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Brine distribution in halite rocks - Inference from measured electrical conductivity

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Intercrystalline fluid can significantly affect rheological and transport properties of rocks. Its influences are strongly dependent on its distribution. The dihedral angle between solid and liquid phases has been widely accepted as a key parameter that controls solid-liquid textures. The liquid phase is not expected to be interconnected if the dihedral angle is larger than 60 degrees. However, observations contradictory to dihedral angle values have been reported. The grain boundary fluid coexists with a positive dihedral angle. Similar thin fluid films might exist in grain boundaries of crustal materials, and play important roles in crustal processes. In order to understand the nature of grain boundary fluid, we measured electrical conductivity of synthetic wet halite rocks at various temperature and pressure conditions.

Halite-water system is used as an analog for crustal rocks. The dihedral angle has been studied systematically at various pressure and temperature conditions. The dihedral angle is larger than 60 degrees at lower pressure and temperature. It decreases to be less than 60 degrees with increasing pressure and temperature. A sample is prepared by cold-pressing (140MPa for 20 minutes) and annealing (T=160C and P=180MPa for 20 hours) of wet NaCl powder. Grains are polygonal and equidimensional with diameters of 50-100 micrometers.

Experiments are performed using a conventional cold-seal vessel with an external heater. The pressure medium is silicon oil (viscosity=0.1 Pa s). Dimensions of a sample are 9 mm in diameter and 7 mm in length. Viton is used as a jacketing material. Platinum electrodes are placed at both ends of the sample. The confining pressure of 30 MPa is first applied to a sample, and then the temperature is increased to 120C and kept for 5days. The temperature is then changed to 180C (162C@sample) and 140C (126C@sample). Electrical impedance of the sample is measured at different pressures. Impedance measurements are made with an LCR meter (NF ZM2353) (40Hz to 200kHz), and a lock-in amplifier (SRS SR830) and a current amplifier (SRS SR570) (40mHz to 400Hz). Debye-type impedance spectra are observed, to which a parallel array of a capacitor and a resistor can be applied as an equivalent circuit. Measured resistance is converted to conductivity.

Measured conductivity is higher than the conductivity of NaCl by 2-3 orders of magnitude, implying that the electrical conduction is dominated by that through brine. Quasi-stationary conductivity observed at T=180C is almost independent of the pressure. This is consistent with a slight change in the dihedral angle with the pressure. The connectivity of brine should mainly be governed by the triple junction tubes, which are difficult to deform. If the interconnection is governed by grain boundary fluid films, the conductivity should be very sensitive to the pressure increase.

The progressive decrease in conductivity at 140C and $P<50$MPa reflects the increase in the dihedral angle, while the increase in conductivity at 100MPa the decrease in the dihedral angle.

Even at conditions of the dihedral angle larger than 60 degrees (e.g., T=140C, P=30MPa), brine is interconnected. However, we cannot say that connected paths are stable or not. No stationary value is observed. Longer runs should be done to study the connectivity of brine at lower temperature and pressure conditions.

Keywords: electrical conductivity, halite rocks, dihedral angle, grain boundary fluid, fluid distribution