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Smectite reactions and slip instabilities in subduction zones

Leslie Gadenne (1), Hugues Raimbourg (1), Remi Champallier (1), and Yuzuru Yamamoto (2)
(1) ISTO, Orleans University, Orleans, France, (2) JAMSTEC, Yokohama, Japan

Though it is of prime importance in terms of seismic and tsunami risk, the mechanical behavior of the shallow (z<5km) domains of accretionary prisms is not well understood. The concomitant progress of mechanical compaction and diagenetic reactions results in the transformation of a soft sediment into a hard sedimentary rock, which modifies the rock potential to localize deformation and be involved in slip instabilities.

While it is the major control on diagenetic reactions, the effect of temperature on the mechanical behavior is not well constrained experimentally. To address this question, we have designed triaxial deformation experiments in the Paterson rig either at ambient temperature or at 300 °C. The tested material includes siltstones from the Boso Peninsula in Japan (corresponding to the shallow domain of a paleo-accretionary prism), either as cylindrical cores or as ground powders as well as powders composed principally of smectite. For this material, the main consequence of the high temperature conditions is to trigger the smectite-to-illite reaction or the smectite interlayer space collapse.

The first result is that at 300 °C, all tested samples show slip instabilities. These instabilities are apparent as a sudden (∼ 4s) and large (∼10 to 45 MPa depending on the starting material and the confining pressure) stress drop in the macroscopic stress-strain curve, in some cases followed by a rapid restrengthening of the material. In contrast, no instability was observed for the experiments at ambient temperature. As slip instabilities are activated by the temperature and occur as well in smectite powders, we attribute these instabilities to the diagenetic reactions of smectite.

An additional experiment on a powder of smectite where the smectite-to-illite reaction has been inhibited by cationic exchanges does not show instabilities upon deformation at 300 °C. We propose therefore that catastrophic dehydration of smectite associated with the smectite-to-illite reaction may be responsible for triggering the instabilities. This catastrophic dehydration is potentially a major control on the genesis of instabilities in natural conditions, as (1) smectite is a major component of subducted sediments and (2) its transformation into illite may occur over a large depth range.