Experimental study of residual CO2 saturation in the sandstones with different pore structures

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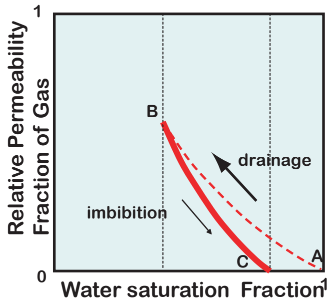
What is Residual Gas Saturation?



A:Water Saturation
B:Irreducible water Saturation
C:Residual Gas Saturation

1. Strong controller of the trapped-gas volume in the reservoir.
2. Function of porosity,permeability and capillary pressure.
3. Maximum value (Sgrm) of natural gas : about 20~40 %

M.H. Holtz (2002)

Introduction

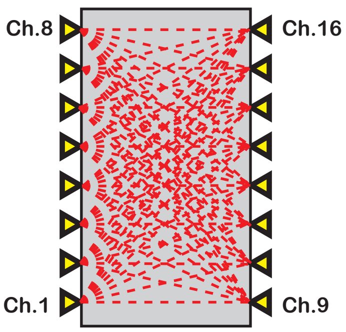
The importance of residual CO_2 saturation (Sgr) is has been pointed out as sequestration of CO_2 into geological formations. Sgr is achieved due the difference in density between CO_2 and water. and it depends strongly on pore geometry, porosity and permeability in the reservoirs (Holtz, 2002).
In this study, we estimated Sgr of CO_2 by using two different methods. We measured the Sgr of supercritical CO_2 in sandstone by using Material-Balance method. It is also important to estimate Sgr of reservoir by using geophysical data as seismic wave velocity.
Thus, we used P-wave velocity (Vp) to estimate the initial and residual CO_2 saturations in the two sandstones (Berea sandstone and Tako sandstone).

Aim of this study

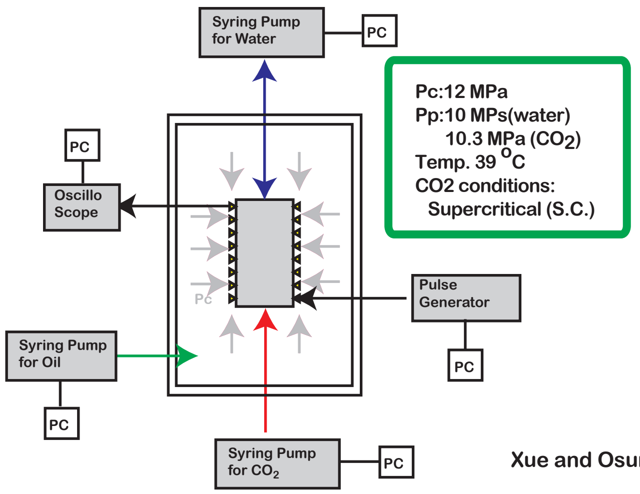
1. Measurements the Residual Gas Saturation of CO_2
2. Imaging the CO_2 movement and distribution in rock sample by using seismic wave imaging method.
3. Evaluate Sgrm value for Supercritical CO_2

Experiment

Arrangement of Vp transuducers and Ray-Path diagram



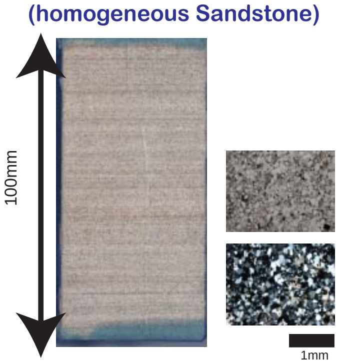
Setup for Vp measurement



Xue and Osumi, 2004

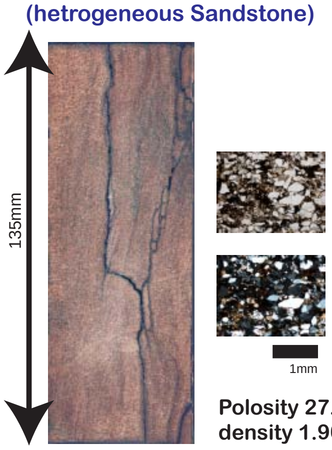
Samples

Berea sandstone (homogeneous Sandstone)



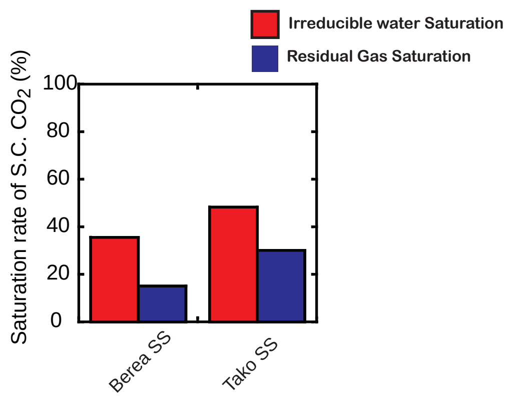
Polosity 18.6 %
density 2.17 g/cm^3

Tako sandstone (hetrogeneous Sandstone)



Polosity 27.7 %
density 1.90 g/cm^3

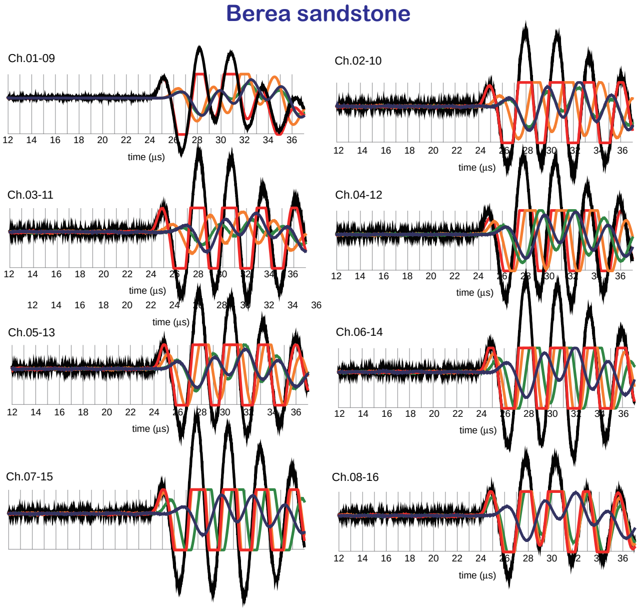
Experimental results of Sgrm of S.C. CO2 using by Material-Balance method



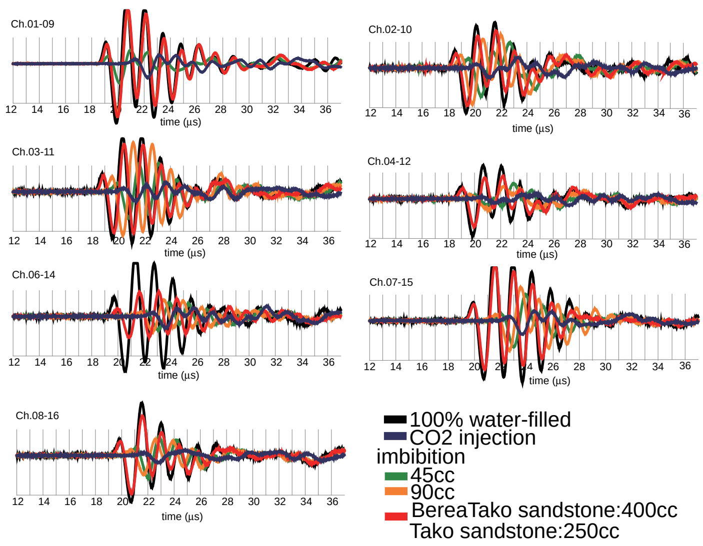
Tako sandstone has more heterogenic pore-streucture than Berea sandstone.

Comparison of waveform changes in drainage (CO2 injection) and Imbibition (water injection) conditions

Berea sandstone



Tako sandstone

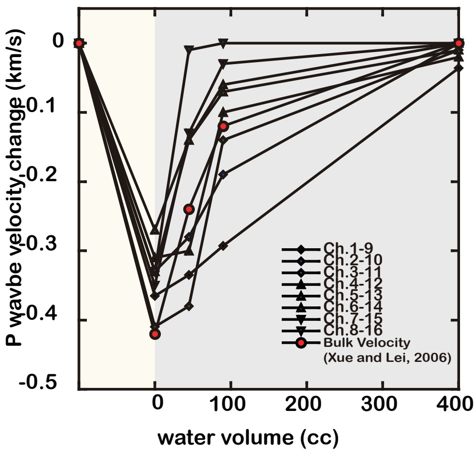


These diagrams show changes in waveforms at the drainage and the imbibition stages (Berea sandstone:8chs, Tako sandstone 7chs). In drainage stage, all channels show obviously reductions of wave intrensity and delay of arrival time (black line).
These results is agreed with previous studies (e.g., Xue et al., 2005).

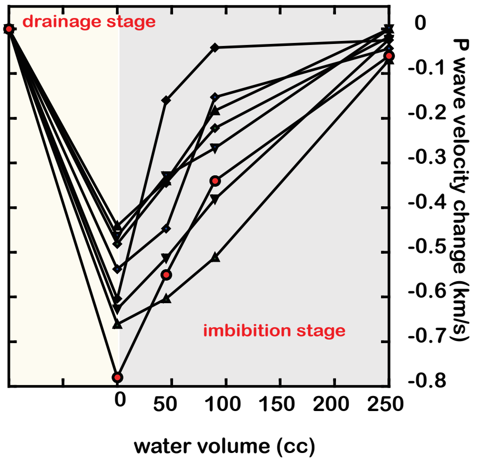
These diagrams also indicate the recovery of intensity of wave and arrival time from irreducible water saturation (blue line). In Berea sandstone, Intensity and arrival time of all channels almost recovered fully of the injecting water of 400cc (red line). On the other hand, Ch02-10 and Ch.06-14 of Tako sandstone did not recover intensity and arrival times (red line).

Vp change with increasing imbibed water

Berea sandstone



Tako sandstone



These diagram indicate the Vp change of each channel and bulk velocity (averaged Vp: Xue and Lei, 2006).
In the drainage stage, Vp showed large changes in both samples (Berea :-0.4km/s , Tako:-0.8km/s).
Both samples indicated differences of Vp changes in drainage stage and imbibition stage at all channels and areraged Vp.
These differences changed with increasing volume of imbibition water.
In case of injecting large volume of water (400cc, 250cc), the averaged Vp almost recovered and Vp-differences of each cannel reduced. These results indicated the effect of imbibition water volume on residual CO_2 saturation.
We have to estimate the residual CO2 saturation after careful discussion about imbibited water volume.

Summary and Future task

In this study, we successfully imaged the displase process between CO2 and water by using seismic wave velocities
We also confirmed the strong effect of CO_2 on seismic wave velocities and heterogenic Vp changes in two sandstones.
These results indicate the strong effect of pore structure of rock on CO_2 distribution and resirdural CO_2 saturation.
We will estimate the residual CO_2 saturation from Vp changes with Gassmann theory.