Structural and stratigraphic review of the Southern Chindwin Basin, Myanmar

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The Chindwin Basin in northern Myanmar has been of interest to the petroleum industry since the discovery of the Indaw oil field in 1915. A century later, after opening of the country to foreign investors and expertise, Pacific Hunt Energy (PHE) was awarded a production sharing contract (PSC) for the C1 Block (Figure 1) by the national oil and gas company of Myanmar (MOGE). Recent work on regional geology and interpretation of existing seismic data has significantly enhanced the prospectivity of PSC-C1. We are presenting our advances in the structural and stratigraphic interpretation of the Southern Chindwin Basin, and we compare these with the legacy interpretation from previous exploration activities in the study area.

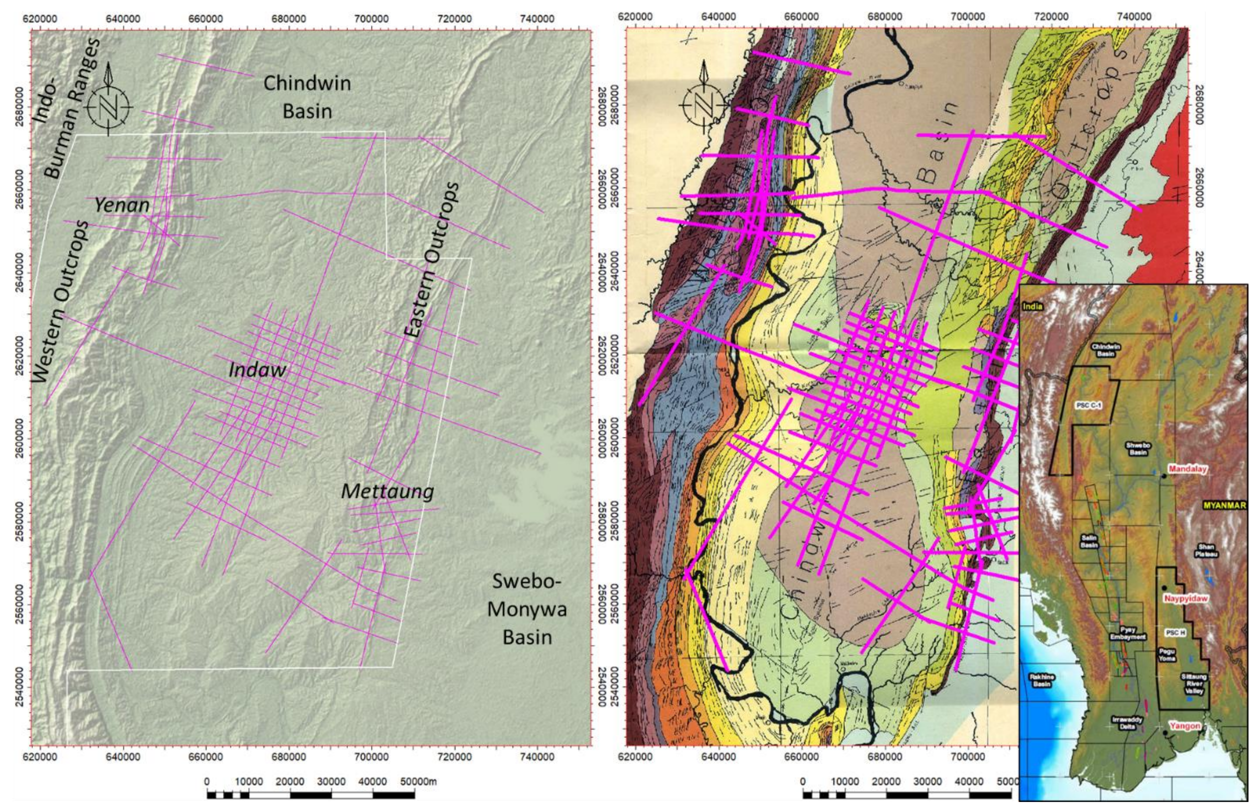

Figure 1: (Left) Digital elevation model of the Southern Chindwin Basin showing the western and eastern outcrops, outline of PSC-C1 (white border) and existing seismic lines (pink). (Right) Geological map of the Southern Chindwin Basin. Inlet shows overview map.

Structural and depositional framework

The Chindwin Sub-Basin is part of the Central Myanmar Basin (CMB). The CMB developed as a continental shelf, located at the western margin of the Myanmar Microplate between the east-dipping subduction of the Indian Plate oceanic crust to the West and the Western Myanmar Continental Magmatic Arc (WMA) to the East, in the Upper Cretaceous to Early Eocene (e.g. *Barber et al. 2017, Kyaw Linn Oo et al. 2015, Racey & Ridd 2015*). Collision of the Indian continental block with the Myanmar Microplate started in the Late Paleocene and compressional dextral strike-slip formed the SSW-NNE striking forearc sub-basins that we find today (*Barber et al. 2017*).

The depositional environment developed from shallow marine carbonate platforms in the Late Cretaceous to shallow marine shale-rich and organic carbon-prone deposits in the Early Eocene to fluvio-deltaic flysch-type cycles in the Middle to Late Eocene and throughout most of the Miocene. The Tertiary stratigraphic record is only notably interrupted by regional hiatus during basin reconfiguration in the Oligocene (*Kyaw Linn Oo et al. 2015*) and at the onset of folding and thrusting in the Late Miocene (*Barber et al. 2017*). The basin centre is covered by orogenic molasse of the Irrawaddy Formation today, concealing the structural and stratigraphic link between the outcropping strata on either elongated basin edge (Figure 1).

Legacy studies and exploration history

The complexity of the tectonic overprint has first been consolidated by regional surface geological mapping campaigns in the late 1960's and throughout the 1970's. It was confirmed that multiple thrust sheets actively formed the outcropping strata on either side of the basin. However, correlation of the >6km thick Cenozoic stratigraphy across the Eastern and Western outcrops is still poorly understood, e.g. eastern outcrops have different stratigraphic subdivision than those in the west (Figure 2).

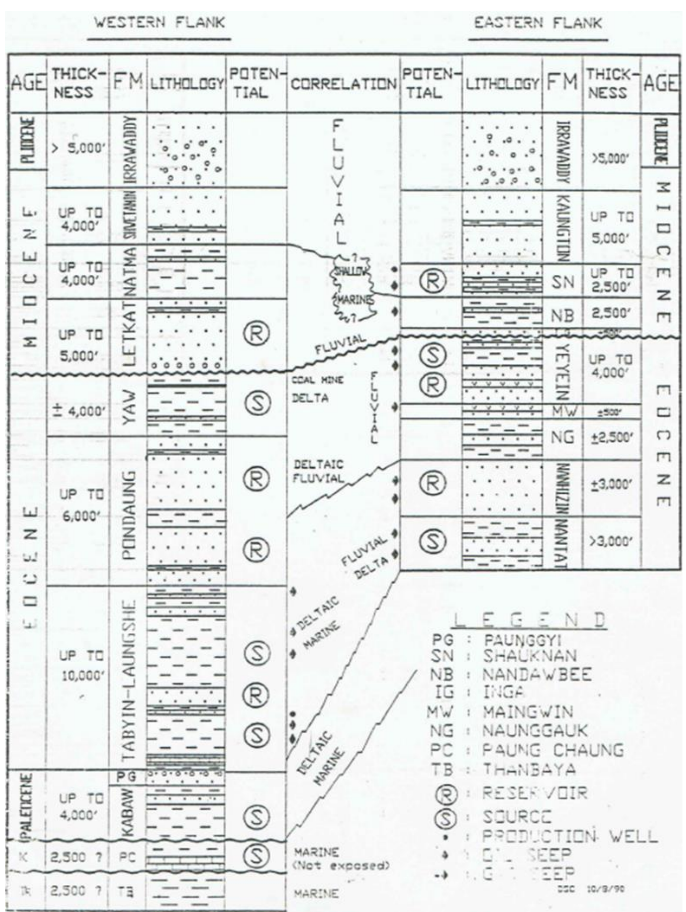

Figure 2: Stratigraphic columns of the Western (left) and Eastern (right) Outcrops and tentative correlation based on a basin review from Yukong Ltd. in 1992.

Early exploration activities in the 19th century were spawned by the occurrence of oil and gas seeps (mud volcanos, gas springs, oil seeps in outcropping Eocene shales, contaminated water wells etc.), traditionally exploited by an indigenous petroleum industry for centuries (*Racey & Ridd 2015*), and by mapping of surface structures (such as Yenan) in the 20th century.

The most prominent structural feature along the basin axis is the Indaw cross-faulted compressional anticline (Figure 3). The shallow Indaw oil field is hosted by the 'Indaw Sand' at 80% net-to-gross and sealed by regional shale barriers that are identified on available well log data. Pre-war drilling campaigns accompanied the initial development of the shallow oil (1915-1942) and ceased with the destruction of the field prior to Japanese invasion in WW2. After the war, exploration wells were drilled in the mid 1960's, late 1970's, 1990-1991, and early 2000's. Four wells on structure have proven gas in the 'Indaw Clay', underlying the sands in the central oil field at about 1000m below ground level. The change from sandy fluvial to shaly deltaic environment coincides with a pressure ramp induced by recent uplift of the Indaw anticline.

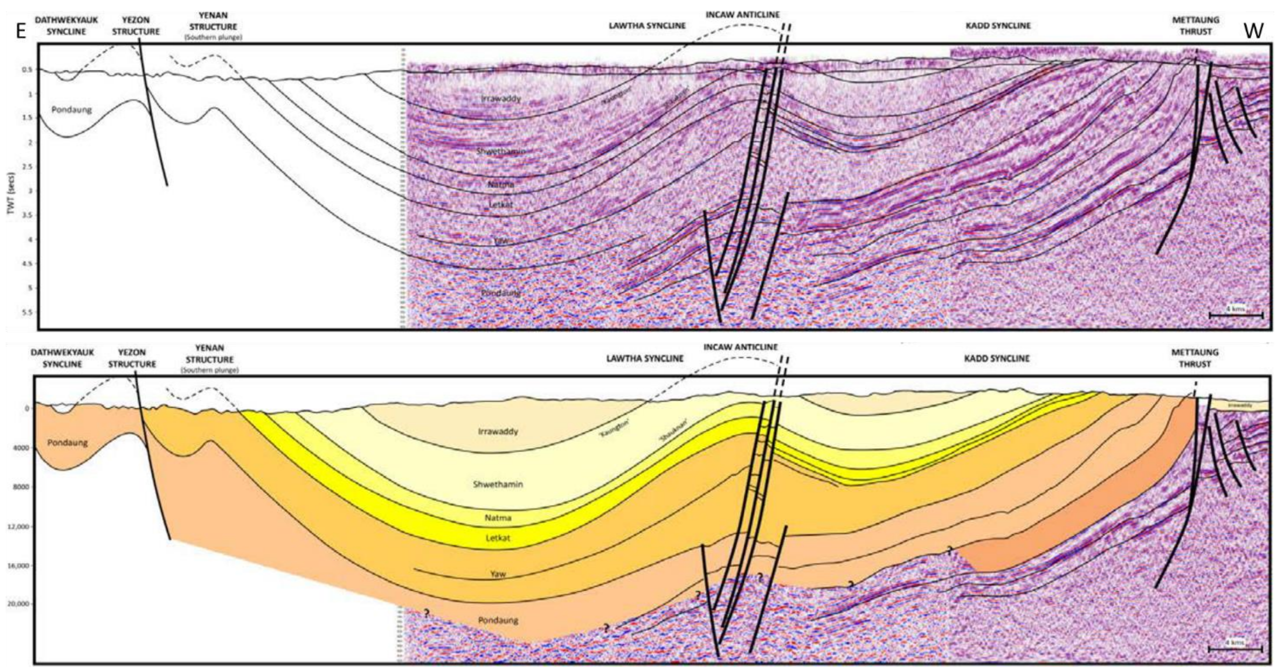

Figure 3: Seismic cross-section through the Indaw anticline with legacy interpretation

Yukong Ltd. drilled the deepest well on structure, YK-1, in late 1990 after first 2D seismic was shot in this underexplored basin by Amoco earlier that year. The well reached TD in the Late Eocene Yaw Formation at ~2800m and was abandoned due to wellbore stability issues caused by overpressures prior to entering the target Pondaung Formation, a reservoir-prone stratigraphic unit sourced by unroofing of the WMA in the east (*Kyaw Linn Oo et al. 2015*). Although prepared to re-drill, Yukong eventually relinquished the licence due to change in economic climate. Pacrim Energy studied the area in late 1990 but pulled out without field operations. Three wells drilled by MOGE in 2002-2004 targeted oil on the southern flank of the Indaw structure. One of the wells tested gas but development was put on hold as there was a limited market for gas at that period. Also, CNOOC explored the licence for some years. PHE has an ambitious plan to appraise both the oil and gas deposits and develop them for the local market and for export.

Review of basin architecture

The architecture of the Southern Chindwin Basin was first visualized on 2D seismic shot in 1990-1992 (Amoco & Yukong), followed by campaigns in 2006-2007 (CNOOC) and 2017-2018 (PHE). Primary objective was the assessment of hydrocarbon prospectivity with focus on trap identification and, equally important, reservoir prediction. The latter requires a better understanding of the east-west correlation of the Cenozoic formations under consideration of the 'Indaw Sand' and 'Indaw Clay' lithological units. Our review supports the idea of a shallow detachment level of the Indaw thrust sheet in the soft lignite beds of the Late Eocene Yaw Formation (Figure 4). Deeper stratigraphic levels reveal a regular fault pattern that strictly follows the basin axis and resembles inverted extensional faults. These structure the Pondaung Formation and boost deep prospectivity underneath the Indaw anticline. Most thrust sheets were only identified when integrating the surface geological maps with the seismic data as thrusting occurs on detachment levels parallel to the depositional bedding. 3D definition of Riedel fractures at the crest of the Indaw structure was achieved by similar integration of surface vs. subsurface data. This exercise will be re-iterated after a high-resolution remote sensing study of the Indaw area is delivered later this year. Seismo-stratigraphically, we tentatively identify the Miocene Letkat Formation as the historic 'Indaw Sand' and the Eocene Yaw Formation as 'Indaw Clay'.

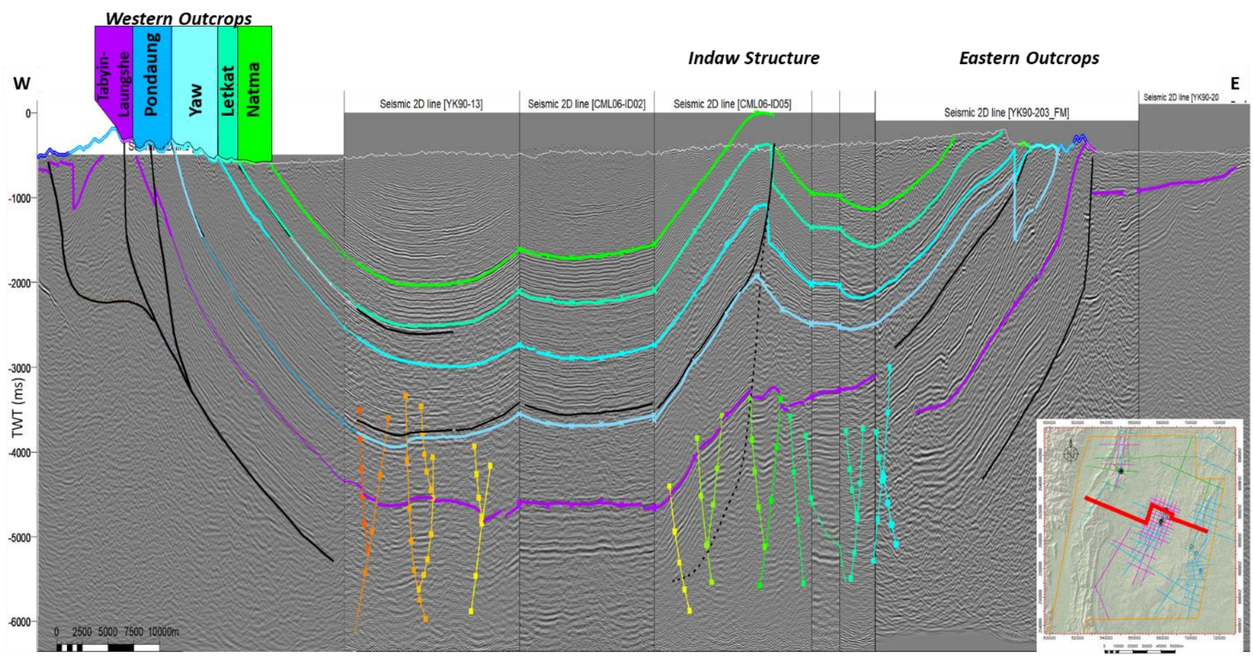

Figure 4: Revised seismic cross-section through the Indaw anticline. Thrust faults are marked in bold black. Note the deep regular fault pattern.

Conclusions

Integration of a large pool of legacy data acquired over the past century reveals the structural and stratigraphic architecture of the Southern Chindwin Basin in PSC-C1 (Figure 5). Seismic correlation under consideration of various surface geological data helped pinpoint the stratigraphic correlation of the formations outcropping in the western ranges with the rocks drilled in the prolific Indaw anticline. Structural re-evaluation of the Indaw boundary fault confirmed the sub-thrust play of the Pondaung reservoir sands. Tie-in with the formations documented across the Eastern Outcrops under consideration of potential W-E facies transitions has yet to be incorporated after revision of the surface geological outcrop profiles from the 1970's.

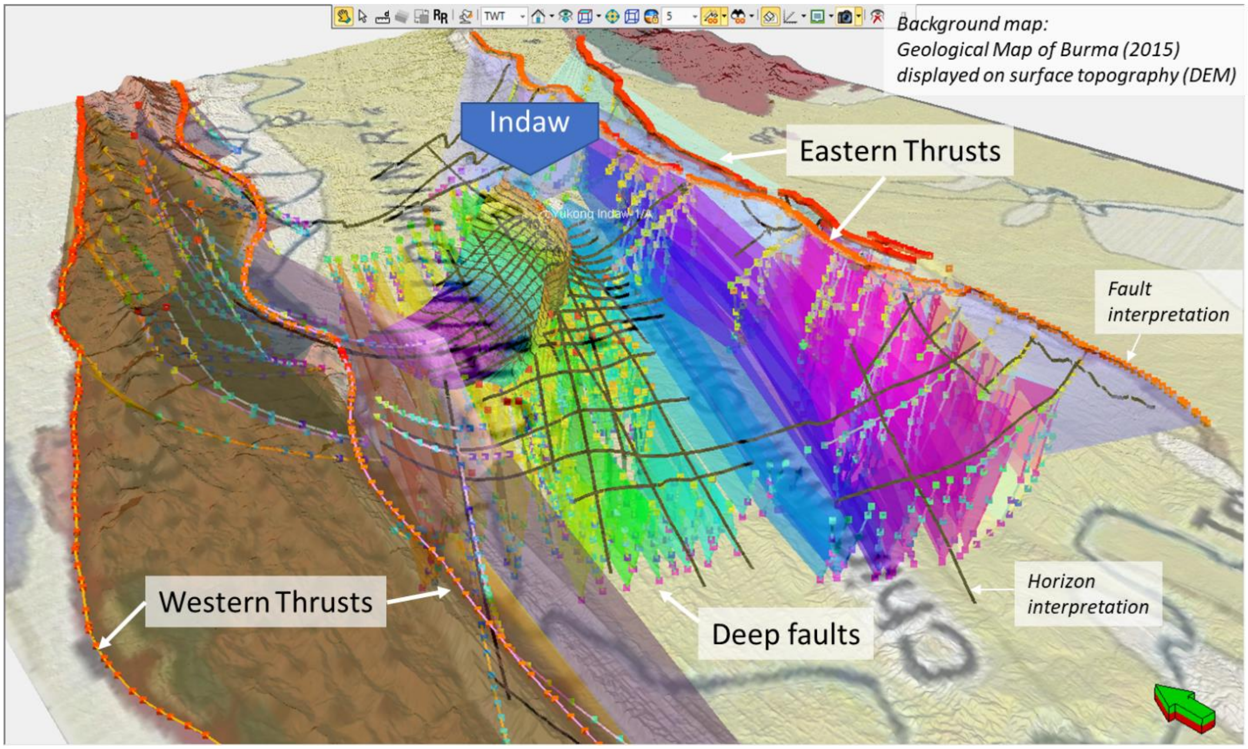

Figure 5: 3D view of the Indaw anticline with thrusts and faults mapped on surface and seismic data.

<u>References</u>

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<u>About the presenter</u>

Ulf Böker is a geoscientist, petrophysicist and an experienced Petrel modeller. He joined PanTerra in 2011 and has since conducted many small and large structural and petrophysical evaluation projects in various geological settings. He is experienced in seismic interpretations in Petrel, Kingdom and Geographix software, and he has built complex static models in clastic and carbonate environments. Ulf is working on the Myanmar licences of Pacific Hunt Energy since September 2017.

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