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Basalt Leaching in Rapa Nui (Easter Island) Rock Gardens Favours Agricultural Surplus Production

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Introduction

Upon settlement of Rapa Nui, slash and burn forest removal and reduced faunal diversity caused major environmental changes including soil aridity (Louwagie et al. 2006; Mann et al. 2008), nutrient depletion (Stevenson et al. 2014), and limited erosion (Mieth and Bork 2005), all factors which could have posed a strain upon agricultural production.

However, the archaeological record presents evidence (Stevenson et al. 2006; Horrocks and Wozniak 2008; Mulrooney 2013; Stevenson et al. 2015) that the prehistoric Rapanui did not experience an ecologically based social demise but adapted agricultural techniques which enabled the surplus production necessary to support the quarrying of monumental lithic sculptures (*moai*) and platform structures (*ahu*). A plethora of archaeological studies evidence intensive wide-spread use of rainfall supported horticulture with technologic features including rock-walled gardens for wind protection (*manavai*) (McCoy 1976; Vargas et al. 2006), stone circled planting pits (Stevenson 1997), and lithic mulch for wind protection, moisture retention and thermal stability (Baer 2008; Stevenson et al. 1999; Stevenson et al. 2006; Wozniak 1999, 2003, 2018).

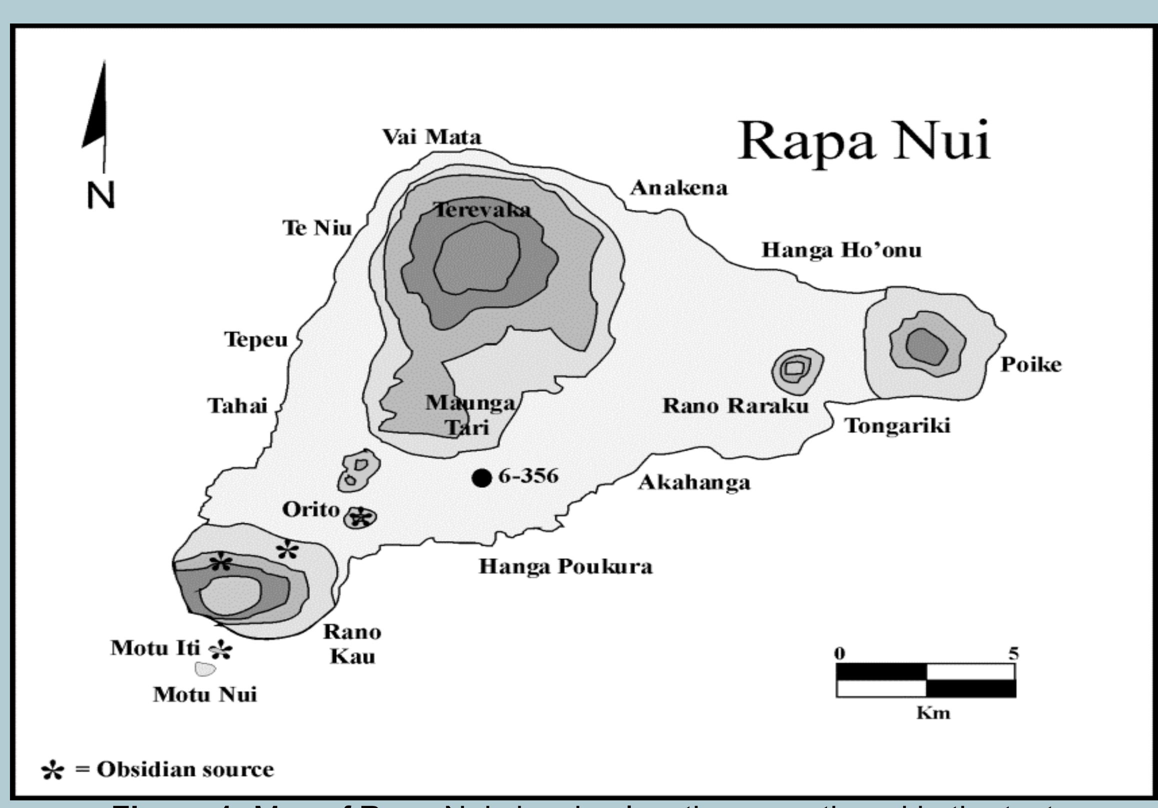

Figure 1: Map of Rapa Nui showing locations mentioned in the text.

Volcanic basalt based mineral fertilizers are often credited with strengthening soils through the dissolution of plant available nutrients vital to agricultural productivity (Fye et al. 2006; Anda et al. 2009; Lopes et al. 2014; Nunes et al. 2014; Ramos et al. 2014). Studies have indicated that higher levels of nutrients for plant growth, potentially derived from basalt dissolution, are present within gardens on Rapa Nui (Hunt and Lipo 2011; Ladefoged et al. 2010; Vitousek et al. 2014). However, with one exception, (e.g., Sherwood et al. 2019), these studies lack the supporting experimental evidence on mineral dissolution and their contribution to the rock garden nutrient pool.

Methodology

In an effort to provide evidential support for the process of basaltic mineral dissolution replenishing soil fertility and enabling productive plant growth in Rapa Nui rock gardens, a simulated leaching experiment was conducted to determine the elemental release rates from the basalt matrix and the availability of these elements for plant absorption. Ultimately, it is of interest to determine if soil nutrient enrichment through basalt leaching was enough to increase crop surplus and facilitate the construction of megalithic architecture.

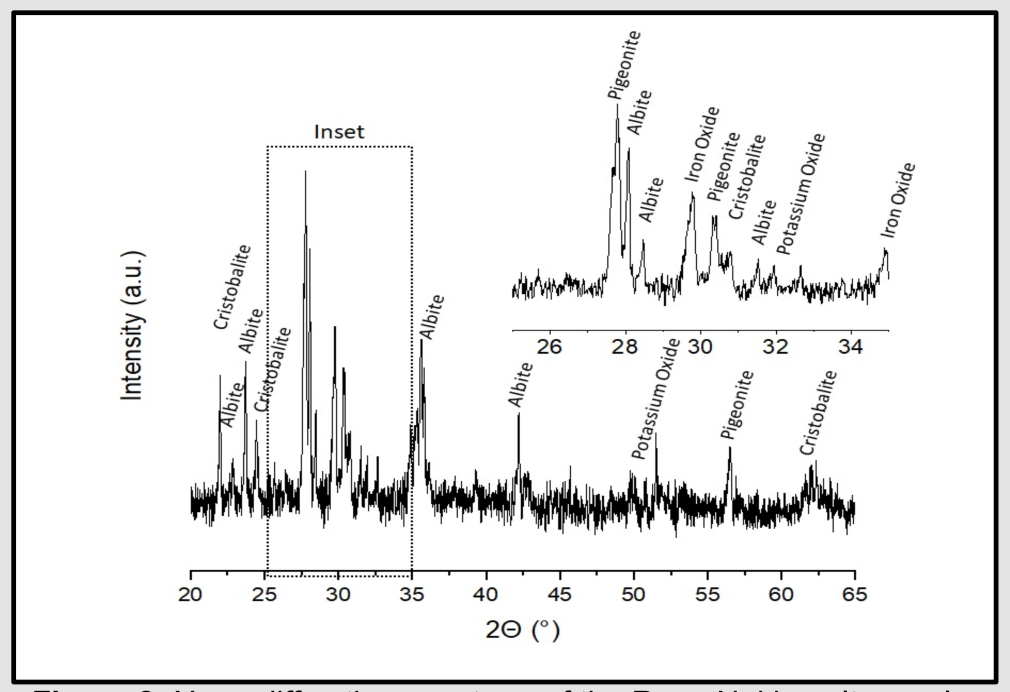

Figure 2: X-ray diffraction spectrum of the Rapa Nui basalt sample.

Sample slabs of basalt were cut from a parent rock [collected from the surface of an archaeological habitation site (6-356) in 1988 (Figure 1)] using an Ameritool circular saw with a Lapcraft diamond saw blade lubricated by water. The slabs were ground into a course powder using a porcelain mortar and pestle then sifted through a nested arrangement of testing sieves producing a powder of 150 microns per diameter or less.

A buffer solution was produced as a mixture of ammonium acetate and glacial acetic acid with a measured pH of 6.28. 1 g samples of basalt powder along with 40 mL of the buffer solution were placed in ten Chemware Teflon cansiters. Two sample canisters were placed in five Thermo Scientific ovens with mechanical convention set to varying temperatures at 50, 60, 70, 80, 90°C. After a total duration of approximately six weeks half of the samples, one sample canister per oven, were removed for analysis.

Samples of basalt solid powder were analyzed using X-ray powder diffraction (XRD) to determine mineral composition while laser ablation inductively coupled plasma mass spectrometry (LA-ICP-MS) was utilized to test for elemental concentrations. Post-leaching solution samples were measured for amounts of elements utilizing inductively coupled plasma optical emission spectroscopy (ICP-OES).

Results

Powder XRD revealed the presence of albite, pigeonite, cristobalite, iron oxide, and potassium oxide; which are all consistent with basalt (Figure 2). The presence of the corresponding minerals is supported by the LA-ICP-MS which confirmed the presence of iron (~64%), silicon (~18%), sodium (7%), magnesium (~7%), potassium (~2%) and calcium (~1%).

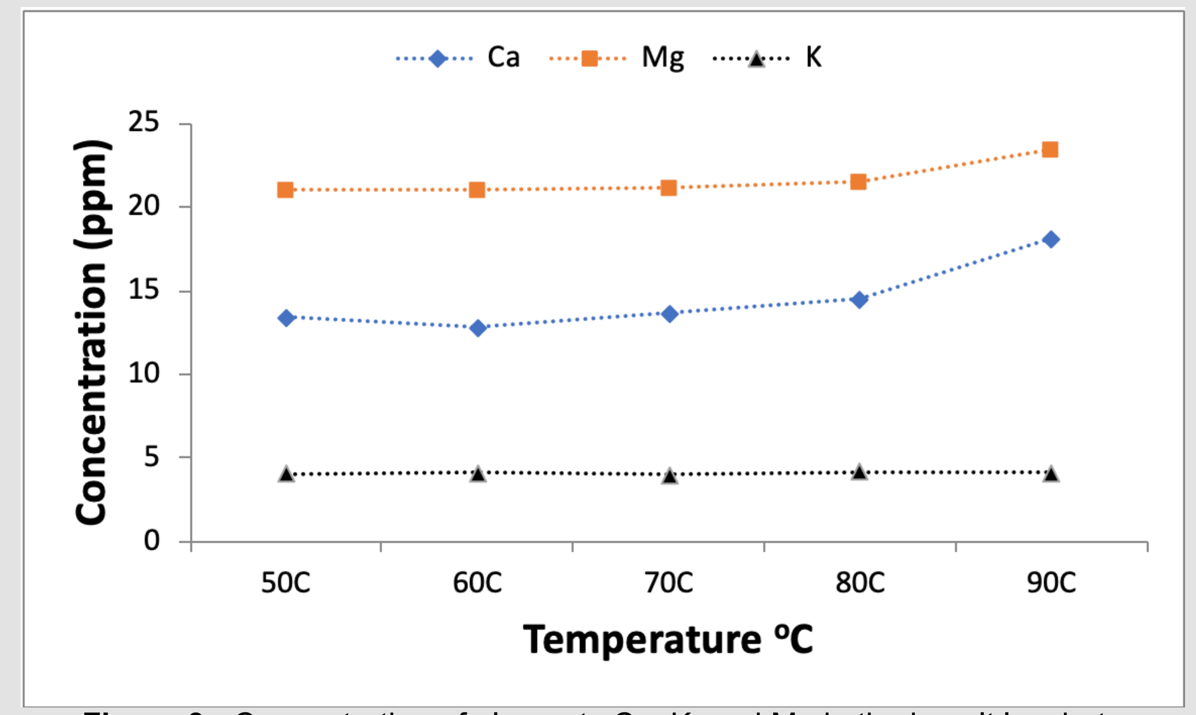

Figure 3: Concentration of elements Ca, K, and Mg in the basalt leachate as a function of temperature (50-90°C).

The ICP-OES method identified fifteen measurable elements in the basalt leachate. The results indicated that Ca and Mg were preferentially leached even with a short-term exposure. Substantial amounts of Ca and Mg are removed at 90°C and decline gradually as temperature decreases. The concentration of K remains relatively unchanged across the 50° temperature range (Figure 3). In comparison, the elements of Mn and Zn present in lower concentration also demonstrated a temperature dependent solubility except for Fe which increased substantially at 60°C and 50°C (Figure 4). The potentially important element of P was not detected during this analysis.

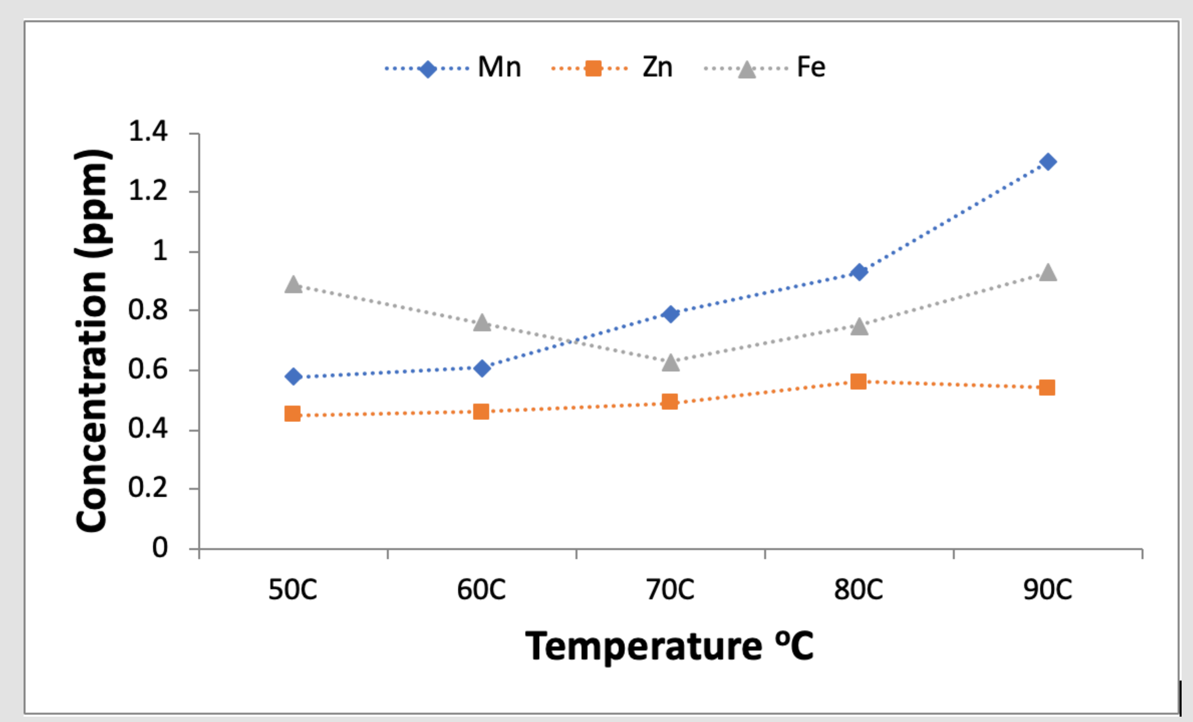

Figure 4: Concentration of elements Fe, Mn, and Zn in the basalt leachate as a function of temperature (50-90°C).

Conclusion

Many gardens on Rapa Nui contain a 10-15 cm thick lithic mulch cap (Figure 5). The prehistoric Rapanui used wooden digging sticks and basalt hand hoes to excavate through the lithic mulch cap during the installation of new planting pits and at harvest time. Excavation through the lithic mulch layer is difficult and requires repeated impacts to loosen the compacted rock which generates fine basalt powder. Multiply the powder created by thousands of planting and harvesting events in a garden and a significant amount becomes available.

Figure 5: Excavation trench within a lithic mulch garden showing the shallow soil profile and deeper disturbances by repeated gardening.

Basalts are composed of essential minerals which are readily available for plant absorption as nutrient constituents (including calcium and magnesium carbonates, phosphorous, potassium, and micronutrients such as zinc, boron, copper, iron, and manganese) that dissolve from the rocks when particle sizes are small.

Calcium would have strengthened cell structure and magnesium would have enhanced photosynthesis but these two nutrients alone are insufficient to produce sustained surplus since, except for the case of the Rano Raraku quarry (Sherwood et al. 2019), calcium levels are at, or just above, the 10meg/100g necessary for dryland farming as observed in Hawaii (Vitousek et al. 2010). Thus, evidence largely suggests that land-use management and additional organic amendments sourcing phosphorus and nitrogen were the primary effective strategies in sustaining agricultural surplus.

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References and contact info available upon request.