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Intracrystalline boron isotope partitioning in illite-smectite: Testing the geothermometer

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Abstract

Intracrystalline B-isotope differences of ~40‰, are observed between the interlayer and tetrahedral crystallographic sites of interstratified illite-smectite (I-S). We tested the hypothesis that partitioning of B-isotopes between these sites could provide a low-temperature, single-mineral geothermometer. Samples studied include a metabentonite transected by a dike in the Cretaceous Pierre Shale (200–500 °C), buried mudstones from the Eocene Wilcox Formation (60–125 °C), and I-S products from hydrothermal experiments (300–350 °C). Different reaction kinetics are represented by these different sample sets, therefore results test the equilibrium partitioning of B in the interlayer vs. tetrahedral sites.

In all samples, interlayer $\delta^{11}B$ values are isotopically heavier than the tetrahedral $\delta^{11}B$. Because ^{11}B prefers trigonal coordination, we infer that $B(OH)_3$ dominates the interlayer sites. Within each sample set, the intracrystalline differences are greatest (20–40‰) in the most expanded I-S (i.e., smectite-rich), and approach 0 as illitization increases. There is good correlation ($R = 0.84$) between the interlayer $\delta^{11}B$ (calculated by mass balance) and water $\delta^{11}B$ indicated by the established maximum temperature of each sample. These results suggest that the interlayer sites of I-S preserve the B isotopic composition of water at the temperature that produced the authigenic illite. Direct measurements of interlayer $\delta^{11}B$ equilibrated with water of known $\delta^{11}B$ are needed to refine the relationship with temperature, but the existing data indicate the following temperature dependent relationship: $T\,(°C) = (\delta^{11}B_{\text{tetrahedral}} - \delta^{11}B_{\text{interlayer}} + 30)/0.05$.

Keywords: Boron isotopes, illite-smectite, isotope equilibrium, intracrystalline geothermometer