Journal of Radiation and Nuclear Applications
An International Journal

http://dx.doi.org/10.18576/jrna/100310

Deriving eU & eTh Concentrations from Total Gamma Ray Logs, A Case Study, Paleozoic Rocks, Gulf of Suez, Egypt

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Received: 28 June 2025, Revised: 3 Aug 2025, Accepted: 25 Aug 2025.
Published online: 1 Sep, 2025.

Abstract: Surface gamma-ray spectrometric survey was conducted in the study area (Um Bogma, Southwestern Sinai) along three vertical sections, one meter as a station separation. The gamma-ray spectrometric sections showed different levels in the surveyed rocks, which reflect the radioelement contents of the various exposed rock types. The highest radio-spectrometric levels in Paleozoic rocks are located along the middle carbonate series of the Um-Bogma formation.

From the radio-spectrometric data, a formula was derived to infer the concentrations of the two major radioelements Uranium (eU, ppm) and Thorium (eTh, ppm) in the surface and subsurface of Paleozoic rocks from the measured T.C. gamma-ray in API units. Excellent relationships, very high correlation coefficients (0.98 and 0.96), and very low error are the results of comparing the calculated eU and eTh from total count gamma-ray (in API unit) with the measured eU and eTh concentrations in the Ras-Ghara oil field in three wells. The derived formulas can be used to solve the problem of inferring eU and eTh concentrations in the case of the absence of gamma-ray spectrometric logs.

Keywords Spectral gamma-ray logs, Paleozoic rocks, Gulf of Suez, Um Bogma Formation.

1 Introduction

components of nuclear fuel in nuclear power reactors. These two radioactive elements can be evaluated in rocks using spectral gamma-ray logs as a quick method in any exploration area. Spectral gamma ray play an Importany role in detection or radioactive mineral ezploration [1]. Determination of spectral gamma ray (K, eU & eTh) concentration, can be used directly to evaluate the radiological hazards [2].

Spectral gamma-ray logs can be used as a hydrocarbon accumulation inference factor or indicator for the suitability of clastic reservoir rocks [3, 4].

Paleozoic rocks, which are exposed in many localities in Southwestern Sinai, Egypt, at the eastern side of the Gulf of Suez, Fig. (1), can be subdivided according to the geological studies of [5, 6 & 7] into two main types of sediments: Early and Late Paleozoic. Early Paleozoic sediments (Cambro-Ordovician) were called as lower sandstone series. Late Paleozoic (Carboniferous) sediments are represented by two main Formations: Um-Bogma Formation of Early Carboniferous, which is considered the main radioactive exploration target and is called the middle carbonate sediments, and the Late Carboniferous Formations, which are called the upper sandstone series.

The main objectives of the present study are to find a proper solution to the problem of the rarity of radio-spectrometric logs that require high costs and long-time measurements in wireline logging. Almost all well-logging devices measure only total gamma-ray and not spectral gamma-ray; thus, that is the problem, i.e., there is no information about the concentrations of the three main radioactive elements (uranium, thorium, and potassium).

2 Geological Setting

The stratigraphy of the Paleozoic rocks in the Gulf of Suez region, Egypt (Fig. 2) has attracted the attention of many geologists, due to its numerous petroleum

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occurrences. The dominant nomenclature of subsurface Nubia Sandstone units was suggested by oil companies, which divided them into four lithofacies arranged from top to bottom: Nubia A, Nubia B, Nubia C, and Nubia D. The subsurface succession of the Nubia sandstones in the Gulf of Suez was studied by [8].

The surface studied sections are represented by rocks that range from Precambrian to Triassic. The Precambrian rocks are represented by granitic rocks. The Paleozoic rocks are classified into seven formations from base to top (Fig.): Sarabeit El-Khadim, Abu-Hamata, Adadia, Um-Bogma, El-Hashash, Magharet El-Maiah, and Abu-Zarab [9].

The lower sandstone series, which is constituted from three formations, includes Sarabit El-Khadim, Abu-Hamata, and Adadia, which are composed mainly of clastic sandstone, shale, and cross-bedded sandstone with conglomerate bands, respectively.

Um-Bogma Formation is the most important Paleozoic rock unit, due to its high content of uranium, besides Fe-Mn ore deposit and secondary copper mineralization. It is composed of carbonate, shale, and marl sediments. The thickness of Um-Bogma Formation reaches 40 m at the type locality.

El-Hashash Formation is composed of sandstone with clay intercalations. Meanwhile, carbonaceous shale and marl are the main components of Magharet El-Maiah Formation. On the other hand, Abu-Zarab Formation is composed of white sandstone or glass sand.

The Carboniferous rocks of Southwestern Sinai were severely affected by normal faults, which are seen everywhere and vary greatly in length and displacement.

Fig. 1: Location map of the study (Um Bogma and Ras Ghara Oil Field) areas, Southwestern Sinai, Egypt.

3 Methodologies

3.1. Ground gamma-ray spectrometric survey

The surface gamma-ray spectrometric survey was conducted in the study area using a ground spectral gamma-ray survey instrument (**RS-230**) along three vertical sections covering the Paleozoic sediments with one meter as a station separation to reflect the radioelement contents for the different exposed rock types. It is shown that the highest radio-spectrometric levels are located within - Bogma Formation.

1- Wadi Abu-Hamata area section

This section was measured in Wadi Abu-Hamata area, Southwestern Sinai, Egypt, at the intersection of the latitude 29° 11' 1.47" N and the longitude 33° 23' 34.05" E, from base to top along 146 m. The lower sandstone series has higher radiation than the upper sandstone series. Um-Bogma Formation shows the highest gamma-ray spectrometric reading, while Abu-Zarab Formation indicates the lowest. Adadia formation yields relatively moderate eTh reading, which is greater than eU reading in this section. This may be due to uranium leaching out, as shown in Fig. 4, which illustrates the vertical distribution of radioactive measurements along the Wadi Abu-Hamata section.

2 -Wadi Abu-Zarab area Section

This section is located at the

intersection of the latitude 29° 0' 53.01" N, and the longitude 33° 23' 24.32" E, with a thickness of about 160 m. From the radio-spectrometric section of Abu-Zarab (Fig. 5), the Paleozoic rocks can be obviously classified into three main categories, from base to the top:

1- The lower weak radio-spectrometric readings are called the lower sandstone series.
2- The highest radio-spectrometric anomalous horizon, which is called the middle carbonate series or Um-Bogma Formation.
3- The weak radio-spectrometric readings of the upper sandstone series.

3- El-Sheikh Soliman area Section

El-Sheikh Soliman section (Fig. 6) was measured at the intersection of latitude 28° 53′ 43.19″ N and longitude 33° 21′ 30.93″ E, which possesses a thickness of about 140 m. From the radio-spectrometric section of El-Sheikh Soliman, the Paleozoic rocks can be divided into three zones, depending on their different radio-spectrometric levels.

This area has the highest measured eU

concentrations in the studied sections, so it needs more detailed studies.

In the three studied sections, Paleozoic rocks were divided graphically into the seven known formations depending on their radio-spectrometric results, which agree with the thicknesses of Paleozoic geological classification.

3.2. Deriving eU & eTh concentrations

The total gamma-ray logs were measured in all wells with the American Petroleum Institute (API) unit, while the total count gamma-ray measurements were gained from surficial surveys that were measured with the Ur unit. To derive the eU and eTh concentrations from the total count gamma-ray surficial data, the concentrations of (eU, eTh, and K) must be converted from (ppm, ppm, and % respectively) to the unit usually used in well logging petroleum measurements (API).

According to [11], one ppm eU equals about 8.1 API, one ppm eTh equals 3.94 API, and one % K equals about 16.2 API. Using these conversion values, it was possible to convert the surficial spectral gamma-ray data to the API unit, which is used in well logging measurements.

Spectral measurements of old drilled wells, measured before the year 2000, faced obstacles of high cost and a long time needed for conducting measurements, besides the rarity of radio-spectrometric measuring devices and their calibration sources [12].

These wells were measured in Paleozoic rocks and graphically plotted with the use of the API unit. Because of the importance of uranium and thorium element concentrations, an empirical formula was derived to convert uranium (ppm), thorium (ppm), and potassium (%) concentrations into total count gamma-ray log data in (API) units.

The three radioactive element concentrations in the three sections of Paleozoic rocks were converted to total gamma in (API unit) using the following equation:

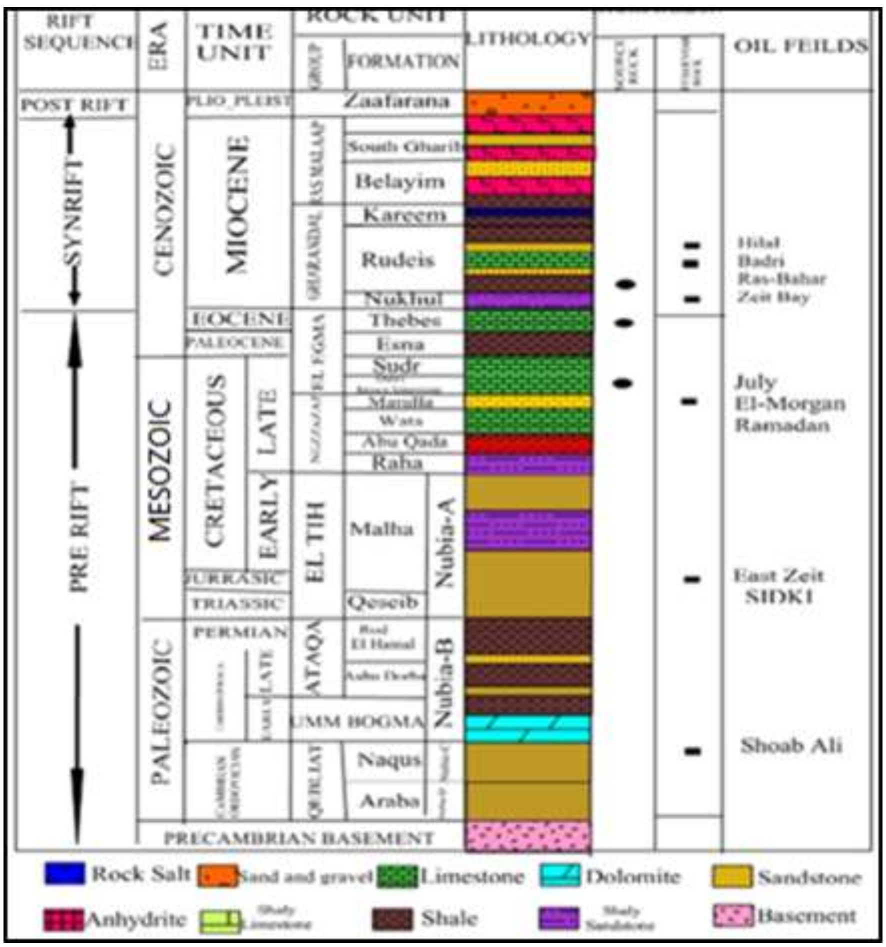

Fig. 2: Generalized stratigraphic succession of the Gulf of Suez rift basin, Egypt [10].

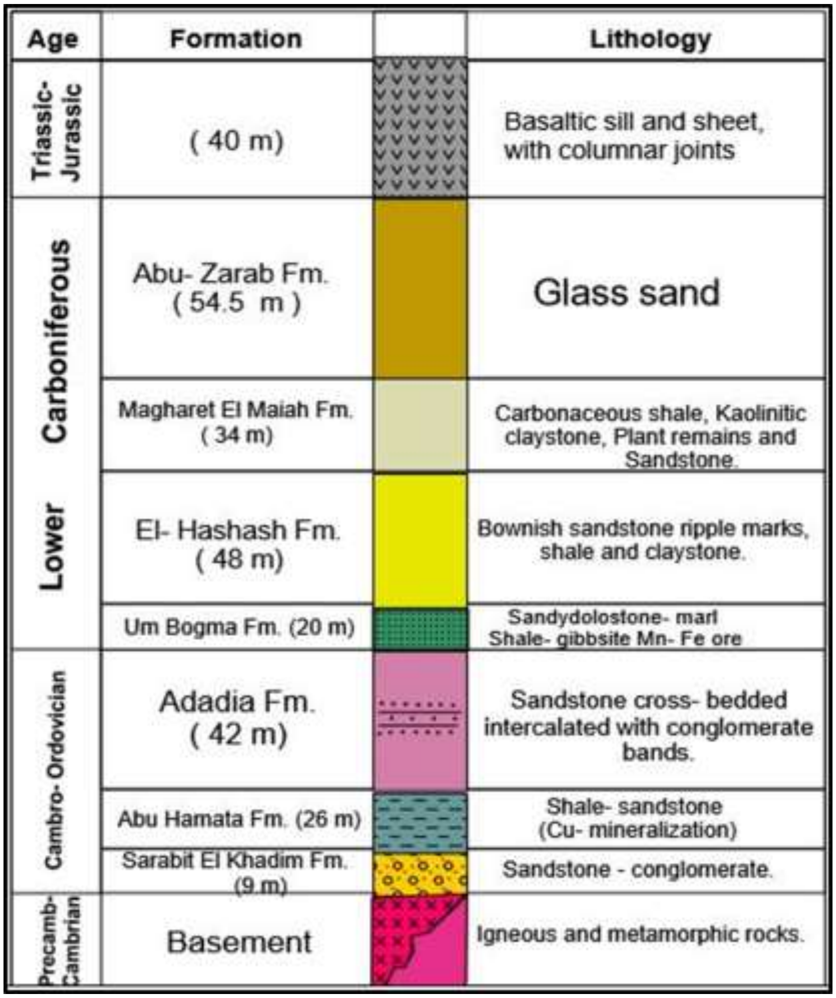

Fig. 3: General stratigraphic column of Um-Bogma area, Southwestern Sinai, Egypt [9]

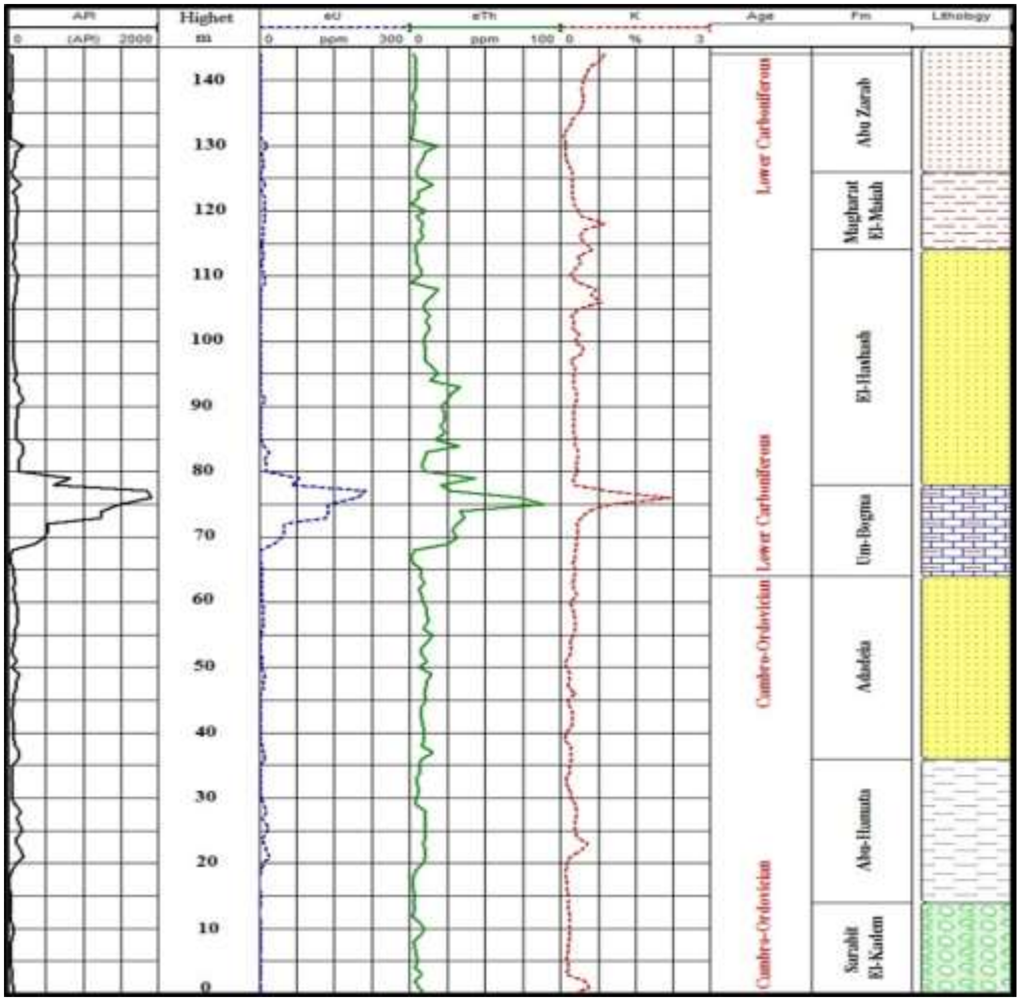

Fig.4: Ground radio-spectrometric vertical section for Paleozoic succession at Wadi Abu-Hamata, Southwestern Sinai, Egypt.

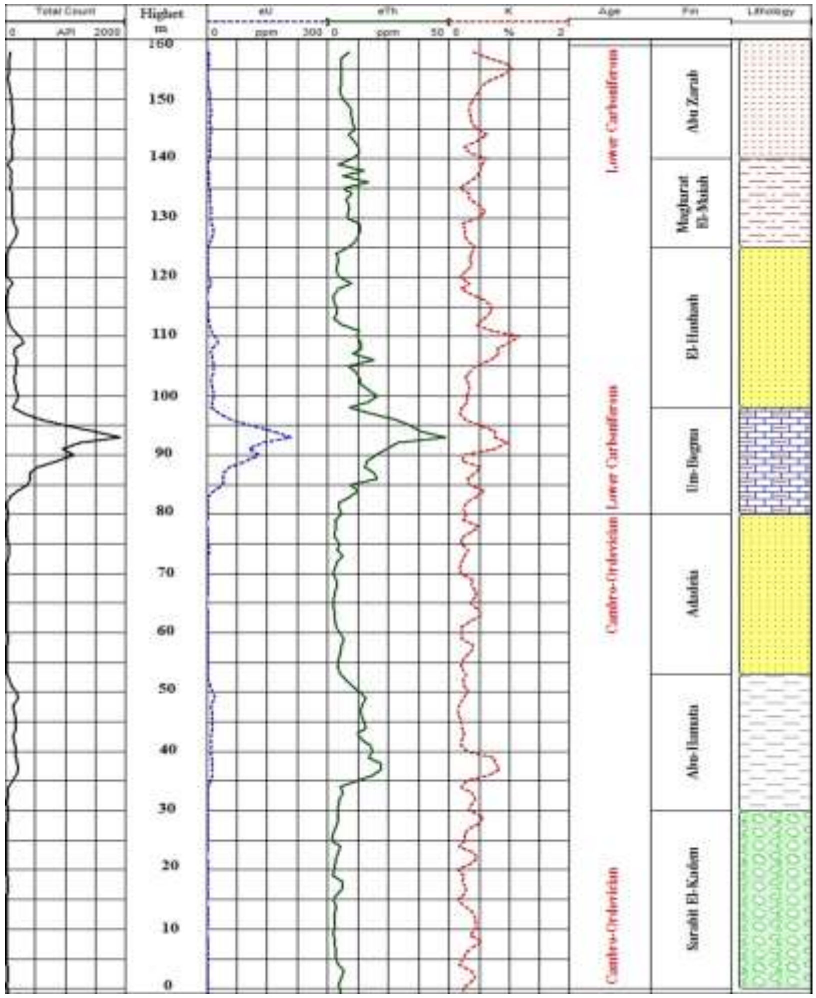

Fig.5: Ground radio-spectrometric vertical section for Paleozoic succession at Wadi Abu-Zarab Area, Southwestern Sinai, Egypt.

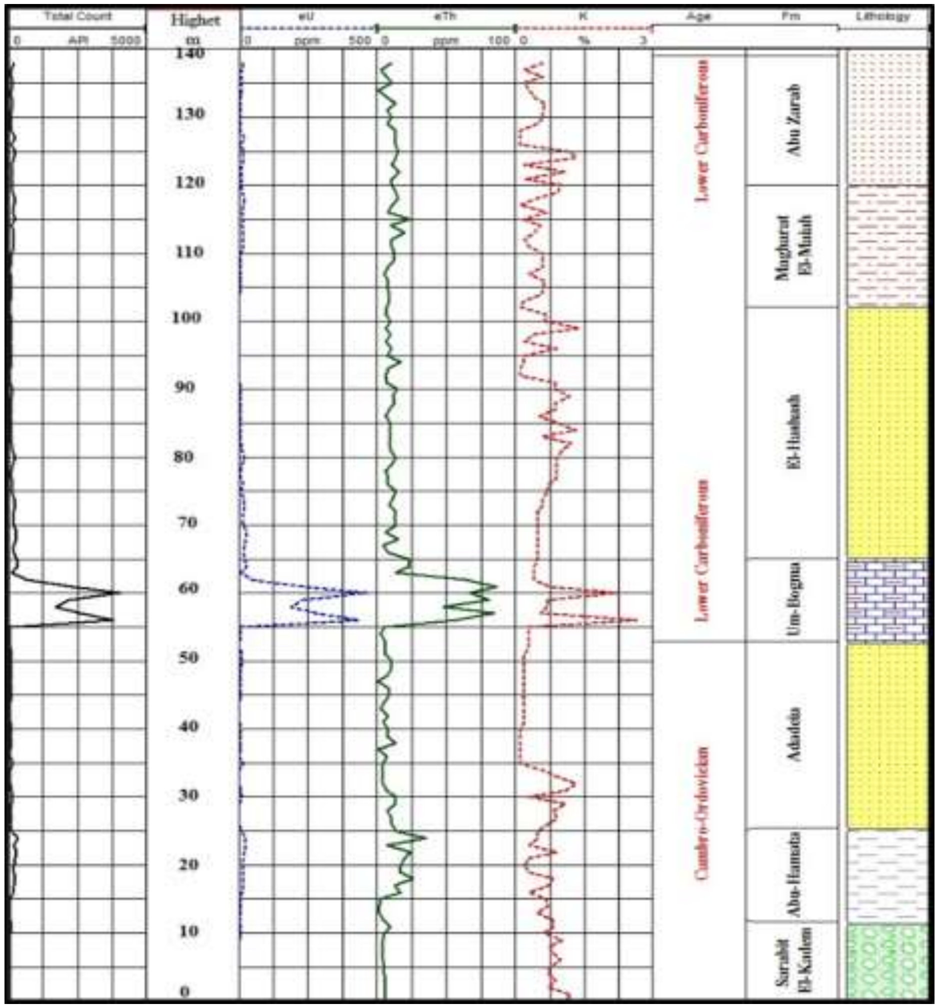

Fig.6: Ground radio-spectrometric section for Paleozoic succession at El Sheikh Soliman, Southwestern Sinai, Egypt.

Figure 7) illustrates the relationship between the total-count gamma-ray in (API) units, and the measured equivalent uranium concentrations in (ppm). The correlation coefficient of this relation reaches 0.96. Consequently, the concentration of equivalent uranium can be calculated from the values of gamma-ray logs, using the linear regression equation of this relation as follows:

$$\textbf{eU (ppm)} = \mathbf{0.023 \times [GR(API)]^{1.22}} \quad (2)$$

where, GR (API) = total count gamma-ray

The correlation coefficient of the relationship Between the calculated total-count gamma-ray (in API) and the measured equivalent thorium (eTh) surface concentrations (in ppm) reached 0.84, as it is shown in Figure 8. The linear regression empirical equation of this relationship can be used to derive the equivalent thorium concentrations from total count gamma-ray logs when the spectral gamma-ray logs are absent.

The derived equation is as follows:

$$\textbf{eTh (ppm)} = \mathbf{0.325 \times [GR\ (API)]^{0.71}} \quad (3)$$

where, GR(API)= total-count gamma ray

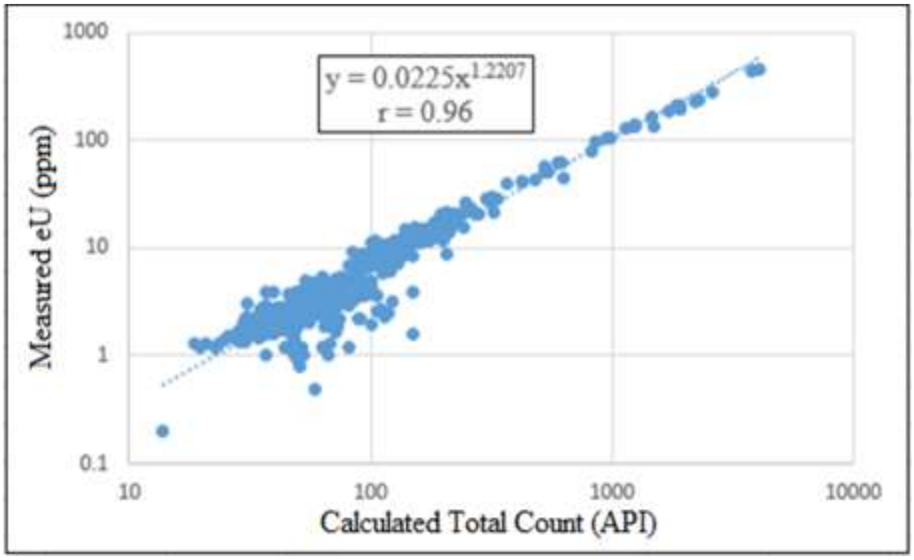

Fig .7: Plot of the relationship between the measured eU (ppm) and the calculated total count (API) of the Paleozoic three surface sections in Um-Bogma area, Southwestern Sinai, Egypt.

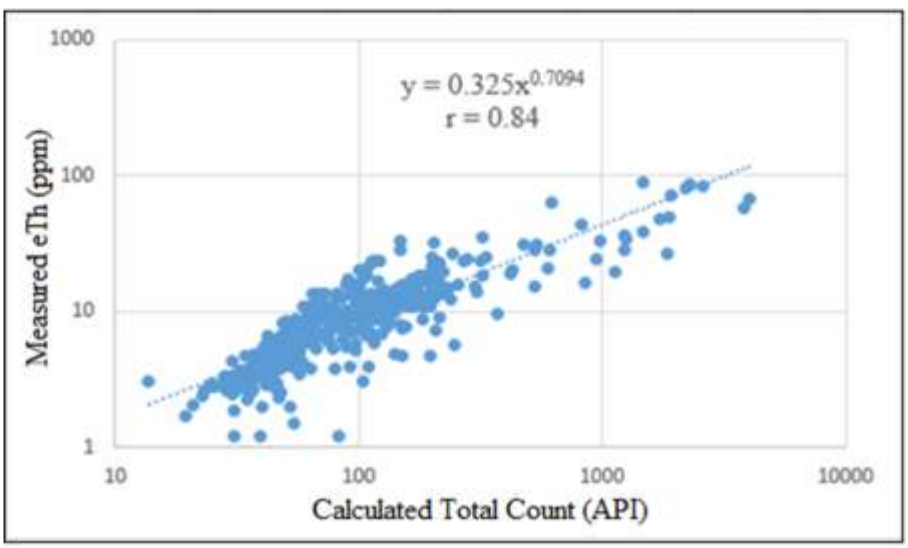

Fig.8: Plot of the relationship between the measured eTh (ppm) and the calculated total count (API) of the Paleozoic three surface sections in Um-Bogma area, Southwestern Sinai, Egypt.

4.1. Verification of the empirical equations

To verify practically, the two empirical equations which were predicted to calculate eU and eTh concentrations from total count gamma-ray logs, two equations (4 and 5) were applied on the Paleozoic Nubian sandstones in three wells at Ras-Ghara oil field (GM-A-1, SINAI 1, and GM-G-1) having gamma-ray spectrometric logs, to compare the calculated eU and eTh (equations 2 and 3) with the measured eU and eTh in the three wells.

From Fig. (9), it can be noticed that the calculated eU concentrations equal mainly the measured eU concentration by borehole logging devices, where:

Calculated eU (ppm) = 1.03 *[Measured eU (ppm)] – 0.94 (4)

Here, the correlation coefficient (r) of this relationship reaches 0.99. Besides, the error between calculated and measured eU concentrations in this relation was found to attain ± 0.69. This error value is the average difference between the standard deviation of the two calculated and measured eU values.

Another relationship was plotted between calculated eTh using equation (3) and the measured eTh concentrations in the three wells of the Ras-Ghara oil field. This plot verified the existence of an excellent correlation coefficient between the two calculated and measured eTh concentrations, which reached 0.98,

(Fig. 10). Meanwhile, the error between the two (calculated and measured) concentrations is ± 0.58. On the other hand, the linear regression equation of this relationship illustrates the convergence between calculated and measured eTh concentration values, as shown in the following equation. (5):

Calculated eTh (ppm) = 0.984 x [Measured eTh (ppm)] – 0.084 (5)

From equations (4 and 5), it can be noticed that the equations Nos. (2 and 3) can be used to calculate eU and eTh from total count gamma-ray data, respectively, in the case of the absence of the spectral gamma-ray logs.

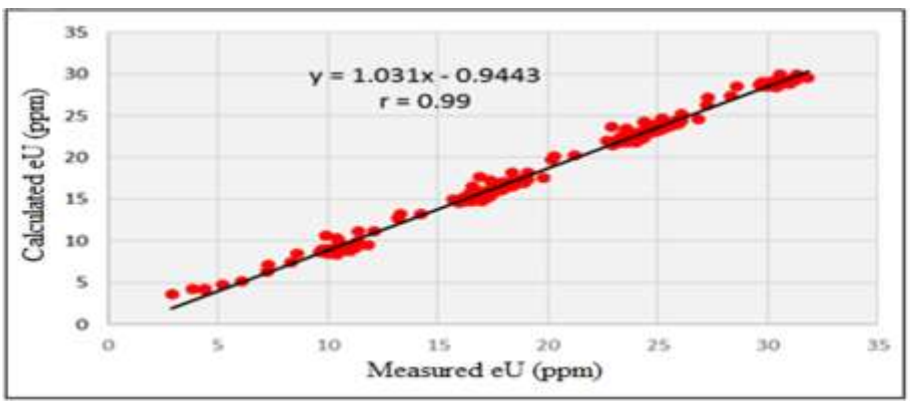

Fig. 9: Plot of the relationship between the measured eU (ppm) and the calculated eU (ppm) in Paleozoic Nubian sandstones in (GM-A-1, Sinai-1, and GM-G-1) at Ras-Ghara oil field, Gulf of Suez, Egypt.

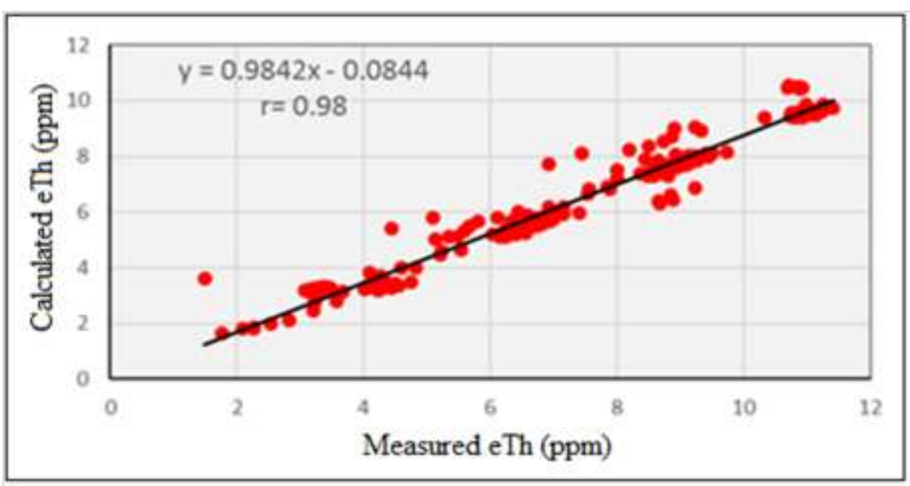

Fig.10: Plot of the relationship between the measured eTh (ppm) and the calculated eTh in Paleozoic Nubian sandstone in (GM-A-1, Sinai-1, and GM-G-1) at Ras-Ghara oil field, Gulf of Suez, Egypt.

4 Summary and Conclusions

The highest equivalent uranium concentration measurements were recorded over the Um-Bogma Carboniferous deposits in the Southwestern Sinai area, Egypt.

From the radio-spectrometric behavior for the Paleozoic succession, it can easily differentiate between the lower sandstone series, middle carbonate series, and upper sandstone series. The radio-spectrometric plotted sections were found to be a good geophysical tool to distinguish between the different lithologic horizons.

According to the importance of uranium and thorium, which represent the main radioactive components of nuclear fuel, two formulas, using surface radio-spectrometric data of Paleozoic rocks, were derived to calculate their spectral concentrations from total-count gamma-ray logging in wells.

The calculated eU and eTh concentrations were verified by comparing them with the measured concentrations, where the correlation coefficient of the two equations for eU and eTh reached 0.99 and 0.98, respectively. Meanwhile, very low errors attaining ± 0.69 and ± 0.58, respectively, for the two relationships of eU and eTh.

Therefore, equations Nos. (2) and (3) can be used to calculate both eU and eTh concentrations in the case of the absence of spectral gamma-ray logs.

References

[1] Mohamed A. Shaheen, 2024, Utilizing the Gamma-Ray Spectrometric and Magnetic Methods for Determining the Radioactive Anomalies and Their Relation to the Subsurface Structures, Wadi Hammad and vicinity area, North Eastern Desert, Egypt. J. Rad. Nucl. Appl. 9, No. 3, 291-306 (2024) http://dx.doi.org/10.18576/jrna/090312

[2] Wael M Badawy, Andrey Yu Dmitriev, Hussein El Samman, Atef El-Taher, Maksim G Blokhin, Yasser S Rammah, Hashem A Madkour, Safwat Salama, Sergey Yu Budnitskiy., Elemental composition and metal pollution in Egyptian Red Sea mangrove sediments: characterization and origin. Marine Pollution Bulletin 198, 115830. 2024.

[3] Al Alfy, I. M., Nabih, M. A., and Eysa, E. A., 2013, Gamma ray spectrometry logs as a hydrocarbon indicator for clastic reservoir rocks in Egypt. Applied Radiation and Isotopes, Vol. 73, pp 90 –95.

[4] Mohamed M Ghoneim, Elena G Panova, Ahmed E Abdel Gawad, Hamdy A Awad, Hesham MH Zakaly, Atef El-Taher., 2023 Analytical methodology for geochemical features and radioactive elements for intrusive rocks in El Sela area, Eastern Desert, Egypt. International Journal of Environmental Analytical Chemistry 103 (6), 1272-1291

[5] El Aassy, I. E., Botros, N. H, Abd-Elrazik, A., Sherif, H, Al Moafy, A., Atia, K., El Terb, R., Ashami, A. S., 1986, Report on the prospection and proving of some radioactive occurrences in West Central Sinai, Egypt. Internal Report, Nuclear Materials Authority (NMA), Cairo, Egypt.

[6] Afifi, S. Y., 1991, Geochemical investigations of some radioactive Lower Carboniferous sedimentary rocks of Wadi Nasib area, West Central Sinai, Egypt, M. Sc Thesis, Suez Canal Univ., Egypt. 253 p.

[7] El Agami, N. L., 1996, Geology and radioactivity studies on the Paleozoic rock units in the Sinai Peninsula, Egypt, Ph.D. Thesis, Fac. of Science, Mansoura Univ., Egypt, 302 p

[8] Hassan, S. O., 1994, Subsurface studies related to basin properties in the Ramadan Oil Field, Gulf of Sez region, Egypt. M. Sc Thesis, Al-Azhar Univ., Cairo, Egypt, 150 P.

[9]Alshami, A. S., 2003, Structural and lithologic controls of uranium and copper mineralization in Um Bogma environs, Southwestern Sinai, Egypt. Ph.D. Thesis, Faculty of Science, Mansoura University, Egypt. 148p

[10] Alsharhan, A. S., 2003, Petroleum geology and potential hydrocarbon plays in the Gulf of Suez rift basin, Egypt. AAPG Bulletin, Vol. 87 (1), pp. 143 – 180.

[11] Rider, M. H., 1996, The geological interpretation of well logs, Second Edition, 280 p.

[12] El-Taher, A., WM Badawy, AEM Khater, HA Madkour., 2019 Distribution patterns of natural radionuclides and rare earth elements in marine sediments from the Red Sea, Egypt. Applied Radiation and Isotopes 151, 171-181.