

Settlement Chronologies and Shifting Resource Exploitation in Ka‘ū District, Hawaiian Islands



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INTRODUCTION

WE REPORT ON RE-ANALYSIS OF TWO KA‘Ū DISTRICT COLLECTIONS from Hawai‘i Island to demonstrate what can be learned when applying new research questions to old collections. Our research goals center on two main themes: re-dating the HA-B22-64 and -248 sites to place them within the newly refined Hawaiian archipelago settlement chronology and using diverse data sources to look at changing resource use in pre-Contact Hawai‘i through time. The case study tackles questions concerning island settlement and changing resource use in the Hawaiian Islands located in remote East Polynesia. Our application of targeted AMS dating of identified wood charcoal allows us to refine the settlement sequence for Hawai‘i Island, similar to efforts utilizing a suite of advanced techniques to refine chronological sequences more broadly in Asia and the Pacific Island region, such as East Timor (Lape 2006), the Mariana Islands (Carson and Kurashina 2012), West Polynesia (Burley et al. 2015; Rieth et al. 2008), the Hawaiian Islands (Carson 2006; Mulrooney et al. 2014; Rieth et al. 2011), and East Polynesia (Allen and Huebert 2014; Allen and Wallace 2007; Kahn 2006; Kahn et al. 2015; Wilmshurst et al. 2011). We also emphasize how diverse lines of analytical data provide a strong interpretive base from which to investigate long-term trends in terrestrial and marine resource exploitation and use, similar to other studies in the Asia-Pacific region focusing on the importance of land and marine resources to trends in regional settlement and trajectories of cultural evolution (Bar-Yosef et al. 2012; Erlandson 2001; Hung et al. 2007; Jones 2007; O’Conner and Veth 2005; Ono et al. 2013; Szabó and Amesbury 2011; Torrence et al. 2009).

Anthropological and archaeological collections held in museums have great utility with respect to re-analysis of Asian and Pacific Island archaeological assemblages utilizing more advanced techniques than those available at the time of the collections’

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original recovery. Such collections have proven invaluable for biological conservation (Longenecker et al. 2014; Reznick et al. 1994) and DNA analyses researching phylogenetics, phylogeography, population genetics, and systematics (Irestedt et al. 2006; Shokralla et al. 2011; Thomas 1994). Re-analysis of archaeological museum collections also demonstrates their anthropological utility. Archived museum collections from East Polynesia have, in the last three decades, proven instrumental for refining the settlement sequence of the region with the Accelerated Mass Spectrometry (AMS) technique of dating identified wood charcoal samples (Anderson and Sinoto 2002; Kahn et al. 2014; Kirch and McCoy 2007; Mulrooney et al. 2014).¹ Genetic investigations of commensal species using DNA analyses have provided more accurate taxonomic determinations (Nicholls et al. 2003) and have successfully tracked the movement of people and animals into the region (Matisoo-Smith 2015; Storey et al. 2013; Wilmshurst et al. 2011). More recently, researchers have used isotopic analyses of faunal samples to investigate questions of subsistence change and trophic interactions (Allen and Craig 2009; Beavan-Athfield et al. 2008). We report on re-analysis of two Ka'ū District collections (Hawai'i Island) to demonstrate how multiple lines of analytical data can be used to investigate site settlement and changing resource use, at the same time highlighting the utility of applying new research questions to old collections.

THE EAST POLYNESIAN AND HAWAIIAN ARCHIPELAGO SETTLEMENT CHRONOLOGY DEBATE

Since the application of radiocarbon dating, the settlement of East Polynesia has been highly debated. Significant advances in refining the region's settlement sequence have been made in the last 20 years due to re-dating archived samples with more precise AMS ¹⁴C methods, utilizing chronometric hygiene or other sorts of typologies to exclude samples lacking precisely human-related contexts, using short-lived dating samples lacking "old wood" problems, and applying Bayesian statistical modeling to datasets (Allen and Huebert 2014; Anderson and Sinoto 2002; Athens et al. 2014; Dye 2011; Kirch 2011). Among the numerous efforts to refine the Hawaiian chronology are Carson and Mintmier's (2006) short-lived specimen chronology for Haleakalā (Maui sites), re-dating of the Hālawā Dune site (Kirch and McCoy 2007), synthesis of Moloka'i Island radiocarbon dates (McCoy 2007), re-dating of the Wai'ahukini Rockshelter site (Mulrooney et al. 2014), synthesis of Hawai'i Island radiocarbon dates (Rieth et al. 2011), re-dating of the Kuli'ou'ou Rockshelter site on O'ahu Island (Kahn et al. 2014), and synthesis of Kaua'i Island radiocarbon dates (Carson 2006).

While advances have been made, there is significant disagreement concerning the date ranges for the settlement of Hawai'i. Discrepancies are due to the small sample sizes of well-dated archaeological contexts and the lack of sites dated via short-lived species. Athens and colleagues (2014) have constructed a settlement model based on Hawaiian palaeoenvironmental and archaeological data that posits initial settlement at A.D. 940–1130, but most probably between A.D. 1000 and 1100. This is earlier than a more conservative model that implies settlement of the Hawai'i archipelago at A.D. 1219–1266 (Wilmshurst et al. 2011). Several recent reviews and re-analyses of settlement data provide an emerging consensus that the Hawaiian archipelago was most likely settled during the period of A.D. 1000–1100 (Athens et al. 2014; Dye 2011; Kirch 2011).

Archaeological sites in the South Point region (Ka'ū District of Hawai'i Island) have played an important role in the history of Hawaiian chronological debates (Dye 1992; Kirch 2011; Mulrooney et al. 2014). Radiocarbon dating estimates utilizing bulk charcoal samples were initially used to date the H1 (Pu'u Ali'i) sand dune site, leading Emory and colleagues (1969) to place H1 at the start of the Hawaiian colonization sequence. The H8 site (Wai'ahukini Rockshelter), dated to c. A.D. 750, was placed mid-sequence, while H2 (Makalai Shelter) was dated to the final part of the sequence. Emory and colleagues refined their Ka'ū chronology through the use of a detailed fishhook typology, ultimately placing the H8 deposits at the start of the sequence c. A.D. 750, with H1 dating around the same time period and up to A.D. 1000–1350. Dye (1992) re-analyzed the available radiocarbon dates for the two sites, suggesting occupation during A.D. 1040–1280. However, a recent Hawai'i Island chronological synthesis by Rieth and colleagues (2011:2743) noted that the Ka'ū region lacked Class 1 dates, again calling into question the available chronometric dates for Ka'ū District.² Recently, Mulrooney and colleagues (2014) re-dated seven H8 (Wai'ahukini Rockshelter) charcoal samples that were identified to short-lived species. The new chronology places the initial use of the rock shelter during the fourteenth to early fifteenth centuries, several centuries later than previously thought.

While much attention has been paid to the chronology and material culture of the H1, H3, and H8 sites, numerous other rock shelters have been surveyed and excavated in Ka'ū District, with the bulk of data published by Sinoto and Kelly (1975). This work included test excavations at 36 sites. Utilizing stratigraphic data (including the number and depth of layers), radiocarbon dating, hydration rind dating, and artifact analysis (particularly seriation of fishhooks), Sinoto and Kelly (1975:13) argued that sites HA-B22-64 and -248 dated to the “early phase” of the Ka'ū sequence (Fig. 1). Because HA-B22-64 and -248 were originally thought to be “early” in the South Point sequence, and because they each had multiple occupation layers, we chose these sites for re-dating and re-analysis.

CHANGING RESOURCE USE THROUGH TIME IN THE HAWAIIAN ARCHIPELAGO

Establishing a firm chronology for the Hawaiian archipelago is key to answering larger questions concerning social processes and economic and political transformations in pre-Contact Hawai'i. Kirch (2010:41–42) has argued that elite art, craft specialization, and wealth finance supported rank gradations separating the Hawaiian social classes, which were highly elaborated at the time of European contact. Elaborate feather capes, cloaks, and helmets were worn by elites. Such wealth items were manufactured with an enormous amount of labor “under chiefly oversight and sponsorship” (Bayman and Dye 2013:68; see also Lass 1998). In the period of European contact, feathered items became political symbols of chiefly power, which has important implications for questions concerning craft specialization and chiefly control over the political economy. Equally important is the specialized production of stone tools, notably adzes, since we can track their production, trade, and exchange to test economic models. Similarly, the extent to which the pre-Contact Hawaiian subsistence economy was intensified and when and how these processes occurred likewise plays a role in larger discussions of the degree to which chiefs controlled staple finance (Bayman and Dye 2013:54; Earle 1997; Kirch 2010:46–47). Of current interest is how

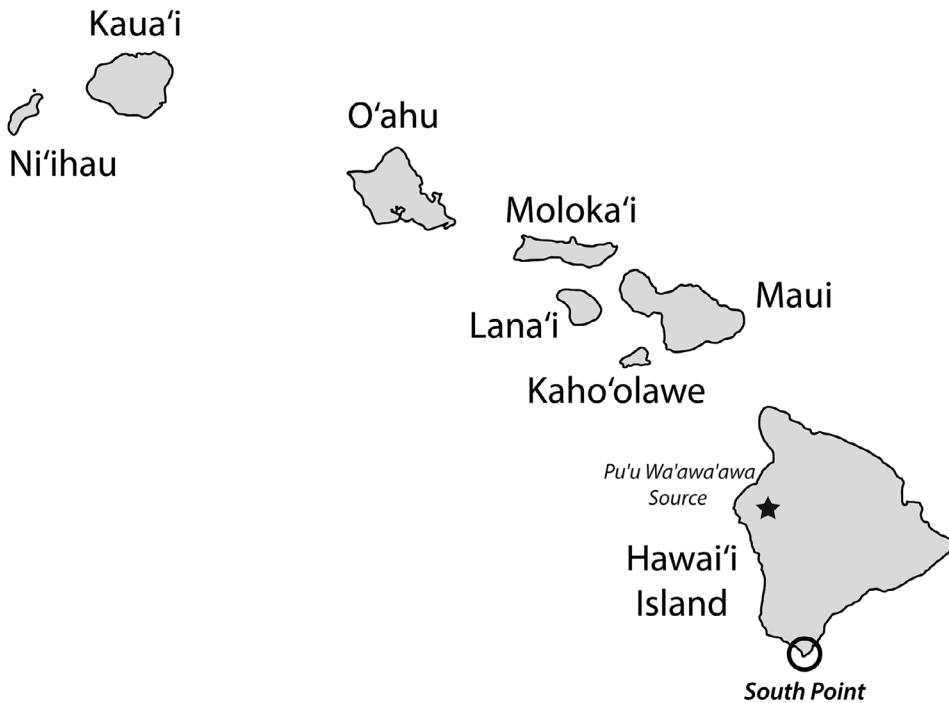


Fig. 1. Location of HA-B22-64 and HA-B22-248 in the Ka'u District of Hawai'i Island.

subsistence intensification had significant impacts on Hawai'i's flora and fauna, which in turn affected the chiefly political economy. For example, intensive taro and sweet potato farming led to significant soil nutrient loss in some areas, limiting localized surplus production (Vitousek et al. 2004). While much focus has been on terrestrial resource change, the degree to which foraging for wild resources such as fish and mollusks may have been impacted by social processes and demographic change is another important question for Hawaiian archaeology.

Variation in Adze Production: Large and Small Quarries, Specialized or Generalized Production, and the Independent Ahupua'a Model

Much of the attention on changing resource use in Hawai'i has focused on adze production, including access to fine-grained basalts for adze manufacture, and labor, whether specialized or non-specialized. In an early synopsis of the Hawaiian sequence, Kirch (1985: 184) argued that the shift from variable adze forms early in the sequence to "highly standardized rectangular/quadrangular forms in late prehistory" might have related to the advent of a specialized class of craft producers. Many have interpreted the large scale of adze production at the Mauna Kea adze quarry on Hawai'i as evidence for highly centralized craft specialization (Cleghorn 1986; Kirch 1985; Mills et al. 2008; Williams 1989), while Lass (1998) viewed the data as supporting adze makers as independent craft producers. Analysis of smaller Hawaiian quarries illustrates production of a wider range of adze types from local materials, suggesting more

generalized production at the local level. These data are perhaps indicative of two adze economies discussed further below: 1) formalized or specialized manufacture at larger quarries with highly prized raw materials; and 2) generalized manufacture at smaller quarries utilizing locally available raw materials and producing for local communities (Bayman and Moniz-Nakamura 2001; Kahn et al. 2009; Mills and Lundblad 2014).

Non-destructive Energy Dispersive X-Ray Fluorescence (EDXRF) studies in the last decade have vastly expanded the geochemical characterization of Hawaiian basalt adze debitage and volcanic glass, both of which are frequently found in domestic archaeological contexts (Kirch et al. 2012; Lundblad et al. 2011; Lundblad et al. 2008; McCoy et al. 2011; Mills and Lundblad 2006, 2014; Mills et al. 2010; Mills et al. 2011; Mills et al. 2008; Mintmier et al. 2012). The EDXRF studies have confirmed Lass' (1994) inference from small sample sizes that residents of Hawai'i Island commonly used basalt from the Mauna Kea adze quarry throughout the six political districts of the island. With the ability to quantify and compare the dispersal of adze materials from quarries of different sizes, it is becoming more evident that material from some smaller quarries, such as the Pololū adze quarry on Hawai'i Island, were not commonly exchanged beyond local source areas. Nonetheless, it is now clear that Mauna Kea adze basalt was also not a dominant part of the general domestic economy on other islands. The presence of low concentrations of basalt adzes on Maui and O'ahu that are consistent with Mauna Kea geochemistry, and that occur more commonly in elite households, suggests that adzes made from Mauna Kea basalt may have been part of elite inter-island exchange networks (Kirch et al. 2012). Quite unexpectedly, another basalt adze source on Kaua'i may have been moving between islands more commonly and more extensively than the Mauna Kea basalt (Mills et al. 2010; Mills and Lundblad 2014).

Recent analysis has centered on whether adze production in Hawai'i simultaneously operated on multiple scales, with some districts engaged in independent production of most of their own adzes, and other districts largely dependent on adzes produced in distant production centers that were quarried through organized logistical support (Bayman and Moniz-Nakamura 2001; Mills and Lundblad 2014). While dealing with adze production rather than irrigated agriculture, the Bayman/Moniz-Nakamura and Mills/Lundblad models are in alignment with Wittfogelian models of the consolidation of political control through the organization of labor (Wittfogel 1957; see also Adams 1966). Although extensive analyses of well-dated lithic assemblages have yet to be conducted, a working hypothesis is that centralized production of adzes increased through time. This may have correlated with other large chiefly projects such as *heiau* (temple) construction and the intensified production of war-canoe fleets.

The largest quarry site with the most abundant concentration of volcanic glass is the Pu'uwa'awa'a trachyte source in Kona District, also located on Hawai'i Island. Again, recent EDXRF analyses demonstrate that this material was not commonly transported between islands (McCoy et al. 2011). Lundblad and colleagues (2014) identify three major geochemical groups of volcanic glass that were regularly in use in Kona District of Hawai'i Island. In combination with distance-decay models by McCoy and colleagues (2011), these data demonstrate the common transport of various sources of volcanic glass across district boundaries with little evidence of chiefly controlled redistribution. If this is the case, it might be expected that Pu'uwa'awa'a volcanic glass distribution would cluster near major chiefly centers around the island,

and not follow distance decay patterns from the quarry based on walking distances on trails or short canoe trips from the source (Putzi et al. 2015).

Now that these baselines have been established, additional analyses of domestic assemblages can be used to test the extant distance decay models and identify potentially anomalous patterns. For this reason, analyses of large museum collections that can be compared on multiple scales—that of the household, political district, and island—can serve to enrich our models of changing economies, exchange, craft specialization, and intensification of political control over domestic resources through time.

Marine Faunal Remains: Resource Depression or Sustainability through Time?

Researchers agree that marine foods played an important daily role in pre-Contact Hawaiian diets, but the extent to which such resources could be sustainably harvested is a question that is only now coming to the fore. Early analyses of Hawaiian marine subsistence economies focused on the adaptability of particular angling techniques and fishing gear to specific local marine environments (Kirch 1985). Some early studies measured the size of individual species in fish catches, but researchers had difficulty linking inter-site variability specifically to cultural, temporal, or ecological factors (Kirch 1982). For example, Goto's (1986) research investigating spatiotemporal trends in Hawaiian fishing practices took an adaptive approach to studying fishhooks, fishing gear, and fishbone and shell assemblages from eight Ka'ū District sites on Hawai'i Island, including sites HA-B22-64 and -248. In general, the proportion of fishbone remained constant at the two sites when stratigraphic levels were compared to one another, while bird decreased and mammal bone increased through time. This was consonant with archipelago-wide models proposing a shift in subsistence through time from an earlier focus on wild resources to a later focus on domesticates. In an effort to quantify variability in the fishbone assemblages, Goto (1986:315–316) estimated mean body weight for each taxon by measuring fish dentaries, premaxillae, lower pharyngeal plates, peduncular plates, or vertebrae, with the specific elements measured depending on taxon. His analysis found that inshore fishes such as Labridae, Scaridae, and Mullidae were more frequent than large offshore carnivores.

Current analyses of Hawaiian marine fauna often take a more explicit human-ecological approach, investigating questions of over-exploitation/resource depression and sustainability in mollusk assemblages (see Kirch 2005 for general overview). Morrison and Hunt (2007) focus on the susceptibility of shellfish communities to human exploitation pressures at the Nu'alolokai site on Kaua'i. They argue that select coral reef and intertidal species including *Turbo sandwicensis* and *Strombus maculatus* declined in abundance due to heavy human exploitation, while shoreline shellfish communities remained fairly resilient.³

In a Moloka'i Island study, McCoy (2008) measured shell sizes of archaeological limpets and modern limpets to document an increase in limpet size from the proto-historic period to the present. He suggested that the size changes might be related to decreased human exploitation pressures because of the massive human depopulation of the study area in the post-Contact period.

Analyses of fish assemblages from the well-stratified site of Nu'alolokai on Kaua'i Island are also illuminating with respect to fish size and fishery sustainability. O'Leary's (2005, 2015) re-analysis of the site's fishbone assemblages highlight differences

between pre-Contact fish abundance and modern fisheries data, illustrating the important role that archaeological collections can play in modern fisheries management. Longenecker and colleagues (2014) measured 23 Scarine parrotfish jawbones excavated from Nu'alolokai to estimate mean fish length. Fish from the site were interpreted as large when compared to modern data. Mean length of the Scarine parrotfish catch was significantly larger in the historic period than in the prehistoric period, suggesting a bounce back in marine resources in the historic period as human populations and their exploitation of marine species rapidly declined. However, when fish size estimates were used to evaluate the reproductive status of the harvest, the overall large and stable (or increasing) average lengths of Scarines were consistent with a stable size structure and the presence of reproductively sized individuals. These data indicate that fishing practices at Nu'alolokai were sustainable in the prehistoric and historic periods.

SITE HA-B22-64

This site is described as a lava tube shelter with stratigraphic deposits of considerable depth (Sinoto and Kelly 1975:15). Based on the recovery of fireplaces, abundant fishing gear, adzes, and animal bone, the shelter was interpreted as a habitation site (Sinoto and Kelly 1975:20, fig. 9), most likely used by fisher folk visiting the area on a seasonal or itinerant basis. Bulk charcoal samples from Firepit 3 in Layer I (15 cmbs) and outside of Firepit 1 in Layer II (25 cmbs) were originally dated by the Gakushin (GAK) laboratory, generating dates of 1790 ± 90 and 1310 ± 100 , respectively (Sinoto and Kelly 1975:26) (Table 1). Later analysis of GAK dates produced for other East Polynesian sites (Kirch 1986:23; Rolett 1998:53) demonstrate that the laboratory often produced unacceptably recent dates, likely due to significant pretreatment errors or errors in laboratory method (Kirch and McCoy 2007), leading many to discount GAK dates or to use them with caution (Kahn 2011). Hydration rind dates from basalt glass found on the site were also processed, but given that this technique is no longer thought to provide reliable dates, these will not be discussed further.

SITE HA-B22-248

HA-B22-248 is a lava tube with a shelter that forms a complex with B22-210 (a rock shelter) and B22-209 (a stone cairn) (Fig. 2). The site has four stratigraphic levels. A number of fireplaces were recovered at the top of Layers I and III (Fig. 3a, 3c, 3d) and a pavement was situated in upper Layer IV (Fig. 3c). The fireplace features and

TABLE 1. ORIGINAL RADIOCARBON DATES FOR HA-B22-64 AND HA-B22-248

SAMPLE #	LAB NO.	SITE #	PROVENIENCE	DATES A.D.
HRC-214	GaK-3237	HA-B22-64	Unit E5, Layer II, outside of Firepit 1, 25 cmbs	1310 ± 100
HRC-215	GaK-3238	HA-B22-64	Unit B6, Layer I, Firepit 3, 15 cmbs	1790 ± 90
HRC-209	I-5255	HA-B22-248	Unit H8, Layer II, ash lens, 25–30 cmbs	1705 ± 90
HRC-210	I-5256	HA-B22-248	Unit G8, Firepit 1, 52 cmbs	1305 ± 90
HRC-211	I-5254	HA-B22-248	Unity G8, ash lens, 100–103 cmbs	1105 ± 120

Note: GaK: Gakushuin University, Tokyo, Japan; I: Isotope Inc.

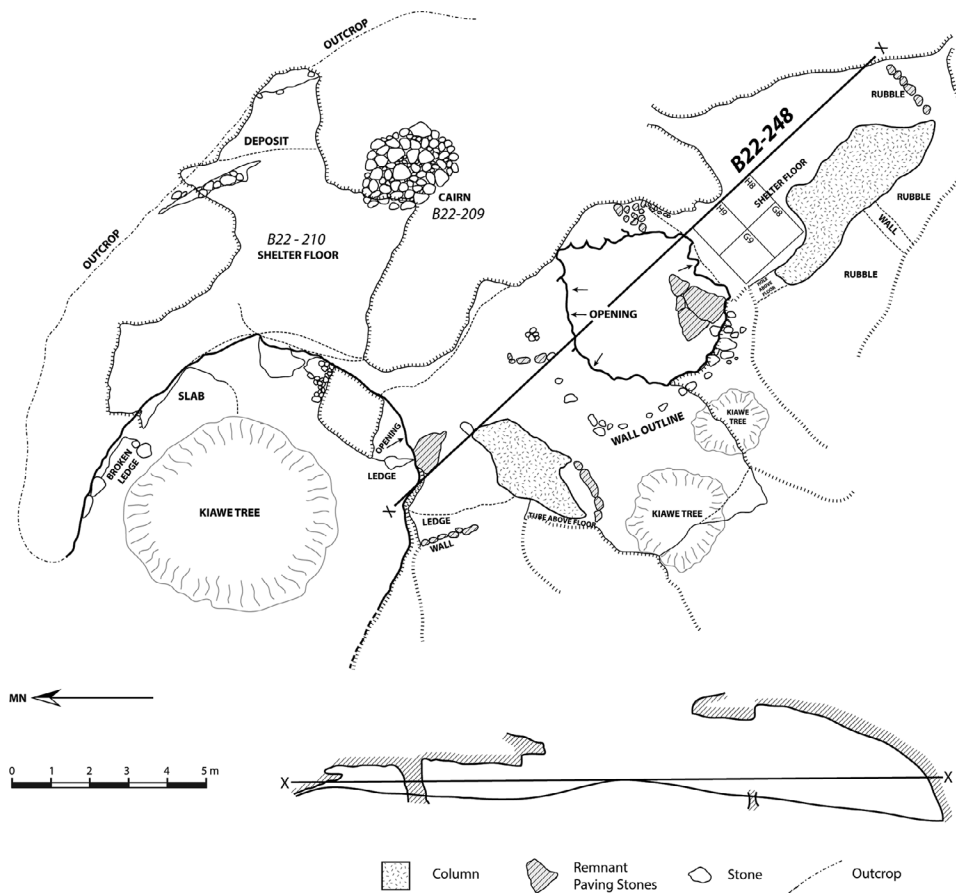


Fig. 2. Plan view of site HA-B22-248.

recovered artifacts suggest a domestic function, with a focus on fishing, similar to site -64.

Based on fishhook seriation, Sinoto and Kelly (1975) argued that -248 was an early site, as it had notched two-point fishhooks similar to H1. Three bulk radiocarbon dates were run from B22-248 (Table 1). These included a Layer II sample 25–30 cmbs in an ash lens, a Layer III sample 52 cmbs in Firepit 1, and a charcoal sample from an ash lens 100–103 cmbs. The three dates were internally consistent and suggested a long sequence of occupation at the site.

ESTABLISHING A REVISED SETTLEMENT CHRONOLOGY FOR SITES
HA-B22-64 AND -248

We report on four radiocarbon dates recently run on samples from sites HA-B22-64 and -248. These dates were provisionally reported in an earlier publication (Longenecker et al. 2014:1326, table 2). Here we provide the full details for each calibrated sample as well as a more precise calibration for the shell sample utilizing two different Delta R values.

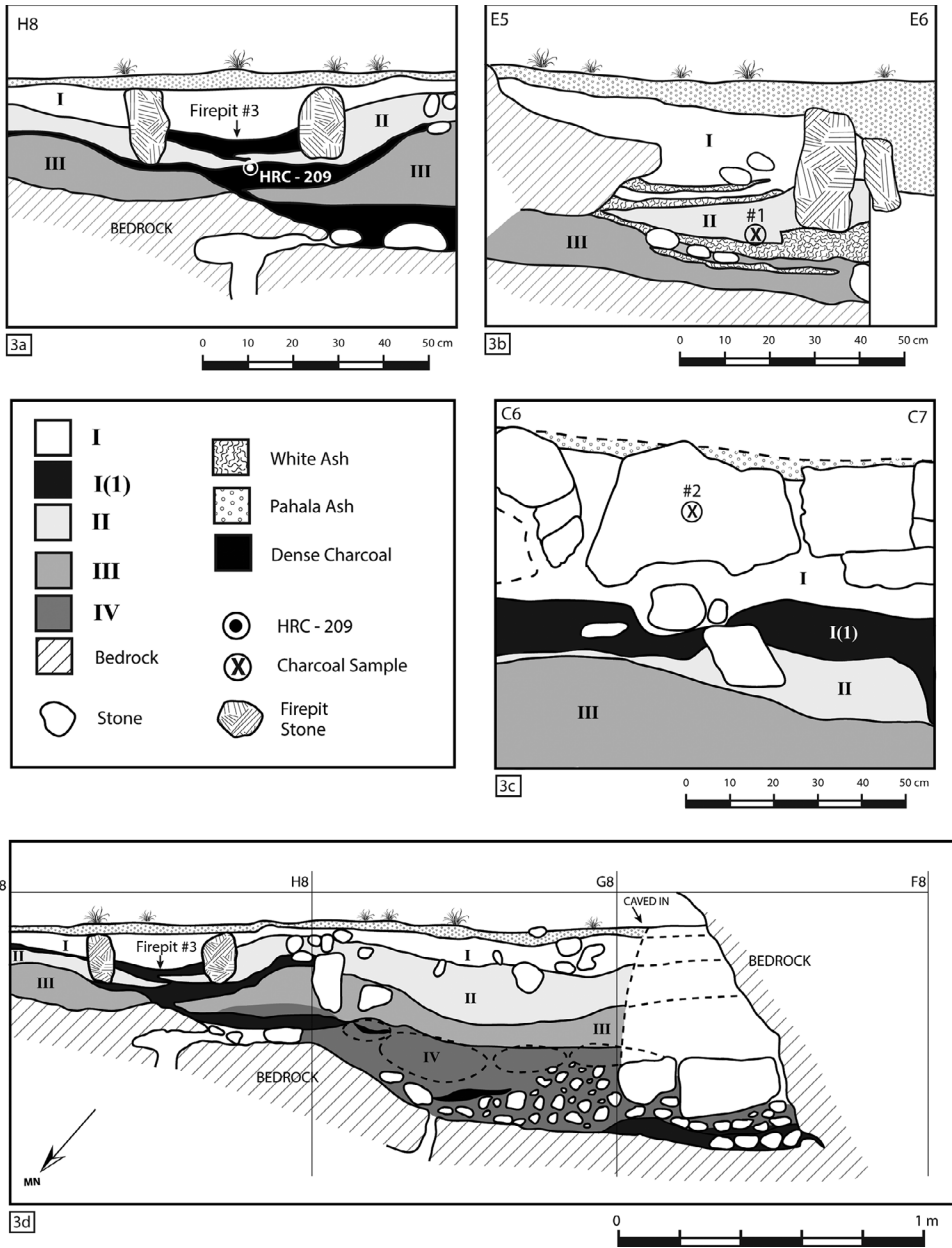


Fig. 3. Stratigraphic profiles, site HA-B22-248.

Site HA-B22-64

Three wood charcoal samples and a shell sample were submitted to Beta Analytic for AMS radiocarbon dating (Table 2). Wood charcoal samples were identified to short-lived species by Gail Murakami. Two *Chenopodium* charcoal fragments and one charred

TABLE 2. NEW AMS RADIOCARBON DATES FOR HA-B22-64 AND HA-B22-248

LAB # BETA-	SITE #	SPECIES	LIFE SPAN	PROVENIENCE	CONVENTIONAL	^{13}C	CALIBRATED
-290195	HA-B22-64	<i>Chenopodium</i>	Short lived (Rieth and Athens 2013: 11, table 1), formerly dated as HRC-215	Unit B6, Layer 1, Firepit 3, 15 cmbs	100 ± 30 B.P.	-24.4	A.D. 1682-1736 (27.1%) A.D. 1805-1935 (68.3%)
-290196	HA-B22-64	<i>Chenopodium</i>	Short lived	Unit E5, Layer III	370 ± 30 B.P.	-22.8	A.D. 1489-1604 (69.6%) A.D. 1610-1654 (25.8%) A.D. 1851-1940 (95.4%)
-290194	HA-B22-248	<i>Nerita Picea</i> shell	Short lived	Unit H12/13, Layer III	700 ± 30 B.P.	+4.0	or A.D. 1872-1940 (95.4%) A.D. 1680-1739 (27.1%) A.D. 1745-1763 (2.8%) A.D. 1802-1938 (65.5%)
-290197	HA-B22-248	<i>Aleurites molucanana</i> nutshell	Short lived (Allen and Huebert 2014: 262, table 2; Rieth and Athens 2013: 11, table 1)	Layers I-IV	110 ± 30 B.P.	-17.7	

Note: The *N. Picea* was calibrated using the Marine13 calibration curve (Reimer et al. 2013). The first calibrated age range uses a Delta R of 290 ± 110; the second age range is with a Delta R of 280 ± 80. Dye (1994) obtained both of these ages, the first from *Cellana exarata* and the second from *Cypinaea caputserpentis* collected in 1923 from Kaulana, a context where there are no concerns about limestone substrate (Petchey 2009).

Aleurites mollucana endocarp sample were dated; these are considered short-lived species with no more than 10–15 years of potential inbuilt age (Allen and Huebert 2014; Rieth and Athens 2013).

At site HA-B22-64, Beta-290196 dates a *Chenopodium* charcoal recovered from Layer III in unit E5. The calibrated sample produced an age range of A.D. 1489–1654, and most likely dates between A.D. 1489–1604. Beta-290195 dates a *Chenopodium* charcoal recovered from fire pit Feature 3 in Layer 1 at 15 cm below the surface. The sample calibrates to A.D. 1682–1935, with the most likely date range post-nineteenth century. This same context had originally been dated as HRC-215 (GAK sample 3238) at 1790 ± 90 , which is in agreement with Beta-290195.

The new AMS dating results indicate that the lower levels of rock shelter HA-B22-64 date to the mid- to Late Prehistoric period during the fifteenth to seventeenth centuries. The upper levels of HA-B22-64 calibrate to the nineteenth century.

Site HA-B22-248

For calibrating the *Nerita* shell sample, we used the Marine13 calibration curve (Reimer et al. 2013), the first time with a Delta R of 290 ± 110 and the second time with a Delta R of 280 ± 80 . Dye (1994) obtained both of these ages, the first from *Cellana exarata*, and the second from *Cypraea caputserpentis* collected in 1923 from Kaulana (there are no concerns about limestone substrate for this locale).

It was more challenging to find appropriate materials to re-date at site HA-B22-248. Beta-290197 dates an *Aleurites mollucana* endocarp recovered from Levels 1 through IV. While the context of the sample is not specific, it represents a Polynesian introduction with little inbuilt age that must belong to the post-colonization period (Athens et al. 2014). We also dated a *Nerita picea* shell deriving from Unit H12/13, Level III. *Nerita* were frequent in this deposit and were not water-rounded, suggesting that they were used as a foodstuff. *Nerita picea* are a dominant shoreline species that lives on rocky substrates (Kay 1979).

The upper levels of HA-B22-64 and both levels of HA-B22-248 calibrate to the late eighteenth to nineteenth centuries. While HA-B22-64 has a two-phase pre-Contact sequence, HA-B22-248 seems to have been exclusively used in the proto-historic period.

ESTABLISHING CHANGES IN RESOURCE USE THROUGH TIME: EDXRF RESULTS OF BASALT AND BASALT GLASS ASSEMBLAGES

We analyzed lithic samples from sites HA-B22-64 and HA-B22-248 using the UH-Hilo ThermoNoran QuanX EDXRF (following procedures outlined by Lundblad et al. 2008 and Lundblad et al. 2013). Diagnostic trace element ratios for small volcanic glass samples were determined (Hughes 2010; Lundblad et al. 2014; Lundblad et al. 2013). We conducted repeat analysis of the USGS standard reference material BHVO-2 to assess the precision and accuracy of the results presented here. We treat major element oxide percentages measured with our EDXRF to be a qualitative measure of actual composition. Trace element concentrations of the mid-Z elements (Rb, Sr, Y, Zr, Nb) are the basis for most of our diagnostic provenance analysis. Group assignments follow those of Lundblad and colleagues (2014; 2013), McCoy and colleagues (2011), and Rieth and colleagues (2013) for volcanic glass on Hawai'i Island,

and Lundblad and colleagues (2014), Mills and colleagues (2011), and Rieth and colleagues (2013) for basalt from the Kona Coast Ka‘ū District of Hawai‘i Island.

All available basaltic and volcanic glass artifacts larger than $1\text{ cm} \times 1\text{ cm} \times 1\text{ mm}$ thick were analyzed for 20 major and trace element concentrations using 4 conditions ranging from 8 kV to 50 kV. Elemental concentrations for smaller pieces of volcanic glass are not accurately measured using our technique. These were analyzed for 8 trace elements to determine diagnostic elemental ratios (as outlined in Hughes 2010 and Lundblad et al. 2013). The combination of raw concentration data and elemental ratios are the key to assigning accurate group designations for these samples. While it is possible that there are artifact groups present in the data, the likelihood is small due to the concentration data measured from adequately sized artifacts.

Group Assignments for Volcanic Glass Artifacts

Consistent with other Hawai‘i Island sites, we identify only three distinct geochemical groups of volcanic glass debitage at these South Point sites (Figs. 4, 5).⁴ Henceforth, numbers in parentheses following a group number represent the number of artifacts for individual sites HA-B22-64 and HA-B22-248. Group 1 (n = 3, n = 5) volcanic glass is from the Pu‘u Wa‘awa‘a (PWW) trachyte cone on the Hualalai volcano, leeward Hawai‘i Island. Relative to other Hawaiian lavas, it is characterized by high SiO_2 ,

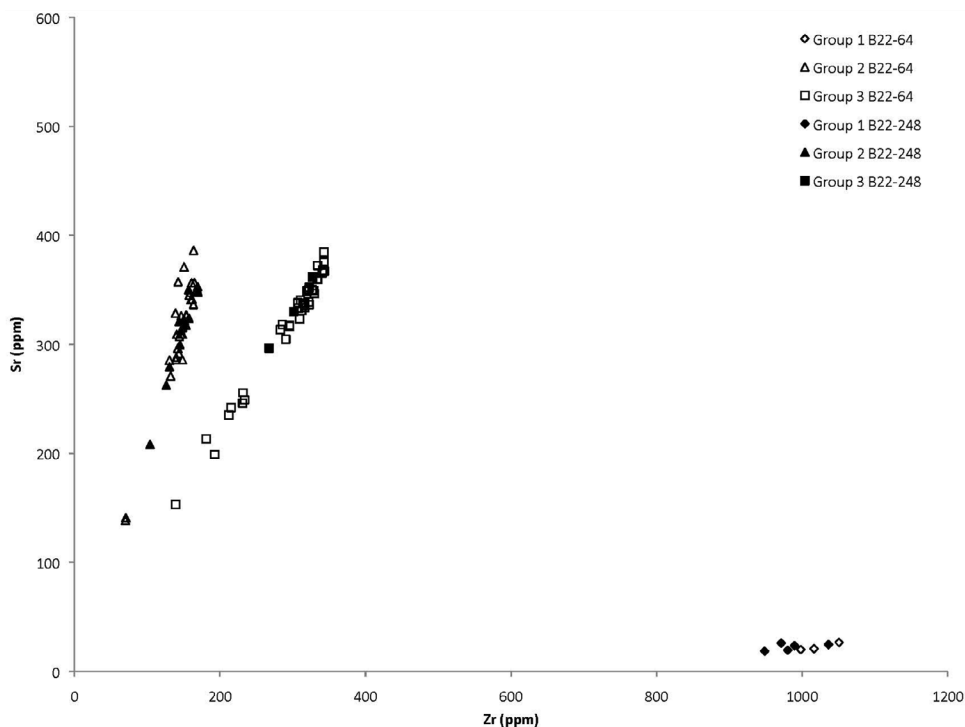


Fig. 4. Bivariate plot of Strontium (Sr) vs. Zirconium (Zr) for volcanic glass from sites HA-B22-64 (open symbols) and HA-B22-248 (filled symbols). For artifacts smaller than $1 \times 1\text{ cm}$, the measured concentration data is reduced and tends to the origin along a line of consistent slope.

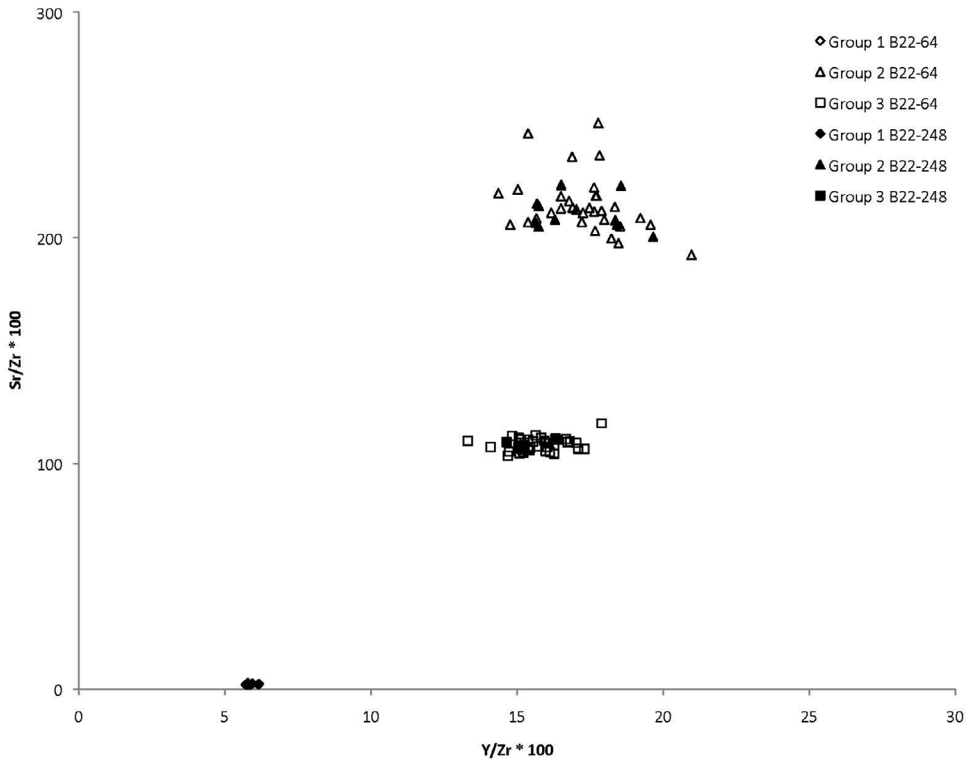


Fig. 5. Bivariate plot of trace element ratios Y/Zr vs. Sr/Zr for all volcanic glass data from sites HA-B22-64 (open symbols) and HA-B22-248 (filled symbols). Small artifacts ($<1 \times 1$ cm) tend to add variance to each cluster.

K_2O , and Na_2O concentrations (Cousens et al. 2003). Trace element geochemistry appears unique for volcanic glass in the Hawaiian Islands (Lundblad et al. 2014; Lundblad et al. 2013; McCoy et al. 2011). For artifacts of sufficient size, Zr concentrations are ~ 1000 ppm and Sr concentrations are ~ 35 ppm. Smaller artifacts can be assigned to this source by high Zr/Sr.

Group 2 ($n = 34$, $n = 11$) volcanic glass consists of material likely found at chilled margins of relatively recent lava flows from the massive Mauna Loa volcano and is distinguishable by its trace element values of $Sr < 340$ ppm, $Y < 30$ ppm, $Rb < 10$ ppm, and $Nb < 16$ ppm. Incompatible element concentrations are lower than those for Group 3 lavas as outlined below for a given $MgO\%$ (Lundblad et al. 2013). Variation within this group is larger than for the other two volcanic glass groups. There are several artifacts that have a lower Zr concentration for corresponding Sr concentrations in this dataset. This reinforces the idea that this distribution is likely the result of sampling a number of different geographic and geologic sources with similar geochemical compositions on the Mauna Loa volcano.

Group 3 ($n = 42$, $n = 3$) volcanic glass is found in relatively small quantities at a variety of leeward Hawai'i Island archaeological sites (Lundblad et al. 2014; Lundblad et al. 2013; McCoy et al. 2011). The group is characterized by lower Sr and higher Zr concentrations relative to Group 2 volcanic glass. Higher concentrations of Rb, Nb,

Zr, and Y than in Group 2 are characteristic of Group 3. Lundblad and colleagues (2013) hypothesize that this group comes from the relatively recent p-type lavas of the Kilauea volcano.

The presence of PWW volcanic glass (Group 1) and Group 3 volcanic glass in the uppermost layer at HA-B22-64 suggests a change in source acquisition over time. Also noteworthy is the distribution of volcanic glass artifacts, which differs from that found in other locations on the leeward side of Hawai'i Island. Pu'u Wa'awa'a volcanic glass is present in small but measurable amounts, which is consistent with other sites in the South Point area, but the high percentage of Group 3 volcanic glass is unusual for the area, and represents the highest percentage for the Kona side of Hawai'i Island (52.5%). Because this is a small assemblage of material, however, these patterns may reflect only the influx of a small number of artifacts to the site.

Group Assignment for Basalt Artifacts

We define 8 geochemical groups and 4 outlier samples in the 121 basalt samples from site HA-B22-64 and four groups and an outlier sample in the 25 basalt samples from site HA-B22-248. Data are presented in Figures 6 and 7.⁵ Geographic source determinations for some of the groups will require approaches with more analytical

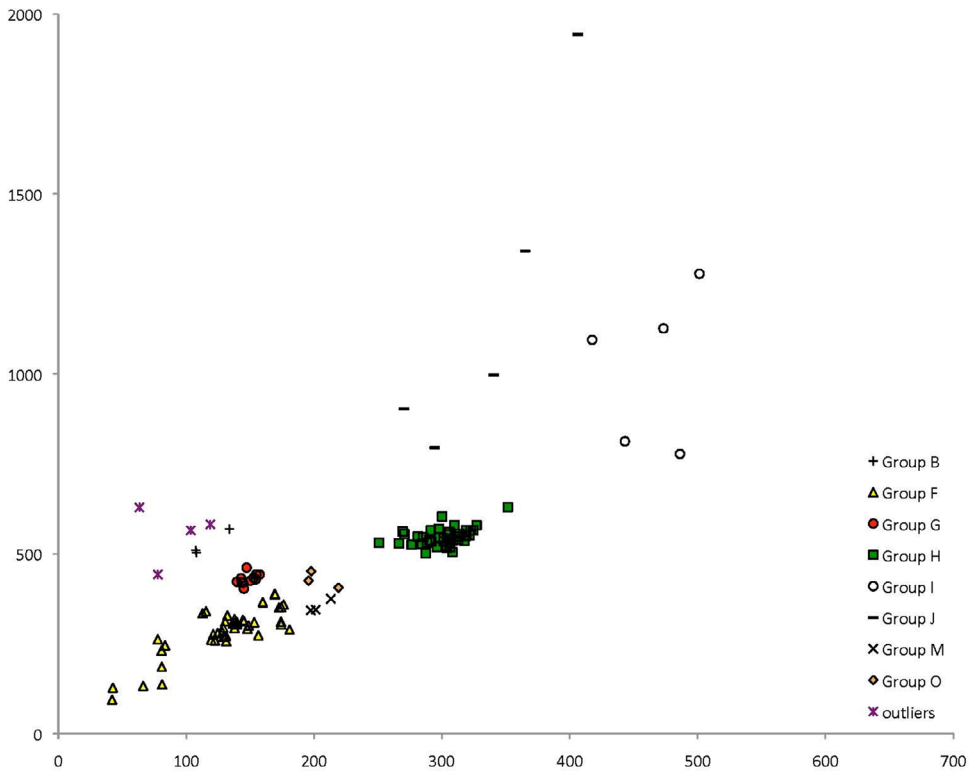


Fig. 6. Bivariate plot of Strontium (Sr) vs. Zirconium (Zr) for basaltic debitage found in site HA-B22-64. While group designations are based on multiple trace elements, much of the variation can be demonstrated with Sr and Zr.

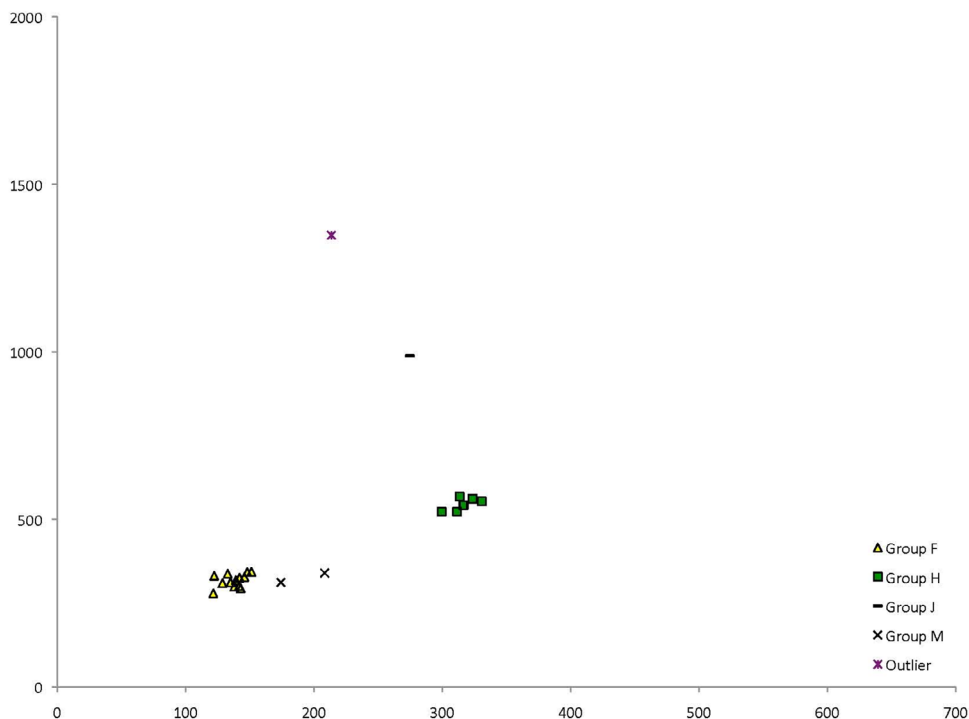


Fig. 7. Bivariate plot of Strontium (Sr) vs. Zirconium (Zr) for basaltic debitage found in site HA-B22-248. While group designations are based on multiple trace elements, much of the variation can be demonstrated with Sr and Zr.

capacity than non-destructive EDXRF can provide. We use the same group designations as from the Kahalu‘u Rockshelter reported by Mills and colleagues (2011) and subsequently by Rieth and colleagues (2013) and Lundblad and colleagues (2014). We interpret some of the groups present (B, F, G, H, I, J) to be the same as those described at Kahalu‘u Rockshelter in Kona District, Hawai‘i Island (Mills et al. 2011), while two other groups (M, O) are similar to other South Point sites (Lundblad et al. 2014).

Group B ($n = 3$, $n = 0$) is present at HA-B22-64 and is consistent with the Keahua I source on Kaua‘i (Lundblad et al. 2014; Mills and Lundblad 2014; Sinton and Sinoto 1997). Mills and colleagues (2011) originally interpreted this as a local source from the Hualalai volcano, but mentioned a tentative match to the Keahua I source. Because the trace element geochemistry of this source is geologically uncommon outside of Kaua‘i, it is a good archaeological tracer for inter-island exchange. The three flakes are adze-related, possibly indicating importation of finished tools to the site.

Group F ($n = 44$, $n = 13$) is consistent with tholeiitic basalt produced during the shield-building phase of Hawaiian volcano growth. Due to the diffuse nature of this group, it likely includes a mixture of sources, such as Mauna Loa, Kīlauea, and the Pololū-series volcanics at Kohala. This source is interpreted to be local; a majority of the material is not obviously adze-related.

Group G ($n = 11$, $n = 0$) is also likely from tholeiitic basalt flows. Group G was separated from Group F at Kahalu'u Rockshelter because of its somewhat higher Sr concentrations. At the Wai'ahukini Rockshelter site (H8), as with other areas along the Kona Coast such as Paumoa and Keone'ele (Rieth et al. 2013), these two groups merge into a single group with two somewhat distinct centroids (Lundblad et al. 2014). The geochemistry of Group G correlates slightly better with certain Kīlauea volcanics, but some Mauna Loa flows also fall in this range (Frey and Rhodes 1993). As with Group F, much of the material is not obviously adze-related and does not represent adze-quality debitage.

Group H ($n = 42$, $n = 7$) is consistent with the Mauna Kea adze quarry (Mills et al. 2008, 2011; Sinton and Sinoto 1997). The main cluster of this geochemical group matches well with geologic and archaeologic samples from the quarry site. Over 50 percent ($n = 25$ at B22-64) of the flakes contain at least one polished surface, so are related to the rejuvenation or breakage of finished tools. This indicates that this was a high-quality source for stone tool production and that the residents of the rock shelter were not commonly engaged in the final stages of flaking unground adze blanks, but were instead fixing tools that had been finished elsewhere.

Group I ($n = 5$, $n = 0$) is a diffuse geochemical cluster, indicative of sampling a number of geochemically related flows. The source is unknown, but it is consistent with the Laupāhoehoe volcanic series on Mauna Kea and some of the Hawi volcanic series from Kohala (Sherrod et al. 2007).

Group J ($n = 8$) is similar to Group I in that it likely samples a number of differentiated lava flows. It is distinguished from Group I by lower Zr/Sr. Hawai'i Island sources include certain Kohala and Mauna Kea volcanics. Group M ($n = 3$, $n = 2$) is a diffuse geochemical group with higher Y, Zr, and Nb than Group F and lower Zr than Group H from Mauna Kea. We consider this material to be from a local source.

Group O ($n = 3$, $n = 0$) is similar in composition to Group H in most elements, but generally falls outside of the measured cluster from the Mauna Kea adze quarry complex and has a lower Y concentration. Its composition is consistent with a different Mauna Kea source.

Due to the large number of basaltic artifacts that do not have an assigned stratigraphic level, it is difficult to draw any conclusions about change of basaltic lithic material use through time at these sites. However, the groups present and their distribution are similar to those found at other South Point sites (Lundblad et al. 2014).

ESTABLISHING CHANGES IN RESOURCE USE THROUGH TIME: FISH CATCHES AND TEMPORAL TRENDS

Scarine oral and pharyngeal jawbones were isolated from the Bishop Museum collections for sites HA-B22-248 and HA-B22-64. Their analysis is presented here as well as in an earlier publication (Longenecker et al. 2014: 1326, table 1). Bone axis lengths were measured to a precision of 0.1 cm with digital calipers (Longenecker et al. 2011; Longenecker et al. 2014). We analyzed biometric relationships to estimate the body length of the scarids present in the archaeological deposits (Longenecker et al. 2011).⁶ The specific DNA methods used permitted some scarid remains to be identified by species, further allowing species-specific relationships to be used when estimating total length (Longenecker et al. 2014). If species identification was not possible, then we used a Scarinae-level relationship (Longenecker et al. 2014).

We analyzed a total of 40 scarine bones from HA-B22-248 and HA-B22-64. Fifteen were genetically identified to species. The mean total length estimate based on scarine bones from HA-B22-248 and HA-B22-64 was 41.2 ± 10.5 cm ($n = 40$) (Longenecker et al. 2014:1326, table 1). When comparing total length estimated from bones from HA-B22-64 Layers I and II (42.5 ± 7.2 cm) and HA-B22-64 Layer III (39.3 ± 15.2 cm), we found a significant increase in total length over time. As Longenecker and colleagues (2014) note, the consistent and stable size structure of the site HA-B22-248 and -64 fish populations, and their large overall size, suggest that fish reproduced before capture. Overall, the fish catch data suggest that some pre-Contact and protohistoric Hawaiian populations occupying the Ka'ū District practiced sustainable fishing techniques.

CONCLUSIONS

The original South Point survey and excavations were carried out during the era of culture historical research in archaeology. Because theoretical paradigms and excavation and survey techniques have dramatically changed since that time, our South Point case study illustrates the utility of using newly developed scientific techniques to re-analyze “old” museum collections in order to address new research questions. Utilizing AMS radiocarbon dating of short-lived species, we have been able to refine the South Point chronology. We show that, while site HA-B22-64 has both a prehistoric and a historic component, site HA-B22-248 was occupied exclusively in the protohistoric period. The new AMS dating results indicate that the lower levels of rock shelter HA-B22-64 date to the fifteenth to seventeenth centuries, slightly later than the first dated use of H8 (Wai'ahuakini Rockshelter) in the fourteenth to fifteenth centuries (Mulrooney et al. 2014). Overall, the refined radiocarbon chronology for Ka'ū District suggests an early mid-sequence settlement date for this region of Hawai'i Island, while sites continued to be occupied into the late pre-Contact and protohistoric periods. Refined site chronologies are key for identifying appropriate assemblages for studying changing resource use through time in the Hawaiian archipelago and the greater Polynesian region.

In using EDXRF for tracking changes in stone tool resources through time, our study is somewhat hampered by small sample sizes. Nonetheless, the stone tool assemblages support the inference that there was spatiotemporal variability in adze production and trade networks across the Hawaiian archipelago. Some inter-island exchange is tentatively suggested by the recovery of Keahua I source materials derived from Kaua'i. In addition, adzes from the Mauna Kea quarry appear to have been used and rejuvenated at these Ka'ū District sites, as the technological attributes of the assemblage do not confirm that there was direct access to the Mauna Kea adze quarry. As Mills and Lundblad (2014) note, sites in East Hawai'i and South Kohala have been found to contain abundant unpolished debitage from the final shaping of Mauna Kea adze blanks before the adzes were ground. The presence of abundant unground Mauna Kea debitage may be one strong indication of where adze production specialists lived. Such individuals may still be identified at the household level in all districts on Hawai'i Island, but as of yet, no such assemblage has been identified in Kona or Ka'ū.

Our use of ancient DNA extraction, amplification, and sequencing techniques to identify scarine bones to species enabled improved morphological analyses and estimates of total length of fish found in the archaeological sites, as well as direct com-

parisons of the prehistoric and historic fish catch to modern population data. This allowed for a more robust conclusion of sustainable nearshore fishing practices at these South Point sites (Longenecker et al. 2014). Current data illustrate that pre-Contact Hawaiian fishing practices were sustainable at multiple sites, including those on different islands and in different ecosystems (O'Leary 2015). This is in stark contrast to the terrestrial-based subsistence practices that severely impacted lowland forests and were less sustainable over the long term (Kirch 2007).

Archaeological collections housed in museums currently serve diverse needs. While most archaeologists recognize the significant cultural value of archaeological collections, the biological value of such collections for questions concerning environmental change, systematics, population genetics, and conservation biology is a substantial source of cross-disciplinary collaboration between archaeologists and natural scientists. In a period of ever-decreasing museum funding, broadcasting what we can learn from old museum collections becomes an ethical responsibility for archaeologists to ensure long-term care of archaeological collections. In this way, the real strength of museums—their collections—can be promoted.

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NOTES

1. Other dating techniques have also been used, but are beyond the scope of the present work.
2. Class 1 dates are defined as dates run on wood charcoal identified to short-lived taxa or dates from terrestrial bone analyzed via ultrafiltration or XAD-2 resin extraction with a standard error of 10 percent of the age determination.
3. Morrison and Hunt (2007) briefly discuss the implications of their results for modern habitat management of Hawaiian mollusk communities.
4. Complete data are archived at Geoarchaeology Laboratory, University of Hawai'i Hilo, 2016. <http://hilo.hawaii.edu/depts/geoarchaeology/>.
5. As with the volcanic glass data, the full dataset can be found on the UH Hilo Geoarchaeology Laboratory webpage noted above.
6. DNA extraction methods are discussed in Longenecker et al. 2014: 1325.

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ABSTRACT

Museum collections contribute valuable information for cultural heritage, biological conservation, and the application of innovative and new methodological approaches. Collections deriving from archaeological projects in Hawai'i serve as a case in point. Here, we report on re-analysis of two Ka'u District collections from Hawai'i Island (HA-B22-64 and -248) to demonstrate what can be learned when applying new research questions to old collections. Our research goals center on two main themes: re-dating the HA-B22-64 and -248 sites to place them within the newly refined Ha-

waiian archipelago settlement chronology; and using diverse data sources to look at changing resource use in pre-Contact Hawai'i through time. Our new AMS dating results indicate that the lower levels of rockshelter HA-B22-64 date to the mid- to Late Prehistoric period during the fifteenth and seventeenth centuries, while upper levels calibrate to the nineteenth century. Both levels of HA-B22-248 calibrate to the late eighteenth to nineteenth centuries. In terms of resource use, Pu'u Wa'awa'a volcanic glass is present at both sites in small amounts, which is consistent with other sites in the South Point area. However, the high percentage of Group 3 volcanic glass is unusual for the area, and represents the highest percentage for the Kona side of Hawai'i Island. HA-B22-64 has a small number of basalt artifacts consistent with the Keahua I source on Kaua'i, while both sites have evidence for artifacts produced from the Mauna Kea quarry. Technological data from our basalt assemblages do not support direct access to the Mauna Kea quarry nor the presence of adze specialists in Ka'u households; rather, we find rejuvenation and use of already finished adzes. Measurements on Scarine oral and pharyngeal jawbones illustrate a consistent and stable size structure of fish populations at both sites. This, along with the large overall fish size, is indicative of sustainable fishing practices. KEYWORDS: East Polynesia, Hawaiian Islands, chronology, marine resource depression, EDXRF, adze production, museum collections.