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Study of the Geologic Features and Uranium Content of the Cataclastic Rocks at Wadi Sikait, South Eastern Desert, Egypt by SSNTDs

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Abstract: Wadi Sikait area is located about 90 km southwest of Marsa Alam town in the Southern Eastern Desert of Egypt. Geological features of the cataclastic rocks at wadi Sikait area are studied in details by the intensive field geology, petrography, and mineralogy in the one new region. The mineralization associated with mineralized cataclastic (mylonite) rocks in wadi Sikait area are columbite, uranothorite, monazite and zircon with uranothorite as inclusion and dissolution attack.

No evidence that the cataclastic rocks extend across wadi Sikait. This may be due to the dilution of the leachable uranium minerals downstream the Wadi or the shallow measurements of radon concentrations. Uranium content in the cataclastic rocks east of wadi Sikai is estimated to reach 1000ppm which triggers a development uranium production cycle at the wadi.

Keywords: Mineralized cataclastic (mylonites) rocks, columbite, zircon, monazite, uranothorite, uranium content, radon and wadi Sikait.

1 Introduction

Radon gas concentration in different rock types reflects the properties of the hosting rocks. The rock properties include the porosity of the rock, radon emanation coefficient and mainly the radium content (parent of radon gas) and accordingly uranium content. The process of transportation of radon gas subsequent to its production at the soil particulate level from a solid to a gas or liquid medium trapped within the pore spaces of soil or rock is termed emanation. This transportation of radon throughout soil is mainly achieved through alpha recoil and the mechanical flow of air and water throughout the soil. Alpha recoil is the process by which a radon nuclide recoils in the opposite direction from the path of alpha particle ejection subsequent to the radioactive decay of its parent atom. Transportation of radon within the soil pores after its release from the mineral grains is then facilitated by the processes of diffusion and convection. Radon diffusion is also a function of the soil porosity, concentration of radon in the soil/gas pores and meteorological factors, including rainfall and atmospheric pressure [1,2,3,4,5].

Several different techniques including scintillation cells, ionization chambers, solid state nuclear track detectors (SSNTDs), solid state surface barrier detectors, thermo luminescent dosimeters and electrostatic precipitation are available for radon measurement. For developing countries wishing to carry out 93 national survey programs in order to monitor environmental radon levels, the most suitable techniques are those making use of SSNTDs (CR-39 and LR-115) because they are adaptable, simple in handling and processing, low cost and insensitive to beta and gamma radiation. Also, these detectors take account of the effects of seasonal and diurnal fluctuation of radon concentrations due to physical and geological factors as well as meteorological conditions [1,2]. The conventional exploration methods such as surveys with gamma sensitive instruments are not only costly and time consuming but are also fruitless when targets are deep, mineralization is young or when displacement of an ore body due to remobilization has taken place [3] On the other hand, methods based on radon survey provide a potential opportunity to locate uranium deposits buried several hundred meters deep without involving expensive apparatus, time and much finance [4,5].

The wadi Sikait area lies in the Southern Eastern Desert of Egypt it covers about 10 km^2 of the crystalline basement rocks in addition to wadi deposits. The studied area is dissected by wadi Sikait crossing wadi El Gemal and wadi Nugrus. The area could be reached from the Red Sea coast through Wadi El Gemal and then WadiNugrus along a desert track. It is located about 90 km southwest of Marsa

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Alam town. It is latitude 24° 36′ 30″and 24° 38′ 30″N and longitude 34° 46′ and 34° 48′00″ E (Fig.1).

The wadi Sikait area is the part of the wadiEl –Gemal and wadi Abu Rusheid area, it described as columbite-bearing metasomtized" psammitic gneiss" (6), contain thorite, cassiterite, galena and fluorite in addition to columbite. The mineralized cataclastic (mylonite) rocks in the Abu Rusheid-Sikait area. In the past, the Abu Rusheid gneisses were named psammitic gneisses [6,7,8,9,10,11,12]. Hassan [7] studied the geology and petrography of radioactive minerals and rocks in wadi Sikait-wadi El Gemal area. Moghazi et al. [13] studied the geochemistry and Rb-Sr isotopes of the leucogranite and meta-sediments at Sikait-Nugrus area. Wadi Sikait area lies to the northeast of the major shear zone known as the Nugrus thrust fault [14] or Nugrus strike-slip fault [15]. This zone marks the boundary between two different lithological domains: the Central and Southern Eastern Desert of Egypt [16]. The orthogneisses and quartz–rich paragneiss's and migmatites of the wadi Hafafit Culmination (wadi Sikait Complex) enclose a set of peculiarity shaped granitoid gneiss-cored macroscopic dome structure [13,14,17]. Wadi Sikait Complex (WSC) is characterized by a complicated history of tectonometamorphic evolution [14,17,18]. Therefore, the Pan-African rocks cropping out in the gneiss domes at Wadi Sikait Complex (WSC), are in their majority either remobilized or mylonitized [19], so that eventual mineral deposits were apt to be destroyed [20].

The cataclastic rocks appear along both the two sides of wadi Sikait at the studied area. This study checks the extension of these rocks across the Wadi Sikait employing the measurement of radon concentrations in the stream sediments across Wadi Sikait. It is also intended to investigate the source minerals of uranium and to evaluate the uranium content in the studied rocks.

2 Field Works and Experimental Methods

2.1 Geologic Setting and Mineral Investigation

Wadi Sikait area is covering about 10 km^2 and is exposed mainly of the basement rocks of the western side of wadi Abu Rusheid extend to eastern side of wadi Sikait, Figure 1.

The mineralized cataclastic (mylonite) rocks in the studied area occur as small exposure in the eastern and western sides of the wadi Sikait (1 km^2). These rocks in the wadi Sikait are forming low land terrain covered by of metasediments (schists) western and eastern sides of wadi Sikait, Figure. 2a to c and crosscut by N-S and NE-SW strike slip faults. Mineralized cataclastic (mylonite) rocks in the studied area are cropping out in the study area and are deformed, strongly foliated and dissected by several major faults.

2.2 Measurement Locations

Between the cataclastic rocks existing on both the sides of the studied area at Wadi Sikait, along more than 2km, 138 locations over the Wadi were chosen to measure uranium content and radon gas concentration in the stream sediments. The width of the Wadi was averaged 200m, so three locations were chosen across the width with spacing of 100m. Along the Wadi, the spacing is 50m. Also, the exploration trenches T5 and T6 were investigated, Figure 3. These locations were determined using a GPS device.

2.3 Gamma-Ray Surveys

To get the uranium content in the studied rocks, an RS-230 BGO (Bismuth Germanate Oxide) spectrometer (1024 channels) was used. This device provides a readout of the concentration of uranium and thorium in ppm and the percentage of potassium in the medium after a time of 30s measurement. This convenient, handheld instrument is more affordable than other more costly, portable units. For example, measurements taken using the RS-230 BGO handheld unit provide comparable quality to an instrument making the same measurement using a much larger 21 in^3 (390 cm^3) NaI portable detector. The spectrometer is auto-stabilizing when measuring naturally occurring radioactive elements K, U and Th and it does not require any test sources [21]. At random 21 locations over Wadi Sikait, a direct reading of uranium was recorded in ppm.

2.4 Measurement of Radon Gas Concentrations in the Stream Sediments and the Cataclastic Rocks

Radon gas concentrations were measured using the solid-state nuclear track detector (SSNTD) type CR-39 employing cup-technique. A plastic cup of about 12 cm height, 7cm diameter at the open mouth and 5.4cm diameter at the bottom, is fitted with a 1x1 cm^2 CR-39 detector attached to its inside bottom. The open mouth of the cup is covered with a filter which permits radon gas to enter the cup and prevents the entrance of radon decay products. Besides, this filter prevents the entrance of thoron gas (because of its short lifetime). Accordingly, CR-39 detector measures only radon gas. CR-39 detectors were calibrated using a standard setup described elsewhere [22]. At each of the 138 locations at the Wadi,one cup containing the CR-39 detector is overburdened at a depth of 20cm inside the location such that the filter is downward and the bottom is upward. After one month, the cups were collected, and the CR-39 detectors were cleaned with distilled water and etched at the optimum etching conditions determined for CR-39 detector as 6.25 N NaOH at a temperature of 70°C and 8 hours for etching time. The revealed α-tracks on each detector were counted under an optical microscope at a magnification of 400X and the track density per day ρ ($T.cm^{-2}.d^{-1}$) averaged over 1000 tracks on each detector, was calculated.

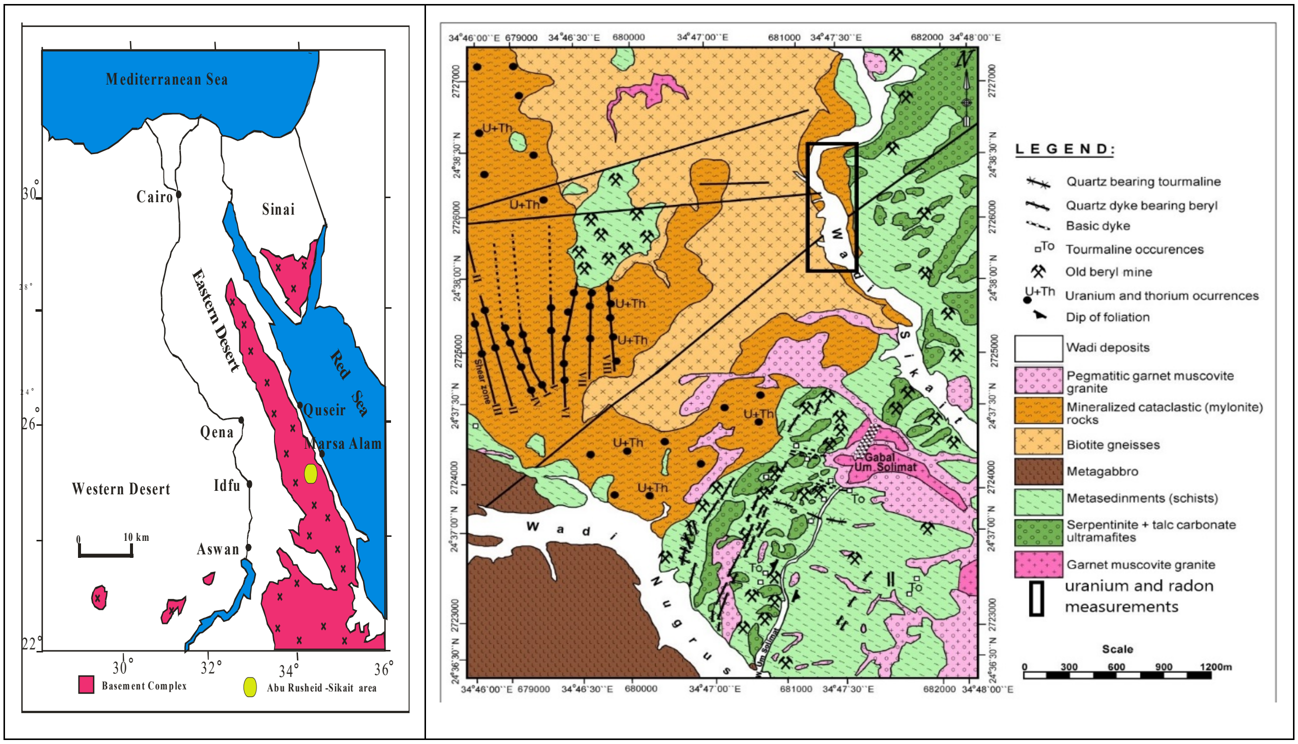

Fig. 1: Location map of and b) Geological map of Um Solimate area, South Eastern Desert, Egypt.

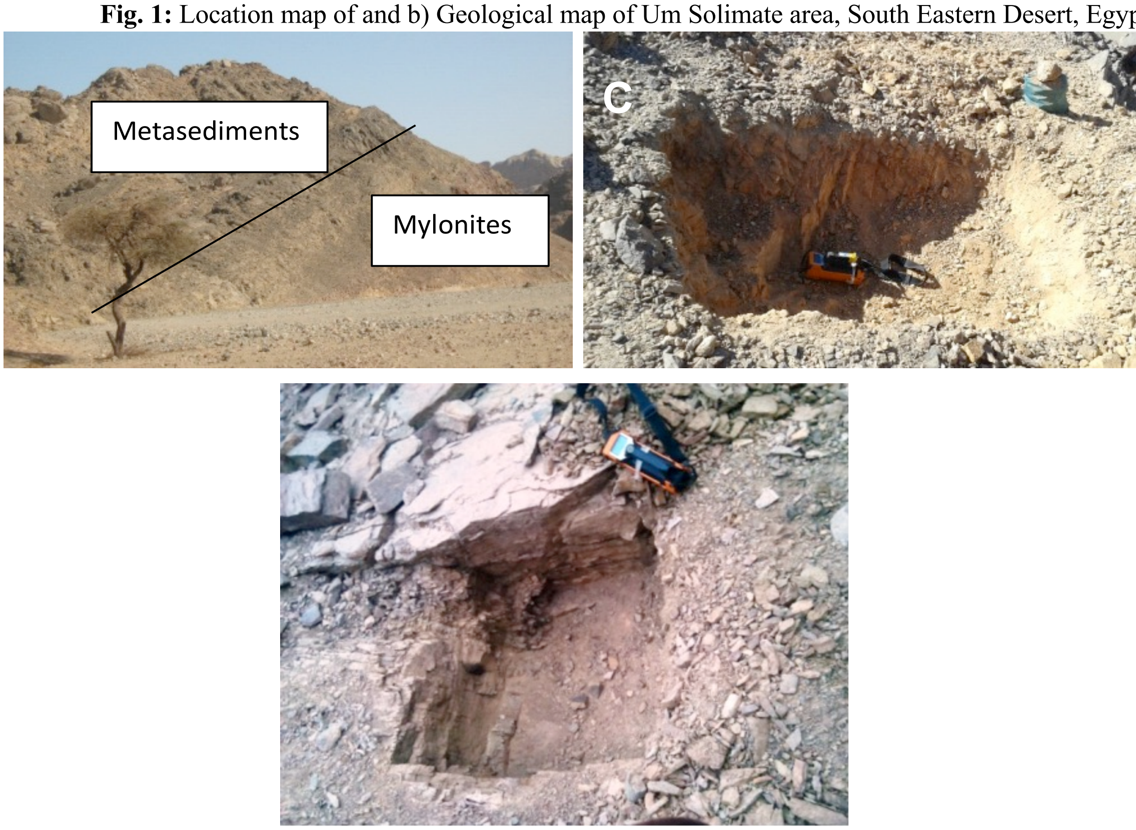

Fig.2: a) Thrust contact between metasediments (schists) over the mineralized cataclastic (mylonites) rocks in Wadi Sikait, looking south, b and c) trenchs no. 5 and 6 in the mineralized catclastic (mylonite) rocks in Wadi Sikait area are characterized high contains of radioactive (eU, eTh) and Nb-Ta minerals, looking north.

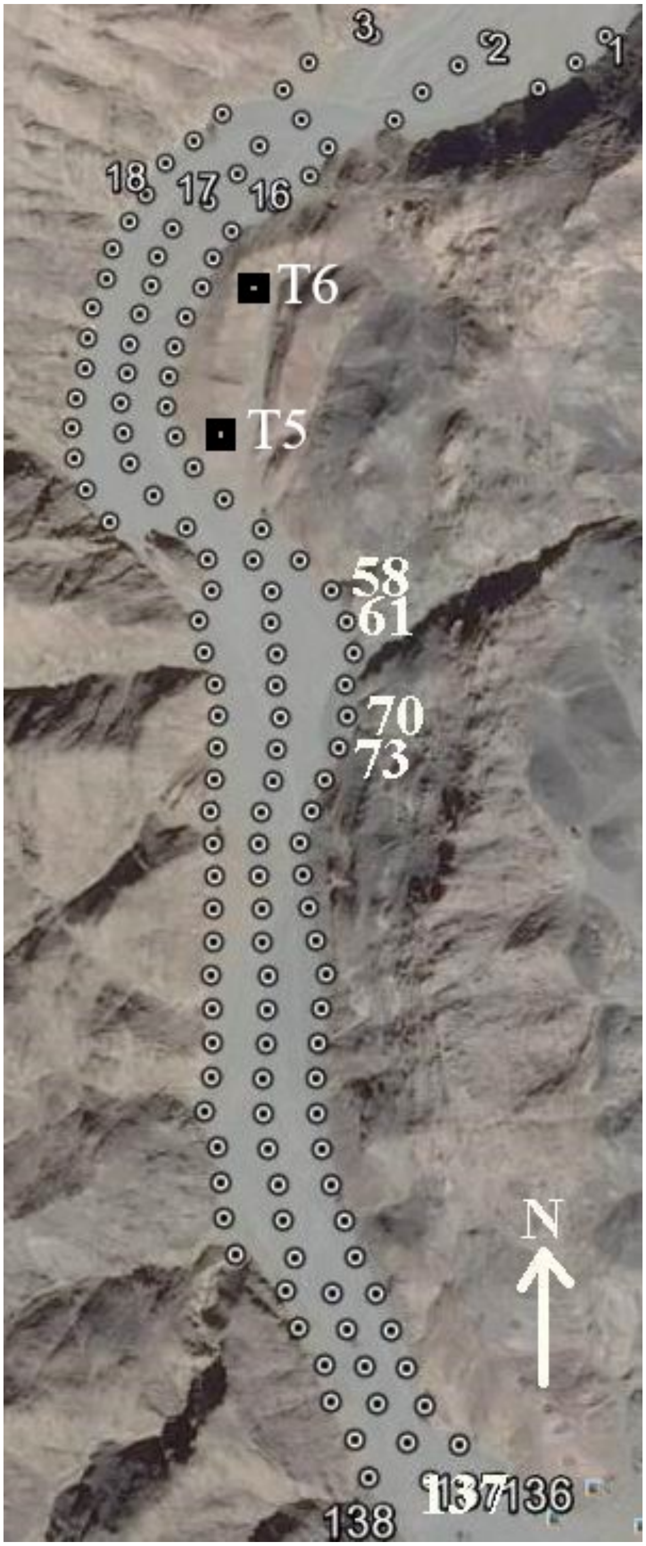

Fig. 3: Distribution of 138 locations at WadiSikait to measure uranium contents and radon gas concentrations in the stream sediments. The trenches T5 and T6 are investigated for radon gas only.

Radon gas concentration C_{Rn}(Bq.m^{-3}) at each location is obtained as follows:

$$C_{Rn} = \rho \ (\mathrm{Bq.m^{-3}}) \qquad (1)$$

where;

C_{Rn} = radon gas concentration, (Bq.m^{-3}),
ρ = track density per day, (T.cm^{-2}.d^{-1}), and
K = calibration factor =0.2217 ± 0.035 (T.cm^{-2}.d^{-1}/(Bq.m^{-3})), [22].

3 Results and Discussions

3.1 Mineral Sources of Uranium

It is evident from SEM and EDX analysis that the main source of uranium content in the cataclastic rocks at Wadi Sikait area comes from the radioactive minerals of uranothorite and bearing uranium minerals such as ferrocolumbite and zircon and zircon, Figure 4.

Thereis one primary mineral species of U-Th (uranothorite) minerals in the mineralized catclastic (mylonite) rocks of WadiSikaitarea.

Uranium and thorium mineralization: They are one primary mineral species of U-Th (uranothorite) minerals in the mineralized catclastic (mylonite) rocks of Wadi Sikait area.

Uranothorite [Th, U (SiO_4)]: Uranothorite [Th, U (SiO_4)] occurs as large to medium crystals (200–500 µm in size) and is associated with zircon (Fig. 4b to e). The SEM-BES analyses show that the thorite is mainly composed of UO_2 (23%), ThO_2 (51%) and SiO_2 (17%) and in the Figure 6f. The SEM-BES shows that the thorite consists essentially of UO_2, ThO_2 and SiO_2 but other elements detected in small to minor amounts are P_2O_5 and Al_2O_3 may be abundant in some samples from WadiSikait area. Also, uranothorite is founded as a solidsoluion in mineralized catclastic (mylonite) rocks of WadiSikait area and contain the high content of REE of Ce and Nd elements rich in the 20% of the volume of the uranothrite minerals.

Zircon ($ZrSiO_4$) is a common accessory mineral in the cataclastic (mylonite) rocks. It is generally present aslarge crystals often enclosed in later minerals but may form large well-developed crystals in granites and pegmatites [23]. Hussein [24] stated that radioactive zircon is usually zoned, and the radioactive zircon is also characterized by metamictization. The explanation for the origin of the “Metamict State” is that the internal order of the originally crystalline form has been destroyed by α-particles bombardment from radionuclides within the structure. Zircon may be partially or completely modified, giving amorphous zircon a more isotropic character (i.e., metamict zircon).

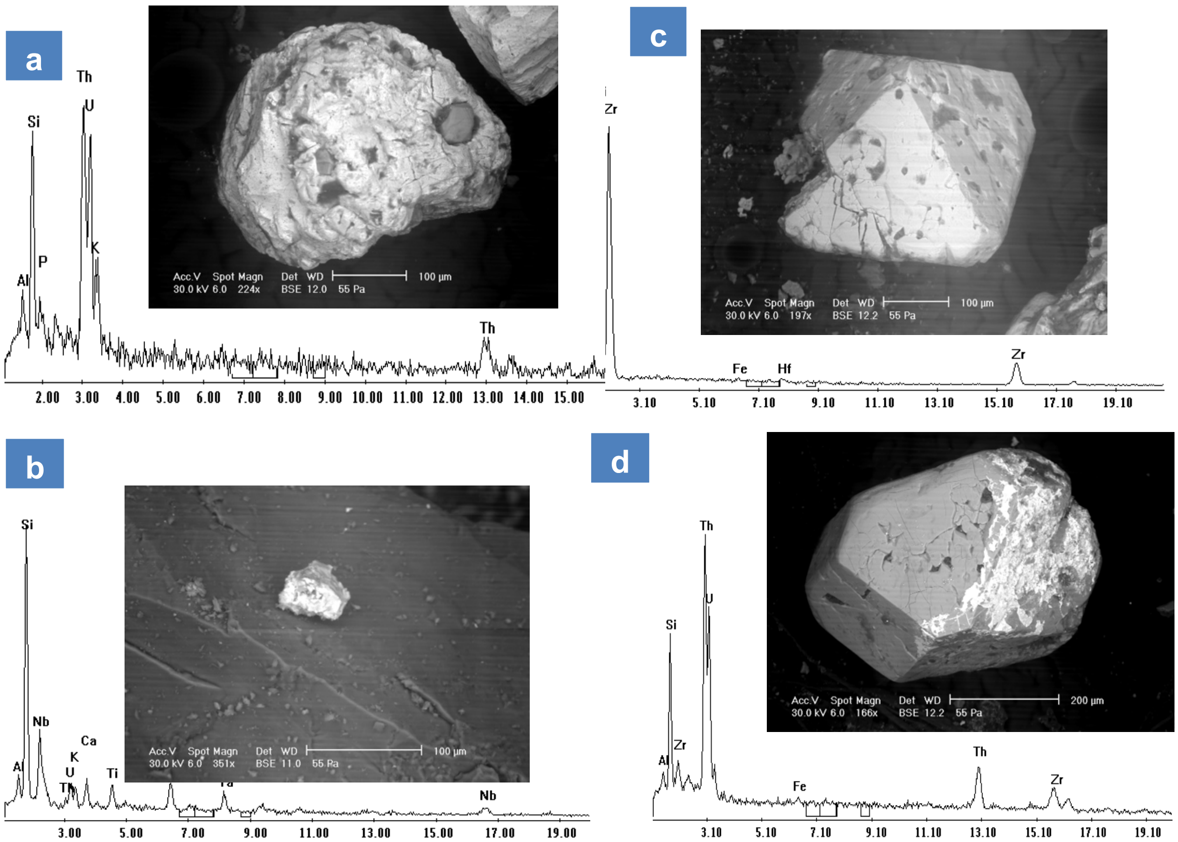

Fig.4: SEM images and EDX. (a) large crystal of uranothorite in Wadi Sikait cataclastic (mylonite) rocks b) ferrocolumbite mineral in Wadi Sikaitcataclastic (mylonite) rocks and c) Large crystals of zircon, d) Zircon corroded by uranothorite mineral Wadi Sikait cataclastic (mylonite) rocks.

Zircon crystals in the studied mineralized catalastic (mylonite) rocks in Wadi Sikait area, is mainly characterized by considerable metamictization, due to uranium and thorium. Zircon has been found as the most abundant accessory mineral in the studied areas of Wadi Sikait area. Zircon occurs as euhedral to subhedral octahedron and prismatic crystals (six or eight sided), found as being 250 to 500 µm in size and occurs as zoned crystals with clusters of inclusions of radioactive minerals, Figure 4a to d.

Columbite-tantalite: Columbite-tantalite group [(Fe, Mn) (Nb, Ta)$_2$O$_6$]: Nb and Ta minerals occur mostly together as complex oxides or hydroxides, rarely as silicates in different rock types. This series represents solid solutions between columbite (Fe, Mn) (Nb, Ta)$_2$O$_6$ and tantalite (Fe, Mn) (Ta, Nb)$_2$O$_6$. In fact, the close relationships between Nb and Ta elements, both being pentavalent, preferring octahedral coordination in oxide compounds with similar ionic radii=0.72Å [25] cause extensive mutual substitution between them. The columbite-tantalite series are most abundant in the granites and pegmatites, particularly those with well-marked albite and Li silicates associated with albite, microcline, lepidolite, and muscovite. Columbite is frequently considered to be a carrier of U-Th and REE. In many cases, its radioactivity is related to inclusions of minute radioactive materials surrounded by conspicuous radioactive halos [26].

Ferrocolumbite [(Fe, Mn) (Nb, Ta)O$_4$] occurs in the mineralized catclastic (mylonite) rocks of wadi Sikait study area. Ferrocolumbite crystals are generally dark gray to black in colour under the microscope. They are present in the form a massive euhedral to subhedral crystals and the SEM image of the columbite crystals are presented in Figure 4c. The SEM-BES shows that the ferrocolumbite consists essentially of Nb_2O_5 (36%), Ta_2O_5 (14.5%), FeO (6.8%) and TiO_2 (3.7%) but other elements detected in large to small amounts are UO_2 (7.7%).

3.2 Extension of the Calclastic Rocks across Wadi Sikait

Radon anomalies declare uranium ore bodies or uranium rocks. To check the extension of the cataclastic rocks at the east of Wadi Sikait towards the west of the wadi beneath the stream sediments, radon anomaly is arbitrarily defined as the measured radon gas concentration C_{Rn}that exceeds twice the average concentration. The average concentration of radon gas in the stream sediments at Wadi Skaite is 3200 (Bq.m^{-3}). So, for a value of C_{Rn} to represent an anomaly, it must exceed 6400 (Bq.m^{-3}). Figure 5 represents the radon gas concentrations C_{Rn} (Bq.m^{-3}) in the stream sediments at

Wadi Sikait. It shows that the anomalous radon concentrations are recognized at the locations; 58, 61, 70, 73 and 137. From figure 5, these radon anomalies are located just next to the cataclastic rocks east of Wadi Sikait. Accordingly, radon measurements in the stream sediments at Wadi Sikait provided no evidence that the cataclastic rocks extend across the Wadi. This may be explained referring to the water drainage along Wadi Sekait which dilutes the leachable minerals of uranium downstream.

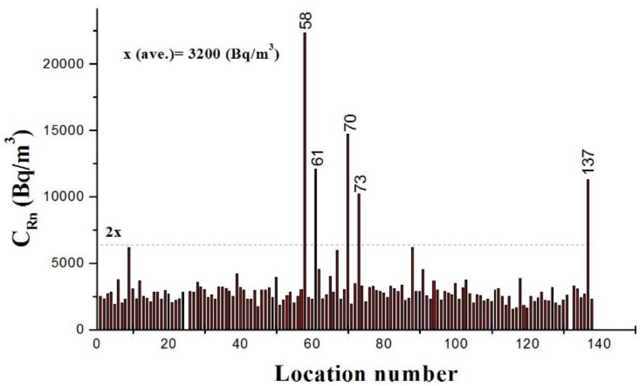

Fig. 5: Radon concentration C_{Rn} (Bq.m^{-3}) in the stream sediments at 138 locations at Wadi Sikait. Dash line represents twice the average value of radon concentration. Numbered columns represent locations of radon anomalies.

On another hand, this study measured the radon gas at a depth of 20 cm in the stream sediment at Wadi Sikait. The missing evidence of the extension of the cataclastic rocks across the Wadi may be found when radon concentrations are measured at deeper depths in the sediments. However, Abdel-Razek and others [27] recommended for reliable radon measurements inside thestream sediments for any application that the porosity of these sediments should be studied to estimate the suitable depth.

3.3 Evaluation of Uranium Content in the Exploratory Trenches

To estimate the uranium content in the cataclastic rocks at Wadi Sikait, radon concentrations in the rocks at the exploratory trenches T5 and T6 are compared to the concentrations in the stream sediments at the Wadi in the scope of the available data on uranium content in the sediments at 21 locations. Figure 6 shows the relation between the uranium content U(ppm) and radon concentration in the stream sediments at Wadi Sikait.

The slope of the regression line equals 626 (Bq/m^3)/(ppm) which leads to the relation:

$$U = C_{Rn}/626, \ \text{(ppm)} \qquad (2)$$

where; U=uranium content (ppm) and C_{Rn}=radon concentration (Bq.m^{-3}).

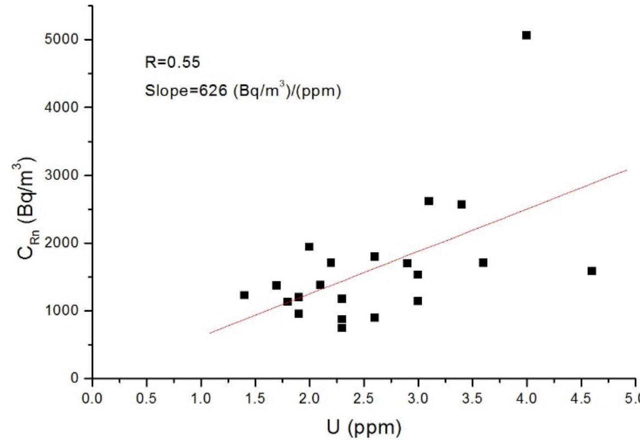

Fig. 6: Relation between the U-content and radon gas concentration in the stream sediments at Wadi Sikait.

Three radon cups were distributed randomly over the bottom of trenches T5 and T6. Each cup was fixed tightly with its filter side to the rocks. After two weeks the cups were collected and treated as above.

Figure 7 represents the track densities on the detectors collected from the studied trenches T5 and T6. It is directly

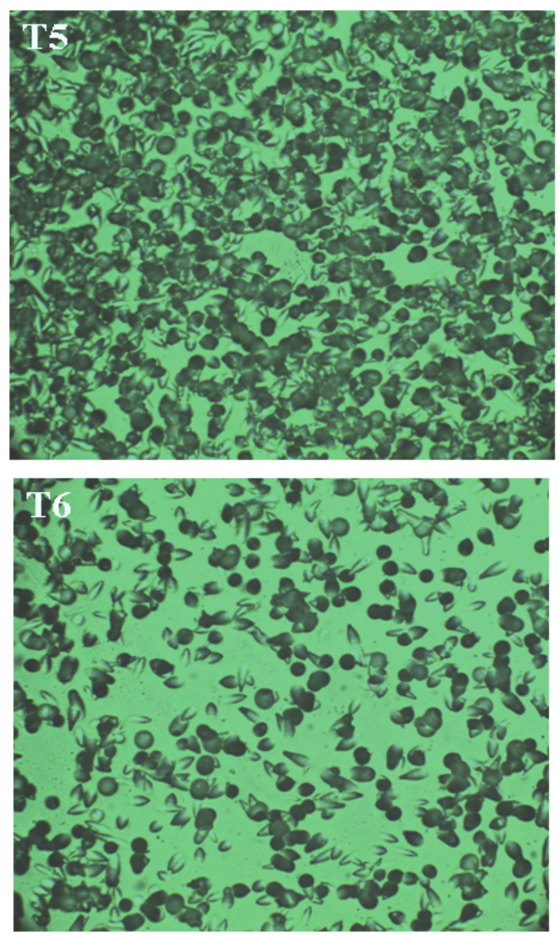

Fig. 7: Uncountable track densities on the detectors from Sikait T5 while the detectors from T6 are hardly countable.

noted that the radon concentration and accordingly U-cont in the rocks at the studied trenches can be arranged as follows:

$$T5>T6 \quad (3)$$

However, the track density on the detectors from T5 is uncountable while it is hardly countable on the detectors from T6. After counting, radon gas concentration in the cataclastic rocks of the U-exploratory trench T6 is 38500 ($Bq.m^{-3}$). According to Equation 2, this concentration yields a U-content of 61.5 ppm. On another hand, it is believed that the porosity of the cataclstic rocks has a value which is only one third that of the stream sediments at the wadi while the exposure time is only one half. Accordingly, U-content in the cataclastic rocks of T6 may reach 400ppm. By comparison, uranium content in the rocks at T5 may reach 1000pm.These promising U-contents may trigger a development uranium cycle at Wadi Sikait.

4 Conclusions

The studied area of Abu Rusheid-Sikait area lies in the Southern Eastern Desert of Egypt, it is located about 90 km southwest of Marsa Alam town. The mineralized cataclastic (mylonite) rocks in the Sikait cataclastic rocks in the Abu Rusheid-Sikait area, revealed the presence of primary Th (thorite and uranothorite), and zircon (Hf), monazite, and xenotime. Scanning electron microscopy (SEM) was used to identify and study columbite, tantalite and zircon are including uranothorite and thorite as inclusion. No evidence that the cataclastic rocks extend across Wadi Sikait. This may be due to the dilution of the leachable uranium minerals downstream the Wadi or the shallow measurements of radon concentrations. Uranium content in the cataclastic rocks east of Wadi Sikai is estimated to reach 1000ppm which triggers a development uranium production cycle at the Wadi.

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