Geophysical Research Abstracts, Vol. 9, 09924, 2007
SRef-ID: 1607-7962/gra/EGU2007-A-09924

Effect of cyclic stress on the rate of pressure solution in halite and calcite

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Pressure solution is a water-assisted physicochemical process driven by excessive stress-induced chemical potential. The mass transfer is achieved through dissolution of solid minerals at non-hydrostatically stressed sites, diffusion of solutes along the grain boundaries or pore space and reprecipitation at stress-free or hydrostatically stressed sites. Pressure solution is a major deformation process of sedimentary rocks as well as endogeneous or metamorphic rocks in the first kilometers of the crust.

Evaporite and carbonate rocks are known to be very susceptible to pressure solution. Although a number of papers deal with laboratory and field study of pressure solution in natural and synthetic materials, the mechanism of the process remains somewhat obscure. In particular, the role of the stress intensity, geometry and evolution in time cannot be exactly quantified in the framework of existing models, because it is likely to act in two opposite ways: on the one hand the stress is the driving force of dissolution, on the other hand the stress may be expected to hinder the process by closing or constricting the paths of mass transfer. Accordingly, a hypothesis was made that cyclic variations of stress might provide an efficient deformation mechanism (Jordan et al., 2005). Some preliminary results consistent with this assumption were reported recently: sinusoidal variations of normal stress were shown to have a large effect on the indentation rate in halite (Dysthe et al., 2003).

We have extensively studied pressure solution creep in halite and calcite in saturated aqueous solutions under periodically loading-unloading. All the experiments show that cyclic loading leads to an immediate manifold creep rate increase which lasted over the whole period of cyclic impact. After returning to the static regime, the initial low strain rate reappears. Increasing impact frequency enhances the effect. A similar behaviour has been observed on calcite filled with a two-phase (hydrocarbon and water) liquid mixture, while any noticeable changes are absent in the pure inert medium (paraffin oil).

The dramatic effects observed not only may be considered as one of probable reasons for seismic impacts in rocks evolution over geological periods, but also should be taken into account in oil recovery as a mechanism for vibration-induced evolution of pore space in carbonate reservoirs .

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