ORAL PRESENTATION

Day 2: 8th March 2023

Session 6: SABAH AND BRUNEI

Co-Chair: Jeff Lobao, Consultant

Co-Chair: Saverio Spagnuolo, Consultant

10:55	Deep Water Sabah: The Past, Present, Future	Pollux Sii	Shell
11:20	Geomorphology of Deep Marine Sediments, Northwest Borneo	Melissa Johansson	Geode
11:45	The Resistivity Log and its Role in Understanding Sediment Unloading, Lower Kutai Basin	Stephen O'Connor	Global Geopressure Advice
12:10	Is it as Mature as you Think? Redefining the Textural Maturity of Sediments in Southeast Asia: Implications for Reservoir Quality	Amy Gough	Royal Holloway

ORAL PRESENTATION

Deep Water Sabah: The Past, Present, Future

Pollux Sii [1], Colin Grant [1], Linibid Light [1], Peter Winefield [1]

[1] *Shell*

Pollux.Sii@shell.com

Shell has had an active exploration and production presence in offshore Sabah since the late 1950's. In fact, Shell was the first company to drill offshore Labuan (Hankin-1) after being granted a marine concession off the Western coast of Sabah in 1958. Early exploration was based on dynamite-sourced single fold 2D seismic with lines targeting large geological features and yielded disappointing well results. However, with the adaptation of airguns and improved seismic penetration complemented with optimal seismic migration techniques, the improved imaging led to a string of commercial discoveries starting with Erb West-1 in 1971. This unlocked the Sabah Inboard TB2.4-2.6 and TB 3.1 Topsets structural plays demonstrated in well-known fields such as Samarang, South Furious, St Joseph and Barton, and a host of smaller lesser-known non-commercial discoveries.

Whilst pioneering multiple detailed basin evaluation and play assessments in support of exploration campaigns, these activities also assisted in deciphering some of the earliest sequence stratigraphic framework of NW Borneo known as "Stages". This unconformity-bounded classification was established by in-house geologists Bol and van Hoorn (1980) in the 1970s. Subsequently in the late 90s, studies began to integrate eustatic sea level changes (Haq et.al., 1988) and tectonic influences resulting in the creation of a "Tertiary Boundary (TB) Sequence Framework" linking NW Borneo deepwater turbidite sequences. Despite multiple nomenclatures being introduced by different researchers in this basin, this foundational work remains central to current understanding of NW Borneo geological evolution.

After discovery of oil and gas in the Kinabalu field in 1989, Shell's exploration focus began to shift away from the shallow water heartland towards the realm of TB 3 Late Miocene turbidite sequences that were postulated to exist outboard and structured within the delta-toe fold belt play. With drilling technology advances allowing for safe cost-effective deepwater exploration, the 90's and 2000's became decades dominated by deepwater activities. The first material success was the giant Kebabangan gas field discovered in 1994 and followed-up with Kamunsu East gas field in 1998, signifying the presence of a major new gas play. Increased drilling activity followed, leading to the discovery of oil as well as gas in the Limbayong, Gumusut, Malikai and Ubah fields. One of the key enablers that allowed these prospects to be drillable was the availability of a carpet of high-quality 3D seismic data resulting in reliable identification of Direct Hydrocarbon Indicators (DHI's) such as flat spots supported by AVO analyses for predicting reservoir fairways. This polarized fold-belt prospects towards a more manageable level of risk. With ever greater 3D seismic coverage and improved seismic fidelity, many of the identified folds were perceived to have limited hydrocarbon retention due to pervasive overlying gas clouds, signifying retention failure. However, bold appraisal wells such as KMEUC-1s1 and Ubah-2 proved that NW Borneo fold-belt fields are dynamic traps leaking hydrocarbons due to mechanical and/or capillary seal failure but were also capable of retaining full-saturation hydrocarbons as seals reformed on pressure drop.

The deepwater turbidite play has been chased into the outer fold belt and ever deeper waters but unfortunately reservoir properties, sand thickness and quality, deteriorate towards the distal edge of the fan systems. Despite hydrocarbons being discovered in many of the fold structures outboard, most remain undeveloped due to insufficient recoverable volumes to meet the economic thresholds. Wells encountered oil in more thin beds resulting in challenging recovery. It was realized that commercial reservoir fairways were not as widespread and abundant as initially envisaged. Following Gumusut field first oil in 2014 and Malikai first oil in 2016, efforts were concentrated on near field exploration with some success. An example was Malikai 103 KMU-1 exploration-keeper where it was brought on stream within 6 months' time. Entering the current decade, it is generally believed that the conventional FTB play has been creamed, and new plays were needed to justify further wild-cat exploration.

Today, Sabah basin remain core to Shell with more wildcat exploration expected in coming years. Attention has now shifted towards the ultra-deep waters of the Sabah trough and foreland. The oil and gas discovery of Tepat-1 (2018) in Oligo-Miocene carbonates has undoubtedly stimulated excitement that another working petroleum system exists in this basin – an extension

of the Nido carbonate play in the Philippines. However, with so few exploration wells having been drilled, the materiality and commercial viability of this play remains yet to be proven.

Offshore Sabah is a world class geological laboratory in which to study the interaction of tectonics and stratigraphy. The study of inboard tectonostratigraphy enabled prediction of the presence of effective turbidite plays outboard long before seismic was acquired to reveal them in all their glory. Over the last six decades seismic data acquisition and wildcat exploration drilling have been crucial in unlocking the potential of this basin, polarising understanding of key hydrocarbon play elements and leading to commercial oil discovery. The scientific methods used here have been exported by geoscientists all over the world and have contributed to unlocking petroleum systems in many other basins.

References

Bol, A.J. and Van Hoorn, B., 1980. Structural styles in western Sabah offshore. Bull. Geol. Soc. Malaysia, 12,1-16.

Haq, B.U., Hardenbol, J., Vail, P.R., 1988. Mesozoic and Cenozoic chronostratigraphy and cycles of sea-level change. Soc. Econ. Paleontol. Mineral. 42, 71–108.

SPEAKER BIOGRAPHY

Pollux Sii is a versatile and curious geoscientist who has been working on the NW Bornean margin since joining Shell in 2017. He worked primarily on maturing fold-and-thrust belt deep water turbidite NFE prospects towards safe well execution. Prior to that, Pollux obtained a PhD in Applied Geosciences at Heriot-Watt University Edinburgh focussing on East African margin tectonic evolution and holds a MSc in Petroleum Geoscience from Imperial College London. Today his work focussed mainly on evaluating and assessing new play potentials in ultra-deepwater Sabah.

ORAL PRESENTATION

Geomorphology of Deep Marine Sediments, Northwest Borneo

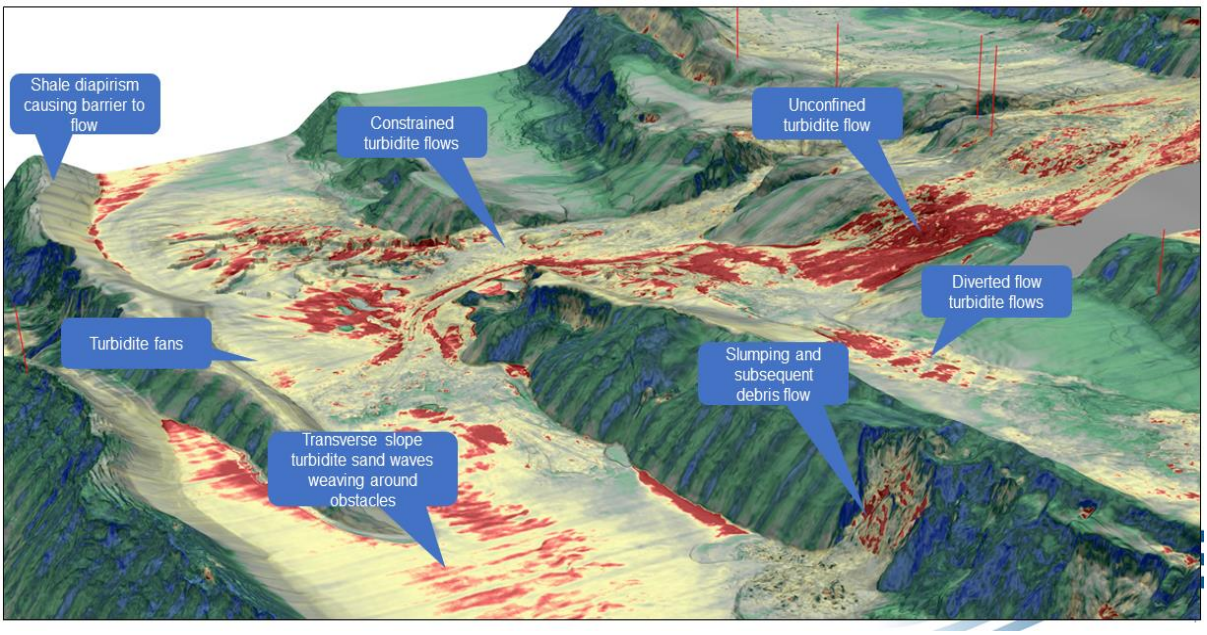
Johansson, M. [1], van Doorn, J.A. [1], Stow, D.A.V. [1], J., Roberts, I. [1] and Phillips, J. Farag, S. [1]

[1] *Geode-Energy Ltd*

mjohansson@geode-energy.com

A well-known series of sedimentary basins of Cenozoic age form a prolific hydrocarbon region situated on the NW Borneo margin. The present-day continental margin off Northwest Borneo shows many similarities to the geomorphological architecture of the Tertiary subsurface. High-resolution seismic data acquired by PGS and its JV Partners around Sabah and the Dangerous grounds reveal striking images of turbidite channels, fans, sediment waves and associated mass-transport deposits.

The downslope processes off Northwest Borneo act across a structurally controlled tectonically-active slope system, with multiple linear shale diapirs transverse to slope that create a stepped slope morphology. The subsequent frontally confined turbidites produce fill-and-spill sediments, where the topographical highs cause ponding, rapid deposition and diverted flows along slope, interacting with and weaving around the structural obstacles. The turbidites interact with megabeds that form from either small slope collapse to vast tectonic mega-slope failure blanketing the basin. These mega-beds (MTDs) are highly erosive and remove the previous turbidite deposits and redeposit the sand mixed in with the chaotic muds forming only partial seals. The modification of these downslope deposits by subsequent contour currents is unclear and identification of contourites is difficult as their seismic characteristics are masked by the slope-parallel geomorphology of some of the turbidite systems. However, the complexity and strength of modern-day oceanographic currents would seem likely to affect the downslope sediments, by cleaning and polishing turbidite sands into a hybrid turbidite-contourite facies and, perhaps, by helping to shape the large-scale sediment waves observed along structurally confined slope terraces.



Examples of high resolution imaging from the Sabah Multiclient 3D Data set highlighting the stepped slope morphology and the resulting deep water sediment geomorphological features (courtesy of PGS and JV Partners)

SPEAKER BIOGRAPHY

Dr Melissa Johansson has a Ph.D. in Deep Marine Sediments from Southampton University under the supervision of Professor Dorrik Stow. After graduation she taught for two years in Unimas Kuching Sarawak before joining Schlumberger in Kuala Lumpur in 1997. She then spent 17 years travelling the world with SLB specialising in sedimentology both carbonates and clastics in Alaska, Egypt, China and Qatar before finishing her career in KL, looking after Myanmar and Brunei in 2014. Since 2015 Geode-Energy Ltd was formed, with Dr Melissa Johansson as the owner and Director of an online consultancy for reservoir characterisation particularly borehole images and petrophysics.

ORAL PRESENTATION

The Resistivity Log and its Role in Understanding Sediment Unloading, Lower Kutai Basin

Stephen O'Connor [1], Agus M. Ramdhan [2], Arifin [2], and Amy C. Ellis [3]

[1] *Global Geopressure Advice*
[2] *Department of Geology and Department of Groundwater Engineering, Institut Teknologi Bandung*
[3] *AE Geosciences, Bristol, UK; currently at bp*

soconnor@globalgeopressureadvice.com

High overpressure is a critical drilling issue in the Lower Kutai Basin. Typical pore pressure prediction approaches involve an empirical relationship, such as Eaton (1975) using sonic log data. In areas with high geothermal gradients such as the Lower Kutai Basin, there is evidence for additional overpressure from gas generation such that sediment unloading must be considered to interpret pore pressure correctly.

In this paper we build on work in Bowers (1995) and Ramdhan and O'Connor (2022) to present a repeatable deterministic model for pore pressure from sonic data and, using selected wells from the Lower Kutai Basin, demonstrate use of the resistivity log in a similar model. In the Lower Kutai Basin, sonic logs are often absent from the logging suite or otherwise run over limited intervals, making an alternative log-based prediction method particularly valuable.

However, shallow freshwater encroachment is reported in the Lower Kutai Basin, meaning the shallow resistivity data is problematic to use to define both top of overpressure and a normal compaction trend. Care must therefore be taken if resistivity is to be used for the interpretation of unloaded pore pressure, and chiefly applied to those wells where this is less pronounced, such as pro-delta shales based on regional published salinity studies.

Assuming the usual caveats in using resistivity data, this paper suggests that resistivity can be a useful tool for pore pressure prediction in unloaded shale at elevated temperatures within the Lower Kutai Basin. At present the technique has been applied to only a limited dataset, due to data availability limitations but it is hoped with further refinement it will form a helpful additional approach in the pore pressure prediction toolkit.

SPEAKER BIOGRAPHY

Steve O'Connor is a GeoPressure Domain Expert in pore pressure and geomechanics who has also been involved in many 100's of projects globally, ranging from basinal studies and exploration risking to well planning/design and field assessments.

He has been involved in knowledge transfer and has taught more than 100 courses including bespoke courses for companies focused on integrating G&G, Asset and Drilling teams.

He has been instrumental in developing "Best Practice" workflows, has been involved in R&D to help reduce uncertainty in pore pressure prediction, and has integrated pore pressure with other disciplines such as rock physics and geomechanics.

Steve has written and been co-author on over 50 published papers.

ORAL PRESENTATION

Is it as Mature as you Think? Redefining the Textural Maturity of Sediments in Southeast Asia: Implications for Reservoir Quality

Amy Gough [1]

[1] *Southeast Asia Research Group, Royal Holloway, University of London*

amy.gough@rhul.ac.uk

Much of our understanding of the textural maturity of sedimentary rocks is based on models developed in temperate and tectonically stable continental settings, such as North America. These models are then applied globally, however new results show that this has led to a misapplication when considering areas such as equatorial Southeast Asia, where a humid climate, long-lasting active volcanism, and a lack of the stability that cratons provide, all affect the resultant composition of sedimentary rocks. These misapplications have implications for the understanding of reservoir quality, especially in areas where the sediments are compositionally mature (quartz rich) but texturally immature (poorly sorted and angular) as the use of traditional models (e.g., QFL & QmFLt) can lead to assigning incorrect sediment properties to the subsurface.

Whilst many models have limitations when applied outside the area in which they were developed, the most important factor to consider when determining reservoir quality is light mineral analysis. When plotting light minerals from around Southeast Asia, it should be considered that the main sediment sources are volcanic arcs, exposed basement terranes, and ophiolites. Therefore all samples should contain moderate amounts of feldspar and lithic fragments, but in contrast to this, datasets show a predominance of quartz. This is largely due to the dissolution of feldspar during transport and burial under humid conditions and the disaggregation of lithic fragments during transport and cycling in a tectonically active regime.

This talk considers over 1000 samples from around equatorial Indonesia and Malaysia, with c. 400,000 individual counted grains, to interrogate the functionality of these traditional QFL and QmFLt plots. These samples are taken from locations where the climate and tectonic setting is well defined to better understand the controls on the disparity between textural and compositional maturity in the region.

SPEAKER BIOGRAPHY

Amy Gough specialises in sediment provenance studies and palaeogeographic reconstructions in Southeast Asia. As the director of the Southeast Asia Research Group since 2020, based at Royal Holloway, University of London, Amy is dedicated to understanding how onshore studies can inform about what is happening in the subsurface offshore. With almost 10 years of experience in the field, Amy's research has focused on studying the geological history of Southeast Asia, particularly the mechanisms driving sedimentation, tectonic events, and basin evolution.