Mineralogy of Cretaceous Reservoir Sandstones and Their Impacts on EOR

Newcastle Project

Peigui Yin
Nick Jones

Enhanced Oil Recovery Institute
University of Wyoming
Cretaceous Oil/Gas Reservoirs
### Methods for Reservoir Study

<table>
<thead>
<tr>
<th>Method</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>XRD</td>
<td>Cation Exchange Capacity</td>
</tr>
<tr>
<td>PETROGRAPHY</td>
<td>SEM</td>
</tr>
</tbody>
</table>

- **100 ft**
- **2.5-5 in**
- **3x10^{-2} in**
- **3.5x10^{-3} in**

**Image:**
- A cross-sectional view of a reservoir rock showing layers and fractures.
- Microscopic images of rock samples: Petrography and SEM.

**Graph:**
- Bar chart representing Cation Exchange Capacity.
SANDSTONE TEXTURE

Cement

Pore
- Intergranular pore
- Intragranular pore

Framework Grain
- Quartz (Q)
- Feldspar (F)
- Rock fragments (R)

Authigenic Clay Minerals

ENHANCED OIL RECOVERY INSTITUTE

UNIVERSITY OF WYOMING
Major Cretaceous Reservoir Sandstones

- **Reservoirs**
  - Lance
  - Almond
  - Shannon
  - Sussex
  - Frontier
  - Muddy
  - Dakota

- **Data**
  - Lithology
  - Mineralogical composition
  - Poroperm distribution
Muddy

7573 ft

8651 ft

7493 ft

3274 ft
Common Characters of Cretaceous Reservoir Sandstones

Upper Cretaceous (Lance, Almond, Shannon, Sussex, Frontier)
- Rich in ductile lithic fragments.
- Rich in feldspar grains.
- Rich in clay minerals.
- Rich in poorly-connected leaching pores.
- Lack of well-connected intergranular pores.

Lower Cretaceous (Muddy, Dakota)
- Clay rich (kaolinite, chlorite, I/S mixed layer, illite, smectite).
- Quartz rich.
- Rich in well-connected intergranular pores.
Clay Effects on EOR

- Clay minerals
  - Large surface area.
  - High reactivity of such surfaces.
  - Success or failure of EOR may be controlled by amount and type of clays.

- Surface area & cation exchange capacity (CEC)
  - Surfactant precipitation.
  - Polymer degradation.
  - Formation damage.
Clay Minerals & Grain Surface Features

Grain surface area & cation exchange capacity
Clay Effects on Well Logs

• Lower resistivity measured by the induction electric logs (Asquith, 1991).
• All the porosity logs (neutron, density, and sonic) to record too high a porosity, except the density logs if the clay density is equal or greater than the reservoir matrix density (Asquith, 1991).
Clay Effects on Reservoir Quality

- Reduce pore-throat size, permeability.
- Total alter the electric log response characteristics.
- Increase irreducible water saturation.
- Increase the surface area of sand grains.
Clays Effects on Permeability

Three Modes of Occurrence of Authigenic Clay in Reservoir Sandstones.

A. Discrete Particle Kaolinite
B. Pore-Lining Chlorite
C. Pore-Bridging Illite

Munson, 1988

Graph showing the relationship between porosity and air permeability.

Asquith, 1991
Clay Effects on Engineering

- Well drilling.
- Well completion.
- Well stimulation.
- Enhanced oil recovery.
### Formation Damage by Clay Minerals

<table>
<thead>
<tr>
<th>Potential Problem</th>
<th>Contributing Minerals</th>
<th>Damaging Fluids and System</th>
<th>Damage Prevention</th>
<th>Damage Correction</th>
</tr>
</thead>
<tbody>
<tr>
<td>Clay swelling (water sensitive)</td>
<td>Smectite</td>
<td>Freshwater-based fluids</td>
<td>Oil-based mud&lt;sup&gt;d&lt;/sup&gt;</td>
<td>Preflush with HCl and NH&lt;sub&gt;4&lt;/sub&gt;Cl</td>
</tr>
<tr>
<td></td>
<td>Illite–Smectite</td>
<td>Any water with inadequate concentration of cations</td>
<td>Potassium</td>
<td>HCl/ HF acidize</td>
</tr>
<tr>
<td></td>
<td>Chlorite–Smectite</td>
<td></td>
<td>Ammonium chloride</td>
<td>Postflush with NH&lt;sub&gt;4&lt;/sub&gt;Cl and clay stabilizer</td>
</tr>
<tr>
<td></td>
<td>Illite</td>
<td></td>
<td>Calcium chloride&lt;sup&gt;e&lt;/sup&gt;</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Kaolinite&lt;sup&gt;a&lt;/sup&gt;</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fines movement (rate sensitive)</td>
<td>Kaolinite&lt;sup&gt;b&lt;/sup&gt;</td>
<td>High transient pressure</td>
<td>Perforate slightly under-balanced (1000 psi)</td>
<td>Preflush if needed with HCl and NH&lt;sub&gt;4&lt;/sub&gt;Cl</td>
</tr>
<tr>
<td></td>
<td>Illite</td>
<td>High flow rates</td>
<td>Increase well rate slowly</td>
<td>Acidize with HCl/ HF</td>
</tr>
<tr>
<td></td>
<td>Chlorite</td>
<td></td>
<td>Maximize perforations per ft</td>
<td>Postflush with NH&lt;sub&gt;4&lt;/sub&gt;Cl and clay stabilizer</td>
</tr>
<tr>
<td></td>
<td>Illite–smectite&lt;sup&gt;c&lt;/sup&gt;</td>
<td></td>
<td>Select rate less than critical velocity</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Chlorite–smectite&lt;sup&gt;c&lt;/sup&gt;</td>
<td></td>
<td>Use clay stabilizer&lt;sup&gt;f&lt;/sup&gt;</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Clay size particles of quartz or other minerals</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<sup>a</sup> Kaolinite
<sup>b</sup> Illite
<sup>c</sup> Chlorite–smectite
Injectivity Problem

4520252 → 4520208 → 4520241
720 ft 660 ft

No response

SP Resistivity Conductivity SP Resistivity Conductivity SP Resistivity Conductivity

4520252 4520208 4520241

No response

Injection
Injectivity Problem

- Injectivity
  - Flow unit correlation.

- Clay mineral effects.

Kaolinite

Chlorite

Illite

Smectite
Clay Mineral in Newcastle Sandstones

Kao: 5%, Chl: 1%, Ill: 1%, I/S: 0

Kao: 5%, Chl: 2%, Ill: 1%, I/S: 0

Kao: 4%, Chl: 1%, Ill: 1%, I/S: 0

\( \phi = 12.3\% \)
\( K = 129 \text{ md} \)

\( \phi = 14.4\% \)
\( K = 350 \text{ md} \)

\( \phi = 16.8\% \)
\( K = 67 \text{ md} \)
Clay Content vs Permeability
Muddy Samples

Clay Content (%) vs Permeability (md)
Cation Exchange – Clay – Gamma Radiation
Muddy Samples

CEC vs Clay

CEC vs Gamma

Donovan, 1979
Technical Workflow

• Semi-quantitatively analyze clay minerals using optical microscope, SEM, XRD.

• Measure gamma ray on analyzed samples.

• Calibrate CEC with gamma ray count.

• Estimate CEC from GR logs.

• Test effects of clay minerals on fluid injectivity in lab.
Muddy/Newcastle Project

Phase I
Overview

Client – Sunshine Valley Petroleum Corporation

Field – Osage and Newcastle trends

Formation – Muddy/Newcastle

Pay – 2 to 10 feet (5 different zones)

Trap Type – Stratigraphic

Problems → Formation clays are water sensitive
Heterogeneous Reservoir – Discontinuous sands
Background

Fluid compatibility studies conducted at Thompson Creek

Conduct studies prior to drilling and or implementing water flood.

Use of clay inhibitors to buffer swelling (KOH)

Known clays – Kaolinite, chlorite, I/S mixed layer, Illite, and smectite

Initial plan to evaluate Mush Creek
Switched focus to Osage

Operator intends to begin developing a water flood at the Bradley Unit in late 2013 or early 2014
Project Objectives

Assist Sunshine Valley Petroleum Corporation with the characterization of clays in the Muddy/Newcastle Formation.

Provide core descriptions and clay analysis data to enable decision making regarding drilling fluids and water flood design.

Keep in line with EORI’s intended purpose and mission through benchmarking, technology transfer, and providing technical expertise.
Scope of Work

Conduct clay analysis for pay intervals in the Muddy/Newcastle formation from four cores for Sunshine Valley Petroleum Corporation.

Analysis will involve generating core descriptions, petrological analysis, XRD, SEM, and CEC.

Additional work will involve compilation of existing core descriptions, and core analysis.

Results will be summarized and presented in a final report.
Project Area

Bradley Unit
Project team

Sunshine Valley Petroleum Corporation
EORI Director/Deputy Director
Nick Jones – Data and core descriptions
Peigui Yin – Core evaluation and petrological analysis
Curtis Chopping – XRD and SEM analysis
Budget & Preliminary Schedule

Travel - $4,030
Analysis - $2,770
Supplies - $1,000
In Kind - TBD
Total - $7,800

Kickoff – July 29
Core description & evaluation - August
Sampling & Analysis – August/September
Prepare report - September
Submit findings and close - November

Funding source → Field Demonstration Budget
Questions?
Contact Information

Nick Jones – PG, Senior Geologist EORI
307-766-3284, njones@uwyo.edu