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A study on grain boundary brine in halite rocks using electrical conductivity measurements

WATANABE, Tohru[1*] ; KITANO, Motoki[1]

[1]Graduate school of science and engineering, University of Toyama

Intercrystalline fluid can significantly affect rheological and transport properties of rocks. Its influences are strongly dependent on the style of distribution. When a fluid fills grain boundaries in a rock, it will significantly reduce the strength of the rock. The fluid distribution is mainly controlled by the dihedral angle between solid and fluid phases. The grain boundary wetting is expected only when the dihedral angle is 0o. The dihedral angle of the halite-water system was studied through microstructural analyses of quenched materials (Lewis and Holness, 1996). The dihedral angle is 50˜70o at P<200 MPa and T<300 oC. However, deformation experiments (e.g., Watanabe and Peach, 2002) and cryo-SEM observations (e.g., Schenk et al., 2006) on halite rocks have indicated the coexistence of grain boundary brine with a positive dihedral angle. In order to understand the nature of grain boundary brine, we have conducted electrical impedance measurements on synthetic wet halite rocks over a wide range of pressure and temperature.

Wet halite rock samples (9 mm diameter and 6 mm long) are prepared by cold-pressing (P=140 MPa, 40 min.) of wet NaCl powder and annealing (T=180oC, P=180 MPa, 160 hours). Grains are polygonal and equidimensional with a mean diameter of 50-100 ?m. The porosity is less than 1 %. The volume fraction of brine is estimated to be 11.1% by the thermo gravimetric analysis. Microstructural observation shows that most of brine is enclosed inside halite grains. Electrical impedance is measured in the axial direction of a sample by a lock-in-amplifier (SRS, SR830) with a current amplifier (SRS, SR570). The cylindrical surface of a sample is weakly dried and coated with RTV rubber to suppress the contribution of surface conduction. A conventional externally heated, cold-seal vessel (pressure medium: silicone oil) is used to control pressure and temperature.

Electrical conductivity of wet halite rocks is higher than that of NaCl by orders of magnitude even at the conditions of the dihedral angle larger than 60 degrees. The conduction through brine dominates the bulk conduction. This is also supported by the quick conductivity change in response to the change in pressure. Brine is interconnected over a whole range of pressure and temperature.

No remarkable change in conductivity is observed around the condition of the dihedral angle of 60 degrees. Although the interconnection of triple-junction tubes might drastically change at the dihedral angle of 60 degrees, its influence on the bulk conductivity is masked by more conductive paths. A triple-junction tube is so stiff that it cannot give observed conductivity changes in response to changes in pressure. The dominant conduction paths are not triple-junction tubes. Grain boundary brine must be the dominant conduction paths.

Electrical conductivity decreases with increasing pressure. Larger change is observed for lower temperatures. A simple model of fluid tube with elliptical cross-section shows that the thickness of a fluid tube decreases by less than 10%. The observed large change in conductivity suggests that the conductivity of brine is strongly dependent on the fluid thickness. When the thickness is comparable to the molecular size, the mobility of ions must be sensitive to the thickness. The observed large change in conductivity might be caused by the decrease in ionic mobility.

Keywords: salt, grain boundary, water, electrical conductivity