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A Technological, Petrographic, and Geochemical Analysis of the Kapohaku Adze Quarry, Lana'i, Hawai'ian Islands

Marshall Weisler
Department of Anthropology, University of California, Berkeley

ABSTRACT

The well known Polynesian ethnographer and archaeologist, Kenneth Pike Emory, surveyed the island of Lana'i, Hawai'ian Islands, in 1921 and conducted one of the first extensive settlement pattern studies in Polynesia. More than 65 years after he visited the largest adze quarry on the island at Kapohaku, this important adze production centre was relocated, and a surface collection of flakes, adze blanks and preforms was made. The assemblage is described and a reduction sequence is proposed for the production of adzes from flakes. Technological comparisons with other adze quarries in Polynesia suggest Polynesian-wide similarities in the production of flake adzes. Petrographic descriptions and geochemical characterisation of quarry rock are presented.

Keywords: HAWAI'I, ADZE QUARRY, ADZE PRODUCTION SEQUENCE, PETROGRAPHY, GEOCHEMICAL CHARACTERISATION, KENNETH PIKE EMORY.

> "...a satisfactory description of a Lana'i native, or village, or custom is nowhere to be found. To lessen the ignorance concerning such a formerly well populated island, it is obviously desirable to conduct investigations while a few natives still survive, and before ruins of early life are obliterated by the modern improvements which have swept over the larger islands." (Emory 1924a: 3)

INTRODUCTION

Today, over 65 years after Kenneth Emory conducted his now classic archaeological and ethnographic survey on Lana'i, this statement holds truer than before. The first two resorts have been constructed on the island and socio-economic 'adjustments' to a predominantly agricultural-based lifestyle are now in place. The time could not be more crucial for archaeological research on Lana'i.

On a recent visit to Lana'i the writer, accompanied by Matthew Spriggs, relocated the largest adze quarry on the island, situated adjacent to the central basin at Kapohaku (Fig. 1). The collections made then allow the first artefact descriptions and technological analyses of the quarry debris since Emory's visit in 1921, and permit petrographic and geochemical descriptions of quarry rock. A model is proposed for the production of adze blanks and preforms from flakes rather than cores—a technology seldom described in the published Hawai'ian archaeological literature, although it has been reported for Samoa (Leach and

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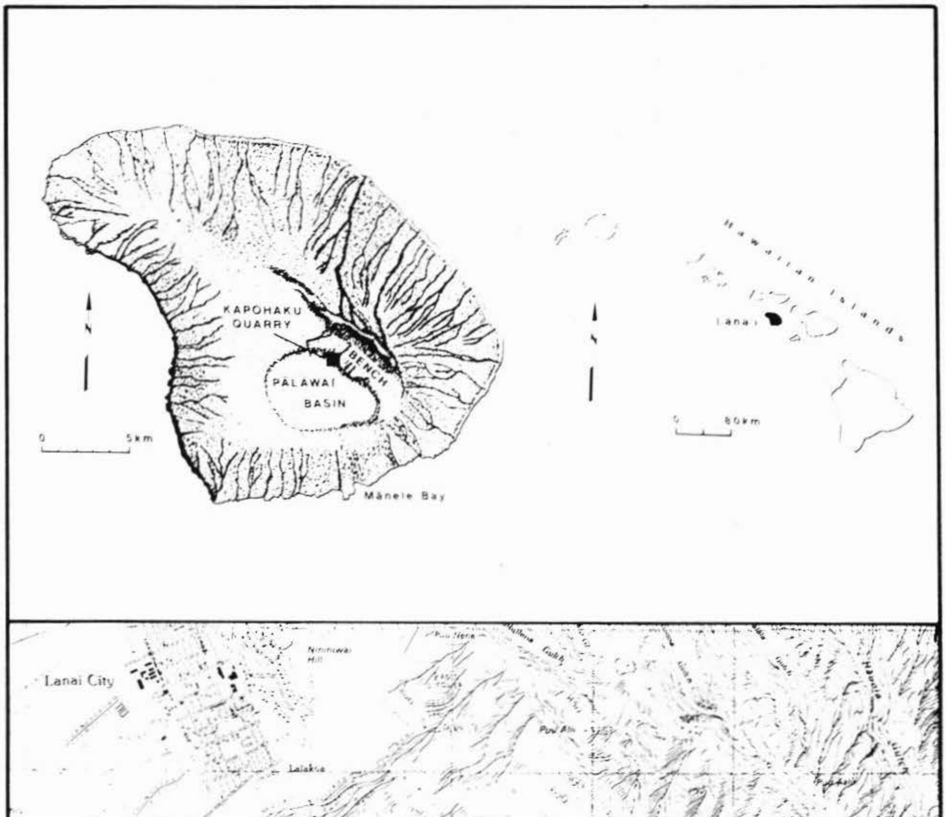

Figure 1: Hawai'ian archipelago, Lana'i and Kapohaku Quarry with selected placenames and site locations discussed in the text. Grid squares on lower map are 1 km.

Witter 1987) and is thought to be the dominant reduction strategy in New Zealand (Leach and Leach 1980: 129) and possibly throughout Polynesia.

ENVIRONMENTAL SETTING

Centrally located in the Hawai'ian archipelago, Lana'i ranks sixth in size among the principal islands and at times in its 1.28 million year geological history has formed a single landmass with its closest neighbours—Moloka'i, Maui, and Kaho'olawe (Macdonald and Abbott 1970: 318–319; Clague and Dalrymple 1987: Table 1.4). Some 225 km square in area, the island is slightly pear-shaped, with its long axis trending northwest–southeast for 27 km along the major volcanic fault zone. A single basaltic volcano formed the island, which reaches a maximum elevation of 1027 m at Lana'ihale where annual rainfall exceeds 1000 mm, dropping to 400 mm at the coast (Giambelluca *et al.* 1986). Numerous gulches emanate from the summit area where torrential rains scour the landscape and transport sediments towards the sea, aggrading the plain fringing the northeast coast. West of the summit, the landscape descends precipitously for 450 m on to the physiographic region known as the Bench. This wide plateau-like feature is 1.6 km across, over 6 km long, and is transected by five large gulches (including Kapohaku). A product of fault escarpments, the Bench borders the east side of the 5.5 km square Palawai Basin—a typical caldera (Stearns 1940: 10; see Wentworth [1925: 45] for an alternative explanation of its origin). This area is of special importance, as its western margin and slopes contain all the known major sources of rock used prehistorically for adze production on Lana'i.

Appearing as outcrops and sub-rounded boulders and cobbles, the raw material used for adze manufacture is the product of extensive *in situ* weathering of basalt flows (cf. Wentworth 1925: 23–25; see also Clague and Hazlett 1989: 18). Wentworth found that

> in most places [on Lana'i] where the products of weathering are not removed by erosion, the entire mass of basalt is reduced to a soft residuum. *At a few localities* where the basalt is more resistant or where partly weathered masses have been uncovered by erosion, are numerous blocks of practically fresh basalt lying about on the ground surface (Wentworth 1925: 24; emphasis added).

These observations have important implications for archaeologists, as the Bench area is a prime source of unweathered basalt for adze production. The west facing slopes of the Bench are eroding from sheet erosion and mass wasting, exposing outcrops of dense, fine-grained basalt, and debris in cobble and boulder form.

The Palawai Basin was probably the most productive agricultural land for the prehistoric Hawai'ians because of its deep, rich volcanic soil, stream-flood from the Bench, and dew precipitation. These factors contribute to its use today as the prime pineapple-growing region on the island. Descending from the Palawai Basin, on the slopes below 150 m, the landscape is very eroded, rocky, and barren. Sparse xerophytic vegetation, although found throughout this area, is denser in gulches where run-off is channelled. A remnant of the former dryland forest lies west of Lana'i City, although most of this area is in pineapple cultivation. The higher elevations support a more luxuriant growth of trees and shrubs.

THE KAPOHAKU QUARRY

EMORY'S VISIT IN 1921

Archaeological research on Lana'i began during the summer of 1921 when Kenneth Emory, sent by the Bernice Pauahi Bishop Museum, "...commenced a work of recording all the heiaus, village sites, fish ponds, ancient roads, and things of similar nature of which any traces are now left" (*Ka Nupepa Kuokoa*, 11 November 1921, vol. 59, no. 45). In six months he located and described over 500 sites (mostly architectural structures) including an 'adz factory' just north of the mouth of Kapohaku Gulch (State of Hawai'i site number 50-40-98-88), and lithic workshops along the nearby ridge at Ko'iahi and at the entrance of Waiapaa Gulch at Ko'i. These sites are situated within the Bench area immediately northeast of the Palawai Basin of central Lana'i.

Writing in his field diary, Emory described the survey of the adze quarry complex. On 22 July 1921, he "climbed the north edge of [Ka]Pohaku gulch onto Hi'i Flat[s]. There were several housesites on this ridge and a few places where the natives had chipped stone. I searched in vain for a long time for stone implements" (1921–22: 6). The following afternoon he met with success, "About 4, I hid the camera and set out for home via the adz quarry at [Ka]Pohaku. I kicked out of the red earth my first valuable specimen an adz ready for the grinding when it was broken in two. Half an hours hunt gave me five more unfinished or broken adzes, and a beautiful ulumaika stone" (1921–22: 12). Emory's published account of his Lana'i expedition provides further details of this area:

> the blocking out of adzes on a large scale occurred at several extensive workshops on the toplands. The most notable is just north of the mouth of [Ka]Pohaku (Stone) Gulch, at Ko'i (adz) [probably Ko'iahi], where spalls and rejects are scattered over an area three hundred square yards among phonolite bowlders [sic] on the slopes of the north ridge. The corners of bowlders [sic] have been broken off to furnish the cores. On top of the ridge are mounds of small chips with no rejects amongst them. These may mark the place where the worker sat to perfect the forms selected (Emory 1924a: 76–77).

In the above passage, Emory is probably referring to Ko'iahi as Ko'i, an area by Kapohaku Gulch. He described Ko'iahi as "a section of ridge. A quarry for adzes" (Emory 1924a: 33, Plate 1) and Ko'i as ("a valley mouth. Place where adz material is abundant" [Emory 1924a: 33]). The locality is situated at the entrance of Waiapaa Gulch 1 km south of Kapohaku Gulch.

Regarding the adze-finishing process, Emory comments that "At Ko'i [Ko'iahi] no partly ground adzes, chisels, and no grindstones were found; the finishing process probably took place at home" (Emory 1924a: 77). Of the 489 house sites Emory recorded during his survey of Lana'i, he mentions only two locales where "the tops of...stones have been ground smooth by the sharpening of stone implements" (1924b: 15). Both sites are located over 8 km from the quarry.

THE KAPOHAKU QUARRY REVISITED (1987)

The Kapohako Quarry (site 88) is located 2.8 km southeast of Lana'i City on the northeast margin of the Palawai Basin (Fig. 1) and lies along the north ridge and slope at the entrance to Kapohaku Gulch. The site consists of large boulder outcrops with probable evidence of flake detachment (although some 'flake scars' may be the ventral face of heat spalls dislodged during brush fires), loose sub-rounded boulders and cobbles, and concentrations of flakes, cores, adze blanks, and preforms. In April 1987, the area was covered with grasses and scattered Christmas Berry (*Schinus terebinthifolius*) and consequently site boundaries are uncertain. However, the quarry extends over at least 2 ha. A bulldozed road truncates the site along the southern margin, exposing a stratum of dense basalt debitage 20 cm thick in the north profile of the road cut. About 30 m north (upslope) of this area (which is also marked by a major bend in the road) is a large stone-faced earthen terrace. Other structures may be present under dense vegetation. A collection of flakes, adze blanks and preforms was made in and along the roadside, beginning at the exposed cultural stratum, and heading northwest for about 1 km. Dense concentrations of debitage were encountered along the entire length of the transect, although it is uncertain whether the quarry extends this far or if debitage was displaced northward during road construction.

OTHER LITHIC REDUCTION SITES WITHIN THE BENCH

Fifty years after Emory's pioneering work, an ambitious program administered by the Department of Land and Natural Resources began in 1974 to inventory the known archaeological sites throughout the State of Hawai'i. Archaeologists from the Bishop Museum spent several weeks on Lana'i mapping, describing, and updating archaeological site data. Because of time constraints and poor ground visibility from seasonally thick vegetation, the quarry and workshops reported by Emory in the 1920s were not relocated, but a new workshop was discovered at Piliamoe Gulch (site 167). Situated at the foot of a ridge on the north side of the gulch, the workshop covers an area approximately 800 m square and was marked by a scatter of several hundred flakes and cores, mostly concentrated in piles, and five adze blanks of fine-grained basalt. Six small structural features were also recorded (see Hawai'i Register of Historic Places, Feature Description Form for site 167, page 4).

In early 1987, a small workshop was found by Matthew Spriggs at the top of the ridge south of the entrance of Koala, associated with a probable shrine and eroding fire pits (site 1530).

Thus at present one major quarry area (Ko'iahi), a sizable workshop (Piliamoe), and a smaller workshop (Koala) form the basis for our knowledge of adze production in the locality on the eastern margin of the Palawai Basin of Lana'i.

THE KAPOHAKU ASSEMBLAGE

The description and classification of finished Polynesian adzes has a long history (Brigham 1902; Best 1912; Duff 1945, 1976; Emory 1968; Green and Davidson 1969; Simmons 1973) and the need for standardised definitions of attributes of finished adzes was an important issue over 50 years ago (see Buck *et al.* 1930; and more recently, Davidson 1961). While recognising attributes of *finished* adzes (for example, poll, butt, bevel, tang, front, shoulder, and the geometric forms of transverse section) is a relatively straight-forward process, the classification of blanks and preforms, by virtue of their unfinished state, proves more difficult and, at times, somewhat subjective. This problem is not unique to Hawai'i and has also been noted by archaeologists working in New Zealand (Leach and Leach 1980: 120). Precise and explicit terms must be used in the classification of Polynesian adze blanks and preforms to permit inter-quarry comparisons. Adapting terms presented by Crabtree (1972: 42, 85), McCoy (1981: 10–11) and Cleghorn (1982) define adze blanks as having indeterminable cross-sections (Cleghorn 1982: 170), while preforms have determinable cross-sections and lack grinding (McCoy 1981: 10–11; Cleghorn 1982: 182). Realising that much formal variability is obscured by 'lumping' blanks into one group, Dye *et al.* (1985) have suggested dividing the continuum from adze blank to preform into: (1) blanks, where it is impossible to predict the cross-section of the intended form; (2) preforms?, defined as "a tool midway between a blank and preform in the reduction sequence, where inferences on the final form of the tool begin to gain confidence"; and (3) preforms, which permit "inferences about the shape of the finished tool...at their greatest degree of confidence" (Dye *et al.* 1985: 11). In a similar vein, McCoy (1986) employed a classification that separated adze blanks into three groups based on refinement of form. While it is clear that precise definitions are needed that encompass the range of formal variability in the steps of Hawai'ian adze production, I have adapted Bradley's (1975) definitions of blank and preform. For example, blanks may "have the morphological potential to be modified into more than one implement type" (i.e., adze cross-section form) and preforms "have the morphological potential of being modified into only one implement type" (or adze cross-section form) (Bradley 1975: 5–6).

ARTEFACT DESCRIPTION

Eight flakes, 1 retouched flake or awl, 40 adze blanks, and 7 preforms were collected from the surface along a 1 km transect of dirt road (Fig. 1). The primary objectives of collecting flakes were to sample the range of macroscopic variability of quarry rock (e.g., rock colour; presence/absence of inclusions and flow structure; surface texture), and describe petrographic thin sections and geochemical composition of the specimens. Collecting flakes, instead of sampling rock from outcrops, allowed the determination of what was used for stone tool manufacture, rather than what was available. Mean flake dimensions are 70 ± 12 mm long, 50 ± 13 mm wide, 15 ± 2 mm thick, and 70 ± 25 g in weight.

Adze blanks and preforms were the dominant products at the Kapohaku Quarry (Figs 2 and 3). Selected metric and discrete attributes of these artefacts are summarised in Table 1. Twenty-two specimens (47%) are whole, while the remaining 25 (53%) are broken at or near the midsection, probably from end shock fracture (see Crabtree [1972: 60, 61] for terms). Where flake or core series could be determined, all specimens are the products of a 'flake series reduction strategy'. As the name implies, the flake series uses a suitable flake rather than a core for the production of an adze. This is the dominant reduction strategy employed at Kapohaku and the eight adze quarries of West Moloka'i. Because of the refined state of adze preforms from the Kapohaku assemblage, all evidence indicating the reduction series had been removed. Only blanks, therefore, could be assigned confidently to a series.

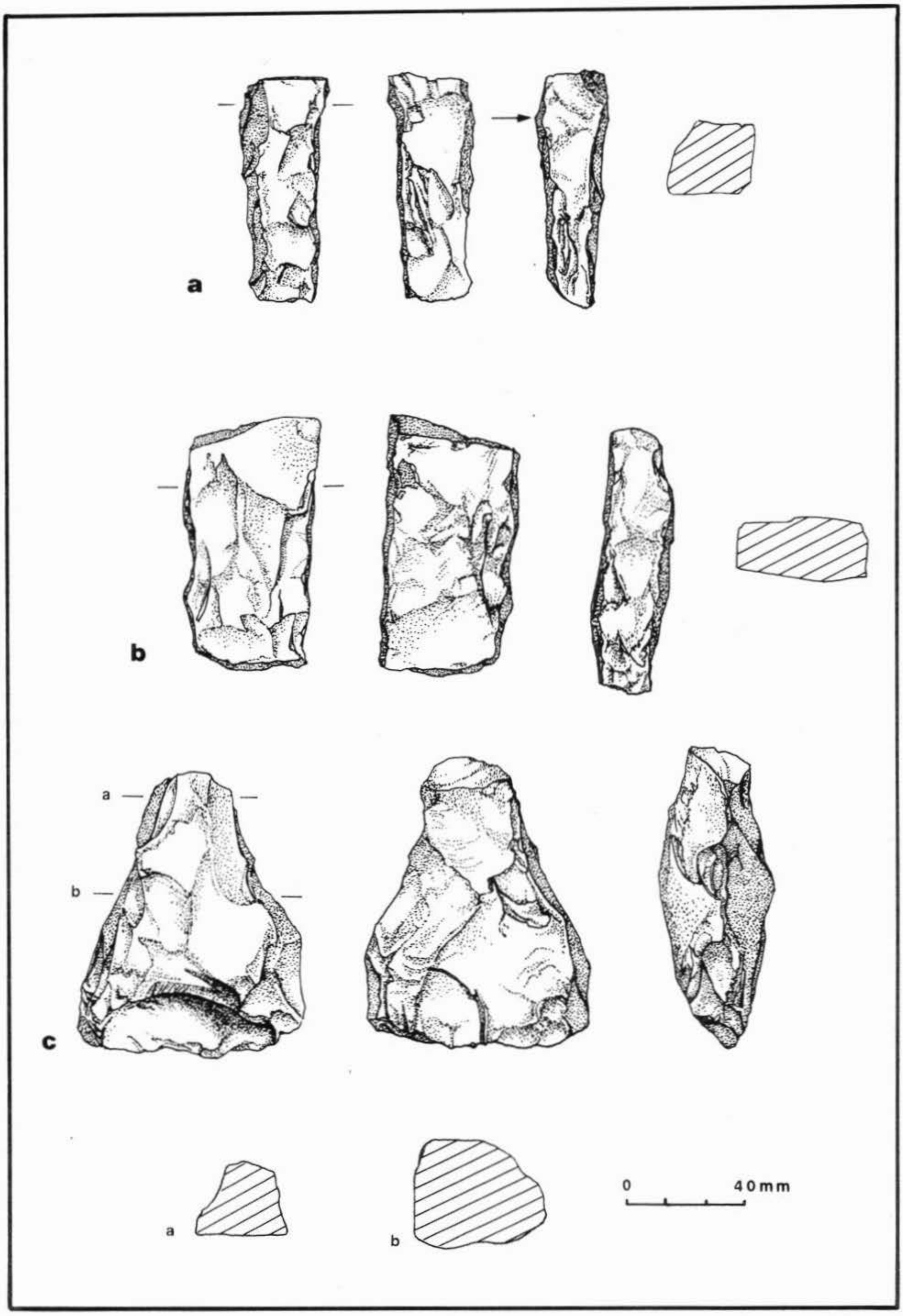

Figure 2: Surface artefacts from Kapohaku. a. Butt section of adze blank with more square transverse-section, arrow points to shoulder and possible tang. b. Preform butt with rectangular-section. c. Possible flake awl. Specimens drawn with butt end down.

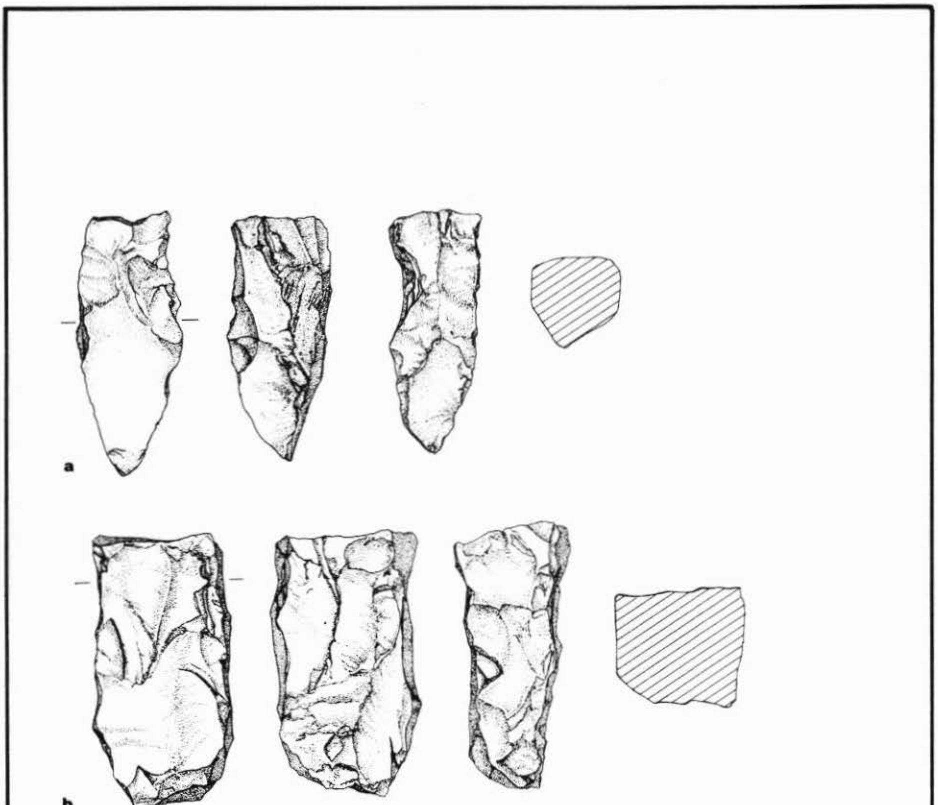

Figure 3: Surface artefacts from Kapohaku. a. More refined adze blank butt with sub-triangular cross-section. b. Preform butt with more square transverse-section. c. Preform butt with rectangular cross-section. Specimens drawn with butt end down.

TABLE 1
METRIC AND DISCRETE ATTRIBUTES OF BLANKS AND PREFORMS
FROM THE KAPOHAKU ASSEMBLAGE

	Blanks	Preforms
Sample Size	40	7
MEAN METRIC ATTRIBUTES*		
Length (mm) [22/0]	84 ± 15	0
Width (mm) [40/7]	43 ± 9	49 ± 16
Thickness (mm) [40/7]	25 ± 7	27 ± 10
Weight (gm) [22/7]	140 ± 80	200 ± 150
DISCRETE ATTRIBUTES		
Condition:		
Whole	22	0
Fragment	18	7
Series:		
Undeterminable	8	7
Flake Series	32	0
Core Series	0	0
Orientation of Ventral Face in Flake Series:		
Undeterminable	20	7
Front	18	0
Back	2	0
Platform Location:		
Undeterminable	17	6
Poll	20	1
Side	1	0
Bevel End	2	0
Cortex:		
Yes	17	0
No	23	7

* only complete dimensions measured. Sample size noted in brackets for blanks, then preforms; for example, [40/7]= 40 blanks and 7 preforms.

Of 20 (43%) specimens where the flake's ventral face could be correlated to the front or back of the adze blank or preform, 18 (90%) exhibited the ventral face as the front. In 37 (79%) of the blanks, the flat, ventral face provided a convenient platform for flake removal along the lateral margins to straighten and refine the transverse section. The original flake platform became the poll end of the blanks and preforms in 21 (88%) of the specimens where the platform could be determined.

The incidence of bi-directional flaking in the Kapohaku assemblage is presented in Table 2. Bi-directional flaking is defined here as a specimen having flake scars that emanate from opposite sides of a blank or preform surface. Additionally, at least one flake scar from each side must cross the medial line of the specimen's surface or intersect with a flake scar from the opposite side. This definition explicitly eliminates less than pronounced bi-directional flaking. Twenty-eight (60%) of all blanks and preforms exhibit one or more surfaces (sides, back, or front) with bi-directional flaking. The more surfaces that are bi-directionally flaked on a specimen, the further along it is in the reduction sequence, a finding that supports Cleghorn's observations of his Mauna Kea assemblage (Cleghorn 1982: 196). The number of flakes removed from a surface through bi-directional flaking is no more than six and averages three to four. Consequently, bi-directional flaking is not an important strategy for thinning blanks and preforms. Of the 55 bi-directionally flaked surfaces on blanks and preforms (29.6% of all surfaces in the assemblage), 62% are found on the specimen's front or back where thinning the transverse section was the goal. Only 38% of the sides exhibited bi-directional flaking for straightening the lateral edges of the flake blank.

REDUCTION MODEL

Several types of adze preforms may exist at the quarry and describing these forms and variations in reduction strategies should be an area of future research. However, on the basis of the above data, I propose a tentative model for the production of one type of quadrangular adze preform:

1) Selection of the raw material (either an outcrop, sub-rounded cobble, or boulder);

2) Detachment of a flake blank by producing a relatively short, thick flake with slightly expanding sides, diffuse bulb of percussion, and a curved dorsal surface that follows the natural curvature of the stone (Fig. 4a, upper);

3) Orienting the ventral face up (the front of the blank) and the dorsal side down (the back of the blank), the margins of the ventral face were used as a platform for flake detachment to straighten the lateral edges of the flake (Fig. 4b, middle);

4) The flake platform became the blank or preform's poll;

5) Bi-directional flaking was used to thin and further straighten the sides and shape the specimen to the desired transverse section (shaded area in Fig. 4b, middle);

6) The flake termination, with additional modification, was used as the cutting edge; and

TABLE 2
OCCURRENCE OF BI-DIRECTIONAL FLAKING

	BLANK	
PREFORM		
Sample Size	40	7
Number of Surfaces Per Class (N X 4)	160	26*
Percent Bi-Directionally Flaked Surfaces Per Class	40	81
Number of Surfaces Bi-Directionally Flaked Per Specimen		
None	19	0
One	13	0
Two	3	3
Three	5	1
Four	0	3

*Includes two sub-triangular transverse-section specimens.

7) The natural curve of the distal third of the dorsal face was shaped to form the bevel (Fig. 4b, middle).

Apart from selection of the raw material and detachment of the flake blank, the order of the reduction sequence is not assumed but technologically controlled. With a larger sample of blanks and preforms, additional steps in the sequence may be defined or existing ones modified. Tang formation may also be part of the sequence, although only one specimen in the Kapohaku assemblage exhibits a shoulder (Fig. 2a) and none show a definite tang. A low frequency of tanged preforms in quarry assemblages has been noted at the Mauna Kea quarry, Hawai'i (McCoy 1977: 241) and at the Riverton quarry, New Zealand (Leach and Leach 1980: 131).

TECHNOLOGICAL COMPARISONS WITH OTHER QUARRIES IN POLYNESIA

Cleghorn (1984: 409–415) has provided a general summary of technological studies of Polynesian adzes. However, with the presentation of the Kapohaku data, the formal similarities of adze blanks and preforms made from flakes at the Tataga-matau quarry in Samoa (Best, Leach, and Witter 1989; Leach and Witter 1987) and, especially, the Riverton quarry in New Zealand (Leach and Leach 1980), are striking. In fact, adze preforms from the Riverton site, illustrated by Leach and Leach (1980: Figs 7, 8, 15, 17 and 18), are quite similar to those collected at Kapohaku and several quarries on West Moloka'i. Not all technological attributes are selected and reported identically across all studies, which makes exact comparisons difficult. However, sufficient data are described to permit some generalisations and comparisons between reduction strategies employed to manufacture adze blanks and preforms from flakes. At the Riverton quarry (Leach and Leach 1980), the bilateral preform is most similar to the Kapohaku assemblage. This kind of preform, 77% of which were made from flakes, represents 86% of the collection (Leach and Leach

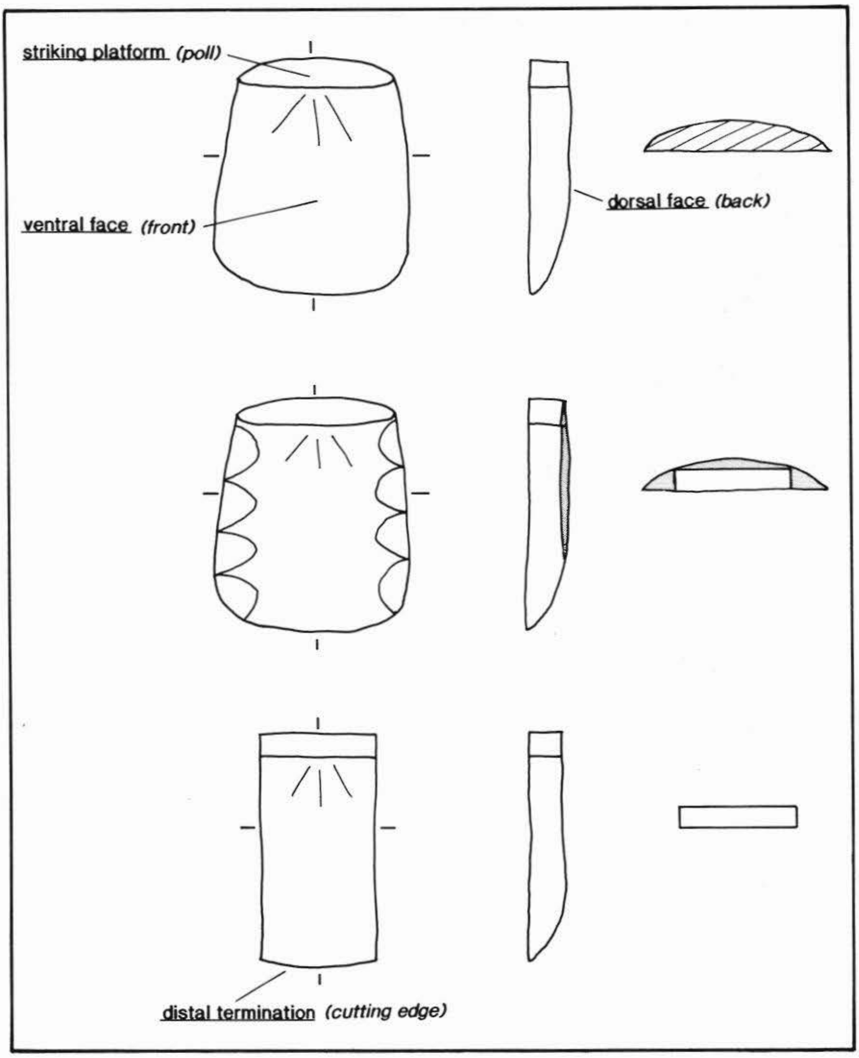

Figure 4: Preform manufacture in a flake series. Flake attributes are underlined with corresponding adze characteristics italicised in parentheses. Areas reduced with bi-directional flaking are shaded. See text for explanation of reduction steps.

1980:129) and thus provides a good comparison for the Kapohaku assemblage. The type A blank from the Tataga-matau quarry, Samoa, is also similar to Kapohaku adze blanks and preforms in shape, although the Kapohaku specimens are somewhat thicker.

Similarities between Kapohaku and Tataga-matau and/or Riverton include: (1) use of cobbles, boulders or 'angular blocks' as the raw material (all three quarries); (2) production of flake blades (all three quarries); (3) use of the flakes' bulbar surface as a platform to trim the sides of the blank (Kapohaku, Riverton); (4) orientation of the flake so its sides become the sides of the adze (Kapohaku, blank types C and D at Tataga-matau); (5) rejection of blank or preform because of transverse or end shock fracture near the mid-point (Kapohaku; large, broken preforms were reworked into smaller adzes at Riverton and probably Tataga-matau); (6) minor use of an anvil (Kapohaku; Tataga-matau, type A blanks); (7) dominant cross-section is rectangular (Kapohaku, Riverton); (8) most specimens are wider at the cutting edge (all three quarries); and (9) similar size classes (all three quarries, especially blank type A Tataga-matau and Kapohaku).

CROSS-SECTION FORM

Even at the blank stage, in many cases, one can be reasonably certain that the end product was a wide, thin adze preform rather than a tool more square or triangular in cross-section. While it is true that "adzes undergo changes in cross-section throughout the manufacturing process" (Leach and Leach 1980: 120), I suggest that some adze blanks have determinable cross-sections that reflect the intended finished product. Adherence to Emory's (1968) classification for finished adzes, which relies on the measurement of percent width of back to front to separate what he refers to as rectangular from trapezoidal forms, is not appropriate for unfinished adzes. It seems that the difference between broad and thin blanks and preforms and those that are more square in cross-section is important (usually reflecting quadrilateral flaking [Leach 1981]); this characteristic is obscured with Emory's classificatory scheme. Figure 5 presents Emory's (1968) classification of finished adzes and one proposed for unfinished forms used in the classification of the Kapohaku assemblage.

Thirty-three specimens (70%) of the Kapohaku assemblage could be classified according to transverse section. Quadrangular section forms accounted for 28 (85%); 73% of these were rectangular. Quadrangular section forms as defined here were subdivided by measuring width and thickness dimensions at the midsection of whole specimens or at the reconstructed midpoint of fragmentary blanks and preforms. With the specimen oriented front face up and bevel end towards the viewer, rectangular cross-sections were defined as having a width to thickness ratio averaging 2:1 (range from 1.5:1 to 3.12:1). This definition explicitly distinguishes broad, thin blanks and preforms (Fig. 3c) from those that are more square in transverse section (Fig. 3b). Of the other classifiable specimens, 2 (6%) were plano-convex, 2 (6%) were sub-triangular, one of which is illustrated in Figure 3a, and 1 (3%) lenticular in transverse section.

OTHER TOOLS

A possible awl is illustrated in Figure 2c. It exhibits bifacial flaking along its lateral margin, and its apex is truncated because of perverse fracture.

PETROGRAPHIC AND GEOCHEMICAL CHARACTERISATION OF THE KAPOHAKU MATERIAL

Because of their durability and widespread occurrence, lithic resources—both raw material and finished artefacts—provide an excellent opportunity for distributional studies and, consequently, for addressing social interaction in prehistory. Early attempts at demonstrating cultural affinities and migratory routes within Polynesia were based on stylistic similarities

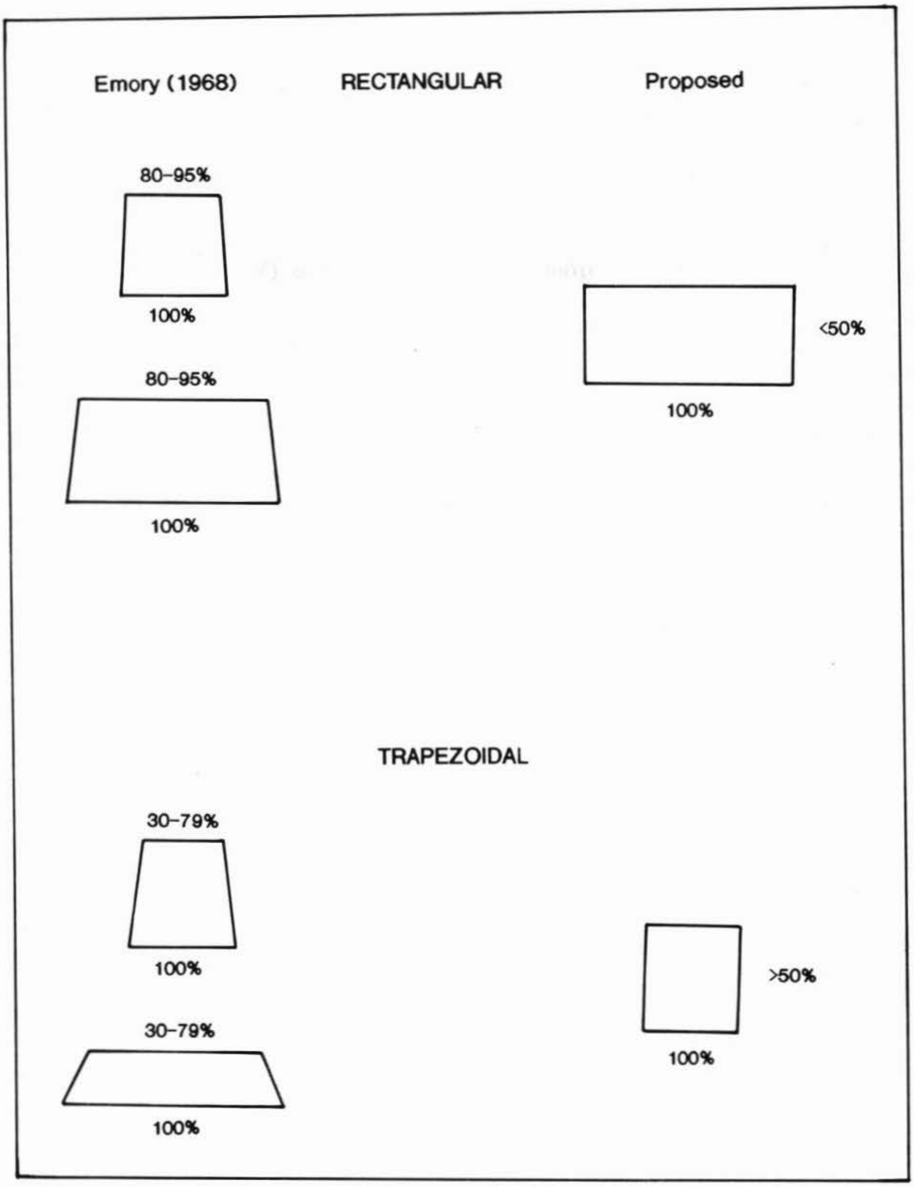

Figure 5: A classification of transverse-section forms of adze blanks and preforms which explicitly separates broad, thin forms from those that are more square in section.

of adzes (Duff 1959; Emory 1968). However, more recent attempts have relied on the physical properties of artefacts described in petrographic or geochemical terms. Kirch (1975: 43–45) compared petrographic descriptions of lava flakes and cores from a habitation site on east Moloka'i, with material from two quarries on the western end of the island to suggest the source of the raw material. A similar technique for sourcing adze material has been used by Best (1984) in Fiji and Withrow (in press) elsewhere in Hawai'i. Ten years after the first attempts at sourcing lithic artefacts in Hawai'i, Cleghorn *et al.* (1985)

compiled and described 43 petrographic thin-sections from 8 of the 13 then known adze quarries. They produced the first key for discriminating source rock of Hawai'ian adze quarries.

Elsewhere I have shown that petrographic data alone may not be adequate for identifying artefacts to their geological sources (Weisler 1989). For example, on the basis of petrographic descriptions, Kirch (1975: 44) suggested that a basalt artefact from Halawa Valley, Moloka'i, was similar to quarry material 48 km away. However, I found that only 1 of 16 trace elements identified in similar artefacts from the Halawa site was within the range of geochemical values from the suggested source (Weisler 1989: 9). Although artefacts and source material may appear identical macroscopically, and petrographic descriptions may seem similar, geochemical characterisation should also be used to discriminate source material and artefacts. Consequently, both petrographic and geochemical data are presented for the Kapohaku Adze Quarry.

PETROGRAPHIC DATA

Presented here are the first petrographic descriptions of the Kapohaku Quarry material:

> [The first specimen is] fine-grained (160 grains/mm) with 5% microphenocrysts (0.1 mm) of plagioclase and augite and about 15% oxide (magnetite?) up to 0.15 mm. The groundmass is mainly plagioclase + augite in a granular texture. [The second flake is] sparsely-phyric lava with 2–3% microphenocrysts of augite + plagioclase up to 0.2 mm and 3% pseudomorphs of iddingsite (having replaced olivine) up to 0.7 mm and 1–2% magnetite up to 0.1 mm in a fine-grained (160 grains/mm) granular matrix of plagioclase, augite, and magnetite.

The specimens are similar in groundmass texture and may be from the same flow, even though the latter specimen has more phenocrysts (Sinton, written communication). On the basis of these petrographic attributes (especially those of texture and absence of biotite), I was able to assign the Kapohaku adze material to the Kaho'olawe quarry, using the tentative key to Hawai'ian adze quarry rock presented by Cleghorn *et al.* (1985). Because this is clearly not correct, it will be necessary to augment the key with new petrographic data from the Kapohaku quarry, and adopt more caution in source assignment in the absence of geochemical data.

GEOCHEMICAL DATA

Best (1984) was one of the first to use X-ray fluorescence spectrometry for geochemical characterisation of adze quarry sources in the Hawai'ian Islands. A single sample was analysed from each of seven quarries from five islands. In addition, data from five samples were acquired from the largest quarry at Mauna Kea, Hawai'i Island (Best 1984: Appendix L). Using a similar technique, I have analysed 35 samples from 8 quarries on Moloka'i and provided data on intra-source variability from one of the largest quarries on the island (see Fig. 6). In order to characterise the Kapohaku adze quarry material and to distinguish it from other quarries nearby, geochemical analyses were conducted on the Kapohaku material

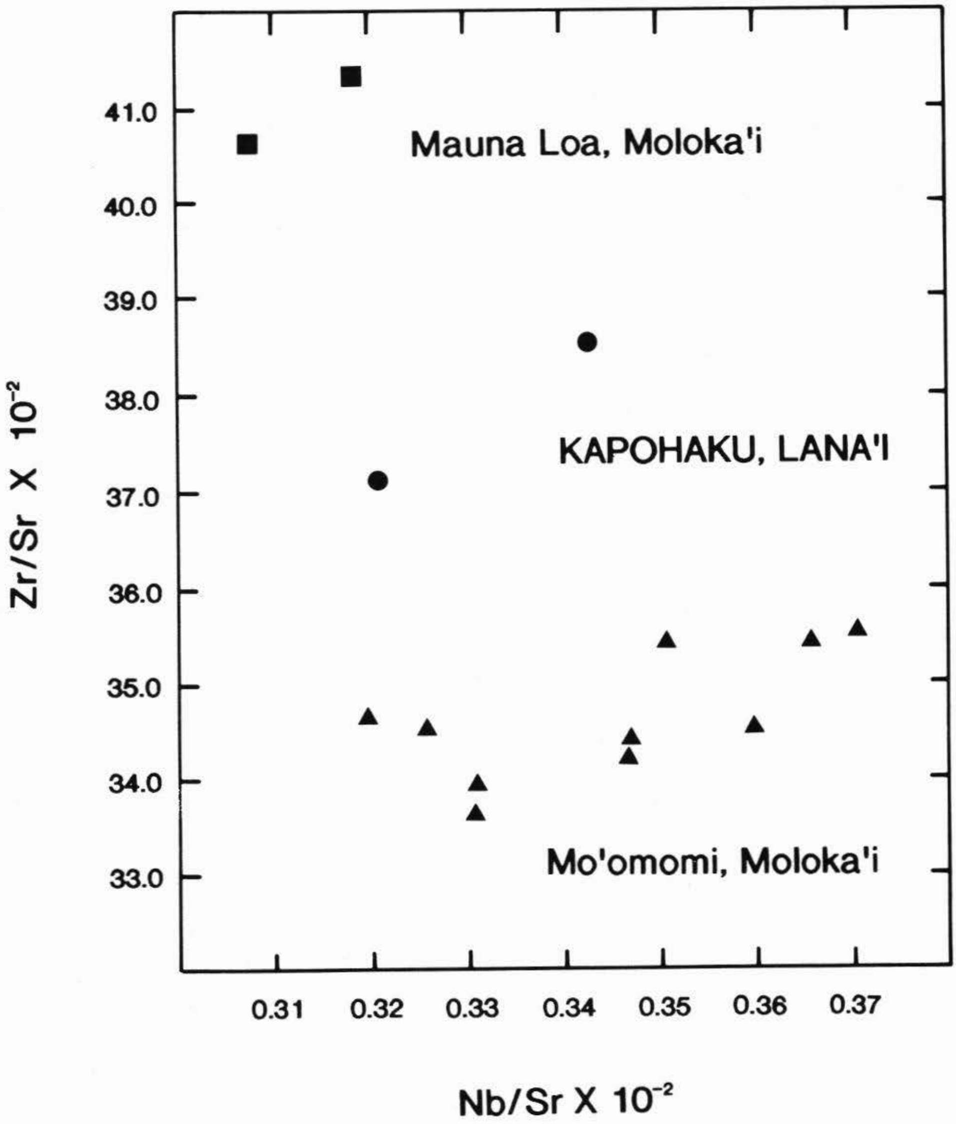

Figure 6: Plot of zirconium/strontium and niobium/strontium ratios for the Kapohaku, Mauna Loa, and Mo'omomi adze quarries. Instrument precision for zirconium is 2.1% of the mean standard value; strontium 4.0%; niobium 0.8%.

and compared to the largest quarries on West Moloka'i. X-ray fluorescence spectrometry has been used successfully to discriminate volcanic glass sources on West Moloka'i and tentatively assign archaeological material to source (Weisler 1990). Using this technique, the concentrations of 23 major and trace element values were analysed (Table 3) and compared between sources. Sample preparation, and levels of precision and accuracy, are explained fully by Hooper and Johnson (1987). Briefly, a powdered rock sample of 3.5 grams is

TABLE 3
AUTOMATIC XRF ANALYSIS FOR THE KAPOHAKU, MAUNA LOA, AND MO'OMOMI ADZE QUARRIES

	KAPOHAKU	MAUNA LOA	MO'OMOMI
Oxides	(n=2)	(n=2)	(n=10)
SiO_2 (0.13)*	53.84 ± 0.06	53.0 ± 0.16	46.2 ± 0.12
Al_2O_3 (0.04)	14.50 ± 0.05	14.00 ± 0.03	15.72 ± 0.04
TiO_2 (0.014)	2.11 ± 0.02	2.46 ±0.091	4.168 ±0.009
FeO (0.22)	10.60 ± 0.16	11.26 ± 0.04	14.2 ± 0.20
MnO (0.002)	0.164 ±0.001	0.168 ±0.001	0.186 ±0.007
CaO (0.03)	10.10 ± 0.65	10.24 ± 0	8.53 ± 0.03
MgO (0.03)	7.04 ± 0	6.55 ± 0.05	6.32 ± 0.08
K_2O (0.01)	0.55 ± 0	0.50 ± 0.04	0.92 ± 0.02
Na_2O (0.05)	2.28 ± 0.03	2.4 ± 0.10	3.52 ± 0.07
P_2O_5 (0.004)	0.256 ± 0.01	0.300 ±0.013	0.623 ±0.006
Trace Elements (PPM)			
Ni (2.0)	98.0 ± 6.5	73.5 ± 0.5	68 ± 1.9
Cr (5.3)	262 ± 7.5	180 ± 20	5 ± 1.7
Sc (2.7)	32 ± 2.0	32.5 ± 0.5	19 ± 2.6
V (10.0)	287 ± 5.0	307 ± 5.5	302 ± 7.7
Ba (16.2)	86 ± 3.5	70 ± 15	220 ± 21
Rb (1.3)	9.0 ± 0	10 ± 1.5	14.4 ± 0.92
Sr (4.0)	343 ± 4.5	360 ± 13	786 ± 6.6
Zr (2.1)	129.5 ± 0.5	150 ± 6.5	273 ± 2.9
Y (1.2)	100 ± 26	60 ± 11	37.8 ± 0.98
Nb (0.8)	11.4 ± 0.25	11.6 ± 0.6	27 ± 1.2
Ga (1.3)	19 ± 3.0	21 ± 1.5	23 ± 1.8
Cu (2.3)	91 ± 3.0	84.5 ± 11.5	12 ± 5.6
Zn (5.7)	98 ± 4.0	111 ± 9.5	133 ± 1.9
Pb	2 ± 1.0	7 ± 1.5	4 ± 1.4
La	40 ± 21	17 ± 9.5	19 ± 9.1
Ce	90 ± 47	45 ± 9.5	63 ± 9.9
Th	1.5 ± 0.5	1.0 ± 0	0.8 ± 0.98

* instrument precision for internal standard (Hooper and Johnson 1987:Table 2). Oxide values are weight percent unnormalised. Analysis by Dr. Peter R. Hooper.

compressed into a fused disk and analysed on an automatic Rigaku 3370 spectrometer. All values are fully corrected for interference and matrix effects and compared to U. S. G. S. standards.

Figure 6 shows that the ratios of zirconium and strontium, and niobium and strontium can distinguish sources. Chromium and yttrium may also be useful indicators of source material. Although it may not be reliable to discriminate quarry rock in the Hawai'ian Islands by petrographic data alone, the geochemical signature of the Kapohaku quarry rock should permit unambiguous discrimination between this major Lana'i source and other adze quarries for which geochemical data are available. As proposed recently by Cleghorn (1986), the spatial and temporal distribution of adze material (both finished artefacts and the bi-products of adze manufacture and reworking) can then form a powerful data base for the analysis of social interaction in Hawai'ian prehistory. The precise characterisation of source material is a necessary precursor to future studies of exchange and interaction.

DISCUSSION AND CONCLUSION

With the presentation of new data from the largest known adze quarry on Lana'i, a model has been proposed outlining the reduction sequence for manufacturing quadrangular adze blanks and preforms from flakes. Although this flake reduction strategy is found at most Hawai'ian adze quarries, a description of the model has never been published. The production of adze blanks and preforms from flakes may well be the dominant reduction strategy throughout Polynesia, as similarities between Kapohaku and quarries in Samoa and New Zealand seem to suggest. Future research may elucidate how adze makers adapted reduction strategies to the kinds of raw material (sizes and shapes) and flaking properties. As Leach stated, "physical principles define broad limits to the working of stone. Only when these general limits are identified can one understand the cultural significance of the specific manner in which stone is worked" (1969: 32).

Small quadrangular adze blanks and preforms, both broad and thin in transverse section, were the dominant type of artefact collected at Kapohaku and it is suggested that final cross-section form may be discerned from some adze blanks.

The average Kapohaku adze blank was less than 85 mm long and weighed about 140 grams, making it the smallest adze blank produced at any Hawai'ian adze quarry thus far studied (cf. Cleghorn 1982; Dye *et al.* 1985). Sample size may not be a factor, as the number of measurable specimens in the Kapohaku assemblage is larger than those from three of the four quarries from which data are already available. The reasons for the small size are uncertain at present. However, the size of the source material can be ruled out, since the raw material is similar to other quarries in Hawai'i, excluding Mauna Kea. This suggests, perhaps, that the answer may lie in the demand for small adzes by households for everyday tasks. That is, large adzes, most often associated with the specialised activities of canoe-making and house-building (cf. Malo 1951; Kamakau 1961, 1964), should have a more restricted distribution and frequency. The distribution of finished adzes by size and kind of site (residential complex, specialised craft area) may contribute data to address this problem.

While discriminating the Kapohaku quarry material from other sources throughout the Hawai'ian Islands has proved difficult with petrographic data alone, geochemical characterisation using X-ray fluorescence spectrometry has shown promise as a method to distinguish adze quarry sources unambiguously. This line of research merits further consideration.

Future research at Kapohaku Quarry should include: (1) an intensive survey of the Bench area to locate and map surface architectural features, debitage concentrations, and define the spatial limits of the quarry; (2) systematic surface collections to expand the sample of blanks and preforms; (3) excavation to collect material for dating, quantitative data on blanks, preforms, and debitage for calculating production estimates, and to ascertain the nature and function of architectural features; (4) technological analysis of debitage, blanks, and preforms; and (5) geological sampling of outcrops and loose cobbles and boulders to expand the range of geochemical data and document the variability in the quarry rock. As Kenneth Emory perceptively remarked 60 years ago, "It is clear that the answer to many questions concerning the various objects and types of ruins can come only...through a laborious compilation of indirect evidence" (1924a: 3). Regarding Kapohaku he stated, "This entire workshop deserves a special study for the knowledge it might give of the stone shaping arts in Hawaii" (1924a: 77).

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