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Hydrothermally altered and fractured granite hosting rare metals at gabal adara adatalob, south eastern desert, Egypt

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Abstract: Gabal Adara Adatalob granite in the south Eastern Desert, Egypt represents a promising example for hydrothermally altered and fractured granite hosting rare metals and rare earths mineralization. This granite host or act as a source for the rare metals (Zr, Y, Nb, Yb and Ga) and rare earths (La, Ce, Pr, Nd, Sm, and Yb) mineralization. It forms isolated pluton crop out in the wadi Ed Direira area. It shows highly alteration and a strong enrichment in some rare metals and rare earths contents (Zr = 1434, Y = 629, Nb = 258, Ga =39, La = 262.18, Ce = 546, Pr = 71.91, Nd = 366.88, Sm = 101. 46, Yb = 8.12 ppm). Field radiometric measurements for this granite revealed that low uranium and thorium content. The radioactivity level reaches up to 10.1 ppm (eU), 24.2 ppm (eTh) respectively. The chondrite normalized rare earth elements, trends indicate strongly fractioned rare earth element pattern with significant strong enrichment in light rare earth elements rather than heavy rare earth elements.

Keywords: Hydrothermally Altered, Gabal Adara Adatalob, Rare Metal, Eastern Desert

1. Introduction

Gabal Adara Adatalob granite is located at the southern extremity of the Eastern Desert of Egypt near the Sudan Frontier between Latitudes 22° 22′ 27″ and 22° 24′ 11″ N and Longitudes 35° 47′ 49″ and 35° 50′ 50″ E. This area lies at a distance of about 65 km North West of Abu Ramad City. The studied area can be reached through Abu Ramad-Shalateen asphaltic road, drive about 35 Km from Abu Ramad City tell road mark 35 km and turn to the west along Wadi Diib about 30 Km to Gabal Adara Adatalob. It forms an isolated pluton along wadi Ed Direira area (Figure 1&2).The area was earlier studied by older authors, e.g. Ball [1], studied the topography and geology of the South Eastern Desert, Egypt. Hume [2] studied the fundamental Precambrian rocks of Egypt and Sudan. Geological Survey of Egypt [3] prepared geologic map on scale 1:250.000 for the basement rocks of Marsa Sha'ab area between Latitude 22° 00' - 23° 00'.

Recently, there is no any previous work about Gabal Adara Adatalob, but there is little previous work around Gabal Adara Adatalob area, e.g. Hussein [4] studied the geology of the Halaib area of the northern Red Sea Hills with reference to the Sol Hamed basic complex. Fitches [5] studied the late Proterozoic ophiolite of Sol Hamed, NE Sudan. El Alfy et.al. [6] prepared geochemical exploration of Elba – Gerf area south Eastern Desert. Nasr et.al. [7] Studied the Tertiary alkaline rocks in Gebel Elba area south Eastern Desert.

Khaliad et.al. [8] studied the results of geochemical, geological and mineralogical exploration of Gebel Elba. Omar et.al. [9] prepared geochemical map sheet No. 36 NE L 1,2,3 Qash Amir area, south Eastern Desert, Egypt. Shahin [10] studied the occurrence of uraniferous iron and manganese oxide deposits in biotite granite north east Gabal El Sela area. He concluded that the uraniferous iron and manganese oxide deposits and the hydroxides associated with kaolinite may represent a gossan on the top of a vein-type U-bearing deposit.

The present work deals with geology, petrography, geochemistry and radioactivity of Gabal Adara Adatalob granite south Eastern Desert of Egypt.

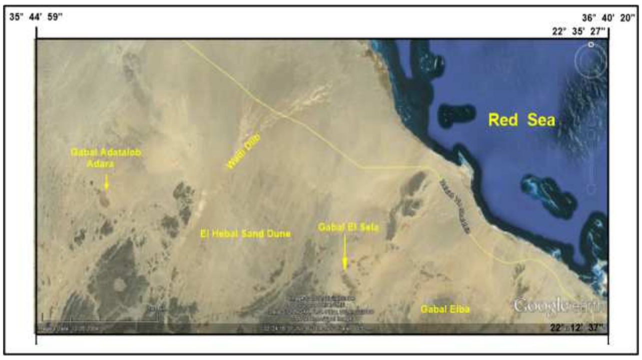


Figure 1. *Google image for the studied area.*

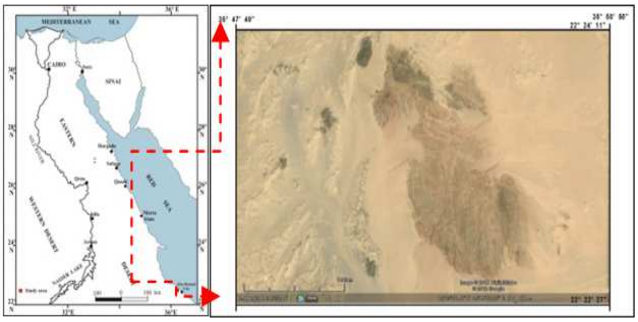


Figure 2. *Location map and Google image forGabal Adara Adatalob granite.*

1.1. Geological Setting

Gabal Adara Adatalob granite is moderate to low, elongated belt occurs as isolated pluton trending NNW-SSE (Figure 3). A detailed geologic study was carried out on this granite (Figure 4).This granite is highly altered, weathered, exfoliated, cavernous, coarse grained, pink to reddish pink in color and composed mainly of K-feldspar, quartz, plagioclase, biotite and some muscovite. Hematitic and kaolinitic alterations are prevalent, especially along the fractures and the intersection of faults (Figures 5&6). It is characterized by the presence of manganese oxides filling joints and fractures indicating the enrichment of this granite by manganese mineralization (Figure 7).

Gabal Adara Adatalob granite is intersected by many fault sets.This granite display strongly fractured and jointed. The main tectonic trends affect this granite are NE-SW, NW-SE, N-S and E-W major fault sets with contemporaneous silica injections (Figure 8). This quartz veins trending NE-SW and dipping 60° to the N. The intersection of these faults, mostly occupied by brecciated quartz veins (Figure 9). Different sets of joints are prevailing. The first set trending NE-SW and dipping 70° to the NW and the second trending NW-SE and dipping 80° to the NE.The emplacement of these injections along the fault zones were associated with high potential fluids which are indicated by the alteration halos. Hematitization and kaolinitization are the main alteration processes in this granite.

This granite is crosscut by different dykes and sheet. Fine-grained granite occurs as sheets trending NW-SE (Figure 10). This fine-grained granite is mainly composed of quartz, K-feldspar, plagioclase, biotite and muscovite and characterized by the presence of extremely abundant manganese oxides filling joints and fractures. Basic dyke dissected this granite and occupy mostly the fault zone. N-S is the main trend of this dyke. Acidic dyke is also recorded in this granite trending in ENE-WSW direction. It is massive, fine-grained and ranges in color from light gray to brownish, grayish color, range in wide from 3-5 meters.

Figure 3. *A photograph showing a general view for Gabal Adara Adatalob granite. Looking NW*

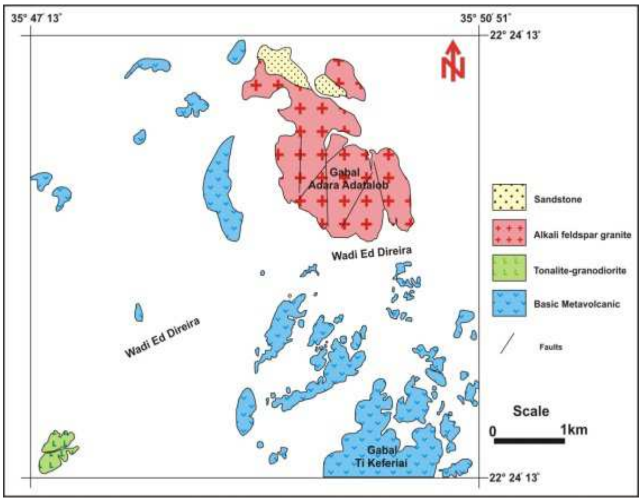


Figure 4. *Geologic Map of Gabal Adara Adatalob area, South Eastern Desert, Egypt.*

Figure 5. *A photograph showing kaolinitic alterations at Gabal Adara Adatalob granite. Looking N*

Figure 6. *A photograph showing hematitic alterations at Gabal Adara Adatalob granite. Looking NW*

Figure 7. *A photograph showing manganese oxides filling joints and fractures at Gabal Adara Adatalob granite. Looking SW*

Figure 8. *A photograph showing a quartz vein intruded the younger granite at Gabal Adara Adatalob granite. Looking NE*

Figure 9. *A photograph showing brecciated quartz vein along the fault plane. Looking SW*

Figure 10. *A photograph showing fine-grained granite occurring as a sheet cutting in Gabal Adara Adatalob granite. Looking E*

Field relations revealed that they are intruded by sandstone with sharp contact. This sandstone rocks fine-grained, yellow to pinkish white in color, highly sheared, highly jointed and banded. This sandstone is found forming a cap cover the top part at the northern side of Gabal Adara Adatalob granite (Figures 11&12). Gabal Adara Adatalob granite intrude the surrounding metavolcanic rocks with sharp intrusive contact (Figure 13). These metavolcanic rocks form moderate to high relief of gray to dark gray color and composed mainly of schistose chloritization metatuffs and metandesite.

Figure 11. *Aphotograph showing metamorphosed sandstone covers the top part in the northern side of the Gabal Adara Adatalob granite. Looking N*

Figure 12. *Closer view showing banding in the sandstone rocks. Looking NE*

Figure 13. *A photograph showing sharp intrusive contact between metavolcanics and Gabal Adatalob Adara granite. Looking NE*

1.2. Petrography

Petrographically, Gabal Adara Adatalob granite is hypidiomorphic, inequigranular, non-porphyritic, coarse-grained and pink to reddish pink color. Microscopically, it is composed essentially of alkali feldspar comprises (orthoclase and perthite), quartz, alkali pyroxenite comprises (aegirine and acmite), minor plagioclase and biotite. The accessory minerals are zircon and iron oxides.

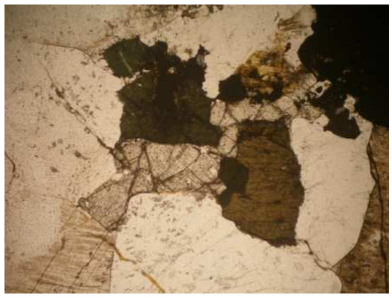
Orthoclase occurs as megacrysts up to 5.3x 2.1 mm. Most of the orthoclase crystals show perthitic texture and still persevered the simple twinning plane (Figure 14A).

Perthite occurs as subhedral megacrysts up to 3.6 x 2.4mm. Perthitic veinlets are the most predominate type of perthite in this granite.

Quartz occurs as subhedral to anhedral megacrysts up to 4 x 4.1 mm andsmall crystals up to 0.1 x 0.2 mm. It is found in two generations, the older fills the interstices between the K-feldspar intergrowth with perthite crystals. Biotite represents the chief mafic minerals. It occurs as subhedral to anhedral crystals. These biotite crystals show strongly alteration to chlorite with the precipitation of iron oxide and carbonate (calcite) (Figure 14B).Aegirine occurs in large idiomorphic forms. It is characterized by its green color and strongly pleochroic(Figure 14C). Acmite occurs as prismatic crystals of dark green color and weakly pleochroic (Figure 14C). The accessory minerals are represented by few euhedral metamict zircon (Figure 13D), colorless fluorite and iron oxides (Figure 14E).

A B

C D



E

Figure 14. A*. Photomicrograph shows simple twinning of Orthoclase perthite with some. C.N.X20.* ***B.*** *Photomicrograph shows Biotite corroded by the effect of hydrothermal solution with precipitation of iron oxide and carbonate (calcite). C.N. X20.* ***C.*** *Photomicrograph shows idiomorphic crystals of agerine and acmite(alkali pyroxene). C.N. X10.* ***D.*** *Photomicrograph shows metamict zircon associated with perthite and altered biotite. C.N. X20.* ***E.*** *Photomicrograph shows colorless fluorite with agerine and acmite crystals.PPLX10*

1.3. Radiometric Investigation

Detailed field radiometric measurements using a portable four channel, gamma-ray spectrometer Model GR-230 were carried out along Gabal Adara Adatalob granite. The detailed field radiometric measurements revealed that low uranium content associated with Gabal Adara Adatalob granite. Radioactivity level was found to vary from 2.5 ppm to 10 ppm (eU) and from 8.5 ppm to 24 ppm (eTh) respectively.

1.4. Solid State Nuclear Track Detectors (SSNTDs)

Solid state nuclear track detectors (SSNTDs) have been recognized by the IAEA as a standard method for estimation of radon, a throne and their daughter products in the environment. The detectors that are commonly used in environmental monitoring are generally made from cellulose nitrate (LR-115) and polycarbonates (CR-39).Alpha Track-etch Detectors (ATD) were installed for registering alpha particles from radon and radon decay products exhaled from the pink granite at Gabal Adara Adatalob, for a period 30 days, by using solid-state nuclear track detectors (polycarbonate films of type CR-39 Kodak). The CR-39 Kodak film fitted into the base of a plastic cup, and then the inverted cup is buried in a shallow hole (30-50cm) deep for one month. The location of track etch cupsis recorded with a Global Positioning System (GPS) (Figures 15&16).The obtained data were studied and counted under the microscope (Figure 17).The observed values of radon concentrations are given in Table (1).Radoncon centrations of Gabal Adara

Adatalob granite are found to vary from 469 Bq/m^3 to 1442 Bq/m^3.The values are quite lower than that reported in other places in the Eastern Desert (e.g. El Sela area). This indicates the weak presence of radioactive occurrence buried beneath the surface of this granite.

Table 1. *Track density and Radon Concentrations (Bq./m^3) for Gabal Adara Adatalob granite.*

Cups No.	Track Density(tr/cm^2)	Radon Concentrations (Bq./m^3)
247	4535.032	1426
248	1490.446	469
249	4331.21	1362
250	4585.987	1442

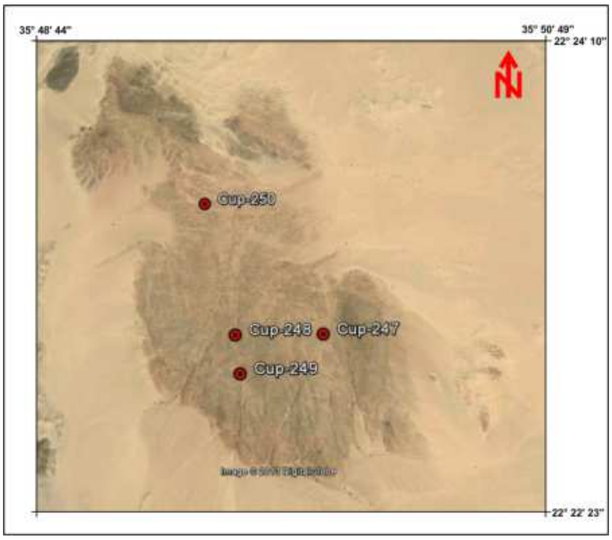


Figure 15. *Google image showing the location of track etch plastic cup at Gabal Adara Adatalob granite.*

Figure 16. *Track Etch plastic cup with polycarbonate film of type CR-39 Kodak is buried in shallow hole.*

Figure 17. *Optical micrograph of the CR-39 traces alpha particles released from radon. PPL X400*

2. Materials and Methodology

Thirty samples from the best exposures of the Gabal Adara Adatalob granite were collected for this study. From these, 14 samples were selected for thin sections to study the mineral constituents of this granite. Sixteen samples were selected and chemically analyzed for their trace elements and REE were analyzed with X-ray fluorescence analyzer (XRF) and inductively coupled plasma mass spectrometry (ICP- MS). Data of the trace elements and rare earth elements of the studied granite are listed in Tables (2&3).

Table 2. *Trace element composition (ppm) for Gabal Atadalob Adara granite*

S. No.	Cr	Ni	Cu	Zn	Zr	Rb	Y	Ba	Pb	Sr	Ga	V	Nb
AD7	36	10	10	312	1384	141	612	254	15	61	13	5	249
AD4	21	9	11	57	1434	112	629	392	16	65	14	7	258
AD2	58	28	11	201	781	75	343	584	24	35	16	22	140
AD15	31	9	10	133	828	139	368	257	12	37	13	4	149
AD14	32	8	10	87	1107	134	491	331	34	50	20	5	199
AD12	22	12	12	112	1409	126	618	417	15	64	14	10	252
AD8/1	31	6	14	123	1195	178	525	268	17	54	18	5	214
AD12/1	37	10	11	76	1068	106	471	586	14	48	10	15	192
AD5/2	37	9	14	83	564	71	249	240	42	25	39	4	101
AD8/2	39	11	10	64	751	136	334	248	17	34	12	4	134
AD12/2	32	14	13	354	1166	113	486	618	20	55	22	12	207
AD12/3	22	10	11	439	1221	126	535	654	18	55	11	12	219

Table 3. *Rare earth elements constituents (ppm) for Gabal Atadalob Adara granite.*

S. No.	Ad1	Ad2	Ad4	Ad12	Ad15	Ad17	Ad19	Ad5/2	Ad8/1	Ad8/2	Ad12/1	Ad12/2
La	4.34	45.26	152.6	40.20	38.99	81.82	104.5	6.60	68.38	7.87	19.46	262.8
Ce	10.72	112.9	364.1	99.53	56.41	179.4	178.6	24.74	157.3	19.45	44.54	546.0
Pr	2.25	15.66	52.11	14.20	8.53	25.29	20.39	2.60	23.46	2.45	6.68	71.91
Nd	15.44	88.43	265	76.57	42.87	132.2	107.2	12.21	121.4	9.98	33.67	366.9
Sm	5.20	26.76	75.63	21.60	11.67	36.14	22.61	3.75	33.72	3.50	9.39	101.5
Eu	8.29	1.82	1.82	1.75	3.98	3.27	2.31	4.60	1.86	4.53	3.34	4.54
Gd	3.49	12.49	14.89	9.94	12.22	13.83	16.51	5.45	9.92	4.81	6.46	22.19
Tb	0.66	2.45	2.75	1.70	2.10	2.30	2.95	0.75	1.85	0.85	1.15	3.50
Dy	6.34	12.54	13.94	11.28	12.81	12.06	18.00	5.74	10.56	6.38	6.14	20.60
Ho	2.39	2.69	3.66	2.35	2.78	3.00	4.23	0.96	3.28	1.45	1.44	6.88
Er	4.85	6.65	5.98	5.94	6.95	4.97	9.62	2.82	7.06	4.98	3.91	9.38
Tm	0.60	0.95	1.05	0.70	0.95	0.62	1.15	0.35	1.00	0.92	0.60	1.30
Yb	3.16	5.67	6.43	4.50	8.12	4.30	5.92	2.13	4.18	7.85	4.51	6.36
Lu	0.33	1.03	0.68	0.59	1.04	0.56	0.67	0.26	0.48	1.15	0.69	0.94

3. Results

3.1. Trace Elements

Concentrations of a wide variety of trace elements are shown in Table 2. Gabal Adara Adatalob granite is distinctive because of its generally higher concentrations of some incompatible trace elements. Zirconium contents range from less than 571 ppm to 1434 ppm. Yttrium ranges from about 249 ppm to about 629 ppm. Niobium abundance ranges from about 101 ppm to over 252 ppm. Gallium contents range from about 10 ppm to about 39 ppm. The higher content in some rare metal and rare earth mineralizations in this granite due to several normal fault movements accompanied with hydrothermal fluids lead to the intense alteration of Gabal Adara Atadalob granite represented by Hematitization and kaolinitization alterations. These alterations, act as a trapped phase and carrier for some rare metal and rare earth mineralizations enriched this granite. So, these hydrothermal fluids are potentially important in the dissolution, transportation and precipitation of these elements in this granite.

3.2. Rare Earth Elements (REEs)

The REEs data of the Gabal Adara Adatalob granite are normalized against chonderite values of Henderson (1996). Table (3) shows the REE chonderite for the studied granite.

Figure (18) shows the normalized REEs patterns for the Gabal Adara Adatalob granite. The REE plots of all samples of the Gabal Adara Adatalob granite showing distinct differences exist in the nature and size of Eu anomaly. The first cluster (red color) shows distinct strong enrichment in LREE and increasing decrease in HREE with moderate negative Eu anomaly. The second cluster (pink color) shows progressively decrease in LREE and depletion in HREE with weak negative Eu anomaly. The third cluster (blue color) shows a slight increase in LREE enrichment and a flat pattern in HREE with positive EU anomaly.

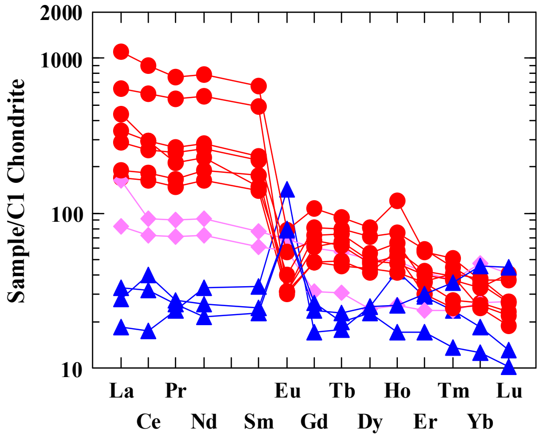


Figure 18. *Chonderite normalized pattern for the studied Gabal Atadalob Adara granite.*

4. Conclusions

Hydrothermal processes enriched by rare metal mineralization accompanied with event of an intensive tectonic structure affected Gabal Adara Atadalob granite. This event is marked by a deformation, fault rocks filled by brecciated quartz vein and alteration phase, which promoted fluids mobilization and deposition. This suggests that mobilization of fluids that formed rare metals mineralization at Gabal Adara Atadalob granite is mainly tectonically-controlled. These hydrothermal fluids processes played an important role in the dissolution, transportation and precipitation of these elements (Zr, Y, Nb, Ga and REE) in this granite. Geochemical data indicating strong enrichment in some rare metal contents (Zr = 1434, Y = 629, Nb = 258, and Ga = 39 ppm). The chondrite normalized rare earth elements patterns indicate strongly fractioned rare earth elements pattern with significantly enriched of LREE and depletion in HREE at Gabal Adara Atadalob granite.

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