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MINERALOGY AND PHYSICAL UPGRADING OF ABU RUSHEID RADIOACTIVE GNEISS, SOUTH EASTERN DESERT, EGYPT

By

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ABSTRACT

A unique occurrence of zircon (Hf-rich) and dark Li-mica (zinnwaldite) was recorded in the altered uraniferous gneiss at Wadi Abu Rusheid area, southeastern Desert of Egypt. Heavy minerals mineralogy for the studied samples revealed that zircon and zinnwaldite can reach 7% and 20% by weight of the original rock sample respectively. Zircon is the main radioactive mineral responsible for both U and Th contents in the studied samples. Detailed microscopic examination, X-ray diffraction (XRD) and Scanning Electron Microscope (SEM) were used to identify and describe the studied minerals. Li-mica of dark color is the most dominant mineral followed by zircon in all size fractions. Beside these minerals, some columbite grains occur in much lower amount.

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

1. INTRODUCTION

Rare metal mineralization is particularly and genetically associated with post – orogenic, geochemically distinctive granitoids.^[16] The importance of these granitoids is reflected in their enrichment in elements such as Li, Zr, Nb, Ta, U, Th, Y and REE. Several rare metals anomalous concentrates are distributed in Abu Rushied area, Southeastern Desert of Egypt. This mineralization is mainly associated with the psammitic gneiss. The type and grade of the rare metal mineralization is greatly variable along the host rock. Abu Rushied gneiss was considered as a metamorphosed sedimentary unit of quartzofeldspathic composition.^[9, 2, 5, 6, 3 & 14] However, it is considered as a highly mylonitic gneissose granitic rock, ranging in composition from granodiorites to adamellites.^[10]

Abu Rushied gneissose granite (psammitic gneiss) is mainly composed of quartz, K-feldspar (orthoclase, microcline and perthite), oligoclase and biotite. Hafnium is found as a major constituent in the mud zircon of Wadi Abu Rusheid and Wadi Nugrus area.^[4] IR spectra for this variety of zircon (hafnium-rich) show remarkable variations in absorption bands with respect to normal zircon.^[8] The studied zircon is dated by U/Pb method and reported a concordia of 1.77 B.Y.^[2]

Abu Rushied - Sikeit area represents a small part of the Precambrian basement of the southeastern desert and is located some 90 km southwest of Marsa Alam on the Red Sea Coastal plane (Fig.1). This study aim to investigate the heavy minerals content and distribution of the accessory heavy minerals as well as physical separation to produce economic minerals with an acceptable recovery using mainly gravity and magnetic separation techniques.

2. EXPERIMENTAL METHODS

A bulk composite sample (~10 Kg) was collected from the highest field recorded radioactive anomalies. Concentrates of heavy minerals were obtained from various representative samples through applying crushing, desliming and sizing. This was followed by heavy liquid separation using bromoform (sp.gr.2.85 gm/cm³) to estimate the heavy mineral content of each size fraction. The sink heavy fractions were then subjected to counting analysis for estimating the abundance of the studied heavy minerals. Several grains of the latter were hand picked from all the obtained sink fractions for X- ray diffraction analysis using Phillips X-ray diffractometer (Model PW- 105018) and for quantitative elemental analysis by the Environmental Scanning Electron Microscope (ESEM). The latter is a Philips Model XL 30 and is supported by an energy dispersive X- ray unit (EDAX).

The magnetic behaviour of the studied heavy mineral fractions was investigated using Frantz Isodynamic separator. Uranium content of the various size fractions and their concentrates was determined using gamma spectrometric analysis.

3. RESULTS AND DISCUSSION

3.1. Mineralogical Investigations

Microscopic examination of the heavy fractions of the three size classes (-0.600 + 0.400 mm), (-0.400 + 0.200mm) and (-0.200 + 0.072mm) revealed that the content of the accessory minerals in the studied Abu Rushied gneiss sample amounts to about 30%. Zircon and Li-rich mica (zinnwaldite) represent about 96% of the obtained heavy fractions. The contents of heavy and accessory minerals have been determined using the counting technique. The

obtained results are shown in Table (1). These data indicate that zinnwaldite is the predominant mineral followed by zircon in all size fractions (-0.600 to 0.072 mm). Also, the average abundance of zircon and zinnwaldite represent about 26% and 70% of the total accessory heavy minerals respectively. Beside these minerals, some scattered columbite grains occur in much lower amount.

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

3.1.1. Zircon

It is clearly evident that zircon crystals of the studied radioactive gneiss are generally characterized by their coarse size and distinctive habit. They are mostly pale to deep brown in colour and generally sub-translucent to opaque with dull luster. The most common habit is the bipyramidal form with various pyramidal faces and outgrowths (Fig. 2A). Some zircon crystals are however characterized by extremely short prisms and are more or less equidimensional and exhibiting square cross section. It is referred to the pyramidal combination with extremely short prisms as mud zircon and to the prismatic type with no tendency to be elongated as murky type.^[17]

Several zircon crystals of distinctive habits were hand picked and subjected to elemental analysis using the Environmental Scanning Electron Microscope (ESEM) at 15-25Kv accelerating voltage and a counting time of 60-100 second. The SEM microphotographs (Figs. 2B, C&D) reflected various morphological features of zircon. The EDAX analysis (Fig. 2 E) reflects the chemical composition of zircon. The latter indicates that the major elements in zircon are Zr (66.20%) and Si (26.25%) with appreciable amounts of Hf (4.13%), U (1.25%) and Fe (1.51%).

The studied zircon variety is characterized by its high hafnium content, a matter which renders the concentration of such variety is very important from economic point of view. The rare-metal bearing granites are generally enriched with Hf-rich zircon.^[11] It was also found that different zircon samples from Abu Rusheid area do contain an appreciable amount of HfO₂ that ranges between 4.8 and 6.5 % with an average of 5.6%.^[1]

3.1.2. Zinnwaldite

Zinnwaldite (Li-rich variety) is the most predominant mineral in the studied radioactive gneiss composite sample. It represents about 20% by weight of the original sample. It occurs as flexible flakes of plate-like shape possessing dark black colour (Fig.2 F). The luster is glassy to pearly and sometimes stained with iron oxides. Pure samples from these flakes were prepared and subjected to both EDAX and XRD analysis. The obtained EDAX data and XRD pattern for the studied mica are shown in (Fig 2.F&G) and (Fig.4) respectively. The average Li₂O content of the studied mica (zinnwaldite) was found to attain 2.88% by electron microprobe analysis.^[13]

3.1.3. Columbite

Few columbite grains were detected in the studied sample of Abu Rusheid gneiss. The grains are generally black in colour and possess a brilliant metallic luster and belong to two shape varieties. The first is manifested in the form of massive subrounded and pitted particles

containing surface cavities. The second variety occurs in form of irregular grains (Fig.3A). SEM microphotograph and EDAX spectra for columbite grains are presented in (Fig.3B&C) respectively. The obtained results confirm the chemical composition of the separated columbite grains. Thus the major elements include Nb (72.98%), Fe (12.83%), Ta (4.17) and Mn (3.57%) with a remarkable amount of uranium (2.48%), zirconium (2.25%) and silicon (1.72%). Indeed, Nb and Ta mineralizations are generally associated with Hf- rich zircon; ^[12] a matter which is in agreement with the Abu Rushied mineralized gneiss.

3.2. Physical Upgrading

An adequate quantity of the total bulk heavy mineral fraction was obtained by heavy liquid separation using bromoform (sp.gr.2.85 gm/cm³). A proper magnetite free - feed was then prepared and subjected to magnetic separation using the Frantz Isodynamic separator (L-I). The purpose was to determine the behaviour of each heavy mineral during magnetic separation. The setting of the separator during this study was (20°) forward slope and (5°) side slope.

The results shown in Table (2) reveal that the majority of the zircon crystals (86.55 %) are concentrated as non-magnetic fraction at 1.5 amps. On the other hand, most of zinnwaldite flakes (96.40%) are attracted and concentrated at 0.5 amperes together with columbite particles. It is thus evident that variations in the magnetic susceptibilities between zinnwaldite and zircon would constitute the basis for their final magnetic separation. In the meantime, differences in the specific gravities between the studied minerals and the associated gangue minerals would render the gravitative concentration by shaking table as an efficient tool for their primary separation.

It is quite possible to attain primary concentrate from both zircon and zinnwaldite by gravitative technique using the wilfely shaking tabling and the obtained concentrate would then be magnetically treated by the high intensity Induced roll magnetic separator (Carpco Model MI27) to attain final concentrate for each mineral.

3.2.1. Comminution and size analysis

The original rock sample of the studied radioactive Abu Rusheid gneiss sample was subjected to controlled size reduction to -3 mm using a combination of jaw crushers and a hammer mill. This was followed by screening at 0.6 mm screen size.

The undersize (-0.6 mm) was deslimed using a desliming cone. The deslimed fraction was dried and fractionated using a set of screens starting from 0.600 mm down to 0.072 mm which represent the best size for good liberation and also suitable for physical processing. Table (3) shows the results of the granulometric analysis and distribution of uranium among the various size fractions. It is evident from these results that U tends to increase with decreasing the grain size, however, it was remarkably decreased in the finest size (-0.072 mm and slimes). These results suggest that the crushing operation was successful for saving the majority of the uranium content within the size fraction (-0.600 +0.072 mm). It must be noted that the presence of a relatively large amount of hard zircon together with a higher amount of mica flakes in the studied gneiss render the liberation of these minerals to occur by both size reduction and detachment; a matter which would reduce overgrinding and excessive slimes.

The degree of mineral liberation increases if the rock to be crushed is made of loosely bound grains and the presence of microstructural weakness as bedding planes and schistosity.

The microstructural differences in physical properties of adjacent minerals as hardness, brittleness and cleavability would actually lead to liberation by detachment. [7]

3.2.2. Gravitative separation

The feed to gravitative separation must be uniform in size. [15] Accordingly, the deslimed size fractions ($-0.600 + 0.400$ mm), ($-0.400 + 0.200$ mm) and ($-0.200 + 0.072$ 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 cleaner 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 zircon and zinnwaldite. The efficiency of tabling was found to increase by decreasing the size range of the feed.

The results of the tabling operations shown in Table (4) reveal that the final concentrates containing 2.5454% U with a recovery of 96.51% in 31.70% by weight out of the deslimed size fraction ($-0.600 + 0.072$ mm) feed having 0.8360% U.

3.2.3. Magnetic separation

The tabling concentrate of each size fraction was then subjected to high Intensity Induced roll magnetic separator (Carpco Model MI27) in order to obtain pure concentrates of zircon and zinnwaldite. Separation was achieved at a medium air gap between the surface of the rotor and the magnetized pole of 1.5 cm and with a magnetic field current of 1.5 amp. The speed of the roll and the feed rate were adjusted at 100 rpm and 400g/min respectively. The obtained results in Table (5) indicated that the final non-magnetic concentrate of zircon assays up to 10.396% U with a recovery of 97.26% in 23.81% by weight out of the concentrate of feed having 2.5454% U.

A material balance for the different processes is shown in Table (6). It is quite clear that the final non-magnetic zircon concentrate contains up to 10.396% U with a recovery of 84.24% in a weight of 6.83% out of the original sample. On the other hand, the magnetic fraction includes mainly zinnwaldite concentrate together with some columbite grains. A schematic sequence of the processes followed in the upgrading operations is presented in the form of a proposed flowsheet in Fig. (5).

CONCLUSIONS

Heavy minerals investigation of the studied radioactive gneiss from Wadi Abu Rushied area revealed that the accessory heavy minerals represent about 30% by weight of the original sample. Zircon (Hf-rich) and dark Li- mica (zinnwaldite) represent about 96% of the total accessory heavy minerals. The average abundance of zircon and zinnwaldite attains about 26% and 70% of these heavy mineral fractions respectively. Physical upgrading for these minerals produced a final non-magnetic zircon concentrate of 10.396% U with a recovery of 84.24%. The magnetic fractions were found to contain a good concentration of mica.

Due to the economic importance of the studied minerals and their metal values (zirconium, hafnium and lithium) as they are used in several industrial applications, it is recommended to subject both of the final concentrates to proper hydrometallurgical treatment to extract their metal content.

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REFERENCES

1-Abdalla, H. M and Helba, H. (1994) : Chemistry of zircon in rare metal granitoids and associated rocks, Eastern Desert, Egypt. The Sixth International Conference on Geochemistry, 15-17 september, Alexandria University. Abstracts.

2-Abdel Monem, A. A. and Hurley. P. M. (1979): U-Pb dating of zircons from psammitic gneisses, Wadi Abu Rusheid- Wadi Sikeitarea, Egypt. Inst. Appl. Geol., Jeddah, Bull. 3, 165-170.

3-Eid, A. S. (1986): Mineralogy and geochemistry of some mineralized rocks in Wadi El-Gemal, Eastern Desert, Egypt, Ph.D. Thesis, Ain Shams Univ. 165.

4-El Gemmizi. M. A. (1979): The mineralogy and concentration of heavy minerals from the psammitic gneiss of Wadi Nugrus- Wadi Sikait area, Eastern Desert, Egypt. Ph.D. Thesis, Faculty of Science, Cairo University.

5-El Gemmizi. M. A. (1984): On the occurrence and genesis of mud zircon in the radioactive psammitic gneiss f Wadi Nugrus, Eastern Desert, Egypt. J. Univ. Kuwait. Sci., V. 11, 285-294.

6-El-Ramly, M. F. Greiling, R. Kroner, A. and Rashwan, A. A. (1984): On the tectonic evolution of the Wadi Hafafit area and environs, Eastern desert of Egypt. Fac. Earth. Sci., King Abdulaziz Univ., Jeddah, Bull. 6, 113-126.

7-Gaudin, A. M. (1980): Principles of mineral dressing, TATA McGraw Hill publishing Co. Ltd, New Delhi.

8-Guirguis, L. A. and El Gemmizi. M. A. (1994): Infrared study of some Egyptian radioactive minerals, Fourth National Conference on Optical Spectroscopy, Academy of Scientific Research & Technology. P. 85-95.

9-Hassan, M. A. (1964): Mineralogical and petrographical studies of radioactive minerals and rocks in Wadi-Sikait-Wadi El Cemal area, Eastern Desert, Egypt. M.Sc. Thesis, Faculty of Sci. Cairo.

10-Ibrahim. M. E., Assaf. S. H. and Saleh. G. M. (2000): Geochemical Alteration and Spectrometric Analyses in Abu Rusheid Altered Uraniferous Gneissose Granites, south Eastern Desert, Egypt, Chem.Erde 60, p. 173-188.

11-Kempe, U. Gruner, T. Renno, A. D. and Wolf, D. (1997): Hf-rich zircons in rare-metal bearing granites: Magmatic or metasomatism, Mineral Deposits, Proceedings of the fourth Biennial SGA Meeting Turku/Finland/11-13 August, Balkema, Rotterdam.

12-Knorrning, O. von and G. Hornung (1961): Hafnian zircons. *Nature*, 190, 1098-099.

13-Mohamed, F. H., Abdalla, H. M. and Helba, H. (1999): Chemistry of Micas in Rare-Metal Granitoids and Associated Rocks, Eastern Desert, Egypt. *INT. GEOL.REV.*, v.41, p.932-948.

14-Saleh, G. M. (1998): The potentiality of uranium occurrences in Wadi- Nugrus area, South Eastern Desert, Ph.D. unpublished Thesis, Faculty of Sci. Mansoura Univ. 171.

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

16-Tischendorf, G. (1977): Geochemical and petrographic characteristics of silicic magmatic rocks associated with rare-element mineralization, in Stempok, M., Burnol, L., and Tischendorf, G., eds., *Metallization associated with acid magmatism: Prague, Czech.Geol. Surv.* p.41-98.

17-Williams, F. A. Meehan, J.A. Paulo, K. L. John, T. U. and Rushton, H.G.: (1956): Economic geology of the decomposed columbite- bearing granite, Jos Plateau, Nigeria. *Econ. Geol.* 51: 303-32.

TABLES AND FIGURES

Table. 1 Heavy mineral content among the various size fractions of the Abu Rusheid radioactive gneiss.

Mineral % Size (mm)	Zircon	Zinnwaldite	Columbite	*Others
-0.600 +0.400	23.80	70..24	-	5.96
-0.400 +0.200	25.25	72.10	0.35	2.30
-0.200 +0.072	28.55	67.85	1.50	2.10

***Iron oxides and fluorite**

Table.2 Cummulative % of the individual minerals separated as magnetic fractions at different current intensities. Frantz Isodynamic Separator at setting of 20° forward slope and 5° side slope.

Current (amp.) Mineral	0.2	0.5	0.7	1.0	1.2	1.5	Non- mag.1.5
Zircon	-	-	-	1.20	5.00	7.25	100.00
Zinnwaldite	3.50	96.40	100.0	-	-	-	-
Columbite	-	97.50	2.5	-	-	-	-

Table.3 Granulometric analyses and uranium distribution among the various size fractions of Abu Rushied radioactive gneiss.

Size (mm)	Wt %	Assay eU%	Distribution eU%
-0.600 +0.400	28.06	0.6079	20.24
-0.400 +0.200	30.38	0.7765	27.57
-0.200 +0.072	32.03	1.1033	41.93
Deslimed -0.600 +0.072	90.47	0.8360	89.74
-0.072 +Slimes	9.53	0.9069	10.26
Original	100.00	0.8428	100.00

Table. 4. Assay and material balance of the various products of gravitative separation.

Size (mm)	Products	Wt%	Assay eU%	Distribution eU%
-0.600 +0.400	Concentrate	8.42	1.9100	19.08
	Tails	19.64	0.0500	1.16
	Feed	28.06	0.6079	20.24
-0.400 +0.200	Concentrate	9.63	2.3155	26.45
	Tails	20.75	0.0456	1.12
	Feed	30.38	0.7765	27.57
-0.200 +0.072	Concentrate	10.63	3.257	41.08
	Tails	21.40	0.0333	0.85
	Feed	32.03	1.1033	41.93

**Table.5. Assay and material balance of the different products of magnetic separation for
The concentrates of tabling.**

Size (mm)	Products	Wt%	Assay eU%	Distribution eU%
-0.600 +0.400	Magnetic fr.	6.58	0.131	1.02
	Non mag. fr.	1.84	8.274	18.06
	Concentrate of tabling	8.42	1.910	19.08
-0.400 +0.200	Magnetic fr.	7.35	0.096	0.84
	Non mag. fr.	2.28	9.47	25.61
	Concentrate of tabling	9.63	2.3155	26.45
-0.200 +0.072	Magnetic fr.	7.92	0.055	0.51
	Non mag. fr.	2.71	12.618	40.57
	Concentrate of tabling	10.63	3.2570	41.08

**Table. 6. Material balance of the proposed flowsheet for upgrading Abu Rusheid radioactive
gneiss.**

Products	Wt%	Assay eU%	Distribution eU%
1) Desliming and sizing:			
-0.600 +0.072 mm	90.47	0.8360	89.74
Slimes and -0.072 mm	9.53	0.9069	10.26
Original (Head Sample)	100.00	0.8428	100.00
2) Gravitative separation:			
Final Concentrates of Tabling	28.68	2.5454	86.61
Final Tails of Tabling	61.79	0.0427	3.13
-0.600 +0.072 mm	90.47	0.8360	89.74
3) Magnetic separation:			
Final zircon Concentrates (non-magnetic)	6.83	10.396	84.24
Final zinnwaldite Concentrates (magnetic)	21.85	0.0917	2.37
Final concentrates of Tabling	28.68	2.5248	86.61

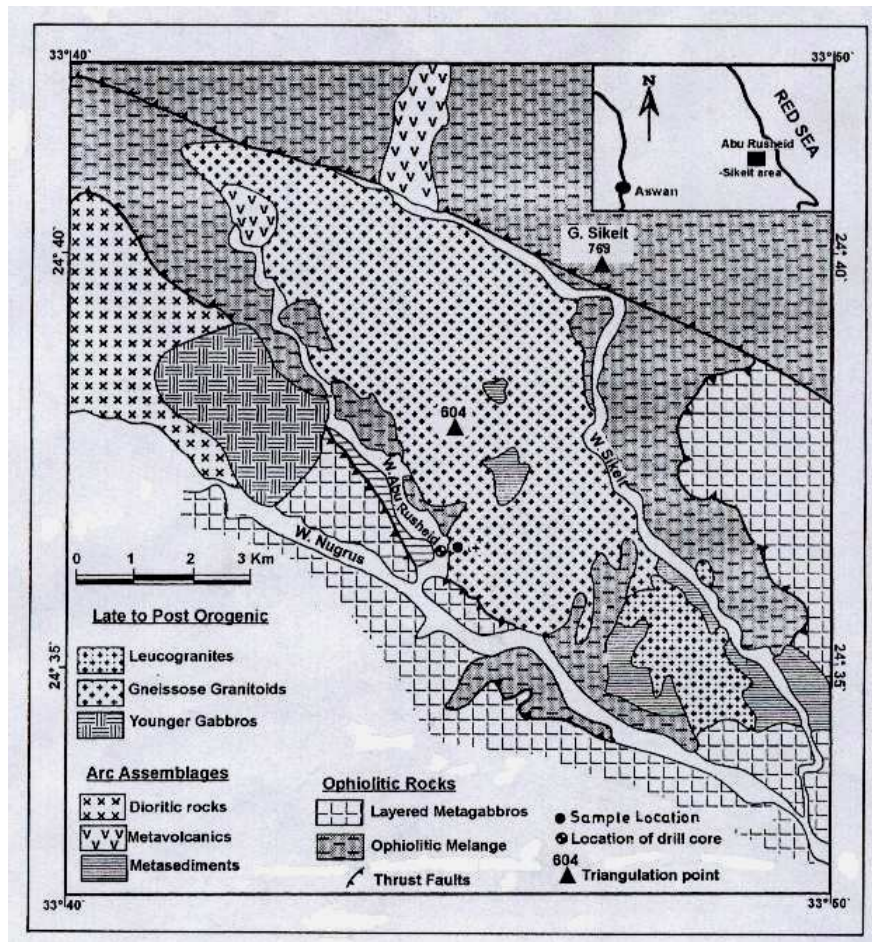


Fig.1. Geologic map of Abu Rushied-Sikeit area, Southeastern Desert of Egypt (After, Ibrahim et al. 2000).

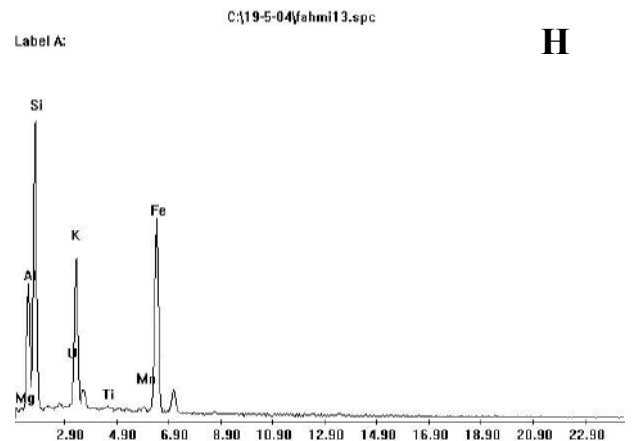
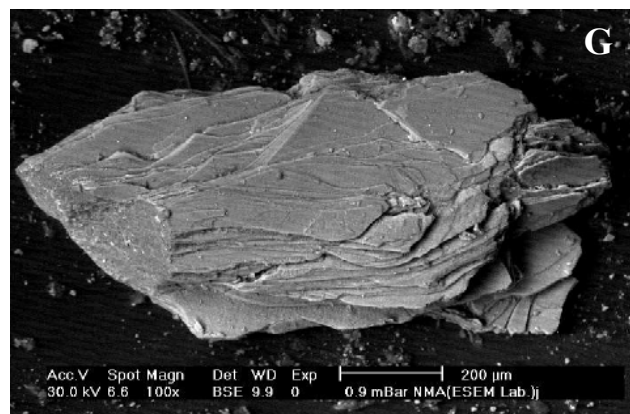
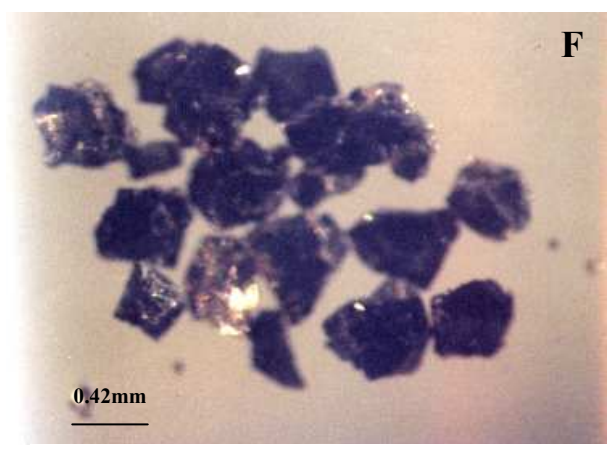
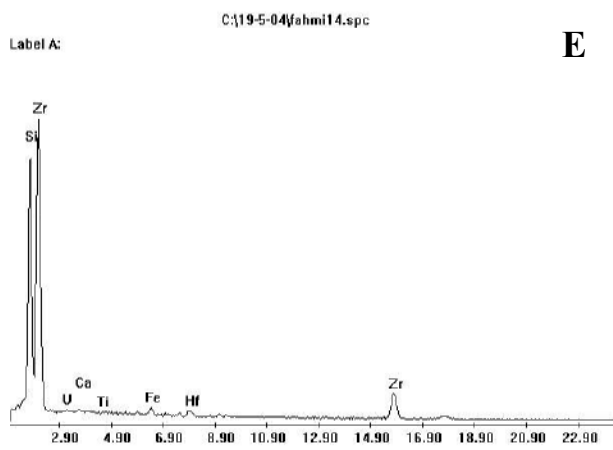
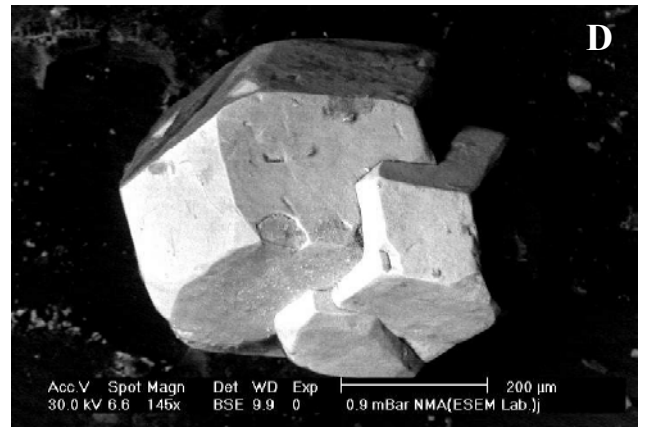
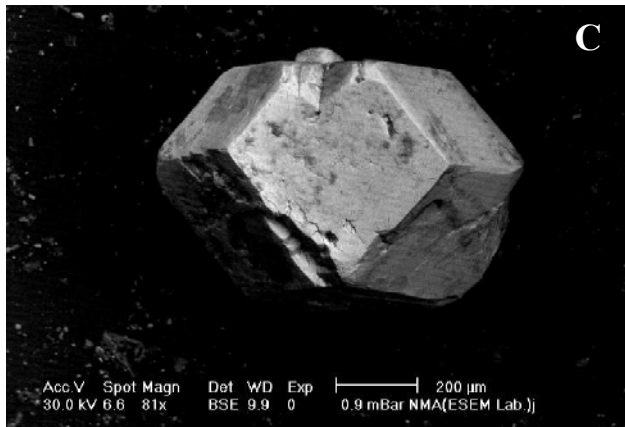
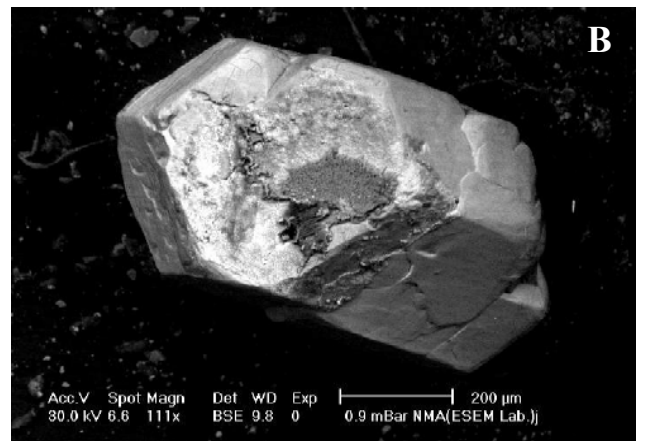


Fig.2 A- Coarse pale to deep brown zircon crystals. Binocular microscope B-C&D- SEM images for the studied zircon exhibiting

pipyramidal form, with various pyramidal faces and outgrowths respectively E- EDAX spectrum for zircon. F- Zinnwaldite flaks of dark color. Binocular microscope. G&H- SEM image and EDAX spectrum for Zinnwaldite.

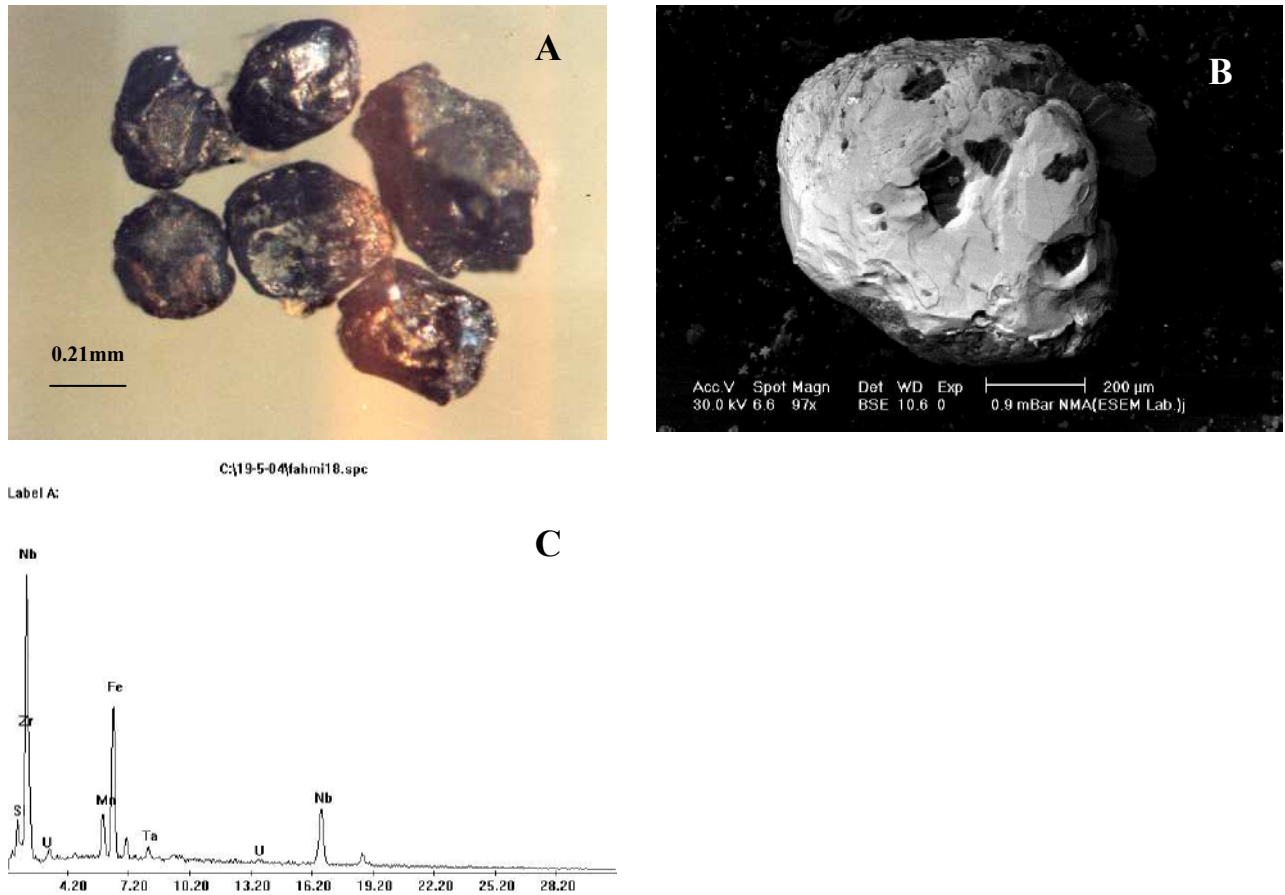


Fig.3. A- Black columbite grains. Binocular microscope. B & C- SEM microphotograph and EDAX spectrum for columbite

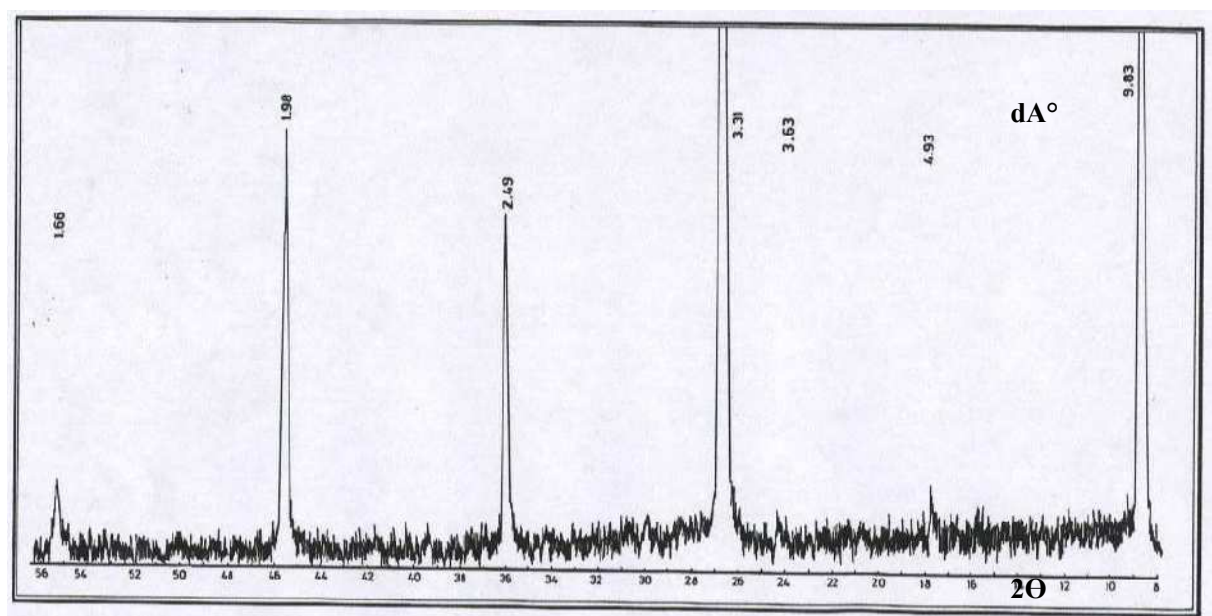


Fig.4 XRD diffractogram for zinnwaldite, (ASTM card No. 13-227).

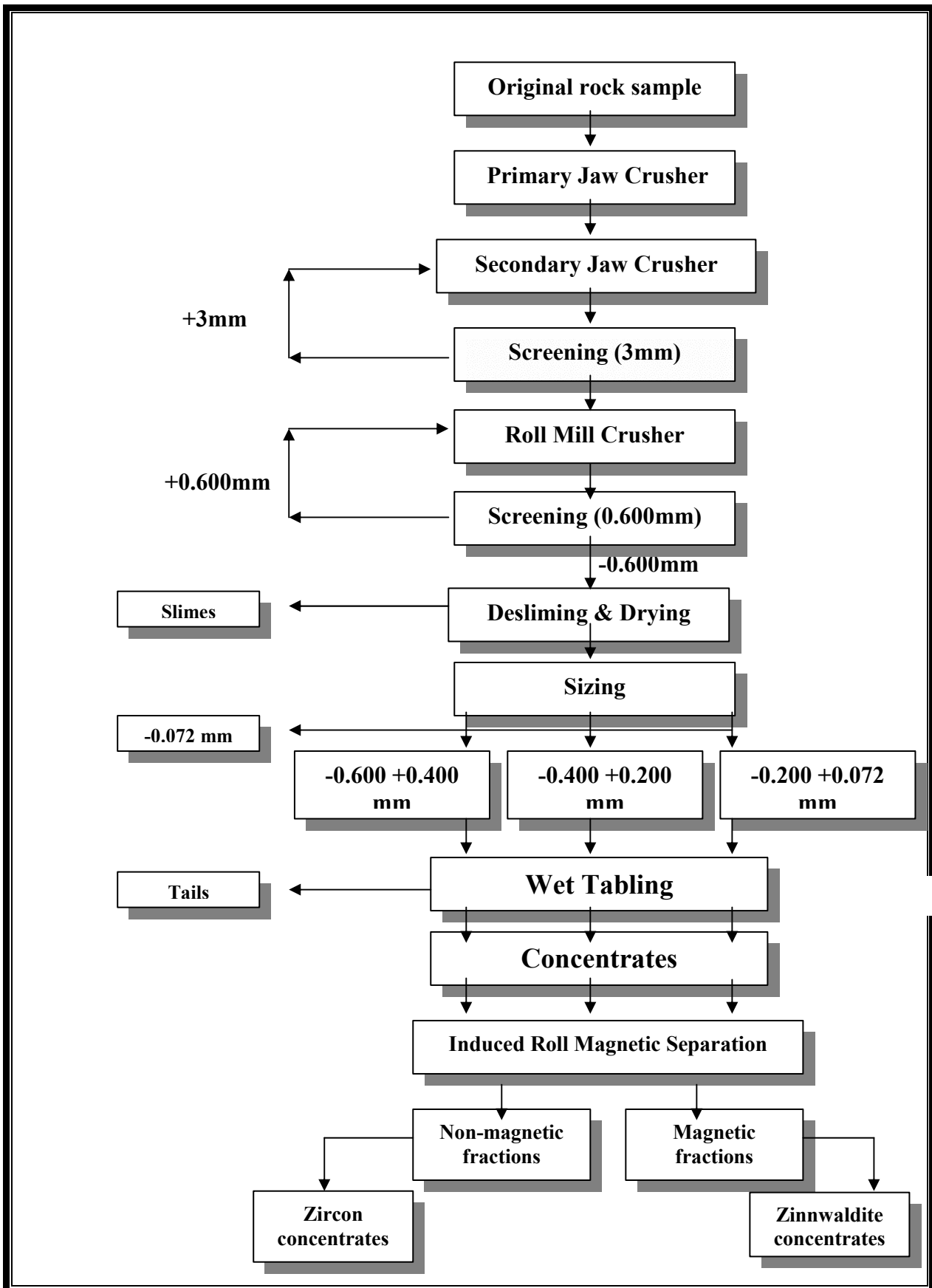


Fig.5. A proposed flowsheet for upgrading the heavy minerals from Abu Rusheid radioactive gneiss.