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Leveraging automated mineralogy analysis to assess paleosol chemical weathering

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Paleosol weathering commonly is characterized by an index of alteration determined from bulk rock elemental abundances. Although a variety of indices exist, they all essentially compare the proportion of immobile major elemental oxides associated with refractory minerals (mainly Al_2O_3 in phyllosilicate clays) to mobile major elements associated with labile minerals (i.e., CaO, Na_2O). Higher proportions of immobile major elemental oxides reflects more intense chemical weathering, which is used to infer warmer, wetter climate conditions. However, bulk rock alteration indices are known to be influenced by variability in particle size, effects of quartz dilution, and authigenic mineralization, which are challenging to account for when destructive analytical approaches are used. We tested a non-destructive method of assessing chemical weathering intensity using automated mineralogy analysis, which relies on SEM BSE imaging and EDS spectrum acquisition with automated matching of whole spectra to reference spectra to generate quantitative mineralogy estimates. Our case study focused on 9 Upper Pennsylvanian Spodosol samples from the Appalachian basin, and the dominant mineralogic group identified by automated mineralogy in all samples were phyllosilicate clays (50-85%). Six samples showed >20% feldspar: however, grain shape analysis indicates often micron-scale clay-sized grains with prismatic crystal habit were assigned a potassium feldspar spectra. This is due to the automated mineralogy algorithm identifying a mixed signal from sub-micron quartz/amorphous silica and illite in the X-ray volume as a feldspar x-ray spectrum. Furthermore, the Chemical Index of Alteration calculated from bulk elemental estimates of automated mineralogy results ranged from ~60-65, and A-CN-K ternary plots indicate samples were influenced by K-metasomatism. Using an algorithm that assigns automated mineral identification on the basis of both whole-spectrum matching and particle morphology attributes (including grain shape/crystal habit and size), we can better constrain mineralogical interpretation of fine-grained sedimentary lithologies. This allows automated mineralogy analysis to be used in a new approach for assessing weathering intensity by analyzing the proportion of mobile versus immobile elements in prismatic grains versus equant grains across a distribution of grain sizes in a way that can mitigate or minimize known limitations to the accuracy of alteration indices (e.g., authigenic skins, K-metasomatism).