Türkiye Jeoloji Bülteni
Geological Bulletin of Turkey
64 (2021) 75—82
doi: 10.25288/tjb.587368

New Petrophysical Equations for the Tanuma-Ahmadi Interval in the East-Baghdad Oil Field

Doğu Bağdat Petrol Sahasında Tanuma-Ahmadi Aralığı için Yeni Petrofizik Denklemler

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• Geliş/Received: 05.07.2019 • Düzeltilmiş Metin Geliş/Revised Manuscript Received: 18.03.2020 • Kabul/Accepted: 24.03.2020
• Çevrimiçi Yayın/Available online: 20.07.2020 • Baskı/Printed: 15.01.2020

Research Article/Araştırma Makalesi *Türkiye Jeol. Bül. / Geol. Bull. Turkey*

Abstract: Porosity and density information were taken from five well logs scattered in East Baghdad oil field. New empirical equations (porosity-depth, density-depth) were established for all the geological formations within the Tanuma-Ahmadi interval. The correlation coefficient (R) of these equations derived for each formation ranged from 0.04 to 0.61 which was attributed to variable lithological effects.

The depth information for (126) velocity analysis sites covering the field were used to apply those new equations.

After the new empirical equations were applied on the whole field, porosity and density contour maps for the period (Tanuma-Ahmadi) were produced. The locations of high porosity zones were identified and related to the compaction and petroleum distribution in the field.

Keywords: East Baghdad oil field, empirical equations, petrophysical parameters, seismic velocity analyses.

INTRODUCTION

A great portion of oil in the world is stored in carbonate reservoirs, which play a major role in the exploration of oil worldwide. The characterization of these reservoirs is very complex compared to other types of reservoirs (Al-Jawad and Kareem, 2016). The East Baghdad oil field extends from Al-Saouira Area (southeast) to Al-Nibayia (northwest) (Figure 1). This field was discovered by the Iraqi National Oil Company (INOC) in 1974. Most of oil wells drilled in this field reached Cretaceous formations, while some of them penetrated all Cretaceous formations and reached upper Jurassic. The field extends about 120 km in length and 20 to 30 km in width. The geological model was created by using seismic interpretation, log information, and core analysis data.

There are many faults in the field with NW-SE trending structure, with oil production coming from the late Cretaceous Tanuma Formation, fractured carbonates of the Khasib Formation and from the early Cretaceous sandstone of the Zubair Formation. In other Cretaceous reservoirs, the oil was successfully examined in the carbonates of Hartha, Mishrif/Rumaila Formations, clastics of Nahr Umr and mixed clastics/carbonate of Ratawi Formations (Al-Ameri and and Al-Obaydi, 2011).

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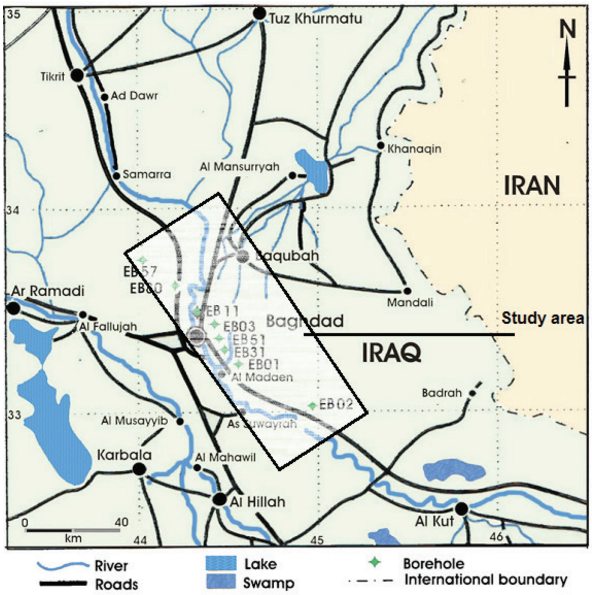

Figure 1. Location map of the study area (modified after Al-Ameri and Al-Obaydi, 2011).

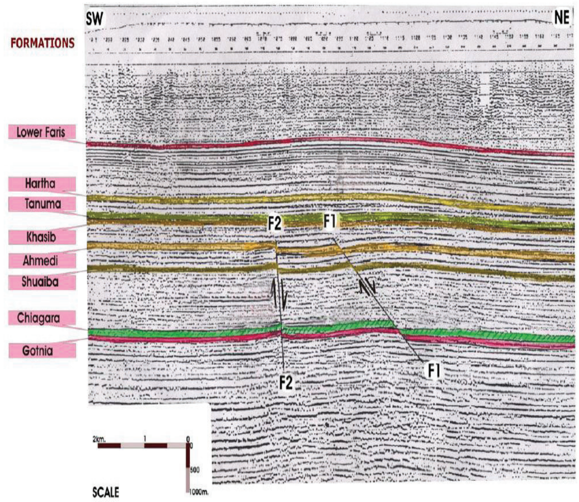

Figure 2. Seismic cross section with hydrocarbon source, reservoir, and seal rock units in East Baghdad Oil Field. Double line arrows indicate directions of migration pathways, while F1 and F2 are normal faults (modified after Al-Ameri, 2011).

Two main faults appear in the seismic section (Figure 2); the first one is normal, while the second is semi-vertical. Both faults cut the tops of Ahmadi, Shuaiba, Chiagara and Gotnia Formations. Good paths along these faults allow oil migration along permeable beds within the Chiagara Formation. The vertical movement of this path finally reaches the anticline traps. The oil spills into the adjacent permeable layers below the trap and then passes through the tensional joints to become trapped in the Fatha Anhydrite seal (Al-Ameri and Al-Obaydi, 2011).

The stratigraphic section consists of many types of rocks such as carbonates, shale, anhydrite, marl, sandstone, and siltstone. These deposits extend from Jurassic, Cretaceous up to Pliocene in geologic time (Al-Ameri and Al-Obaydi, 2011).

Figure 3 shows the stratigraphic section for the formations in this field

The purpose of this study is divided into three major aims.

1) Obtain empirical equations (density-depth, porosity-depth) for all the formations within the Tanuma-Ahmadi interval using well log data.
2) Estimation of the porosity and density for that interval in the whole field using the new empirical equations derived from this study.
3) Later, the maps of both porosity and density for the Tanuma - Ahmadi interval will be created.

Petrophysical Properties

Compaction and leaching are the most important parameters influencing primary porosity (Kharaka and Berry, 1976; Wolf and Chillingarian, 1976; Schmidt et al., 1977). The porosity of a permeable zone can be measured by different porosity logs. The variation of porosity with pressure may lead to a decrease in porosity with depth.

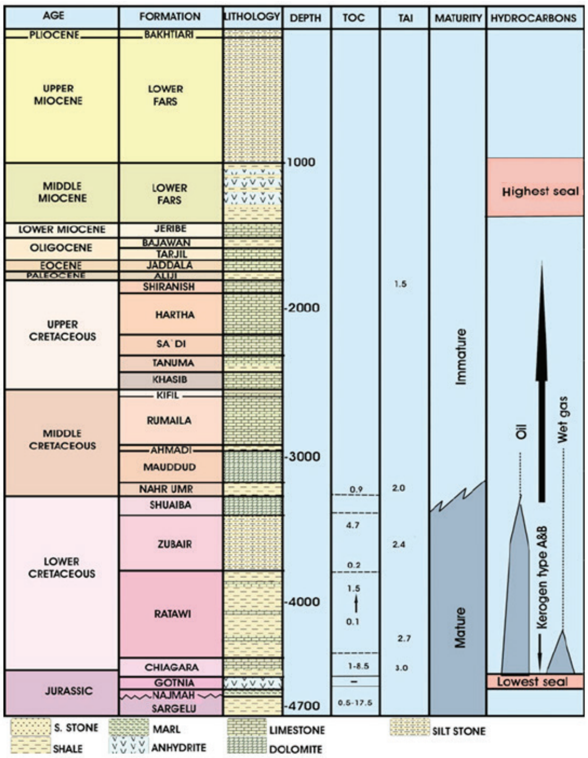

Figure 3. The stratigraphic section for the East-Baghdad oil field in the study area (after Al-Ameri and Al-Obaydi, 2011).

The increase in overburden pressure can help to preserve porosity at great depths above the overpressure zone. At a specific depth and lithology, porosity is greatly affected by confining pressure (Telford et al, 1976). The presence of hydrocarbons also preserves porosity as pointed out by Fuchtbauer (1967).

Dieokuma et al. (2014) established an equation for the change of porosity with depth in two wells (equation 1).

$$Z = -138.76\ \phi z + 12383 \qquad (1).$$

Where: z = depth, and ϕz = porosity at given depth.

According to this equation, the porosity can be estimated at any depth despite the absence of core samples. Dieokuma et al. (2014) concluded that the thickness of the reservoir is largely related to its porosity. Thicker reservoirs have higher porosity. At normal compaction, the porosity in both wells decreases with the depth.

MATERIALS AND METHODS

The collected data used in this work were obtained from two main sources. The first is based on the analysis of a set of seismic data from Al-Majid (1992) to extract the reflectors depths which was used to produce the porosity and density maps. These data, 126 in total, include velocity analyses scattered on a network of 22 seismic lines. The second was obtained from the log data of five wells scattered in the north part of the field to calculate the values for density and porosity at different depths.

Data Sources

Velocity Analysis Data

The seismic data for two reflectors (Tanuma - Ahmadi) were obtained from the seismic velocity analyses for 126 locations scattered in the East Baghdad oil field (Al-Majid, 1993) (Figure 4). These data contain the depths (Z) between the two reflectors.

Well Log Data

The well log data for five wells (EB02, EB04, EB16, EB34, and EB88) were obtained from the Oil Ministry in Iraq. These data include information about the petrophysical properties of the reservoir. The analysis of well log data requires removal of any external influences that cause errors in the readings of the logs such as mud cake and the effect of drilling mud and others.

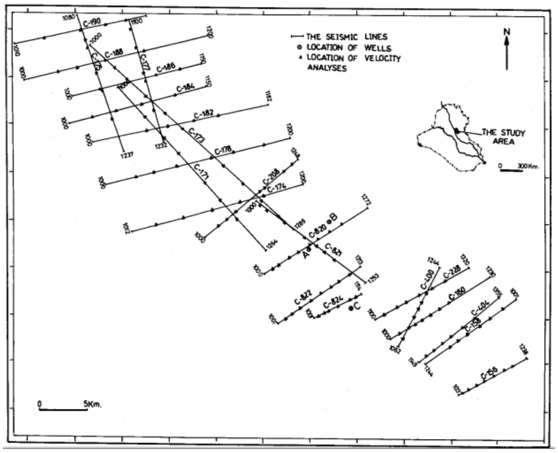

Figure 4. Location map of the seismic lines in the study area (Al-Majid, 1993).

Corrections for shaliness must be made to determine porosity values with more accuracy. After measuring the shale volume from the gamma ray log, the neutron-density readings were corrected. By using the Interactive Petrophysics program (IP), the environmental corrections were performed for log data. Figure 5 shows one of the well log records used in this study.

According the following formulae, the corrections were performed on neutron and density logs to derive porosity:

$$\phi Ncorr = \phi N-(Vsh*\phi Nsh) \quad (2)$$

$$\phi Dcorr = \phi D-(Vsh*\phi Dsh) \quad (3)$$

Where: Vsh = shale volume, ϕNsh = neutron porosity in shale formation, and ϕDsh = density porosity in shale formation.

Neutron and density measurements are widely used to calculate the average porosity ϕN.D, which gives more accurate porosity (Asquith and Krygowski, 2004). The combination formula is

$$\phi N.D = (\phi N+\phi D)/2 \quad (4).$$

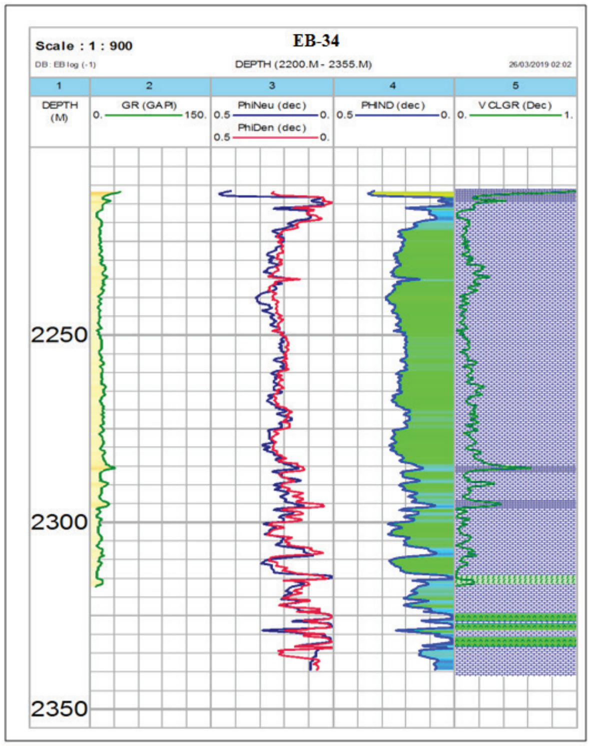

Figure 5. Corrected well log data for well EB-34.

New Empirical Equations for the Study Area

The empirical equations for porosity-depth and density-depth of all the formations within the Tanuma-Ahmadi interval were predicted based on porosity, density, and depth values obtained from well log data from the five wells. These equations were produced using Excel program V.10. Later, the average empirical equations (porosity-depth, density-depth) for each formation within the period were deduced and generalized for the whole field.

Tanuma-Ahmadi Interval

This interval consists of four formations in the stratigraphic column (well log data), which are Tanuma, Khasib, Kifl, and Rumaila Formations. The data available for this period were recorded in all five wells. The following are brief descriptions of all the formations in this interval and their new empirical equations:

Tanuma Formation

Limestone is only included in this formation which extends between depths 2097 m – 2213 m with thickness 116 m. The porosity and density relationships with the depth of this formation and their parameters are shown in Figures 6a and b.

Khasib Formation

Limestone in this formation extends between depths 2429 m – 2537.5 m with a thickness of 108.5 m. The porosity and density relationships with the depth of this formation and their parameters are shown in Figures 6c and d.

Kifl Formation

Anhydrite and limestone only appear in this formation which extends between depths 2537.5 m – 2582.5 m with a thickness 45 m. The porosity and density relationships with the depth of this formation and their parameters are shown in Figures 6e and f.

Rumaila Formation

The main rock type in this formation is limestone which extends between depths 2582.5 m –2917 m with a thickness of 334.5 m. The porosity and density relationships with the depth of this formation and their equations are shown in Figures 6g and h.

The porosity and density relationships with the depth of the whole interval (Tanuma-Ahmadi) and their parameters are shown in Figure 6i, and j.

$$Y = -1.8 * 10^{-4} x + 5.89*10^{-1} \quad (5)$$

Equation for porosity

Where Y is the porosity in %, and X is the depth in m.

$$y = 1.92*10^{-4} x + 1.96 \quad (6)$$

Equation for density

Where Y is the density in g/cm3, and X is the depth in m.

Although the correlation coefficient (R) for the period (Tanuma-Ahmadi) is weak, these equations were applied to the whole field to produce average porosity and density maps for this interval (Figures 7a and b).

DISCUSSION

The interpretations were performed using Interactive Petrophysics Program (IP). The formations in the study area consisted mainly of limestone with inclusion of anhydrite, shale, siltstone, and others.

In the present study, the porosity and density equations with depth were determined using the well log data. After applying these equations to the seismic velocity analyses information for 126 sites, the average porosity and density contour maps for the Tanuma - Ahmadi period were produced.

The correlation coefficient (R) for these equations ranges from weak (0.013) to strong (0.61) depending on the consistency of porosity and density within the formation. The low R values in Kifl and Rumaila Formations can result from the heterogeneity of formation components and existence of anhydrite, which has a very high density value (2.96 gm/cm3) and very low porosity value (approximately zero). The high values of R in the Tanuma and Khasib Formations may be caused by homogeneity and normal compaction. The decrease in the porosity values with depth in the Khasib Formation, which is mainly composed of limestone, indicates homogeneity of the components in this formation and its effect on normal compaction resulting from overburden pressure.

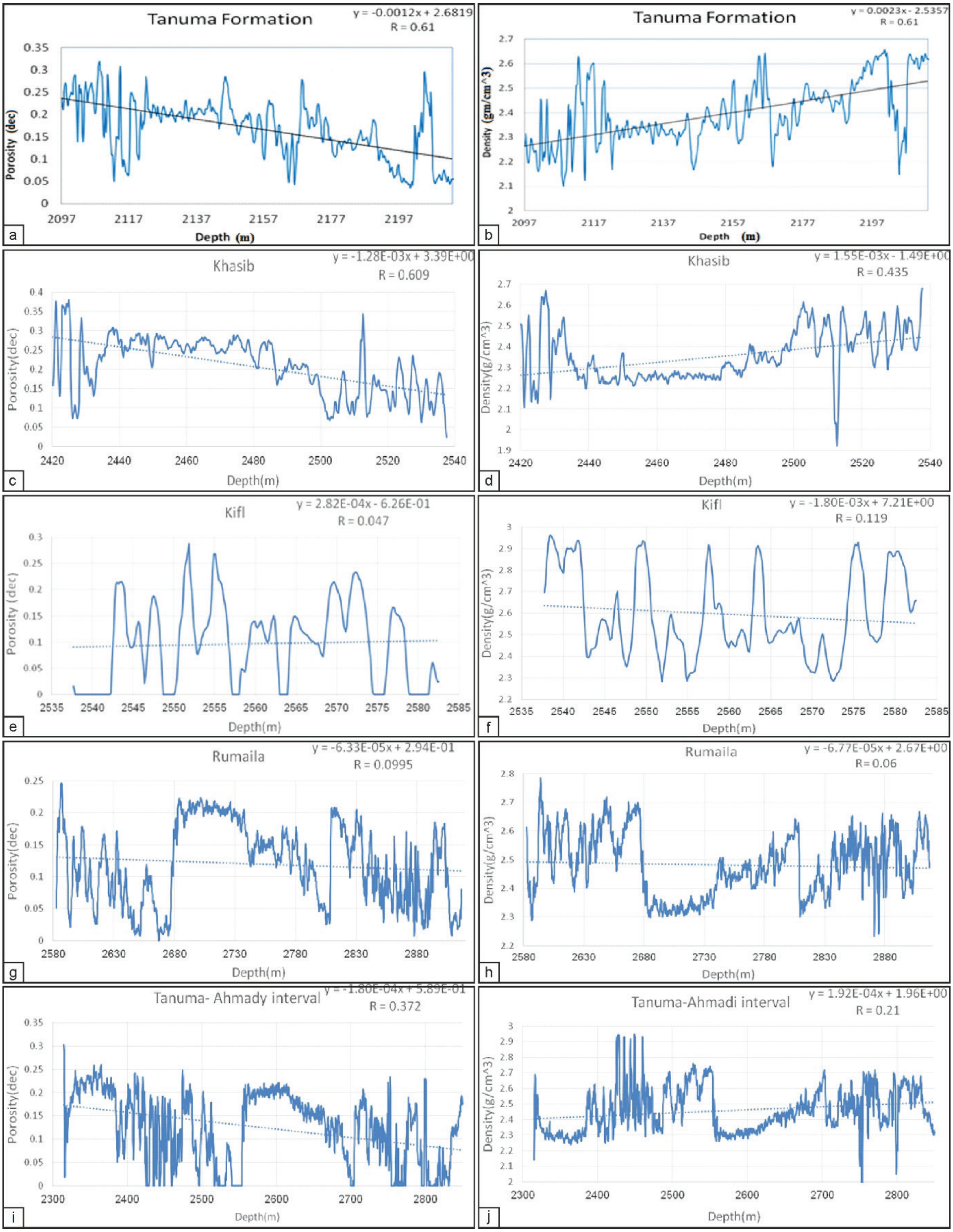

Figure 6. The porosity-depth relationships of **a)** Tanuma, **c)** Khasib, **e)** Kifl, **g)** Rumaila, **i)** Tanuma–Ahmadi, formations and their equations; The porosity-depth relationships of **b)** Tanuma, **d)** Khasib, **f)** Kifl, **h)** Rumaila, **j)** Tanuma–Ahmadi, formations and their equations.

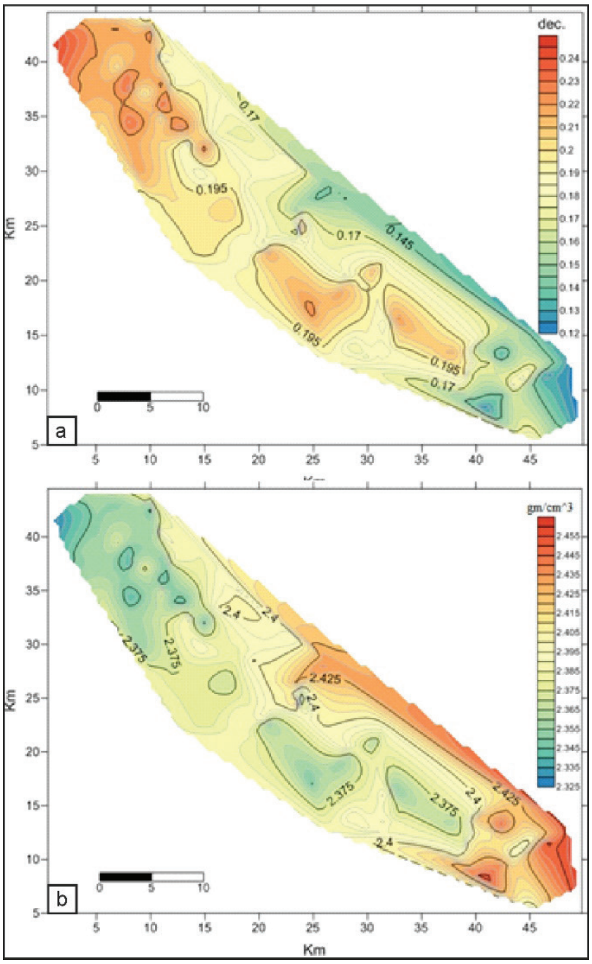

Figure 7. a) Porosity and **b)** density maps of Tanuma–Ahmadi interval.

Although the value of R in the equation for the Tanuma-Ahmadi period is relatively small (0.37, 0.21), it can be valid for calculation of porosity and density rates with depth for the whole area. In this interval, the porosity distributes gradually. It reaches 14% in the southeast part, while it increases to 15.5% towards the northwest. The density has inverse behavior with increases in the southeast and decreases towards the northwest part. The increased porosity in the southwestern parts of the study area accompanied with a decrease in density may provide indications about the strike of major faults (NW-SE) in the field.

From the maps shown in the two figures (Figures 7a and b), the main contour lines extend towards the main fault affecting the field (NW-SE), and the increase and decrease in density and porosity contours dip in vertical directions to the main fault, which gives an approximate picture of the relationship of porosity and density with the structure of the studied area.

CONCLUSION

This study deduces new equations (porosity-depth, density-depth) for all formations in the Tanuma-Ahmadi seismic interval using well log data. The average porosity and density maps for that interval in the study area were established by applying the new equations to 126 velocity analysis sites. Depending on the distribution of porosity and density values in the maps, the direction of the main faults affecting the field was illustrated.

The values of R produced from this study can be a function of homogeneity and compaction difference among formation components.

ACKNOWLEDGMENT

The authors are very grateful to the University of Mosul/college of petroleum and mining engineering, department of petroleum reservoir engineering for their facilities, which helped to improve the quality of this work.

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