WESTCARB Regional Partnership

Laboratory seismic and X-ray CT monitoring of supercritical CO2 floods in sandstone cores

Timothy J. Kneafsey and Seiji Nakagawa

tjkneafsey@lbl.gov

Lawrence Berkeley National Laboratory

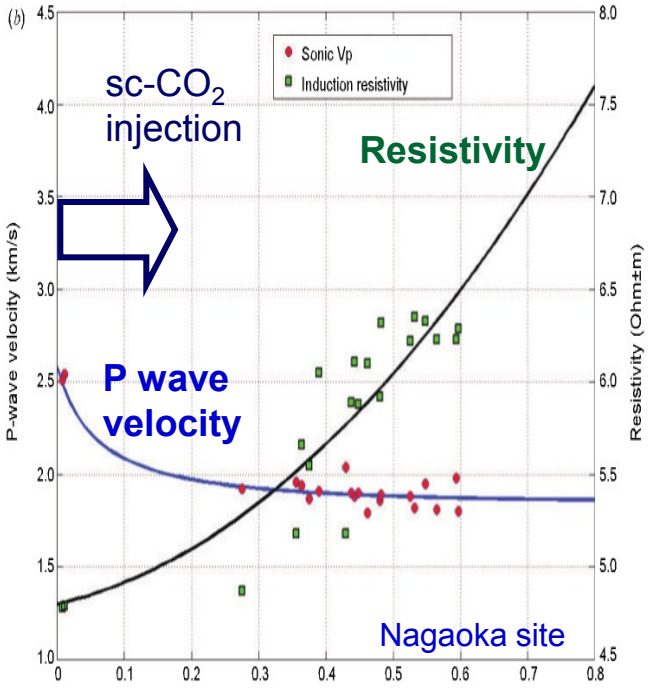
WESTCARB Annual Business Meeting
Bakersfield, CA

October 15–17, 2012

Introduction

Goal:

Relate seismic (velocity and attenuation) and electrical (resistivity) responses to reservoir CO2 saturation and distribution



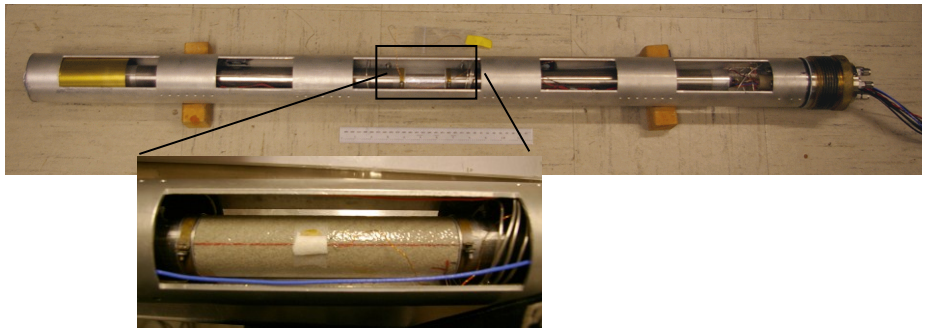
CO_2 saturation (from neutron porosimetry)

(Xue and Watanebe, 2008; Kim et al., 2011)

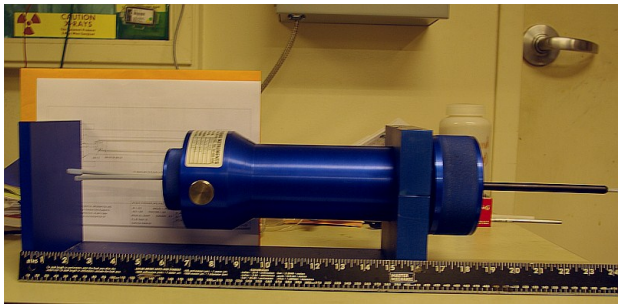
Introduction

Laboratory petrophysics experiments:

- Sonic-frequency (~1 kHz) seismic measurements on King Island reservoir rock cores (Citizen Green#1 well) with concurrent fluid imaging via x-ray CT
- Electrical resistivity measurement with imaging also planned

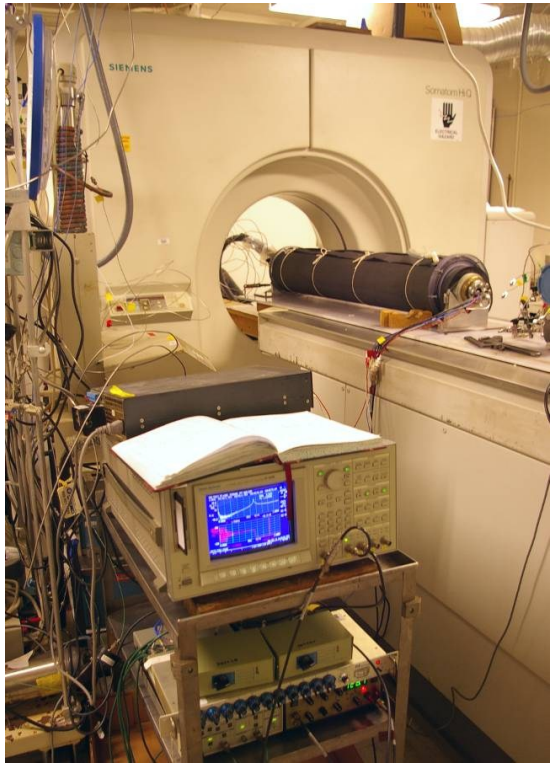


Seismic Split Hopkinson Resonant Bar (short-core resonant bar, Nakagawa, 2011, Rev. Sci. Instr.) apparatus



X-ray transparent flow-through electrical resistivity measurement cell

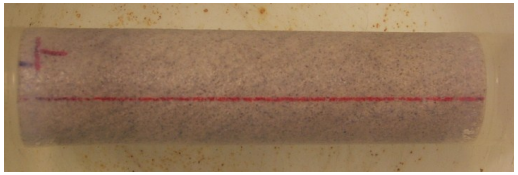
$scCO_2$ flood experiments



Step I: Brine injection (Initially dry sample)
Step II: First sc-CO_2 flood (Initially brine saturated)
Step III: Brine flood
Step IV: Resaturation with brine
StepV: Second scCO2 flood (reverse direction)

X-ray CT imaging
$\Rightarrow CO_2$ distribution & saturation

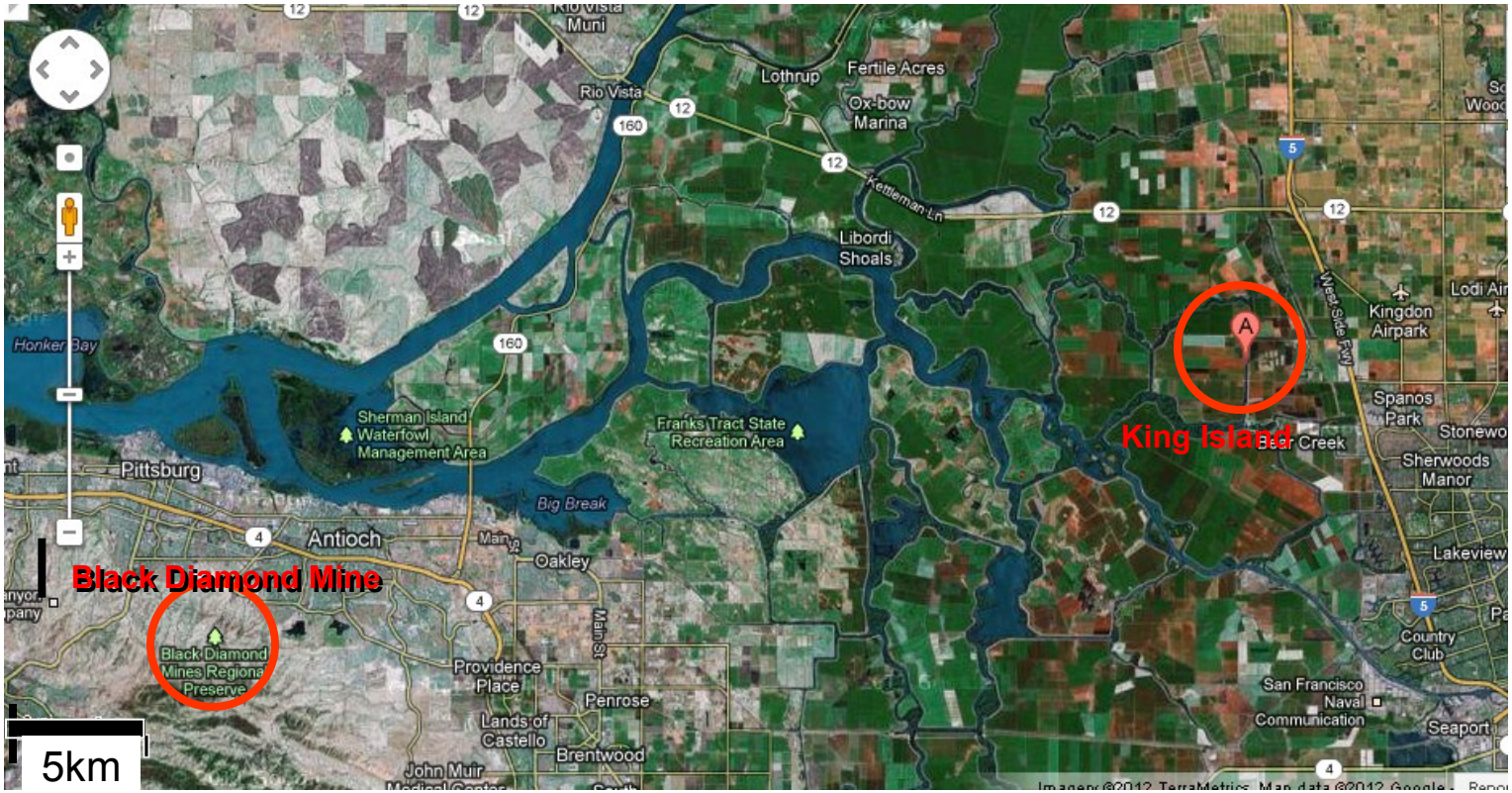
Resonant bar test
$\Rightarrow$Seismic properties at low frequencies
(~1 kHz: wavelength» core length)



Domengine
Porosity: 33.5%
Permeability: **3-4 Darcy* (significantly reduced after the test)**

T=56.6˚C
Pc=4,000 psi
Pp=2,000 psi
Brine: 1% NaCl aq.

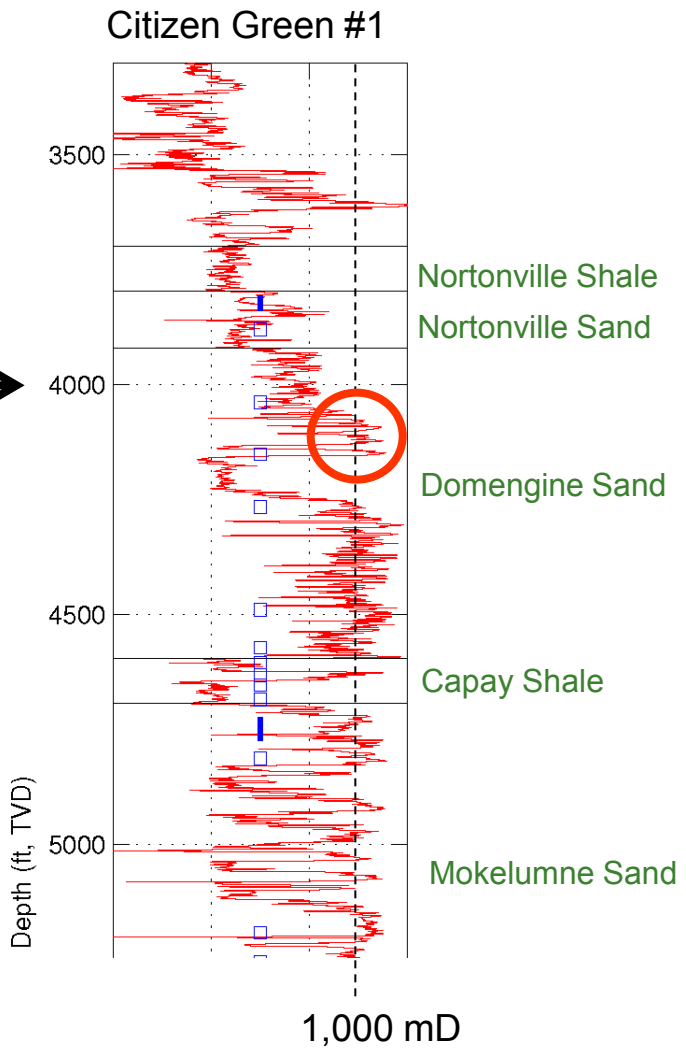
$scCO_2$ flood experiment

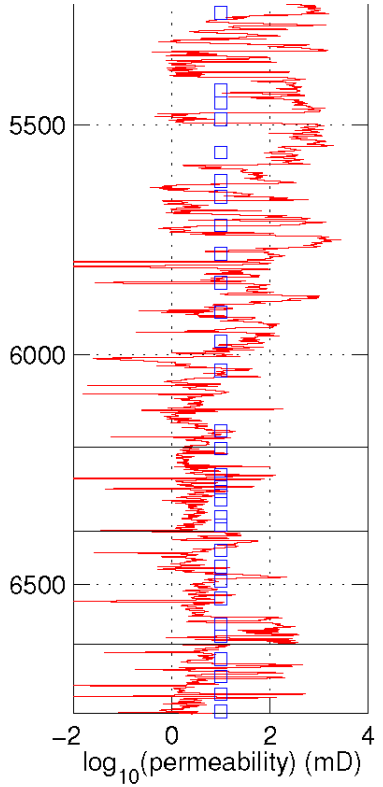


$scCO_2$ flood experiment

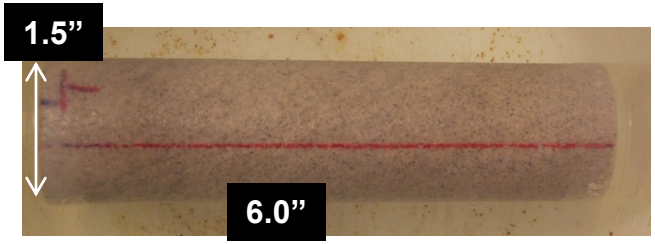
Approximate in-situ test conditions

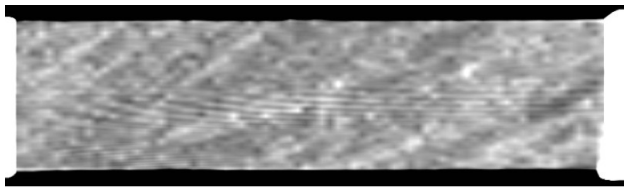
Pc=4,000 psi
Pp=2,000 psi
T=56.6°C

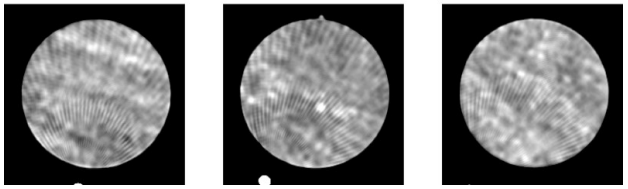


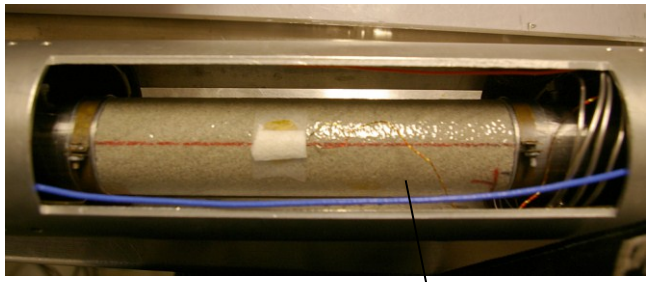


$scCO_2$ flood experiments



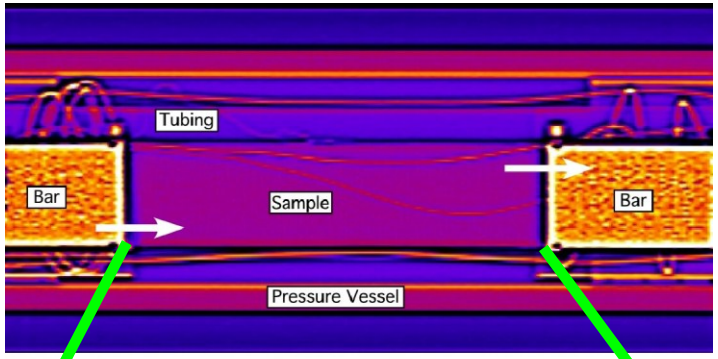


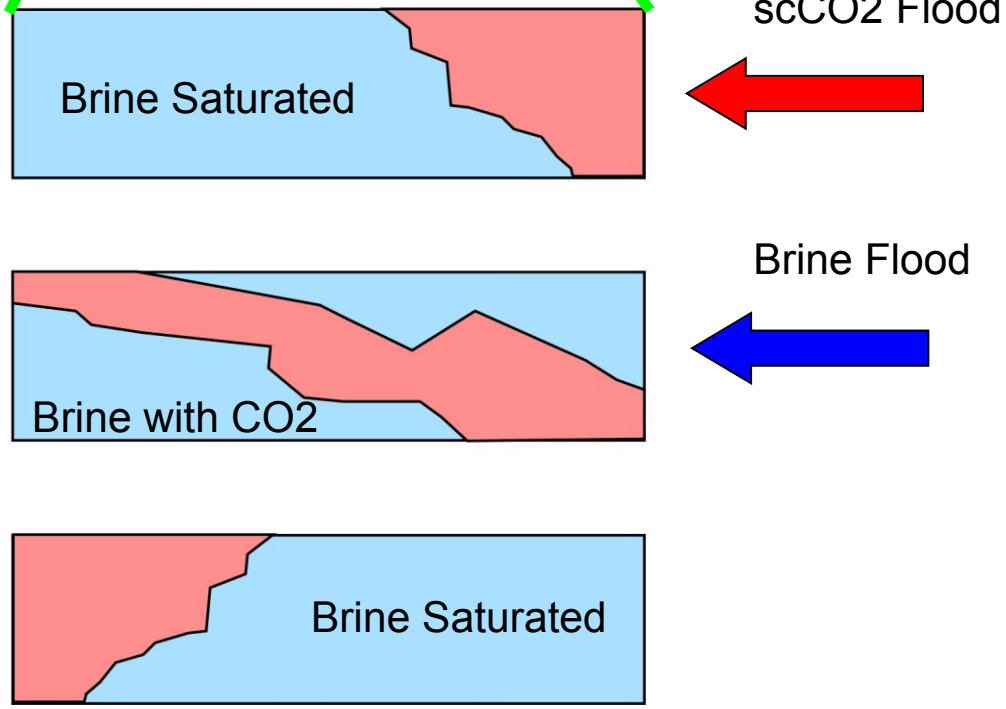




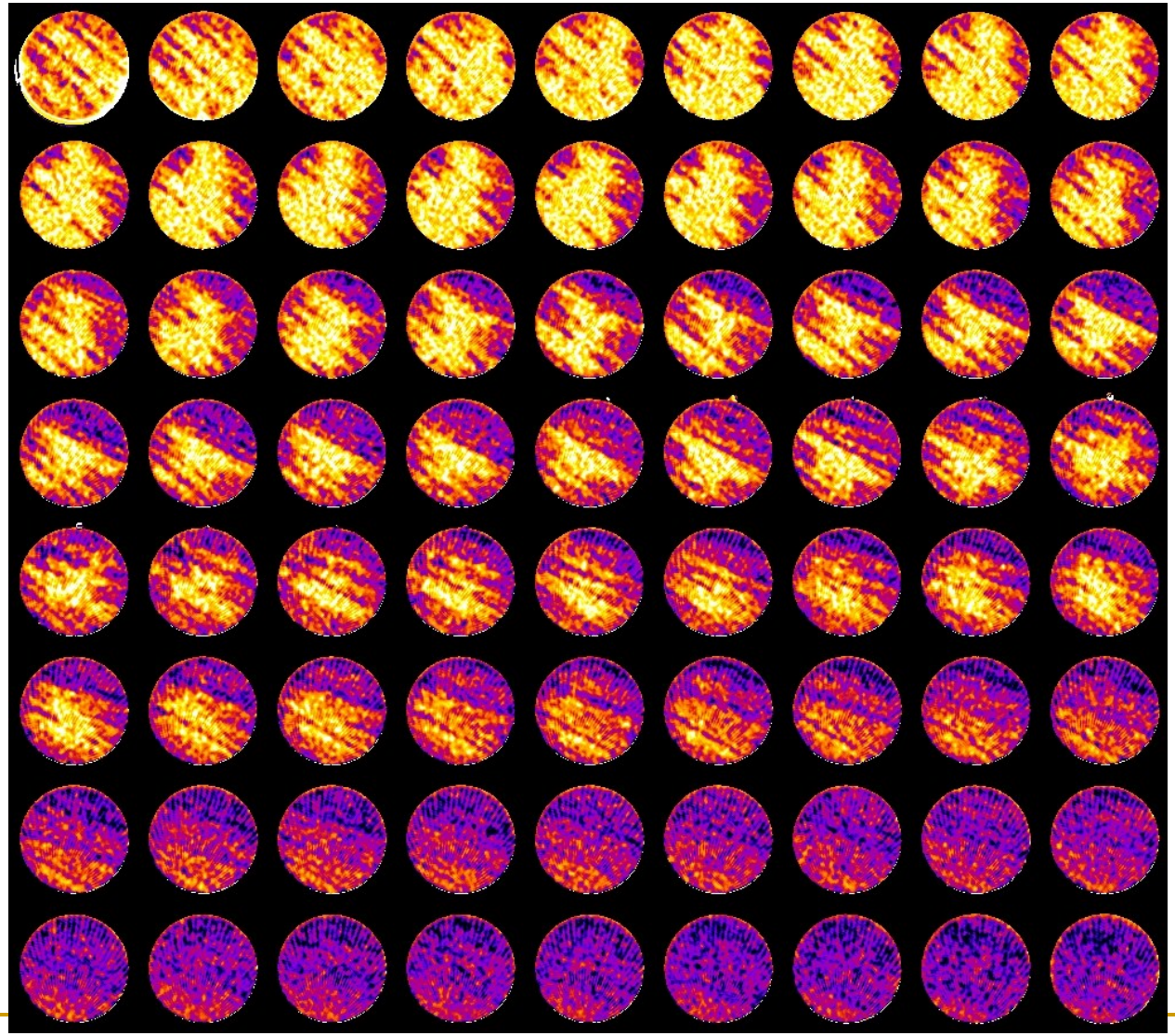
- Relatively large grain sizes (very high initial permeability)
- Mostly quartz/feldspar grains with layers of iron oxide; some clays
- Strongly heterogeneous
- Friable. Some core damage and fines migration observed during test. (in-situ cores not recovered)
- Possible permeability change during the experiment—Currently under investigation

Test Sequence

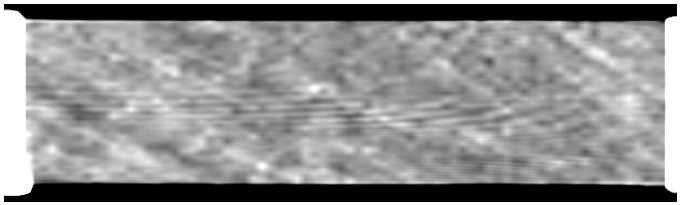




3-D Heterogeneity

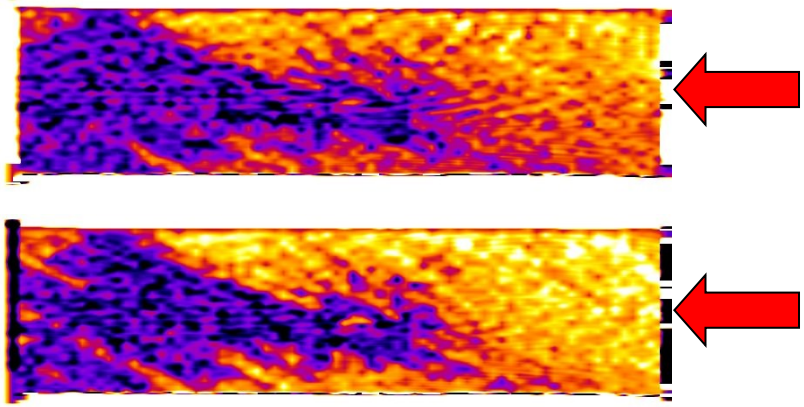


First $scCO_2$ flood experiment

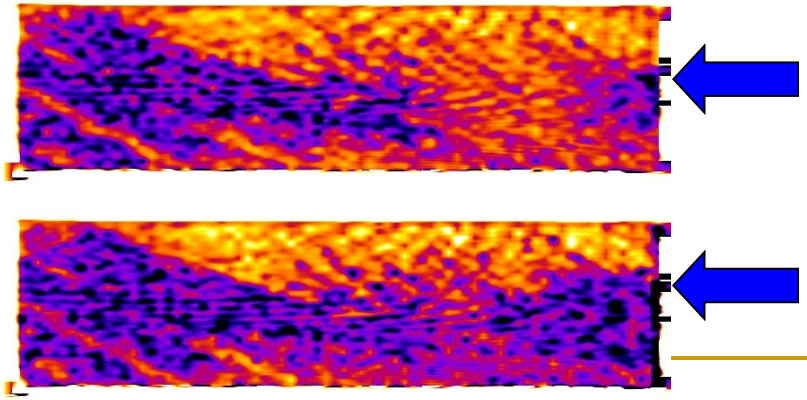


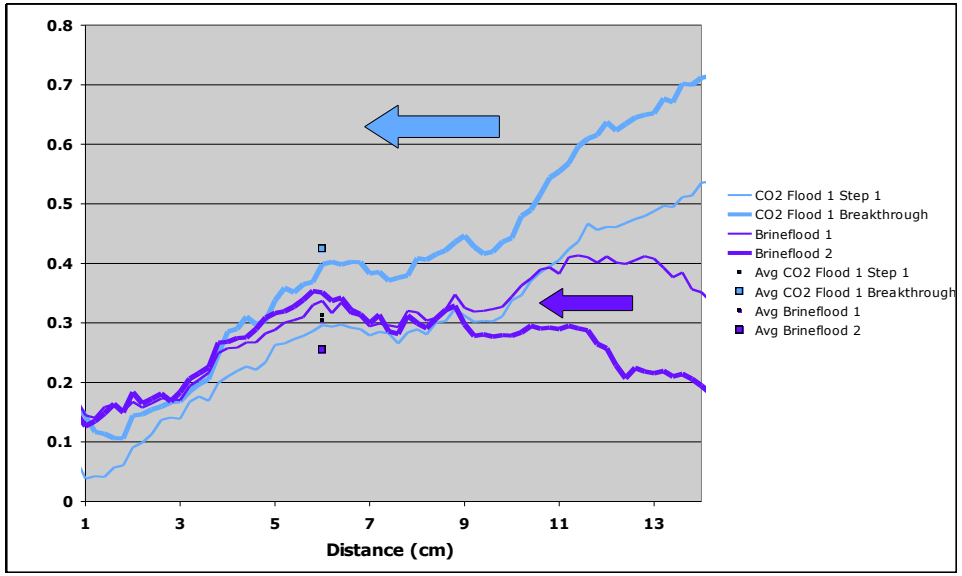
Density (bright higher, dark lower)

CO2 Flood



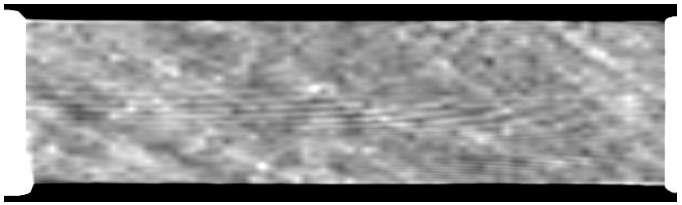
Brine Flood





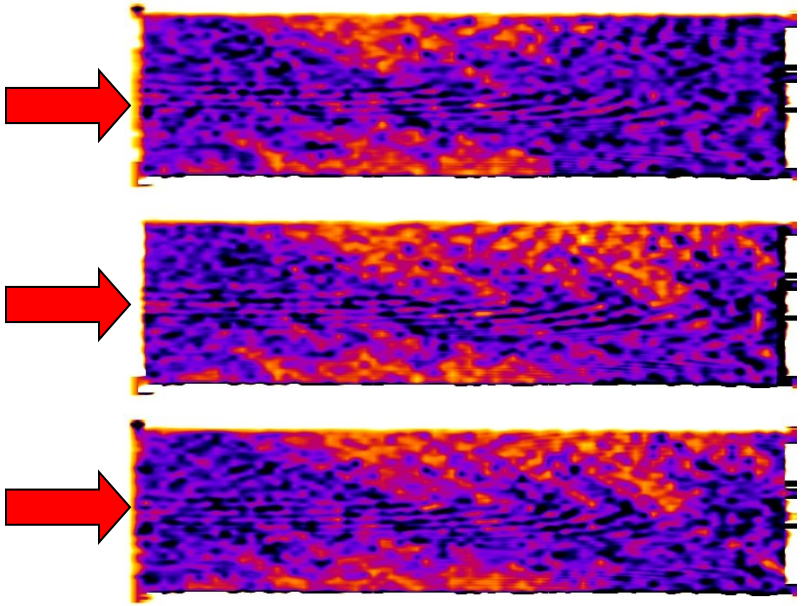
Bright color indicates high scCO2 saturation

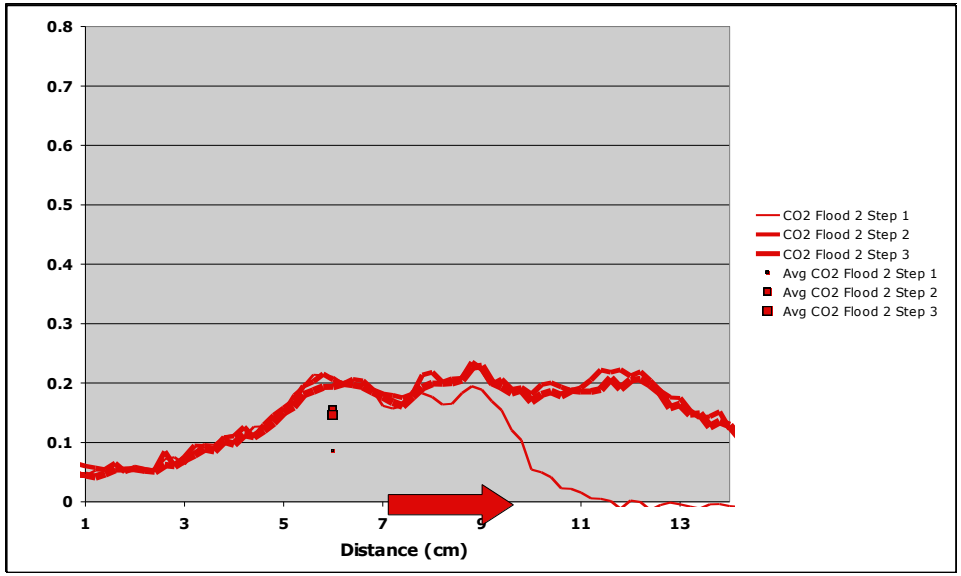
Second $scCO_2$ flood experiment



Density (bright higher, dark lower)

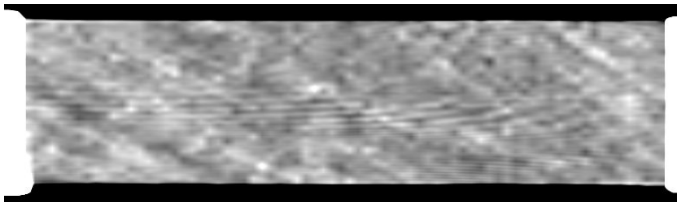
CO2 Flood





Bright color indicates high scCO2 saturation

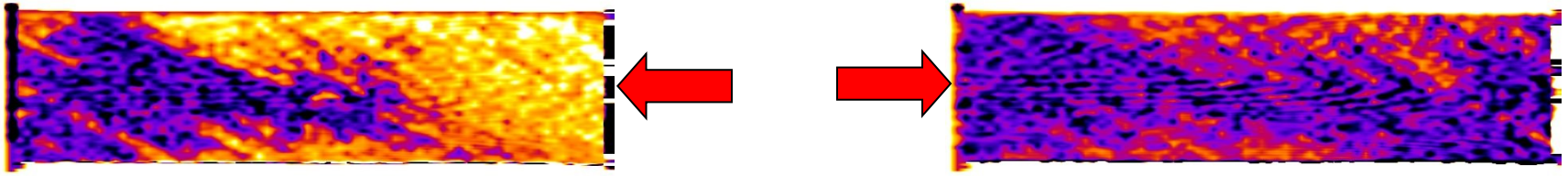
Comparing $scCO_2$ flood experiments

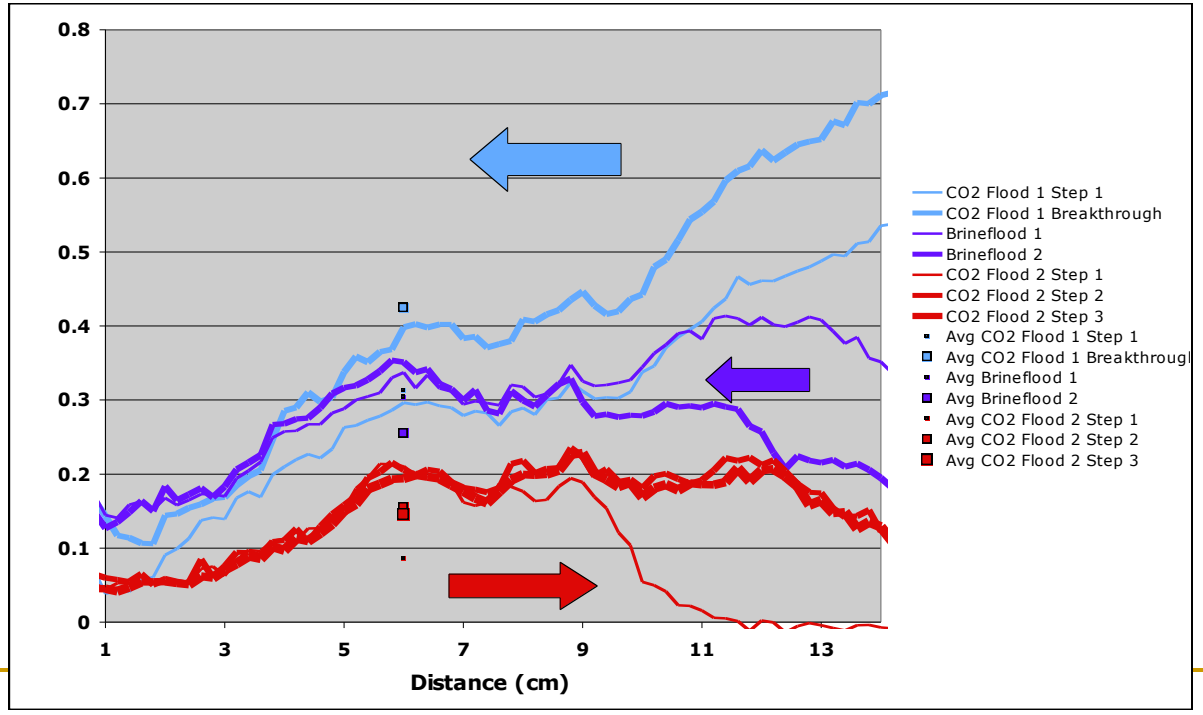


Density (bright higher, dark lower)

First CO2 Flood

Second CO2 Flood

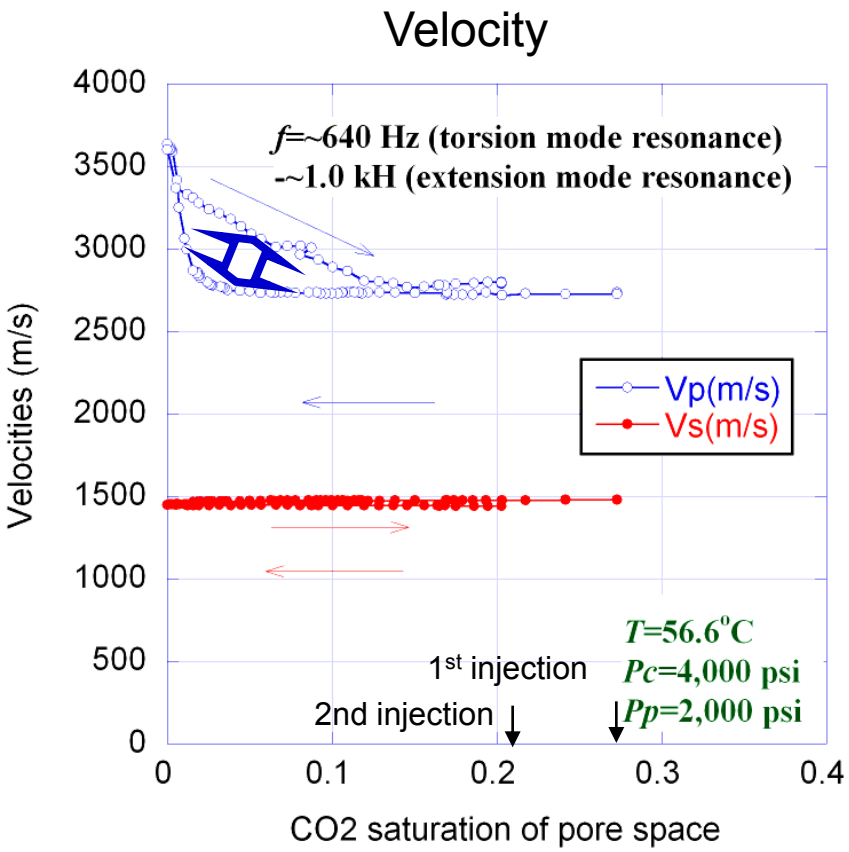


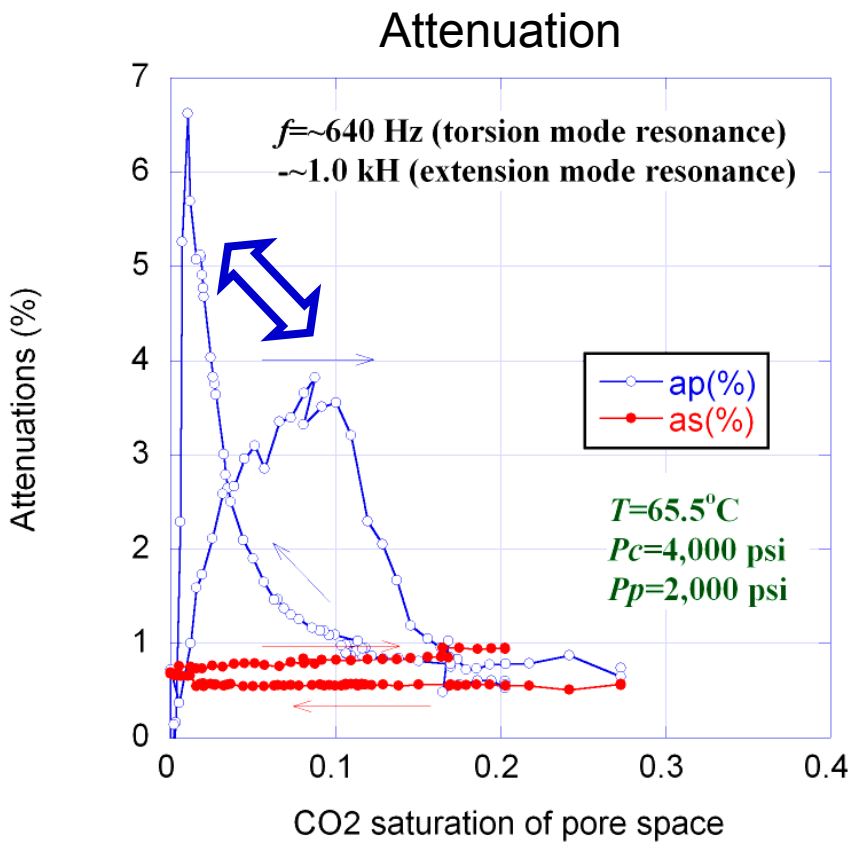


Bright color indicates high scCO2 saturation

$scCO_2$ flood experiments

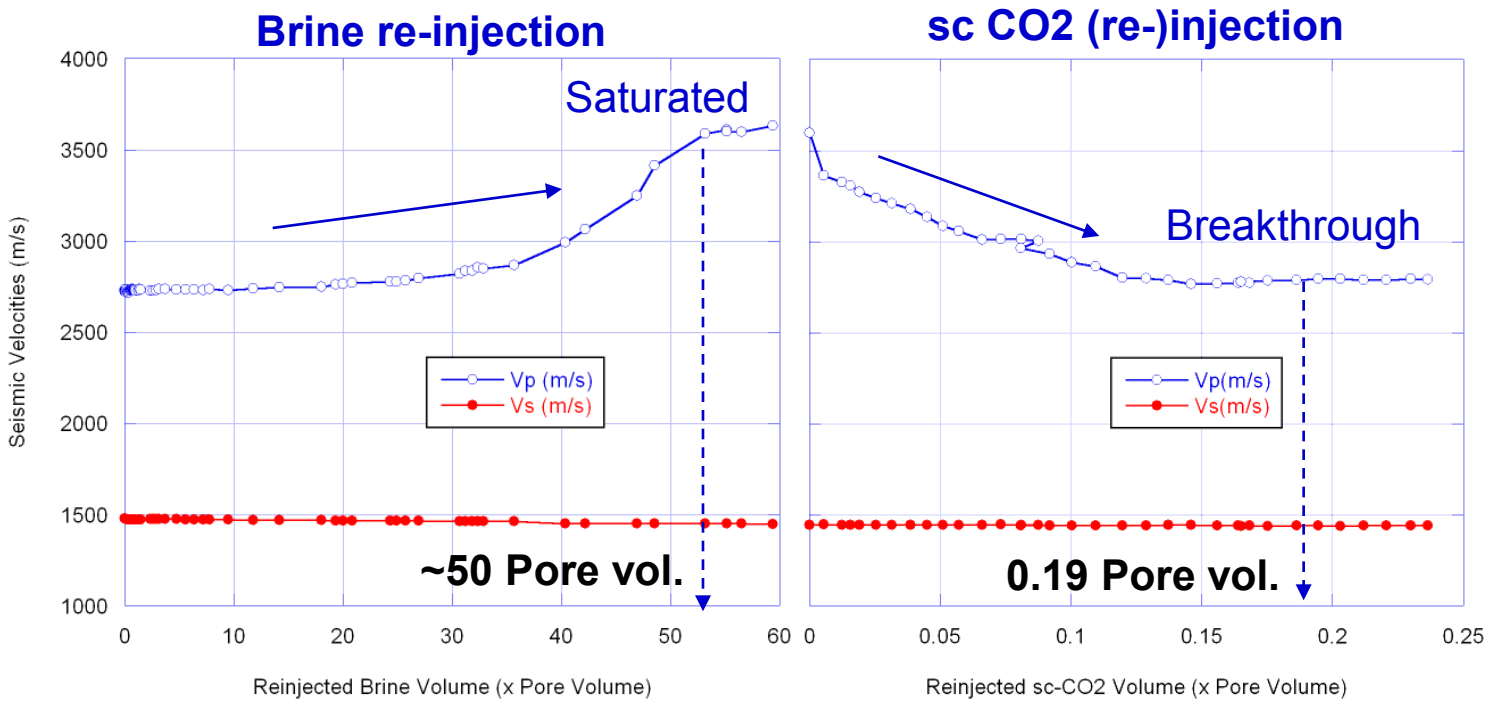
Changes in P and S-wave seismic velocity and attenuation during sc-CO2 injection/brine reinjection in Domengine sandstone sample



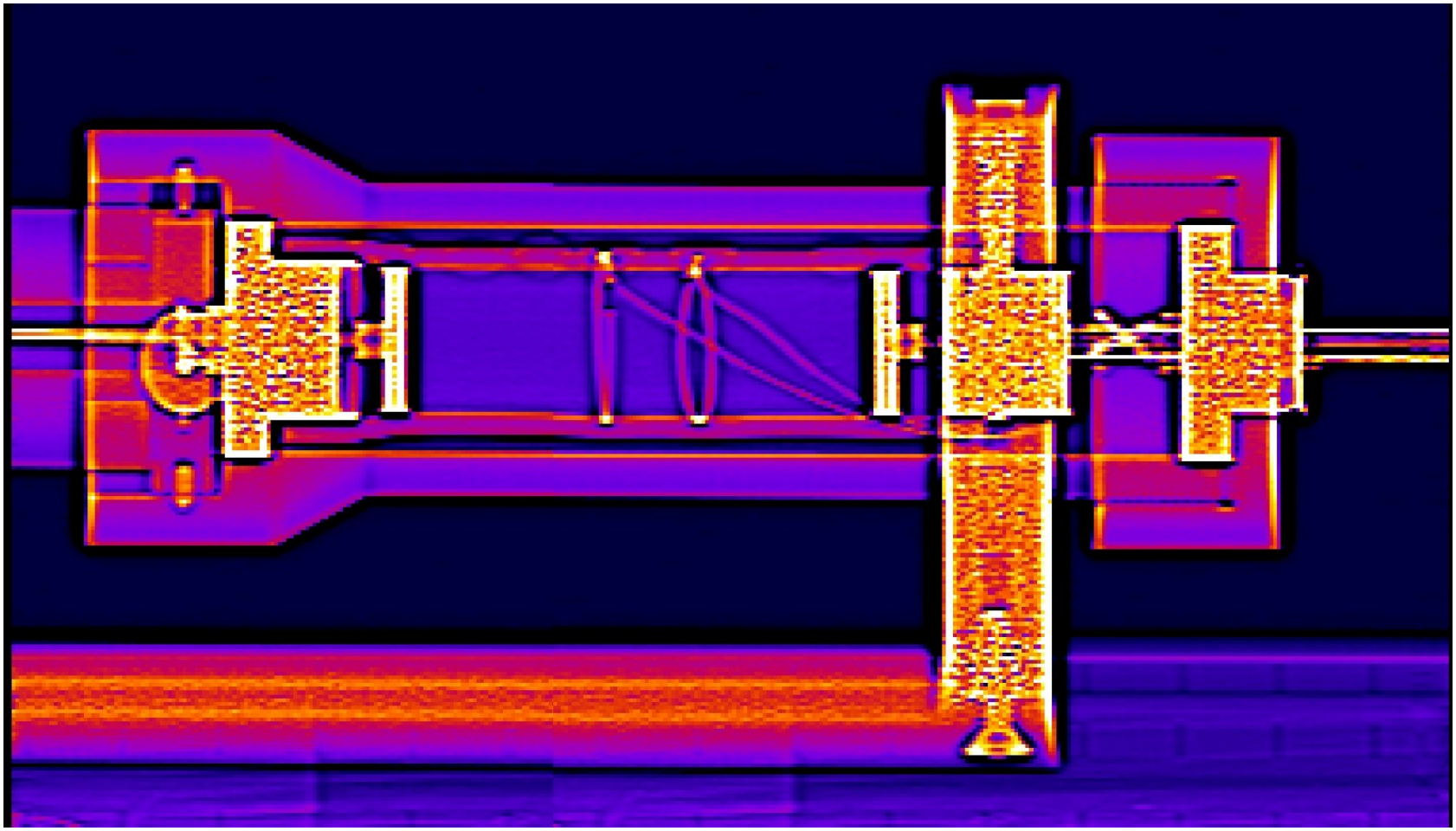


$scCO_2$ flood experiment

P-wave velocity vs injected fluid volume—
Differences in the recovery time



Electrical Resistivity Cell



Conclusions and Future Work

- Heterogeneity plays large role in scCO2 flow, residual distribution and displacement/ dissolution.
- P-wave velocity is very sensitive at low scCO2 saturations; P-wave attenuation is sensitive over a much larger scCO2 saturation range.

- Laboratory tests of electrical resistivity with X-ray CT vs. scCO2 saturation are beginning, and possible combination of resistivity, resonance, and X-ray CT techniques is being considered.
- Laboratory tests on samples from other units will be performed to provide baseline information on field measurement techniques.