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GRANT:

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TITLE:

Experimental Investigation of Kinetics and Rheology During Diagenesis

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Objectives: To determine the dehydration rate of laumontite and its effect on the frictional rheology of laumontite.

Project Description: Two processes of enormous economic consequence occur within the upper to middle crust: the formation, migration, entrapment, and degradation of hydrocarbons, and hazardous seismicity. Substantial scientific evidence suggests that both these processes are influenced by devolatilization reactions during diagenesis. However, surprisingly few laboratory studies have been conducted on materials actively undergoing low-grade metamorphism or diagenesis. Because of this, there exists no suitable basis for understanding the rates at which devolatilization occurs, and what effects this process has on deformation at shallow to moderate depths in the crust.

We are conducting a coordinated deformation and kinetic study of an important devolatilization reaction: the breakdown of laumontite. Laumontite is a common zeolite whose equilibrium phase relations and room-temperature frictional behavior are well understood. Besides serving as a model system for more complicated rocks, laumontite is an important mineral in its own right, particularly for hydrocarbon fields in sandstones and for fault zones in the crust. Hydrostatic experiments are being conducted to investigate (1) the kinetics and mechanism of laumontite dehydration, and triaxial deformation experiments will enable characterization of (2) the effect of differential stress on the reaction and (3) the effect of synkinematic dehydration on the mechanical behavior of rock. We anticipate results of significant import for hydrocarbon exploration and recovery and for understanding the strength and seismic potential of crustal fault zones.

Results: The rate and mechanism of a key diagenetic reaction, laumontite $\rightarrow$ wairakite + H_2O , has been determined in experiments as long as 3 months at $P_{H_2O} = 100$ MPa and temperatures of 350–450 °C. In the lower temperature range, 350–400 °C, nucleation of wairakite occurred on the smallest laumontite fragments in the starting material. Growth then proceeded by the dissolution of large laumontite grains, transport within the fluid, and precipitation of euhedral-subhedral wairakite. At higher temperatures, 425 and 450 °C, each sample contains two product phases: wairakite and an unidentified plagioclase-like phase. The plagioclase-like silicate was stabilized by the uptake of Na and formed early, as ~ 10 μm wide skeletal grains along laumontite grain boundaries. The wairakite grains subsequently nucleated on and grew into the interiors of large laumontite grains.

Nucleation rates at 425–450 °C were 10–100 wairakite grains per square meter of laumontite surface per second. Growth rates varied from 1.5×10^{-11} m/s at 350 °C to 2.1×10^{-10} m/s at 450 °C; the low-temperature data can be fit with an apparent activation energy of 72 ± 13 kJ/mol and a pre-exponential 'interface jump distance' of $\sim 1 \times 10^{-18}$ m. This activation energy and these growth rates are comparable to those calculated by Walther and Wood (1984) to characterize interface-controlled reactions in silicates under H_2O -saturated conditions. Our data predict transformation rates for geologic conditions that are too fast to account for the commonly observed incomplete natural reaction of

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laumontite $\rightarrow$ wairakite, indicating that transformation in nature must be limited by slower nucleation rates or by slower intergranular diffusion—perhaps as a result of lower H_2O activity or slower heating rates.

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Keywords

Laumontite, devolatilization, kinetics.