HOST-MINERAL WEATHERING AND REE REDISTRIBUTION DURING WEATHERING OF VOLCANIC ROCKS IN SEDENTARY LANDSCAPES: EXAMPLES FROM HAWAI'I AND GUATEMALA. M. A. Velbel[1], L. C. Patino[1], J. A. Wade[2], A. R. Donatelle[1] and J. R. Price[3], [1]Department of Geological Sciences, 206 Natural Science Building, Michigan State University, East Lansing, Michigan 48824-1115, USA (velbel@msu.edu; patinol@msu.edu; donatel4@msu.edu), [2]Department of Earth Sciences, Boston University 685 Commonwealth Ave., Boston, MA 02215, USA (jwade@bu.edu), [3]Department of Earth Sciences, P.O. Box 1002, Millersville University, Millersville, PA 17551-0302, USA (Jason.Price@millersville.edu).

Introduction: This study examines the weathering of volcanic rocks of the sedentary/relict/residual landscape/regolith association and illustrates how this regolith/landscape association and its geomorphic evolution influence the geochemical evolution of the regolith. Samples from six localities were examine for this study [1]. Spheroidally weathered basalt was sampled at three localities in SE Guatemala, and at one locality on each of three Hawai'ian islands (Hawai'i, Oahu and Maui).

Bulk-sample REE distribution: In sedentary/relict/residual landscapes, the rate of chemical weathering equals or exceeds the rate of physical erosion, and surface material consists of deeply weathered saprolite. Volcanic rocks of Plio-Pleistocene age from Hawai'i and Guatemala, in sedentary landscapes, have experienced spheroidal or corestone weathering in which corestones of minimally weathered rock are surrounded by concentric saprolitic shells and saprolite derived from the decomposition of the volcanic rock. These corestone–shell complexes are geochemical dynamic systems. Many major elements and some minor elements (REE) are depleted from the saprolitic portions of these regoliths. However, several of these minor elements (REE) are enriched in the inner portions of corestone-shell complexes, suggesting that these minor elements and REE leached from saprolite are transferred within the regolith to secondary minerals formed during incipient weathering of the corestones. The major elements and some of the minor elements are progressively lost from the system as the degree of weathering increases, producing a systematic decrease in concentration from the least weathered part of the system to the most weathered. However, several of the minor elements (e.g. REE) are re-distributed within the regolith, displaying more complex patterns of abundance.

The REE are mobilized to incipiently weathered portions of the corestones, where they are incorporated into secondary minerals, resulting in increased concentrations of these elements. The concentration pattern for the REE shows an initial increase during incipient weathering stages, and then a decrease as weathering progresses. As the weathering front moves inward into the corestone, these secondary minerals break down and the weathered rock acquires a similar REE composition to the initial composition of the lava flow. The overall pattern of REE distribution in sedentary regoliths suggests that REE leached from saprolite are transferred within the regolith to secondary minerals formed during incipient weathering. It is not until the most advance stages of weathering that these elements are mobilized out of the weathering system. REE-enriched corestones and rinds occur in major-cation-deplete saprolitic regoliths on basalts several million years old, suggesting that REE export from the weathered landscape is not entirely synchronous with major-element leaching.

Weathering relations of host phases: Hawai'ian basalts commonly contain olivine phenocrysts; plagioclase and pyroxene are common phenocryst phases in the SE Guatemalan basalts. Phenocrysts were examined from a slightly weathered corestone and its attached weathering rind at each of the localities on sedentary landscapes. Both core and rind bulk samples had enriched REE and a negative Ce anomaly, indicative of a slight to moderate degree of weathering [1]. All samples were examined by optical petrography, secondary and backscattered scanning electron microscopy (SSEM & BSEM, respectively) and energy-dispersive elemental analysis of polished thin-sections.

Olivine: Optical petrography of weathered vesicular basalt showed abundant olivine preserved with only slight staining of grain boundaries and trans-mineral fractures by ferruginous products. Numerous fine-scale parallel "beads-on-a-string" features occur in the immediate vicinity of trans-mineral fractures. SEM reconnaissance revealed individual funnel-shaped etch pits (each with a pointed end, that probably defines the dislocation around which the etch pit develops), and chains of funnel-shaped pits aligned and joined laterally along the shorter of the two geometric axes exposed by the intersection of the pits with the surface of the olivine (Fig. 2 in [2]). These etch pits range in size from less than 1 μm to 20 μm across. At high magnifications in the petrographic microscope, the "beads on an string" can be seen to be *en echelon* arrays of diamond-shaped etch pits, aligned and joined along the shorter of the two geometric axes visible in the cross-section view of the thin-section. SSEM &

BSEM of polished thin-sections reveal more detail, including widespread occurrence of arrays of micron- to submicron-scale etch pits that appear to be smaller-scale and more widespread near fractures than the larger occurrences visible by optical petrography. At more advanced stages of weathering, larger pits that penetrate the entire thickness of a thin-section are up to 80 µm in their longest dimension. Etch pits are devoid of weathering products, even though the etch pit arrays are within tens of microns of product-filled fractures. Olivines are not primary REE hosts in these core-stones, but product in the fractures includes REE-phosphates, implying REE import to the corestone's olivine from elsewhere in the regolith.

Pyroxene: Pyroxenes are among the primary REE hosts in the SE Guatemalan basalts. Pyroxenes in corestones from the best-studied of the SE Guatemalan localites show evidence of lenticular etch-pits in the earliest stages of weathering, followed by denticulated margins that form by coalescence of etch pits along fractures; products are absent at both these textural stages of weathering in pyroxenes. Both corrosion textures are difficult to detect using petrographic mi-croscopes, due to their small scale (ranging from 0.5-20 µm in longest dimension), they may appear as streaks or cracks (with smooth edges) within the crys-tals in optical microscopy, and are only distinct in BSEM. Fractures in pyroxenes, and weathering prod-ucts, increase in abundance and size from corestone to rind.

Summary: The REE are mobilized from the saprolitic portions of these regoliths to incipiently weathered portions of the corestones, where they are incorporated into secondary minerals, resulting in in-creased concentrations of these elements. REE-bearing primary minerals (e.g., pyroxenes) weather and may contribute to the overall ensemble of REE redis-tribution processes. Secondary REE host phases can be associated with incipiently weathered primary phases, despite the absence of REE in the primary mineral (e.g., secondary REE phosphates in minimally weathered olivine). The original source of P in this type of occurrence remains to be established.

References: [1] Patino L. C. et al. (2003) *Chem. Geol. 202,* 343-364. [2] Velbel M. A. (1993) *Amer. Mineral., 78,* 408-417.