Minimizing Offshore Exploration Risks by Evaluating the Charge of Subsea Structures*

Rick Schrynemeeckers¹

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General Statement

For each prospective area, a map is delivered of probable hydrocarbon charge based on direct measurement of C₂-C₂₀ hydrocarbons emanating from the reservoir. Technology permits analysis of microseepage, which is considered to be the result of a nearly vertical pathway; this means that microseepage essentially overlies source/reservoir. Short summaries show good results in offshore settings—in the deepwater Gulf of Mexico and South China Sea. In the latter, predictions were 100% accurate.

Reference

Minimizing Offshore Exploration Risks by Evaluating the Charge of Subsea Structures

by Rick Schrynemeeckers
W.L. Gore & Associates, Inc.
Where Do We Start
What Do We Deliver

GORE delivers a map of probable hydrocarbon charge based on direct measurement of C2-C20 hydrocarbons emanating from the reservoir.

High oil probability

Low oil probability
How is it Applied

GORE delivers a map of probable hydrocarbon charge based on direct measurement of C2-C20 hydrocarbons emanating from the reservoir.

Dry Well

Oil Well

High oil probability

Low oil probability
Vertical Migration - The Earth’s Fractionation Process

Macroseepage:
- Detectable in visible amounts
- Pathway follows discontinuities
- Offset from source/reservoir

VS

Microseepage:
- Detectable in analytical amounts
- Pathway is nearly vertical
- Overlie source/reservoir
The Perfect Seal - Salt

Egypt, onshore

Targets are overlain by 8000 ft of evaporitic salt and anhydrite sequences with interbeds of shale.
GORE™ Module

Based on Patented ePTFE Technology

- Patented, passive, sorbent-based
  - Chemically-inert, waterproof, vapor permeable
  - Direct detection of organic compounds
  - Sample integrity protected
- Engineered sorbents
  - Consistent sampling medium
  - Minimal water vapor uptake
- Time-integrated sampling
  - Minimize near-surface variability
  - Maximize sensitivity (up to C20)
  - Avoids variables inherent in instantaneous sampling
- Duplicate samples
**GORE™ Surveys - Collection**

- $C_2$-$C_{20}$ molecules are $\sim 5$-$10\text{Å}$
- Membrane pores are $\sim 1000\text{Å}$
- Water drops are $>5000\text{Å}$

**ePTFE - 50,000 x magnification**

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Thermal Desorption GC/MS Analysis

- Yields sensitive, compound specific results
- Analytical compound standards
- Approximately 87 compounds
  - C2 through C20
  - Aliphatics
  - Aromatics
  - Oxygenated compounds
## Analytical Compound List by Compound Class: C2 – C20

### Typical Petroleum Constituents

**Hydrocarbon number in ( )**

<table>
<thead>
<tr>
<th>Normal Alkanes</th>
<th>Iso-alkanes</th>
<th>Cyclic Alkanes</th>
<th>Aromatics and PAH*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ethane (2)</td>
<td>2-Methylbutane (5)</td>
<td>Cyclopentane (5)</td>
<td>Benzene (6)</td>
</tr>
<tr>
<td>Propane (3)</td>
<td>2-Methylpentane (6)</td>
<td>Methylcyclopentane (6)</td>
<td>Toluene (7)</td>
</tr>
<tr>
<td>Butane (4)</td>
<td>3-Methylpentane (6)</td>
<td>Cyclohexane (6)</td>
<td>Ethylbenzene (8)</td>
</tr>
<tr>
<td>Pentane (5)</td>
<td>2,4-Dimethylpentane (7)</td>
<td>cis-1,3-Dimethylcyclopentane (7)</td>
<td>m,p-Xylenes (8)</td>
</tr>
<tr>
<td>Hexane (6)</td>
<td>2-Methylhexane (7)</td>
<td>trans-1,3-Dimethylcyclopentane (7)</td>
<td>o-Xylene (8)</td>
</tr>
<tr>
<td>Heptane (7)</td>
<td>3-Methylhexane (7)</td>
<td>trans-1,2-Dimethylcyclopentane (7)</td>
<td>Propylbenzene (9)</td>
</tr>
<tr>
<td>Octane (8)</td>
<td>2,5-Dimethylhexane (8)</td>
<td>Methylcyclohexane (7)</td>
<td>1-Ethyl-2/3-methylbenzene (9)</td>
</tr>
<tr>
<td>Nonane (9)</td>
<td>3-Methylheptane (8)</td>
<td>Cycloheptane (7)</td>
<td>1,3,5-Trimethylbenzene (9)</td>
</tr>
<tr>
<td>Decane (10)</td>
<td>2,6-Dimethylheptane (9)</td>
<td>cis-1,3/1,4-Dimethylcyclohexane (8)</td>
<td>1-Ethyl-4-methylbenzene (9)</td>
</tr>
<tr>
<td>Undecane (11)</td>
<td>Pristane (19)</td>
<td>trans-1,2-Dimethylcyclohexane (8)</td>
<td>1,2,4-Trimethylbenzene (9)</td>
</tr>
<tr>
<td>Dodecane (12)</td>
<td>Phytane (20)</td>
<td>Ethylcyclohexane (8)</td>
<td>Indane (9)</td>
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<tr>
<td>Tridecane (13)</td>
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<td>Cyclooctane (8)</td>
<td>Indene (9)</td>
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<tr>
<td>Tetradecane (14)</td>
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<td>Propylcyclohexane (9)</td>
<td>Butylbenzene (10)</td>
</tr>
<tr>
<td>Pentadecane (15)</td>
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<td></td>
<td>1,2,4,5-Tetramethylbenzene (10)</td>
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<tr>
<td>Hexadecane (16)</td>
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<td></td>
<td>Naphthalene (10)</td>
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<tr>
<td>Heptadecane (17)</td>
<td></td>
<td></td>
<td>2-Methylnapthalene (11)</td>
</tr>
<tr>
<td>Octadecane (18)</td>
<td></td>
<td></td>
<td>Acenaphthylene (12)</td>
</tr>
</tbody>
</table>

### Byproduct / Alteration and Other Compounds

<table>
<thead>
<tr>
<th>Alkenes</th>
<th>Aldehydes</th>
<th>Biogenic</th>
<th>NSO* and Other Compounds</th>
</tr>
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<tbody>
<tr>
<td>Ethene (2)</td>
<td>Octanal (8)</td>
<td>alpha-Pinene</td>
<td>Furan</td>
</tr>
<tr>
<td>Propene (3)</td>
<td>Nonanal (9)</td>
<td>beta-Pinene</td>
<td>2-Methylfuran</td>
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<tr>
<td>1-Butene (4)</td>
<td>Decanal (10)</td>
<td>Camphor</td>
<td>Carbon Disulfide</td>
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<tr>
<td>1-Pentene (5)</td>
<td>Octanal (8)</td>
<td>Caryophyllene</td>
<td>Benzofuran</td>
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<tr>
<td>1-Hexene (6)</td>
<td>Nonanal (9)</td>
<td></td>
<td>Benzothiazole</td>
</tr>
<tr>
<td>1-Heptene (7)</td>
<td>Decanal (10)</td>
<td></td>
<td>Carbonyl Sulfide</td>
</tr>
<tr>
<td>1-Octene (8)</td>
<td>Decanal (10)</td>
<td></td>
<td>Dimethylsulfide</td>
</tr>
<tr>
<td>1-Nonene (9)</td>
<td>Decanal (10)</td>
<td></td>
<td>Dimethyldisulfide</td>
</tr>
<tr>
<td>1-Decene (10)</td>
<td>Decanal (10)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1-Undecene (11)</td>
<td>Decanal (10)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Superior to conventional surface geochemical techniques

- Drier
- Wetter
- Sands
- Clays
- Silts
- ppt
- ppb
- ppm

Schematic Volume Percent of Fraction

“Soil Gas”

- C₁
- C₂
- C₅
- C₁₀
- C₁₅
- C₂₀

Geological Universe

- Normal Paraffins
- Iso-paraffins

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Superior to conventional surface geochemical techniques

“Amplified Geochemical Imaging”

Normal Paraffins
Iso-paraffins
Cyclo-Paraffins
Aromatics
Naphtheno-Aromatics

“Soil Gas”

Petroleum Compound Universe

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Limited range of compounds commonly reported by conventional surface geochemical techniques.

“Model Oil Well Signature”
- 300 BOPD
- 41 API
Model development
Offshore Applications

- **Slick sampling** and analysis to validate petroleum systems
- **Macroseep** & seabed feature targeting to validate petroleum system
- **Transition zone** (0-40 meters) mapping of direct hydrocarbons for prospect ranking
- **Shallow (40 m) to Deep water (3000 m)** coring & mapping of direct hydrocarbons for prospect ranking
- **Site Survey Sampling.** Collecting seabed samples while geotech/env site surveying
Offshore Application

Boat

Gravity Corer

Vibrocorer

Core Extraction

Subcropping

Sample Jar + Module

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Case Study 1 - Macroseepage

Gulf of Mexico offshore study by the Energy & Geoscience Institute (EGI)
Survey Operations

- Cruise duration 5 – 7 days
- GORE contracted Peregrine Ventures to conduct core subcrop sampling
- Core samples obtained near Marco Polo Field (Green Canyon Block 608)
- 93 geochemical samples total
Hydrocarbon Response

GORe™ Survey for Exploration Sample Signature

Example “Low aliphatic compound response” sample
Hydrocarbon Response

Example “Medium (transition) aliphatic compound response” sample

Significant C6-C15 compound response
Aliphatic Sum
mass sum
- 1-100
- 100-300
- 300-1000
- 1000-20000
- 20000-200000

Figure 8: DTM plan view map of the high resolution multibeam bathymetry showing the sea surface locations from which the piston coring device was deployed for each core gathered. Dembicki and Samuels (2007)
Hydrocarbon Response

alkane/alkene Ratio

- Gore C3-C5
- TDI C3-C4

Mound

Mud Volcano

Core Label

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Area of Operation – South China Sea

Geochemical Survey Area
- Water Depth: <500 m
- Sediment: clay, poorly sorted sands and gravels
- (difficult core penetration)
- Vessel: survey vessel contracted in China
- Coring equipment: vibrocorer
- Cruise duration: 2 weeks

Microseepage
Geochemical Survey Design

Western Prospects

Depth to top target formation >2,500 m
Interval of 10 m

Eastern Prospects

Calibration area: oil production from several horizontal well sections
Field Operations

- 75+ survey core samples over prospects
- 75 calibration core samples from oil production and dry hole areas
  - 45 cores from over-producing reservoirs
  - Used to develop models and to study reservoir areas
- Marine vessel contracted from Shanghai, supervisory staff from USA
Interpretation of Eastern Prospects

Ancillary prospect (evaluated as too small)

Post-survey well #2. Commercial oil discovery of 4000+ BOPD
Interpretation of Eastern Prospects

- Oil production platform
- Fault lines
- Postsurvey well #1
- Client’s highest priority target P&A

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Interpretation of Eastern Prospects

- Oil production platform
- Fault lines
- Saddle between north and south field areas
Interpretation of Eastern Prospects
Survey Results

- Three prospects recommended for further attention as very positive prospects
- Three prospects recommended as ill-defined prospects with less potential
- Three prospects were recommended as nonprospective

Three wells were drilled post-survey.

Predictions 100% accurate
Frequently Asked Questions

• Can you tell at what depth a reservoir is situated?
• Can your data determine if a positive anomaly is economic?
• What happens when you have stacked zones?
• How deep can you see?
• Are there situations where your technology doesn’t work?
Thank you!