Time-Lapse EM and Seismic Imaging of a CO₂ Plume

GCCC Digital Publication Series #05-04d

K. Dodds

Keywords:
CO₂ Sources, Gulf Coast- CO₂ Sinks, Gulf Coast- CO₂ EOR, Reservoir- Screening Criteria

Cited as:
Fourth Annual Conference on Carbon Capture & Sequestration

Developing Potential Paths Forward Based on the Knowledge, Science and Experience to Date

Geologic – Frio Brine Field Project (2)

Time-Lapse EM and Seismic Imaging of a CO2 Plume

Kevin Dodds CO2CRC, Australia

May 2-5, 2005, Hilton Alexandria Mark Center, Alexandria Virginia
Motivation

Why is CO2CRC involved in Frio Brine?

• Frio Brine was nominated as one of 10 International projects that would provide insight into Carbon sequestration

• CO2CRC Contributed acquisition of crosswell EM

• Presence of a researcher on-site for 5 weeks.

• Developing collaborative relationship with LBNL

• Value the input of Susan Hovorka in planning our project, and the interaction with BEG.
Frio Crosswell EM Survey Objectives

- The objective of the survey is to evaluate the CO2 injection progress after two weeks of injection in the C sand in the Frio formation in Texas using crosswell EM technique.
- Injector well: 5x2500071 (Cased)
- Monitoring well: SHG 1-4 (Cased)
- Well separation: 114ft
The Crosswell EM system
transmitter tool and a receiver tool connected with surface wire telemetry and deployed with standard wireline equipment.
The Technology

Model

Field Result

Misfit
Survey Challenges

- Both wells are steel cased => Low frequency measurement.
- Well separation is close => direct signal (Primary magnetic field) much stronger than formation signal (secondary field)
- High magnetic noise
Time table

- **Aug 2004**: Baseline survey
- **Sept 2004**: Petrophysical model
- **Oct 2004**: Processing and Inversion of Baseline survey
- **Nov 2004**: Baseline survey reports
- **Dec 2005**: Post injection Survey
- **Jan 2005**: Processing and Inversion of Post Injection survey
Baseline Survey Acquisition

- 40 stations every 8ft between 4707ft and 5028ft (SSTVD).
- Frequency: 80Hz
- Stacking: 1000
- Logging time: 8Hrs
Post Injection Survey Acquisition

- 44 stations every 8ft between 4723ft and 5091ft (SSTVD).
- Frequency: 80Hz
- Stacking: 1600
- Logging time: 20 Hours
Resistivity Model

Resistivity Logs

0.2 - 2.0 ohms

Down Dip Injector

Interpolated logs used to build starting model

Up Dip Monitor

Top of C Sand
Petrophysical Model
Well Profile

<table>
<thead>
<tr>
<th>Measured Depth ft.</th>
<th>Resistivity (ohmm)</th>
<th>Porosity</th>
<th>Petrophysical</th>
<th>Permeability (md)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Down Dip Injector</td>
<td>0.2</td>
<td>0.5</td>
<td>0.0</td>
<td>Solution</td>
</tr>
<tr>
<td></td>
<td>20.0</td>
<td></td>
<td></td>
<td>0.1</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>10,000</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Measured Depth ft.</th>
<th>Resistivity (ohmm)</th>
<th>Temp (°F)</th>
<th>Porosity</th>
<th>Petrophysical</th>
<th>Permeability (md)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Up Dip Monitor</td>
<td>0.2</td>
<td>120-140</td>
<td>0.5</td>
<td>0.0</td>
<td>Solution</td>
</tr>
<tr>
<td></td>
<td>20.0</td>
<td></td>
<td></td>
<td></td>
<td>0.1</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>10,000</td>
</tr>
</tbody>
</table>

* A Sand
* B Sand
* C Sand

Injection interval
August Survey
Resistivity
Intrinsic Permeability
Differential Saturation
1.-5.run

Borehole salinity: run 1 high, run 5 fresh water.

5.run: pressure gradient in borehole: water gradient.

Pressure gradient change in the borehole from water gradient to gas gradient during and shortly after CO2 injection (run 2-4).

2. & 3. run: Temperature change during and after CO2 injection.

5. run: constant temperature.

Run 2&3: lowest sigma \(\rightarrow\) highest supercritical CO2 saturation.

Sigma decrease after 4.run (5.run) due to cement squeeze and CO2 in the formation.
Post Injection Survey Results

- Data reprocessed (including baseline) for better depth matching using RST logs.

- Data inversion using resistivity statistical constraints (boundaries).
Seismic Crosswell:
Acquisition Details

• 40 3-component sensors at 25 ft. spacing per shot
• 5 source 'fans' interleaved to give 5 ft. source and sensor spacing
• 250 ft. per source fan, approximately centered on reservoir
• Orbital vibrator source gives both P- and S-wave energy (in-line and cross-line source components)
• Source frequency content ~ 70 Hz to 350 Hz
Seismic Crosswell

- Combination of 3-component sensors and 2-component source gives 6-component data
- Pre Injection Survey: July, 2004
- Post Injection Survey: Nov. 28, 2004
- Both wells perforations were cemented during both surveys
LBNL Recording Truck,
Paulsson Sensor Cable on Reel,
LBNL Source Wireline
LBNL Orbital Vibrator
Borehole Seismic Source

Operating principle is a spinning eccentric mass controlled by an electric motor.
Seismic Crosswell – Raw Data
6-Component O.V. Receiver Gather at 4992'

In-Line (left) has P and SV; Cross-Line (right) has SH
Example Crosswell Time Picks

P-Wave

S-Wave
Seismic Crosswell - Acknowledgments

• Data acquisition by LBNL
• Unique 3-component geophone sensor string provided with support of Paulsson Geophysical
• Seismic source provided by LBNL
• Field support by Sandia Technologies
CO2CRC Pilot Project

Otway Basin Pilot Project (OBPP) Location

Buttress
Boggy Creek-1
Naylor-1
Naylor South
Croft-1

Minerva BHP

MELBOURNE

GIPPSLAND BASIN

Otway Basin

MURRAY BASIN

Western Australia
South Australia
New South Wales
Tasmania
Northern Territory
Queensland
Conceptual Representation of Pilot Project

- Plan to inject 100,000 tons of CO$_2$ over 1-2 yrs @3MMSCFD
- Ongoing monitoring program till 2009
Wells and Facilities
Reservoir/Well Status

Buttress:

• Reservoir gas is high CO$_2$ content: 85-92%
• Most likely reserves 250Mt of CO$_2$
• Buttress-1 completed with 13 Cr 3 $\frac{1}{2}$ in casing (tubingless completion)
• Not perforated

Naylor:

• Depleted gas field (recovered 4 Pj from 8 Pj GIP)
• Naylor-1 completed with 13 Cr 3 $\frac{1}{2}$ in casing (tubingless completion)
Acknowledgements

Mike Wilt, Jeff Little, P Zhang Schlumberger
T Daly, L Myer, M Hoversten LBNL Berkeley
Don Sherlock CO2CRC Australia
Especially Susan Hovorka BEG