Multiscale core-seismic analysis for karst characterisation of MX field, Central Luconia Province, Offshore Sarawak, Malaysia.

Introduction

In the Oil and Gas industry, carbonate reservoirs play an important role in holding most of the world’s hydrocarbon reserves. They account for 60% of the world’s oil and 40% of the world’s gas reserves. Nonetheless, carbonate reservoirs continue to pose challenges due to their multi-scale heterogeneities from depositional and post-depositional physical and chemical diagenetic processes that alter the rock’s structure, affecting its porosity and permeability. The Middle Miocene Central Luconia province located in offshore Sarawak has received much attention since its discovery by Shell as one of Malaysia’s largest gas fields in 1971. Over 250 carbonate build-ups occur offshore in the Central Luconia province. Around 60 platforms have been drilled and almost every field has encountered indications for high permeability zones likely associated with karst such as mud losses and drill bit drops during drilling activities. Some fields were left abandoned due to the mud losses that could not be controlled. Geometries, distribution, and the dimension of karst in Central Luconia fields remain unknown. They have not been studied in detail. Due to the current lack of understanding of karst morphology, a regional integrated study has been initiated in this research to establish a systematic multidisciplinary approach and acquire detailed geological understanding from one-dimensional to three-dimensional aspects. The heterogeneity of carbonate reservoirs arises from the differences of porosity/permeability, which are marked, by diagenetic overprint and/or meteoric dissolution resulting in Reservoir Rock Types (RRTs) with different petrophysical properties (Jimenez et al., 2020).

MX field is located in the central region of Central Luconia province approximately 175km north-northwest from Bintulu (Figure 1) has been chosen in this research. MX field was discovered in 1969 and is known as the largest gas field in Central Luconia with a GIIP of 6 to 7 TCF over an area of 90.5 km² (Koster et al., 2008).

Methodology and Result

This research involves multiscale data analysis from 1-dimension to 3-dimension data. This research involves the analysis of drilling data, core, thin sections, which were correlated with well logs response in specific depth intervals, and seismic attributes interpretation (Figure 1). Baomin et al., 2009 has proposed on major identification of karst geomorphology specifically for paleokarst as according to this author all the logging, testing, and seismic response characteristics are the most critical marks for the identification of paleokarst. Data use in this research is MX drilling data extracted from drilling reports, MX-2 and MX-3 total of 300m core description & thin section analysis, two wireline wells; MX-2 and MX-3, and high quality three-dimensional seismic cube of an MX platform.

![Figure 1](image_url)

**Figure 1**  
Methodology and workflow carried out in this research
A. 1-Dimension; Drilling parameters, core description, and thin section analysis.

An analysis of drilling and mud losses data was analysed on 45 build-ups and 68 wells of Central Luconia for this research. This data is important to give a preliminary insight into regional patterns of karst distributions in Central Luocnia province. In MX platform, potential karst interval depth with perforated intervals and total mud losses reported in MX-2 well and MX-3 well has been captured to calibrate with well logs and seismic data (Table 1).

Table 1  
*Drilling parameters analysis shows possible karst depth in MX-2 and MX-3 as below.*

<table>
<thead>
<tr>
<th>Well</th>
<th>Depth (ft)</th>
<th>Status</th>
</tr>
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<tbody>
<tr>
<td>MX-2</td>
<td>X451- X455</td>
<td>Perforated Interval</td>
</tr>
<tr>
<td>MX-3</td>
<td>X282</td>
<td>Total mud losses</td>
</tr>
</tbody>
</table>

According to Epting (1980), chalkified texture in carbonate rocks is formed from the leaching of skeletal grains and mid-sized crystal dissolution due to a carbonate build-up emergent when there is a considerable fall in sea level. MX-2 and MX-3 core samples have been described to highlight the sedimentological pattern and depositional environment in MX build up. Identification of its exposure and flooding surface intervals are to be correlated with the diagenetic interpretations. Observation from core analysis shows 50m of chalkified interval and rubble discovered and were recorded as possible karst interval. Thin section analysis shows some dissolution process with mouldic porosity in both wells.

B. 2D Dimension; Well logs correlation and seismic interpretation

Zhao et al. (2014) use wireline logs, core, thin section, seismic, and hydrocarbon production data to analyse karst reservoirs in the Tarim Basin of western China. In this research, karst interval depths were recorded from drilling parameters and core analysis. The karst depth interval is then correlated with porosity and density logs to recognize the different architecture element of karst in well logs response (Figure 2).

![Figure 2](image)

*Figure 2*  
Low density and high porosity observed in well logs response observed in MX-2 and MX-3 chalkified intervals. Thin section photos show mouldic porosity and rubble/chalky core observed in both wells also at the chalkified intervals.
C. 3D-Dimension; Seismic Attributes analysis

Seismic interpretation is the key to see the geometric and behaviour of karst in the specific field and area. Koster et al., (2008). In this work seismic interpretation has been using a combination of seismic attributes (spectral decomposition, acoustic impedance, etc.) and structural oriented semblance to deploy karst geometries. Karst pattern could be recognized as ‘Bright-dots’ and ‘pair-of-beads’ in detail seismic interpretation (Zheng et. al, 2011). Figure 3 shows MX-2 well 50m chalkified core correlated with seismic which falls on the dendritic patterns.

![Figure 3](image)

Figure 3  (A) Chalkified intervals on MX-2 correlated with MX seismic. (B) MX-2 well with chalkified intervals observed on seismic time slice falls on the dendritic patters, which were believed as karst.

Seismic amplitudes enhance the seismic base on the amplitude signal as the basis of their computation. Three attributes have been deployed on MX seismic to enhance the seismic for characterization of karst. The analysis was done on seismic amplitude, RMS amplitudes, spectral decomposition, and acoustic impedance attributes. Seismic amplitudes interpretation on MX seismic shows a bright dark of negative amplitudes on the chalkified intervals as probably possible karst features. The RMS Amplitude attribute represents the measure of reflectivity and allows the detection of amplitudes variation mainly for channels and bright spots. Interpretation of chalkified intervals shows high RMS amplitude variation along with the chalkified intervals as shown in Table 2.

The Spectral decomposition attributes highlight the geological features by creation of seismic trace-based attributes. The main purpose of this tool is to decompose the seismic signal into different energies corresponding to each frequency in the volume to create a spectrogram. In this research, the spectral decomposition using the wavelet transform Morlet style and frequency of 60Hz was applied to the seismic. The result shows a value of 600-900 spectral value along with the chalkified intervals. Relative acoustic impedance enhances the seismic by minimizing the noise and multiple contaminations on the seismic. These attributes can be related to high porosity contrast and can assist to indicate possible sequence boundaries, discontinuities, and unconformities surfaces. The results show a contrast of high acoustic impedance values that appeared in the chalkified area (Table 2).
Table 2: Multiattributes analysis of MX seismic correlated with MX-2 well 50m chalkified intervals.

<table>
<thead>
<tr>
<th>Seismic Attributes</th>
<th>Seismic signal</th>
<th>Seismic Patterns</th>
</tr>
</thead>
<tbody>
<tr>
<td>Amplitude</td>
<td>Bright ‘black’ negative amplitude along the chalkified interval.</td>
<td></td>
</tr>
<tr>
<td>RMS Amplitude</td>
<td>High RMS Amplitude along the chalkified interval.</td>
<td></td>
</tr>
<tr>
<td>Spectral Decomposition</td>
<td>600-900 spectral value scattered along the chalkified interval.</td>
<td></td>
</tr>
<tr>
<td>Acoustic Impedance</td>
<td>High acoustic impedance along the chalkified interval.</td>
<td></td>
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</table>

Conclusions

- The multiscale seismic analysis is important to have a better understanding of the geological karst features. In this study, core samples act as a geological control for the seismic multi attributes analysis.
- The result shows that RMS amplitudes, spectral decomposition, and Acoustic impedance attributes are used to highlight karst features on seismic.
- Karst characterization is important for well development planning in order to reduce the risk of mud loss drilling hazards.

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References


