High-Strain Deformation of Mantle Minerals and Seismic Anisotropy

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Recent advances in experimental deformation apparatus coupled with new technologies for characterization of deformation textures have permitted new understanding of the development of texturing in mantle rocks that can give rise to measured seismic anisotropies. Deformation experiments have been performed on single-phase aggregates of clinopyroxene, olivine and magnesiowüstite. Samples were strained in a torsional configuration to total shear strains of up to gamma = 16 under conditions normally favouring high-temperature dislocation creep processes. In all cases, the samples initially developed lattice preferred orientations consistent with slip on the easiest dislocation slip systems and shape preferred orientations with grain elongations that rotate towards the shear direction. All three materials also showed dynamic recrystallization by subgrain rotation, resulting in a significant grain refinement and concomitant major weakening of the shape fabric. With increasing strain the deformation textures evolved from one typical of dislocation creep to one more consistent with recrystallization. Despite the reduction in grain size and evolution of the deformation textures, the samples showed no significant strength reduction or change in deformation mechanism, which had been predicted from previous studies in uniaxial compression where samples were deformed either in dislocation or diffusional creep. This failure to produce changes in deformation mechanism despite the relatively high stresses, and associated fine recrystallized grain size, suggests that flow in the asthenosphere and lower lithosphere should remain dominated by dislocation creep processes and can be adequately modelled with existing flow laws for the major constituent minerals.

Core infiltration experiment and modelling of reactive transport of high-pH solution in clay stone

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Clay rocks display coupling between chemical and physical properties. The coupling of chemical reaction to transport properties in intact rock has not been studied in laboratories owing to the very low hydraulic conductivity ($<10^{-12}$ m/s). We present a unique and well constrained long-term experiment to elucidate both on the chemical interaction of clay rock with hyperalkaline solutions and its effect on the evolution of hydraulic conductivity. See Adler et al. 1999 for review and results of scoping experiments.

A preserved drill core sample of claystone was infiltrated by a K-Na-Ca-OH solution (pH 13.2) for 400 days at 30°C and 3 MPa hydraulic head. Monitoring of the chemical composition of effluent solutions recorded a buffering of pH below 9.8 for the entire duration attributed to the formation of secondary Mg-hydroxide (hydrotalcite, talc/sepiolite), calcite and illitic clay minerals identified after termination of the experiment. Substantial precipitation of secondary calcite and illitic clay minerals continuously reduced the hydraulic conductivity of the rock sample during the experiment, suggestive of self-sealing. The observed cessation of fluid flow after 400 days was not the result of complete plugging of porosity as measurements of porosity in reacted rock show values unchanged. The sealing effect may operate at the scale of pore throats and affect only a small portion of the pore space, or may involve other mechanisms.

Reactive transport was simulated with a one-dimensional model coupling advective/diffusive transport with ion exchange and kinetic mineral reactions. The calculated composition of the column effluent and mineral alteration in the column are in good agreement with the experiment. Based on simulations, the observed mineral alteration resulted from dissolution of primary quartz, kaolinite and dolomite. Dedolomitisation resulted in abundant calcite precipitation and is the main source of Mg in neoformed Mg-hydroxides. Additional Ca and Mg was supplied by displacement from exchange sites by infiltrating K. Precipitation of Mg-hydroxide phases lowers the pH of the infiltrating hyperalkaline solution over extended periods of time.

In contrast to experiments on dispersed clay systems, CSH and zeolite are minor secondary phases compared to calcite and illitic clay minerals during high-pH alteration of claystone under in situ flow conditions.

Adler M., et al. (1999) Swiss Bull. Min. Pet. 79, 445-454.