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Volcanic islands as model systems to quantify pedogenic thresholds and determine their impact on Polynesian land-use

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Soils and weathering profiles are complex emergent features at the surface of terrestrial Earth. They form a boundary layer hosting the chemical and physical interaction of biology and hydrology with rock. Soil development derives from the dissipation of chemical energy through reaction with rock minerals; few of the original reactants survive, but they are replaced by secondary products unique to the weathering environment. Soil processes filter and transform gasses and liquids passing through them, which in turn leads to chemical and mineralogical evolution of the fabric of soil itself. Soil chemical reactions are controlled by a number of feedbacks that buffer the system from rapid changes in external inputs, however there are limits beyond which the chemical system rapidly shifts into a new chemical domain governed by different buffer reactions. Globally soil distribution patterns are underlain by specific soil process domains that are separated by pedogenic thresholds at points of domain failure. Considering how soil process domains and thresholds determine the global distribution of properties, which control everything from agricultural productivity to carbon sequestration is a primary research focus for modern biogeochemistry. Soils are complex systems, which makes it difficult to develop clear understanding of how specific driving factors control soil process domains. It is common therefore to develop model systems that allow us to tackle specific questions with fewer complications. Here I discuss the use of volcanic islands in the Pacific Ocean as a model system to study how pedogenic thresholds control phosphorus and calcium availability to plants. I then combine that knowledge with archeological information to understand how the geographic constraints imposed by these thresholds determined Polynesian land use and agricultural productivity. As Polynesians radiated across the Pacific they encountered islands that presented many different local environments ranging from reef protected lagoons and minimal high island terrain to high volcanic islands with still active volcanoes. They brought with them an agricultural starter kit, but from there on they needed to adapt to their new surroundings. They practiced two major types of intensive agriculture: non-irrigated dryland and flooded-field irrigated farming. Typically young islands had soils with rich nutrient stores, whereas older islands had depleted soils that were not productive. By contrast, young islands had few large valleys to support irrigated agriculture, whereas the older ones had broad valleys allowing development of highly productive irrigation systems. Thus cultivators in rainfed systems brought their crops to areas where near-surface rocks were still weathering and supplying nutrients such as calcium and phosphorus, whereas in irrigated systems flowing water brought the products of weathering to crops. The contrast had profound implications for the development of culture across Polynesia. Behind these anthropological observations lies an equally fascinating story about how dramatically different soil properties are produced by non-linear responses to environmental forcing. In this talk I will explore the pedology of volcanic islands and relate it to pre-industrial human land-use decisions.

Keywords: Soil Chemistry, Biogeochemistry, Andisols, Soils