Estimation of supercritical CO_2 threshold pressure by the mercury intrusion method and direct method

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In order to perform safety and economical design of CO_2 geological storage, the precise estimate of the threshold pressure of the cap rock to determine the CO_2 storage capacity of the reservoir is important in the CCS. Threshold pressure caused by capillary pressure at which to penetrate supercritical CO_2 into the porous rocks saturated with brine, is governed by pore size distribution, interfacial tension and contact angle. At first, the pore size distribution of Tertiary mudstone was analyzed by mercury intrusion method. Capillary pressures were estimated with contact angle, interfacial tension and pore throat diameter. Then using a core sample, threshold pressure was measured by the direct method such as step by step method and residual pressure method. In the experiment, pore pressure was 10MPa, temperature was 40 ℃, the diameter of specimen was 50mm, length 50mm, and was attached to the strain gauge in the circumferential direction at the position of 10mm from the both end faces.

Before the step by step method, the residual-pressure method was applied, and then flushed water sufficiently in order to return to the initial state. Threshold pressure was estimated to 0.60MPa by the residual pressure method. Flow rate is stopped at point A in the figure of the step by step experiment; it suggests that supercritical CO_2 has reached to the face of the specimen. A slight increase of flow rate was confirmed at point B. Threshold pressure was estimated to 0.71MPa by the step by step method. However, Flow rate did not increase although the differential pressure was increased. Then obvious increase of flow rate was observed at point C, flow rate also increased with the subsequent differential pressure increases. Here, the threshold pressure is estimated to 1.64MPa. A slight inflatable strain was observed at point B, significant inflatable strain was observed at point C the flow rate was increased obviously.

Results of the mercury intrusion method, pore size distribution showed bimodal characteristic with a peak at 0.09μm and 0.16μm. Capillary pressure Pc, is expressed as pore size D, interfacial tension γand contact angle θ.

$Pc = 4\gamma\cos\theta / D$

where γis the interfacial tension of brine and supercritical CO_2: 28.5 mN / m, θis the contact angle: 0 °at 40 ℃ and 10MPa, the capillary pressures were estimated 1.27MPa and 0.71MPa respectively corresponding to the two mode diameters.

The 0.71MPa estimated by step by step method and the 0.6MPa estimated by residual pressure method were consistent with the 0.71MPa calculated by the pore size of 0.16μm with the equation described above. Also the 1.65MPa estimated by step by step method at which the flow rate increased obviously was consistent with the 1.27MPa calculated by the pore size of 0.09μm.

The reason for the flow rate followed by a slight flow did not increase is related to volume, distribution and continuity of the pore. Such information are not be obtained by the mercury intrusion method because of hydrostatic condition.

Residual pressure method is reported easily under estimation of threshold pressure as compared to step by step method. The capillary pressure corresponding to the mode diameter of 0.16μm in this case coincides with the result of the residual pressure method. As the equilibrium of pressure is observed after stopping flow in the residual pressure method, it is conceivable that asymptotically approaches the capillary pressure so that the pressure propagates in the displacement of a small fluid.

Pore distribution characteristics that are analyzed by the mercury intrusion method are to provide a lot of useful information in estimating the threshold pressure. On the other hand, It is not possible to correspond to the anisotropy, it is impossible to omit the direct method using a core such as step by step method.

Keywords: Mercury intrusion method, supercritical CO2, Threshold pressure, Step by step method, Residual pressure method, Bimodal