Seismic reservoir characterization of gas-sand deposits in the Kutei basin, Indonesia

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Abstract. Kutei Basin has the second largest hydrocarbon reserve in Indonesia. In addition to the Miocene inversion related structural traps, slope-fan and channel stratigraphic traps are also important traps in this basin. To guide stratigraphic traps explorations in the basin, the seismic stratigraphy, attributes, and AI inversion methods are integrated to identify and map the reservoir seismic facies, porosity, and pore-fluid. Well data indicates that the studied reservoirs are filled by gas. Seismic data shows that there are two main gas-sand reservoirs corresponding to strong amplitude anomaly. Seismic stratigraphy analysis, guided by seismic attributes, shows that these gas-sand reservoirs were deposited in the channel and local fan facies. The AI inversion is applied to identify and map the porosity and pore-fluid of these two sand reservoirs. Future well locations are identified by integrating the facies, porosity, and pore-fluid maps.

1. Introduction
Kutai Basin, which lied in East Kalimantan – Indonesia (Figure 1), is the country’s second largest hydrocarbon basin with oil reserves of 2.47 MMBO and 28.1 TCF of gas [1]. The basin has been dominated by deltaic deposition during the Neogene, but carbonate buildups are also common [2]. During the late Pleistocene, the channel-levee and incised valleys/canyons were developed on slopes, while downslope of the slope the strata are dominated by mass-transport complexes [3]. The study in [3] shows that seismic inversion can be used to identify porous and gas-filled sand reservoirs but only for thick reservoirs close to or above tuning thickness, while for the thin reservoirs, seismic amplitude is more reliable for seismic reservoir characterization.

The most instrumental hydrocarbon traps in the basin are structural traps located mainly in the south-western part of the study area and is related to the Miocene inversion (Figure 1), while the stratigraphic traps in the north-eastern part of the study area (Figure 1) are more difficult to be identified as the potential reservoirs are often associate with thin layers. This paper discusses the integration of seismic stratigraphy, attributes, and AI inversion methods to characterize the gas-sand reservoirs which stratigraphically trapped in the north-eastern part of the study area. The main reservoir parameters to be characterized are depositional facies, porosity, and pore-fluid. The results can be used to guide the exploration of stratigraphic traps in the study area.

The selection of appropriate seismic methods is the main key for successful hydrocarbon reservoirs characterization using integrated seismic data. The study in [4] discussed the application of seismic
attributes to map channel deposits in Melandong, NW Java basin area. The study in [5] proposed the application of neural-network based attributes analysis to map the fluvio-deltaic facies for supporting water-flood program. Meanwhile, the integration of amplitude and complex seismic attributes were used to assist exploration well program in the Talang Akar channel deposits in SW Betara field, Sumatra [6]. The study in [7] emphasizes the importance of seismic anisotropy analysis to guide the channel facies characterization in south Sumatra basin, Indonesia. For exploration area with no well data, there are also several possibilities on seismic attributes integration to identify rocks facies and physical properties as discussed in [5]. As a common guidance, study in [6] discussed the general seismic interpretation workflow for interpreting various reservoirs in Indonesia.

2. Data and Methods
In this study, the main data used are the 3D post stack time migration seismic and 5 wells data as shown in Figure 1b. In the studied interval, the 5 wells discovered gas only, while oil is discovered in the deeper sand intervals. The combination of seismic stratigraphy, RMS amplitude and variance attributes is used to deduce the depositional facies of the gas-sand reservoirs. Typical seismic expression of the gas-sand reservoirs in the study area is shown in Figure 2. The shallower reservoir associates with discontinuous reflectors and mounded external shape, while the deeper one has continuous reflectors and wedge shape. Figure 3 displays the cross-plot between well’s AI and total porosity. The RMS amplitude maps in Figure 4 shows that both reservoirs are reflected by high amplitude anomalies, but the shallower reservoir has a wider and lobate geometry, in contrast with the narrower and elongate geometry of the deeper reservoir. The combination of typical seismic stratigraphy expression and RMS amplitude maps strongly suggests that the upper reservoir associates with local-fan facies, while the lower-one with the channel-fill facies.

To verify the facies type and their porosities, Acoustic Impedance (AI) inversion was processed using five (5) wells. The related AI maps of both reservoirs overlain to their depositional surface’s where AI map shown in Figure 5. The variance maps in Figure 6 shows a more detail lateral geometry and interpreted facies of both reservoirs. It can be concluded that the shallower reservoir is related with slope-fan facies, while the deeper reservoir with channel-fill facies. By using the cross-plot of total porosity, AI and water saturation as shown in Figure 6, then it’s possible to identify the porous and gas-filled sands in both reservoirs. From the cross-plot it can be seen also that the ranges of porosity and water-saturation in the reservoirs are between 15-35% and 30-60% respectively.
Figure 1. (a) A sample of SW-NE seismic section in the study area showing structural high related to the Miocene inversion, (b) TWT map of the studied interval which showing also the 5 wells locations used in the study. Contours in the TWT map is msec; blueish and reddish colors are respectively related to shallower and deeper contours. Inset map in Figure b shows the study area location.
Figure 2. A sample of seismic section showing typical seismic expression of the shallower and deeper gas-sand reservoirs: shallower reservoir associates with local-fan deposit, while the deeper one related with channel-fill deposit. The TWT map of the red horizon is given in Figure 1b.

Figure 3. The cross-plot of well’s AI versus total porosity with water saturation as the colour legends. The shallower slope-fan and deeper channel reservoirs intervals are integrated in this cross-plot.
Figure 4. The RMS amplitude maps showing the lateral geometry of the gas-sand reservoirs in the (a) shallower-fan deposit between red and black horizons in Figure 2, and (b) deeper-channel fill deposit between black and blue horizons in Figure 2.

Figure 5. The Acoustic Impedance (AI) maps showing the lateral geometry of the gas-sand reservoirs in the (a) shallower-fan deposit between red and black horizons in Figure 2, and (b) deeper-channel fill deposit between black and blue horizons in Figure 2.
Figure 6. The variance maps showing a more detail lateral geometry and interpreted facies of the (a) shallower-fan deposit between red and black horizons in Figure 2, and (b) deeper-channel fill deposit between black and blue horizons in Figure 2.

3. Conclusions

Previous studies suggest that thick gas-sands in the Kutei basin can be identified by using pre-stack elastic impedance inversion. This paper shows that by using the integration of acoustic impedance, RMS amplitude and variance attributes, the facies containing the thick and thin gas-sands can be identified and mapped. There are two gas-sand reservoirs identified in the studied area. Both reservoirs are reflected by low AI anomalies, but the shallower reservoir was deposited in a higher AI scarp slope environment, in contrast with the deeper reservoir which deposited on much gentler slope and lower AI environment with narrower and elongate geometry. The variance attribute shows a more detail lateral geometry and interpreted facies of both reservoirs. It can be concluded that the shallower reservoir is related with local slope-fan facies, while the deeper reservoir with channel-fill facies. The total porosity and water saturation of both reservoirs can be mapped using AI inversion.

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