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Formation and transformation of clay minerals influenced by biological weathering in a red soil profile in Yangtze River, China

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ABSTRACT

Organic acids involved in biological weathering exhibit a strong affinity toward aluminum, thereby facilitating mineral decomposition and leading to the preferential loss relative to immobile elements. Consequently, the process impedes the reprecipitation of clay minerals and affects the congruency of mineral weathering and elemental cycling. However, the effects of organic acid-dominated biological weathering on the composition and structure of clay minerals in natural systems, including sediments, sedimentary rocks, and soils, remain unclear. In this study, we focused on a reticulate laterite profile from the middle reach of the Yangtze River in China, which is characterized by distinct redox features. We conducted a detailed investigation into various indicators, including clay mineral content and crystallinity, iron minerals, weathering intensity, weathering congruency, and biotic weathering proxies along the profile. Our findings reveal a gradual decrease in weathering intensity from the bottom to the top of the profile, concomitant with a transition from warm, humid to arid conditions. The clay-mineral characteristics show significant differences between the upper modern soil layer, which is nearly devoid of smectite, and the lower plinthic horizon, which is almost entirely devoid of vermiculite. Enhanced biotic weathering was associated with organic acid-driven congruent weathering, favoring the preservation of illite and inhibiting its transformation into kaolinite. However, in the lower part of the profile, there was no apparent coupling between clay mineral changes and congruent weathering. This observation suggests that different organic acids dominate weathering processes in the upper and lower layers. Moreover, the alkaline environment and frequent wetting and drying cycles in the lower soil layers favored the formation of smectite. Compared with biotic weathering, the transformation of clay minerals showed a closer association with the overall trend in changes in weathering intensity, suggesting that both biotic and abiotic weathering factors influence the genesis and transformation of clay minerals. The influence of biotic weathering on the composition and structure of clay minerals in natural systems could have significant implications for global elemental cycling, warranting further exploration.

Keywords: Clay minerals, biological weathering, incongruent weathering, weathering congruency, illite, subtropical China, Yangtze River, China