Shale Oil & Gas
Overview of Shale HC Potential in Onshore East Malaysia

May 2016
Driver for unconventional in Malaysia

Globally, reserves size of unconventional is higher than conventional

- Unconventional resources are widely distributed across the globe and are found in abundance.

Malaysia has untapped unconventional potentials that can grow domestic resource base

- Unconventional is a new resource base for Malaysia, to support long term sustainability
- Exploration and monetization of unconventional resources in Malaysia will spur development of new and niche service sector
- A right time to enter now as commercialization has started and there are untapped potential in Malaysia
**Status Quo of Malaysia Unconventional**

**PETRONAS yet to tap unconventional resources**

<table>
<thead>
<tr>
<th>CATEGORY</th>
<th>CBM</th>
<th>SHALE OIL / GAS</th>
<th>TIGHT OIL / GAS</th>
<th>GAS HYDRATE</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>DEFINITION</strong></td>
<td>HC formed during the coalification process or thermal maturation of coal bed which can be liquid or gaseous</td>
<td>Oil &amp; Gas: Trapped in shales that have very low permeability, typically less than 0.1mD</td>
<td>Oil: Crude that occurs in silty-fine sandstones with tight carbonate reservoir</td>
<td>“Flammable ice” - a crystalline substance like ice, composed of molecules of water and methane, exist in low temperatures and high pressure.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>BASIN</th>
<th>Sabah</th>
<th>Sarawak</th>
<th>Sarawak / Malay</th>
<th>Sabah</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>POTENTIAL RESERVES / SIZES (MALAYSIA)</th>
<th>6Tscf (non-commercial)</th>
<th>Unknown</th>
<th>Not-established yet</th>
<th>&gt;150Tscf</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>CHARACTERISTICS</th>
<th>Porosity</th>
<th>Permeability</th>
<th>Configuration</th>
<th>Resource</th>
<th>Technology</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Characteristics applicable to full spectrum of Unconventional Resources</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>OTHER FACTORS FOR CONSIDERATION</th>
<th>Local Supply-Demand Gap</th>
<th>Sustained High Oil / Gas Price</th>
<th>Fracturing Technology</th>
<th>Technology Devt.</th>
<th>Technology Devt.</th>
<th>Subsurface Knowledge</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pipeline Access / Availability</td>
<td></td>
<td></td>
<td></td>
<td>Pipeline Access / Availability</td>
<td>Environment Protection</td>
<td>Pipeline Access / Availability</td>
</tr>
<tr>
<td>LATEST PROGRESSION (PETRONAS)</td>
<td>CBM assets in Australia</td>
<td>Shale Gas assets in Canada (Progress Energy), JV Argentina, Shale Evaluation in China</td>
<td></td>
<td>Nil</td>
<td>Preliminary gas hydrates assessment In volume Sabah Deepwater</td>
<td></td>
</tr>
</tbody>
</table>
INTRODUCTION – East Malaysia potential

- East Malaysia comprises of Sabah and Sarawak is a vast area totaling almost 200,000 sq km, making up approximately 60% of the Malaysia land mass.

- Much of the land is covered by primary or secondary rainforest, with many ranges of mountains and high hills, making access to the interior difficult.

- Onshore East Malaysia is largely unexplored for conventional hydrocarbons. A few clusters of oil and gas exploration wells have been drilled near the coast (about 40 in total, many pre-1950’s), and a number of outcrop and mapping studies have been carried out historically.

- This area has been identified as potential area for Unconventional Play and the exploration stage is still at early stage with no well yet to test the unconventional play.
Geological Map of East Malaysia and outcrops

Upper shoreface (tidal channel and sand bars)

SW

NE

Setap Shale

LEGEND

- Cretaceous_deepwater_sediments
- Cretaceous-Paleogene_deepwater_sediments
- Jurassic-Cretaceous_deepwater_sediments
- Cretaceous_sediments
- Paleogene_deepwater_sediments
- Eocene_sediments
- Paleogene_volcanics
- Paleogene_sediments
- Oligocene_deepwater_sediments
- Oligocene_sediments
- Miocene_sediment
- Miocene_BrokenFormation_melange
### Stratigraphic Chart

<table>
<thead>
<tr>
<th>Formation</th>
<th>EOD</th>
<th>Lithology Description</th>
<th>SR Potential</th>
</tr>
</thead>
<tbody>
<tr>
<td>SIBUTI</td>
<td>Inner Neratic</td>
<td>shale, siltstone interbedded, sst, limestone.</td>
<td>NA</td>
</tr>
<tr>
<td>SETAP-SHALE</td>
<td>Inner neritic</td>
<td>Inner neritic clay-shale &amp; silty clay Occasionally interbedded with ss, calcareous ss &amp; moderate thick limestone</td>
<td>Poor-Fair Organic matter. Termally Immature – Early Mature.</td>
</tr>
<tr>
<td>NYALAU</td>
<td>Lower-middle shoreface</td>
<td>Hard and semi to unconsolidated sandstone, massive, heterolithic succession, coal seam, paleosol and thick mudstone (probably shelf and marginal marine mudstone)</td>
<td>TGC:78% Oil &amp; gas prone HI:219-475</td>
</tr>
</tbody>
</table>
Onshore Sarawak, Outcrops (Miocene Sequence)

Meligan Formation

Setap Formation
Oligocene Outcrops

Folded and faulted Crocker Formation.

Duplex structures in the Crocker Formation.

Moderately deformed Temburong Formation.

Highly deformed Temburong Formation.
Stratigraphy of Engkabang West-1 Well

- Setap shale is thick at the Engkabang area (~2800m).
- The shale was deposited in the marine environment, within the cycle I–III.
- Some shows were observed in the Setap shale succession (mainly gas shows and some oil shows).

Modified from EW1 well proposal
### Comparison with North America Shale Gas Criteria’s

<table>
<thead>
<tr>
<th>Criteria</th>
<th>North America</th>
<th>Onshore sarawak</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shale thickness (m)</td>
<td>&gt;40</td>
<td>2800</td>
</tr>
<tr>
<td>Depth from surface (m)</td>
<td>1000-3500</td>
<td>0-2800</td>
</tr>
<tr>
<td>TOC (%)</td>
<td>&gt;2.0</td>
<td>0.5-4.0</td>
</tr>
<tr>
<td>VR (%)</td>
<td>3.0</td>
<td>0.23-2.76</td>
</tr>
<tr>
<td>Area (km²)</td>
<td>&gt;100</td>
<td>~320</td>
</tr>
<tr>
<td>Porosity</td>
<td>Very low</td>
<td>N/A</td>
</tr>
<tr>
<td>Permeability</td>
<td>Low</td>
<td>N/A</td>
</tr>
<tr>
<td>Mineralogy</td>
<td>High non-clay minerals</td>
<td>N/A</td>
</tr>
</tbody>
</table>
Surface Geochemical results

Legend
Petronas_Tinjar-Limbang-Klias_PSG-PrelimMapData_TM-CM114_WGS84
$\frac{\sum(C_{16}-C_{20})}{\sum(C_{6}-C_{7})}$

- $>1.00$ Heavy Hydrocarbons
- $0.00 - 0.50$ Light Hydrocarbons
- MicrobialAnomalies_MSZt
- VaporAnomalies

Ratio ($\frac{\sum(C_{16}-C_{20})}{\sum(C_{6}-C_{7})}$):
- $<1.0$ is dominated by Light Oil (RED)
- $>1.0$ is dominated by Heavy Oil HC (GREEN)
THE 1D BASIN MODELLING – EW-1

- Basin modelling work
  Oil window interval = 600-1050m (450m) Gas window interval= 2400-2800m (400m)

- Log
  Oil show = 790m
  Gas show = 1050-1080m (30m)
  = 2710-2720m (10m)

After Dembicki, 2013

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Based on preliminary resource assessment, Malaysia has an estimated total of 8.8Tcf/2.8Bstb (HIIP) of shale gas resources in focus area

- Total area: 900 sq.km
- Target depth: 1000m – 3500m
- Thickest prospective shale: 157m
- Type of HC: Oil and Gas
Stage gate approach is needed to manage progress, risks and uncertainties – guided by long term aspirations

What we want to answer in Stage Gate 1
- Realizing of full shale potential in domestic land
- Establishing production profile
- Ways to entice participation of industry players

This will include:
- Several wells drilling
- Data acquisition and G&G studies
- Collaboration with unconventional group & available third parties
Thank you