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Pressure Solution Creep of Wet Calcite Aggregate at Temperatures up to 150 °C and Effects of Pore Fluid Chemistry

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Uni-axial compaction experiments have been carried out on crushed limestone and reagent grade calcite powder (~10-100 μm) at temperatures ranging 30-150 °C and 20-47 MPa effective pressures with saturated $CaCO_3$ solution as pore fluid for 7 to 40 days. SEM micrographs showed microstructures such as sutured grain contact, indentation, grain growth in the wet compacted samples. Dissolution pits and precipitation layers were developed in the surfaces of cleaved crystals added in the powder sample as reference microstructure. These microstructures clearly indicated the operation of pressure solution in our experiments. Substantial compaction strains were obtained in the wet compacted samples. The compaction strain rates systematically increased with increase of effective stress and decrease of grain size. Temperature has little effects on the compaction strain rates between 30 to 150 °C.

The effects of pore fluid chemistry have been examined under the comparable conditions (T=150 °C; Pe=30 MPa). Samples filled with saline pore fluid with 0.6 mol/l NaCl compacted 5 times faster than those with NaCl free pore fluid. Magnesium and phosphate ions with typical seawater concentrations (0.05 and 0.001 mol/l respectively) in the pore fluid reduced the strain rates significantly at 150°C. Flow-through enhanced the compaction rate of samples which had been compacted for a long time in a previously closed system. However, flow through had no effects on short-term compacted calcite sample. Chemical analysis showed that Ca^{2+} concentration in pore fluid increased with lapse of experimental time in each single compaction phase in a chemically close system. Impurities in the pore fluid released from samples, among them are known calcite precipitation/dissolution inhibitors, were measured systematically increased during compaction.

The microstructures, effects of grain size, effective stress (changes), effects of impurities in the sample and in pore fluid, together with the comparison between the experimental rate data and pressure solution modelling results suggest that the dominate compaction mechanism was pressure solution and the rate-limiting mechanisms were transitional from grain boundary diffusion controlled to interfacial reaction controlled. Experimentally derived grain boundary diffusion production of DS in calcite (diffusion coefficient and effective thickness of water film) are between 4.77×10^{-18} to $5.97\times10^{-19} m^3/s$ at 150 °C. The transition of rate limiting mechanisms was probably caused by the impurities built up in the pore fluids.

Keywords: Deformation; Pressure Solution; Calcite