Rock Physics Diagnostic and Density Velocity Analysis for Nahr-Umr Formation in Kumaite Oil Field, Southern Iraq

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Abstract
Density velocity analysis is quite important. In litho-rock physics prediction, this is due density can be an important character in differentiate lithologies and estimate other petrophysical properties. In the Kumaite Oil Field's Kt-1 and Kt-2 wells, a new empirical equation was established, especially for Nahr-Umr Formation, and this relation was compared to other global equations. Both Petro-physics and rock physics analysis was initiated to classify litho-units and determine the productive layer that could be contain hydrocarbons. The litho-probability (petrophysics) was giving a good match with hydrocarbons possibility (Rock Physics), well log interpretations (RHOB-NPHI) and cross plot of Vp/Vs versus Acoustic Impedance, MuRho and LambdaRho cross-plots) were used for lithology identification, which showed that the litho-prediction for Nahr-Umr is Limestone with sandstone in the middle and lower part, also the results were appeared that the lower part of formation has a good reservoir characterization.

Keywords: Rock physics; Litho-Prediction; Density velocity analysis; Nahr-Umr Formation

1. Introduction
Many interpretations and geological analyses include the ordinary connections between velocity and density of rock. Pore fluids, overburden stress estimation, identification of lithologies and pore pressure prediction, all these properties require more information about density. Consequently, density is frequently evaluated based on acoustic velocities utilizing many relationships developed by Lindseth (1979), Gardner et al. (1974), and Birch (1974 and 1961). Han et al. (1986), Castagna et al. (1985) and Domenico (1984), and go into greater detail about some of these methodologies (1986). Birch (1961), in particular, suggested a relationship between density velocity, and the mass of an atom of a chemical element. Gardner et al. (1974) reconditioned the P-wave velocity variability together with bulk density for popular sedimentary rocks from various depths, ages and basins, were used to construct a density-velocity relationship after many significant changes (e.g., Schreiber 1967; Simmons, 1964). Litho-probability volumes based on conventional interpretation models, e.g., low Vp/Vs levels imply the presence of gas, that do not include a knowledge of rock-physics lead to biased conclusions. Vp/Vs, can be confusing since it is unclear if an unusual ratio is generated by the denominator or numerator. As a traditional gas indication, low Vp/Vs values due to fall in Vp as a result of gas substituting brine in a rock. Utilizing Lamé Impedance concepts and, that gives an alternative interpretation template does not quite rely on ratios and can help with comprehension into rock qualities. As demonstrated in this case

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study, LMR can be a useful technique when s velocity has increased relatively to (P) velocity, regardless pore-fluid change (Close et al., 2015). Albian clastic deposits provide hydrocarbon reservoirs, seals and source rocks. Sandstones contain large reservoirs, although distant shales play an important role in offshore sealing (Alsharhan 1991, 1994). The Nahr Umr Formation (Albian) is a significant siliciclastic deposit in Iraq's cretaceous period. In southern Iraq, the Nahr-Umr Formation was as interpreted by (Owen and Nasr ,1958). It is 200 m thick and composed of black shales interbedded with medium- to fine-grained sandstones containing lignite, amber, and pyrite (Bellen et al., 1959). A carbonate part could be existed in its upper portion, particularly to the eastern part. The main in target is to re-classify the litho-units by using rock physics template and petrophysics’ tools, then refitting the litho-units velocity according to RHOB-Vp relationship

2. Location and Geological Setting of the Study Area

The studied region lies near the platform edge of the Mesopotamian Foredip Basin in southern Iraq (Fig.1), Kumait oil field is located in Missan Governorate to the north west of Amara city. The subsurface geology of Kumait oil field can be identified by studying the two drilled wells in the field that penetrate the formations of Triassic and tertiary Epochs. The well Kumait-1 reaches Suliay formation (4410m), and well Kumait-2 drilling reaches to Shuaiba to (3874m). Fig. 2 depicts the geological column. The type of deposition which represent shallow Marian environment compose of many depositions cycles separated by erosion surfaces resulted from Epeirogenic movements which effected the SE part of Iraq and resulted in sequences of progress and drop in shoreline.
3. Methodology

Petro-physical analysis was used to identify rock characterization utilizing well log data e.g., as RHOB, GR, NPHI, and others. The RHOB log can give information for reservoir characterization when studied a mineralogical composition function, porosity, hydrocarbon fluid type, and fluid saturation
Various text book authors provided tables with density value ranges e.g., Sandstone (1.9-2.5), Limestone (2.2-2.75), Shale (2.1-2.6), Dolomite (2.6-2.8), and Anhydrite (2.8-2.95). These values were utilized as a standard for evaluate the RHOB of the investigated rocks (Akhter et al., 2018). GR log is an excellent indication for shale presence, since it indicates the natural radiation emission in the rock. Whereas a high gamma value implies shale rock due to its high potassium, uranium, and thorium content, a low gamma result proves sandstone and limestone (Nwozor et al., 2017). NPHI log is based on the quantification of (H) in the formation (Albakr et al., 2022) it is employed to evaluate the porous structure of the formation and provides an important index of fluid content and lithology when combined with other logs (Fig.3).

Many elastic parameters, such as AI, SI, V_p/V_s, ratio, Young's Modulus, etc., can be calculated using V_p, V_s, and density (ρ) values. Following that, these moduli of elasticity were cross-plotted to conclude oil-gas zones and lithologies. Elastic logs have been derived for cross plotting where (P) and (S) sonic velocity log data are available, also RHOB data. Lambda-Mu-Rho (LMR; Goodway et al., 1997) logs have been calculated moreover elastic properties such as, V_p/V_s, and AI. Poisson's ratio.

LMR method has been developed by Goodway et al. (1997), which characterizes impedance and velocity in terms of the Lamé parameters of incompressibility (Lambda – λ) and rigidity (Mu – μ). By generating Lamé impedances, the utility of these parameters is increased Lambda-Rho (λρ) and Mu-Rho (μρ), that expressed by:

\[ \lambda \rho = AI^2 - 2SI^2 \]  
\[ \mu \rho = SI^2 \]

Where, AI = acoustic impedance and SI = shear impedance.

(λ) is a function a material's compressional and shear jointly, whereas μ is solely determined by shear properties. Because (μ) is reliant upon shear properties, it is fluid independent (Avseth, and Bachrach, 2005). This has upsides when plotting in LMR space, since one axis is fluid independent, as opposed to conventional domains such as AI vs V_p/V_s, in which both axes are influenced by pore data from gas and brine saturated wells were cross plotted especially in comparison with (RPM) templates based on influential Media "Contact Models" to examine the main reason decreasing in V_p/V_s value, data highlighted in Fig. 3. RPM templates allow you to visualize the effect of pore fluids, grain contact relationships, different rock texture and mineral ratios on elastic properties.

4. The Petro-physics and Rock physics Diagnostic

The formation is belonging to the Albian subcycle deposition sequence its defined by Glynn Jones in 1984 from Nahr Umr structure south Iraq (Jassim and Goff, 2006). Major two depocenters in central and S Iraq they receive classics sediment from Rutba uplift and Arabian shield and it considered as Clastic - Carbonate inner shelf facies (Jassim and Goff, 2006). Nahr Umr is very important reservoir in 37 structure (Aqrawi, 2010). Both contact of the formation is conformable in Iraq (Jassim and Goff, 2006). Nahr Umr deposit represent Transgressive condition accompanied by uplift in west part of Arabian Shield. The uplifting contributed in cease of calcite deposit and dominance of clastic deposit of Nahr Umr Formation, they featured by shallowing upward where carbonate deposit of Moudod which represent the end of Transgressive cycle (O.E.C, 2013).
Fig. 3. The lithology of the Nahr Umr Formation in Kt1 and Kt2 was determined utilizing a (RHOB) and (GR) cross-plot. The data sets are colored based on their (NPHI) values. The cross-plot has been split into three zones: Tight limestone zone, the Sandstone zone, and the Shale marl zone.

Figs. 4 and 5, demonstrates rock physics analysis the formation in the upper part of Kumait oil field is represented by a thin stratum of tight limestone 3630-3660 m. Then a thin layer of sandstone laminated with thin beds of Limestone and Shale at depth 3660 -3760 m. then thick layer of tight limestone from 2685-2755m. from 3660-3780 m found to be Limestone interbedded with thin stratum of dolomite. The formation's lower part is signified by interbedded layers of clastic sandstone could be a potential reservoir (characterized by low gamma and resistivity log values) as shown in (fig. 6) laminated with tight limestone and shale with marl as a caprock for depth 3800-3805 m.

Fig. 4. $V_p/V_s$ versus (AI) plot of Kt1 and Kt2 wells. The data sets are colored based on their (RHOB) values, which are categorized into three zones: shale marl, sandstone, and tight limestone. With possible reservoirs indicated by a black circle and low gamma values.
Fig. 5. MuRho and LambdaRho cross-plot of Kt1 and Kt2 well. The data point are colored, which three zones these are Shale marl zone, Sandstone zone and tight limestone zone. With potential reservoir in pointed in black circle that have low GR values.

Fig. 6. The lithological column of well Kt-1 and Kt2. represent the lithological columns of rock-physics and petrophysics analysis column analysis via using AI vs Vp/Vs versus and MuRho and LambdaRho cross-plot, where the results are very closely related, where the Shale and Marl zone (turquoise), Limestone zone (yellow), tight limestone zone (yellow), tight limestone zone (blue)
5. Density Velocity Analysis

The petrophysical parameters e.g., density (ρ), tensional wave velocity (%), and heat flow vary significantly depending on the rock type. The empirical relationship involving density and velocity that can be utilized to estimate RHOB from (Vp) reciprocally the velocity could be derived from density. These correlations vary by region according to depositional history, rock physical qualities, and geological contexts (Ojha et al., 2014). Many relationships are not just influenced by lithology, but also by local circumstances in each place (Hilterman, 2001) Many researches have been performed by many authors to demonstrate the density-velocity relationships of various lithologies, for example the Nafe-Drake curve (Brocher, 2005); Nafe–Drake curve (Ludwig et al., 1970)

Nafe–Drake curve (Ludwig et al., 1970)

\[
ρ(\text{g/cm}^3) = 1.6612V_p(\text{km/s}) - 0.4721V_p^2 + 0.0671V_p^3 - 0.0043V_p^4 + 0.000106V_p^5 
\]  
(3)

Gardner et al., 1974

\[
ρ(\text{g/cm}^3) = 1.74V_p^{0.25} 
\]  
(4)

Christensen and Mooney (1995)

\[
ρ(\text{g/cm}^3) = 0.541 + 0.360 V_p 
\]  
(5)

Godfrey et al. (1997)

\[
ρ(\text{g/cm}^3) = 2.4372 + 0.0761 V_p 
\]  
(6)

The 2nd polynomial (fig. 7) relation of density - velocity relations of Kt-1 well give an equation:

\[
ROB = 0.732339 + 0.55998 * x - 0.0384848 * x^2 
\]  
(7)

Fig. 7. Density-velocity relation depending on the data of Kt-1 well of the Kumate oil field, where ρ represent density and Vp represent longitudinal wave velocity. green line is the best fitting line. With correlation coefficient (R) = 0.839, Nahr Umr formation shows closely related to Nafe–Drake curve (fig. 8). The main lithological units give the following velocity. Tight Limestone 5.2 -5.9 km/s. Sandstone 4.1 - 4.8 km/s, Shale laminated with Marl 3.8 -4.5 km/s
Fig. 8. Comparison of the density-velocity curve obtained in Kt-1well of the Kumate oil field, with global equations usually used to estimate density from seismic data

6. Conclusions

The density values equation established for the density-velocity connection in Kt-1well provides a key value for the velocity consideration of lithological units. The density-velocity curve of Kt-1well is nearly identical to the Nafe-Drake curve. Limestone, Sandstone, Shale, and Marl rocks comprise the Nahr Umr Formation. The rock physics and petrophysics study of the available well data log of the Nahr Umr clastic Formation yields favorable results in terms of lithology, with a possible reservoir (5 m) in the lower part of formation.

References


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