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Significance of the depth-related transition montmorillonite-beidellite in the Bouillante geothermal field (Guadeloupe, Lesser Antilles)

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Abstract

The crystal structure and crystal chemistry of dioctahedral smectites in high-enthalpy geothermal systems were investigated through samples collected in two wells drilled in the Bouillante geothermal area to understand the factors that control their vertical variation. Smectites were examined by optical and scanning electron microscopy, electron microprobe analysis, X-ray diffraction (XRD), Fourier transform infrared spectrometry (FTIR), and oxygen-isotope analysis. Smectites predominate within the upper part of the drill holes (up to 260 m depth; temperature range: 67–163 °C). The XRD, FTIR, and chemical microanalyses clearly demonstrate a transition from montmorillonite to beidellite with increasing depth and temperature that proceeded through interstratification of beidellite-like and montmorillonite-like layers. Montmorillonite predominates at temperatures below 100 °C, whereas beidellite predominates between 110 and 163 °C. However, this transition is not explained by a thermally controlled beidellitization process but appears to be related to hydrothermal fluids from which these smectites precipitated. The $\delta^{18}O$ values of the fluids that equilibrated with smectites (–3.3 to 0.4‰) indicate that beidellitic smectite precipitated from the hot geothermal fluid associated with minor amounts of residual solutions resulting from local boiling. In the same way, montmorillonitic smectite precipitated from reacting solutions whose origin lies in the phreatic water table (±seawater contribution) associated with minor amounts of liquids resulting from the condensation of vapors escaped from the boiling zones. The mixing rate of geothermal fluid with meteoric waters exerted a major influence on the montmorillonite vs. beidellite ratio of the smectite material as underlined by the irregular depth-related smectite transition.

Keywords: Beidellite, montmorillonite, crystal chemistry, crystal-structure, oxygen isotope, high enthalpy geothermal field, Bouillante, Guadeloupe