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Impact of fluid injection velocity on CO_2 saturation and pore pressure in porous sandstone

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The elucidation of CO_2 behavior in sandstone is an essential issue to understand the fate of injecting CO_2 in reservoirs. Injected CO_2 invades pore spaces and replaces with resident brine and forms complex two-phase flow with brine. It is considered that this complex CO_2 flow arises CO_2 saturation (S_{CO2})and pore fluid pressure(P_p) and makes various types of CO_2 distribution pattern in pore space. The estimation of S_{CO2} in the reservoir is one of important task in CCS projects. Fluid pressure (P_p) is also important to estimate the integrity of CO_2 reservoir and overlying cap rocks. Generally, elastic waves are used to monitor the changes of S_{CO2}. Previous experimental and theoretical studies indicated that S_{CO2} and P_p are controlled by the fluid velocity (flow rate) of invaded phase. In this study, we conducted the CO_2 injection test for Berea sandstone (ϕ=18.1%) under deep CO_2 reservoir conditions (confining pressure: 20MPa; temperature: 40 ˚C). We try to estimate the changes of S_{CO2} and $P_p$with changing CO_2 injection rate (FR) from 10 to 5000 μl/min for Berea sandstone. P-wave velocities (V_p) are also measured during CO_2 injection test and used to investigate the relationships between S_{CO2} and these geophysical parameters. We set three V_p-measurement channels (ch.1, ch2 and ch.3 from the bottom) monitor the CO_2 behavior. The result shows step-wise S_{CO2} changes with increasing FR from 9 to 25 % in low-FR condition (10-500 μl/min). V_p also shows step wise change from ch1 to ch.3. The lowermost channel (ch.1) indicates that V_p-reduction stops around 4% at 10μm/min condition. However, ch.3 changes slightly from 4% at 10 μl/min to 5% at 100 μl/min. On the other hand, differential P_p (ΔP) dose not shows obvious changes from 10kPa to 30kPa. Over 1000 μl/min, S_{CO2} increases from 35 to 47 %. V_p of all channels show slight reductions and V_p-reductions reach constant values as 8%, 6% and 8%, respectively at 5000μl/min. On the other hand, ΔP shows rapid increasing from 50kPa to 500 kPa. It suggests a drastic change of CO_2 behavior with injection rate. CO_2 flows gently and enlarges S_{CO2}up to 25 % under low FR conditions without arisen ΔP (<500μl/min). Over 1000μl/min, CO_2-flow causes rapid increment of S_{CO2} and ΔP. From these experimental results clearly indicate that S_{CO2} and ΔP are strongly controlled by CO_2 injection rate.