A New Field Tested Technique for Surveillance of CO$_2$ in the Reservoir

Presented at the
21$^{st}$ Annual CO$_2$ Flooding Conference

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Agenda

• The method and sensors
  • Capacitive vs galvanic sensors
  • Deep current injection

• EOR Application – Case history

• Conclusions
Method and Sensors – Resistivity Mapping

1D Standard Resistivity Log
Range ~1ft / 0.3m from Wellbore

3D + 4D
Full-Field Resistivity Mapping
Range ~ 2mi / 11,000 ft. depth laterally

eQube™ Surface Sensors

Downhole Sensors
Capacitive E-field Sensors vs Galvanic Sensors

![Graph showing comparison between Capacitive E-field Sensors and Galvanic Sensors](image)

Spectral Amplitude of Fundamental - 0.1 Hz (V/A/Hz)

FFT Segment Size (30 min)
Deep Current Injection

DCS – Down Casing Source

TCS – Top Casing Source
Deep Current Injection

Current Distribution

Target Reservoir
Deep Current Injection

Current Distribution

Target Reservoir
Input Signal and Recorded Response
Data Processing and Inversion

• Denoising/outlier rejection of recorded data
• Preparation of transfer functions
• E-field anomaly map
• Casing current estimation
• Resolve for shallow effects
• Invert data to produce resistivity volume
Case Study

Map CO₂ in the subsurface using Far Field Resistivity for a CO₂ EOR field.

- Field in Texas
- 100% CO₂ saturated sediment ~12 ohm-m resistivity
- Data acquired summer 2015
- Area in survey about 1 sq. mile
Array in Populated Area
CO₂ EOR | Resistivity Map From Inverted Volume
CO₂ EOR | Resistivity Map From Inverted Volume

112.5 ft below Top
CO$_2$ EOR | Resistivity Map From Inverted Volume
CO₂ EOR | Resistivity Cube

eQube™ Sensor Locations
CO₂ EOR | Use Real Time Resistivity Data to Calculate Saturation

+ Contrast between resistive hydrocarbons and conductive formation water is the basis for hydrocarbon detection.

Use resistivity to calculate saturation levels with Archie’s equation

\[ S_w = \frac{1}{\phi} \sqrt{\frac{R_W}{R_t}} \]
Conclusions

• Injected CO$_2$ can change formation resistivity in the subsurface.

• Far Field Resistivity can identify CO$_2$ in the subsurface – provided e-field sensors are stable and sufficient, stable, measured, current can be injected at formation intervals.

• Provided there is sufficient resistivity contrast between the CO$_2$ and other fluids, saturation, leak points, sweep efficiency, and ROZ can be directly determined with Far Field Resistivity.