ORAL PRESENTATION

Day 3: 5th April 2019

Session 10: Myanmar and Bangladesh: Success and Potential

Chairs: Romain Courel – Ophir Energy, Peter Grant – International Energy Solutions

11:15	New Perspectives and Learnings from Three Years of Successful Drilling in Myanmar	Tony Almond	Woodside Energy
11:40	Where Did They Come From, Where Did They Go? Oligocene Fluvio-Deltaic Sediments of the Salin sub-basin, Myanmar	Amy Gough	SE Asia Research Group, Royal Holloway, University of London
12:05	The Hydrocarbon Potential of the Channel Sands and Basin Floor Fans of Block SS-11, Hatia Trough, Offshore Bengal Basin	Edwin Bowles	KrisEnergy

ORAL PRESENTATION

New Perspectives and Learnings from Three Years of Successful Drilling in Myanmar

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Woodside holds one of the largest deep-water acreage positions and has been the most active deep-water explorer in Myanmar over the past three years. In that time, Woodside has discovered four fields from seven exploration wells. Two of these fields have subsequently been appraised, with the most recent well successfully appraising the 2016 Shwe Yee Htun-1 discovery.

The Rakhine Basin, offshore northwest Myanmar, hosts a complex interaction of structural, sedimentological and geomorphological systems. Woodside has leveraged its extensive exploration datasets, including petrophysical data, 2D seismic and over 33,000km² of 3D seismic data, to understand the depositional history and trap generation in this complex basin. The rapid evolution of this understanding underpinned our three successful drilling campaigns.

Woodside's long-term, integrated approach, and our commitment to technical and operational excellence, were key factors in the success of the drilling campaigns. This presentation will provide perspectives on the elements behind Woodside's drilling success and the learnings gained along the way.

SPEAKER BIOGRAPHY

Tony Almond has over 20 years of experience in the oil and gas industry and is currently General Manager Asia Exploration for Woodside. Woodside holds interests in nine permits offshore Myanmar and is the most active company in the deep-water Rakhine Basin. Woodside is also actively looking to expand further in Asia. In his current role, Tony is responsible for Woodside's exploration activity in the region.

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Fairmont Hotel, Singapore
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Where Did They Come From, Where Did They Go? Oligocene Fluvio-Deltaic Sediments of the Salin Sub-Basin, Myanmar

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Increasing accessibility to Myanmar has allowed a resurgence of geological research in the country. Myanmar is geologically rich, with the famous Mogok Mineral Belt in the east and shows evidence for oil and gas in both the Central Basin and the offshore basins to the south and west. Despite numerous plays with proven reserves, very few field-based studies have been conducted on land and the sedimentary systems are still poorly understood.

The Central Myanmar Basin, bounded to the west by the Indo-Myanmar Ranges and to the east by the Sino-Myanmar Ranges, is a north–south elongate basin. It is subdivided into a series of sub-basins, including the centrally located Salin sub-basin. During the Cenozoic, there was up to eighteen kilometres of subsidence in the sub-basin, exceeding even that in the nearby Pattani and Malay basins. Sediment supply kept pace with subsidence resulting in preservation of a thick sedimentary succession. In this study we focus on sediments of the Oligocene Shwezetaw, Padaung, and Okhmintaung Formations to reconstruct the depositional environment, sediment routing pathways into the basin, and source changes. This work is based on field observations, light and heavy mineral analysis, and U–Pb LA-ICP-MS dating of detrital zircons. This comprehensive study provides an opportunity to document changes in sediment sources and tectonics during the early stages of India–Asia collision and helps to constrain the timing of the uplift of the Indo-Myanmar and Sino-Myanmar ranges.

In terms of depositional environment, the Shwezetaw Formation is interpreted as a southward-flowing fluvial system, grading into deltaic and shallow marine environments. A gradual regression through the Rupelian caused southward progradation of the delta. The Padaung Formation records deepening, with limited fluvial deposits in the north and abundant deltaic–marine deposits in the south. The Okhmintaung Formation is interpreted as tidally- to fluvially-dominated shallow marine deposits.

Before this study, the Himalayan area (notably the Lhasa Terrane) was considered to be the most likely source for the sediments, with episodic influx from the Sino-Myanmar Ranges. However, in conflict with this hypothesis, the heavy mineral suites of the Oligocene formations are very immature and indicate a significant contribution from local metamorphic sources and from ophiolites. Nearby sources are more important than potential distant contributions. Furthermore, the detrital zircon ages show no correlation with those from the Lhasa Terrane, although a small contribution is possible. There is a large contribution of Late Cretaceous to Eocene zircons, interpreted to have been reworked from the nearby Myanmar magmatic arc but, there is little evidence of contemporaneous Oligocene magmatism. The new data suggest that the Central Myanmar Basin is an intra-montane rather than a forearc basin. They indicate little contribution to Oligocene sediments of the Salin sub-basin from the India–Asia collision zone and suggest a Himalayan source for offshore sediments further south in the Oligocene is even less likely.

SPEAKER BIOGRAPHY

Amy Gough is a lecturer in Southeast Asian geology at Royal Holloway, University of London, working with the Southeast Asia Research Group. Amy had worked in the region since 2015.

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The Hydrocarbon Potential of the Channel Sands and Basin Floor Fans of Block SS-11, Hatia Trough, Offshore Bengal Basin

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Block SS-11 provides an exciting opportunity to test multiple plays in the southern part of the Hatia Trough, offshore Bengal Basin. SS-11 is located 60km northwest of the multi-TCF Shwe gas discovery and occupies this same play fairway trend. With genetically similar play types and drillable structures, these two areas occur in the Bengal and Rakhine Basins respectively, with the international boundary of Bangladesh and Myanmar separating the two. This is purely down to political affinity and does not reflect any significant change in geological setting.

As exemplified by the Shwe discovery, of particular interest are the basin floor fans and sand filled channels that are prevalent throughout Block SS-11, illustrated through 3,146 km of 2D seismic acquired in 2015. Through the mapping of this data, several prospects and leads have been identified across the Block, occurring at different stratigraphic intervals. One of these, the Sheemanto Prospect, is of specific significance as it provides the opportunity to test several targets in a number of different plays, with the predicted presence of both slope and basin floor turbidite sands that are genetically related to the Lower Pliocene G-sands of the Shwe Field. At a water depth of 90 m, the Sheemanto Prospect has been the focus of a 305 km^2 3D seismic survey completed in 2018. This paper will present the exploration highlights of Block SS-11 in terms of its hydrocarbon potential through the newly acquired 3D seismic data and will provide a review of the petroleum systems of the Hatia Trough of the Bengal Basin system and the inferences that can be made from the spatially- and temporally-associated Shwe discovery in Myanmar.

Regionally, Block SS-11 is located offshore in the southern part of the Hatia Trough, eastern portion of the Bengal Foredeep, which lies between the north-easterly trending Barisal High to the west, and the north-westerly trending Chittagong Foldbelt to the east. It is the deepest of all basinal areas in Bangladesh, with around 20-22 km of sedimentary fill. Located near the northern apex of the Hatia Trough, the Begumganj and Feni Fields form its most northerly gas discoveries. At the Shahbazpur Field, gas is reservoired in Boka Bil Formation and Upper Bhuban Formation sandstones of Pliocene age. The 1996 discovery of the offshore Sangu Field, with biogenic and thermogenic gas in Pliocene sands, opened up offshore exploration of the Bengal Basin in the shallow waters of the northern delta. Since then, the Field has not proved to be a catalyst for continued success; encountering both geological and technical problems that resulted in a rapid decline in gas production from around 150 mmcfd in 2002 to 7-8 mmcfd in early 2012. One of the principal reasons for this has been the lack of detailed knowledge of reservoir distribution: the sandstone reservoirs are not uniformly distributed across the structure and channel cuts, along with faults, often disrupt reservoir continuity. As a consequence, the application of 3D seismic and follow-up attribute analyses are vital to exploration and development success and, as a result, have been adopted for the exploration of Block SS-11.

The essential play elements of Block SS-11 and the basin as a whole will be presented and are briefly summarised here as follows:

- **Source rocks and charge**. Sources are thought to be dominated by Miocene to Pliocene organic shales, which provide both biogenic and thermogenic gas charge. Gas prone, type III kerogens are predominant and are dispersed throughout the Basin within both sands and shales. A mixed biogenic and thermogenic signature is present in the hydrocarbons of the trough and analogies are made with similar systems in the Baram and Kutai Basins of East

Kalimantan. Naturally occurring oil seeps have been identified on St Martin's island to the east of the block, and multiple gas chimneys have been recognised on seismic throughout the Block indicative of an active petroleum system.

- **Reservoirs**. Miocene to Pleistocene sands of the Bengal Fan form the reservoirs of the basin. They represent part of a southerly prograding and aggrading delta system sourced from the Ganges-Brahmaputra rivers to the north. Various depositional environments have been identified in Block SS-11, ranging from deep water basin floor fans and slope fans to shallow marine delta tops.
- **Traps.** Traps are structural (rollovers into faults and anticlines) in the north and east, some with a significant stratigraphic component of closure, to purely stratigraphic in the west of the Hatia Trough. Folds trend north-north-easterly with fold amplitude decreasing westward. This phenomenon can be clearly seen on seismic between the Sangu and Magnama discoveries, which are approximately 35 kms apart. The anticlines are the result of thick-skinned tectonics and related detachment folding in the shallower section. Anticlines forming part of the Magnama-Shwe anticlinal trend have been recognised and mapped in the eastern part of Block SS-11. Stratigraphic traps are largely associated with shale filled channels or canyons which cut into stacked, reservoir quality sands and interbedded shales. SS-11 is characterised by these various trap types from broad and tight anticlines, through to stratigraphic/structural and fault dependent closures.
- **Seals**. Seals are largely regional shales of the Pliocene (Upper Marine Shale) and/or Plio-Pleistocene (Girujan Shale), which form top-seals, with intraformational and shale filled channel cuts forming additional lateral and/or top-seals.
- **Migration**. Vertical gas migration appears to be efficient largely through near vertical wrench faults, resulting in gas chimneys and seeps. These vertical faults are mostly absent from the Mio-Pliocene section in the western part of the block. Other types of migration could involve migration along the margins of the erosive channels and updip migration from a lateral (basinal) source kitchen that could explain charging of faulted structures.

Block SS-11 and, in particular, the Sheemanto Prospect, provides an exciting and unprecedented opportunity to drill a set of targets that are in close proximity and within the same play fairway trend as one of the most prolific gas discoveries - Shwe Gas Field - made along the Myanmar-Bangladeshi offshore margin.

SPEAKER BIOGRAPHY

Edwin has geology degrees from Southampton University and Imperial College. After working for Exlog in South East Asia for 5 years, he joined British Gas after privatization. His 25 year career encompassed roles in America, Africa and South Asia culminating in Pakistan, where he was GM, and India where he was Managing Director of Gujurat Gas. He then worked as an independent consultant before joining KrisEnergy as GM – Bangladesh, where he has been for the past 5 years. He oversees production and exploration activities, both onshore and offshore in Bangladesh