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K-Ar dating and $\delta^{18}O$-δD characterization of nanometric illite from Ordovician K-bentonites of the Appalachians: Illitization and the Acadian-Alleghenian tectonic activity

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Abstract

Nanometric (<0.02, 0.02–0.05, 0.05–0.1, 0.1–0.2 μm) illite fractions were separated from K-bentonite samples from northwestern Georgia, and studied by X-ray diffraction, oxygen and hydrogen isotope geochemistry, and K-Ar dated to more tightly constrain the tectono-thermal history of the Appalachian orogeny. Their XRD patterns are very similar for a given sample with respect to the peak shapes and positions. They are ordered illite-smectite mixed layers with only small variations in the relative proportions of illite and smectite interlayers. The illite crystal thickness distributions also are very homogeneous across the various size fractions of the same sample, but crystallite thickness varies from sample to sample. It can be concluded from the α-β^2 diagram that illitization occurred in all fractions by simultaneous nucleation and crystal growth, except for one sample. In that sample, a period of growth without nucleation was detected on top of the nucleation and growth episode.

The K-Ar ages organize into two isochrons, the first at 319.9 ± 2.0 Ma with an initial $^{40}Ar/^{36}Ar$ ratio of 271 ± 66 Ma, and the second at 284.9 ± 1.2 Ma with an initial $^{40}Ar/^{36}Ar$ ratio of 310 ± 44. One data point above the older isochron and three between the two isochrons suggest a detrital contamination for the former separate and a possible further generation of nanoparticles for the three others. The samples with the older crystallization age consist of illite and illite-rich mixed-layers, and those with the younger age contain smectite-rich mixed-layers without illite, or illite-enriched illite-smectite mixed-layers. The K-Ar ages fit the age trends published previously for similar K-bentonites with regional age patterns between 240 and 270 Ma in the southwestern region, between 270 and 300 Ma in the central zone and the southern Appalachians, and between 315 and 370 Ma in the northernmost.

Each of the two generations of illite crystals yields very consistent $\delta^{18}O$ (V-SMOW) values at 17 ± 1‰ for the older and at 21 ± 1‰ for the younger. If crystallization temperatures of the nanometric illite were between 100 and 200 °C, as suggested by microthermometric determinations, the hydrothermal fluids had $\delta^{18}O$ values of 4 ± 1‰ in the Dalton district and of 8 ± 1‰ in the Lafayette, Trenton, and Dirtseller districts at 100 °C, and of 11 ± 1 and 15 ± 1‰ in the same locations at 200 °C, probably because the water-rock isotope exchanges at elevated temperature occurred in rock-dominated systems. The $\delta^{18}O$ of the fluids remained unchanged during local crystal growth, but varied depending on the geographic location of the samples and timing of illitization. The δD (V-SMOW) values of the different size fractions do not provide consistent information; they range from –70 to –45‰ for most nanometric and micrometric fractions (V-SMOW), but with no apparent coherent pattern.

Nanometric illite-rich crystals from K-bentonite that underwent tectono-thermal alteration yield constant ages, constant clay mineralogy, constant crystallite size distributions for all of the nucleating and growing illite-type crystals of each sample, as well as constant $\delta^{18}O$ values implying constant fluid chemistry, all pointing to geologically sudden crystallization.

Keywords: Nanometric "fundamental" particles, XRD mineralogy, K-Ar dating, $\delta^{18}O$ and δD geochemistry, Ordovician K-bentonites, U.S. midcontinent, Acadian/Alleghenian orogeny