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The role of parent lithology in nanoscale clay-mineral transformations in a subtropical monsoonal climate

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Abstract

Clay minerals are among the most important reactive components of soil systems, acting as a bridge linking organic and inorganic components. Lithology is a key factor in clay-mineral genesis and transformation, yet it has received scant attention to date at the nanoscale. Inferences regarding pedogenic clay-mineral transformations based on X-ray diffraction (XRD) are sometimes speculative, whereas mineralogic relationships documented by high-resolution transmission electron microscopy (HRTEM) are more robust due to direct evidence from lattice-fringe observations. In this contribution, the mineralogical and geochemical characteristics of four soils derived from different parent rock types (a gneiss, an Fe-rich siltstone, a sandstone, and a dolostone) from subtropical China were determined using HRTEM, XRD, and geochemical elemental data. The predominance of 2:1 clay minerals and kaolinite in the investigated soils is typical of subtropical climatic settings. Lattice-fringe images suggest the prevalence of topotactic transformations during clay-mineral alteration. Two distinct alteration pathways were observed in the investigated soils, one starting with chlorite and the other with illite, with convergence of mineralogic compositions toward kaolinite and crystalline iron and aluminum (oxyhydr)oxides. In the early stages of weathering, chlorite transformed into expandable clays through a continuous, solid-state mechanism with corrensite and/or randomly interstratified chlorite-vermiculite/chlorite-smectite as intermediate products. Unlike chlorite, which tends to form a 1:1 regularly interstratified phase, the weathering of illite commonly starts at layer edges. Under subtropical monsoonal climates, the precursor minerals in host rocks and aeolian materials determine the starting composition and, to a certain extent, the trajectory of clay-mineral transformation over time. With advanced weathering, mineralogic convergence toward kaolinite and Fe/Al-(oxyhydr)oxides tends to obscure the initial substrate composition. This study advances our understanding of the role of parent lithology in clay-mineral evolution at the nanoscale.

Keywords: Pedogenesis, chemical weathering, HRTEM, smectite, chlorite, corrensite