115

Exploration Potential of the Sandakan Basin, off the Coast of East Sabah: Insights from new seismic data

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Summary

In this study we take a new look at the petroleum potential of the Sandakan Basin using newly acquired and reprocessed 2D seismic data mainly over the South Dent Trough. Existing leads are better defined and new leads identified from interpretation of the newly acquired and reprocessed
seismic data.

3499km of new 2D seismic, gravity and magnetic data were acquired together with reprocessing of 2676km of existing legacy 2D seismic data in the Sandakan Basin. The new data are tied to the available well data and have been processed through broadband PSTM & PSDM workflows including dynamic matching full-waveform inversion. A pseudo-3D seismic volume has been generated through structurally conformable interpolation of the newly acquired and reprocessed 2D seismic data to provide a 3D seismic volume for regional seismic interpretation across the basin.

Interpretation of the new available seismic data has been undertaken to identify new leads across the Offshore Sandakan Basin within both existing and new plays. Results from regional seismic interpretation are presented identifying potential new exploration targets in this relatively under-explored basin.

Introduction

Exploration in the Sandakan Basin, Offshore East Sabah has proven the presence of an active petroleum system with several sub-commercial oil and gas discoveries made prior to 1994. More recent wells drilled in the basin have had gas shows with the most recent exploration wells (2012 & 2015) drilled within the South Dent Trough to the south of the basin.

In this study we take a new look at the petroleum potential of the Sandakan Basin using newly acquired and reprocessed 2D seismic data mainly over the South Dent Trough. Existing leads are better defined and new leads identified from interpretation of the newly acquired and reprocessed seismic data.

New Data

3499km of new 2D seismic, gravity and magnetic data were acquired together with reprocessing of 2676km of existing legacy 2D seismic data in the Sandakan Basin (Figure 1). The new data are tied to the available well data and have been processed through broadband PSTM & PSDM workflows including dynamic matching full-waveform inversion. A pseudo-3D seismic volume has been generated through structurally conformable interpolation of the newly acquired and reprocessed 2D seismic data to provide a 3D seismic volume for regional seismic interpretation across the basin.

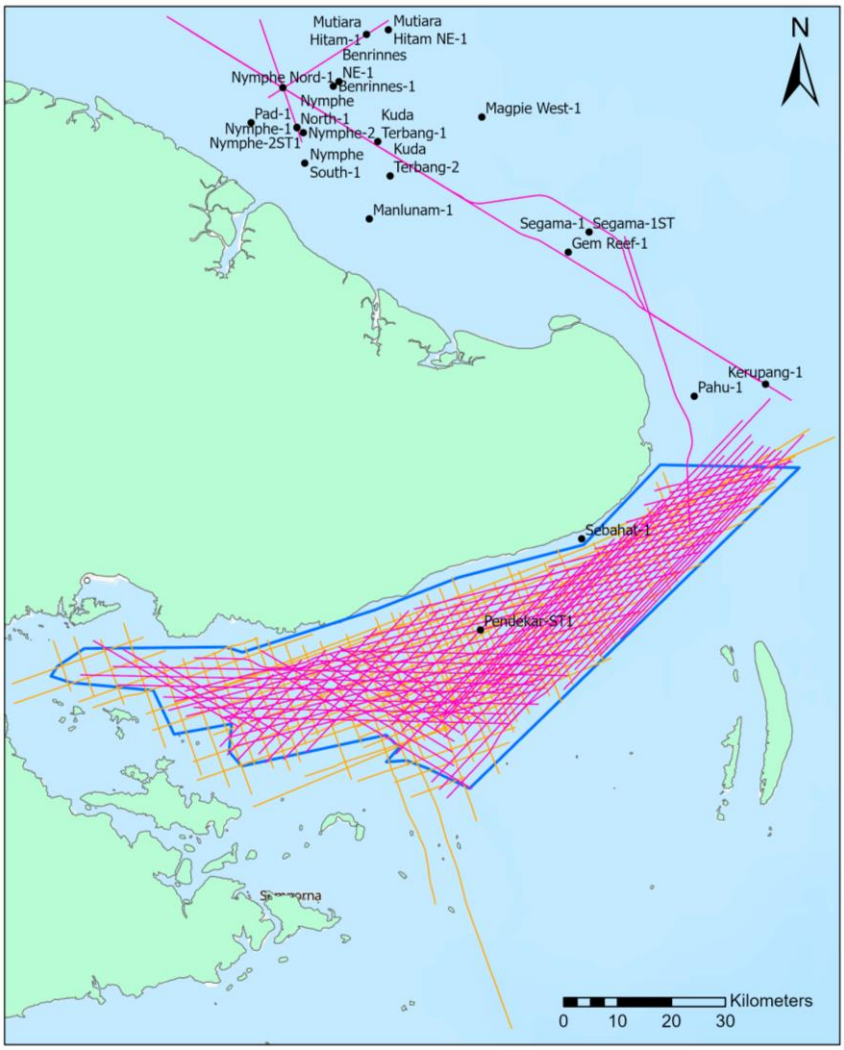

Figure 1 *Location map of the seismic data used in this study. Pink lines show new 2D seismic acquisition, orange lines are reprocessed 2D seismic and blue outline is the pseudo-3D seismic cube.*

Regional Geology

The Sandakan Basin is a Neogene age sub-basin of the NE Sabah Basin which formed in the Palaeogene (Leong, 1999). The Sandakan Basin has been interpreted as a rift system associated with the opening of the Sulu Sea (Hutchison, 1988; Tjia et al., 1990). The Crystalline Basement in the area is composed of a metamorphic and igneous rocks that have been dated as Cretaceous to Triassic age. Above the crystalline basement is a series of extrusive igneous rocks (composed of volcanic breccias, basalts and spilites) and radiolarian cherts that have been named as the Chert-Spilite Formation. The crystalline basement and chert-spilite formation are considered together as an ophiolite series of preserved remnants of oceanic crust. Rifting began in the Mid-Eocene and the rift-basins were filled by deepwater turbidites and shales of the syn-rift Kulapis and Labang Formations. There was uplift in the Late Oligocene-Early Miocene observed as a regional unconformity on the seismic data. Shallowing of the environment at this time led to deposition of coral limestones throughout Sabah at this time.

Regional extension and volcanism associated with the opening of the Sulu Sea then took place forming deep marine basins. This period was characterised by deposition of chaotic olistostromes of the Ayer Formation formed by slumping of sediments into the deep basins. Extension and associated volcanism continued to the Mid-Miocene with deposition of the Tungku Formation volcanics and the lateral equivalent shallow marine sediments of the Tanjong Formation. The cessation of this extension is marked by a Mid-Miocene Unconformity associated with uplift and erosion of the Tungku/Tanjong Formations.

Following this uplift episode there was then rapid post-rift subsidence of the basin with progradation of Sebahat Formation deltaic sediments towards the South East. There is a major compressional event in the Late Miocene that uplifts and erodes the top of prograding Sebahat Formation in the area. This Late Miocene Unconformity marks the boundary between the Sebahat Formation and the overlying Ganduman Formation composed of deltaic clastic sediments. Plio-Pliestocene sediments of the Togopi Formation are the youngest sediments to be deposited in the basin and are fluvial-deltaic sediments. The Sebahat, Ganduman and Togopi Formations compose the post-rift successions within the Sandakan Basin.

Exploration History

Exploration in the Sandakan Basin can be grouped into four discrete phases. The first Exploration phase taking place between 1970 to 1975 with 10 exploration wells drilled resulting in three sub-commercial oil and gas discoveries primarily within Miocene Sebahat Formation sandstones with resource estimates ranging from 28 to 42 MMboe (Madon & Jong, 2022). During this phase in the South Dent Graben, the well Sebahat-1 encountered gas shows in Sebahat Formation Carbonates. The second exploration phase took place in 1994 with the drilling of two wells with one sub-commercial gas/condensate discovery at Mutiara Hitam-1. In the third phase of exploration between 2005 to 2008 five wells were drilled with only minor gas shows being found. The final and most recent phase of exploration in the basin took place between 2012 and 2015 and was focused on the northern and southern margins of the South Dent Trough (the focus area of this study). Three exploration wells were drilled with the Pahu-1 well being plugged and abandoned before reaching the target due to operational problems and the Kerupang-1 and Pendekar-1 wells only encountering minor gas shows.

A post-well review of the early wells drilled in the basin (Walker, 1993) states that many of the early wells failed due to being invalid structural tests with poor seismic data quality being the main contributary factor. These failed wells were drilled outside of structural closure based on more modern data or targeting carbonates that are clearly volcanics when imaged on more modern seismic data. These factors demonstrate the importance of having the best high-quality seismic data available for exploration well planning.

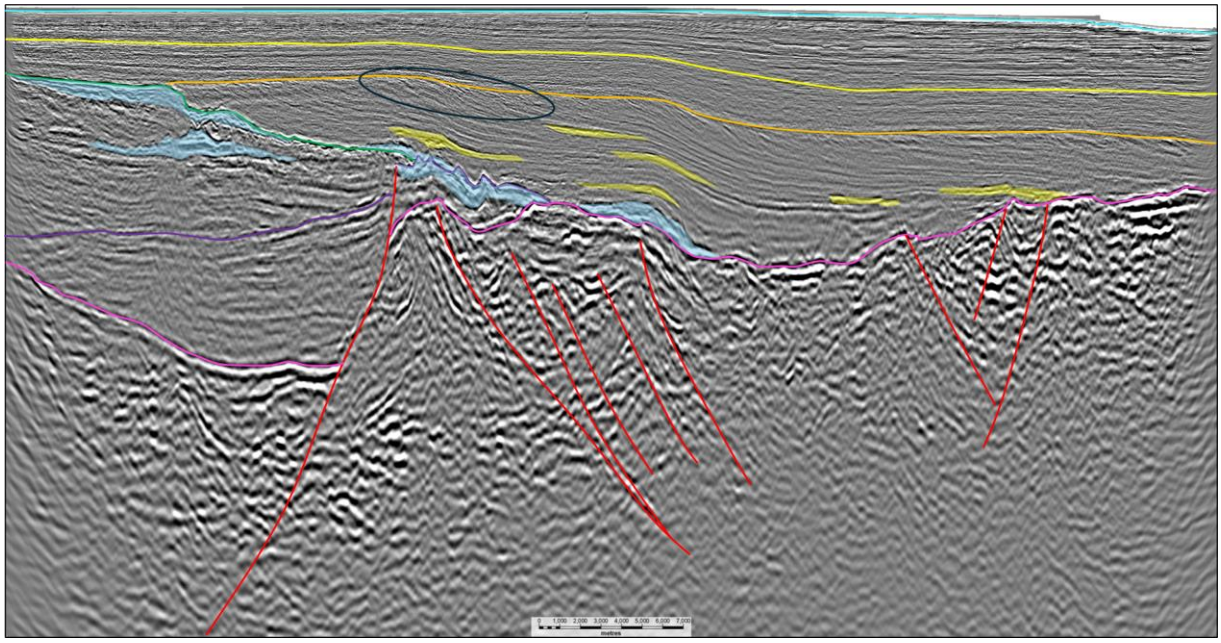

Figure 2 *PSDM seismic line showing the Sebahat prograding delta and potential carbonate ramp and reef targets (light blue). Circled are potential Sebahat Fm. shoreface sand targets and basin floor sand targets are highlighted (yellow fill). Interpreted seismic horizons are Top Togopi Fm. (water bottom) (light blue), Top Ganduman Fm. (yellow), Top Sebahat Fm. (orange), Top Tungku Fm. (green), Top Libong Fm? (purple) and Top Ayer Fm? (pink).*

Sandakan Basin Petroleum System and Plays

Exploration to date has proven an active petroleum system is present within the Sandakan Basin with multiple target play levels. Source rocks in the basin lie below the current depths of well penetration and are believed to be deposited in the Segama Group interval. Geochemical analysis of the discovered hydrocarbons show that the source rocks are type II/III typical of deltaic settings that are composed mainly of coals, coaly shales and shales with high content of terrestrial matter.

Reservoir targets in the Sandakan Basin include the siliciclastic reservoirs and shallow water carbonate buildups of the Plio-Pliestocene Togopi Formation. Presently there have been no discoveries in the Togopi Formation and this is most likely due to lack of top seal for this shallow formation due to insufficient burial. There are hydrocarbon shows in the Late Miocene Ganduman Formation in the Sandakan Basin and the shallow marine sandstones at this level are an additional potential play target.

The most prolific reservoirs in the basin are shoreface deltaic sands of the Sebahat Formation. The Sebahat Formation is observed as a prominent South-Eastward prograding delta on the seismic data (Figure 2). Shoreface sands of the Sebahat Formation are the main reservoir for discoveries in the Sandakan Basin with porosities greater than 20% and good reservoir permeability (average 1410mD, Kuda-Terbang-1).

Deeper targets in the basin are the Early to Middle Miocene “Segama Play” which consist of the deltaic to shallow marine sandstones of the Tanjong Formation and the co-eval volcaniclastic sediments of the Tungku Fomation. Hydrocarbons have been found in this play to the north of the Sandakan Basin (Nymphe-2) although volcanics are more likely to the south of the basin which could impact expected reservoir quality in this area. There was uplift and erosion of the Tanjong/Tunku Formations in the Mid-Miocene with potential for deposition of carbonates on the flanks of the South

Dent Trough as demonstrated by Sebahat-1. These potential carbonate ramp and reef targets are identified on the seismic data (Figure 2).

Coral limestones deposited during Late Oligocene to Early Miocene uplift are the next potential reservoir target in the basin. The deepest reservoir targets in the basin are the deepwater turbidites of the Oligocene Labang and Kulapis Formations with hydrocarbons found in these reservoirs to the north of the Sandakan Basin.

Conclusions

Interpretation of the new available seismic data has been undertaken to identify new leads across the Offshore Sandakan Basin within both existing and new plays. Results from this regional seismic interpretation are presented identifying potential new exploration targets in this relatively under-explored basin.

Acknowledgements

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