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– ARTICLE –

Reappraising Craft Specialisation and Exchange in Pre-Contact Hawai'i through Non-destructive Sourcing of Basalt Adze Debitage

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ABSTRACT

Depictions of pre-Contact Hawaiian complex societies are framed in self-sufficient small land units (*Ahupua'a*) that minimised the occurrence of long-distance commodity exchange and chiefly redistributive networks. We test the *Ahupua'a* model by using non-destructive Energy-Dispersive X-Ray Fluorescence (EDXRF) to source 955 basalt flakes and cores recovered from Kahalu'u Habitation Cave in the Kona district (~AD 1600–1800). Findings suggest that less than 7% of the basalt debitage was obtained from local sources.

Keywords: Archaeology, Oceania, Craft Specialisation; Exchange, Hawai'i

INTRODUCTION

The significance of craft specialists in early civilisations continues to be discussed in theoretical frameworks from neo-evolutionary theory to neo-Marxism (Clark and Parry 1990; Costin 1991; Kirch 2005; Patterson 2005). We use the term to refer both to the production of specialised goods for elites and to highly centralised modes of production where small groups were responsible for producing commodities for general consumption. In Hawai'i, most of the known specialists were involved in managing ritual, healing, and genealogical knowledge (Lass 1998; Kirch 2005), but some specialists made feathered cloaks and helmets for the chiefs, bark-cloth (*kapa*), and canoes (Lass 1998; Bayman and Nakamura 2001).

Hawai'i's stone adze economies may have involved some form of craft specialisation (Cleghorn 1986; Lass 1998; Bayman and Nakamura 2001), but the ethnohistoric data are ambiguous, as is the timing of any changes in the organisation of adze production. The high demand for iron adzes by the beginning of the nineteenth century contributed to the lack of detailed accounts of Hawaiian stone adze production. Bayman (2003, 2009) demonstrates the persistence of some stone adze use through the nineteenth century, but iron adzes quickly replaced most stone adzes in port communities.

ADZES AND THE *AHUPUA'A* SYSTEM

Iron adzes were usually appropriated by chiefs and then redistributed. This system contrasts with pre-Contact Hawaiian exchange models (Earle 1977; Cordy and Kaschko 1980; Hommon 1986; Sahlins 1992) which emphasise that each polity was subdivided into small economic and social units that ran from the sea to the interior (*Ahupua'a*), thereby facilitating local commodity production and exchange. Cordy (2000) estimates that Hawai'i Island contained over 600 *Ahupua'a* distributed between six larger political districts (*moku)*. These *moku* were often independent polities controlled by high chiefs. In the last several centuries before Western contact, paramount chiefs sometimes controlled several *moku*, and occasionally, more than one island. The general validity of self-sufficient *Ahupua'a* is well established for the late prehistoric era (Earle 1977, Hommon 1986; Sahlins 1992). Nevertheless, exceptions to the practice of intra-*Ahupua'a* exchange have significant political and economic consequences (Hommon 1986; Mills 2002).

Stone adze exchange may have been among the exceptions. Dense, fine-grained basalts suitable for adze production are uncommon and were not necessarily available in every *Ahupua'a*, because most eruptions in Hawai'i produce vesicular or coarse-grained basalts not preferred for adze production.

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The modes of Hawaiian adze production and distribution are still poorly understood. Archaeologists have not systematically addressed whether members of Hawaiian households produced their own adzes, or if production varied regionally. Whether chiefs or guilds of specialists directly controlled any adze quarries remains debatable. For example, at the Mauna Kea Adze Quarry on Hawai'i Island (McCoy 1977, 1990; Cleghorn 1982, 1986; Lass 1994; Mills *et al.* 2008), the scale of production clearly supported an economy that extended beyond the *Ahupua'a* containing the quarry. This quarry (Figure 1) is larger than all other known Hawaiian quarries combined, but rather than concluding that it is proof of inter-district *exchange*, Lass (1994) and McCoy (1990) have suggested that it might have been a special class of resource that was commonly and directly exploited by all the polities of Hawai'i Island.

In the most substantial previous study of Hawaiian adze distribution, Lass (1994) examined thin-sections of 155 adze fragments from Hawai'i Island, which she then supplemented with 28 wavelength-dispersive XRF analyses (Lass 1997). Lass found Mauna Kea material in all the districts, but she concluded 'the distribution of Mauna Kea material does not at any time differ from that of other materials which would probably be expected if centralised redistribution had developed. Adzes were probably acquired by direct access and/or informal exchange among commoners within the subsistence economy and not collected and distributed by Hawaiian chiefs' (1994, 28). Alternative interpretations remain possible, and Lass's findings of Mauna Kea material in every district could still be consistent with chief-controlled distribution.

Here, we present the results of the first intensive geochemical study of adze debitage in a Hawaiian domestic site, Kahalu'u Habitation Cave (site 50–10–37–7702), located in the leeward Kona district of Hawai'i Island (Figure 2). The deep midden deposits allow us to examine patterns in late prehistoric adze procurement over a period of approximately two centuries using a large data set.

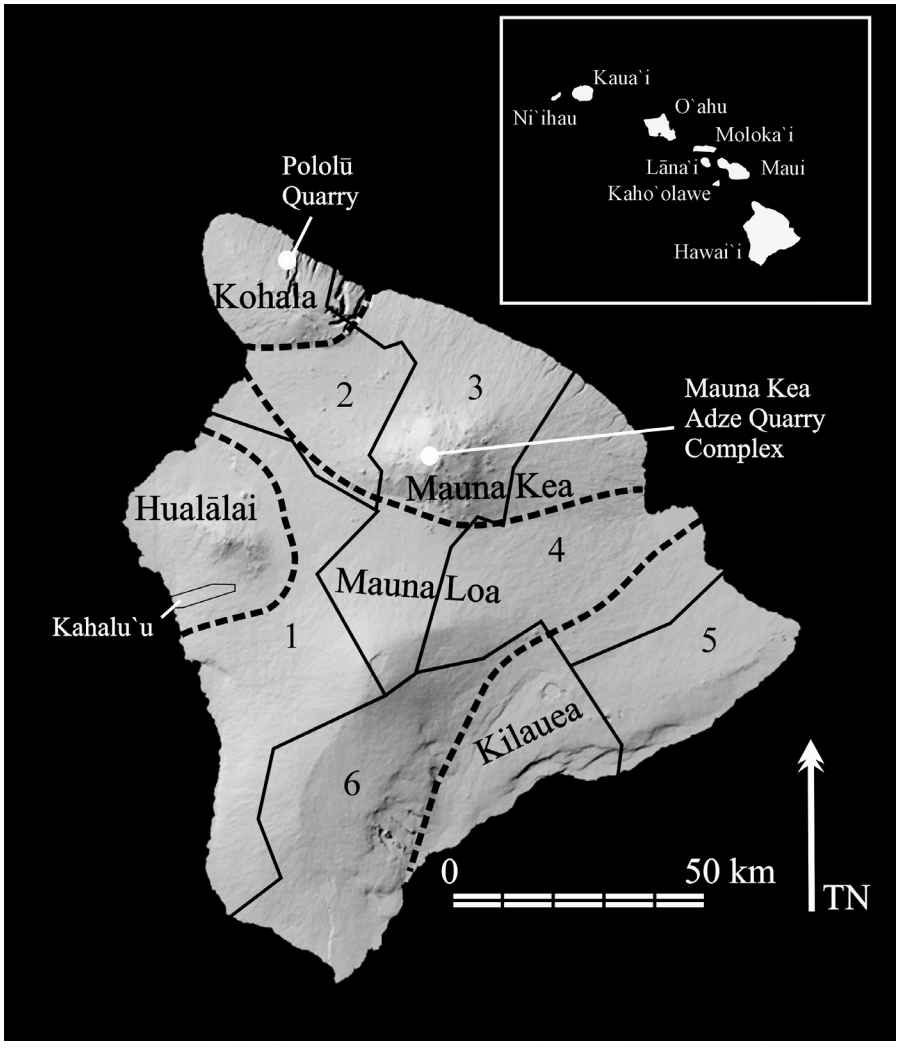

Figure 1. Map of Hawai'i Island showing the relationship between the five main volcanoes (dashed boundaries) and the six traditional political districts (*moku*, demarcated with solid black lines): 1) Kona; 2) Kohala; 3) Hāmākua; 4) Hilo; 5) Puna; 6) Ka'ū.

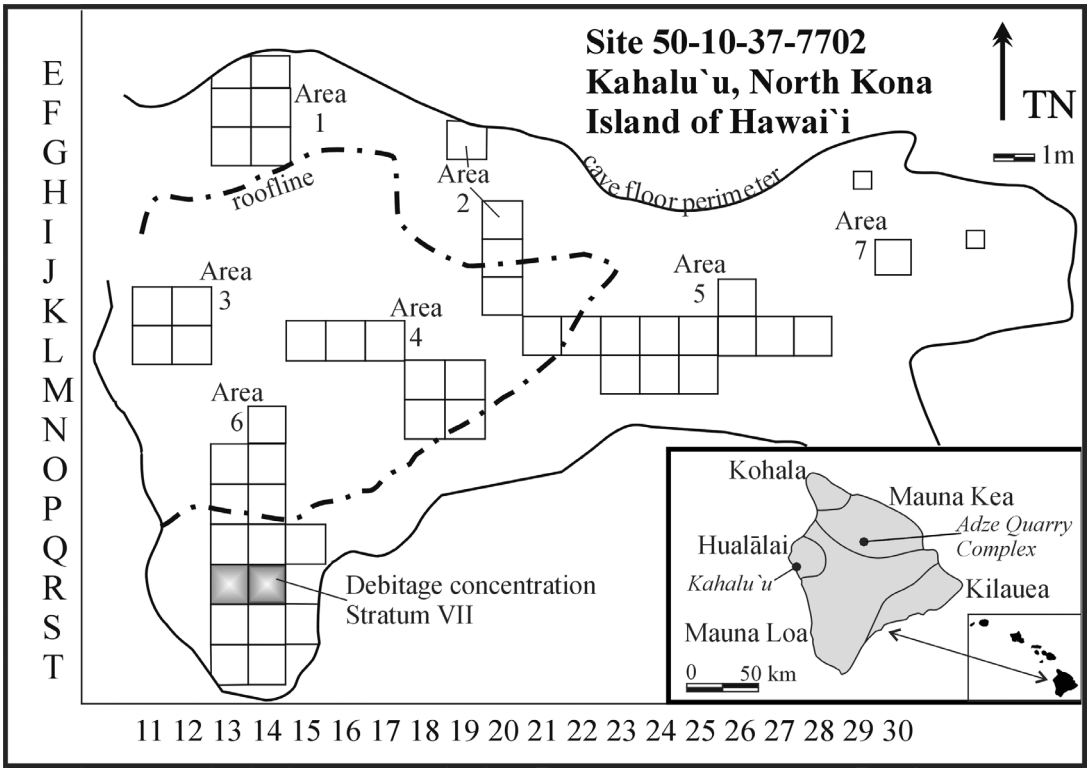

Figure 2. Plan Map of excavation areas in Kahalu'u Habitation Cave.

KAHALU'U HABITATION CAVE, KONA DISTRICT

Kahalu'u Habitation Cave is located 300 metres from Kahalu'u Bay in an *Ahupua'a* of the same name, on the western flank of Hualālai Volcano. The majority of Kona is situated on Hualālai volcanics, but peripheral portions are on Mauna Loa (Figure 1). Kahalu'u is one of over 100 *Ahupua'a* in the district of Kona. Kona and leeward portions of the adjacent Kohala district are well known for massive agricultural field systems that developed prior to Captain Cook's arrival (Ladefoged *et al.* 2003; Ladefoged and Graves 2000, 2008; Allen 2004). Cordy (2000) estimates that the population of the Kona district in 1778 was greater than any other district on Hawai'i Island, and contained 27% of an island population of over 100,000 people. In 1980 and 1981, the consulting firm of Paul H. Rosendahl, Inc. (PHRI) excavated approximately 50% of the cave (49.75 m^2) using ⅛th inch mesh screens (Hay *et al.* 1986), and exposed dense midden deposits that were over a metre deep. PHRI excavated in seven non-contiguous areas within the site that contained between three and eight cultural strata each. Shortly after completion of the fieldwork, the site was graded and buried under the development.

The nearly complete absence of Western artefacts suggests that the site was abandoned early in the historical era. Based primarily on 15 standard radiocarbon dates (Table 1), Hay *et al.* concluded that the cave was occupied nearly continuously between the AD 1400s and 1700s. Only four of the radiocarbon sample date ranges, however, extended earlier than the AD 1600s. As was common in the early 1980s, the charcoal taxa used in radiocarbon dating also had not been identified, and were submitted as bulk samples. To evaluate whether or not the early dates were due to the sampling of 'old wood,' we submitted *kukui* (*Aleurites moluccana)* endocarps from the two strata that had yielded the earliest radiocarbon dates, and a third sample was submitted from the area with the greatest concentration of debitage (Area 6, stratum VII). All three of the newly obtained dates were in the mid-AD 1600s at the earliest, and limit the occupation of the rockshelter to less than two centuries.

Because the radiocarbon dates in this era have numerous intercepts with the calibration curve, and the standard deviations for the dates have a large degree of overlap with each other (Figure 3), one must rely on stratigraphic relationships to interpret chronological changes in the assemblage. Unfortunately, the excavation units were arranged in seven non-contiguous areas. This strategy precluded the construction of a single relative chronology for the entire assemblage. For the current analysis, we do not attempt to classify the samples into different chronological groups, and instead evaluate the general pattern of lithic procurement in the last two centuries before Western contact.

The late prehistoric intensive occupation can be partially explained due to the cave's proximity to one of the most significant chiefly complexes in Kona, which con-

Table 1. *Radiocarbon dates arranged by increasing stratigraphic depth within each excavation area. All samples analyzed by Beta Analytic. Conventional Radiocarbon Age (CRA) calculated from the delta ^{13}C value. The calibrated date range is expressed as 2δ.*

ID	Location	Method	$^{13}C/^{12}C$ ratio	CRA	+/–	Calibrated date range AD	Taxa
B-10664	Area 1, F13-IV	standard	–14.74	1080	120	670–1180	Unidentified
B-10679	Area 1, G13-IV	standard	–8.36	380	50	1420–1650	Unidentified
B-284821	Area 1, G13 -VI	AMS	–20.80	200	40	1640–1700 1720–1820	*Aleurites moluccana*
B-10665	Area 2, G19-II-3	standard	–19.44	130	50	1650–1950	Unidentified
B-10666	Area 3, L12-V	standard	–23.96	170	50	1640–1950	Unidentified
B-10667	Area 3, L12-IV	standard	–20.88	230	50	1505–1675 1710–1805	Unidentified
B-10668	Area 4, N18-III	standard	–23.11	110	60	1655–1950	Unidentified
B-10669	Area 5, L27-III-1	standard	–21.28	190	50	1620–1890	Unidentified
B-10670	Area 5, M23-I	standard	–21.48	140	60	1650–1950	Unidentified
B-10671	Area 5, M23-II	standard	–23.02	80	60	1665–1940	Unidentified
B-10677	Area 5, M23-III-1	standard	–17.50	150	60	1645–1950	Unidentified
B-10678	Area 5, M23-III-2	standard	–22.44	100	60	1815–1845 1885–1920	Unidentified
B-10672	Area 5, M23-IV	standard	–12.72	340	60	1420–1650	Unidentified
B-284822	Area 5, M24-VII	AMS	–23.90	140	40	1660–1960	*Aleurites moluccana*
B-10680	Area 6, Q13-III	standard	–26.51	100	60	1875–1925	Unidentified
B-10674	Area 6, R13-III	standard	–23.30	140	50	1650–1950	Unidentified
B-10673	Area 6, Q15-VI	standard	–17.05	160	50	1645–1950	Unidentified
B-10676	Area 6, R13-VII	standard	–26.01	100	70	1680–1705 1810–1855	Unidentified
B-284823	Area 6, R15-VII	AMS	–21.10	80	40	1680–1740 1800–1940	*Aleurites moluccana*
B-10675	Area 6, R13-VIII	standard	–19.15	70	50	1665–1765 1790–1940	Unidentified

tains two large stone *heiau*, or ritual temples, Keʻekū and Hāpaialiʻi. Their construction would have involved a large amount of corvée labor. The chief Lfonoikamakahiki is remembered for developing much of this centre, and maintained his primary residence there. By applying a 20-year generational average to chiefly genealogies, Lonoikamakahiki's reign would have begun around AD 1610 (Cachola Abad 2000: 224).

Hay *et al.* (1986) suggest the site was a permanent habitation of commoners due to the lack of status goods in the midden. While their conclusion is justifiable, the intensity of use of the cave may be related to the support of the nearby chiefly complex and temporary habitation by visiting retinues and laborers.

Adzes and adze debitage from Kahaluʻu Habitation Cave

Excavations uncovered 29 adzes and 2,113 provenanced basalt flakes. Although most of the adzes are at least partially damaged or broken, at least 11 of the adzes appear to have been between 4 and 10 cm in length at the time that they were discarded. Adze blanks of this small size are not typically found at the Mauna Kea Adze quarries and other formal known quarries. They could either be the result of repeated rejuvenation episodes on formerly larger adzes, or they could have been produced from smaller cores of fine-grained basalts that were locally available. Because of excellent preservation conditions, the debitage is minimally weathered. Of the collection, 668 basalt flakes (31.6%) have ground dorsal surfaces, platforms, or both, indicating that they were removed from finished adzes through accidental breakage during use, resharpening or recycling. This percentage is consistent with ratios found in Hālawa Valley, Oʻahu, in sites primarily containing adze recycling debitage (Olzewski 2007; personal communication 2011). Weight and size ranges for polished flakes at Kahaluʻu also fall within the ranges reported by Olszewski for tasks associated with adze recycling and resharpening.

Comparative weight classification of the flake assemblage is also skewed towards smaller flakes. Only 13 flakes weigh over 20 g and six of those exhibit polish on

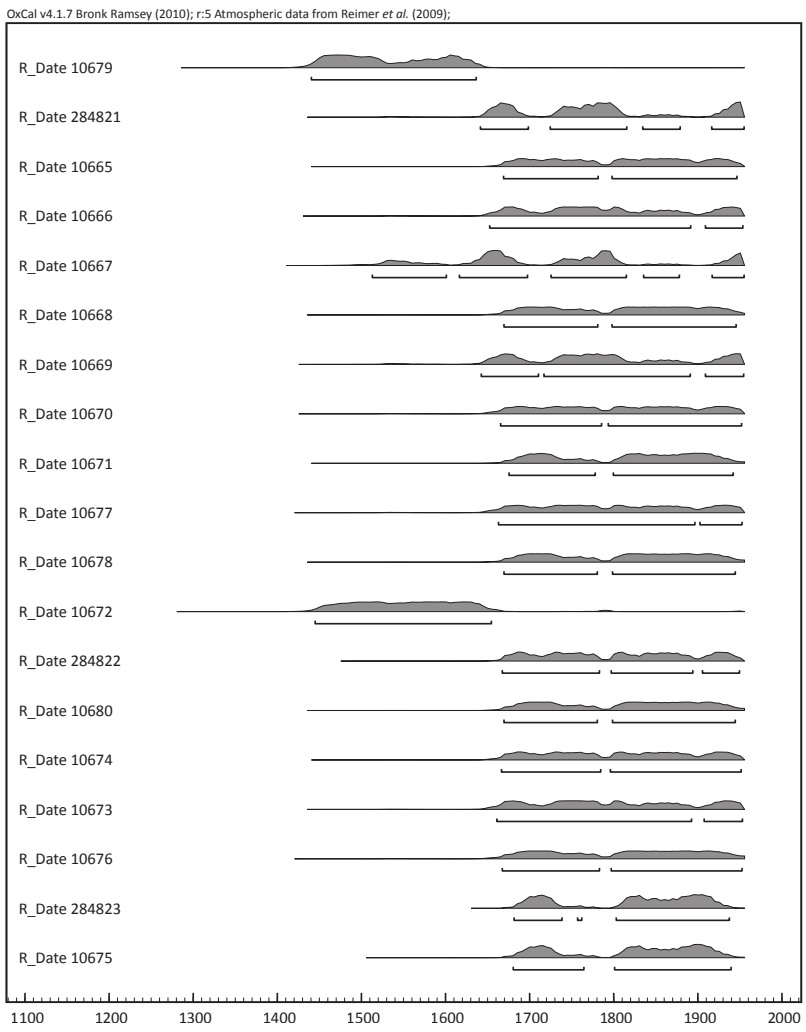

Figure 3. Calibrated ranges of radiocarbon dates from Kahaluʻu Habitation Cave, using OxCal v. 4.1.7. The anomalously early date from Area 1 Layer IV (Beta 10679, Table 1) is excluded.

the dorsal surfaces or platforms, indicating that they were removed from polished adzes during use or rejuvenation.

The 29 adze fragments and 2,113 basalt flakes could derive from hundreds of different adzes. Some of the debitage would likely be associated with the reduction events that resulted in the disposal of adzes/adze fragments, but successful rejuvenation would result in debitage deposits only. Due to the lack of large flakes and limited concentrations of unpolished flakes, we infer that initial adze blank production from quarried material (Cleghorn 1982; Williams 1989) is not evident in this assemblage that spans two centuries.

Area 6, stratum VII contains the greatest single concentration of debitage, with 997 of the flakes (47.2%). The percentage of polished adze flakes in this stratum (27.2%) is slightly lower than that in the overall assemblage, but it is still 5% higher than the highest reported ratio for Hālawa Valley, Oʻahu, indicating that it is still rejuvenation related. The pattern could be explained by an episode of chiefly-sponsored public works in Kahaluʻu. As itinerant laborers arrived to assist with projects, the expedient use of natural shelters might be expected to increase.

Geochemical sampling with EDXRF

Lass (1994) conducted petrographic analyses of 31 pieces of basalt debitage from Kahaluʻu Habitation Cave as part of her island-wide study of adze provenance. This is the largest number of samples from a single site in Lass's study. Unfortunately, we have been unable to identify the samples analyzed by Lass for re-analysis. Results of Lass's classification of her samples from the cave are presented in Table 2.

In a self-critique of her sample, Lass stated 'there is no way to meaningfully document the relative abundance of adzes from various sources or to quantify regional differences in the occurrence of adzes made from different materials' (Lass 1994, 15–16). We increased sampling of the Kahaluʻu Cave deposits from 31 to 955 specimens using

Table 2. *Summary of petrographic source interpretations of 31 adze debitage samples from Kahalu'u Habitation Cave, from Lass (1994).*

Mauna Kea	Pololū	Kīlauea	'Type B'	Unidentified
18	5	1	3	4

non-destructive EDXRF. These samples comprise all of the available basalt debitage that is large enough to reliably analyze.

We used a ThermoNoran QuanX™ EDXRF spectrometer for nondestructive analysis. Concentration data on 19 elements were acquired using the methodology of Lundblad *et al.* (2008). Analytical precision drops significantly for samples under 1 cm in diameter. This size roughly corresponds with flakes weighing under 0.5 g. As a buffer, and given the more irregular shape of unpolished flakes, we selected all unpolished debitage weighing over 1 g for analysis. Polished flakes provide smooth, flat surfaces optimal for analysis. For polished flakes, we analyzed all flakes over 1 g, and any flake with a flat surface that exceeded 10 mm in both length and width. Polished debitage that met our size criteria include 434 of the 668 total polished flakes (65%). Four-hundred and ninety-two unpolished basalt flakes of 1,445 (34%) met our size criteria. The 29 adze fragments were also analyzed.

Figure 4 illustrates variation in basalt quarries most relevant to this study. Because multiple sources may have similar geochemical signatures, it is often easier to demonstrate where an artefact is *not* from than it is to conclude that an artefact derives from a specific source. Because Hawaiian volcanism follows a repetitive process of shield-building and post-shield volcanism, similar geochemical units can be widespread throughout the islands.

Sinton and Sinoto (1997) compiled geochemical data on Hawaiian adze quarries, but that database contained only a few samples from each of the major quarries. EDXRF analyses at UH Hilo have expanded the available information on Hawai'i Island adze quarry sites (Lundblad *et al.* 2008; Mills *et al.* 2008). Sample sites include the Mauna Kea adze quarry, Pololū Valley Quarry in Kohala (Tuggle 1976; Lass 1994), and material quarried from volcanic bombs near Kīlauea caldera (www.uhh.edu/uhh/faculty/lundblad/EDXRFandtheGeoarchaeologyLab.php). For this study, we also characterised 184 control samples of Hualālai volcanics (Figure 4). Part of the control set consists of 99 geological specimens from a 1,890-foot deep well core from Kohanaiki, Kona. This core extends through Hualālai Volcanics as far back as the Pu'u Wa'awa'a trachyte eruptive series dating to approximately 114 ka (Cousens *et al.* 2003). The core exposes flows that may no longer be present on the surface, but which could have been used in the pre-Contact era. The Pu'u Wa'awa'a deposits

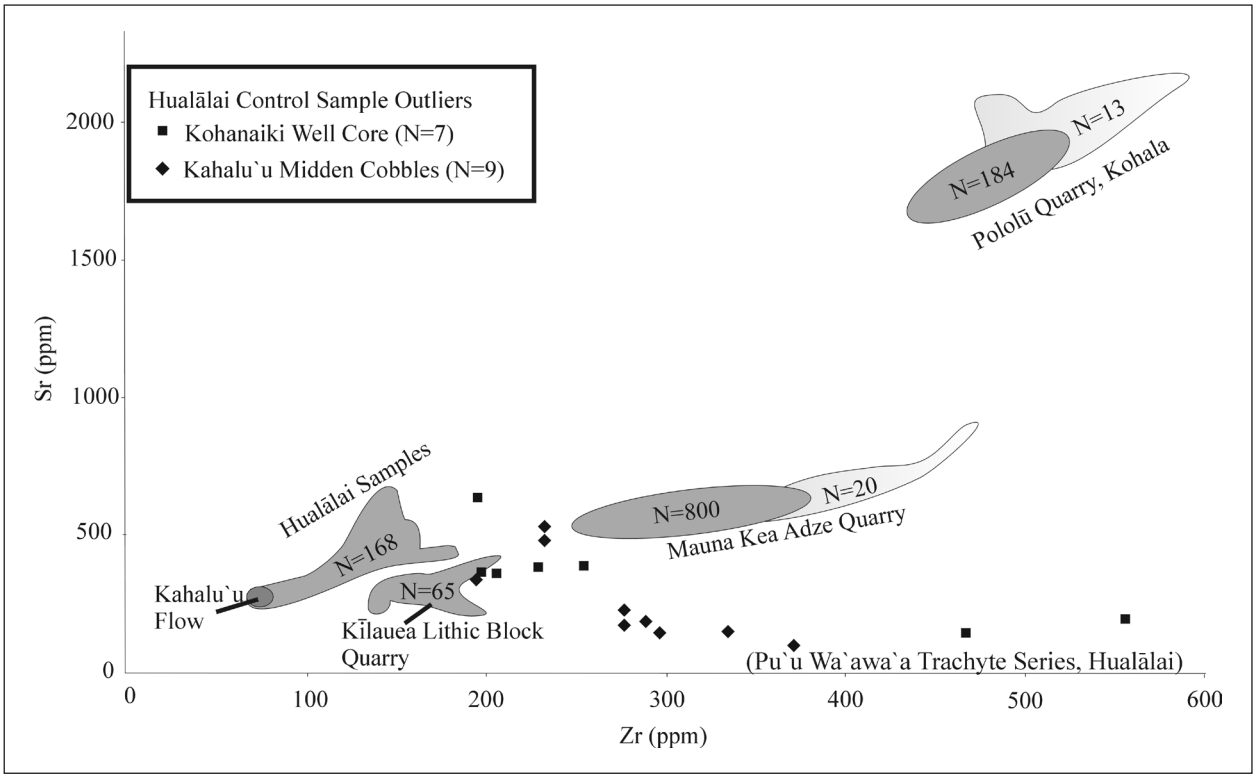

Figure 4. Comparison of strontium (Sr) and zirconium (Zr) concentrations for Hualālai Volcano geological samples compared to known Hawai'i Island adze quarries.

at the bottom of the core are still exposed on the surface in northern portions of the Kona district. The main cluster matches alkalic basalts in Sherrod *et al*. (2007). An outlier trend is related to flows of which Puʻu Waʻawaʻa trachytes are a part, and are characterised by low Sr and high Zr concentrations (Figure 4).

To supplement the Kohanaiki core, we also analyzed 75 dense basalt cobble fragments from the Kahaluʻu midden deposits that we assume were predominantly collected from local sources, and 10 pelletised samples of unmodified vesicular rock from the local lava flow. This flow appears on the periphery of the geochemical range of Hualālai volcanics (Figure 4).

Because the geochemical range of Hualālai volcanics could potentially mimic other Hawaiian basalts for the target elements used in this study, it is possible that we have misclassified some non-local material as 'local.' We therefore consider the quantity of unknown samples within the 'local' range in our analyses as a *maximum* number of samples that can be attributed to Hualālai volcanics.

Mauna Loa offers the other potential source of adze material that would have been available on the fringes of the Kona District. There is no current geological database for Mauna Loa flows on the UH Hilo EDXRF spectrometer, but Sherrod *et al*. (2007) characterise Mauna Loa surface flows as being consistently tholeiitic. Hawaiian tholeiitic basalts are low in incompatible trace elements such as Rb, Sr, Y, Zr, and Nb. Niobium serves as a good discriminator between Mauna Loa and Hualālai because Mauna Loa surface geology tends to have lower Nb concentrations (Frey and Rhodes 1993).

'Non-local' groups are defined as those that fall outside the measured range of the Hualālai control samples. Trace element geochemistry provides excellent discrimination between Hualālai volcanics, the Mauna Kea adze quarry, and the smaller Pololū adze quarry in the Kohala district. Kīlauea Volcano is also a reported source of adze basalt (Kamakau 1976; Cleghorn *et al*. 1985; Lass 1994), and although its trace element geochemistry is closer to Hualālai, it exhibits some compositional differences from Hualālai, particularly Sr and Nb (Figure 4). Our sampling of 65 archaeological basalts recovered from the area around Kīlauea caldera produced only minimal overlap with Hualālai control samples.

We establish our initial groupings using Zr and Sr, which exhibit the highest precision and accuracy on the spectrometer. They occur in Polynesian basalts at levels well above detection limits, and exhibit a measurable amount of variation between quarry sites (Lundblad *et al*. 2008). Other trace elements are then used to identify additional clusters that are not evident on the Sr and Zr scatter-plots. We then employ Cluster Analysis (CA) and Principal Component Analyses (PCA) to observe how these qualitatively defined groups cluster when multivariate statistical analyses are applied to all the trace element data and semi-quantitative major element data.

RESULTS

We define 12 geochemical groups (Tables 3 and 4). Eight outlier samples do not fit within the twelve groups. We consider these groupings to be a conservative estimate of the sources represented at the site. Exclusive geographic source determinations for all the groups may require approaches that provide more analytical range and precision, such as isotopic analyses which Collerson and Weisler (2007) employed to find a Hawaiian adze in Central Polynesia, but for our current purposes, the technique has proven more than adequate. Figure 5 presents concentration data for Sr and Zr. Figure 6 presents the results of a multivariate principal component analysis incorporating the trace elements rubidium (Rb), strontium (Sr), yttrium (Y), zirconium (Zr) and niobium (Nb). The entire data set and additional supporting PCA analyses are available online (www.uhh.edu/uhh/faculty/lundblad/EDXRFandtheGeoarchaeologyLab.php).

Local Sources (Groups A and B)

Geochemical groups A and B are similar to the Hualālai volcanic control samples. They account for 66 of the 955 archaeological samples (6.9%). These findings indicate that very few adzes in Kahaluʻu Habitation Cave were derived from Hualālai volcanic, and as we discuss below, these figures may be inflated by the incorporation of fire-cracked rock and flakes unrelated to adze production. No samples match the geochemistry of the flow that formed the cave.

Group A (N=41) covers a range of common geochemistry in the Kohanaiki core. Prior to the geochemical analyses, we identified angular spalls that exhibit coarse textures and poorly developed or missing bulbs of force, and interpreted them as possible fire cracked rock (FCR). Group A contains 22 samples of possible FCR (54% of Group A). Only seven other samples in the population of 955 analyzed specimens carry the same designation. Twelve of the Group A samples also have classic cobble cortex (weathered curved surfaces with remnant incipient cone cortex). None of the 29 adze fragments are composed of Group A material. In sum, the main geochemical group of Hualālai volcanics is poorly represented in the Kahaluʻu adze debitage assemblage, and the samples that are present are only tenuously associated with adze technology.

Group B (N=25) forms a tight cluster for Sr and Zr on the margin of Hualālai's expected range. Because Group B plots slightly outside of the range of Hualālai control samples in a PCA analysis of five trace elements, we only tentatively assign Group B to a local source. Keeping with our stated approach, however, we include this group in our 'local' category. The group also matches well with a known Kauaʻi source labeled 'Keahua 1' (Mills *et al*. 2010; Sinton and Sinoto 1997: 200). None of the 75 dense basalt cobbles analyzed from the midden match this cluster, suggesting that if Group B is from Hualālai, the specific flow is not

Table 3. *Average concentration values and standard deviations for 12 defined geochemical groups (A–L), compared with 21 analyses of the USGS standard BHVO-2. Reported concentrations and standard deviations on quantitative analyses are rounded to 1 ppm. Semiquantitative data are rounded to reflect varying degrees of analytical accuracy: Na_2O, K_2O, TiO_2, and Fe (rounded to 0.1%); MgO, Al_2O_3, and SiO_2, (1%); Zn (10 ppm); Ba, Ni and Cu (20 ppm); V (50 ppm); MnO (100 ppm); Total Fe is reported in format following Shackley (2005). Missing data on Ba for Groups K and L are due to Ba being added to the analytical method in the middle of the project, and analyses for that element were completed on 341 samples.*

Group	A (39)		B (25)		C (28)		D (21)		E (21)		F (79)		G (102)	
	Quantitative Analyses													
	Av.	S.D.	Av.	S.D.	Av.	S.D.	Av.	S.D.	Av.	S.D.	Av.	S.D.	Av.	S.D.
Rb ppm	27	4	20	3	30	7	30	9	28	5	10	4	22	9
Sr ppm	442	44	512	18	396	18	389	48	465	15	291	28	419	41
Y ppm	22	2	25	2	49	12	154	100	37	4	25	2	26	4
Zr ppm	139	10	117	7	229	16	235	43	265	11	137	14	161	19
Nb ppm	21	3	23	3	16	3	18	4	29	6	10	2	10	2
	Semi-Quantitative Analyses													
Na2O %	2.0	0.4	2.5	0.6	2.5	0.4	2.7	1.2	2.6	0.5	1.9	0.2	2.1	0.4
MgO %	5	1	5	2	3	1	3	2	3	1	6	2	4	1
Al2O3 %	12	2	14	3	13	1	13	5	11	2	12	1	12	2
SiO2 %	36	6	39	6	46	4	42	11	40	7	43	5	44	7
K2O %	0.8	0.1	0.7	0.1	0.9	0.1	0.8	0.1	0.9	0.2	0.6	0.1	0.7	0.1
CaO %	10	1	11	1	9	1	9	1	9	1	11	1	11	1
TiO2 %	1.9	0.2	2.2	0.2	3.0	0.2	3.1	0.3	3.3	0.3	2.2	0.2	2.3	0.3
V ppm	250	50	300	0	400	0	400	50	400	50	300	50	300	50
MnO ppm	1600	100	1600	200	1700	200	1600	200	1700	200	1700	100	1800	300
Fe %	10.0	1.8	9.4	1.8	9.8	1.9	9.7	3.2	8.8	1.9	8.2	1.7	7.5	1.4
Ni ppm	140	40	60	0	40	0	40	20	20	20	100	40	100	20
Cu ppm	80	20	40	20	80	20	80	40	60	20	110	40	100	20
Zn ppm	130	10	130	10	140	10	150	40	140	10	130	10	130	10
Ba ppm	500	60	470	40	370	160	530	320	550	130	120	40	220	60

Group	H (494)		I (88)		J (43)		K (3)		L (2)		BHVO-2 (21)		
	Quantitative Analyses												
	Av.	S.D.	Av.	S.D.	Av.	S.D.	Av.	S.D.	Av.	S.D.	Av.	S.D.	Acc. Value
Rb ppm	36	6	67	8	54	13	46	5	48	2	13	1	9.8
Sr ppm	540	23	993	82	1065	186	1709	40	587	3	380	11	389
Y ppm	40	3	48	3	39	5	63	3	53	1	27	2	26
Zr ppm	309	20	422	26	304	45	450	10	439	1	188	6	172
Nb ppm	34	3	73	6	57	11	61	3	41	0	18	2	18
	Semi-Quantitative Analyses												
Na2O %	2.4	0.4	4.5	0.9	3.4	0.7	3.5	1.2	3.2	0.4	2.1	0.1	2.22
MgO %	3	1	2	1	3	1	1	1	3	0	7	0	7.23
Al2O3 %	12	1	15	2	15	2	14	2	14	0	12	0	13.5
SiO2 %	42	4	46	7	42	4	43	6	46	1	45	1	49.9
K2O %	1.0	0.1	1.8	0.1	1.3	0.2	1.4	0.2	1.3	0.1	0.6	0	0.52
CaO %	9	0	7	1	9	1	8	1	8	0	11	0	11.4
TiO2 %	3.6	0.2	2.5	0.3	3.4	0.4	2.7	0.3	4.1	0.1	2.7	0.1	2.73
V ppm	450	50	200	50	350	50	200	0	450	50	350	0	317
MnO ppm	1800	200	2800	300	2000	300	2500	100	1900	100	1500	0	1666
Fe %	10.9	5	7.3	1.5	9.6	1.2	9.3	1.2	10.2	0.1	8.8	0.4	8.6
Ni ppm	20	0	0	0	0	0	0	0	20	0	100	0	119
Cu ppm	60	20	0	0	20	0	20	0	40	20	120	0	127
Zn ppm	150	10	140	10	140	10	130	0	160	10	120	0	103
Ba ppm	620	80	1460	80	1160	200	1200	–	–	–	170	20	130

Table 4. *Quantities and percentages of geochemical groups.*

A	B	C	D	E	F	G	H	I	J	K	L	Outlier
41	25	28	21	21	79	102	494	88	43	3	2	8
4.3%	2.6%	2.9%	2.2%	2.2%	8.3%	10.7%	51.7%	9.2%	4.5%	0.3%	0.2%	0.8%

present along nearby beaches or drainages. Three of the remaining seven possible FCR samples are included in this group, but none of the samples exhibit cobble cortex. Unlike Group A, many samples in the group are fine-grained flakes with diagnostic attributes of adzes.

Non-local sources (Groups C–L and Outliers)

Ten groups fall outside the expected range of Hualālai geochemistry. Unlike Group A, most of these specimens are well-suited for adze manufacture. Cortex is lacking in all but four of the 889 samples in the non-local assemblage, with one sample each present in Groups E, F, G, and H.

Group C (N=28) is higher in Y and Nb than Hualālai samples, and shares similarities with the Pu'u Mōiwi adze quarry on Kaho'olawe (Sinton and Sinoto 1997:200). Without additional analyses, any association with Kahao'olawe is tentative. The cluster also shares many similarities to Group D, except that the latter group has higher Y concentrations.

Group D (N=21) is a dispersed geochemical group that has uncharacteristically high Y concentrations (72–488 ppm). The only known source of adze basalt in Hawai'i with similarly high concentrations of Y derive from Moloka'i (Sinton and Sinoto 1997). Lavas with Y levels greater than 100 ppm are rare in Hawai'i, and are mostly associated with enrichment of trivalent rare earth elements (REE) in relatively fresh basalt as a result of sphereoidal weathering (Fodor *et al.* 1992a, 1992b, 1994, Patino *et al.* 2003). Spheroidal weathering is typical of dense, equigranular rocks (Ol-

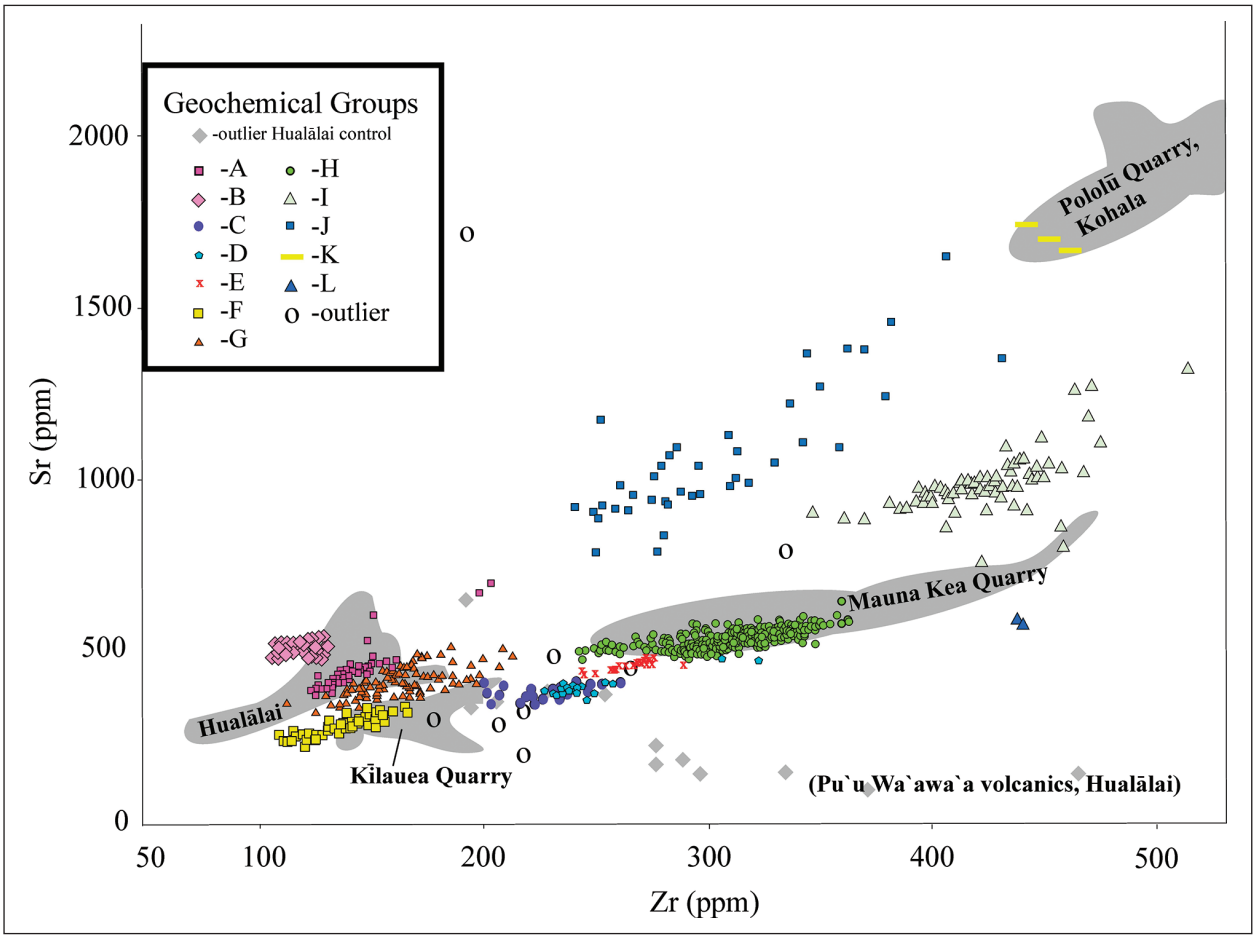

Figure 5. Sr and Zr concentrations for the defined groups compared with geological control samples from Figure 2.

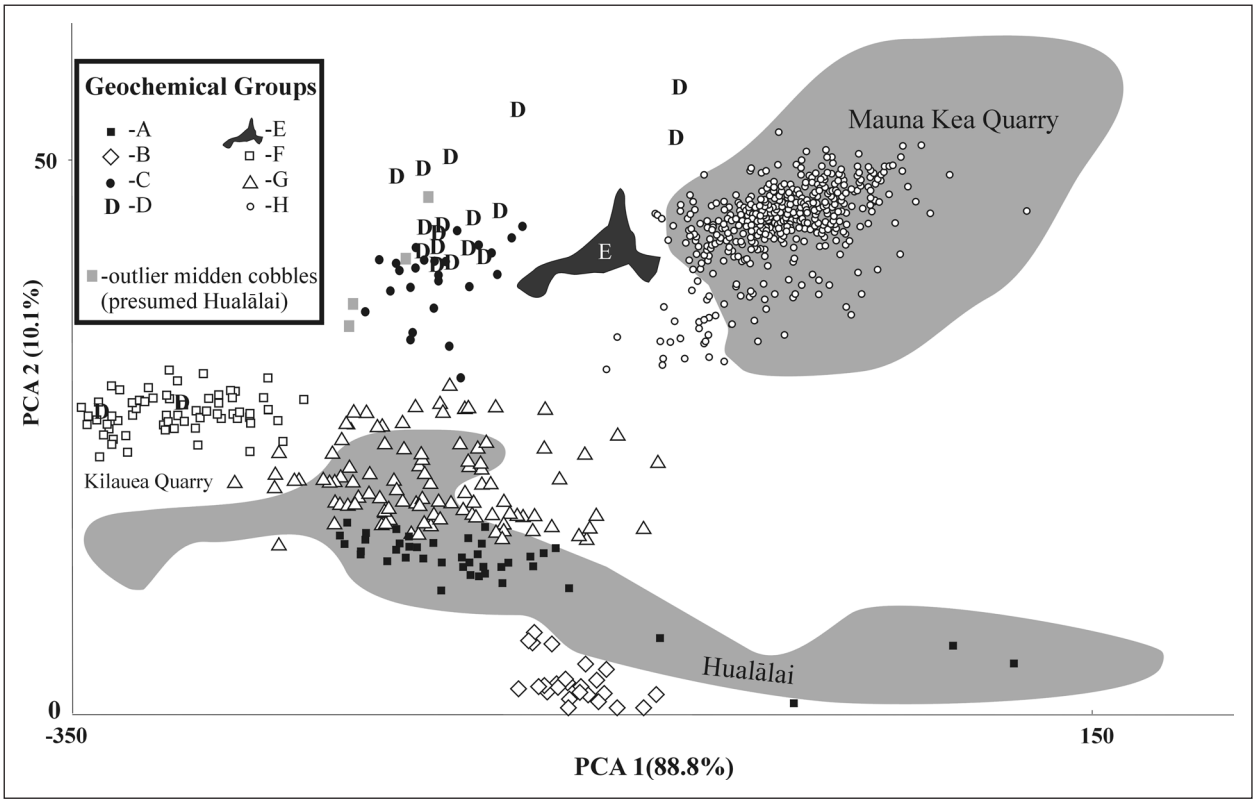

Figure 6. Principal Component Analysis (PCA) plot of Rb, Sr, Y, Zr, and Nb using a covariance matrix.

lier 1971), the type of material that is useful in tool making. Core stones are frequently found in surface outcrops and may also be preserved as stream boulders and cobbles.

Basalts with enriched Y contents are known from Koʻolau, West Molokaʻi, Haleakalā, and Kahoʻolawe volcanoes (Fodor *et al.* 1992; Fodor and Jacobs, 1994; Patino *et al.*, 2003; Xu *et al.* 2007). Weaker spheroidal weathering of samples from Kohala Volcano did not produce significant Y enrichment (Patino *et al.* 2003). This suggests that some of the debitage from Group D may derive from islands other than Hawaiʻi.

Group E (N=21) is higher in Sr and Zr than any of the Hualālai control samples. Group E may derive from a Mauna Kea source in the Hāmākua Volcanic Series, but it does not match well with the adze quarry.

Group F (N=79) is the third most common group in abundance. It displays lower Sr relative to Zr than the Hualālai control samples and also lower concentrations of Nb. Partially quantitative major element data also indicate that Group F is lower in Na_2O and K_2O relative to SiO_2 than the Hualālai samples. This group's geochemistry is similar to adze debitage obtained from volcanic bombs surrounding Kīlauea caldera (Figure 4). Although these samples match well with Kīlauea volcanics, the similarity of the lavas to other sources such as Kapōhaku on Lānaʻi (Weisler 1990, Sinton and Sinoto 1997), and certain flows from the Mauna Loa, and earlier Kohala series, presently confounds any definitive association for this group.

Group G (N=102) appears more tholeiitic than Group A and exhibits the significant difference of lower Nb concentrations (Figure 7). This trait is consistent with Mauna Loa and Kīlauea (Sherrod *et al.* 2007). Group G does not match any currently known quarry source, yet it is second in abundance only to the Mauna Kea Quarry. If this group is from Mauna Loa, it may represent intra-district production of adzes in Kona, but it is equally possible that the material derived from outside the Kona district. Kapōhaku adze quarry on Lānaʻi and Waiāhole on Oʻahu (Sinton and Sinoto 1997) are other established tholeiitic basalt adze sources, but Group G is a poor match with those sites with respect to Rb concentrations.

Group H (N=494) is consistent with the Mauna Kea adze quarry (Mills *et al.* 2008; Sinton and Sinoto 1997: 200 (Figures 5, 6, and 7). The few flakes in Group H that fall outside of the defined Mauna Kea Quarry cluster could still originate from the quarry considering the potential for presently uncharacterised geochemical groups or differential flake weathering and size issues (Lundblad *et al.* 2008). Another alternative is that outliers could derive from other Mauna Kea localities similar to the large quarry, such as small

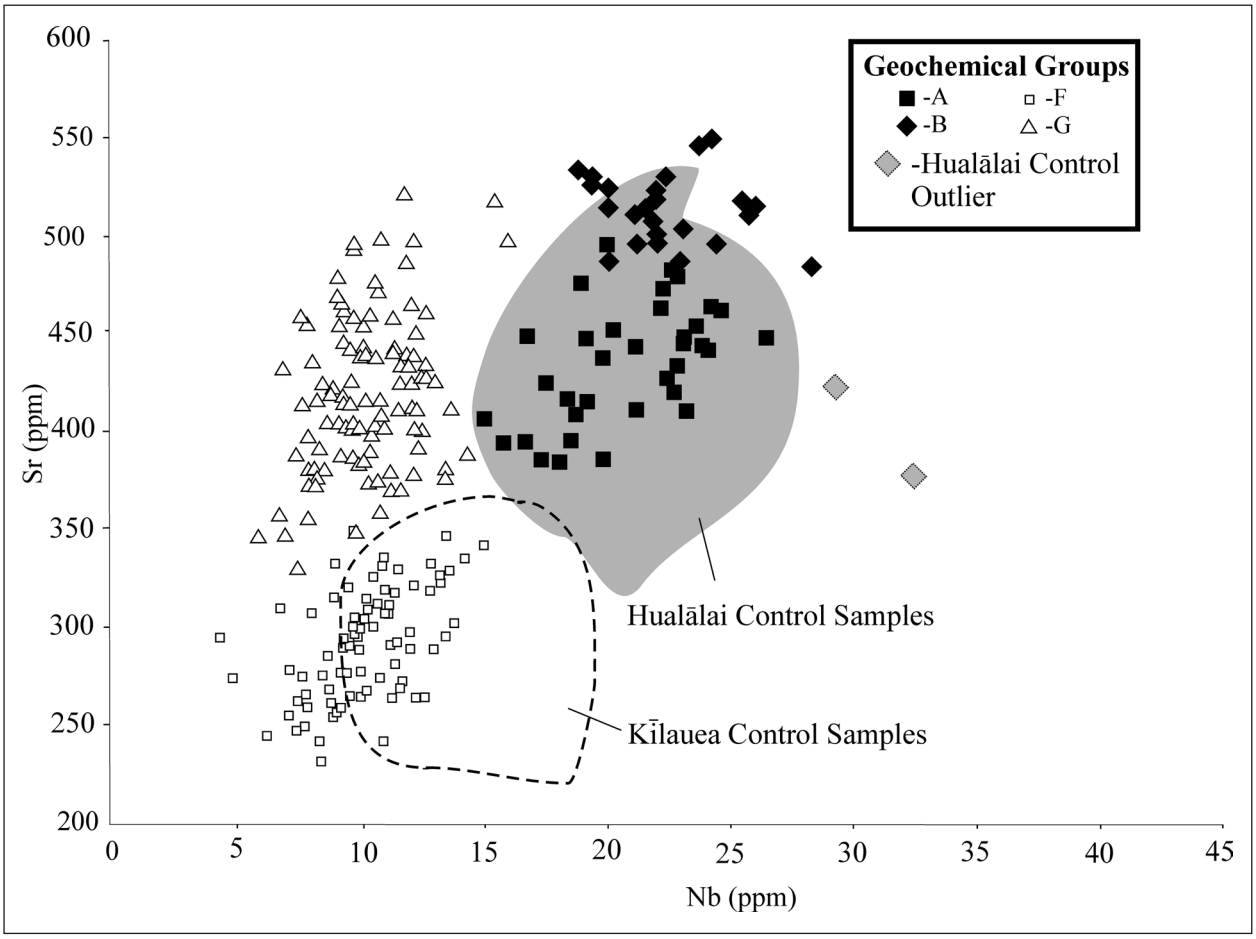

Figure 7. Sr and Nb scatterplot demonstrating the separation of Groups F and G from Groups A and B, compared with expected ranges of variation for Hualālai and Kīlauea.

workshops discussed by Bayman and Nakamura (2001).

Group I (N=88) is diffuse, suggesting that it includes a number of geochemically related flows. It is more alkalic (in the range of mugearites and hawaiites) than the Mauna Kea Quarry source and well beyond the typical range of volcanic geochemistry from Hualālai, Mauna Loa, and Kīlauea (Figure 5). It does not match well with any presently identified source. Good candidates from Hawai'i Island include Mauna Kea and Kohala volcanoes. Both the Laupāhoehoe volcanic series on Mauna Kea and some Hāwī volcanics from Kohala share similarities with this cluster (Sherrod *et al* 2007).

Group J (N=43) is similar to Group I, but exhibits a lower Zr/Sr ratio. It appears to be hawaiite, and potential sources on Hawai'i Island are limited to Mauna Kea and Kohala.

Group K (N=3) is a good match with the Pololū adze quarry in the Kohala district (Sinton and Sinoto 1997: 200).

Group L (N=2) includes a broken adze from Area 6, stratum VI and an adze flake from Area 5, stratum V that are nearly identical in their measured geochemistry, but have no other close matches in the 955 samples. Zr, Y, and K_2O concentrations are well above the typical concentrations at the Mauna Kea adze quarry.

Other outliers (N=8) are also present. These represent single specimens with no clearly associated geochemical matches. Outliers and groups represented by small numbers of specimens (such as Group L), are the best candidates for lithic sources that derive from distant sources because they are poorly represented over centuries of domestic use of Kahalu'u Habitation Cave. Another interpretation, however, is that these samples represent tools made from rarely used Hawai'i Island flows.

CONCLUSIONS

This study offers the first intensive examination of the sources of adze debitage on Hawai'i Island in a single large domestic assemblage. Over a dozen geochemical groups of adze basalt have been defined in Kahalu'u Habitation

Cave. By conducting similar studies in other sites, the current sampling strategy may offer some of the best opportunities for addressing broad patterns in Hawaiian lithic exchange networks.

Several new inferences pertaining to Hawaiian adze production and consumption economies are apparent from this analysis. First, Hualālai volcanics do not appear to have been commonly used to make adzes. In Kahaluʻu Habitation Cave, which is surrounded by Hualālai volcanics, we found that basalts used to make adzes overwhelmingly derive from sources other than Hualālai Volcano. We argue that no more than 7% of the debitage is from Hualālai (Groups A and B). One of these groups (A) is potentially inflated by the inclusion of low grade fire-cracked rock spalls that mimic adze debitage morphology, and by the inclusion of flakes incidentally created from the percussive use of cobbles in non-adze production activities. Group B is only tentatively considered to derive from Hualālai Volcano. Two other groups (F and G) may derive from Mauna Loa volcanics (not available in Kahaluʻu *Ahupuaʻa*, but present nearby on the fringes of the Kona district) and comprise only 19% of the overall assemblage.

Secondly, we have clarified the relationships between the production of large and small adzes. As stated earlier, adze blanks located at formal quarries tend to be much larger than the small and medium-sized adzes recovered in the rockshelter. These small adzes have been viewed as either the final stage of adze rejuvenation of larger adzes, or as the products of local adze production from smaller cores of locally available fine-grained basalts. This study conclusively demonstrates that the smaller adzes in Kahaluʻu derive from the same non-local sources as the larger adzes, and there is no evidence to suggest that small adzes were being manufactured as part of a separate industry. They instead represent the culmination of the use-life of the core tools.

Taken together, these findings indicate that the highly populated Kona district commonly relied on imported adzes, and rejuvenated those tools until they were much smaller than the original tools before discarding them. The heavy reliance on basalt sources outside of the Kona district calls into question the extent of economic self-sufficiency often attributed to Hawaiian *Ahupuaʻa* and to larger political districts. We accept the validity of *Ahupuaʻa* self-sufficiency where reciprocal exchange of domestic staples and commodities were often *emphasised,* but not to the extent that they were necessarily *maximised*. Hawaiian *Ahupuaʻa* were geographically designed to facilitate exchange of local resources, but we challenge the position that because of this structure, inter-district exchange in Hawaiʻi was 'relatively rare' and 'quite limited' (Earle 1977, 225; 1997, 234).

The apparent rarity of Hualālai adze sources would also disassociate most portions of the Kona population from learning the craft of large adze production as part of their regular economic activities in their own *Ahupuaʻa*. Rejuvenation of broken or dull adzes into small adzes, however, appears to have been commonly practiced.

The exploitation of numerous sources (predominantly non-local) is consistent with aspects of the economic model proposed by Lass (1994), where individuals could obtain adzes through non-centralised exchange networks. Two scenarios for supplying adzes to Kona through non-centralised exchange systems seem plausible. First, non-attached craft specialists from Kona could have traveled to distant quarries to make adzes (either through negotiated relationships with those in the districts where the quarries existed, or through the existence of chiefly-sanctioned privileges that allowed non-local craftspeople to quarry high quality basalt), and then engaged in some form of reciprocal exchange with other Kona residents upon their return. Alternatively, people in neighbouring districts could have engaged in significant surplus adze production to support the Kona population through inter-district reciprocal exchange and without the intervention of chiefs. In both non-centralised models, the structured inequality in commodity production has implications beyond adzes. Both models increase the complexity of economic and social relationships between districts and raise the question of what other commodities might have moved between *Ahupuaʻa* in reciprocal exchange for adzes. Furthermore, both systems may have operated simultaneously and continued to operate even if chiefly-sponsored centralised production developed at some point (Bayman and Nakamura 2001).

Each model necessitates a system of distribution and exchange between the centres of production and consumption. John Whitman, a resident of Honolulu between 1813 and 1815, described individuals on Oʻahu who he referred to as 'Pee-erry' [*Piele*] that distributed commodities between districts: 'These [people] travel from one district to another carrying their wares in large calabashes, though I could never discover the ultimate object of the Pee-erry man as it seems he cannot acquire riches or accumulate great store of perishable commodities' (Whitman 1979, 60).

By AD 1650–1800, Kona had a well-developed agricultural system and regularly served as a residential centre for paramount chiefs. The relatively deep, extensive, and concentrated midden in Area 6, stratum VII of Kahaluʻu Habitation cave corresponds with the beginning of this era and approximates the reign of Lonoikamakahiki, who sponsored the construction of a monumental heiau adjacent to the rockshelter. Interestingly, the adze debitage in Area 6, stratum VII is not spread throughout the extensive stratum, but is concentrated in a small activity area (mostly units R13 and R14), which contains eight of the 12 defined geochemical groups. Mauna Kea material also comprises 65.5% of that specific cluster. Perhaps there was a shortage of habitation space as itinerant laborers arrived in Kona to assist in constructing the chiefly centre, and some itinerant laborers opted to use the nearby natural shelter of Kahaluʻu Habitation Cave, resulting in the ex-

ceptionally dense midden. As adzes were dulled or broken during work, it appears that a single small activity area developed in the cave where one or a few individuals sat down to rejuvenate numerous tools.

If chiefs directly subsidised expeditions by craft specialists to the Mauna Kea adze quarry to obtain new and socially valued materials for the construction of chiefly centres, voyaging canoes, or other elite projects, we would expect intensified use of the Mauna Kea Quarry (and presumably other major centralised quarries on other islands) in comparison with earlier periods of occupation in the Hawaiian Islands. This would not negate the continued use of smaller non-centralised quarries in the domestic economy, but would result in proportionally fewer individuals needing to engage in adze production from more dispersed secondary sources. Addressing this question will require large-scale regional and diachronic assessments of the changing reliance on the Mauna Kea source.

In any of the models proposed above, Hawaiians would have commonly transported basalt adzes between *Ahupua'a,* and larger political districts. Given the diversity and extent of non-local sources that arrived in Kona, Hawai'i Islanders appear to have relied upon integrative economic strategies that have been overshadowed by normative discussions of self-sufficient, functionally equivalent, and insular *Ahupua'a*.

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References

Allen, M.S. 2004. Bet-hedging strategies, agricultural change, and unpredictable environments: historical development of dryland agriculture in Kona, Hawai'i. *Journal of Anthropological Archaeology* 23(2): 196–224.

Bayman, J.M. 2003. Stone adze economies in post-contact Hawai'i, In: C.S. Cobb (ed.) *Stone Tool Traditions in the Contact Era.* Tuscaloosa: University of Alabama Press: 94–108.

Bayman, J.M. 2009. Technological Change and the Archaeology of Emergent Colonialism in the Kingdom of Hawai'i. *International Journal of Historical Archaeology* 13(2): 127–157.

Bayman, J.M. and J.J. Moniz Nakamura. 2001. Craft Specialization and Adze Production on Hawai'i Island. *Journal of Field Archaeology* 28: 239–252.

Cachola Abad, C.K. 2000. The Evolution of Hawaiian Socio-Political Complexity: an Analysis of Hawaiian Oral Traditions. Ph.D. thesis, Anthropology, University of Hawai'i, Mānoa.

Clark, J.E. and W.J. Parry. 1990. Craft Specialization and Cultural Complexity. *Research in Economic Anthropology* 12: 289–346.

Cleghorn, P.L. 1982. The Mauna Kea Adze Quarry: Technological analyses and experimental tests. Ph.D. thesis, Anthropology, University of Hawai'i, Mānoa.

Cleghorn, P.L. 1986. Organizational Structure at the Mauna Kea Adze Quarry Complex, Hawai'i. *Journal of Archaeological Science* 13: 375–387.

Cleghorn, P.L., T. Dye, M.I. Weisler and J.M. Sinton. 1985. A preliminary petrographic study of Hawaiian stone adze quarries. *Journal of the Polynesian Society* 94: 235–251.

Collerson, K.D. and M.I. Weisler. 2007. Stone adze compositions and the extent of ancient Polynesian Voyaging and Trade. *Science* 317(5846): 1907–1911.

Cordy, R.H. 2000. *Exalted Sits the Chief: the ancient history of Hawai'i Island.* Honolulu: Mutual Publishers.

Cordy, R.H. and M.W. Kaschko. 1980. Prehistoric archaeology in the Hawaiian Islands: Land units associated with social groups. *Journal of Field Archaeology* 7: 403–416.

Costin, C.L. 1991. Craft Specialization: Issues in defining, documenting, and explaining the organization of production. *Archaeological Method and Theory* 3: 1–56.

Cousens, B.L., D.A. Clague, and W.D. Sharp. 2003. Chronology, chemistry, and origin of trachytes from Hualālai Volcano, Hawai'i. *Geochemistry Geophysics and Geosystems* 4(9), 1078.

Earle, T.K. 1977. A reappraisal of redistribution, In: T.K. Earle and J. Ericson (eds.) *Exchange Systems in Prehistory*. New York: Academic Press: 213–29.

Earle, T.K. 1997. Exchange in Oceania: Search for evolutionary explanations, In: M.I. Weisler (ed.) *Prehistoric Long-Distance Interaction in Oceania: an interdisciplinary approach*. Auckland: New Zealand Archaeological Association Monograph 21: 224–37.

Fodor, R.V., F.A. Frey, G.R. Bauer, and D.A. Clague. 1992. Ages, rare-earth element enrichment, and petrogenesis of tholeiitic and alkalic basalts from Kaho'olawe Island, Hawai'i, *Contributions to Mineralogy and Petrology* 110(4): 442–462.

Fodor, R.V., G. Dobosi, and G.R. Bauer. 1992b. Anomalously high rare-earth element abundances in Hawaiian lavas. *Analytical Chemistry,* 64: 639A–643A.

Fodor, R.V., R.S Jacobs, and G.R. Bauer. 1994. Hollandite in Hawaiian basalt: a relocation site of weathering-mobilized elements: *Mineralogical Magazine* 58: 589–596.

Frey, F.A. and J.M. Rhodes. 1993. Intershield Geochemical Differences among Hawaiian Volcanoes: Implications for Source Compositions, Melting Processes, and Magma Ascent Paths. *Philosophical Transactions of the Royal Society of London 342:* 121–136.

Hay, D., A.E. Haun, P.H. Rosendahl, and C.J. Severance. 1986. *Kahalu'u Data Recovery Project*. Paul H. Rosendahl, Inc. Prepared for the County of Hawai'i, Contract No. 82–146. Copies available at the Hawai'i State Historic Preservation Division, Kapolei.

Hommon, R.J. 1986. Social Evolution in Ancient Hawai'i, In: P.V. Kirch (ed.) *Island Societies: Archaeological approaches to Evolution and Transformation.* Cambridge: Cambridge University Press: 55–68.

Kamakau, S.M. 1976. *The Works of the People of Old*. Bernice P. Bishop Museum Special Publication 61. Honolulu: Bernice P. Bishop Museum.

Kirch, P.V. 2005 From Chiefdom to Archaic State: Social Evolution in Hawai'i. Grace Elizabeth Shallit memorial Lecture Series Publication. Provo, Utah: Department of Anthropology, Brigham Young University.

Ladefoged, T.N. and M.W. Graves. 2000. Evolutionary Theory and the Historical Development of Dry Land Agriculture in North Kohala, Hawai'i. *American Antiquity* 65: 423–448.

Ladefoged, T.N. and M.W. Graves. 2008. Variable Development of Dryland Agriculture in Hawai'i: A Fine-Grained Chronology from the Kohala Field System, Hawai'i Island. *Current Anthropology* 49(5): 771–801.

Ladefoged, T.N., M.W. Graves and M.D. McCoy. 2003. Archaeological evidence for agricultural development in Kohala, Island of Hawai'i. *Journal of Archaeological Science* 30: 923–940.

Lass, B. 1994. *Hawaiian Adze Production and Distribution.* Los Angeles: UCLA Institute of Archaeology.

Lass, B. 1997. New Names for Old Rocks: A comparison of geochemical and petrographic analysis in sourcing Hawaiian stone adzes. Unpublished paper presented at the 10th Annual Society for Hawaiian Archaeology Meetings, April 11–13 Lihue, Kaua'i.

Lass, B. 1998. Crafts, Chiefs, and Commoners: Production and Control in Precontact Hawai'i, In: C. Costin and R. Wright (eds.) *Craft and Social Identity*. Archaeological Papers of the American Anthropological Association Number 8: 19–30.

Lundblad, S.P., P.R. Mills and K. Hon. 2008. Analysing Archaeological Basalt Using Non-destructive Energy-dispersive X-ray Fluorescence: effects of post-depositional chemical weathering and sample size on analytical precision. *Archaeometry* 50(1): 1–11.

McCoy, P.C. 1977. The Mauna Kea adze quarry project: A summary of the 1975 field investigations. *Journal of the Polynesian Society* 86: 223–244.

1990. Subsistence in a Non-Subsistence Environment. In: D.E. Yen and J.M.J. Mummery (eds.) *Pacific Production Systems*. Canberra: Australian National University: 85–119.

Mills, P.R. 2002. Social Integration and the Ala Loa: Reconsidering the Significance of Trails in Hawaiian Exchange. *Asian Perspectives* 41(1): 148–166.

Mills, P.R., S.P. Lundblad, J.G. Smith, P.C. McCoy, and S.P. Nāleimaile. 2008. Science and Sensitivity: A Geochemcial Characterization of the Mauna Kea Adze Quarry Complex, Hawai'i Island, Hawai'i. *American Antiquity* 73(4): 743–759.

Mills, P.R., S.P. Lundblad, J.S. Field, A.B. Carpenter, W.K. McElroy, and P. Rossi. 2010. Geochemical Sourcing of Basalt Artifacts from Kaua'i, Hawaiian Islands. *Journal of Archaeological Science* 37: 3385–3393.

Ollier, C.D. 1971. Causes of spheroidal weathering. *Earth-Science Reviews*. 7: 127–141.

Olszewski, D.I. 2007. Interpreting Activities in North Halawa Valley, O'ahu: Adze Recycling and Resharpening. *Hawaiian Archaeology* 11: 18–32.

Patino, L.C., M.A. Velbel, J.R. Price and J.A. Wade. 2003, Trace element mobility during spheroidal weathering of basalts and andesites in Hawai'i and Guatemala. *Chemical Geology* 202: 343–364.

Patterson, T.C. 2005. Craft Specialization, the reorganization of production relations and state formation. *Journal of Social Archaeology* 5(3): 307–337.

Sahlins, M. 1992. Historical Ethnography. Volume 1 of *Anahulu: The Anthropology of History in the Kingdom of Hawai'i,* by P.V. Kirch and M. Sahlins. Chicago: University of Chicago Press.

Sherrod, D.R., J.M. Sinton, S.E. Watkins, and K.M. Brunt. 2007 *Geologic Map of the State of Hawai'i.* USGS open file report 2007–1089, version 1.0. http://pubs.usgs.gov/of/2007/1089/

Sinton, J. and Y. Sinoto. 1997. A Geochemical Database for Polynesian Adze Studies. In: M.I. Weisler (ed.) *Prehistoric Long-Distance Interaction in Oceania: an interdisciplinary approach*. Auckland: New Zealand Archaeological Association 21: 194–204.

Tuggle, D. 1976. Windward Kohala-Hāmākua archaeological zone, island of Hawai'i. Department of Anthropology, University of Hawai'i at Mānoa.

Weisler, M. 1990. A Technological, Petrographic, and Geochemical Analysis of the Kapōhaku Adze Quarry, Lāna'i, Hawaiian Islands. *New Zealand Journal of Archaeology* 12: 29–50.

Whitman, J.B. 1979. *An Account of the Sandwich Islands: The Hawaiian Journal of John B. Whitman 1813–1815*. Honolulu: Topgallant Publishing Co.

Williams, S.S. 1989. A Technological Analysis of the Debitage Assemblage from Ko'oko'olau Rockshelter No. 1, Mauna Kea Adze Quarry, Hawai'i. M.A. Thesis, Department of Anthropology. Pullman: Washington State University.

Xu, G., F.A. Frey, D.A. Clague, W. Abouchami, J. Blichert-Toft, B. Cousens, and M.A. Weisler. 2007. Geochemical characteristics of West Molokai shield and postshield stage lavas: Constraints on Hawaiian plume models: *Geochemistry Geophysics and Geosystems* 8(8): 1–40.