

Hydration Dynamics of Swelling Clays: Intercalation versus Percolation

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Introduction: The hydration of swelling clays is a complicated problem, and is also of technological importance because of the widespread use of clay slips and drilling muds [1]. The unique rheological properties of clays derive partly from their plate-like morphology and partly from the strong interactions with water, the latter being determined primarily by microscopic properties such as crystal structure and surface charge. As a consequence, hydration of swelling clays depends partly on the ability of water to intercalate into the silicate layers, and partly on percolation through the nanoscale pore structure produced by the clay particles. In most studies so far, these two effects are not distinguished from each other.

Results: To properly identify the effects of intercalation and percolation in clays, we have performed x-ray scattering studies of pressed samples of synthetic Na fluorohectorite, which are aligned along the stacking direction. Bragg peaks at d-spacings corresponding to dry and water-intercalated clays are monitored as a function of time, while hydration is controlled by temperature and relative humidity (Fig. 1).

In a humid atmosphere, hydration of a bulk sample begins when the temperature is reduced below 130°C (Fig. 2 [right panel]). The intensity of the dry (001) peak decreases steadily with time, as the volume of clay occupied by water increases. As long as $T > 60^\circ\text{C}$, hydration proceeds slowly (requiring >60 hours for the peak intensity to fall to $1/e$ of its initial value). When the temperature is dropped below 60°C , the peak intensity drops much more quickly, with a time constant of about four hours. For $T < 45^\circ\text{C}$, the time constant decreases to 0.66 hours.

One possible explanation for the two-stage hydration is that high temperature hydration may be limited by diffusion of water into pore spaces between the micron-sized clay platelets. To test this assumption, we compared the bulk results to similar measurements made from the clay surface (not shown), where water can enter the interlayer spaces directly in the volume sampled. In this case, fast hydration begins at a higher temperature ($T < 55^\circ\text{C}$). More complete temperature-, humidity-, time- and composition-dependent studies are underway, and will form a foundation from which to better understand the clays' complicated phase behavior.

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References: [1] J. O. Fossum, Physica A, in press.

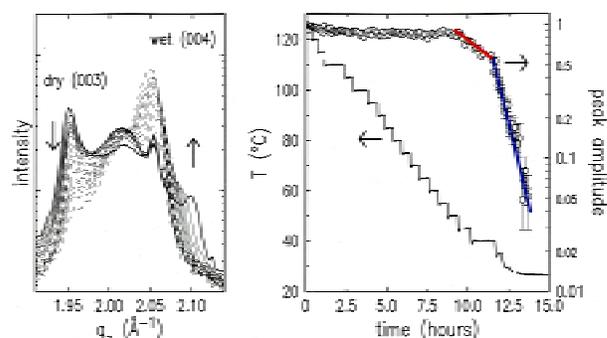


Figure 1. *Left panel:* X-ray intensity (arbitrary log scale) near the (003) and (004) peaks of dry and hydrated regions of the clay. Traces are taken at intervals of ~ 1 min. during hydration. *Right panel:* time dependence of the intensity of the dry (001) peak during hydration of a bulk sample (circles, right axis), controlled by the steps in temperature (solid line, left axis). Colored guidelines in the x-ray data highlight the two time scales that are observed for hydration in different temperature regions.