Delineating prograding deposit in North Malay Basin via application of seismic attributes and wheeler transformation

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Summary

This study was carried out in the Late Oligocene to Early Miocene interval of the North Malay Basin offshore Peninsular Malaysia. This paper demonstrates an integrated interpretation of geological information from seismic mapping, attributes analysis and seismic sequence stratigraphy via wheeler transformation in assessing the prograding deposit within the top synrift of the area. The result of this study shows that alternative methodologies from semi-automated interpretation and Relative Geological Time (RGT) model to the application of Wheeler Transform are able to enhance the definition and delineation of prograding sequence within the top synrift of North Malay Basin. The combined approaches of refined interpretation of the seismic supplemented by generation of instantaneous phase and thinning attribute from RGT, have successfully mapped the strata terminationplus its associated thinning and thickening patterns. Together with other attributes, the clinoform outline within the interval were greatly enhanced which helps in extracting potential prospect. The overall results indicate a series of interesting stratigraphic/seismic geomorphological features representing the potential prospects (prograding sandy deposit?) that could add to the Yet-To-Find (YTF) resources candidates.

Introduction

Malay Basin is located offshore east of Peninsular Malaysia. The basin has undergone exploration and production since the last five decades with more than 181 oil and gas discoveries (Madon, 2021). Since the first discovery, more than 700 wells have been drilled in this matured basin. Nonetheless, an estimated total over 14.8 billion barrels of oil equivalent (bboe) of recoverable hydrocarbon resources have been discovered in the basin since 2014. According to Madon (2021), major structural plays of anticlinal features have been tested, thus further exploration towards stratigraphic plays are highly encouraged. This study focuses on remaining upside potential within the North Malay Basin (NMB) that comprise a central/basinal gas-rich area, flanked on both sides to the south by mixed oil and gas zones. Most of the oils occur in faulted traps and are prevalent on the eastern part of the NMB (Madon et al., 2004). Development study by Adnan et al., 2016 shows there is proven gas discovery atdeeper sections through the integration of geophysical application and well data, which subsequently prompted a study to evaluate the remaining potential within the NMB.

This study was carried out in the Late Oligocene to Early Miocene interval of the North Malay Basin offshore Peninsular Malaysia. This paper demonstrates an integrated interpretation of geological information from seismic mapping, attributes analysis and seismic sequence stratigraphy interpretation via wheeler transformation in assessing the prograding deposit within the top synrift of the studied area. The result of this study shows that these alternative methodologies from semi- automated interpretation and Relative Geological Time Model (RGT) to the application of Wheeler Transform are able to enhance the definition and delineation of prograding sequence within the top synrift. The combined approaches of refined interpretation on instantaneous phase volume and thinning attribute from RGT have successfully mapped the strata termination plus its associated thinning and thickening patterns. Together with other attributes, the clinoform outlines within the interval were greatly enhanced which helps in extracting geobodies. The overall results indicate a series of interesting stratigraphic/seismic geomorphological features representing the potential prospects (prograding sandy deposit?) that could add to the Yet-To-Find (YTF) resources candidates.

Methodology

High resolution three-dimensional seismic data of North Malay Basin is used for this study. The 3D seismic survey covered an area approximately 9, 204 km^2 of the northern area of the Malay Basin. The approach of this study started with semi-automated volume interpretation and Relative Geotime Model (RGT) introduced by PaleoScan™, focusing on a specific interval of interest. These processes were then continued with refined interpretation on 3D seismic data supplemented by generation of thinning and instantaneous phase attributes. Thinning and instantaneous phase seismic attributes were performed on the seismic volume to identify the strata termination and strata deposition. The approachwas then followed by strata slicing analysis, and wheeler transformation. Seismic attributes on amplitude and frequency based such as RMS, Envelope, Sweetness and spectral decomposition were performed on each strata slices and isochore maps to assist in defining the depositional trend.

Result

Integrated interpretation of geological information from seismic mapping, attributes analysis and seismic sequence stratigraphy interpretation via wheeler transformation reveals the prograding deposits within the Late Oligocene to Early Miocene interval.

Thinning attribute computed on the geomodel highlight the zones showing the convergence and divergence of the geological layer that exhibit the overall features of sigmoid progradational configuration. Prograding clinoform pattern were clearly displayed by superposed sigmoid reflection with gently dipping depositional angles. The lower segments of the strata approach the lower surface unit at a very low angle which is represented by the seismic reflectors showing downlap terminations as the strata terminates or became too thin to be recognized on the seismic. As shown in the thinning

attributes section (Figure 1), cold (blue) colour are showing the thickening of the strata while the hot (red) colour show the thinning of the strata, where lense-like features were recognized and interpreted as the prograding deposit. These superposed lense deposits allow successively younger lenses to be displaced laterally in a depositional downdip direction towards the basin center from NW to SE direction forming an overall outbuilding or progradational sequence (Figure 3).

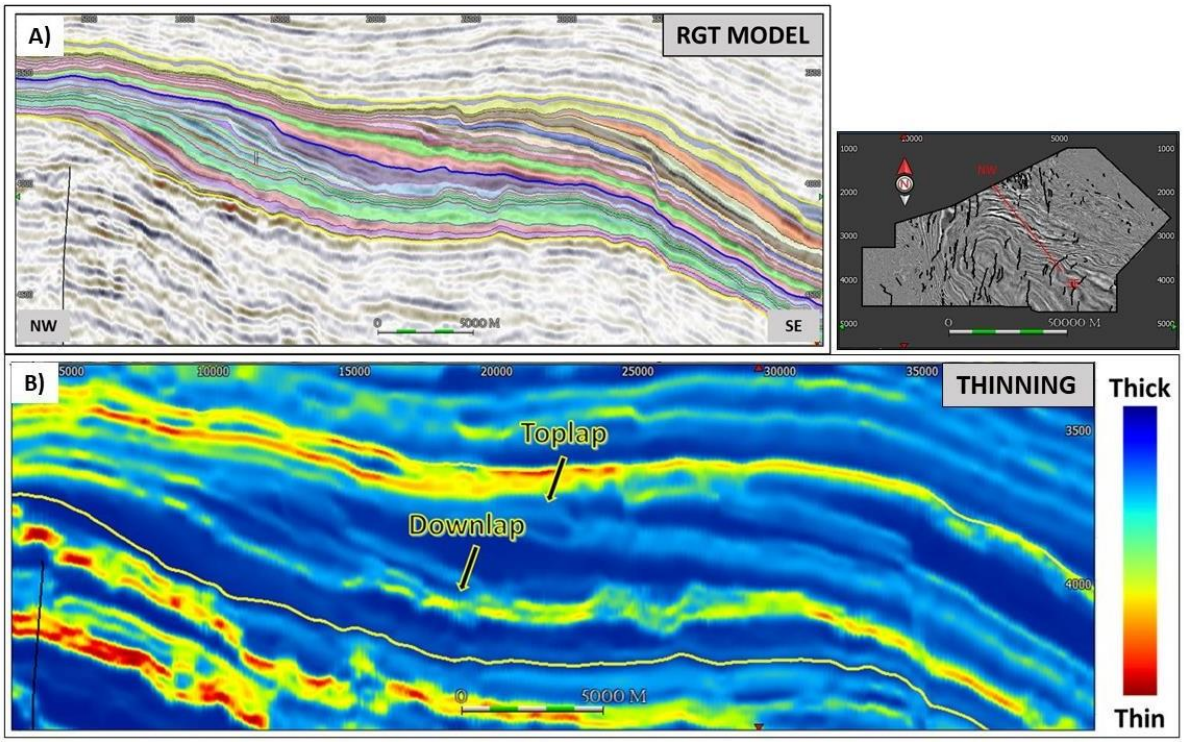

Figure 1 *A) RGT model showing the strata slices generated within the Late Oligocene to Early Miocene interval to further analyze the study area. B) Cross section along NW-SE of the thinning attribute volume highlights the thickening and thinning of the strata enhancing the prograding deposits trend on the seismic.*

Utilization of the wheeler transformation features in PaleoScan™ allow to flatten out the seismic, where this approach helps in gaining further insight on the prograding deposits. Significant surfaces were identified within the studied interval and possible geological causes were interpreted to explain those events. The flooding surfaces interpreted represents the onset of the prograding sequence that are feeding into the basin centre. As shown in Figure 2, the hiatus in the early stage of the sequence portrays the sediment starvation occurring at the distal part located at the SE of the study area. Meanwhile, the later hiatus interpreted to be caused by an erosion since it is located within proximal distance from the provenance at the NW side. The sequence boundary defined indicates the cessation of the prograding sequence of the studied interval. Envelope attributes were mapped on the significantsurfaces to further enhance the occurrence of the prograding deposit showing a bright amplitude response towards the basin centre (to the south). This supports the prograding event and is supplemented by the isochore map (Figure 3) that shows the sediment accumulation at the prograding region indicated by the cold colour (blue).

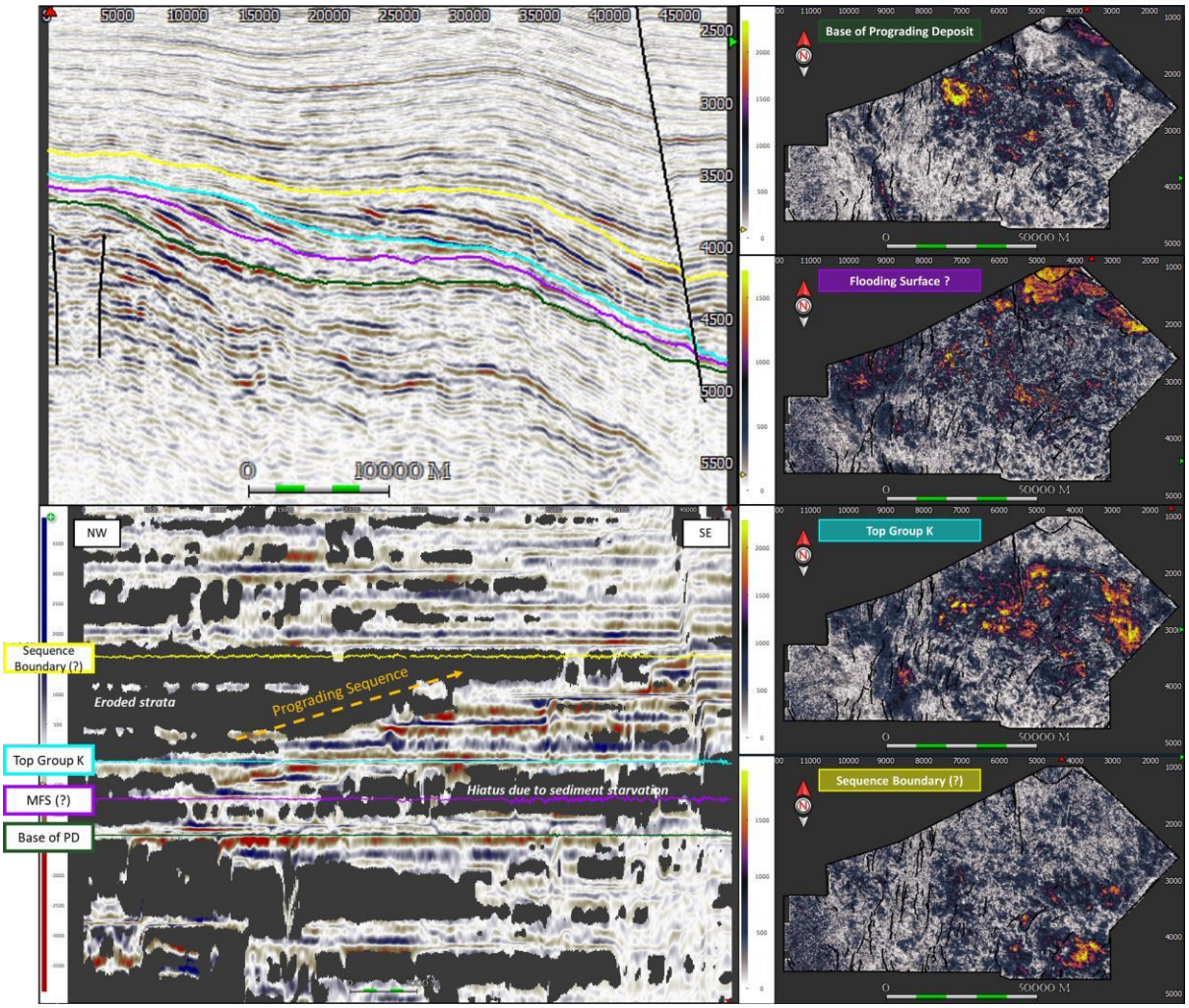

Figure 2 *Further insight on the prograding deposit through the application of the wheeler transformation allows the flattening of seismic data along the chronostratigraphic surfaces. Wheeler diagram supplements the interpretation of the prograding deposit and helps to understand the sediment interplay and hiatuses. Envelope attributes maps the prograding deposit.*

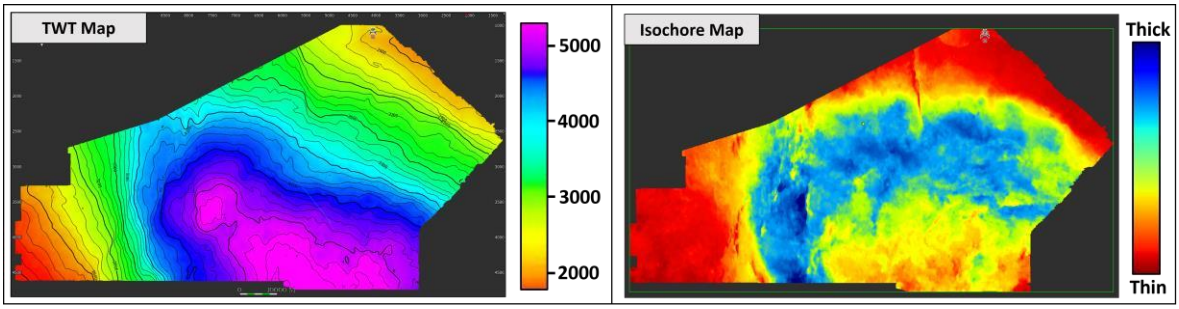

Figure 3*. The time structure and isochore maps generated within the studied interval to support the interpretation of sediment accumulation.*

Followed by the interpretation from attribute analysis and wheeler diagram, a stratigraphic model of the prograding sequence within studied interval were deduced (Figure 4). The sigmoid progradational features represented by the bright amplitude responses are delineated, where a total of six (6) geobodies have been extracted. The potential prospect from these extracted geobodies characterized by the bright sigmoid reflection with gently dipping depositional angles and thicker middle segment that form lense-like features. An analogue to a nearby well infers that the sigmoid lenses represent sand deposits through the bright amplitude anomalies detected from Envelope attribute map.

Volumetric assessment conducted for those extracted geobodies have a total volume of Gas-Initially-In- Place (GIIP) of up to 4.2 Tscf.

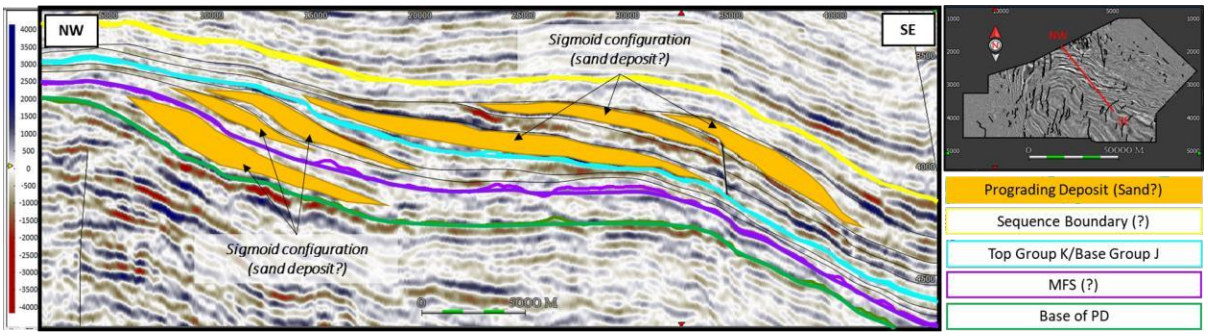

Figure 4 *Seismic cross-section showing a sigmoid progradational configuration which has been extracted as geobodies. Prograding clinoform pattern formed by superposed sigmoid reflection with gently dipping depositional angles. The lower segments of the strata approach the lower surface of the unit at very low angles and seismic reflection shows downlap termination as the strata terminates or became too thin to be recognized on the seismic line.*

Conclusions

Integrated interpretation of geological information from seismic mapping, attributes analysis and seismic sequence stratigraphy via wheeler transformation reveals the prograding deposits within the Late Oligocene to Early Miocene interval. Significant sequence stratigraphic events are well presented through the Wheeler diagram such those of hiatuses and erosion that assist in the geological analysis. This is supported by the attributes analysis of Thinning and Envelope that highlight the progradational deposits. A total of six (6) geobodies were extracted that opens new possibilities of deeper potential within the North Malay Basin.

Acknowledgement

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References

Madon, M., Jiu-Shan Yang, Abolins, P., Redzuan Abu Hassan, Azmi M. Yakzan & Saiful Bahari Zainal, 2006. Petroleum systems of the Northern Malay Basin. Bulletin of the Geological Society of Malaysia, 49, 125-134.

Madon, M., 2021. Five decades of petroleum exploration and discovery in the Malay Basin (1968-2018) and remaining potential. Bulletin of the Geological Society of Malaysia, 72, 63-88.

M. Mohd Adnan, W. Wan Ismail, A.S. Setiawan & S. Tanprasat, 2016. Deepest gas sand discoveries in North Malay Basin: Integration of Geophysical Applications and Well Data Leading to an Effective for Robust Development Plan, Malaysia-Thailand Joint Development Area. International Conference, Bangkok 14-16 November. IPTC-18677-MS.