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MINERALOGICAL INVESTIGATIONS AND PHYSICAL UPGRADING OF ABU RUSHEID CATACLASTIC ROCKS, SOUTH EASTERN DESERT, EGYPT

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ABSTRACT

An economically important rare-metal mineralization is recorded in the cataclastic rocks at Wadi Abu Rusheid area, South Eastern Desert of Egypt.

Radiometric measurements of the main varieties of cataclastic rocks (protomylonites, mylonites, ultramylonites) show that their equivalent thorium (eTh) content is 7560, 8660 and 6210 ppm, whereas the equivalent uranium (eU) is 2544, 4170 and 790 ppm respectively.

Microscopic examination, X-ray diffraction (XRD) and grain counting techniques revealed that thorite, zircon and columbite are the predominant radioactive minerals in all rock varieties , together with minor amounts of xenotime, cassiterite and sulphides. Beside these minerals, uranophane, kasolite and meta-autunite occur as inclusions in other minerals.

Physical upgrading of these minerals was carried out using gravitative separation technique. Applying the proposed flowsheet, it is possible to attain a good concentrate for these minerals with an acceptable recovery. It is recommended to subject the final concentrates to hydrometallurgical treatments to extract the important metals.

INTRODUCTION

Abu Rusheid area occupies a small part of the Precambrian basement of the south Eastern Desert of Egypt. The investigated area is located between Long. 34° 46' 00" to 34° 46' 35"E and Lat. 24° 38' 12" to 24° 37' 34"N.

Abu Rusheid rocks are a matter of controversy. Some workers as Hashad and Hassan (1959); Hassan (1964 & 1973); Saleh (1997); Assaf et al. (2000) and Ibrahim et al. (2002, 2004, 2007a&b) refers the Abu Rusheid rocks to sedimentary origin (paragniesses), while others as Hume (1934); Basta and Zaki (1961); El Gaby (1983); Hegazy (1984); Abdalla et al. (1998); Ibrahim et al. (2000); Rashed (2005); Khaleal (2005) and Osman et al. (2007) reconsidered these rocks to be of igneous origin (orthogneises) which is more accepted. Few workers on the Abu Rusheid rocks draw their attention to some mineralization (Nb–Ta–Zr). During the last few decades, since 2001 until now, the Nuclear Materials Authority of Egypt (NMA) conducted comprehensive programs for exploration on uranium mineralization in Egypt. These programs led to the discovery of thorium, uranium, base metals and REEs mineralization related to cataclastic rocks.

Saleh (1997) studied the potentiality of uranium occurrences in Wadi Nugrus area which has resulted in locating a number of radioactive anomalies and manifested the influence of both lithology and structure in their localization. Ibrahim et al. (2013) recorded some shear zones (NNW-SSE and ENE-WSW) extruded by basic lamprophyre dykes which acted as physical and chemical traps for polymineralization. They classified the gneissic rocks as cataclastic rocks and carried a detailed geologic study on Abu Rusheid cataclastic rocks and discovered new occurrences of mineralization. Ibrahim et al. (2007a) studied epithermal base metal mineralization in lamprophyre dykes which cut cataclastic rocks at Abu Rusheid area.

Raslan (2005) identified Hf-rich zircon, columbite and dark Li- mica (zinnwaldite) in Abu Rusheid radioactive gneiss. Ishikawaite, with an average assay of about 50% Nb_2O_5 and 26% UO_2 has been identified for the first time in Egypt in the mineralized Abu Rusheid gneissose granite (Raslan, 2008).

The present work is focused to identify the rare-metal mineralization of Abu Rusheid cataclastic rocks and the potentiality of physical upgrading of these minerals to attain a good concentrate with an acceptable recovery using mainly gravitative separation technique.

GEOLOGIC SETTING

Abu Rushied area represents a small part of the Precambrian basement of the South Eastern Desert and is located some 90 km southwest of Marsa Alam on the Red Sea coastal plain. According to Ibrahim et al. (2006 and 2007a), the tectonostratigraphic sequence of the Precambrian rock units of Abu Rusheid area (Fig.1) are arranged in the following order from the oldest to youngest into: (1) Metagabbros; (2) Ophiolitic mélange consisting of ultramafic rocks and layered metagabbros set in meta-sedimentary matrix; (3) Cataclastic rocks consisting of protomylonites, mylonites, ultramylonites and silicified ultramylonites rocks; (4) Granitic rocks; (5) Post granitic dykes and veins (lamprophyre dykes and pegmatite veins).

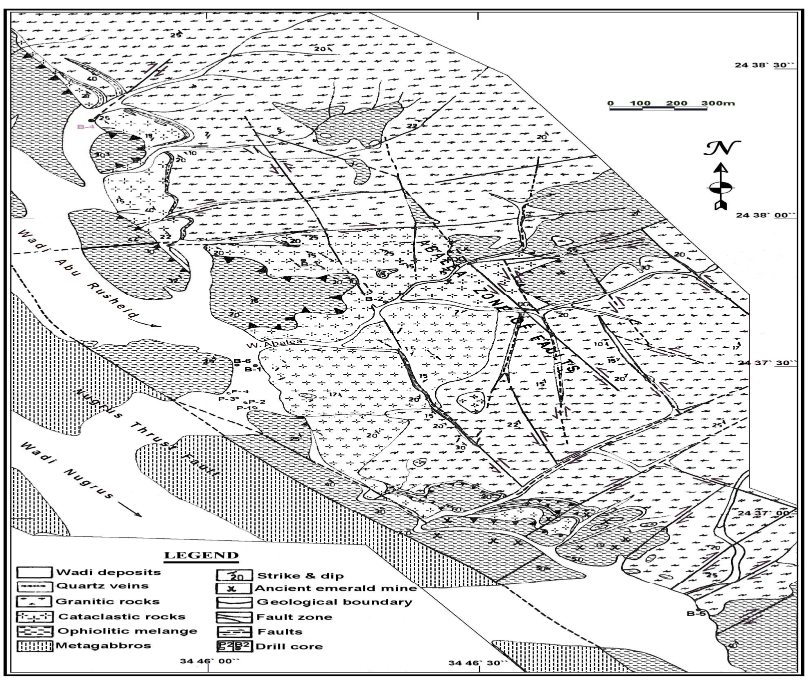

Fig. 1:Semi-detailed geological map of Abu Rusheid area, South Eastern Desert, Egypt (Modified after Ibrahim, 2006)

The cataclastic rocks are highly sheared, foliated, banded and folded especially at their contacts with the ophiolitic mélange. The cataclastic rocks at Abu Rusheid area show one of the high radioactive zones in the South Eastern Desert of Egypt. They also contain high contents of Nb, Ta, Sn, Pb and Zr (Ibrahim et al., 2006). They are intersected by two sets of shear zones (NNW-SSE & ENE-WSW) ,(Ibrahim et al., 2006 and 2007 a, b and 2013 in press).

The main varieties which constitute the cataclastic rocks of the studied area are: a- protomylonite b- mylonite c- ultramylonite and quartzite (Ibrahim et al., 2002 & 2004;Saleh et al., 2010& 2012).

a- Protomylonites crop out at the eastward flank of W. Abu Rusheid around Khour Abalea as elongated scattered bodies, covering about 13% in volume of the cataclastics. Lithologic contacts with ophiolitic mélange; where exposed; are tectonized and well defined, whereas with other cataclastics are gradational. The rocks are highly foliated (WNW–ESE), and characterized by absence of enclaves together with the frequent occurrence of greenish-microcline vienlets running parallel to the foliations. They are invaded by two quartz veins. The oldest one is mineralized (U, Sn, Nb and Ta) and parallel to the foliation planes (WNW-ESE). Whereas the youngest one is non–mineralized and cross-cutting the foliation planes, trending NE to ENE (Ibrahim et al., 2004). Microscopically, these rocks are coarse- to very coarse-grained (>50 in vol. % porphyroclasts), green to dark greenish grey in color.

Microscopically, these rocks are mainly consisting of oriented K-feldspars, quartz, plagioclase and very minor amounts of biotite flakes. The muscovite, sericite, kaolinite and chlorite are secondary minerals while zircon, apatite and opaques are accessories.

b- Mylonites cover a large area representing 65% in volume of the cataclastic rocks with low to medium relief. They are medium- grained, well banded, intercalated with protomylonite and strongly foliated. The mylonites are affected by weathering in a variable degrees producing red to yellow colors due to the alteration of sulphides producing iron oxides (hematite-limonite). Mylonites developing in the semi-brittle regime have a characteristic fabric with two main components: porphyroclasts and matrix. The matrix or groundmass forms finely layered and fine-grained recrystallized material with a planer and linear fabric. The mylonite rocks contain blocks of mafic-ultramafic rocks and bands of tremolite-actinolite (Saleh, 1997 and Ibrahim et al., 2004). In south Wadi Abu Rusheid at Mediant Nugrus, the intercalations between the protomylonite and mylonite rocks are common indicating the sedimentary origin.

Microscopically, it consists of porphyroclasts of quartz, K-feldspar, plagioclase, muscovite and minor biotite flakes. Sericite, kaolinite, titanite and epidote are secondary minerals.Cordierite, zircon, topaz, apatite, monazite, fluorite and opaques (iron oxides) are accessories.

c-The ultramylonites cover about 17% in volume of the cataclastic rocks. They are highly brecciated and enriched by polymineralization and cross-cutting the ultramylonites. The ultramylonites are frequently dissected by pegmatite and quartz viens, which are usually concordant with the foliation planes. The altered rock acquires reddish to yellowish color due to staining with iron solutions. Columbite-tantalite occurs abundantly as disseminated minute grains or as single crystal and aggregates visible by naked eyes (Ibrahim et al., 2004). Microscopically, the rock consists essentially of quartz, K-feldspars, plagioclases biotite and muscovite embedded in cryptocrystalline groundmass. Zircon, fluorite, apatite and opaques (iron oxides) are accessories. Sericite, kaolinite, epidote and chlorite are the common alteration products (Ibrahim et al., 2004).

EXPERIMENTAL METHODS

A three bulk representative composite samples were collected from the highest field recorded radioactive anomalies from protomylonite, mylonite and ultramylonite (Fig.2). The weight of studied mylonite sample is 7 kg (MD1), protomylonite sample is 8 kg (MD2), and 7.5 Kg for ultramylonite (MD3). The latter was subjected to the conventional mineral separation procedures namely; disintegration, sizing and heavy liquid separation by bromoform >2.85 to estimate the heavy mineral content of each size fraction. The heavy fractions were then subjected to counting analysis for estimating the abundance of the studied heavy minerals. Several grains of the latter are hand picked from all the obtained sink fractions for X-ray diffraction analysis using Phillips X-ray diffractometer, Model PW- 105018.

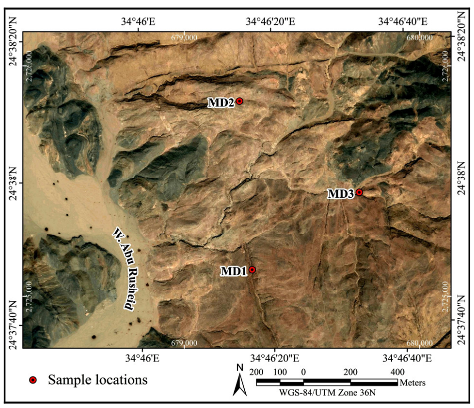

Fig. 2: False color composite land sat TM ratios image map of samples from Abu Rusheid area, South Eastern Desert, Egypt

The X-ray fluorescence technique (XRF) is used to determine the trace element contents using PHILIPS X, Unique-II spectrometer with automatic sample changer PW 1510.

The physical beneficiation applied in the present study mainly consists of comminution and concentration processes. The latter are carried out using the laboratory wet Wilfely shaking. Uranium content of the various size fractions and their concentrates is determined using gamma spectrometric analysis.

RESULTS AND DISCUSSION

Radiometric Analysis and Trace Elements Contents

The radioactive elements, uranium, thorium, radium and potassium contents are analyzed radiometrically using gamma ray spectrometry multichannel analyzer. In this technique, four energy regions of interest representing ^{234}Th, ^{212}Pb, ^{214}Pb and ^{40}K isotopes are used to estimate eU, eTh, Ra and K_{40}, respectively. Uranium and thorium are measured indirectly using their corresponding gamma-ray emitting daughters, ^{234}Th and ^{212}Pb (Matolin, 1991) consequently, uranium is expressed as eU (equivalent U) and thorium is expressed as eTh (equivalent Th).

The probable measurement error is generally 10%. The results of the radiometrical analyses for U and Th are listed in Table (1). The eU of the cataclastic rocks range from 4170-790 ppm with an average of 2480 ppm. The eTh range is 8660-6210 ppm with an arithmetic average of 7435 ppm. This means that mylonite rock sample is more radioactive than both protomylonite and ultramylonite rocks.

The trace elements content of the study original rock varieties is evaluated by XRF analysis performed on seven trace elements in some representative samples of the cataclastic rocks. The results are summarized in Table (2), the obtained results indicates quite clearly that the studied samples are enriched in Zr, Nb, Y, Pb, Zn, Rb and Cu.

Table 1: The results of radiometric analyses of the different verities of Abu-Rusheid cataclastic rocks

Rock Variety	eU (ppm)	eTh (ppm)	Ra (ppm)	K_{40} (%)
Mylonite sample (MD1)	4170	8660	2620	ULD
Protomylonite sample (MD2)	2544	7560	281	0.57
Ultramylonite sample (MD3)	790	6210	50	ULD

ULD= under limite of detection

Table 2: Trace element contents (ppm) of the studied cataclastic rocks by XRF technique.

Rock Variety	Zr	Y	Nb	Pb	Zn	Rb	Cu
Mylonite (MD1)	1045	1330	1979	110	1088	269	45
Protomylonite (MD2)	873	1388	877	276	2667	269	70
Ultramylonite (MD3)	534	242	979	97	444	303	43

Mineralogical Investigations

The detailed mineralogical characteristics of the separated minerals showed the following:

Thorite ($ThSiO_4$) and Uranothorite ($(Th, U) SiO_4$)

Angular to subangular black massive thorite grains were actually detected in the studied samples from mylonite, protomylonite and ultramylonite. Thorite occurs as metamictized short prismatic crystals exhibiting deep brownish color and sometimes associated with uranothorite and confirmed by X-ray diffraction (Fig.3). Some crystals exhibit the bipyramidal habit, like zircon, where the prism faces are diminished. It is characterized by reddish brown or yellow color in polarized light. Thorite is isotropic due to metamictization.

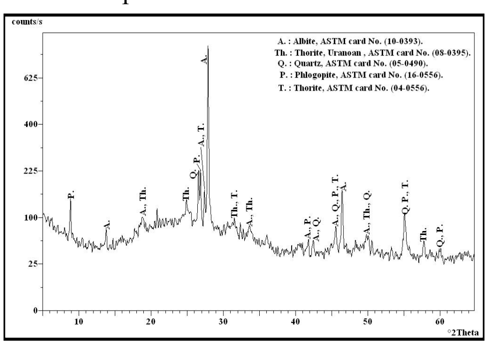

Fig.3:X-ray diffractograms of thorite and uranothorite associated with albite, quartz, and phlogopite minerals

Zircon ($ZrSiO_4$)

It is clearly evident that zircon crystals of the studied radioactive samples are generally characterized by their coarse size and distinctive habit. They are mostly pale to deep brown in color and generally sub-translucent to opaque with dull luster and confirmed by X-ray diffraction (Fig.4). The most common habit is the bipyramidal form with various pyramidal faces and outgrowths. Some zircon crystals are generally colorless and transparent. This type was found to be concentrated in the fine size fractions. Another some zircon crystals are characterized by the presence of outgrowth of sulphide mineral and by the presence of minute inclusions of kasolite crystals.

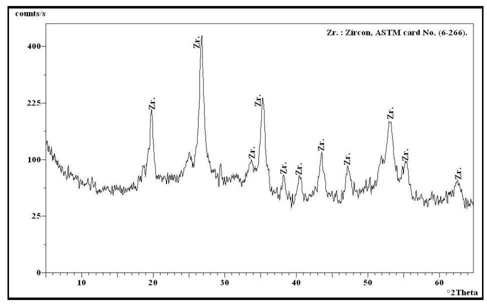

Fig.4: X-ray diffractograms of zircon mineral detected from cataclastic rocks

Columbite [(Fe, Mn) Nb_2O_6]

Columbite grains were detected in the studied samples of Abu Rusheid area and confirmed by X-ray diffraction (Fig.5). Columbite is a natural oxide of niobium, tantalum, ferrous and manganese. Therefore it is considered the principal ore of niobium and tantalum. The grains are black to deep brown with metallic appearance, flattened, prismatic and euhedral to subhedral crystals. Most crystals are broken and stained with iron oxide which are partially coated grains or coated all surface of grains. Few grains form massive aggregates.

Abdalla et al. (1998) explained the columbite at Abu Rusheid area ranges in composition between Fe Nb_2O_6 and Mn Nb_2O_6. They (Op. Cit.) mentioned also that columbite is characterized by its high Ti and U, and low Ta contents, reflecting their alkaline nature (K^+, Na^+ rich) and relatively high-temperature fluids.

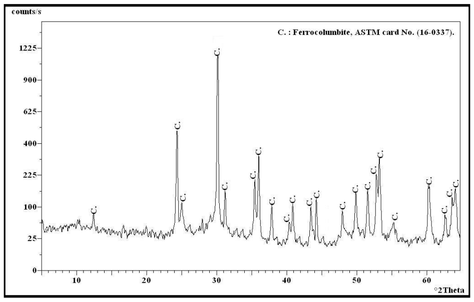

Fig.5:X-ray diffractograms of ferrocolumbite mineral detected from protomylonite rocks

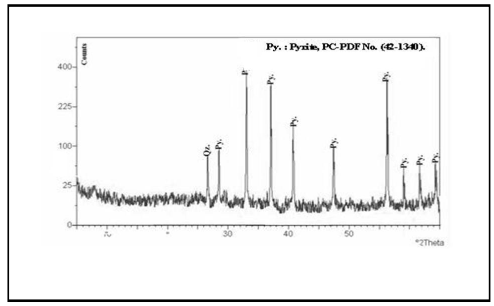

Fig.6: X-ray diffractograms of pyrite mineral recorded from protomylonite rocks

Sulphides

Sulphides are relatively common in the studied cataclastic rocks. They are represented by pyrite (FeS_2), galena (PbS), chalcopyrite ($CuFeS_2$) and covellite (CuS). Sulphides grains were detected in the studied cataclastic samples of Abu Rusheid area and confirmed by X-ray diffraction (Fig.6).

Pyrite is considered as the mother of the widely distributed iron minerals in the study area. Pyrite is found as euhedral crystals of cubic habit or as semi-rounded form. The fresh pyrite is characterized by its pale brass yellow color. This color varies from deep red to black in case of alteration. The orientation of lenticular aggregates of granulated pyrite within foliation and the presence of pressure shadows around many pyrite grains, suggest that pyrite is formed during the formation of the foliation. Generally, concentration of sulphides minerals is common in protomylonite and scarcely in mylonite samples.

Galena and chalcopyrite minerals are recorded especially in ultramylonite and protomylonite samples and appear as outgrowth in between zircon crystals in ultramylonite and protomylonite samples.

Hassan (1964), Saleh (1997) and Ibrahim et al. (2002 and 2004) recorded the sulphide minerals as a series of pseudomorphic oxidation products of pyrite such as chalcocite, covellite, cuprite, goethite and hematite minerals.

Xenotime

Xenotime occurs in cataclastic rocks as small disseminated crystals in association with zircon and columbite, muscovite and hematite (Figs.7&8) brownish in color, occasionally pleochroic from pale pink to pale yellow. Xenotime is characterized by short to long prismatic bipyramidal crystal shape. Fielding (1970) showed that xenotime exhibits significant substitution of Y by U, Ca and Si. Also, he considers the colored crystals may be associated with the presence of U. They are colorless or pale yellow and the majorities are honey as well as stained by iron oxides.

Kalita, (1961) stated that xenotime is common in mica-bearing rare metal acidic rocks where processes of albitization and silification have been sufficiently important. Increased

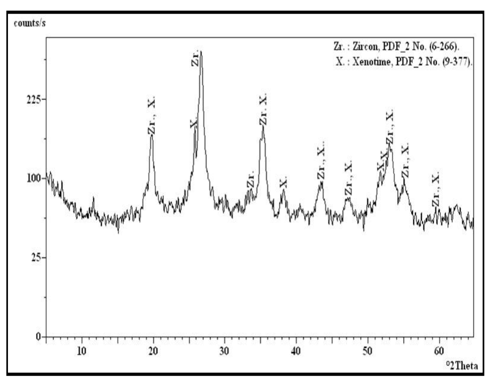

Fig.7: X-ray diffractograms of xenotime associated with zircon mineral collected from ultramylonite rock

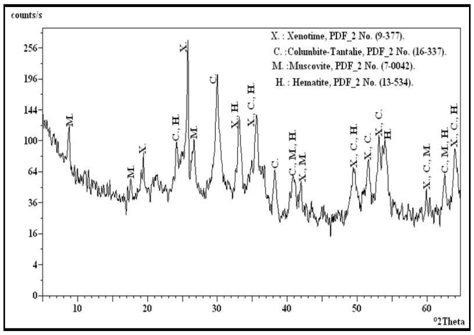

Fig.8: X-ray diffractograms of xenotime associated with columbite, muscovite and hematite minerals recorded from protomylonite rock

REE-bearing minerals suggest a direct dependence on the intensity of albitization and silicification is often present in amount up to several percent, presumably in substitution for (PO_4) but in some resistance at least due to admixed zircon (Dana, 1965).

Secondary uranium minerals

Uranophane Ca $(UO_2)_2SiO_3$ $(OH)_{2\cdot5}(H_2O)$

It has been confirmed by XRD analysis, (Fig.9). Under the binocular microscope, it occurs mainly in massive form with yellow color and dull luster and sometimes exhibits radiated shape.

Kasolite [Pb (UO_2) $SiO_4.H_2O$]

It is identified in the studied cataclastic rocks. Figure (10) shows the XRD pattern of the studied kasolite associated with uranophane. It occurs as massive granular masses having resinous to greasy luster and lemon yellow color.

Meta-autunite Ca $(UO_2)_2(PO_4)_{2.2\text{-}6}(H_2O)$

It is a dehydration product of its close cousin, autunite. Meta-autunite is detected in the investigated cataclastic rocks by XRD analysis (Fig.11). Its crystals have sub-parallel growth and grading into fan-like aggregates. It is pale yellowish green and strained brown in color.

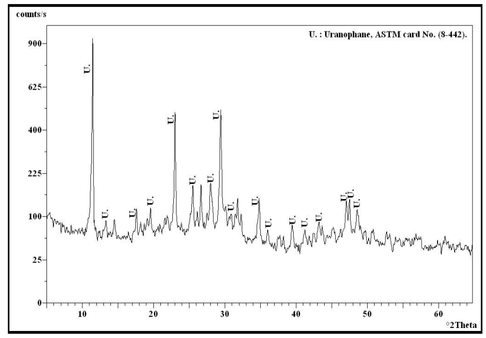

Fig.9: X-ray diffractograms of uranophane mineral detected from cataclastic rocks

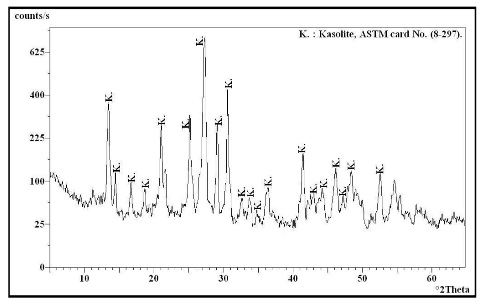

Fig.10: X-ray diffractograms of kasolite mineral detected from cataclastic rocks

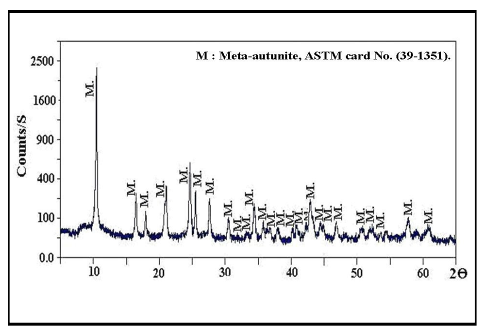

Fig.11: X-ray diffractograms of meta-autunite mineral detected from cataclastic rocks

Cassiterite

Cassiterite is a tin mineral recorded in mylonitic rocks of Abu Rusheid area (Fig.12). Cassiterite is found in the form of irregular grains and sometimes prismatic accumulations as brown to black in color, varying greatly in deepness.

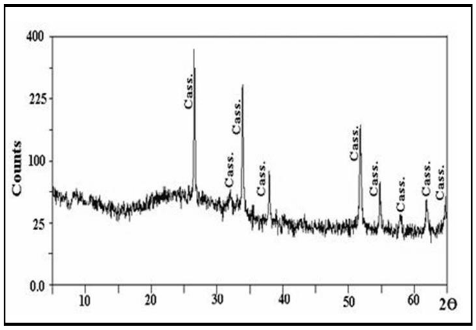

Fig.12: X-ray diffractograms of cassiterite mineral detected from cataclastic rocks

Grain Counting Technique

Microscopic examination of the heavy fractions of the three size classes (-0500 + 0.250 , -0.250 + 0.125 and -0.125 + 0.063 mm) revealed that the content of the heavy minerals in the studied Abu Rusheid cataclastic samples amounts to 3.82% for mylonite, 3.67% for protomylonite and 3.67% for ultramylonite, respectively. Thorite, zircon, columbite and sulphides are the most predominant mineral. The contents of heavy and accessory minerals have been determined using the counting technique according to indicator mineral method after Jones (1987). The obtained results are shown in Tables (3, 4 & 5).

Sample preparation and gravitative separation

Preparation of a suitable feed for the separation is very useful for attaining the maximum efficiency of the used equipment. The size of the separated particles is the most important factor affecting separation. This matter has been discussed by several authors (Taggart 1944; Pryor 1974 and Gaudin 1980). According to Wills (1979), the correct degree of liberation is the key to the success in mineral processing. Controlled comminution operation (crushing and grinding) was carried out on representative bulk sample collected from the three varieties of cataclastic rocks (assaying 0.7560% eTh and 0.7560 eU for prtomylonite sample; 0.8660% eTh and 0.4170 eU for mylonite sample and 0.6210% Th and 0.0790U for ultramylonite sample) in order to reduce the size of the head sample to pass 5.0 mm screen. This has been achieved by applying a combination of jaw crushers and a roll mill crusher. The oversized (+5 mm) fraction was recycled to the secondary jaw crusher. The under size (-5 mm) fraction was fed to a roll mill crusher followed by screening at 0.5 mm. The + 0500 mm fraction was recycled to the roll mill while the under size (-0.500 mm) was deslimed using a desliming cone. The deslimed size fraction (-0.500 mm) was dried and screened using a set of screens represented by (0.500, 0250, 0.125, 0.0630 mm) screens. The latter was chosen in the light of liberation investigation and to save the majority of heavy

Table 3: Specimen particle count tabulation of mineralized mylonite sample, Abu Rusheid area

Sp. No.			Mylonite sample (MD.1)
Weight Sp.			7 kg
Heavy fraction weight			267.4 g = 3.82%
Sieve fraction	-0.5 + 0.25	- 0.25 + 0.125	-0.125 + 0.063
Weight Percent (a)	27.27g = 10.2%	39.58g = 14.8%	200.55g = 75%
Mineral variety and grain count (b)			
Thorite	285	643	1530
Zircon	198	382	890
Columbite	31	45	110
Sulphide	9	13	20
Relative density (c)			
Thorite	6.70	6.70	6.70
Zircon	4.68	4.68	4.68
Columbite	5.2	5.2	5.2
Sulphide	5.02	5.02	5.02
(b) x (c) = (d)			
Thorite	1909.5	4308.1	10251
Zircon	926.64	1787.76	4165.2
Columbite	161.2	234	572
Sulphide	45.18	85.26	100.4
	Total = 3042.52	Total = 6415.12	Total = 15088.6
Fraction percent =100 x (d) / □ (d)			
Thorite	62.761	67.16	67.94
Zircon	30.46	27.87	27.60
Columbite	5.30	3.64	3.77
Sulphide	1.48	1.33	0.67
Sample percent =(a) x (d) / □ (d)			
Thorite	6.40	9.49	50.95
Zircon	3.11	4.12	20.70
Columbite	0.54	0.54	2.84
Sulphide	0.15	0.20	0.51

Therefore the approximate composition of heavy minerals in the three fractions:
Thorite 6.40 + 9.94 + 50.95 = 67.29%
Zircon 3.11 + 4.12 + 20.70 = 27.93%
Columbite 0.54 + 0.54 + 2.84 = 3.92%
Sulphide 0.15 + 0.20 + 0.51 = 0.86%
Total = 100%
The approximate concentration in the original representative mylonite sample = 7 kg
Thorite = 2.57% Zircon = 1.07% Columbite = 0.15% and Sulphides = 0.03%

Table 4: Specimen particle count tabulation of mineralized protomylonite sample, Abu Rusheid area

Sp. No.			Protomylonite sample (MD.2)
Weight Sp.			8kg
Heavy fraction weight			293.4 g = 3.67%
Sieve fraction	-0.5 + 0.25	- 0.25 + 0.125	-0.125 + 0.063
Weight Percent (a)	26.72g = 9.11%	30.89g = 10.52%	235.81g = 80.38%
Mineral variety and grain count(b)			
Thorite	72	250	390
Zircon	60	140	235
Columbite	35	40	48
Sulphide	8	27	35
Relative density (c)			
Thorite	6.70	6.70	6.70
Zircon	4.68	4.68	4.68
Columbite	5.2	5.2	5.2
Sulphide	5.02	5.02	5.02
(b) x (c) = (d)			
Thorite	482.4	1675	2613
Zircon	280.8	655.2	1099
Columbite	182	208	249.6
Sulphide	40.16	135.54	175.7
	Total = 985.36	Total=2673.74	Total= 4137.3
Fraction percent =100 x (d) / □(d)			
Thorite	48.96	62.65	63.16
Zircon	28.50	24.50	26.56
Columbite	18.47	7.78	6.03
Sulphide	4.07	5.07	4.25
Sample percent =(a) x (d) / □ (d)			
Thorite	4.46	6.59	50.76
Zircon	2.60	2.58	21.34
Columbite	1.68	0.82	4.85
Sulphide	0.37	0.53	3.41

Therefore approximate composition of heavy minerals in the three fractions:
Thorite 4.46 + 6.59 + 50.76 = 61.81%
Zircon 2.60 + 2.58 + 21.34 = 26.52%
Columbite 1.68 + 0.82 + 4.85 = 7.35%
Sulphide 0.37 + 0.53 + 3.41 = 4.31%
Total = 99.99%
The approximate concentration in the original representative protomylonite sample = 8kg
Thorite = 2.27% Zircon = 0.97% Columbite = 0.27% and Sulphides = 0.16%

Table 5: Specimen particle count tabulation of mineralized ultramylonite sample, Abu Rusheid area

Sp. No.			Ultramylonite sample (MD.3)
Weight Sp.			7.5 kg
Heavy fraction weight			275.34 g = 3.67%
Sieve fraction	-0.5 + 0.25	- 0.25 + 0.125	-0.125 + 0.063
Weight Percent (a)	36.90g = 13.4%	51.21g = 18.60%	187.23g = 68%
Mineral variety and grain count(b)			
Thorite	395	563	975
Zircon	125	280	375
Columbite	40	38	45
Sulphide	9	6	8
Relative density (c)			
Thorite	6.70	6.70	6.70
Zircon	4.68	4.68	4.68
Columbite	5.2	5.2	5.2
Sulphide	5.02	5.02	5.02
(b) x (c) = (d)			
Thorite	2646.4	3772.1	6532.5
Zircon	585	1310.4	1755
Columbite	208	197.6	234
Sulphide	45.18	30.12	40.16
	Total = 3484.58	Total=5310.22	Total=8561.66
Fraction percent =100 x (d) / □(d)			
Thorite	75.95	71.03	76.30
Zircon	16.79	24.68	20.50
Columbite	5.97	3.72	2.73
Sulphide	1.29	0.57	0.47
Sample percent =(a) x (d) / □ (d)			
Thorite	10.18	13.21	51.88
Zircon	2.25	4.59	13.94
Columbite	0.80	0.69	1.86
Sulphide	0.17	0.11	0.32

Therefore approximate composition of heavy minerals in the three fractions:
Thorite 10.18 + 13.21 + 51.88 = 75.27%
Zircon 2.25 + 4.59 + 13.94 = 20.78%
Columbite 0.80 + 0.69 + 1.86 = 3.35%
Sulphide 0.17 + 0.11 + 0.32 = 0.60%
Total = 100%
The approximate concentration in the original representative ultramylonite sample = 7.5kg
Thorite = 2.76% Zircon = 0.76% Columbite = 0.12 and Sulphide = 0.02%

minerals in the liberation size fraction. The size fractions were collected, weighed and the representative portions from each fraction was subjected to uranium determination using gamma spectrometric analysis. The sequence of processes followed in the crushing and liberation of the studied samples is presented in the flowsheet (Fig. 13).

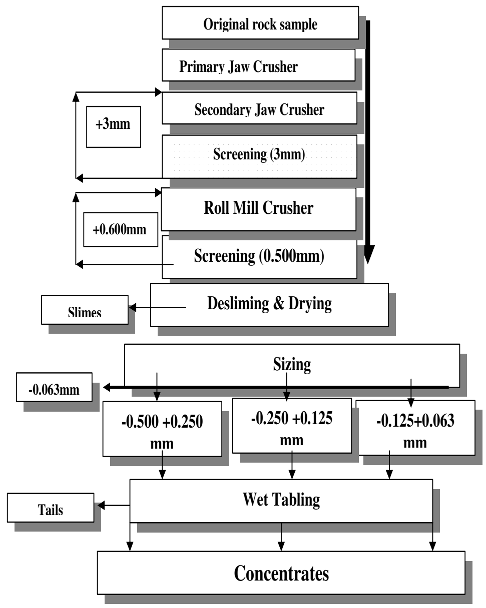

Fig.13: A proposed flow sheet for upgrading the heavy minerals from Abu Rusheid cataclastic rocks

According to Taggart (1994) the feed to gravitative separation must be uniform in size. Accordingly, the deslimed size fractions (-0.500 + 0.250 mm, -0.0250 + 0.125 mm) and (-0.125 + 0.063 mm) were separately fed to the Wilfely table to obtain a primary concentration. The purpose was to reduce the bulk light gangue minerals from the deslimed size fractions and attain clean concentrate for each size fraction. This operation was optimized by using less feed, less water, less tilt as much as possible, shorter length of stroke beside a low speed of the deck. The obtained cleaner concentrates were mainly composed of thorite, zircon columbite together with sulphides and mica. The efficiency of tabling was found to increase by decreasing the size range of the feed.

Material balance for upgrading Abu Rusheid samples are given in Tables (6, 7 and 8). These results reveal that about 86.53% and 93.90% from the original thorium and uranium present in the original sample of protomylonite was saved within 81.26% by weight. Also, 85.77% and 90.01% from the original thorium and uranium present in the original sample of mylonite was saved within 84.99% by weight. The obtained results reveal that about 85.69% and 68.20% from the original thorium and uranium respectively present in the original sample of ultramylonite was saved within 82.78% by weight. Also, these results indicate that the crushing operation was successful for saving the majority of radioactive minerals.

According to the results of the tabling operations shown in Table (6) which reveal that ,the final concentrates of mylonite sample containing 5.2800 %Th with a recovery of 73.65% and 2.60% U with a recovery 75.32% in 12.08% by weight out of the deslimed size fraction (-0.500 +0.063mm) feed having 0.8660% eTh and 0.417% eU.

The results of the tabling operations shown in Table (7) reveal that the final concentrates of protomylonite sample containing 4.2900 % Th with a recovery of 75.47% and 0.601% U with a recovery 31.42% in 13.30% by weight out of the deslimed size fraction (-0.500 +0.063mm) feed having 0.7560% eTh and 0.2544eU.

Table 6 : Material balance of upgrading Abu Rushied mylonite sample

Sp. Variety	Products	Wt. (%)	Assay Th %	Distribution Th%	Assay eU %	Distribution eU%
Mylonite	Concentrate	12.08	5.2800	73.65	2.60	75.32
	Tailings	72.91	0.1440	12.12	0.084	14.69
	Deslimed (-0.500 + 0.063)	84.99	0.8860	85.77	0.434	90.01
	Slimes (-0.063)	15.01	0.8210	14.23	0.352	9.99
	Original	100.00	0.8660	100.00	0.417	100

Also, the results of the tabling operations shown in Table (8) reveal that the final concentrates of ultramylonite sample containing 3.0300 % Th with a recovery of 71.77% and 0.32% U with a recovery 59.58% in 14.71% by weight out of the deslimed size fraction (-0.500 +0.063mm) feed having 0.6210% eTh and 0.0790% eU.

Table 7 : Material balance of upgrading Abu Rushied prtomylonite sample

Sp. Variety	Products	Wt. (%)	Assay eTh %	Distribution eTh%	Assay eU %	Distribution eU%
Prtomylonite	Concentrate	13.30	4.2900	75.47	0.601	31.42
	Tailings	67.96	0.1230	11.06	0.2339	62.48
	Deslimed (-0.500 + 0.063)	81.26	0.7690	86.53	0.2392	93.90
	Slimes (-0.063)	18.74	0.6120	13.47	0.1281	6.10
	Original	100	0.7560	100	0.2544	100

Table 8 : Material balance of upgrading Abu Rushied ultramylonite sample

Sp. Variety	Products	Wt. (%)	Assay Th %	Distribution Th%	Assay eU %	Distribution eU%
Ultraomylonite	Concentrate	14.71	3.0300	71.77	0.320	59.58
	Tailings	68.07	0.1270	13.92	0.0100	8.62
	Deslimed (-0.500 + 0.063)	82.78	0.6860	85.69	0.0710	68.20
	Slimes (-0.063)	17.22	0.5162	14.31	0.0421	31.80
	Original	100.00	0.6210	100.00	0.0790	100

CONCLUSIONS

Cataclastic rocks of Abu Rusheid area are subdivided into protomylonites, mylonites and ultramylonites. The cataclastic rocks at Abu Rusheid area show one of the high radioactive zones in the South Eastern Desert of Egypt. They also contain high contents of Th, U, Nb, Zr, Y and Pb.

The identified minerals in the studied cataclastic rocks (protomylonite, mylonite and ultramylonite) are represented by thorite and uranothorite as thorium minerals, columbite and ferrocolumbite as niobium-tantalum minerals, zircon and sulphides as well as secondary uranium minerals (uranophane, kasolite and meta-autunite), xenotime and cassiterite.

Microscopic examination of the heavy fractions of the three size classes (-0500 + 0.250 , -0.250 + 0.125 and -0.125 + 0.063 mm) revealed that the content of the heavy minerals in the studied Abu Rusheid cataclastic samples amounts to 3.82% for mylonite, 3.67% for protomylonite and 3.67% for ultramylonite respectively. Thorite, zircon, columbite and sulphides are the most predominant minerals respectively.

Physical upgrading of the studied rocks using gravity separation technique indicates a rather good potential to obtain a rich concentrate of heavy minerals, a matter which will be beneficial in reducing leaching plants costs.

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REFERENCES

Abdalla, H. M.; Helba, H., and Mohamed, F.H.,1998. Chemistry of columbite-tantalite minerals in rare metal granitoids, Eastern Desert, Egypt. Mineral. Mag., 62, 821-836.

Assaf, H.S.; Ibrahim, M. E.; Zalata, A. A.; Metwally, A. A., and Saleh, G. M.,2000. Polyphase folding in Nugrus – Sikeit area South Eastern Desert, Egypt. Earth Sci., 12, 1 -16.

Basta, E. Z., and Zaki, M.,1961. Geology and mineralization of Wadi Sikait area, South Eastern Desert. J. Geol. Egypt.,5, no.1, 1-37.

Dana, E.S.,1965. John Wiley and Sons, Inc., New York and London, 851p.(ed.K h. Wedepohl)Vol. 11/4,pp 40 B-O. Springer.

El Gaby, S.,1983. Architecture of the Egyptian basement complex. (Abstract) 5th Int. Conf. Basement tectonics, Cairo.

Fielding, P. E., 1970.The distribution of uranium rare earth's; and colour centers in a crystal of natural zircon. Am. Mineral., 55,428-440.

Gaudin, A.M., 1980. Principales of mineral dressing. TATA McGraw Hill publishing Co.Ltd, New delhi.

Hashad, A. H., and Hassan, M. A.,1959. Report on the prospection work carried out in Wadi El Gemal area, south Eastern Desert, Egypt. Inter. Report, AEE, Cairo, UAR.

Hassan, M.A.,1964. Geology and petrographical studies of the radioactive minerals and rocks in Wadi Sikait-Wadi El Gemal area. Eastern Desert, UAR. M.Sc. Thesis, Fac. Sci., Cairo Univ., 165p.

Hassan, M. A.,1973. Geology and geochemistry of radioactive columbite-bearing psammatic gneiss of W. Abu Rusheid, South Eastern Desert, Egypt. Ann. Geol. Surv. Egypt., III, 207 – 225.

Hegazy, H. M., 1984. Geology of wadi El-Gemal area, Eastern Desert, Egypt. Ph.D. Thesis, Assuit Univ., Egypt, 271 p.

Hume, W. F.,1934. Geology of Egypt. Pat I. The metamorphic rocks,11. Geol. Serv. Egypt.,. 293 p.

Ibrahim, M.E.; Abd El-Wahed, A. A.; Rashed, M. A.; Khaleal, F. M.I.; Mansour, G. M., and Watanabe, K.,2007a. Comparative study between alkaline and calc-alkaline lamprophyres, Abu Rusheid area, south Eastern Desert, Egypt. The 10th Inter. Min., Petrol., and Metall. Eng. Conf., Assuit univ., 99-115.

Ibrahim, M. E.; Assaf, H. S., and Saleh, G. M.,2000. Geochemical alteration and spectrometric analysis in Abu Rusheid altered uraniferous gneissose granites, South Eastern Desert,Egypt. Chem. Erde, 60, 173-188.

Ibrahim, M. E.; El Tokhi, M. M.; Saleh G. M., and Rashed, M. A.,2006. Lamprophyre bearing-REEs, South Eastern Desert, Egypt. 7th Intern. Conf. Geochem., Fac. Sci., Alex. Univ., Alex., Egypt.

Ibrahim, M. E.; Saleh, G. M.; Amer, T.; Mahmoud, F. O.; Abu El Hassan, A. A,; Ibrahim, I. H.; Aly, M. A.;Azab, M. S.; Rashed, M. A; Khaleal, F. M., and Mahmoud, M. A., 2004. Uranium and associated rare metals potentialities of Abu Rusheid brecciated shear zone II, south Eastern Desert, Egypt. (Internal report).

Ibrahim, M.E.; Saleh, G.M.; Abd El Naby, H.H.; Amer, T.; Mahmoud, F.O.; Abu El Hassan, A.A.; Ibrahim, I.H.; Aly, M.A.; Azab, M.S.; Rashed, M.A.; Khalel, F.M., and Mahmoud, M.A.,2002. Uranium and associated rare metals potentialities of Abu Rusheid brecciated shear zone I, south Eastern Desert, Egypt, (Internal Report), 107 p.

Ibrahim, M.E.; Saleh, G. M.; Hassan, M. A.; El-Tokhi, M. M., and Rashed, M. A.,2007b. Geochemistry of lamprophyres bearing uranium mineralization, Abu Rusheid area, south Eastern Desert, Egypt. The 10th Inter. Min., Petrol., and Metall. Eng. Conf., Assuit univ., 41-55.

Ibrahim, M.E.;Watanaba,K.; Saleh, g.M., and Ibrahim, W.S., 2013. Abu Rusheid lamrphyre dykes, South Eastern Desert;As physical-chemical traps for REEs, Zn, Y,U, Cu, W and Ag. (in press).

Jones, M. P.,1987. Applied Mineralogy; A Quantitative Approach. Springer, 259 p.

Kalita, A.P.,1961. Rare-earth pegmatite's of alkurttia and ladoga coast. USSR Academy Sci. Press, Moscow, 120p. (in Russian).

Khaleal, F.M.,2005. Geologic evaluation of some rare metal resources in Nugrus-Sikait area, Eastern Desert, Egypt. Ph.D. Thesis, Fac. Sci., Al Azhar Univ., 187 p.

Matolin, M.,1991. Construction and use of spectrometric calibration pads. A report to the Government of the Arab Republic of Egypt. EGY/4/030-03, Laboratory Gamma Ray Spectrometry.

Osman, R. A.; Osman, A. M., and Ibrahim, M.E.,2007. REE geochemistry of mineralized mylonitic granites at Abu Rusheid area, South Eastern Desert, Egypt.

Pryor, E. J.,1974. Mineral processing. Applied Science publishers Limited. 3rd Edition, London.

Rashed, M.A.,2005. Geologic studies on a new occurrence of Nuclear Materials in Abu Rusheid Area, South Eastern Desert, Egypt. , Ph.D. Thesis, fac. Sci. (Demiatta), Mansoura Univ.,179p.

Raslan, M. F.,2005. Mineralogy and physical upgrading of Abu Rusheid radioactive gneiss, South Eastern Desert, Egypt. The 9th Inter. Mining, Petrol. and Metall. Engineering Conf., Fac. Engineering-Cairo Univ.

Raslan, M. F.,2008. Occurrence of Ishikawaite (Uranium-Rich Samarskite) in the ineralized Abu Rushied Gneiss, Southeastern Desert of Egypt. Inter. Geol. Review J., 50 12: 1132-1140.

Saleh, G. M., 1997. The potentiality of uranium occurrences in Wadi Nugrus Area, South Eastern Desert, Egypt. Ph.D. Thesis, Mansoura univ. Egypt, 171 p.

Saleh, G.M.; Ibrahim, I.H.; Mahmoud, F.O.; Abu El Hassan, A.A.; Rashed, A.A.; Khalel, M.A., and Mahmoud, F.M.,2010. Uranium potentiality of Abu Rusheid area, South Eastern Desert, Egypt. (Internal report).165p.

Saleh, G.M.; Mahmoud, F.O.; Abu El Hassan, A.A.; Rashed, M.A.; Khalel, F.M., and Mahmoud, M.A., 2012. Uranium mineralization and evaluation of ores in the cataclastic rocks of Abu Rusheid area, South Eastern Desert, Egypt. (Internal report).145p.

Taggart, A.F.,1944. Hand book of mineral dressing and industrial minerals. John Wiley and Sons, Inc. New York, London, Sedney.

Wills, B.A.,1979. Mineral processing technology, Pergamon Press, Oxford, New York, Toronto,Sydney, Paris, Frankfurt.

الفحص المعدنى والتركيز الفيزيائى للصخور المهشمة بمنطقة أبو رشيد، جنوب الصحراء الشرقية، مصر

مصطفى السيد محمد درويش

تم تسجيل تمعدنات الفلزات النادرة الإقتصادية للصخور المهشمة بمنطقة وادى أبو رشيد، جنوب الصحراء الشرقية، مصر. أظهرت القياسات الإشعاعية للصخور المهشمة المدروسة أن محتوى الثوريوم المكافىء يتراوح من ٦٢١٠ الى ٨٦٦٠ جزء من المليون بينما يتراوح محتوى اليورانيوم المكافىء يتراوح من ٧٩٠الى ٤١٧٠ جزء من المليون. أثبت الفحص الميكروسكوبى وتقنية حيود الأشعة السينية وكذلك حسابات العد للحبيبات ان معادن الثوريت، الزيركون والكولومبيت هى المعادن الرئيسية المسجلة فى كل أنواع الصخور المدروسة بالإضافة الى كميات قليلة من معادن الكبريتيدات، الكاسيترايت والزينوتيم بجانب بعض تمعدنات معادن اليورانيوم الثانوية مثل اليورانوفين، الكازوليت والميتا-اوتونيت كمكتنفات محتواه ببعض المعادن الأخرى .أشتمل هذا العمل على دراسات بالتركيز الفيزيائي لرفع درجة تركيز المعادن حيث استخدمت تقنية الفصل بالجاذبية. وبتطبيق اللوحة الإنسيابية المقترحة تم التوصل الى ركازات جيدة لبعض المعادن محل الدراسة. وقد أوصت الدراسة بضرورة معالجة الركازات النهائية بهذه الطريقة وذلك لإستخلاص الفلزات الهامة منها.