Nuclear Materials Authority
P.O.Box 530 Maadi, Cairo, Egypt

ISSN 2314-5609
Nuclear Sciences Scientific Journal
5, 33-47
2016
http://www.ssnma.com

GENETIC AFFILIATION OF GOLD AND URANIUM MINERALIZATION IN EL-MISSIKAT GRANITE, CENTRAL EASTERN DESERT, EGYPT

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ABSTRACT

Gabal El-Missikat granitic pluton is affected by two fault systems trending NW-SE (the oldest) and ENE-WSW directions. It is one of the uranium occurrences in the Eastern Desert of Egypt. The northwestern margins of El-Missikat pluton, along its contact with the gneissose quartz diorite, are dissected by numerous reactivated fractured shear zones running generally ENE-WSW to NE-SW and dipping about 60^0-70^0 to SE. Many white (oldest), smoky or black and jasperoid (youngest) silica veinlets fill the fractures of these shear zones.

These veins are of irregular shape and variable thickness ranging from few centimeters to about three meters. They are chiefly affected by silicification, sericitization, hematitization , kaolinization and hydrothermal alterations processes. The smoky black veins are hosting secondary uranium and fluorite-, sulphide-gold mineralizations.

Polished surface studies, ICP-ES and Atomic Absorption as well as Scanning Electron Microscope measurements recorded galena, pyrite chalcopyrite, sphaleriteand molybdenite in the black and jasperoid mineralized veins. Gold associated with ore mineral assemblage as pyrite, chalcopyrite, sphalerite, galena, sheelite and iron oxides. The identified sulphide minerals not bearing gold are recorded. Gold are relatively coarse-grained, massive and metallic yellow or stretched bronze colored particles.

The recorded secondary U minerals associates the sulphide gold-mineralization in the black and jasperoid silica veins.

Regarding the mobility of both uranium and gold, U^{4+}mobilized in oxidizing medium and migrate and transport as U^{6+}, then deposited later as U^{4+} when the medium changes to be reducing characterized by high fO_2 . On contrary, gold mobilized when the medium is complex $AuCl^{3-}$ ion bearing. Consequently, El-Missikat granitic pluton affected by oxidizing Au and Cl^{3-} bearing high temperature hydrothermal solutions that leached U^{4+}, W and Mo from the granitic mass as U^{6+}, later decrease of temperature, both U and gold deposited as well as the sulphide minerals of Pb, Zn, cu, Fe and Mo in the high temperature hydrothermal fluids were deposited with increase of S^{+2} ion.

INTRODUCTION

Gabal El-Missikat granitic pluton lies at the extreme northwestern corner of the central Eastern tectonic Domain, directly south to Qena-Safaga paved road at km 85 from Qena. This pluton is bounded by lat. 26° 15' to 26° 30' N and long. 33° 15' to 33° 30' E as a high mountainous peak (891 m. a.s.l) of younger granite. It covers about 377.4 km^2 as an area with an oval outline elongated roughly in a NW direction.

El-Missikat granitic pluton representing one of the important uranium occurrences in the Eastern Desert of Egypt have been studied by several workers (El-Kassas, 1974; Bakhit, 1978; El-Shazly et. al., 1981; Habib, 1982; Attawyia, 1984; El-Tahir, 1985; Bakhit et. al., 1985; Abu Deif, 1985 and 1992; Hussein et. al., 1986; Mohamed, 1988 and 1995; Ahmed, 1991; Abu-Deif et. al., 1997; Orabi, 1999; Ibrahim, 2002; Amer et. al., 2005, Ammar, 2007 and El-Sherif, 2013). These studies concentrated on the uranium mineralization existing in the shear zone. On studying the sulphide mineral constituents associating the uranium mineralizations, Ammar, (2007) recorded gold mineralization. In this respect, gold mineralization associating U mineralizatiom is also recorded in the younger granite pluton of El Aradiya and northward in the Gattar granite (Hassaan, 2011). The present work aims at probable genetic affiliation of the gold mineralization in association with the U-mineralization of El-Missikat granitic pluton to interpret this feature.

SAMPLING AND METHODS OF ANALYSES

Ten samples were collected from the mineralized zones related to the silica veins cutting El-Missikat granite. These samples represent white silica (three samples), black silica (three samples), jasperoid silica (two samples) and host granite (two samples). The white silica samples collected from a site nearby the black silica are coated by hematite and limonite. The collected black silica samples filling the fractures of the shear zone, being hematitized, containing vugs that coated by enriched secondary uranium minerals. The jasperoid silica samples were collected from the highly brecciated veins that contain fragments of proper granite and deformed fragments of silica. The granite samples were collected from a site nearby the alteration zones. This granite is highly altered, kaolinitized and/or sericitized.

Each of the studied rock samples as well as prepared composite sample, from the three silica varietes, were crushed, ground, quartered, splitted and sieved with (-30 +60), (-60 +230) and (-230) mesh sizes. Heavy liquid separation using bromoform (sp.gr = 2.85) was carried out to separate the heavy minerals constituents from the (-60 +230) mesh size fractions, followed by removing magnetite from the heavy fraction by hand magnet. The heavy minerals were picked under the binocular microscope for Scanning Electron Microscope (SEM) investigations.

Polarized and ore microscopes were used to investigate the thin sections and polished surfaces, respectively. EDX investigations and probe analysis of some separated grains were carried out using equipment Model JEOL {with System Resolution = 93 eV, Quantitative method (ZAF, 2 interations) at 20 K eV} .

The X-ray fluorescence technique (XRF) was used to determine the trace element, content using PHILIPS X-Unique-II Spectrometer with automatic sample changer PW 1510, (30 positions). The detection limit for the elements measured by XRF technique is estimated at 2 ppm for Rb, Nb, Ga, Co, Y and Sr and at 8 ppm for Pb and Cu and 5 ppm for other measured trace elements. ICP-AES (Plasmaquant, MO Analytic, Jeva) for major elements analyses and ICP-MS (PQ EXAZ, Thermo-Elemental) Technique for rare earth elements (REE) measurements were used.

Gamma-ray, X-ray fluorescence (XRF) and Scaning Electron Microscope (SEM) as well as the other applied techniques were carried out in the laboratories of the Egyptian Nuclear Materials Authority (NMA). The ICP analyses and probe analysis were undertaken in the Geology, Mineralogy and Geochemistry Institute, Martin-Luther University, Halle, Germany.

GEOLOGIC SETTING

The country rock types are granitic gneiss, ophiolitic serpentinite, amphibolites, island metagabbro, metadiabase, metabasalt, metaandesite, cordelarian calc-alkaline granite types, felsite and alkaline granite. These rock types at El-Missikat younger granite pluton crop out as concentric oval body extending NW-SE. This granite body is affected by several NW-SE (the oldest) and ENE-WSW (the youngest) trending faults expressed by wadis. It forms the highest peak in the area (Fig. 1). The Northwestern margins of El-Missikat granite, along its contact with the gneissose quartz diorite (Fig. 2) are dissected by numerous reactivated fractured shear zones running generally ENE-WSW to NE-SW and dipping about 60^0-70^0 to SE (Fig. 3).

The ENE trend is apparently representing reactivated tensional fractures genetically related to the NW left-lateral strike slip fault (Habib, 1982). This shear zone contains different silica veins concentrically arranged. The white siliceous veins are arranged directly along the walls of the shear zone grade inward into the black type and end by the jasperized ones in the core. The most significant mineralization bearing are the smoky to black and red jasperized zones of the veins (Fig. 4). These veins are of irregular shape with variable thickness ranging from few centimeters

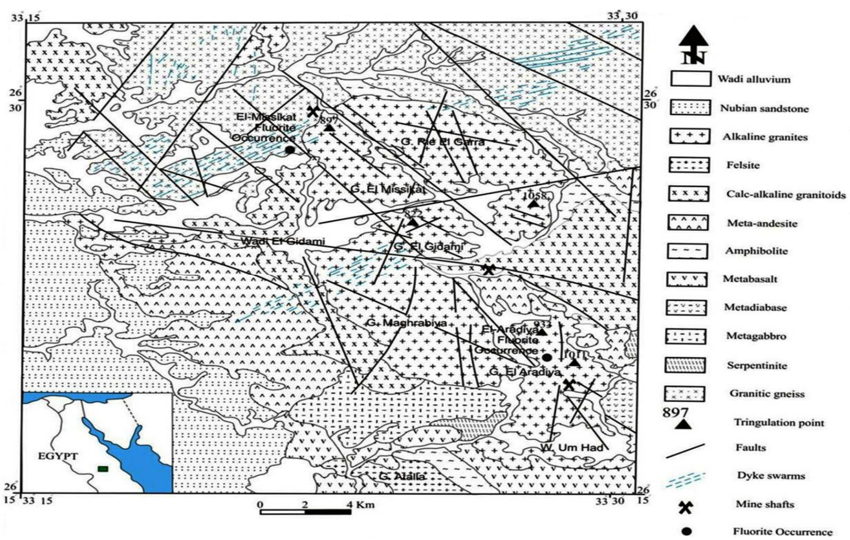

Fig. 1: Geologic Map of El-Missikat Area (After Abu Dief, 1985)

Fig. 2: Photograph Showing panoramic view of Gabal El-Missikat granite

Fig. 3 : Photograph Showing general view of El-Missikat granitic shear zone

Fig. 4: Photograph showing brecciated and hematitized black and red silica fragments

to about three meters. The black silica veins host secondary uranium minerals, fluorite, galena, pyrite, chalcopyrite and molybdenite.

The light colored veins display white, light-grey, pale-brown colors. Under microscope, they consist mainly of anhedral quartz grains 0.2-1.5 mm in length and as coarse aggregates of quartz which show interlocking grain boundaries with undulose extinction.

Alteration Features

The field studies indicated that G.El-Missikat area had suffered hydrothermal alteration processes viz., silicification, sericitization, kaolinitization and ferrugination in the form of hematitization associated with denderitic manganese oxides, chiefly concentrated along faults, joints and fracture zones. These alteration processes led to bleaching and various degrees of red colorization of the shear zone (silica vein). Silicification is the most important alteration process in the chief shear zone. The process manifested by more than one generation of silica veins, white silica, black silica and red jasper. The light colored siliceous veins represent the earliest generation followed by the black and finally by the red jasperized ones which seems followed immediatly the black silica. Each generation is brecciated and cemented by the younger type. Intensive kaolinitization, sericitization and hematitization affect the granite along the contacts with the silica vein in some sites (Figs. 5&6). The last silicification process is expressed (Fig. 7) as small zone of red and black quartz fragments cemented by silica forming breccia occupying the sides of the shear plane ranging from 30 to 40 cm in width and is the richest in uranium, fluorite and sulfide mineral constituents.

Through the process of silicification; secondary quartz is liberated as fine crystals or amorphous silica and as chalcedony filling fractures and cavities (Fig. 8). This stage of alteration is characterized by reduction of magnetite to euhedral crystals (Fig. 6).

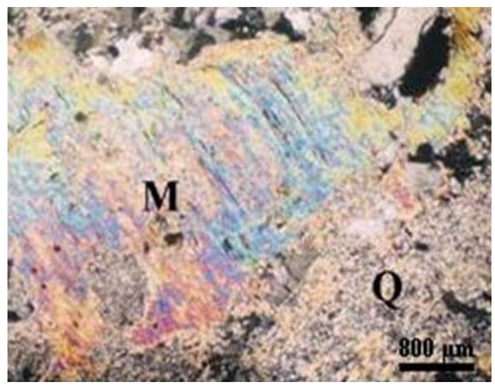

Fig. 5: Photograph Showing Sericitization associated with secondary muscovite (M) and fine-grained to cryptocrystalline quartz (Q).

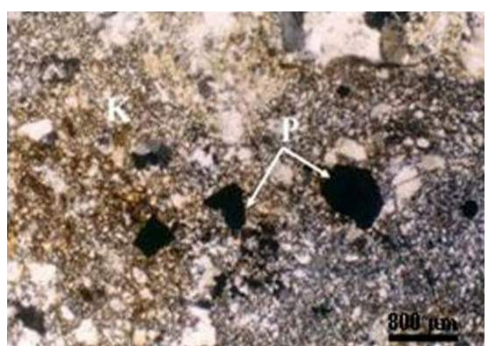

Fig. 6: Photograph showing kaolinization (K) of plagioclase surrounded with secondary quartz. Some cubes of opaque (pyrite P ??) are distributed inside the kaolinized groundmass

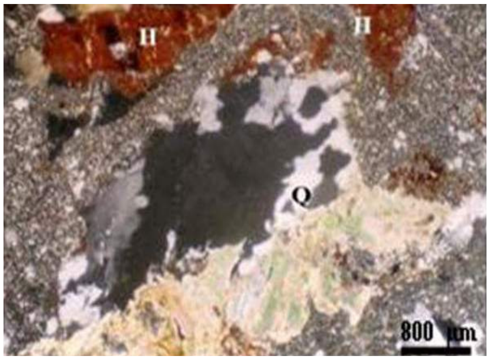

Fig. 7: Photograph showing silicification (Q) and hematitization (H) associating primary quartz

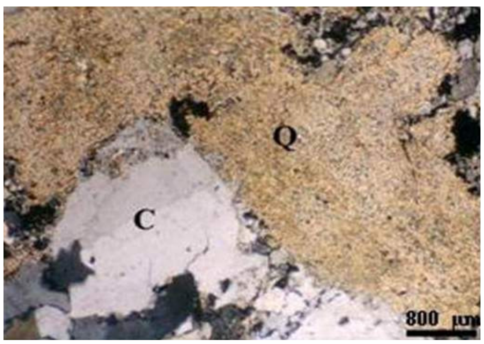

Fig. 8: Photograph showing chalcedony (C) embedded in cryptocrystalline quartz groundmass (Q)

URANIUM MINERALIZATION

The field radiometric measurements were carried out using GR-110 to estimate eU, eTh and K%. The obtained field radiometric measurements show that the white silica veins possess radioactivity ranging from 250 c.p.s up to 300 c.p.s, the black silica samples more than 3000 c.p.s. and jasperoid silica samples 1500 c.p.s. Table (1) shows the eU, eTh, Ra (ppm) and ^{40}K (%) contents as well as the chemically measured uranium ($U_{ch.}$ in ppm) of the studied rock samples manifested that the black silica veins have the highest (eU and/or $U_{ch.}$), eTh and Ra contents, while the white silica veins and the altered granitic samples show the least (eU and/or $U_{ch.}$), eTh and Ra contents through the jasperoid the silica veins.

The strongly brecciated jasperized silica veins show obvious variation in U content (16-465 eU; 4-217 Uch). The gold content is recorded in the analyzed samples. However, the jasperoid silica vein contains the highest Au content (116 and 118ppm). Meanwhile, the U_{ch} and Au contents are reversible to each other in the black silica samples. The Au content is the least in the sample containing the

Table 1: Gamma-ray spectrometric measurements, chemical uranium content and gold (ppm) of El-Missikat shear zone samples

Rock type	S.No.	eU (ppm)	eTh (ppm)	^{40}K%	Ra (ppm)	eTh/eU	U (chemically) (ppm)	Gold (ppm)
White silica	1	16	19	4	12	1.19	8	64
	2	13	17	0.25	12	1.31	5	58
	8	27	36	--	18	1.33	11	154
Black silica	3	1983	474	--	2007	0.24	965	89
	5	571	49	--	449	0.09	248	155
	7	654	47	--	599	0.07	261	200
Jasperoid Silica	4	465	37	--	435	0.08	217	118
	6	16	28	--	12	1.75	4	116
Altered granites	9	15	32	2.34	13	2.13	7	81
	10	16	27	3.98	12	1.69	6	74

highest content of eU and U_{ch} and vice versa.

This U-mineralization was considered by El-Kassas, (1974) and Bakhit, (1978) to be of fracture-filling type of hydrothermal origin and related to the latest phase of alkali feldspar granites magma.

Ore Minerals Assemblages

The recorded assemblage of ore minerals are gold, uranium, pyrite, pyhrrolite, sphalerite, galena, magnetite, scheelite, fluorite, barite, goethite, and hematite being secondary ore minerals.

Binocular microscope investigations show that gold exhibits relatively coarse-grained, sometimes massive and/or stretched bronze colored particles (Fig. 9). Polished surfaces show that gold exhibits bright golden specs

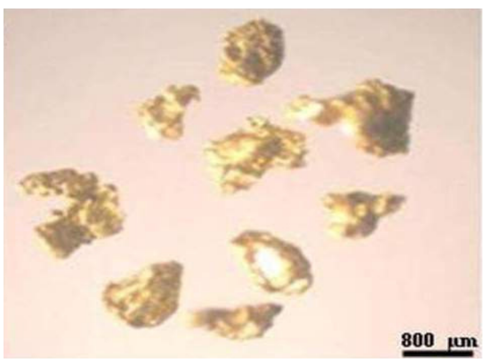

Fig. 9: Photomicrograph showing massive and bronze-colored gold particles

distributed individually in the samples, while the present sulphides were free from any gold content (Fig. 10).

The Ore Mineral Constituents

The polished surface studies show that pyrite of cubic form is the main sulphide mineral constituent (Fig. 11) and the pyritohedral form (Fig. 12). Occasionally, some of the pyrites are altered to pyhrrotite (Fig. 13). Deformed galena is distributed in the sample surfaces (Fig. 14). Sphalerite cubes and mag-

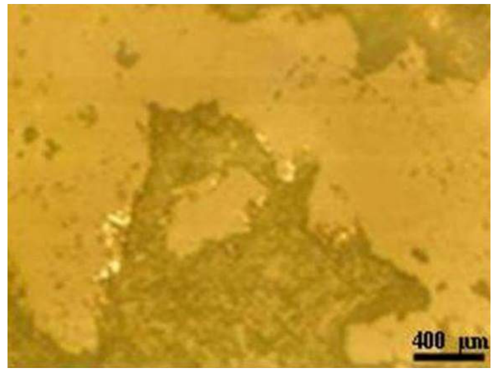

Fig. 10: Photomicrograph showing native bright golden specs of gold

Fig. 11: Photograph showing aggregates of pyrite (P)

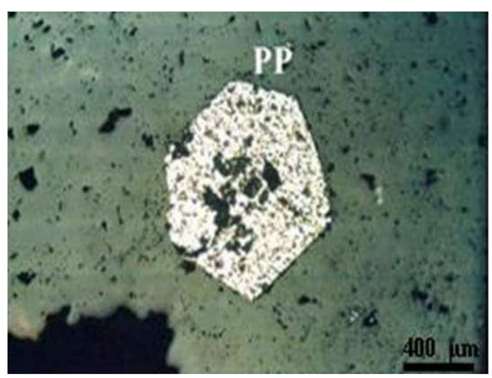

Fig. 12: Photograph showing pyritohedral pyrite crystal (PP)

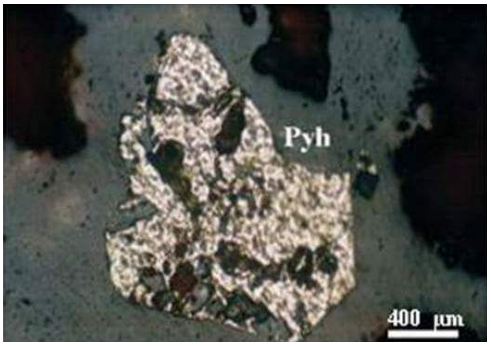

Fig. 13: Photograph showing pyhrrotite (Pyh) after pyrite

Fig. 14: Photograph showing galena aggregates (G)

netite crystals (Figs. 15&16) were identified. Native gold specs are distributed in-between the main components (see Figs. 11&12). It is clear that the recorded sulphide minerals are free from any gold specs.

Figures 17-24 show grains of the ore mineral assemblages and the constituents associating gold mineralization investigated by the Scanning Electron Microscope (Figs. 25-30) and analyzed with the probe (Tables 2 and 3) in order to explain their chemical features and to clarify presence of any gold specs.

The other ore mineral constituents include magnetite, hematite and goethite, scheelite, fluorite and barite.

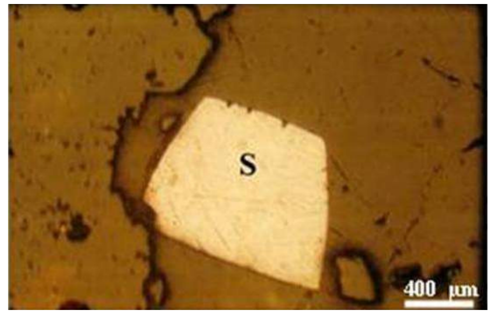

Fig. 15: Photograph showing cube sphalerite (S) crystal

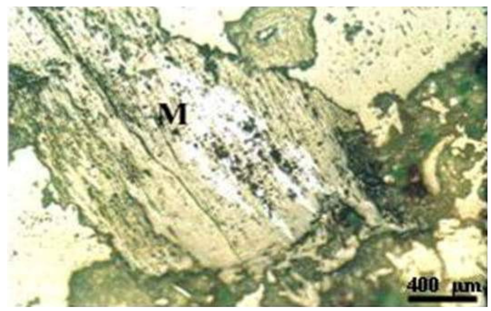

Fig. 16: Photograph showing coarse-grained magnetite (M)

Fig. 17: Photograph showing galena particles, some are altered and enclosed quartz impurities,

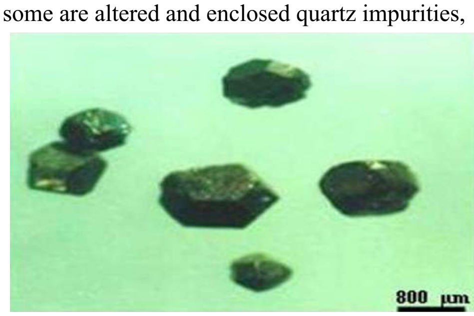

Fig. 18: Photograph showing Pyritohedral, dark brown pyrite particles

Fig. 19: Photograph showing cubic and prismatic yellowish brown sphalerite particles

Fig. 20: Photograph showing dark brown, fine- to medium-grained iron oxides particles

Fig. 21: Photograph showing reddish brown hematite particles

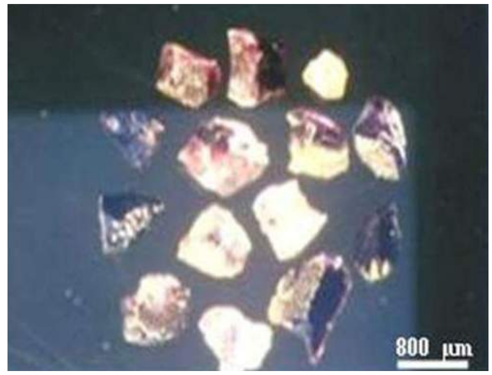

Fig. 22: Photograph showing white, pale violet and violet fluorite particles

Fig. 23: Photograph showing coarse-grained barite particles, some are stained with iron oxides

Fig. 24: Photograph showing yellowish and coarse-grained scheelite grains

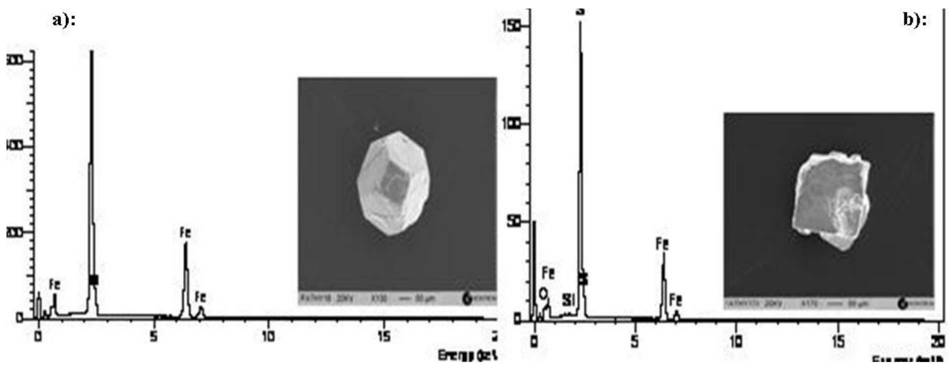

Fig. 25: EDX analysis and back scattered image of (a): pyritohedral (b) :cubic pyrite particle

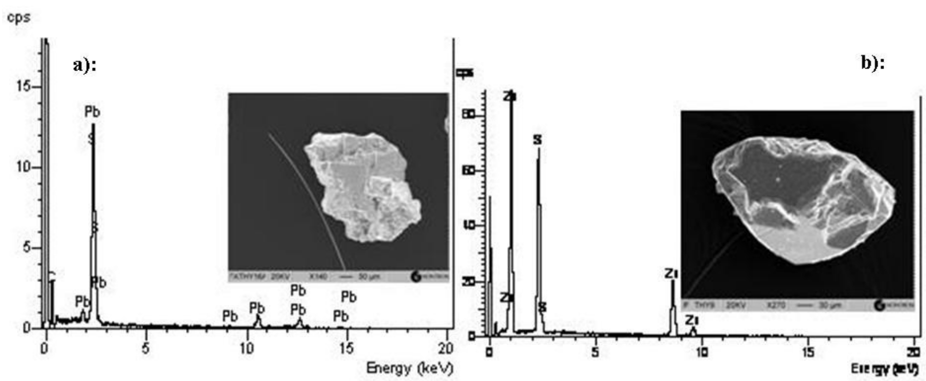

Fig. 26: EDX analysis and back scattered image of grains (a): galena (b): sphalerite

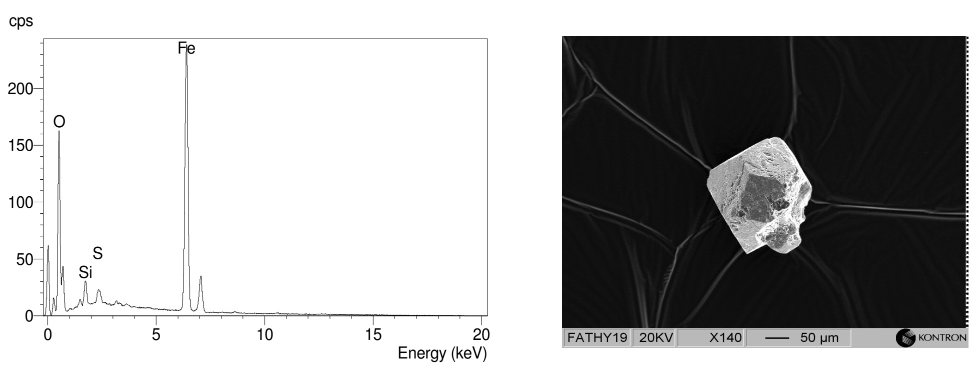

Fig. 27: EDX analysis and back scattered image of goethite after cubic pyrite particle

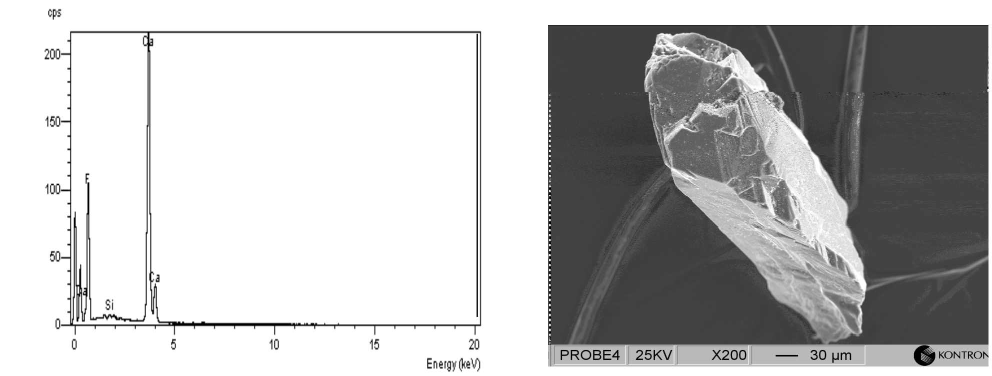

Fig. 28: EDX analysis and back scattered image of fluorite particle

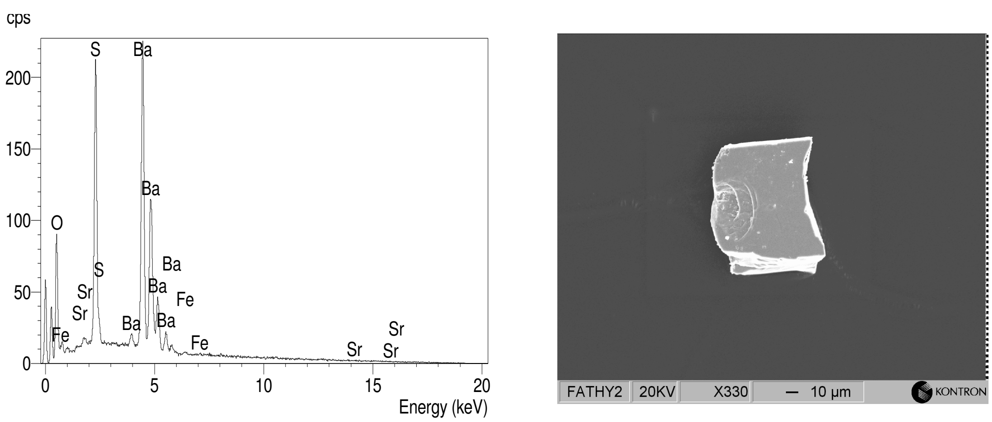

Fig. 29: EDX analysis and back scattered image of barite grain

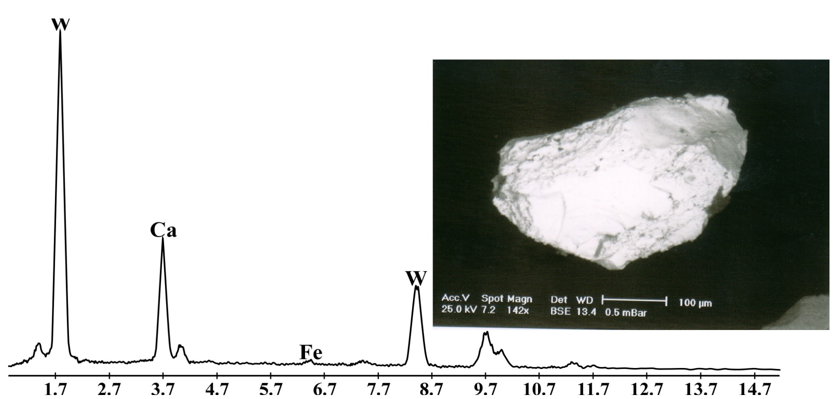

Fig. 30: EDX analysis and back scattered image of scheelite grain

Table 2: Probe analyses of sulphide ore minerals in wt%

Element / Mineral	Pyrite: Pyritohedral Pyrite	Pyrite: Cubic Pyrite	Galena	Sphalerite
O	2.98	2.16	13.52	…
Si	0.22	0.17	0.62	…
S	50.71	52.07	18.23	33.48
Pb	…	…	67.63	…
Fe	45.93	45.60		
Zn	...	…	…	66.52
Al	0.16	…	…	
Ba	…	…	…	…
Total	100	100	100	100

Table 3: Probe analyses of the other ore assemblage minerals in wt%

Element / Mineral	Iron Oxide	Fluorite	Barite	Scheelite
F	…	62.48	…	…
Ca	…	35.88	…	17.48
Si	2.29	0.39	0.16%	…
S	0.63	0.12	14.14	…
Fe	61.86	0.15	…	00.90
K	…	0.14	…	…
Th	…	0.25	…	…
U	…	0.59	…	…
O	35.22	…	20.46	…
Ba	…	…	65.06	…
W	…	…	…	81.63
Cr	…	…	…	…
Total	100	100	100	100

GENESIS OF GOLD MINERALIZATION

The ten analyzed samples representing the three silica vein types and the surrounding alteration zones were analyzed in order to measure the gold and silver contents using ICP and Atomic Absorption Techniques. The obtained data were listed in Table (4) which shows that the black and jasperoid silica have relatively high gold contents, whereas silver traces are recorded in the black and white veins. At the same time, the altered granitic samples have the lowest gold contents.

Table 4: Gold contents (ppm) in the different studied silica samples and altered granite.

Rock type	S.No.	Au	Ag
White silica	1	64	5
	2	58	4
	8	154	3
	Av.	92	4
Black silica	3	89	5
	5	155	4
	7	200	3
	Av.	148	4
Jasperoid Silica	4	118	
	6	116	
	Av.	117	
Altered granites	9	81	
	10	74	
	Av.	77.5	

SEM and EDAX semi quantitative analysis (Fig. 31) clarify the presence of native gold specs.

Genetic Affiliation

The interrelationship between the uranium mineralization and the recorded gold in only the black and jasperoid silica veins of El-Missikat shear zone can be explained through some changes of the oxidation/reduction geochemical parameters of the hydrothermal fluids affected El Missikat pluton.

DISCUSSION AND CONCLUSIONS

1- The northwestern margins of El-Missikat pluton, along its contact with the gneissose quartz diorite are dissected by numerous reactivated fractured shear zones running generally ENE-WSW to NE-SW and dipping about 60^0-70^0 to SE. Many white (oldest), smoky or black and jasperoid (youngest) silica veinlets fill the fractures of these shear zones.

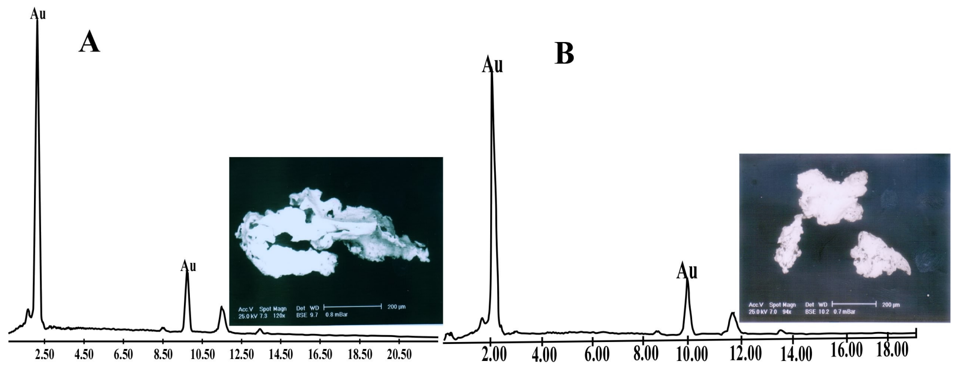

Fig. 31: SEM and EDX analysis and back scattered image of native gold particles

2- Galena, pyrite chalcopyrite, sphalerite- and molybdenite are present in the black and jasperoid mineralized veins. Gold is associated with ore mineral assemblage pyrite, chalcopyrite, sphalerite, galena, sheelite and iron oxides. The identified sulphide minerals not bearing gold are recorded. Gold are relatively coarse-grained, massive and metallic yellow or stretched bronze colored particles.

3- Regarding the mobility of both uranium and gold, U^{4+}mobilized in oxidizing medium and migrate and transport as U^{6+}, then deposited later as U^{4+} when the medium changes to be reducing characterized by high fO_2 . On contrary, gold mobilized when the medium is complex $AuCl^{3-}$ ion bearing. Consequently, El-Missikat granitic pluton affected by oxidizing Au and Cl^{3-} bearing high temperature hydrothermal solutions that leached U^{4+}, W and Mo from the granitic mass as U^{6+}, later decrease of temperature, both U and gold deposited as well as the sulphide minerals of Pb, Zn, Cu, Fe and Mo in the high temperature hydrothermal fluids were deposited with increasing of S^{+2} ion.

Table (5) shows that the conditions required for Au transport are intermediate between those mentioned by Dubessy et al. (1987) for U and Sn-W. This may explain why discrete Au-mineralizations are associated in some cases with U (Vanhanen, 1987, for instance) but more frequently with Sn-W deposits.

Table 5: Conditions of mobilization and deposition of Au, U and Sn-W

Operation	Factor / Element	Au	U	Sn-W
Soliability and transport	pH	Acidic	Neutral	Neutral to acid
	fO_2	Low	High	Very low
	fS_2	High	Moderate	
	T °C			
Deposition	pH	Decrease	Neutral	Neutral to acidic
	fO_2	Low	Decrease	Low
	fS_2	Moderate	Increase	Moderate
	T °C	150° – 250° 300° - 600°	150° - 300°	350° - 400°

These mineral associations are recorded in the studied silica veins as: uranium minerals, Au specs and scheelite. In fact, the presence of scheelite and the absence of cassiterite is a further evidence for the prevalence of reducing conditions during the deposition of U, Au and Sn-W mineralizations since the crystallization of cassiterite necessitates oxidizing condition.

It may be concluded that the hydrothermal fluids responsible for the formation of the studied silica veins and the deposition of U and Au mineralizations in these veins, suffered different physico-chemical changes namely: fO_2, FS and pH changes allowing transportation and the associated deposition of U and Au together with sulphides in the study silica veins.

Acknowledgements

We would like to express our deep thanks to Prof. Zeinab Abed El-Kader and Prof, Mahmoud Hassaan for their supporting and helpful comments which led to an important of the manuscript.

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الإنتماء الوراثي لتمعدنات الذهب واليورانيوم في جرانيت المسيكات، وسط الصحراء الشرقية، مصر

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يتأثر جرانيت جبل المسيكات والذي يعتبر واحداً من أهم تواجدات اليورانيوم في الصحراء الشرقية المصرية بصدوع ذات اتجاه جنوب شرق- شمال غرب (أقدم) وكذلك في اتجاه غرب جنوب غرب- شرق شمال شرق.

تتأثر الحواف الشمالية الغربية لجرانيت المسيكات بمتاخمتها لصخور الكوارتزدايوريت النيسوزي بنطاقات قص ذات اتجاه من غرب جنوب غرب- شرق شمال شرق الي جنوب غرب- شمال شرق وذات ميول في اتجاه جنوب شرق بزاويه من ٦٠° إلي ٧٠° وتمتلئ هذه النطاقات بعروق من الكوارتز الأبيض (الأقدم) والمدخن أوالأسود والجاسبرويد غير منتظمة في الشكل والسمك وتأثرت بشكل رئيسي بعمليات تحول حارمائيه (sericitization, hematitization and kaolinitization) وتحتوي عروق الكوارتز المدخن والأسود علي تمعدنات يورانيوم ثانويه وفلوريت وكبريتدات وكذلك الذهب.

أثبتت دراسات الأسطح المصقوله لصخور الدراسة والتحليل بواسطة الميكروسكوب الإلكتروني

الماسح والإمتصاص الذري والبلازما وجود معادن الجالينا والبيريت والكالكوبيريت والسفاليريت والموليبدينيت في عروق السيلكا السوداء والجاسبر، أما الذهب فيتواجد في صورة حبيبات خشنة صلبه ذات اللون الأصفر والبرونزي المميز مصاحب لتجمعات معادن البيريت، الكالكوبيريت، السفاليريت، الشيبليت وأكاسيد الحديد.

من البيانات التجريبيه يتحرك اليورانيوم بسهوله في الوسط المؤكسد في صورة ايون سداسي الشحنة U^{6+} ويترسب فيما بعد علي هيئة ايون رباعي U^{4+} في بيئات مختزلة وتتطلب عملية نقل اليورانيوم في صورة U^{6+} كثيرا من fO_2 وفي المقابل فإن الذهب يبدأ في التمعدن حينما يكون الوسط حامل لأيون كلوريد الذهب ($AuCl^{3-}$). يتأثر جبل المسيكات بمحاليل أيونات كلوريد الذهب الحارمائيه المؤكسدة ذات درجات حرارة عالية والتي تعمل على إستخلاص اليورانيوم من جرانيت المسيكات علي هيئة أيون سداسي U^{6+} وحينئذ يترسب كلاً من اليورانيوم والذهب بالإضافة إلى كبريتدات معادن الرصاص، الزنك، الحديد والموليبدنوم مع زيادة ايونات الكبريت S^{+2} في المحاليل الحارمائية ذات درجات الحرارة المرتفعة.