EDXRF Analysis of Lithics from Lapakahi State Historical Park, Kohala District, Hawai‘i Island

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We used energy-dispersive X-ray fluorescence (EDXRF) to geochemically characterize legacy lithic collections from William Bonk's 1969 Lapakahi excavations in the southern portions of Koai‘e Village, including volcanic glass, basalt debitage, abraders, and stone sinkers. A contemporary collection of a volcanic glass surface scatter in Lapakahi also improved our sample size, and expands on the lithic sourcing work for leeward Kohala regions immediately to the south. Significant findings include the abundance of volcanic glass from Pu‘uwa‘awa‘a in excess of previously published predictive models, and the absence of any adze material from the nearby Pololū adze quarry. Furthermore, lead (Pb) residue on abraders imported from a Mauna Loa source confirms the use of scoria abraders in the historical era.

Keywords: Hawai‘i, exchange, lithic sourcing, volcanic glass, basalt, leeward Kohala

Introduction

Former University of Hawai‘i at Hilo archaeologist William J. Bonk (1924–2008) made many contributions to Hawaiian archaeology, including his coastal survey of leeward Kohala over three weeks in 1967. The final section of his unpublished field report (Bonk 1968) described archaeological features in the coastal village of Koai‘e that demonstrated its long-term occupation into the historical era (Figures 1 and 2). The place name, Koai‘e, refers to a strong hardwood (*Acacia koaia*) that was used for multiple purposes including house timbers, shark hooks, paddles, spears, and *kapa* beaters (Malo 1951:42; Neal 1965:405). Due to the presence of many historical artifacts, Bonk felt that Koai‘e Village was particularly important for documenting cultural transitions between the historic and pre-Contact periods, and there was enormous research potential for the relatively intact *ahupua‘a* (traditional land division; Figure 1) of Lapakahi in which Koai‘e is located. Bonk also realized that the upland Leeward Kohala Field System (LKFS) provided an opportunity to evaluate the relationships between coastal settlements and intensive upland agricultural production. He pressed the State of Hawai‘i to designate Lapakahi as a state historic park, to be preserved for research and education (Bonk 1968:65–66). Lapakahi State Historical Park (LSHP) now includes 262 acres, with 17 coastal acres added in 2009

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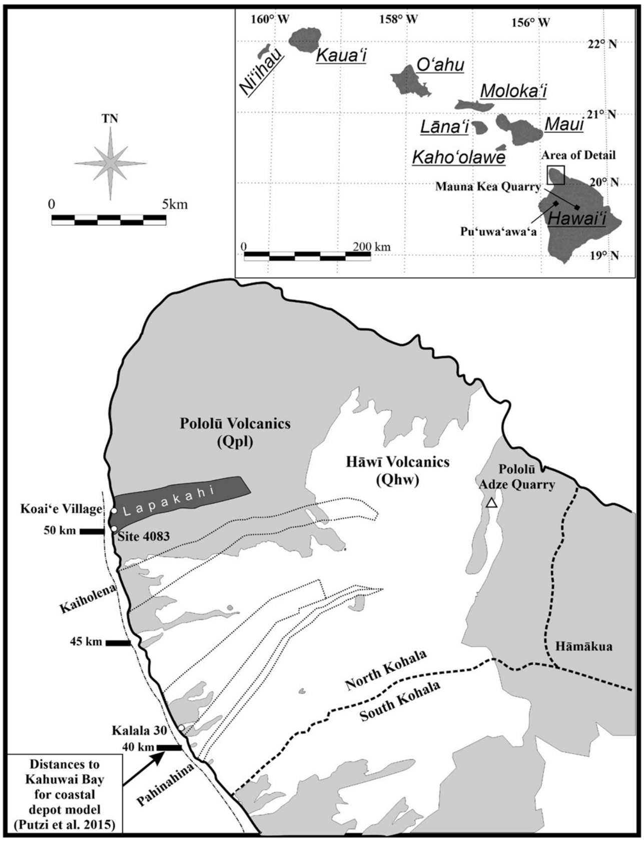

Figure 1. Lapakahi Ahupua'a and features mentioned in the text.

(Lapakahi State Historical Park, n.d.). The park boundaries only partially encompass the prehistoric complexes within the *ahupua'a*. LSHP has features that include "house enclosures, living platforms, temples, pens, markers, salt pans, trails and agricultural areas" (Tuggle & Griffin 1973:24).

Bonk's survey also provided impetus to fund the 1968 Lapakahi Project sponsored by the Hawai'i Division of State Parks and a National Science Foundation Undergraduate Research Participation Grant (Spriggs 1993:22). Over subsequent years, Bonk and his UH Hilo students participated in excavations at Koai'e Village with a team from UH Mānoa led by graduate students Richard J. Pearson and T. Stell Newman (Newman 1968, 1969). The archaeological collections from Bonk's portion of the UH field schools have remained in UH Hilo collections and contain materials from features in the southern part of Koai'e Village, labeled at the time as "H73" (for "Hectare 73") in the survey grid of the *ahupua'a* (Figure 2).

In 1969 and 1970, UH Mānoa field schools continued at Koai'e Village and expanded to include more upland agricultural features (Griffin et al. 1971; Rosendahl 1972; Tuggle & Griffin 1973). The 1968–1970 fieldwork made Lapakahi one of the most archaeologically studied *ahupua'a* in Hawai'i at the time. While these reports produced detailed descriptions

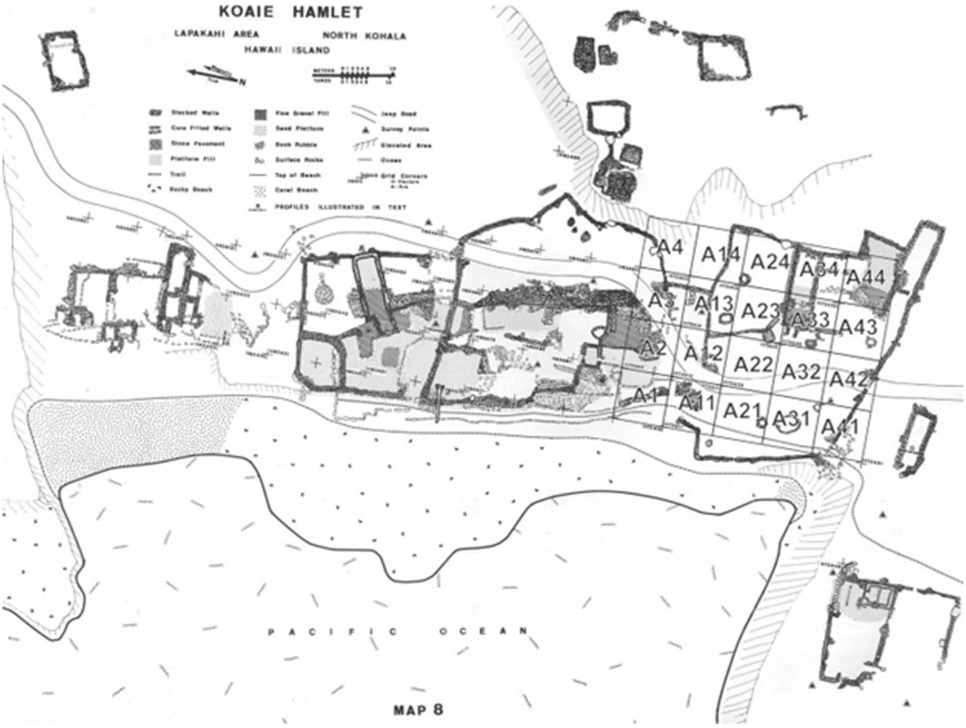

Figure 2. Koai‘e Village Map. The portions of hectare 73 where Bonk collections are derived from are demarcated in a grid (modified from Newman et al. 1970).

of settlement patterns and feature types, most of the chronological interpretations are now revised. Hydration dating of Hawaiian volcanic glass artifacts proved to be unreliable (Graves & Ladefoged 1991; Tuggle 2010; Stevenson & Mills 2013). In addition, radiocarbon dates from earlier reports were performed on unidentified wood species that could have contained centuries of in-built age.

By the 1990s, intensive examination of the LKFS resumed through collaborative efforts of archaeologists at the University of Hawai‘i at Mānoa and the University of Auckland (Ladefoged et al. 1996). In the 2000s, the National Science Foundation (NSF) funded the Hawai‘i Biocomplexity Project to examine the dynamics of population growth and agricultural intensification and productivity in leeward Kohala (Ladefoged & Graves 2000, 2007, 2008, 2011; Kirch et al. 2012). These cross-disciplinary collaborations have produced a diachronic model of population dynamics, household growth, agricultural intensification, and the eventual decline of the LKFS.

Lapakahi is notable because its development was early and rapid (Ladefoged & Graves 2008:785). Field et al. (2011a) suggest the earliest residential occupation for the region to be between AD 1400 and 1520. The upland LKFS also began development around AD 1400 (Field et al. 2011b:7327) and according to Rosendahl (1994:22), it reached its peak agricultural development between 1800 and 1850, and then fell into rapid decline. Koai‘e Village, however, remained in at least limited use through most of the historical era.

Portions of what now form the state park were inhabited until the early 1900s by at least one person, Tommy Awai, the last recorded man living in the village (Bonk 1968:54).

One objective of this research is to restore some understanding of pre-Contact economic exchange systems in a cultural landscape that was vastly different than what is observed today. Archaeological and historical information point to leeward Kohala supporting a densely populated and highly integrated system, whereas visiting the state park can leave the misimpression that Lapakahi was a remote hinterland. In 1793, botanist Archibald Menzies described the leeward North Kohala district as being treeless, but laid out in "industrious cultivation," with more houses along the shore than he had seen in any other part of the islands (Menzies 1920:52). Similar accounts left by missionaries and travelers continue at least into the 1830s (Ladefoged & Graves 2011). Rosendahl (1994) and Ladefoged and Graves (2007:86–87) argue that the LKFS continued to grow in production after Westerners arrived, which would have been partially driven by the provisioning market for foreign vessels. Ranching enterprises, however, rapidly created an incompatible form of land use, but some habitations and agricultural systems remained in the uplands where occupants built retaining walls to keep out roaming cattle and ungulates (Rosendahl 1972; Dye 2014).

By the mid-1800s, as depopulation from disease and ranching took their tolls, the field system was largely abandoned. Two first-hand accounts from the second half of the nineteenth century describe the environmental changes in leeward Kohala that accompanied the field system's abandonment. In 1853, George Washington Bates passed by Lapakahi and described the abandoned field systems in a 12-mile hike along the shore from Māhukona towards Father Elias Bond's mission in ʻIole (Bates 1854:335–336). Bates described an abandoned region of 300 square miles covered with many relics of what he inferred to be a formerly dense population, well in excess of the 400,000 archipelago inhabitants estimated by the Cook expedition. He estimated "village" populations scattered in the field system of between 50 and 100 people. In 1862 (nine years after Bates's account), ranch hand B. W. Macy arrived at Puʻuhue Ranch (immediately north of Lapakahi). Three decades later, Macy recalled the environmental changes he had observed while living and working there. He described a coastline formerly covered in *pili* grass (*Heteropogon contortus*) that had been destroyed by fires. By the 1890s, the uplands of Lapakahi were covered in castor oil brush (*Ricinus communis*), *wiliwili* trees (*Erythrina sandwicensis*), and an invasive tropical American weed, *oī* (also called *ōwī*, either *Verbena litoralis* or *Stachytarpheta jamaicensis*; Macy 1898). Other invasive species have now overtaken the ones described by Macy. *Kiawe* (*Prosopis pallida*) and *koa haole* (*Leucaena leucocephala*) provide a dispersed overstory and invasive fountain grass (*Pennisetum setaceum*) obscures many ground features where soil is present.

The arid coastal climate of Lapakahi State Historical Park receives less than 250 mm of rainfall annually and is also one of the windiest areas on Hawaiʻi Island, with an average wind ground speed of 19.2 mph (Ladefoged & Graves 2011:92). However, the village is situated at what is probably the best landing in the area along the coast (Newman 1970:93), and midden deposits at Koaiʻe demonstrate that residents engaged in marine subsistence activities (Newman 1970:88–89, 202–207).

The Significance of Lithic Analysis at Lapakahi

The surface geology at Lapakahi lacks appropriate source material for producing adzes. It also lacks volcanic glass for producing expedient cutting tools and scoria for making abraders. It is assumed that these artifacts (or at least the raw materials), and possibly other tool types, must have been imported. Determining where the stone tools at Lapakahi came from helps contextualize Koaiʻe Village in pre-Contact and early post-Contact exchange networks and interaction spheres. Territorial land divisions, such as the Kohala District, were subdivided into *ahupuaʻa*, which generally run from forested uplands, through agricultural fields, and to the coast (Kirch 2010:1). These territories encompassed several ecozones (McCoy et al. 2011) and were designed to promote economic self-sufficiency (Sahlins 1992:79). Many *ahupuaʻa*, however, contain limited or no source material suitable for manufacturing specific stone tools such as basalt adzes, volcanic glass cutting tools, and scoria abraders. Volcanic glass, high-quality basalt, and scoria must have been moved about the island and were probably distributed through different systems with varying degrees of elite control (Mills & Lundblad 2014; Mills et al. 2022).

In the largest lithic study of leeward Kohala to date, Mills et al. (2022) completed an examination of 2947 basalt and volcanic glass artifacts from various leeward Kohala *ahupuaʻa* located to the south of Lapakahi. They found concentrations of Puʻuwaʻawaʻa volcanic glass artifacts in excess of concentrations predicted by recent time and distance decay models for leeward Hawaiʻi Island (McCoy et al. 2011; Putzi et al. 2015), and no adze material from the nearby Pololū adze quarry. Technological and geochemical descriptions of lithics from the Lapakahi sites extend the Mills et al. (2022) findings northward, and offer a new node of data to test against various lithic distribution models.

For example, McCoy et al. (2011) and Putzi et al. (2015) debate time and distance-decay models for volcanic glass either using overland interconnecting trail systems or a combination of trails and canoe transport. A linear regression cost-surface model based on the time required to travel on overland routes to sites relatively near the Puʻuwaʻawaʻa source (McCoy et al. 2011) has demonstrated strong correlations between time traveled and relative percent of Puʻuwaʻawaʻa volcanic glass ($R^2 = 0.9154$). Putzi et al. (2015) point out that McCoy et al.'s (2011) linear cost-surface model does not work at all for sites with more than 25 hours of travel time to the source, and that when exponential decay includes a larger range of sites, the correlation of the model drops to $R^2 = 0.56$ (Putzi et al. 2015:348). They offered two alternative exponential models based on distance decay that could be calculated without specialized GIS software: (1) exponential decay based on straight line distance from source ($R^2 = 0.53$), and (2) travel distance from a depot at the nearest bay (Kahuwai Bay) to Puʻuwaʻawaʻa, and then along the coastline ($R^2 = 0.65$). None of these models, however, closely predicted the concentrations obtained in the subsequent Mills et al. (2022) data set for leeward Kohala, which was in excess of the predictions.

Volcanic glass artifacts at Lapakahi are often present in areas with concentrated midden, and are typical artifacts in areas with marine midden (Kirch 1985:183–184, 195). These artifacts are limited to "small and informal tool types," typically multifunctional in use (Schousboe et al. 1983; Lundblad et al. 2013:67). The sharp, freshly fractured edges were useful for cutting, scraping plant material, intricate carving of *kapa*-pounding sticks, other woodworking, cutting hair, and virtually any activity that benefited from using a razor-sharp edge.

Geologically, volcanic glass in the Hawaiian Islands appears in a number of contexts from chilled surface flows, to dikes, to trachyte domes (Weisler 1990; Lundblad et al. 2013). Geochemical sourcing of volcanic glass in leeward Hawaiʻi is dominated by three broad groups, Puʻuwaʻawaʻa, Mauna Loa source(s), and an unidentified source flow labeled

Group 3 (Lundblad et al. 2013) that is presumed to be from Kīlauea based on its geochemistry. Hawaiian volcanic glasses are not high enough in silica (~49%–63%) to be considered rhyolitic obsidian (~73%) but they display similar textural qualities (Lundblad et al. 2013:67). This unevenly distributed resource appears to have been available for use outside of elite control (Putzi et al. 2015:341), but Mills et al. (2022) point to evidence of increasing centralized quarrying activity from Puʻuwaʻawaʻa in late prehistory.

Volcanic glass from the Puʻuwaʻawaʻa cinder cone can have a greenish or greyish color, and is occasionally embedded with lamellar ash that researchers can easily mistake for geological cortex on small flakes. Puʻuwaʻawaʻa in the Kona district is the only known location on Hawaiʻi Island that produces large blocky pieces of volcanic glass, and it has been identified in sites as far away as Oʻahu (Divito et al. 2020). Mauna Loa glasses most likely derive from geographically dispersed chilled surface flows of pāhoehoe lavas. The thin, glassy rinds (usually no more than a few centimeters thick) produce coarse-textured glass relative to the Puʻuwaʻawaʻa trachytes. Group 3, like Puʻuwaʻawaʻa, has a fine glassy texture but has not been matched with specific quarry sites, and has only been observed in relatively small pieces of debitage. Occasionally Group 3 is seen to have a blue tinge and minor pitting while other pieces appear to be black (Lundblad et al. 2013:71–72).

Adze production was a specialized craft, sometimes involving intensive production at a centralized quarry, and other times involving dispersed, opportunistic quarrying of locally available material (Mills & Lundblad 2014). Adzes on Hawaiʻi Island were generally produced from a limited number of sources of high-quality basalt and often provide evidence of exchange across districts (Mills et al. 2010, 2011, 2022; Mills & Lundblad 2014). Hawaiʻi's hierarchical production systems arose to support its chiefs as populations and agriculture grew, and some evidence supports the idea that adze production became more centralized as the sociopolitical system intensified (Mills et al. 2011, 2022). According to Kirch (2010:7332), "management and tribute requirements supported the increasingly hierarchical social, political system of archaic states which emerged in Hawaiʻi ca AD 1600–1800." Although adze debitage in leeward Kohala appears relatively uncommon, Mills et al. (2022) found no adze material from the nearby Pololū adze quarry in their large lithic sample. This study offers the opportunity to test if that pattern is repeated in the Bonk assemblage.

Scoria abraders are produced from vesicular scoriaceous lava, quarried from the top of pāhoehoe flows, then ground to preferred shapes in nearby depressions (Kirch 1979:18). One popular shape is a flat cone that would have been suitable for grinding the small curved shape of a bone or shell fishhook. Hawaiians manufactured scoria abraders in several extensive quarries along the Kona coast and Kaʻū, and abraders made from Kohala volcanics accounted for 4 out of 9 abraders in a recent study of lithics in leeward Kohala (Mills et al. 2022). Although less is known about the extent of abrader production, these tools, too, may have involved exchange across political districts. However, functionally equivalent tools for fishhook manufacture could be fashioned from local sea urchin spines and corals.

Another class of stone tools typically found in fishing villages are weights for *luheʻe* (octopus lures) and other kinds of stone sinkers. Hawaiians had many fishing techniques which required the use of weights. "Stone sinkers were used with nets, fishing lines, squid lures, and ground bait" (Buck 1957:342). The *luheʻe* uses a cowry-shaped stone as the weight in the lower portion of the lure (Kamakau 1976:68). These lures are similar in size and weight and have similar height and width ratios, demonstrating a specific preference for particular proportions and adequate weight. The lure is typically sized relative to the size of the prey sought (Newman et al. 1970:61–62, 68). Newman interpreted the lures found during the 1968 Lapakahi Project to be related to offshore canoe fishing, but not necessarily for deep-sea fishing. Kamakau describes the stone used in a *luheʻe* as having to be a "handsome stone" and that the "fisherman of old especially looked for certain ones." He lists the Hawaiian names of nine types of stones suitable for octopus lures, noting more have been forgotten (Kamakau 1976:68).

Pōhaku (stone) for *luheʻe* would have been chosen for surface characteristics that might look appealing to an octopus. "Octopus did not want the cowry or the stone to eat; papaʻi and ʻohiki crabs and other small Crustacea (mea ʻano papaʻe) were its food, but fisherman enticed it with a type of hula, and the octopus was 'taken in' (ua puini)" (Kamakau 1976:68). Fishers chose cowry shells for their reddish color and patterning, and such shells were considered precious. Anglers would change the shells depending on the time of day and would stop fishing to limit the time a shell was underwater. "A choice cowry was given the name of a grandparent, a father, a mother, a wife, or of a chief" (Kamakau 1976:69). Occasionally if the background color was not right, the shells were heated to a deeper shade of red to create a more vivid contrast, according to fish reports from the late 1800s and early 1900s (see Newman 1970:42). Such preparation indicates the fishermen's attention to detail, color, and the lure's appearance underwater during its fabrication. In this collection, we see some of the selected basalts displaying large vesicles, which would have provided a texture that, when underwater, might reflect light in an organic pattern simulating aquatic life.

Luheʻe have multifunctional designs. One of many examples of variable potential uses would be a less well-known lure called an "*okilo heʻe*," in which "several nohu blossoms substituted for the cowry shell" (Buck 1957:345; Emory et al. 1959:28; Kamakau 1976:69). While some stone sinkers were most certainly chosen for their physical properties and characteristics for use on a lure, it is not to say that typical forms such as bread-loaf, coffee bean, or flat-bottom sinkers had no other functions.

Finally, this study also examines *ʻiliʻili* (rounded pebbles), often used for floor pavings which are classes of manuports commonly found around stone enclosures and alignments. These stones were most likely collected from nearby beaches and gulches, and their analysis in large quantities can provide a reasonable proxy for the geochemical groups that might be present in any particular drainage or along a coastline. While some cobbles were used as hammerstones, the majority are unmodified.

Methods

We conducted energy-dispersive X-ray fluorescence (EDXRF) analyses of two collections of lithics from Lapakahi in this study: (1) A collection of 54 lithic artifacts from Professor William J. Bonk's 1968 field school collections from Koaiʻe Village, now housed at UH Hilo (Figure 2); and (2) 122 pieces of volcanic glass and three basalt flakes that were surface-collected in the spring of 2021 from State Inventory of Historic Places (SIHP) 50-10-02-04083 (Figures 1 and 3), which is approximately 1km south of Koaiʻe Village. Temporary collection was conducted with the permission of Division of State Parks archaeologist, Tracy Tam Sing, as part of Adam Johnson's Ph.D. dissertation project at Southern Methodist University, and as part of the lead author of this study's undergraduate project at UH Hilo.

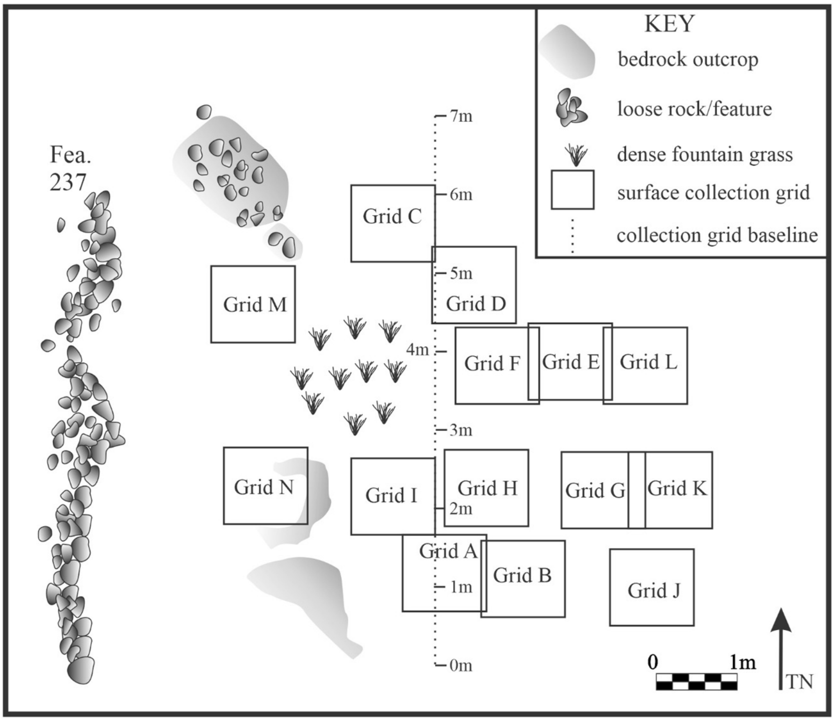

Figure 3. Map of SIHP 50-10-02-04083 showing 2021 volcanic glass surface collection grids (based on field map by Heather Bailey).

The Bonk Collections

Newman (1970) includes excavation data from three areas of Lapakahi. William Bonk supervised the first, labeled “H73” (Figure 2). Richard Pearson from UH Mānoa led excavations in the second portion of Koaiʻe Village, labeled “H63,” directly north of H73. The third area, “Apaʻapaʻa I,” was examined by a team headed by Michael Seelye and mapped by Paul Rosendahl. Apaʻapaʻa I is located in the Leeward Kohala Field System, *mauka* of the coastal hamlet. Newman (1970:198) reports that 3913 artifacts were collected from Koaiʻe, but it appears that the cultural material collected under William Bonk’s supervision from H73 remained with him at UH Hilo. Additonal volcanic glass collected at Koaiʻe Village is in State Parks collections. Notes indicate a full pound of volcanic glass was collected at Koaiʻe Village (Newman 1970:207). Other collections from the UH Mānoa teams are now curated at a Hawaiʻi Division of State Parks facility.

The H73 materials at UH Hilo are stored in six archival boxes and entered into a Filemaker Pro^{TM} collections database. Provenience information is recorded on artifacts using (removable) white backgrounds and India ink and stored in various containers. We relocated 54 lithics from the Bonk collections, including basalt, volcanic glass, slate, chert, *luheʻe*/sinkers, *ʻiliʻili* pebbles, scoria abraders, and hammerstones (Table 1). For EDXRF analysis, we assigned the samples new labels beginning with “XRF,” followed by a number.

Table 1. List of provenience for artifacts pulled for analysis from the Bonk collection.

H73	Total#	Abrader	Sinker	VG	CCS	Adze	GS	BF	C/I	FCR/FB	HS
A13	1				1						
A14	1								1		
A22	19	1		11		1		1	4	1	
A23	16	4		6		1	1	1	1		2
A24	1									1	
A43	2				2						
A44	13	2	6	1	1	1		1	1		
Other	1	1									

VG, volcanic glass; CCS, cryptocrystalline silicate; GS, groundstone; BF, basalt flake; C/I, cobblestone *ʻiliʻili*; FCR/FB, fire cracked rock/fractured basalt; HS, hammerstone.

Under the supervision of Adam Johnson, our field team conducted a surface survey in the summer of 2020, and identified at least six features with visible surface scatters of volcanic glass in several areas, around and inside structures. SIHP 50-10-02-04083 (State Parks temporary site T-271), which is located near the coast and 1km south of Koaiʻe Village, had a prolific amount of volcanic glass and was chosen for a temporary collection for the EDXRF study. Collection was performed over 2 days in the spring of 2021 (Figures 3 and 4). Subsequent to lab analysis, artifacts were returned to the site, with each artifact being placed back in the designated location from which it had been mapped and collected.

LSHP is currently overgrown with invasive fountain grass (*Pennisetum setaceum*) which we hand-cleared to increase surface visibility. Then, using a 1 × 1m grid, sectioned into 20 × 20cm squares, with alignment to magnetic north (Figure 4), we collected 122

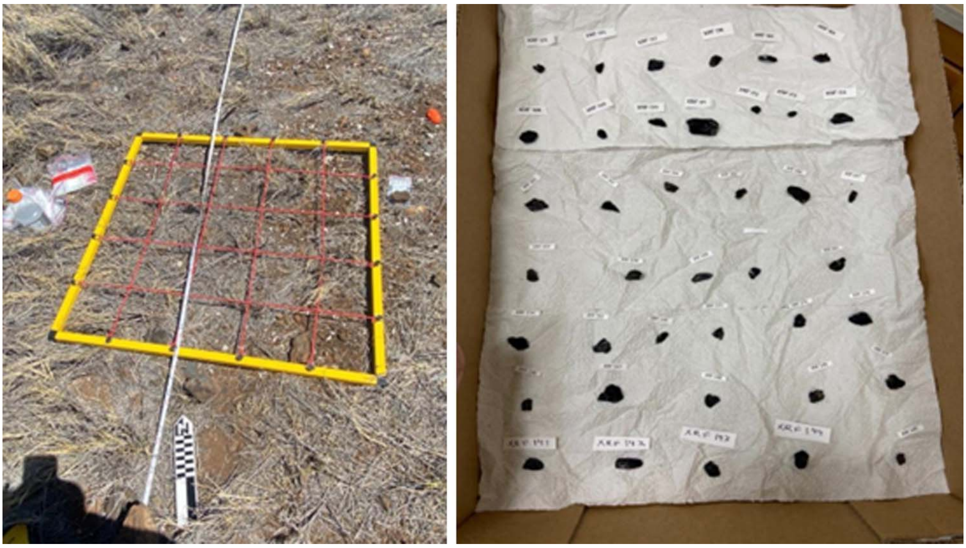

Figure 4. SIHP 50-10-02-04083 collection Grid A on baseline.

pieces of volcanic glass and three basalt flakes from 13 grid sections labeled A–P. We labeled the samples "XRF," followed by a numerical sequence starting at 100.

EDXRF Analysis

An extensive database of lithic geochemistry on Hawai'i Island (Mills & Lundblad 2014; Mills et al. 2022) contextualizes the artifacts surveyed in this study. EDXRF was employed for geochemical characterization of the lithic material (UH Hilo Geoarchaeology Lab 2023) and provides quantitative or partially quantitative results for twenty-six elements on samples over 1cm^2. For volcanic glass samples under 1cm^2 in diameter, an abbreviated "Short Method" is used, which relies on ratios of key trace elements rather than raw concentration data. It only analyzes eight elements best seen at 28 kV with a thick palladium (Pd) filter: copper (Cu), zinc (Zn), rubidium (Rb), strontium (Sr), yttrium (Y), zirconium (Zr), niobium (Nb), and lead (Pb). The ratioed data on each element allows for the association of small volcanic glass samples to three known geochemical groups common in leeward Hawai'i. These three geochemical groups are highly distinctive in their trace element concentrations: Pu'uwa'awa'a, a member of Hualālai volcanics, is exposed on the surface in the northern portions of the Kona district (Mills 2011:85); Mauna Loa; and "Group 3" from an unknown source location presumed to be associated with Kīlauea Volcano (Lundblad et al. 2013:70–73).

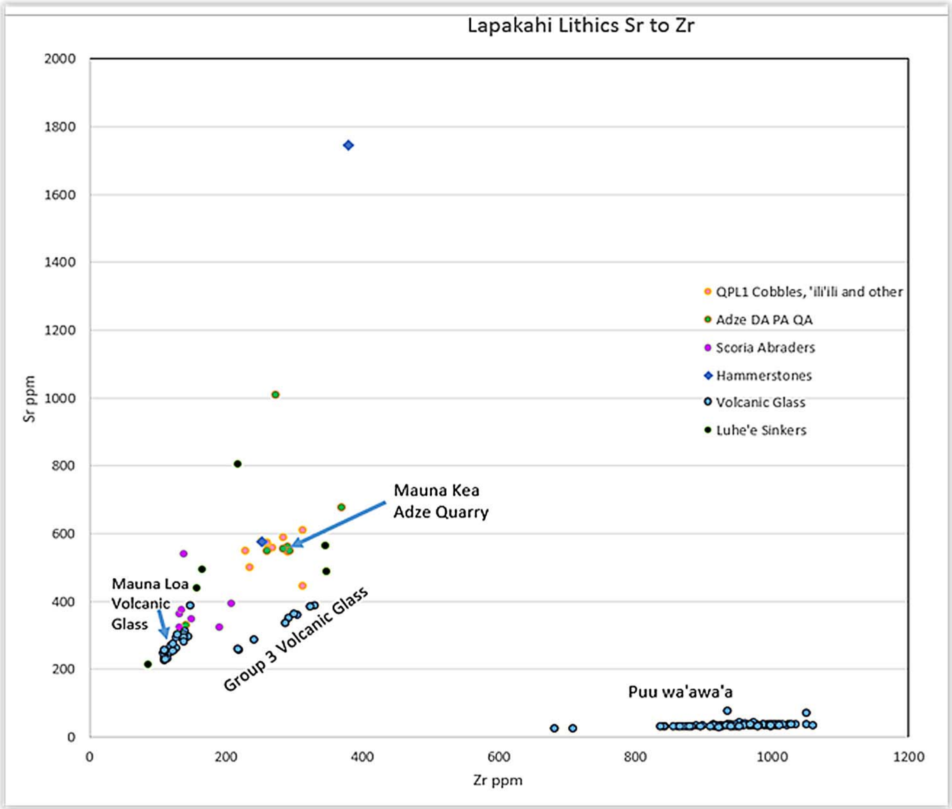

Figure 5. Lithic geochemical groupings from Koai'e Village.

Results

A biplot of Sr to Zr concentrations in the analyzed samples (Figure 5) is within the range of results obtained by Mills et al. (2022) for other lithic assemblages in leeward Kohala. As expected, *ʻiliʻili* and unmodified rocks generally reflect the range of geochemistry for the known surface geology of Lapakahi. The surface flows are part of the "Pololū volcanics" from Kohala Volcano, whereas many of the sites further south analyzed in Mills et al. (2022) are on Hāwī volcanics. One hammerstone from Lapakahi, however, matches well with Hāwī volcanics labeled Qhw-2 in Mills et al. (2022). Results for the major classes of artifacts are presented below.

Volcanic Glass

Like the results obtained in much larger studies of volcanic glass from Hawaiʻi Island (McCoy et al. 2011; Lundblad et al. 2013; Mills et al. 2022), the three volcanic glass groups observed are all tightly clustered, which would not occur if volcanic glass material was regularly appearing in Kohala and Kona from a multitude of sources throughout Hawaiʻi. While the ratios of Sr to Zr observed in these clusters are similar to some groups on Oʻahu (Divito et al. 2020) and Kauaʻi (Mills et al. 2010), the concentration data on a variety of trace elements are quite different from these off-island sources. The volcanic glass samples from both Lapakahi collections are all smaller than 20mm in diameter, and most are under 10mm. A total of 87 out of 122 volcanic glass flakes from the Lapakahi sites match with the Puʻuwaʻawaʻa source (71.3%; Table 2). The "coastal" model with a depot at Kahuwai Bay (Putzi et al. 2015:350) calculated from the distance along the shoreline from Kahuwai Bay near Puʻuwaʻawaʻa to KAL 30 is at a distance of 41.05km. The closest site in this study (SIHP 50-10-02-04083) is approximately another 9km north along the coast from KAL 30 (approximately 50km from Kahuwai Bay), and estimates of volcanic glass concentrations using Putzi et al.'s (2015) logarithmic distance decay model would predict half of the Lapakahi volcanic glass assemblage to be from Puʻuwaʻawaʻa (Table 2). McCoy et al.'s travel time frequency decay model (2011:2555) would plot the SIHP 04083 assemblage near 19 hours of travel time (3.9 hours farther than site KAL 30), which would predict a Puʻuwaʻawaʻa assemblage near 28.3% instead of the observed 72.1%. In sum, three separate leeward Kohala data sets (KAL 30 in McCoy et al. 2011, Mills et al. 2022, and the current study), all find concentrations of Puʻuwaʻawaʻa volcanic glass in leeward Kohala that are well in excess of the predictive models in McCoy et al. (2011) and Putzi et al. (2015).

Adze Debitage

Despite the relatively common presence of volcanic glass artifacts in leeward Kohala, Mills et al. (2022) and this study both note relatively small quantities of adze debitage in the same assemblages. Furthermore, like the leeward Kohala sites analyzed by Mills et al. (2022), none of the adze debitage in Bonk's Lapakahi collections matches with the nearby Pololū adze quarry, and instead appears to derive from nonlocal sources. Unfortunately and coincidentally for analysis of basalt adze material, the surface geology at LSHP (QPL-1) overlaps with the geochemical composition of the Mauna Kea Adze Quarry (Mills et al. 2008). The texture of QPL-1 flows, however, is much more coarse so that distinctions based on texture are possible. Mills et al. (2008) also found that the fine-grained material similar to QPL-1 that they examined with WDXRF and isotopic analyses all supported a Mauna

Table 2. Comparison of predicted and actual concentrations of Puʻuwaʻawaʻa volcanic glass for leeward Kohala.

	Distances along coast to Kahuwai Bay (km) used for depot model	Predicted coastal depot model for PWW (Putzi et al. 2015)	Predicted overland cost-surface for PWW (McCoy et al. 2011)[a]	Group 1 PWW (actual values)	Group 2 Mauna Loa	Group 3 Kīlauea	Total
Leeward Kohala, Pahinahina to Kaiholena (Mills et al. 2022)	39.4–49.3	62.3%–51.1%	~55.8%–30.3%	1197 (76.5%)	320 (20.4%)	47 (3%)	1564
KAL 30, Kohala	41.05	197 (60.3%)	168 (51.4%)	211 (64.5%)	–	–	327
Lapakahi, SIHP 50-10-02-04083 (this study)	50	52 (50.4%)	~29 (28.3%)	75 (72.1%)	23 (22.1%)	6 (5.7%)	104
Koaiʻe Village (this study)	51	9 (49.4)%	~5 (25.9%)	12 (66.7%)	3 (16.7%)	3 (16.7%)	18
Lapakahi combined	50.2	61 (50.2%)[b]	~35 (28.4%)	87 (71.3%)	26 (21.3%)	9 (7.4%)	122

[a] Cost-surface estimates for leeward Kohala sites are based on the value used in McCoy et al. (2011) for KAL 30 of a 34.9km overland distance to source and a 15.1 hours RT travel time (0.433 RT hours per km). Additions and subtractions to the overland distance are estimated from 34.9km ± coastal distance to KAL 30.

[b] "Lapakahi combined" distance along coast is not a simple average of the distance between the two sites (74.5km) but is calculated by adjusting for the relative concentrations of volcanic glass in the two Lapakahi sites.

Kea source, and not QPL-1 (Mills et al. 2022:745). Based on these observed differences, the fine-grained basalts matching the Mauna Kea geochemistry at Lapakahi are assumed to be from the Mauna Kea Adze Quarry and not QPL-1.

Of the seven basalt samples grouped as definite, possible, and questionable adzes, three were sourced to the Mauna Kea Adze Quarry, one from Group J (a less common grouping in leeward Hawai‘i Island sites, presumed to be from off-island), and three belong in Group F (Mills et al. 2011:88; Mills et al. 2022). Group F has chemical characteristics of tholeiitic lava, which is common in eruptions of shield volcanoes represented in a large percentage of early flows throughout the Hawaiian island chain (MacDonald & Katsura 1964). In the nearby vicinity, these include early shield building flows exposed in Waipi‘o Valley in windward Kohala from Pololū volcanics, and many flows from Mauna Loa. Although EDXRF can rule out certain sources, like the Hāwī volcanics for Group F, the common occurrence of “Group F” lavas in Hawai‘i shield building flows confounds any definitive association for the group with EDXRF methods alone (Mills et al. 2011:88). Isotopic analyses of Group F material indicate that more than one source appears to be contributing to this group on Hawai‘i Island (Mills et al. 2022).

Abraders

There were seven abraders analyzed from the Bonk collection. Two fell within Group F, and two in an ancillary group F′. Two abraders are from Group A (Mills et al. 2011:85–86), which is highly consistent with Hualālai volcanics. One abrader matches with Group C (Mills et al. 2011:87). Group C has higher Y and Nb than samples from Hualālai and the elevated Y in particular suggests a source off of Hawai‘i Island such as Moloka‘i or Kaho‘olawe.

One scoria abrader (XRF 23) that fell within Group A exhibited lead (Pb) levels at 1142 ppm when Hawaiian basalts typically contain almost no lead at all. Three other abrader fragments (XRF 40, 41, 42) exhibit Pb values between 36 and 124 ppm. These high levels of lead indicate surface residue and use of the abraders during the post-Contact period. Possible uses might include shaping a lead sinker for fishing or filing down the sprue off of a locally-cast musket ball. Regardless of the purpose, this finding indicates a post-Contact economy in which traditional abrading tools continued to be used despite much evidence that Hawaiians regularly incorporated foreign material into many aspects of their daily lives (Flexner et al. 2018:34).

Lūhe‘e/Sinkers

The Lapakahi Bonk collection had six *lūhe‘e*/sinkers. The *lūhe‘e* originated from different sources, including the local geology at LSHP. Two display geochemistry consistent with Group A (Hualālai; Mills et al. 2011:85), while a third is a slight outlier of that group (A′). Two others match with local geology QPL-1. One is a plutonic gabbro ejecta that cannot be readily sourced due to its different composition from surface geology. Several other sinkers are also not typical of surface pāhoehoe such as conglomerates and breccia, and display textures that may have been chosen for their appearance as a lure. XRF 43 is the largest sinker, consisting of a grooved oblong stone weighing 635.5g. This artifact has large vesicles and reflective phenocrysts on the surface. Another basalt *luhe‘e* (XRF 44) displays large olivine xenoliths that may have attracted *he‘e* (octopi).

Chert

Chert/Flint, a cryptocrystalline silicate (CCS), is found in Hawaiian lithic assemblages, particularly in the historical period, and four samples are in Bonk's Lapakahi collection. Flint has been noted in the smoking kits as a strike-a-light "each Kanaka [person] on the beach had a pipe, flint, steel, tinder, a hand of tobacco, and a jack-knife, which he always carries about with him" (Dana 1947:131). This commodity was exchanged and manufactured somehow; however, conclusions about the foreign origins of the CCS in Hawaiʻi are complicated by several known local sources that may have seen increased use in the historical era (Mills n.d.). Although the CCS was analyzed with EDXRF (XRF 1 and 6), the extremely high percentages of silica and the increased heterogeneity of sedimentary inclusions diminish the value of trace elements in sourcing the chert. Therefore no attempt to distinguish sources with EDXRF was attempted beyond its classification as CCS.

Discussion and Conclusions

This geochemical study of lithics from the near coastal regions of Lapakahi State Historical Park leads to several conclusions about long-term household patterns relating to lithic resource exploitation strategies, adze use, and daily activities in a leeward Kohala coastal village, which are summarized below.

Models of Volcanic Glass Distribution

Kirch wrote, "communities with access to a particular resource sometimes specialized in its extraction and materials may have been widely exchanged or traded between communities" (Kirch 1985:32). Volcanic glass was a versatile and prolifically used material for making expedient cutting tools. Although there is a coastal village in the *ahupuaʻa* of Puʻuwaʻawaʻa, the district lacks the agricultural fields typically seen in many leeward districts (Putzi et al. 2015). Questions concerning political and social relationships between *ahupuaʻa* arise here as the high-quality volcanic glass was transported to other *ahupuaʻa*. This study confirms earlier results that demonstrate the typical movement of three volcanic glass geochemcial groups throughout leeward Hawaiʻi Island, with the Puʻuwaʻawaʻa source dominating leeward Kohala assemblages. The common appearance of Puʻuwaʻawaʻa volcanic glass at significant distances from the source and the logarithmic distance-decay of the material, however, is most likely more complicated than McCoy et al. (2011) or Putzi et al. (2015) have proposed.

For example, a factor in McCoy's direct least-cost surface distribution analysis is daylight hours for a single day round trip. Round trip time factors, including daylight from leeward Kohala to Puʻuwaʻawaʻa and back, could certainly be a factor in decay distribution models, but there is much evidence that Hawaiians often traveled at night and that many coastal trails were adapted with white coral stones to assist in that purpose (Hommon 2013:107). The advantages of night travel along hot, arid, leeward coasts are obvious. The use of *kukui* nut (candlenut or *Aleurites moluccana*) lanterns would enable a hiker to go further at night and can often be an indicator of night-time activities (Van Gilder 2017). Earlier reports from Ellis's journal reported night fishing all along the leeward Kohala coast from canoes at night (Newman et al. 1970:249). Hawaiians did not cease activity at dark, and they were accustomed to "talk and sing all night" (Ellis 1917:258). Malo describes the names of the people who sat up with the chief at night as “ma-ko‘u,” the same name as the lamp kept at that hour, and the people who came in when the midnight lamp was burning were called “pohokano” (Malo 1951:83). The Hawai‘i Volcanoes National Park website states that in 1914, anthropologist Martha Beckwith interpreted a petroglyph that was a cross with a dot at each end as being a “a cross before a chief at night traveling” (Beckwith 1914). In this context, it may be that the limits of Pu‘uwa‘awa‘a material from the source may be driven by factors other than daytime travel hours from the source or distance traveled along the coast, and will instead involve a more complicated interaction between different sources and down-the-line social interaction spheres, such as overland transport to various canoe landings as suggested in Putzi et al.’s (2015) “depot” model.

If higher percentages of Pu‘uwa‘awa‘a in leeward Kohala is validated with continued sampling, it may be due to canoes more efficiently moving centrally quarried materials up the coast. Putzi et al. (2015:347–348) state that Pu‘uwa‘awa‘a glass was “transported regularly to sites of about 21 h round trip travel time” by taking the volcanic glass from Pu‘uwa‘awa‘a to a nearby depot at Kahuwai Bay, and then transporting the glass by canoe or by foot along the coast. Canoe transport, which is a near certainty, seems likely to have greater influence on the modeling over greater distances, with intermediary distances being covered both through overland routes and by canoe. Another factor that none of the extant models take into account is the locations and influences of other volcanic glass sources in the geological landscape. If there are more options for volcanic glass sources heading south from Pu‘uwa‘awa‘a than there are in a northerly direction, then different decay rates may occur depending on which direction one heads from Pu‘uwa‘awa‘a.

Changing factors in Hawaiian socio-economics and political economies may also have affected volcanic glass distribution through time, and volcanic glass distribution patterns can be affected by variables other than distance, including perceived value (Putzi et al. 2015). The abundance of Pu‘uwa‘awa‘a glass in leeward Hawai‘i is interpreted by McCoy et al. as the result of “unfettered access” (2011:2547). Similarly high ratios of Pu‘uwa‘awa‘a along the leeward Kohala coast illustrate how overlapping travel times can exist between a cost-surface analysis and other models such as canoe transport. Exponential modes combined with various distribution depots could explain the similar frequencies at sites in leeward Kohala. Other factors such as temporal changes in resource procurement could also influence the influx of Pu‘uwa‘awa‘a glass. For example, does “unfettered access” mean that no reciprocal exchange occurred when people traveled to the district to obtain the glass? A large core would be a highly tradable item; any model suggesting direct access must still consider the reciprocal obligations of that access across communities, and provide some continued acknowledgment for the possibility of down-the-line exchange.

Adzes and Canoe Construction in Leeward Kohala

This analysis provides some indication of household activities and the distribution of traditional tools in the pre- and post-Contact activities near the coast in Lapakahi. First, given the apparent long occupation of Koai‘e Village (AD 1200 to the twentieth century), adze production, use, and rejuvenation appear to be uncommon activities. The limited soil development provides archaeologists with the opportunity to observe the lithic detritus that has accumulated over centuries, and there is no evidence of adze manufacturing such as abundant basalt debitage, and limited evidence of adze rejuvenation. The adzes that were being rejuvenated came from Mauna Kea Adze Quarry and other imported sources. Like the findings in Mills et al. (2022), there is no evidence of adzes from the nearby Pololū adze quarry in windward Kohala. In a fishing village, adze debitage would certainly be expected from building canoes (if that activity did indeed occur at Lapakahi), and some debitage may be expected from repairing canoes. The concentration of basalt debitage could support canoe repairs and house building, but there is little evidence of heavy adze use in daily life, such as might be generated from regular canoe building. This finding suggests that the pre-Contact fishermen at Lapakahi may have used canoes that were completed elsewhere, which has its own implications for reciprocal exchange networks across the *ahupuaʻa*.

Sinkers and Abraders

The presence of sinkers and abraders both support the use of canoes for offshore fishing. Like the adzes, and like the findings for a broad section of the leeward Kohala coast (Mills et al. 2022), it appears that abraders were arriving in Kohala from scoria abrader quarries to the south on Hualālai and Mauna Loa. The stones used for *lūheʻe* were also not the typically available local rocks, and contain phenocrysts or conglomorate material that add to the visual complexity of the rock, presumably to better attract *heʻe*.

This study demonstrates the importance of building broad geochemical contexts for the sourcing of lithics. One of the axioms of the scientific method is to repeatedly test conclusions, and legacy collections in Hawaiʻi offer a tremendous opportunity to contribute to this goal. McCoy et al. (2011) and Putzi et al. (2015) proposed models for volcanic glass distribution that Mills et al. (2022) found to be in need of adjustment for Kohala. This study confirms Mills et al.'s (2022) findings on the higher reliance on Puʻuwaʻawaʻa glass for Kohala than predicted in the earlier models, and contributes to an extension of that trend further northward in Kohala. Production and exchange of other tool classes, including adzes, scoria abraders, and octopus lures are all adding to our understanding of Hawaiian economic systems that counter the self-sufficiency of *ahupuaʻa*, and demonstrate the continued use and distribution of certain scoria abraders into the post-Contact era.

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References

Bates, G.W. 1854. *Sandwich Island Notes: By a Haölé*. New York: Harper & Brothers Publishers.

Beckwith, M. 1914. "Field notes." Hawaiian Sources Collection, Bishop Museum Archives, Honolulu.

Bonk, W.J. 1968. An archaeological survey of a coastal tract North and South Kohala Hawaii. *State Archeology Journal: The Archaeology of North and South Kohala – From the Ahupuaʻa of Kawaihae to the Ahupuaʻa of Upolu*, 68(3), draft. DLNR Division of State Parks, Hawaiʻi.

Buck, P.H. 1957. *Arts and Crafts of Hawaii. Vol. VII Fishing*. Honolulu: Bishop Museum Press.

Dana, R.H. Jr. 1947 [1841]. *Two Years Before the Mast*. New York: Heritage Press.

Divito, N.J., T.S. Dye, K. Elington, J.L. Gunness, E. Hellebrande, E. Jourdane, S. Lundblad, N. Mello, P.R. Mills, & J.M. Sinton. 2020. Volcanic glass at Kualoa, Oʻahu, Hawaiian Islands: paired technological and geochemical sourcing analyses of an expedient tool industry. *Journal of Archaeological Science: Reports* 30:102–117.

Dye, T.S. 2014. Structure and growth of the Leeward Kohala Field System: an analysis with directed graphs. *PLoS ONE* 9(7):e102431.

Ellis, W. 1917. *A Narrative of a Tour through Hawaii in 1823*. Honolulu: Hawaiian Gazette Co.

Emory, K.P., W.J. Bonk, & Y.H. Sinoto. 1959. *Fishhooks: Hawaiian Archeology*. Bishop Museum Special Publication No. 47. Honolulu: Bishop Museum Press.

Field, J.S., T.N. Ladefoged, W.D. Sharp, & P.V. Kirch. 2011a. Residential chronology, household subsistence, and the emergence of socioeconomic territories in leeward Kohala, Hawaiʻi Island. *Radiocarbon* 53(4):605–627.

Field, J.S., T.N. Ladefoged, & P.V. Kirch. 2011b. Household expansion linked to agricultural intensification during the emergence of Hawaiian Archaic States. *Proceedings of the National Academy of Sciences* 108(18):7327–7332.

Flexner, J., J.S. Field, M.D. McCoy, T.N. Ladefoged, & P.V. Kirch. 2018. Foreign material culture from Hawaiian households in leeward Kohala. *Australasian Historical Archaeology* 36:29–37.

Graves, M.W. & T.N. Ladefoged. 1991. The disparity between radiocarbon and volcanic glass dates: new evidence from the Island of Lanaʻi, Hawaiʻi. *Archaeology in Oceania* 26:70–77.

Griffin, P.B., T. Riley, P.H. Rosendahl, & H.D. Tuggle. 1971. Archaeology of Halawa and Lapakahi – windward valley and leeward slope. *New Zealand Archaeological Association Newsletter* 14(3):101–112.

Hommon, R.J. 2013. *The Ancient Hawaiian State: Origins of a Political Society*. New York: Oxford University Press.

Kamakau, S.M. 1976. *The Works of the People of Old: Na Hana a ka Poʻe Kahiko*. Honolulu: Bishop Museum Press.

Kirch, P.V. 1979. *The Ecology of Marine Exploitation in Prehistoric Hawaii*. Pacific Archaeological Records, 29. Honolulu: Bernice P. Bishop Museum.

Kirch, P.V. 1985. *Feathered Gods and Fishhooks: An Introduction to Hawaiian Archeology and Prehistory*. Honolulu: University of Hawaiʻi Press.

Kirch, P.V. 2010. *How Chiefs Became Kings: Divine Kingship and the Rise of Archaic States in Ancient Hawaiʻi*. Berkeley: University of California Press.

Kirch, P.V., G. Asner, O.A. Chadwick, J.S. Field, T.N. Ladefoged, C. Lee, C. Puleston, S. Tuljapurkar, & P.M. Vitousek. 2012. Building and testing models of long-term agricultural intensification and population dynamics: a case study from the Leeward Kohala Field System, Hawaiʻi. *Ecological Modelling* 241:54–64.

Ladefoged, T.N. & M.W. Graves. 2000. Evolutionary theory and the historical development of dry-land agriculture in North Kohala, Hawaiʻi. *American Antiquity* 65(3):423–448.

Ladefoged, T.N. & M.W. Graves. 2007. Modeling agricultural development and demography in Kohala, Hawaiʻi. In *The Growth and Collapse of Pacific Island Societies: Archaeological and Demographic Perspectives*. P.V. Kirch & J.L. Rallu (eds.):70–89. Honolulu: University of Hawaiʻi Press.

Ladefoged, T.N. & M.W. Graves. 2008. Variable development of dryland agriculture in Hawai‘i. *Current Anthropology* 49(5):771–802.

Ladefoged, T.N. & M.W. Graves. 2011. The Leeward Kohala Field System (LKFS). In *Roots of Conflict: Soils, Agriculture, and Sociopolitical Complexity in Ancient Hawaii*. P.V. Kirch (ed.):89–110. Santa Fe: SAR Press.

Ladefoged, T.N., M.W. Graves, & R.P. Jennings. 1996. Dryland agricultural expansion and intensification in Kohala, Hawai‘i Island. *Antiquity* 70:861–880.

Lapakahi State Historical Park. n.d. Retrieved April 18, 2021, from https://dlnr.hawaii.gov/dsp/parks/hawaii/lapakahi-state-historical-park/

Lundblad, S.P., P.R. Mills, M.D. McCoy, J.G. Kahn, K. Mulliken, & D. Kaylor. 2013. Identification of volcanic glass sources inferred from geochemical analysis of artifacts on Leeward Hawai‘i Island. In *Pacific Archaeology: Documenting the Past 50,000 Years. Papers from the 2011 Lapita Pacific Archaeology Conference*. G.R. Summerhayes & H. Buckley (eds.):67–75. Dunedin: University of Otago. Studies in Archaeology No. 25.

MacDonald, G.A. & T. Katsura. 1964. Chemical composition of Hawaiian lavas. *Journal of Petrology* 5(1):82–133.

Macy, B.W. 1898. An old Kamaaina gives valuable facts concerning forest destruction and droughts. *Hilo Tribune* 22 January 3(10):1.

Malo, D. 1951. *Hawaiian Antiquities*. N.B. Emerson (ed.). Honolulu: Bishop Museum Press.

McCoy, M.D., P.R. Mills, S.P. Lundblad, T.M. Rieth, J.G. Kahn, & R. Gard. 2011. A cost surface model of volcanic glass quarrying and exchange in Hawai‘i. *Journal of Archaeological Science* 38(10):2547–2560.

Menzies, A. 1920. *Hawaii Nei, 128 Years Ago*. W.F. Wilson (ed.). Honolulu: New Freedom Press.

Mills, P.R. n.d. Cryptocrystalline silicates in Hawaiian lithic assemblages. Paper presented at the 12th Annual SHA Conference, Kapiolani Community College, Honolulu, 1999.

Mills, P.R. & S.P. Lundblad. 2014. Current perspectives on Hawai‘i’s stone tool economies. *Journal of Pacific Archaeology* 5(2):30–39.

Mills, P.R., S.P. Lundblad, J.G. Smith, P.C. McCoy, & S.P. Naleimaile. 2008. Science and sensitivity: a geochemical characterization of the Mauna Kea adze quarry complex, Hawai‘i Island, Hawaii. *American Antiquity* 73(4):743–758.

Mills, P.R., S.P. Lundblad, J.S. Field, A.B. Carpenter, W.K. McElroy, & P. Rossi. 2010. Geochemical sourcing of basalt artifacts from Kaua‘i, Hawaiian Islands. *Journal of Archaeological Science* 37 (1):3385–3393.

Mills, P.R., S.P. Lundblad, K.A. Hon, J.J. Moniz Nakamura, E.L. Kahahane, A. Drake-Raue, T.M. Souza, & R. Wei. 2011. Reappraising craft specialization and exchange in pre-contact Hawai‘i through non-destructive sourcing of basalt adze debitage. *Journal of Pacific Archaeology* 2(2):79–91.

Mills, P.R., S.P. Lundblad, C. Cauley, D.S. Coleman, J.S. Field, A.L. Hafner, J.G. Kahn, J.M. Sinton, & P.V. Kirch. 2022. Provenance, production, and distribution of basalt and volcanic glass artifacts in leeward Kohala, Hawai‘i Island. *Geoarchaeology* 37(5):733–749.

Neal, M.C. 1965. *In Gardens of Hawaii*. Honolulu: Bernice P. Bishop Museum. Special Publication, 50.

Newman, T.S. 1968. The archaeology of North Kohala: the Ahupua‘a of Lapakahi: excavations at Lapakahi – selected papers. Richard J. Pearson. *State Archeological Journal* 69-2.

Newman, T.S. 1969. Cultural adaptations of the Hawaii Island ecosystem: the theory behind the 1968 Lapakahi Project. In *Archaeology on the Island of Hawaii*. R.J. Pearson (ed.). Asian and Pacific Archaeology Series, No. 2. Honolulu: Social Science Research Institute, University of Hawaiʻi.

Newman, T.S. 1970. *Makai-Mauka: Fishing and Farming on the Island of Hawaii in A.D. 1778*. Doctoral dissertation, Dept. of Anthropology, University of Hawaiʻi at Mānoa. Honolulu, HI. Ann Arbor: University Microfilms International.

Newman, T.S., E. Murabayashi, & D. Kelso. 1970. *Hawaiian Fishing and Farming on the Island of Hawaii in AD 1778*. Hawaii: Department of Land and Natural Resources.

Putzi, J.L., N.J. DiVito, C.E. Sholin, P.R. Mills, S.P. Lundblad, B. Camara, & T.S. Dye. 2015. Alternative models of volcanic glass quarrying and exchange in Hawaiʻi. *Journal of Archaeological Science: Reports* 2:341–352.

Rosendahl, P.H. 1972. *Aboriginal Agriculture and Residence Patterns in Upland Lapakahi, Island of Hawaii*. Doctoral dissertation, Dept. of Anthropology, University of Hawaiʻi at Mānoa, Honolulu, HI. Ann Arbor: University Microfilms International.

Rosendahl, P.H. 1994. Aboriginal Hawaiian structural remains and settlement patterns in the upland agricultural zone at Lapakahi, Island of Hawaiʻi. *Hawaiian Archeology* 3:14–70.

Sahlins, M.D. 1992. *Anahulu: The Anthropology of History in the Kingdom of Hawaii, Volume 1. Historical Ethnography*. Chicago: University of Chicago Press.

Schousboe, R., M. Riford, & P.V. Kirch. 1983. Volcanic glass flaked stone artifacts. In *Archaeological Investigations of the Mudlane-Waimea-Kawaihae Road Corridor, Island of Hawaiʻi: An Interdisciplinary Study of an Environmental Transect*. J.T. Clark & P.V. Kirch (eds.):348–370. Departmental Report Series 83-1. Honolulu: B.P. Bishop Museum.

Spriggs, M.J.T. 1993. University of Hawaiʻi Archaeology Field Schools 1950–1984. *Hawaiian Archaeology* 2:18–27.

Stevenson, C.M. & P.R. Mills. 2013. A chronometric tool for Hawaiian archaeology: the hydration dating of Puʻuwaʻawaʻa trachytic glass. *Journal of Archaeological Science* 40:405–415.

Tuggle, H.D. 2010. Lady Mondegreen's hopes and dreams: three brief essays on inference in Hawaiian archaeology. In *Research Designs for Hawaiian Archaeology: Agriculture, Architecture, Methodology*. T. Dye (ed.):157–184. Special Publication 3. Honolulu: Society for Hawaiian Archaeology.

Tuggle, H.D. & P.B. Griffin 1973. *Lapakahi, Hawaii: Archaeological Studies*. Asian and Pacific Archaeology Series No. 5. Honolulu: Social Science Research Inst., University of Hawaiʻi.

UH Hilo Geoarchaeology Lab. 2023. Retrieved January 7, 2023 from https://hilo.hawaii.edu/depts/geoarchaeology/TheUHHiloEDXRFMethod.php

Van Gilder, C. 2017. In the sea of night: ancient Polynesia and the dark. In *Archaeology of Night: Life after Dark in the Ancient World*. N. Gonlin & A. Nowell (eds.):139–154. Boulder: University Press of Colorado.

Weisler, M. 1990. Sources and sourcing of volcanic glass in Hawaiʻi: implications for exchange studies. *Archaeology in Oceania* 25(1):16–23.