V_p monitoring for the channel formation of CO_2-brine flow in two different types of sandstones

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Recent pore-scale studies for CO_2-water two phase flow in porous materials illustrated strong effect of capillary number (C_a) on channel formation mechanism by theoretical and experimental methods. In this study, we tried to up-scale those results to core-scale CO2-water flow and to monitor the channel flow by using compressional-wave velocities (V_p) by using experimental method. C_a is controlled by changing CO2 injection rate (FR). We conducted two CO_2 injection experiments into different types of sandstone with changing FR under reservoir P-T conditions (40°C and 10 MPa). This study used high-permeable Berea-sand stone (10 mD) and ultra-low permeable-Ainoura sandstone (0.01mD) for CO_2 injection tests and estimated CO_2 saturation (S_{CO2}) and differential pressure (DP) between up- and down-stream of sandstones. This studies also measured P-wave velocities (V_p) with injecting super critical CO_2. In ultra-low FR condition (0.01 ml/min), these samples showed different values, Berea sandstone is around 5 % and Ainoura is over 20 %. also showed large difference between Berea sandstone (0.005MPa) and Ainoura sandstone (0.3 MPa). V_p-reductions are 3% for Berea sandstone and 9% for Ainoura sandstone. Increasing FR up to 0.1 ml/min, Berea sandstone indicated increment both of S_{CO2} (16%) and DP (0.01 MPa). Ainoura sandstone reached large value both of S_{CO2} (near 60%) and DP (0.9 MPa). On the other hand, V_p did not indicate clear changes. The experiment for Ainoura sandstone was terminated this FR condition, because DP reaches safety limit (1MPa). The experiment for Berea sandstone increased FR up to 5 ml/min, stepwisely. Over 1 ml/min, S_{CO2} showed large changes form 35% at 1ml/min to 47.5 % at 5m/min. DP also changed from 0.05 MPa to 0.53 MPa. V_p showed large reduction from 5.5% to 7%. The experiment for Berea sandstone implied the changes CO_2 flow pattern between low FR (<0.5 ml/min) and high FR (>1.0m/min). In low-FR conditions, CO_2 indicated still flow without pore-pressure buildup and CO_2 saturation. Vp reduced around 3% from water saturation condition at 0.01ml/min. Over this FR-condition V_p-reduction did not show large changes to 0.5ml/min. During this FR changes, S_{CO2} increased up to 9.7%. In high-FR conditions, it seemed that CO_2 flow pattern changed. High-FR experiments, CO_2 flowed with increasing DP and S_{CO2}. V_p-reduction showed clear changes again from 5.5 % to 7.1 %. In Ainoura sandstone experiment, it was suggested that CO_2 flow pattern is controlled only single mechanism. During this experiment, S_{CO2} and DP increased almost linearly. In this experiment, V_p-indicated large reduction at 0.01ml/min. However, V_p-reductions showed no clear changes at 0.02 ml/min and 0.1 m/min. Then, we estimated changes of CO_2-cluster size during CO2 injection with Gassmann-CRM model. This estimation suggested that CO_2 cluster size is reduced from 10mm to 5mm between 0.5 ml/min and 1 ml/min. In case of 5ml/min, the cluster size was estimated 2mm. In case of Ainoura sandstone, it was seemed that the cluster size did not change with increasing FR from 0.01 ml/min to 0.1 ml/min. These experimental results illustrated two types of CO_2 flow mechanisms into water filled pores. In low-FR conditions of Berea sandstone, CO_2 indicated still flow through the high porosity zone without build-up of DP. Increasing FR, CO_2 started the invasion to connected low-porosity zone with increasing DP. During this process, CO_2 cluster size were reduced. On the other hand, CO_2 did not easily intrude pore space of low-permeable Ainoura sandstone. Thus, CO_2 cluster was crushed in to small size with arising DP. These experimental campaigns suggested that the cannel-formation is monitored by the

changes of V_p and DP in porous sandstone.

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