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Anatomy of a metabentonite: Nucleation and growth of illite crystals and their coalescence into mixed-layer illite/smectite

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Abstract

The illite layer content of mixed-layer illite/smectite (I/S) in a 2.5 m thick, zoned, metabentonite bed from Montana decreases regularly from the edges to the center of the bed. Traditional X-ray diffraction (XRD) pattern modeling using Markovian statistics indicated that this zonation results from a mixing in different proportions of smectite-rich R0 I/S and illite-rich R1 I/S, with each phase having a relatively constant illite layer content. However, a new method for modeling XRD patterns of I/S indicates that R0 and R1 I/S in these samples are not separate phases (in the mineralogical sense of the word), but that the samples are composed of illite crystals that have continuous distributions of crystal thicknesses, and of 1 nm thick smectite crystals. The shapes of these distributions indicate that the crystals were formed by simultaneous nucleation and growth. XRD patterns for R0 and R1 I/S arise by interparticle diffraction from a random stacking of the crystals, with swelling interlayers formed at interfaces between crystals from water or glycol that is sorbed on crystal surfaces. It is the thickness distributions of smectite and illite crystals (also termed fundamental particles, or Nadeau particles), rather than XRD patterns for mixed-layer I/S, that are the more reliable indicators of geologic history, because such distributions are composed of well-defined crystals that are not affected by differences in surface sorption and particle arrangements, and because their thickness distribution shapes conform to the predictions of crystal growth theory, which describes their genesis.

Keywords: Illite, smectite, diagenesis, mixed-layer clay, bentonite, metabentonite, crystal growth