



Nanoscale properties of rocks and subduction zone rheology: Role of grain-boundary energy

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Nanoscale material properties may affect global geodynamic processes: It has been shown, e.g., that grain boundaries may serve as reservoirs of incompatible elements in the Earth's mantle. Segregation of incompatible elements results in a marked difference between the composition of the interiors and the boundaries of grains within the rocks that comprise the Earth's mantle (Hiraga et al., 2004).

Grain boundaries are also the key for the understanding of mineral reaction kinetics. Nanometer scale structures in geological materials such as crystal defects, grain- and phase boundaries and small scale chemical zoning patterns provide, more generally, insight into processes that occur at the atomic level and that control in many respects the transport properties of rocks. Processes involved in breaking and establishing bonds at reaction sites determine how and at which rate bulk rock properties change in response to external tectonic forcing and possibly feed back into various geodynamic processes.

Here I discuss a particular problem, the role of grain-boundary energy for the kinetics of polymorphic phase transformations. Slab rheology is affected in many ways by (metastable) mineral phase changes. Sluggish kinetics due to metastable hindrance is likely to cause particular difficulties, because of possible strong non-linear feedback loops between strain-rate and change of creep properties during transformation.

In order to include detailed kinetics into thermo-mechanical modelling of convergent plate margins, reliable kinetic data of high-pressure mineral phase transformations is required. The measurement of grain-boundary energies is, however, a difficult problem. Methods of grain boundary surface tension measurement include (a) equilibrium angles at triple junction (b) rotating ball method (c) thermal groove method, and others (Gottstein & Shvindlerman, 1999).

Here I will discuss a new method how measured (in-situ) kinetic data at the laboratory time scale can be used to extract grain-boundary energies for the specific kinetic mineral reaction and how this can be used to extrapolate kinetic laboratory data to the geological time scale (Riedel and Karato, 1997).

According to this approach, any given kinetic phase boundary measured at the laboratory time scale can be "scaled" to the corresponding critical isotherm at subduction zones, under experimentally "forbidden" conditions (Liou et al., 2000).

References:

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