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Thermodynamic modelling of clay dehydration, stability and compositional evolution from early diaganesis to blueschist facies conditions along subduction P/T gradients

Olivier Vidal
CNRS, Isterre-Ujf, Grenoble, France (olivier.vidal@ujf-grenoble.fr)

The evolution of clays with temperature, such as the breakdown of smectite into illite, has been proposed to explain the elevated pore pressure associated with very low frequency earthquakes near the trench of subduction zones, or local overpressuring in sedimentary bassins. The discontinuous character of smectite dehydration has important geological implications because the loss of smectite water layers is accompanied by large and sudden volume changes (about 30% variation at each transition) and the release of about 150 kgH_2O/m3 smectite. The implications of clay evolution are possibly not restricted to diagenetic and incipient metamorphism conditions. The thermal breakdown of smectite is generally assumed to occur at 100-150°C in K-rich sedimentary rocks. However, smectite is observed to crystallize at much higher temperature conditions in K-poor geothermal systems, and various experiments have shown that the dehydration of smectite is shifted at higher temperature with increasing pressure (e.g. Huang et al., 1994; Wu et al., 1997).
We have developed a macroscopic thermodynamic model for di- and trioctahedral smectites and illite, which reproduces the experimentally observed $3 \rightarrow 2 \rightarrow 1 \rightarrow 0$ water-layer transitions and volume changes associated with increasing temperature or decreasing aH_2O, and the stability and compatibility relations of smectite with other minerals at high temperature and pressure condition. The model has been used to calculate by energy minimisation the stability conditions of clays from the conditions of early diagenesis to blueschist facies conditions, in pelites and in the altered oceanic crust. The results show that in contrary to the common assumptions, the stability of clays does not depend on temperature only. The hydrostatic pressure conditions, the Pfluid/Plithostatic ratio and the rock bulk composition are first-order parameters that control the conditions of smectite breakdown into illite, mica and chlorite. Strong and abrupt volume changes and water release from the upper altered oceanic crust are predicted to occur within the sismogenic zone up to 300°C. The results of calculation suggest a possible role of clay reactions and dehydration in the onset of < 30 km seismicity in subduction zones.