Sixth Annual Conference on Carbon Capture & Sequestration

Geologic Storage - MMV

Continuous Crosswell Seismic During CO2 Injection: A New Monitoring Technology Deployed at the Frio-II Experiment

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Summary and Outline

Key Points:

1) Development and demonstration of new in-situ seismic monitoring technology.
2) Observation of CO2 plume growth in-situ at Frio site.

Outline:

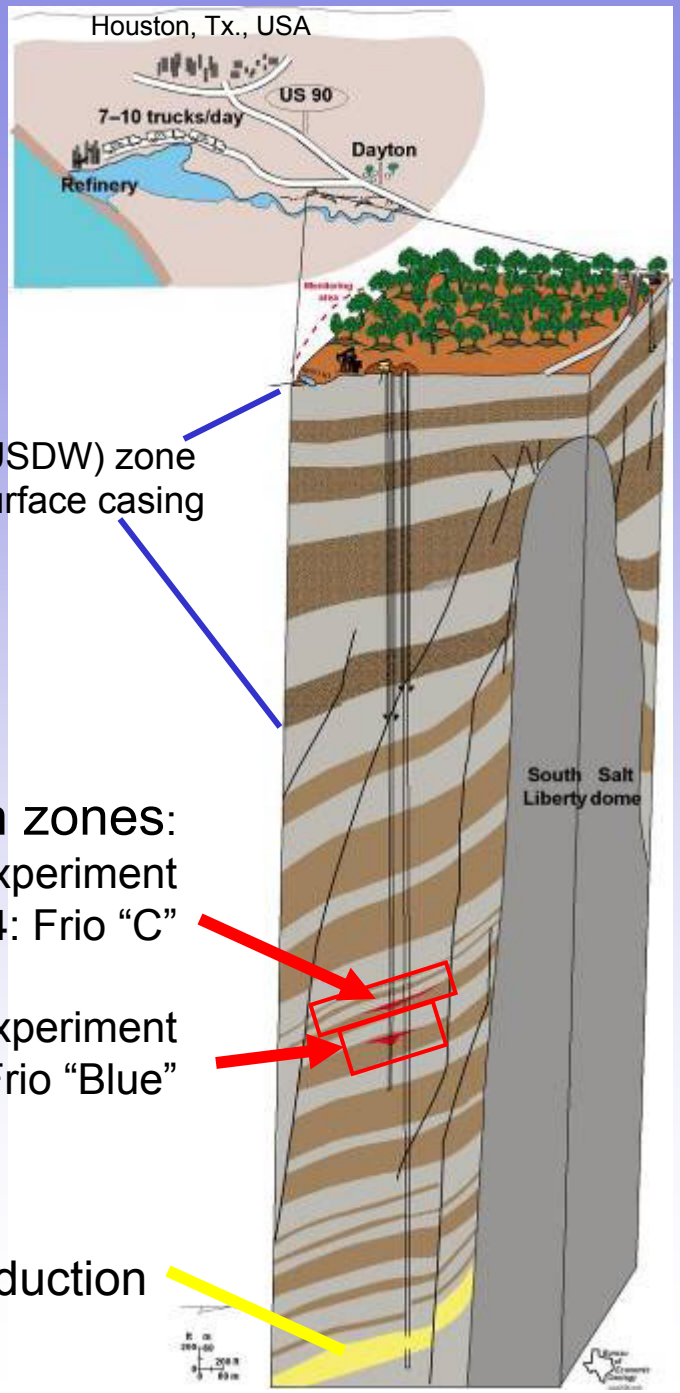
Background of Frio-II Test

Seismic Detection of CO2 in Frio-I

CASSM Experiment Design and Deployment

Results and Conclusions

Frio Brine Pilot Site
Two test intervals



- Injection intervals: reworked fluvial sandstones,
- Porosity 24%, permeability 4.4 to 2.5 Darcys
- Steeply dipping 11 to 16 degrees
- Seals – numerous thick shales, small fault block
- Depth 1,500 and 1657 m
- Brine-rock system, no hydrocarbons
- 150 and 165 bar, 53 -60 degrees C, supercritical CO_2

From: S. Hovorka, TBEG

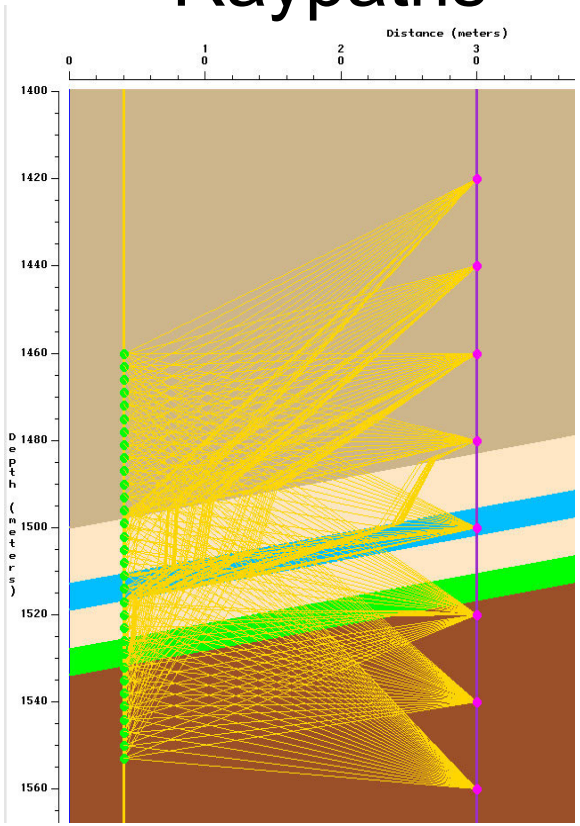
Seismic Detection of CO2 in Brine (Frio-I)

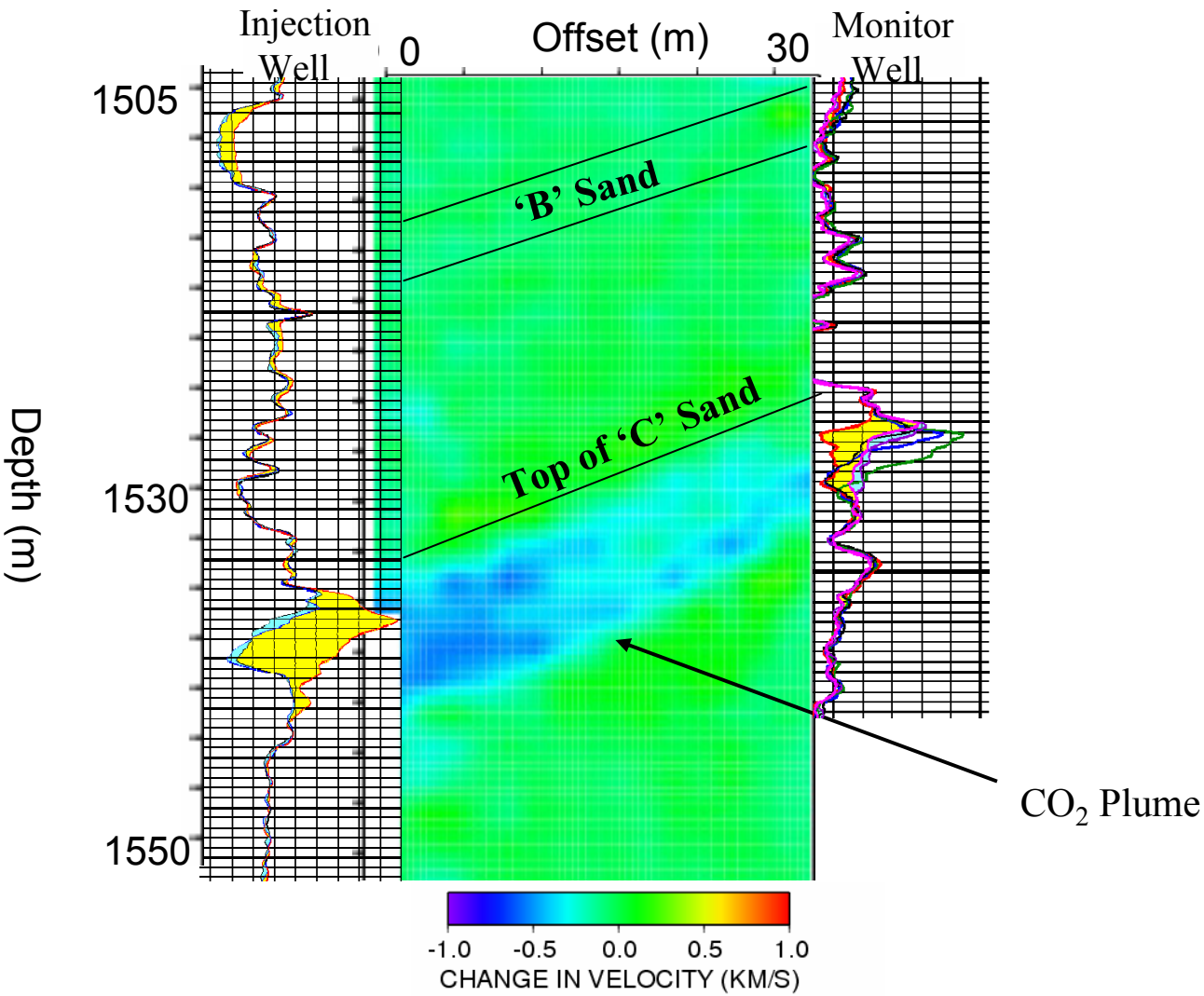
In addition to surface-to-borehole (VSP) seismic, Frio-I had crosswell tomography.

Time-Lapse tomography (1.5 months) gave good results, which allowed confidence in Frio-II design.

Frio-I Seismic Imaging of CO_2 Plume:
Seismic P-wave Tomography and RST Logs

Tomography Raypaths





Daley, et al, Env. Geol., in press

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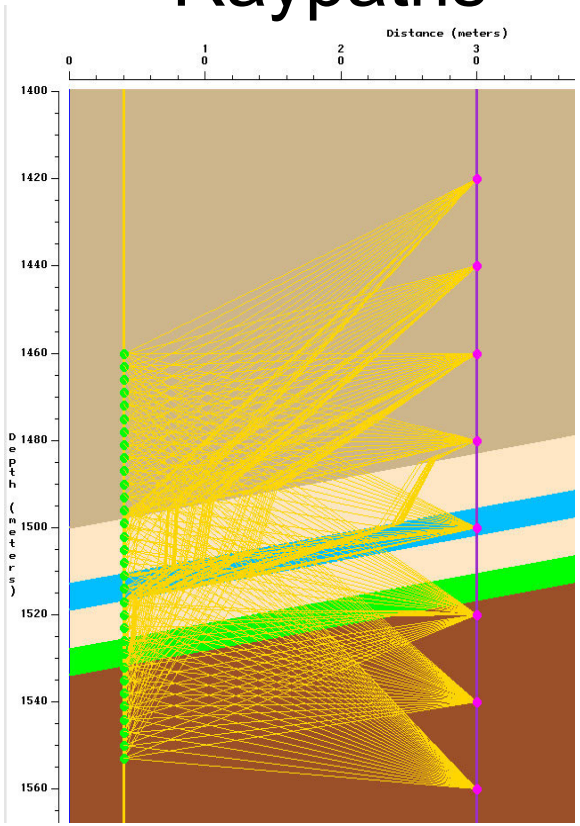

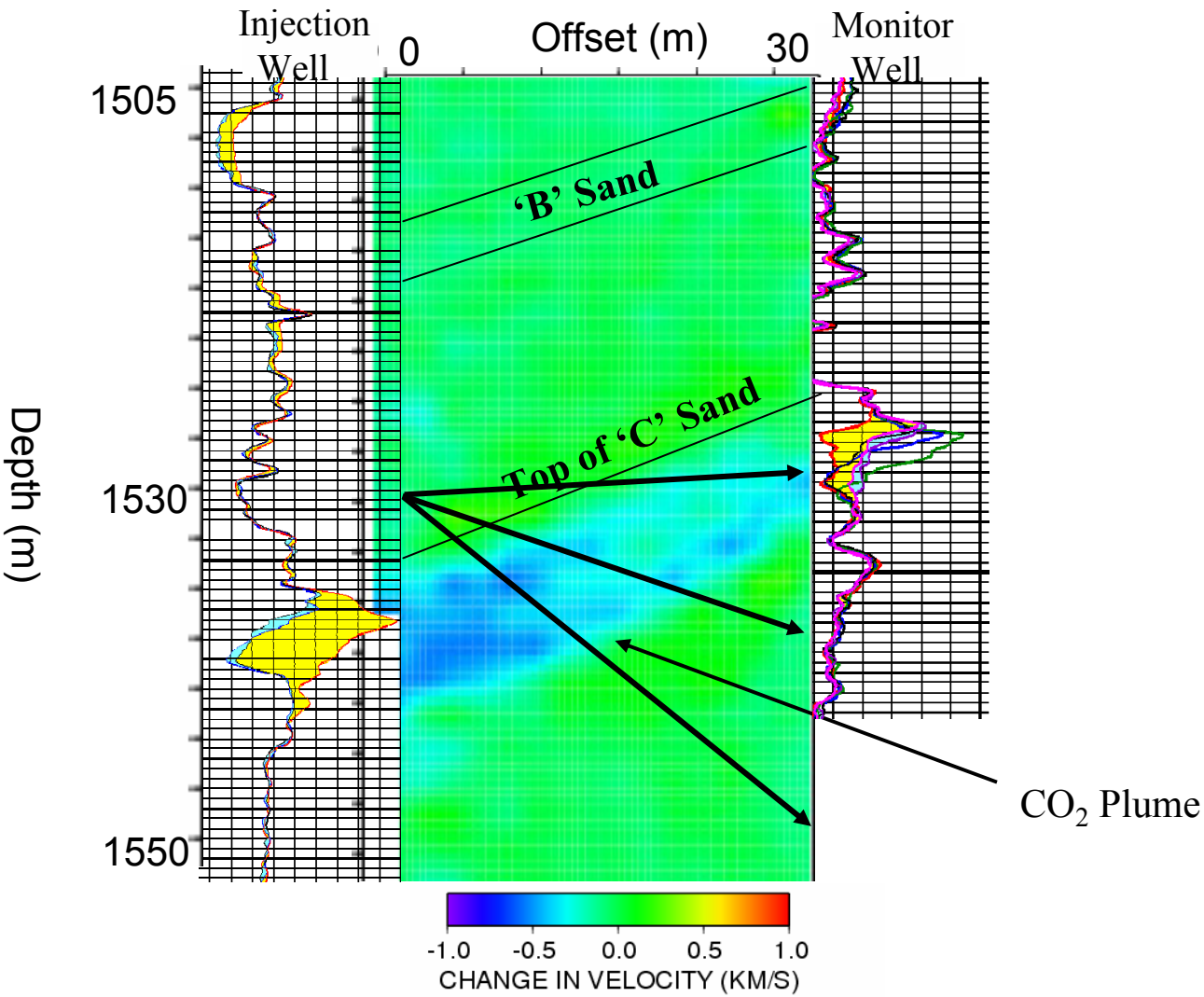

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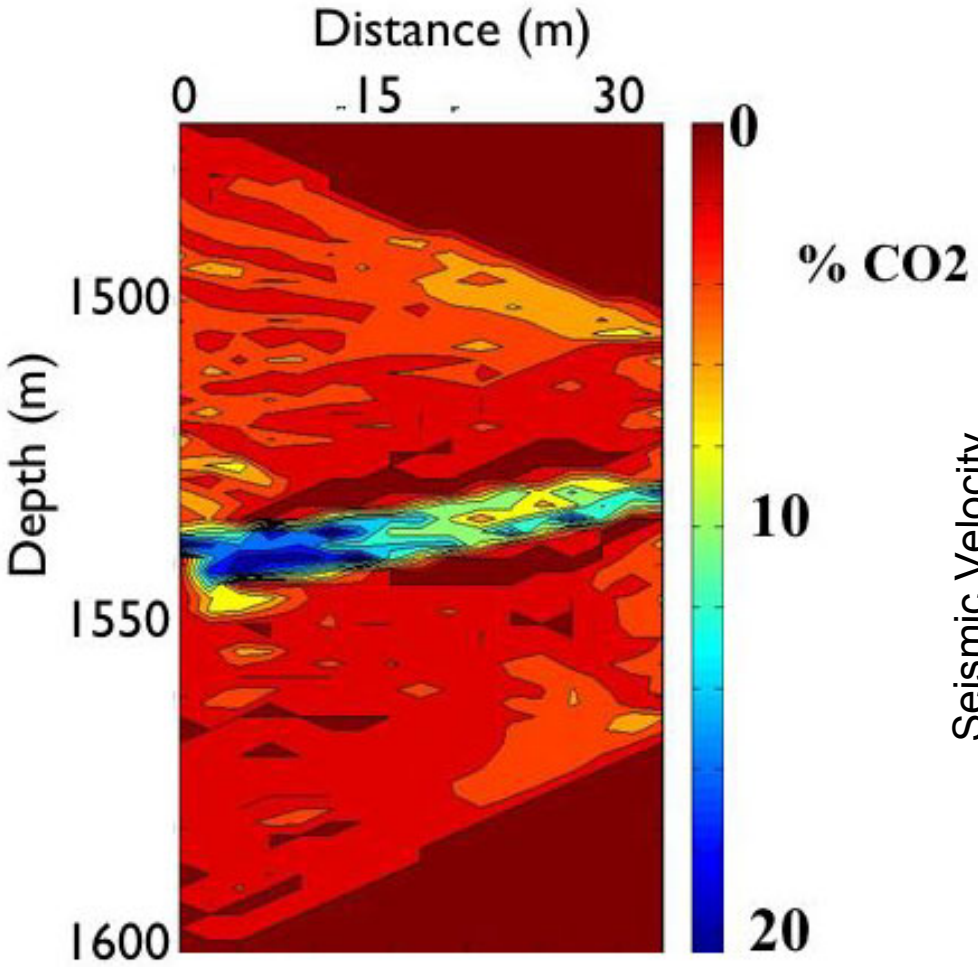
Frio-I: CO_2 Saturation from Seismic



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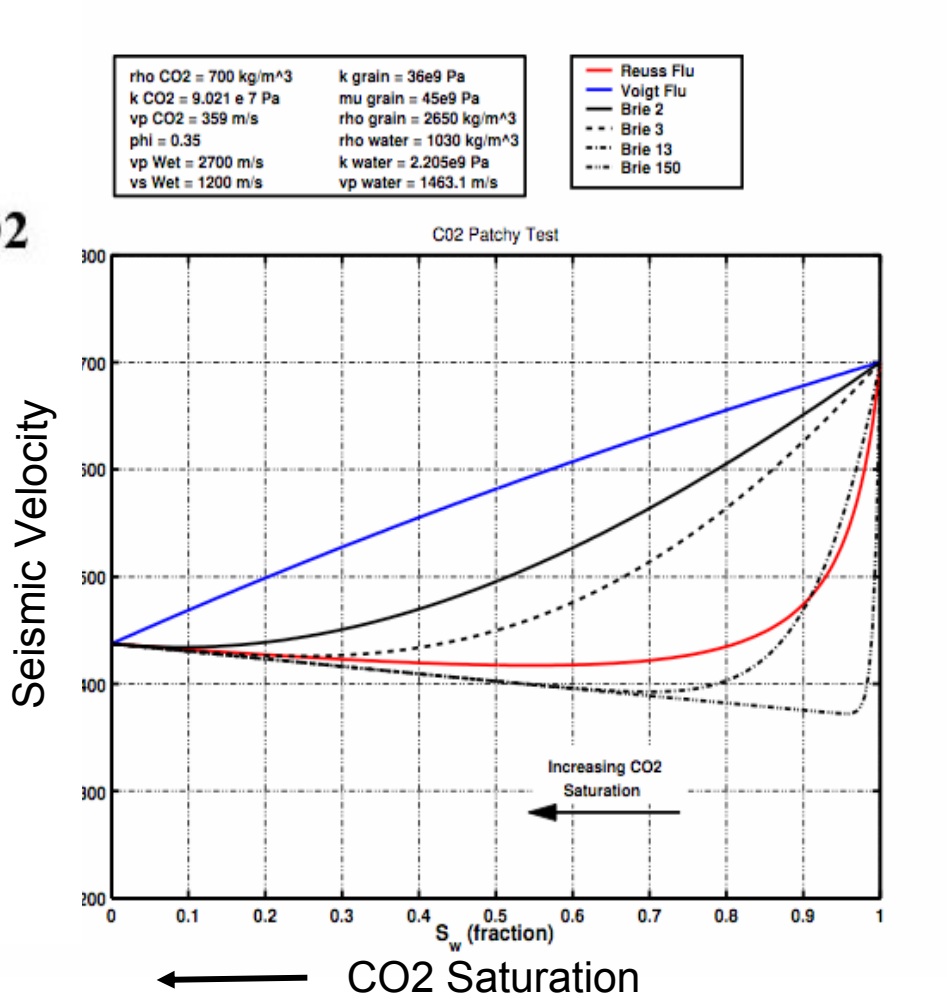
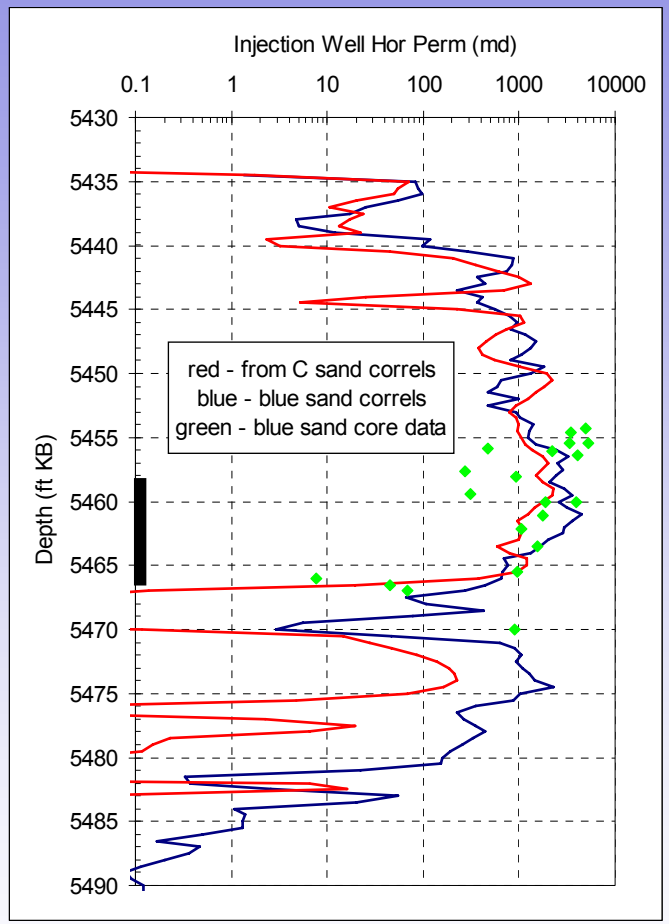


J.B. Ajo-Franklin, pers. comm

Frio-II: Why In-situ monitoring?
One Example: Uncertainty in permeability profiles



Difficult to predict permeability, especially vertical.

Seismic monitoring used to measure horizontal and vertical (buoyant) transport of CO2.

Estimating the effect of buoyancy one of the project goals.

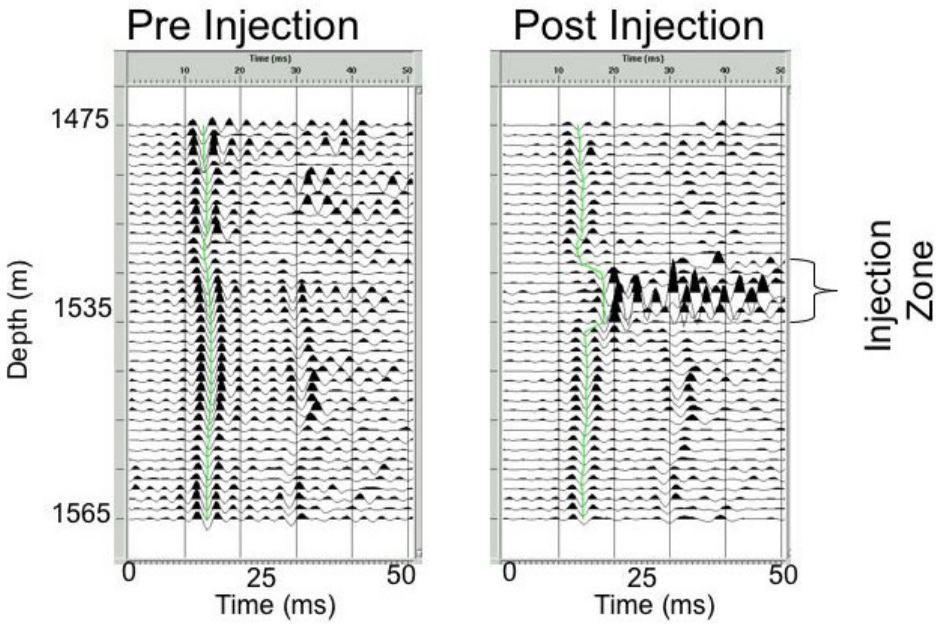
- Red curve: preliminary model (June 2006)
- Blue curve: current model (Sept 2006)

Christine Doughty LBNL

Motivation for Frio-II Monitoring

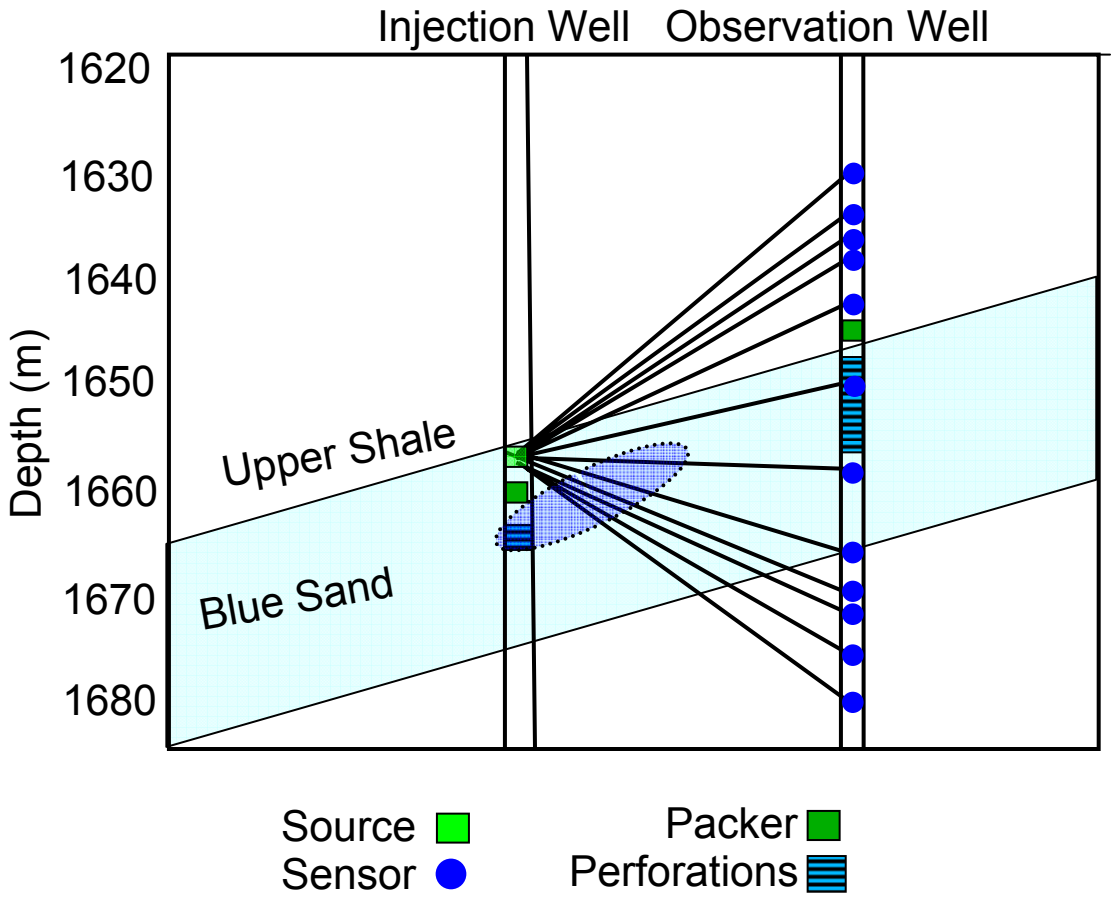
Frio-I results show that CO2 had clear affect on the seismic velocity and that crosswell tomography can image the change at a fixed point in time.

How could we monitor the change during injection?



Schematic of Frio-II CASSM

Continuous Active Source Seismic Monitoring



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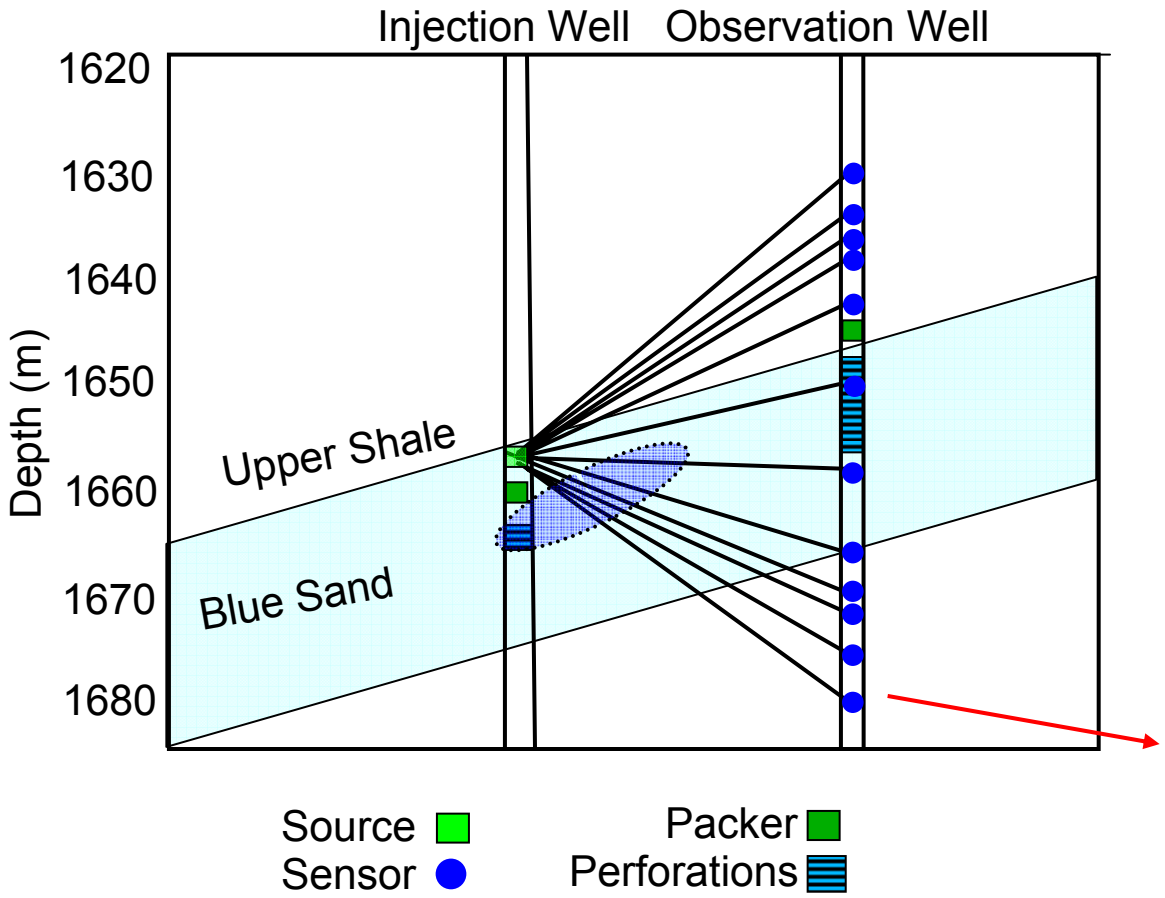

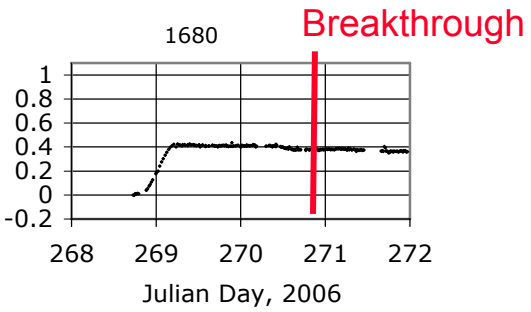

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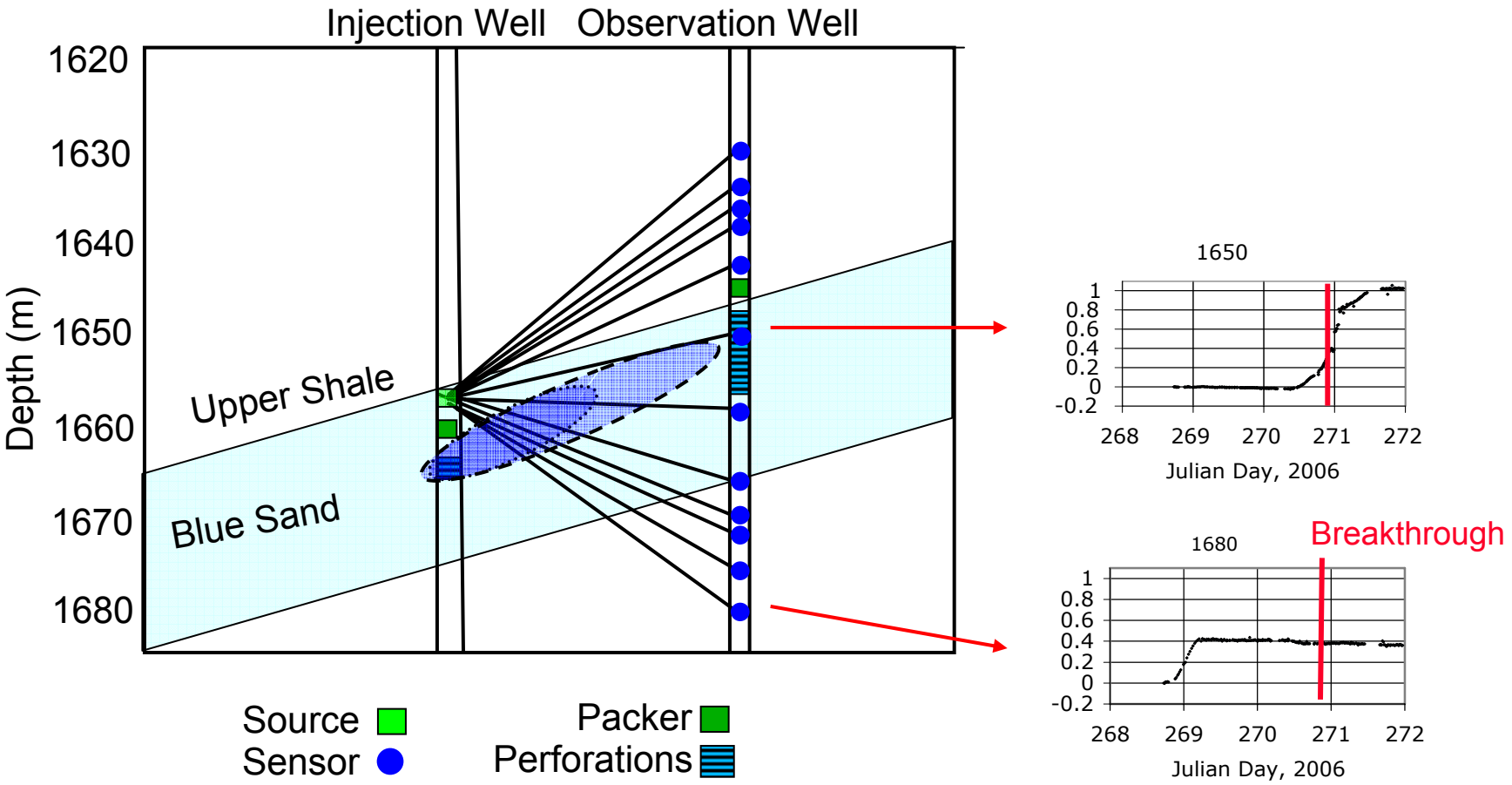

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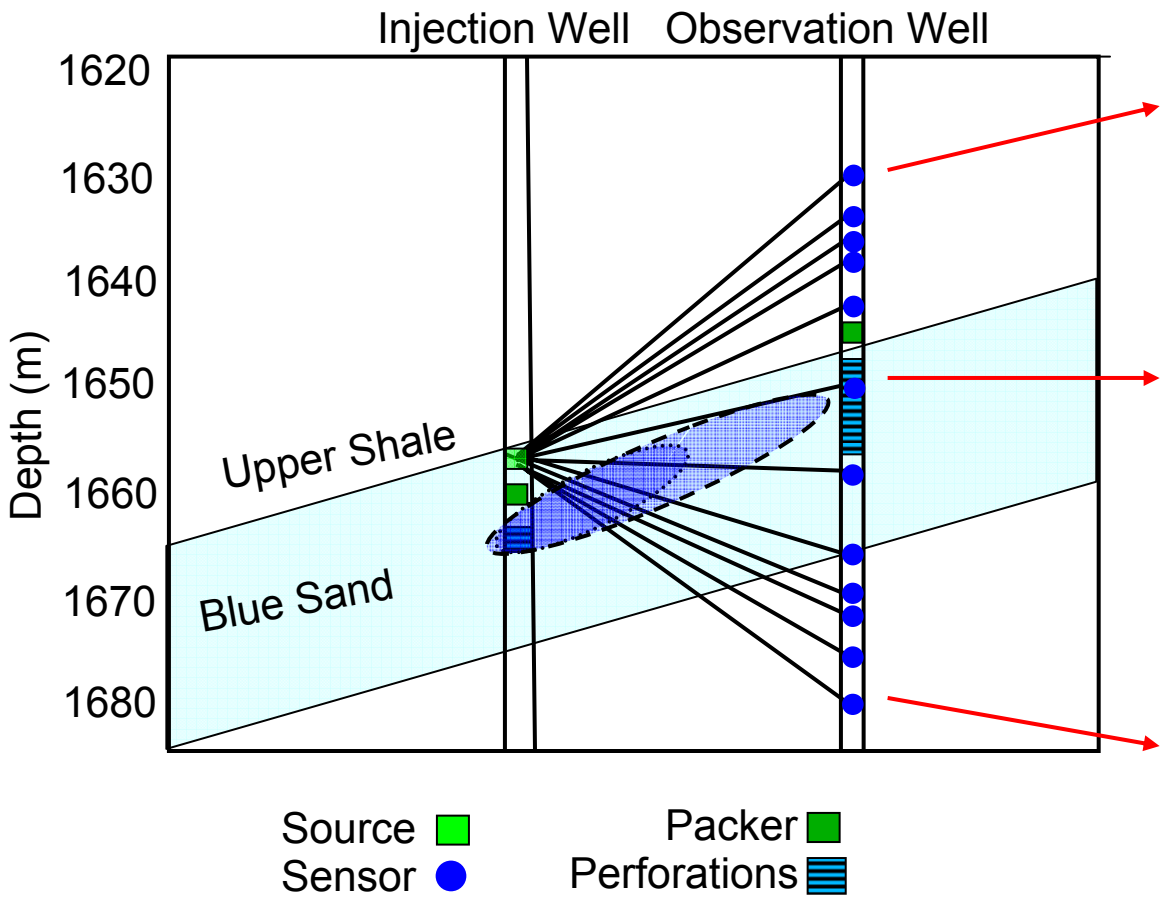

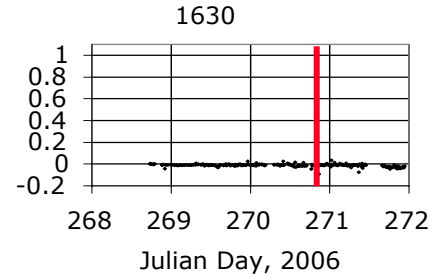

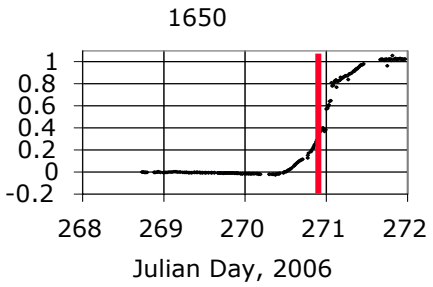

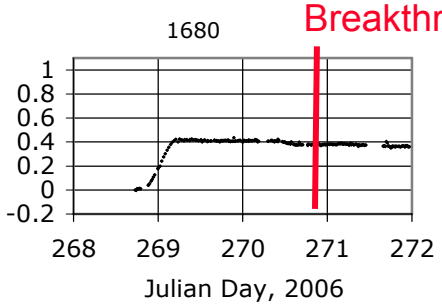

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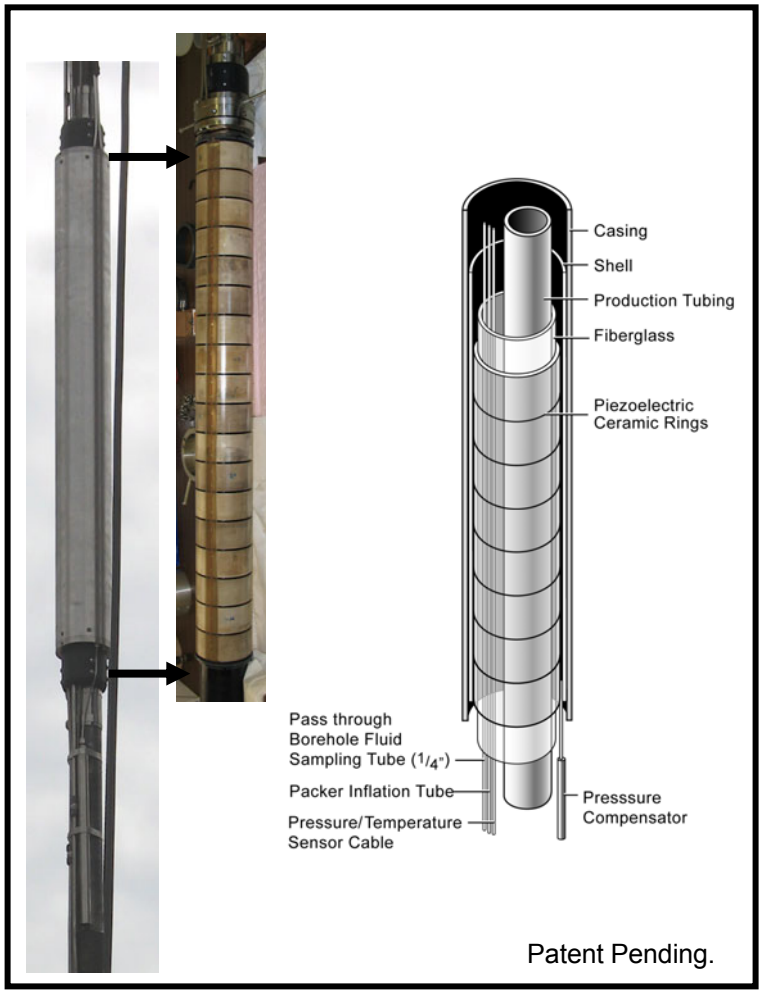
Experiment Deployment

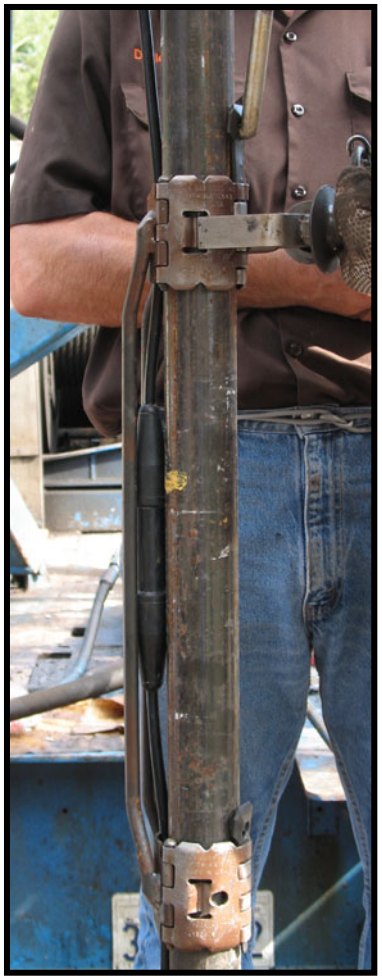
Carrying out the CASSM experiment required design and fabrication of a unique tubing deployed seismic source.

CASSM had to be deployed in conjunction with injection and fluid sampling equipment using standard production tubing.

Tubing Deployment of Sampling/Monitoring Equipment

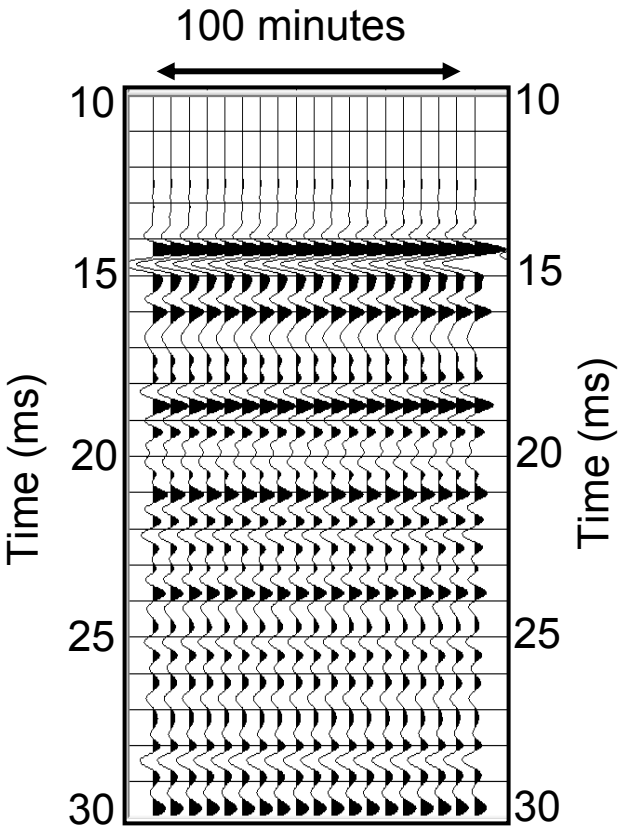
"Piezotube" Source and Hydrophone Sensor



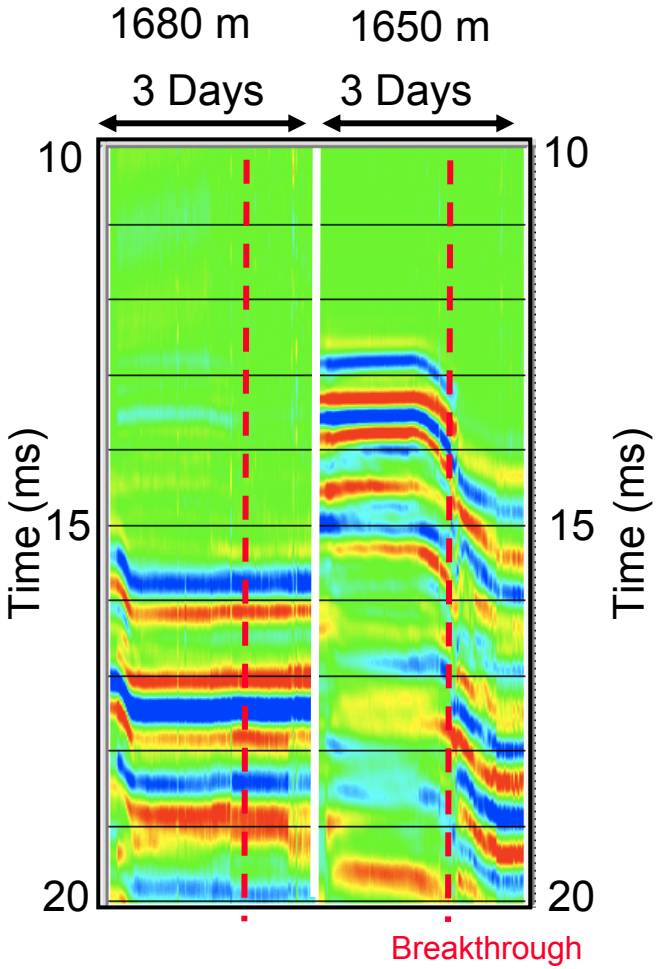


Daley, et al, Geophysics, submitted.

Frio-II CASSM Data



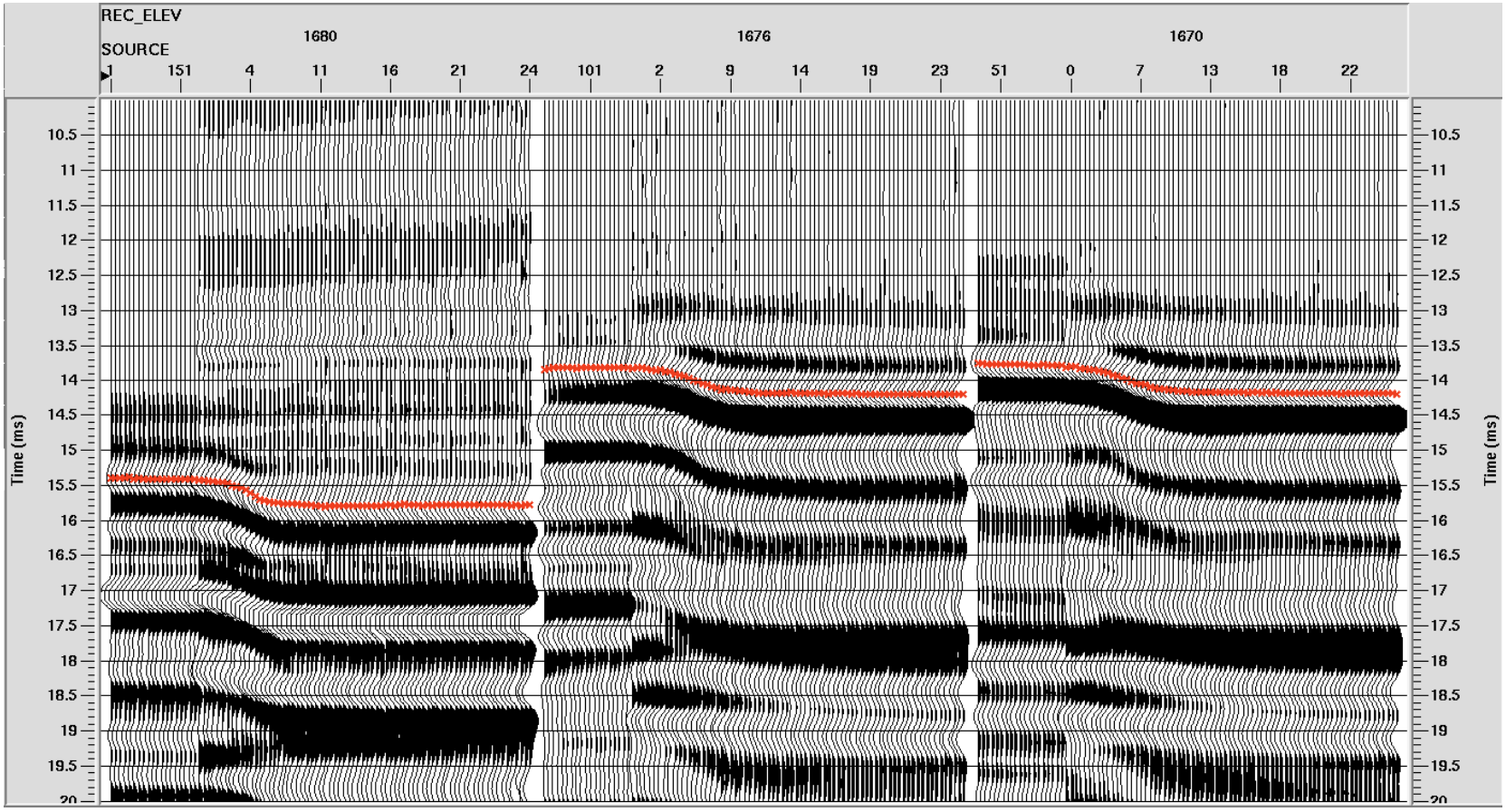
Preinjection



Field Data Display

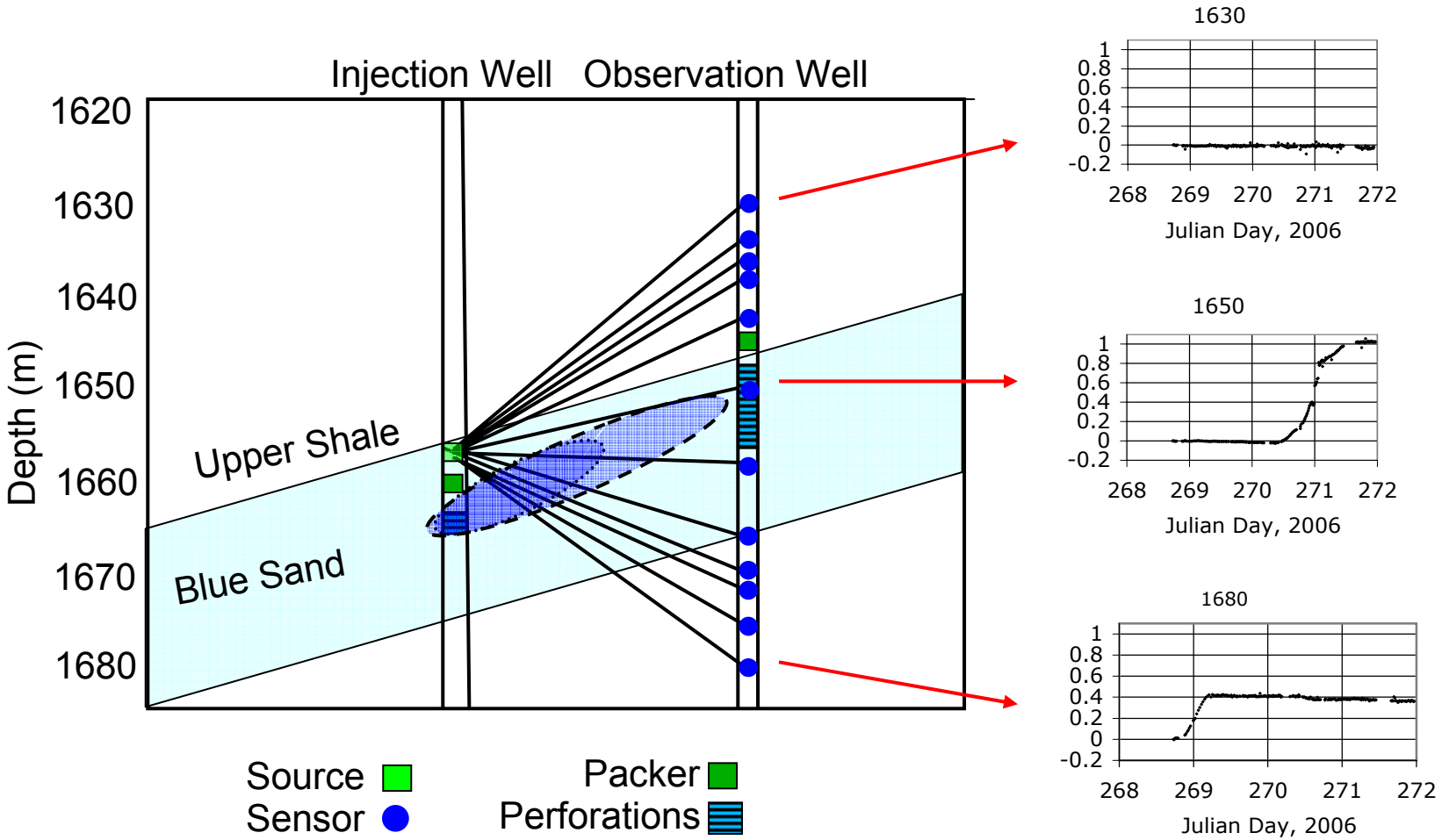
Daley, et al, Geophysics, submitted.

Picking Travel Time



Example travel time picks (in red) for 3 sensors (1680, 1676, 1670 m) for the initial 24 hours of monitoring.

Schematic of Frio-II CASSM



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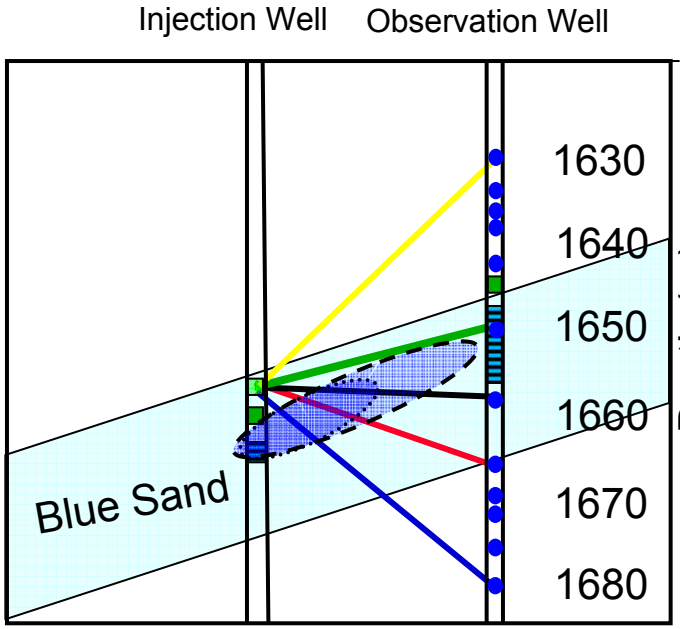
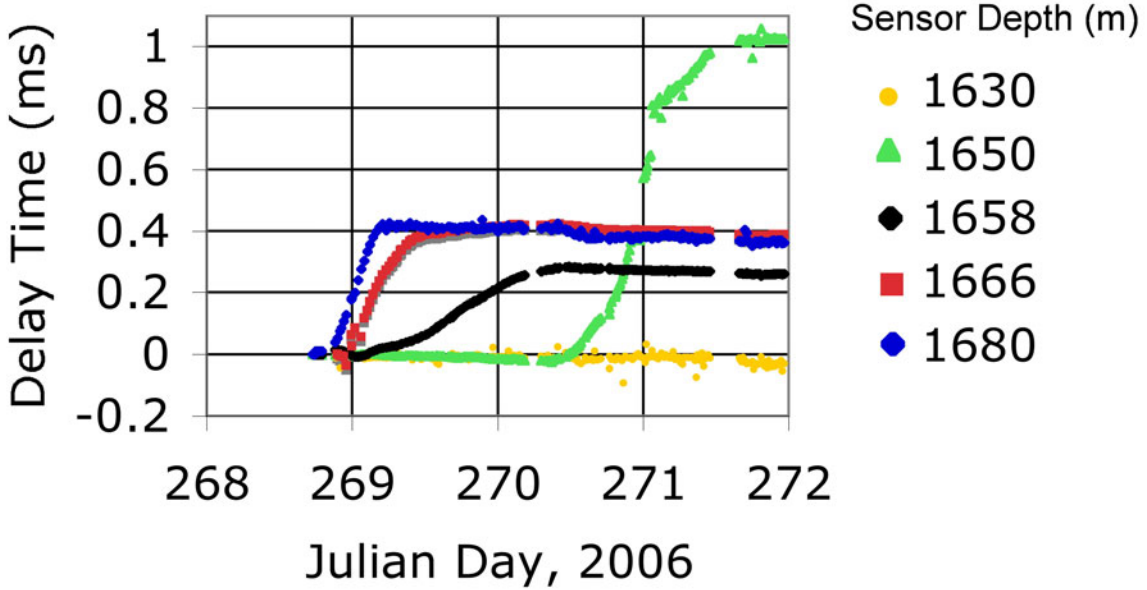
Frio-II CASSM Results





Summary

- Development and demonstration of new in-situ monitoring technology: CASSM - Continuous Active Source Seismic Monitoring.
  - Piezo-tube seismic source developed.
- Tubing deployment utilizes injection well for monitoring.
- Observation of CO2 plume growth rate in-situ.
  - Buoyant rise of CO2 to top of sand.
  - Real time monitoring allows in-field optimization of sampling in observation well.

Acknowledgments

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- Thanks to Don Fussell of VCable LLC and Ernie Majer of LBNL for discussions and advice, and to Fenglin Niu of Rice Univ. for field support.