The Potential for a Potential Method*

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*HGI does not condone the play on words
Problem Statement

- Fluid is forced in to competent rock through a well
  - Deep
  - High pressure
  - High pumping rates
  - The rock succumbs to geomechanical failure
  - A fraction of the produced water is recovered

- Acoustic methods are used to monitor fracture growth

- However, we propose that electrical resistivity can be used to trace the movement of fracturing fluids
Resistivity measurements
Recent Advances*

- Rapid acquisition systems
- Real-time assessment
- The use of wells as electrodes
- Optimized configurations

*This is not your parent’s resistivity anymore*
1. Rapid Acquisition

- Full 180 channels
- Pole-pole array
- 32,220 measurement combinations in 20 minutes
- Towable
- Multi-core cables plug into side panels
- Generator or AC powered
- UL rated with safety disconnects
- Satellite communications
1. Rapid Acquisition

- Data!
  - Current output (I)
  - Voltage measurements (V)
  - Geometry
  - Time

- Example: Injection well
  - 8 days of measurements
  - 780 snapshots
  - 23K values/snapshot
1. Rapid Acquisition
1. Rapid Acquisition
2. Real-Time Assessment

- Measured through current output
- No additional processing
- Benchmarked at electrode
- Other processing: Inverse modeling (not real time)
  - Uses voltage and current data
  - Requires significant processing
  - Produces volumetric images

\[ I = \frac{V}{R} \]

Output current:
\[ I = \frac{V}{R_c} \]

We hold \( V \) constant

\[ I = f\left(\frac{1}{R_c}\right) \]

\[ R_c \downarrow \quad I \uparrow \]
2. Real-Time Assessment

Benchmarking the increase in electrical current
2. Real-Time Assessment
3. Long Electrodes

- **Two words: Well field**
  - Electrodes in place
  - Well grounded
  - At depth of injection
  - Can be TX or RX

- **Algorithms**
  - Validated though numerous examples
  - Can be combined with surface or buried electrodes

* I totally ripped these off of the internet
3. Long Electrodes

Pilot-scale Validation
3. Long Electrodes

Point Electrode Results

Long Electrode Results

3. Long Electrodes

4. Optimized Arrays

- Pole-pole array (2-pole array)
  - Advantage: fast, deep, lowest noise
  - Disadvantage: low resolving power
- 4-pole array
  - Advantage: high resolving power
  - Disadvantage: too many combinations, highest noise
- Best of 2-pole + 4-pole =
  - Awesome!
4. (non) Optimized Arrays

Data

Resistivity Inversion

Resolution

2-pole (727/756 data)

4-pole (5940/40950 data)
4. Optimized Arrays

Any 4-pole array combination can be calculated from a complete 2-pole array dataset.
4. Optimized Arrays
Final Thoughts

- New advances in resistivity
- Resistivity is cheap
- Can track the fluid movement*
- Good complement to acoustic methods

*if you want that information