Correlation of the radioactivity (uranium/ thorium ratio) map with the geology of the eastern part of SABHA NG 332- Sheet

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ABSTRACT

The area of this study is situated on the southern flank of the Gargaf uplift and in the northern part of the Murzuq basin. The main exposed rocks are Paleozoic shelf deposits of the Jabal Fezzan and Wadi Shatti areas, the Mesozoic and Tertiary to Quaternary continental deposits. The southwestern part of the area is covered with Quaternary eolian sands of the Idhan Awbari which continue towards NE as Ramlat Azzallaf. The area was included in the airborne gamma-ray spectrometric survey carried out by Industrial Researches Centre in 1977 in the region Wadi Shatti. The survey measured gamma ray radioactivity in of the radioactive Uranium, Thorium and Potassium as well as the Total Radioactivity of the area. The knowledge of the geology at that time was little so the interpretation of the geophysical data merit more reinterpretation since the regional geological mapping of the area was carried 7 years later. In this work a combined interpretation of the radioactive data and the geological data was carried out.

The interpretation lead to the establishment of an understandable correlation between the radioactivity map and the geological units, mainly clear differentiation of the Carboniferous Mrar formation, its contact with the upper Ashkidah Formation as well as clear outlook of a NNE-SSW tectonic trend that was in harmony with well known tectonic history of the area. The radioactivity in Mrar formation may be correlated with the analcimolite beds that exist in Carboniferous Mrar Formation in Bir Nagaza (Ghat area) or this radioactivity may be due to the minor phosphatic traces, founds in the conglomerates in upper levels of Mrar Formation, which are usually radioactive. This study is a good example of the use of nuclear geophysics techniques as a sound tool for the identification and mapping of different lithological units and the identification of expressive tectonic elements which are very important parameters in the process of geological mapping.

Key Words: Nuclear Geophysics, Geology, Sebha, Correlation, Radioactivity

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Geology and tectonics of Sebha sheet area

The area of this study is located within the geological map of Libya sheet Sabha NG 33-2 (Figure-1). The exposed rocks in the area (Table-1) may be described from the oldest to the youngest in the followings after **(Seidle and Rolich, 1984):**

(A) – Cambro-Ordovician

The oldest exposed unit is the Hasawnah Formation, quartzose to quartzitic sandstones, frequently cross-bedded, with rare siltstone layers. Its outcrop area corresponds to the northern part of the Sabha map-sheet.

(B) - Devonian

Mamuniyat Formation (Ashgillian)

It consists of quartzose to quartzitic sandstones, largely fine- to medium-grained. The Mamuniyat Formation is only marginally represented in the western part of the study area; its maximum preserved thickness is estimated at 20 m **(Goudarzi, 1970).**

The other parts of Devonian belongs to the unit originally named Aouinet Ouenine Formation (Lelubre, 1946) and recently raised to the rank of Group by Massa and Moreau-Benoit (1976). The work of the Industrial Research Centre (Seidle and Rolich, 1984), divided this group into six new-defined formations ranging from Eifelian to Tournaisian. This subdivision is based on the cyclic development of sedimentation "usually negative cycles with a gradual coarsening: claystone -siltstone-sandstone, and/or ferruginous oolite" **(Banerjee, 1980, Belline and Massa, 1980, Conant and Goudarzi, 1964)**.

1. Bir al Qasr Formation

The Formation consists of claystones, siltstones and various types of sandstone (quartzose to quartzitic, argillaceous, and ferruginous).

2. Idri Formation

The Formation prevalently consists of quartzose to quartzitic sandstones, largely cross-bedded. Siltstones and claystones occur only in the western part of the map-sheet.

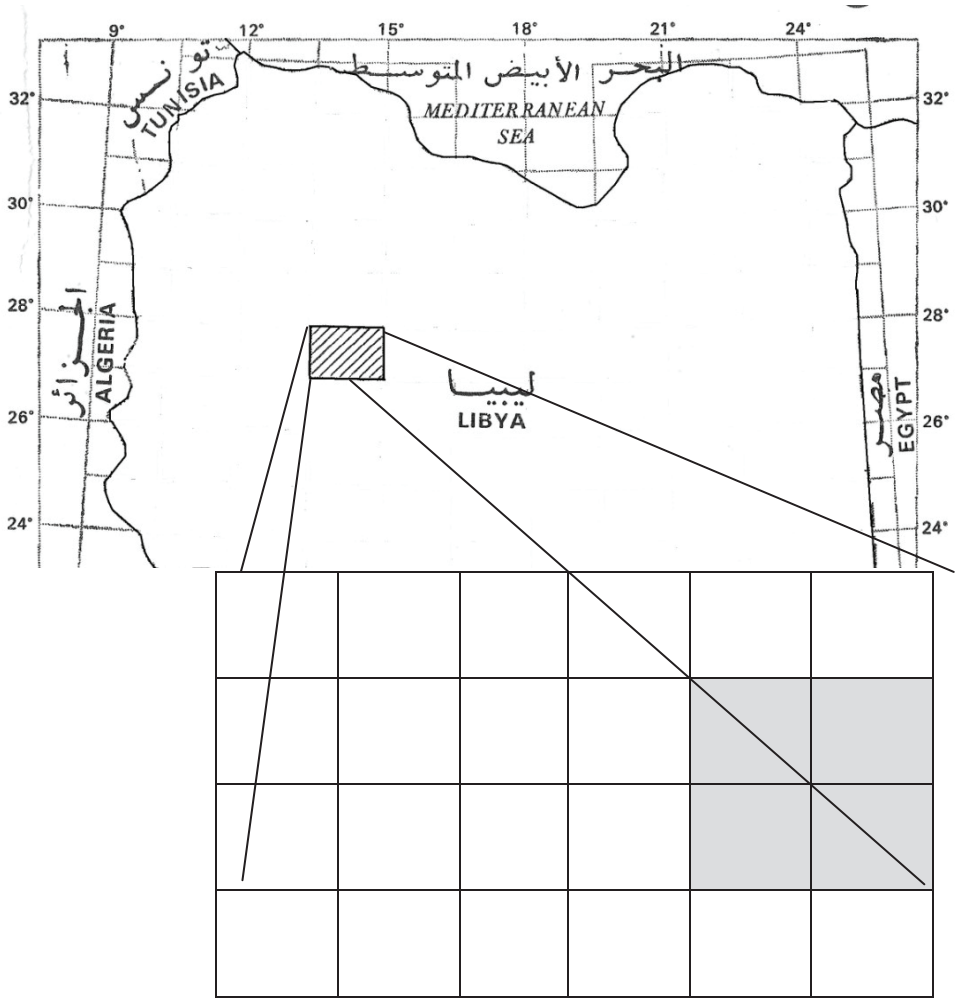

Figure-1 Location of Sebha geological map and the location of the area of this study (the gray colored subset), which is composed of 4 of 1:50 000 maps. The subset is lied in the eastern part of Sebha geological map of scale of 1:250 000 (white colored)

3. Quttah Formation

Formation begins with claystones and silty claystones with thin intercalations of fine-grained quartzite containing the typical trace fossil Bifungites fezzanensis. It is the "Lower Bifungites Member'" after Collomb (1962). The middle and upper parts of the Formation are prevalently built of sandstones, fine to coarse-grained. The thickness of the Quttah Formation amount to 25-30 m. The lower boundary is sharp, probably disconformable (uneven top of the Idri Formation).

Dabdab Formation

The formation corresponds to the "Lower Iron Bearing Formation" of the (**French Study Group, 1972 and 1976**); Turk et al (1980). The type section has been described 3.5 km north of Dabdab. The uppermost preserved layer consists of ferruginous oolite representing the so-called "L-horizon", the ore-bearing member "L" is developed with variable thickness and intensity of mineralization ferruginous layers thin out westwards in the silty-argillaceous facies. The age of the Dabdab Formation is late Frasnian.

Table-1 Lithostratigraphical column of the geological formations and units exposed in the study area

AGE	FORMATION
Quaternary	Al Mahrugah Formation
Tertiary	Zmam Formation
Jurassic - Cretaceous	Mesak Formation
Carboniferous	Mrar Formation
Devonian	Ashkidah Formation
	Tarut Formation
	Dabdab Formation
	Quttah Formation
	Idri Formation
	Bir al Qasar Formation
	Mamuniyat Formation
Cambro - Ordovician	Hasawnah Formation

After (IRC: Seidl and Rolich, 1984)

4. Tarut Formation

The formation corresponds to the lower part of the "Upper Iron Bearing Formation" of the French Study Group (1972), comprising the "Green or Grey claystones" and "A" horizon. The lower and middle parts of the Formation are prevalently built of claystones with subordinate interbeds of siltstones. A prominent sandstone layer, the so-called "Bivalves key bed", is developed amidst the claystones. The upper part is the ore-bearing member "A", mostly composed of ferruginous oolites and "speckled sandstones", which are con-

nected with lateral transitions. The total thickness of the Formation varies between ca. 45 and 10 m. The age is considered to be Famennian.

5. Ashkidah Formation

The formation corresponds to the "Ashtray Sandstones" forming the upper part of the "Upper Iron Bearing Formation", after the French Study Group (1972). The type section has been described on the western side of Wadi Dabdab, 4 km W of Ashkidah. The Ashkidah Formation consists mostly of fine-grained sandstone, siltstone and claystone alternating in various proportions. In the central and eastern parts of Wadi ash Shatti there is developed the ore-bearing member "B" amidst the Formation, dividing it into the lower, middle and upper parts. Only in the uppermost part of the Formation there occurs a rich assemblage of brachiopods in the central part of the map-sheet area (the Brachiopod sandstone marker).

Ashkidah Formation developed very similarly as in the Tarot Formation (lagoonal to swamp environments), except for the youngest part when the connection with the open sea extended significantly (rich assemblage of brachiopods, occurrence of cephalopods). At present, the Ashkidah Formation is considered to be the Devonian-Carboniferous boundary unit.

(C) - Carboniferous

Mrar Formation

The formation begins with the "Roof beds of the French Study Group (1972) and includes the rest of the Lower Carboniferous strata exposed in the Sabha sheet area. The lower boundary of the Mrar Formation with the Ashkidah Formation is conformable. Besides the Lithological change from sandstones to claystones, the boundary is marked by the reappearance of the trace fossil *Bifungites fezzanensis* "Bifungites key bed", (Desio 1949). The age of the Mrar Formation ranges from Tournaisian to Visean, as documented by fossils (mainly brachiopods) found at various levels.

(D) – Jurassic-Cretaceous

The Mesak Formation

The formation_unconformably overlies the Carboniferous strata in the southeastern part of the map-sheet area. This sequence of Mesozoic continental deposits has been divided into the lower Jarmah Member and the upper Awbari Member (Strojexport, 1980). Most of the Mesak Formation preserved in the map-sheet area belongs to the Jarmah Member. It consists of alternating sandstone, siltstone and claystone; the total thickness exceeds 80 m near the

southern sheet border. The Awbari Member is represented by several denudation relics of sandstones with conglomerate layers. The sandstones are mostly cross-bedded and belong to the flood and fluvial facies. The claystones and siltstones are deposits of lakes and swamps. The age of the Awbari Member remains uncertain **(Jurassic-Early Cretaceous)**.

(E) - Tertiary

Zmam Formation

It is represented by the Bin, Affin Member preserved as denudation relics in the eastern marginal part of the study area. The Bin, Affin Member consists of poorly cemented argillaceous, silty and calcareous sandstones with conglomerate layers near the base. The age is Maastrichtian, according to fossils found in the Al Washkah sheet area **(Woller, 1978)**.

Tertiary to Quaternary

Tertiary to Quaternary deposits are continental deposits, exposed along the northern margin of the Ramlat Azzallaf and at several places. The sequence begins with conglomerate or pebble with calcareous and argillaceous sandstones; dolomite usually terminate the sequence. The maximum observed thickness is about 25m.

(F) - Quaternary

Al Mahrugah Formation

The formation type section has been described 7 km E of Al Mahrugah where the formation consists of sandy dolomite with clay galls a main rocks composing the Formation. Dolomite and calcareous conglomerate is locally developed. The Formation forms erosional remnants along the northern side of Wadi Shatti continues towards east. It overlies varies Paleozoic and Mesozoic formations unconformably.

TECTONICS

From the tectonic point of view, the bedrock of the study area consists of five structural stages, separated from each other by unconformities:

(I) The Caledonian structural stage is mostly represented by the Hasawnah Formation exposed in the Gargaf uplift. The Mamuniyat Formation belong to the Upper Caledonian structural substage is only marginally preserved in the west.

(2) The Variscan structural stage (Devonian-Carboniferous) belongs to the

northern flank of the Murzuq basin and is characterized by a gentle southward dip of strata (generally less than 1 degree) in the outcrop area

(3) The Continental Mesozoic structural stage is represented by the Mesak Formation beds in the SE sector of the map-sheet, laying almost horizontally with a very slight dip towards SSE.

(4) The Upper Cretaceous-Eocene structural stage is only represented by the Maastrichtian Bin' Affin Member near the eastern boundary of the sheet.

(5) The Continental Tertiary-Quaternary structural stage forms a flat basin filling in the Ramlat Azzallaf area (mostly covered with eolian sand and outliers on the northern side of Wadi ash Shatti

The faulting was observed only in the Paleozoic structural stage; it is frequent in the Gargaf uplift (Hasawnah Formation) and in the adjoining narrow zone of Devonian deposits. The main fault directions are aligned parallel to the Gargaf uplift (ENE -WSW). The jointing measurements are presented in the form of rose diagram showing no essential differences in particular structural stages.

PRINCIPLES OF RADIOACTIVITY SURVEY

Radioactive elements in nature, radiate alpha, beta, and gamma rays. As a result of its high penetrating power, gamma-ray is used for the radiometric detection of radioactive elements. Using airborne radiometric geophysical data, one can easily investigate a wide region in a short time and with little cost to finally find areas that are rich in radioactive elements. Airborne gamma-ray spectrometry has been used for many years in direct prospecting for radioactive minerals and also as a tool in the delineation of lithological units, and its environmental uses have also been highly expanded (Cassidy,1981).

All detectable gamma radiation from earth materials come from the natural decay products of only three elements, i.e. uranium, thorium, and potassium. While many naturally occurring elements have radioactive isotopes, only potassium, uranium and thorium decay series, have radioisotopes that produce gamma rays of sufficient energy and intensity to be measured by gamma ray spectrometry. This is because they are relatively abundant in the natural environment. Average crustal abundances of these elements quoted in the literature are in the range 2-2.5% of K, 2-3 ppm of U and 8-12 ppm of Th. The basic purpose of radiometric surveys is to determine either the absolute or relative amounts of U, Th., and K in the surface rocks and soils (Cassidy, 1981).

Gamma rays are defined by their energies, measured in electron volts, or eV. One eV is the amount of kinetic energy that a single electron would acquire in falling through an electrical potential difference of 1 volt. The gamma rays from Tl208, the thorium indicator, have an energy of 2.62 million electron volts or 2.62 MeV.

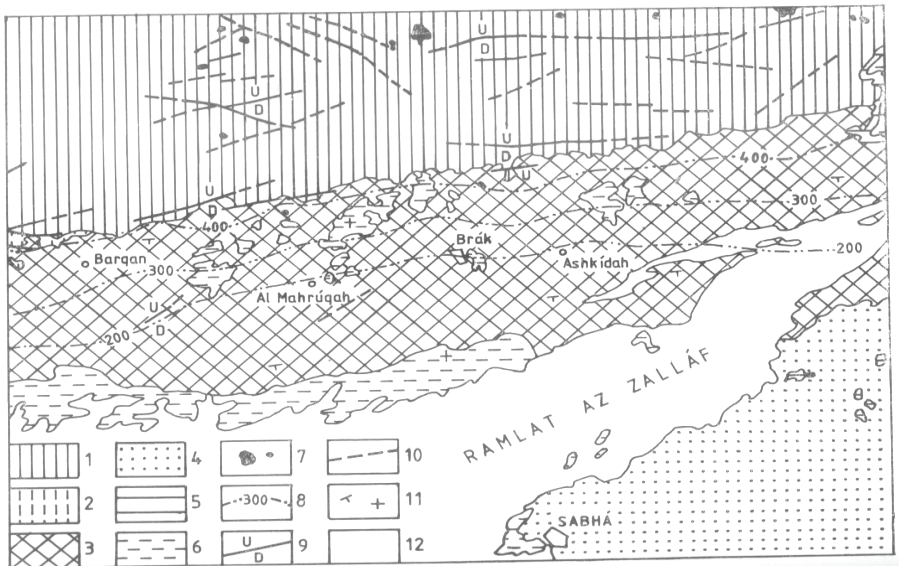

Figure-3 Geological and Structural sketch map of SABHA sheet NG 33-2. (IRC: Seidl and Rplich, 1984). Legend: 1 - Lower Caledonian structural substage(Cambrian - Caradocian), 2 - Upper Caledonian structural substage (Ashgillian - Llandoverian), 3 - Variscan structural substage (Devonian - Carboniferous), 4 - Continental Mesozoic structural stage (Jurassic - Lower Cretaceous), 5 - Upper Cretaceous - Eocene structural stage, 6 – Continental Tertiary - Quaternary structural stage (Neogene - Pleistocene), 7- Tertiary basalt extrusions and intrusions, 8 - stratoisohypse of the base of the Devonian, 9 -fault,. U - Upthrow side, D – downthrown side, 10 - probable fault, 11- strike and dip of strata. Horizontal strata, I2 – Quaternary eolian sand seas.

The gamma rays from Bi^{214} have an energy of 1.76 MeV; while those from K^{40} have an energy of 1.46 MeV. All three of these energies are constant; they never change, they therefore constitute well defined peaks in the energy spectrum emanating from rocks.

Airborne radioactivity survey of the area

In 1977 and 1978 the Department of Geological Researches and Mining of the Industrial Research Centre, carried out an airborne gamma-ray spec-

trometric and magnetic survey of the Wadi Shatti area. The survey covered an area of approximately 10,700 sq. km., and had two main objectives:

1) To define possible extensions of the known iron deposits at Wadi Shatti,

2) To evaluate the potential of the area for other types of mineral deposits.

Flight-lines, spaced at 0.5 km. intervals, were oriented north-south; tie-lines, spaced at 3 km. intervals, were oriented east-west. The surveys were flown at a ground clearance of 122 +/- 24 meters above mean ground level, which leads to a sampling distance of 50, but in areas of extreme relief pilots increased ground clearance to ensure the safety of the aircraft.

The measurements were conducted with a Cessna Caravan I aircraft. The radiation measuring equipment is a gamma-ray spectrometer that consists of 5 Nail crystals. The crystal package installed in the Cessna Caravan has a total volume of 20.5 liters, The overall radioactivity level is recorded with a total count window. In the range of 0.01-3.0 MeV. Three additional windows record gamma rays of K^{40}, Bi^{214} from the uranium decay series and Tl^{208} from the thorium decay series.

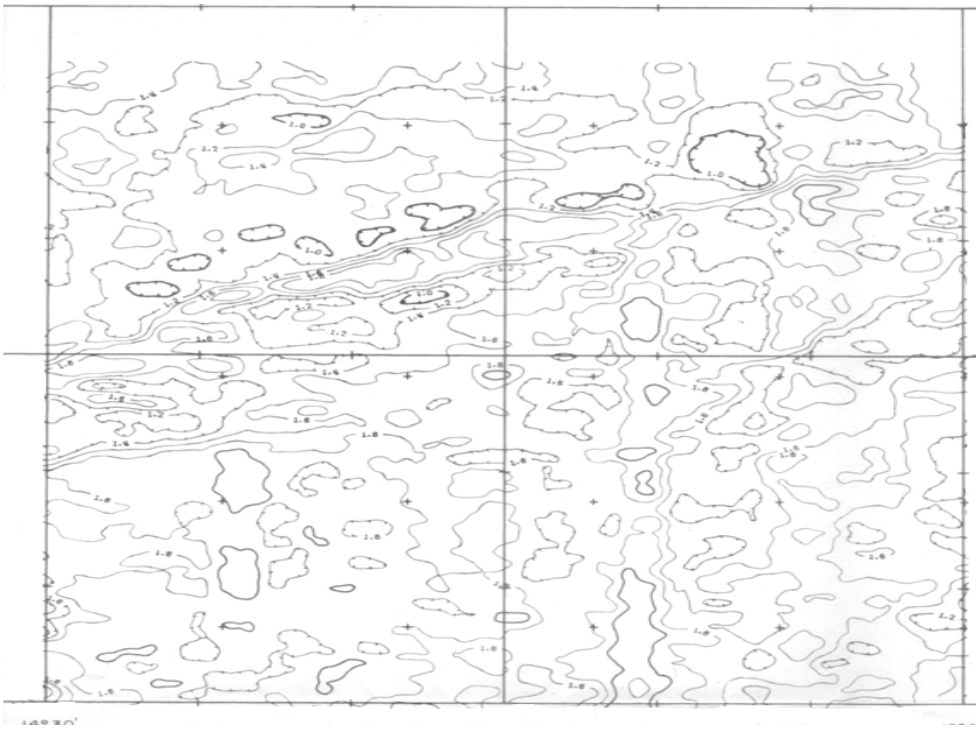

Figure-4 Radioactivity Uranium/thorium ratio map of the subset of the geological map of Sabha (see Figure-1), (IRC, 1979) unpublished internal report

RADIOACTIVITY OF THE EXPOSED ROCK UNITS

During the mapping field work of the geological sheet of Sebha as being part of the regional geological mapping program of Libya, radioactivity of the different lithological units exposed in the map area were measured using SCINTREX GR-101 Scintillometer. The radioactivity background in the area was very low and was in the range of few tens of counts per seconds (c/s). Whenever there is an anomaly (i.e. radioactivity reach values several times more than the background radioactivity) 2 samples were taken then for chemical analysis. The chemical analyses were carried out mainly for the determination of the presence of any phosphatic beds alone or combined with uranium bearing beds since both of them could be co-existed in many deposits. Increased contents of P_2O_5 were found in the following units:

1. Some oolitic iron ores in the ore-bearing members L and A (3.0-6.37 %),
2. Conglomerates of the Ashkidah Formation (8, 3-11.61 %)
3. Thin beds of conglomerates in the Mrar Formation (2.0-13.05 %).
4. The highest content of phosphorus was observed in conglomeratic rocks of the iron ore-bearing member I (at the top of the Dabdab Formation). The estimated content of P_20_5 in two samples of this units is 25.00 % and 26.22 %. Scintillometric measurements in the field indicate 200 to 220 cps at both localities. These samples were analyzed by the gamma spectrometric method. The result of the analysis is as illustrated in table -2

Sample	U content	Ra content	Th content
1	47.2	49.6	10.9
2	92.2	99.7	11.3

Table-2 radioactive content of 2 phosphatic thin layers in the area (concentrations are given in ppm)

The composition is therefore comparable to phosphates extracted in some phosphate-producing countries. However, the small thickness of the Wadi ash Shatti bone beds, as now known, does not promise economical exploration on a large scale.

GEOPHYSICAL – GEOLOGICAL CORRELATION

By the examination of Figure 3 which shows the geological formations

exposed in the area, and comparing that with the radioactivity map (uranium/thorium) ratio map showed in figure-4, it is clearly that:

1. The radioactivity of the Carboniferous (Tournaisian-Visean) Mrar formation appear clearly and distinguish as compared with the other formations in the map.
2. The radioactivity map defines and shows almost clearly the lower and the upper contacts of Mrar formation
3. The tectonic lineaments which runs in NNE-WSW are mapable in the radioactivity map.

This study hence showed a clear sound correlation between the radioactivity gamma ray Uranium/thorium ratio maps with the geological map of the study area.

SUMMARY AND CONCLUSIONS

The processes of geological mapping is may be simply stated as the identification of the different lithological units exposed on the earth's surface and putting them in a map by following certainly defined rules. Nuclear Geophysics is the science that use nuclear physics principles to study the earth. Beyond the main objective of nuclear geophysics which is the detection of radioactive minerals its scope goes beyond than that and extends to be as a tool in geological mapping. The area included in this study was subjected to gamma ray airborne geophysical survey carried in 1977 by the Industrial researches Center. The main goal of the survey was not geological mapping of the area which was poorly known at that time, but objective was solely the exploration of any radioactive minerals that may be existed in the area. In 1984 geological mapping of the area was carried out as a part of the regional geological mapping program of Libya. The two works were conducted in different times and for different purposes. This work is a combined interpretation of the two works (i.e., geological mapping a geophysical exploration). The interpretations leads to show very good correlation between relatively high radioactive areas which coincide with the Carboniferous Mrar Formation as well as clear contact relationships of this formation and clear observation of the main tectonic trend in the area.

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خريطة ارتباط النشاط الإشعاعي (اليورانيوم نسبة / الثوريوم) مع جيولوجيا الجزء الشرقي من سبها NG 33 -2

* بشير يوشاح

الملخص

تقع منطقة هذه الدراسة بين الحافة الجنوبية لما يعرف بمرتفع قرقاف وبين الجزء الشمالي لحوض مرزق الرسوبي. تتكون معظم الصخور الرسوبية المتكشفة في المنطقة من رواسب الجرف القاري للعصر الباليوزوي القديم والتي يتكون منها جبل فزان و منطقة وادي الشاطئ كما تحتوي المنطقة على رواسب قارية ترسبت في العصر الوسيط و الرباعي و الثلاثي. تمثل المنطقة الجنوبية الغربية رواسب رمال العصر الرباعي والتي تعتبر امتدادا لبحر الرمال المسمى ادهان أوباري والذي يمتد في اتجاه شمال الشرق حيث يعرف برملة الزلاف. لقد شمل المنطقة المسح الجيوفيزيائي الجوي الإشعاعي وذلك بتسجيل طيف أشعة جاما لكل من اليورانيوم و الثوريوم و البوتاسيوم بالإضافة الى النشاط الإشعاعي الكلي والذي قام به مركز البحوث الصناعية في 1977 حيث غطى منطقة وادي الشاطئ. استهدف المسح استكشاف المنطقة من حيث تواجد معادن و صخور مشعة. لم يعرف الكثير عن جيولوجية المنطقة في ذلك الوقت حيث لم يشملها برنامج التخريط الجيولوجي التفصيلي لليبيا الى بعد 7 سنوات من اجراء المسح الجيوفيزيائي الجوي. تعتبر هذه الدراسة دراسة تحليلية تجرى لأول مرة للتحليل و التفسير المشترك لبيانات المسح الجيوفيزيائي الإشعاعي الجوي ونتائج التخريط الجيولوجي التفصيلي في منطقة الدراسة متمثلا في لوحة سبها الجيولوجية. بينت الدراسة وجود علاقة وارتباط واضح بين شدة النشاط الإشعاعي المعبر عنه في خريطة نسبة اليورانيوم الى الثوريوم وبين الوحدات الجيولوجية المختلفة وبالتحديد تكوين مرار المترسب في العصر الكربوني كما بينت الدراسة بوضوح الفاصل الذي يفصل بين تكوين مرار و تكوين أشكدة كما أظهرت الخريطة الإشعاعية مسلكا تكتونيا واضحا والذي هو في اتجاه شمال شمال شرق – جنوب جنوب غرب. يتناسق هذا الإتجاه التركيبي مع التاريخ التركيبي للمنطقة. بالإمكان مقارنة النشاط الإشعاعي في تكوين مرار بطبقات الأنسيمولايت المتواجدة في منطقة بئر النقازة بمنطقة غات حيث تقع هذه الطبقات في نفس تكوين مرار ويعرف عن هذه الطبقات على أنها طبقات ذات نشاط اشعاعي عال نسبيا مقارنة بباقي الوحدات الصخرية المتواجدة في نفس التكوين كما قد يعزي النشاط الإشعاعي في تكوين مرار في منطقة الدراسة الى التركيزات الفوسفاتية القليلة المتواجدة في الصخور الكونجلوميراتية المتواجدة في الأجزاء العلوية من تكوين مرار. تعتبر هذه الدراسة مثالا حيا لإستعمال طرق الجيوفيزياء النووية كأداة مهمة في عمليات التخريط الجيولوحي من حيث تمييز بعض الوحدات الصخرية و استكشاف بعض العناصر التركيبية مثل الفوالق الرئيسية و غيرها.

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