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Determination of Radioactive and Phosphatic Layers by Measuring Natural γ Ray Intensities in Well Logging in the South Al-Babter Region in Syria, Using Numerical Methods of Analysis

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ABSTRACT. A new interpretation of the variation of natural gamma rays intensity in well logging, using numerical analysis has been proposed and applied successfully for the lithological description of boreholes. This approach aims at accurately determining radioactive intensity levels of some lithological units, and their thicknesses. A model with four main radioactive distributions types (K, H, A and Q), which was earlier suggested and applied in the prospecting region for phosphatic and radioactive deposits in the Syrian Palmyrides, has been used in the present study of the south Al-Abter region boreholes. Good correlation has been found between the resulting interpretations and the lithological descriptions of the studied boreholes.

Introduction

Well logging plays an important role in prospecting programs. In this study, we are interested in the detection of radioactive and phosphatic layers. For this purpose, γ ray intensity measurements are quite suitable.

A straight forward interpretation of these measurements in the studied area is not easy, especially when we attempt to determine the lithological boundaries. This is because of the rapid facies variations both lateral and vertical.

The main objective of the present work is to provide an interpretation for natural gamma ray data, depending on the technique of numerical analysis[1].

The idea of the new proposed methodology is based on the study of a derivative function $y'(Z)$, where y: radioactive intensity at depth Z), which allows determination of the inflection points. Each of these inflection points may be considered to represent a lithological boundary.

The mathematical procedure of finding the inflection points allows determining the thickness of each layer traversed by the studied borehole independent of its thickness. Further, the proposed technique seems to be perfectly suitable for the interpretation of gamma ray logs in the area under consideration. In fact, the sites of the inflection points could be efficiently determined, due to the smooth nature of the filed curves obtained in the phosphatic regions.

However, this technique needs some development and calibration to be used for general purposes. In reality, the gamma log is usually a rather nervous log with abundant statistical variations, which makes difficult to obtain the inflection points. This basically constitutes the limitation of concern technique. Therefore, it is necessary to first smoothening the log trace by means of averaging or other techniques, applying for example laplace filters.

The qualitative study of γ ray logging data in the phosphatic prospecting regions is based on the four theoretically assumed types of logging curves, labeled K, H, A and Q. These types, which are most frequently obtained in the phosphatic region, where programmed and studied theoretically by the computer program (RAD). This program, which was developed and written using the Windows operating system, distinguishes between these types of curves during the interpretation of gamma ray logging data. This software has been tested successfully at several areas in the phosphatic regions (Palmyride-Syria) where it provides precise thicknesses and radiation levels for all layers which compose the studied region. The proposed methodology has been applied in the study of nine boreholes drilled in the south Al-Abter region for phosphatic prospecting. It is to note that the classification of types relates only to the lithology of the layers under investigation where there are only two log responses, low for barren layers and high for radioactive layers.

Finally, the merits of this technique in the phosphatic region is related to the fact that it is easy applicable and gives a rapid and quite accurate interpretation of the γ ray log. Whereas, application of this technique on the other lithology rather than phosphatic units necessitates a detail study to know the γ log responses of every units from which is composed the studied lithological section.

Geological Setting

The stratigraphic column of Syria includes phosphatic sediments situated with the calcareous formation of the upper Cretaceous and the Eocene, Fig. 1. These sediments have an economic importance in the Palmyrides mountain belt especially the southern central part[2]. Phosphorite deposits in the region belong to Cambanian (Sawaneh formation) with a general thickness of 17 to 317 m.

Al Hamad uplift, which represents the southern border of the Palmyrides depression, plays an important role in forming the phosphorites within the central part of the northern flank of the Al Hamad uplift. The phosphorite deposits in the region are attributed to enrichment processes of phosphorus and plankton particles, which indicate a paleogeographic evolution, related to Cenonian transgression and the movement of the Arabian platform. The Al Sawaneh formation consists entirely of calcareous marl and marly limestone interbedded with phosphorite beds varying in thickness (10-12 m).

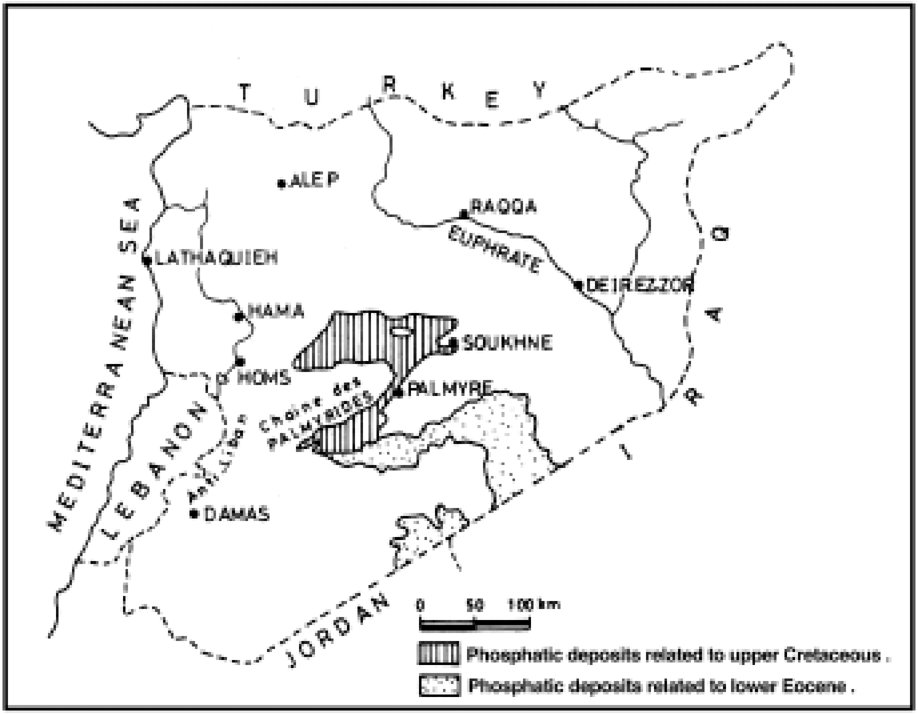

FIG. 1. Phosphatic deposits related to Cretacious and Eocene age in Syria (Atfeh, 1967).

The upper part of the formation comprises mostly reddish yellow clayey marls interbedded with marly limestone beds with epigenetic cement. This part of the sedimentary unit is known as the Arak formation, which is overlain by glauconitic and marly phosphorites known as the Tantour formation that contains local siliceous stripes. The phosphatic layers appear to be thick in the central part of the Palmyrides and become thinner towards the west until they completely disappear under the marly formations of the Arank and Tantour units. In addition, it has been found that the phosphatic deposits are associated with secondary uranium concentrations within the porosity and fractures of the rocks[3]. These concentrations can be interpreted as the result of syngentic precipitation along with the formation of phosphates or, perhaps a secondary concentration caused by surface runoff and ground water movement. Earlier studies indicate that most of the phosphatic formations in the Palmyrides are of Campanian age[4]. These deposits are currently under mining in two main locations, Khneifiss and Al-Sharkuieh phosphates mines. The Al-Abter deposits are located between these two mines, 10 km from Khneifiss and 20 km from Al-Sharkuieh, Fig. 2.

It is known that there is a proportional relationship between the radioactive level and the concentration of P_2O_5 in the rocks[5,3,6 and 7]. We found a linear regression relationship between the radioactive measurements carried out in the wells and chemical analysis of phosphate samples taken from the same wells as shown in Figure 3. From this relationship, it is possible to recognize the horizons, which are rich in phosphorite and contain uranium concentrations by using natural gamma ray measurements.

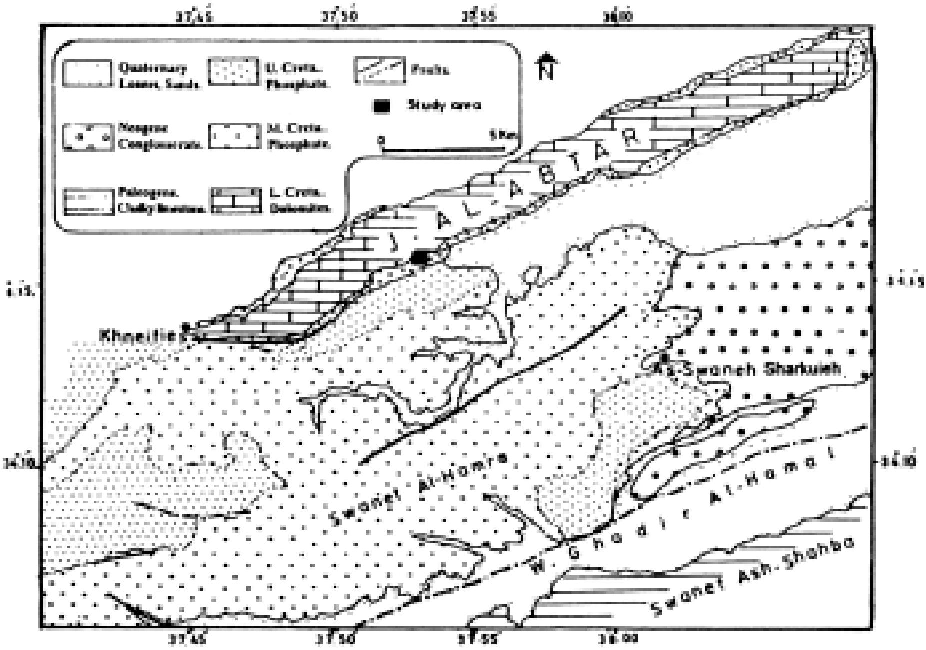

FIG. 2. The location of the Al-Abter deposits in simple geological map.

Types of Geophysical Curves

A comparison study between the radioactive data obtained during measurements and known geological sections for the studied wells, was carried out. This study enabled four principal types of radioactive curves to be distinguished.

The first type

The first type, identified as K, represents a layer having high radioactive intensity, when compared with its surroundings. Figure (4a) shows this case, with Y and derivative Y′ shown as a function of depth (z). As may be seen, the upper and lower lithological boundaries of the layer are in agreement with the inflection points Z_n and Z_{n+1} determined manually. Consequently, the thickness of this layer is equal to $(Z_{n+1}-Z_n)$. Concerning the level of radioactive intensity, which characterizes this layer, we attribute the maximum intensity $Y_{(max.)}$ to this layer. If we compare the derivative function $Y'(z)$ and $Y(z)$, we see how Z_{n+1} and Z_n correspond to the positions of $Y'_{(min.)}$ and $Y'_{(max.)}$ respectively.

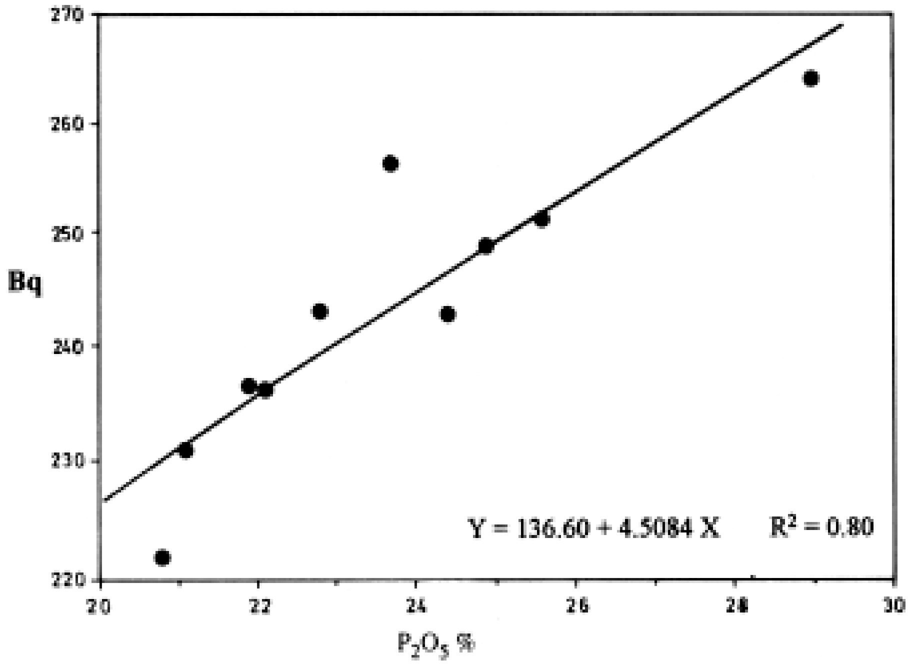

FIG. 3. Linear regression relationship between radioactive intensity measured and the content of P2O2, in the boreholes of studied area.

The second type

This type identified as H, represents a layer having low radioactive intensity when compared with its surroundings. Figure (4b) shows the variation of the function Y(z) and its derivative. Concerning the level of radioactive intensity, which characterizes this layer we attribute the minimum measured intensity $Y_{(min.)}$ to this layer. The two lithological boundaries, Z_{n+1} and Z_n correspond to $Y'_{(max.)}$ and $Y'_{(min.)}$ respectively.

The third type

This type, referred to as A, represents a layer which is characterized by radioactive intensity larger than radioactive intensity of the upper layer and smaller than the radioactive intensity of the lower layer. Figure (4c) shows the variation of Y(z) and its derivative. The upper and lower boundaries correspond to the points Z_n and Z_{n+2}. Hence, the thickness of this layer is determined by the relationship $(Z_{n+2}\text{-}Z_n)$. Concerning the level of radioactive intensity, which characterizes the layer, we attribute the radioactive value taken at Z_{n+1}. We use the derivative $Y'(z)$ to accurately determine the three inflection points. We also note that Z_n, Z_{n+1}, Z_{n+2} are in agreement with $Y_{(max.)}$ Z_n, $Y_{(min.)}$ Z_{n+1} and $Y_{(max.)}$ Z_{n+2} respectively.

The fourth type

This type, referred to as Q, represents a layer characterized by a radioactive intensity less than that of the upper layer and larger than that of the lower layer. Figure (4d) shows the variations in Y(z) and its derivative. This type is an opposite of that of type A. In this type the points Z_n, Z_{n+1}, Z_{n+2} are in agreement with $Y'_{(min.)}$ Z_n, $Y'_{(max.)}$ Z_{n+1} and $Y'_{(min.)}$ Z_{n+2} respectively; its natural radioactivity is obtained as it was in type A.

Therefore, if the thickness of layers is too small we can imagine how difficult it is to determine the lithological boundaries between the layers manually, due to the complex nature of the curve Y. For this reason, we developed special software, which could automatically interpret the radioactive intensity curves.

Radioactive characteristics of lithological section in the prospecting region

The natural γ ray logs, measured in the Al-Abter region, show the variation of radiation intensities as a function of depth. These intensities are in the range 20-275 Bq. The lithological section in the studied region is composed of two main groups:

– The first group: composed of calcareous marl, clay, organic limestone and quaternary alluvium.

– The second group: forms the phosphatic layer with their interbedded rocks. This phosphatic group can be found either as one unit or as a combination of an upper and a lower unit. The thickness of the upper unit varies from 0 to 0.9 meter, and is composed of hard phosphatic rocks with gray color, changing gradually into alternating phosphatic rock and phosphatic sandstone. This unit appears only in the W2 and W3 boreholes. The lower unit is marked by alternation of phosphatic rock and phosphatic sandstone. It is sometimes interbedded with clayey limestone, having a thickness, which varies from 0.2 to 0.6 m. This unit appears in all the studied boreholes.

Figure 5 indicates an example of the described lithological section with natural γ ray measurement obtained in the W3 borehole. It is obviously clear that phosphatic group can be distinguished easily, due to its high radiation intensities compared with other rocks encountered in the studied lithological section.

Experimental

The area under study, 0.5 km^2, is chosen because of the favorable economic conditions, with posphatic layers of sufficient thickness and mineral quality and because of the shallow overburden. There are nine boreholes in this region. Their depths vary from 8 to 34 m. Figure 6 indicates the location of these boreholes. Natural gamma ray well logging was carried out in these boreholes. An American borehole logging 1000-c logger system was used in this study. This equipment is a complete, fully portable, lightweight (27.3 kg), backpack mountable borehole logging unit. Using the standard probe (G375/A), it is possible to record up to three different logs in one tip in the borehole: (1) Gross count, dead-time corrected gamma radiation, (2) self-potential, and (3) single point resistance.

The natural gamma ray data recorded from the studied boreholes were interpreted by the methodology proposed in this study.

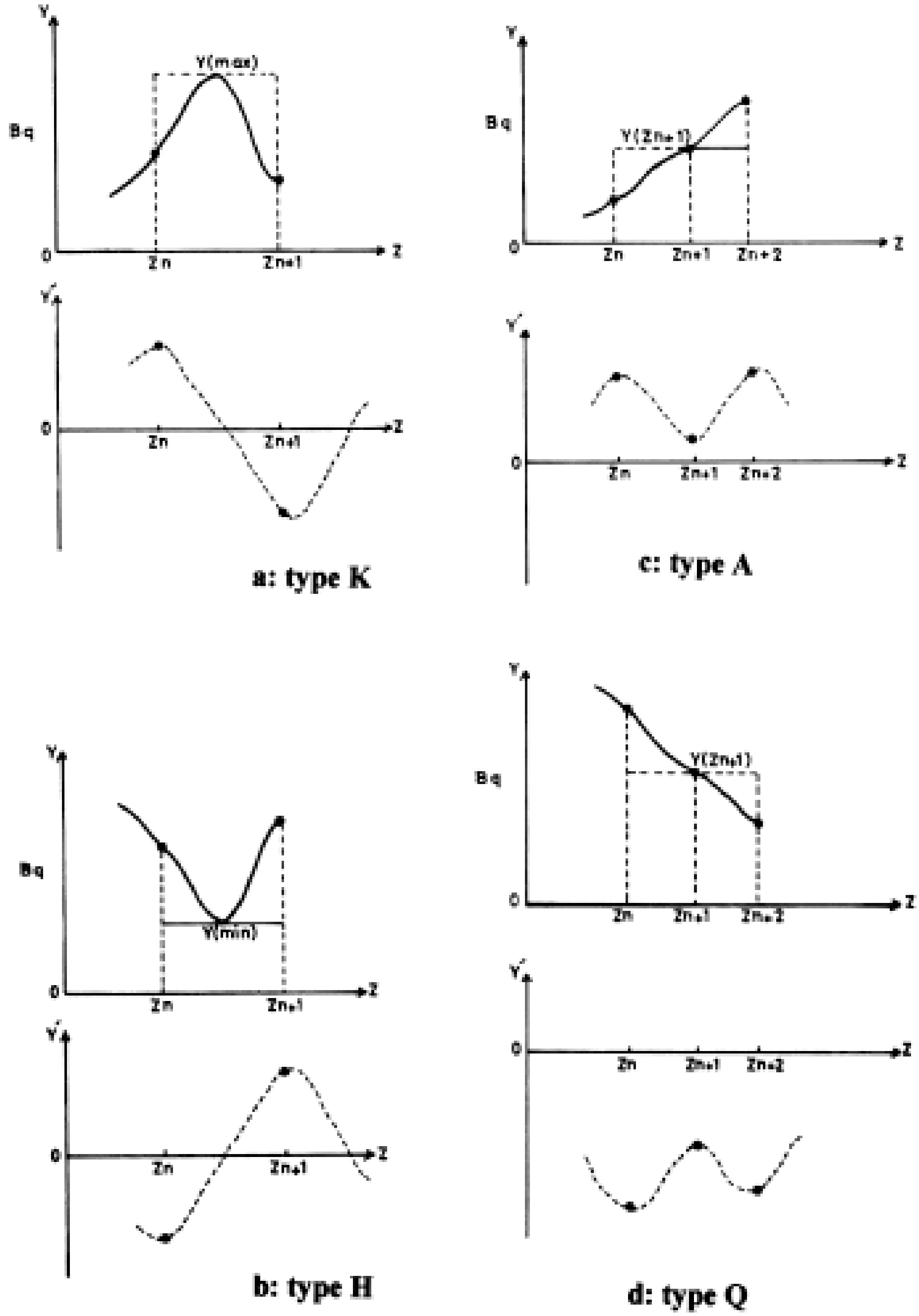

FIG. 4. The four types of K, H, A and Q.
Y(z): radioactive intensity as a function of depth.
Y¢(z): the derivative of Y(z).

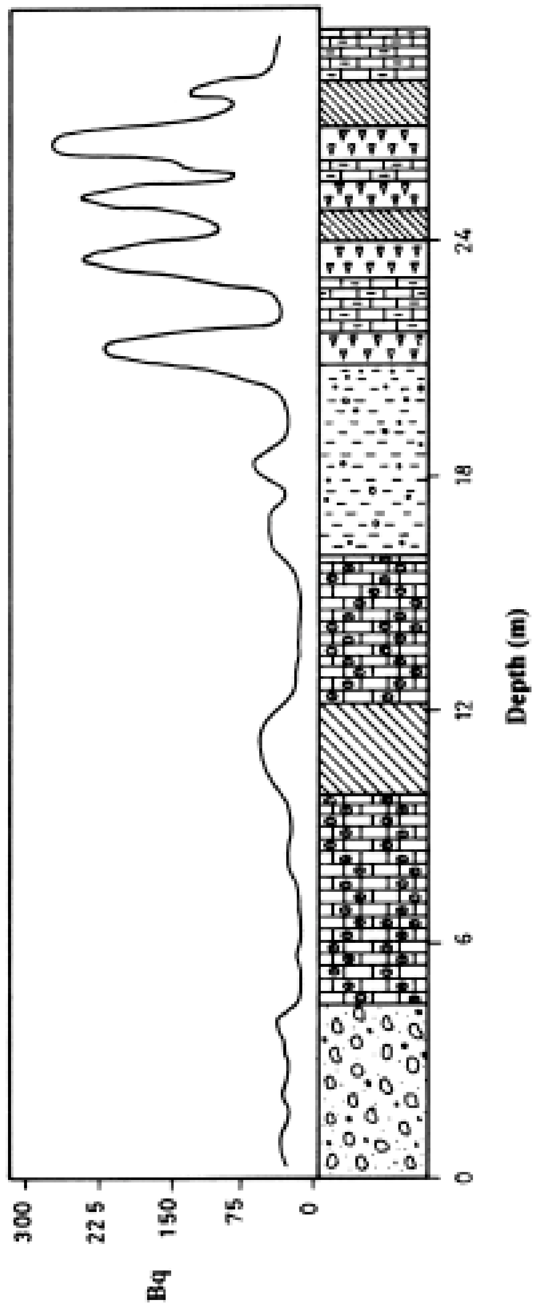

FIG. 5. Natural γ ray log obtained in the W3 borehole and its lithological description.

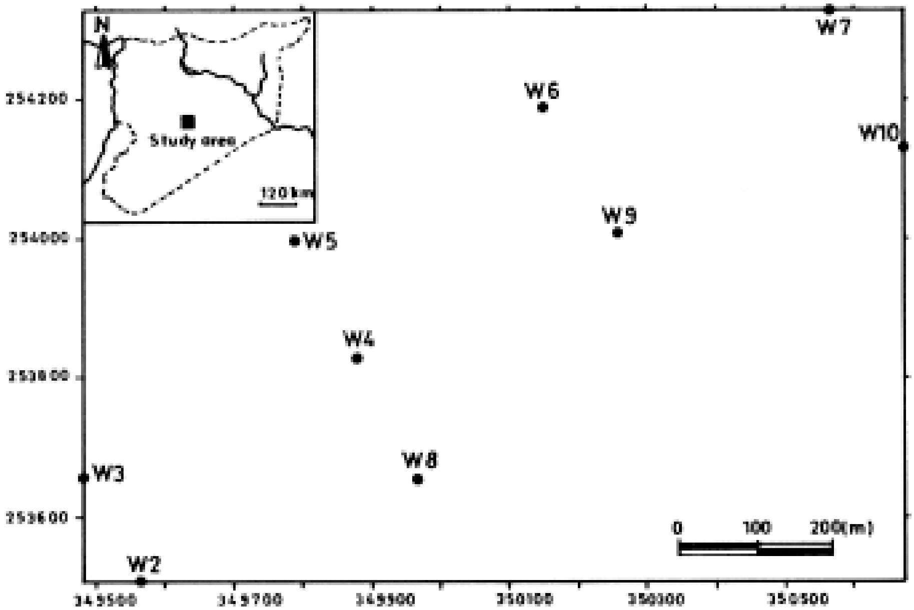

FIG. 6. Location of the studied boreholes in the Al-Abter region.

Results and Discussion

Field data are inserted in the form of a file including the radioactive intensities as a function of depth Yi(Zi), as shown in Fig. 5. This file is the base for further analysis in which the first derivative Y′(z) will be computed to determine the inflection points, which are considered to be the lithological boundaries of the different layers forming the studied section, as shown in Fig. 7.

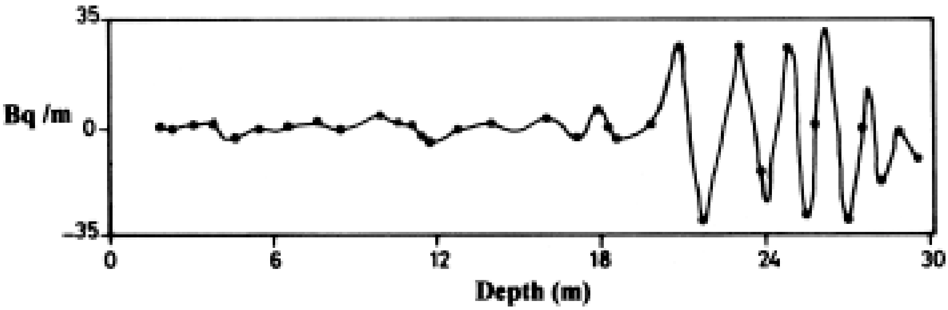

FIG. 7. The derivative function Y′(z) and the sites of inflection points, obtained in the W3 borehole.

By using the four types of radioactive intensity variation curves described above and the lithological boundaries determined by the first derivative, the program classifies the layers within the studied section, assigns the radioactive intensity and computes the thickness of each layers as indicated in Fig. 8.

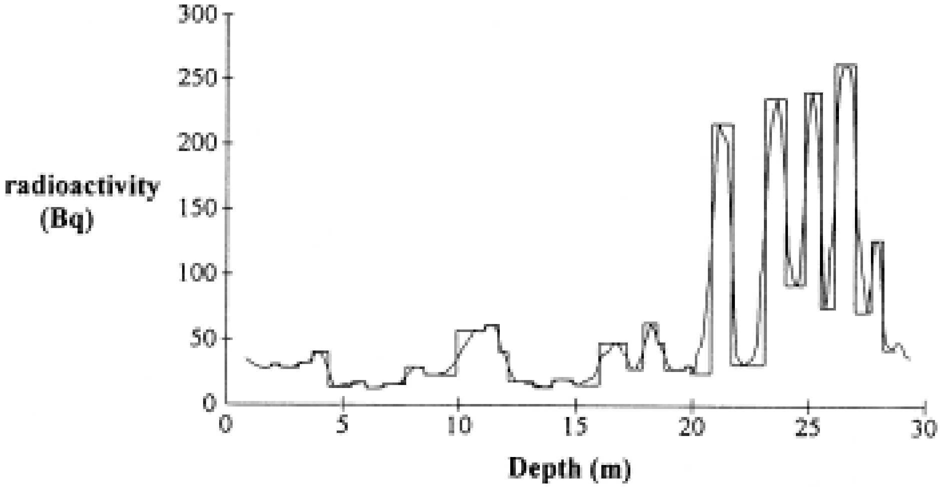

FIG. 8. The theoretical model resulting from the application of the proposed methodology in the W3 borehole.

Figure 9 shows the results of these treatments obtained by applying the new interpretation to the eight boreholes related to the south Al-Abter region. The comparison between these results and the lithological description for each studied boreholes indicates that the present interpretation gives quite accurate results, as is evident from the good agreement between the computed boundaries and the lithological description.

In case of W8 borehole, the field curve of natural γ ray, obtained in this borehole and its new interpretation, does not agree with the lithological section composed only of two upper and lower parts as shown in Fig. 9. This difference could be related to the presence of layers in the lower part. The lithological nature of these layers needs to be more clarified and identified. The agreement between lithology and computed models will be excellent as the studied and traversed layers have a big radioactive contrast. All the Figures of the interpretation in this study indicate examples regarding the accurate determination of the phosphatic layer thicknesses. As such this interpretation is a helpful tool to formulate rapidly the lithological section computed theoretically for each studied borehole.

Conclusion

The methodology, proposed and applied successfully in this work appears to be a powerful tool for rapid interpretation of the natural γ ray logging data in the phosphatic region. The technique described here is quite accurate in determining the lithological boundaries, even for layers having small thicknesses.

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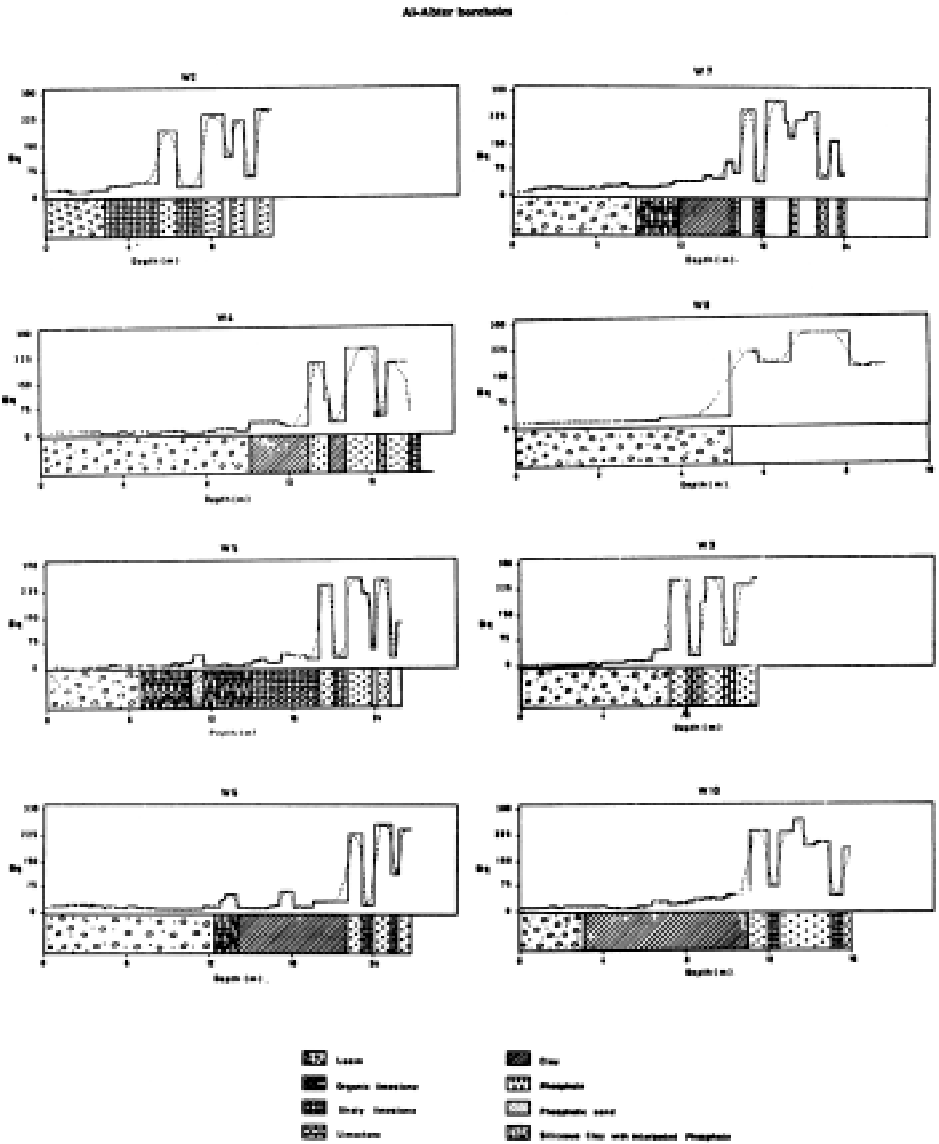

FIG. 9. The theoretical models and the lithological descriptions for the eight studied boreholes in the Al-Abter region.

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تحـديد الطبقات الإشعاعية والفوسفاتية بواسطة قياسات غاما الطبيعيـة البئريـة في منطقـة جنوب الأبتـر – سوريا باستخـدام طرائـق التحليل العـدديـة

جمال عبده أصفهاني

هيئـة الطاقـة الذريـة ، دمشـــق – *سوريــــــــا*

المستخلص . تم اقتراح طريقة جديدة لتفسير منحنيات غاما الطبيعية البئرية اعتماداً على تقنيات التحليل العددي ، وتطبيق هذه الطريقة كان فعالاً .

تهدف الطريقة إلى تحديد دقيق للسويات الإشعاعية ولسماكات بعض الوحدات الليثولوجية . تبنينا موديلاً مؤلفًا من أربعة نماذج (K, H, A, Q) ليطبق في أماكن التوضعات الفوسفاتية والإشعاعية في السلسلة التدمرية في سوريا ، واستخدمناه من أجل دراسة آبار جنوب الأبتر . وكان التوافق جيداً مابين نتائج التفسير وفق هذه الطريقة والوصوفات الليثولوجية للآبار المدروسة .