The potential of $V_p$ and $V_s$ monitoring for MVA program of offshore CCS project

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For the safe operation of CCS, we are required to monitor the CO$_2$ behavior and to accurately account for the storage volume of CO$_2$ in deep reservoirs. It is well-known that the P-wave velocity measurements ($V_p$) can be used for monitoring the CO$_2$ behavior in deep reservoirs. However, it is difficult to accurately estimate the storage volume of CO$_2$ by only using $V_p$. Takahashi (2000) indicated the potential of S-wave velocity for monitoring of fluid behavior and accounting for the storage volume of natural gas in deep reservoirs. S-wave monitoring can be achieved by deploying a permanent ocean bottom cable (OBC) system at the off-shore CCS sites. In our own study, we conducted a simultaneous measurement of $V_p$ and $V_s$ of porous sandstone by injecting various types of fluids under set in-situ pressure and temperature conditions. For this study, we use the Tako sandstone, which is an early Miocene marine sandstone, mainly composed of quartz and plagioclase. Tako sandstone has near 10mDarcy of permeability and almost 24% porosity. The sample was cut into a column shape (5cm in diameter and 10cm in length), and polished on both ends (1PV=47ml). In this study, we tried to estimate CO$_2$ saturation, and to monitor the CO$_2$ behavior in porous sandstone by measuring $V_p$ and $V_s$. First, we injected near 1.3PV water into the vacuumed specimen (Water injection). After this process, over 2.2PV CO$_2$ is injected into the water saturated specimen (Drainage). Finally, CO$_2$-saturated water over 2.3 PV is re-injected into the CO$_2$-injected specimen (Imbibition). We illustrated the $V_p$-$V_s$ relationships of all the processes. This $V_p$-$V_s$ relationship diagram clearly illustrates the obvious differences between water injection and drainage. On the other hand, drainage and imbibition show the similar tendency of $V_p$-$V_s$ change with injecting CO$_2$ and CO$_2$-saturated water. These changes indicate the changes of CO$_2$ saturation during drainage and imbibition stage. This result suggests the potential to estimate CO$_2$ saturation by using the $V_p$-$V_s$ relationship. Additionally, $V_p$ does not recover to pre-drainage levels after end of imbibition process. This $V_p$ difference is considered to be the effect of residual trapped CO$_2$. This result also indicates the potential of monitoring the residual trapped CO$_2$ from seismic wave velocities.

Keywords: P-wave velocity, S-wave velocity, Porous sandstone, CO$_2$ saturation, MVA