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VEIN-TYPE URANIUM MINERALIZATION IN THE EASTERN DESERT OF EGYPT

Mohamed Mahmoud Fathy Ghoneim[1,2]
moh.gho@mail.ru
Ahmed El Sayed Abdel Gawad[2]
gawadnma@gmail.com

[1]Saint Petersburg State University
Saint Petersburg, Russia
[2]Nuclear Material Authority
P.O. Box: 530 El Maadi, Cairo, Egypt

Мохамед Махмуд Гхонеим[1,2]
moh.gho@mail.ru
Ахмед Эль Саид Абдель Гавад[2]
gawadnma@gmail.com

[1]Санкт-Петербургский государственный университет
Россия, Санкт-Петербург, Университетская наб., 7/9
[2]Управление ядерных материалов
Египет, Каир, Эль Маади, 530

Урановая минерализация жильного типа в Восточной пустыне Египта

Урановые месторождения жильного типа, в которых урановые минералы выполняют различные полости, такие как трещины, жилы, поровые пространства, зоны сдвига, брекчии и штокверки в магматических, метаосадочных и метаморфических породах, являются главным источником урана во всем мире. В Египте урановая минерализация Эль-Эредия, Эль-Миссикат и Эль-Села находится в молодых гранитных плутонах в Восточной пустыне Египта. Эти плутоны считаются хорошими примерами внутригранитной урановой минерализации жильного типа.
Цель этой обзорной статьи – изучить характеристики гранитов и Th-U-жильной минерализации района Эль-Села.
Основными задачами статьи являются описание характеристик минерализации урана в мире и Египте, характеристик рудоносных интрузивных пород в районе Эль-Села, минералогии Th-U-минерализации жильного типа в районе Эль-Села и вторичных минералов U и Th в гранитах.
Результаты. В статье показано, что граниты Эль-Села являются пералюминиевыми, высококалиевыми кальциево-щелочными гранитами. Двуслюдяной лейкогранитный плутон считается источником U-минерализации в районе Эль-Села, а измененные микрогранитные и долеритовые дайки – хорошие ловушки для этой минерализации. Реактивированная система трещин с направлением ВСВ-ЗЮЗ и ССЗ-ЮЮВ создает благоприятные условия для формирования минерализации урана, связанной с полиметаллической минерализацией, которые суммарно накладываются на двуслюдяные граниты и дайки микрогранитов и долеритов. Металлоносные минеральные ассоциации в жилах состоят главным образом из пирита, халькопирита, галенита, сфалерита и флюорита, которые связаны с первичной (уранинит, коффинит) и вторичной U-минерализацией (уранофаном и отенитом), которые встречаются либо в виде отдельных скоплений, либо в качестве выполнения микротрещин или покрывая поверхности пород. Можно выделить пять типов минералов группы торита: сам торит, Zr-содержащий торит, фосфоторит, ураноторит и Zr-содержащий ураноторит. Уранинит содержит ThO_2 в пределах от 1,1 до 3 мас. %, PbO – от 1,16 до 2,35 мас.%, P_2O_5 – от 0,17 до 1,56 мас. % и CaO – от 3,8 до 7,6 мас. %. Кроме того, в незначительных количествах присутствуют LREE и Y. В восстановительных условиях уранинит изменяется до коффинита с потерей радиогенных Pb и Y с HREE. Главной характеристикой жильного типа Эль-Села, включая минеральный парагенезис и региональный тектонический контроль, является то, что она относится к жильному типу полиметаллических месторождений, связанных с измененными гранитами.

Ключевые слова: жильный тип; уран; Восточная пустыня; Египет; разрывная зона; минерализация; Эль-Села.

Vein type uranium deposits where uranium minerals fill cavities veins, fractures, fissures, pore spaces, shear zone, breccia and stockworks in igneous, meta-sediments and metamorphic rocks are common source of uranium mineralization all over the wold. In Egypt, El-Erediya, El-Missikat and El Sela uranium mineralization occur in younger granite plutons in the Eastern Desert of Egypt. These plutons are considered as good examples of intra-granitic vein-type uranium mineralization.
The goal of this review article is to study the characteristics of granites and Th-U vein mineralization El Sela area.
Main tasks are characteristics of vein type uranium mineralization in the world and Egypt, characteristics of ore-bearing intrusive rocks in the El Sela area, mineralogy of Th-U vein-type mineralization in El Sela area and secondary U and Th minerals in granites.
Results. The article revealed that El Sela granite is a peraluminous, high-K Calc-Alkaline (HKCA) granite. Two-mica leucogranitic pluton is considered the source rock of U-mineralization at El-Sela area, while the altered microgranite and dolerite dikes are good traps for these mineralizations. The reactivated faults system trending ENE-WSW and NNW-SSE make favorable condition to form uranium mineralization associated with polymetallic mineralization that are redeposited in the two mica granite, microgranite and dolerite dikes. The metallic mineral assemblages in the veins mainly consist of pyrite, chalcopyrite, galena, sphalerite and fluorite that are associated with primary (uraninite, coffinite) and secondary U-mineralization (uranophane and autunite) that occur either as disseminated clusters or as microfracture filling and coating joint surface. Five types of thorite-group minerals can be distinguished: thorite, Zr-rich thorite, phosphothorite, uranothorite and Zr-rich uranothorite. ThO_2 content of uraninite vary from (1.1 to 3 wt.%), for PbO contents from 1.16 to 2.35 wt.%, P_2O_5 contents from 0.17 to 1.56 wt.% and CaO contents from 3.8 to 7.6 wt.%. Also, minor amounts of LREE and Y are present. Under reducing conditions, uraninite may be altered to coffinite, with loss of radiogenic Pb and Y with HREE. The main characteristics of El Sela vein-type including mineral paragenesis and regional tectonic control show that it belongs to granite-related vein-type polymetallic deposits.

Keywords: vein type; uranium; Eastern Desert; Egypt; shear zone; mineralization; El Sela.

Introduction

Vein-type uranium deposits have been the source of uranium since its discovery by Martin Klaproth in 1789. The vein-type deposits constitute 7% of the global reserves and about 10% of uranium has been produced from deposits of this type.

Vein-type uranium deposits are those in which uranium minerals fill cavities such as cracks, veins, fractures, fissures, pore spaces, shear zone, breccia and stockworks in igneous, meta-sediments and metamorphic rocks [1–4].

Two subtypes of uranium vein deposits can be identified according to their metallic mineral composition:

(1) Monometallic, where uranium minerals occur as the sole metallic constituents in a simple mineral assemblage. Typical example of monometallic uranium vein-type deposits is the Fay-Ace-Verna zone in Canada (2) Polymetallic, where uranium minerals are accompanied by other metallic elements, such as nickel, cobalt, arsenic, zinc, bismuth, copper, lead, manganese, selenium, vanadium, molybdenum, iron and silver. The metallic minerals are commonly associated with gangue, typically carbonate, quartz or clay minerals. Polymetallic veins-type deposits are represented by the deposit at Port Radium in Northwest Territories, Canada; the Jachymov deposits in the Erzgebirge region, Czechoslovakia; and the Shinkolobwe deposit in the Shaba province of Zaire. Uranium reserves of all these deposits have been depleted. Uranium oxides (pitchblende), arsenides and sulpharsenides of nickel and cobalt, copper sulphides, native silver, were principal ore constituents

of the deposit at Port Radium Granite-related U deposits uranium mineralization occurs as disseminations or veins composed of ore and gangue minerals in granite or adjacent (meta-) sediments and resources are small to large and grades low to high. Classification of the uranium vein-type uranium deposits, based on their geological setting, structural and lithological controls in their localization. The granitic or syenitic rocks host vein deposits (intragranitic veins), by whatever rocks surround the granitic plutons (perigranitic or peribatholithic veins) or by sheared or comminuted metamorphic, sedimentary or igneous complexes (veins in shear mylonite).

(1) Endo (or intra-) granitic vein deposits (Limousin-Vendée Type) are typically developed in highly differentiated granitic rocks, e. g., in two-mica leucocratic granites that were subjected to preceding alteration, such as albitization and desilicification (episyenitization). The deposits are spatially related to regional faults. The principal uranium minerals, pitchblende and coffinite, are commonly associated with sulphides and gangue minerals, such as carbonates, quartz, chalcedony, fluorite and barite. These deposits comprising two sub-types:

(i) Mostly discontinuous, linear ore bodies as veins or stockworks localized in fractured granite example endogranitic vein deposits: Fanay-Les Sagnes/La Crouzille District, Massif Central, France [5].

(ii) Disseminations in pipes or columns of episyenite as Bernardan/La Marche District; Massif Central, France [6, 7]. Contact granitic veins persist from inside the granite across and beyond the granite contact but also exist only in enclosing rocks in vicinity of the contact. Type example contact-granitic deposits: L'Écarpière ore field/Vendée District, France [8].

(2) Perigranitic vein deposits are typically developed in in meta-sediments and metamorphic rocks at their contacts with intrusive granitic plutons. They are also structurally controlled by regional faults. The host rocks are often cut by lamprophyre and aplite dikes. The deposits consist of subvertical veins, breccia zones, stockworks and irregular bodies spatially associated with major faults.

(i) Perigranitic veins in meta-sediments can be monometallic (essentially pitchblende and gangue minerals) or polymetallic (U, Co, Ni, Bi, Ag or other metals in economic quantities). The gangue minerals include carbonates (calcite, dolomite) and quartz. The wall rocks and the gangue near the uranium minerals are commonly hematitized. The U and other elements are not genetically related.

(ii) Perigranitic deposits in metamorphosed rocks confined to the contact-metamorphic aureole of a granitic intrusion are monometallic and mineralization occur in the form of veinlets and disseminations in intensely fractured hornfels, speckled andalusite-cordierite schist, and similar rocks up to approximately 2 km wide around the granite. Host rocks are severely altered. Example: Nisa/Alto Alentejo District, Iberian Meseta, Portugal [9].

Vein-type uranium deposit mines in the world

In the European Hercynian belt (EHB), a large proportion of the uraniferous deposits are spatially associated with Late-Carboniferous peraluminous leucogranites or, less frequently, monzogranites. The vein-type, episyenite-type, breccia-hosted or shear zone-hosted U deposits related to these granites can be either intra- or perigranitic. This spatial relationship can be observed in the Iberian Massif [10], in the French part of the EHB (Armorican Massif and Massif Central [11]), in the Black Forest [12] and in the Bohemian Massif [13–16]. In the Bohemian Massif, Black Forest, Massif Central and Armorican Massif, most of the U mineralization was emplaced between 300 and 260 Ma [11, 12, 16–19].

Typical examples range from the thick and massive pitchblende veins of Pribram (Czech Republic), Schlema-Alberoda (Germany) and Shinkolobwe (Democratic Republic of the Congo), to the stockworks and episyenite columns of Bernardan (France) and Gunnar (Canada), to the narrow cracks in granite or metamorphic rocks, also filled with pitchblende of Mina Fe (Spain) and Singhbhum (India). In Australia, many small vein deposits occur in various geological settings, including Proterozoic metamorphics near Port Lincoln, in the Mount Lofty Ranges, and in the Peake and Denison Ranges (all in SA), and Palaeozoic granites in the Lachlan and New England Fold Belts (NSW, Victoria and Tasmania).

Some other mines of vein-type uranium deposits in the world [4]

(1) Great Bear Lake area, Northwest Territories, Canada (Port Radium deposit);

(2) Beaverlodge area, Saskatchewan, Canada (Fay-Ace-Verna zone);

(3) Vend6e area, France (la Commanderie, Chardon and Escarpiere deposits);

(4) La Crouzille area, France (Fanay, Margnac and Bellezane deposits);

(5) Vitkov II deposit, Czechoslovakia;

(6) Pribram deposit, Czechoslovakia;

(7) Jachymov area, Czechoslovakia (Jachymov deposit), and Aue area, East Germany (Niederschlema, Obserschlema and Johanngeorgenstadt deposits);

(8) Rozna area, Czechoslovakia (Rozna, Olsi and Slavkovice deposits);

(9) Shinkolobwe deposit, Shaba Province, Zaire;

(10) Chanzipin deposit, Guanxi Province, China;

(11) Xiazhuang area, Guandong Province, China (Zhushanxia, Shijiaowei and Xiwang deposits).

Many vein-type uranium deposits are closely associated with unconformities and resemble, to a certain degree, unconformity-related deposits. For example, the now depleted Fay-Ace-Verna uranium system in the Beaverlodge area, Saskatchewan, Canada, which was considered a typical representative of the vein-type deposits, was associated with the Middle Proterozoic sub-Martin unconformity. The Pribram deposit in Czechoslovakia was associated with the sub-Cambrian unconformity.

Conversely the Eagle Point deposit in Saskatchewan, Canada, which is classified as a deposit associated with the sub-Athabasca unconformity, contains pitchblende that fills cavities and fractures in Aphebian metamorphic rocks. The Nabarlek, Ranger I and III, and Koongarra deposits in Northern Territory, Australia, which are associated with the Middle Proterozoic sub-Kombolgie unconformity, also exhibit many features like those that are characteristic for uranium vein deposits, such as mineral composition of the ore bodies, host rocks and the wall rock alterations.

Vein-type uranium mineralization in the Eastern Desert of Egypt

El-Erediya, El-Missikat and El Sela uranium mineralization occur in younger granite plutons in the Eastern Desert of Egypt. The three plutons are considered as good examples of intra-granitic vein-type uranium mineralization.

In both El-Erediya and El-Missikat occurrences, the mineralization is structurally controlled by faults and their feather joints which are associated with NE-SW to ENE-WSW shear

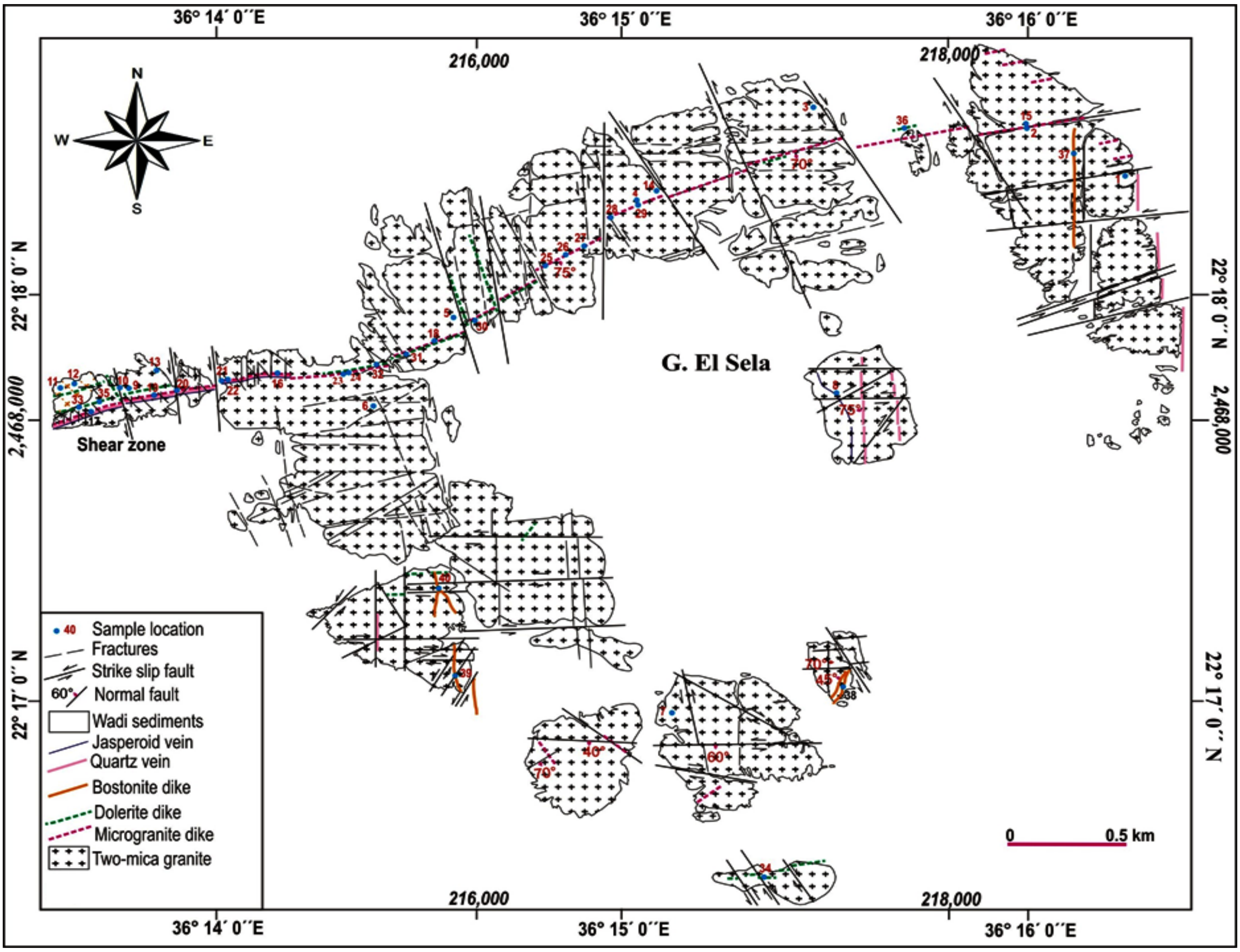

Fig. 1. Detailed geologic map of El Sela shear zone, southeastern Desert of Egypt [31]. Modified after [36].

zones. The shear zones are usually filled with siliceous veins and veinlets of white (milky quartz), black (smoky quartz) and red (red jasper) colors of abnormal radioactivity with visible uranium mineralization. Both the jasper and quartz veins are not equally distributed, so they are denser and closely spaced in the northern granitic mass of G. El-Missikat than those at the southern mass of G. El-Eridiya. Along shear zones, the walls are stained with reddish brown colors due to hematitization, faint greyish green to whitish buff color due to kaolinization and sericitization and yellowish to dark green coloration due to epidotization and chloritization [20–22]. There is a special interest with jasper veins after the discovery of several radioactive anomalies with visible yellow secondary uranium mineralization along the northern fringe of G. El-Missikat and the southern fringe of G. El-Eridiya plutons. These anomalies are associated with highly brecciated grayish black and red jasper filling fractures and shear zones.

Hussein et al. [22] suggest that the mineralizing fluids have their source in the granitic magma itself with possible contributions from meteoric waters. Uranium was leached out from the accessory U-bearing minerals, with possible addition from the mantle carried up by the hydrothermal fluids. The origin of secondary uranium mineralization in El Erediya area has been previously related to the alteration of pitchblende [22–26].

The U-minerals in the jasperoid veins are represented essentially by disseminated uraninite and uranphane as its main secondary alteration product. The secondary U-minerals are mainly uranophane, beta-uranophane, soddyite and renardite. Subordinate amounts of sulphides as well as fluorite and gangue minerals are the main associates of the mineralization [20, 22, 24, 27, 28]. The sulphides are mainly represented by pyrite, chalcopyrite, galena and sphalerite. The gangue minerals are mainly represented by fluorite, iron and manganese oxides. The uranium deposit at El-Missikat and El-Eridiya plutons represent a case of siliceous vein-type deposit [22], and is related to polymetallic vein-type, probably formed in a reducing condition [29].

El Sela shear zone intra-granitic vein-type uranium mineralization southeastern Desert of Egypt

A number of studies were carried out in El Sela shear zone, which covered various aspects including: detailed geological, structural, spectrometric survey, geochemical, mineralogical, geophysical methods to explore for uranium mineralizations [30, 31–33, 34–40].

Geological and structural setting

Field investigations revealed that El Sela area is composed of two-mica (muscovite-biotite) granite intrusions trending ENE-WSW. It is jointed in different directions, and defines low to moderate reliefs. Two mica granite is injected by microgranite, dolerite and bostonite dikes, and quartz and jasperoid veins. They are mostly injected along ENE-WSW and/or NNW-SSE to N-S directions which represent the most important tectonic trends in the study area (Fig. 1).

Microgranite dike host the most radioactive anomalies in the study area. They are whitish pink, pale pink, reddish pink to pale grey colors and is 3 to 20 m thick and injected into the two-mica granite along an ENE-WSW shear zone with dip of about 75° to south. They are also essentially composed of quartz, K-feldspar, plagioclase, biotite and muscovite also enriched in uranophane and pyrite megacrystals.

Dolerite dikes are greyish green to dark grey colors, fine- to medium-grained and range in thickness from 0.5 to 6 m. They are injected into the two-mica granite along ENE-WSW, NNW-SSE and N-S directions. They are mainly composed of plagioclase, olivine and pyroxene. Accessories are apatite and opaque minerals while chlorite, sericite and calcite are alteration minerals. The dolerites have higher U-contens which may reach up to 3500 ppm U and 75 ppm Th. They are highly altered to clay minerals and cavities are filled with pyrite cubes and/or secondary uranium minerals (uranophane and autunite). Many open cuts have been made to recognize the importance of the U mineralization within the microgranite and dolerite dikes.

Many semi-industrial technological procedures for the leaching and recovery of the U incorporated within these mineralized dikes have been performed [41].

Bostonite dikes invade two-mica granite along N-S and NNE-SSW structures. They are usually fine-grained, pale brown to deep red colors, fractured, jointed, sheeted, and range in thickness from 0.5 to 2 m. They are essentially composed of K-feldspar, plagioclase, quartz and iron oxides set in a finely crystalline groundmass of K-feldspar microlites. They have U-contents from 4.1 to 25.4 ppm U.

Milky quartz vein dissected two-mica granite along the ENE-WSW shear zone. This vein is non-radioactive, brecciated and ranges in thickness from 1 to 4 m. The milky quartz vein is dissected by red and grey to black jasperoid veins. Red and grey to black jasper veins are strongly jointed, fragmented, brecciated and range between 0.5 and 1 m thick, contain visible pyrite megacrysts and uranophane minerals. Some other quartz veins are trending NNW-SSE and N-S.

Structure analysis of the ductile deformation reveals the presence of three generations of folds [34]. ENE–WSW and NNW–SSE trends can be considered as preexisting discontinuities and mechanical anisotropy of the crust in the following structure episodes, while the brittle deformation reveals the importance of those trends which control the multi-injections and many alteration features in the study area. Thus, the structural controls of the uranium mineralization appear related to the interaction between inherited ductile fabrics and overprinting brittle structures. During reactivation, a simple shear parallel to the inherited ductile fabrics was responsible for the development of mineralized structures along the ENE-WSW and NNW-SSE trends so they can be considered as paleochannel trends for deep-seated structures and can act as a good trap for uranium mineral resources. Most of the uranium anomalies are delineated along ENE-WSW and NNW-SSE shear zones where quartz-bearing veins bounded the microgranite and dolerite dikes and dissected them in relation to the successive fracture formation and brecciation corresponding to the repeated rejuvenation of the structures.

Geochemical and mineralogical characteristics

Generally, granitic rocks are one of the most favorable host rocks for U-mineralization in many parts of the world. Genetically, the economic uranium deposits associated with granites are mostly located in anatectic melts or in strongly peraluminous two-mica granites [42, 43]. The U fertility of igneous rocks not only depends on their total U content but also on the capacity of the igneous U-bearing phases they host to be dissolved by the fluids. In peralkaline or high K Calc-alkaline granites, most of the uranium is hosted in refractory minerals such as zircon, monazite and/or uranothorite. In contrast, in peraluminous leucogranites, uranium is mainly hosted as uranium oxides and, as such, represent an ideal source for the formation of U deposits [44] as uranium oxide is an extremely unstable mineral and consequently easily leachable during oxidizing fluid circulations. The formation of an economic uranium concentration generally requires the remobilization of the uranium from these primary sources followed by deposition in tectonic structures with higher grades.

Most Egyptian uranium occurrences in granite rocks of Um Ara [45–47], Gattar [48], El-Missikat [23, 29, 49], El-Erediya [20–22, 28] and El Sela [32] are associated with per-aluminous granites. Uranium mineralization in these granites belongs to the vein-type except Gattar and Um Ara granites, where U-mineralization belongs to metasomatites. The El Sela granite complex is composed of two mica granite. Geochemically, El Sela granite is very leucocratic, peraluminous and enriched in lithophile elements (Ba, Rb and Sr), high field strength elements (Y, Zr and Nb), light rare earth elements (LREE) mostly hosted in monazite and allanite. Most of them have a negative Eu anomaly. Their characteristics correspond to those of A-type granites (high-K Calc-alkaline granite).

Scanning electron microscope (SEM) and electron microprobe analyses (EMPA) were used to identify the nature of Th-, U and REE bearing minerals accessory minerals and sulphides at El Sela granite.

Th-, U-, REE-mineralization

Thorite, phosphothorite, uranothorite, brannerite, coffinite, uraninite and pitchblende have been identified by SEM and EMPA analyses. Thorite, phosphothorite and uranothorite are represented in the El Sela two mica granites. Thorite-group minerals form euhedral to subhedral crystals and enclosed in biotite, quartz, zircon and monazite. Five types of thorite-group minerals can be distinguished: thorite, Zr-rich thorite, phosphothorite, uranothorite and Zr-rich uranothorite [35, 36].

Uranophane and autunite recorded as secondary visible U minerals that occur either as disseminated clusters or as microfracture filling and coating joint surface in the different alterations. The EDX analysis data suggest that uranophane contains U ranges between 54.29–77.75 wt.%. It contains considerable amounts of P, Ca and Al with a mean average 3.12 wt.%, 8.46 wt.% and 1.97 wt.%, respectively. The EDX analysis data suggest that it contains 57.44 wt.%, 5.7 wt.%, 17.43 wt.%, and 1.24 wt.% of U, Ca, P and Fe^{3+}, respectively.

ThO_2 content of uraninite vary from (1.1 to 3 wt.%), for PbO contents from 1.16 to 2.35 wt.%, P_2O_5 contents from 0.17 to 1.56 wt.% and CaO contents from 3.8 to 7.6 wt.%. Also, minor amounts of LREE and Y are present. Under reducing conditions, uraninite may be altered to coffinite, with loss of radiogenic Pb and Y with HREE [50]. The variable amounts of SiO_2 indicate Si diffusion in the structure along fractures at the beginning of coffinitization. EMPA analyses show the major elements are SiO_2 vary from (12 to 25.1 wt.%) and UO_2 vary from (27.8 to 61.7 wt.%) correspond to the composition of coffinite [36].

EMPA analyses show a wide variation of the pitchblende composition which exhibit very weak zoning and occurs as botryoidal form or vein surrounded metallic sulphides especially pyrite. Most samples have no Th or traces (up to 0.03 wt.%) but significant contents (wt.%): SiO_2 (up to 4.69), CaO (5.28), Y_2O_5 (0.96), ZrO_2 (0.25), Nb_2O_5 (0.48), PbO (0.73) and REE (0.30), Moreover the trace elements in pitchblende may occur in the form of minute inclusions (galena, pyrite, sphalerite etc.) or as amorphous mixtures such as Ca, Pb, Th and REE which have similar ionic size to that of U^{4+}. The high iron contents in some samples (3.98 or 6.51 wt.%) is not attributed to substitution of U because of the large difference in atomic radii (Fe^{3+} = 0.64 Å; U^{4+} = 0.97 Å). It may correspond to some inclusions such as hematite and pyrite. The U contents fluctuate between 76.84 wt.% and 82.15 wt.% in relation with the effect of the substitutions of other elements. Silica contents range between 1.05 to 4.69 wt.% [36].

Monazite is recorded as as LREE-bearing mineral, especially Ce. Xenotime is one of the most enriched in HREE in two mica granite. It occurs as bipyramidal crystals, with short prisms and noticeable elongate fractures. EDX analysis data indicates that the obtained xenotime has 30.1–33.20 wt.% P and Y varies between 18.78–37.72 wt.%. It has considerable amounts of HREE especially Dy (3.63–7.68 wt.%), Er (3.21–11.46 wt.%) and Yb (9.75–22.15 wt.%).

Accessory minerals

Rutile, fluorite, betafite, zircon have been also identified by SEM and/or EMPA analyses [30, 35, 36, 40, 51]. Rutile is common mineral in most samples from the El Sela granite. It occurs as angular to subangular, elongated, cylinder and rod-like grains associated with zircon, fluorite, monazite, uranothorite.

Fluorite crystals are usually octahedral and have various colors including; colorless, shades of purple-blue, green, also pink and black. It is widespread as a common mineral enriched in visible uranophane and autonite in argillic dolerite dikes trending ENE-WSW and NNW-SSE.

Betafite is detected as Nb-Ti-bearing mineral occurring as anhedral to subhedral mineral. The obtained results confirm from chemical analyses of the studied betafite minerals by EMPA analysis, the major elements are included Nb_2O_5 (22.8 wt.%), TiO_2 (46.3 wt.%), FeO (8.48 wt.%) and Ta_2O_5 reach 2.7 wt.%. It obvious that betafite has lower U concentration reaches 1.57 wt.% and ThO_2 content reaches 5.8 wt. %.

Zircon is generally included as idiomorphic crystals variably enriched with HfO_2 ranges from 1.26 to 10.87 wt.%), UO_2 (up to 2.23 wt.%) and ThO_2 up to (up to 1.22 wt.%). The granite from the El Sela shear zone area are enriched in the lighter isovalents Nb and Zr relatively to the heavier isovalents Ta, Hf elements. The lower Zr/Hf ratio is in accordance with the presence of Hf-rich zircons (3 to 4 wt.% HfO_2).

Sulphides

Pyrite, chalcopyrite, arsenopyrite, galena, and sphalerite, occur as disseminations and fracture-fillings in mineralized smoky and red jasperoid veins, dolerite and microgranite dikes, in the El Sela granite. Magnetite, hematite, illmenite, rutile and apatite are also spatially associated with the sulphide minerals.

Pyrite is the most common sulphides and is recorded as well developed cubic crystals with pale brass-yellow color. Some of the pseudomorphic pyrite in the altered samples is displayed framboidal textures (goethite) that can be held as an evidence of an older anaerobic bacterial activity [52].

Pyrite is preserved in the samples from the drillings and seems to control the deposition of uraninite, brannerite, pitchblende and coffinite at the margin of the crystals [36].

Conclusion

1. Vein type uranium deposits are common source of uranium mineralization all over the wold. In Egypt El-Erediya, El-Missikat and El Sela uranium mineralization occur in younger granite plutons in the Eastern Desert of Egypt. The three plutons are considered as good examples of intra-granitic vein-type uranium mineralization.

2. In El Sela peraluminous high K calc alkaline two-mica granite is considered the source rock of U-mineralization at El-Sela area, while the altered microgranite and dolerite dikes are good traps for these mineralizations.

3. The ENE-WSW and NNW-SSE reactivated perpendicular faults make favorable conditions to form good structural trap in the altered and sheared granite, microgranite and dolerite dikes.

4. Th-, U and REE bearing minerals, accessory minerals and sulphides were identified in El Sela granite.

5. Uranophane and autunite recorded as secondary visible U minerals that occur either as disseminated clusters or as microfracture filling and coating joint surface in the different alterations.

6. ThO_2 content of uraninite vary from (1.1 to 3 wt.%), for PbO contents from 1.16 to 2.35 wt.%, P_2O_5 contents from 0.17 to 1.56 wt.% and CaO contents from 3.8 to 7.6 wt.%. Also, minor amounts of LREE and Y are present. Under reducing conditions, uraninite may be altered to coffinite, with loss of radiogenic Pb and Y with HREE.

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