Iraqi Bulletin of Geology and Mining *Vol.17, No.2, 2021* *p 77 – 88*

STUDY OF RADIOMETRIC ANOMALIES IN THE HIT – ABU JIR AREA AND THE SURROUNDINGS, WEST IRAQ

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Received: 13/ 09/ 2021, Accepted: 22/ 11/ 2021
Keywords: Radiometric anomalies; Uranium; Potassium; Euphrates Formation; Anah – Abu Jir Fault Zone; Iraq

ABSTRACT

Processing and qualitative interpretation of the radiometric data in the Hit – Abu Jir area, west Iraq, is carried out in the present work. The data is analyzed and separated to its residual and regional (background) maps. The regional maps show an increase in radioactivity background towards the northeast, while the residual radiometric anomaly maps show consistent and semi continuous belt of radioactive anomalies along the Euphrates River basin and mostly at the southern and western sides of the basin. The radioactivity in the study area is connected with certain lithological and stratigraphic units, located within the carbonate rocks of the Euphrates Formation (Lower Miocene) as well as around spring-water deposits. A comparison between radiometric map and geological map is executed; showing radioactivity range of each geologic formation. A correlation is carried out between two geologic sections and the radiometric map which shows conspicuous change in radioactivity level at the contact of different geologic formations. It is concluded that the structural setting of the study area played an important role in increasing the concentration of the radioactive elements and controlled their location and extension.

دراسة الشواذ الاشعاعية لمنطقة هيت – ابو جير والمناطق المجاورة، غرب العراق

عباس محمد ياس

المستخلص

أجريت معالجة وتفسير نوعي للمعلومات الإشعاعية لمنطقة هيت أبو جير والمناطق المجاورة حيث تم تحليل المعلومات وفصلها الى خرائط محلية وإقليمية. أظهرت الخرائط الإقليمية زيادة في النشاط الإشعاعي الإقليمي باتجاه الشمال الشرقي، بينما أظهرت خرائط الشواذ الإشعاعية المتبقية حزام من الشواذ الإشعاعية المتناسقة وشبه المستمرة على طول حوض نهر الفرات وخصوصا الجزء الجنوبي والغربي من الحوض. ان النشاط الإشعاعي في منطقة الدراسة ارتبط مع وحدات صخرية وطباقية محددة ضمن الصخور الكاربونيتية لتكوين الفرات، بالإضافة الى الترسبات حول العيون المائية. أجريت مقارنة بين الخريطة الإشعاعية والخريطة الجيولوجية لمنطقة الدراسة وتم تعيين مدى النشاط الإشعاعي لكل تكوين جيولوجي، أجريت علاقة ترابط بين مقطعين في الخريطة الجيولوجية والخريطة الإشعاعية وقد أظهرت هذه العلاقة او المضاهاة تغيرات واضحة في مستوى النشاط الإشعاعي عند مواقع تماس (حدود) التكاوين الجيولوجية. تم الاستنتاج ان الوضع التركيبي لمنطقة الدراسة لعب دورا مهما في زيادة تراكيز العناصر الإشعاعية والتحكم في مواقعها واتجاهات توزيعها.

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INTRODUCTION

Radioactive minerals are usually difficult to locate and identify in rocks by normal megascopic and microscopic techniques due to their occurrence usually in very low content (< 1%). However, the intrinsic property of radioactivity resulting in spontaneous emission of alpha–beta particles and gamma rays of radioactive minerals is taken as advantage for their location as well as estimation of the contents of U and Th (Bristow, 1979).

Numerous radioactive anomalies have been detected in western Iraq by the regional airborne radiometric survey carried out by the Companie General de Geophysique in 1974 (C.G.G., 1974).

Generally, most of these anomalies are found to be related to the primary uranium that exists within the Upper Cretaceous – Paleocene phosphate rocks which are widely exposed in the Western and Southern Deserts of Iraq (Al-Bassam, 2007). Another radioactive anomaly was found to be related to uranium and thorium that exist within the heavy minerals of the Amij Formation (Jurassic) (Mahdi and Al-Kadhimi, 2007). The other radioactive anomalies are related to potassium and associated with mud and fine sediment in depression (faidhah) (Al-Bassam, 1988). This study deals with another significant set of radioactive anomalies which are related to the primary and secondary uranium concentrations that exist within the upper parts of the Euphrates Formation (Lower Miocene) along the Euphrates River basin as well as around spring-water deposits and bitumen seepages along the Anah – Abu Jir Fault System.

LOCATION AND AIM

The study area is located in the western part of Iraq (Fig.1), within Longitudes 42° 00' 00" – 43° 30' 00" and Latitudes 33° 00' 00" – 34° 00' 00". The purpose of this study is to define the radioactivity range of different geological formations in the study area, locations of radioactive anomalies related to U and K and explication the source of these anomalies and its relationship to the geologic setting of the study area.

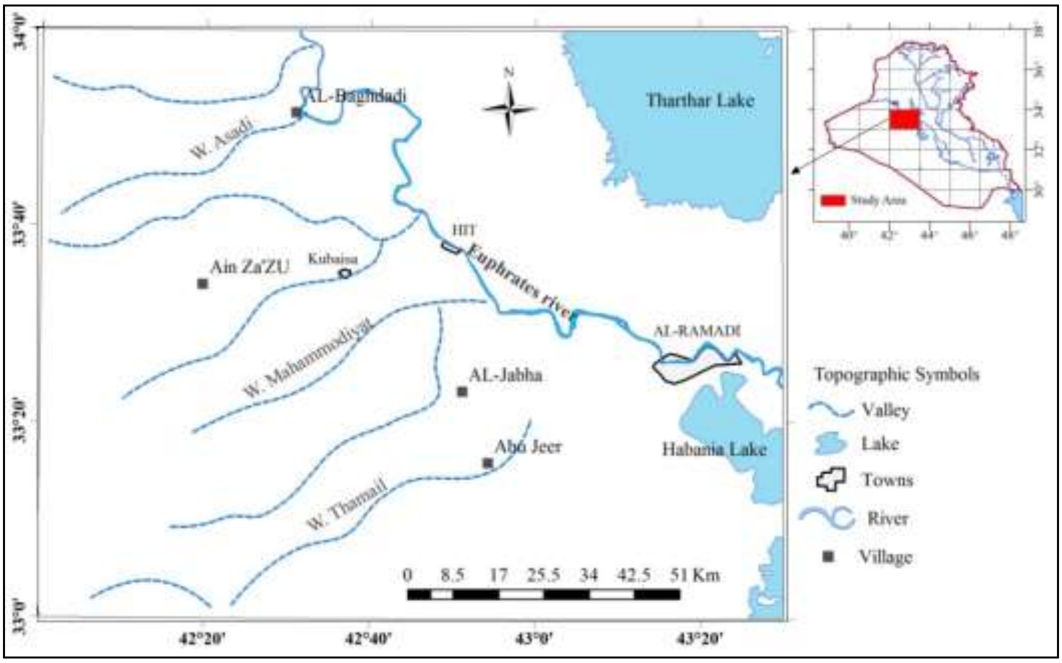

Fig.1: Location map of the studied area

PREVIOUS WORK

The issue of radioactive anomalies and the occurrence of radioactive elements in Iraq have been studied and discussed by several workers from various points of view including geophysics, geochemistry, mineralogy, and genesis. Some of these studies are presented hereinafter.

- C.G.G. (1974) conducted regional airborne radiometric survey for most of the Iraqi territory and introduced interpretation maps of the radioactive anomalies for the whole surveyed area in a final report.
- Al-Atia *et al*. (1977) presented a genetic model for the uranium occurrences of Hit and Shithatha areas, where a primary uranium source of magmatic origin close to the basement rocks was suggested. They concluded that uranium was leached by hydrothermal solutions and travelled long distances upward, through fractures and faults and the dispersed uranium may have been trapped in certain horizons where favorable conditions for uranium accumulation existed.
- Al-Bassam (1988) carried out geochemical investigation of potassium anomalies in the Western Desert of Iraq and confirmed the presence of relatively high concentrations of potassium in the fine sediments filling depressions and in some saltern deposits in comparison with adjacent areas.
- Al-Atia and Mahdi (2005) discussed the origin of the epigenetic uranium mineralization at Abu-Skhair deposit and suggested leaching by groundwater and upward migration of uranium from the epigenetic uranium-bearing dolomite horizons in the upper part of the Euphrates Formation and redeposition in swamp deposits at the contact of the Euphrates Formation with the overlying units.
- Al-Dabbagh (2005) presented a qualitative interpretation of airborne radiometric data for the Ga'ara area west Iraq. This study showed that the high level of radioactivity is conjugated with phosphate-bearing rock formations and also with some clastic units and found that the structural setting play an important role in forming the radioactive anomalies.
- Al-Bassam *et al*. (2006) presented a new model explaining the regional "syngenetic" uranium mineralization in the upper part of the Euphrates Formation (Lower Miocene). They proposed a model considers thick uranium-rich Paleozoic shales and sandstones as primary sources of uranium.
- Yass *et al*. (2016) carried out qualitative interpretation of the airborne radiometric data of the Rutba and Saba'a ebyr Quadrangles, They appointed six radiometric anomalies related to some geologic formations that contain phosphate rocks and some of the anomalies were related to Quaternary sediment (valley- and depression-fill deposits). The sources and dominant radioactive element were appointed for each anomaly.
- Mahdi (2019) presented an overview of the extensive exploration for radioactive minerals in Iraq, based on previous reports and published papers.

GEOLOGICAL SETTING

The study area is located within the Inner Platform of the Arabian Shelf from the west and the Outer Platform (Mesopotamia Foredeep) from the east (Fouad, 2012). Amij – Samarra – Halabcha Transverse Fault crosses the uppermost part of the study area; it is one of the main sub-surface structural features in the study area. Another important structural feature is the Anah – Abu Jir Fault Zone, which is a sub-surface system of faults, running NW – SE.

The age and lithology of the exposed formations and Quaternary sediments are shown in the geologic map of the study area (Fig.2).

The limestone of the upper part of the Euphrates Formation (Lower Miocene) is characterized by anomalous uranium concentrations in most of the exposures and shallow subsurface sections along the Euphrates River. Two genetic types of uranium enrichment were identified in these rocks: syngenetic and epigenetic (Al-Bassam *et al*., 2006). The latter is younger and was developed by the remobilization of uranium from older uranium-rich carbonate horizons lying underneath (Al-Atia and Mahdi, 2005).

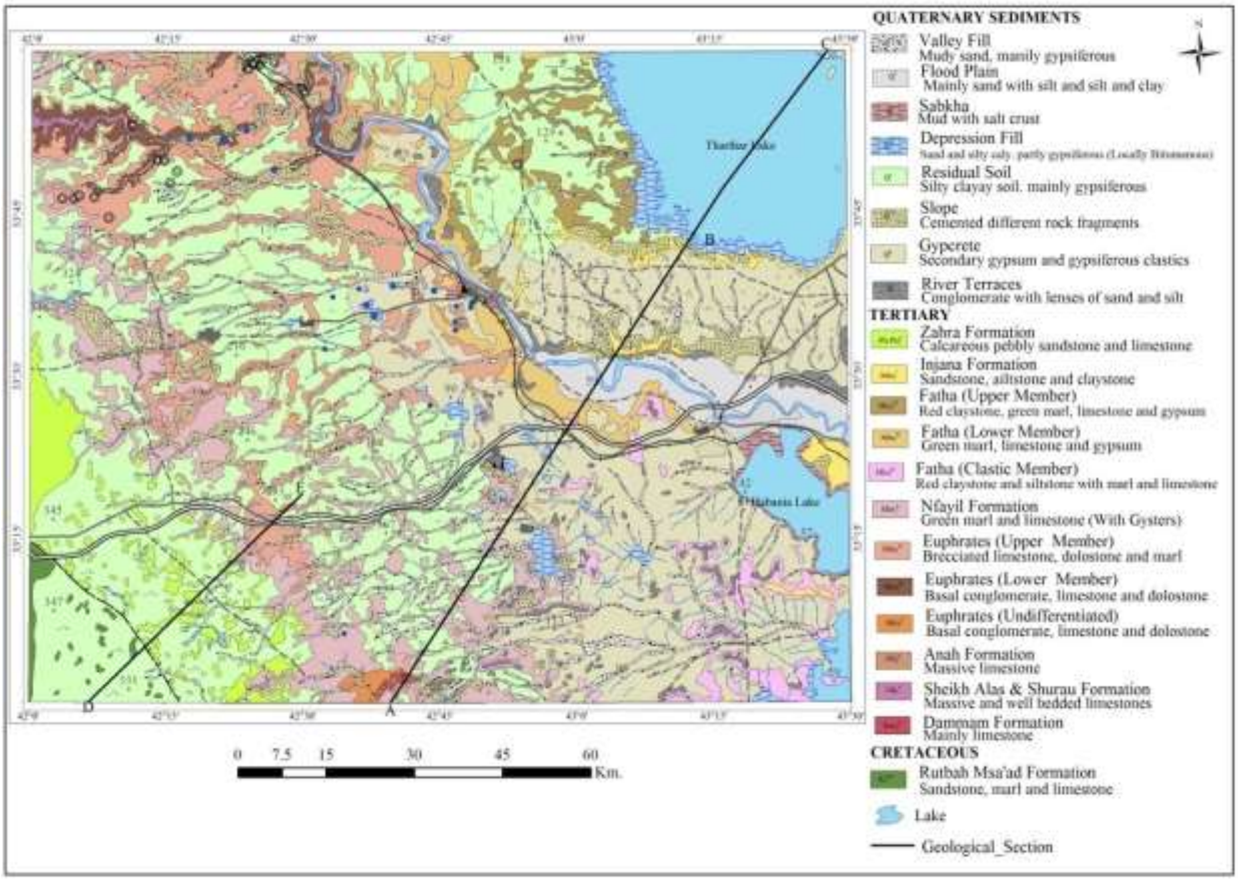

Fig.2: Geological map of the studied area (after Sissakian and Muhammad, 1994)

The linear distribution of the uranium-rich zones along the Euphrates River basin and not all over the physiographic distribution of the Euphrates Formation requires controlling geological factors. The Anah – Abu Jir Fault Zone, in its two parts: The Hit – Abu Jir – Nassirya and Anah – Al-Qaim is the only linear geological feature that coincides, in space and time, with the distribution of uranium mineralization in the Upper Miocene Euphrates Formation (Al-Bassam *et al*., 2006). The spatial distribution of the radiometric anomalies is in close association with surface expressions, as well as with subsurface extensions, of this fault zone (Al-Bassam *et al*., 2006).

The Anah – Abu Jir Fault system was important in the localization of the uranium mineralization in the Euphrates Formation (Al-Atia *et al*., 1977). The faults retarded the natural flow of groundwater down dip and thus allowed uranium to be transported upward via fault surfaces, conduits and fracture zones and to contaminate the Miocene Sea in the area of influence of these faults; they also allowed the seepage of reductants (H_2S and bitumen) to the depositional environment (Al-Atia *et al*., 1977).

DATA USED AND METHODOLOGY

The sources of the used data are the raw digital radiometric data of C.G.G. (1974), geologic and tectonic maps of Iraq Geological Survey, relevant reports and studies and airborne radiometric map which is used to identify the radioactive range of each geological formation. Residual radiometric map and tectonic map are used to study the relationship between the radioactive anomalies and the tectonic setting. Surfer software (Trend surface analysis) is used for separating the relatively large-scale systematic changes (background) from essentially non-systematic small-scale variations due to local effects (residual). Three regional and residual radiometric maps are constructed for the radiometric data of the study area.

Trend surface analysis is used for separating Regional from Residual radioactivity. The method can be applied to any contour-type map. The regional field (background in this work) can be represented as a low-degree mathematical polynomial surface, the differences between the observed values and this surface represent the residual anomaly (Nettleton, 1976), The mathematical expression of the polynomial surface depends on the complexity of the regional geology, if the regional field is planar and diagonal the mathematical surface expresses the first order planar surface by equation (1):

$$Z = Ax + By + c \text{ .... (1)}$$

The second order polynomial surface (Quadratic surface) is applied to the complex regional surface field and is expressed by equation (2):

$$Z = Ax2 + By2 + Cxy + Dx + Ey + F \text{ .... (2)}$$

The third order polynomial surface (Cubic surface) is applied to the more complex regional surface field and is expressed by equation (3):

$$Z = A + Bx + CY + Dx + Exy + FY + Gx + Hxy + Lxy + Jy \text{ .... (3)}$$

The coefficient, A, B and C are specified by the least square fitting, noticing that as the order become higher, the complexity of the pattern increases. Surfer software ver.10 is used for appliance trend surface analysis method on the total count radiance value to calculate the natural background activity using polynomial regression gridding at which introducing the wanted surface and used order, then drawing residual and background maps for each order.

RESULTS AND DISCUSSION

- **Background Radiometric Maps (Regional Maps)**

The first order map gives straight isorad contour lines in count/second (c/s) units, which reflect the general background of radioactivity distribution in the study area. It shows an increasing regional trend towards the northeast (Fig.3). The second order map reflects the main radioactive anomalies in the study area (Anah – Abu Jir Fault Zone anomaly) which extends in NW – SE direction with rounded to elongate shape and located in the midst of the study area (Fig.4). Whereas, the third order map is more detailed than the other two orders (Fig.5). It should be noted that as the order become higher, the complexity of the pattern increases using the similar analysis method (Trend surface analysis).

- **Residual Radiometric Map**

Residual radioactive anomaly maps are prepared in three orders, where large similarity in the distributions and locations of the residual radioactive anomalies is noticed in these maps. Therefore the three order residual radioactive map (Fig.6), is prepared in order to study and explain the residual anomalies in terms of their relation to the geology of the study area.

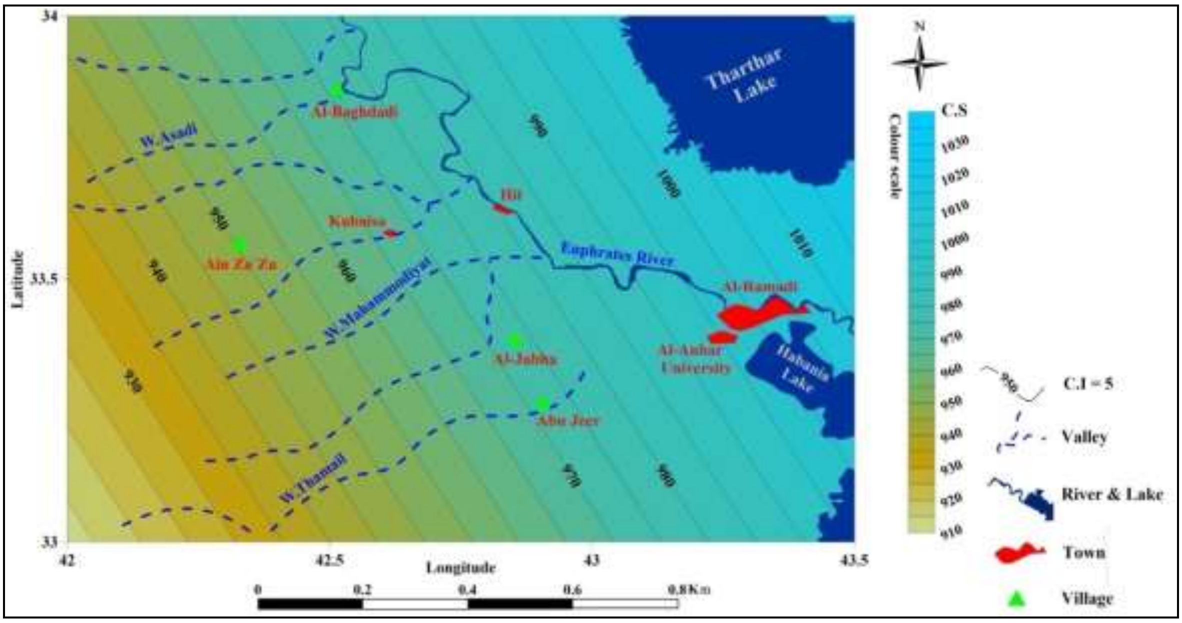

Fig.3: Background (regional) radiometric map of the study area (1st .order)

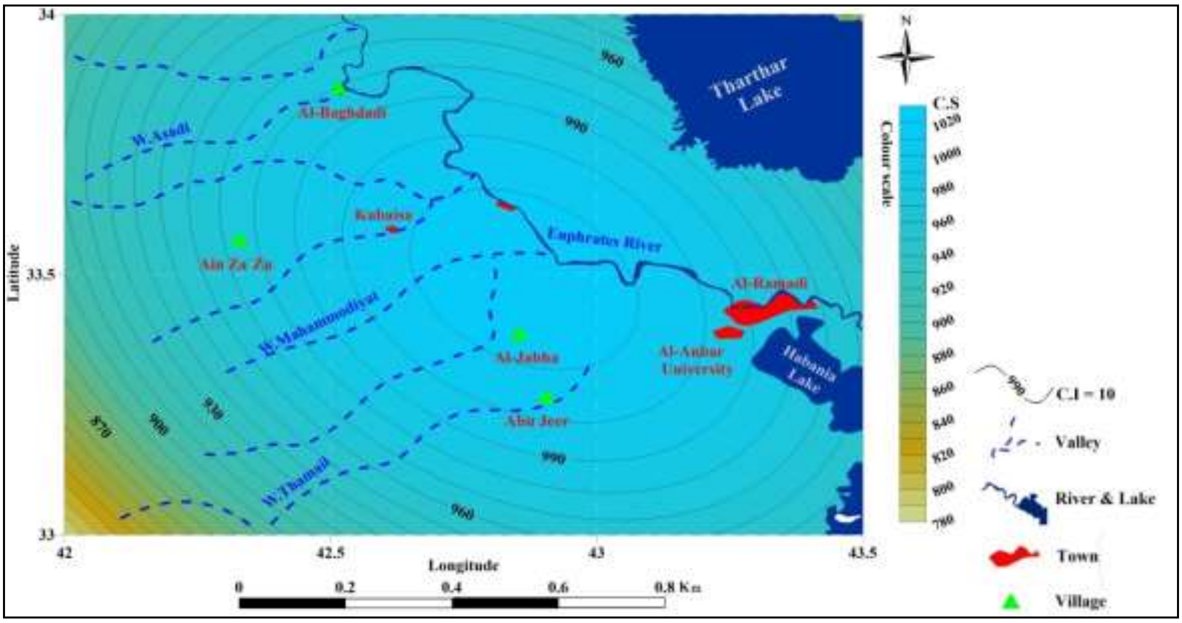

Fig.4: Background (regional) radiometric map of the study area (2nd.order)

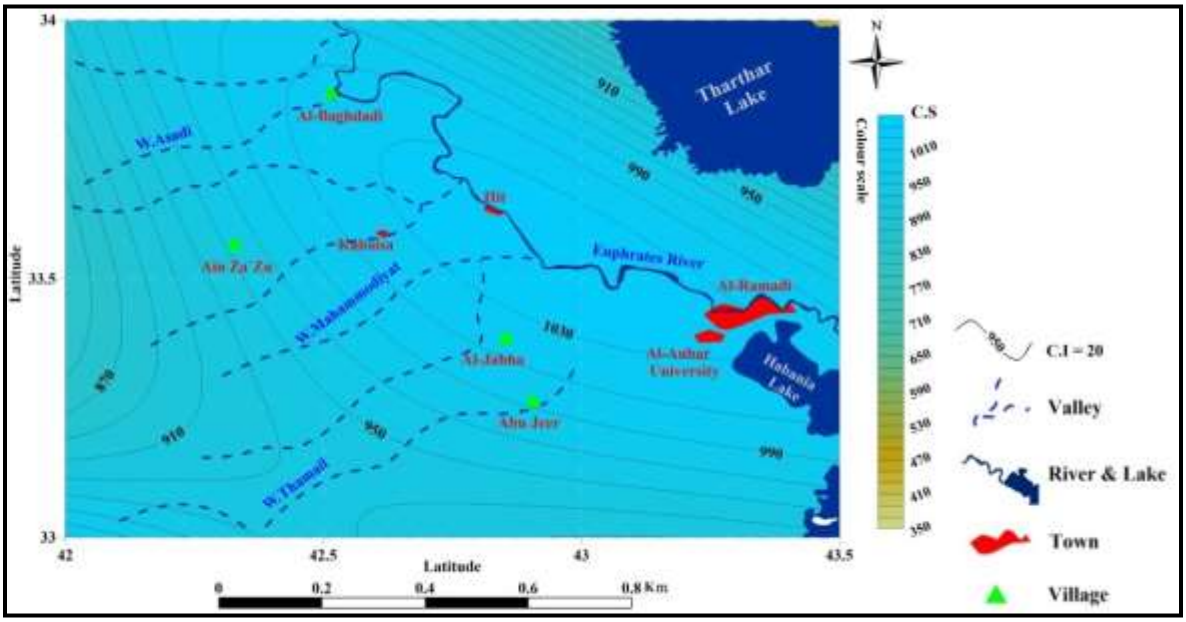

Fig.5: Regional radioactive map of the study area (3^{rd}.order)

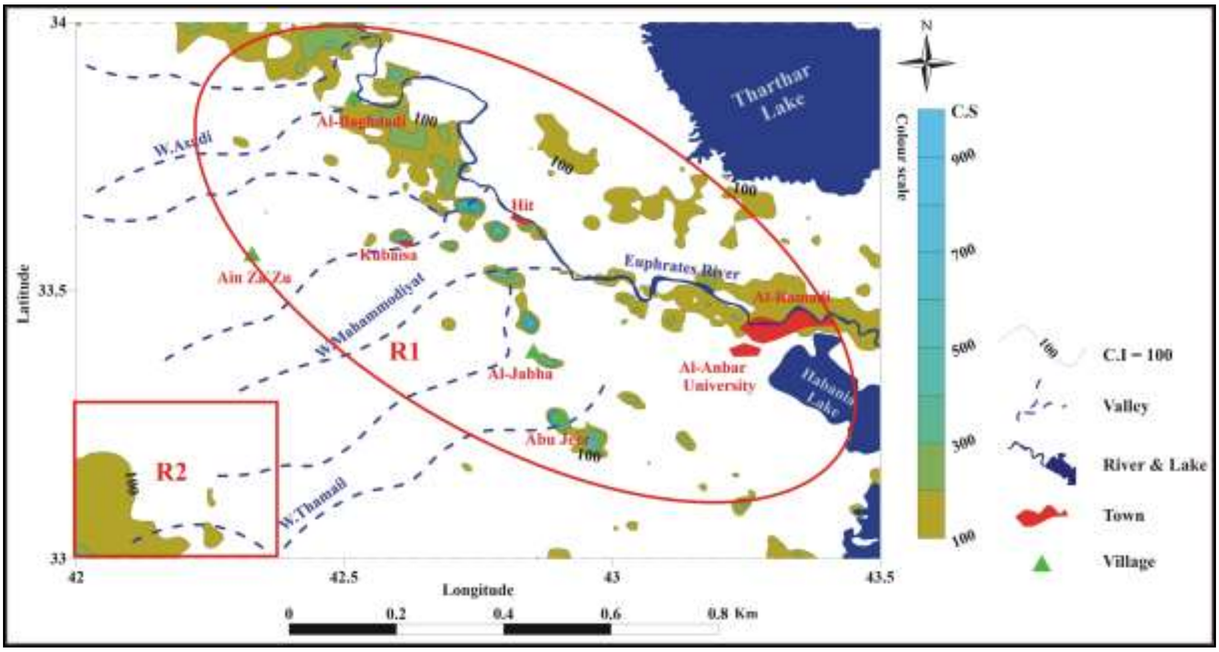

Fig.6: Residual radiometric map of the studied area (3^{rd} order)

Two radioactive anomalies in the study area were identified by the airborne radiometric survey (C.G.G., 1974) and verified with more details in the present study (Fig.6).

– **Anomaly (R1):** This is a set of anomalies (Fig.6) which shows consistent and semi continuous belt of radioactive anomalies along the Euphrates River basin and mostly at the southern and western sides of the basin. They coincide on surface with two geological features. They are mostly related to the exposures of the Euphrates Formations, and with the Anah – Abu Jir Fault Zone (Al-Bassam *et al*., 2006). The western part of these anomalies (west of the Euphrates River) includes a group of circular and elongate pattern of anomalies, running in NW – SE direction and coincide within the Anah – Abu Jir Fault Zone (from north Al-Baghdadi village in the north of the study area to Kubaisa, Al-Jabha, Abu Jir village and Wadi Thumail in the south). These anomalies are found to be related to the radioactivity of primary uranium enrichment in the Upper part of Euphrates Formation and to the radioactivity of uranium and radium in or around the deposits of spring and bitumen seepages (C.G.G., 1974). In the east of the Euphrates River there are numerous radioactive anomalies extending in NW – SE direction with the general trend of the Anah – Abu Jir Fault Zone and coincide with the Quaternary sediments and exposures of the Injana Formation which are rich in mica minerals and contain potassium in their chemical composition. These anomalies were found to be related to radioactivity of potassium (C.G.G., 1974).

– **Anomaly (R2):** It is located in the southwestern part of the study area, This anomaly corresponds to the Faidht Al-Awaj which is formed as Al-Awaj fault intersects with Wadi Al-Awaj which led to complete closure and formation of a topographic depression at the intersection area; locally known as Faidht Al-Awaj (Al-Dabagh, 2005). According to the radioactive anomaly distribution appointed by the C.G.G. (1974), anomaly (R2) was found to be related to potassium radioactivity coinciding with topographic (structural?) depression, similar to most potassium anomalies in the Western Desert which were related to mud flats and fine sediments filling depressions (Al-Bassam, 1988).

- **Geological Setting and Radioactivity**

A comparison is made between the radiometric map and the geological map of the study area, and then the radioactive range for each formation is identified. The results obtained are presented in Table (1) and Fig. (7).

Table 1: Radioactivity range of geologic formation in the study area

Formation name	Radiometric intensity c/s	Age	Lithology
Zahra Formation	880 – 1000	Pliocene – Pleistocene	Alternation of sandstone and limestone
Injana Formation	625 – 1100	Upper Miocene – Pliocene	Claystone, siltstone, and fine sandstone
Fatha Formation (U.Member)	800 – 1100	Middle Miocene	Marl, limestone, gypsum, claystone, siltstone, and sandstone
Fatha Formation (L.Member)	800 – 1175	Middle Miocene	Marl, limestone and gypsum.
Fatha Formation (Clastic. Member)	825 – 1225	Middle Miocene	Marl, siltstone, claystone and fine sandstone with secondary gypsum.
Nfayil Formation	800 – 1600	Middle Miocene	Marl and limestone
Euphrates Formation (U.Member)	800 – 1750	Lower Miocene	Marl, brecciated limestone, dolostone, marly limestone and dolomite limestone.
Euphrates Formation (L.Member)	825 – 1225	Lower Miocene	Basal conglomerate overlain by limestone, dolomitized, recrystallized and very hard.
Euphrates Formation (Undifferentiated)	900 – 975	Lower Miocene	Basal conglomerate, limestone and dolostone.
Sheikh Alass and Shura Formations	825 – 1000	Lower Oligocene	Limestone recrystallized, hard to very hard and splintery.
Damam Formation	900 – 925	Lower Eocene	Limestone and phosphatic limestone
Rutba and Msa’ad Formations	900 – 1050	Upper Cretaceous	Marly limestone with thin horizons of recrystallized fossiliferous limestone.

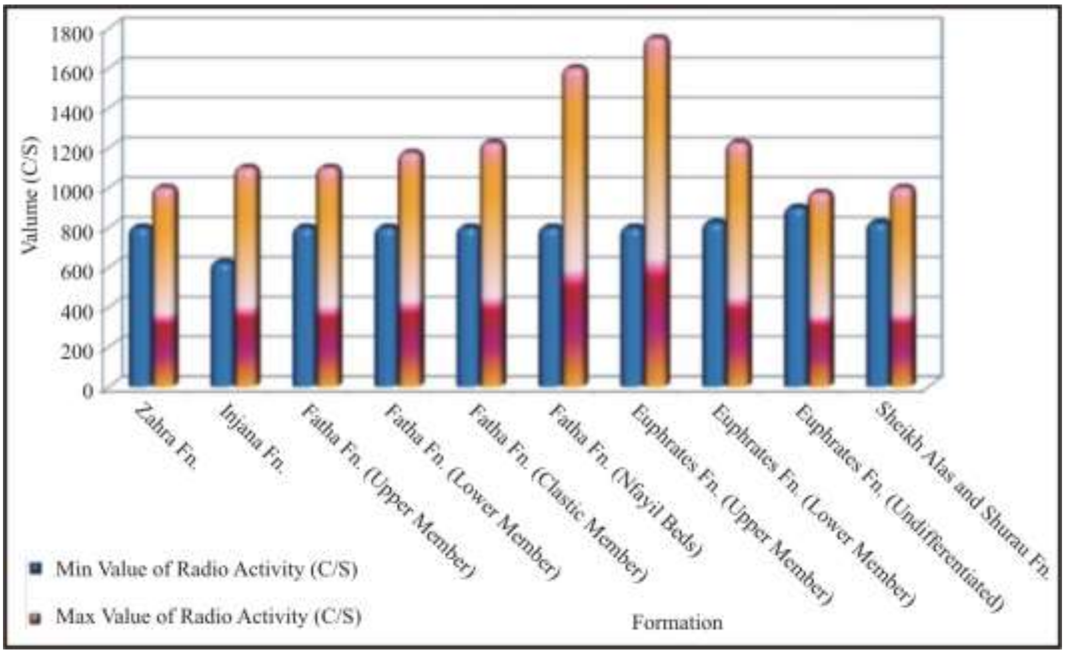

Fig.7: Radioactivity range of geologic formation in the study area

A correlation is carried out between two geological sections and radiometric profiles (Figs.8 and 9; for location refer to Fig.2). The correlation shows conspicuous change in radioactivity level at locations of contacts between different geological formations, the first sharp anomaly in (Fig.8) related to the radioactivity range of Rutba and Msa'ad Formations (900 – 1050 c/s) (Table 1), The second sharp anomaly related to the radioactivity range of Zahra Formation (880 – 1000 c/s) we could see large change in radioactivity range at the contact between Rutba Msa'ad Formation and Zahra Formation at the location of Al-Qsair Fault, the descending of radioactivity at the right side of the section (Fig.9) above Tharthar Lake is due to the absorption of radioactivity by the water (C.G.G., 1974).The radioactivity anomaly in the right side of the (Fig.9) after Tharthar Lake correspond to the exposure of Indiana Formation and related to potassium radioactivity.

- **Tectonic Setting and Radioactivity**

The residual radioactive anomaly map (Fig.6) superimposed on tectonic map (Buday and Jassim, 1984) (Fig.10), shows a coincidence between the radioactive anomaly and subsurface structures. Faults, joints and fractures may form areas of weakness zones and passageways for increasing movement of the groundwater, which acts in the transmission of radioactive elements from its source rocks to be precipitated on the ground surface.

The Anah – Abu Jir Fault Zone has clear surface expressions (physiographic expressions) such as linear cliffs, especially in its southern extension. In the northern part it is well defined in subsurface by seismic reflection; consisting of a system of faults making a fault zone in the Hit – Abu Jir area (Fouad, 2004). This fault zone is characterized by numerous mineral springs associated with H_2S and occasionally with bitumen. They are located along faults and lineaments. Most of the radiometric anomalies with high radioactivity level are located at the locations of these mineral springs (Al-Dabbagh, 2005).

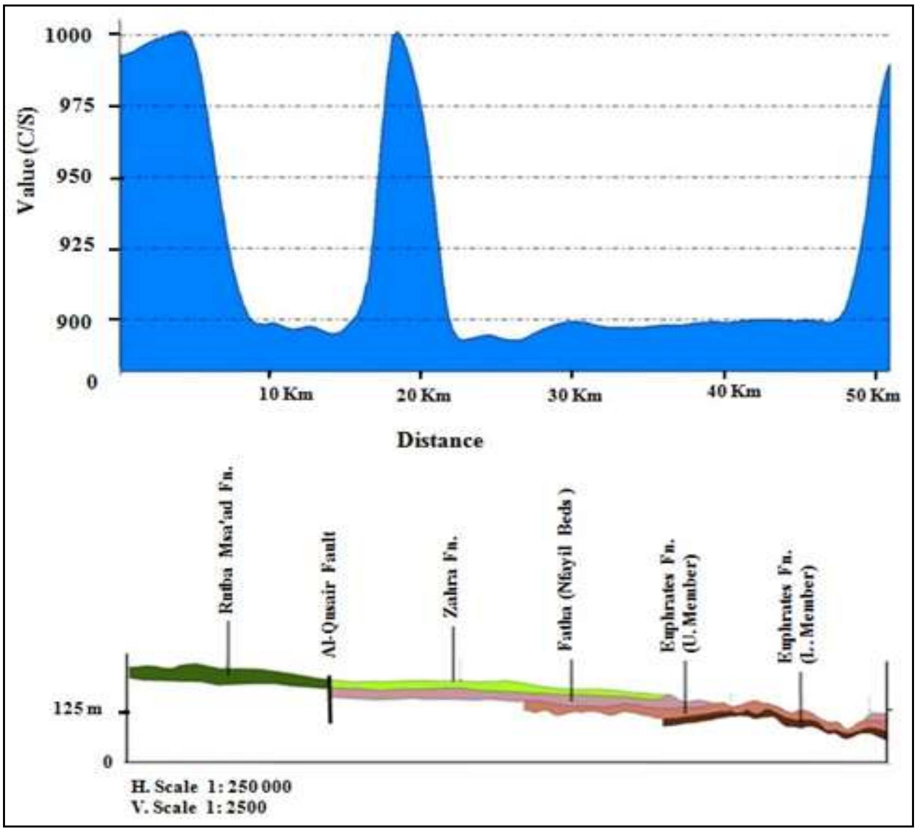

Fig.8: Correlation between geological section and radiometric profile DE

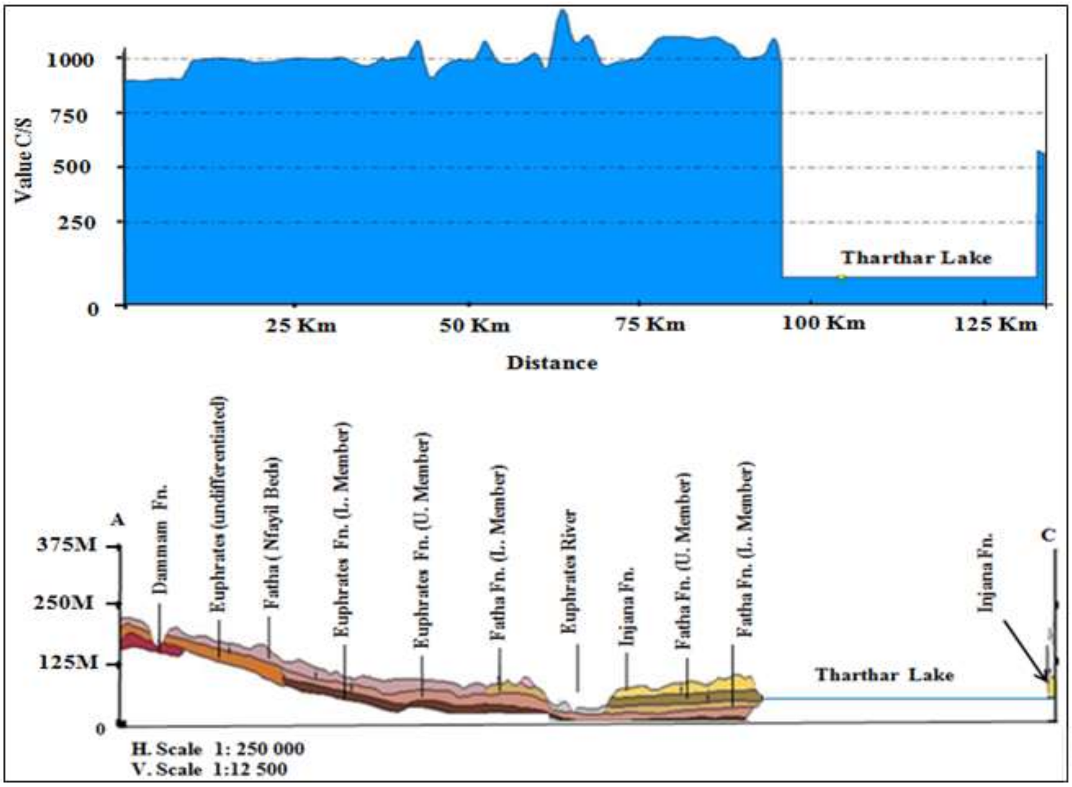

Fig.9: Correlation between geological section and radiometric profile AC

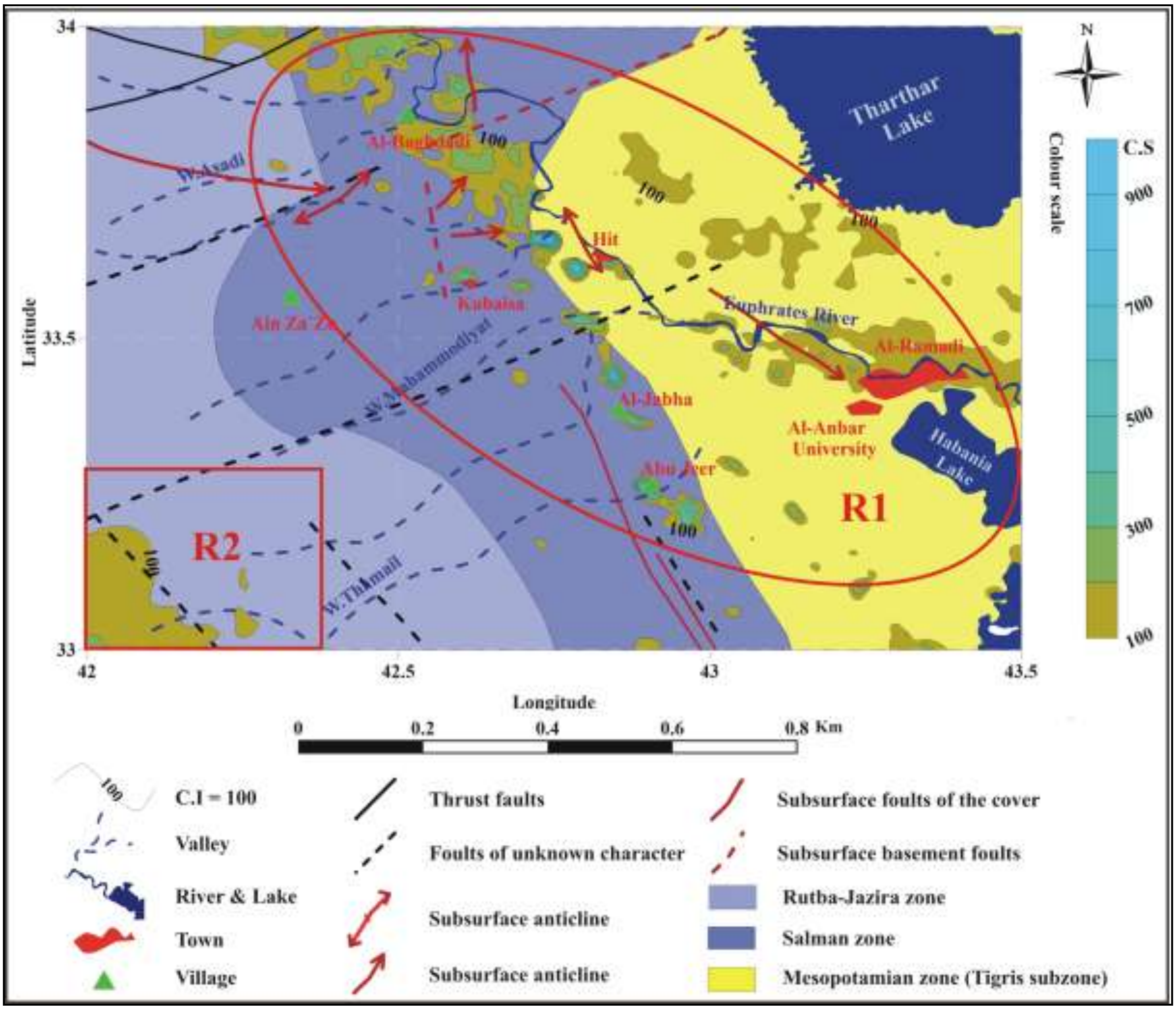

Fig.10: Residual anomaly map superimposed on tectonic map of the study area (Buday and Jassim, 1984)

CONCLUSIONS

- The background radioactivity in the study area increases to the northeast, while the residual radiometric anomaly maps shows consistent and semi-continuous NW – SE belt of radioactive anomalies along the Euphrates River basin and mostly at the southern and western sides of the basin.
- The geological formations in the study area show different radioactivity levels; the highest is found in the Upper Member of the Euphrates Formation with up to 1750 c/s.
- The correlation between the geologic sections and the radiometric map shows conspicuous change in radioactivity level at the contact of different geologic formations.
- Two residual radioactive anomalies were verified, Anomaly R1 (uranium) and Anomaly R2 (potassium).
- The structure and tectonic of the study area played an important role in the formation of the radioactive uranium anomalies and control their location and extension.
- Topographic depression with sediments having K-rich mica minerals played important role in the localization of the radioactive K anomaly.

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