

Plainware Ceramics from Sāmoa: Insights into Ceramic Chronology, Cultural Transmission,
and Selection among Colonizing Populations

Ethan E. Cochrane ^{a*}, Timothy M. Rieth ^b, William R. Dickinson ^c

^a The University of Auckland, Department of Anthropology, Private Bag 92019, New Zealand; email: e.cochrane@auckland.ac.nz
phone: +64 9 373 7599 ext. 88571

^b International Archaeological Research Institute, Inc. 2081 Young Street, Honolulu, HI 96826, USA; email: trieth@iarii.org

^c Department of Geosciences, University of Arizona, Tucson, AZ 85721, USA;
email: wrdickin@dakotacom.net

*Corresponding author

REVISED MANUSCRIPT

1 August 2013

Abstract

The first people in Sāmoa produced a varied ceramic archaeological record including a single deposit with decorated Lapita ceramics on the island of ‘Upolu in the west of the archipelago and a nearly contemporaneous plainware deposit over 250 km to the east on Ofu Island. Post-Lapita ceramic change across Sāmoa is similar with almost no decoration, local ceramic production, limited vessel form diversity, and changing frequencies of thin- and thick-wares. This Samoan ceramic record is different from nearby Tonga and Fiji where early decorated Lapita ceramics are widely distributed, there are no thickness-defined ware types, and for Fiji, post-Lapita ceramics are more variable. Here we investigate the apparent uniqueness of the Samoan ceramic record through an analysis of early plainware ceramics, the second oldest after the Ofu deposits, from Tutuila Island in the center of the Sāmoan archipelago. Our assemblage-specific findings are similar to other Sāmoan plainware analyses, but we suggest the ceramic and other archaeological evidence from Sāmoa and the region indicates Sāmoa was colonized by a few isolated groups and that within the context of cultural transmission of ceramic variants, selection explains thickness variation and likely other aspects of Sāmoan ceramic change.

Keywords

Ceramics, Colonization, Cultural Transmission, Lapita, Sāmoa, Selection, Tonga, West Polynesia

Introduction

It is becoming more and more apparent that archaeological research in Sāmoa will be key to answering significant questions in Oceania concerning, for example, the results of interaction between indigenous and migrant populations (Addison and Matisoo-Smith 2010), the origin of postulated phylogenetic units of culture and language (Burley et al. 2011), and the influence of demography on the successful human colonization of pristine and changing environments (Rieth et al. 2008). Lying at the far eastern edge of a large portion of Remote Oceania colonized around 2900 BP, Sāmoa (Figure 1) is an archipelago of contrasts: the large shield volcanoes of the western islands (the independent nation of Sāmoa), the smaller, typically heavily weathered and dissected islands to the east (the territory of American Sāmoa); the prolific cultural resource management archaeology in the eastern islands, the relatively little amount of archaeological research in the west; the Mulifanua deposit as the single Sāmoan representative of decorated Lapita ceramics, and the contrastingly numerous plainware ceramic deposits found throughout the islands.

We present an analysis of recently excavated plainware ceramics from Sāmoa and situate this analysis within a comparison of both similarly aged plainware assemblages from across the archipelago and with the decorated Lapita ceramics from Mulifanua. Our comparisons are made with reference to chronology and ceramic technology and have ramifications for our understanding of Sāmoa, in particular cultural transmission (Boyd and Richerson 1985) between local populations during and after colonization, and the different processes that explain ceramic change in West Polynesia. Regarding the ceramics, our results generally support previous research: we find a chronological trend in sherd thickness from relatively thin to thick vessels, possible use-related differences between wares, exclusively local production throughout the ceramic sequence, and diminished vessel forms relative to

the earliest Sāmoan assemblage at Mulifanua. We discuss these findings with reference to other assemblages and move beyond ceramics to suggest that Sāmoa was colonized by a severely diminished population, relative to nearby Tonga and Fiji, and one that consisted of isolated local groups. We propose that within the context of cultural transmission of ceramic variants, selection explains aspects of ceramic change at Tula and other plainware deposits in Sāmoa.

Archaeology of Sāmoa

We leave the detailed description of Sāmoan archaeology to a series of general publications on a range of themes (e.g., Barnes and Hunt 2005, Best 1992, Best 1993, Clark 1996, Davidson 1979, Green and Davidson 1969, Green and Davidson 1974, Herdrich and Clark 1993, Jennings et al. 1980, Jennings et al. 1976, Kirch and Hunt 1993, Rieth and Hunt 2008) and here concentrate on the environmental setting, ceramic archaeology of the archipelago, and the Tula deposit.

Environmental Setting

The islands of Sāmoa are composed of basaltic lavas and pyroclastics from a linear series of shield volcanoes that extend from beyond 'Uvea (Wallis) Island in the west to Rose Atoll in the east (Nunn 1994:46, Wright 1986). The large islands of Savai'i and 'Upolu in Sāmoa are formed from multiple cones along axial ridges, with the resulting volcanics of differing ages (up to 2.5 million years to historic times) and compositions, although most are olivine-rich basalts (Keating 1992). In contrast, cones are now largely absent on the largest island in American Sāmoa, Tutuila, having been eroded from intense weathering. Three

eruptive centers form the backbone of Tutuila, which emerged approximately 1-1.5 million years ago, and produced olivine basalts, breccias, and tuffs (Keating 1992, McDougall 1985). The large Tafuna plain on the southwestern coast of Tutuila formed from a fourth eruptive center during the Holocene with volcanic activity continuing until approximately 1300-1400 BP (Addison and Asaua 2006, Addison et al. 2006).

The landforms, fauna and flora that would have been encountered by Sāmoa's colonizers have changed over time, both naturally and as a result of human modification. In addition to the recent volcanism creating the Tafuna plain, other portions of Sāmoa's coastline were likely geomorphologically different in the past. Rieth et al. (2008) developed a GIS and sea level model of the Tutuila shoreline that suggests many coastal flats did not form until 2500 BP or later (see also Addison and Asaua 2006, Dickinson and Green 1998, Green 2002, Morrison et al. 2010). Even without many coastal flats, the richest faunal resources encountered by Sāmoa's colonizers were likely the near-shore marine taxa. An abundance of fish, molluscs, and turtles are available along most coastlines. However, from a terrestrial perspective, the Sāmoan islands would have been relatively poor in faunal resources, particularly land birds (Steadman 2006:194-203). Polynesian rat, pig, chicken, and dog were introduced to the islands prior to European contact (summarized in Smith 2002). Indigenous flora and fauna must have been dramatically altered by these non-native species, in addition to vegetation clearance over almost 3,000 years of human occupation that produced, as Kirch (1993:16) describes, "a mosaic of coconut stands, breadfruit and banana orchards, and aroid gardens interspersed with second growth."¹

Sāmoan ceramic archaeology

¹ The limited number of paleoenvironmental studies in American Sāmoa (Athens and Desilets 2003; Cleghorn 2003) have not sampled deposits spanning the pre-human and early to late cultural sequence, and thus provide limited evidence for long-term vegetation change.

In Sāmoa the only known Lapita ceramic deposit is at Mulifanua off the west coast of ‘Upolu. Mulifanua represents the initial phase of Sāmoan colonization between approximately 2900-2600 cal BP, associated with dentate-stamped pottery (Green 1974, Petchey 1995, Petchey 2001), lithic artifacts (Leach and Green 1989), and a typical coastal location (Dickinson and Green 1998). Although no other deposits containing dentate-stamped ceramics have been identified, nearly contemporaneous or slightly more recent Plainware deposits have been reported from ‘Aoa (Clark and Michlovic 1996) on Tutuila and To‘aga on Ofu (Hunt and Erkelens 1993). The context of the ‘Aoa deposit and associated dated material lead Rieth and Hunt (2008) to reject the earliest proposed date ranges for this deposit. The earliest dated material is unidentified charcoal from general layer contexts (Clark 1993), the deposit is formed in the main by colluvial and alluvial processes, and other more recent date ranges that seem out of place in the sequence are interpreted by Clark and Michlovic (1996:162) as possibly influenced by intrusive materials and admixture. For To‘aga, the earliest date ranges overlap with the Mulifanua date ranges, but Rieth and Hunt (2008:1916) suggest that given the lack of dentate stamping in the To‘aga ceramic assemblage, these deposits may have formed after the beginning of cultural deposition at Mulifanua. More recently, Clark (2013) reported date ranges and ceramic forms from Ofu Island that also suggest human use of the island penecontemporaneous with Mulifanua.

The ceramics from Mulifanua exhibit both a range of rims and Lapita motifs (Petchey 1995), the latter mostly simple designs similar to other regional assemblages characterized as Eastern Lapita (Kirch 1997), and the former including notched-collared rims found in Fiji-West Polynesia (e.g., Burley et al. 2002, Cochrane et al. 2011). Petchey (1995:68-69) reconstructs multiple vessel forms from Mulifanua, including shallow and deep bowls, square bowls, shouldered bowls and deep globular pots. While these vessel forms might be somewhat speculative given the fragmented condition of the assemblage (Petchey 1995:57),

they indicate the greater range of vessel forms at Mulifanua compared to later plainware deposits from across the archipelago which include almost entirely undecorated simple bowl forms (e.g., Addison et al. 2008, Holmer 1980, Hunt and Erkelens 1993). Pottery production appears to cease in Sāmoa sometime between 1500 and 1000 BP (Addison and Asaua 2006, Addison et al. 2008).

All ceramics in Sāmoa, Lapita and plainware, appear to be made in the archipelago, except for a single sherd from Mulifanua that likely derives from Fiji (Petchey 1995). This exclusively local pottery production and distribution has been confirmed through extensive petrographic (Dickinson 2006:Appendix 1) analyses and a single clay paste geochemistry analysis (Eckert and James 2011). Eckert and James (2011) used LA-ICP-MS to exclude aplastics in their chemical characterization of ceramics and examined 170 archaeological sherds from ‘Upolu, Tutuila, and Ofu islands. One hundred and thirty-seven of these sherds were from early contexts (pre 2100 BP), including Mulifanua, and the remaining 33 were undated, but likely used during the first millennium AD. Only a single sherd, in a pre-2100 BP context, from this analysis was interpreted as non-local, but of Sāmoan origin, having been made on Tutuila and moved to Ofu.

More so than ceramic production and distribution, there has been much discussion of variation in the thickness of ceramics over time in Sāmoa and the larger region (Burley and Clark 2003:238). After Green’s (1974) identification of the earlier thin-ware and later thick-ware ceramics on ‘Upolu, archaeologists have consistently attempted to verify the chronological association of thickness-defined wares. In West Polynesia, outside Sāmoa, sherd thickness distributions do not seem to have distinct thin and thick modes (Dye 1988, Kirch 1988). Within Sāmoa, relatively thin- and thick-wares continue to be identified. However it is now recognized that sherd-thickness is not a proxy for sherd-age, but instead the median thickness of populations (i.e., assemblages) of sherds typically increases over

time (Hunt and Erkelens 1993, Smith 1976). Clark (1996:450) notes that vessels of different thicknesses may have been used for different purposes such as cooking and storage, but no studies have examined the use of plainwares beyond the suggestion that carbon residues indicate cooking (Hunt and Erkelens 1993).

The Tula archaeological deposit

Against this background of Sāmoan ceramic archaeology we conducted an exploratory analysis of the Tula ceramic assemblage. The assemblage was excavated at Tula Village along the eastern coast of Tutuila (see Figure 1). The area surrounding Tula village has received extensive archaeological investigation (Clark 1980, Clark 1989, Clark and Herdrich 1988, Frost 1978, Gould et al. 1985, Moore and Kennedy 1996). The majority of this work has been survey of upland ridges and the documentation of numerous prehistoric and historic structures and complexes, particularly *tia seu lupe* (star mounds) and terraces. Inland from modern Tula village is the site of the former village, Tulauta, which was recorded to varying degrees by multiple researchers. The Lau‘agae Ridge basalt quarry is a few hundred meters north of the Tula coastal flat.

With the exception of Lefutu village, an upland fortified settlement, and prior to the research presented here, no absolute dates had been obtained for Tula and adjacent areas. However, two lines of evidence raise the possibility of early deposits along the east coast of Tutuila. First, excavations at Utumea and Aganoa along the eastern end of the south coast produced plainware ceramics and early, if ambiguous, radiocarbon dates (Moore and Kennedy 1999, see Rieth and Hunt 2008). Second, Rieth et al.’s (2008) GIS-based predictive model of Tutuila’s paleocoastline highlighted the larger Alao village coastal flat bordering Tula to the south as a probable early settlement location.

A single 1 meter (m) by 2 m excavation unit was located approximately 90 m from the present high-tide line in Tula village. Due to time constraints, the unit was changed to 1 m by 1 m at 260 centimeters below the modern ground surface (cmbs), and at 296 cmbs a shovel test pit was excavated to 307 cmbs. After the mechanical removal of the upper 30 cm of modern deposit, all sediment was wet-screened using 1/8-inch mesh. Eight strata were recorded that document periods of dynamic deposition and stability (Figure 2, Table 1). A shallow scoop hearth was bisected at the base of the lowest primary cultural layer. Pottery, basalt debitage and formal tools, shell ornaments, sea urchin spine abraders, a shell fishhook fragment, and a single volcanic glass flake were collected along with nearly 15 kg of invertebrate remains and over 8,000 vertebrate faunal specimens. A full description of the Tula excavation and laboratory results is presented in Rieth and Cochrane (2012).

Five AMS radiocarbon dates from coconut wood and coconut shell charcoal were obtained for Layers V-VII (

Table 2). The dates were calibrated using a Bayesian model created with the BCal software (<http://bcal.sheffield.ac.uk>, Buck et al. 1999) and the IntCal09 Northern Hemisphere curve (Reimer et al. 2009). The Northern Hemisphere curve was used because the boundary between the northern and southern hemisphere atmospheres lies along the thermal equator or the Inter-tropical Convergence Zone (ITCZ) (McCormac et al. 2004:1088), with Sāmoa lying within the limits of the ITCZ. In practice, however, use of the Northern or Southern Hemisphere curves for the calibration of Sāmoan radiocarbon dates produces negligible differences. We conducted a Bayesian analysis to quantify the uncertainty of continuous radiocarbon age distributions associated with superposed ceramic bearing deposits.

The model includes three groups (Layers V-VII) with the known stratigraphic relations of the Tula radiocarbon dates ($\theta_{1,5}$) to the layer boundaries as follows (α indicates initiation of deposition, β means cessation of deposition, $>$ means “is older than”):

$$\Phi_1 > \alpha_{\text{Tula-VII}} > \theta_{4,5} > \beta_{\text{Tula-VII}} = \alpha_{\text{Tula-VI}} > \theta_3 > \beta_{\text{Tula-VI}} = \alpha_{\text{Tula-V}} > \theta_{1,2} > \beta_{\text{Tula-V}} > \Phi_2$$

The following group parameters and relations were used for the model:

- Initial Lapita settlement of Samoa is assumed to post-date colonization of Tonga, which is modeled here as a uniform distribution, $\phi_1 = 2846-2830$ cal. BP (Burley et al. 2012). This assumption is based on geography and the regional ceramic sequence.
- The age for the initial evidence for human activities at Tula, $\alpha_{\text{Tula-VII}}$, is dated by two burning events, $\theta_{4, 5}$. The burning events, including one hearth, are stratigraphically unordered.
- The calendar ages of a single burning event, θ_3 , fall within the period of time represented by Tula Layer VI.
- The calendar ages of two burning events, $\theta_{1,2}$, fall within the period of time represented by Tula Layer V, the youngest intact ceramic-bearing deposit. The burning events are stratigraphically unordered.
- The end of deposition of the ceramic-bearing deposits at Tula was before the cessation of pottery production in Samoa, which is modeled here as a uniform distribution, $\phi_2 = 1500-1200$ cal BP (Rieth and Addison 2008).

The 95% highest posterior density (HPD) region, which is equivalent to a two standard deviation estimate, for the onset of deposition at Tula ($\alpha_{\text{Tula-VII}}$) is 2550-2195 cal. BP with the end of deposition of the ceramic-bearing deposits ($\beta_{\text{Tula-V}}$) 2260-1876 cal. BP (Figure 3, Table 3). The elapsed time between the initial deposition of Layer VII and end of deposition of Layer V is 20-580 years (95% HPD; 67% HPD is 60-260 years). The HPD regions for the onset and cessation of deposition for the individual ceramic-bearing layers are: 2550-2195 cal. BP and 2319-2188 cal. BP for Layer VII (elapsed time 1-360 years, 95% HPD), 2319-2188 cal. BP and 2275-2157 cal. BP for Layer VI (elapsed time 1-100 years, 95% HPD), and 2275-2157 cal. BP and 2260-1876 cal. BP for Layer V (elapsed time 1-373

years, 95% HPD). While the Bayesian analysis produces overlapping date ranges for each layer and a total range for all ceramic bearing deposits of perhaps 700 years, it seems most likely that layers VII-V were deposited over a few hundred years.

Tula Village ceramic analysis

A suite of macroscopic, microscopic, and petrographic attributes were examined for samples of the Tula sherds. Macro- and microscopic attributes were chosen to provide a general description of ceramic technology and to integrate this analysis with previous research. Attributes include sherd type (body, rim, or neck [orthogonal curvatures]), sherd size (< or > 1 cm in longest dimension), weight, thickness (median of three measurements across range), firing core (Figure 4), temper (dominant calcareous, dominant terrigenous, or mixed), temper abundance (1, 5, 10, and 20% templates), temper size (< 0.25 mm to < 4 mm size templates), surface modification (none observed), carbon residue (presence-absence on interior-exterior), and for rim sherds, rim orientation (inverted, direct, everted), rim symmetry (Figure 5), and lip shape (flat, angled, rounded). Thirty-nine sherds from the assemblage were subjected to thin-section petrographic analysis by Dickinson (2011) following standard protocols (Dickinson 2006).

Table 4² displays the distribution of sherd types across stratigraphic layers with extrapolated sherd density for each layer shown in the far-right column. Sherd density estimates are greatest for Layers V and VII, the two deposits whose sedimentological characteristics and artifact inventories suggest in situ deposition and the most intense human activity recorded in site layers. Fifteen sherds were found in the otherwise culturally sterile Layer VIII. These were likely originally deposited in Layer VII, but fell to the bottom of the

² This table was previously published in Rieth and Cochrane (2012:Table 56) with some errors. They are corrected here.

test unit when removing the large coral cobbles and small boulders near the base of Layer VII. For the following analyses, Layer VIII sherds are placed within Layer VII.

The percentage of very small sherds (second column from right in Table 4) is quite high, though roughly comparable in each layer. This suggests similar depositional or post-depositional processes led to the abundance of small sherds across layers, possibly trampling. Extensive movement of sherds after they entered the archaeological record is unlikely as only three water-worn sherds in Layer VII, and one eroded sherd in Layer V, were recovered.

Sherd thickness: thin and thick wares

Since the beginning of modern archaeology in Sāmoa the thickness of body sherds has been used to identify different ceramic types (e.g., Green 1974, Holmer 1980), thin and thick or thin-fine and thick-coarse wares (referring to thickness and paste-type). However, the procedures for identifying thick versus thin ware, or the explanatory value of these categories, has often been ambiguous (Clark 1996). For example, Hunt and Erkelens (1993) define thin sherds as those less than 7.5 mm in cross-section, but do not provide a quantitative reason for this “cut-off” measurement, although their multi-modal histogram of sherd thicknesses (Hunt and Erkelens 1993:Figure 9.4) does contain a frequency peak at about 6 mm thickness. Hunt and Erkelens (1993:147) offer that the distribution of the sherds in the thin-ware group may simply track stochastic mechanisms, like frequency-dependent cultural transmission. Prior to this, Green (1974:250) seemed to suggest a similar explanation for thin-ware, albeit using a different terminology. He argued that thin-ware “developed by differentiation out of the Lapita ceramic complex,” but without the complex vessel forms and decoration (see also Holmer 1980:108). This post-Lapita Plainware tradition itself changed

over time with thick-ware replacing thin-ware, but the relative frequencies of thin- and thick-ware sherds in assemblages are not an accurate measure of assemblage age (Clark 1996:450).

Considering the assemblage as a whole, the Tula body sherds have a median thickness of 8.1 mm (Figure 6). While bin sizes affect histogram shape, the distribution may be considered bi-modal. Additionally a PP-plot and Kolmogorov-Smirnov (K-S) test comparing the observed distribution and a normal distribution ($F = 0.063, df = 206, p = 0.048$, reject H_0) indicate sherd thickness is not normally distributed. The distribution is skewed, as expected given a physical limit constraining overly thin vessel walls on usable pots. The thicknesses of Tula sherds place them generally between the thicknesses of sherds from assemblages Hunt and Erkelens (1993:124) describe as early (1250 – 500 BC) and middle (500 BC – 0 AD).

There is a slight directional change in thickness of sherds deposited in Layers VII (older) to V (younger). The body sherds of Layer V with a median thickness of 8.7 mm are thicker than those in Layer VII with a median thickness of 7.1 mm. K-S tests show the Layer V sherd thicknesses are normally distributed ($F = 0.068, df = 112, p = 0.2$, fail to reject H_0), while the Layer VII sherds are not, although just barely significant at an alpha level of 0.5 ($F = 0.109, df = 68, p = 0.045$, reject H_0). Regardless, the difference in thicknesses is significant using both parametric ($t=5.312$ [equal variances not assumed], $df=164.6, p < 0.00$) and non-parametric tests (Mann-Whitney $U = 2129, z = -4.955, p < 0.00$). While the median difference of 1.6 mm seems unremarkable, the trend towards thicker sherds does mirror the thin- to thick-ware transition mentioned above.

To further examine the distribution of putative thin- and thick-ware sherd groups, K-Means cluster analysis of 205 body sherds described by thickness and temper size was undertaken with two clusters given as the solution (thickness and temper measurements were not possible on all body sherds). For the cluster analysis, temper size was coded as an ordinal variable to describe sherds by the maximum size of their tempers with values 1-5 so that $1 = \leq$

0.25 mm, 2= ≤ 0.5 mm, 3= ≤ 1 mm, 4, ≤ 2 mm, and 5= ≤ 4 mm. Body sherd thickness and temper size were normalized (z-scores) prior to clustering by Euclidean distance. Initial cluster centers were determined by the default settings in IBM SPSS Statistics (version 21) that generate well-spaced cluster centers. Cluster centers are re-calculated after every iteration and iterations cease when all cluster centers change by 2% or less.

Unsurprisingly, the two-cluster solution produces a thick-coarse ware group (n=97, median thickness 9.3 mm, median temper size of ≤ 2 mm) and a thin-fine ware group (n=108, median thickness 6.8 mm, median temper size of ≤ 1 mm). The thin-fine ware is evenly distributed between Layers VII and V (within 95% confidence intervals), but the thick-coarse ware increases over this same stratigraphic and temporal interval (Figure 7).

Given the algorithm implemented in SPSS, there may be concern that the order of sherds (i.e., cases) in the data file affects the calculation of cluster centers and therefore cluster membership for each sherd. To examine this possibility, the two-cluster K-Means analysis was also run following a randomization procedure as follows: 1) a 10% random sample of sherds was analysed by K-Means using the iterative cluster-center calculation procedure in SPSS; 2) these cluster-center definitions were then used to classify all the sherds without iteratively changing the cluster-center definitions; 3) steps 1 and 2 were done ten times, so that each sherd was classified into one of two clusters ten separate times; 4) the modal cluster to which each sherd was assigned was calculated.

After this procedure, nine of the 205 sherds were classified into a modal cluster different from their original cluster. The distribution of modal clusters across layers is almost identical to Figure 7 and modal cluster sherd characteristics are very similar as well with a thick-coarse cluster (median 9.4 mm thickness, median temper size of ≤ 2 mm [37% of sherds ≤ 4 mm, 62% ≤ 2 mm]) and a thin-fine cluster (median 6.9 mm, median temper size of ≤ 2 mm [40% of sherds ≤ 1 mm, 49% ≤ 2 mm]). To be clear about these cluster analyses, we

are interested in examining potentially relevant patterning associated with statistically generated groups and other aspects of archaeological variation such as depositional layers or ceramic use-wear. We are not proposing new definitions for thick and thin wares, but are simply giving descriptive labels to the groups. New data generated from additional sherds or different clustering procedures (or both), would necessarily alter both the summary statistics of the groups and the distributions of these groups. For example, K-means cluster analysis using three and four group solutions produced groups described by relatively thick and thin sherds, respectively, but also groups with thicknesses closer to the middle of the range. Temper sizes describing clusters in the three and four group solutions did not always neatly divided into easily recognizable fine and coarse wares.

However, the stratigraphic patterning of thick-coarse and thin-fine wares in Figure 7, and the Layer VII to Layer V change in thickness (noted above) suggest variation over time in ceramic production and use. Green (1974:129) proposed that because they comprised similar vessel forms, thin- and thick-wares were likely used for similar purposes. One way to evaluate this proposition is to examine use-related variation associated with carbon residue on thick- and thin-ware sherds. Twenty three sherds exhibit either interior or exterior carbon residue and can be assigned to ware clusters by their thicknesses and temper sizes. The distribution of carbon residues across ware types suggests a possible non-random association between thin-fine ware and interior carbon deposits, and thick-coarse ware and exterior carbon deposits (Table 5), but the small sample size precludes definitive assessment as two of the cells in the 2 x 2 table have expected counts less than 5 and the null hypothesis of random association cannot be rejected at a fairly stringent alpha of 0.05 ($\chi^2 = 3.453$, $df = 1$, $p = 0.063$; Fisher's Exact, $p = 0.103$).

Paste characteristics

Firing cores, macroscopic temper attributes, and petrographic analysis suggest the Tula ceramics were locally made in open firings. A majority of firing cores (80%) are either completely oxidized or have a reduced core (A or C from Figure 4). Firing core types are randomly distributed across thick- and thin-ware groups ($\chi^2 = 9.172$, $df = 8$, $p = 0.328$, fail to reject H_0) indicating thick and thin vessels were not subjected to different firing regimes. Observed tempers are solely terrigenous, no calcareous temper was identified. Based on macroscopic analysis of all sherds larger than 1 cm, temper is largely basaltic, and largely found in the paste in proportions of 5-10% (in 46% of sherds) and 10-20% (in 46.8% of sherds).

Petrographic analysis (Dickinson 2011) of 39 sherds distributed across all layers (Table 6) confirms the macroscopic observations. Four temper variants were identified, but all are dominated by poorly sorted and variably rounded basaltic sands. The different types of volcanic rock fragments (VRF) in each temper variant and their abrasive rounding suggests that tempers were not procured through manual breakage of lava to form crushed-rock temper, but were instead most likely collected from alluvial deposits in ravines draining the generally basaltic rock of Mt. Olomoana at the eastern tip of Tutuila. Strong size contrasts between the finest temper grains and the coarsest silt particles in the clay pastes imply manual mixing of temper sand with clay bodies collected separately. None of the tempers contain trachytic detritus derived from trachyte plugs of interior Tutuila that are found in selected sherds of 'Aoa Valley only about 2.5 km away (Dickinson 2006:37).

The temper variants largely contain two sand grain types, VRF and monocrystalline mineral grains, overwhelming dominated by plagioclase. The temper variants, labelled A through D in order of greatest to least abundant in the Tula sherds, are distinguished mostly by the different types and quantities of VRF. Temper Type A (n=28) is further divided into

four subvariants (A1, A2, A3, and A4) based on the presence or absence of different non-plagioclase mineral grains. The ratio of plagioclase to non-plagioclase minerals in Type A tempers (except for Type A2 which contains only plagioclase) is 50 (+/- 20) to 1. This relatively low frequency of non-plagioclase minerals suggests that the incorporation of different minerals defining Type A subvariants may be a fortuitous result of thin-sectioning and lacks statistical significance. Type B (n=5) tempers are composed exclusively of VRF with no mineral grains. Type C and D tempers contain VRF with only olivine phenocrysts in the VRF grains and with the ratio of plagioclase to olivine mineral grains consistently less than 5:1. In Type C (n = 3) tempers olivine phenocrysts are intergranular and in Type D (n = 3) tempers they are subophitic. Temper variants A-D were likely collected from different locations, but, as noted above, all most likely from alluvial deposits of Olomoana volcanics.

Vessel forms

Vessel forms in the Tula assemblage include only bowls, represented by rim sherds with largely parallel sides, flat or rounded lips, and inverted orientations (Figure 8). A single rim sherd exhibits an everted orientation and another (both in Layer V) exhibits a slight inflection point in its curvature, an exceedingly rare characteristic in Sāmoan Plainware assemblages. No rim sherds were large enough to accurately estimate vessel diameter.

Discussion

The relative isolation of Sāmoa's colonizers

Considering that the known archaeological record for Tutuila adequately represents the distribution of cultural deposits, and using standard calibrations of radiocarbon dates, two of the authors previously suggested that there was “a severely diminished or absent prehistoric population in Sāmoa after occupation of Mulifanua, until about 550-250 BC” (Rieth and Cochrane 2012:338). Our new Bayesian and age-depth analyses of Mulifanua and the earliest Plainware sites (Rieth et al. no date) supports the conjecture of a severely diminished population, as only Mulifanua on ‘Upolu and To‘aga on Ofu, at the western and eastern ends of the archipelago respectively, have the earliest potentially reliable dates that are contemporaneous within the precision of Bayesian radiocarbon analysis, at approximately 2800 – 2500 cal. BP. The next uncontroversial early deposit is Tula with cultural deposition beginning no earlier than 2550 cal. BP. Soon thereafter, cultural deposition may have commenced at Vainu‘u, an upland site on Tutuila, with the earliest evidence of human activity occurring sometime after 2360 cal. BP³, and at Jane’s Camp on ‘Upolu after 2300 cal. BP (Rieth and Hunt 2008:1917). As noted above, depositional and sample selection issues at ‘Aoa (Clark and Michlovic 1996) raise questions about the integrity of the earliest dates there.

In addition to the likelihood of being an anomalously small colonizing population, relative to Tonga (Burley and Connaughton 2007) and Fiji (Anderson and Clark 1999), the first human populations in Sāmoa appear to be relatively isolated groups. Similarities in

³ The recent detailed reporting (Eckert and Welch 2013; see also Eckert and Welch 2009) of Vainu‘u dates casts some doubt on the oldest age determinations there. The oldest date range (at 2 σ) from Vainu‘u is 2710-2350 cal. BP (Beta 240791, CRA 2440 \pm 40) on soot from a sherd in the deepest cultural deposit, Layer III, but not in a feature context. Soot from another sherd in Layer III, but from an earth-oven, Feature 4, dates to exactly the same range (Beta 240800). However, three additional date ranges on unidentified charcoal from the Feature 4 earth-oven are 2472-2181 (incorrectly reported as 2360-2330, Beta 240793), 2340-2150 (Beta 240799), and 2462-2178 (incorrectly reported as 2360-2310, Beta 240797) cal. BP. Additionally, a date range from a third sooted sherd from another Layer III earth-oven, Feature 5, is 1420-1300 cal. BP. The fact that the Feature 4 charcoal date ranges are several hundred years younger than the ceramic soot date ranges from the same feature and layer suggests that the soot date ranges do not accurately date the cultural context of the ceramics. The third soot date from Layer III, but from a sherd in Feature 5, is anomalously young by a millennium and therefore corroborates the questionable reliability of the soot dates. Eckert and Welch seem to also discount the soot dates as their Table 6 shows the earliest component at Vainu‘u dated to 2440-2270 BP, apparently using the ¹³C adjusted ages to derive this range (Eckert and Welch 2013: Tables 5 and 6).

ceramic attributes such as temper and paste geochemistry that are plausibly explained by the movement of artifacts—that is, cultural transmission—between populations are nearly absent. Other artifact similarities cited as possible evidence for cultural transmission between the earliest Sāmoan populations are also absent or equivocal. Hunt and Erkelens (1993:147) imply that the similar archipelago-wide change in the frequencies of relatively thick and thin vessels amongst the earliest populations might be a result of cultural transmission, but we offer a different explanation (see below). And while Clark and Wright (1995:261) suggest their geochemical analysis of ‘Aoa volcanic glass flakes demonstrates movement of this material across the archipelago, Sheppard et al. (1989) noted earlier that Sāmoa volcanic glass sources could not be pinpointed to specific islands. Regardless, the chronology of the ‘Aoa volcanic glass samples, like the ceramics, must be treated with caution and therefore ‘Aoa volcanic glass geochemistry may not measure *early* cultural transmission between populations.

Petrographic analysis of the Tula sherds also indicates that the population here almost certainly manufactured all their ceramics from local sands of the Olomoana volcanic series. Temper Types A and B account for approximately 85% of the sherds analysed and are most parsimoniously interpreted as collected near Tula. It is less clear if Temper Types C and D, representing the remaining 15% of sherds, derive from the Olomoana volcanic series, but their composition is not anomalous for this source.

The little evidence of cultural transmission between the earliest Sāmoan populations, in particular Mulifanua, To‘aga, and the slightly later Tula, but also between Sāmoa and Tonga (Burley et al. 2011), contrasts with the colonizing populations of other Remote Oceanic archipelagos (see also Burley 1998, Davidson 1979). Early Lapita sites in the Reef/Santa Cruz Islands, for example, contain obsidian from the Bismarcks and the Banks Islands indicating populations continued to move around after settling new islands (Sheppard

2011:804-805). Lapita surface decorations (Clark and Murray 2006, Cochrane and Lipo 2010) and clay geochemistry (Bedford and Galipaud 2010) also demonstrate some degree of cultural transmission between different archipelago populations during the colonization of Remote Oceania (see also Clark and Anderson 2009, Clark and Bedford 2008), although cultural transmission decreased after colonization. We are not suggesting that the first people to land at Mulifanua, To‘aga or other areas in Sāmoa never left them again, but that there is certainly less intra- and inter-archipelago cultural transmission involving early Sāmoan populations, particularly in reference to ceramic recipes, than is typical for early colonizing populations in Remote Oceania. The little evidence for cultural transmission involving Sāmoan early colonizing populations is also puzzling considering that the orthodox reasons given for Lapita interaction in Remote Oceania are, in a proximate sense, to maintain social networks and, in an ultimate sense, to foster demographic viability (Green and Kirch 1998, Kirch 1991). The successful early colonizing populations in Sāmoa, with little archaeological evidence for inter-group cultural transmission, suggest neither of these are sufficient explanations on their own.

Selection and Samoan plainware variation

The Tula ceramic analyses address another issue of cultural variation in Sāmoa that has both local and regional significance: the timing and explanation of the change in median thicknesses of ceramic assemblages. Based on radiocarbon analyses associated with the To‘aga ceramic assemblage, Kirch (1993:91) argues that the decline of thin-wares and the increased production of thick-wares occurs at approximately 2400 cal. BP. At Tula this change is recorded across the Layer VII and Layer V assemblages with Layer VI, between them, most likely deposited within 100 years or less between 2540-2190 to 2320-2190 cal.

BP (see Table 3). This date range for the rising dominance of thicker vessels at Tula is roughly equivalent to that for To‘aga. A similar date range for the rising dominance of thicker vessels is also suggested by Green and Davidson’s work on ‘Upolu. They document a relative increase in thick-ware sherds in Layer F-1b of site SU-Va-4 (Green and Davidson 1974:216-217). Using the accepted date from Rieth and Hunt (2008:Table 7) for the Hearth Horizon at site SU-Va-4 that caps Layer F-1b, the increased relative production of thicker vessels probably occurred before 2350-1920 cal BP.

A similar change in the relative frequencies of thin- and thick-wares seems to occur near the same time across the archipelago, from Ofu to ‘Upolu. Hunt and Erkelens (1993:147) propose that this coordinated change in ceramic thickness is explained by the transmission of selectively neutral thickness variants between local populations and an associated process of drift (see Dunnell 1978; Neiman 1995). While there is nothing wrong with such a hypothesis in general, we find it an unlikely explanation in this case as it *requires* transmission between local populations. As summarized above, there is almost no evidence for non-local pottery in Sāmoan deposits. And while cultural transmission of pottery-making behaviors between local populations may have occurred without the movement of pots, we argue that the almost complete lack of evidence for any movement of pots suggest cultural transmission between local populations concerning pottery-making was effectively absent.

If not cultural transmission between local populations, what process explains the common change in median ceramic thickness at a similar time across Sāmoa? We argue that selection for thicker vessels within local populations resulted in analogous ceramic similarities across these populations. To be clear, we propose that the higher frequency of thicker vessel variants, their replicative success (Leonard and Jones 1987), relative to thinner vessel variants is explained by an advantage conferred by thicker pottery in terms of manufacturing costs or performance in particular use-contexts (see e.g., Feathers 2006). To

consider ceramic performance, we might begin by identifying the ceramic uses of penecontemporaneous local populations in Sāmoa. Like others (e.g., Kirch 1997), we suspect the varying uses of ceramics changed in tandem with the varying proportions of decorated Lapita ceramics, thin-wares, and thick-wares in assemblages, probably changing from some non-cooking uses such as display to predominant use in cooking and storage. Indeed our analysis of the distribution of carbon residues suggests that at Tula thicker vessels were used differently than thinner vessels, although small sample size may influence this result. To generate data on the variable performance of thick and thin pots in cooking contexts we can make ceramic test vessels and tiles from local raw materials and subject them to cooking experiments (e.g., Pierce 2005) or experiments that measure thermal shock resistance (e.g., Bronitsky and Hamer 1986) or other qualities likely valuable in a cooking pot (see Skibo 2013). If thicker test vessels and tiles do not perform better in these experiments than thinner vessels and tiles, our selection hypothesis will not be supported. Such an experimental program will be a focus of our future work.

If selection explains directional change in vessel thickness within a setting of changing vessel use in Sāmoa, then this implies that the same changing vessel uses were not occurring in other areas of West Polynesia where the thin- to thick-ware transition has not been documented (Dye 1988, Kirch 1988). Interestingly, it is in these areas, Niuaotupapu and Tonga, where there is evidence of cultural transmission between early inter-island populations (e.g., Reepmeyer et al. 2012). Thus an important social and demographic context of the selection hypothesis for Sāmoan ceramics may be the relative lack of cultural transmission between groups.

Conclusion

Sāmoa was likely colonized by a small population comprised of relatively isolated groups. Decorated Lapita ceramics were almost immediately abandoned upon arrival in the archipelago and there was a relatively swift directional change in the median thickness of plain vessels over the subsequent centuries. The Tula ceramic assemblages exemplifies this change, as well as the local focus of ceramic manufacturing and cultural transmission.

The successful, albeit demographically modest, colonization of Sāmoa by groups that apparently did not often engage in inter- or intra-archipelago networks supports the idea that the Lapita colonization of Remote Oceania was variable in terms of the processes of colonization (cf. Burley 2012, Irwin 2008) and transmission (Cochrane in press) that explain variation in the earliest cultural deposits of the region.

Identification of the relative isolation of the earliest Sāmoan populations, coupled with similar chronological variation in median thickness of the ceramic assemblages suggests a selection process explains this coordinated change. Although we have not addressed the similar, and pan-West Polynesian, coordinated change in vessel form diversity across assemblages this too is likely explained by selection, but at a larger scale. Future research should confront these proposals with empirically testable hypotheses.

Acknowledgements

Several colleagues commented on a draft of this article and we thank them for their time and effort: David Addison, David Burley, Thomas Dye, Patrick Kirch, Seth Quintus, Peter Sheppard, and John Terrell. The fieldwork and analyses were conducted as part of cultural resource management services performed by International Archaeological Research Institute, Inc. under contract to the United States Federal Emergency Management Agency and in response to the September 29, 2009 tsunami that affected Sāmoa.

Figures Captions

Figure 1. Map of the Sāmoan archipelago and places mentioned in the text.

Figure 2. Stratigraphic profile of the west wall of the 1 x 2 m Tula excavation unit.

Figure 3. Estimated ages of the Tula stratigraphic events based on a Bayesian model: top left, early boundary of Layer VII; top right, late boundary of Layer VII (note that this is the same as the early boundary of Layer VI); middle left, early boundary of Layer VI; middle right, late boundary of Layer VI (note that this is the same as the early boundary of Layer V); lower left, early boundary of Layer V; lower right, late boundary of Layer V.

Figure 4. Schematic firing core categories (redrafted from Teltser 1993:Figure 2). Exterior of sherd is at top. Dark sections are reduced and white sections are oxidized.

Figure 5. Rim symmetry categories: 1 parallel, 2 exterior thickened, 3 interior thickened, 4 thickened, 5 thinned, exterior thickened and thinned, 7 thickened and thinned (from Cochrane 2009).

Figure 6. Histogram of sherd thicknesses, Tula ceramic assemblage. N = 206, median 8.2 mm.

Figure 7. Distribution of thick-coarse ware (patterned bars) and thin-fine ware clusters across layers in the Tula excavation unit. Error bars are 95% confidence intervals.

Figure 8. Selected rim profiles from ceramics in the Tula excavation unit, American Sāmoa. Lines to right of rims indicate vessel interiors.

Table Captions

Table 1. Soil and Sediment descriptions for the Tula Test Unit.

Table 2. AMS data for sample materials from Tula Test Unit, American Sāmoa

Table 3. HPD estimates for Tula stratigraphic events.

Table 4. Sherd distributions in Tula Excavation Unit, American Sāmoa.

Table 5. Observed and expected counts for carbon residue across Thin-fine and Thick-coarse ware ceramic groups from the Tula Excavation Unit, American Sāmoa.

Table 6. Number of sherds of each Temper Type recovered from Test Unit 2, Tula, American Sāmoa. Number in parentheses is percentage of that temper type identified in layer.

References

Addison, D. J. and T. S. Asaua (2006). "One Hundred New Dates from Tutuila and Manu'a: Additional Data Addressing Chronological Issues in Sāmoan Prehistory." The Journal of Sāmoan Studies 2: 95-117.

Addison, D. J. and E. Matisoo-Smith (2010). "Rethinking Polynesians origins: a West-Polynesia Triple-I Model." Archaeology in Oceania 45(1): 1-12.

Addison, D. J., T. Tago, J. Toloa and E. Pearthree (2006). "Ceramic Deposit Below Fifth to Sixth Century AD Volcanic Ash Fall at Pava'ia'i, Tutuila Island, American Samoa: Preliminary Results from Site AS-31-171." New Zealand Journal of Archaeology 27: 5-18.

Addison, D. J., J. Toloa, T. Tago and S. Vaueli (2008). Samoan Plain Ware Ceramics of Tutuila Island, American Sāmoa: Some thoughts on their Spatial and Chronological Distribution. Recent Advances in the Archaeology of the Fiji/West-Polynesia Region. D. J. Addison and C. Sand. Dunedin, University of Otago. 21: 97-115.

Anderson, A. and G. Clark (1999). "The age of Lapita settlement in Fiji." Archaeology in Oceania 34(1): 31-39.

Athens, J. S. D., M (2003). Archaeological Monitoring and Sampling for Pago Pago and Aua Villages, Tutuila Island, American Samoa. Honolulu, Report prepared for U.S. Army Corps of Engineers.

Barnes, S. S. and T. L. Hunt (2005). "Samoa's Pre-Contact Connections in West Polynesia and Beyond." Journal of the Polynesian Society 114(3): 227-266.

Bedford, S. and J.-C. Galipaud (2010). Chaînes d'îles: les occupation Lapita du nord-Vanuatu/ Chain of Islands: Lapita occupation of Northern Vanuatu. Lapita: Ancêtres océaniens/Oceanic Ancestors. C. Sand and S. Bedford. Paris, Musée du quai Branly/Somogy: 122-137.

Best, S. (1993). "At the Halls of the Mountain Kings. Fijian and Samoan Fortifications: Comparison and Analysis." Journal of the Polynesian Society 102(4): 385-447.

Best, S., P. Sheppard, R. Green, and R. Parker (1992). "Necromancing the Stone: Archaeologists and Adzes in Samoa." Journal of the Polynesian Society 101(1): 45-85.

Boyd, R. and P. J. Richerson (1985). Culture and the Evolutionary Process. Chicago, University of Chicago Press.

Bronitsky, G., Hamer, R. (1986). Experiments in ceramic technology: The effects of various tempering materials on impact and thermal-shock resistance. American Antiquity, 89-101.

Burley, D. V. (2012). "Exploration as a Strategic Process in the Lapita Settlement of Fiji: the Implications of Vorovoro Island." Journal of Pacific Archaeology 3(1): 22-34.

Burley, D. V. (1998). "Tongan Archaeology and the Tongan Past, 2850-150 B.P." Journal of World Prehistory 12(3): 337-392.

Burley, D., M. I. Weisler and J-X Zhao (2012). "High Precision U/Th Dating of First Polynesian Settlement." PLoS ONE 7(11): e48769.

Burley, D. V., P. J. Sheppard and M. Simonin (2011). "Tongan and Samoan volcanic glass: pXRF analysis and implications for constructs of ancestral Polynesian society." Journal of Archaeological Science 38(10): 2625-2632.

Burley, D. V. and S. P. Connaughton (2007). "First Lapita Settlement and Its Chronology in Vava'u, Kingdom of Tonga." Radiocarbon 49: 131-137.

Burley, D. V. and J. T. Clark (2003). The Archaeology of Fiji/West Polynesia in the post-Lapita Era. Pacific Archaeology: assessments and prospects. C. Sand. Nouméa, Service des Musées et du Patrimoine de Nouvelle-Calédonie. 15: 235-254.

Burley, D. V., A. Storey and J. Witt (2002). On the Definition and Implication of Eastern Lapita Ceramics in Tonga. Fifty Years in the Field. Essays in Honour and Celebration of

Richard Shutler Jr's Archaeological Career. S. Bedford, C. Sand and D. V. Burley. Auckland, New Zealand Archaeological Association. 25: 213-226.

Clark, G. and A. Anderson (2009). Colonisation and culture change in the early prehistory of Fiji. The Early Prehistory of Fiji. G. Clark and A. Anderson. Canberra, The Australian National University. 31: 407-437.

Clark, G. and S. Bedford (2008). Friction zones in Lapita colonisation. Islands of Inquiry: Colonisation, seafaring, and the archaeology of maritime landscapes. G. Clark, F. Leach and S. O'Connor. Canberra, The Australian National University. 29: 59-73.

Clark, G. R. and T. Murray (2006). "Decay characteristics of the eastern Lapita design system." Archaeology in Oceania 41(3): 107-117.

Clark, J. T. (1980). Historic Preservation in American Samoa: Program Evaluation and Archaeological Site Inventory., On file at the American Samoa Historic Preservation Office.

Clark, J. T. (1989). The Eastern Tutuila Archaeological Project, 1988, Final Report. On file at the American Samoa Historic Preservation Office.

Clark, J. T. (1993). "Radiocarbon Dates from American Samoa." Radiocarbon 35(2): 323-330.

Clark, J. T. (1996). Samoan Prehistory in Review. Oceanic Culture History: Essays in Honour of Roger Green. J. Davidson, G. Irwin, F. Leach, A. K. Pawley and D. Brown. Dunedin, New Zealand Archaeological Association: 445-460.

Clark, J. T. and D. J. Herdrich (1988). The Eastern Tutuila Archaeological Project, 1986, Final Report. On file at the American Sāmoa Historic Preservation Office.

Clark, J. T. and M. G. Michlovic (1996). "An early settlement in the Polynesian homeland: Excavations at Aoa valley, Tutuila island." Journal of Field Archaeology 23: 151-167.

Clark, J. T. and E. Wright (1995). Volcanic Glass in Sāmoa: a Technological and Geochemical Study. The Journal of the Polynesian Society 104(3): 239-266.

Cochrane, E. E. (in press). Quantitative Phylogenetic Analysis of Lapita Decoration in Near and Remote Oceania. Lapita Directions. G. R. Summerhayes and H. Buckley. University of Otago Studies in Prehistoric Anthropology, Vol. 25. University of Otago Press, Dunedin.

Cochrane, E.E. (2001). Style, Function, and Systematic Empiricism: The Conflation of Process and Pattern, in: Hurt, T.D., Rakita, G.F.M. (Eds.), Style and Function: Conceptual Issues in Evolutionary Archaeology. Bergin and Garvey, Westport, Conn., pp. 183-202.

Cochrane, E. E. and C. P. Lipo (2010). "Phylogenetic analyses of Lapita decoration do not support branching evolution or regional population structure during colonization of Remote Oceania." Philosophical Transactions of the Royal Society B: Biological Sciences 365(1559): 3889-3902.

Cochrane, E. E., I. C. Rivera-Collazo and E. Walsh (2011). "New Evidence for Variation in Colonization, Cultural Transmission, and Subsistence from Lapita (2900 BP) to the Historic Period in Southwestern Fiji." Journal of Pacific Archaeology 2(1): 40-55.

Davidson, J. (1979). Samoa and Tonga. The Prehistory of Polynesia. J. D. Jennings. Cambridge, Massachusetts, Harvard University Press: 82-109.

Dickinson, W. R. (2006). Temper Sands in Prehistoric Oceanian Pottery: Geotectonics, Sedimentology, Petrography, and Provenance. Boulder, Colorado, Geological Society of America.

Dickinson, W. R. (2011). Petrography of Temper Sands in Prehistoric Potsherds from Tula, Tutuila, American Samoa (Petrographic Report WRD-298).

Dickinson, W. R. and R. C. Green (1998). "Geoarchaeological Context of Holocene Subsidence at the Ferry, Berth Lapita Site, Mulifanua, Upolu, Samoa." Geoarchaeology 13(3): 239-263.

Dunnell, R.C. (1978). Style and Function: A Fundamental Dichotomy. American Antiquity 43, 192-202.

Dye, T. S. (1988). Social and Cultural Change in the Prehistory of the Ancestral Polynesian Homeland Unpublished PhD dissertation, Yale University.

Eckert, S. L. and W. D. James (2011). "Investigating the production and distribution of plain ware pottery in the Samoan archipelago with laser ablation-inductively coupled plasma-mass spectrometry (LA-ICP-MS)." Journal of Archaeological Science 38(9): 2155-2170.

Frost, J. (1978). Archaeological Investigations on Tutuila Island, American Samoa, Unpublished Ph.D. dissertation, University of Oregon.

Feathers, J. K. (2006). "Explaining Shell-Tempered Pottery in Prehistoric Eastern North America." Journal of Archaeological Method and Theory 13(2): 89-133.

Gould, R. A., K. E. Honor and K. J. Reinhardt (1985). Final Project Report for Tulauta and Fagatele Bay Prehistoric Villages and Leone Bay Petroglyphs. On file at the American Sāmoa Historic Preservation Office.

Grant-Mackie, J., C. Sand, F. Valentin, B. M. Fitzgerald and B. Richer de Forges (2013). Human cultural and related remains from Mé Auré Cave (site WMD007), Moindou, New Caledonia.

Green, R. C. (1974). Excavation of the Prehistoric Occupations of SU-Sa-3. Archaeology in Western Samoa. R. C. Green and J. M. Davidson. Auckland, The Auckland Institute and Museum. II: 108-154.

Green, R. C. (1974). Pottery from the Lagoon at Mulifanua, Upolu (Report 33). Archaeology in Western Samoa. R. C. Green and J. M. Davidson. Auckland, The Auckland Institute and Museum, Vol. II: 170-175.

Green, R. C. (1974). A Review of Portable Artifacts from Western Samoa. Archaeology in Western Samoa. R. C. Green and J. M. Davidson. Auckland, The Auckland Institute and Museum. Vol. II: 245-275.

Green, R. C. (2002). A Retrospective View of Settlement Pattern Studies in Samoa. Pacific Landscapes: Archaeological Approaches. T. N. Ladefoged and M. W. Graves. Los Osos, CA, Easter Island Foundation Press: 125-152.

Green, R. C. and J. Davidson, Eds. (1969). Archaeology in Western Samoa Bulletin of the Auckland Institute and Museum. Auckland, The Auckland Institute and Museum.

Green, R. C. and J. Davidson, Eds. (1974). Archaeology in Western Samoa Bulletin of the Auckland Institute and Museum. Auckland, The Auckland Institute and Museum.

Green, R. C. and J. Davidson (1974). A Radiocarbon and Stratigraphic Sequence for Samoa. Archaeology in Western Samoa. R. C. Green and J. Davidson. Auckland Auckland Institute and Museum. II: 212-224.

Green, R. C. and P. V. Kirch (1998). Lapita exchange systems and their Polynesian transformations: seeking explanatory models. Prehistoric Long-Distance Interaction in Oceania: an Interdisciplinary Approach. M. I. Weisler. Auckland, New Zealand Archaeological Association. 21.

- Herdrich, D. J. and J. T. Clark (1993). Samoan Tia 'Ave and Social Structure: Methodological and Theoretical Considerations. The Evolution and Organization of Prehistoric Society in Polynesia. M. W. Graves and R. C. Green. Auckland, New Zealand Archaeological Association. 19: 52-63.
- Holmer, R. N. (1980). Samoan Ceramic Analysis. Archaeological Excavations in Western Samoa. J. D. Jennings and R. N. Holmer. Honolulu, Bernice P. Bishop Museum. 32: 104-116.
- Hunt, T. L. and C. Erkelens (1993). The To'aga ceramics. The To'aga Site: Three Millennia of Polynesian Occupation in the Manu'a Islands, American Samoa. P. V. Kirch and T. L. Hunt. Berkeley, University of California. 51: 123-150.
- Irwin, G. (2008). "Pacific Seascapes, Canoe Performance, and a Review of Lapita Voyaging with Regard to Theories of Migration." Asian Perspectives 47(1): 12-28.
- Jennings, J. D., Holmer and N. R. (1980). Archaeological Excavations in Western Samoa.
- Jennings, J. D., R. N. Holmer, J. C. Janetski and H. Smith, Eds. (1976). Excavations on Upolu Western Samoa. Honolulu, Bernice P. Bishop Museum.
- Keating, B. H. (1992). The Geology of the Samoan Islands. Geology and Offshore Mineral Resources of the Central Pacific Basin. B. H. Keating and B. R. Bolton, Springer New York. 14: 127-178.

Kirch, P. (1997). The Lapita Peoples. Cambridge, Blackwell.

Kirch, P. V. (1988). Niutoputapu, the Prehistory of a Polynesian Chiefdom. Seattle, Thomas Burke Memorial Washington State Museum.

Kirch, P. V. (1991). "Specialization and Exchange in the Lapita Complex of Oceania (1600-500 B.C.)." Asian Perspectives(20): 141-165.

Kirch, P. V. (1993). Ofu Island and the To'aga Site: Dynamics of the Natural and Cultural Environment. The To'aga Site: Three Millennia of Polynesian Occupation in the Manu'a Islands, American Samoa. P. V. Kirch and T. L. Hunt. Berkeley, University of California. 51: 9-22.

Kirch, P. V. (1993). Radiocarbon Chronology of the To'aga Site. The To'aga Site: Three Millennia of Polynesian Occupation in the Manu'a Islands, American Samoa. P. V. Kirch and T. L. Hunt. Berkeley, University of California. 51: 85-92.

Kirch, P. V. and T. L. Hunt, Eds. (1993). The To'aga site : three millennia of Polynesian occupation in the Manu'a Islands, American Samoa. Berkeley, University of California Archaeological Research Facility.

Leach, H. M. and R. C. Green (1989). "New Information for the Ferry Berth Site, Mulifanua, Western Sāmoa." Journal of the Polynesian Society 98: 319-329.

Leonard, R. D. and G. T. Jones (1987). "Elements of an Inclusive Evolutionary Model for Archaeology." Journal of Anthropological Archaeology 6: 199-219.

McCormac, F. G., A. G. Hogg, P. G. Blackwell, C. E. Buck, T. F. G. Higham and P. J. Reimer (2004). "SHCAL04 Southern Hemisphere Calibration, 0-11.0 Cal kyr BP." Radiocarbon 46: 1087-1092.

McDougall, I. (1985). "Age and Evolution of the Volcanoes of Tutuila, American Samoa." Pacific Science 39(4): 311-320.

Moore, J. R. and J. Kennedy (1996). Archaeological Resources on Lau'age Ridge: A Phase II Cultural Resource Evaluation of Site AS-21-100 (The Lau'age Ridge Quarry) for Phase III of the Onenoa Road Project Located in East Vaifanua County, Tutuila Island, American Sāmoa. On file at the American Sāmoa Historic Preservation Office.

Moore, J. R. and J. Kennedy (1999). Results of An Archaeological Cultural Resource Evaluation for the East and West Tutuila Water Line Project, Tutuila Island, American Samoa. Archaeological Consultants of the Pacific, Inc. Hawleiwā, Hawaii, Prepared for the American Samoa Power Authority.

Morrison, A. E., T. M. Rieth and D. J. Addison (2010). A GIS Based Model for Locating Lapita Aged Settlements in American Sāmoa. The Gotland Papers: Selected Papers from the VII International Conference on Easter Island and the Pacific: Migration, Identity, and Cultural Heritage. P. Wallin and H. Martinsson-Walin. Visby, Sweden, Gotland University Press. 11: 377-391.

Neiman, F. (1995). Stylistic Variation in Evolutionary Perspective: Inferences from Decorative Diversity and Interassemblage Distance in Illinois Woodland Ceramic Assemblages. American Antiquity 60, 7-36.

Nunn, P. D. (1994). Oceanic Islands. Cambridge, Blackwell.

Petchey, F. J. (1995). The Archaeology of Kudon: Archaeological Analysis of Lapita Ceramics from Mulifanua, Samoa and Sigatoka, Fiji. Masters Thesis, University of Auckland.

Petchey, F. J. (2001). "Radiocarbon determinations from the Mulifanua Lapita site, Upolu, Western Samoa." Radiocarbon 43: 63-68.

Pierce, C. (2005). Reverse Engineering the Ceramic Cooking Pot: Cost and Performance Properties of Plain and Textured Vessels. Journal of Archaeological Method and Theory 12, 117.

Reepmeyer, C., G. Clark and P. Sheppard (2012). "Obsidian Source Use in Tongan Prehistory: New Results and Implications." The Journal of Island and Coastal Archaeology 7(2): 255-271.

Reimer, P. J., M. G. L. Baillie, E. Bard, A. Bayliss, W. Beck, P. G. Blackwell and C. Bronk Ramsey (2009). "IntCal09 and Marine09 Radiocarbon Age Calibration Curves, 0-50,000 Years Cal BP." Radiocarbon 51: 1111-1150.

Rieth, T. M. and D. J. Addison (2008). How Dark Are They? The Sāmoan Dark Ages, ~1500-1000 BP. Recent Advances in the Archaeology of the Fiji/West-Polynesia Region. D. J. Addison and C. Sand. Dunedin, University of Otago: 87-96.

Rieth, T. M. and E. E. Cochrane (2012). Archaeological Monitoring and Data Recovery in Support of the Federal Emergency Management Agency Permanent Housing Construction Program, Tutuila Island, American Samoa. International Archaeological Research Institute, Inc. Honolulu, Hawaii, Prepared for the Department of Homeland Security, Federal Emergency Management Agency.

Rieth, T. M. and T. L. Hunt (2008). "A radiocarbon chronology for Samoan prehistory." Journal of Archaeological Science 35(7): 1901-1927.

Rieth, T. M., A. E. Morrison and D. J. Addison (2008). "The Temporal and Spatial Patterning of the Initial Settlement of Sāmoa." Journal of Island and Coastal Archaeology 3: 214-239.

Rieth, T. M., A. E. Morrison and E. E. Cochrane (no date). Reanalysis of the Earliest Archaeological Deposits in Sāmoa using Bayesian and Age-Depth Models. Manuscript in preparation.

Sheppard, P. (2011). "Lapita Colonization across the Near/Remote Oceania Boundary." Current Anthropology 52(6): 799-840.

Sheppard, P. J., R. G. V. Hancock, L. A. Pavlish and R. Parker (1989). "Samoan Volcanic Glass." Archaeology in Oceania 24(2): 70-74.

Skibo, J.M. (2013). Understanding pottery function. Springer, New York.

Smith, A. (2002). An archaeology of West Polynesian prehistory. Sydney, Pandanus Books.

Smith, H. (1976). A Principal Components Analysis of Samoa Ceramics. Excavations on Upolu Western Samoa. J. D. Jennings, R. N. Holmer, J. C. Janetski and H. Smith. Honolulu, Bernice P. Bishop Museum. 25: 83-96.

Steadman, D. W. (2006). Extinction and Biogeography of Tropical Pacific Birds. Chicago, University of Chicago Press.

Valentin, F. and G. Clark (2013). "Early Polynesian mortuary behaviour at the Talasiu site, Kingdom of Tonga." Journal of Pacific Archaeology 4(1): 1-14.

Whistler, W. A. (1992). "Vegetation of Samoa and Tonga." Pacific Science 46(2): 159-178.

Wright, E. (1986). Petrology and Geochemistry of Shield Building and Post Erosional Lava Series of Sāmoa: Implications for Mantle Heterogeneity and Magma Genesis. PhD dissertation, University of California, San Diego.

Layer	Depth (cmbs)	Sediment Description	Interpretation
I	0-45	Light gray (7.5YR 7/1) calcareous sand; no mottling; weak, coarse, subangular blocky; loose-moist, slightly sticky, nonplastic-wet; no roots; sand is fine to very coarse, well rounded to subangular; contains 5% rock, common and well-rounded cobbles; abrupt, wavy boundary; some modern material, lithic artifacts, small amount of invertebrate and vertebrate faunal remains	Relatively recent sediment incorporating material from modern occupation along with remixed (e.g., through crab burrowing) traditional artifacts
II	45-125	Light brownish gray (10YR 6/2) to very pale brown (10YR 8/3) calcareous sand, contains many white (10YR 8/1) grains; no mottling; structureless to weak, coarse, single grain to subangular blocky; loose-moist, nonsticky, nonplastic-wet; sand is fine to very coarse, rounded to subrounded, sand grain size varies horizontally and vertically within stratum indicating intermittent periods of differing depositional agents; coral cobbles and small boulders common; abrupt, wavy boundary; Sfeas. 3-5 (hearths) recorded during monitoring; small amount of modern material, lithic artifacts, invertebrate and vertebrate faunal remains, charcoal present	Generally dynamic beach deposit with intermittent periods of stability evidenced by features and deposition of cultural material
III	125-168	Very pale brown (10YR 7/3) to pale brown (2.5Y 7/3) calcareous sand; no mottling; weak, fine to medium, single grain to subangular blocky; loose-moist, nonsticky, nonplastic-wet; sand is very fine to very coarse, well rounded to subrounded; common coral cobbles and pebbles, some basalt pebbles; abrupt, wavy boundary; small amount of lithic artifacts, vertebrate and invertebrate faunal remains, charcoal present	Dynamic beach deposit with intermittent deposition of cultural material
IV	168-234	Pale brown (2.5Y 8/3) calcareous sand; no mottling; weak, fine to coarse, single grain to subangular blocky; loose-moist, nonsticky, nonplastic-wet; sand is very fine to very coarse, well rounded to subrounded; common coral cobbles and pebbles, some basalt pebbles; abrupt, smooth boundary; Sfea. 2 (hearth) recorded during monitoring; small amount of lithic artifacts and pottery, abundant vertebrate and invertebrate faunal remains, charcoal present	Dynamic beach deposit with intermittent deposition of cultural material
V	234-250	Dark grayish brown (10YR 4/2) calcareous loamy sand; no mottling; structureless, very fine, subangular blocky; loose-moist, slightly sticky, nonplastic-wet; sand is medium to very fine, rounded to angular; abundant coral gravel; abrupt, smooth boundary; abundant pottery, some lithic artifacts, shell ornaments, and sea urchin spine abraders, abundant vertebrate and invertebrate faunal remains, charcoal present	Stable shoreline deposit allowing occupation and development of intact ceramic-bearing cultural deposit 2220±30 BP
VI	250-265	Very pale brown (10YR 7/4) calcareous sand; no mottling; weak, fine, single grain to granular; loose-moist, nonsticky, nonplastic-wet; sand is medium to very fine, rounded to angular; common coral cobbles and gravel; abrupt, wavy boundary; numerous lithic artifacts, some pottery, some	Decreased cultural material compared to Layers V and VII, but presumed continuous occupation with lesser

		vertebrate and invertebrate faunal remains	frequency of activity and/or increased natural deposition of sand 2230±30 BP
VII	265-296	Dark grayish brown (10YR 4/2) calcareous loamy sand; no mottling; weak, very fine, subangular blocky; loose-moist, slightly sticky, nonplastic-wet; sand is medium to very fine, rounded to angular; >50% coral angular to subangular pebbles to small boulders, ~1% rounded basalt cobbles; abrupt, smooth boundary; one hearth present (Sfea. 1); numerous pottery, some lithic artifacts, abundant vertebrate and invertebrate faunal remains	Stable shoreline deposit allowing occupation and development of intact ceramic-bearing cultural deposit 2220±30 BP 2230±30 BP
VIII	296-307+	Very pale brown (10YR 7/4) cobbly calcareous sand; no mottling; weak, fine, granular; friable-moist, nonsticky, nonplastic-wet; 30-40% coral pebbles to cobbles; a very few pottery sherds and lithic artifacts, small amount of invertebrate and vertebrate faunal remains at boundary with Layer VII	Cobbly beach deposit with small amount of cultural material that is presumed to have originated in Layer VII

Provenience	Lab No.	Sample Material	$^{13}\text{C}/^{12}\text{C}$ Ratio (‰)	Conventional Radiocarbon Age (BP)	Event Dated	Potential In-Built Age
Tula Test Unit, L. V	Beta-308717	<i>Cocos nucifera</i> wood	-25.1	2220 ±30	Occupation creating L. V	Yes
Tula Test Unit, L. V	Beta-308718	<i>Cocos nucifera</i> wood	-24.3	2220 ±30	Occupation creating L. V	Yes
Tula Test Unit, L. VI	Beta-308719	<i>Cocos nucifera</i> wood	-26.1	2230 ±30	Occupation creating L. VI	Yes
Tula Test Unit, L. VII	Beta-308720	<i>Cocos nucifera</i> endocarp	-26.6	2220 ±30	Occupation creating L. VII	No
Tula Test Unit, L. VII Subfeat. 1	Beta-308721	<i>Cocos nucifera</i> wood	-26.0	2230 ±30	Creation of hearth, subfeat. 1	Yes

Table(s)

Model Group	Event	HPD-95%	HPD-67%	Elapsed time - 95% (alpha- beta)	Elapsed time - 67% (alpha- beta)
Tula-V	alpha-5	2275-2157	2231-2172	1-373	1-93
	beta-5	2260-1876	2209-2110		
Tula-VI	alpha-6	2319-2188	2307-2203	1-100	1-42
	beta-6	2275-2157	2231-2172		
Tula-VII	alpha-7	2550-2195	2370-2239	1-312	1-99
	beta-7	2319-2188	2307-2203		

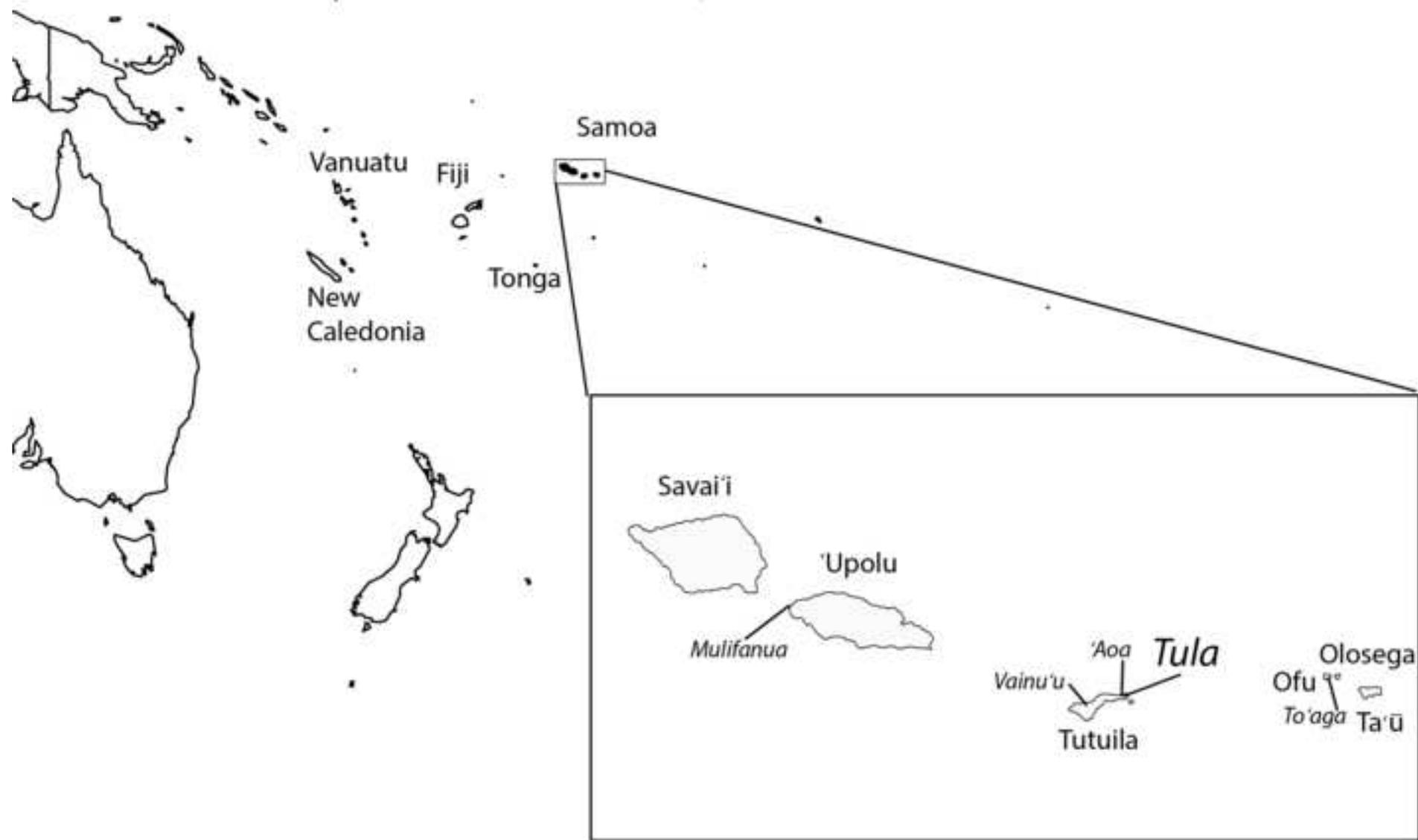
Layer	n Sherds	Sherd Type			n (%) of sherds < 1 cm	*Estimated sherds per m ³
		n Body	n Rim	n Neck		
IV	18	11	3	0	4 (22)	15
V	225	120	20	1	84 (37)	753
VI	39	21	1	0	17 (44)	190
VII	143	76	6	0	61 (41)	363
TOTALS	425	228	30	1	166 (40)	-

* Sediment matrix volumes calculated during excavation.

		Thin-Fine	Thick-Coarse
Carbon Exterior	Observed	3	5
	Expected	1.4	6.6
Carbon Interior	Observed	1	14
	Expected	2.6	12.4

Layer	Temper Type							
	Total A	A1	A2	A3	A4	B	C	D
IV	1 (25)	1					2 (50)	1 (25)
V	11 (84)	5	5		1		1 (8)	1 (8)
VI	5 (71)	1	3		1	2 (29)		
VII	11 (73)	3	1	7		3 (20)		1 (7)
Totals	28	10	9	7	2	5	3	3

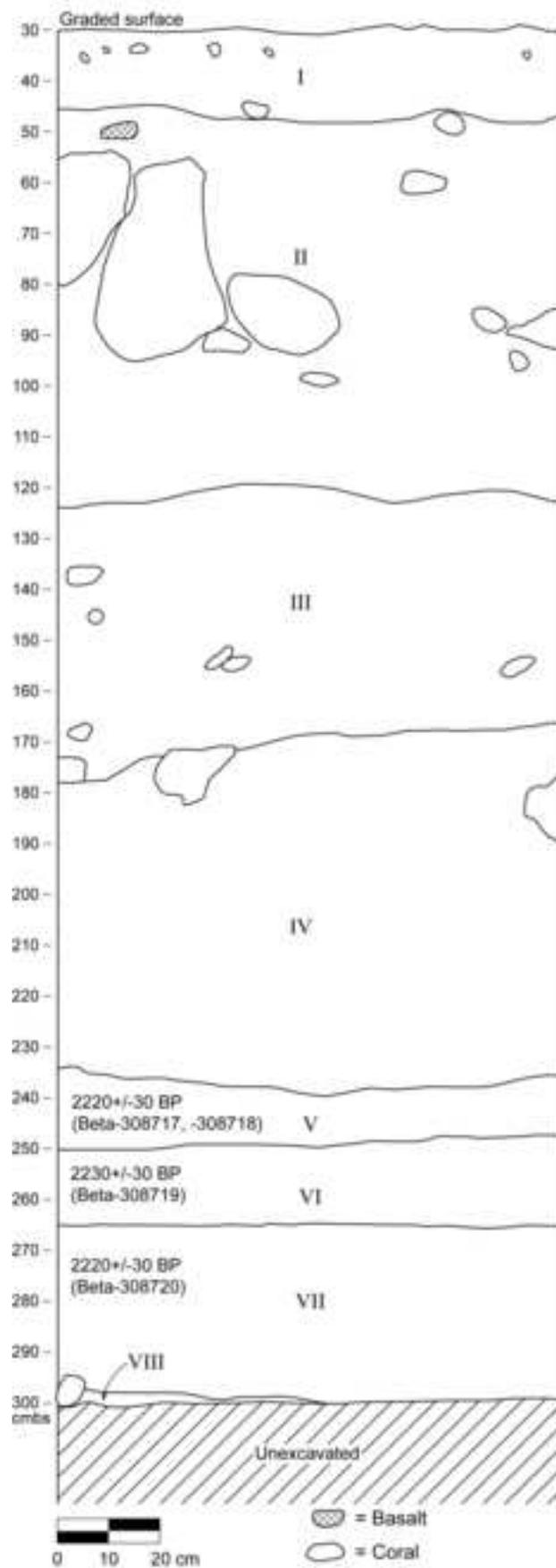
Figure(s)
[Click here to download high resolution image](#)



Figure(s)

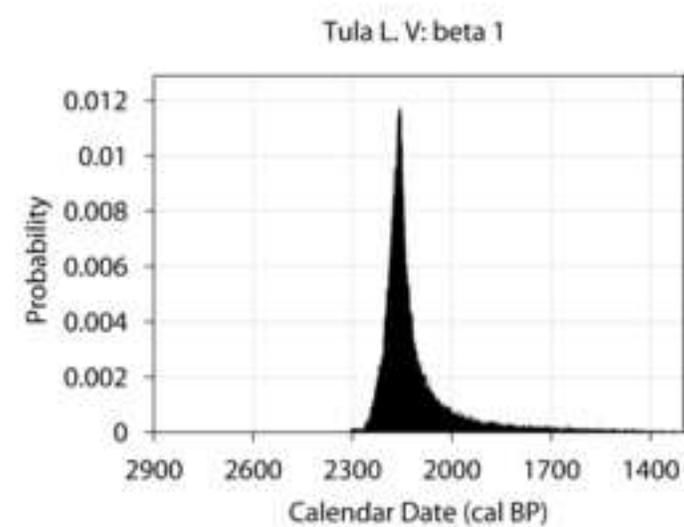
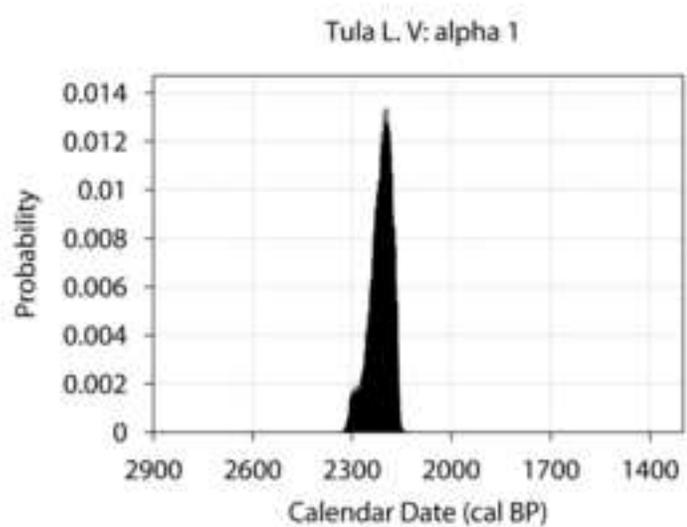
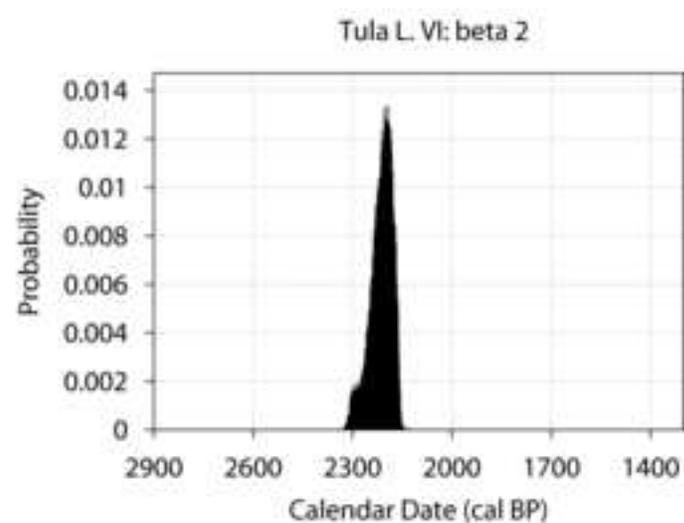
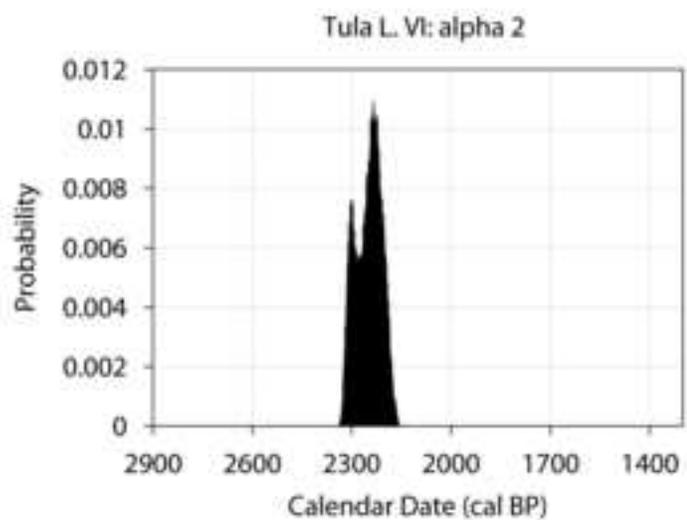
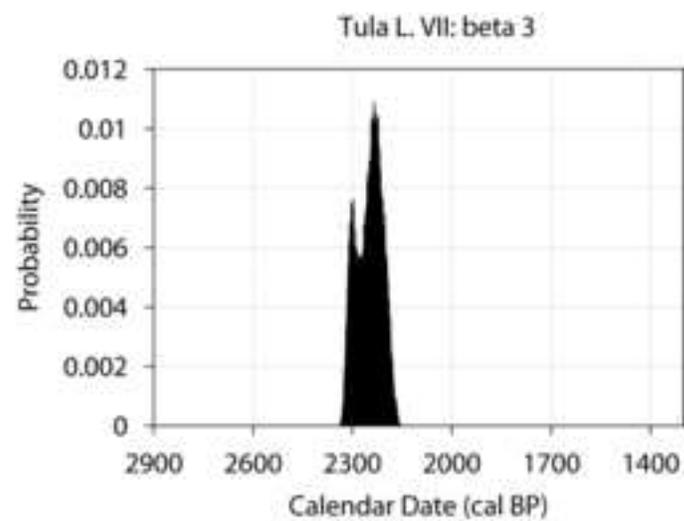
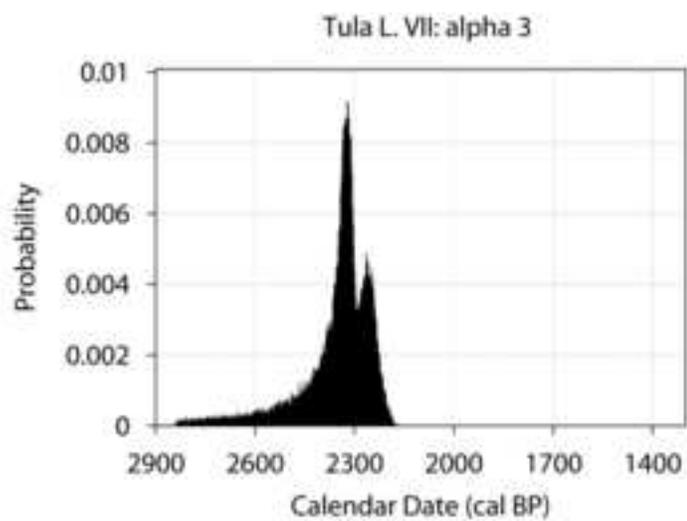
[Click here to download high resolution image](#)

0- Original ground surface



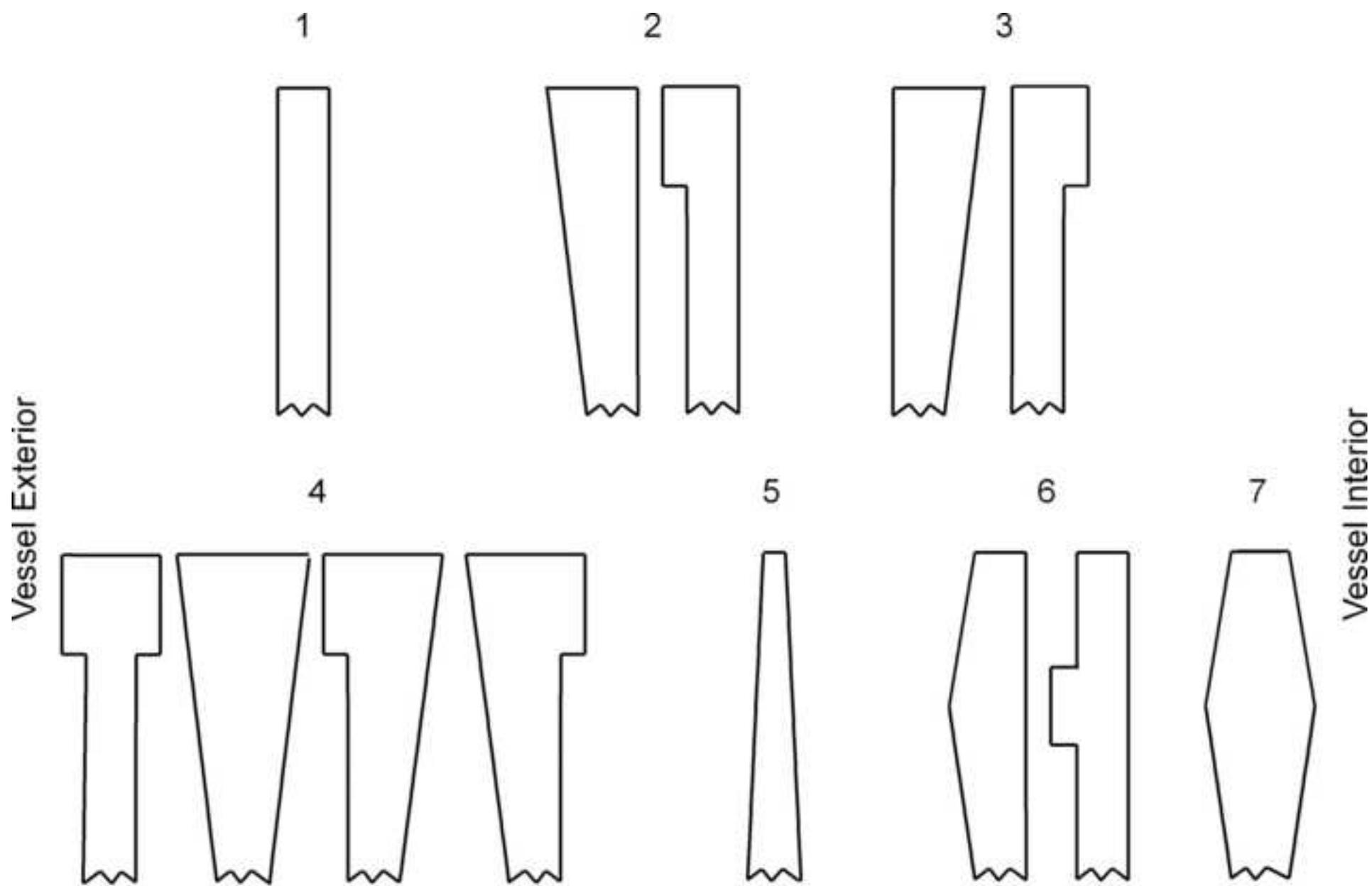
Figure(s)

[Click here to download high resolution image](#)



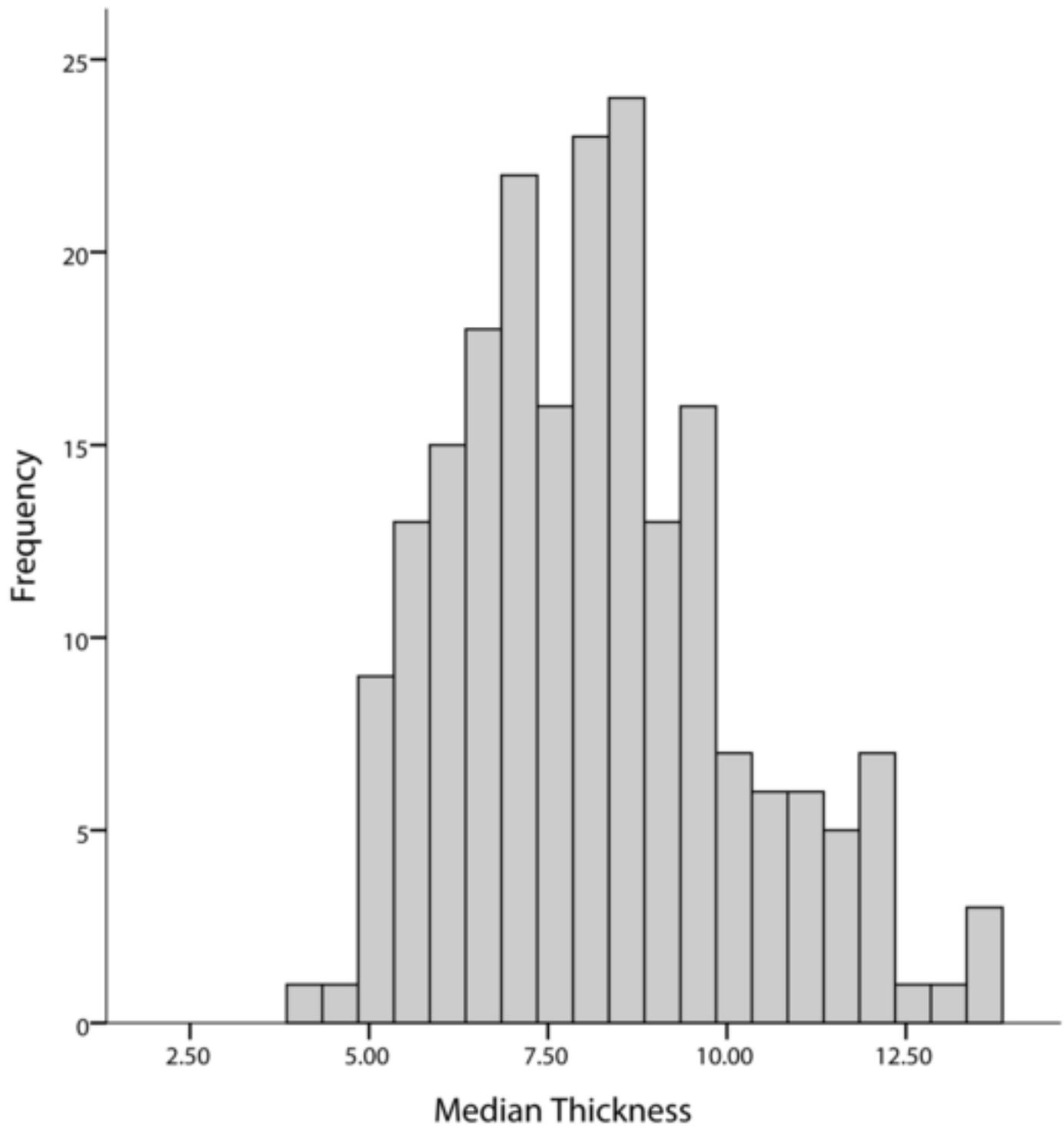
Figure(s)
[Click here to download high resolution image](#)



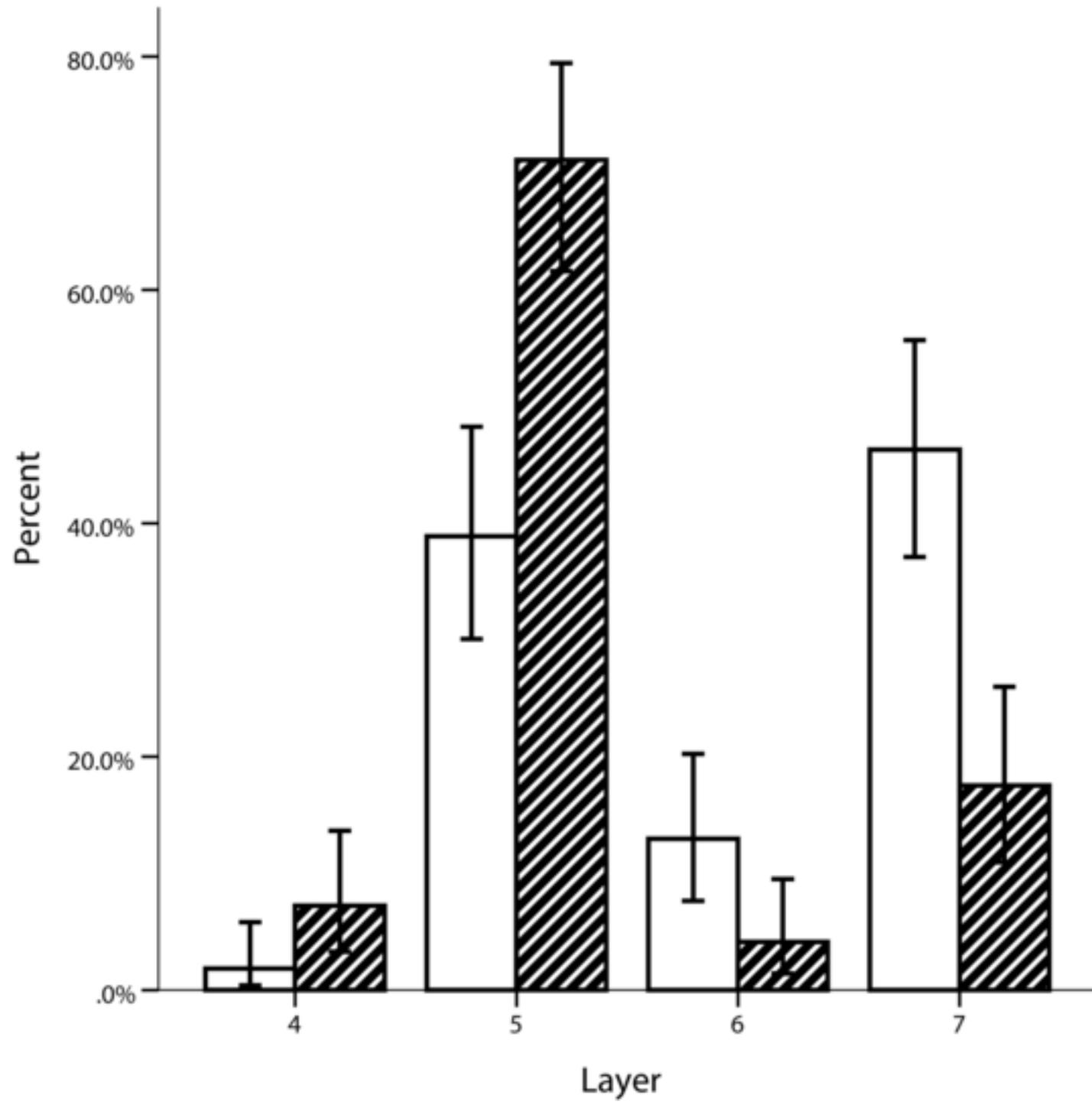


Figure(s)

[Click here to download high resolution image](#)



Figure(s)
[Click here to download high resolution image](#)



Level 15



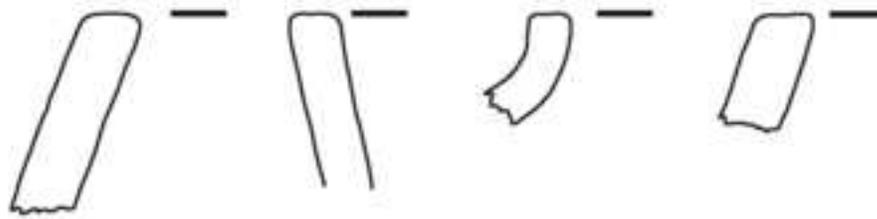
Layer IV

Level 16

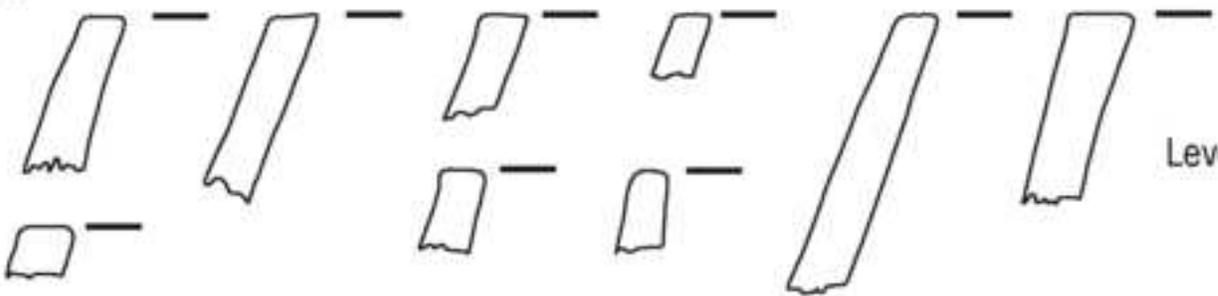


Level 17

Layer V



Level 18



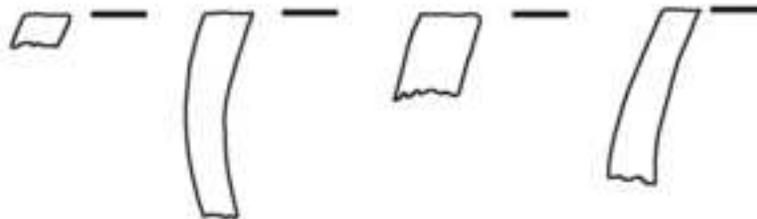
Layer VI

Level 19



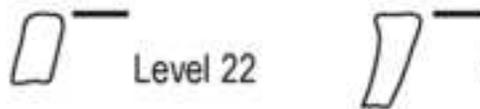
Layer VII

Level 21



Level 22

Level 23



0 2 cm