Optimizing seismic attribute to unlock facies change at Eocene-Oligocene fluvial deltaic sandstones of Pematang formation: Case study the “M” field, Central Sumatera Basin

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Abstract. The “M” Field is in the Northern most of the Oil Prolific Central Sumatera Basin at Barumun sub-Basin. The field was originally discovered by drilling M-1 well. This well became the first well proving up the presence of hydrocarbon at Pematang Formation in this region. Pematang Formation is unique because it can serve as reservoir rock as well as source rock. The MX reservoir is part of the Pematang Formation. Based on the last drilling data it flows 200 barrels of oil. However, the sand of this reservoir disappeared at the other well, even though the location is not too far. This paper addresses the strategic approaches to interpret facies change using Acoustic Impedance (AI) Inversion. The facies change is detected using AI. It is a challenging reservoir since its individual thickness is below seismic resolution. Geologically the MX reservoir was deposited under fluvial deltaic lacustrine environment. The result shows that M-2 is in the delta front facies while the M-1 is in the pro-delta facies. Even though only 1.6 km distance between M-2 and M-1 well cause significant facies change. Result of this study is useful for determining development drilling program in this field.

Keywords: Pematang reservoir, acoustic impedance, Central Sumatera Basin

1. Introduction

The “M” Field is in the Northern most of the Oil Prolific Central Sumatera Basin at Barumun sub-Basin (figure 1). The field was originally discovered by drilling the M-1 well. This well penetrated the Pematang Formation with TD’s 9000 ft MD and encountered oil. Two DSTs were performed but not at MX reservoir. Next, the M-2 well was drilled and flowed 200 barrels of oil from the MX reservoir. Figure 2 shows the position of M-2 and M-1 well overlay on the seismic section. Based on this seismic data, the MX reservoir is bounded by two seismic horizons (top is purple and bottom is blue) and the sand layers continue from the M-2 until the M-1. The question is how big we believe that we will find oil at the M-1 well at MX reservoir level? The objective of the study is to unlock facies change using AI seismic attribute including predicting oil distribution.

The MX reservoir consists of multi stack sands and shale dominated facies. The individual sand thickness varies from 10-23 feet (figure 3). The individual sand thickness is far below seismic resolution (40 m with seismic frequency 15 Hz). The gross sand thickness is 196 feet.
analysis shows coarsening upward grain size. It means the reservoir was deposited in deltaic environment. Pematang Formation regionally was deposited under fluvial-deltaic-lacustrine. The objective of the study was to unlock facies change between well M-2 and M-1. Then, the result will be used as an input for field development.

1.1. Geology
Study area is in the Barumun Sub-Basin, Central Sumatera Basin. The exploration target is sandstone of Pematang Formation. The brown shale unit of Pematang Formation is the source rock for oil in this basin. In Barumun Sub-Basin, Pematang fills some depositional environment such as alluvial, deltaic, marginal lacustrine, alluvial fan, open lacustrine and fluvial (figure 4a) [1].

![Figure 1. Location of the M Field (red circle).](image1)

![Figure 2. Seismic section with two exploration wells, M-1 and M-2 across the “M” Field.](image2)
Pematang Formation is grouped into three namely the Lower red beds (lower part), the Brown shale (middle) and the Upper red beds (the upper part) [2]. M-1 and M-2 well have penetrated the upper section of the Pematang with some the Brown shale (figure 4b) [1]. The lowest formation in the Central Sumatera Basin is the Pematang Formation where it believed as source rock as well as reservoir rock [1]. It has total organic carbon (TOC) more than 2 % of TOC and high Ro.

1.2. Theory

1.2.1. Acoustic impedance (AI). Acoustic Impedance is formulated as compression wave velocity multiply by rock density. Its unit depends on those two parameters. AI value provides subsurface geology more detail than the normal seismic section [3]. In hydrocarbon exploration, it is used as tool for reservoir characterization to determine distribution of reservoir property [4]. In hydrocarbon bearing porous reservoir always shows low AI value, meaning the reservoir rock has good porosity and permeability. Another benefit of AI is used to guide better seismic interpretation or to refine the existing interpretation [5].

1.2.2. AI model based seismic inversion. In geophysics, there are many ways to produce impedance using seismic data. One of them is Model Based Seismic Inversion (figure 5) [5, 6]. Below is the procedure to generate AI model. To get the final AI with Model Based Inversion is by updating predicted AI value hence the difference between synthetic seismic with its real one is small/ high correlation [3, 6].

2. Data and methodology
The study used several data such as small cube of 3D seismic data, two exploration wells and two seismic horizons for the MX reservoir. Figure 6 shown illustrates the procedures implemented to perform the study.
Figure 4. (a) Tectonic condition and depositional environment, the Barumun Sub Basin, and (b) Stratigraphy of the Central Sumatera Basin.

Figure 5. Acoustic Impedance (AI) model based seismic inversion.

Figure 6. Study workflow
3. Results and discussion

3.1. Electrofacies analysis
Electrofacies analysis at the M-2 and M-1 well highlights that MX reservoir almost disappears at M-1 (figure 7). Look sand layers inside black circle for both two wells. At M-2 sands are many vice versa at M-1. In other meaning, geologically it looks there is facies change although it is close. This real condition caused the previous block operator did not performed well test at this well. It will be evaluated detail if using seismic data as an input.

3.2. Seismic interpretation
Seismic interpretation produces some faults and two seismic horizons. These horizons are used as input for seismic inversion and time structure map. Based on the analysis, the M Field is segmented by some major faults which direct NE-SE. The field is tilted to west where it is the deepest part. To the North, the reservoir outcropped due to local uplift tectonic. figure 8 and figure 9 is the result of the interpretation.

![Figure 7](image1.png)

**Figure 7.** The “M” field well correlation. Based on electro facies analysis M-2 well has more sand layers than at M-1. The distance is 1.6 km.

![Figure 8](image2.png)

**Figure 8.** Seismic interpretation at Inline 445.
3.3. Cross plot analysis
Reservoir zone defined using GR cut-off below 100 GAPI (red polygon). The reservoir AI value is 9000-10000 m/s*g/cc. This value still overlaps with its shales (figure 10).

3.4. Integrated interpretation
Based on AI attribute, we see at figure 11 and figure 12. M-2 well (delta front) is located at different facies than at M-1 well (pro-delta). Some parts of delta front were outcropped resulting in these parts eroded. Previous well interpretation supports that these two wells are located under delta system (coal seams from mud log indicating swampy area/delta).

AI attribute has successfully unlocked the facies change at MX Reservoir between those two wells. At the same time, we predict that oil distribution related to blue AI color in range 9000–10000 (m/s*g/cc). the oil disappears at M-1 well as AI value is different (high AI value, purple color). The success of AI method can be applied to the other basins around the world.
4. Conclusion
Acoustic impedance (AI) attribute can be successful tool to unlock the facies change at MX reservoir, the M Field. M-2 well is located in the delta front facies while the M-1 is at pro-delta facies. This proves that why sandstones at M-1 is less than at M-2 because M-1 is in the distal area (more shale,
fine grain area). In order to get better result for further drilling location, it is strongly recommended to perform other seismic attributes such as Poisson impedance (PI). Theoretically PI can distinguish tight sands from shale lithology.

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