Introduction

Accurate pore pressure prediction is an essential step in well planning and drilling to ensure the optimal well path design, mud weight and suitable equipment are considered during drilling. Unexpected changes in pore pressure may increase all risks related to drilling operation. Understanding and modeling pore pressure could mitigate hazards by avoiding overpressure zones and ensuring wellbore integrity while drilling. The main idea behind this study is to use pore pressure gradient model as an effective tool for investigating the geomechanical reservoir compartmentalization in Mishrif carbonate reservoir from an oil field located in Persian Gulf.

Geological setting

The studied oil field evolved during the late Permian Neo-Tethys I stage and the Jurassic Neo-Tethys II stage. Throughout the Jurassic and Cretaceous, the Arabian platform in its equatorial position was attached to the northern part of Africa (Smith et al., 1994). Due to this geographic position, widespread Mesozoic carbonate platforms covered the NE edge of the Arabian plate which included the present day Persian Gulf to its SE (Sharp et al., 2010). From the structural point of view, the field of study is a four-way, elongate structural closure. Most of the faults, intersecting the field strike NNE-SSW and some strike WNW-ESE. Pressure and log data suggest significant lateral compartmentalization, particularly in Mishrif reservoir, most of which is believed to be caused by intense diagenesis and cementation along some of the geologically older faults.

Available data

The available data set for this study consists of a 3D post stack seismic cube, eight wells with full log dataset and check shots, as well as several interpreted surfaces such as Ilam, Gurpi, Pabdeh and Mishrif. These data are used to set up 3D seismic pore pressure model.

Methods

To create three-dimensional pore pressure gradient model for the studied oil field, the following steps are considered:

Optimal time-depth relation (TDR) determination

The optimal TDR is an essential log for correlating geological data with seismic reflection profile and conversion of seismic time to depth. To determine an optimal time-depth relation, a synthetic seismogram is made by convolving a Ricker wavelet with reflection coefficient log at well locations. As shown in Figure 1, time shifting is then implemented to get the best correlation between synthetic seismogram and real seismic data that will result in obtaining an optimal time-depth relation (TDR) for each well.

Wavelet extraction

The seismic wavelet links seismic data to stratigraphy and rock properties of the subsurface. The Extended Roy White method is used to extract a suitable wavelet from 3D seismic data based on the concept of predictability (White and Simm, 2003). The predictability in frequency domain can be defined as bellow:

\[ P = \frac{C_{rs}(f)C_{sr}(f)}{C_{rr}(f)C_{ss}(f)} \]  

(1)

where P is predictability, \( C_{rs}(f) \) and \( C_{sr}(f) \) are cross-correlation of the reflectivity series and the seismic trace, respectively. Also, \( C_{rr}(f) \) and \( C_{ss}(f) \) are autocorrelation of the reflectivity series and seismic trace, respectively.
Low frequency acoustic impedance and density model building

To recover low frequency data (between 0 to 8 Hz) that might be lost during seismic processing by band-pass filtering, a low frequency acoustic impedance model plus a density cube is generated.

Figure 1 An optimal time-depth relationship (TDR) log generated through well tie analysis for well No. 4.

High-definition acoustic impedance cube generation

The generated low frequency acoustic impedance model is used to invert a full frequency range model by simultaneous seismic inversion algorithm. Creating such model can extensively increase the data coverage in the field of study. The inverted model is then used for extracting density cube and a high definition velocity model.

Figure 2 Extracted wavelet of the seismic cube.
1D pore pressure modeling

In this study, Eaton’s method is used for pore pressure estimation at well location. The method considers disequilibrium compaction and defines a direct transformation from velocity to pore pressure as follows (Eaton, 1975):

\[
\frac{\sigma_{eff,o}}{\sigma_{eff,n}} = \left(\frac{V_{po}}{V_{pn}}\right)^3
\]

(2)

where \(\sigma_{eff,o}\) is the predicted effective stress, \(\sigma_{eff,n}\) is the normal or hydrostatic effective stress, \(V_{po}\) is the observed P-wave velocity, and \(V_{pn}\) is the expected P-wave velocity at hydrostatic pore pressure.

In this study, another version of Eaton’s equation is used which directly provides pore pressure (equation 3):

\[
P_P = P_{ob} - (P_{ob} - P_{hyd})\left(\frac{V_{po}}{V_{pn}}\right)^3
\]

(3)

where \(P_{ob}\) is the pore pressure of the formation measured from log and \(P_{hyd}\) is the hydrostatic pore pressure. Using available data the equation is calibrated and employed to generate pore pressure log at well location.

3D seismic pore pressure modeling

As shown in Figure 3, applying calibrated Eaton’s equation on obtained velocity model generated a 3D pore pressure gradient model that can be used for whole area of the studied field. The validity of the obtained model is evaluated by modular dynamic tester (MDT) and drill stem test (DST) data.

![Figure 3 3D model of pore pressure gradient in the field of study.](image)

Discussion

Figure 4a shows a horizontal cross section on obtained 3D pore pressure model. As it is seen, based on pore pressure gradient values at least one sharp discontinuity can be identified that might reflect the presence of two different geomechanical zones in the region. Geological evidences confirm one old major fault crossing central part of Mishrif reservoir at this region (Figure 4b). Further investigations
reveal that the formation under study can be divided into two segments based on fluid contact/pressure data and geomechanical attributes.

**Figure 4.** A horizontal cross section on obtained 3D pore pressure model: A sharp discontinuity can be identified at central part of the section (a) that is in good agreement with old major fault (b).

Table 1 summarizes a detailed information about fluid contact at each identified zone.

**Table 1 GOC and OWC depth from mean sea level in Mishrif reservoir.**

<table>
<thead>
<tr>
<th>Mishrif Block/Zone</th>
<th>Zone A</th>
<th>Zone B</th>
</tr>
</thead>
<tbody>
<tr>
<td>GOC (m)</td>
<td>2781</td>
<td>2786</td>
</tr>
<tr>
<td>OWC (m)</td>
<td>2896</td>
<td>2900.5</td>
</tr>
</tbody>
</table>

**Conclusion**

Pore pressure prediction is a key necessity for successful drilling operation during exploration phase. In this study, an application of pore pressure modeling in reservoir geomechanical compartmentalization using data related to an oil field located in Persian Gulf is presented. To this end, a 3D velocity-based pore pressure model is generated for the studied reservoir and evaluated by modular dynamic tester (MDT) and drill stem test (DST) data. Results confirm that from geomechanical point of view, pore pressure can be used as an effective tool for compartmentalization of the reservoir under study into two different zones.

**References**


