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Fracture Pressure Predict Based on Well Logs of Depleted Reservoir in Southern Iraqi Oilfield

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Abstract—Fracture pressure is the main parameter applied in wells design and used to avoid drilling problems like lost circulation. Thus, this study aims to predict the fracture pressure of oil reservoirs in the southern Iraq Oilfield. The data required to implement this study included bulk density, compression wave velocity, gamma-ray, and leak-off test. In addition, this model is based on the pore pressure which is measured based on the Modular Formation Dynamics Tester (MDT). Many measured values of pore pressure were used to validate the accurate model. Using sonic velocity approaches, the mean absolute percentage error (MAPE) was about 4%. The fracture pressure results were consistent with the measurement data, actual drilling report, and events. The model's results will be a guide for successful drilling in future wells in the same oilfield.

Keywords—Pore pressure, fracture pressure, overburden pressure, effective stress, drilling events.

I. Introduction

TO safe drilling and reservoir modeling should be estimated the pore pressure. An accurate prediction of formation pressure gives a more efficient casing seat design. Generally, all pore pressure methods are based on the formation resistivity log, sonic log, and the actual value in overpressure zones or using exponents (a function of drilling parameters) [1]-[5]. Several methods mainly exhibited a strong relationship with normal compaction trends and pore pressure established on shale behavior [6], [7]. Nonetheless, overpressure might occur in the hard formation (carbonate) and well-cemented; therefore, most methods are based on shales that they might lead to potentially dangerous errors with carbonates [8].

Terzaghi et al. explain the in-situ state of stress and relation with the bulk of a rock (pore space and solid structure) [9]. Therefore, the rock is at equilibrium, or the rotational momentum of the rock is equal to zero, meaning a stable state of stress has been reached [9]. Reaching the equilibrium condition is during a deposition when the fluid maturation and rock deformation evolve with burial; therefore, the overburden pressure will deform the pore and rock. The main source of in-situ stress in the stress tensor and compaction of the sedimentary formations with depth is the vertical stress. The pore volume of the rock decreases with the increase of the vertical stress because of the burial. Therefore, the pores drove out the formation fluid and compacted when there is no impermeable upper layer. In contrast, when an impermeable layer occurs, the fluid will remain trapped in the pores; therefore, the fluid gets a part of the stress load and becomes overpressured. As a result, the fluid confine held the amount of exceeding stress, known as overpressure. Hottman and Johnson [6] used resistivity and sonic-log data to present a geopressured prediction technique [6]. This method applies only to Tertiary rocks in the Gulf of Mexico, but it was used widely accepted. They mentioned that this technique could apply only in rock compaction, which caused geopressured. Giles et al. [10] showed the relation between effective stress and normal compaction trends as shown in (1) [10]. For formations of different ages, this equation was developed.

$$\emptyset = \emptyset_0 e^{-\frac{\sigma_{eff}}{K_\emptyset}} \quad (1)$$

$$\sigma_{eff} = P_c - \alpha' P_p \quad (2)$$

$$\alpha' = \left[\left(\frac{\partial \emptyset}{\partial P_P}\right)_{P_C} \Big/ \left(\frac{\partial \emptyset}{\partial P_C}\right)_{P_P}\right] \quad (3)$$

$$K_\emptyset = -\frac{1}{\emptyset}\left(\frac{\partial \emptyset}{\partial P_C}\right)_{P_P} \quad (4)$$

$$P_p = \left[\frac{(1-\emptyset)C_b}{(1-\emptyset)C_b - \emptyset\, C_b}\, \sigma_{eff}\right]^{\gamma} \quad (5)$$

Equations (2) and (3) were published by Atashbari and Tingay [11] which predict pore pressure in carbonates and represent (5). They considered compaction disequilibrium as the main source of pore pressure, and excess pressure is applied to the reservoir by a total deposition rate of overlying strata. Moreover, Terzaghi et al. established their study on rock compressibility defined by [12]. Using special core-analysis data were built equation to measure rock compressibility.

The study aims to predict the fracture and pore pressure profile that matches the equivalent mud-weight (MW) curve in the operator window. Thus, the well-logging data will be used to estimate the full pressure profile in carbonates and we use measurement data to validate the model's accuracy.

A. Geologic Setting

The field stratigraphy was described based on three exploration wells and two appraisal wells with much literature on the geology of Iraq [13], [14]. The main reservoir is the Mishrif, subdivided into several units, where the oil exists in the middle and lower it. Furthermore, a thin and continuous layer separates the upper and middle Mishrif.

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B. Workflow

The workflow can be classified into four parts as shown in Fig. 1.

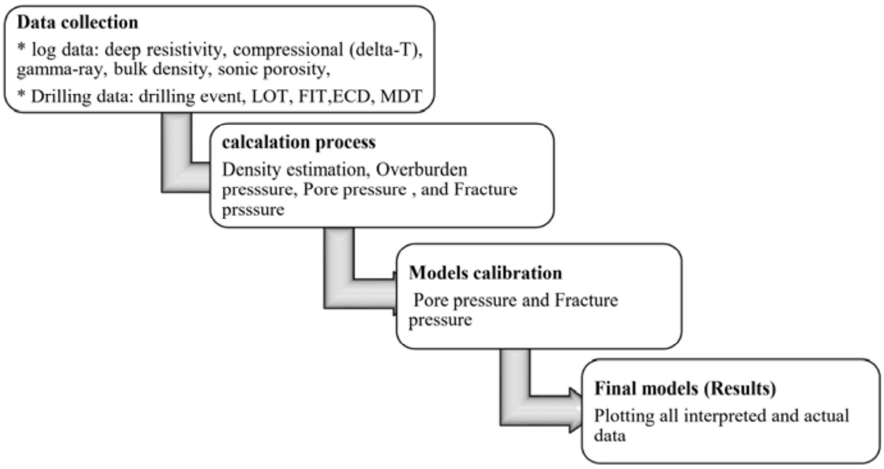

Fig. 1 Workflow

C. Data

The essential data, including MDT Tester, compression (delta-T), gamma-ray, bulk density, and drilling exponent data, are taken from one development well, J40. This study is essentially based on integrating of formations, measurement data, and drilling events that can drive best results to pore pressure evaluation using Techlog® (Schlumberger) software to calculate and interpret the data for output models.

D. Overburden Pressure

It is called vertical stress σv, which is dependent on the weight of the rock matrix (ρ_b) and depth (z), shown as:

$$\sigma_V = \int_0^Z \rho_b(\mathrm{z})\ \mathrm{g}\ d_Z \tag{6}$$

The overburden pressure increases with depth and depending on the depth. A density log is used to evaluate lithostatic pressure, but the density log data are primarily unavailable at shallow depths. Therefore, shallow density can estimate using Empirical relations.

E. Pore Pressure

The pore pressure is based on effective stress and total vertical stress. Moreover, the fluid pressure in the formations supports part of vertical stress, and the other part is called effective stress. Terzaghi's effective stress equation presents effective stress σ_e , as shown in (7) [9], [15]:

$$\sigma_e = \sigma_V + P_h \tag{7}$$

From Biot's equation, we can find the effective normal stress as following:

$$\sigma_e = \sigma_V + \beta P_h \tag{8}$$

$$\beta = 1 - \mathrm{Kd/Ks} \tag{9}$$

Pore pressure can be measured using repeat formation test (RFT), MDT, and drill stem test (DST). The pore pressure can be predicted by indirect measurements. The Eaton method presents the widely quantitative methods to predict pore pressure [7], [17]. This study has been based on well log and drilling data to predict the geopressured. Eaton in 1975 found a mathematical formula to predict the formation pressure based on compression wave velocity [17]. He assumed that the overburden stress effect by pore pressure and effective vertical stress according to Terzaghi's principle.

$$P_{pg} = OBG - (OBG - P_{pn})\ (\frac{\Delta t_n}{\Delta t_o})^x \tag{10}$$

where P_{pg}: gradient of pore pressure, OBG: gradient of overburden, $P_{pn:}$ normal gradient of hydrostatic formation pressure, R_0: shale resistivity log, R_n: normal resistivity of shale, x: dependent on normal compaction trend line, Δt_n: Shale slowness at normal trend line, Δt_0: Shale slowness derived from sonic log.

The exponent values are 1.5 when using resistivity log and 3 when using Sonic Log (or seismic data). The exponent values were derived from the Gulf of Mexico data, so globally, the exponent should be updated for the area of study [16].

F. Fracture Pressure

The fracture pressure is faction of the minimum horizontal stress. So, the magnitudes of the minimum horizontal stress were predicted using the poroelastic model. Equation (11) is essentially based on elastic parameters and pore pressure.

$$\sigma_h = \frac{v}{1-v}\,\sigma_v + \frac{1-2v}{1-v}\,\alpha P_p + \frac{E}{1-v^2}\,\varepsilon_x + \frac{vE}{1-v^2}\,\varepsilon_y \tag{11}$$

$$\varepsilon_x = \frac{v\,\sigma_v}{E}\left(1 - \frac{v^2}{1-v}\right) \tag{12}$$

$$\varepsilon_y = \frac{v\,\sigma_v}{E}\left(\frac{1}{1-v} - 1\right) \tag{13}$$

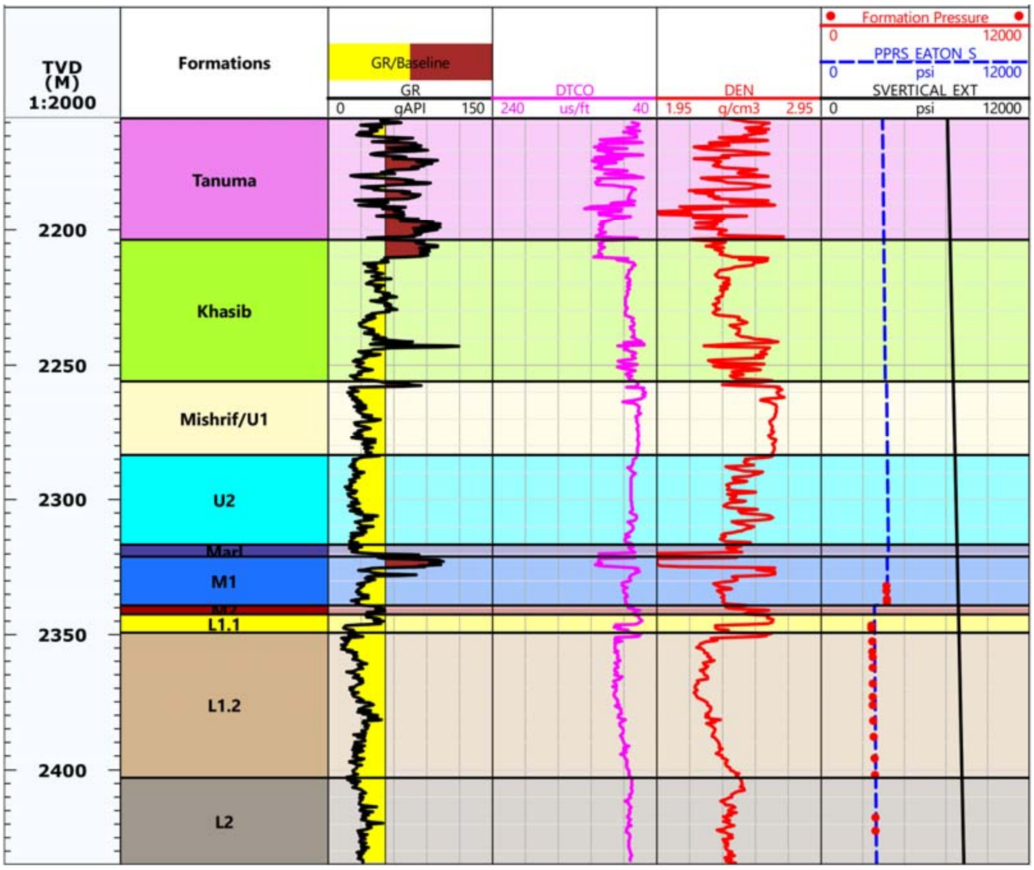

Fig. 2 Pore pressure

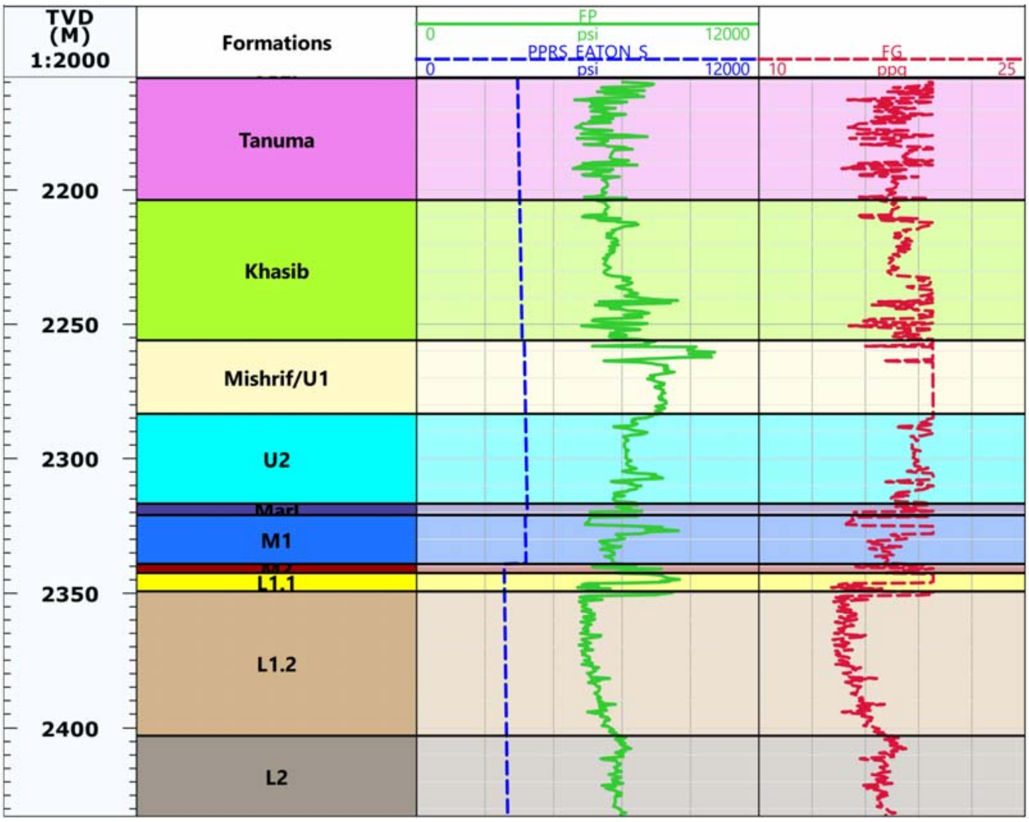

Fig. 3 Fracture pressure

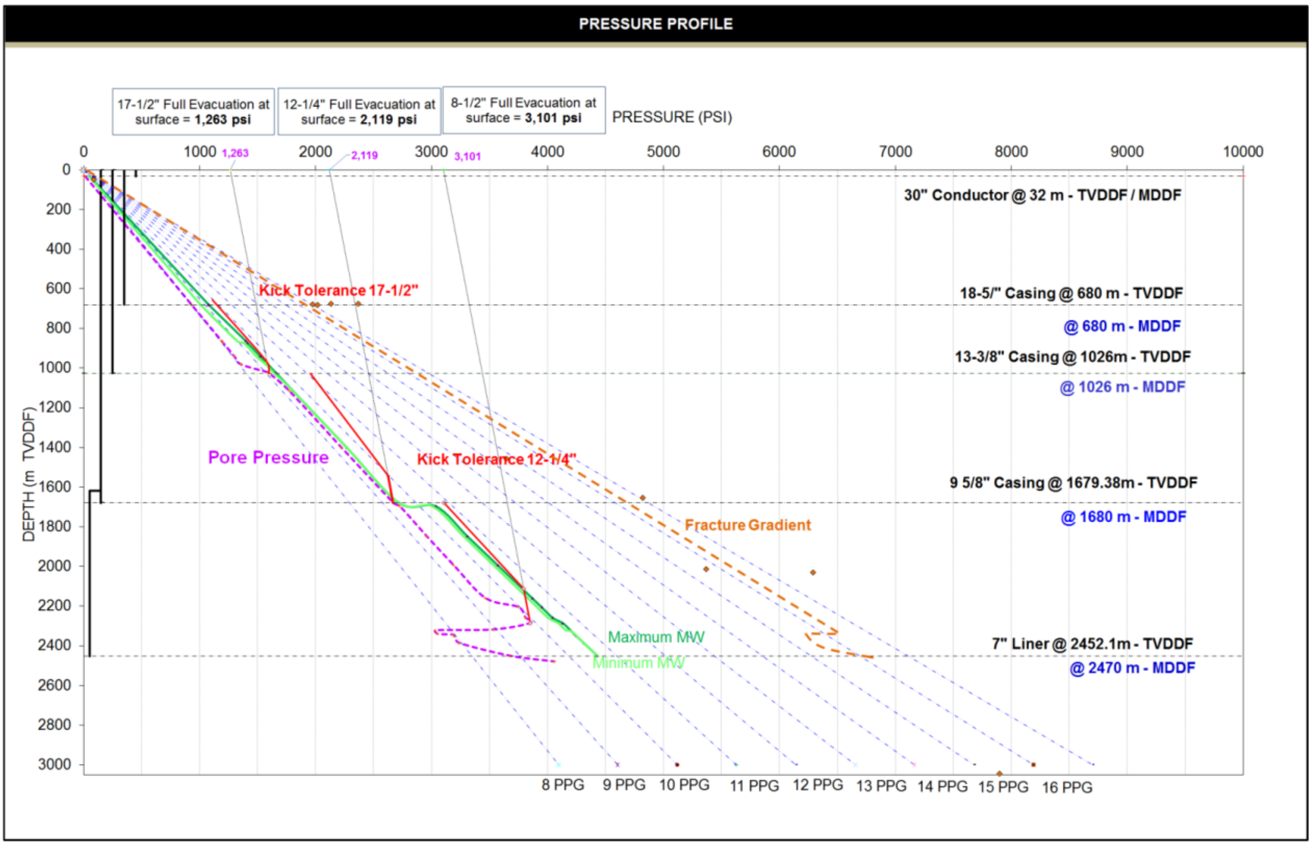

Fig. 4 Pore pressure gradient and fracture gradient measurement for well J40

where ε_x: Tectonic strains in maximum horizontal stress, ε_y: Tectonic strains in minimum horizontal stress, σ_H: maximum principal stresses, σ_h: minimum principal stresses, α : Biot's coefficient ($\alpha = 1$, conventionally)

II. Results and Discussion

The pore pressure was estimated using Eaton method and validated using measurement pore pressure (MDT), as shown in Fig. 2. The MAPE was 4% using the sonic velocity approach. Then, the fracture pressure was estimated using the poroelastic model, as shown in Fig. 3. The fracture pressure results were fully consistent with the actual drilling report and drilling events, as shown in Fig. 4. The fracture gradient was about 16.2 ppg at Tanuma formation and then decreased to 15 ppg at Mishrif formation (depletion zones).

III. Conclusion

This study aims to predict the fracture pressure of a depleted reservoir. Therefore, the pore pressure was validated using pore pressure measurements (MDT) and then we predicted fracture pressure. The fracture pressure was matched with the measurement of fracture pressure. Thus, the fracture gradient is about 16.2 ppg at Tanuma formation and then decreased to 15 ppg at Mishrif formation (depletion zones). Therefore, future drilling wells can depend on this model's results, leading to reduced drilling problems and non-productive time.

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