Gas penetration characteristics of a water-saturated rock as evaluated by the gas breakthrough method

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Evaluation of the gas penetration characteristics of a rock is important for considering the preservation and accumulation of gas inside a geologic medium. When gas penetrates into a water-saturated rock, pore water is expelled. The correlation between gas pressure and pore radius can be described by the following equation on the capillarity (e.g., Gelinas and Angers, 1986; Innocentini and Pandolfelli, 2001):

deltaP=2Ycos(theta)/r

where deltaP is the differential pressure (Pa), theta is the contact angle (degree), Y is the surface tension (N/m), and r is the pore radius (m). It follows from this equation that larger pressure is required to expel water from smaller pores. Let us consider the condition where gas penetrates into a water-saturated rock from the high pressure side and water is expelled from the low pressure side. When gas pressure is gradually increased, in the beginning the pressure is low and gas does not flow, but at a certain pressure water is expelled and gas begins to flow. With increasing pressure, the amount of expelled water increases and thus the permeability increases. To quantitatively evaluate such correlation between pressure and permeability, we applied the gas breakthrough method which was reported in Yokoyama and Takeuchi (2009).

The Fontainebleau sandstone (France), composed of ˜100% quartz with a grain size of about 200-250 micron meter, was used for the experiment. A cylindrical core was cut from the sandstone (porosity 5%), and its lateral side was sealed with a resin. Firstly, the change in flow rate with increasing gas pressure was evaluated for a dried sample. From this result, the permeability was determined to be 1.5E-14 m2. Then, a similar experiment was carried out for a water-saturated sample. No gas flow was detected at differential pressures of 185 h Pa. The initial breakthrough of gas was observed at 185 hPa (corresponding to a pore radius of 8 micron meter), and at that time the permeability was 4.2E-17 m2. The permeability of the wet sample increased with increasing the pressure, and the value eventually became equal to that of dry sample at 2100 hPa.

In considering the gas penetration into a rock under a geologic environment, the effects of gas pressure and water content on permeability need to be known. The above technique can be used to evaluate such permeability-pressure relationship.