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URANIUM MINERALS HOSTED IN THE ZARZAITINE FORMATION AT TAHUGHATIN AREA, SW LIBYA

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Abstract

The present study showed that the Zarzaitine Formation at Tahughatin area is rich in uranium minerals, especially the claystone units. The detected uranium minerals are uraninite, schoepite, compreignacite, autunite, torbernite, uranophane, carnotite, tyuyamunite, rutherfordine and zeunerite. These minerals show many textures. The uranium reserves range from 100 to 2225 ton, indicating that the Zarzaitine Formation in the study area can be considered as an important source of uranium in Libya.

Keywords: Uranium Minerals, Zarzaitine Formation, Tahughatin Area, Libya.

1. Introduction

The Zarzaitine Formation was first described by Lapparent and Lelubre (1948) in the Zarzaitine field area of eastern Algeria. Most of this formation is located in the Illizi Basin in Algeria and smaller part of it is in Libya. According to Protic (1984) the lithological characteristics indicate that the Zarzaitine Formation was deposited in a fluvial environment. Previous studies (e.g., Protic, 1984; Dahoumane *et al.*, 2016) showed that the possible age of this formation is the Triassic. The uranium minerals were first discovered by Assaf *et al.*, (1976) in the Zarzaitine Formation at Al Awaynat-Serdles area, Murzuk Basin, SW Libya. Since that time the whole area has been considered as potential for uranium and became the subject of extensive geological and geophysical exploration. The geology of these uranium occurrences, together with their postulated genesis, has been described in detail elsewhere (Pejatovic, 1979; Obrenovic, 1981; Assaf *et al.*, 1988; Assaf *et al.*, 1994).

The Tahughatin area (study area) is situated within the Murzuq Basin, SW Libya (Fig. 1). The distribution of the Zarzaitine Formation in the study area is shown in Fig. (2). The purpose of this work is to describe the uranium minerals hosted in the Zarzaitine Formation at Tahughatin area. This study also aims to know the uranium reserves in this formation. We did not find a published paper on this subject in the Tahughatin area. Thus, the authors believe that the current study may be the first work on uranium minerals in this area. The Zarzaitine Formation consists of three members: Adrar Ben Drich, Zarzaitine and Teknioune members (Lefranc, 1958). Based on the lithology, only the Zarzaitine and Teknioune members can be distinguished in the Tahughatin area (Protic, 1984), but in the present study we found that the three members are present in the study area (Fig. 3).

2. Methodology

Forty eight representative samples were collected from the Zarzaitine Formation (Fig. 3). Each sample was divided into two parts:

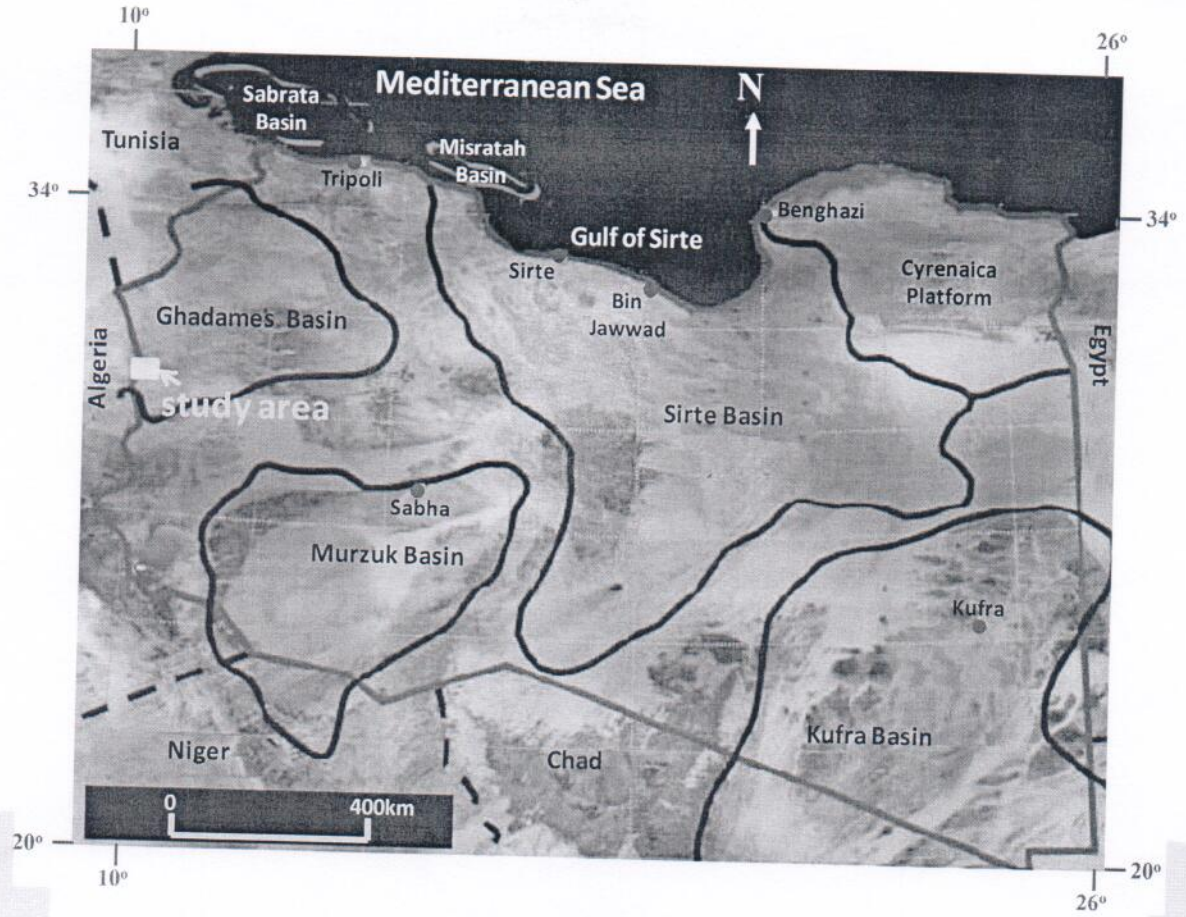

Fig. 1: Landsat image showing the location of the Tahughatin area

1) The first part was prepared as polished thin section to study the uranium minerals under the petrographic microscope. Moreover, the Scanning Electron Microscope (SEM) analysis was used to identify some minerals.

2) The second part was grinded to a powder to determine the concentration of uranium using the Inductively Coupled Plasma-Mass Spectrometry (ICP-MS) technique.

The thin section preparation was done in the Central Laboratories of the Geological Survey of Egypt in Cairo, while the SEM and ICP-MS analyses were done in the Nuclear Material Authority of Egypt.

3. Results and Discussions

3.1. Uranium Minerals

Uraninite, uranophane, carnotite and tyuyamunite are the most common uranium minerals, and occur in a broad range of U deposits (Arakel, 1988; Assaf *et al.*, 1994; Onac *et al.*, 2001; Min *et al.*, 2005; Schindler *et al.*, 2009; Pownceby and Johnson, 2014; Ozha *et al.*, 2017). According to Assaf *et al.*, (1994) the detected uranium minerals in the Zarzaitine Formation at Al Awaynat-Serdles area include carnotite, tyuyamunite, and uranophane. In the present study, the microscopic examination and SEM analysis show that the observed uranium minerals in the Zarzaitine Formation are as follows:

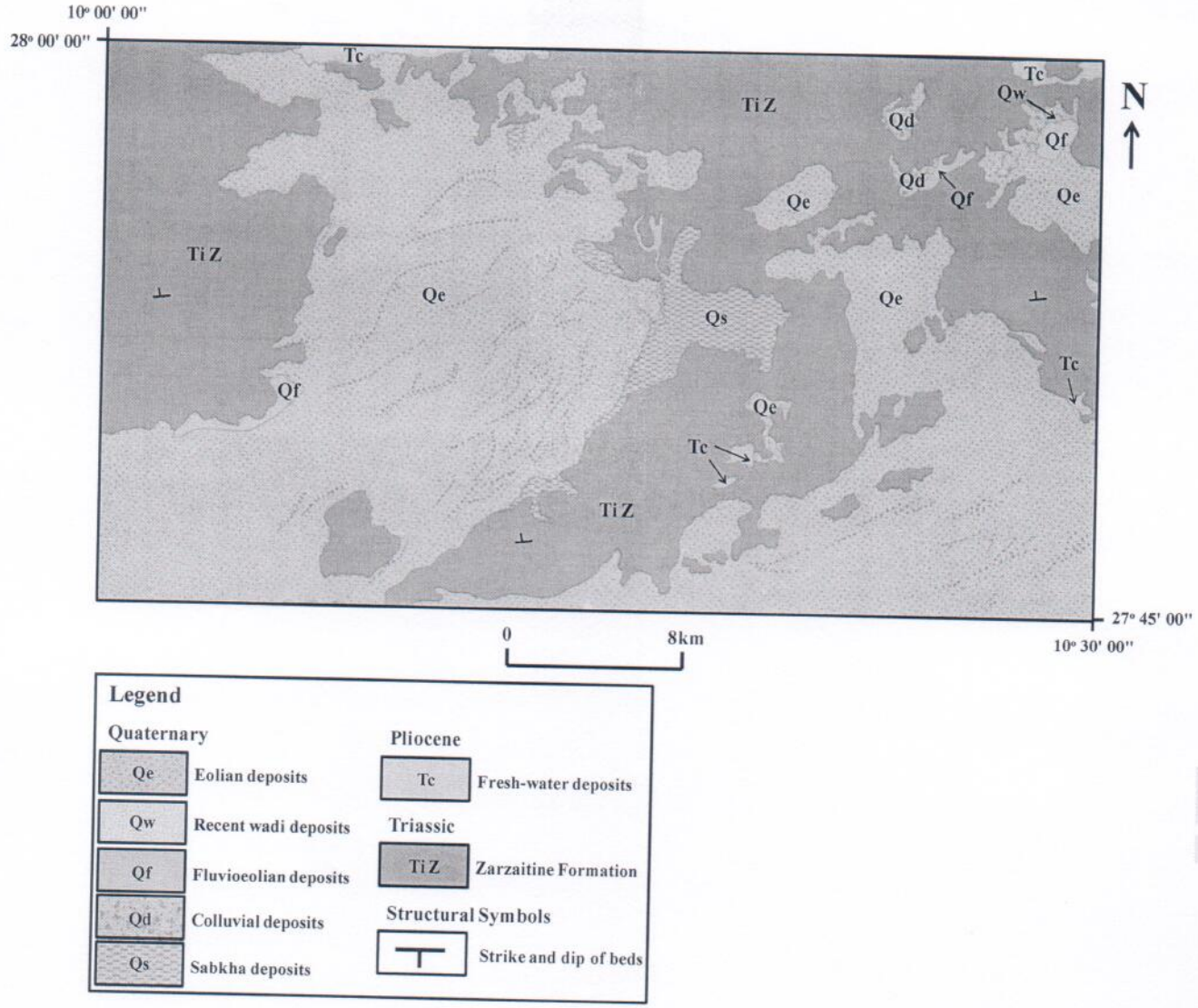

Fig. 2: Geological map showing the distribution of the Zarzaitine Formation in the Tahughatin area (modified after Protic, 1984)

1) Uranium oxides [uraninite (UO_2), schoepite ($(UO_2)_8O_2(OH)_{12}.12H_2O$) and compreignacite ($K_2(UO_2)_6O_4(OH)_6 \cdot 7H_2O$)].

2) Uranium phosphates [autunite ($Ca(UO_2)_2(PO_4)_2 \cdot 10\text{-}12H_2O$) and torbernite ($Cu(UO_2)_2(PO_4)_2 \cdot 8\text{-}12H_2O$)].

3) Uranium silicates [uranophane ($Ca(UO_2)_2(HSiO_4)_2 \cdot 5H_2O$)].

4) Uranium vanadates [carnotite ($K_2(UO_2)_2(VO_4)_2 \cdot 3H_2O$) and tyuyamunite ($Ca(UO_2)_2(VO_4)_2 \cdot 5\text{-}8H_2O$)].

5) Uranium carbonates [rutherfordine ($(UO_2)CO_3$)].

6) Uranium arsenates [zeunerite ($Cu(UO_2)_2(AsO_4)_2 . 10\text{-}16H_2O$)].

These minerals display many textures in the studied samples. It should be noted that the concentration of the uranium minerals in the claystone and marl units is more than in the sandstone and limestone units.

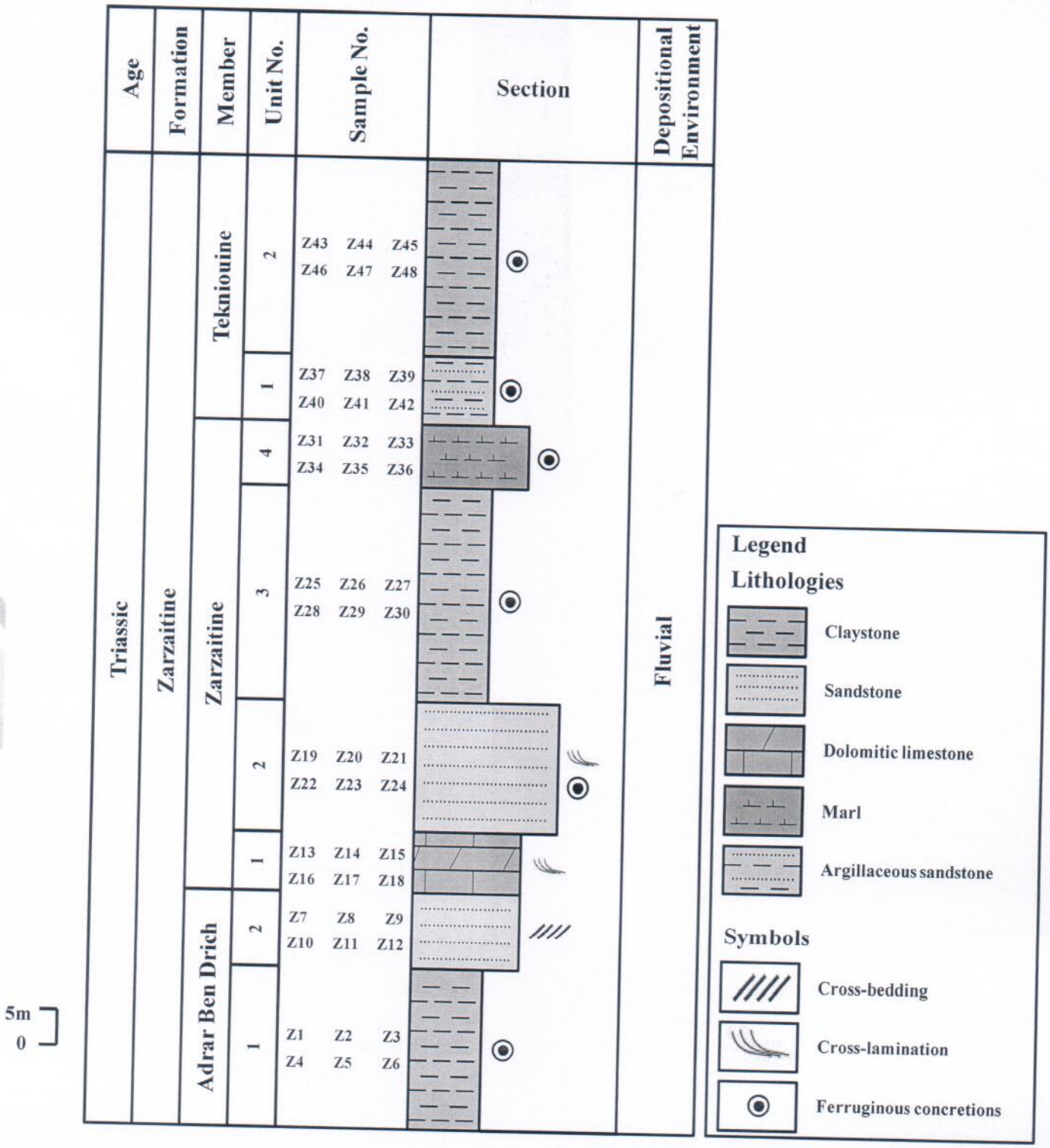

Fig. 3: Composite columnar section of the Zarzaitine Formation in the Tahughatin area

3.1.1. Uraninite (or Pitchblende)

The secondary uraninite is found in the three members (Adrar Ben Drich, Zarzaitine and Teknioune) of the Zarzaitine Formation, especially in the claystone units. It commonly replaces goethite and pyrite (Figs. 4-5).

3.1.2. Uranophane (or Uranotile)

The secondary uranophane is only detected in the Zarzaitine and Teknioune members. Some uranophane grains show clear planes of cleavage and the others alter to torbernite (Figs. 4-5).

3.1.3. Carnotite

The secondary carnotite is observed in all parts of the Zarzaitine Formation (except for the dolomitic limestone unit). There are several uranium minerals that replace carnotite such as tyuyamunite, compreignacite, rutherfordine and schoepite (Fig. 4).

3.1.4. Autunite

The secondary autunite is only observed in the Teknioune member. Some autunite grains show cracks caused by dehydration and the others alter to goethite and limonite (Figs. 4-5).

3.1.5. Zeunerite

Like the secondary autunite, the secondary zeunerite is only detected in the Teknioune member. It commonly replaces skutterudite (Fig. 4).

3.2. Uranium Concentration

Pejatovic (1979) found that the concentration of U in the Zarzaitine Formation at Al Awaynat-Serdles area varies from 115 to 4882 ppm. In the present study, the claystone units are richer in U than other units (Table 1). The concentration of U ranges from 1777 to 5091, 1009 to 2020, 119 to 999 and 117 to 183 in the claystone, marl, sandstone and dolomitic limestone units, respectively.

3.3. Economic Reserve

The reserves of uranium in the Zarzaitine Formation in the study area are listed in Table (2). The reserve evaluation was done as follows:

1) Calculate the area (km^2) of exposed rocks from the Zarzaitine Formation
2) Calculate of the bulk volume of the rock using the measured density (1.375gm/cm^3)
3) Calculate of the weight of the rock
4) Calculate of the total weight of uranium

Conclusions

The main objectives of this work are to describe the uranium minerals hosted in the Zarzaitine Formation at Tahughatin area and to evaluate the uranium reserves in this formation. The concentration of the uranium minerals in the claystone and marl units is more than in the sandstone and dolomitic limestone units. The detected textures in these minerals are as follows: uraninite replaces goethite and pyrite, uranophane alters to torbernite, carnotite alters to tyuyamunite, compreignacite, rutherfordine and schoepite, autunite alters to goethite and limonite, and zeunerite replaces skutterudite. The Zarzaitine Formation at Tahughatin area can be considered as a major source of U in Libya, because it contains a high reserve of this element (100-2225 ton).

Recommendation

Previous studies and this work showed that the Zarzaitine Formation at Al Awaynat-Serdles and Tahughatin areas contains an economic reserve of uranium. This formation is widely distributed in the Murzuq Basin, so we recommend additional studies in the other parts of this basin to know the total reserve of uranium in the Zarzaitine Formation.

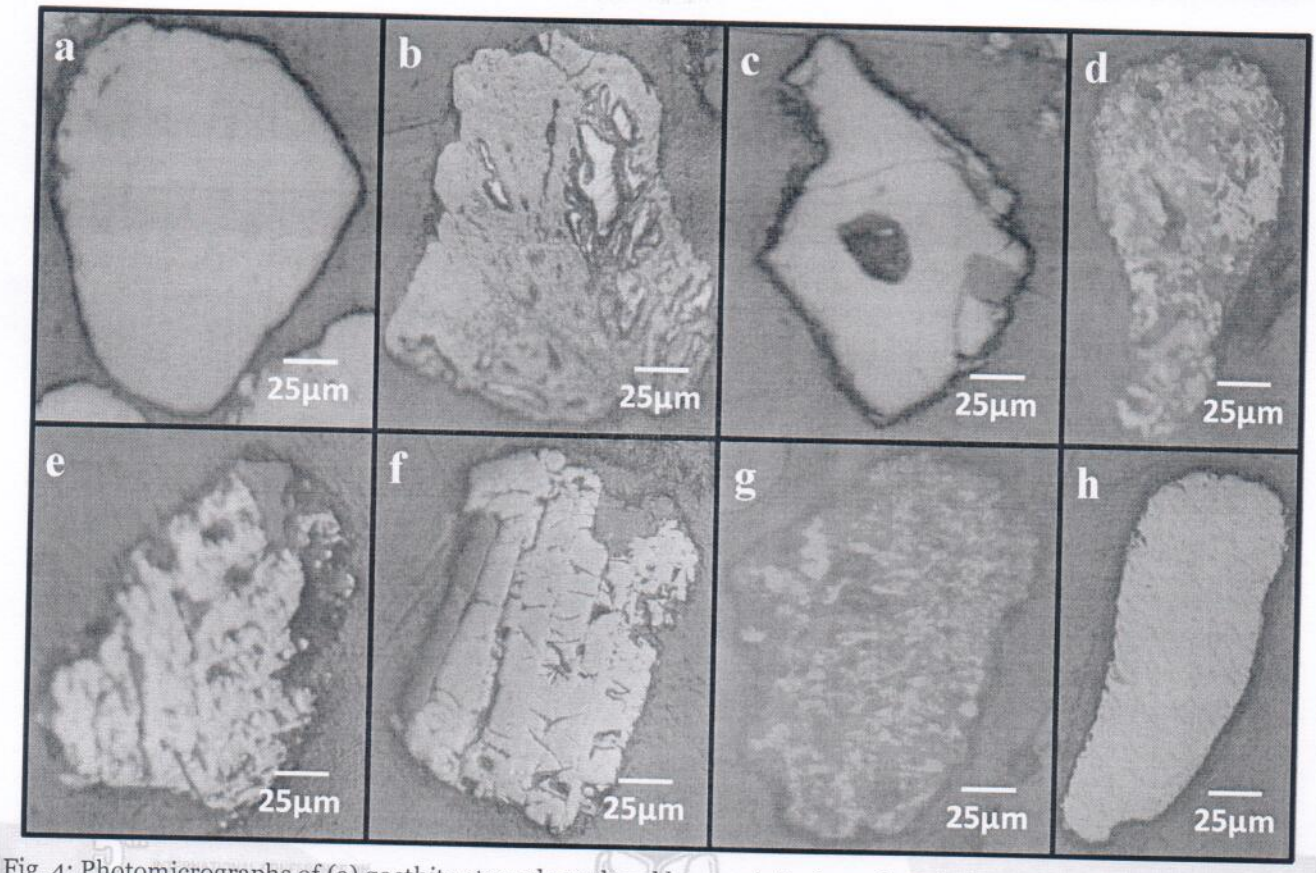

Fig. 4: Photomicrographs of (a) goethite strongly replaced by uraninite (sample Z2), (b) pyrite strongly replaced by uraninite, (c) uranophane altered to torbernite (sample Z27), (d) carnotite partially replaced by tyuyamunite, compreignacite and rutherfordine (sample Z39), (e) skutterudite altered to zeunerite (sample Z39), (f) cleavable uranophane (sample Z28), (g) autunite altered to goethite and limonite (sample Z39) and (h) carnotite altered to schoepite (sample Z27)

Fig. 5: BSE images of (a) goethite completely altered to uraninite (sample Z29), (b) uranophane strongly replaced by torbernite (sample Z29) and (c) autunite with cracks as a result of dehydration process (sample Z41)

Table 1: Concentration of uranium (ppm) in the Zarzaitine Formation at Tahughatin area

Member	Lithology	Unit No.	Sample No.	U ppm
Adrar Ben Drich	Claystone	1	Z1	5091
			Z2	4432
			Z3	3890
			Z4	4813
			Z5	3000
			Z6	2809
	Sandstone	2	Z7	393
			Z8	404
			Z9	401
			Z10	331
			Z11	200
			Z12	119
Zarzaitine	Dolomitic limestone	1	Z13	121
			Z14	129
			Z15	183
			Z16	117
			Z17	167
			Z18	155
	Sandstone	2	Z19	229
			Z20	207
			Z21	188
			Z22	194
			Z23	124
			Z24	139
	Claystone	3	Z25	4508
			Z26	4600
			Z27	2041
			Z28	3000
			Z29	2271
			Z30	4392
	Marl	4	Z31	1088
			Z32	1115
			Z33	2020
			Z34	1346
			Z35	1500
			Z36	1009
Teknioune	Claystone	1	Z37	3041
			Z38	2007
			Z39	2813
			Z40	2071
			Z41	1851
			Z42	1777
	Sandstone	2	Z43	973
			Z44	999
			Z45	807
			Z46	955
			Z47	900
			Z48	861

Table 2: The estimated reserve (ton) of uranium in the Zarzaitine Formation at Tahughatin area

Litology	Reserve
Claystone	2225
Marl	909
Sandstone	553
Dolomitic limestone	100

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