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Elastic Modulus and Unconfined Compressive Strength Study of Middle Cretaceous Formations, Dhifriya Field Middle Iraq

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ABSTRACT

Dynamic elastic properties are calculated from the measurements of elastic compressional and shear velocities with corrected bulk density in Middle Cretaceous Formation, Dhifriya Middle Iraq. Static elastic properties were calculated from the correlation equations with dynamic elastic properties. The differences between dynamic and static elastic properties are caused by the presence of microfractures. From the dynamic young modulus and total porosity which was derived from Neutron –Density logs; the Unconfined Compressive rock Strength (UCS) was calculated. Compressional velocity was derived from sonic data and then shears velocity was estimated from Vp using Green Castagna equations. Techlog software were used to calculate static and dynamic elastic properties with rocks strength UCS based on well log data taken from two wells in Dhifriya field Dh-1, Dh-2. The results show that the rocks with high porosity and low density have low rock resistance for drilling and breaking (low UCS), while the rocks with high density and low porosity have high resistance for drilling and breaking(high UCS).

KEYWORDS: *Elastic Moduli, Static and Dynamic properties, Poisson's Ratio, Middle Cretaceous, Dhifriya field.*

INTRODUCTION

The elastic modulus of a body is the proportionality constant of the stress- strain linear relationship. It is an important physical property that explains the extent of the resistance of bodies or masses to the applied stress (Schlumberger, 1989).

The elastic properties (Young, Shear and Bulk Modulus and Passion's ratio) are considered as the basic rock properties in the mechanical operation (drilling, modeling and any rock analysis); two methods exist and are used to measure these parameters (static and dynamic). Static method usually done in the laboratory by applying one direction stress on the rock sample and measuring the strain obtained from this stress. Dynamic method is used in the lab on rock sample by measuring the travel time of compression and shear waves that travel through the sample between a known distance of two points(transmitter and receiver) along rock sample .The difference between static and dynamic measured data is caused by the presence of microfractures and cracks on the formation rock (Fjaer, 2008).This method is depending on rock sample and it is considered an expensive method because it needs a long time of work, in addition to unavailable samples in many wells. The accuracy of the obtained result of physical properties is relatively low due to the difference in the measurement conditions in the laboratory from the real condition in the well. So the log data can be used to calculate the dynamic and static elastic constants (Yale and Swami, 2017).

Bulk density is the most important physical parameter that affects our results and reflects the density of rock matrix and pore fluid density. RHOB is the symbol of this parameter in the log set normally. To have a good result from using bulk density log data, environmental correction must be applied using schlumberger special charts such as correcting RHOB to reduce the effect of hole size change and drilling fluid density (Al-Ameri and Al-Kattan, 2012).

Compressional transit time is the second physical parameter we need to complete our calculations. The symbol for these parameters is DT in the log set, it measures the first arrival wave in each receiver and it is used to calculate compressional velocity (Vp). Vp is the speed of the first measured wave (primary compression wave) (Mavko, Mukerji and Dvorkin, 2009).

Shear sonic or transit time (DTs) refer to the differences between two measured time periods for shear or secondary wave. It is usually not exist in the field set of log because of high cost and difficulty to run in field especially in old oil fields logs. The shear velocity (Vs) in this study was calculated using Green Castagna 1992 equation depending on Vp with respect to the type of lithology in each zone (Greenberg and Castagna, 1992).

These velocities are affected by many factors (lithology type, porosity, water saturation, depth, density, age, temperature, overburden stress and pores stress).

From DT, DTs and corrected RHOB we can calculate each elastic property beginning with Vp/Vs, AI, Poisson ratio, dynamic and static modules and finally rock strength as unconfined compressive strength (UCS) (the strength of rock which represents the rock resistance to maximum vertical unconfined stress until rupture happened) (Zoback, 2007).

The aim of this study was to calculate dynamic and static elastic properties and then calculate UCS for rock at four formations from middle cretaceous (Mishrif, Rumiala, Ahmadi and Mauddud), the data were taken from two wells Dh-1, Dh-2 from Dhifriya oil field.

LOCATION OF THE STUDY AREA

Dhifriya oil field is located in Waist Governorate about 12 Km northeast of Al Kut city on the eastern side of the Tigris River, 25 Km northeast of well Ahdab1 and 55 Km southwest of Badra1. Dh2 well located at distance 8 Km southeast Dh1 well (Midland Oil Company, 1987).The U.T.M coordinate of Dh1 is between 3603 426 north and 585 958 east, Df2 is between 3909 north 986 and 559 712 east.

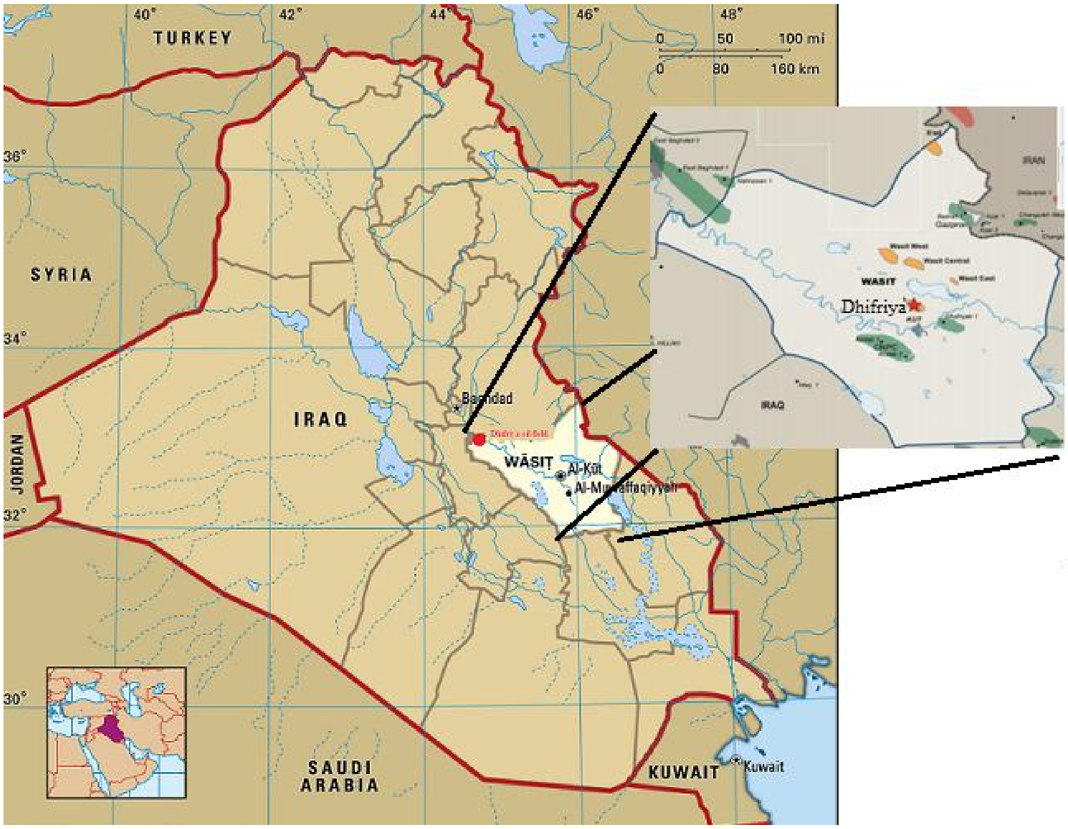

Figure 1: The location of Dhifriya field middle of Iraq modified after (Oryx Petroleum, 2013)

Dhifriya oil field structure was discovered for the first time by the Romanian seismic teams who made a survey in the Diyala- Kut region in 1977. The structure is symmetrical anticline extending from northwest to southeast (Oil Exploration Company, 1989).

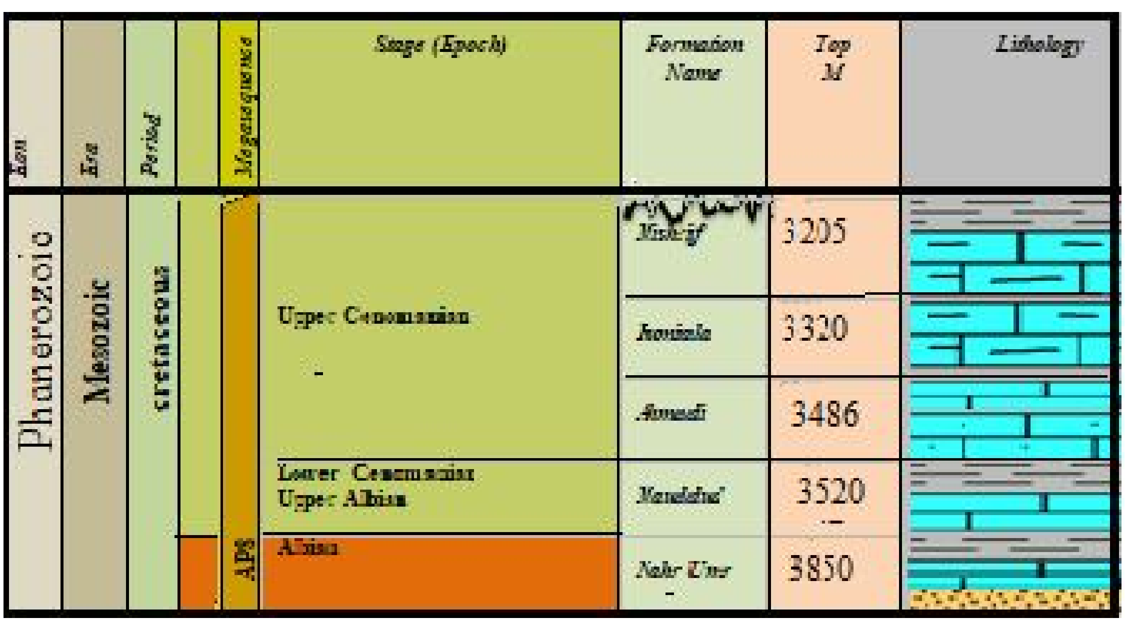

Figure 2: The stratigraphy section in Dh-2, middle of Iraq (Oil Exploration Company, 1987)

METHODOLOGY

A full profile of elastic rock properties (dynamic and static) were calculated from two well log data at Dhifriya oil field (Dh1 and Dh2) for four formations from middle cretaceous (Mishrif, Rumiala, Ahmadi and Mauddud formations). The Las data files were loaded into Techlog software and the depth matching was applied with environmental corrections to the log data. The shear velocity was calculated using Green Castagna 1992 equation.

For limestone Vs = - 0,05508VP2+ 1.01677 VP-1.03049
For sandstones Vs = 0.8042 VP – 855.88
For shale Vs = 0.76969 Vp – 867.35

By using Vp, Vs and corrected RHOB logs as insert values the dynamic elastic properties were calculated using the following equations:-

Dynamic Elastic modulus properties

Dynamic elastic properties measured from the relation between density and compressional and shear velocities from log data

1. Young constant is the proportionality constant in the linear relation that connects stress and strain (Fjaer, Holt, Horsrud, Raaen and Risnes, 1992).

$$E_{dyn} = \frac{\rho V_s^2 (3V_p^2 - 4V_s^2)}{(V_p^2 - V_s^2)} \quad \text{………….(1)}$$

Where
$\rho - bulkdensity$ Vp- compressional velocity Vs - shear velocity

2. Shear modulus is the ratio between shear stress and shear strain

$$\mu_{dyn} = \rho V_s^2 \quad \text{……………. (2)}$$

3. Bulk modulus is the volume change caused by stress applied to the body (Yu and Smith, 2011).

$$K_{dyn} = \rho\left(V_p - \frac{4}{3}V_s\right) \quad \text{……..…. (3)}$$

Acoustic impedanceis defined to be the product of velocity and density.

$$Z = Vp*\rho \quad \text{………. (4)}$$

4. Poisson ratiois the ratio between transverse strain to the longitudinal strain (Karakan, 2009), in this study poisson ratio was calculated using the below equation

$$\sigma_{dyn} = \frac{V_p^2 - 2V_s^2}{2(V_p^2 - V_s^2)} \quad \text{………... (5)}$$

Poisson ratio is a good lithology indicator where each specific lithology has a range of Poisson ratio as shown in the table below

Table 1: The common values for Poisson ratio (Gercek, 2007)

Lithology	Dolomite	Limestone	Sandstone	Shale	Siltstone
Poisson's Ratio	0.1-0.35	0.1-0.325	0.05-0.4	0.05-0.325	0.012-0.35

Static elastic modulus constants

Many theoretical correlations can be used to determine static young modulus from dynamic young modulus, since young's modulus can be estimated easily from physical properties (Elkatatny, Mahmoud, Mohamed and Abdulraheem, 2018). Good estimation of static Young's Modulus is basic for reducing the risk linked to exploration and production operations (Zong, Yin, and Wu,2013).During exploration the estimates of Young's modulus can affect the quality of well-logging data. In this study the static young modulus was calculated from dynamic young modulus using the following equation (Morales and Marcinew, 1993).

$$E_{sta} = E_{dyn}\,(-2.21\emptyset + 0.963) \;\ldots\ldots\ldots (6)$$

In the equation above the total porosity was used to estimate static young modulus. Dynamic and static Poisson ratios have the same values when they are calculated using Techlog software. The static young modulus and Poisson ratio were used then to calculate static shear and bulk moduli (Balarabe and Isehunwa, 2017).

$$G_{sta} = \frac{Esta}{2(1+\sigma sta)} \qquad \ldots\ldots\ldots\ldots (7)$$

$$K_{sta} = \frac{Esta}{3(1-2\sigma sta)} \qquad \ldots\ldots\ldots\ldots (8)$$

Total and effective porosity used to calculate static young modulus was calculated from Neutron- Density logs in Techlog software.

Unconfined compressive strength (UCS)

It is the strength measure of rocks according to which can resist the maximum compressive stress on the longitudinal axes of the sample when confining stress equal to zero so it is also called uniaxial compressive strength, it can be measured from rock sample in the lab and from using many empirical relations with elastic properties (Attewell and Farmer, 1976), (ASTM, 2014). Equations from Bradford who proposed correlation with young modulus was used in this study to calculate this important geotechnical property.

$$UCS = 2.28 + 4.1089E_{sta} \qquad \ldots\ldots\ldots\ldots (9)$$

RESULTS AND DISCUSSION

The final interpretation images (CPI) for all derived logs from this study represented with depth for each well are shown in figures 3 and 4. The used symbols definition was as following: Vp is compressional velocity, Vs is derived shear velocity from Vp, Vp/Vs ratio, AI is the acoustic impedance derived from the relation between density and velocity for each point in the formation, PR sta and PR dyn is the static and dynamic Poisson ratio respectively and in this study was the same value. YME represented young modulus static and dynamic, SMG represented the shear modulus in static and dynamic, BMK bulk modulus is in static and dynamic and finally the last column represent the UCS for rocks.

From this study the zones with high total and effective porosities and less density will have low velocity and Acoustic impedance with low rock resistance while the zones with low porosity will have high velocity with high Acoustic Impedance and high elastic modulus with high rock resistance. The lowest porosity value is in Ahmadi formation consisting of limestone with highest value of both elastic modulus and rock strength. The other formations distributed through the profile of elastic modulus with depth clearly at figures 3 and 4 so the depths with high values of elastic properties and rock strength showed and separated by hard rock with high resistance and low porosity.

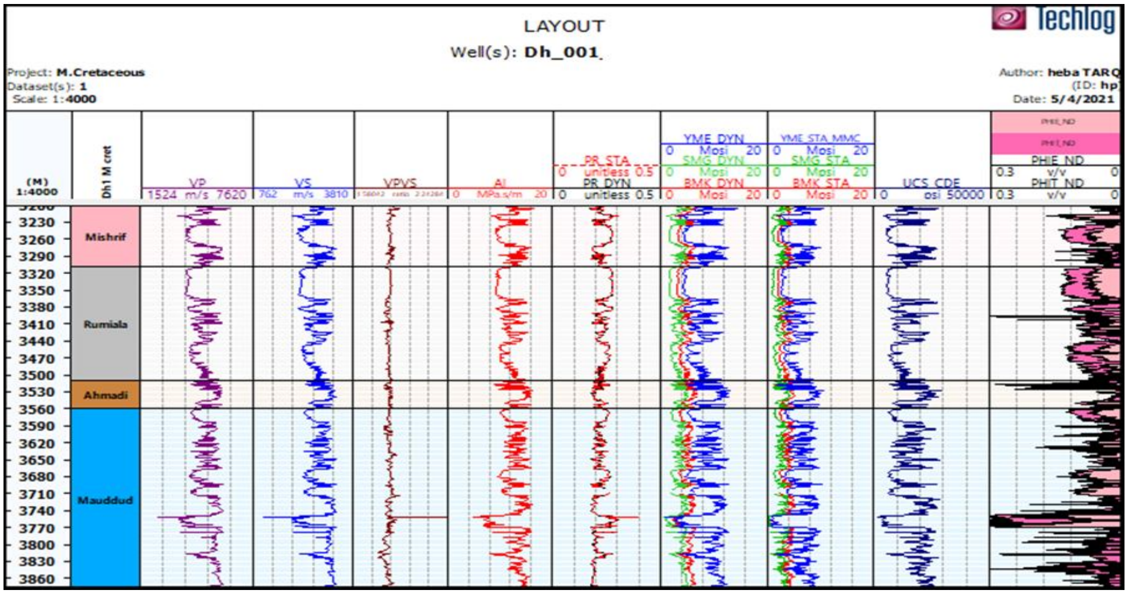

Figure 3: The final interpretation image for physical and elastic properties for Dh-1- at Dhifriya oil field, middle of Iraq

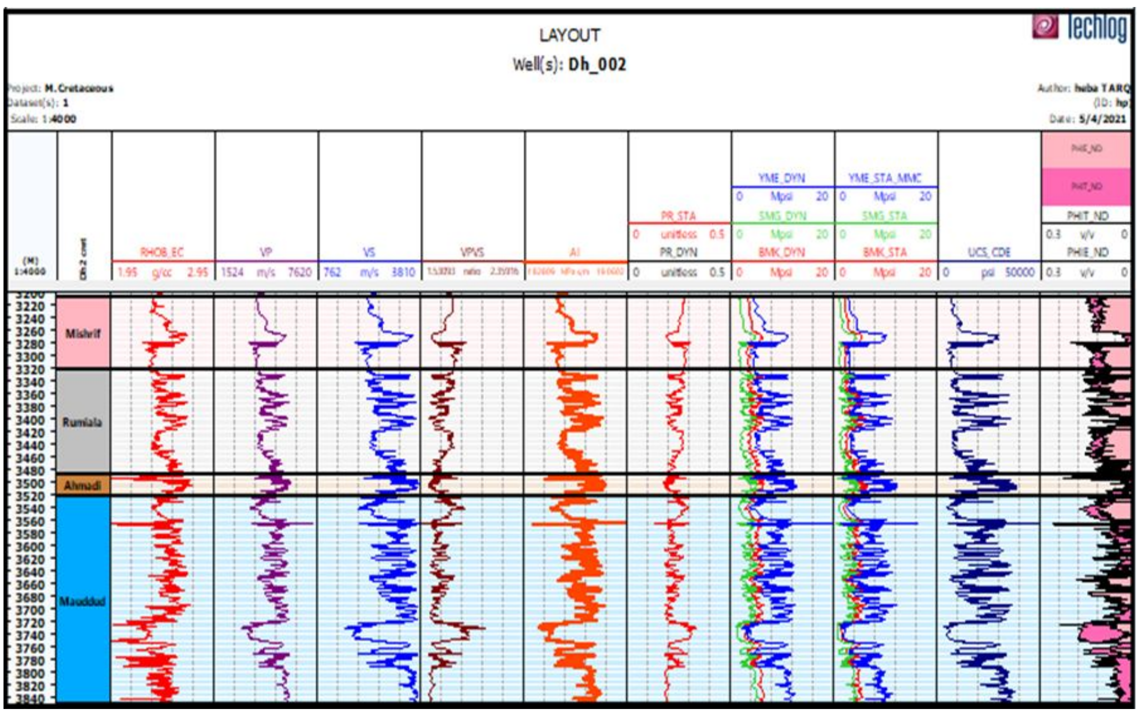

Figure 4: The final interpretation image for physical and elastic properties for Dh-1- at Dhifriya oil field, middle of Iraq

Table 2 and 3 represent the average values of measured static and dynamic elastic constants with rock strength and porosity (total and effective).

Table 2: The average value for elastic modulus total porosity and rock strength UCS for the four considered formations in the Dh-1 well

Zone	BMK-DYN Mpsi	BMK-STA Mpsi	PR-DYN unitless	PR-STA unitless	SMG_ DYN Mpsi	SMG_ STA Mpsi	YME_ DYN Mpsi	YME_ STA Mpsi	UCS_ CDE Psi	PHIT %
Mishrif	4.58076	3.331231	0.2340788	0.2340788	3.079939	2.254059	7.52417	5.501264	12874.62	7.14
Rumiala	4.120697	2.884874	0.2461516	0.2461516	2.585049	1.817698	6.399025	4.49633	10505.92	9.31
Ahmadi	5.414611	4.028357	0.2082797	0.2082797	3.998496	2.989052	9.612728	7.179701	17754.38	4.94
Mauddud	5.031892	3.565562	0.2160694	0.2160694	3.629775	2.589525	8.760724	6.226337	16182.7	7.79

Table 3: The average value for elastic moduli total porosity and rock strength UCS for each zone in the Dh-2 well

Zone	BMK-DYN Mpsi	BMK-STA Mpsi	PR-DYN unitless	PR-STA unitless	SMG_ DYN Mpsi	SMG_ STA Mpsi	YME_ DYN Mpsi	YME_ STA Mpsi	UCS_ CDE Psi	PHIT %
Mishrif	3.995332	2.811494	0.2572488	0.2572488	2.3884	1.715739	5.956489	4.262938	10861.1	11.7
Rumiala	4.41736	3.212332	0.2408631	0.2408631	2.839798	2.096901	6.999724	5.154434	14215.42	10.9
Ahmadi	5.447107	4.646236	0.2094688	0.2094688	4.008679	3.451889	9.642463	8.28963	24681.5	5.5
Mauddud	4.8844	3.766242	0.2253001	0.2253001	3.419958	2.675356	8.291713	6.471418	20054.07	8.9

CONCLUSIONS

As a result of calculating elastic modulus the UCS illustrated in the final image; the depths with high UCS value become more resistant to drilling and cuttings and are hard rock's with low porosities, while the low values of UCS reflect high fractures and high porosity rocks that need to less stress to breakdown. The dynamic elastic properties are higher than static measurements especially in the zone with higher porosity. Ahmadi formation has the highest values of elastic moduli in both wells, lower value of porosity and has more resistant rocks because it needs to 24681.5 Psi for breaking.

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