Geophysical Research Abstracts
Vol. 17, EGU2015-3998, 2015
EGU General Assembly 2015

Using Uranium-series isotopes to understand processes of rapid soil formation in tropical volcanic settings: an example from Basse-Terre, French Guadeloupe

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Uranium-series isotopes fractionate during chemical weathering and their activity ratios can be used to determine timescales and rates of soil formation. Such soil formation rates provide important information to understand processes related to rapid soil formation in tropical volcanic settings, especially with respect to their fertility and erosion. Recent studies also highlighted the use of U-series isotopes to trace and quantify atmospheric inputs to surface soils. Such a process is particularly important in providing mineral nutrients to ecosystems in highly depleted soil systems such as the tropical soils.

Here, we report U-series isotope compositions in thick soil profiles (>10 m) developed on andesitic pyroclastic flows in Basse-Terre Island of French Guadeloupe. Field observations have shown heterogeneity in color and texture in these thick profiles. However, major element chemistry and mineralogy show some general depth trends. The main minerals present throughout the soil profile are halloysite and gibbsite. Chemically immobile elements such as Al, Fe, and Ti show a depletion profile relative to Th while elements such as K, Mn, and Si show a partial depletion profile at depth. Mobile elements such as Ca, Mg, and Sr have undergone intensive weathering at depths, and an addition profile near the surface, most likely related to atmospheric inputs. (238U/232Th) activity ratios in one soil profile from the Brad David watershed in this study ranged from 0.374 to 1.696, while the (230Th/232Th) ratios ranged from 0.367 to 1.701. A decrease of (238U/232Th) in the deep soil profile depth is observed, and then an increase to the surface. The (230Th /232Th) ratios showed a similar trend as (238U/232Th). Marine aerosols and atmospheric dust from the Sahara region are most likely responsible for the addition of U in shallow soils. Intensive chemical weathering is responsible for the loss of U at depth, consistent with these observations of major element chemistry and mineralogy. Furthermore, U-series chemical weathering model suggests that the weathering duration from 12m to 4m depth in this profile is about 250kyr, with a weathering advancing rate of $\sim$30 m/Ma. The rate is also about one order of magnitude lower than the weathering rate ($\sim$300 m/Ma) determined by river chemistry for this watershed. In this profile, the augered core didn't reach the unweathered bedrock. Hence, the derived slow weathering rate most likely represents the intensive weathering of clay minerals, while the transformation of fresh bedrock to regolith occurs at much great depth beneath the thick regolith. The marine aerosols and atmospheric dust are important sources of mineral nutrients for highly depleted surface soils.