Morondava Basin

*Petroleum potential of the Morondava Basin*

Madagascar Promotional Meeting.

Houston, May 25th 2006

Chris Matchette-Downes adapted from Graham Hyden’s London presentation 23rd May

TGS-NOPEC Geophysical Company
Morondava Basin

Introduction

Stratigraphy & geological setting of the Morondava Basin

Hydrocarbon systems

Source rocks
Reservoir rocks
Seals
Traps
Maturation and expulsion

Conclusions
Morondava Basin

Simplified geological map of Madagascar

- Cretaceous – Recent igneous activity
- Tertiary continental facies
- Tertiary marine facies
- Jurassic – Cretaceous sedimentary strata
- Karoo strata
- Basement metamorphic complex
Morondava Basin

Satellite Gravity Bouguer Anomaly

200 km high pass filter

(White lines are TGS 2001 survey)
Morondava Basin

Madagascar
Summary of onshore stratigraphy

From
Jeans, P.J.F. & van Meerbeke, G.L.E.
Chesterfield well drilled to 4,775 into Karoo, Trias
Morondava Basin

TGS surveys, offshore Madagascar
11,825 kilometres

Blocks available for bids in the present licence round are shown in

Pink – Morondava Basin
Yellow – Nord Ile de St. Marie & Cap d’Ambre basins
Morondava Basin

Inversion structure with 100 km (blue) and 50 km (green) high-pass filtered gravity profiles superimposed
Modelling of TGS survey seismic and ship track gravity and magnetic data.
Morondava Basin

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## Morondava Basin

<table>
<thead>
<tr>
<th>Age</th>
<th>Tanzania-Mozambique</th>
<th>Morondava Basin</th>
</tr>
</thead>
<tbody>
<tr>
<td>Early Tertiary/Late Cretaceous</td>
<td>Some Eocene enrichment (immature) Open marine, little or no Cretaceous source</td>
<td>Lagoonal up to 5% TOC (immature)</td>
</tr>
<tr>
<td>Late Jurassic/Early Cretaceous</td>
<td>None present Open Marine</td>
<td>Duvaila Marls, II/III up to 5%TOC, up to 300HI</td>
</tr>
<tr>
<td>Middle Jurassic</td>
<td>Onshore Tanzania</td>
<td>2.2% TOC, II/III. Up to 570kg HC-1 tonne</td>
</tr>
<tr>
<td>Early Jurassic</td>
<td>Onshore Tanzania Several coastal oils</td>
<td>Andafia / Beronono Up to 69.4% TOC &amp; 268kg HC-1 tonne &amp; still in the oil window</td>
</tr>
<tr>
<td>Permo-Trias</td>
<td>Onshore Tanzania lacustrine derived oil Mozambique</td>
<td>Skamena lacustrine shales and coals up to 17.4 TOC</td>
</tr>
</tbody>
</table>
Somalia
Mandura Basin oil seeps/shows

Kenya
Mandura Basin oil seeps and shows
Pandangua #1: Oil shows
Ria Kalui: Tarry bitumens - Permo Triassic / fish beds
Cities wells offshore Kenya: Oil shows

Tanzania
Makarawe: Tarry bitumens - Karroo age / Jurassic
Tundaaua: Oil seep - Jurassic (not campanian)
Pemba # 5: Oil shows – Jurassic (sames as Pemba # 5)
Kiwigwa: Tarry bitumens – Jurassic?
Pemba #5: Oil shows – Jurassic (sames as Pemba # 5)
Kiwangwa: Tarry bitumens – Jurassic?
Zanzibar: Gas shows
Kimbiji East #1: Gas shows
Tancan: Gas shows
Mafia Island: Oil & gas shows
Songo Songo: ca. 1 tcf, Condensate in wells # 1,3,7,9 - Jurassic
Okoza island: Oil shows - Jurassic
Nyuni Island & well: Oil & gas shows - Jurassic
Lipwapwatwawe: Oil seep
Mikandani: Oil seep
Kisangire: Oil shows - Jurassic
Wingayongo: Oil seep – Jurassic
Wingayingo #1 & #2 - 30m & 40m of tar sand
Ruholi River (5km from Wingayongo) - Oil seep
Lukuliro: Gas shows - tars, sands in wells
Mita Gamma: Oil shows
Mandawa: Oil Oils
Mbuo: Oil shows
Pindiro # 1: Wet gas
Lindi #1: Shallow gas blow out
Manzi Bay: Gas reservoir, Ca.1 tcf
Mtwara # 1 Wet gas blowout
Misimbati: Oil and gas seeps

Mozambique
Mocimboa # 1: Oil & gas shows
Ruvuma basin: Oil shows
Sunray wells: Oil shows

Madagascar
Bemolanga Tar Sands 23Bbbl in place
Tsimiroro 2.2B bbl in place
Morondava Basin

Well locations Madagascar

Red - Gas shows
Green - Oil shows
Purple - Oil and gas shows
Black - Dry hole
Morondava Basin

Tertiary mud / gas mounds fed via Mesozoic faults
Morondava Basin

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<tr>
<td>Tertiary</td>
<td>Oligocene sands - Mnazi Bay</td>
<td>Marine coastal sands and deeper water fan deposits</td>
</tr>
<tr>
<td>Late Cretaceous</td>
<td>&gt;200 m sands with up to 25% porosity</td>
<td>Marine sands present in offshore wells</td>
</tr>
<tr>
<td>Early Cretaceous</td>
<td>Sands with 20% porosity</td>
<td>Sands in on- and offshore wells</td>
</tr>
<tr>
<td>Late Jurassic</td>
<td>Transgressive marine sands</td>
<td>Similar sands expected in offshore</td>
</tr>
<tr>
<td>Middle Jurassic</td>
<td>Fluvial/deltaic sands</td>
<td>Limestone</td>
</tr>
<tr>
<td>Early Jurassic</td>
<td>Karoo sands with good porosity</td>
<td>Karoo sands with good porosity</td>
</tr>
<tr>
<td>Permian – Triassic</td>
<td>Karoo sands with porosity up to 30%</td>
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</table>

**Reservoirs strata in Mozambique Channel region**
Morondava Basin

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Onshore and offshore wells in the Morondava Basin have demonstrated the presence of thick accumulations of shales throughout the sedimentary succession.
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**Middle Jurassic and later**
- Rotated fault blocks
- Flower structures
- Structural-stratigraphic traps
- Normal and reverse faulted anticlines
- Drape anticlines

**Permo-Triassic and early Jurassic**
- Rotated fault blocks occur in the Morondava Basin and adjacent to the Davie Fracture Zone.
Morondava Basin

Interpretation showing flower structures. Section is approx. 240 kilometres from west to east.
Morondava Basin

Late Cretaceous – Tertiary inversion with thick Mesozoic sequence
Morondava Basin

Drape anticlines, stratigraphic traps, ?mounds
Morondava Basin

30 km wide channel and stratigraphic trap
Morondava Basin

Rotated fault blocks
Morondava Basin

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Modified from Rusk & Bertagne
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The offshore sector of the Morondava Basin is under explored

Only six wells, drilled in less than 40 metres of water, have tested the offshore Morondava Basin, an area of > 135,000 sq.km.
Morondava Basin

New geophysical data indicates the onshore Morondava Basin extends into the marine environment to the west of the Davie Fracture Zone.

The basin contains a sedimentary sequence of Mesozoic to Recent strata at least 8,000 metres thick.

A potent Karoo source system (and younger source) and optimal maturity conditions are indicated.
Morondava Basin

Thank you