The determination of prospective reservoirs in the slope environment of the Tarakan Basin (Indonesia) by using sequence stratigraphy, rock physics and AI inversion

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Abstract. Prospective reservoirs in the Tarakan Basin are mostly deposited in the Middle Miocene to Pliocene and related to the change of depositional environment from transgressive to regressive sedimentary environment. Log sequence stratigraphic analysis in well AST 1 shows that transgressive and lowstand system tracts were deposited during the study area. Hashin-Shtrikman method is used in the rock physics analysis to identify the relative rock hardness and integrated with gamma ray log, NPHI, and resistivity data analysis. The result show that potential reservoir exist at the depth range of 7650-7725 feet and associates with low velocity, low gamma ray, low NPHI, high resistivity values. The potential reservoir interval was deposited under low stand system tract of slope depositional environment. The acoustic impedance (AI) map shows that the low AI's are mostly located in the northwestern part of the study area.

1. Introduction
The Tarakan Basin is geographically located in the north of the Mahakam Basin (Figure 1). The regional stratigraphy of the Tarakan Basin is shown in Figure 2. In the Middle to Late Miocene, the Meliat, Kabul and Santul formations were deposited. Meliat Formation is composed mainly of quartz sandstones interspersed with conglomerate shale and sandstones. Tabul Formation is dominated by shales with alternating sandstone and silt. Santul Formation comprises thicker sandstone intercalation with claystone and streak of lignites. In the Late Miocene to Pliocene, the delta system in the Tarakan Formation was deposited and composed mainly of sandstones with a cross-sectional structure and conglomerate sandstones, alternating shale, and coal. In the Pliocene to Recent, there is a reactivation of transform movements along the horizontal faults through the Makassar Strait which began in the Upper Pliocene period and continues until now.

Prospective reservoirs in the Tarakan Basin are mostly deposited in the Middle Miocene to Pliocene and related to the change of depositional environment from transgressive to regressive sedimentary environment [1]. This study integrates sequence stratigraphy, rock physics and bandlimited acoustic impedance (AI) inversion to identify Middle Miocene to Pliocene prospective reservoirs in the slope environment of the Tarakan Basin.
2. Data and Method

The AST-1 well is used as the main data for the sequence stratigraphy and rock physics analysis. The well penetrates the Pleistocene to Late Miocene rock interval deposited under stable regressive cycle in slope depositional environment.

Sequence stratigraphy analysis in the Well AST-1 found that there are 4 depositional cycles in the studied interval. From the oldest to the youngest, they are the slope fan of the low-stand system tract (LST), the low stand wedge of the LST, the transgressive system tract (TST), and finally another LSW LST. The LST slope fan is deposited when the relative sea level rises slowly and sediment deposition
shifting to the land. In the study area, the LST slope fan is equivalent to Tabul Formation and characterized by fining upward pattern in the gamma-ray log (Figure 3).

![Figure 3](image)

**Figure 3.** Stratigraphic sequence analysis of gamma ray log data

The low stand wedge (LSW) prograding complex is formed when sea level is relatively stillstand and the sediments were deposited rapidly. In the study area, the LSW is equivalent to the lower-middle Santul Formation. In the gamma-ray log, this system tract is indicated by upward pattern of grain coarsening related to the decrease in the gamma ray value (Figure 3). The TST cycle is deposited when there is a rapid rise of the relative sea and sedimentation that cannot catch-up the sea level rises. The cycle usually ends at the maximum flooding surface (MFS), so that the sediment grains will show fining upward pattern. In the study area, the TST cycle is represented by the upper Santul Formation (Figure 3). The Santul formation is upper bounded by a sequence boundary indicating sedimentation hiatus after the cycle reaches the MFS. Another LSW prograding complex, equivalent to the Tarakan Formation with Plio-Pleistocene in age, was deposited above the sequence boundary.

Rock physics analysis result by using the Hashin-Shtrikman boundary method is shown in Figure 4. The Hashin-Shtrikman method is one of the best approaches to predict the upper and lower limits of the effective elastic modulus of a medium [7]. In the cross plot between Vp data versus porosity, when the data points clustered to the lower bound line, they are interpreted as soft and deformable lithology and vice versa. If the data points are distributed to the right of the critical porosity line and attached to the lower bound line, the data is interpreted as suspension lithology. By using this principle, the prospective reservoir zone is interpreted as the interval with Vp < 2300 m/s and porosity >20% (marked by yellow zone in Figure 4).
The log data analysis (Figure 5) is used to narrow down the hydrocarbon reservoir prospect zone and to increase the validity confidence on the prospective zone determination. The yellow zone in the DT (Vp) and the density log (RHOZ) in Figure 5 is equivalent to the prospective reservoir interpreted in Figure 4. The prospective zone of this reservoir is lied in the LSW LST prograding complex cycle and marked by yellow interval bounded by dashed red. The log-based sequence stratigraphy analysis is ideally combined with the seismic-based and anisotropy analysis as discussed in [2], [3], [4], [5] and [6]. However, due to the data limitation, in this study the analysis is done by using log data only.
Figure 5. Prospective reservoir zone determination in AST-1 by using log data

Figure 6 is a bandlimited AI section passing thru the AST-1. In this section, the prospective reservoir is marked by green area inside blue line. It has acoustic impedance values ranging from 14000 ((ft/s) * (gr/cc)) to about 10000 ((ft/s) * (gr/cc)). On the related AI map in Figure 7, the prospective reservoir around the AST-1 well is shown low AI area bounded by pink line in the northwestern part of the map. Another prospective zone can be identified in the southwest part of the map and marked as low AI area bounded by blue.

Figure 6. AI Seismic Section Inline 1550 passing thru AST-1
3. Conclusion
The integration of sequence stratigraphy, rock physics and log data analysis show that the prospective reservoir interval in AST-1 well is located at a depth of 7650–7725 feet. It is characterized by low velocity, low gamma ray, low NPHI, low density and high resistivity. The prospective interval was deposited in the Late Miocene slope setting as the LSW prograding complex equivalent with bottom to middle interval of Santul Formation. The AI map shows that the distribution of the prospective zone is around the AST-1 and in the northwestern part of the study area.

![AI horizon slice map showing prospective areas](image)

**Figure 7.** AI horizon slice map showing prospective areas

References
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