Corporate Outreach and Strategic Alliances

Lon D. Whitman
January 13, 2010
Welcome Chris Heavner
Does this look like an “over weight” athlete?

Lindsey Vonn - US Ski Team
Conference Updates

**WY CO₂ Conference** – June 22, 23, 24th - Casper

**EOR/IOR Conference** – September 13-14th - Jackson

**Chemical EOR** - TBA
UPDATES

• Minnelusa Consortium
• Steve Melzer’s CO$_2$ Conference
• Denbury in Wyoming
• EORI Speakers Series – Larry Lake
• ARI – Advanced Resources International
• New Projects
  - Residual Oil Zones in Wyoming
RESIDUAL OIL ZONES
(A GAME CHANGER?)

Origin of Residual Oil Zones and Emergent Commercial Exploitation

• ROZ Background
• Where ‘We’ Are
• The Anecdotal Evidence
  - Lateral Flushing and the Sources of Water
  - Discharge Path Concepts
  - Oil Shows
  - Titled O/W Contacts
  - Pervasive Dolomitization
  - Water Salinities
  - Sulfur Deposits
  - Corrosive Zones
• Is the PB Unique?
• A Wyoming Study
## Attributes of the ROZ Types

<table>
<thead>
<tr>
<th>ROZ Type</th>
<th>Oil-Water Contact</th>
<th>Base of Oil Saturation</th>
<th>Other Characteristics</th>
</tr>
</thead>
<tbody>
<tr>
<td>Regional Tilt (1)</td>
<td>Horizontal</td>
<td>Tilted</td>
<td>Wedge with thin side Downdip</td>
</tr>
<tr>
<td>Breached Seal and Reaccumulation (2)</td>
<td>Horizontal</td>
<td>Horizontal</td>
<td>Stratified Tar Mats, Anomolously Low GOR</td>
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<tr>
<td>Hydrodynamic Tilt (3)</td>
<td>Tilted</td>
<td>Horizontal</td>
<td>Wedge with thin side in Direction of Flow (to Spill Point)</td>
</tr>
</tbody>
</table>

Original Oil Accumulation Under Static Aquifer Conditions
(A Hypothetical Example)
Change in Hydrodynamic Conditions, Sweep of the Lower Oil Column, Oil/water Contact Tilt, and Development Of The Residual Oil Zone
Post-Subsidence Phase of Permian Basin Development*

~50% of Permian Basin Production
Permian Basin Stratigraphic Column
San Andres (Permian Guadalupian)

<table>
<thead>
<tr>
<th>SYSTEM</th>
<th>SERIES</th>
<th>DELAWARE BASIN</th>
<th>CENTRAL BASIN PLATFORM</th>
<th>NORTHWEST SHELF</th>
<th>MIDLAND BASIN</th>
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<tbody>
<tr>
<td>PERMIAN</td>
<td>GUADALUPE</td>
<td>Delaware Mtn. Group</td>
<td>Dewey Lake</td>
<td>Dewey Lake</td>
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<td>Castile</td>
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<td></td>
<td>OCHOA</td>
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<td>Dewey Lake</td>
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<td>Bell Canyon</td>
<td>Yates</td>
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<td>Queen</td>
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<td>San Andres</td>
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<td></td>
<td></td>
<td>Gorieta</td>
<td>Gorieta</td>
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</tbody>
</table>

**Captured**:
- Delaware Mtn. Group
- Dewey Lake
- Rustler
- Salado
- Castile
- Guatemala
- Lamar
- Bell Canyon
- Seven Rivers
- Queen
- Grayburg
- San Andres
- Gorieta

**Word**
- Whitehorse
MIDDLE SAN ANDRES PALEOGEOGRAPHY
with Location of Active Industry ROZ Zones/CO\textsubscript{2} EOR Projects*

* Adapted from Sagnak (2006), Chevron Presentation at the 12/06 CO\textsubscript{2} Flooding Conference
Extensional Phases and Reduction of Hydrodynamic Gradients in the Permian Basin*

Phase III: Slow Extension, Pliocene - Recent
Phase II: Rapid Extension, Middle - Late Miocene

RIO GRANDE RIFT
Formation of Basin & Range Province
Horsts & Grabens
Drastically Reduced Meteoric Recharge Area

Permian Basin
Displaced Oil Columns Resaturate with Oil, Some with Gas,
& Some Stay at Residual Oil Saturation to Water ($S_{ow}$)

West:
Scattered Mountain Ranges Directly Attached to West Side of Permian Basin

EAST

* Ref: Lindsay, R.F. (2001), W. Tx Geological Society Fall Symposium, Oct 01, Midland Tx USA
SOURCES OF WATER

• Updip Origins
  – Surface Caverns
  – Karst
• Evidence of “Connection” to Petroleum Sources and Entrapments
  – Sulfur?
• Temporal Effects
OIL SHOWS

• Residual Oil in Cuttings
• Utility of Mud logs
Oil, Gas and Water Saturation for Continuous Phase and Residual Hydrocarbon Oil Shows*

<table>
<thead>
<tr>
<th></th>
<th>Oil</th>
<th>Gas</th>
<th>Water</th>
<th></th>
<th>Oil</th>
<th>Gas</th>
<th>Water</th>
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<tr>
<td><strong>At Surface %</strong></td>
<td>12</td>
<td>40</td>
<td>48</td>
<td></td>
<td>12</td>
<td>40</td>
<td>48</td>
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<tr>
<td><strong>In Core Barrel %</strong></td>
<td>30</td>
<td>0</td>
<td>70</td>
<td></td>
<td>30</td>
<td>0</td>
<td>70</td>
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<tr>
<td><strong>In Reservoir %</strong></td>
<td>70</td>
<td>0</td>
<td>30</td>
<td></td>
<td>30</td>
<td>0</td>
<td>70</td>
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</tbody>
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CONTINUOUS PHASE   RESIDUAL OIL

TILTED OIL/WATER CONTACTS

- Previous Work
- Sponsor’s Fields
- New Field Evidence
Distribution of Tilted Oil-Water Contacts in the Northern Shelf and Central Basin Platform Areas of the Permian Basin*
DOLOMITIZATION

- Magnesium Rich Waters
- Porosity Enhancements
- Pervasive Zonations
- Geological Timing
WATER SALINITIES

- Sulfur Water Occurrence
- Source to Discharge Mixing
- Evidence of Pathways
SULFUR ACCUMULATIONS

- Biological Processes
  - Aerobic
  - Anaerobic
- Associations
- Geographical Occurrence
- Quantitative Estimates of Petroleum ‘Consumption’
CORROSIVE ZONES

- ATTRIBUTES OF EXIT PATHS
- ACIDIC NATURE OF WATER
- WHAT WORK EXISTS ON THESE ZONES?
  - From Corrosion Engineers?
  - Geographically Speaking
    - Coleman Junction
    - Lower San Andres
    - Wichita Albany

- OTHER
Is the PB Unique?

A Wyoming Study?
Frannie Oil Field, Big Horn Basin Illustrating the SW OWC Tilt of ~600 ft/mi
Regional Structure of the Mission Canyon Fm. and Location of Important Oil Fields and Greater Billings Nose Study Area, Williston Basin *
Sequence Of Oil Migration And Accumulation In The Billing Nose Fields, Williston Basin *

A

OIL
FRACTURES
"A" ZONE POROSITY

B

RESIDUAL OIL ZONE
OIL POTENTIO-
BRACKISH WATER
METRIC SURFACE
SALINE WATER

Φ₀
Hydrodynamic Traps
Where the Oil Goes?

- Porosity pinchout
- Structural form lines
- Oil accumulation
- Hydrodynamic flow direction
Lon D. Whitman, P.Eng.
Corporate Outreach and Strategic Alliances

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