Abstract

The Mann field is the third in size of the onshore producing oil fields of Myanmar. The field is located in the Salin Basin, the most productive of the Central Myanmar Basins (“CMB”). State enterprise MOGE discovered the field in 1970, and put it in production in 1972. The field has produced a total of some 120 MMbbls and 123 Bscf gas, with a maximum output of 24,700 bopd in 1979. MPRL E&P has been the contractor for MOGE to enhance the oil recovery of the field since 1999 and is rewarded with a share of the incremental production. The field now produces some 1,320 bopd including some 970 bopd of incremental production due to MPRL E&P’s and MOGE’s efforts, with an average decline rate of only 4% compared to more than 12% before 1997.

Incremental petroleum has been produced by a combination of infill drilling, deepening, additional perforations and some innovative technologies pioneered by MPRL E&P and MOGE in the Myanmar onshore oil scene, such as hydro-fracturing and the use of enzymes and other paraffin scavengers. MPRL E&P and MOGE have also introduced international practices of HSE and CSR in the field long before they were enforceable by law in the country, including a mechanism of resolution of operational grievances praised by international watchdogs and nearly 90% of all formation and wastewater reinjected in the formation.

The Mann structure is a 30-km long asymmetrical anticline with a northwards dipping axis, increasingly tight flanks southwards and a major westwards dipping reverse fault complex bounding the anticline to the East, where the flank is steeper than to the West. The Mann anticline is one of about a dozen similar structures described by U Ko Ko 2016 as belonging to a late Pleistocene N-S strike-slip deformation belt nearly parallel to the axis of the basins along the Ayerwaddy River, from the Letpando oil field in the North of the Salin Basin to the Shwepyithar wet gas field in the Pyay Embayment in the South. This deformation belt is characterised by en-échelon asymmetrical anticlines, partly filled with shallow oil and/or gas, with wet gas in deeper tighter reservoirs as proven in a few structures (such as Mann and Pyay fields).

The Mann field, located just north of the well-known Minbu mud volcanoes, is very compartmentalized, with three main fault blocks separated by late cross-field normal faults, each with their different exploitation challenges in terms of depth, stratigraphy, compartmentalization and
pressure regime of reservoirs. The field produces a variety of oils spanning from 24° to 47° API from 22 Oligo-Miocene stacked reservoirs in 59 pools.

One of the means of enhancing production has been infill drilling. MPRL E&P has drilled about 21 deep infill wells, six of which exceeding 6,000 ft, most of them commercially quite successful. Mann-665 was drilled in the southernmost much compartmentalised DS fault block and has been producing since November 2009 some 5-6 bpd of the lightest oil in Mann practically without decline. The oil density measures some 47° API with very low paraffinic content by contrast with all other oils of the field. This peculiar oil probably migrated through a deep-seated network of faults intersecting the well bore near the main bounding fault to the East. The result of M-665 has been one of the incentives to drill in 2011-2012 the deep exploratory well of Mann Deep East-1, which discovered a wet gas play in the Lowermost Oligocene Shwezetaw sandstones. This challenging well could not be tested because of excessive tectonically induced formation pressures needing a drilling mud of up to 21 ppg (sg 2.5) to be contained. MPRL E&P has attempted to integrate the basic oil analyses of M-665 with other oil analyses in the field, as well as with stratigraphical, sedimentological and structural aspects to sketch some conclusions on exploration-appraisal prospectivity of the Mann field.
WHAT DOES THE QUAIN'T OIL OF MANN-665 TELL ON REGIONAL GEOLOGY?

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MPRL E&P in short:

- 20 years of successfully operating in both the onshore/offshore upstream sectors of Myanmar as a respected, efficient & trusted partner
- Workforce of >99% Myanmar skilled personnel
- Introduced quite a few technical innovations and HSE modern practices in the Mann oil field
- Some of the highest levels of social management in the country, such as pioneering the use of operational grievance mechanism process in 13 communities within Mann Field
- Pioneer of successful exploration in offshore southern Rakhine Basin with the Pyi Thar-1 gas discovery in March 2012
Mann oil field in short

- Discovered in 1972 by MOGE based on sparse seismic
- Second best onshore oil producing field in the country
- Estimated STOIIP: 500 MMbbls oil
- Peak production 24,711 bopd in 1979
- Baker Hughes signs PCC in 1997, pulls out in 1999 when MPRL E&P picks up operatorship
- Produced so far 120 MMbbls oil and 125 Bscf gas, incl. 13 MMbbls of incremental oil by MPRL E&P / MOGE JV
- 22 reservoirs in Oligo-Miocene sandstones, four main fault blocks
- Main deformation during late Pleistocene, hardly any OWC, initially overpressured
- Amazing range of oil gravity from 24° to 46° API
Mann Field: innovation and environment

- Standard operations include new wells, deepening of existing wells and additional perforations,

- **Successful innovations** introduced by MPRL E&P in the field include: Greenzyme treatment & mini-hydraulic fracturing

- MPRL E&P introduced international environmental management practices, such as **re-injection of formation water back to reservoir** (91% water so far)

- Zero-wastewater discharge outside of the field installations

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**CSR: MPRL E&P pioneered in the Mann Field:**

- Refurbishment of community infrastructure
- Waste management facilities
- Operational grievance mechanism
- Community based volunteers
- Community investment initiatives
- Voluntary initiatives by employees
Regional structural map

Main kitchen of Salin Basin is to the West of oil-charged anticlines by contrast with Pyay Embayment

- **Mann Field** located in Salin Basin
- **Mann structure** belongs to major late Pleistocene deformation belt of en-échelon structures related to NNE-subduction of India plate beneath SE Asia plates

A superimposed structural trend of en-échelon folds runs all along the Salin Basin southwards towards the Pyay Embayment: the Salin-Pyay trend
Mann Field: Stratigraphy & Reservoirs

- **Mann producing reservoirs**: middle-upper Oligocene Padaung and Okhmintaung; middle Miocene Pyawbwe and Kyaukkok sandstones
- **Mann Deep prospective reservoir**: Lower Oligocene Shwezetaw sandstones
- Main source rock likely to be Upper Eocene Yaw lower coastal plain shales and coals

- **Sands**: Litharenite, older stratigraphy => cleaner and more quartzitic
- **Porosity vs permeability**: 15-30% porosity, 1-1000 mD permeability
- Weak depth trend, strong stratigraphic trend; older sands => better poroperm trend

**Grain composition**

**Poroperm trend**
Mann Field: Structure

- 3D survey in 1997
- Four main fault compartments
- More intensely compartmentalized southwards
- Excellent correlation between blurred seismic and overpressures

Minbu mud volcanoes
Mann-665 history

- **MPRL E&P** drilled **M-665** to TD 4,100 ft in *Padaung Intra-5300' Sd*, tested and completed in DS southernmost and most compartmentalized fault block in June-Nov. 2009
- **M-665** perforated and completed in a sand named at the time **5050' Sands** (initial production gas and after three weeks suddenly 14 bopd, stabilized at 7 bopd after few days)
  - This sand has produced the lightest oil of the field (ca 46°API) with low wax content for a nearly constant flow rate of 4-6 bopd with hardly any decline
  - This oil drastically contrasts with other oils of the **Mann Field** including other light oils
  - **Geochemistry**: How different is **M-665** light oil from other oils in the field? Any geochemical explanation such as gas mixed with oil, source-rock issue, etc?
Mann-665 correlation

- Note apparent reverse fault through M-665, including light oil 5050' Sd in downthrown compartment
- However the purple section appears absent in nearby M-58 and M-663, due to complex (normal?) faulting?
**Mann-665 correlation vs seismic**

- Poor seismic does not tell the story, due to complex faulting and related shale injections

Oil migration path sketch
(U Than Hlut, Geomyanmar 2012)

Deep rooted faults system (?)
**Mann oil characteristics**

- Oil densities vary from 24° to 46°API;
- Fair correlation of lighter oil vs deeper stratigraphy

- Refinery fractionation curve offers a cheap geochemical differentiation tool to apply on a wide variety of samples
- *M*-665 oil shows to be distinctly different compared to other Mann oils
- Note *M*-663 oil (~200 m from *M*-665) from the same stratigraphical interval is relatively heavy with a very different fractionation curve

- Good correlation of lower viscosity vs lighter oils
- *M*-665 oil distinctly different from other Mann oils
Are Mann oils biodegraded?

- Most Mann oils appear to be from a mature source rock
- Mann oil samples contain little NSO suggesting absence of or low biodegradation
- By contrast, oil isolated from the mud of the Minbu volcanoes S of Mann oil field contain significant amount of NSO as expected, because of biodegradation
- Probably short migration path from kitchen
- Mann oil contains less than 0.5% sulphur, less prone to biodegradation

- GC-MS on M-665 shows oil to be generated at peak of generation time

Biodegradation

Crossplot of Triterpane Maturity Parameters

M-665

Maturity ranges for clastic source rocks after Miles, 1989
Both parameters are relatively higher in coastal/coal source oils
Gas chromatography (1/2)

- Chromatograms appear to show higher plant (waxy) derived oil for both M-665 light crude oil and ~30° API oil from HSB Field, located in the same Minbu anticline structural trend.
- Oils from M-665 and HSB clearly different from the non-waxy oil of the Rakhine coast, generated mostly from algae and with a mixed estuarine/marine pro-deltaic or shallow lacustrine depositional setting.
**Gas chromatography (2/2)**

- Oils of *Salin Basin* fields including *Mann* are generated from mixed source, mainly from terrigenous (land plant) origin
- Is *M-665* oil deriving more from higher plant? From a more terrigenous source-rock? => Lighter oil for same maturity than other crudes?
Some conclusions on *M-665* oil

**GEOCHEMISTRY**
- *M-665* oil is significantly different from all other *Mann* oils, and even from nearby oils of the same reservoir.
- API gravity correlates fairly well with stratigraphy (the older the reservoir, the lighter the oil).
- *Mann* oils sweet and almost non-biodegraded.
- *Mann* oils mostly sourced from the same type III or mix SR.
- Maturity analysis of *M-665* indicates the oil was generated in the peak oil maturity window.
- ENI now analyzing three different oils from *Mann* Field to be integrated with other *Central Myanmar Basins* data.

**OCCURRENCE**
- *M-665* is a very stable producer by contrast with other mostly declining wells of the *Mann* Field.

**PROVISIONAL CONCLUSION**
- *M-665* oil appears to belong to a different HC charged system possibly a more mature SR.
- Is *M-665* tapping in an open fault system with oil migrating from deep kitchen?
- *M-665* oil and presence of oil in Minbu mud volcanoes were encouraging enough to drill *Mann Deep East-1* in 2011-2012 to test Lower Oligocene *Shwezetaw* sandstones.
**M-665 as a teaser for deep exploration potential: the MDE-1 well**

- 196 days of operations in 2011-12
- Incl. 4 sidetracks and MW up to 21 ppg (sg 2.52)
- Lower Oligocene Shwezetaw wet gas bearing sandstones present (thinner than expected and could not be logged)
- HC appears yet different from M-665
MPRL E&P thanks Operator MOGE for allowing to present this study

Q & A

Thank You