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Fluid distribution in grain boundaries of natural fine-grained rock salt deformed at low shear stress: implications for rheology and transport properties

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We used a combination of broad ion beam (BIB) cross-sectioning and high resolution (cryogenic) SEM to image polished surfaces and corresponding pairs of fractured grain boundaries in an investigation of grain boundary (GB) microstructures and fluid distribution in naturally deformed halite from a salt glacier (Kum Quh, central Iran). At the scale of observations, four types of fluid or gas filled grain boundaries can be distinguished: (1) straight boundaries with thick (up to 10 μm) GB tubes (2) straight boundaries with narrow (about 50 nm) GB tubes (3) wavy (tens of μm wavelength) GB with isolated inclusions of a few μm, and (4) wavy (μm wavelength) GB with small (μm) isolated inclusions. Grain boundary fluid inclusions can have three types of morphologies: the inclusion of Type 1 is intruded completely in one grain, inclusion of Type 2 has its major part included in one grain with a minor part in the second grain and the inclusion of Type 3 is located in both grains. Solid second phases in GB are mainly euhedral anhydrite crystals. The mobility of the brine is shown after cutting the inclusions by BIB in vacuum and fine-grained halite forms efflorescence and precipitates on internal walls of inclusions. At cryogenic temperature, in-situ brine is seen as continuous film in GB of type (1) and (2), and in isolated inclusions in GB of type (3) and (4). The structure of halite-halite contact between isolated fluid inclusions in GB of type (3) and (4) is below the resolution of SEM. GB of type (3) and (4) are interpreted to have formed by healing of mobile fluid films. First results of deformation experiments on the same samples under shear stress corresponding to conditions of natural salt glacier, show very low strain rates (7.43x10-10 s-1 and 1x10-9 s-1), up to one order of magnitude below of expected strain rates by solution precipitation creep. Both microstructures and deformation experiments suggest interfacial energy-driven GB healing, in agreement with the healing criterion of Van Noort et al. (2008). This suggests that PS creep is not active in our samples. Therefore, there is a disagreement with previous microstructural studies (Schléder and Urai, 2007; Desbois et al., 2010) of similar samples, which have shown active PS creep (and dislocation creep) in of salt glaciers. We discuss different explanations for this, which imply that both healing and reactivation of grain boundaries is important in salt glaciers, leading to heterogeneous distribution of deformation mechanisms and strain rates in both space and time.

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Van Noort, R., Visser, H.J.M., Spiers, C.J., 2008. Influence of grain boundary structure on dissolution controlled pressure solution and retarding effects of grain boundary healing. J. Geophys. Res. 113.