Characterization and Monitoring at the Hanford 100H Site using Geophysical Data

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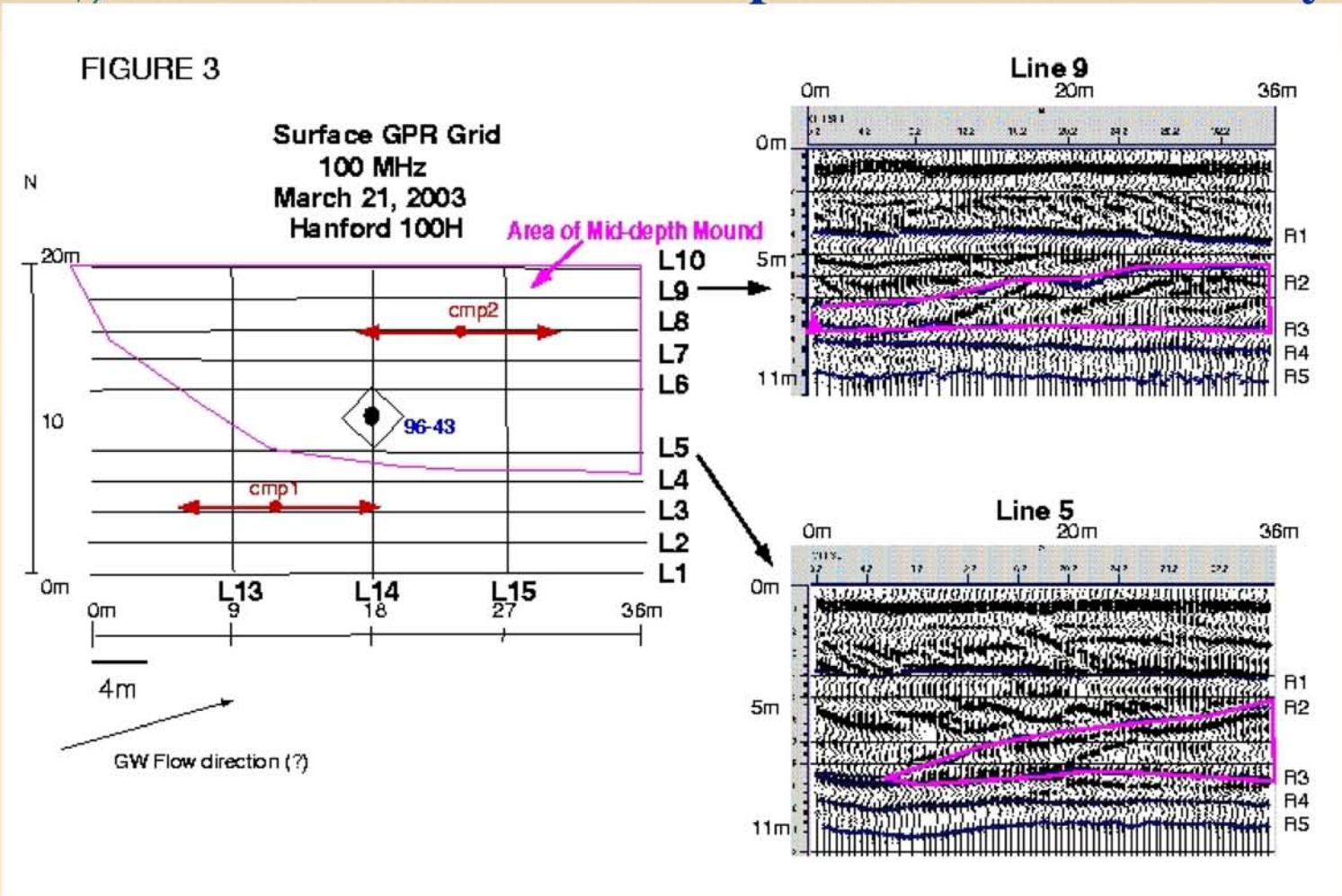
Uses of Geophysical Data at the 100 H Hanford Site

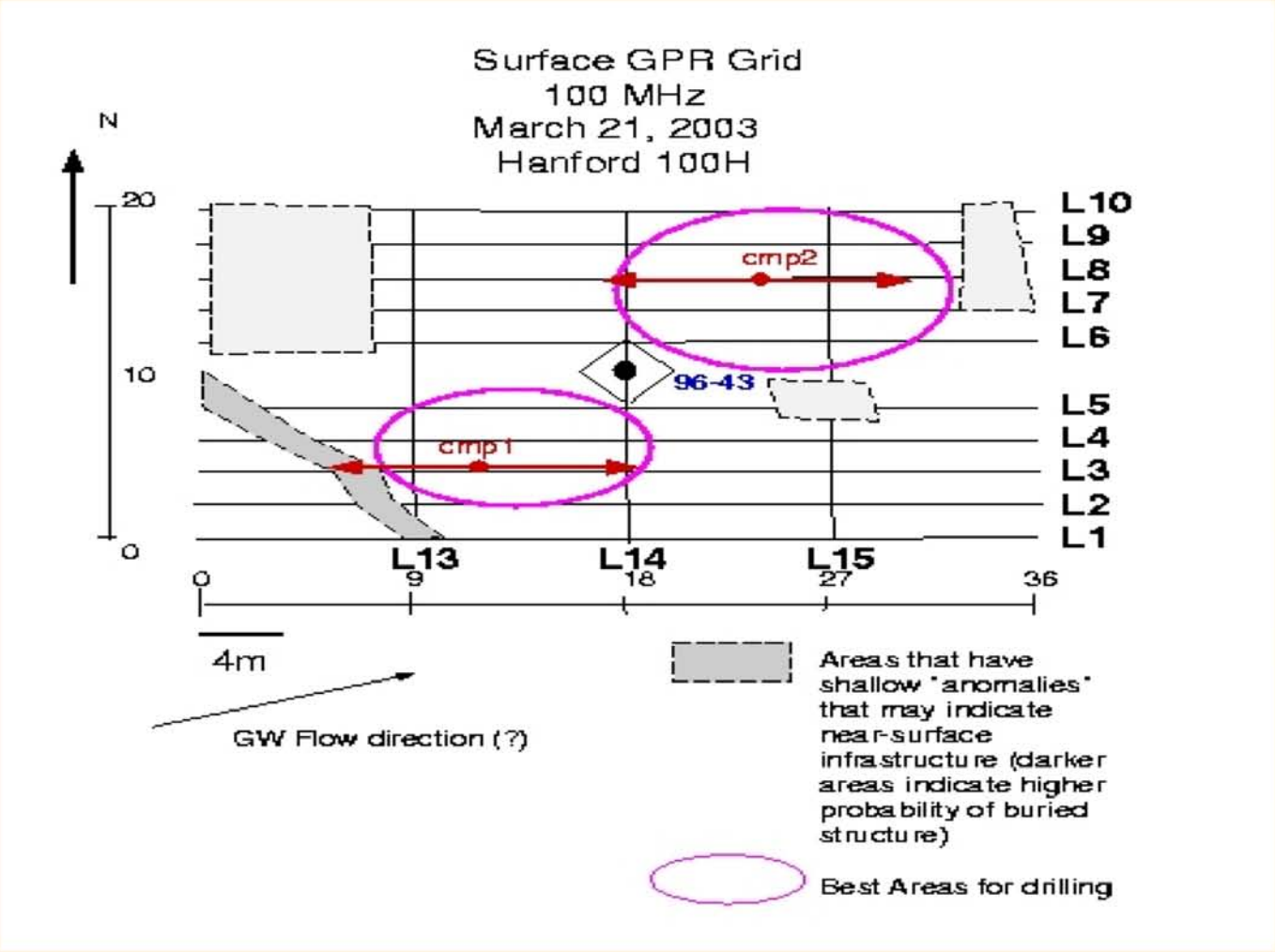
- *Field Scale_Characterization and Monitoring*
  - Use to develop field plan:
    - Location of Injection Experiment
    - Location of Lactate injection interval(s)
    - Injection rate and sampling scenarios
  - Use to monitor system transformations during stimulation
    - Estimate size and status of Injectate around borehole
    - Detect evolved N2 gas - provide an indication of redox status
    - Water table fluctuations

Use of Surface GPR to map subsurface variability

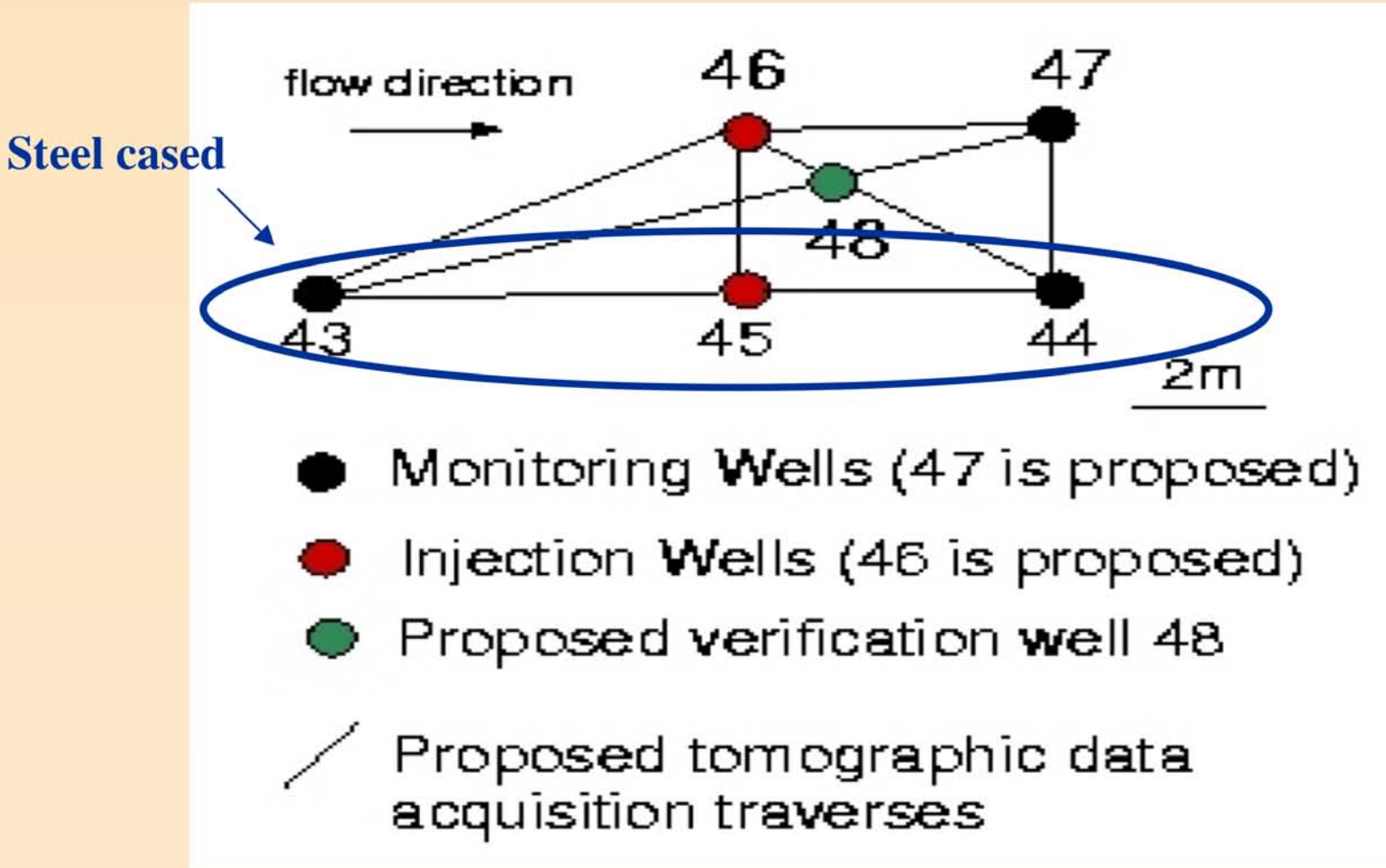


Experiment Location:
Choose location that has minimal lateral variability!!

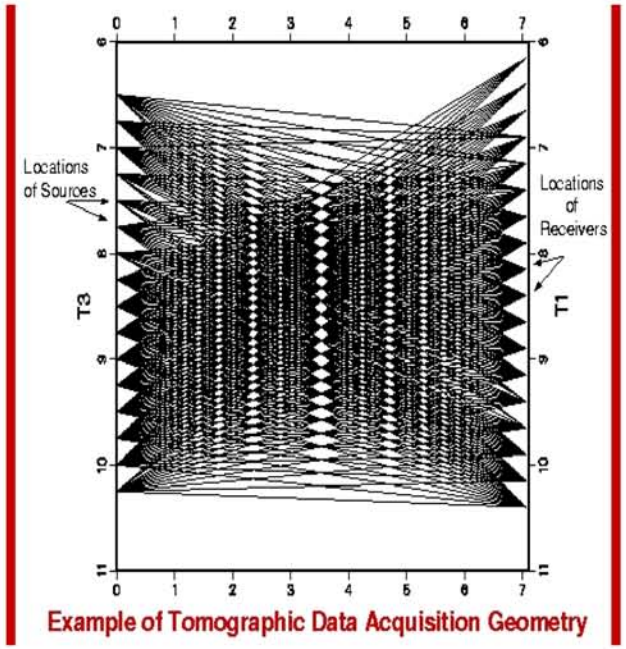
Use of GPR to map near-surface 'utilities'



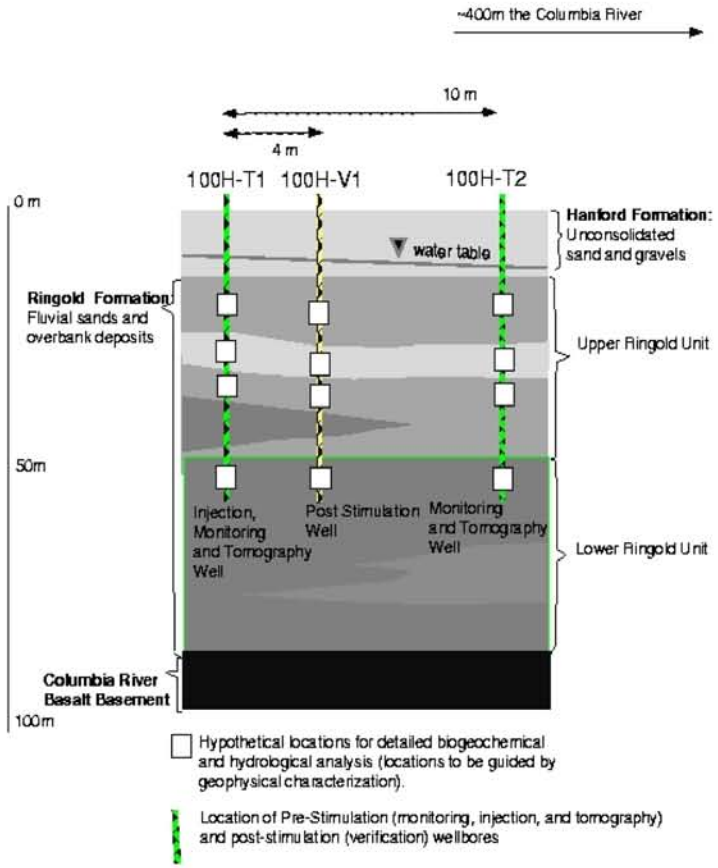
Choose a location that avoids near-surface clutter!


Steel cased
flow direction
46
47
48
43
45
44
2m
Monitoring Wells (47 is proposed)
Injection Wells (46 is proposed)
Proposed verification well 48
Proposed tomographic data acquisition traverses

- **Radar Tomography: 45-44 (vadose and saturated zones)**
  - **100 MHz**
  - **1/8m spacing**
- **Seismic Tomography: 43-44 and 45-44 (saturated zone)**

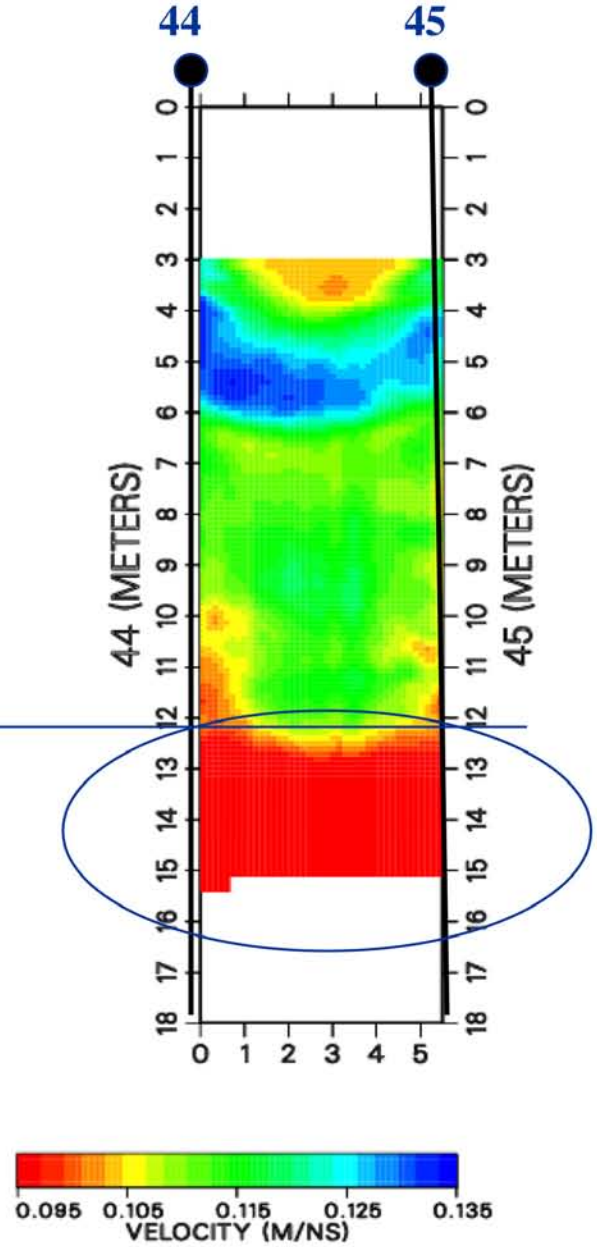


Example of Tomographic Data Acquisition Geometry

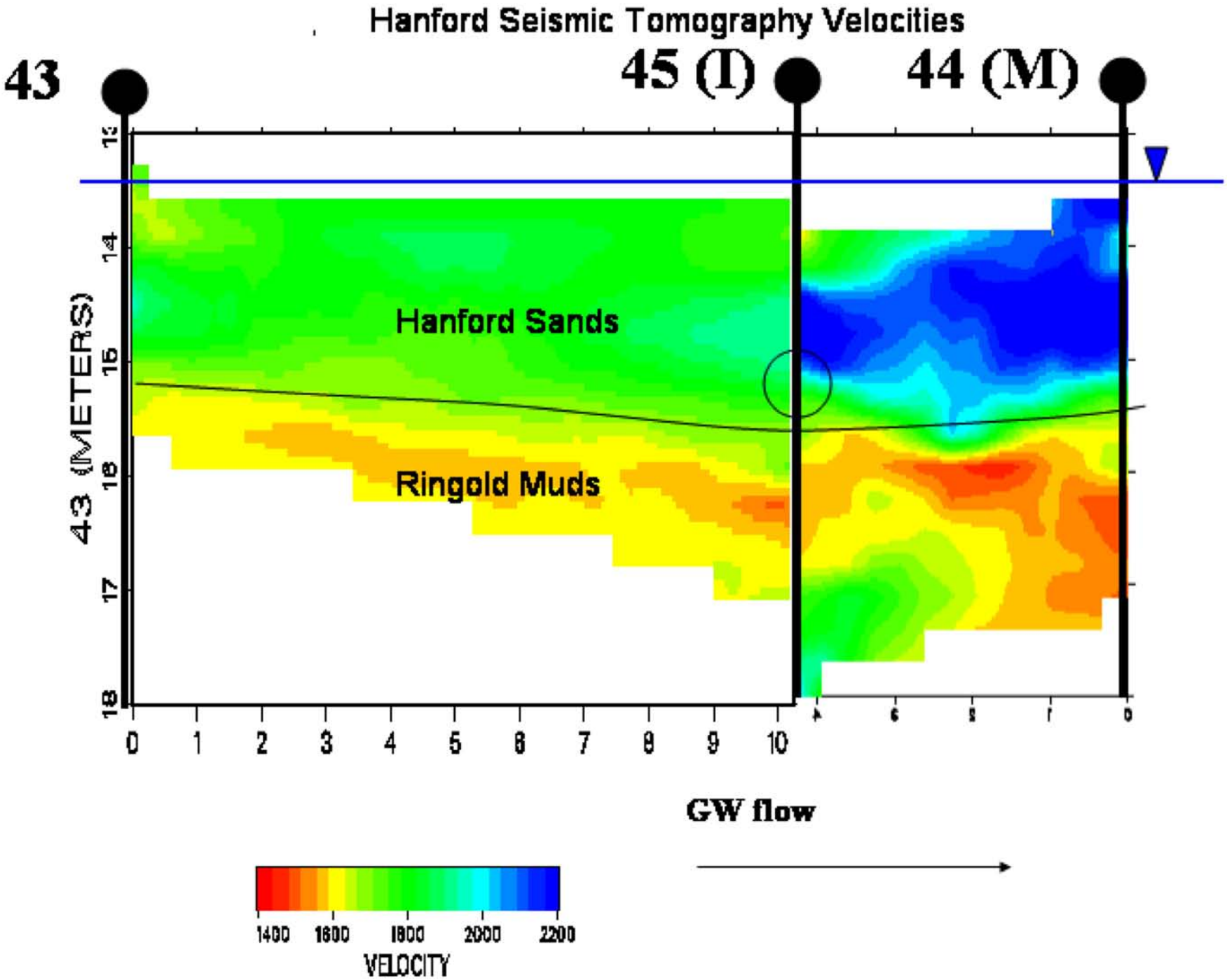


Radar Tomography:

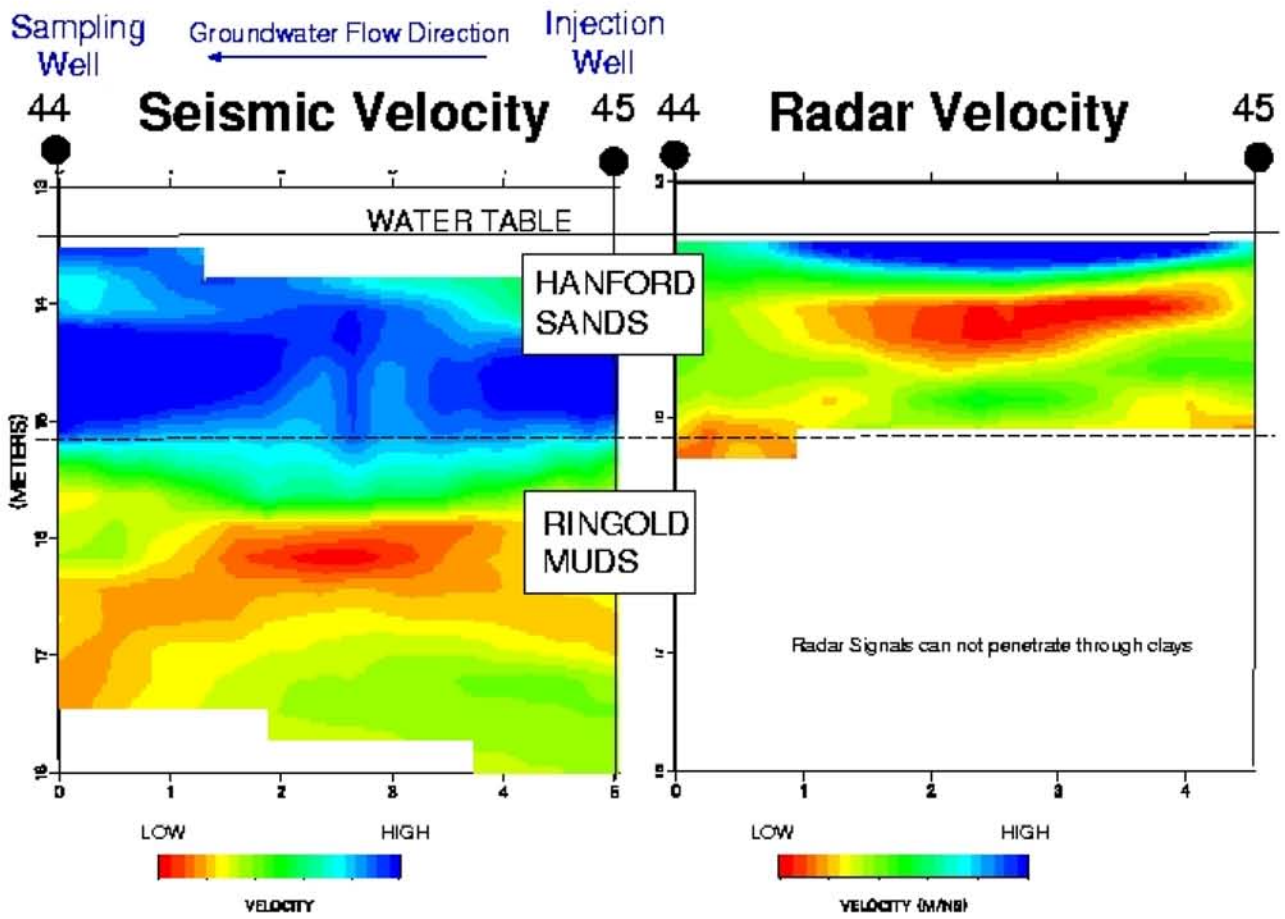
Vadose Zone versus the Saturated zone



Subsequent Images all in saturated zone


Hanford Seismic Tomography Velocities
43
45 (I)
44 (M)
Hanford Sands
Ringold Muds
43 (METERS)
13
14
15
16
17
18
0
1
2
3
4
5
6
7
8
9
10
GW flow
1400
1600
1800
2000
2200
VELOCITY

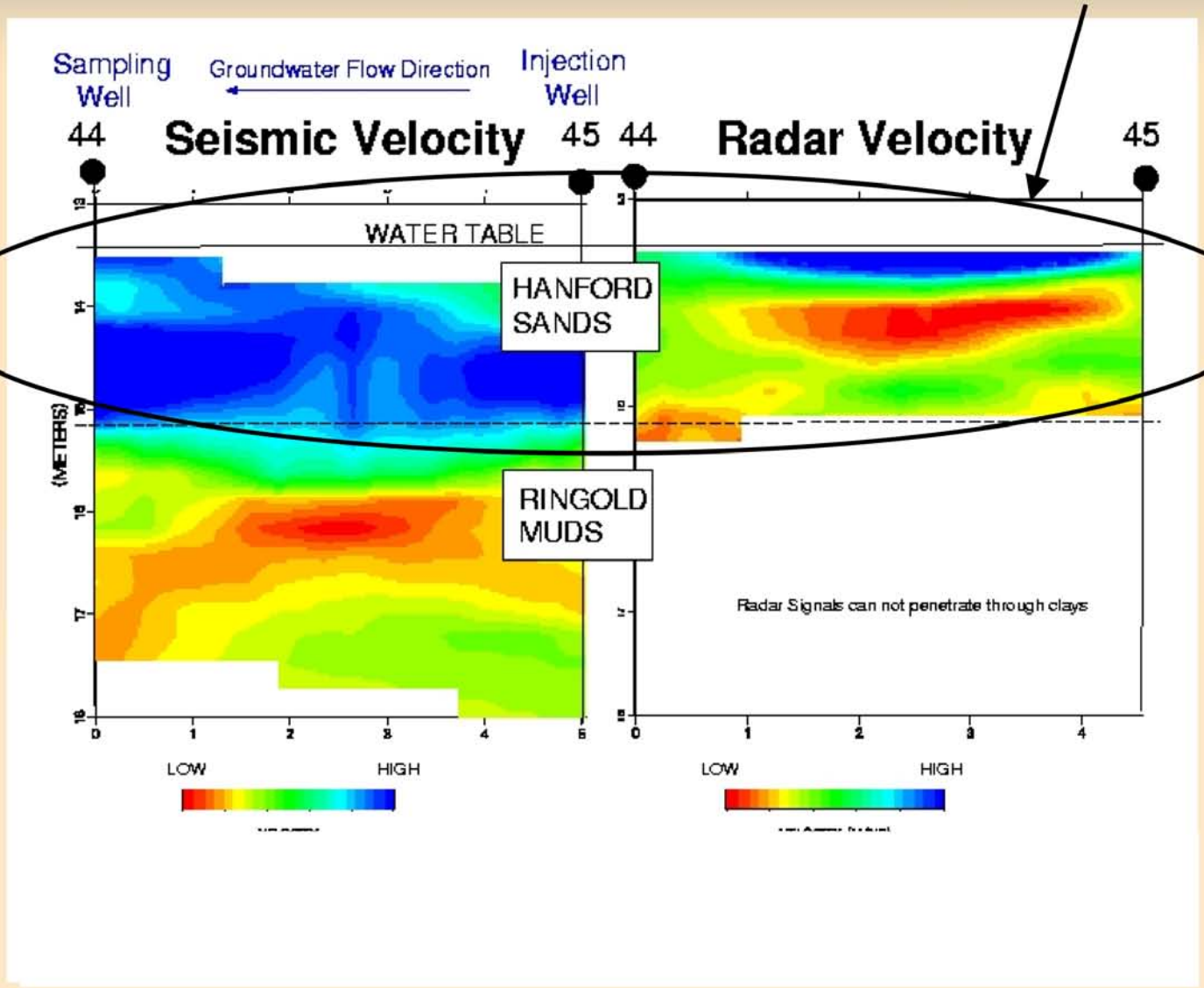
- **Hanford Sands and Ringold Muds Distinguished;**
- **Radar signals attenuated within muds;**
- **Small variability within Hanford Sands.**



Comparison of Radar and Seismic Images between 44-45

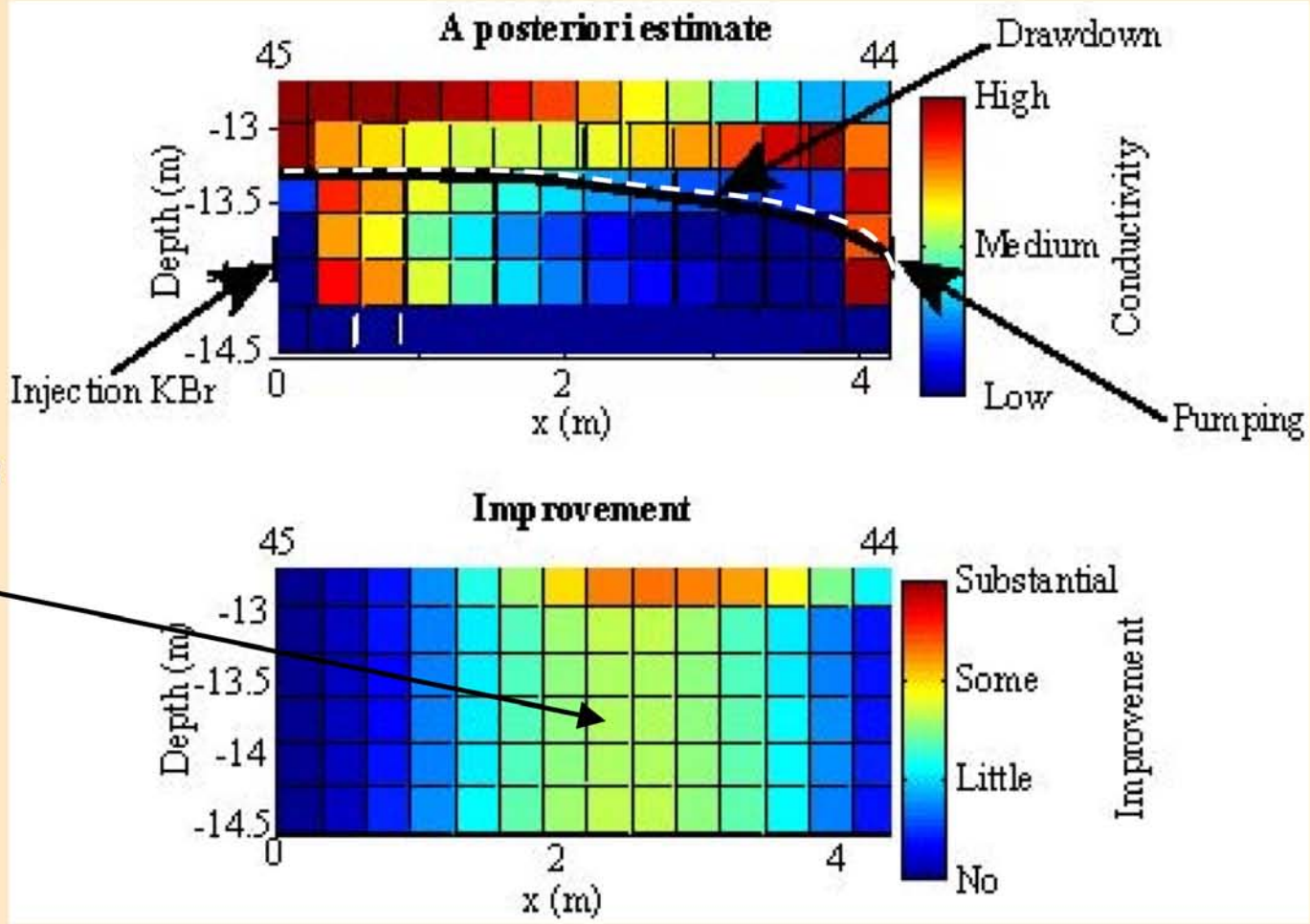
Estimate K within Hanford Sand Injection Zone

- Radar signals attenuated within muds;
- Hanford Sands and Ringold Distinguished;
- Small variability within Hanford Sands.

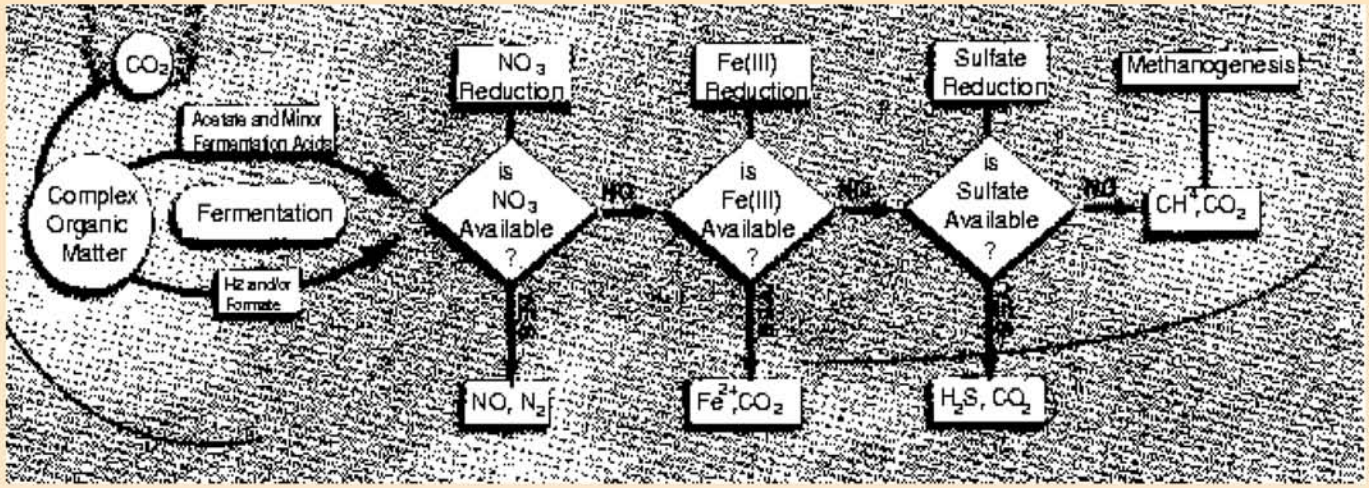


Estimation of Hydraulic Conductivity using Flowmeter and Tomography Data And a Bayesian Estimation Approach

- Uncertainties in K estimates due to lack of pump test and inaccurate wellbore locations;
- K mean ~ 10- m/s
- Information content from tomography greatest away from wellbores



Plans for Geophysical Monitoring during Stimulation



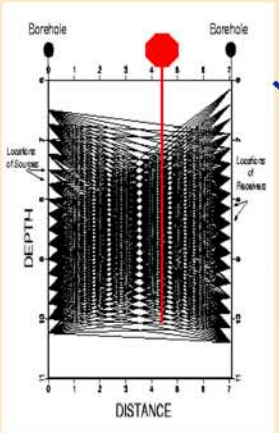
Chapelle, 2000

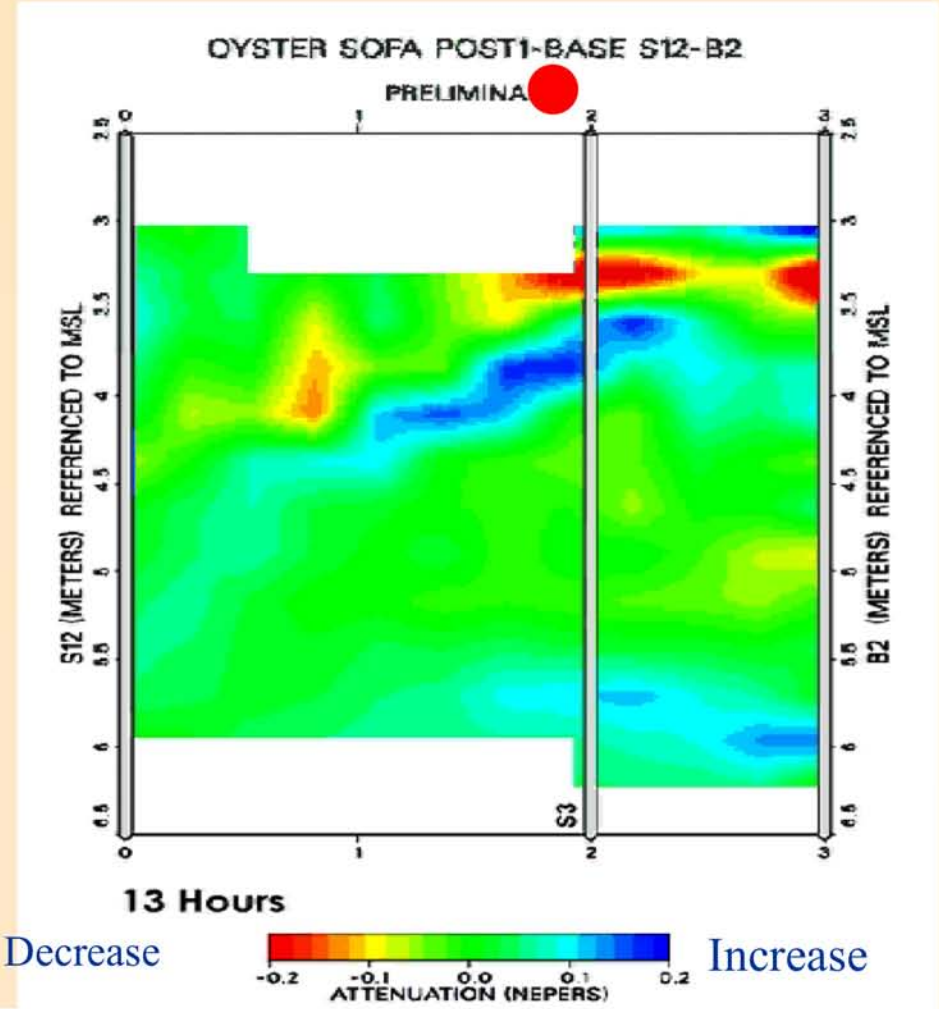
- System may produce N_2 gas (and ppts?) on the way to Cr reduction - this may be detectable using time-lapse geophysical measurements.

- HRC injection zone should be visible

Field-Scale Biostimulation Monitoring using Time-Lapse Seismic Tomography

Lactate Injection Well





Change in Seismic Attenuation (blue=gas)

Biostimulation Experiment.
Nitrate Initial Concentration <12 mg/L (avg. 7mg/L)

Mailloux et al., 2002

Variations in seismic amplitude correlated with N2 production near the wellbore AT THE FIELD SCALE

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Monitoring of Gas Evolution during biostimulation

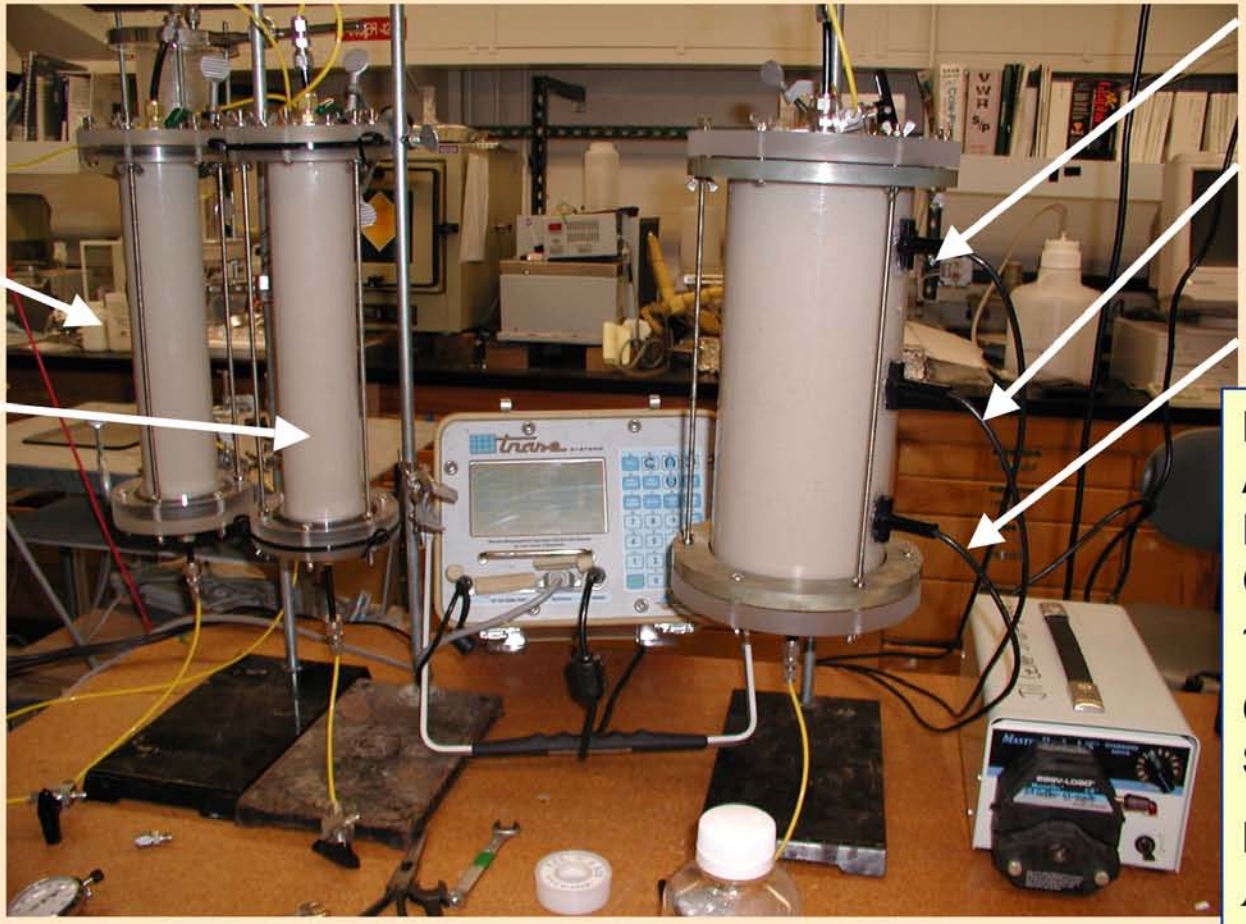
Probe 1

Probe 2

Probe 3

Ksat

Seismic Columns



Electron Acceptor: Nitrate, Initial Concentration ~300mg/L

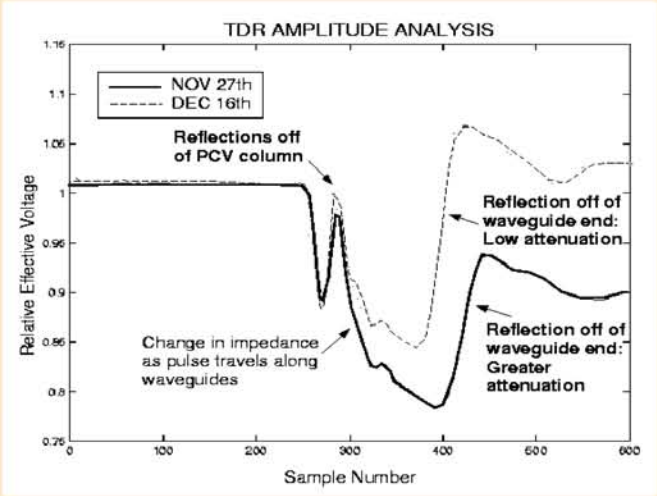
Carbon Source: Acetate

Microbe: *OY107 Acidovorax*

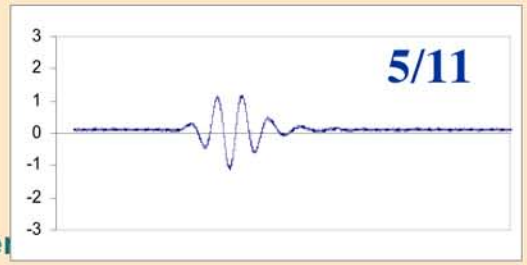
Grown to ~2 x 10^7 cells/gram in sand and suspended in a nutrient depleted growth media

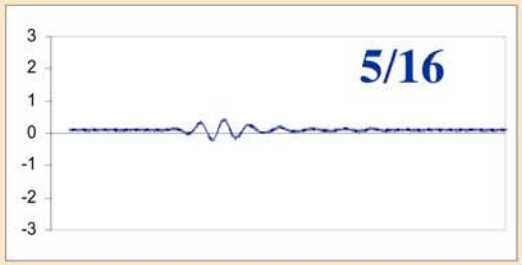
Column-Scale Geophysical Monitoring of N2 Production

- **Radar velocities and amplitudes were increased as gas replaced water in pore space;**
- **Radar velocities were used within a mixing model to estimate that 40% of the pore space was ultimate filled with N2 gas, which was verified by column weight-loss measurements;**
- **Geophysical observations were coincident with a 55% reduction in K.**



- **Seismic Amplitudes decreased dramatically as gas was generated;**
- **Changes were coincident with a 70% drop in K.**





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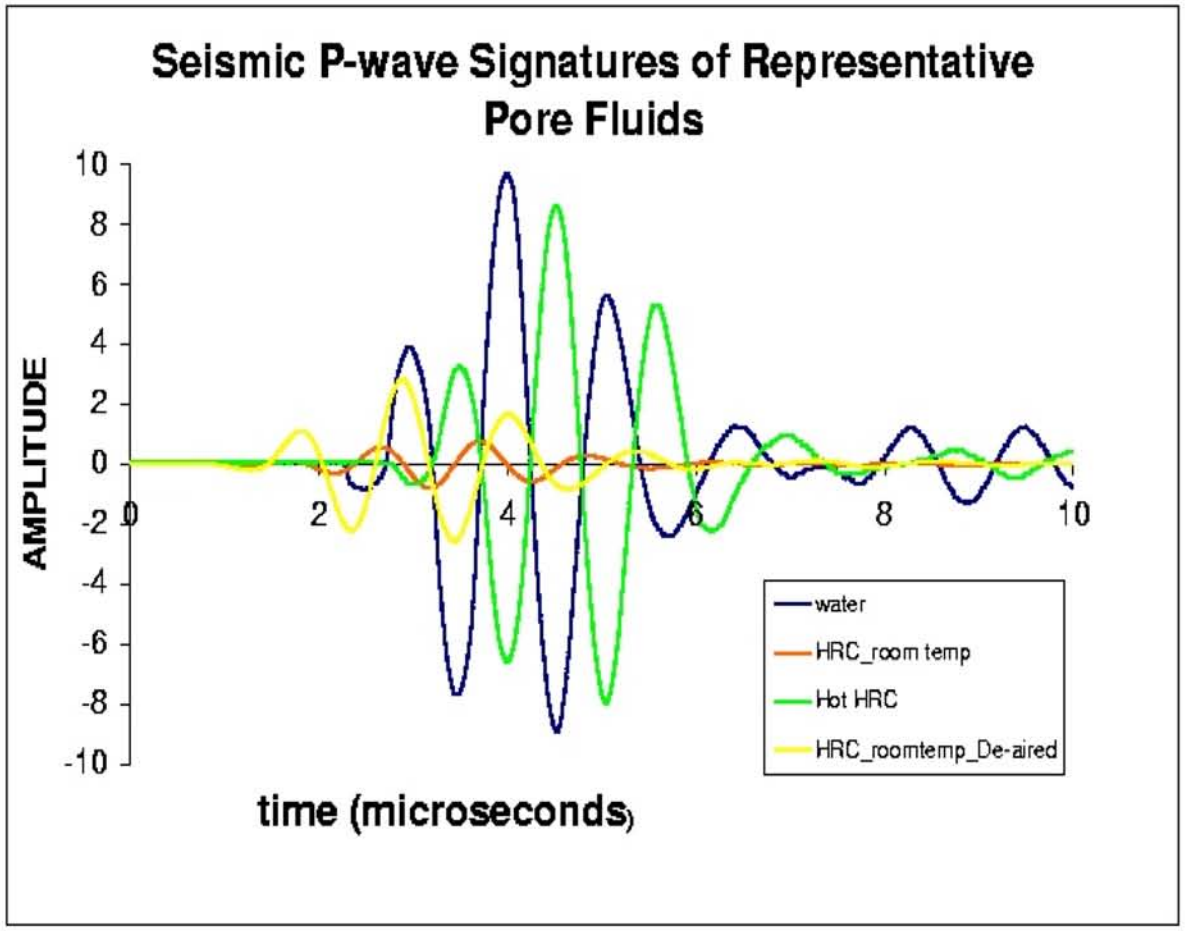
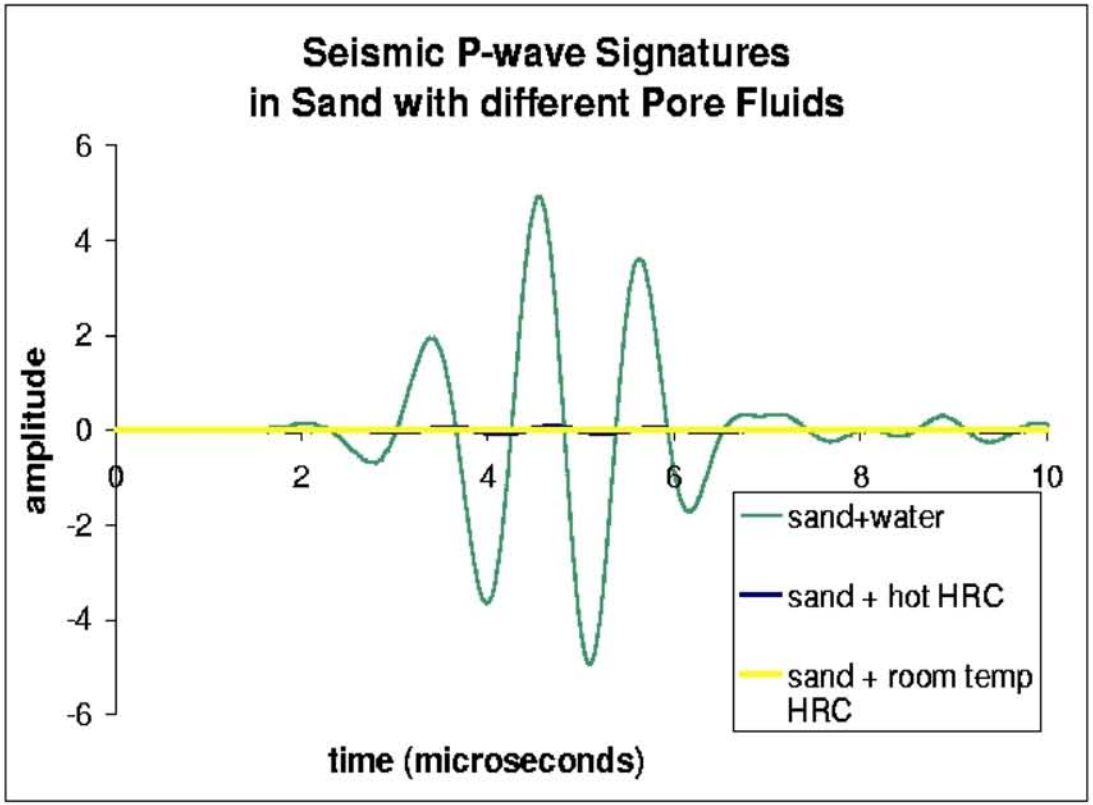
Seismic Signatures of HRC: Can we remotely 'image' the HRC injectate?



- **HRC decreases the seismic amplitude and velocity relative to water.**

- **The velocity of the is a function of the HRC temp:** ***the waves travel slower in hot HRC and faster in room temp HRC than room temp water***

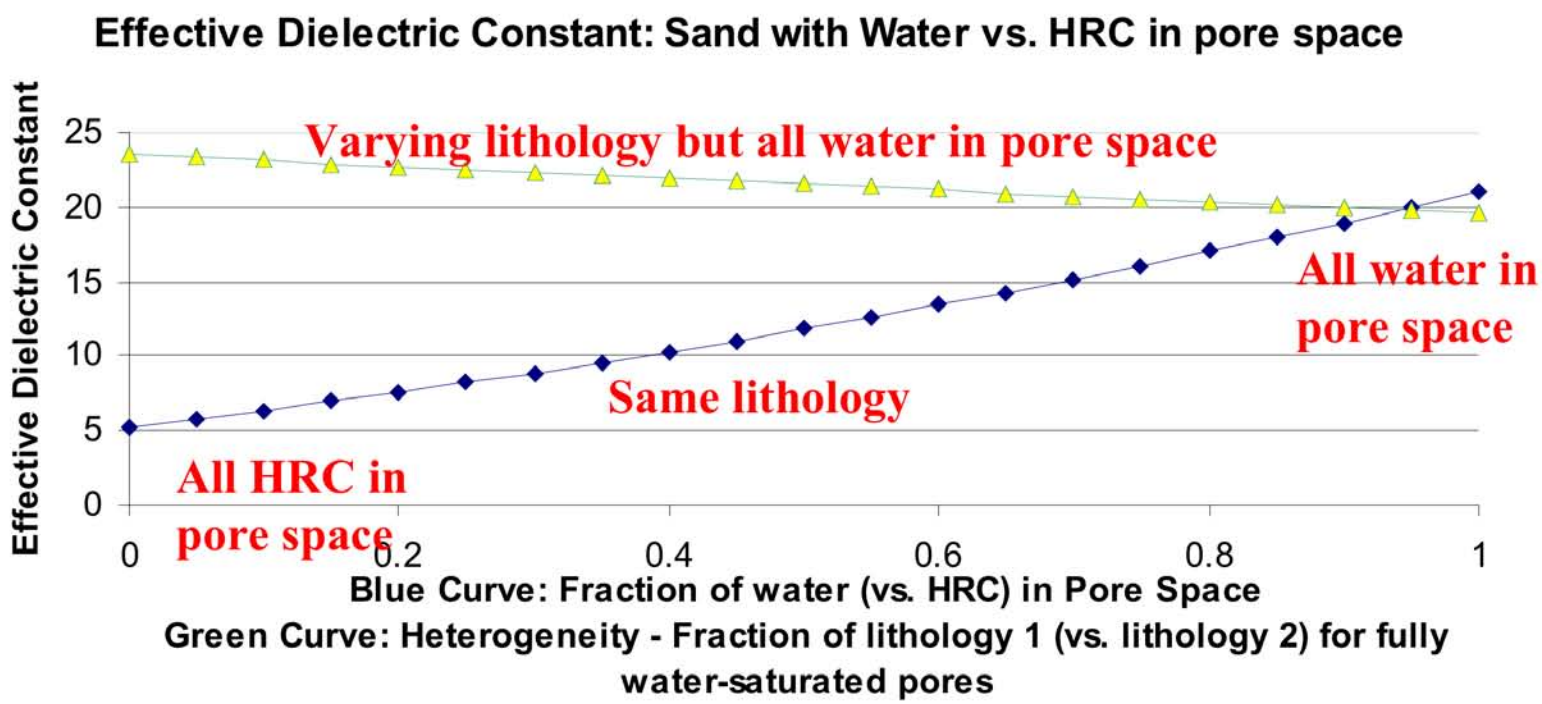
Seismic Signature of HRC versus water within Hanford-like soils



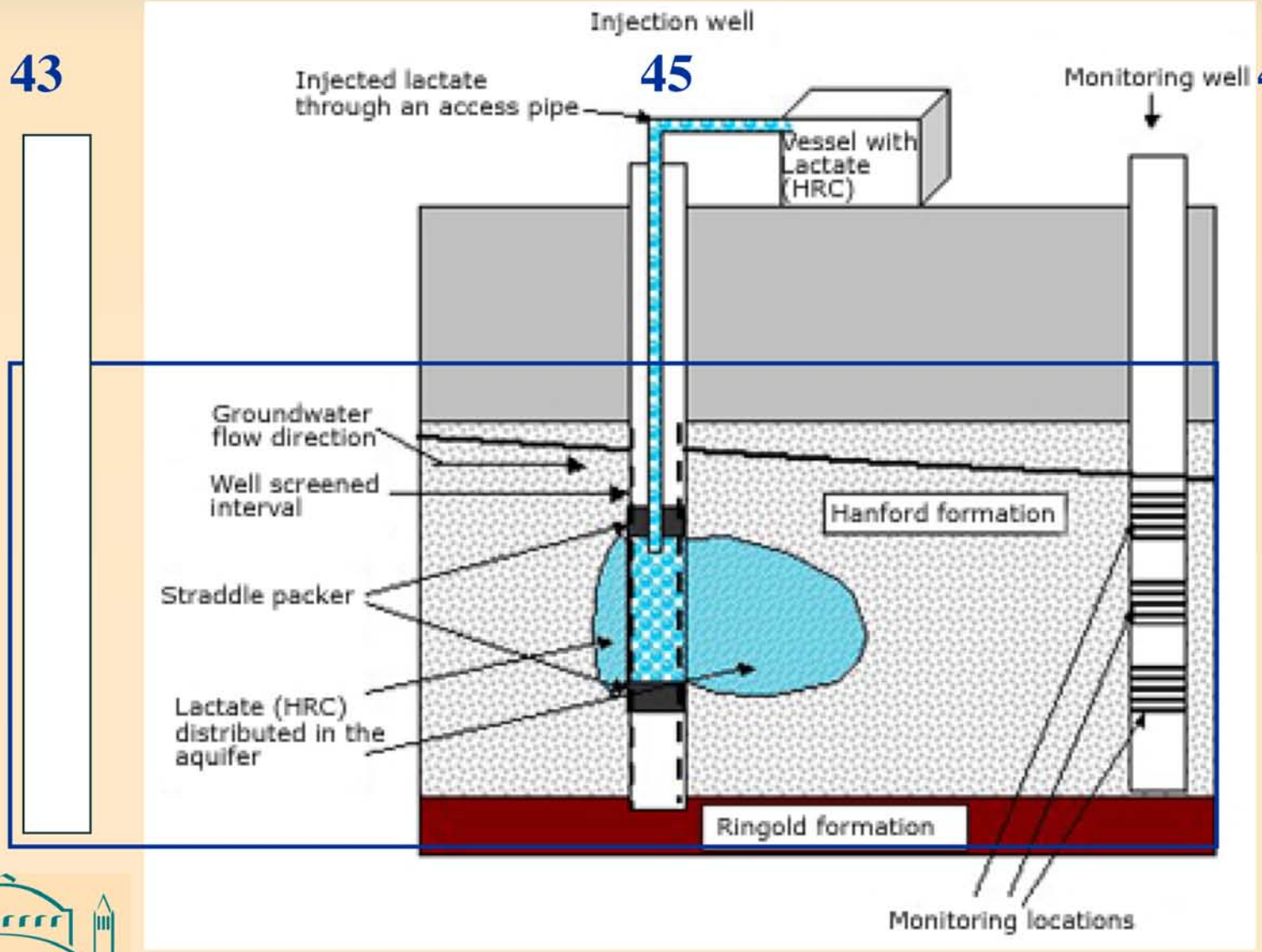
Significant reduction in seismic amplitude when hot or cold HRC replaces pore water in the pore space of a Hanford sand sample
(patchy distribution → scattering?)

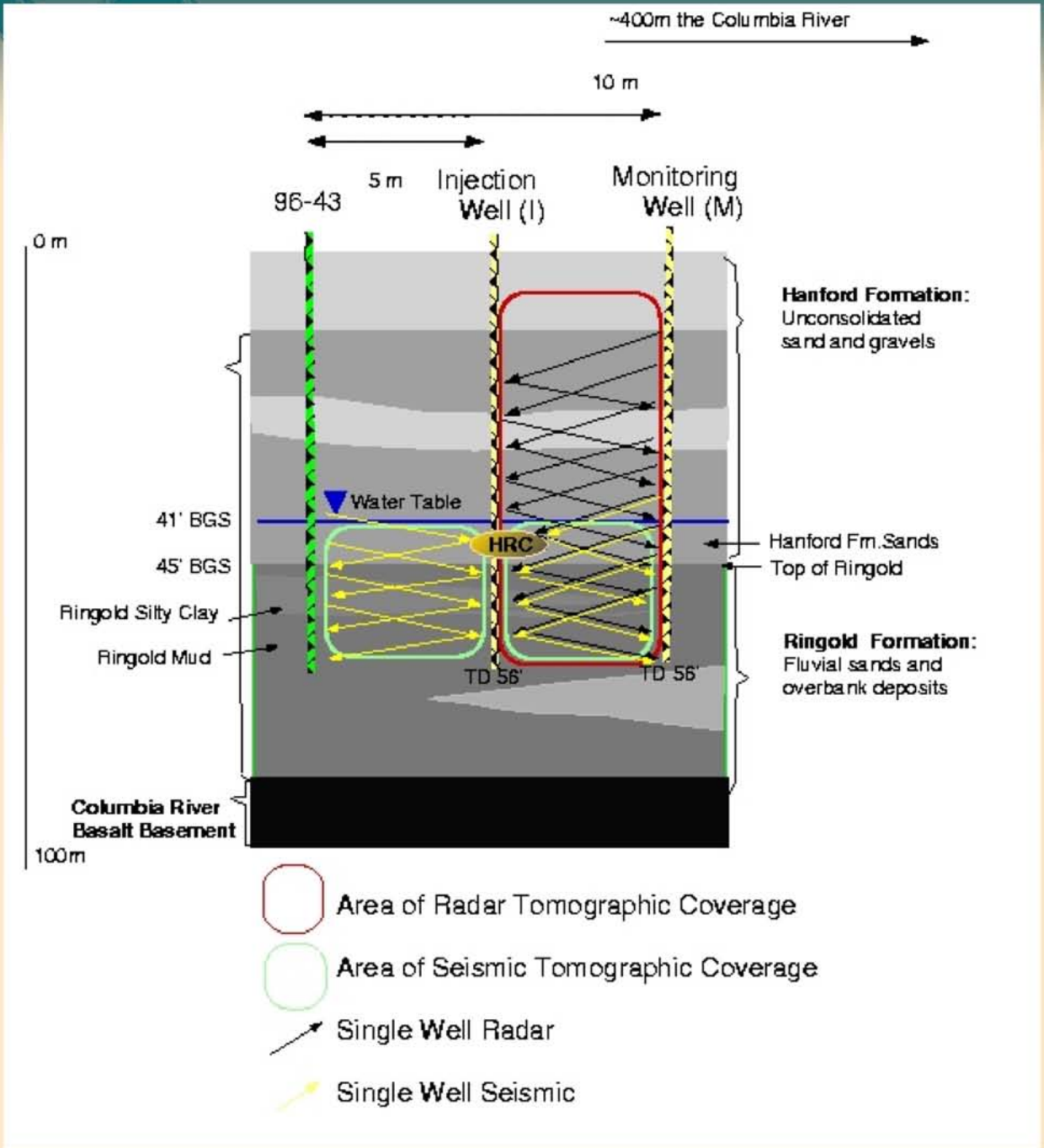
Dielectric Constant of air=1, water=80, HRC=6

Modeled Effect of HRC on Radar Dielectric Constant compare to influence of heterogeneity



Time-Lapse Monitoring of HRC Injection





Prior data collection (baseline) June 21-23;

Posterior data collection:

- hours
- days
- weeks
- months

after injection and in conjunction with wellbore samples.

Uses of Geophysical Data at the 100 H Site

- To develop field site/plan
- Characterize heterogeneity
- To monitor system transformations during stimulation