Integration of sequence stratigraphy, rock physics and AI inversion to determine the prospective reservoir in the shelf environment of the Tarakan Basin, Indonesia

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Abstract. The Tarakan Basin is one hydrocarbon basin in Indonesia with approximately 40 discoveries and more than 1000 MBOE reserves. This study discusses an approach to integrate the sequence stratigraphy, rock physics and acoustic impedance (AI) inversion analysis to determine the prospective reservoirs in the basin. PRG-1 well data is used in the sequence stratigraphy and rock physics analysis. The sequence stratigraphy analysis of PRG-1 shows that there are three system tracts: transgressive, low stand tract and high stand system tracts. The integration of sequence stratigraphy, rock physics and log data analysis show that the prospective reservoir interval in PRG-1 well is located at a depth of 4730-4780 feet. It is characterized by low gamma ray, low NPHI, low density and high resistivity. The prospective interval was deposited in early Pliocene as Tarakan Formation in the low stand system tract of shelf depositional environment. The AI map shows that the distribution of the prospective is around the PRG-1 and in the eastern part of the area.

1. Introduction
The Tarakan Basin is in East Kalimantan, Indonesia (Figure 1). It is a productive basin with approximately 40 discoveries and more than 1000 MBOE reserves [1]. The hydrocarbon in the Tarakan Basin is mostly discovered in the Middle to Late Miocene interval (Figure 2). During this era, the depositional facies vary from the proximal delta to deep sea. Shallow and continental marine facies also develop at local high in the south, east of the carbonate shelf. Super tidal found in the western and northern basins. Facies delta front of the Meliat Formation is composed of quartz sandstones interspersed with conglomerate shale and sandstones in several places. In the Bunyu and Tarakan Islands, the facies change to the delta front and prodelta. South of the Tarakan Basin, the entire clastic sequence was terminated by shallow marine limestone in the Late Miocene. The middle to late Miocene Tabul Formation is a delta complex that is graded to the east and is dominated by shale with alternating sandstone and silt. The Menumbar Formation, which is laterally equivalent, is composed of calcareous claystone, marl and limestone. In the northeastern part of the Tarakan sub-basin, Menumbar Bawah extends as a thick limestone layer which is equivalent to the Tabul Formation in the west of the Tarakan and Tidung Sub-basins. Delta front deposition during Middle to Late Miocene shifted southward in the Late Miocene to Early Pliocene period. The Sejau Formation delta deposit in the Tarakan is composed of sandstones with a cross-sectional structure and conglomerate sandstones, alternating shale and coal.
This study discusses an approach to integrate the sequence stratigraphy, rock physics and AI inversion to determine the Middle to Late Miocene prospective reservoirs deposited in the shelf environment of the Tarakan Basin.

![Figure 1. Location of the Tarakan Basin [1]](image)

![Figure 2. Stratigraphy of the Tarakan Basin [1]](image)

2. Data and Methods
For sequence stratigraphy and rock physics analysis, the PRG-1 well is used. PRG-1 is located on the Middle to Late Miocene shelf environment and contains Bunyu, Tarakan, Santul and Tabul formations. Based on the system tract analysis, PRG-1 well has 4 cycles of deposition, from the bottom to the top: the 1st transgressive system tract (TST), low stand system tract (LST), the 2nd TST and high stand system
tract (HST) (Figure 3). Tabul and Santul formations were deposited in the 1st TST cycle. Tarakan formation was deposited on the LST overlying the 1st TST. Above the LST, the 2nd TST cycle containing Bunyu formation was deposited.

The transgressive system tract occurs when the sea level rises, and the sediment deposition rate is smaller than the sea level rise. It is characterized by fining upward trend and upward increase of gamma ray values. The LST, is deposited when the sea level relatively falls, and the sedimentation rate is high. It is characterized by coarsening upward pattern where the gamma ray values decrease upwards. The HST is formed when the sea level is still standing, and the rate of the sediment is high. It is characterized by coarsening upward sequence and upward decrease of gamma ray value.

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.

Rock physics analysis was done by using the Voigt-Reuss bounding method [6] and the result is displayed in Figure 4. When the data distribution is closer to the Reuss lower bound line, the data point is interpreted as a softer and more deformable lithology and vice versa. The reservoir prospect zone is interpreted to have a low P wave velocity below 2.5 km/s and porosity above 20%. It is indicated by yellow zone in the Vp vs Porosity cross-plot in Figure 4. The cross-plot also suggests that PRG-1 well data distribution tends to be closer to the lower bound line.

3. Results

The rock physics result is used to guide the determination of reservoir interval in the log data analysis (Figure 5). In the log data, the reservoir zone is marked as an interval bounded by dashed red lines. It is characterized by a low gamma ray, low P wave velocity, high porosity, low density, low neutron porosity and high resistivity values. On the contrary, the interval bounded by dashed blue lines is not a reservoir zone because it has high neutron porosity value. The correlation with the system tract and stratigraphic sequence analysis shows that the reservoir interval is in the low stand wedge prograding complex of the LST cycle.

Figure 6 is an AI section crossing the PRG-1 well. It is derived from the model-based AI inversion. The reservoir interval is marked with a layer in green with the AI value of 17,000- 20,000 (ft/s) * (gr/cc). The related AI map of the reservoir level is shown in Figure 7. As the AI value is proportional to the density value, then by using the log analysis result, the distribution of the reservoir zone in the AI map can be identified. It is marked by areas with red line around the PRG-1. Using the same principle, another prospective zone with low AI is identified in the eastern part of the map.
Figure 3. Sequence stratigraphy analysis of PRG-1 well

Figure 4. Rock physics analysis to determine the prospective reservoir zone
Figure 5. PRG-1 Well log data analysis

Figure 6. AI section crossing the PRG-1 well.
4. Conclusions
The integration of sequence stratigraphy, rock physics and log data analysis show that the prospective reservoir interval in PRG-1 well is located at a depth of 4730-4780 feet. It is characterized by low velocity, low gamma ray, low NPHI, low density and high resistivity. The prospective interval is equivalent to the early Pliocene Tarakan Formation which deposited as LST in the shelf depositional environment. The AI map shows that the distribution of the prospective is around the PRG-1 and in the eastern part of the area.

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