ORAL PRESENTATION

Day 3: 9th March 2023

Session 10: CIRCUM-INDIAN OCEAN

Co-Chair: Mike Whibley, Naga Api Resources

Co-Chair: John Chambers, Wollemi Energy Consultants

10:55	New Airborne Gravity Gradiometry, Gravity and Magnetic Data over the Mannar & Cauvery basins	Colm Murphy	Bell Geospace
11:20	Study of Gas Generation and Accumulation in Cenozoic Strata, Offshore Eastern Sri Lanka	Chaminda Kularathna	PDASL
11:45	Hydrocarbon Potential of the Basin Floor Fan Complex – A Comparative Study between the Offshore Bengal Basin and the Rakhine Basin, Myanmar	Abdus Samad Azad / Zabir Hossain	KrisEnergy (Bangladesh)
12:10	Exploring the DHI led Bampo sandstone gas play in the Andaman II block, Offshore Aceh, Indonesia	Nick Comrie-Smith	Harbour Energy

ORAL PRESENTATION

New Airborne Gravity Gradiometry, Gravity and Magnetic Data over the Mannar & Cauvery Basins

Colm Murphy [1], Richard Farnell [1], Michal Ruder [2], Gaud Pouliquen [1], Chris Bellamy [1]

[1] *Bell Geospace Ltd,* [2] *Wintermoon Geotechnologies, Inc.*

cmurphy@bellgeo.com

Introduction

At the end of 2021, Bell Geospace acquired 14,000 line-kilometres of airborne full tensor gravity gradiometry (FTG), gravity and magnetic data over Sri Lanka's offshore western Cauvery and Mannar basins (Figure 1). The lines were flown 1 km apart and ties 5 km. Water depth in the Cauvery basin doesn't exceed 30 m and makes it a particularly suited area for FTG. This data provides new insights into the structural and tectonic history of the region, as well as on the hydrocarbon potential, particularly in Cauvery where modern 3D seismic is non-existent and exploration relies on vintage 2D lines.

Basement and overlying basin shape complexity are clearly imaged. NE basin forming structures are displaced by both NNW and NW trending regional faults. Together with ENE and WNW trending fault patterns we evidence the complex development of the region providing insight on the prospectivity of these two important basin areas offshore Sri Lanka.

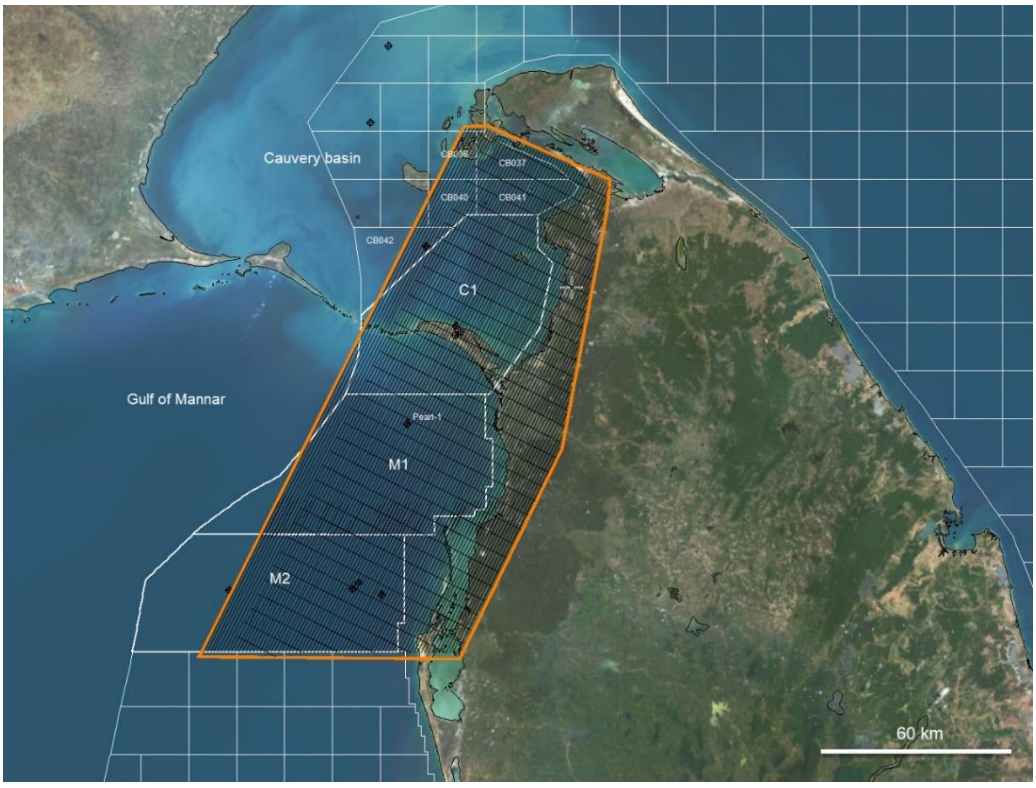

Figure 1: Air-FTG survey over the Cauvery and Mannar basins, flight lines are 1 km spaced and ties 5 km apart. PDASL exploration license blocks are indicated in white.

Geological background

The Geology of onshore Sri Lanka is primarily of Precambrian age, dominated by high-grade metamorphism. On the transition zone to the west, Miocene limestones outcrop and are present at shallow depths in Cauvery. Cauvery, Mannar and the Lanka basins to the South were formed during successive failed rift events, and associated rift-related subsidence, which were initiated during late Jurassic, at the break-up of East-West Gondwana and the Indian subcontinent moving apart from SE Africa. Later, in the early Cretaceous ~130 Ma ago, it is inferred that the partial separation of India and Sri Lanka resulted in a near 30 degree clockwise rotation which contributed to further opening. In addition to rift-subsidence, the early Cretaceous saw rifting induced volcanism which has been observed in the Barracuda and Pearl-1 wells in Mannar but the extent is still poorly mapped, yet critical for exploration.

Structural analysis of FTG gravity and magnetic data

Gravity anomalies reflect density contrasts within the subsurface. The gravity anomaly, Tz, and its tensor components (Tzz, Txx, Tyy, Txy, Txz, Tyz) respond differently to density distribution with depth. The gravity anomaly is more sensitive to deeper sources, associated with longer wavelength in the signal, whilst the gravity tensor components respond to shallower density contrasts, and produce shorter wavelengths. Both are combined to produce a full spectrum gravity anomaly, Tze, which takes advantage of both sensors strength to image the entire density distribution. In the Cauvery and Mannar basins, these are dominated by higher density rocks of the Precambrian basement at depth, and the Miocene limestones in the shallower subsurface, particularly within Cauvery.

The magnetic data detects basement and volcanic rocks with a high mafic content and, like, the gravity also show sensitivity to the deeper geology. The dominant fault trends evident from the magnetics are oriented ENE in the offshore over Cauvery, but more NE for the onshore and again over Mannar. A regional scaled set of NW oriented faults appear to displace the underlying basement fabric beneath both Cauvery and Mannar.

Both the gravity and tensor data show a strong NE-SW trend in the northern half of the survey over Cauvery and are associated with the rifting episodes, where highs and lows in the NE corner of the survey area are interpreted as being associated with horst and graben structures on the Precambrian basement. Regional structures between anomalies are also defined, where a WNW-ESE trend cross cuts the survey, showing a sense of displacement on the series of NE-SW trending anomalies.

Other regional fault trends include a NNW oriented system that impacts both Cauvery and Mannar. Two significant gravity lows are aligned along this regional trend at the northern end of Mannar. Their gravity expression points to the presence of deep synforms containing low-density material interpreted as sedimentary troughs. The corresponding tensor data reveals internal structural complexity defining a set of linear fault blocks forming the western part of Mannar and shallow pockets of low-density material within Cauvery.

These regional scaled NW & NNW structures show clear intersection with the ENE and NE oriented structures and together define the complex structuring within the Cauvery and Mannar basins. Localised potential for closed structural fault block presence are mappable in the tensor data; and where proximal to the primary trends, help delineate primary migratory pathways from deeper source rocks in Mannar to the south or Cauvery to the north.

Basement depth and volcanic layer

A basement depth map has been derived from depth profile analysis and 3D modelling of the gravity and magnetic data. Basement deepens from the onshore where it is near surface to depths from 2,500m to greater than 5,000m beneath Mannar. A volcanic layer is also identified at depths from 1,000m to 3,500m in the Mannar, but is not uniform.

The magnetic basement is generally shallow in the eastern and northern regions beneath Cauvery. Near shore, magnetic sources are very shallow, well within the sedimentary section. Iron-rich formations have been mapped both onshore Sri Lanka and southern India. These are interpreted as the source to the very short wavelength magnetic anomalies. Basement deepens beneath Mannar as predicted by the gravity data.

In addition to basin-forming events, Late Cretaceous basalt and diabase intrusive rocks intersect the clastic sedimentary section, especially in the Mannar Basin. Strong evidence for a basalt layer in the southern region of the survey area is supported by a significant EW trending magnetic anomaly. The overall higher magnitude in magnetic response for this volcanic layer sets it apart from the rather low amplitude magnetic anomaly character for the basement to the north and onshore.

Inversion of the FTG, gravity and magnetic data identifies depth and rock property relationships across the area and identify both high density and high susceptibilities for the interpreted volcanic sequences in Mannar. Basement is modelled otherwise with density and susceptibility ranges more akin of felsic / granitic composition.

Summary and Conclusions

FTG, gravity and magnetic data were acquired over Sri Lanka's offshore, over the Cauvery and Mannar basins. The data image a complex suite of structural elements. The detailed survey resolves important structures which have not previously been imaged in public domain satellite derived or in marine gravity data. Both the Cauvery and Mannar basins have a set of NE-trending, basement controlled, first order crustal lineaments. These set up local areas of basement uplift and depression. The gradiometry data are particularly diagnostic for mapping local grabens and mini-basins which are of notable interest for exploration. Fault patterns pertinent to tracking potential migratory pathways and defining potential for closed structures presence are easily mapped.

Inversion of the magnetic and both the FTG and gravity datasets identifies basement depth and composition.

SPEAKER BIOGRAPHY

Colm Murphy is Chief Geoscientist with Bell Geospace, the leading providers of FTG Gravity gradiometry data solutions to the industry. He leads the team that assesses FTG's application on projects, designing the work programmes and delivering optimal solutions leading to informed geological decisions ranking areas for exploration potential. Colm is both a geologist and geophysicist specialising in gravity, magnetics and FTG data workflows for efficient exploration. He holds a PhD from the University of Galway, Ireland and 30 years industry experience working FTG, gravity and magnetic data solutions for Energy, Geothermal and Mineral exploration projects world-wide.

ORAL PRESENTATION

Study of Gas Generation and Accumulation in Cenozoic Strata, Offshore Eastern Sri Lanka

Tu, C.[1], Schenk, O.[1], Ngo, L. S.[1] and **Kularathna, C.[2]**

[1] Schlumberger EXD and D&I, [2] PDASL Sri Lanka

kularathna@pdasl.gov.lk

As part of the energy transition and with the objective of reducing greenhouse gas emissions, natural gas exploration has become essential in energy exploration. Results of our previous study showed that potential source rocks within syn-rift depocenters offshore East Sri Lanka are able to generate thermogenic hydrocarbons (Tu & Schenk, 2021). Post-rift marine shales are predicted to be immature and represent seal rocks. However, we observe direct hydrocarbon indicators (DHIs), showing the potential for a deep hydrocarbon kitchen to charge shallower Cenozoic reservoirs.

Although Eastern Sri Lanka offshore basins are still un-explored, they show a strong affinity to the Krishan-Godavari basin within the Bay of Bengal depositional systems. Well-understood biogenic and mixed biogenic/thermogenic producing gas fields from Myanmar (Myint, 2018) and the east coast of India (Das et al., 2008; Collett et al., 2019) provide an additional aspect to assess the Cenozoic depositional and petroleum systems along offshore East Sri Lanka.

Based on geophysical data observations, the Mahaweli fan system lies on the approximately continental-oceanic transition. The surface sedimentary system supply from Mahaweli river and deposit Trincomalee Canyon in Eastern Sri Lanka offshore, showing that sediments have washed down and deposited in deep marine fan systems. Sediments have also been transported from the Bay of Bengal downward to the lower fan; gas hydrates are thus likely to be trapped. In this study, we deliberately focus on gas generation and trapping mechanisms for gas accumulations. The area is being evaluated to understand the geological conditions for potential biogenic gas plays and gas hydrate systems to work.

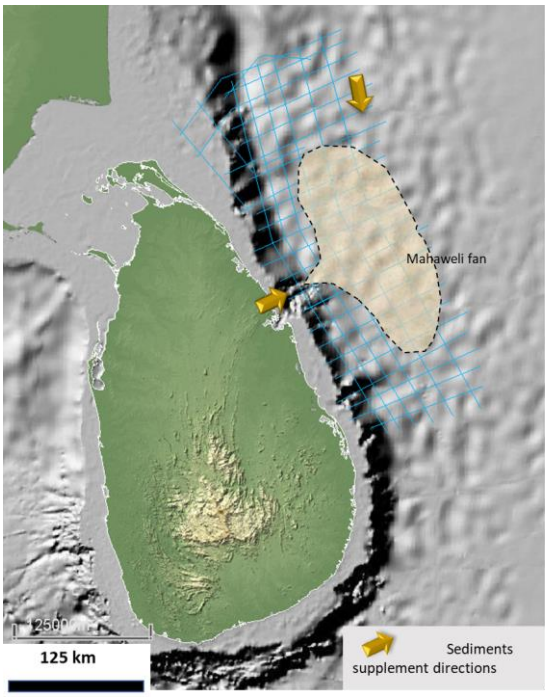

Figure 1. Mahaweli fan and sediment supply directions from onshore Sri Lanka and Bay of Bengal

References

Collett, T. S., Boswellb, R., Waitec, W. F., Kumard, P., Roye, S. K., Choprae, K., Singhe, S. K., Yamadaf, Y., Tenmag, N., Pohlmanc, J., Zyrianovaa, M., and the NGHP Expedition 02 Scientific Party, 2019, India National Gas Hydrate Program Expedition 02 Summary of Scientific Results: Gas hydrate systems along the eastern continental margin of India, Marine and Petroleum Geology

Das, S., Sastry, Y., Mohan, S., and Rao S. V., 2008, Biogenic Petroleum System of India's East Coast Deep Water Basins

Myint, L., 2018, Biogenic Gas Potential of Myanmar, 2018 AAPG Asia Pacific Region, The 4th AAPG/EAGE/MGS Myanmar Oil and Gas Conference

Tu, C. and Schenk, O., 2021, Frontier Basin Study: Offshore Eastern Sri Lanka Basin, 2D Petroleum System Modelling, European Association of Geoscientists & Engineers, Conference Proceedings, EAGE Asia Pacific Virtual Geoscience Week, Apr 2021.

SPEAKER BIOGRAPHY

Chaminda Kularathna presently serving as a Petroleum Geologist attached to the Petroleum Development Authority of Sri Lanka (PDASL), possesses over thirteen years of hands-on industry experience and has been able to excel in his present role since joining the PDASL in 2011. However, he was able to obtain his maiden degree in Geology from the University of Peradeniya, Sri Lanka and began pursuing his career driven aspirations along the same lines. The early three years of his career working as an Engineering Geologist, witnessed greater involvement in geotechnical work.

In his present capacity, he continues to contribute immensely towards driving forward the PDASL institutional work related to Sri Lanka's offshore hydrocarbon data management, assessment of Sri Lanka's offshore hydrocarbon potential and providing much valued insight on such areas to interested international operators and service providers. Chaminda Kularathna is skilled and conversant in a myriad of oil and gas exploration subjects such as petroleum systems, play evaluation, basin modelling, petroleum geochemistry, prospect risk and resource assessment, statistical treatment of uncertainty, structural geology, mapping, and GIS and is aptly able in the use of Kingdom, Petrel, AutoCAD and Arc GIS software.

While dedicating his services in planning geophysical data acquisition programmes (Multi-client seismic/ Gravity, Gradiometry and Magnetic data acquisition programmes), negotiating oil and gas contracts with international operators and service providers, managing bid rounds, preparing bid documents, evaluating bids and providing technical assistance to the cabinet of ministers, he remains committed towards delivering his best in all institutional endeavours.

ORAL PRESENTATION

Hydrocarbon Potential of the Basin Floor Fan Complex – A Comparative Study between the Offshore Bengal Basin and the Rakhine Basin, Myanmar

Abdus Samad Azad [1], Zabir Hossain [1] and Michael Whibley [1]

[1] *KrisEnergy Bangladesh Ltd.*

mike.whibley@krisenergy.com

Hydrocarbon exploration activities in the offshore Bengal and Rakhine Basins commenced during the mid-1970s. Nine (9) offshore wells were drilled in the offshore Bengal Basin from 1974 to 1979, with Kutubdia the first successful discovery in 1976. In the Rakhine Basin, seven (7) wells were drilled during the same period, with most abandoned because of the drilling hazard related to overpressure. Although intended as an oil-play, based on oil-seeps identified in the onshore portion of the Rakhine Basin, only a few wells were found with gas shows. Exploration activities effectively remained suspended both in the offshore Bengal and Rakhine Basins until the mid-1990s, with the sole commercial discovery being made by Cairn Energy in 1996. Some 500 bcfg were produced from Sangu, with production ceasing in 2014. Apart from Sangu, some sporadic unsuccessful exploration drilling was carried out from 1998 to 2007 (Reju, Sonadia, Hatiya, and Magnama). In the Rakhine Basin, exploration drilling restarted in 2003 with the first commercial discovery being made in the Shwe-1ST-1 well shortly thereafter (Shwe Field). To date, around fifty exploration wells have been drilled in the offshore Rakhine Basin with further large gas discoveries made at Shwe-Phyu, Mya, Thalin and Mahar.

Comparative exploration history suggests that the offshore Bengal Basin is amongst the least explored frontier Basins in the world, although it has been considered petroliferous for a long time and has attracted many research scientists and studies. Apart from maritime boundary conflicts with Myanmar and India, which resolved in 2012 and 2014 respectively, issues related to a lack of governmental policies and efforts, prioritizing bureaucrats over the technocrats, delay in decision making, failure in attracting IOCs, an over dependency on import-based energy, and an obscure energy strategy are the primary reasons for the restricted exploration activities.

A southeastern shallow water offshore area of the Bengal Basin, Bangladesh, has been extensively studied, with several interesting prospects (basin floor fans, slope fans, channel-fill sands, shelfal sands, channel leveed sand, complex channel-fill and mass flow deposits) identified and mapped. Most of these are proven successful in both the Bengal Basin (complex channel fill, low relief anticline with stratigraphic elements – Sangu Field) and Rakhine Basin (basin floor fans – Shwe Field, mass flow deposits – Thalin Field).

Recently acquired, good quality seismic data sets and its comprehensive interpretation, offset well data analysis and the analogue Shwe discovery suggest that apart from the proven reservoirs in the Sangu Field, basin floor fans and subsequent sand-filled feeder channels may be of particular interest for future hydrocarbon exploration. Several basin floors fans have been mapped which are comparable to the Shwe fan lobes. These fans have a similar progradational trend and are believed deposited under comparable depositional settings with similar provenance, sediment transport direction and reservoir quality; although they are geologically older compared to Shwe. All essential play elements required for a successful petroleum system are proven in the area, and analysis suggests this area is ideal for future vigorous exploration opportunities.

SPEAKER BIOGRAPHY

Abdus Samad Azad (PhD)

Abdus Samad Azad (PhD) has more than twenty years' experience within the oil and gas industry. Dr. Azad started his career in 2001 as a geologist in the national exploration company of Bangladesh (BAPEX) in 2001, before joining KrisEnergy Bangladesh in 2014 where he currently works as the Geological Manager.

He earned his PhD doctorate in sedimentology from the University of Oslo in 2013, following completion of a MSc degree in petroleum geoscience from the Norwegian University of Science and Technology (NTNU) in 2004. He also obtained his MSc

degree in geological science from the Jahangirnagar University, Bangladesh. He is an active member of several professional and social groups (Bangladesh Geological Society (BGS), Norwegian Geological Society (NGF), American Association of Petroleum Geologists (AAPG), Southeast Asia Petroleum Exploration Society (SEAPEX)).

S. M. Zabir Hossain

S. M. Zabir Hossain has more than twenty years' experience within the oil and gas industry. Zabir commenced his career in 2002 as a geophysicist in the national exploration company of Bangladesh (BAPEX) in 2001, before joining KrisEnergy Bangladesh in 2014 where he currently works as the Geophysical Manager.

He earned his MSc in geology from the University of Dhaka, Bangladesh in 1998, and completed a second MSc in applied geophysics from the Chiang Mai University, Thailand in 2009. He is an active member of several professional and social groups (Bangladesh Geological Society (BGS), American Association of Petroleum Geologists (AAPG), Society of Exploration Geophysicist (SEG)).

Michael Whibley

Mike is an international geologist with over 40 years of extremely wide and varied management, operational, and interpretive experience in exploration, appraisal/development and production projects and new business development.

He graduated with a BSc (Hons) in geology from the University of Western Australia in 1979, subsequently working for Phillips Petroleum in Australia as a graduate geologist prior to working for a variety of IOCs such as Oxy, Apache, Santos, Santa-Fe/Devon Energy, Pearl Energy-Mubadala and KrisEnergy. He currently works as an aged consultant based in Singapore.

ORAL PRESENTATION

Exploring the DHI led Bampo sandstone gas play in the Andaman II block, Offshore Aceh, Indonesia

Nick Comrie-Smith [1], Fauzan Arif [1], David Jessup[1] and Damion Rudd [1]

[1] *Harbour Energy Indonesia*

nick.comrie-smith@harbourenergy.com

The Andaman II PSC was signed by Premier Oil (now Harbour Energy), as Operator (40% interest) in April 2018, with Partners Kris Energy and Mubadala Energy, (30% each). The block was initially a Joint Study Area (JSA) in 2011 with Premier Oil and Serica (then Kris Energy) as operator; Premier Oil assumed Operatorship in 2014 when Kris Energy sold half of its stake to Mubadala Energy. In 2020 Kris sold its 30% interest to BP. Andaman II is a Gross Split PSC with a 30-year term, commencing with an exploration term of up to 10 years. The block is located 120km north of Lhokseumawe, Aceh Province, in the northern part of Sumatra Island. The northern boundary of the block is defined by the Indonesia/Thailand maritime boundary. The water depth varies from 900m to 1400m. A multi-client 3D seismic survey was acquired by PGS over the western part of the block in 2019 with processing to PSDM completed in December 2020. 2D seismic has been acquired by previous operators in the area: Mobil in the 1980's, Inpex in the early 1990's and two multi-client 2D surveys cover the area: the NS06 survey by PGS in 2006, and the MCG North Sumatra survey in 2012. One well had been drilled on the block: Bayu Laut Dalam-1 (BLD-1) by Inpex in 1994. The well was a dry hole with minor shows. Across the border in Thailand key offset wells are W9-E1 and W9-B1, a gas discovery in Bampo sands, both drilled by Esso in the 1970's. A drilling campaign was undertaken by Unocal, also in Thailand, in the 1990's discovering gas in Bampo equivalent carbonates at Kantang-1. More recent (post 2000) seismic has identified DHI/amplitude anomalies and flatspots, which have been increasingly enhanced with later vintages of seismic. In May 2022 the Timpan-1 well, targeting one such DHI flatspot on the most recent North Sumatra Multi-Client 3D dataset, was drilled by the Andaman II JV, discovering gas in the Bampo Fm clastics.

The geology of the Andaman II block is characterised by a north-south trending graben system, similar in age to many other Sundaland basins, with rift initiation in the late Eocene and active extension through the Oligocene. The basin is connected to the North Sumatra basin to the south, but also forms the southern part of the Mergui basin to the north in Thailand. The area has experienced numerous (at least six) tectonic episodes but can be more simply subdivided in to syn-rift, post-rift and passive margin megasequences. The syn-rift has not been fully tested by any offshore wells. Seismic data indicates the presence of a high reflectivity package in the lower syn-rift, believed to be coal/carbonaceous rich sediments. This is overlain by fluviodeltaic sands of the Parapat Fm the top of which marks the base of the post-rift megasequence. The onset of post-rift thermal subsidence in the upper Oligocene was accompanied by the deposition of the Bampo Fm, which is confirmed as a deep water deposit from biostratigraphy in surrounding wells, including Timpan-1. The Lower Bampo is sand prone and provides the reservoir at Timpan and across the block; the Upper Bampo is shale dominated and provides the regional top seal to the underlying clastics. The overlying Belumai, Baong and Keutapang Fms comprise the remaining part of the post-rift megasequence. This is conformably overlain by the Sereula Fm, which has been designated as a passive margin megasequence. The post-rift and passive margin sequences were also deposited in a deep water environment and consist almost entirely of pelagic shales. The Timpan prospect is a faulted 4-way structure that had been identified earlier on the pre-existing 2D seismic and together with some other structures, has become more robust on the recent 3D seismic data.

Timpan-1 was spudded in May 2022 and drilled to a total vertical depth of 13,818 feet subsea, utilizing the West Capella drillship. The well encountered a 390 foot gas column in a very fine-grained deep water sandstone Bampo reservoir. Sands are high net-to-gross with moderate porosity and relatively low permeability (1-2mD). On DST the well flowed at 27 mmscfd of gas and 1,884 bopd of associated 58 degrees API condensate through a 56/64 inch choke. The amount of non-hydrocarbon gas encountered is <1%.

Further E&A drilling on Andaman II is planned for 2023 and 2024 using the West Capella rig. It is hoped that this will identify sufficient resource to move forward with a gas development centred on the Timpan field. In the east of the PSC a 3400sqkm 3D seismic survey was acquired in Q4 2022 and is currently being processed. As a result, it is anticipated that further DHI supported prospects will be matured for drilling in 2025 and beyond.

SPEAKER BIOGRAPHY

Nick Comrie-Smith is Exploration Manager with Harbour Energy based in Jakarta. He has geoscience degrees from Leeds University and Imperial College in the UK and has been working SE Asia basins for the last 25 years with Conoco, Salamander Energy and Premier Oil. Most recently he has given up geology for paper shuffling, email management and meeting attendance.