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Differentiation between Fe and Sc in phyllosilicate clays as a proxy for the redox state of the weathering front

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The redox state of the weathering front plays a critical role in determining the structure and functions of the Earth's critical zone. Characterizing the redox state of the weathering front, however, is challenging due to the thick regolith coverage that generally prevents direct observation. The heterogeneity of parent rock lithology and development of fluid/gas-conductive macro fractures would also result in small scale changes in the redox state at the weathering front. This study differentiates Fe and Sc in phyllosilicate clays as a method to assess the redox state of the weathering front on a catchment scale.

The method is based on the fact that Fe released during weathering is rapidly oxidized into iron oxides and hydroxides while Sc is mainly incorporated into phyllosilicate clays in an oxidative weathering environment. In contrast, under a reductive weathering environment, the Fe^{2+} released by weathering is readily incorporated into the lattice of phyllosilicate clays together with Sc. Subsequent dissolution of phyllosilicate clays in the regolith would release the Fe and Sc into iron oxides and hydroxides congruently. Thus, the Fe/Sc ratio of phyllosilicate clays would keep its initial value at the weathering front regardless of subsequent alteration.

Catchments comprised of crystalline bedrock with contrasting lithologies in Hainan Island, China, were investigated to test the new proxy. The relatively thin regolith developed over mafic bedrocks compared to that developed over felsic bedrocks indicates lithological control on the redox state of weathering fronts. In catchments dominated by mafic bedrock, a substantial portion of Fe is released by weathering, relative to Sc, and is subsequently incorporated into primitive phyllosilicate clays. In contrast, only a small fraction of the Fe released by weathering is retained in the primitive phyllosilicate clays in felsic catchments.

The contrasting behavior of Fe between the mafic and felsic catchments indicates lithological control on the redox state of weathering fronts, and thus the partitioning of Fe between phyllosilicate clays and iron oxides/hydroxides. The new method provided by this study can be used to trace the redox state of weathering fronts for both the past and present-day conditions of critical zones of the Earth.

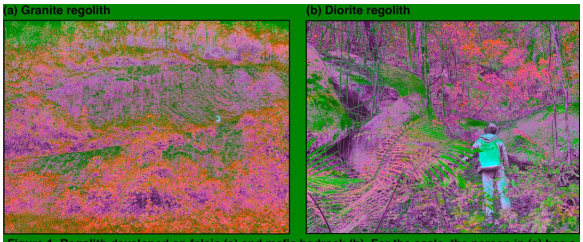

Figure 1. Regolith developed on felsic (a) and mafic bedrock (b). For the scale, the person in (a) has a height of 1.85 m and the person in (b) has a height of 1.72 m.