



## Genesis of kasolite associated with aplite-pegmatite at Jabal Sayid, Hijaz region, Kingdom of Saudi Arabia

Yehia H. Dawood<sup>a,b,\*</sup>, Hesham M. Harbi<sup>a</sup>, Hamdy H. Abd El-Naby<sup>a,c</sup>

<sup>a</sup> King Abdulaziz University, Faculty of Earth Sciences, P.O. Box 80206, Jeddah 21589, Saudi Arabia

<sup>b</sup> Department of Geology, Faculty of Science, Ain Shams University, Cairo, Egypt

<sup>c</sup> Nuclear Materials Authority, P.O. 530 El-Maadi, Cairo, Egypt

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### ABSTRACT

In this study, we report kasolite  $Pb(UO_2)SiO_4 \cdot (H_2O)$  for the first time as a main uranyl mineral in the mineralized aplite-pegmatite of Jabal Sayid, Hijaz region. It commonly forms clusters of yellow acicular crystals in the voids and fractures. The mineral chemistry and mineralogical characteristics of kasolite were investigated using different techniques. Calcium, iron and phosphorus are detected in kasolite in addition to its major constituents; uranium, lead and silicon. Lead does not exist as a radiogenic product and not even as a substitute for uranium in the mineral structure. Alternatively, galena mineralization could be considered as a source for lead. The fluoride and carbonate complexes played a significant role in the formation of kasolite. High temperature hydrothermal solutions reacted with pre-existing uranium-bearing metamictized accessory minerals such as pyrochlore, U-rich thorite and zircon to form uranous fluoride complexes. These complexes are predominant in reducing environment and at pH 4. When the fluids approached the surface passing through fracture system, the oxygen fugacity ( $fO_2$ ) and the pH increased because of the loss of volatile components. At these conditions, uranous fluorides would convert to uranyl fluoride complexes  $UO_2F_3^-$ . Further decrease in temperature was associated with the decay of the activity of fluorine ion by the dilution of hydrothermal solutions and precipitation of fluorite. At this condition, uranyl-carbonate complexes are favoured. These complexes were combined later with silica and lead to form kasolite.

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### 1. Introduction

The radionuclides and trace elements released during the corrosion of the primary uranium minerals may become incorporated into the structures of the secondary uranyl phases. This incorporation depends on the interaction between solute and rock surfaces, which is mainly governed by sorption/desorption or precipitation/solubility processes. Kamineni et al. (1986), Casas et al. (1994) and Drot et al. (2007) have documented sorption of the uranyl ion on iron oxides and montmorillonite. Natural uraninite and its alteration products can be used to investigate trace element incorporation into these secondary alteration phases (Ewing 1991, 1993). Therefore, investigations of natural uraninite and migration of its components during corrosion as well as secondary uranium phases have attracted much attention in the last few years (Janeczek et al., 1996; Fayek et al., 1997; Gorman-Lewis et al., 2008).

Uranyl silicates belong to the most abundant group of uranium minerals. Due to their relatively low solubility in natural ground-

water (Finch and Murakami, 1999), most uranyl complexes encountering free silicate ions might precipitate in the form of uranyl silicates. Investigation on this mineral group is important for understanding the mineral genesis and the mobility of uranium in different environments.

The Jabal Sayid aplite-pegmatite is a mineralized, radioactive body located at 23°49'03"N, 40°56'30"E (Fig. 1). This aplite-pegmatite was discovered by car-borne radiometric survey in 1956 (Ahmad, 1957), and subsequently drill tested for uranium mineralization (Schaffner, 1957). Later, its potential for Nb and other granitophile elements was investigated by Shepherd (1965). Further geological, mineralogical and geochemical data were presented by Turkistany and Ramsay (1982). The latter work confirmed the presence of REE-bearing minerals assemblage with economic potential. Surface study (Hackett and Ramsay, 1982) and drill testing for a wider range of granitophile elements (Hackett, 1984) delineated a highly mineralized body with internal layering, and led to a better understanding of its mode of emplacement and morphology. Although the previous studies carried out on the aplite-pegmatite have not delineated occurrence of primary uranium mineralization, the rock shows anomalous uranium contents (49–134 ppm; with an average of 93 ppm) (Hackett, 1986). Sources of uranium in this rock were identified by the same author as

\* Corresponding author. Address: King Abdulaziz University, Faculty of Earth Sciences, P.O. Box 80206, Jeddah 21589, Saudi Arabia. Tel.: +966557567738; fax: +966026952095.

E-mail address: [yhdawood@yahoo.com](mailto:yhdawood@yahoo.com) (Y.H. Dawood).

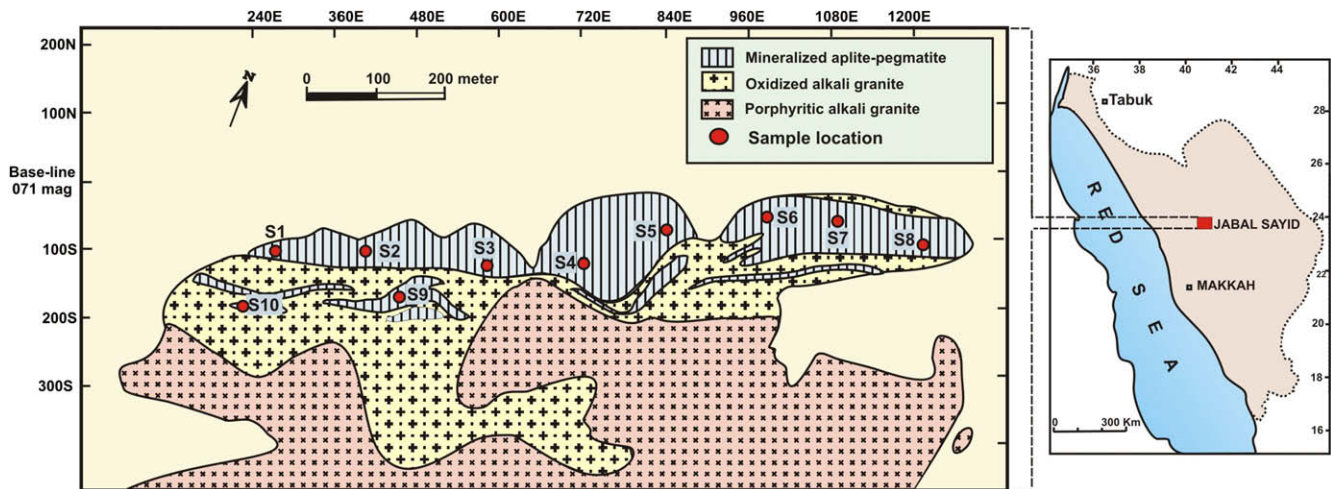


Fig. 1. Geologic map of the study area.

uranium-bearing accessory minerals such as U-rich thorite, zircon and pyrochlore. This paper presents the first contribution of the Electron Probe Micro Analysis (EPMA) of uranyl mineralization and some associated minerals at Jabal Sayid area. This might elucidate the factors involved in uranyl minerals genesis in such an oxidizing and arid environment.

## 2. Geologic setting and petrography

In the Sayid area and its vicinity, widespread late tectonic, alkaline to peralkaline granite massifs intrude the late Proterozoic acidic volcanic rocks of Sayid Formation, volcanosedimentary unit of the Mahd group, the arcuate belt of Bir Umq ophiolitic complex and various granodiorite and quartz diorite outcrops. The Jabal Sayid aplite-pegmatite body lies along the northern margin of the alkali microgranite pluton of Jabal Sayid (Fig. 1). The mineral composition of this granite is dominated by arfvedsonite, aegirine, quartz, microcline and albite. This granitic rock is considered as the chilled carapace of typical Arabian Shield alkali granites (Hackett, 1986). It is a part of the Jabal Hadb ash Sharar complex, which comprises a core of pink monzogranite surrounded by a broad zone of gray hornblende-biotite monzogranite to granodiorite. The foot-wall of the alkali microgranite is highly altered close to the contact with the aplite-pegmatite body.

The aplite-pegmatite is a sheet-like body of about 5–13 m width and a strike length of about 2 km (Turkistany, 1979). The main aplite-pegmatite, however, crops out almost continuously for about 1 km and dips N at 45–75° (Fig. 1). Below the sharp contact with alkali microgranite, dikes and veins invade joints and fractures parallel to this contact (Fig. 2a–c). This indicates a late-stage emplacement of the aplite-pegmatite (Hackett, 1986). Based on iron oxide contents, the color of these rocks varies from buff and pink, to darker red and brown varieties; in addition to uncommon black color. The aplite-pegmatite exhibits a fine-grained and homogeneous chilled margin against the confining metavolcanic rocks. According to Hackett (1984), the internal structure of the aplite-pegmatite is layered and its composition is varied. The layers are 0.3–5.0 m thick and consist of coarse pegmatite, with crystals up to 3 cm long, micropegmatite and aplite. Aplite has a genetic affinity to the intersected alkaline granite. It is the last part of the magma to crystallize, and corresponds in composition to the quartzo-feldspathic aggregates that fill up the interspaces between the early minerals in the main body of the rock. The essential components of aplite are nearly equi-dimensional grains of quartz and alkali feldspar (microcline and albite). Aplite crystallization has

been apparently rapid as the rock is so fine-grained. These phases are commonly homogeneous and have sharp contacts. Trace-elements data show that there is no significant difference between the granitophile elements content of these phases (Hackett, 1986). Quartz, microcline, aegirine, arfvedsonite, albite and iron oxides were identified in the pegmatite using polarizing microscope. Hackett (1986) reported the occurrence of several ore minerals in the aplite-pegmatite of Jabal Sayid. These are: bastnaesite, synchysite, monazite, thorite, zircon, pyrochlore, magnetite, anatase, brookite, rutile, pyrite, siderite, sphalerite and sphene. Fluorite is common throughout but is prominent in the alteration zones. Uranyl mineralizations are discovered for the first time in the present study. These mineralizations are found mainly as cavity fillings and encrustations on quartz veins and along their contacts with the host rock. In many places, these mineralizations are found associated with iron oxides (Fig. 2c). Other minerals such as calcite, galena and sphalerite are also observed (Fig. 2d).

## 3. Sampling and analytical procedures

Ten samples from the main mineralized zones of the aplite-pegmatite were collected. The locations of these samples are shown in Fig. 1. The collected samples show surficial enrichment of yellow-colored uranyl mineralization associated with malachite, reddish brown iron oxides and sulfide minerals (Fig. 2c and d). Polarizing microscope was used to study the mineral constituents of the aplite-pegmatite and associated uranyl mineralization. Crusts of this uranyl mineralization were scrapped from the surfaces of the host granitic rocks using a stainless steel blade. Some of the scraped minerals representing all locations were isolated under binocular microscope based on their color and identified using X-ray Diffraction. The X-ray diffractograms were made with Siemens diffractometer using Ni filter and Cu K $\alpha$  radiation at 40 kV and 20 mA. The machine is equipped with D 500 goniometer, a graphite monochromator and a scintillation detector. The pulverized samples were scanned for about 30 min counting time at a rate 1 degree 2 $\theta$  per half minute with step size 0.02 2 $\theta$ . Peaks search and identification were performed by the DIFFRAC-AT software connected to the diffractometer. In addition, crusts of uranyl mineralization were mounted with epoxy on glass slides then ground to the desired thickness prior to polishing. A JEOL JEE-400 Vacuum Evaporator was used to coat samples with a carbon layer prior to analysis. Secondary Electron Imaging (SEI), Back Scattered Electron (BSE) imaging, Wavelength-Dispersion Spectral (WDS) scans and

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