Weathering in Volcanic Terrains: Processes, Products and Implications

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Volcanic substrates are imposed on Earth's surface as constructional features that bury earlier deposits on varying time scales. Eruptions that ocurr in the same place on short timescales build deep relatively unweathered deposits whereas those that happen less frequently or spread over greater distances from earlier emplacements create surfaces that can be weathered for long periods prior to further burial. Mantle-plume eruptive centers provide well-spaced, different-age surfaces where we can study time- and climate-dependent weathering processes.

Volcanic ejecta and surface flows contain large amounts of void space that are filled with locally produced tephra or mineral aerosols. It is those fines that are initially weathered chemically due to high surface area relative to the host material. Accumulation of fines and their subsequent weathering lowers pore sizes and hydraulic conductivity. Thus flow paths start out with a strong vertical component shifting with time toward more lateral flow and development of a stream network.

Differences in water flux drives non-linear changes in weathering rate and depth of weathering with rapidly declining rates due to accumulation of relatively insoluble secondary products rich in silicon, aluminum and iron. Alkali and alkaline earth elements are lost very rapidly (mostly depleted after 20 ky weathering time). The pathways of seconday mineral synthesis are similar regardless of long-term water flux (primary --> short-range-order (SRO) --> halloysite & hemitite), although rates of secondary mineral transformation are enhanced in drier regions (10^4 yr) compared with wetter regions (10^5 yr) – wetting and drying enhances mineral ripening and passage through the metastable SRO phase.

SRO minerals drive the chemical behavior of soils in active volcanic terrains. These high surface area, hydrated metal and silicon nano-crystals (dominantly allophane and ferrihydrite) are chemically reactive forming inner-sphere complexes with trivalent metals, phosphorus and carbon. The average residence time of C in these soils is much longer than for most soils because of the mineral protection afforded by the SRO minerals – C residence time drops rapidly as mineral ripening occurs. In the early stages of volcanic weathering ecoystem nutrients are readily available but rapid leaching and accumulation of trivalent metals and high C/N organic products leads to profound infertility over longer timescales.