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Refractory element and titanium isotope constraints on volcanic parent material variability and elemental mobility in the Critical Zone

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Chemical weathering changes Earth’s surface environment through loss of mobile elements. To understand the extent of weathering, elemental mass losses are calculated by comparing a mobile element of interest to an immobile or “index” element in the weathered soil and un-weathered parent material. For accurate mass loss calculations, it is critical that the immobile element is conservative in the soil environment, and total elemental variability of the parent material is well constrained. Titanium (Ti) is commonly used as an ‘index’ element as well as tantalum (Ta) and niobium (Nb). However, the true mobility or variability of Ti in complex parent materials is not well understood, which results in uncertainty in mass loss determinations. Further, it can be difficult to uniquely identify parent material in highly weathered and vegetated settings.

In volcanic landscapes, parent material can be complex due to extended and overlapping eruptive events. To infer parent material variability in late-stage Hawaiian volcanics, we use systematic geochemical relationships to calculate initial parent material elemental concentrations and elemental mobility. We test the immobility of Ti-Nb-Ta system in on a climate transect underlain by transitional tholeiitic to alkalic basalts by measuring TiO_2, Nb, Ta, as well as $d^{49}Ti$ in both soil regolith samples and fresh volcanic material. Nb/Ta ratios are consistent with a value of 16.9±02 in all measured volcanic and regolith samples. TiO_2/Nb ratios vary from 0.007 to 0.03 across the magmatic sequence. Using Ti isotopic analysis, we show there is no fractionation in Ti isotopes between regolith and parent material volcanics. $d^{49}Ti$ increases from 0.056 ‰ to 0.816‰ as TiO_2/Nb decreases. The fresh volcanics follow the trend expected for Ti fractionation resulting from oxide saturation; the highly weathered soils follow the same trend in $d^{49}Ti$ - TiO_2/Nb space. The magmatic $d^{49}Ti$ signatures are inherited by the soil and unaltered during weathering. We can derive original un-weathered parent material geochemistry using $d^{49}Ti$ and/or TiO_2/Nb ratios which are conserved between parent and soil. This technique can be used to constrain parent material in environments where it has been previously impossible to constrain mass losses.