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Mesoproterozoic lacustrine clay-mineral record of weathering prior to greening of the continents

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Vascular plants accelerate the weathering of clay minerals from silicate rocks, promote carbon burial, and deepen soil horizons. The evolution of land plants has therefore long been considered a step-change to the continental weathering regime, with flow-on impacts on atmospheric composition and temperature. This idea is challenged by bulk geochemical and mineralogical studies that suggest that the composition of sedimentary sequences has remained largely unchanged since the formation of the first continents. However, a major shortcoming of conventional bulk rock approaches is that they are unable to differentiate sedimentary constituents and geochemical signals formed as a result of subaerial weathering versus those from post-depositional (burial) alteration. This research investigates the clay mineralogy of Precambrian lacustrine mudrocks from the Wester Ross Supergroup (“Torridonian” strata of NW Scotland), which record a snapshot of weathering conditions prior to the greening of the continents. We employ a novel petrographic approach, combining SEM-EDS mineral mapping and TEM imaging, permitting the quantitative differentiation of detrital versus diagenetic phases, overcoming the limitations of previous studies. The clay mineralogy is predominantly chlorite and illite, while quartz and feldspars dominate the remaining clastic component. We find µm-size feldspar grains are anomalously abundant and an absence of chemically weathered clays as detrital clays are consistently of physical weathering origin. We interpret many pre-existing detrital minerals have been converted to illite and chlorite via burial alteration, forming products of post-depositional 'subsurface' weathering. This indicates subaerial weathering was controlled by physical mechanisms, which is in contrast to mudstones deposited in vegetated Phanerozoic environments. Combined with a near absence of terrestrial mudrock deposited in the Proterozoic [1], these findings argue for a weak chemical weathering regime prior to the development of land plants. We conclude that the lack of a plant weathering signal in bulk rock studies is due to the pervasive post-depositional alteration of chemically immature sediments during post-depositional 'subsurface weathering'. This has implications for bulk rock studies that use the sedimentological record to investigate terrestrial weathering, as minerals formed by burial alteration can produce similar signals to minerals formed subaerially.

[1] McMahon and Davies (2018), *Science* 359(6379), 1022-1024.