A geochemical overview of selected Palaeozoic and Mesozoic petroleum source rock analogues from outcrop studies, Peninsular Malaysia

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Study area

Why Palaeozoic & Mesozoic petroleum source rocks?
- Depleting petroleum resources
  - Need to look for unconventional hydrocarbons, including those derived from older & deeper petroleum source rocks
- Positive results from drilling of petroleum accumulations in older rocks (e.g. Anding Utara-1 oil discovery in metamorphic rocks, SW Malay Basin (Shahar, 2005); however these hydrocarbons are thought to be sourced from younger sediments positioned lower/deeper in grabens
- New technologies & increasing knowledge in the geology

Why should we be excited?
- Previous analysis of pre-Tertiary outcrop samples never showed strong signs for the presence of hydrocarbon
- A new type of petroleum system will open up new opportunities & lead to discoveries in places never thought possible

Geochemistry analysis workflow

Outcrop rock sample
- Rock samples crushed to fine powder
- Rock samples crushed to small granule & mounted in resin (polished block)
- Source Rock Analyzer (SRA-THP/TOC)
- Leica DM6000M petrogaphic microscope
- Gas chromatography-mass spectrometry (GC-MS)
- Bitumen extraction (Soxhlet apparatus)
- Bitumen/EO/M fractionation separated hydrocarbon fraction analysis by GC-MS
- Total Organic Carbon (TOC), S1, S2, S3, hydrogen index (HI), oxygen index (OI), Tmax
- Maceral description, vitrinite reflectance
- n-alkanes, isoprenoids, biomarkers

Results: Geochemistry analysis

Tembeling Group (lacustrine delta)

Semantan Formation (deep marine)

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Samples studied come from the:
- West Crocker Fm
- Kota Gelanggi, Central Pahang
- Gelanggi plateau
- Kota Gelanggi, Central Pahang
- Upper delta shale, Kota Gelanggi, Central Pahang
- Tembeling Toll outcrop, Semantan Fm, Central Pahang
- Black Shales, Beseri, Perlis, NW Peninsular Malaysia

Outcrop points
- Bukit Chondon, Beseri, Perlis, NW Peninsular Malaysia
- Kota Gelanggi silty mudstone
- Kota Gelanggi delta shale
- Kota Gelanggi Upp Delta Sh, edited

Problems with the existing set of data
- Limited number of samples
- Evidences of possible hydrocarbon generation in the past might no longer be there due to hydrocarbon generation itself
- It is still difficult to estimate the initial conditions for the source rock (e.g. initial Hydrogen Index, initial Total Organic Carbon)

Formation
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Result: Geochemistry analysis (continued)

Possible properties of Palaeozoic & Mesozoic petroleum source rock analogues

<table>
<thead>
<tr>
<th>Source rock analogue</th>
<th>Palaeozoic</th>
<th>Mesozoic</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Beseri black shales, Peninsular Malaysia</td>
<td>Kota Gelanggi terigenous sediments (delta?), Central Pahang, Peninsular Malaysia</td>
</tr>
<tr>
<td>Geological unit</td>
<td>Kubang Pasu Formation</td>
<td>Semenang Formation</td>
</tr>
<tr>
<td>Depositional environment</td>
<td>Shallow marine</td>
<td>Deep marine</td>
</tr>
<tr>
<td>Age</td>
<td>Permian (?)</td>
<td>Middle-Late Triassic</td>
</tr>
<tr>
<td>Geometry of geological unit (bathyal extent)</td>
<td>Extensive</td>
<td>Localised to extensive</td>
</tr>
</tbody>
</table>


<table>
<thead>
<tr>
<th>Type of organic matter</th>
<th>Organic geochemistry</th>
<th>Other remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Marine</td>
<td>Marine, possibly with transported mesogenetic organic matter</td>
<td>Terigenous, possibly lacustrine (Tam, 2004)</td>
</tr>
<tr>
<td></td>
<td>Total Organic Carbon content at present day (weight %)</td>
<td>Up to 1.07 to 1.32</td>
</tr>
<tr>
<td></td>
<td>Hydrogen index, HI at present day (mg HC/g TOC)</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>Tmax (° C)</td>
<td>Up to 494.2</td>
</tr>
<tr>
<td></td>
<td>Thermal maturity at present day</td>
<td>Overmature</td>
</tr>
<tr>
<td></td>
<td>Possible type of hydrocarbon generated</td>
<td>Oil, Gas</td>
</tr>
</tbody>
</table>

Vitrinite reflectance-Tmax relationship

<table>
<thead>
<tr>
<th>Average vitrinite reflectance (%Ro)</th>
<th>Tmax (° C)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.00</td>
<td>494.2</td>
</tr>
<tr>
<td>1.22</td>
<td>494.2</td>
</tr>
<tr>
<td>0.80</td>
<td>672.9</td>
</tr>
</tbody>
</table>

Sandstone-shale, Tembeling Group, Central Pahang

Total Organic Carbon, TOC (weight %): 4.43
Hydrogen index, HI (mg HC/g TOC): 57
Tmax (° C): 494.2

Sandstone-shale, Tembeling Group, Central Pahang

Total Organic Carbon, TOC (weight %): 1.32
Hydrogen index, HI (mg HC/g TOC): 92
Tmax (° C): 672.9

Some outstanding questions

- Are the deltaic sequences seen in Kota Gelanggi of Mesozoic age or younger (Tertiary)?
  - Work by Tam (2004) suggested a probable Tertiary age based on Cycas sp. plant fossils, in which a new formation (Putat Formation) was proposed.
  - Tmax and vitrinite reflectance of the Kota Gelanggi samples is close to the West Crocker Formation of NW Sabah which is of probable Eocene age (Lambiase et al., 2008).
  - If the sediments in Kota Gelanggi are of Tertiary age, how would they relate & compare to the other Tertiary basins in Peninsular Malaysia?
  - Which reservoirs would hold the hydrocarbon accumulations that are sourced from Palaeozoic and Mesozoic source rocks in Peninsular Malaysia?
    - Northern part of the Straits of Melaka (?)

What else is needed?

- More samples from various lithologies & depositional facies
- Laboratory analyses:
  - Gas chromatography-mass spectrometry (GC-MS)
  - Pyrolysis-gas chromatography (Py-GC)
  - Biostratigraphy
  - Source rock kinetics (e.g. SRA-Kinetics, hydrous pyrolysis)
  - Detailed petrographic analysis
- Better understanding of the geological & thermal history & evolution for future basin modelling studies
  - Studies on igneous rocks & metamorphism & how they could affect the petroleum system

Concluding remarks

- Palaeozoic & Mesozoic sedimentary rocks from Perlis & Central Pahang do exhibit the presence of hydrocarbons
- Further detailed laboratory & field analyses need to be carried out to confirm whether petroleum systems sourced by Palaeozoic & Mesozoic source rock intervals can produce & hold economic accumulations of hydrocarbons