

Experimental and numerical investigations on the deformation of mudstone caused by chemical osmosis

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Generally mass transport and water flow in underground are smaller than these on ground surface. The properties of underground are useful for projects to isolate specific substances, for example CO₂ and high-level radioactive wastes, from human societies for long time. In such projects low-permeable formations such as argillaceous formations perform as effective seal layer and it is important to make clear the behavior of seal layer in such projects.

However it is known that some physical processes that are negligible in aquifers can play great role in low-permeable area (e.g. Sato and Murota, 1971). One of them is semipermeable properties of mudstone and chemical osmosis. Chemical osmosis is water flow across semipermeable membrane driven by the gradient of osmotic pressure between two solutions (Marine and Fritz, 1981). It is known that some mudstones behave as an imperfect semipermeable membrane. This is because negative charges of clay mineral form Electric potential in the pores and it retards solute transport. In low-permeable area osmotic flow causes pressure change (e.g. Marine and Fritz, 1981; Neuzil, 2000). Previous research shows the pressure change caused by chemical osmosis can reach 20MPa (Neuzil, 2000). Change of pore pressure causes deformation of porous medium. In previous research, deformation of overall formation or rock sample caused by chemical osmosis is discussed (Greenberg et al., 1973; Noy et al., 2004).

When pore water concentration gradient exist in a narrow area, osmotic flow occurs only in the area and that causes large pressure change and rock deformation locally. If the pressure change or deformation are very large, it is possible that the properties of seal layer changes. So it is important to discuss mudstone's semipermeable behavior and deformation caused by osmotic flow including local scale.

The purposes of this study are to conduct measurement of strain caused by chemical osmosis in lab-scale experiment and to develop the model to describe pressure, concentration and strain in semipermeable mudstone.

Mathematical model is developed by combining reported government equations of chemical osmosis (Malusis et al., 2012) and linear poroelasticity (Wang, 2000). Calculating this model, the behaviors of strain related to processes of chemical osmosis and poroelasticity are observed.

Lab-scale experiment is conducted with core sample of siliceous mudstone collected from Wakkanai formation. Four strain gauges are put on the side of mudstone. Two measure axial and circumferential strain near top side of the sample and the rests measure axial and circumferential strain near bottom side. In the experiment, the lateral side and bottom side are sealed with silicon rubber and topside touches solution with different concentration from pore water. The strain caused by chemical osmosis is measured by strain gauges. In the measurement of strain, large systematic error are observed. That is considered to be derived from heating of strain gauges. However the initial behaviors of strain are consistent with that calculated with model developed in this research.

Keywords: mudstone, chemical osmosis, poroelasticity