Mechanisms for Strain Hardening Behavior of Serpentinite during Dehydration Reaction

Takehiro Hirose[1]; Misha Bystricky[2]; Holger Stünitz[3]; Karsten Kunze[4]

[1] Dept. Geol. & Mineral., Kyoto Univ.; [2] LMTG, Université de Toulouse; [3] Department of Earth Sciences, Basel University; [4] Geologisches Institut, ETH Zentrum

Recent geophysical data suggest that serpentinites are a significant component of the oceanic lithosphere and play an important role in subduction dynamics. However mechanical properties of serpentine-bearing rocks are poorly understood especially at large strains and during the dehydration of serpentine to olivine and hydrous phases. In order to investigate the effect of the dehydration reaction on the strength and ductility of serpentinite, torsion experiments were performed using a Paterson high PT apparatus at constant shear strain rates of 10^-6 to 10^-4 s^-1, temperatures of 500 to 750 C and confining pressures of 200 to 400 MPa, to bulk shear strains up to 3.4 under drained conditions. We deformed three natural serpentinites during the dehydration reaction: an antigorite from Val Malenco, Switzerland, a lizardite from Elba Island, Italy, and another lizardite from an unknown location.

All serpentinites showed a similar mechanical behavior. Yielding occurred at shear strain of ~0.1, and was followed by a progressive increase in stress (strain-hardening stage). In some experiments (at 550 C for lizardite and at 700 C for antigorite), strain hardening stopped at a peak stress value of 300 MPa before continuous strain weakening. In this study, we have mainly focused on the strain hardening stage. The hardening was typically observed when the reaction took place pervasively through the sample. In the Elba lizardite, this stage occurred while strong crystallographic preferred orientations (CPO) developed with increasing shear strain typically after shear strain of ~1.5. In samples where strain weakening was observed at large strains, the weakening was associated with the formation of visible fault zones in the microstructures.

The hardening behavior is thought to occur by three factors; (1) dilatancy hardening (effective pressure increases due to fluid escape through pores and microfractures), (2) compaction hardening (the reaction produces about 26 % pore volume and pore collapse is driven by pressure and deformation), and (3) progressive formation of a harder reactant assemblage (olivine plus talc and water is stronger than lizardite). Therefore factors controlling the hardening rate in the stress-strain curve include permeability, compaction rate and reaction rate. These parameters are related with each other. Compaction rate depends on pore strength and permeability, which determine pore fluid pressure. If the compaction rate is faster than the fluid escape rate, fluid pressure increases with compaction. Higher fluid pressure leads to a decrease in reaction rate. Once fluid pressure is equal to the minimum principle stress, fracturing occurs, fluid pressure rapidly drops and the reaction rate becomes faster, producing pores and fluid. The strain hardening behavior during the dehydration reaction must be described by these feedback processes.