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Quantification of the clay mineralogy of a typical Vertic Planosol in south-western Ethiopia: impact on soil formation hypotheses

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Planosols, characterised by a surface horizon abruptly overlying a dense subsoil, are a very common soil type in Ethiopia. The origin of the abrupt textural change is still often debated in literature. One of the processes frequently put forward to explain the coarse textured material in the topsoil, is 'ferrolysis': an oxidation-reduction sequence driven by bacterial decomposition of soil organic matter, resulting in the destruction of open 2:1 clay minerals. Recent studies of representative profiles of Vertic Planosols in south-western Ethiopia indicate that these these soils are composed of a weathered volcanic ash layer deposited on top of a deflated vertic subsoil, which refutes the ferrolysis hypothesis. To strengthen the geogenetic origin of these profiles, a quantitative mineralogical analysis of the clay fraction was undertaken.

Textural analysis of the fine earth fraction ($<$2mm) was done using successive sedimentation after removal of organic matter with H_2O_2 at 60˚C. The separated clay ($<2\ \mu$m) was further subdivided in two aliquots, one of which was DCB-treated to remove Fe oxides. Sequential fractionation using centrifugation was done on 1g aliquots of both untreated and pretreated clay fractions yielding four sub-fractions (2-0.2μm, 0.2-0.1μm, 0.1-0.05μm and $<0.05\mu$m). The $<2\mu$m fractions and their sub-fractions were Ca^{2+}-saturated and oriented samples were prepared for XRD analysis. X-ray diffraction patterns were recorded before and after glycolation. Additionally, an in-situ analysis was performed on the clay fractions ($<2\mu$m) by heating the samples while a linear detector recorded an XRD pattern every 4 seconds over a range of 20˚ 2θ.

Results of the sequential fractionation revealed a strong aggregation of clay particles in the bleached horizon, while the effect of aggregation was far more limited in the vertic horizon. This is believed to be related to the dispersed, impregnative nature of free iron oxides in the bleached horizon, compared to the segregated nature of the sharp, nodular concretions found in the vertic horizon. The in-situ XRD analysis revealed only minor changes in dehydroxylation temperatures between untreated and pretreated samples, indicating the pretreatment did not significantly alter the mineral lattices. Multi-specimen, full-profile fitting of XRD patterns revealed no significant qualitative difference between the bleached and vertic horizons. Interestingly, in good agreement with the proposed neoformation of kaolinite in these soils, it was observed that the $<0.05\mu$m fraction is largely composed of a complex mixture of kaolinite and smectite mixed-layer minerals. Quantitatively, the relative proportions of the mineral phases present, together with the proportions of the sub-fractions, change with depth, influencing the net quantitative result, and explaining the observed differences in the XRD patterns of the clay fraction.

These results confirm the conclusion that the ferrolysis process cannot be considered responsible for the abrupt textural change between both horizons, as this would have resulted in a mineralogical differentiation. Additionally, a more detailed view on the mineralogical composition of the clay fraction of a typical Vertic Planosol has been obtained, providing insights in the complex nature of these duplex soils.