds were formed between formation of arc-inter-arc rock association and the intrusion of the syenitite granitoids 660–730 Ma [13]. The intrusion of these granites represent the end of folding-thrusting episode (E1).
## Late-tectonic granite: upright folding episode (E2)

It was associated with compression and shortening to the NE-SW direction which different from the NW-SE shortening direction during (E1). At the end of the E2 numerous plutons of the late-tectonic granites in the Eastern Desert are intruded parallel to the NNW-SSE to NW-SE trend [22]. The folding and foliation during the E1 and E2 provided most of the space for the granitic plutons intrusion [23].

## Post-tectonic granitic episode (E3)

The syenogranite and alkali feldspar granite of Nikeiba exhibit A-type affinity intruded during this episode. On the basis of petrological and geochemical data, this batch displays anorogenic features of post orogenic environment [20, 24] (E3). So, this batch of Nikeiba post-tectonic granites can be occurred during a prolonged heating event by post-collision extension [25, 26]. It is consistent with the concept that represents a continuation of magmatism in a post-orogenic environment, which reactivates major structures.

### Early Cretaceous to Post Pleistocene episode (E4 and E5)

The fourth episode (E4) is manifested by syncline folding along the axial plane bedding of F3 (N84°E/84°S) that existed after the intrusion of younger granites which were detected in the Nubian sandstone at Fileita area.

### Fracturing, faulting episode (E5)

Fracturing, faulting episode (E5) is manifested in the studied area by successive events of compressional reverse, strike slip faulting and extensional normal faulting. They are detected in syenogranite, alkali feldspar granite and quartz syenite. The area is dissected by multi-trends of fault populations arranged according to relative chronology starting from the oldest event: E-W strike slip (right), N-S strike slip (left), E-W dip slip, NE-SW strike slip (right) and NE-SW dip slip main trend clusters. The N-S reactivated left lateral strike-slip faults which cross cut clayey sandstone at Fileita.

### Discussions and conclusion

1. The detailed structural study reveals four tectonic episodes that affected the studied area; E1: Folding-thrusting episode; it is represented by tight and isoclinal folds (F1) associated with metavolcanics association. The compression during early folding-thrusting episode continued in the same direction to generate nearly coaxial folds (F2) with the isoclinal folds (F1). The intrusion of syntectonic granites (tonalite-granodiorite) marks the end of this episode 660–730 Ma [13].

2. E2: Upright folding episode; It is associated with compression and shortening in the NE-SW direction, which is different from the NW-SE shortening direction during E1.

3. E3: Post tectonic granitic intrusion episode; the syenogranite and alkali feldspar granite of Nikeiba exhibiting A-type affinity and post orogenic environment formed during a prolonged heating event by post-collision extension.

4. E4 and E5: Early Cretaceous to Post Pleistocene episode; syncline fold, fracturing and faulting episode show the analysis of paleostress and relative chronological data indicate that the area experienced successive events of compressional and extensional regimes starting with the oldest event; E-W strike slip (right), N-S strike slip (left), E-W dip slip, NE-SW strike slip (right) and NE-SW dip slip (main trend). Trends of the main tensions occurred along the inherited axial planes of F1, F2, F3 and F4 folds in sites (104A, 109B, 111N, 3/6C) and 91A, respectively.

### Table 1: Tensor data of paleostress

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<th>Site No.</th>
<th>Tensor</th>
<th>Axe σ1</th>
<th>Axe σ3</th>
<th>Axe σ2</th>
<th>D</th>
<th>P</th>
<th>D</th>
<th>P</th>
<th>Φ</th>
<th>ANG</th>
<th>RUP</th>
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<td>78°</td>
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<td>22°</td>
<td>162°</td>
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<td>71°</td>
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<td>243°</td>
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<td>8°</td>
<td>80°</td>
<td>0.422</td>
<td>5°</td>
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</table>

Symbols: Ex (Extensional system), Cp2 (strike-slip shear system), Cp1 (pure compression reverse system), σ₁, σ₃ and σ₂ = principal stress axes, D = trend of axis, P = plunge of axis, Φ = (σ₁ – σ₂)/ (σ₁ – σ₃), ANG = angle between calculated and measured shear. RUP = ratio upsilon (in %) of the function defined by [9] from 0% to 200% and Conj. No. = number of conjugate fault systems (total = 166).
Figure 7. Lower-hemisphere Schmidt projection of fault slips data corresponding tensor for compressional and extensional phases showing their distributions on the geological map for Nikeiba plutons at Wadi Road El-Sayalla, Eastern Desert Egypt. Symbols: as 5-pointer star (red color) = σ₁, 4-pointer star (green color) = σ₂, 3-pointer star (blue color) = σ₃; Large blue and red arrows = direction of extension and compression, small arrows indicate slickenside sense of movement.

Рисунок 7. Нижняя полусфера проекции Шмидта данных истинной высоты сброса; соответствует тензору для растянутых и сжатых фаз, показывающих их распределение на геологической карте, для плутонов Никейба на Вади-роуд Эль-Саялла, Восточная пустыня (Египет). Обозначения: в виде звезды с 5 наконечниками (красный цвет) = σ₁, звезда с 4 наконечниками (зеленый цвет) = σ₂, звезда с тремя наконечниками (синий цвет) = σ₃; Большие синие и красные стрелки = направление растяжения и сжатия, маленькие стрелки указывают на зеркало скольжения.

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**Table:**

<table>
<thead>
<tr>
<th>Orogenic tectonic setting</th>
<th>Anorogenic tectonic setting</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Tectonic episodes</strong></td>
<td><strong>Sedimentation &amp; deformation</strong></td>
</tr>
<tr>
<td>~ 750 Ma [13]</td>
<td>Folding-thrusting episode (E1)</td>
</tr>
<tr>
<td></td>
<td>652.3±2.6 Ma [26]</td>
</tr>
<tr>
<td></td>
<td>Upright folding episode (E2)</td>
</tr>
<tr>
<td></td>
<td>595–605 Ma [26]</td>
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<tr>
<td></td>
<td>Post-tectonic granite episode (E3)</td>
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</tbody>
</table>

**Figure 8.** Tectono-stratigraphic sequence of rock association of the basement complex and non-conformable Nubian sandstone at Wadi Road El-Sayalla in the Eastern Desert, Egypt, modified after [6].

Рисунок 8. Тектоно-стратиграфическая последовательность ассоциирующих пород из комплексов основания и несогласие нубийского песчаника в Вади-роуд Эль-Саялла в Восточной пустыне, Египет, с изменениями по [6].

5 – The NW-SE, NE-SW, E-W, NNW-SSE and N-S normal fault trends control multi injections and many alteration features. They are considered as important trends for deep seated structures from aeromagnetic map and may have acted as good directions for the radioactive mineral (thorite and uranothorite).

6 – Mineralization appears to be structurally controlled by the interaction between inherited ductile fabrics and overprinting brittle structures. During reactivation, simple shear parallel to the inherited ductile fabrics was responsible for development of mineralized structures. Also, uranium and thorium are concentrated in accessory minerals, especially uranothorite, monazite, zircon, allanite yttrocolombite and fluorite in which they are associated with the highly altered syenogranite, alkali feldspar, quartz syenite, felsite dikes and pegmatite pockets in Nikeiba plutons at Wadi Road El-Sayalla.

**REFERENCES**


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Структурная эволюция района Вади-роуд Эль-Саялла, Восточная пустыня (Египет)

Халед Гамаль АЛИ1,
Хасан Али ЭЛИВА2,
Масуд Салах МАСУД1,
Мамору МУРАТА3,
Ахмед Эль Саид АБДЕЛЬ ГАВАД1,*

1Управление ядерных материалов, Каир, Египет
2Университет Минуфия, Каир, Египет
3Университет Наруто, National University Corporation, Наруто, Япония

Район Вади-роуд Эль-Саялла является частью юга Восточной пустыни Египта. Он состоит из двух плутонов, основания комплексов горных пород Никейба и песчаников Филейта Нубиа. В состав плутонов Никейба входят метавулканиты, сиенограниты, щелочные полевошпатовые граниты и кварцевые сиениты, прорванные дайками фельзитов и долеритов и кварцевыми жилами, все эти комплексы пород несогласно перекрываются нубийскими песчаниками в районе Филейта.

Цель работы. Исследование заключается в выяснении взаимодействия между унаследованными пластическими структурно-текстурными элементами и наложением хрупких структур. Важно реконструировать тектоническую эволюцию района Вади-роуд Эль-Саялла, что поможет определить границы минерализации в исследуемой области.

Методы исследования. Аналитировалось сгибание, связанное с пластическими структурно-текстурными элементами, с использованием программных пакетов стереографической проекции GE Orient версии 9.4.5. Анализ трещин, связанных с хрупкими структурами, проводился количественно с использованием палеостресс анализов различных наборов для расчета тензоров, связанных с различными событиями сжатия и экспансии с использованием программы Tensor.

Результаты. Структурная эволюция в исследуемой области подразделяется на пять структурных эпизодов: E1: синтектонический гранит (тоналит-гранодиорит); эпизод сгибания, связанный с кратонизацией островодужных и междуговых комплексов пород. E2: позднетектонический гранит; эпизод прямой складки, связанный со сжатием в направлении NE-SW. E3: Интрузии посттектонических гранитов с образованием сиеногранитов и щелочно-полевошпатовых гранитов Никейба. E4 и E5: от раннемелового до постплейстоценового периодов проявляется синклинальное сгибание вдоль направления ENE-WSW в нубийском песчанике Филейта (E4). С другой стороны, E5: Разрушение, тектоническая зона характеризуется многочисленными разломами (сдвиговый разлом EW (правый, самый старый), сдвиговый разлом NS (левый), вертикальное смещение E-W, сдвиговый разлом NE-SW (правый) и NE-SW вертикальное смещение (самое молодое)). Акцессорные минералы, такие как торит, ураноторит, монацит, циркон, аланит, иттроколумбит и флюорит, по-видимому, структурно контролируются взаимодействием между унаследованными пластическими структурно-текстурными элементами и наложением хрупких структур. Нормальные сбросы NE-SW, NW-SE, E-W, NNW-SSE и N-S являются важными глубоко залегающими структурами, которые контролируют многочисленные дайки фельзитов и долеритов и соответственно наложенные изменения, которые могут нести различную рудную минерализацию.

Ключевые слова: Вади-роуд Эль-Саялла, Никейба, Филейта, Египет, сдвиговая складчатость, кратонизация, образование складчатости, образование разломов.

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* gawadnma@gmail.com
http://orcid.org/0000-0002-2014-2677