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Density Estimation from Compressional Velocity Using New Gardner Factors for Two Carbonate Formations, Amara Oil Field.

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Abstract

Bulk density (matrix density and pores fluid density) is a very important physical property that is used as main parameter to estimate physical characteristics (porosity, water and hydrocarbons saturation, shale volume and many others). The compensation from bulk density and sonic velocity is used to calculate acoustic impedance, reflection coefficient, and other elastic properties. Gardner equation have default values for (a) (factor) = 0.31 if Vp in (m/sec) and (b) (exponent) = 0.25 for Vp (m/sec) and these values change according to the lithology condition in the study area to give more accurate results, for this reason The object of the presented work is to calculate new (a) factor and (b) exponent to measure bulk density from compressional velocity using Gardner1974 equation for two formations from middle Cretaceous age, the data was taken from two open hole well logs Am-6 and Am-10 in Amara oil field. Techlog 2015 software was used to complete this work. The results showed that the new values for Mishrif Formation factor (a) were (1.21) in Am-6 and (1.32) in Am-10 and (b) exponent values were (0.46) in Am-6 and (0.40) in Am-10, while for Rumiala Formation factor (a) were (1.35) in Am-6 and (1.333) in Am-10 and (b) exponent value was (0.40) in both Am-6 and Am-10, these values give best fitting with minimum err with field measuring bulk density logs data and these values can be used to measure bulk density log in the study area and surrounding near wells when field measuring bulk density log is not available.

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1. Introduction

Bulk density the first property used in seismic exploration, formation evaluation, and elastic properties determination and formation stability evaluation. Many studies were used Gardner equation to derive bulk density [1] calibrated Gardner equation on 15 wells of carbonate rocks and three wells with anhydrite. The comparison between the Gardner fitting density and measured density (indicate that Gardner equation is the best one and can be applied to clastic and carbonate rocks but not to anhydrite rocks). [2] Summarized the relationship between compressional velocity and bulk density for different sedimentary rocks type in San Andres reservoir. [3] derived a- factor and b – exponent of relationship between density-velocity for the specific lithology in the Niger Delta basin, They concluded that these coefficient different from Gardner default equation according to the lithology condition in the study area.[4] conclude that Gardner empirical equation is not general and different according to the condition in sedimentary basins around the world [5] estimated density using density- velocity relation by two method Gardner and lindseth method The comparison between the two method indicate that Gardner equation is the best one [6] apply Gardner equation to found density for two wells with sand and shale formation formations in Niger Delta. They concluded that the Gardner equation is easily use and useful in well which not contain density log.

In this study the Gardner equation is used to measured bulk density from two M. cretaceous formation (Mishrif and Rumiala formations) using the open hole log data from two wells Am-6 and Am-10 using default value for factor a and exponent b then by using fitting value for each formation.

2. Location and Geology setting of the study area.

The Amara oil field is located within Mesopotamian basin unstable shelf [7]. This field is considered one of the small fields located in the region, such as Al-Rafidain, Al-Rafidain Al-Sharqi, Kumait, Dujailla and Al-Rifai [8]. This field reflect anticline structure extend from NW-SE [9]. The surface of the area is covered with sediments of the quaternary (Pleistocene and Modern Era), which consist of fine sand, clay and gravel [10]. The stratigraphic section in the field was distinguished and the formation depths were determined through the study of geology derived from the wells of the Amara oil field in addition to the analysis of the well log records as represented in figure (1).

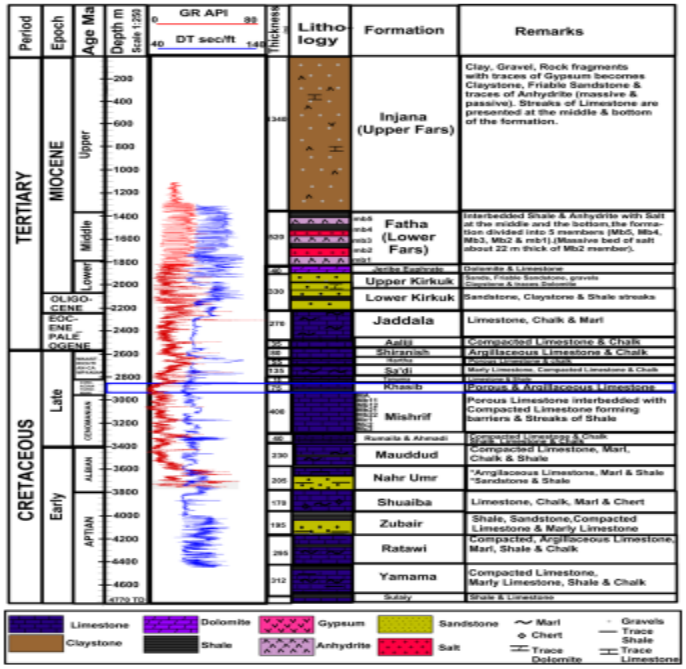

Figure 1: The stratigraphic Column of the southern region in Iraq [13] Wells Am6 and Am10 the studied formation description concluded below:

- **Mishrif Formation** composes mainly of many type of limestone with shale layers. Mishrif formation is from late Cenomanian middle cretaceous, the average thickness of Mishrif formation in Amara oil field ≈400 m. [14]
- **Rumiala Formation** from M. Cretaceous –M. Cenomanian, with low thickness $\approx 14\,m$ in total, it composes from compact limestone. [15], Table [1] shows the formation tops at studied wells.

Table 1: The formation tops at studied wells [11][12]

formation	Top well Am-6	Top well Am-10
Mishrif	2864.5	2874
Rumiala	3270	3272

Amara oil field was discovered from seismic surveys on Messan province in 1970, it locate about 10km south west Amara city [9]. Table [2] shows the coordinate location of the studied wells.

Table 2: the coordinate of wells Am-6, Am-10

well	E	N	RTKB elevation	Ground elevation
AM-6	699 045	351 8582	14.4	5.8
AM-10	697 150	351 9250	14.4	5.6

3. Methodology

Gardner 1974 suggest an equation to estimate bulk density from the relationship between density and velocity after study a number of field and laboratory measurements on rock symbols for different location, lithology and depths

The relationship depends on two different factors that depend on local lithology and physical parameters. The default values for these factors are a (factor) = 0.31 if Vp in (m/sec) or 0.23 for Vp (ft/sec) and b (exponent) = 0.25 for Vp (m/sec) and 1.74 for Vp (ft/sec).

$$\rho = a\,Vp^{b} \qquad (1)$$

Where:

Vp is compressional velocity that calculated from compression interval transit time DT. This equation deal with shale, sandstone and carbonate rocks.

The first step the density will calculated with default values for (a) and (b) factors.

Second step the density will calculated with different value for (a) and (b) to give the best fitting with the measured (field data) for density log.

The standard Error computed between two logs (original and Gardner fit value), (original and Gardner default value) using this equation:

((Gardner (default or fit) density- original density)/original density)*100 (2)

The best fitting between two densities data for each formation will table and consider as references to measure bulk density in these two wells for studied formations.

4. Result and discussions

The study applied on two formations from Am-6 and Am-10 in Amara oil field. These wells have logs data and dipole sonic log because we needed it as main input data to measure Gardner density, this log used to calculate compressional velocity which used to complete the relation with original bulk density to found the a factor and b exponent, these constants used to complete our measurement according to the equation at the studied area to give

best fitting value. Figure (2) represent the relation between density and compressional velocity as logarithm cross-plot of Amara oil field for data of (Mishrif and Rumiala formations) , the slope of the line with best fitting to the points is approximation of Gardner exponent value (b) and the intercept of y axis with best fitting point line given as the value of Gardner factor (a) [16].

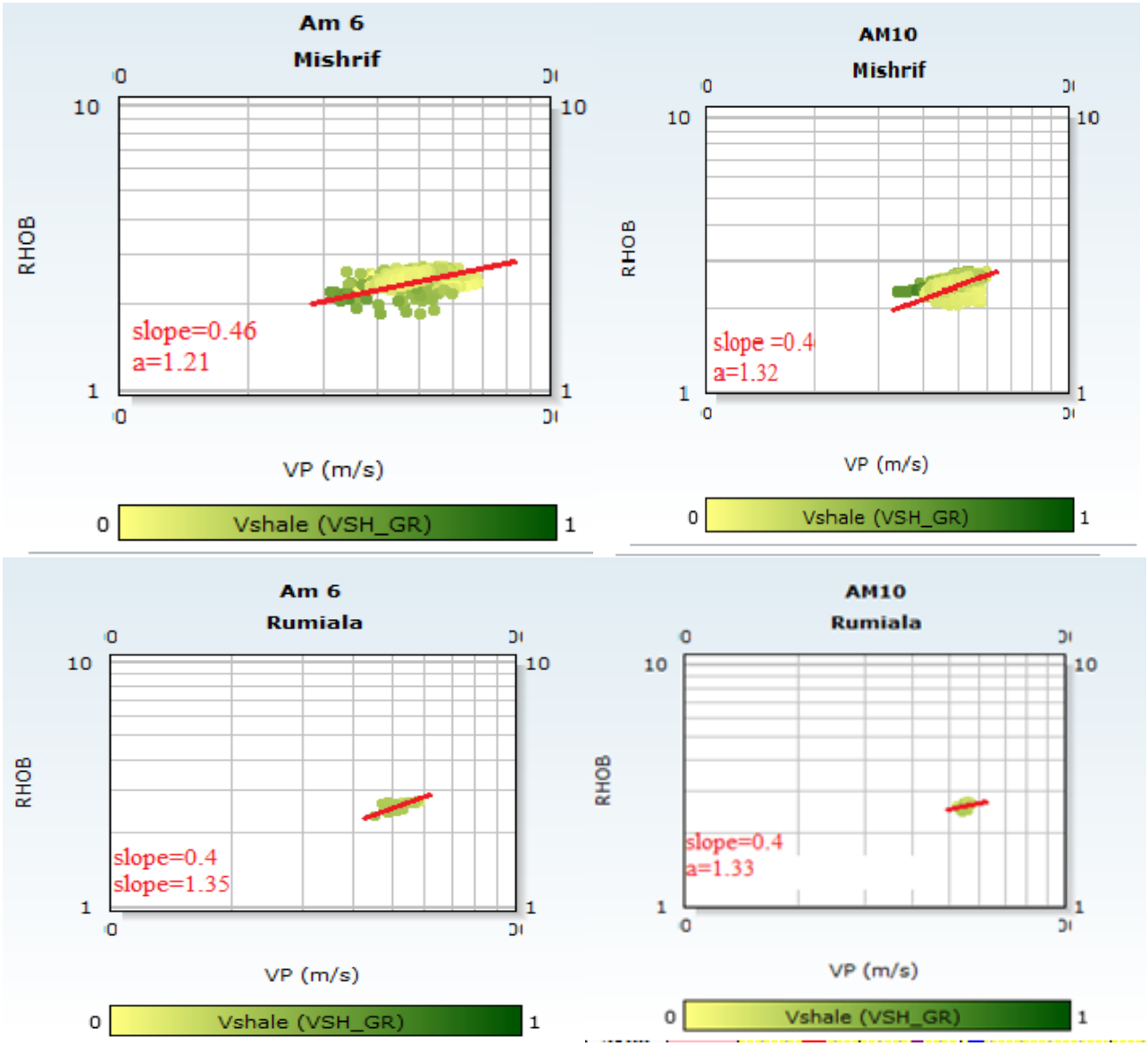

Figure 2: The VP, RHOB log-log crossplot with linear fitting curve of Am-6 and Am-10.

Figures (3,4) shows the interpretation of measured logs RHOB in the red log represent the field measured bulk density and RHOB from default value for Gardner equation and RHOB for most fitting values according to the lithology and other properties for each formation. Interval transit time (DT) log which needed to calculate compressional velocity and the standard error for default Gardner value and best fitting factor with exponent value for studied formation in wells Am6 and Am10 at Amara oil field.

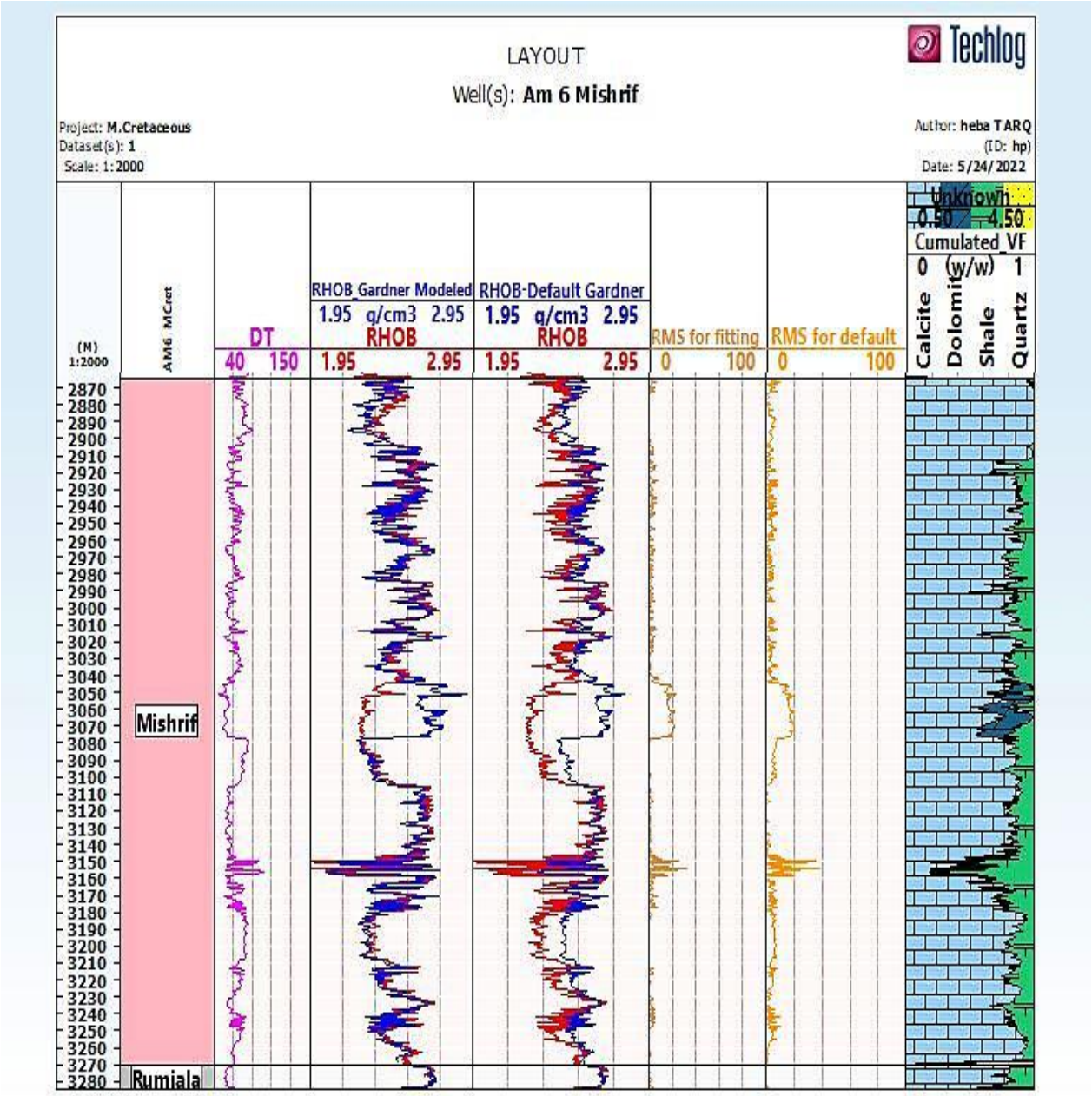

Figure 3: The interpretation logs from apply Gardner equation and the obtained equations in Am-6 well of Amara oil field

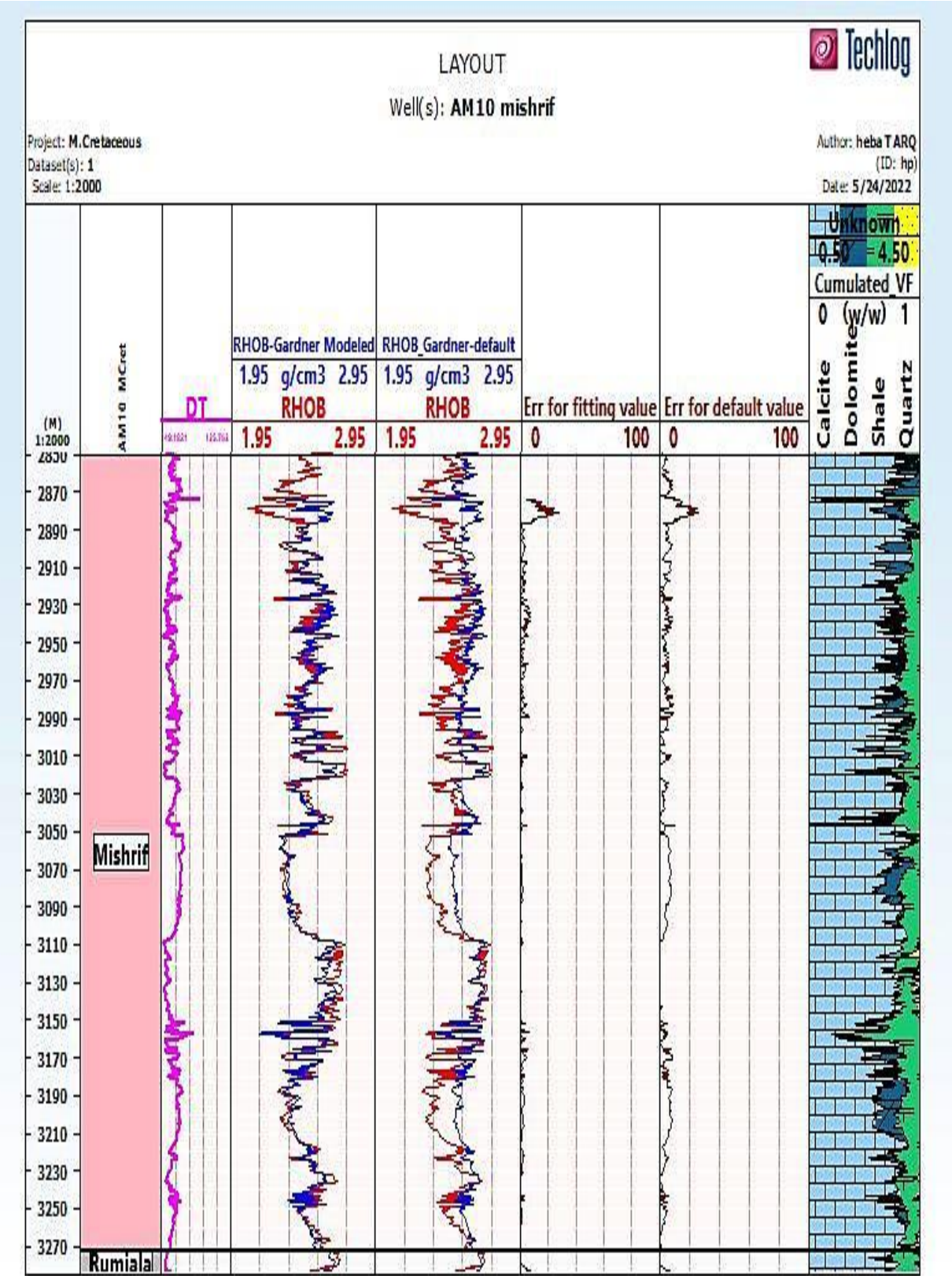

Figure 4: The interpretation logs from apply Gardner equation and the obtained equations in Am-10 well of Amara oil field.

(DT in pink color represents interval transit time, in the second column the red line for field bulk density and blue line for Gardner fitting bulk density, third column in red line field bulk density in blue line default Gardner bulk density the fourth column represent the standard error from best fitting equation, the final column represent the standard error between field density and default value equation.

The resulted data of best fitting value for a factor and b- exponent for all formation in the two wells are listed in the table 3.

Table 3: The best fitting values of the factors a and b those obtained using the data of density and velocity of the considered formations in Am-6 and Am-10 wells in Amara oil field.

well	formation	A factor	b exponent
	Mishrif	1.21	0.46
AM-6	Rumiala	1.35	0.40
	Mishrif	1.32	0.40
AM-10	Rumiala	1.333	0.40

The average values of original bulk density and default Gardner bulk density with best fitting Gardner bulk density are listed in the table 4.

Table 4: The Bulk density values and standard error of the studied formations in Am-6 and Am-10- wells in Amara oil field.

well	formation	RHOB Field	RHOB fitting	RHOB default	Err% Fitting	Err% default
	Mishrif	2.47	2.48	2.57	0.4	14.8
AM-6	Rumiala	2.662	2.661	2.668	0.03	0.22
	Mishrif	2.4846	2.4849	2.58	0.012	4.03
AM-10	Rumiala	2.648	2.647	2.67	0.03	1.13

5. Conclusion

Gardner empirical equation is an important relation used to estimate bulk density when log data is unavailable. The log data of Am-6 and Am-10 wells is used to obtain the relation between density and compressional velocity as logarithmic cross-plot of Amara oil field for data from (Mishrif and Rumiala formations), the slope of the line with best fitting to the points is approximation of Gardner equation exponent value (b) and the intercept of y axis with best fitting point line given as the value of Gardner equation factor (a). The results showed that the new values for Mishrif Formation factor (a) were (1.21) in Am-6 and (1.32) in Am-10 and (b) exponent values were (0.46) in Am-6 and (0.40) in Am-10, while for Rumiala Formation factor (a) were (1.35) in Am-6 and (1.333) in Am-10 and (b) exponent value was (0.40) in both Am-6 and Am-10, these values give best fitting with minimum err with field measuring bulk density logs data and these values can be used to measure bulk density log in the study area and surrounding near wells when field measuring bulk density log is not available.

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