Kaolinite-to-chlorite conversion: three reaction pathways in a single system

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Résumé

The kaolinite-to-chlorite conversion is one of the chloritization processes occurring in low-temperature diagenetic and hydrothermal systems. The mechanism of this mineralogical transformation remains under debate, with several hypotheses proposed: direct transformation, conversion via berthierine as intermediate phase, or direct formation of berthierine/chlorite mixture – either through dissolution-recrystallization, solid-state transformation, or a combination of both. In this context, each documented occurrence of kaolinite-to-chlorite conversion provides an opportunity to shed new light on and further this discussion. Studying Carboniferous shale–crosscut by large quartz-kaolinite-carbonate veins–from the mining basin of northern France, we report an uncommon kaolinite-sudoite-Fe-rich chlorite assemblage. This assemblage occurs as 20 μm-wide chlorite fringes along interfaces between the shale and the veins, or as kaolinite-chlorite pockets within the veins, situated between quartz or ankerite crystals. Such textures are often interpreted as early chlorite lining of fractures, subsequently filled with quartz, kaolinite or carbonates. However, Scanning Electron Microscope (SEM-EDX) observation, Transmission Electron Microscope observations and analysis on Focused Ion Beam cut sections (FIB/TEM-EDX), and X-ray near Edge Spectroscopy (XANES) data (from Scanning Transmission X-ray microscope, STXM) all indicate that the chlorite is a later phase, resulting from the interaction between the shale and the Si,Al-rich vein material. Each pocket of kaolinite acts as a microsystem: kaolinite can transform into dickite (a polymorph) when completely isolated by quartz, into Fe-rich chlorite when located near the shale, or into Mg-rich sudoite when enclosed within a carbonate-rich part of the vein. The spatial distribution of these microsystems – separated by only a few millimeters – plays a critical role in the transformation pathway, and demonstrates that fracture infill predates the kaolinite-to-chlorite transformation. These kaolinite–Fe-chlorite and kaolinite–Mg-sudoite conversions thus appear to be controlled by the local geochemical conditions (minerals and fluids), and proceed via a dissolution–recrystallization mechanism. In some specific locations, sudoite itself transforms into Fe-chlorite, but in this case through a unique and evident diffusion process. These observations have important implications, particularly for understanding the P–T–X evolution of the system, and for contributing to the ongoing discussion on the stability and conversion processes of these mineral phases.

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