Geochemical and Geotectonic Setting for Island Arc Related rocks on Um Taghir Area, Central Eastern Desert, Egypt

H A Awad¹², A V Nastavkin¹

¹Southern Federal University, Russia, 344103, Rostov-on-Don, Zorgest., 40
²Geology Department, Faculty of Science, Al-Azhar University, Assuit Branch, 71524 Assuit

E-mail: hamdiawaad@gmail.com

Abstract: Um Taghir area located in the Central Eastern Desert of Egypt a long road of Safaga-Qena. It is represented by island arc related rocks that are intruded by late to post tectonic magmatism. The island arc belonging to oceanic terrain, divided into metavolcaniclastic and metagabbroic rocks. Metavolcaniclastic sequence is represented as the older rock unit of the study area, it is noted that metavolcaniclastic intruded by metagabbro. Island arc assemblage is classified into schist and metagabbro that give clean different of their mineral constituents according to petrographical studies. Geochemically, the investigated rock units and most of dikes have sub alkaline nature. Tectonically, metavolcaniclastic sequence is related to back arc basin basalts, while metagabbro related to volcanic arc.

1. Introduction
The study area is represented in the Central Eastern Desert of Egypt on the road of Qena-Safaga (Fig. 1). It covers about 900 km², between longitudes 33° 35′ 00″ and 33° 50′00″ and latitudes 26° 35′00″ and 26° 49′00″. It forms a part of Neoproterozoic evolution of the North Arabian-Nubian Shield (ANS) in the NE Africa which is belonging to the East African Orogen (EAO) as results of accretion plateaus in the course of consolidation of the Gondwana (Gass, 1982; Stern, 1994; Kröner et al., 1994; I. A. Thabet, 2017; Gahlan H. A., Azer M. K., Asimow P., Al-Kahtany K., 2016; Hamimi Z., Zoheir B. A., Younis M. H., 2015 and Stern, 1996). Generally, the ANS is considered one largest regions of mantle-derived, juvenile Neoproterozoic crust in the world, which is extended over 3500 km as length and more than 1500 km as width, otherwise African Orogen area (EAO) of Arabian Nubian Shield is covered about 2.7*106 km² (Johnson 2014). Investigated rocks represent in the north part of ANS are middle-late Cryogenian age (~780 – 680 Ma), on the other hand the studied area of the northwestern part of ANS related to the late Cryogenian-Ediacaran age (~690-600 Ma) (Johnson, 2014). The investigated rock units of the western arc of ANS, are studied by (Stoester and Forst, 2006; Ali et al., 2009; Johnson et al., 2011). The rock unites are classified into oceanic arc terrains magmatism (metavolcaniclastic sequence and metagabbro) and the late and post magmatism. Um Taghir area has been examined by (Hume, 1934; Akaad et al., 1973; Habib, 1987a; El Gaby and Habib, 1982; El Gaby et al., 1988; Fowler et al., 2006 and Hassan SM, Ramadan TM 2014; El-Bialy MZ, Omar. M.M 2015; Hamdy Ahmed Awad et al., 2020). The current study aims to detect the classification, magma type and tectonic setting of investigated rock units of studied area.
2. Geologic setting
The exposed rock units in the studied area have been differentiated into:

2.1. Metavolcanoclastic sequence
It considers as older rock unit of the mapped area (Fig. 1), is represented by highly weathered and joints. It is intruded by the metagabbro and late to post orogenic rocks.

2.2. Metagabbro
It is restricted in the south part of study area (Fig. 1). Metagabbro is recognized by low hills to moderate relief. It is characterized by massive rocks, highly weathered and fine to coarse-grained.

Figure 1. Geological map of Um Taghir area created from integrated remotely sensed data processing and field observation.

3. Geochemistry of the investigated rock units
Nine fresh or less altered samples were selected for geochemical analysis in order to work out their geochemical affinity and their geotectonic setting. The major and a range of trace and rare earth elements were analyzed. (at laboratories of Russian Geological Institute and Institute of Biology, Southern Federal University). The results are given (Table.1).

3.1. Geochemical classification of the investigated rock units
A lot of parameters are used hereunder to classify and follow up the chemical affinity of the investigated rocks. According to Pearce and Cann (1973), the samples of metavolcanoclastic sequence plot within the field of basalt + dolerite sills (Fig. 2a). On the other hand, according to classification of Na2O + K2O versus SiO2 binary diagram of Cox et al., (1979), the plots of analyzed samples of metagabbro are falling in gabbro (Fig. 3a).

3.2. Magma type of the investigated rock units
The magma type of the studied rock units are discussed on the base of the following proposed diagrams. According to Irvine and Baragar (1971) that used (Na2O+K2O)-SiO2 binary diagram to distinguish between the alkaline and sub-alkaline rocks, all the investigated rock units of study area have sub alkaline nature as shown in (Figs. 2b & 3b). However, both of them tend to be tholeiitic according to AFM diagram of Irvine and Baragar (1971), as shown in (Figs. 2c &3c).
3.3. Tectonic setting of the investigated rock units

According to Zr versus Ti relationship of Pearce (1982), shows that the investigated metavolcanoclastic sequence plots in the field of MORB series as shown in (Fig. 2d), while Floyed (1991) Zr versus Ba relationship, quite shows that the samples are related to the back arc basin basalts (Fig. 2e), on the other hand, Rb versus Y+Nb diagram of Pearce et al., (1984), plotting of the analyzed metagabbro samples are falling in volcanic arc field (Fig. 3d). On the MORB normalizing diagram (Fig. 2f), the metavolcanoclastic is similar to MORB but with enrichments in Ba, Rb and Th with clear declination in Nb and Y, which are characteristic for back arc lavas. On ORG normalizing diagram, metagabbro show enrichments in LILE (eg: Rb and K) and depletion in HFSE with clear negative Nb, similar to the I-type granites from subduction zones. (Fig. 3e).

3.4. Rare earth elements of the investigated rock units

The chemical concentrations of the rare earth elements (REE) of the analyzed samples are given in (Table 1). The distribution of the rare earth elements in the metavolcanoclastic varies in the spectrum (La to Lu), which shows slightly increased of REE pattern (La to Pr) and slightly decreased of REE (Pr to Lu) with a significant little or no Eu-anomaly, while the metagabbro shows slightly depletion of REE pattern (La to Lu), and slightly increased of REE pattern (Tb to Lu), all of them have a significant little or no Eu-anomaly as shown in chondrite-normalized REE diagrams of Boynton, (1984), (Figs. 2g& 3f).

| Sample. No. | SiO₂ | Al₂O₃ | Fe₂O₃ | FeO | CaO | MgO | TiO₂ | Zr | Nb | Y | Cr | Ni | Cu | Zn | Zr | Rb | Sr | Ga | V | Nb | Co | U | Th |
|-------------|------|-------|-------|-----|-----|-----|------|----|----|----|----|----|----|----|----|----|----|----|----|----|----|---|----|---|
| 71          | 48.7 | 15.4  | 15.3  | 1.7 | 8.9 | 3.86 | 2.08 | 0.24 | 0.19 | 0.42 | 0.98 | 0.21 | 0.34 |
| 72          | 48.8 | 15.8  | 14.5  | 1.86| 8.5 | 4.2  | 2.05 | 0.4  | 2.7 | 0.45 | 0.99 | 0.2 | 0.62 |
| 72a         | 49   | 15.6  | 14.0  | 1.9 | 9.0 | 4.2  | 2.1  | 0.6  | 2.8 | 0.5 | 0.3 | 0.19 | 0.34 |
| 73          | 50.2 | 16.1  | 12.4  | 3.7 | 7.78| 3.57 | 1.88 | 0.31 | 28.1| 0.23| 1.02 | 1.0 | 99.5 |
| 73a         | 50.0 | 16.0  | 12.5  | 3.9 | 7.8 | 3.6 | 1.8 | 0.3 | 27.2| 0.2 | 0.8 | 1.0 | 99.7 |
| 70a         | 48.1 | 17.6  | 12.7  | 1.2 |10.2 | 5.36 | 1.55 | 0.18 | 2.6 | 0.23| 0.55 | 0.7 | 0.4 |
| 70b         | 47.0 | 16.3  | 12.8  | 1.7 | 11.3 | 6.0 | 1.56 | 0.3 | 2.6 | 0.2 | 0.8 | 1.0 | 0.4 |
| 70c         | 47.2 | 16.5  | 12.6  | 1.6 | 11.2 | 6.02 | 1.5 | 0.3 | 2.5 | 0.7 | 1.0 | 1.22| 0.4 |
| 74a         | 47.3 | 18.2  | 11.2  | 1.4 | 12.3 | 5.2 | 1.5 | 0.7 | 1.0 | 0.66| 1.09| 0.41|

| Trace Elements |
|-----------------|
| Cr 168 | 175.2 | 176 | 177.6 | 178 | 607.2 | 609 | 606 | 608.5 |
| Ni 67.2 | 68 | 69 | 68.7 | 69 | 182 | 185 | 174 | 181.3 |
| Cu 45.7 | 46.3 | 47 | 47.7 | 48 | 148.3 | 149 | 147 | 150.8 |
| Zn 131.2 | 128.6 | 129 | 126.8 | 127 | 123 | 125 | 118 | 117 |
| Zr 112 | 108 | 107 | 115 | 116 | 156 | 160 | 174 | 172 |
| Rb 2.69 | 2.85 | 2.9 | 2.35 | 2.4 | 9.2 | 10 | 10.2 | 9.8 |
| Y 33.2 | 28.3 | 28.1 | 27.2 | 27 | 12.6 | 13 | 12.9 | 13.3 |
| Ba 78.3 | 79.2 | 79.5 | 81.8 | 83 | 50.6 | 51 | 51.5 | 53.5 |
| Pb 13 | 12 | 12.2 | 11.8 | 12 | 24.8 | 25 | 24 | 25 |
| Sr 169 | 175 | 174 | 176 | 175 | 437.2 | 439 | 441 | 442.7 |
| Ga 3 | 4 | 4 | 5 | 4 | 12 | 10.5 | 11 | 13 |
| V 249.9 | 246 | 245 | 239.7 | 240 | 208.8 | 209 | 177 | 176 |
| Nb 3 | 2 | 2 | 3 | 2 | 2 | 1.9 | 2 | 2 |
| Co 144.8 | 141 | 142 | 140.8 | 141 | 155 | 156 | 155.3 | 154.4 |
| U 0.14 | 0.21 | 0.2 | 0.23 | 0.2 | 0.16 | 0.2 | 0.15 | 0.14 |
| Th 0.34 | 0.62 | 0.6 | 0.64 | 0.6 | 0.42 | 0.4 | 0.4 | 0.41 |

| Rare Earth Elements (REE) |
|---------------------------|
| La 5 | 6 | 6 | 7 | 7 | 7 | 6 | 5 | 6 |
| Ce 13 | 12 | 13 | 20 | 14 | 15 | 16 | 17 | 16 |
| Pr 2.1 | 2.4 | 2.5 | 3 | 3.1 | 2.2 | 2.3 | 2.7 | 2.4 |
| Nd 12 | 11 | 12 | 13 | 12 | 12 | 11 | 13 | 11 |
| Sm 4 | 5 | 5 | 4 | 5 | 2.5 | 2.4 | 2.6 | 2.7 |
| Eu 1.3 | 1.7 | 1.4 | 1.5 | 1.6 | 0.8 | 0.9 | 0.9 | 1 |

Table 1. Major oxides, trace and REE of investigated rocks.
Table 1. Average rare earth element abundances (ppm) for the studied schist.

| Element | Gd | Tb | Dy | Ho | Er | Tm | Yb | Lu | ΣREE | Eu/Sm |
|---------|----|----|----|----|----|----|-----|-----|-------|-------|
|         | 6  | 1  | 6  | 1.3| 4  | 0.6| 3.4 | 0.5 | 60.2  | 0.3   |
|         | 4  | 1.2| 7  | 1.2| 3  | 0.5| 3.2 | 0.6 | 58.8  | 0.34  |
|         | 5  | 1.1| 6  | 1.3| 3  | 0.6| 3.1 | 0.5 | 59.2  | 0.35  |
|         | 5  | 0.8| 5  | 1  | 3  | 0.4| 3   | 0.4 | 67.3  | 0.41  |
|         | 4  | 0.7| 6  | 1.1| 3.2| 0.5| 3.3 | 0.3 | 68    | 0.41  |
|         | 5  | 0.3| 7  | 0.6| 3.0| 0.3| 3.3 | 0.2 | 48.3  | 0.33  |
|         | 4  | 0.4| 6  | 1.3| 3.0| 0.4| 3.3 | 0.2 | 49    | 0.34  |
|         | 2.9| 0.5| 6  | 1.4| 3.0| 0.4| 3.3 | 0.12| 50.8  | 0.37  |

Figure 2. (a): Zr (ppm)-TiO₂ (Wt %) diagram of Pearce and Cann, (1973) of the studied schist (b): TAS diagram of Irvine and Baragar (1971) of the studied schist. (c): Plots of the investigated schist on AFM diagram (Irvine and Baragar, 1971), (d): Zr-Ti diagram of Pearce (1982) of the studied schist, (e): Zr-Ba diagram of Floyd (1991) of the studied schist (f): Spider diagram for the studied schist normalized to MORB, (Sun1980) and (g): Chondrite-normalized REE (Byntton, 1984) for the study metavolcaniclastics.
Figure 3. (a): Plots of the investigated metagabbro SiO2-(Na2O+K2O) diagram of Cox et al., (1979) for plutonic rocks, (b): Plots of the investigated metagabbro on SiO2 vs. K2O+Na2O diagram of Irvine and Baragar (1971), (c): Plots of the investigated metagabbro on AFM diagram (Irvine and Baragar, 1971), (d): Plots of the investigated metagabbro on Rb-Y+Nb diagram of Pearce (1984), (e): Spider diagram for the studied metagabbro normalized to ORG, (Pearce et al, 1984).

Figure 4. (f): Chondrite-normalized REE diagram (Boynton, 1984) for metagabbro.
4. Conclusion
Um Taghir located in the Central Eastern Desert of Egypt on the Qena-Safaga road. It represents the diversity of the East African Orogeny (EAO) of Neoproterozoic rocks that belong to the Arabian Nubian Shield (ANS). It is classified into island arc related rocks and late to post-tectonic magmatism. The island arc related rocks are represented by metavolcaniclastic and metagabbroic rocks. Metavolcanoclastic sequence represents the older rock units of the investigated study area and intruded by the metagabbro and the late to post tectonic magmatism. Geochemically, the investigated rock units have sub-alkaline nature, in addition to metagabbro has tholeiitic affinity. Tectonically, metavolcanoclastic sequence is related back arc basin basalts, while metagabbro related to volcanic arc intrusions. metavolcanoclastic varies in the spectrum (La to Lu), which shows slightly increased of REE pattern (La to Lu) while the metagabbro shows slightly depletion of REE pattern (La to Lu), and slightly increased of REE pattern (Tb to Lu).

5. References
[1] Akaad M K, El-Gaby S and Habib M E 1973 The Barud Gneisses and the origin of Grey Granite Bull. Fac. Sci. Assiut Univ. 2 55–69
[2] Ali B H, Wilde S A and Gabr M M A 2009 Granitoid evolution in Sinai, Egypt, based on precise SHRIMP U-Pb zircon geochronology Gondwana Research 15 38–48
[3] Boynton W V 1984 Geochemistry of rare earth elements: Meteorite studies In: Henderson P (ed) Rare Earth Elements Geochemistry Elsevier Pub. Co., Amsterdam 63-114
[4] Cox K G, Bell J D, and Pankhurst R J 1979 The interpretation of igneous rocks (London) Allen and Unwin 450 p
[5] El-Bialy M Z, Omar M M 2015 Spatial association of Neoproterozoic continental arc I-type and post-collision a-type granitoids in the Arabian-Nubian Shield: the Wadi Al-Baroud older and younger granites North Eastern Desert, Egypt. J Afr Earth Sci 103 1–29
[6] El-Gaby S and Habib M S 1982 Geology of the area southwest of Port Safaga, with special emphasis on the granitic rocks Eastern Desert, Egypt. Ann. Geol. Surv. Egypt XII 47-71
[7] El-Gaby S, List F K and Tahran R 1988 Geology, evolution and metallogenesis of the Pan-African belt in Egypt In. The Pan-African belt of the northeast African and adjacent area by S El Gaby and R O Greiling (Eds) Earth Evol. Sci., Braunschweig (Vieweg) pp 17-66
[8] Floyd P A 1991 Oceanic Basalts Blackie & Son Ltd. (New York) 465 p
[9] Fowler A-R, Khaled G A, Omar S M and Eliva H A 2006 The significance of gneissic rocks and synmagmatic extensional ductile shear zones of the Barud area for the tectonics of the North Eastern Desert, Egypt Journal of African Earth Sciences 46 201–220
[10] Gahlan H A, Azer M K, Asimow P, Al-Kahtany K 2016 Late Ediacaran post-collisional a-type syenites with shoshonitic affinities, northern Arabian-Nubian Shield: a possible mantle-derived a-type magma Arab J Geosci 9 603
[11] Gass I G 1982 Upper Proterozoic (Pan-African) calc-alkaline magmatism in northeastern Africa and Arabia In: Andesite and related rocks R S Thorpe (ed.) Wiley and sons (New York) pp 591-609
[12] Habib M F 1987a Arc ophiolites in the Pan-African basement between Meatiq and Abu Furud, Eastern Desert, Egypt. Bull. Fac. Sci. Assiut Univ. 16 241-283
[13] Hamdy A M Awad et al. 2020 Geological and petrographical studies around Um Taghir area, Central Eastern Desert (Egypt) 1(57)7
[14] Hamimi Z, Zoheir B A, Younis M H 2015 Polyphase deformation history of the Eastern Desert tectonic terrane in northeastern Africa In: XII international conference “new ideas in earth sciences” (Moscow)
[15] Hassan S M, Ramadan T M 2014 Mapping of the late Neoproterozoic Basement rocks and detection of the gold-bearing alteration zones at Abu Marawat-Senna area, Eastern Desert, Egypt using remote sensing data Arab J Geosci 8(7) pp 4641-4656
[16] Hume W F 1934 The fundamental Precambrian rocks of Egypt and the Sudan Geology of Egypt Vol 2 Part 1 Geol. Surv. of Egypt.

[17] Thabet A 2017 Strain geometry, microstructure and metamorphism in the dextral transpressional Moharak shear belt, central Eastern Desert, Egypt Geotectonics 51 pp 438-462

[18] Irvine T N, Baragar W R A 1971 A guide to the chemical classification of the common volcanic rocks Can. Jour. Earth. Sc. 8 523-548

[19] Johnson P R 2014 An expanding Arabian-Nubian Shield geochronologic and isotopic dataset: defining limits and confirming the tectonic setting of a Neoproterozoic accretionary orogeny open geology journal 8(1)

[20] Johnson P R, Andresen A, Collins A S, Fowler T R, Fritz H, Ghebreab W, Kusky T 2011 Late Cryogenian-Ediacaran history of the Arabian-Nubian Shield: a review of deposition, plutonic, structural, and tectonic events in the closing stages of the northern East African Orogen Journal of African Earth Sciences Vol 61 pp 167-232

[21] Kröner A, Krüger J, Rashwan A A A 1994 Age and tectonic setting of granitoid gneisses in the Eastern Desert of Egypt and south-west Sinai GeologischeRundschau 83 502-513

[22] Pearce J A 1982 Trace elements characteristics of lava from destructive boundaries In: Thorpe RS (ed) Andesites (Wiley, Chichester) pp 525-548

[23] Pearce J A, Cann J R 1973 Tectonic setting of basic volcanic rocks determined using trace element analyses Earth Planet., Sci. Lett. Vol 19 pp 289-300

[24] Pearce J A, Harris N B W, Tindle A G 1984 Trace element discrimination diagrams for the tectonic interpretation of granitic rocks J. Petrol 25 956-983

[25] Stern R J 1994 Arc assembly and continental collision in the Neoproterozoic East African Orogen: implications for the consolidation of Gondwanaland Annual Reviews of Earth and Planetary Sciences 22 315-319

[26] Stern M, Goldstein S 1996 From plume head to continental lithosphere in the Arabian-Nubian Shield Nature 382 773–778

[27] Stoeser D B, Frost C D 2006 Nd, Pb, Sr, and O isotopic characterization of Saudi Arabian Shield terranes Chemical Geology 226 163-188

[28] Sun S S 1980 Lead isotopic study of young volcanic rocks from mid-ocean ridges (Ocean Island and island arcs) Phil. Trans. R. Soc. A 297 409-445

Acknowledgment
This publication was carried out as part of the program of supporting the publication activity of the Southern Federal University.