A New Field Tested Technique for Surveillance of CO_2 in the Reservoir

Presented at the
21st Annual CO_2 Flooding Conference

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Midland, Texas

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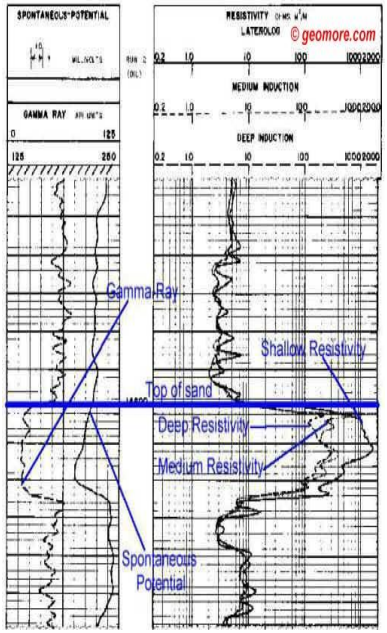
Agenda

- The method and sensors
  - Capacitive vs galvanic sensors
  - Deep current injection
- EOR Application – Case history
- Conclusions

Method and Sensors – Resistivity Mapping



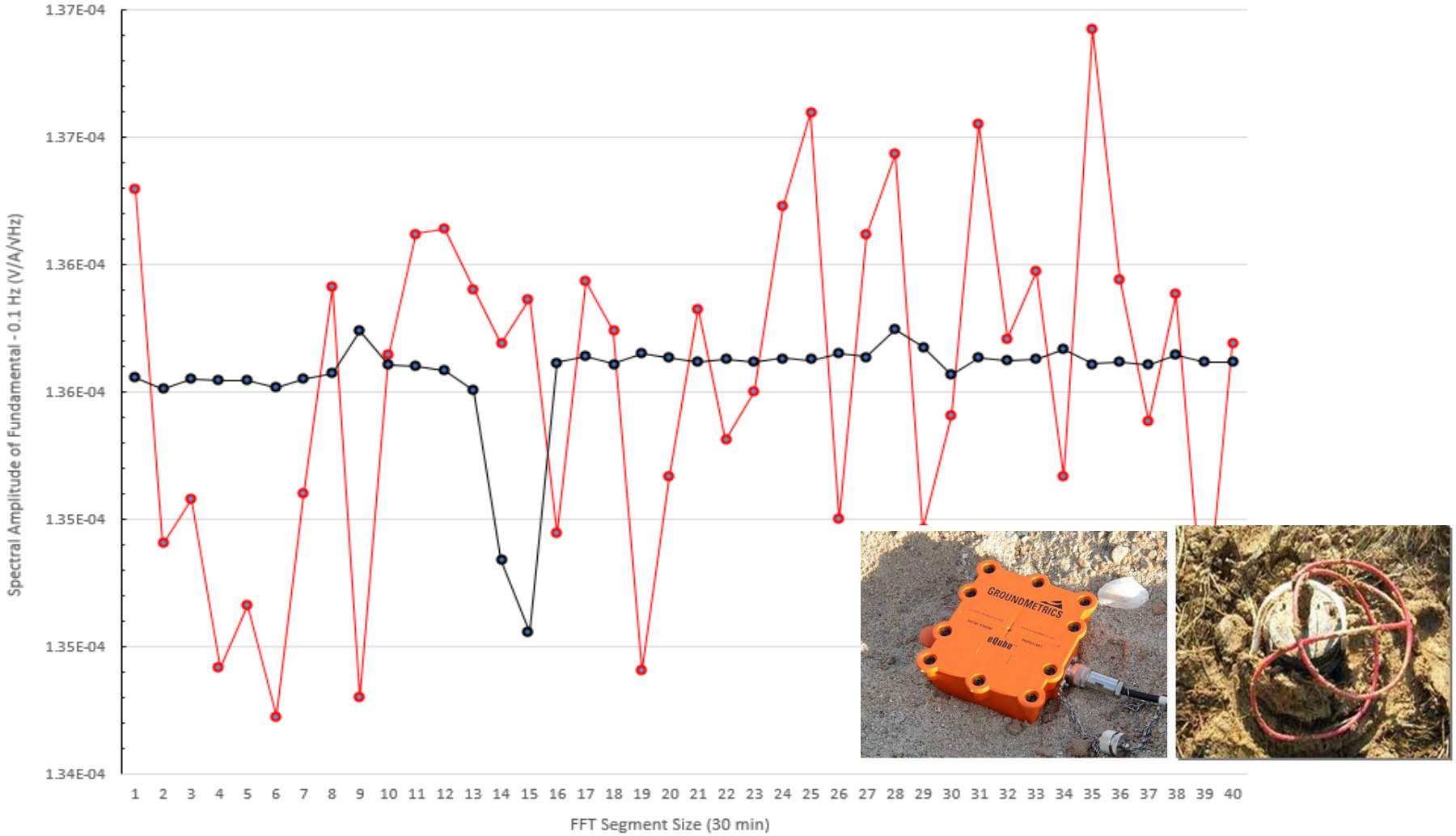
Downhole Sensors

eQube™ Surface Sensors

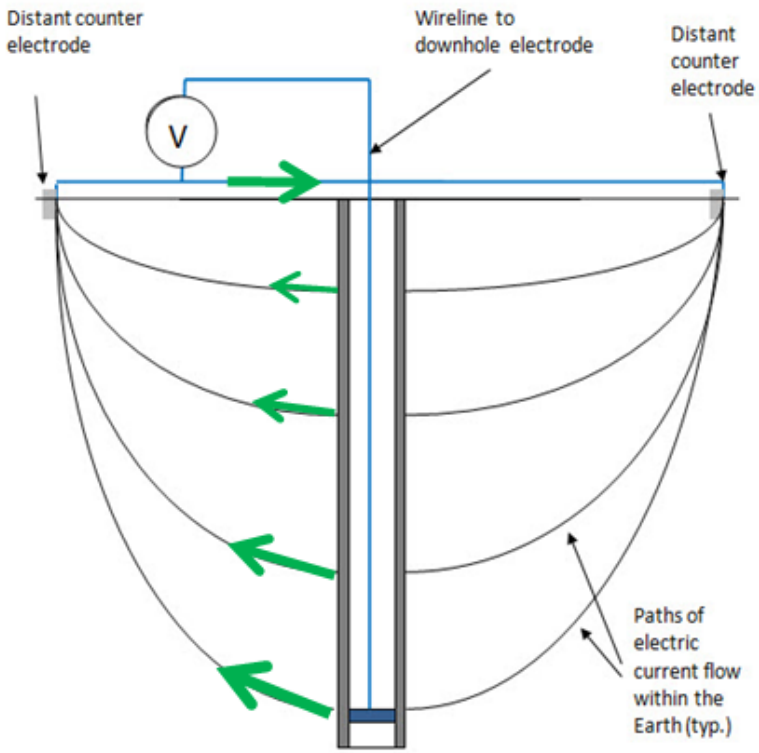
1D Standard Resistivity Log
Range ~1ft / 0.3m from Wellbore

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

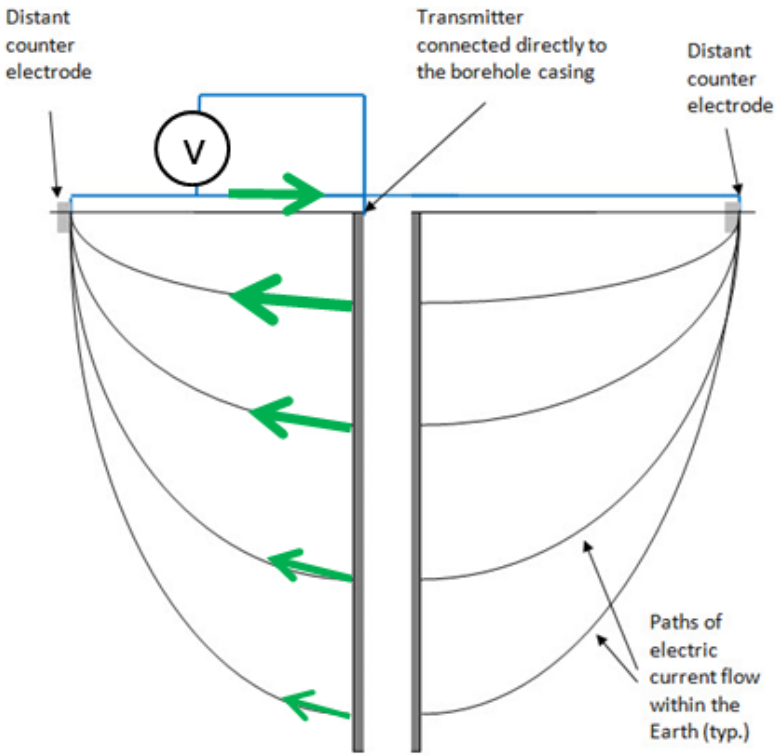
Capacitive E-field Sensors vs Galvanic Sensors



Deep Current Injection

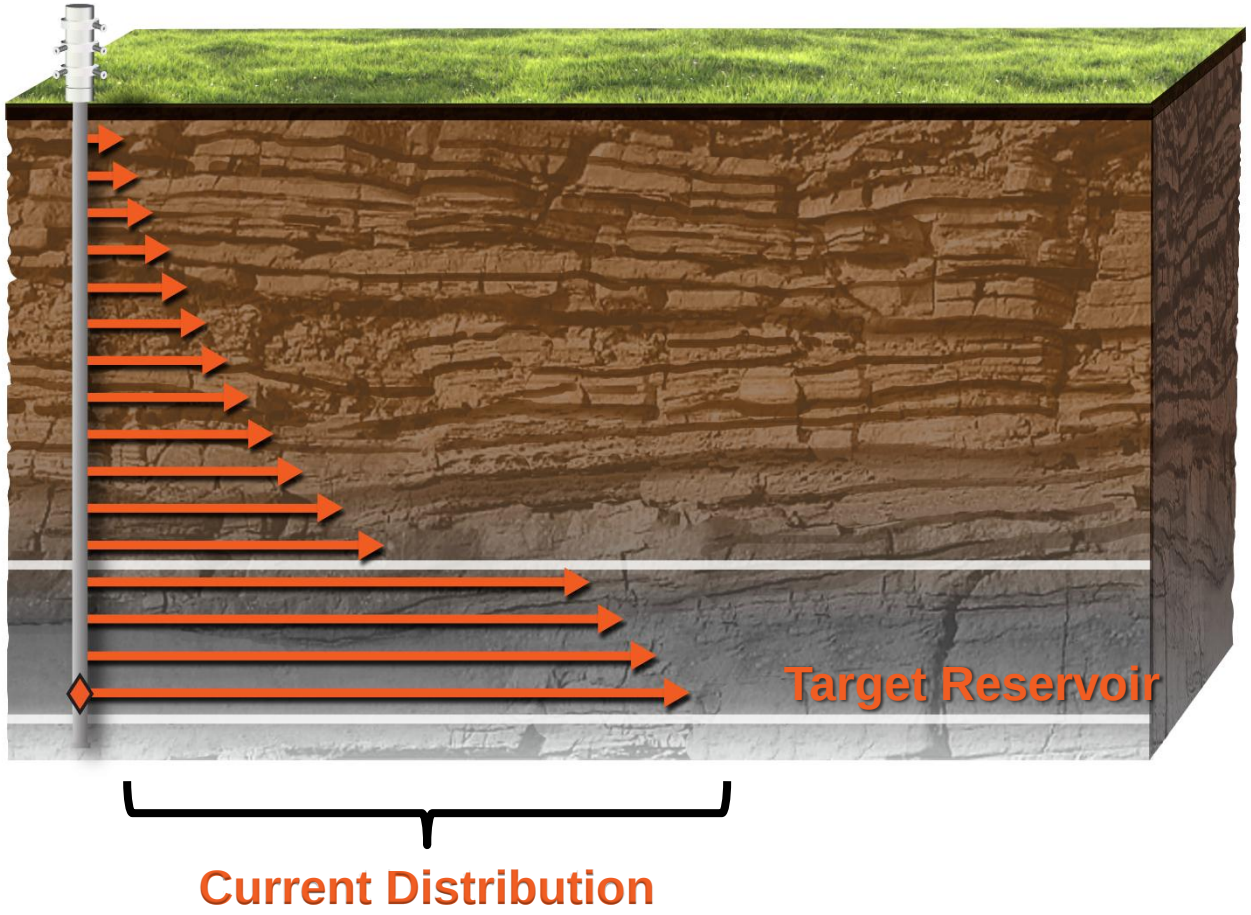


DCS – Down Casing Source

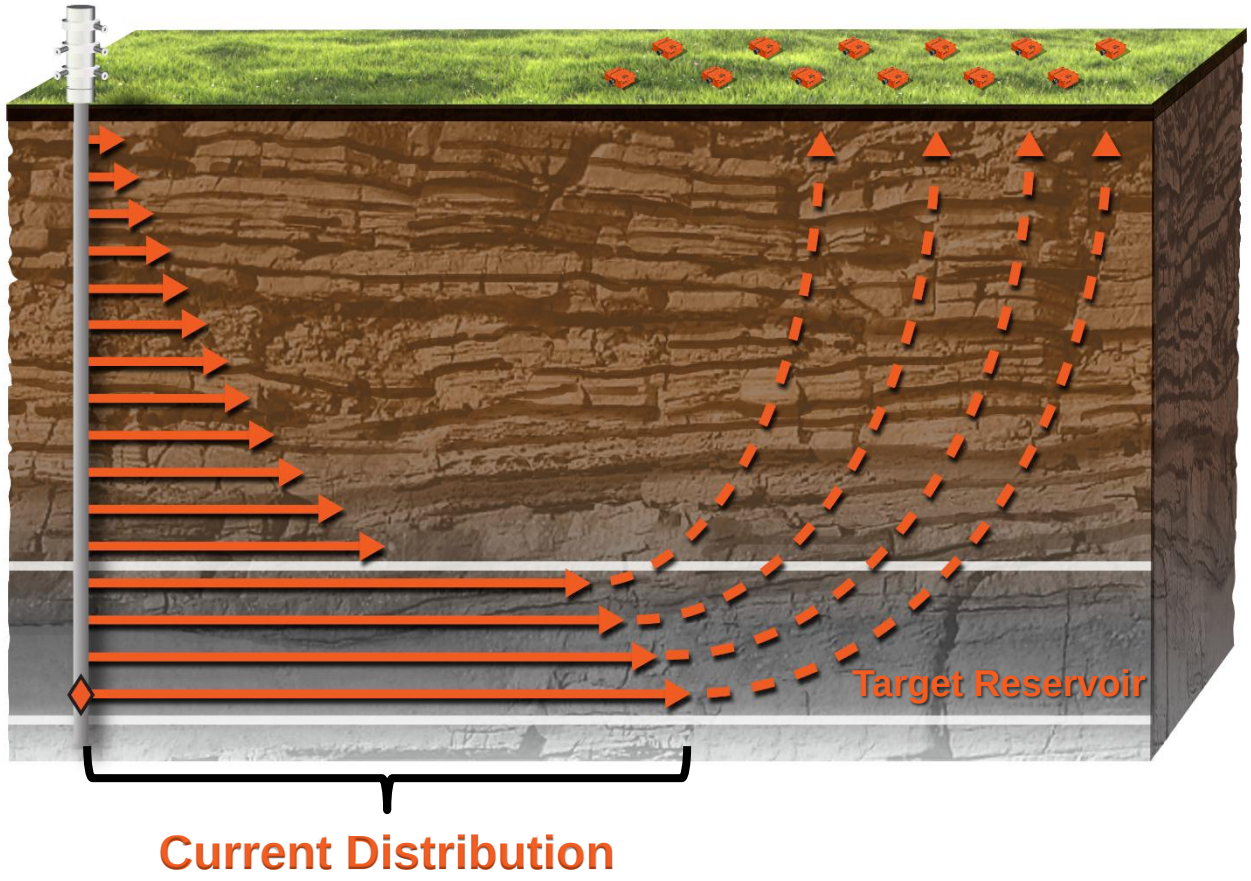


TCS – Top Casing Source

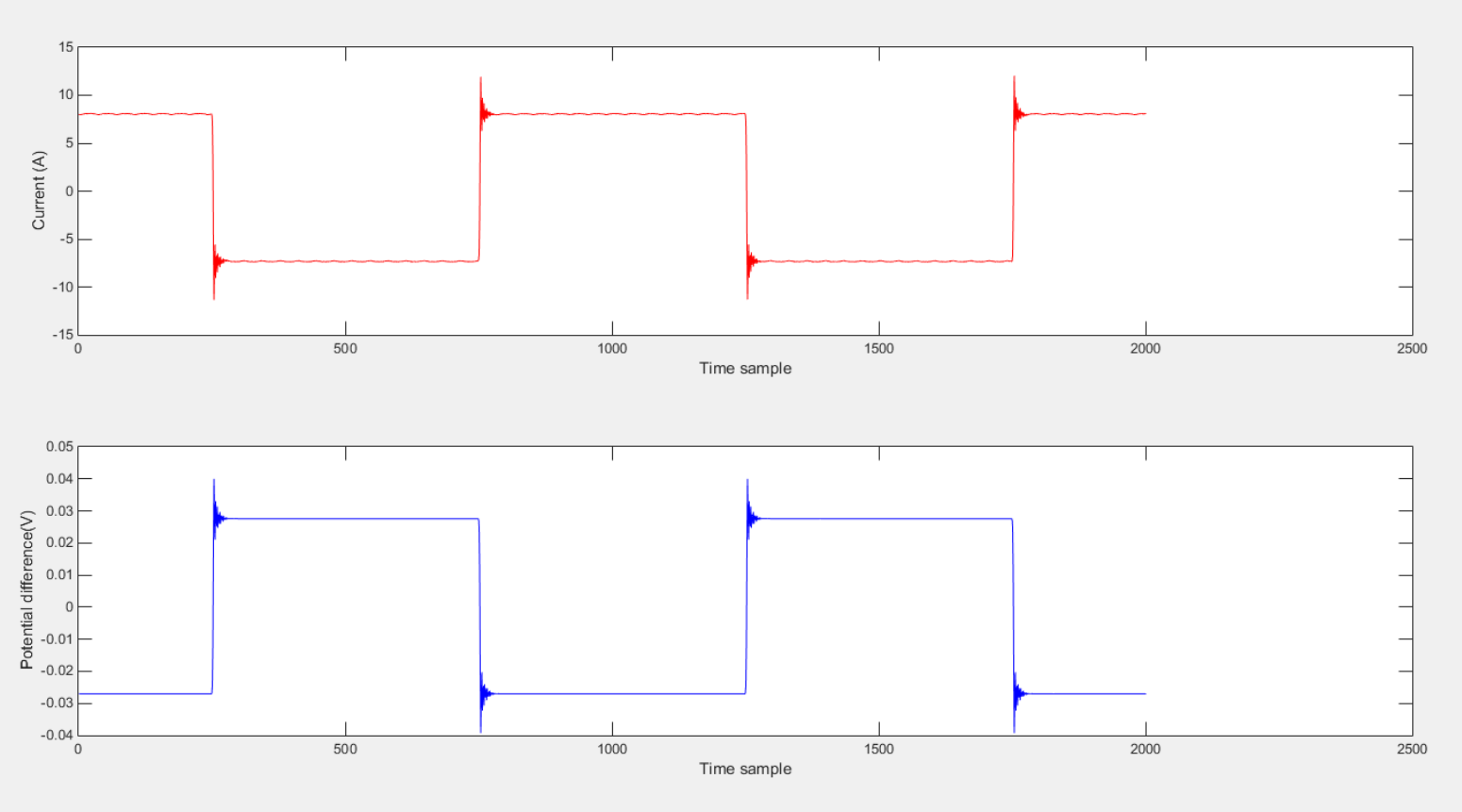
Deep Current Injection



Deep Current Injection



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

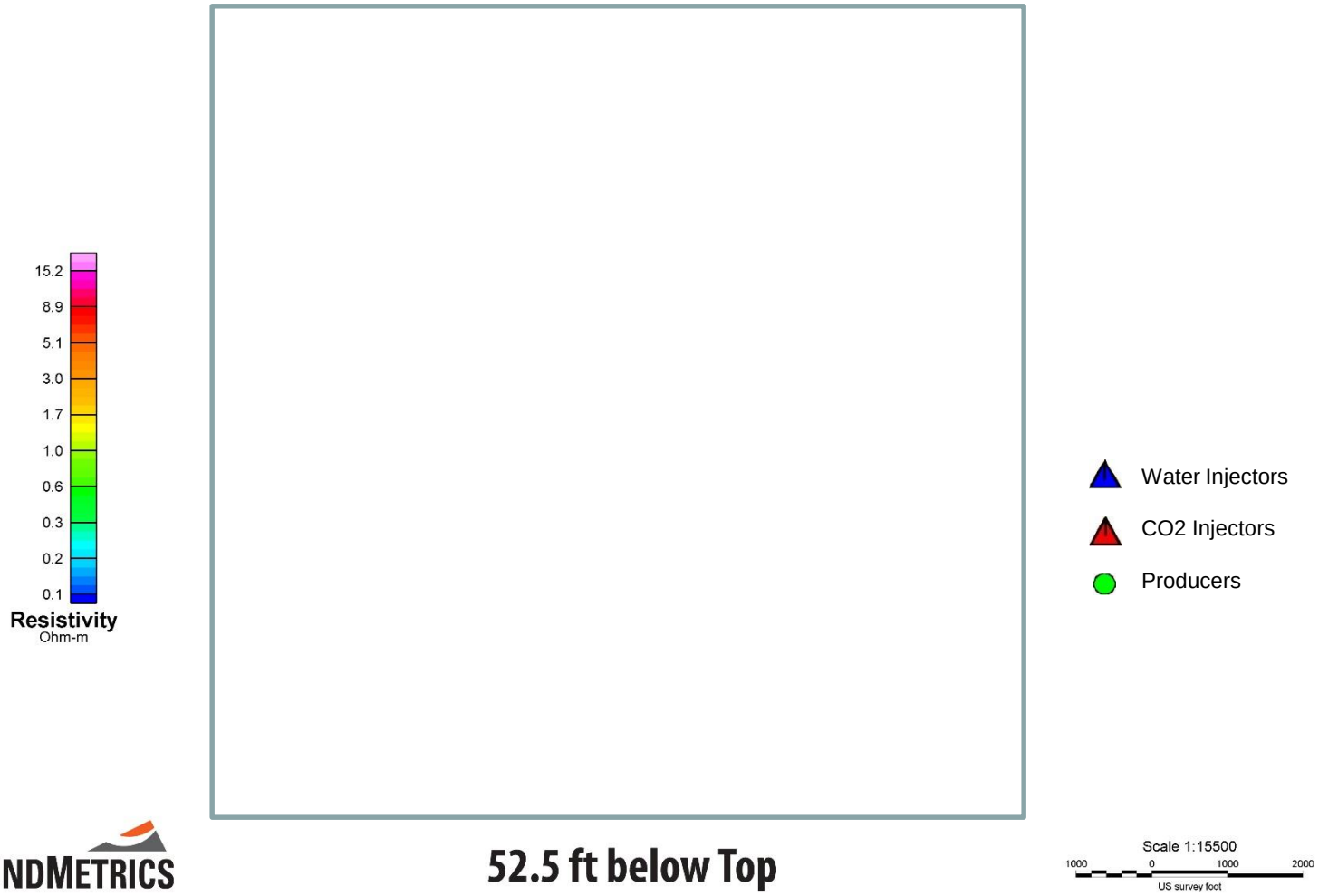
Case Study

Map CO_2 in the subsurface using Far Field Resistivity for a CO_2 EOR field.

- Field in Texas
- 100% CO_2 saturated sediment ~12 ohm-m resistivity
- Data acquired summer 2015
- Area in survey about 1 sq. mile

Array in Populated Area

CO_2 EOR | Resistivity Map From Inverted Volume



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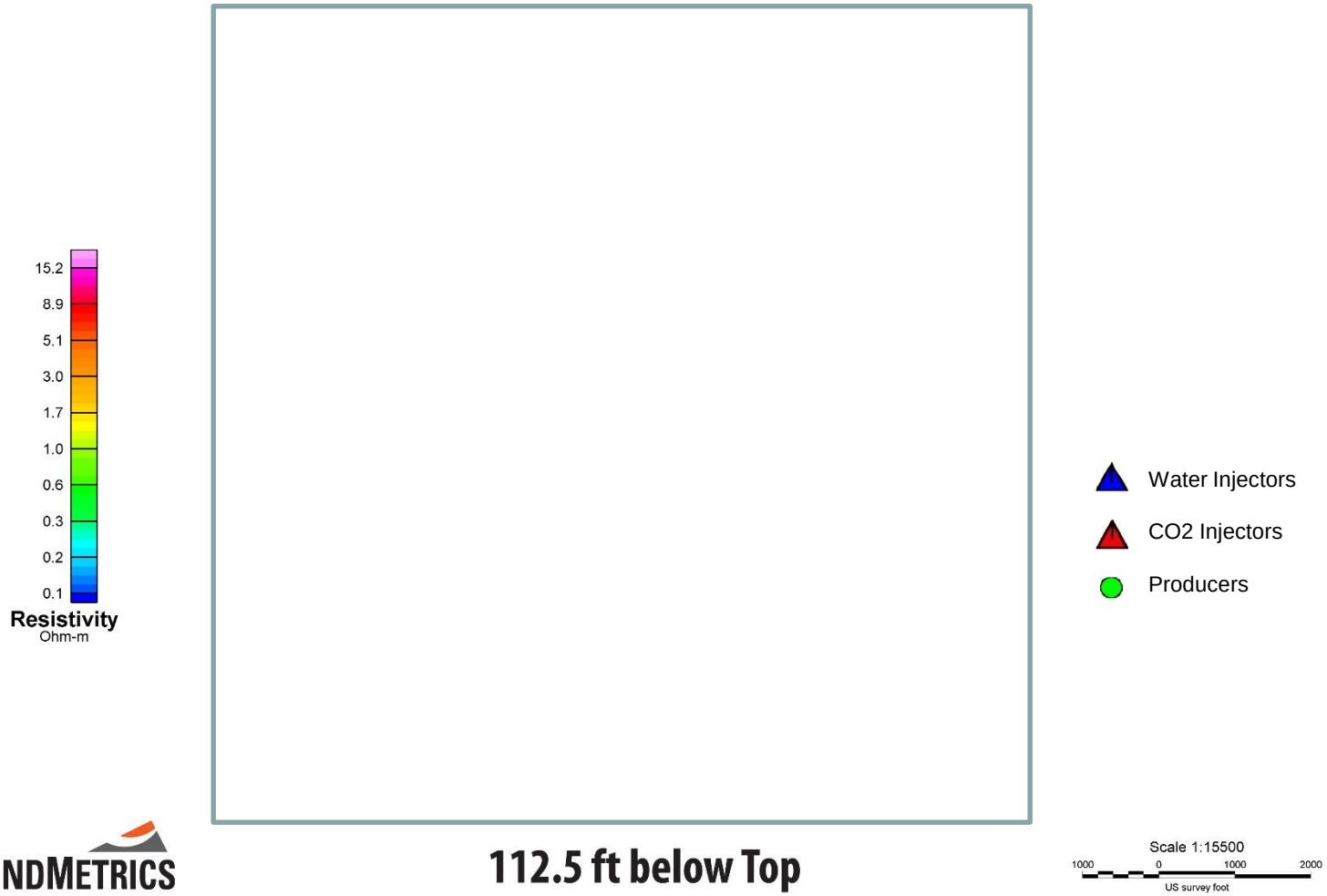
CO_2 EOR | Resistivity Map From Inverted Volume



CO_2 EOR | Resistivity Map From Inverted Volume

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227.5 ft below Top

CO_2 EOR | Resistivity Map From Inverted Volume

CO_2 EOR | Resistivity Cube

eQube™ Sensor Locations

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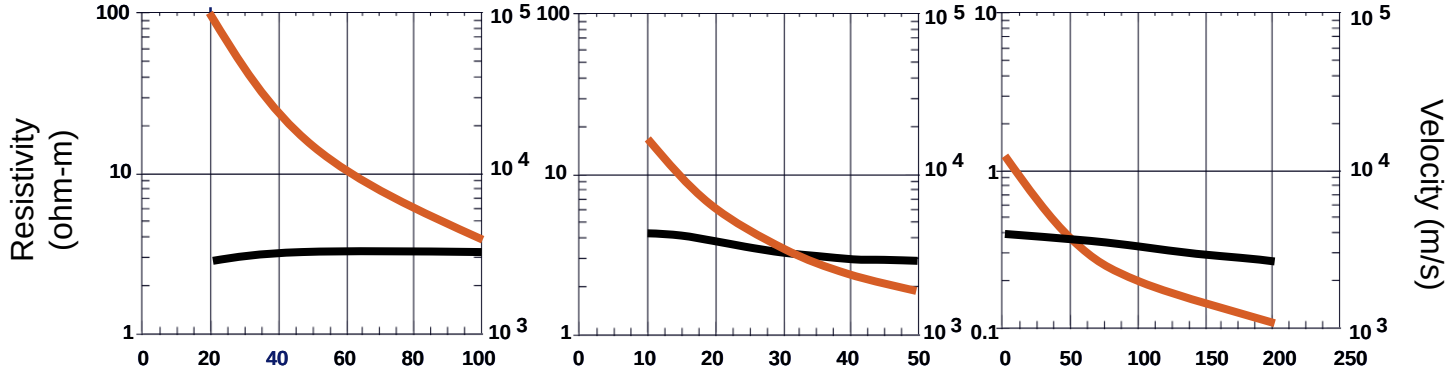
CO_2 EOR | Use Real Time Resistivity Data to Calculate Saturation

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



Unconsolidated Sandstone
Water/Air
Φ = 30% - T = 20 degC
R_w = 0.65 ohm-m at 20 degC

Unconsolidated Sandstone
Water/Air
Sw = 50% - T = 20 degC
R_w = 0.65 ohm-m at 20 degC

Unconsolidated Sandstone
Water/Air
Sw = 50% - Φ = 30%
R_w = 0.65 ohm-m at 20 degC

- Use resistivity to calculate saturation levels with Archie's equation

$$S_w = \frac{1}{\varphi}\sqrt{\frac{R_w}{R_t}}$$

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.