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Scientific Communication

Occurrence of Uraniferous Iron Grains at Gabal Gattar, El Missikat and El Erediya Granites in Eastern Desert of Egypt

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Abstract

Uraniferous iron grains occur in some radioactive granite plutons in the Eastern Desert of Egypt. Modal analysis of these grains indicates that weight abundance of uraniferous grains amounts to 17.50%, 18.00% and 26.00% of the total accessory heavy minerals of the uranium-mineralized samples of Gabal Gattar, El Missikat and El Erediya, respectively. These grains are mainly restricted to shear zones associated with strong hematitization, and occur either as fracture fillings or as interstitial grains among the main rock-forming minerals. Uraniferous iron grains are mainly composed of uranophane and β-uranophane coated and stained with limonite. These grains represent the main radioactive minerals in addition to the bright canary yellow to yellow uranophane and β-uranophane mineral grains. The data obtained on scanning electron microscopy and electron microprobe analysis confirm the abundance of iron in the darker colored varieties with respect to the light colored varieties. This mode of occurrence of the uranium minerals requires special consideration during mineral processing by physical means.

Keywords: β-uranophane, limonite, radioactive granite, uraniferous iron grains, uranophane.

1. Introduction

The granitic rocks in Egypt are broadly classified into two main groups: older syn- to late tectonic granite referred to as gray granites, and younger or post-tectonic granites referred to as pink granite (Akaad & El-Ramly, 1960; El Ramly & Akaad, 1960; El Ramly, 1972; Sabet, 1972; El Gaby, 1975; Akaad & Noweir, 1980). Some of the younger granites in the Eastern Desert of Egypt have been found to host significant uranium mineralization (Hussein *et al.* 1986; Hussein & Sayyah, 1992; Abu Dief, 1993). Those are El Missikat and El Erediya plutons in the central Eastern Desert as well as Gabal Gattar pluton in the north and Um Ara pluton in south (Dawood & Abdel-Naby, 2001) (Fig. 1). The uranium mineralization is structurally controlled and restricted to shear zones where uranium-bearing minerals occur either as small veinlets or as minute dissemination associated with hydrothermal alteration.

Hussein and Sayyah (1992) estimated as much as 8000 tons of uranium metal as speculative resources in the El Missikat and El Erediya occurrences, and as much as 4000 tons in the mineralized granites in the Gabal Gattar area. Osmond *et al.* (1999) show that the secondary ore uranium minerals at central Eastern Desert formed sometimes during the period 150,000–60,000 years ago. A hydrothermal origin of the aforementioned four uranium occurrences was suggested by many authors (Abdel Monem *et al.*, 1990; Hussein & Sayyah, 1992; Abu Dief, 1993).

Hematitization always exists close to uranium mineralization in the recorded uraniferous occurrences and its intensity increases in the mineralized sites. This is interpreted as due to the high ability of iron oxides for uranium adsorption from its bearing solutions

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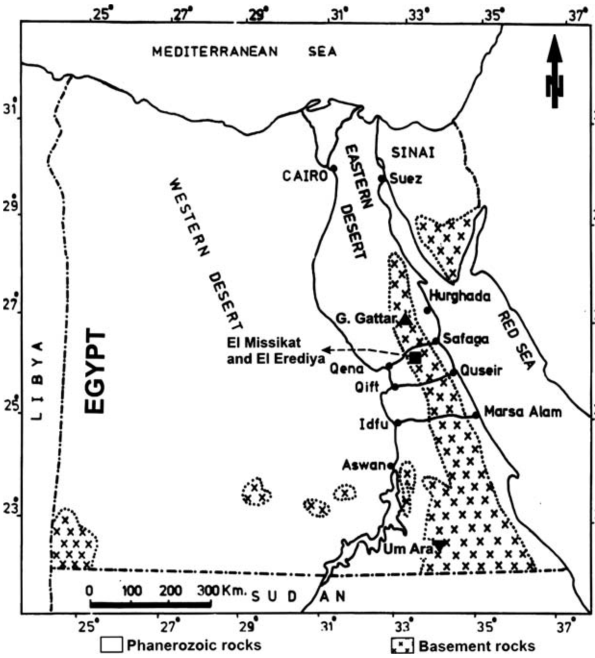

Fig. 1 Location map of the uranium occurrences in younger granites.

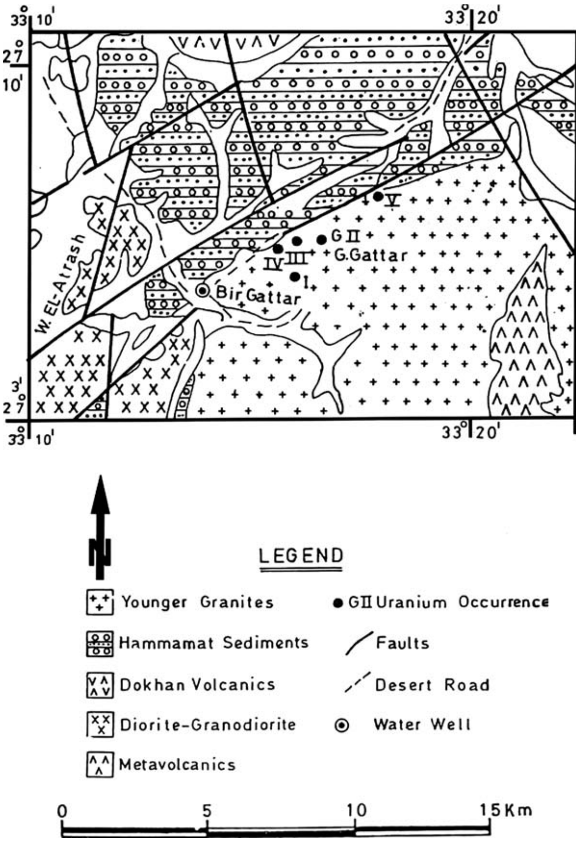

Fig. 2 Geologic map of uranium occurrences, Gabal Gattar prospect (after Dardir & Abu Zeid, 1972).

(Hussein *et al.* 1965). Dawson (1956) suggested that iron and uranium are geochemically related and that ferric oxide is abundantly found with uranium. He also referred to the staining feature of the secondary uranium minerals due to ferric oxide.

We report the occurrence of the dark uraniferous iron grains at Gabal Gattar, El Missikat and El Erediya granites of the Eastern Desert.

2. Geology of the studied areas

Gabal Gattar area encloses several rock units. The oldest are the Hammamat sedimentary rocks, Dokhan volcanics, and dioritic rocks, while the youngest are granites and related dikes. Gabal Gattar uranium prospect includes five occurrences: GI, GII, GIII, GIV and GV (Fig. 2). The radioactive anomalies in the GII occurrence are present in a patchy form, covering an area reaching approximately 70–330 m^2. The uranium mineralization is confined to shear zones and fault planes and is present as secondary yellow minerals. The uranium mineralization is associated with deep violet fluorite, smoky quartz, hematitization and silicification of the granite. The total length of the mineralized zone extending from GI to GII is approximately 4 km with an average width of 2–10 m (Salman *et al.*, 1990).

El Missikat and El Erediya granitic plutons intrude into the Precambrian igneous and metamorphic basement, which is unconformably overlain to the west by the undeformed Nubia sandstone (Fig. 3). The uranium minerals in El Missikat are mainly uranophane (Bakhit, 1978) and kasolite (Raslan, 1996), which fill fractures or are disseminated in the black silica and jasper. The uranium minerals in El Erediya plutons also occur in the shear zone filled by jasperoid veins. They are represented by uraninite, sooty pitchblende at depth (El Kassas, 1974; Assaf, 1994) and by uranophane, soddyite and renardite at surface (Attawiya, 1984). Exploratory mining was carried out along the shear zones in El Missikat and El Erediya. A total of approximately 3829 m of galleries were excavated in both areas.

3. Sampling and techniques

Three bulk composite samples were collected from the Gabal Gattar, El Missikat and El Erediya uranium occurrences. The first sample was collected from the shear zone

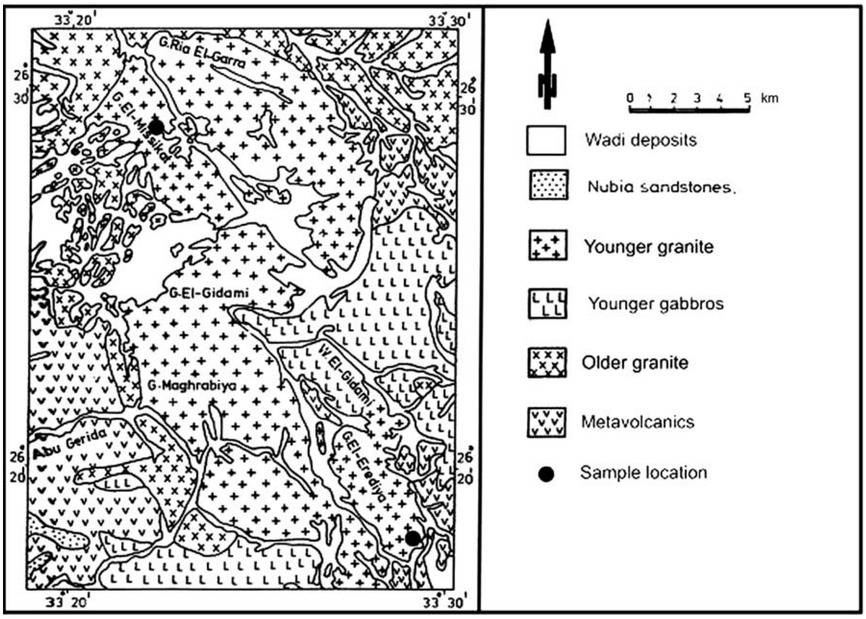

Fig. 3 Geologic map of El Missikat and El Erediya occurrences.

in the GII uranium occurrence in the northern parts of Gabal Gattar granite (Fig. 2). The other two samples were collected from the mineralized sheared granite of El Missikat and El Erediya (Fig. 3). These samples are sheared and characterized by the presence of visible secondary uranium minerals. In order to determine the petrographic characteristics of these occurrences, several thin sections were prepared and studied. The collected samples were subjected to conventional mineral separation steps; crushing, grinding and sizing followed by heavy liquid separation using bromoform (sp.gr. 2.85). The purpose was to estimate the heavy mineral content of each size fraction.

The samples were first crushed, ground to –0.800 mm and were then sieved down to 0.063 mm to determine the liberation size of the uranium minerals as well as to avoid overgrinding and eventual loss of the interesting mineral grains. Because liberation was attained only below 0.400 mm, the oversize was re-ground to pass this sieve size in order to facilitate counting and ensure quantitative balance. The sink heavy fractions of the obtained size fractions of the three studied samples were then subjected to counting analysis for estimating the abundance of the uraniferous iron grains. Several grains were handpicked from all the obtained sink fractions for X-ray diffraction analysis. The samples were analyzed using the field emission scanning electron microscope (JEOL 6335F) at XXXX. Resolution of the instrument is around 15 Å. This instrument is fitted with an Oxford energy dispersive X-ray spectrometer for elemental analysis of micro areas, a backscattered electron detector that allows compositional analysis, and a cathode luminescence detector that can image complex, characteristic-visible spectra for detailed molecular structure information. The applied analytical conditions involved 0.5–30 accelerating voltage, 1.5 nm (at 15 KV)/5.0 nm (at 1.0 KV).

Several thin-polished sections were prepared for some of the uraniferous iron grains as well as for some of the bright colored uranium minerals for electron microprobe analyses (JEOL Superprobe 733; University of Florida, USA) with an accelerating voltage of 15 Kv and a beam size of approximately 1 μm. The used standards included biotite (Fe-Si), uranium metal (U), monazite (Th), and fluorite (Ca).

4. Results and discussion

4.1 Petrographic characteristics

In thin sections, uraniferous iron grains (uranophane and β-uranophane) from Gabal Gattar, El Missikat and El Erediya are similar in petrographic characteristics. They occur in fracture and cavity and usually attain an orange color due to staining with reddish brown limonite (Fig. 4a). These grains are closely associated with opaque minerals (Fig. 4b). Some of the uraniferous iron grains occur interstitially between quartz and perthite (Fig. 4c, d). Some other grains occur in the form of aggregates of needle-like crystals (Fig. 4e). The coated and stained uranophane and β-uranophane grains are predominant in the ferruginated samples with quartz and perthite (Fig. 4f).

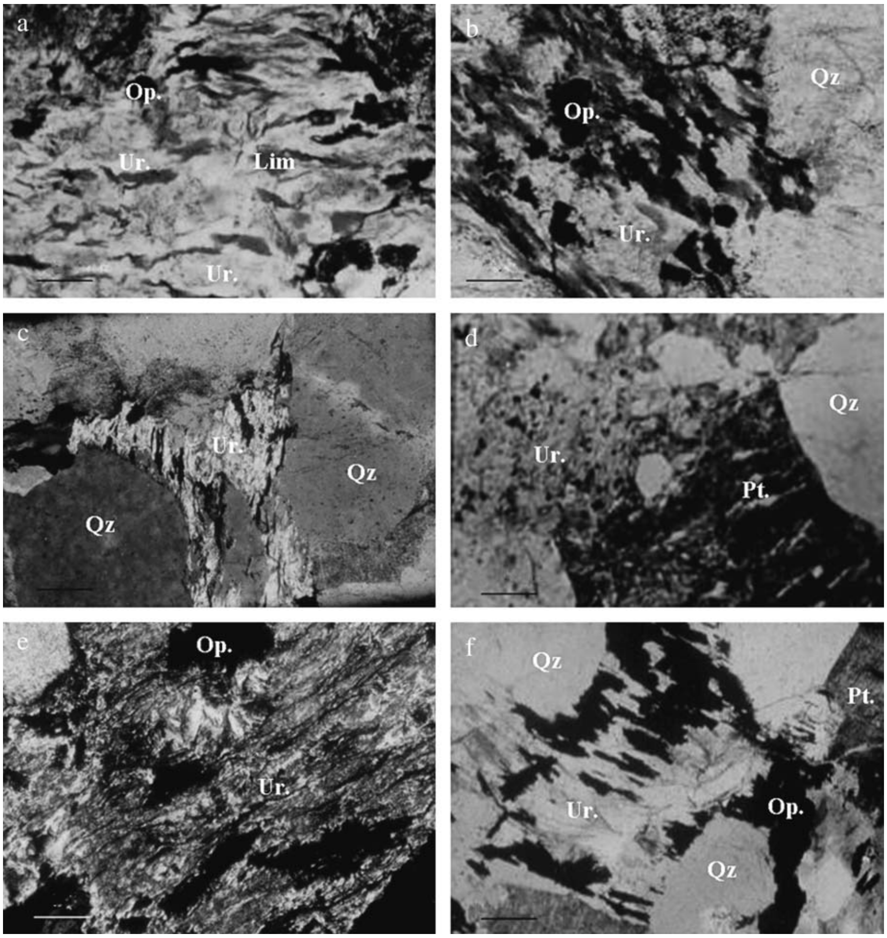

Fig. 4 (a) Stained uranophane and β-uranophane with reddish brown limonite. El Erediya uranium occurrence. Polarized light; bar, 0.025 mm. (b) Secondary uranium minerals associated with opaques, El Erediya uranium occurrence. Polarized light; bar, 0.025 mm. (c) Secondary uranium minerals occurring interstitially between quartz, Gabal Gattar uranium occurrence. Crossed nickels; bar, 0.18 mm. (d) Stained uranophane and β-uranophane occurring interstitially between quartz and perthite. El Missikat uranium occurrence. Polarized light; bar, 0.05 mm. (e) Fibrous uranophane and β-uranophane crystals associated with opaques. Gabal Gattar uranium occurrence. Crossed nickels; bar, 0.1 mm. (f) Secondary uranium minerals associated with opaques and occurring interstitially between quartz and perthite. El Missikat uranium occurrence. Crossed nickels; bar, 0.18 mm. Lim, limonite; Op, opaques; Pt, perthite; Qz, quartz; Ur, Uranophane and β-uranophane.

4.2 Mineralogical investigation

The studied uraniferous iron grains are distributed in almost all size fractions (−0.800 + 0.063 mm) with a tendency to increase with decreasing grain size. Based on liberation size, two predominant varieties are distinguished. The first variety is massive and of plate-like shape. This variety is distinguished by a reddish orange color and almost complete staining with iron oxides. The grains of this variety are liberated in the coarse size fractions (>0.400 mm) possibly by detachment rather than size reduction and appear as encrustation and fracture-filling materials. Some of these coarse grains are in the form of massive granular habit and are characterized by complete mixing of both limonite and uranium minerals. The second variety of the uraniferous iron grains occurs also in massive granular habit, but it is characterized by various color shades including dark yellow, orange yellow, orange red and reddish orange. These grains attain their liberation in the size fraction (0.400–0.063 mm) and mostly occur as intergranullar grains. Some grains of this variety also occur in minute acicular or fibrous aggregates.

Khazback and Raslan (1994) and Raslan (1996, 2000) indicated that the size fraction (0.400–0.063 mm) is the best grain size for liberation and subsequent mineral separation and/or upgrading. Further grinding of the inter-mixed coarse grains resulted in finer grains having, however, the same characters. In other words, these grains are still stained and coated with iron oxides in the liberated size fractions (0.400–0.063 mm).

The X-ray diffraction data obtained confirm that all the grains are almost completely composed of uranophane and β-uranophane minerals (Fig. 5). Raslan (2004) remarked that the presence of both uranophane and β-uranophane as a mixture in some samples is attributed to the presence of both habits (massive granular and fibrous acicular crystals) as intergrown mixtures.

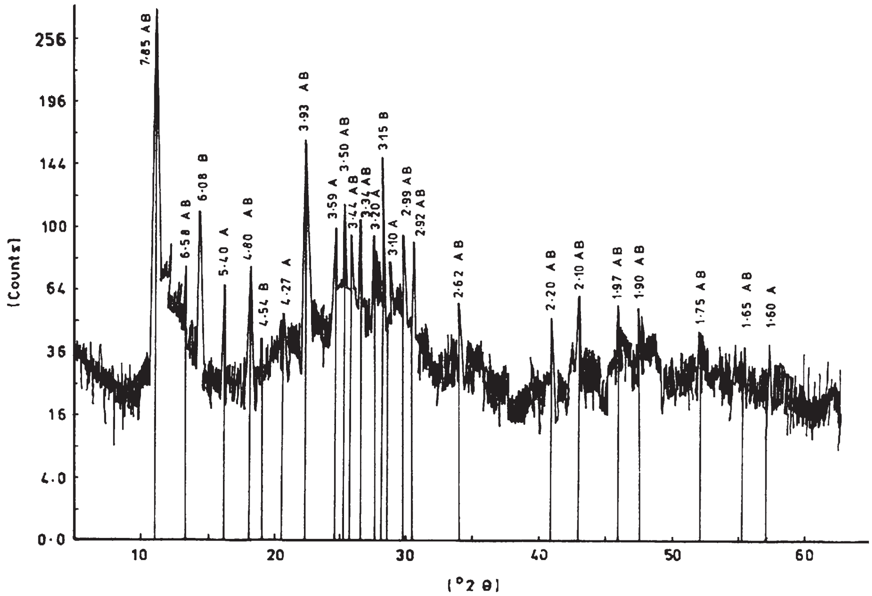

Fig. 5 X-ray diffraction chart of the studied uraniferous iron grains. A, uranophane; B, β-uranophane.

4.3 Abundance and nature of the uraniferous iron grains

Systematic mineralogical counting of the uraniferous iron grains in the sink fractions of the size fraction 0.400–0.063 mm indicated that their average abundance represents approximately 17.50%, 18.00% and 26.00% of the total accessory heavy minerals of Gabal Gattar, El Missikat and El Erediya samples, respectively (Table 1). Excluding the heavy fraction counting of the −0.100 to +0.063 mm size fraction of Gabal Gattar (6.80%), the average abundance of these grains would increase to 21.14% in this mineralization. The rest of the uranium minerals in the studied samples are represented by canary yellow to bright yellow uranophane and β-uranophane.

Monomineralic sample fractions from both of the dark colors grains and those of light colors were subjected to elemental analysis using field emission scanning electron microscope (JEOL 6335F) at University of Florida, USA. The obtained data including scan map confirmed the abundance of iron in the darker colored varieties (10.52%) with respect to the light colored varieties (1.60%) (Fig. 6). This analysis also confirms the elemental composition of uranophane and β-uranophane, in addition to the presence of iron in reddish yellow grains.

Electron microprobe analyses (JEOL Superprobe 733) for the studied grains (Table 2) makes it clear that the bright zones in uranophane and β-uranophane are depleted in iron (ranging from 0.13 to 0.23%) and the dark zones are usually enriched with iron (ranging from 3.86 to 5.27%).

Table 1 Abundance of the uraniferous iron grains in the heavy fractions of the studied uraniferous granitic samples (wt%)

Sample size (mm)	Gabal Gattar	El Erediya	El Missikat
−0.400 + 0.300	20.00	24.30	15.60
−0.300 + 0.200	21.40	26.50	17.85
−0.200 + 0.100	22.00	27.90	20.20
−0.100 + 063	6.80	25.40	18.45
Average	17.50	26.00	18.00

5. Summary and conclusion

The present work indicates that the dark-colored uranophane and β-uranophane in the studied uranium occurrences is attributed to limonite staining and coating or impregnation of these minerals. This limonite must have resulted from hydrolysis of coexisting magnetite, goethite and hematite at or near the surface. The mineralogical study indicates that the uraniferous iron grains should be considered as composite grains; a matter that would render their separation into completely pure varieties by grinding to fine size an almost impossible task. In contrast, the iron oxide staining and intense ferrugination of some uranophane and β-uranophane grains represent a good potentiality for their magnetic concentration. According to Raslan (1996,

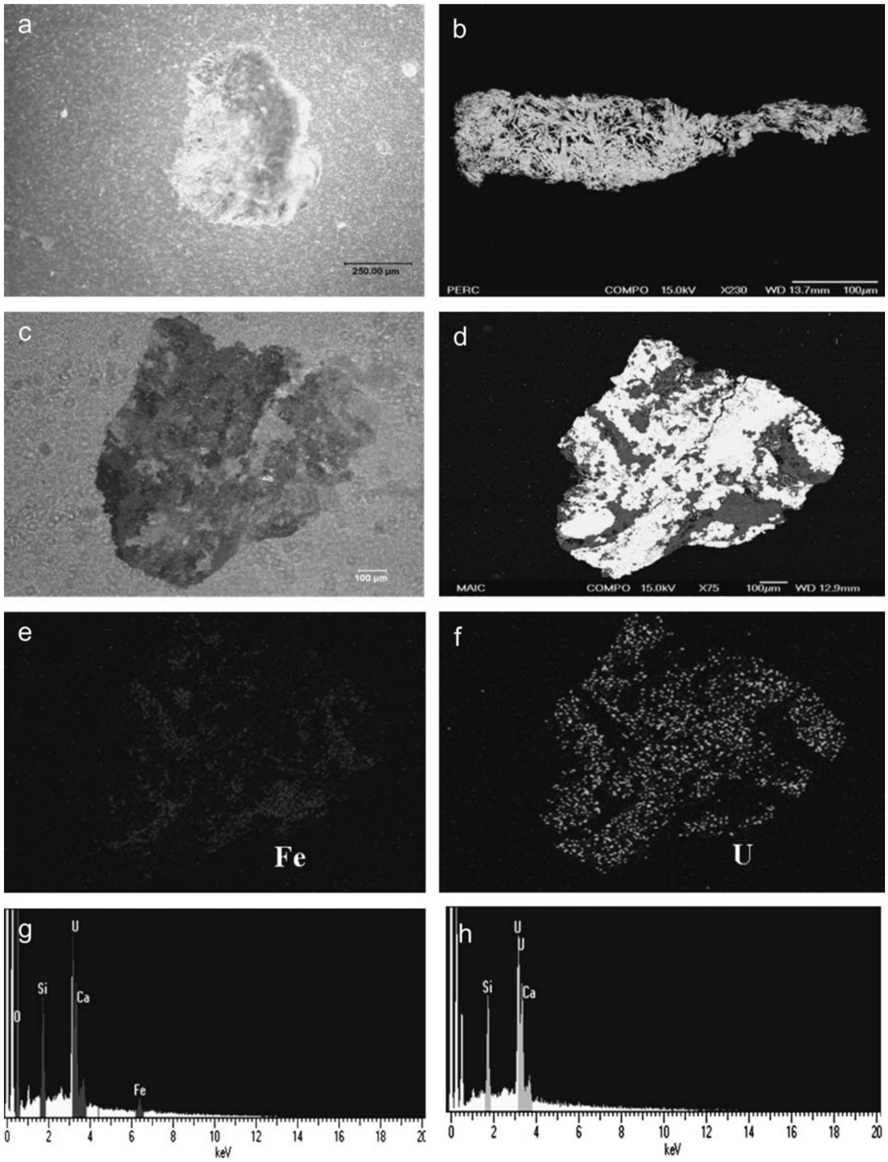

Fig. 6 (a) Fibrous iron uraniferous grain with dark and bright zones, PL, Gabal Gattar uranium occurrence. Bar, 250 μm. (b) Backscattered electron (BSE) image for fibrous uranophane and β-uranophane, El Erediya uranium occurrence. Bar, 100 μm. (c) Granular massive grain of Fe-rich uranophane and β-uranophane, PL, El Missikat uranium occurrence. Bar, 100 μm. (d) BSE image of the grain (Fig. 6c). Bar, 100 μm. (e,f) Scan map showing distribution of (e) Fe and (f) U. (g,h) Energy-dispersive x-ray (EDX) spectra for (g) dark and (h) bright regions in iron uraniferous grain.

2000) and Khazback and Raslan (1994), concentration of such grains using the isodynamic magnetic separator at a current intensity ranging from 0.5 to 1 A is possible. The light colored varieties of uranophane and β-uranophane (canary yellow to yellow) are concentrated mainly as non-magnetic at a current intensity of 1.5 A.

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Table 2 Microprobe analysis (wt %) of dark and bright zones in iron uraniferous grains of fibrous and massive granular habits

Analyses	Bright	Bright	Bright	Bright fibrous	Dark fibrous	Dark	Dark	Dark
SiO_2	16.03	18.85	16.97	15.94	16.07	14.70	15.71	16.07
UO_2	76.61	77.50	79.16	78.01	75.83	80.23	76.93	69.57
ThO_2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CaO	5.32	6.18	4.47	6.13	6.28	4.60	5.41	5.59
FeO	0.13	0.17	0.23	0.00	3.90	3.86	5.27	5.20
Total	98.09	102.70	100.83	100.08	102.08	103.39	103.32	96.43

respectively, University of Florida, USA. The author sincerely thanks Professor Dr Hassan El-Shall, Professor of Material Science and Engineering, University of Florida, USA, for his interest as well as for providing EMPA analyses.

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