Further Insights on the Prospectivity of the Morondava Basin, Offshore Madagascar, based on New Seismic Data.

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The authors give an update to their 2013 AAPG and HGS/PESGB poster papers (*) on the Petroleum prospectivity of the Morondava Basin, Offshore Madagascar.

That work was based on an analysis of a ~13,000 line km long offset 2D Multi-Client seismic survey (plus gravity and magnetic data)(fig 1) acquired in 2013 in the offshore part of the Morondava Basin by BGP as a multi-client survey under the jurisdiction of the government authority OMNIS; and in preparation for a new International Bid Round.

Figure 1: BGP/TGS MAD-13 Survey location (10 x 10 km grid covering 70,000 sq kms (35 Blocks); License map (Omnis).
The 2013 poster papers presented initial observations on the hydrocarbon potential of the basin; the nature of the Davie Ridge; the relationship between the Basin and its conjugate margin in Tanzania and the recent discoveries there and offshore Northern Mozambique.

This update is based on further work on the Pre Stack Time Migrated data-set.

Evidence from the dataset shows large (e.g. 20 x 80 km) sandbodies of both Tertiary (fig 2) and Cretaceous age; fluvial channels of Cretaceous to Tertiary age (fig 3); Tertiary (gas filled) patch reefs (fig 4a) and other reefal features of Cretaceous age (fig 4b & c); drape-over plays (fig 5); gas escape structures (fig 6a) with large regional seals (fig 6b); basin floor fans (fig 7); horsts/grabens of Jurassic/Permo-Triassic age (fig 8) and toe thrust plays of Cretaceous age (fig 9).

Prospects occur in the Coastal Platform area and at the foot of its slope; east of the Davie Ridge (ie onlap from the east); and west of the Davie Ridge in the Kerimbias Graben (Cretaceous onlap from the west; large basin floor fans and thrust faulting) – some of these elements are indicated in fig 10 (map) and fig 11 (type section).

Since the initial work performed last year, new observations made by both the JV G & G team (Tyrell 2014) and by the authors include the following:

1) Whilst the onshore and shelfal part of the Morondava Basin contain rocks of Permo-Triassic age, the deeper offshore parts (either side of the Davie Ridge) are believed, in the main, not to. Instead we can propose that there is a thicker than initially expected syn rift Late-Jurassic/Early-Mid Cretaceous section.

2) The current working hypothesis is that the Davie Ridge is Palaeozoic or metamorphic and does not contain Mesozoic sediments. A closer examination of its structure and its gravity response (in the survey area) shows that in addition to the low gravity readings along the Ridge, its eastern side corresponds to a gravity high. The seismic data however does not indicate any great differences between either side. Unseen physical differences must exist. These are currently unresolved but are suspected to be related to large scale crustal processes which brought Madagascar to its current position.

3) Source rocks include those of Late Jurassic to Early Cretaceous and basin modelling indicates that these are mature for oil as well as gas generation.

4) Syn-rift structures were formed before the expulsion of hydrocarbons. Large (e.g. 200 sq km) structures show closure and a number of flat spots have been noted (e.g fig 12).

5) Numerous other plays are seen – as detailed above and in the seismic examples.

The authors also note the recent exploration activity along the East African margin which has been amazingly successful for gas but not so for oil (albeit BG and partners recent Sunbird discovery offshore Kenya); and believe that the Morondava
Basin survey area could contain elements (as outlined in Table 1) which are more favourable for oil generation and preservation than those found in the deep offshore of Northern Mozambique and Tanzania. The evidence for liquid hydrocarbons is borne out from the reported results of seep analysis and coring in SAPETRO’s immediately neighbouring blocks of Juan de Nova and Belo Profond (SAPETRO 2013, 2014, Olayemi et al 2014). However we also see evidence on the seismic data (e.g figs 4a, 6a and 6b) of gas generation in the survey area – this is not ubiquitous though – its nature and extent is currently the subject of further study.

In conclusion, the survey area covers 70,000 sq kms of unlicensed territory. It has undoubted hydrocarbon potential. The authors look forward to the next development which will start with an International Bid Round and hopefully lead to success for the companies involved and for Madagascar.

Notes: (*) 2013 papers referred to above:

Morondava Basin, Offshore Madagascar – New Long Offset Seismic Data highlights the Petroleum Prospectivity of this Emerging Frontier Basin. Roberts, GF; Christoffersen, T and Weining, H. Poster presentation at the AAPG Annual Convention and Exhibition, Pittsburgh, Pennsylvania, May 2013. Published as Search and Discovery article #10493, June 2013.

New Insights on the Prospectivity of the Morondava Basin, Offshore Madagascar, based on New Seismic Data. Roberts, GF; Christoffersen, T and Weining, H. Poster Presentation: PESGB/HGS Africa Conference, London, Sept 2013. {11 page Expanded Abstract available from the authors but note that some of our initial observations have now changed – as reported above}.

Note also: an oral paper at this conference ‘Regional Setting and Prospectivity of the offshore Morondava Basin, Madagascar, seen in the newly acquired MAD13 2D dataset’ by Matt Tyrell of TGS. We acknowledge use of figures from this paper and fruitful discussions with the author.

References

An extensive list of References were included in the 11 page version of our PESGB/HGS 2013 paper (available from the authors). New references are listed below:


Acknowledgements


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Figure 2: Large 80 km long Tertiary (Neogene) sandbody (located above 4 secs) in the Morondava Basin. Seen on parallel lines also (40 km wide). Section width = 125 kms. {All figures are PSTM from BGP/TGS’s MAD-13 MC2D seismic dataset}.

Figure 3: 5 – 8 km wide fluvial channels of Tertiary age – similar to those offshore Tanzania reported by Ophir. These are seen on a number of lines in the area. Section width = 40 kms.
Figure 4a: Gas filled patch reefs (?) – note velocity pushdown – an indication of gas. These can be seen on many lines and cover an area of approximately 2000 sq kms. The largest individual reefs are 4 to 5 km in diameter. Section width = 50 kms.

Figure 4b: Large reefs of Cretaceous age. These (and those in fig 4c) lie east of the Davie Ridge adjacent to deep syn rift grabens of Jurassic/Cretaceous age i.e a good hydrocarbon source kitchen. Section width = 40 kms
Figure 4c: Two contrasting reef types of Cretaceous age. Upper section is 150 km wide and shows the position of the two reefs. Upper right section is from the intersecting line over the right hand side reef. Lower sections show zoomed in detail. Flat spot (?) at 4.4 seconds within left hand side reef. Lower Sections width = 15km.
Figure 5: Drapeover with dimming in the Tertiary (Paleogene). Section width = 40km

Figure 6a: Possible gas escape/trapping in the Tertiary. Section width = 50 kms.
Figure 6b: Left half of section shows gas escape chimneys under good regional seal. Right half of section shows the channels featured in Fig 3. Section width = 130 kms

Figure 7: Large 15km x 40 km Cretaceous basin floor fan in the Kerimbas Graben. Dip line is 22km wide, Strike line is 55km wide (different horizontal scales). Intersection – red line
Figure 8: Horsts/Grabens of Permo-Triassic age are seen on the Platform (Key: UC = Upper Cretaceous, UJ = Upper Jurassic, PT (Permo-Triassic). Section width = 90kms.

Figure 9: Toe Thrust play in the Kerimbas Graben (western margin of the Davie Ridge) - Rollover (with possible flatspot) and onlap plays. Similar to those shown by both SAPETRO in their (on trend) Bela Profond acreage to the north (SAPETRO 2013) and Mahanjane 2014 further north along the Ridge. Section width = 35 kms.
Satellite Gravity Maps

Key:
CP: Coastal Platform
MB: Morondava Basin
DR: Davie Ridge
KG: Kerimbas Graben
C1: Chesterfield 1 well
H1: Heloise 1 well

Fig 10: Satellite Gravity Map. Regional inset modified from Tyrell 2014.
Fig 11: Type section over the Davie Ridge (Tyrell 2014). Section width = 180 kms.
Figure 12: Syn Rift structural play with flat spot – mapable over 280kms on 2D (Tyrell 2014)

Table 1: Circumstances suitable for Oil generation/preservation in the study area

<table>
<thead>
<tr>
<th>Reasons for Gas dominating Oil</th>
<th>What could we have in our study area?</th>
</tr>
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<tbody>
<tr>
<td>- the organic content of the main source rock is more gas prone (e.g. terrigenous Type III kerogen).</td>
<td>- We postulate marine shales of Upper Jurassic &amp; Lower Cretaceous age.</td>
</tr>
<tr>
<td>- the source rock is deeply buried and lies in the gas window (e.g. LBM shales).</td>
<td>- We don’t see thick Tertiary deltas in our area – the equivalent underlying source rocks will be at a shallower burial depth.</td>
</tr>
<tr>
<td>- conditions were not conducive to producing a younger/shalfer source rock (e.g. Cretaceous where the conditions were open marine) which could fall in the oil window.</td>
<td>- There is evidence (from wells and clots) that the Cretaceous may possess suitable oil prone source rocks (Nizami and Siahkoohi 2011).</td>
</tr>
<tr>
<td>- Oil was possibly flushed and flushed out of the system by the release of deeper gas (and the timing of this may not have allowed trapping; Penna-Ragio et al. 2013).</td>
<td>- Evidence showing the physical presence of oil is numerous:</td>
</tr>
</tbody>
</table>

1. There are major deposits of heavy (Permo-Triassic/Lower Jurassic) oil onshore Morondava Basin.
2. Light oil has also been found onshore – in the Manandasa 1 well.
3. Oil has been reported from seeps and cores in the neighboring offshore (SAPETRO 2013/14).

Ref: This paper plus our 2013 HGS Africa paper.

Table 1: Circumstances suitable for the generation and preservation of oil in the study area.

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