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CONTRIBUTION TO THE MINERALOGY OF EL SELA URANIFEROUS SHEAR ZONE, SOUTHEASTERN DESERT, EGYPT

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ABSTRACT

El Sela area is one of the most important localities for uranium mineralization in the granites of the southeastern Desert of Egypt. Radiometric analyses for the light and heavy fractions from composite mineralized channel samples collected from the kaolinized granite proved the presence of high uranium concentration in both fractions. The light fraction represents about 84.80% by weight of original sample, containing an average of 26.90% of the total uranium present in these samples. Detailed microscopic examination, X-ray diffraction (XRD) analysis and scanning electron microscope (SEM) were used to identify and characterize the uranium bearing –minerals responsible for the radioactivity in both heavy and light fractions of the studied samples. The heavy fraction (15.2 wt %) is characterized by the presence of secondary uranium minerals (lead-meta-tautunite and phurcalite) together with zircon. In addition of non-radioactive minerals (fluorite, apatite and titanite) are recorded. On the other hand, the high radioactivity of the light fraction is mainly attributed to the presence of secondary uranium minerals coating the light minerals and most probably to the adsorption of hexavalent uranium onto clay minerals (kaolinite) resulting from alteration of feldspars. This mode of occurrence of the uranium must be considered during mineral processing whether by physical or direct hydrometallurgical treatments.

INTRODUCTION

El Sela area is located about 20 Km west of Abu Ramad town. The studied area is bound by longitudes 36º 08\ - 36º 17\ E and latitudes 22º 13\ - 22º 20\ N (Fig. 1). This area covers about 185 Km^2 and is occupied mainly by different Precambrian basement rocks of the southeastern Desert of Egypt. El Sela area is represented mainly by two mica peraluminous monzogranite. Two separate granite plutons are recognized; Gabal (G) Qash Amir and Gabal El Sela. The northern part of El Sela granite is considered as the more U-fertile. It was injected by micro-granite, mineralized quartz veins and lamprophyre dykes. It is dissected by two shear zones perpendicular to each others and sub-parallel normal faults (Fig.2). These shear zones show appreciable wall rock alteration as hematitization, episyenitization and argillic alteration (Ibrahim et al., 2003). At these places there is also old occurrence of gold and Roman ruins.

The mineralization is associated with alteration processes such as kaolinization, silicification, hematitization and fluoritization, Assaf et al., (1999) and Rashed (2001). Ibrahim et al., (2003) mentioned that, among the different rock units in Halaib area; G. El Sela and G. Qash Amir are the most favorable host rocks for uranium mineralizations; they are peraluminous in nature with visible primary and secondary uranium minerals. Also they classified El Sela shear zone as an example of vein type uranium deposit. More attention was paid in this work to the high radioactivity of the light minerals.

Accordingly, and due to the high radioactivity of the light minerals, the present work aims to study in details the mineralogy of both light and heavy fractions in the uraniferous kaolinized granite of El Sella shear zone.

Geologic outlines

The area of study is covered by two main granite plutons namely G. Qash Amir and G. El Sela. The former is characterized by gradational contact with G. El Sela. The area is characterized by presence of vast wadis such as W. Eikwan and W. Yoider (Fig.2) and dissected by many dykes of different compositions cross cutting the biotite granite and two mica granite. They are represented by micro-granite, quartz, basic, lamprophyre, pegmatite, felsite and bostonite. There are two sets of bostonite dykes trending N-S and NE-SW with thicknesses varying from less than one meter to up to 2 meters and extends more than 1 kilometer. They are usually fractured and jointed by several sets of joints. Around these dykes, there are intensively bleached altered zones.

The area is also characterized by a number of shear zones and the most important one is that located in the northern block of biotite-muscovite granite and extends NE-SW (Fig.3). The sheared granite is highly weathered, cavernous and exposed as low to moderate separately hills, coarse-grained. It is characterized by the presence of iron and manganese oxides filling joints and fractures indicating the enrichment of this granite by iron and manganese mineralization. The studied shear zone is characterized by perpendicular fault sets and possess anomalous concentrations of the radioelements proved by the field measurements and airborne readings. Many trenches were excavated along the studied shear zone (Fig. 4) and the studied samples were collected definitely from three trenches with variable depths varying from 1m, 1.5m to 3.5m (Figs.5&6).

Petrographic features

El Sela granite is medium-grained monzogranite (3.0-4.0mm length), pink to pinkish gray in color, composed essentially of plagioclase, potash feldspars and quartz with mica minerals as biotite and muscovite. Close to the shear zones, it is subjected to several post-magmatic processes and intensively altered (kaolinization, silicification, sericitization and hematitization).

The kaolinized granite paid a great attention due to its high radioactivity. It is medium-grained granite ranging in color from whitish to yellowish buff and characterized by plenty of clay minerals as proved by XRD technique. It is composed essentially of quartz, altered feldspars and biotite. The principal occurrences of kaolinite are primary residual deposits formed by weathering or low-temperature alteration of feldspars, muscovite and other Al-rich silicates, (Deer et al, 1992). Most of the potash feldspars are completely altered to kaoline giving quartz (Fig.7a) and release K+ ions following the equation of Walther, (2005).

$2H^{+} + H_2O + 2KAlSi_3O_8 \leftrightarrow Al_2Si_2O_5(OH)_4 + 4SiO_2 + 2K^{+}$

K- feldspar Kaolinite Quartz

Then, this process is considered as the main source of the secondary quartz leading to silicification of Sela granite, producing Qz-rich granite (silicified granite) (see fig.7a). The produced K+ ions play an important role in alteration of plagioclase to clay minerals (Abu Deif et. al., 2007) and may cause transformation of plagioclase to microcline through a process of microclinization by potash-metasomatism (Fig.7b). Accessory minerals are mainly zircon which is partially metamectized (Figs.7b&7c). Secondary uranium minerals are also present as orange material filling the fractures in the clay-transformed plagioclase (Fig.7d)

Bostonite rock is fine-grained, massive rock composed essentially of potash feldspars, quartz and iron oxides. Potash feldspars are represented mainly by sanidine and orthoclase occurring as very fine lathes (<1mm) associated with few crystals of plagioclase and quartz forming bostonitic texture (Fig.8a). Most of the feldspars subjected to post-magmatic processes of alteration and hematitization leading to further enrichment by iron oxides. This rock encloses cubic crystals of pyrite completely oxidized and transformed to pseaudomorphozed hematite (Fig.8b).

Mineralogical Studies

Bulk composite mineralized samples (10kg) were collected from the uraniferous kaolinized granite of El Sela shear zone representing the highest values of anomalous field radioactivity and uranium mineralization. The collected samples were subjected to various mineral separation steps, including disintegration (crushing, grinding), desliming, sizing, followed by heavy liquid separation by bromoform (sp. gr. 2.85 gm/cm3).

In order to determine the distribution of uranium in both heavy and light fractions of the studied rocks, the deslimed size fraction (-0.500 + 0.072 mm) of the original sample, heavy and light fractions were subjected to gamma spectrometric analysis which emphasized that the light fraction (84.80 wt %) contains 26.90% of the total uranium in the original deslimed sample. Such features clearly indicate the percolation of late magmatic, highly fractionated melt associated with high potential fluid phases in the shear zone led to the simultaneous enrichment of uranium, thorium (Michel Cuney report 2001). On the other hand, the heavy fraction (15.20 wt %) contains 73.10% of the total uranium (Table1).

Microscopic examination using stereo-microscope was carried out for the heavy and light fractions and the minerals picked to be recognized by X-ray diffraction (XRD) (Philips X-ray diffractometer, Model PW- 1050/80) supported by the environmental scanning electron microscope (ESEM) (Philips Model XL 30 with energy dispersive X- ray unit)

I-Mineralogical investigation of the heavy fraction:

Microscopic examination followed by XRD identification of the minerals separated from the heavy fraction recognized radioactive minerals and radioelements- bearing minerals as following:

A) Radioactive minerals

1- Lead –Meta Autunite

$(Pb(UO_2)_2(PO_4)_2 \bullet 8(H_2O))$

It is hydrated autunite that characterized by presence of lead ions on the account of calcium ions (Pb++ substitute Ca++). The mineral grains are present as massive granular particles, fibrous and rod-like aggregates, distinguished by their bright colors (canary to greenish yellow) and pearly luster (Fig.9a). It could be recognized by XRD where the diffraction lines are in accordance with the ASTM card no. (29-391) for Pb-meta autunite (Fig.9b). ESEM data reflect the morphological features and chemical composition of lead-meta autunite (Fig.9c).

2- Phurcalite $(Ca_2 (UO_2)_3O_2(PO_4)_2 . 7H_2O)$

It is a calcium uranyl hydrated phosphate mineral contains the same elements as autunite, i.e. Ca, U, P and less water molecules. It occurs as secondary uranium mineral found in cracks and fractures of granite and granite pegmatites. It is found associated with autunite, and meta-autunite or other secondary uranium minerals. They are generally characterized by their softness to crushing by pressing with picking needle. Also, they are present as massive granular particles of platy shape, distinguished by their bright colors (canary to lemon yellow) (Fig.10.a). It could be identified by X-ray diffraction (fig. 10.b). The diffraction lines are in accordance with the ASTM card no. (29-391) for phurcalite. Its composition is confirmed by ESEM reflecting its morphological features and chemical composition (Fig. 10c).

B) Radio-elements bearing minerals

The semiquantitative analyses by ESEM (EDX) for the heavy minerals separated from El Sela sheared granite clarified that they contain appreciable contents of trace elements and REEs (Figs. 11a, b, c, d and e).

1-Goethite (FeO (OH))

Iron oxides are good adsorbents for uranium ions and they are found in the sheared granite as goethite mantled by the secondary uranium mineral lead-metautonite as proved by XRD diffractogram (see fig. 9). EDAX analyses of these oxides clarified that they are associated with uranium minerals and contains uranium ions in their structures (Fig. 11a).

2-Zircon

It is colorless, transparent and generally prismatic with bipyramidal terminations. ESEM data reflect the morphological features and chemical composition of zircon indicating that it has an appreciable amount of trace and rare earth elements (Fig. 11b).

3- Monazite $(Ce,La,Nd,Th)PO_4$

Monazite is the sole thorium mineral that present in El Sela sheared granite. EDAX analysis confirmed its composition and clarified that it contains some of the trace elements such as U, Y and Nb (Fig. 11c).

4-Rutile (Ti,FeO_2)

It occurs as well-formed crystals exhibiting its characteristic brown color and translucent appearance. EDAX spectrograph showed that Ti and Fe are the main components (Fig.11d).

5-Pyrite (FeS_2)

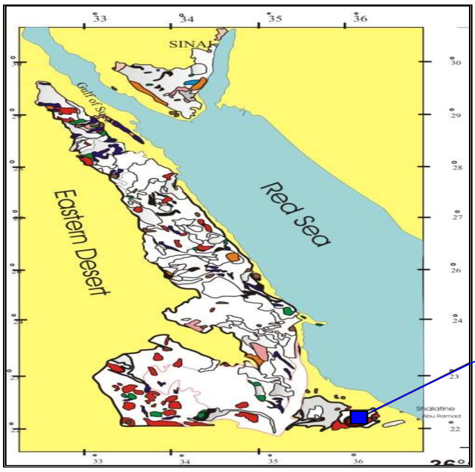
Pyrite occurs as fresh massive subhedral to anhedral opaque grains of brass yellow color and metallic luster. EDAX analysis clarified presence ions of rare metals such as Ag, Bi and (Te) beside the main metal (Fe) and sulfide as the main components (Fig. 11e).

2-Mineralogical investigation of the light fraction:

In fact, clay minerals (Fig.12). play an important role as natural adsorbent to heavy and nuclear metals such as vanadium and uranium (Katayama et. Al., 1974, Hussein et al., 1992, Dent et al., 1992, Thompson et al., 1998, Ibrahim et al., 2007 a, b & c and Raslan et al., 2004). The altered feldspars were also subjected to EDAX analysis. The EDAX analyses for these grains (Fig.13) reflect the chemical composition of feldspar with remarkable amounts of iron and uranium,as autunite. Kaolinite is present as very soft massive grains of whitish yellow color associated with

Table.1: Assay and U-distribution of heavy liquid separation products of the uraniferous kaolinized granite of El Sela Shear zone.

Products	Wt %	Assay eU %	Distribution eU %
Heavy fraction	15.20	1.6830	73.10
Light fraction	84.80	0.1110	26.90
Total	**100**	**0.3500**	**100**



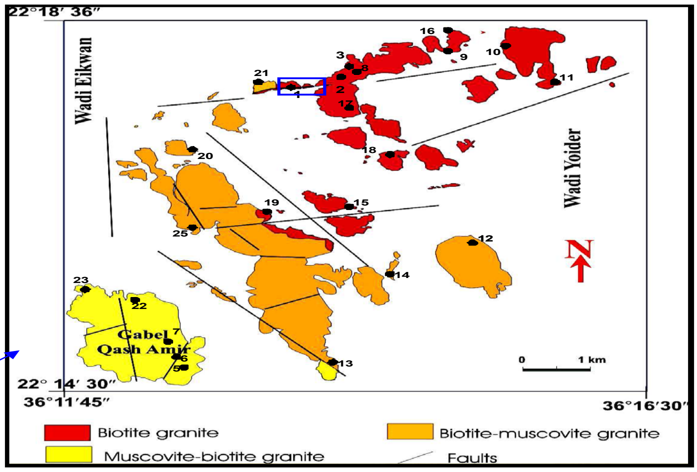


Fig. (1): Location map of Gabal El Sela area. **Fig. (2): Location of the collected samples on the geologic map of El Sela area, after Ibrahim, *et al.* (2013).**

Study area

= Shear Zone in two-mica granite

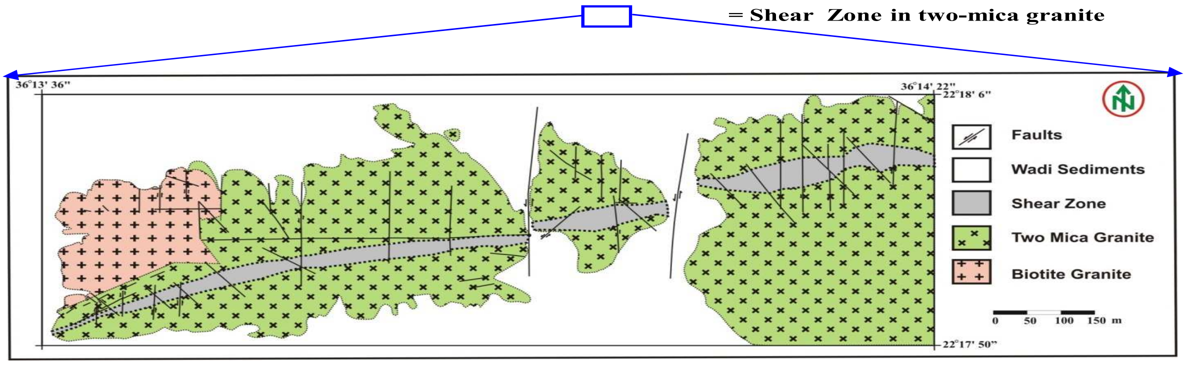


Fig. (3): Geologic map of Sela two-mica granite showing the shear zone

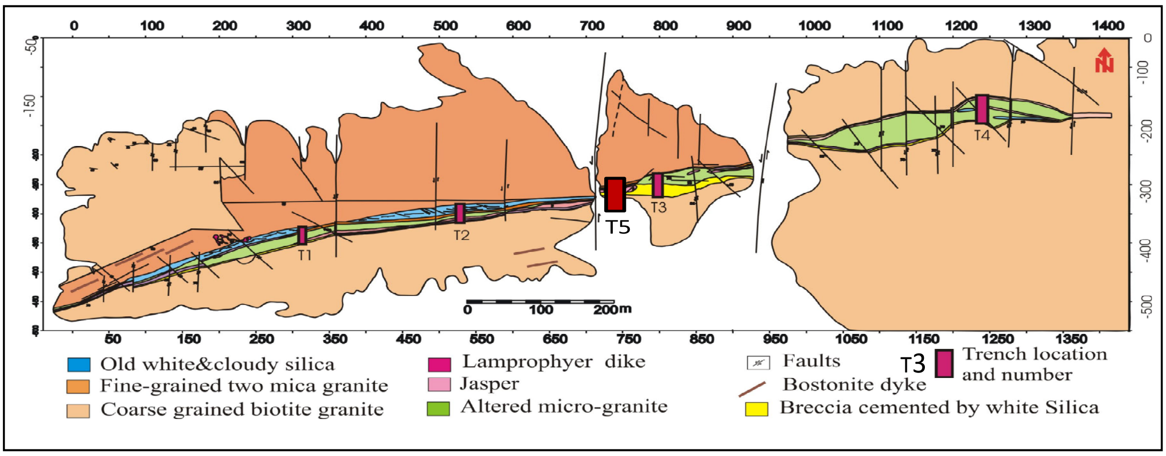


Fig. 4: The detailed geologic map of El Sela shear zone and the locations of trenches.

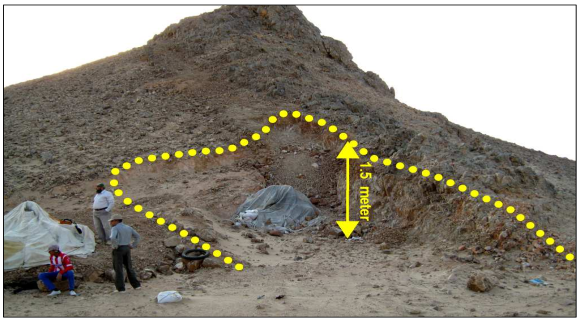


Fig. 5: Field photograph for 1.5m-trench of El Sela shear zone

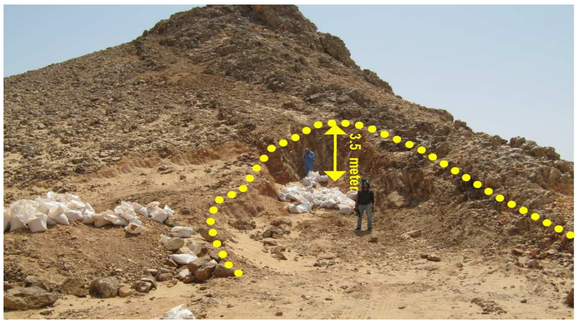


Fig. 6: Field photograph for 3.5m-trench of El Sela shear zone

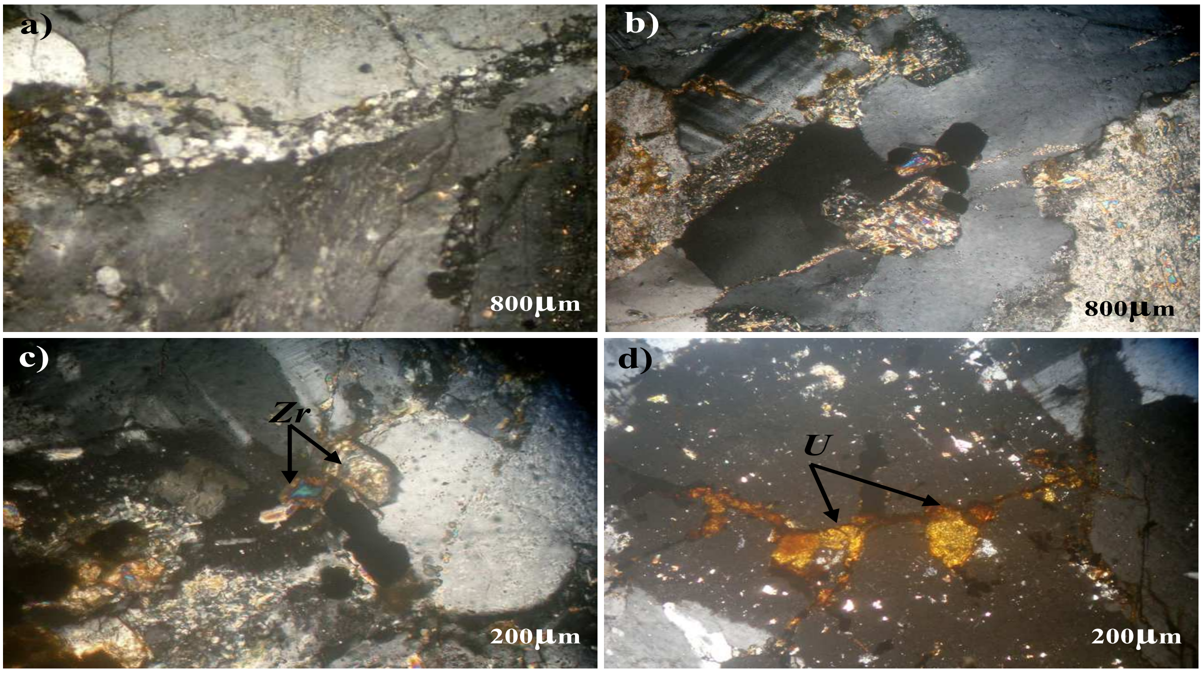


Fig. 7: photomicrographs of Sela granite showing: a) Secondary quartz resulting from silicification of potash feldspar (string perthite). CN. b) Saussiritization of plagioclase accompanied with transformation to microcline. CN. c) Metamectized zircon crystal (Zr) associating saussiritized plagioclase.CN. d) Secondary uranium mineral (U) filling fractures in the altered plagioclase. CN.

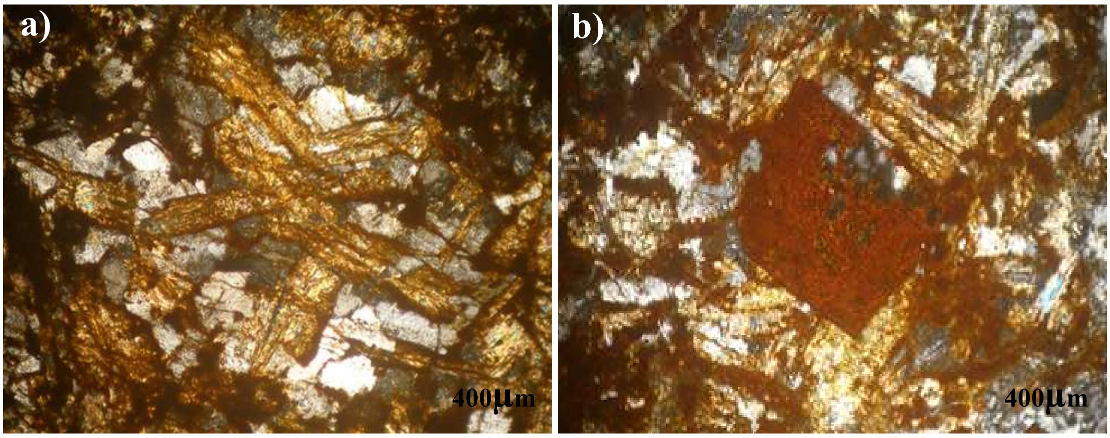


Fig. 8 : photomicrographs of bostonite dyke cutting Sela granite showing:
a) Euhedral laths of potash feldspars forming bostonitc texture, partially altered and stained by iron oxides CN.
b) Hematitized cubic crystal as oxidation of pyrite surrounded by laths of sanidine and orthoclase. CN.

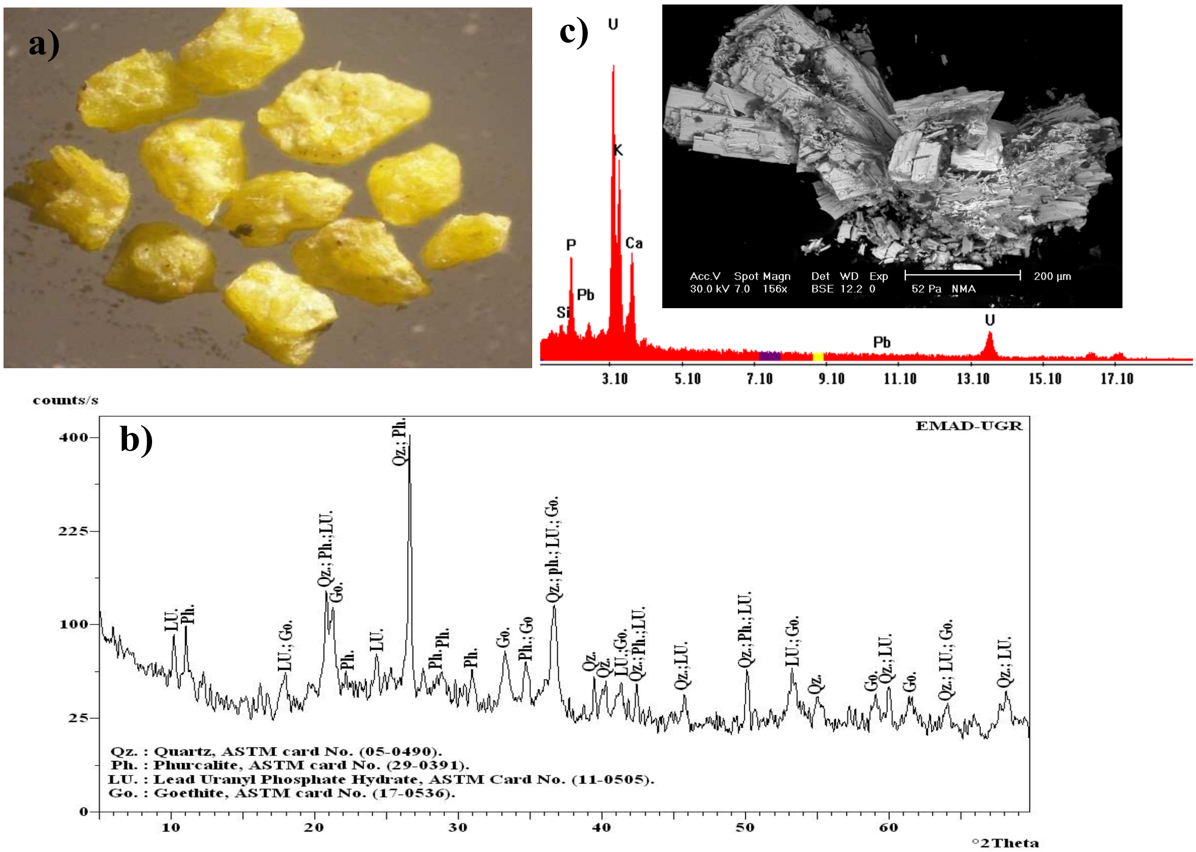


Fig. 9: Stereophotograph of lead-metautunite grains separated from El Sela sheared granite tailed with ESEM spectrograph and XRD diffractogram.

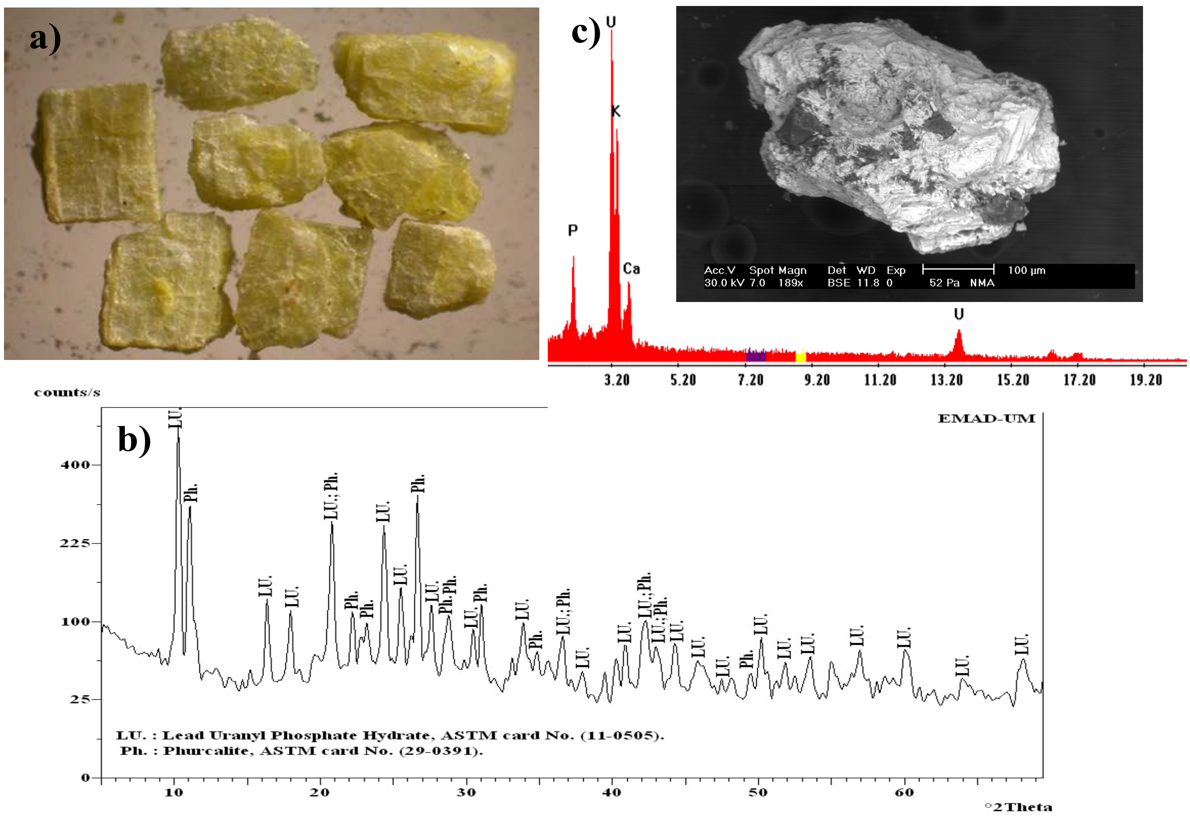


Fig. 10: Stereophotograph of phurcalite grains separated from El Sela sheared granite tailed with ESEM spectrograph and XRD diffractogram.

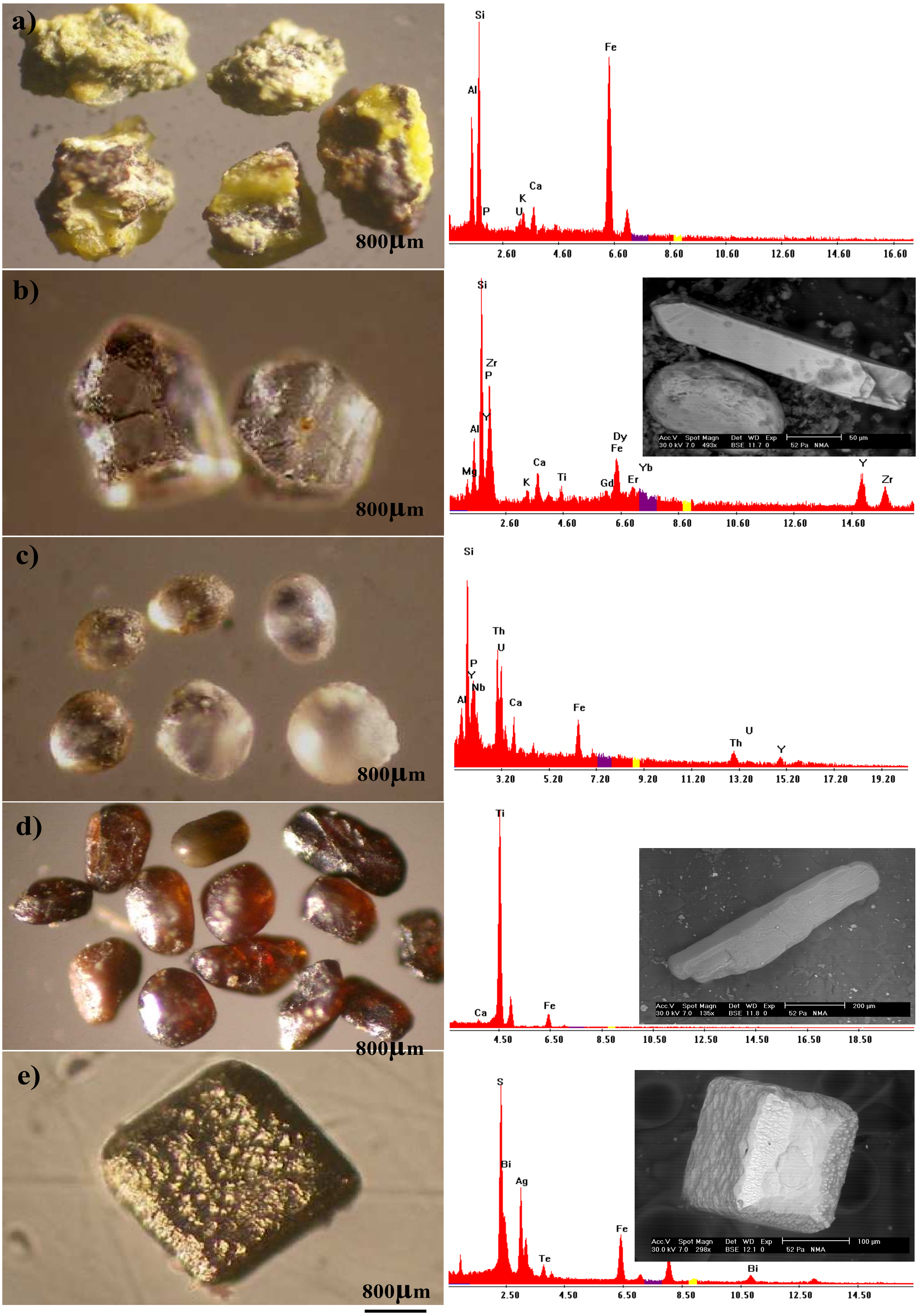


Fig. 11: Stereophotographs of radioelements-bearing minerals separated from El Sela sheared granite and its crosspondin ESEM spectrograph sowing: a) Goethite, b) Zircon c) Monazite d) rutile and e) Pyrite.

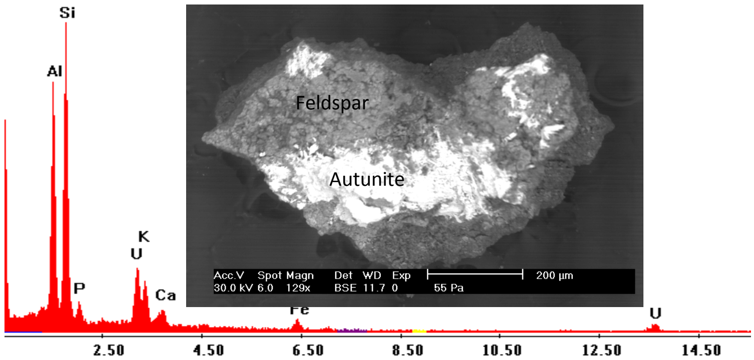


Fig. 12: ESEM spectrograph with EDAXfor the altered feldspars from light fraction of El Sela sheared granite.

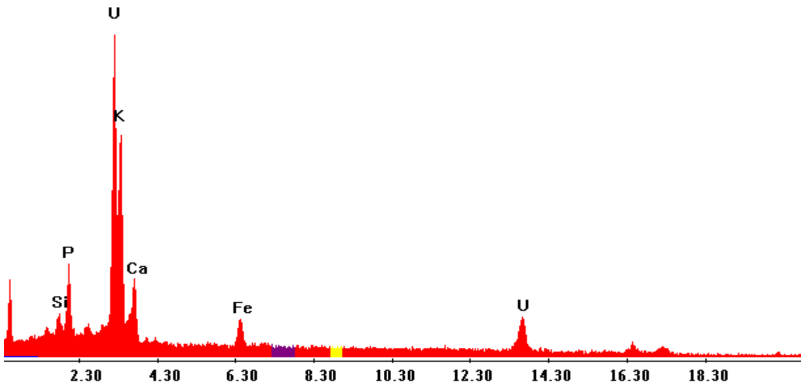


Fig. 13: ESEM spectrograph of autunite separated from light fraction of El Sela sheared granite.

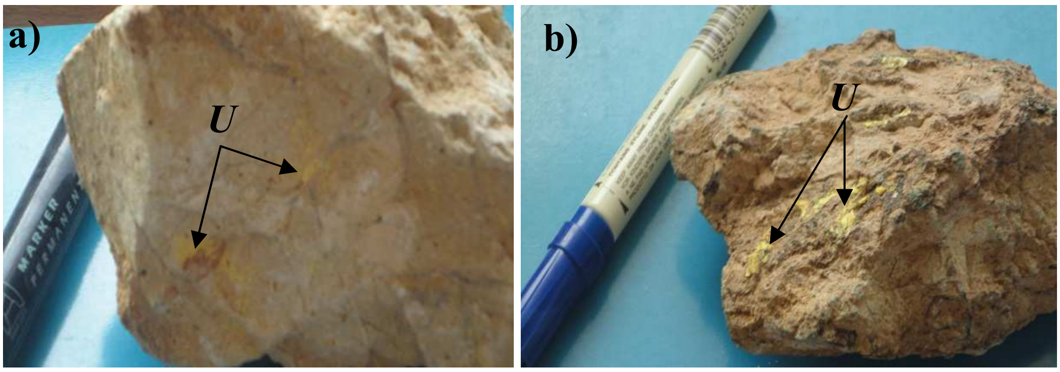


Fig. 14: Close up view for El Sela sheared granite showing the secondary uranium minerals (U) associating the kaolinized feldspars.

secondary uranium minerals (Fig.14a&b).

CONCLUSIONS

El Sela granites are dominated by a number of shear zones; the studied shear zone is the most significant one according to its high uranium potentiality. Important secondary uranium-minerals were recognized for the first time in this zone namely, lead-metautunite and phurcalite where lead is the main constituent referring to enrichment of lead in El Sela granites. The other heavy minerals (goethite, zircon, monazite and pyrite) are enriched by trace elements (U, Th, Y and Nb), rare earth elements (Gd, Yb, Er and Dy) and rare metals (Bi and Ag).

In this study the author gave attention to the light fraction beside the heavy fraction, that separated by bromoform, as source of radioactive minerals (autunite). In fact, clay minerals play an important role as natural adsorbent to heavy and nuclear metals such as vanadium and uranium. Kaolinite is the most common alteration product associated with secondary uranium minerals. The principal occurrences of kaolinite are primary residual deposits formed by weathering or low- temperature alteration of feldspars, muscovite and other Al-rich silicates.

Accordingly, the high radioactivity of the light fraction in El Sela sheared granite is mainly attributed to the adsorption of uranium onto kaolinite and altered feldspars. Such features clearly indicate the percolation of late magmatic, highly fractionated melt associated with high potential fluid phases in the shear zone led to the simultaneous enrichment of uranium, thorium.

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REFERENCES

Abu Deif A., El Balaksy S.M., El Hoseiny M.O. and Abu Zeid E.K. (2007): Wall rock alteration and uranium mineralization at M-III uranium occurrence, Gabal El-Missikat younger granites, Central Eastern Desert, Egypt. Proceedings of the Second International Conference on the Geology of Tethys, Cairo University. Vol. II.

Assaf, H. S., Ibrahim, M. E., Ammar, S. E., Shalaby, M. H. and Rashed, M. A. (1999):" Geological, mineralogical studies on the radioactive mineral occurrences at Qash Amir area, South Eastern Desert, Egypt" Egypt Min., v. 11, p. 135-156.

Cuney M., Report (2001): Uranium resource development in the Eastern Desert of Egypt, Metallogenic studies of the granite. IAEA-TCR 00456 , Department of technical co-operation.

Ibrahim, M.E., Zalata, A.A., Assaf, H.S., Ibrahim, I.H. and Rashed, M.A. (2003): "El Sela shear zone, South Eastern Desert, Egypt: An example of vein-type uranium deposit." Egy. J. of Geol., v. 42/2, p. 690-704.

Deer, W. A., Howie, R. A. and Zussman, J. (1992): "An introduction to the rock-forming minerals" low-priced edition, ELBS, Longman group limited, p. 528.

Dent, A.J., Ramsay, J.D.F. and Swanton, S.W. (1992): "An EXAFS study of urinal ion in solutions and sorbed onto silica and montomorillonite clay colloids." J. Coll Inter Sci 150:45-60.

Hussein, H.A., Abdel Monem, A.A., Mahdy, M.A., El Aassy, I.E. and Dabbour, G.A. (1992): "On the genesis of surficial uranium occurrences in West Central Sinai, Egypt." Ore geology Reviews, V. 7, p. 125-134.

Ibrahim, M.E., Abd El-Wahed, A. A., Rashed, M. A., Khaleal, F. M.1, 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., 99-115p.

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., 41-55p.

Ibrahim, M., Saleh G., Rashed M., and Watanabe, K. (2007c): Base metal mineralization in lamprophyre dykes at Abu Rusheid area, south Eastern Desert, Egypt. The 10th Inter. Min. Petrol., and Metall. Eng. Conf., Assuit Univ., p. 31-40.

Katayama, N. Kubu, K. and Hirono, S. 1974, Genesis of uranium deposits of the Tono Mine, Japan.Proc. Symp. Formation of Uranium deposits, Athens. IAEA, Vienna, pp. 437-425.

Rashed, M.A. (2001): "Geology, petrography and uranium potential of G. Qash Amir-El Sela granitic mass, South Eastern Desert, Egypt." M. Sc. Thesis, Fac. of Sci., Mansoura Univ., Egypt.

Raslan, M.F., Mahmoud Kh. F. and Roz, M.E. (2004): "Contribution to the mineralogy of the uranium bearing-Hammamat sediments, Gabal Gattar prospect, North Eastern Desert, Egypt." 6th Intern. Conf. on Geochem. Alex., Univ., Egypt. P. 147-158.

Thompson, H.A., Parks, G.A. and Brown, JR. G.E (1998): "Structural and composition of uranium (VI) sorption complexes at the kaolinite-water.

Walther, J. V. (2005): Essentials of geochemistry. Jones and Bartlett, U. S. A. 704p.