Transformation of Smectite to Illite in Bentonite and Associated Sediments from Kaka Point, New Zealand: Contrast in Rate and Mechanism

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Abstract: Smectite and mixed-layer illite/smectite (I/S) in Triassic heulandite-rich bentonite from Kaka Point, New Zealand, have been investigated by scanning electron microscopy (SEM), transmission electron microscopy/analytical electron microscopy (TEM/AEM) and X-ray diffraction (XRD) for comparison with matrix phyllosilicates in closely associated siltstones and analcimized tuff. Samples that were treated to achieve permanent expansion showed that some smectite in bentonite occurs as curved packets of wavy 10.5- to 13-Å layers enveloping relict glass shards, the centers of which consist of an amorphous clay precursor. The dominant clay minerals in bentonite are smectite-rich randomly disordered (R0) I/S with variable proportions of 10-Å illite-like interlayers, only locally organized as 1:1 ordered (R1) I/S. R0 I/S was also observed in separate packets retaining the detailed texture of packets that replaced shards. Such relations are consistent with a "solid-state"-like, layer-by-layer replacement of original smectite layers by illite-like layers with partial preservation of the primary smectite texture, in contrast to textures observed elsewhere, such as in Gulf Coast mudstones. The smectite, as in other examples in marine sediments, has K as the dominant interlayer cation, suggesting that precursor smectite may be a major K source for reaction to form illite.

Only a small proportion of illite (35%) occurs in mixed-layer smectite-rich I/S in bentonite and the dominant trioctahedral phyllosilicate is disordered high-Fe berthierine, implying that little mineralogical change has occurred with burial. This contrasts with observations of closely associated siltstones and analcimized tuff, which contain well-defined packets of illite and chlorite but which have no detectable matrix smectite component. These data imply that the rate of transformation of smectite to illite is much slower in bentonites than in associated sediments of the same burial depth and age. Such relations emphasize the significance of factors other than temperature, (e.g., organic acids, permeability and pore fluid compositions) in affecting the rate and degree (and perhaps mechanism) of transformation of smectite to illite.

Key Words: Analcimized Tuff • Bentonite • Berthierine • Illite • Kaka Point • Mixed-layer I/S • New Zealand • Siltstone • Smectite • Zeolite Facies

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