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Estimation of Static Young Modulus for the Third section in Zubair Oil Field :A Comparison Study

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Abstract

A detailed analysis for the mechanical properties of the rock is necessary to maintain a well bore and avoid problems with well bore instability. Static young's modulus is one of the most crucial rock mechanical properties utilized in the drilling process to assess wellbore integrity and setting-up geomechanical earth model. Static young's modulus change with varies of formation lithology's which arise the critical need for estimation.

The current study, a static young modulus values of different formations in section 12.25"in Zubair oil field are determined by depending on correlation to indicate variations in units and layers. Data of Gamma ray (GR), density log, sonic compression log (DTCO), and sonic shear log (DTSM) logs of well ZA-2 are utilized to estimate this attribute. Four different correlations that are set-up in Techlog 2015 software are used to achieve the aim of this study. These outcomes are calibrated using the fundamental laboratory tests (Brazilin and Triaxle test). The results showed that the modified Morales correlation provides a good matching with Calibration data, while four key data points are poorly correlated with the results of John Fuller's analysis.Also, Morales correlation shows unconformity when porosity reduced by less than 10% at different intervals, and Plumb Bradford correlation produces incorrect findings of static young's higher than the dynamic. The results declare inversely relationship between porosity and young's modulus.

Keywords: Static young modulus, Modified Morales correlation, John Fuller, Zubair oil field.

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1. Introduction:

The assessment of wellbore stability, reserve compacted, and management of the layer's the rock mechanical characteristics and static young's modulus estimation for the reservoir formation is crucial, [1]. Young's modulus is an elastic mechanical rock characteristic that indicates a stone layer's resistance to an unaxial load, [2]. Estimating the static modulus is a critical step in the creation of geomechanical earth models, [3]. it is particularly vital in the static drilling of hydrocarbon wells since it helps to describe the formation and total stresses, which is utilized for manage wellbore instability, [4]. Static young's modulus changes greatly with the different of the lithology, [2, 5]. For shale, the static Young's modulus varies from 0.1Mpsi to 0.99 Mpsi. It ranges from 8 and 12 Mpsi in limestone and 2 to 10 Mpsi in sandstone, [5]. These differences in young's modulus values emphasize that this characteristic changes with lithology, making it essential in prediction of the static young modulus along hydrocarbon wells.

Probability of failure rises with depth in deep wells deeper than 1500 meters, it is crucial to determine the mechanical characteristics of the rock. One essential elastic rock mechanical property for wellbore stability study is static young's modulus. Also best indication for unconfined compressive strength is young's modulus, this is because young's modulus directly measures the load-bearing rock structure and has a relationship with geometry, [6,7,8]. The majority of drilling failure issues are brought on by unstable boreholes, whether they are brought on by stuck pipe or lost circulation as a result of wellbore instability. The capacity of a rock to fracture under a minimum amount of deformation or strain is characterized by the important mechanical feature of brittleness, [9].

A geomechanics distinguishes rocks mechanisms, such as young's modulus, uses solid mechanics and geological interpretations to includes the influences of anthropogenic agents. The multidisciplinary branch of engineering known as engineering mechanics requires cooperation across the physical, mathematics, and geological sciences, as well as civil, petroleum, and geotechnical engineering, [10]. For reservoir development, management, and prospect appraisal in exploratory locations with very little to no borehole-based rock mechanical data, predictive methods for rock mechanical parameters are crucial. There are certain methods existing for measurement or evaluating the young modulus. Lab testing for plugs are the most direct method of obtaining the rock mechanical data. An indirect approach

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should be used because it is impossible to derive rock mechanical characteristics directly using logging tools. This study demonstrates an alternative method for calculating static Young's modulus, which is a frequently used dynamic Young's modulus that is obtain from sonic log by utilizing Techlog software in 2015.

1.1. Area of Study

One of Iraq's largest crude oil reserves was located in the Zubair oil field that was discovered in 1949 and the oil recovered in 1951. As depict in Figure (1), this area is located around 20 kilometers southwest of Basra. Figure (1) shows the thick column of Cretaceous carbonates forms the main lithology at Zubair oilfield's geological column, which is rich in numerous and substantial hydrocarbon accumulations. The primary hydrocarbon-prone and oil-producing reservoirs in the Iraqi field are the Zubair and Mishrif formations, [11].

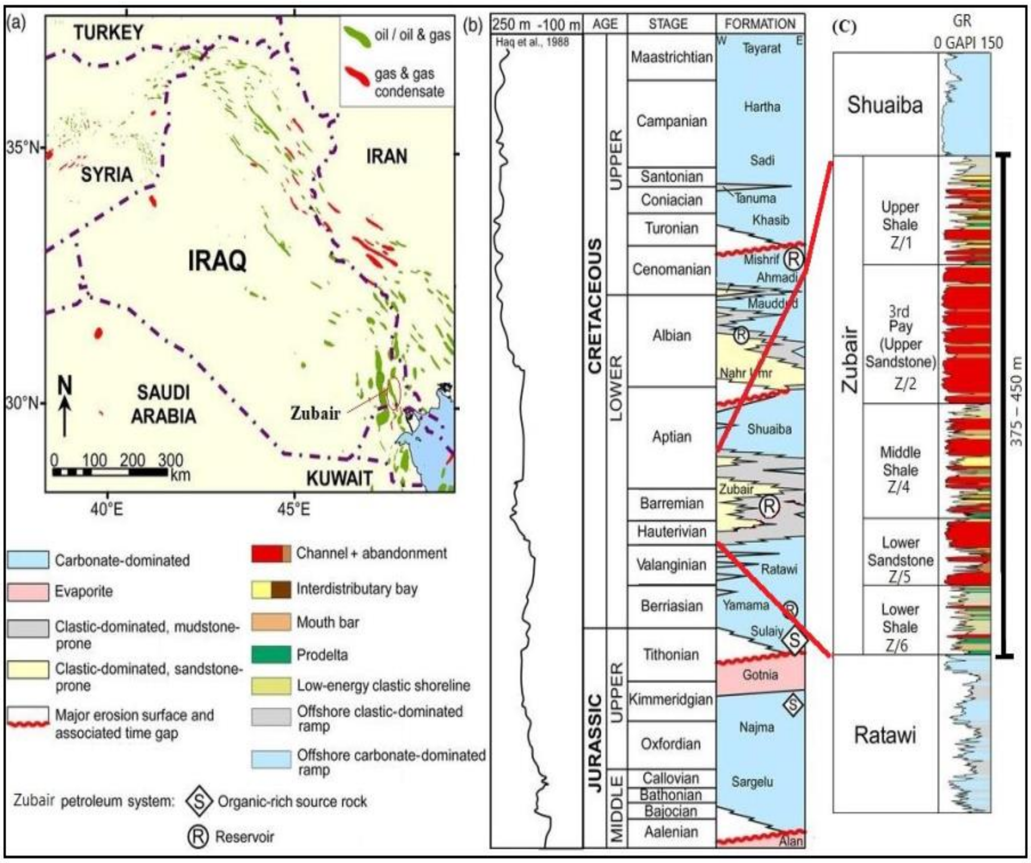

Fig. (1): Location map and a geological column, [12].

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2. Methodology

The most prevalent issue is the variety of required data. Data was gathered from ZA-2 production well in the Shuaiba dome of the Zubair oil field. Due to drilling difficulties such drilling mud loss and wellbore instability, Section 12.25" was considered for studying since its penetrated six formations (Sadi, Tanuma, Khasib, Mishrif, Rumulla, and Ahmadi).

The focus of elasticity theory is that there is a linear relationship between the applying force (stress) and the resulting deformation(strain). As seen in Figure (2), Hooke's law states that the Young's modulus E or the Modulus of Elasticity is represented by the stress-strain diagram's slope, [2,9,13]. dynamic Young's modulus is first determined from sonic log since static cannot be derived directly from it. The elastic characteristics were computed using the sonic log data under the assumption of a homogeneous, isotropic, and elastic formation as follows.

$$E = \frac{\sigma}{\varepsilon}$$

(1)

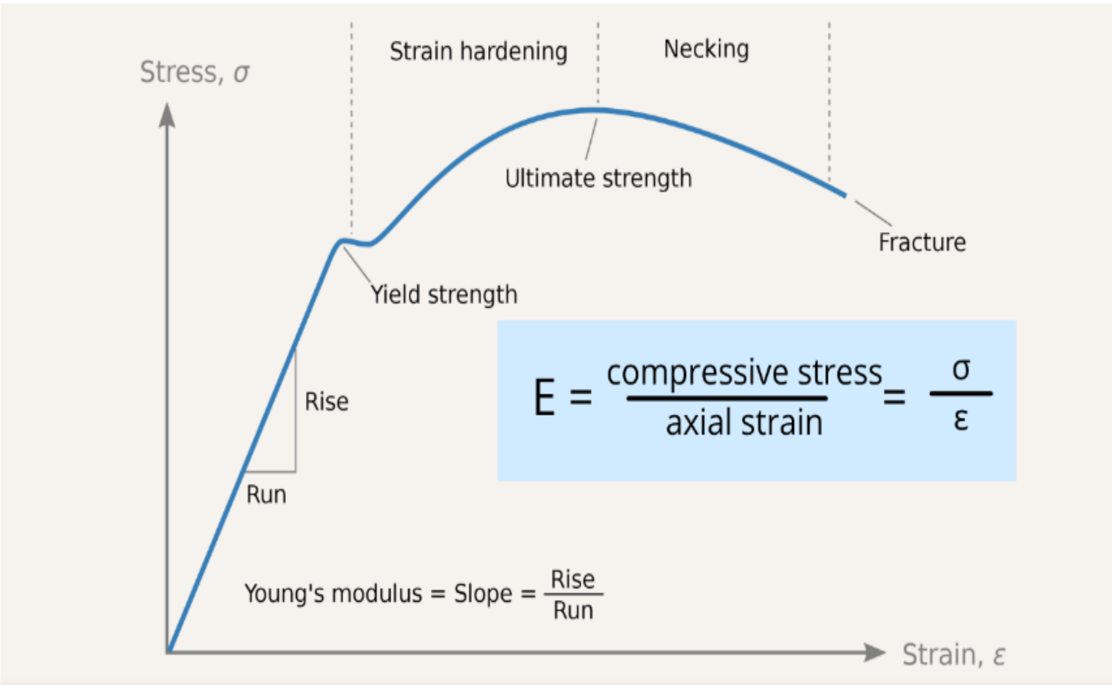

Fig. (2): Stress and strain Relationship, [10].

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2.1. Dynamic Modulus

These mechanical rock characteristics can be calculated from logs with aid of (sonic shear, compression log, and density log). Equations (2) and (3) can be used to calculate dynamic shear and bulk modulus (Gdyn and Kdyn) at the first, then equation (4) can be used for calculate dynamic young's modulus. The dynamic young's modulus may be larger than the static young's modulus, according to various previous research, [14,15]. The dynamic Young's modulus may be 1.5 to 3 times higher than the static one [16] and other studies indicate that dynamic may be 10 times bigger than static, [17,18].

$$Gdyn = 13474.45 \frac{\rho_b}{(\Delta t\ shear)^2} \quad (2)$$

$$Kdyn = 13474.45 \frac{\rho b}{(\Delta t\ shear)^2} - \frac{4}{3}\ Gdyn \quad (3)$$

$$Edyn = \frac{9\ Gdyn \times Kdyn}{Gdyn + 3\ Kdyn} \quad (4)$$

Where Gdyn is dynamic shear modulus, Kdyn dynamic bulk modulus, ρ_b is bulk density in gm/cm3 and t shear is sonic shear velocity while Edyn is dynamic young's modulus.

2.2. Static Young Modulus

In-situ stress state on the reserve was a consequence of the static and dynamic young modulus value, [19]. For calculation the static young modulus precisely, an expensive experimental test on an actual core sample was needed, [20]. For reducing this high cost of several experimental test for estimate static young modulus, there are four typical correlations that are used. These correlations depend on the dynamic Young's modulus, which is computed from the density and sonic logs.

John Fuller correlation is supported by a collection of North Sea sandstone samples from roughly 20 samples. This correlation can be used for sandstone and shale formation and range of unconfined compressive strength (UCS) is primarily between 2000 and 10000 psi. Only dynamic Young's modulus was used as input data for this model, as shown in equation (5), [21].

$$E_{st} = 0.032 \times E_{dyn}^{1.632} \quad (5)$$

Morales correlation among static and dynamic young modulus were derived in 1993 using

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linear regression analysis and then recovered using a variety of high-permeability materials. The following equations (6), (7), and (8) demonstrate how this correlation was used for sandstone formations with various porosity levels, [22].

For porosity between (10% to 15%) using equation (6).

$$\log E_S = 2.137 + 0.6612 \times \log E_{dyn} \quad (6)$$

For porosity between (15% to 25%) using equation (7).

$$\log E_S = 1.829 + 0.692 \times \log E_{dyn} \quad (7)$$

For porosity between more than 25% using equation (8).

$$\log E_S = -0.4575 + 0.9404 \times \log E_{dyn} \quad (8)$$

Plumb Bradford correlation was developed in 1998 for sandstone rock. Dynamic young's modulus was used as the input data for this correlation as follows, [23].

$$E_s = 0.0018 \times E_{dyn}^{2.7} \quad (9)$$

The last correlation was Modified Morales correlation which is developed in 1997 by Tom Bratton using Morales data from 1993. The total porosity and dynamic young modulus served as the input data with this correlation as shown in equation (10). For sandstone and shale rock with porosity less than 35%, this correlation is recommended as follows, [24].

$$E_{st} = (-2.21 PHIT_{ND} + 0.965)\, E_{dyn} \quad (10)$$

3. Results and Discussion

According to Figure (3), the dynamic modulus (YME-DYN) in Mpsi unit is at the fifth track, while the dynamic shear modulus (SMG-DYN) in the third track and the dynamic bulk modulus (BMK-DYN) in fourth track. As can be seen from the findings, the Tanuma, Khasib, and Ahmadi formations include the least values of these attributes, which may indicate that the formation was weak and possibly collapsed.

Only dynamic Young's were used as the input data for John Fuller correlation, as seen in Figure (4). The Mishrif and Rumailla formations exhibit good, stronger rock, whereas

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Tanuma and Khasib have low values and may collapse during drilling, according to the results. Four core data points in black circles have poor match with the outcomes.

The findings are shown in Figure (5), Morales correlation's for prediction the static young's modulus. Total porosity with dynamic young modulus are the input values for the third and fourth tracks, respectively. Because there was no correlation study with porosity less than 10%, some results in the fifth track were missing as porosity decreased and young's modulus increased.

Figure (6) illustrates the findings of the static Young's modulus using Plumb Bradford correlation. The findings show that this correlation gives static values that are higher than dynamic values, which is incorrect because a previous research showed dynamic values to be higher than static.

The third and fourth tracks were used as input data for the Modified Morales correlation, as seen in Figure (7). The last track was estimating the static young modulus using this correlation, and as can see, the black circles containing the core data were an excellent fit. According to the findings, minimum values of this characteristic make the formation would failure and collapse, as porosity increases the young's modulus decreased.

The Modified Morales correlation was the best method for estimating the static young modulus, according the findings of the four correlation. In comparison to previous approaches, the best correlation included input data on total porosity and dynamic young modulus, which increased the accuracy of the estimations.

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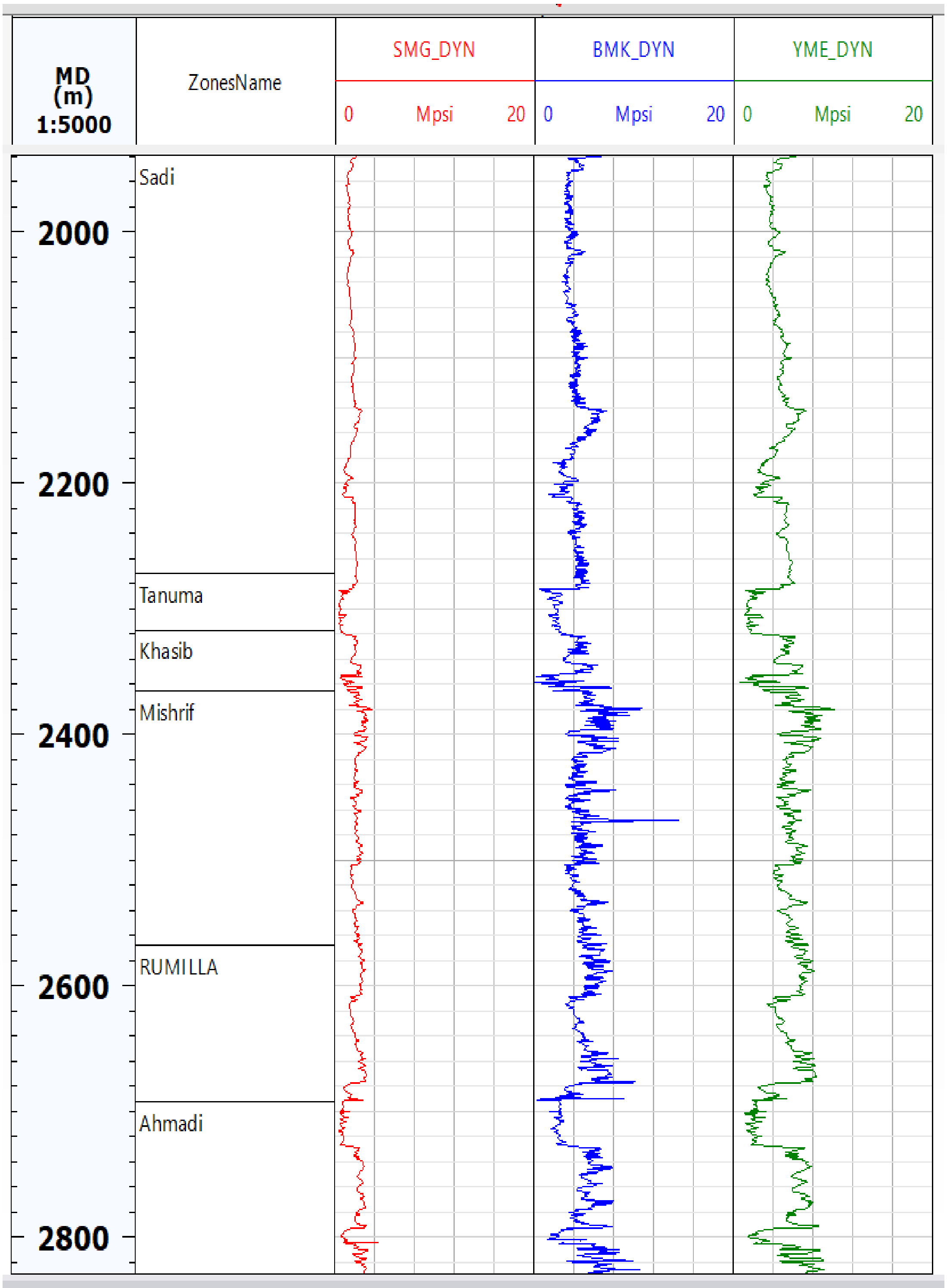

Fig. (3): Dynamic rock mechanical properties.

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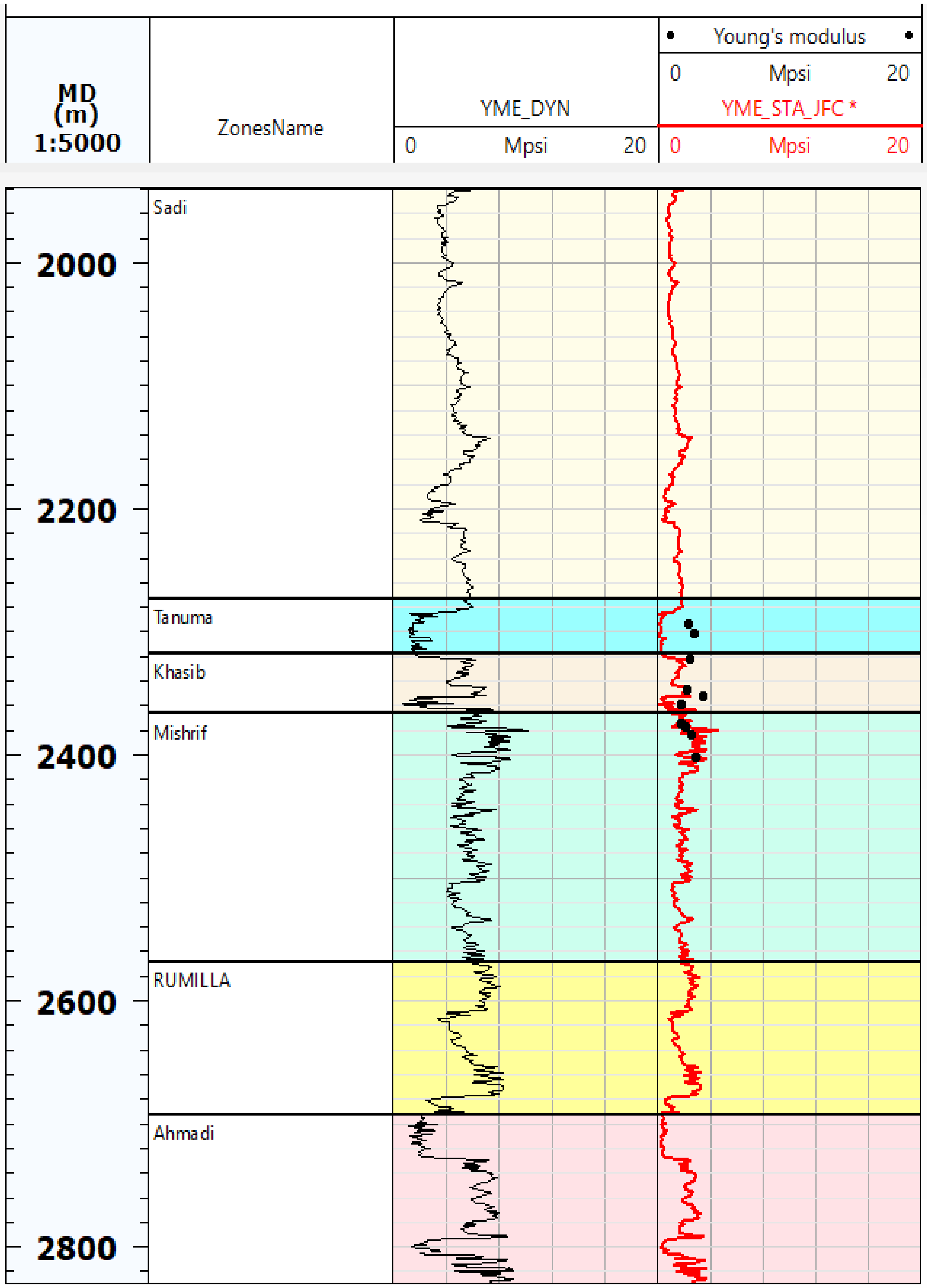

Fig. (4): Static young modulus by John Fuller correlation.

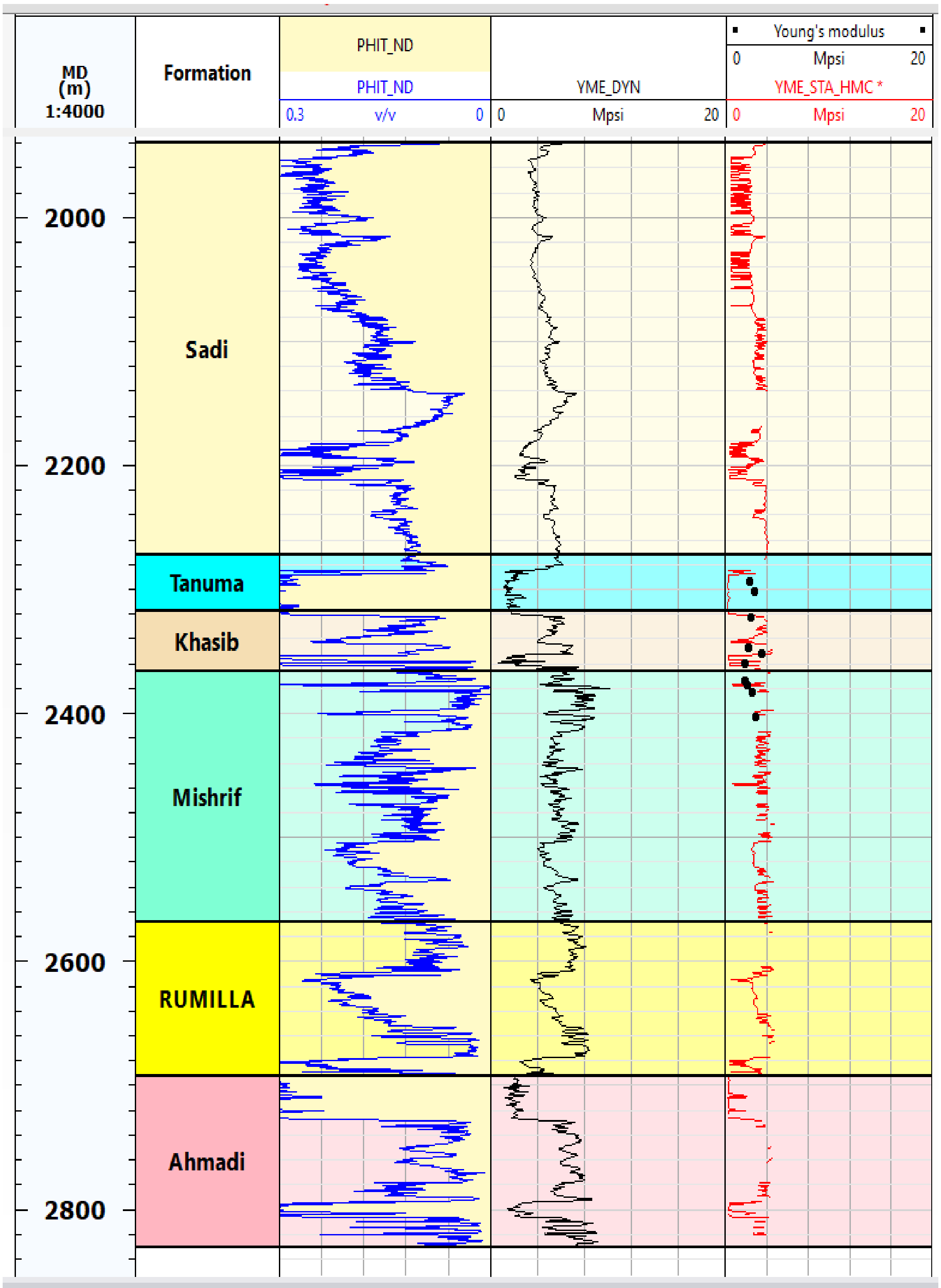

Fig. (5): Static young's modulus by Morales correlation.

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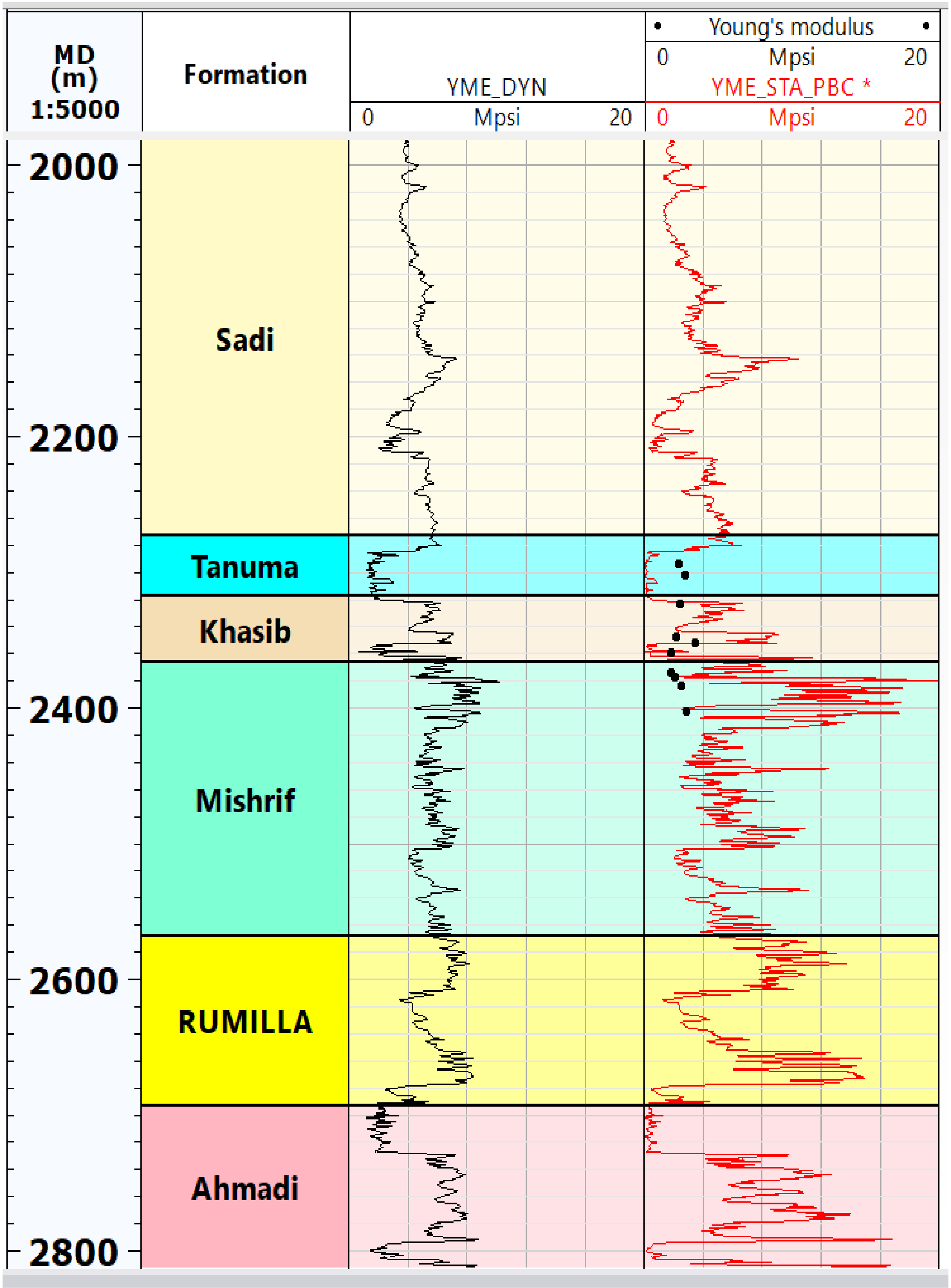

Fig. (6): Static young's modulus by Plumb Bradford.

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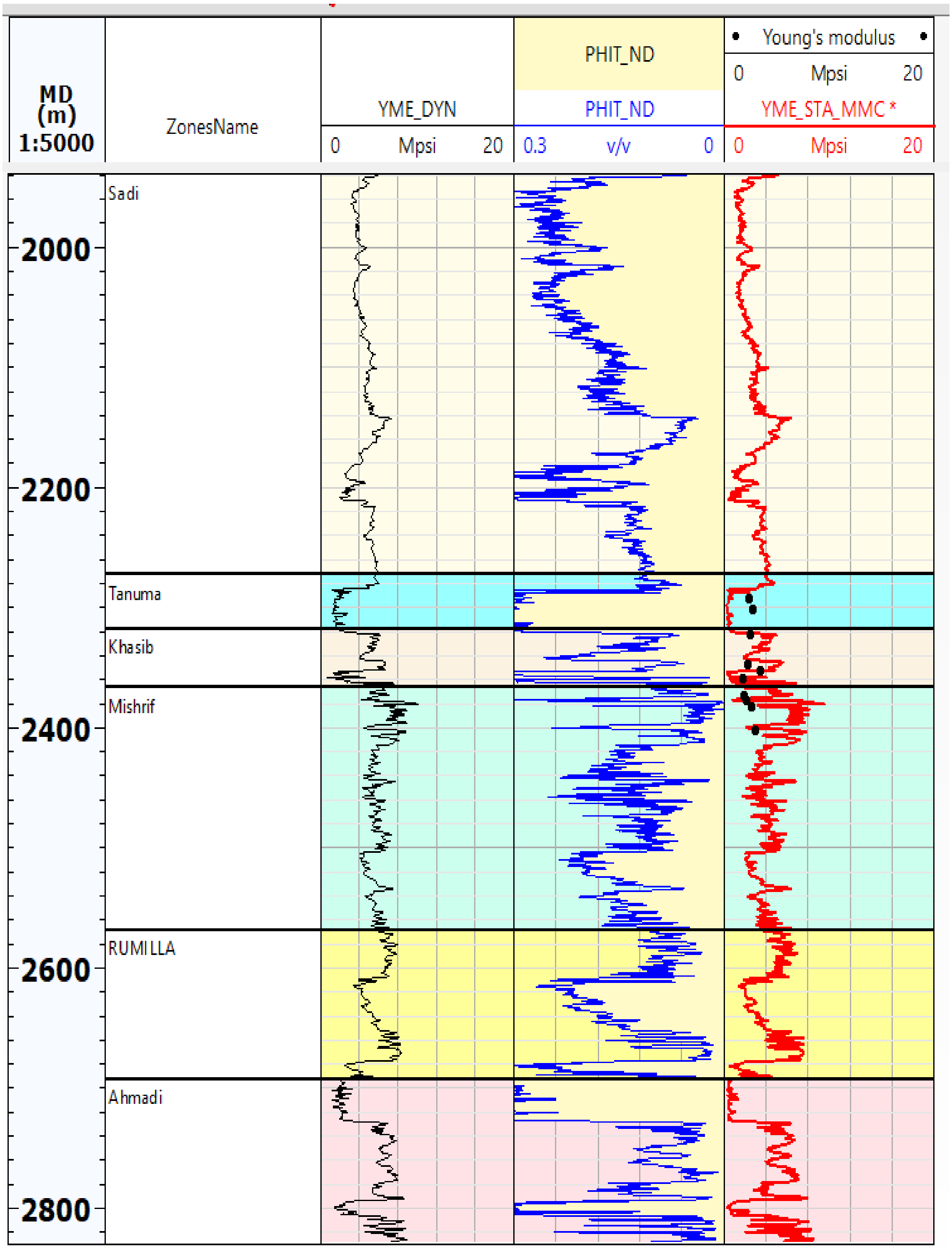

Fig. (7): Static young modulus by Modified Morales correlation.

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4. Conclusion

Based on the obtained results from the previous section, the following conclusions can be drawn as follows:

- The high cost of dynamic estimation from core samples will be reduced by using young's modulus from sonic and density logs.
- Core circle data and the modified Morales correlation's findings match good together.
- Porosity and static Young's modulus had an inverse relationship; as porosity decreased, static Young's modulus increased.
- Morales correlation cannot work with porosity less than 10% so that there was missing results values by this correlation.
- Plumb Bradford correlation produces inaccurate findings.
- When comparing several approaches for calculation the static young modulus by modified Morales correlation produces the best results.

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E- ISSN: 2710-1096

References

[1] Britt, Larry K., et al. "Rotary Sidewall Cores-A Cost Effective Means of Determining Young's Modulus.," SPE Annual Technical Conference and Exhibition. OnePetro, 2004. https://doi.org/10.2118/90861-MS.

[2] Erling Fjær, Rune Holt, Per Horsrud, and Arne Raaen., "Petroleum related rock mechanics", Elsevier, DEVELOPMENTS IN PETROLEUM SCIENCE 53, 2nd Edition, 2008.

[3] Chang, Chandong, Mark D. Zoback, and Abbas Khaksar, "Empirical relations between rock strength and physical properties in sedimentary rocks," Journal of Petroleum Science and Engineering, vol. 51, pp. 223-237, 2006. doi: https://doi.org/10.1016/j.petrol.2006.01.003.

[4] Nes, Olav-Magnar, et al, "Drilling time reduction through an integrated rock mechanics analysis," Journal of energy resources technology, vol. 134.3, 2012. doi: https://doi.org/10.1115/1.4006866.

[5] Howard, G.C.; Fast, C.R, "Hydraulic Fracturing," In Doherty Memorial Fund of AIME, Society of Petroleum Engineers of AIME; Henry L.: New York, NY, USA, Volume 2, ISBN 10.1970.

[6] Digby, P. J. "The effective elastic moduli of porous granular rocks," J. Appl.mech, pp. 803-808,1981.

[7] Dobereiner, L., and MH De Freitas. "Geotechnical properties of weak sandstones." Geotechnique 36.1, pp. 79-94, 1986.

[8] R. A., Plumb, S. L. Herron, and M. P. Olsen, "Composition and texture on compressive strength variations in the Travis Peak Formation", SPE Annual Technical Conference and Exhibition. OnePetro, SPE 24758, DC. October 4-7, 1992.

[9] Zoback, Mark D., "Reservoir geomechanics," Cambridge university press, 2010.

[10] Bernt S. Aadnøy and Reza Looyeh, "Petroleum rock mechanics: drilling operations and well design," Gulf professional publishing, Second Edition, 2019. https://doi.org/10.1016/C2017-0-03371-2

[11] Deng, H., Fu, M., Huang, T., Gluyas, J.G., Tong, M., Wang, X., Zhou, W. and Liu, F., "Ahdeb oil field, Mesopotamian Basin, Iraq: Reservoir architecture and oil charge history,"

Open Access
No. 39, June 2023, pp. 16-31

P- ISSN: 2220-5381
E- ISSN: 2710-1096

AAPG Bulletin, vol. 102.12, pp. 2447-2480, 2018. doi: https://doi.org/10.1306/0424181617217089.\

[12] Al-Jafar, M.K. and Al-Jaberi, M.H., "Well logging and electrofacies of Zubair formation for upper sandstone member in Zubair oil field, southern Iraq," The Iraqi Geological Journal, pp.101-124, 2019.

[13] Jaeger, J.C., Cook, N.G. and Zimmerman, R., "Fundamentals of rock mechanics. John Wiley & Sons, 2009.

[14] Rinehart, John S., Jean-Pierre Fortin, and Lorraine Burgin, "Propagation velocity of longitudinal waves in rocks. Effect of state of stress, stress level of the wave, water content, porosity, temperature, stratification and texture," The 4th US Symposium on Rock Mechanics (USRMS). One Petro, 1961.

[15] King, M. Soo, "Wave velocities in rocks as a function of changes in overburden pressure and pore fluid saturants," Geophysics, vol.31.1, pp. 50-73, 1966. https://doi.org/10.1190/1.1439763.

[16] I. Larsen, E. Fjær, and L. Renlie, "Static and Dynamic Poisson's Ratio of Weak Sandstones", Paper presented at the 4th North American Rock Mechanics Symposium, Seattle, Washington, July 2000.

[17] Hui, C.; Lian-Ku, X.; Li-Jie, G.; Hu-Xin, W.; Biao, C," Rock mechanics study on the safety and efficient extraction for deep moderately inclined medium-thick orebody," Electron. J. Geotech, vol. 20, pp. 11073–11082, 2015.

[18] Peng, Li, Liu Xinrong, and Zhong Zuliang, "Mechanical property experiment and damage statistical constitutive model of Hongze rock salt in China," Electron. J. Geotech. Eng., vol. 20, pp.81-94.2015.

[19] Canady, Wyatt., "A method for full-range Young's modulus correction," North American unconventional gas conference and exhibition. One Petro, 2011. doi: https://doi.org/10.2118/143604-MS.

[20] Abbas Khaksar, Philip Geoffrey Taylor, Zhi Fang, Toby John Kayes, Abraham Salazar, and Khalil Rahman, "Rock strength from core and logs, where we stand and ways to go," EUROPEC/EAGE Conference and Exhibition. One Petro, 2009. DOI:10.2118/121972-MS

Open Access
No. 39, June 2023, pp. 16-31

P- ISSN: 2220-5381
E- ISSN: 2710-1096

[21] Schlumberger., “Techlog Pore Pressure Prediction and Wellbore Stability Analysis Workflow / Solutions Training,” 2015.

[22] Morales, R. H., and R. P. Marcinew., "Fracturing of high-permeability formations: mechanical properties correlations," SPE annual technical conference and exhibition. One Petro, 1993. doi: https://doi.org/10.2118/26561-MS.

[23] I.D.R. Bradford; J. Fuller; P.J. Thompson; T.R. Walsgrove., "Benefits of assessing the solids production risk in a North Sea reservoir using elastoplastic modelling," SPE/ISRM rock mechanics in petroleum engineering. One Petro, 1998. doi: https://doi.org/10.2118/47360-MS.

[24] La Vigne, Jack, Barber, Thomas D., and Tom Bratton, "Strange Invasion Profiles: What Multiarray Induction Logs Can Tell Us About How Oil-Based Mud Affects The Invasion Process And Wellbore Stability", Paper presented at the SPWLA 38th Annual Logging Symposium, Houston, Texas, June 1997.