Gore® Amplified Geochemical Imaging℠ -
The advanced tool for derisking HC exploration

FINDING PETROLEUM, Feb 15, 2011

Presented by
Dirk Hellwig, W.L. Gore & Associates
Today’s Menu

• Innovation Runs through everything we do, Gore Enterprise & Surveys

• Amplified Geochemical Imaging
  • Earth’s Fractionation Process
  • AGI – How it works
  • The advanced tool

• Case studies

• Track Record & Wrap-up
Innovation Runs Through Everything We Do

- Established in 1958, Privately held
- ~$2.5 billion annual sales
- 9,000+ associates
- Recognized as a “Best Company to Work For”
- 50 offices worldwide
- Dedication to R&D
<table>
<thead>
<tr>
<th>Location</th>
<th>Resources</th>
</tr>
</thead>
<tbody>
<tr>
<td>Elkton, MD, USA</td>
<td>Manufacturing, Lab, Interp., Sales, Leadership</td>
</tr>
<tr>
<td>Munich, Germany</td>
<td>Interp., Sales, Sales Admin.</td>
</tr>
</tbody>
</table>
GORE Amplified Geochemical Imaging service is:

- a surface based
- passive
- geochemical method
- Direct Hydrocarbon Indicator

It measures and maps
- HC compounds from the soil gas in the sub part per billion range

It uses
- Gore’s unique and highly sensitive passive diffusion module
- advanced mathematical and statistical techniques to identify and analyze the microseepage signal

It creates
- a comprehensive geochemical dataset that can be interpreted with various techniques (incl. AGI modelling)
Benefit of AGI to your Exploration Program

- Frontier Acreage – is my concession prospective (evidence of a petroleum system)?
- Assess charge potential in defined leads to help reduce drilling risks
- Field development to find field extents and/or bypassed pay
- Onshore & Offshore Capability
The Earth’s Fractionation Process

**Vertical Migration**

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

**Microseepage:**
- Detectable in analytical amounts
- Pathway is nearly vertical
- Overlie source/reservoir

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The Earth’s Fractionation Process

**Vertical Migration - Microseepage**

Four possible mechanisms:
1) Diffusion - gradient movement of dissolved gases
2) Aqueous transport - movement in ascending water
3) Continuous gas phase flow

Favoured mechanism:
4) Microbuoyancy - transport in buoyant microbubbles
   - Direct surface projection of reservoirs
   - Migration in the absence of faults
   - Rapid changes in surface anomalies as production starts


The Earth’s Fractionation Process

**Hydrocarbon Seepage – Response Speed**
Keota Dome Iowa – 700 m
CST Oil & Gas
Exeter Oil & Gas

Before Charge - July

During
Draw down - January

After Charge - October

After
Draw down - April
Amplified Geochemical Imaging - How it works

Gore Sampler (Module)

- 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
Module installation & retrieval

Onshore

Create installation hole

Secure module, mark field location, record GPS data and field notes

Insert module into hole & cover
Amplified Geochemical Imaging - How it works

Offshore Application

- **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
Amplified Geochemical Imaging - How it works

**Offshore Application**

- **Slick sampling and analysis** to validate petroleum systems

GORE® Slick Sampler has been validated by customers and industry consultants.

- Most sensitive survey tool
- Fastest compound range from C₅ to C₉
- Slick sampling and analysis to validate petroleum systems

**Global Seeps**

![Image of a seep](image)

- **GORE** Slick Sampling Kit
- Rugged hard water proof case includes everything you need:
  - 25 ml sample containers
  - Slick sampling equipment
  - Weather resistant storage
  - GIS mapping software
  - Spare parts

Gore is the only provider of the Amplified Geochemical Imaging technology for petroleum reservoirs onshore and offshore.

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Amplified Geochemical Imaging - How it works

Offshore Application

- **Shallow (40 m) to Deep water (3000 m)** coring & mapping of direct hydrocarbons for prospect ranking

Collection of shallow seabed cores
  - Gravity coring / vibrocoring
  - Penetrating 3 - 5 meters

Grid sampling over defined prospects
  - Multiple data points

Modeling of charged fields, when possible

Applicable anywhere a core sample can be taken
Amplified Geochemical Imaging - How it works

**Offshore Application**

- **Tools of trade**
  - Boat
  - Gravity Corer
  - Vibrocorer
  - Core Extraction
  - Sub-cropping
  - Sample Jar + Module
Amplified Geochemical Imaging - How it works

Survey Design

Regular to Irregular grid

Sample distance 200 m to 1.5 km
Amplified Geochemical Imaging - How it works

**TD/GC/MS Module Analysis**

- Yields sensitive, compound specific results
- Analytical compound standards
- 87+ compounds – C\textsubscript{2} through C\textsubscript{20}
  - Aliphatics
  - Aromatics
  - Oxygenated compounds
Amplified Geochemical Imaging - How it works

Target Analytical List for GORE™ Survey for Exploration

Typical Petroleum Constituents

<table>
<thead>
<tr>
<th>Normal Alkane: 17</th>
<th>Iso-alkane: 11</th>
<th>Cyclic Alkane: 15</th>
<th>Aromatic and PAH: 17</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-1,3,4-Dimethylcyclohexane (8)</td>
<td>1-Ethyl-4-methylbenzene (9)</td>
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<tr>
<td>Undecane (11)</td>
<td>Pristane (19)</td>
<td>trans-1,3,1,4-Dimethylcyclohexane (8)</td>
<td>1,2,4-Trimethylbenzene (9)</td>
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<tr>
<td>Dodecane (12)</td>
<td>Phytane (20)</td>
<td>trans-1,2-Dimethylcyclohexane (8)</td>
<td>Indane (9)</td>
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<tr>
<td>Tridecane (13)</td>
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<td>Ethylcyclohexane (8)</td>
<td>Indene (9)</td>
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<td>Tetradecane (14)</td>
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<td>Cyclooctane (8)</td>
<td>Butylbenzene (10)</td>
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<td>Pentadecane (15)</td>
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<td>Propylcyclohexane (9)</td>
<td>Naphtalene (10)</td>
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<td>Hexadecane (16)</td>
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<tr>
<td>Heptadecane (17)</td>
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<td>Acenaphthylene (12)</td>
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<tr>
<td>Octadecane (18)</td>
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</table>

Byproduct and Alteration Compounds

Included in this method to provide a comprehensive inventory of the geochemical system in the surface soil zone

<table>
<thead>
<tr>
<th>Alkene: 10</th>
<th>Alteration/Bioprodut: 3</th>
<th>Biogenic: 4</th>
<th>NSO: 5</th>
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</thead>
<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>
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<td>Caryophyllene</td>
<td>Benzoafuran</td>
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<td>1-Hexene (6)</td>
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<td></td>
<td>Benzothiazole</td>
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<tr>
<td>1-Heptene (7)</td>
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<td></td>
<td>Carbonyl Sulfide (ng)</td>
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<tr>
<td>1-Octene (8)</td>
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<td></td>
<td>Dimethylsulfide (ng)</td>
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<tr>
<td>1-Nonene (9)</td>
<td></td>
<td></td>
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<td>1-Decene (10)</td>
<td></td>
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<td></td>
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<tr>
<td>1-Undecene (11)</td>
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<td></td>
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</tr>
</tbody>
</table>
Amplified Geochemical Imaging - How it works

Data Interpretation

>conditions the data to enhance signal/noise and uses multivariate statistical techniques to distinguish differences in hydrocarbon signatures

1. After Quality C&A of Data Set
   Qualified Compounds & Samples

2. Utilize Principal Component Analysis
   Transform data from measured space into components space. From compounds per sample to patterns of compounds in sample per survey. Focuses on relationships of natural mixtures of compounds—“essence of the petroleum system”

3. Develop Geochemical Models
   Identify HC/background fingerprints in Survey (oil, gas, condensate, more)

4. Run Multivariate Discriminant Analysis
   A classification technique to compare samples to models. (Yield is a probabilistic distribution based on chemical differences between groups.)

5. Interpret Results & Corroborate
   G&G earth models
   Integrate into exploration model
Amplified Geochemical Imaging - How it works

Quality Assurance / Quality Control

- Analytical QA/QC blanks
- Calibration & tuning standards
- Industry standard instrumentation
- Clean facility standards & practices
- Good Laboratory Practices
- ISO guidelines

Field Data Distinguished from QA Information

Canonical Variate Scores

<table>
<thead>
<tr>
<th>Groups</th>
<th>Count</th>
</tr>
</thead>
<tbody>
<tr>
<td>TYPE 1</td>
<td>Count</td>
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<tr>
<td>TRIP BLANK</td>
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</tr>
</tbody>
</table>

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Amplified Geochemical Imaging – The advanced tool

Geochemical Data Differentiation

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

Oil Well

“Oil Well Signature”

• 300 bopd
• 41 API

Organic Compound

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**Geochemical Data Differentiation**

Amplified Geochemical Imaging – The advanced tool

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

<table>
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<th>Organic Compound</th>
<th>Response</th>
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<tbody>
<tr>
<td>Ethane</td>
<td></td>
</tr>
<tr>
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<tr>
<td>Propane</td>
<td></td>
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<tr>
<td>Butane</td>
<td></td>
</tr>
<tr>
<td>1-Butene</td>
<td></td>
</tr>
<tr>
<td>2-Butene</td>
<td></td>
</tr>
<tr>
<td>2-Methylbutane</td>
<td></td>
</tr>
<tr>
<td>1,1,2,2-Tetrafluoroethane</td>
<td></td>
</tr>
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Gas Well

- 99% Methane
Amplified Geochemical Imaging - How it works

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Amplified Geochemical Imaging – The advanced tool

Geochemical Model Development

- Dry Well Model
- Gas Well Model
- Oil Well Model

LEGEND
- Soil Gas Sample Location
- Model Sample Location
- Oil + Gas + Dry
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**Geochemical Model Development**

**Cluster Analysis**

Identify geochemical similarities in data patterns
- Soil gas data grouped by clusters

Assumptions/Requirements
- Identify & remove noisy variables
- Cluster structure isolates “petroliferous” vs “background” character
- Sufficient cluster membership to sample signal variance
- Clusters have subsurface geochemical meaning

Example shown: Gas/Condensate Well and Dry well models; No oil discoveries in this area, HCA performed on Compounds post S/N, HCA clearly detects an oil signature in the data
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Interpretation & Integration

Final Report:
- Objectives, design, & field work
- QA/QC summary
- Geochemical modeling
- Results
- Summary & conclusions
- Color contour probability maps
- Supporting appendices
- Available electronically


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Amplified Geochemical Imaging

Case histories  Onshore

Development – Egypt

Figure 1: Stratigraphic column of the West Gebel El Zeit field shows massive salt.

Figure 2: Top of Karama formation structure merged with the GORE™ Survey oil & gas hydrocarbon probability map, showing new well FH85-8, initial potential 800 b/d.

Survey Summary

- Egypt – Development
- Producing oil field
- Detected microseepage through massive salt
- 150 GORE™ Modules Installed
- Sample spacing - 250 to 250 m regular grid along seismic lines

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Case histories  Onshore

Multi-layer Gas Exploration – Texas

Survey Summary
- Texas, USA, multi-layer prospect
- Natural deep Wilcox gas, overlying shallow production
- 150 sample collectors installed
- Sample spacing – 150 to 250 m irregular grid
- Three economic natural gas wells drilled in positive geochemical anomaly

Figure 1: Surface geochemical anomaly for Wilcox gas, Texas USA. Three wells have been drilled on the positive geochemical anomaly identified by the survey, all of which have encountered natural Wilcox gas.
Amplified Geochemical Imaging – The advanced tool

Methane can skew interpretation:
- it is ubiquitous
- biogenic > thermogenic
- can be misleading

Amplified Geochemical Imaging

“Soil Gas”

C_1 \rightarrow C_2 \rightarrow C_5 \rightarrow C_{10} \rightarrow C_{15} \rightarrow C_{20}

Drier \rightarrow Wetter

Geological Universe

Geological Universe

ppm

ppb

Shorter Sampling

Longer Sampling

Petroleum Compound Universe
Amplified Geochemical Imaging – The advanced tool

Track Record

- More than 600 surveys in O & G EXP

- Gore Surveys for Exploration has been used effectively in over 130 basins / 56 countries worldwide
  - Through sediment, volcanic cover & thick-evaporite sequences
  - Structural, stratigraphic, combination & salt traps

- Including all continents, terrains and climate (e.g. desert, jungle, plains, tundra, offshore)

- for more than 150 companies

- with a success rate of +90%
Thank you for your Time and Interest

GORE® Surveys

FOR OIL AND GAS EXPLORATION
Success Rates

Prediction Rates for Drilling Positive Geochemical Features

- Incorrect Prediction - False Positive Rate 7%
- Correct Prediction Rate 93%

- Known no. wells drilled on our results – 179 [worldwide]
- Oil & Gas Discovery Well Prediction → 93%
- Dry Well Prediction → 92%
- Correct Predictions Total → 93%

Prediction Rates for Drilling Negative Geochemical Areas

- Incorrect Prediction - False Negative Rate 8%
- Correct Prediction Rate 92%