Insights into the Petroleum Potential of the Western Philippines from New Regional Seismic Data*

Mark Ballesteros[1], and Paul Robinson[2]

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[1]Searcher Seismic Ltd, Perth Australia (m.ballesteros@searcherseismic.com)
[2]Spectrum Petroleum Solutions, Perth Australia

Abstract

The Pala Sulu long offset 2D seismic survey was acquired in 2011 over the Northwest, Southwest and East Palawan, and Sulu Sea basins and the Mindoro-Cuyo platform of the western Philippines (Figure 1). Although these basins, particularly the Northwest Palawan Basin, are important petroleum-producing areas in the country, they are still very lightly explored and efforts to date have been primarily focused on the Oligo-Miocene carbonate plays. The 6026 line kilometre Pala Sulu survey ties 25 existing wells and was designed to image the pre-Miocene section and deeper targets, including Paleogene half grabens analogous to those that have been identified as the source of the substantial hydrocarbons encountered to date in the Northwest Palawan Basin (Branson, et. al., 1997). The survey also provides a unique opportunity to create a cohesive tectonic and stratigraphic framework as well as advancing the understanding of the region's petroleum prospectivity.

Discussion

The ability to assess the extent and potential of the petroleum systems surrounding Palawan has historically been constrained by limited data availability and quality. In addition, significant portions of the study area are situated in water depths greater than 1000 m, which introduced substantial economic and technical challenges during previous exploration cycles; however, recent innovations have demonstrated the feasibility and economic viability of operating in these environments. As a result, extensive portions of the study area remain virtually unexplored.

Identifying and understanding the tectonic and stratigraphic evolution of these basins is fundamental to defining and extending the petroleum prospectivity of the western Philippines. The regional tectonic framework of the study area is complex and has been the subject of numerous investigations (e.g. Hall, 2002; Hall and Morley, 2004; and Hall, Clements, and Smyth, 2009). For the most part, the western Philippines is

underlain by “Sundaland” continental crust that rifted and separated from southern China during the opening of the South China Sea in the Oligocene and Early Miocene. This is in distinct contrast to much of the Philippines archipelago that is characterized by mobile arcs, accretionary terrains, and spreading centers.

Although affected by the same regional tectonic episodes, it is evident from the Pala Sulu seismic data that the foundations and subsequent sedimentation patterns vary between the various basins in the study area. The East Palawan and Sulu Sea basins and adjacent Mindoro-Cuyo platform comprise elements of Palawan, Cagayan, and east Borneo terrains, respectively; whereas the Northwest and Southwest Palawan basins comprise Palawan and northeast Borneo (Sundaland) terrains. Consequently, these basins have recognizably discrete tectonic and sedimentation histories that have given rise to a variety of play types.

The integration of the regional seismic data with age and stratigraphic data from wells within a plate tectonic framework has enabled the identification of several key Tertiary sequences that define phases of structuring conducive to the deposition and burial of source rock intervals, the development of a variety of clastic and carbonate potential reservoirs, and the creation of hydrocarbon traps.

Preliminary interpretation of the Pala Sulu seismic data has revealed new, and extended known depocenters surrounding the island of Palawan, including possible Paleogene and Neogene rift grabens and half-grabens that are more extensive than previously recognized. A number of these sub-basins are broad and likely to comprise thick Tertiary sedimentary sequences that include mature source rocks capable of generating significant volumes of hydrocarbons. Improved imaging in the new seismic data also confirms the presence of previously suspected play types as well as revealing new play types over the distal and deeper water areas. In addition, it provides strong evidence for extending the distribution of potential reservoir facies, and suggests the potential for substantial accumulations.

The Mindoro-Cuyo area is an extensive elevated platform of pre-Tertiary sediments, volcanics, and metasediments that outcrop on Palawan and the islands on the Mindoro-Cuyo platform (Figure 1). However, several substantial rift-related grabens have been identified across the platform; these sub-basins are imaged on the Pala Sulu seismic data and appear to have a similar late Paleogene history to depocenters known to underlie oil and gas producing areas in the Northwest Palawan Basin. Their subsequent Neogene development differs, however, and is more analogous to the depocenter associated with the Maniguin oil discovery near the eastern edge of the Mindoro-Cuyo platform. This area contains good quality Miocene source rocks and reservoirs deposited under paralic to shallow marine conditions (Forbes, 2002) with subsequent Late Miocene to Pliocene compression resulting in the development of inversion structures. The demonstrated presence of a working petroleum system within sub-basins on the Minodoro-Cuyo platform provides an encouraging analogy for these additional grabens.

The Balabac and Bancauan Sub-basins are located in the southern part of the East Palawan Basin (Figure 1). These northeast-trending depocenters developed between Palawan and the Cagayan Ridge during the Neogene. Regional plate reconstructions place the precursor of the

Balabac and Bancauan Sub-basins over the boundary between the Palawan terrain of Sundaland affinity and the Cagayan-Sulu terrain of Philippines affinity (Rangin and Silver 1991). During the Late Oligocene and Early Miocene the Palawan terrain drifted southeast with consequent subduction beneath the Cagayan-Sulu terrain. The latter developed as a volcanic arc with back-arc extension that manifested in the Oligocene and Early Miocene as rifting and spreading in the Sulu Sea. The Pala Sulu seismic data depicts several depocenters that are likely to have thick Early Miocene and possibly Eocene to Oligocene synrift sediments, although there are no well penetrations to provide direct evidence of Paleogene sedimentary section in the region.

As continent-to-continent collision of the Palawan and Cagayan-Sulu terrains occurred in the Early to Middle Miocene, foreland loading and sedimentation was initiated across the Balabac and Bancauan Sub-basins in the north. The seismic and well data indicates that the bulk of these foreland sediments were likely derived from the elevated continental Palawan terrain rather than from the Cagayan-Sulu block and there is evidence of associated compression and inversion structuring.

By the Late Miocene, Sulu Sea spreading had ceased and subduction of this recently formed ocean crust commenced beneath the Sulu archipelago in the southeast. As a consequence, a period of relative quiescence occurred across the Balabac and Bancauan Sub-basin area that was underlain by the now “melded” Palawan and Cagayan terrains. During this time thick sedimentary sequences were deposited in progressively subsiding basins along the eastern margin of Palawan, but as sedimentation rates declined in the Pliocene continued subsidence resulted in increasing water depths in the eastern Palawan basins with platform carbonates developing only along the shallow marginal areas.

The Sandakan Sub-basin, located in the southern Sulu Sea Basin (Figure 1), is different from other parts of the region and different from most basins within the Philippines. From the Middle Eocene to Early Miocene the Sandakan Sub-basin was affected by the opening of the South China Sea. The proto-Sandakan Sub-basin was predominantly in a forearc setting with an associated accretionary wedge to the northwest and by the early Middle Miocene possible initial deep marine turbidite deposition graded into shallow shelf and paralic conditions with associated coal measures (Balaguru and Hall, 2009). However, much of this early basin history is not readily recognized in the seismic primarily due to the extremely high sedimentation rates that occurred since the Middle Miocene.

Reworked, quartzose sands were shed from the uplifted Crocker Formation in northeast Borneo into the Sandakan Sub-basin throughout the Miocene (Balaguru and Hall, 2009). These high quality sands were deposited within an active delta system that prograded to the northeast during the Middle Miocene with likely paralic and shelf facies extending into the Sulu Sea Basin. Subduction along the Sulu arc at this time is likely to have created substantial accommodation space in a foreland basin setting that in turn gave rise to sediment loading and gravity slide tectonics.

The Pala Sulu seismic data acquired across the Sandakan Sub-basin and delta illustrates the structuring and sedimentation that define the delta top, front and slope settings through the Miocene and Plio-Pleistocene. The extensive listric, growth-faulting and associated toe-thrust

development has created numerous potential target structures that comprise slope and turbidite sandstone reservoirs and may include viable Middle Miocene shelf and shoreface clastic reservoir objectives in the core of the toe-thrusts; possibly the target of the recent deepwater Sandakan Sub-basin discoveries by ExxonMobil, Dabakan-1, and Pelendag-1. This coastal plain delta to shelf to slope settings are on-trend and analogous to the modern Mahakam-Makassar Delta that is known to include abundant, high quality source rocks.

To date, West Palawan has provided the greatest encouragement for the Philippines region hydrocarbon prospectivity. Oil and gas discoveries and subsequent production have encouraged exploration activity over the last two decades. Although the essence of the play types and associated petroleum systems are relatively well known, key elements remain poorly understood, such as the identification of the prime mature source rock centers, the hydrocarbon migration routes, and trap configuration. The new seismic data provide a clearer image of the structural framework and sedimentary sequences along the western margin of Palawan, including deeper Paleogene and older sequences not previously recognized. The identification of these strata may better guide future exploration enabling the derisking of likely hydrocarbon source locations, levels of maturity and migration pathways.

Exploration success in the western Philippines is best achieved by first understanding the regional tectonic and sedimentation histories and then by acquiring focused seismic data where the fundamental elements of petroleum systems and play fairways have been located. The 2011 Pala-Sulu 2D seismic survey provides this initial key step and extends the knowledge of petroleum provinces for the region. Preliminary interpretation of the survey shows a number of encouraging features that suggest significant unexplored potential remains in the area. For example, in the East Palawan Basin, these features include areally extensive depocenters with thick sedimentary sequences likely to contain mature source rocks located adjacent to large structures. The data also suggests that the distribution of potential reservoirs is likely to be more extensive than previously recognized. The potential of these features is reinforced by the Managuin oil discovery, which demonstrates the existence of a working petroleum system in an analogous setting – and yet only one well had been drilled in the area in the last 40 years. Observations like this, taken in conjunction with the paucity of data in many areas and a relatively low level of exploration activity in recent years, suggest that potential remains for substantial discoveries in the western Philippines.

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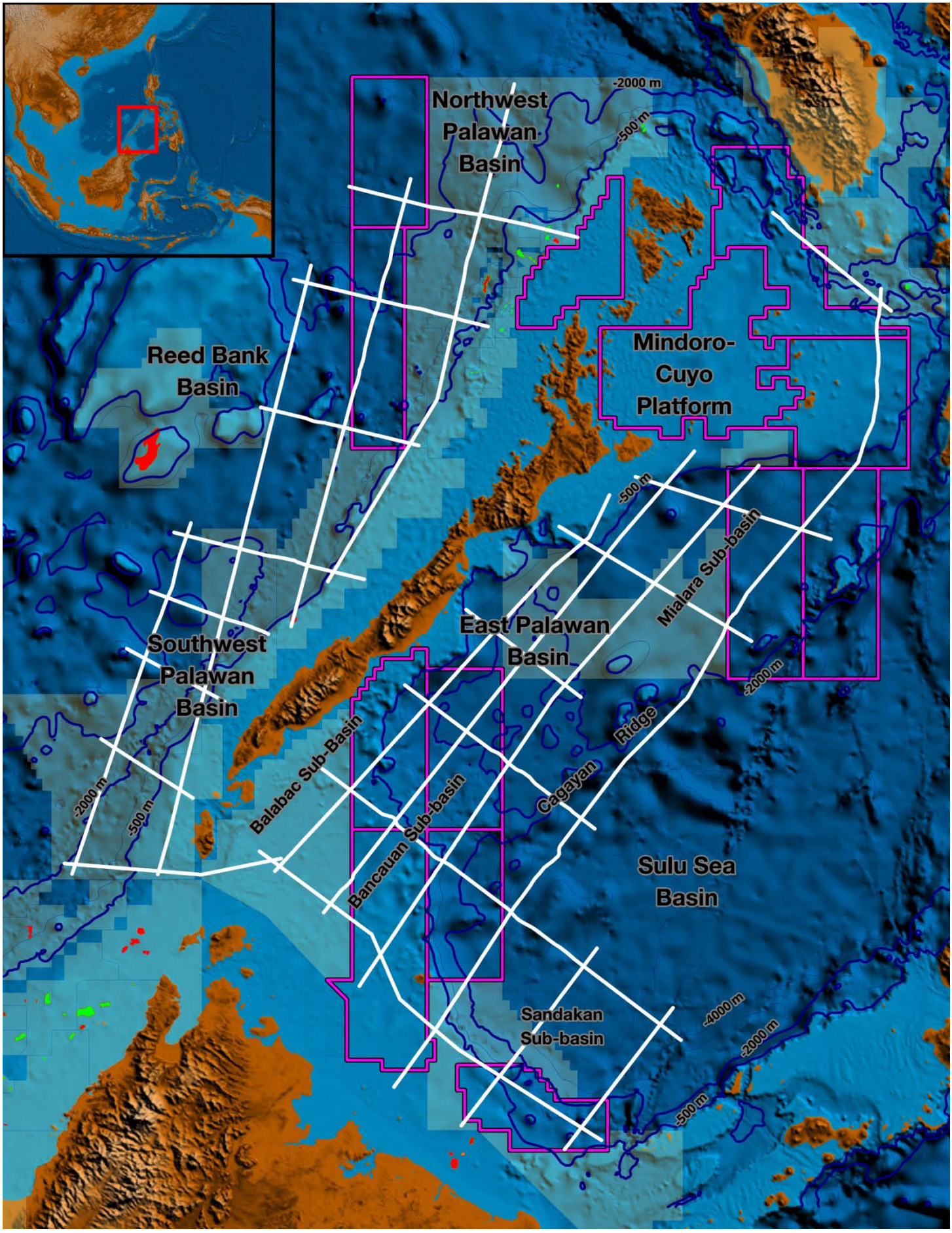

Figure 1. Location Map showing location of Pala Sulu seismic survey.