Necromancing the Stone: Archaeologists and Adzes in Samoa

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NECROMANCING THE STONE: ARCHAEOLOGISTS AND ADZES IN SAMOA

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Archaeologists are always on the lookout for evidence that prehistoric populations were in touch with one another. This is usually attainable, apart from often questionable stylistic similarities, only when a piece of the earth's surface from one area ends up in another, where it can be distinguished from the local material by various analyses. There are pitfalls, of course: even across large water gaps humans may not be the only agent of transportation, with stones hitching a ride in the roots of drifting trees (Leach 1981:13, 66), but, in general, it is a fairly safe bet that foreign matter in a site indicates human transportation.

The history of such studies goes back almost 350 years (Shotton 1971:571) and in the last 30 years has become commonplace in archaeology, encompassing many types of inorganic materials. In the Pacific only three major projects have been undertaken, featuring obsidian (Smith *et al.* 1977), sand temper in ceramics (Dickinson and Shutler 1979), and stone axes (Binns and McBride 1972). The first of these involves geochemical analysis, the others petrographic examination.

Stone tools in general have tended to fascinate Pacific Island archaeologists; many of these are manufactured from fine-grained basalts, and many Oceanic island groups contain these rocks in various quantities, often with evidence of exploitation in the form of substantial quarries. An analysis was carried out by Best in 1984, using petrographic and geochemical data, which attempted to distinguish between various Oceanic island basalts, and to compare specific adzes obtained during research in Fiji with samples from the vicinity of a traditional quarry site in Samoa (Best 1989:398-407). Since then, the project has been enlarged by a more representative sample from this quarry; Tataga Matau at inland Leone on Tutuila, American Samoa (Best *et al.* 1989), and by another physically and geochemically separate quarry area at the base of the Tataga Matau hill; this is identified as the Leafu subsource (Fig. 1).

Other researchers have recently located further adze sources on Tutuila, and examples of these have been added to the analysis (Clark 1989; Wright and Clark). In addition, the sample of archaeological material from other island groups has also been improved.

In this paper, data are presented on 161 archaeological and geological

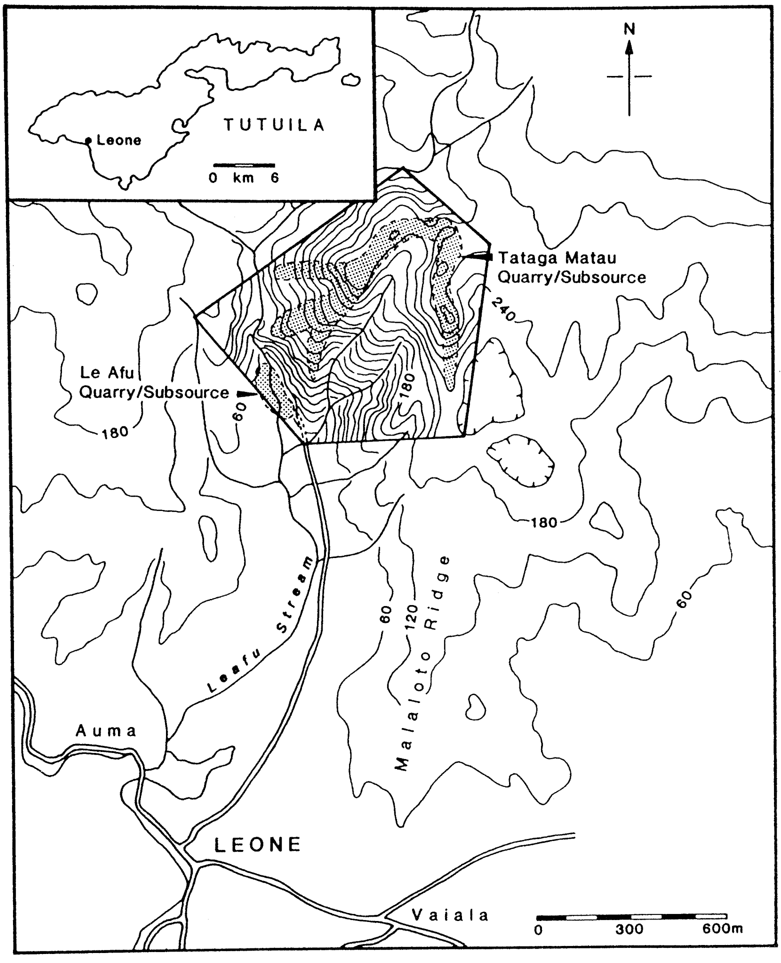

Figure 1. Map showing study area: Tataga Matau (Tutuila) and other Samoan quarries.

basalt samples from the Fiji-Polynesian region. The focus is primarily on the characterisation of the inland Leone quarry complex (the Tataga Matau and Leafu quarries) and its discrimination from other sources/areas both in Samoa and throughout the region (for provenance, see Appendix A). Sourcing of some archaeological adzes to the Leone quarry complex is attempted, and the results used to assess how long it has been used, the extent of its influence, and when that portion of the complex known as Tataga Matau was in full production.

FIELD WORK

In the course of field work in Fiji between 1975 and 1978, Best had noted the presence on specific fortified sites of adzes differing in their raw material from most of the assemblages. These artefacts were made from a very fine grained basalt, and were typologically similar to adzes described from Samoan sites (e.g., Green and Davidson 1969). Their distribution in the Lau group of Fiji appeared to coincide with fortified sites built along rocky limestone ridges, often with impressive stonework involving terraces and defensive walls. The largest of these forts, site 101/7/47, was radiocarbon-dated to 900±19 B.P. (Best 1989:129-30). The remainder, characterised by similar artefact assemblages, are probably of the same general age, given the pottery collected from their surfaces (Best 1989:252). Initial thin section microscopy showed that these basalts differed from those in the remaining adzes and in the local rock samples mainly in the presence of biotite or celadonite, which mineral had been noted as characteristic of Samoan adzes (Campbell and Wood n.d.:4).

A pilot study compared the geochemistry of these Lauan adzes (and one additional specimen from Taveuni) with many of the known sources of quarried basalt in the Fiji-Polynesian region, using x-ray fluorescence analysis. The results are described in Best (1989:405 and Fig. 6.4). Major/minor elements only were measured, with the main variation between sources occurring in the elements iron, titanium and phosphorus (Fe_20_3, TiO_2 and P_2O_5).

The initial results were promising, the basalts from island groups forming discrete clusters, with some notable exceptions for the Hawai'ian islands. These results are displayed later in the paper, with additional samples from other sources. The archaeological specimens, and the samples from Tutuila, were unusual in that they clustered in two discrete groups, as different from each other as any two widely separated island groups.

At that time, knowledge of Oceanic basalt adze quarries in Samoa was extremely limited. None had been found during site surveys in Western Samoa in the 1960s (although Best does not regard this as particularly significant); thus, the only one known remained that of Tataga Matau on Tutuila, with the possibility that another might have been present on 'Upolu in the vicinity of Mt Vaea (Green and Davidson 1969:18; Green 1974:141). The former had been located and described by Sir Peter Buck in 1927 (Buck 1930:330-1) and, despite various searches in the 1960s and since, no certain evidence of the latter has been found. In addition, suitable rock for adze production based on the ethnohistorical account from the 1840s was thought by Green (1974:141) to be present only on Tutuila.

For some time, archaeologists were unsuccessful in relocating Buck's quarry, but, in 1985, Leach and Witter rediscovered, surveyed and mapped it, and took some samples of the rock. They interpreted the site as a fortified quarry complex, with a defensive ditch at the uphill end (Leach and Witter 1987:38). Of the six rock samples collected, four were from locations outside the quarry itself; from the base or flanks of the hill and from an area some distance away which was subsequently found to be just off the end of a fortification which included the quarry. Analysis of these showed that the four from outside the central quarry zone fell into the two discrete archaeological clusters previously obtained, while the two from the quarry plotted somewhere between.

In 1988, Best, Leach and Witter (1989) returned to Tataga Matau for the second stage of the project, which involved excavation of selected features in the quarry and further site surveys of the surrounding area. Best had noted that the site as interpreted by Leach and Witter (1987) was similar to the ends of large Fijian fortifications, and had targeted the high ground above the quarry for more intensive investigation. The ridge above the quarry, on which Leach and Witter had noted some terraces and mounds during the previous season but which were considered by them to be either part of an unrelated site or merely outworks of the quarry itself (Leach and Witter 1987:38), was found to have been modified for over a kilometre, with a central high part defended by a large ditch, and two major terraced ridges leading down from this, one of which contained the quarry relocated during the previous season (Fig. 2).

Two other large stoneworking areas were located in the complex, and many places on the south-west trending spur which had been dug into for terrace construction also had evidence of adze manufacture. Small test excavations were carried out in stoneworking area 1 (Units P1 & P2, T2 and T8), and on the terrace immediately above this spur (Square 1, and seven test units not shown in Figure 2). The status of this mapped complex as a fortification is questioned by Leach and Witter (1990:55), who suggest that similar features occur throughout the area with no obvious beginning or end.

The three main stoneworking areas within the central quarry zone were sampled for geochemical analysis, with flakes being selected for size, that is, large enough to provide samples for both major and trace elements analysis with some remaining, (i.e., c. 5 cm plus in length) and from the extent of each exposure. Minor flaking scatters from the boundaries of the south-east trending spur were also sampled. Table 1 includes codes for sample locations on Tataga Matau which correlate with codes in Figure 2.

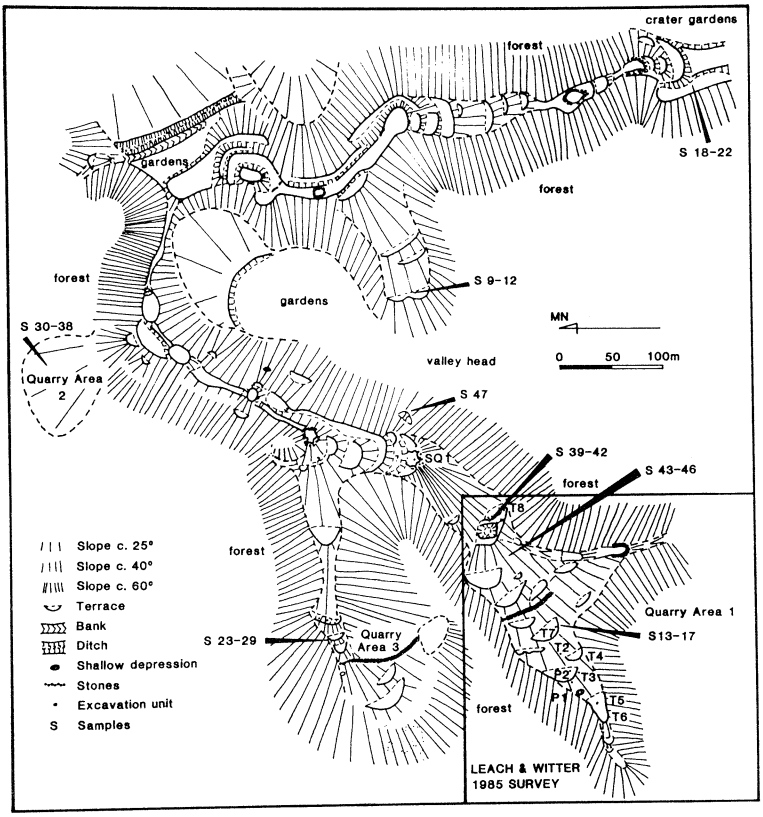

Figure 2. Detailed plan of Tataga Matau (Tutuila, American Samoa).

GEOLOGICAL SETTING

The geographical area sampled was bounded by Hawai'i, Pitcairn, Easter Island, Tonga, Lau and Samoa. Most island groups within this region are oriented in a linear north-east direction as a result of the migrating Pacific Plate, and their oceanic island basalts originate as plumes from the underlying mantle. Variation in mineralogy and chemistry within and between these groups is a result of the composition of the source material, the history of the melting process, and the processes involved in the life of the magma and its eruption and cooling. One might, therefore, expect differences in the source materials between geographically distinct distant islands, differences in the melting process along each linear island group, and differences in crystal fractionation between individual eruptions on one island. Mullen (1983) has shown the value of ternary plots of MnO, TiO_2 and P_2O_5 for differentiating between basaltic rocks of oceanic environments and the value of TiO_2 / P_2O_5, in particular, for differentiating between ocean island alkalic basalts and ocean island tholeiitic basalts. Early fractionation of magnetite or titanomagnetite could account for variation of iron and titanium within magmatic sequences as has been indicated for American Samoa by Wright (1986). Variation between island groups may be noted in the amount of P_2O_5 as its abundance seems "related to the degree of partial melting and the initial composition of the magmas rather than fractionation of any phase" (Mullen 1983:58).

SAMPLING

Ideally, a sampling programme for sourcing basalt artefacts made of basalt should, in the authors' opinion, meet the following criteria:

A The sample should be as fresh as possible.

B An adequate sample size for various analytical and petrographic procedures such as:

1. High-quality petrographic descriptions, possibly including electron microprobe and x-ray diffraction work.
2. Major element analysis.
3. Trace element analysis.
4. Lead isotope analysis.

Sample sizes, other than that for the Tataga Matau part of the Leone quarry complex, are unfortunately far from ideal, a natural result of the vast extent of the study area and the difficulty of travel within it. Samples from quarries other than Tataga Matau were obtained only through the generosity of other researchers in parting with their valuable material, and are, thus, characterised by only one or two flakes. The number of artefacts available for sampling is also limited, both by their rarity and by the reluctance of institutions or owners to allow holes to be drilled into, or chunks to be cut out of, their specimens.

The first step in any attempt to source rock material is a comprehensive petrographic study of the quarry itself (cf. Cleghorn *et al.* 1985). This initial step was omitted here on the assumption that the petrographic variation in these very fine grained basalts probably did not warrant the considerable amount of work required. Samoan basalts similar to those used for adzes had been previously described by geologists (see Green 1974:141), as had adzes found elsewhere and thought to be from Tutuila; for Fiji (Best 1989, App. K, artefacts 1, 26), for Tonga (White, 1987:280), for Savai'i (Buist 1969:37), and for islands as far distant as the Solomons (Campbell and Wood n.d.). These descriptions were of varying quality, the rock in general being classified as a fine or very fine grained olivine basalt, often containing biotite or celadonite, and depending on their silica/alkali component ranging from hawaiites to limburgites or nephelinites.

When the geochemical analyses were completed, three thin sections, representing the variation identified among the samples from the quarry and those in the immediate vicinity, were examined by P. Black of the Geology Department, University of Auckland. Her descriptions follow:

1. Main Quarry Sample (TTM A3/3)
Basalt — fine grained and probably from near the surface of a flow since in thin section it is very fine grained with leucocratic coarser grained clots of feldspar and minor pyroxene. The rock has a subtrachytic texture of plagioclase phenocrysts, minor anhedral olivine microphenocrysts, leucocratic feldspar patches and occasional large anhedral brown biotite crystals. The groundmass is more granular than intergranular being composed of fine grained granules of augite and oxides, minor feldspar laths and interstitial felsic and glassy material.
2. Leafu Stream bed Sample; Low Titanium (An40)
Basalt — probably alkaline. Thin section shows phenocrysts (< 0.5 mm long) of plagioclase feldspar with minor small anhedral olivine crystals and patches of brown biotite. The rock has an intergranular groundmass of feldspar microlites with granules of pale brown augite, iron oxides and occasional small olivines with interstitial glass.
3. Leafu Stream bed Sample; High Titanium (A9).
Basalt — very fine-grained. Similar to the sample from Tataga Matau quarry. Phenocrysts of plagioclase showing subtrachytic texture. Small anhedral phenocrysts of olivine occur in minor amounts. Occasional leucocratic patches of felsic material and anhedral brown biotite. The groundmass is composed of a fine grained granular aggregate of augite and oxide grains and interstitial felsic or glassy material.

Since major element analysis requires only one third the amount of sample needed for trace element work, these were examined first. One hundred and sixty-one samples were analysed by x-ray fluorescence (University of Auckland Geology Department) over a 6-year period.

The variation in the analytical data over this period is estimated for major elements to be less than 3 per cent relative. For trace elements, the results are considered to be generally consistent to within 5-10 per cent relative over this time. These estimates are based on data from counting statistics, precision runs and standard calibration errors.

Trace element analysis was conducted on 36 samples, either to confirm differences established using majors or to check on paired items that, on archaeological grounds (time and space relationships), should not have been similar.

Fifteen samples have been submitted for lead isotope analysis to the Department of Geology, University of Leicester; these results are not yet available.

ANALYSIS

Artefact sampling

Adzes were sampled mainly by coring down the long axis of the artefact from the butt end, using a 10 mm exterior diameter diamond-tipped corer which produced a core of 8 mm diameter. When this technique was not possible, a thin slice was cut on one side of the butt end, using a standard geological saw, the cut parallel to the front of the tool. When the artefact was small a Wafering saw was used. The resulting damage was masked by plugging with Emerkit epoxy putty, obtainable when the analysis started as a three-part nonshrinking filler in grey to black tones, now available only as a two-part filler requiring tinting.

X.R.F. Analytical Procedures

The major and trace analyses were carried out using an automated Phillips PW1410 XRF spectrometer and multistandard calibration lines. The following international rock standards were used: PR, MRG, JB-1, W-1, AGV-1, JG-1, GH, GA, GZ, SY-Z, NIM-S, NIM-L. Major element methods were based on techniques described in Parker (1978). Data reduction was done using a suite of programmes similar to those in Parker and Willis (1977). In trace element analysis, corrections were made for background curvature, analyte and tube line overlaps, matrix effects and machine drift.

RESULTS

The results of the geochemical analysis are presented both as a table of raw data ordered by cluster analysis and as a series of figures (Figs 3-8) starting with all known sources on Tutuila, widening the area to include Western Samoa, enlarging it further by adding all sampled adzes from the Fiji-Polynesian region, and then distinguishing between various sources within that region. An attempt was also made to correlate stoneworking areas on Tataga Matau with adzes that plotted in the main cluster. Trace elements (Fig. 7) were used to check on five adzes that fell in the Tataga Matau cluster itself, and to separate out two Western Samoa basalts which plotted on three majors close to Tataga Matau.

The same three elements, iron, titanium and phosphorus, were used as in the earlier analysis (Best 1989) to provide a simple graphical distinction between sources, this time with P_2O_5 plotted against Log TiO_2/Fe_2O_3. A series of multivariate analyses (cluster analysis, stepwise discriminant analysis) using all the major elements was run to check the utility of these elements in discriminating sources.

The results of a stepwise discriminant analysis (SAS version 6.01) using only the data (log10) on the various Samoan sources and other island groups (Cooks, Marquesas, Societies, Hawai'i, Easter, Henderson and Pitcairn) indicated that the following elements are most useful in discriminating between sources. These are in descending order of importance: CaO, TiO_2, Fe_2O_3, P_2O_5, MnO, SiO_2, MgO, K_2O, and Al_2O_3. Sodium did not contribute to discrimination in any significant manner. Calcium varies considerably between many island groups (Table 1) and appears to be a significant discriminator between Tutuila and 'Upolu with geological evidence indicating that the lower calcium in Tutuila Shield volcanics (Taputapu and Pago) is the result of derivation of magma from greater depth than similar basalts on 'Upolu (Natland 1980:718; Wright 1986:61). The three elements Ti_2O, Fe2O3, and P_2O_5 are the most efficient detailed discriminators of fractionation within source areas.

The data in Table 1 are ordered according to the results of average linkage cluster analysis (UPGMA) (SAS version 6.01) on log10 transformed data which was then standardised to a mean of 0 and a standard deviation of 1. These transformations had the effect of more closely approximating normal distributions in the data and equally weighting the data for multivariate analysis (Bishop and Neff 1989:63).

Weathering

Initial study indicated that, if a group of samples from a given locality contained a sample with a loss on ignition (LOI) figure of more than 1 per cent, this sample plotted away from the main group. Although the upper limit for LOI values in unweathered rocks is usually taken to be 2 per cent, the smaller percentage is considered more applicable for Oceanic island basalts (personal communication R. Parker). All such samples were omitted from the plots, but are listed in Table 1.

Results of the Cluster Analysis

Cluster membership for each sample is indicated in Table 1. The cut point for distinguishing major clusters was made at an average squared euclidean distance between clusters of 0.5. Within cluster 1, which is made up primarily of Samoan samples, further splitting was made at a distance of 0.3. Outliers are indicated by an O in Table 1.

Cluster 1 is subdivided into four subgroupings: A, B, C, and D. The division of subgroup A, B and C is based primarily on the amount of titanium (A=moderate, B=high and C=Low). Subgroup D is distinguished from the others by having lower values of manganese. Cluster 1A consists of flakes from all parts of the Tataga Matau quarry proper and includes a group of adzes (see Appendix A for exact provenance) from Fiji, Taumako, Tokelau and Western Samoa as well as one adze flake from Ma'uke (RW-M) in the Southern Cooks. These adzes are all typologically similar to Samoan forms (see discussion below). Cluster 1B consists predominantly of East Tutuila quarry samples, one sample of general provenance within the Ololua crater on the inland end of the Tataga Matau fort, an east Tutuila adze, a series of Tokelauan adzes and a geological sample (3C) from 'Upolu. Cluster 1C is made up solely of adzes and one archaeological flake from a series of sites in Western Samoa, Fiji, Tonga, Tokelau, San Cristobal (Solomon Islands) and Tuvalu. This is equivalent to the low titanium group in Best's earlier work (1989) and is discussed further below. One sample (B8809) from Pukapuka forms an outlier to this group. Cluster 1D, like cluster 1A, is made up of samples from the Tataga Matau quarry proper plus two samples from eastern Tutuila quarries; these, however, have higher titanium and aluminium values than other members of the group.

Cluster 2 is made up predominantly of material from the base of the hill below the Tataga Matau quarry which are characterized by their high titanium content and low calcium. One quarry sample from Eastern Tutuila is also included in this group although its calcium and titanium values are significantly lower than those of the rest of the source material in the group. Again a series of six adzes from a variety of sources (Taumako, Tokelau, Western Samoa, Fiji-Lau) also fall into this cluster.

Cluster 3 is formed by three Marquesan samples while a fourth appears as an outlier further down the table. Cluster 4 consists of two samples from the east Tutuila Asiapa quarry plus an archaeological adze from the Outer Reef Islands (Nupani, Re-51) and another from Ma'uke (RW-F) in the Southern Cook Islands. Cluster 5 consists solely of archaeological samples from Pitcairn Island, while cluster 6 contains the two samples from Easter Island.

Cluster 7 contains a sample from the adze fragment recovered from dredgings near the Mulifanua Lapita site and an archaeological flake from Ma'uke in the Cooks. These samples are most similar in their low silica content to the Cook Islands group formed by cluster 8. Problems of weathering plague most of the low silica basalts and it may be that the samples in group

7 are altered enough to be misplaced. Similarly, the two samples from Ma'uke which form cluster 13 probably have the Southern Cook Islands origin suggested by their low silica values, but their high iron values push them away from the rest of the Cooks grouping. Although the loss on ignition for these two samples is relatively low, it is possible that weathering effects have played some role in their differentiation.

Cluster 9 consists of two samples collected by geologists (Natland and Turner 1985) from the basalts on the coast some distance west of Leone. The basalts belong to the Taputapu formation, as do those from the inland Leone quarry complex. Cluster 10 is composed entirely of archaeological adzes and one flake from a wide suite of islands from Fiji to Western Samoa and Tuvalu. This formed part of the high titanium group in Best's earlier work (1989). The next most similar group is cluster 11, which is made up of two geological (Natland and Turner 1985) samples from Mt Vaea ('Upolu, Western Samoa). The other two geological samples from Mt Vaea form a separate low titanium group (cluster 14).

Clusters 12 and 16 contain only Mauna Kea and Oahu samples, respectively, with cluster 15 containing one sample from Molokai and one from Kahoolawe.

The final cluster (17) consists of two very distinctive high silica, low titanium Tongan adzes. The remaining samples are outliers which have been mathematically trimmed from the cluster analysis on the basis that they had very low similarity with any other samples (i.e., low estimated probability densities). This is undoubtedly the result of weathering, as they have, for the most part, very high values for loss on ignition.

The results of the cluster analysis indicate that it is possible to differentiate most of the major island groups and to some extent intra-island sources by simply applying a blind multivariate approach using the equally weighted major elements (with the exception of sodium). From a theoretical point of view, it is better to work with a restricted set of elements for which there is some understanding of the geological processes underlying elemental variation, and in this manner to produce a weighted set of elements for differentiating sources. A small set of elements also facilitates presentation of results. Previous work by Best (1989:404), supported by the results of discriminant analysis, suggests that titanium, iron (total) and phosphorus are important discriminators and, as discussed above, the geological mechanisms behind this are understood or are the subject of geological investigation. For this reason, we have used these elements in our fine-scale analysis of the Tataga Matau quarry and its relationship to other Pacific basalt sources. The results of this analysis are presented below beginning with the quarry complex itself.

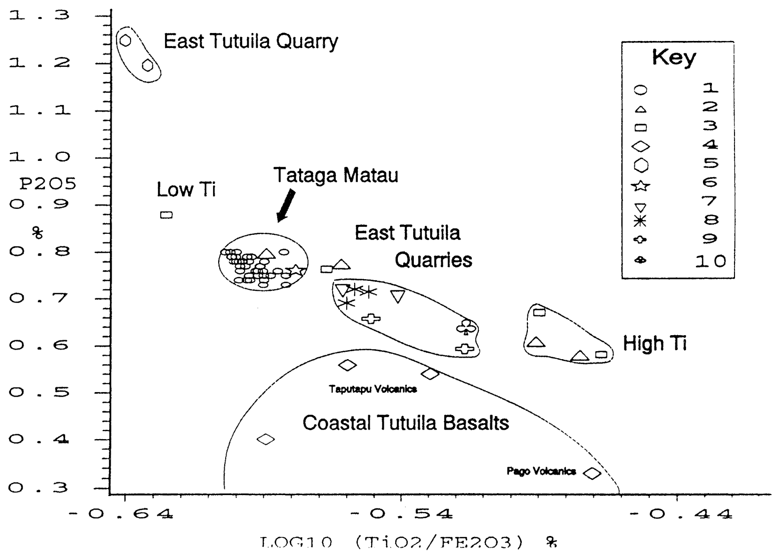

Figure 3. 1 = Tataga Matau quarry flakes, 2 = Geological samples from Tataga Matau and base of hill, 3 = Misc. flakes from Tataga Matau area and base of hill, 4 = Geological samples from west of Leone (Taputapu Volcanics) and 1 sample from Fagasā Bay (Pago Volcanics — Turner and Natland 1985), 5 = Archaeological flakes East Tutuila Asiapa quarry (AS-22-31), 6 = East Tutuila Laeano quarry (AS-21-110), 7 = East Tutuila Lauagae quarry (AS-21-100), 8 = East Tutuila Mapua geological samples, 9 = Archaeological flakes East Tutuila (AS-21-5), 10 = East Tutuila Sa'ilele quarry.

Tataga Matau Quarry Complex

In Figure 3, the Tataga Matau quarry flakes are compared with samples from seven sites in Eastern Tutuila, (four of these are small quarries), with the archaeological flakes and geological samples from around the Tataga Matau quarry itself, and with four geological samples collected by Natland and Turner (1985:146). Three of Natland and Turner's samples were from basalt formations west of Leone in the same Taputapu volcanic formation, and the other was from Fagasā Bay on the north central part of the island, an area associated with the Pago volcanics. As can be seen, the stone working areas within the fortification complex, which occur over a 1.4 kilometre length of ridge and encompass a vertical distance of 140 metres, form a tight cluster

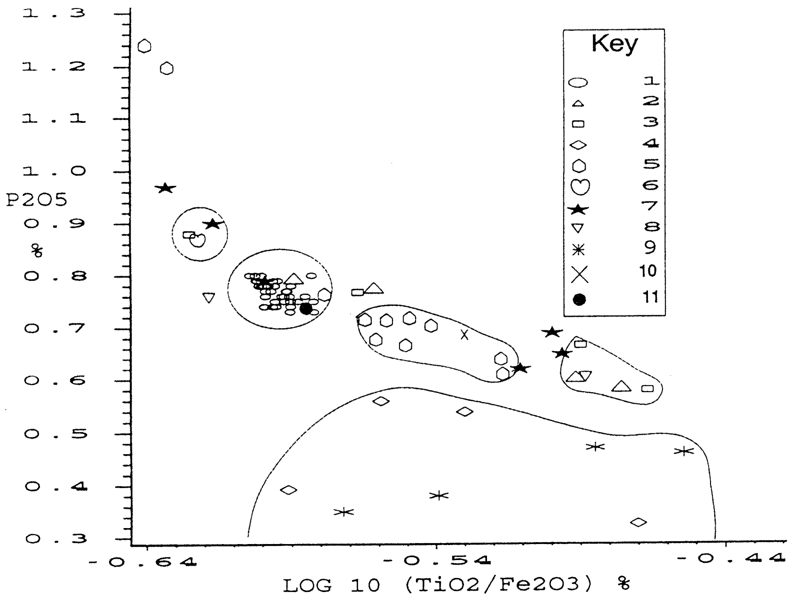

Figure 4. 1 = Tataga Matau quarry flakes, 2 = Geological samples from Tataga Matau and base of hill, 3 = Misc. flakes from Tatagmatau area and base of hill, 4 = geological samples from west of Leone (Taputapu Volcanics) and 1 sample from Fagasā Bay (Pago Volcanics — Turner and Natland 1985), 5 = East Tutuila quarries (combines 5 to 10 of Figure 3), 6 = Archaeological flake Manu'a Islands, 7 = Adzes from Western Samoa, 8 = Geological samples Mt Vaea Western Samoa (Leach), 9 = Geological samples Mt Vaea Western Samoa (Turner and Natland 1985), 10 = Geological sample Ti'avea, 'Upolu, 11 = Adze from east Tutuila.

distinct from any other sampled basalt in Tutuila, with the exception of one flake from an east Tutuila quarry.

Of interest is the distribution of the geological samples from the vicinity of Tataga Matau (category 2) and the archaeological flakes from just outside the site (category 3). One of these category 2 samples is from an outcrop within stoneworking area 1, and this falls within the cluster for the quarried material. The category 2 and 3 samples just off to the right of the quarry cluster are a flake collected about 100 metres from the end of the south-east trending spur, in the Ololua crater gardens, and an unused cobble from the basal layer excavated in square 1 on the quarry ridge itself. Of the remaining five examples in categories 2 and 3, four group on the high titanium end of the total spread, while the remaining flake (category 3), characterised by a low titanium content, plots to the left of the main quarry group.

The east Tutuila flake comes from Leaeno quarry (AS-21-110). This quarry was a small scatter of flakes (c.50 metres square), and no obvious source for these was apparent to the finder (Clarke 1989:21, 22).

There is, it appears, as much variation between the rock at the back of the Leone flats and that from the fortified complex which starts a few metres above it as there is between Tataga Matau and the most distant used basalt on Tutuila itself. It should, however, be remembered that only the two ends of the island are represented here, and that when, as seems likely, archaeological surveys of the present terra incognita between are carried out, the picture will become more confused.

Samoan Sources and Adzes

In Figure 4, archaeological adzes from Western Samoa (category 7), one from east Tutuila (category 11) and a flake from the Manu'a Islands (category 6) have been added to the previous results. Two of the adzes fall into the main Tataga Matau cluster, while the others group with the East Tutuila spread and the high titanium Leafu cluster. Two of the remaining adzes, together with the Manu'a flake, plots with the low titanium flake collected from along the Leafu stream at the base of Tataga Matau. A geological sample from Ti'avea, 'Upolu (3C) groups with the east Tutuila cluster (as it did in the cluster analysis subgroup).

Chemical analyses were also run on six basalt samples from around Mt Vaea, 'Upolu (3, 5 and Upo 1-4) and an adze fragment found in the dredge tailings at Mulifanua by Rhys Richards in 1988 (8c), andwhich probably came from the earliest known site in Samoa (Leach and Green 1989). Although 3 and 5 are similar to the Leone source basalts in their $P_2O_5/TiO_2/Fe_2O_3$ ratios, they differ in the other major elements (see Table 1). They can also be distinguished petrographically, and even hand specimens appear to be coarser-grained than the Tataga Matau material. These samples were included in the subsequent trace element analysis (Table 2, Fig. 7), where they are shown to be markedly different from the Leone source material. The Mulifanua adze was also sampled; this was the coarsest basalt encountered in the analysis and, as Table 1 shows, is not similar to any Tutuila source.

Samoa plus Distant Archaeological Adzes

A total of 43 adzes or adze flakes in nonquarry context has been sampled over the years, from localities as distant from Samoa as San Cristobal in the Solomon Islands, Pukapuka in the Northern Cooks, and the Lau group in Fiji. All these either appeared, on typological grounds, to resemble Samoan adzes,

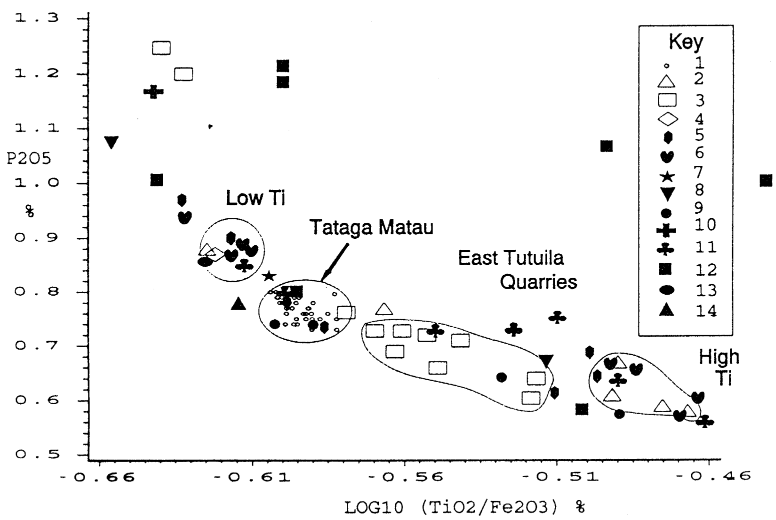

Figure 5. 1 = Tataga Matau quarry flakes, 2 = Geological samples and miscellaneous flakes main ly from base of the hill (combines 2 and 3 of Figure 4), 3 = East Tutuila quarries, 4 = Arch. flake Manu'a Islands, 5 = Adzes from Samoa, 6 = Adzes Fiji, 7 = Adze Tonga (TO-6 Horizon 1), 8 = Arch. flakes Tuvalu (Temei site), 9 = Adzes Taumako, Kahula and Kongo, 10 = Adze Reef Islands, Nupani (RE-51), 11 = Adzes Tokelau, 12 = Adzes and flakes Southern Cook Islands, 13= San Cristobal adze, 14 = Pukapuka adze.

or were manufactured from a fine-grained basalt foreign to the islands on which they were found. In addition, 17 adzes or adze flakes and one core from the Southern Cooks were sampled by R. Walter and added to the total.

As can be seen (Fig. 5), most of the adzes tend to fall at the two extremes of the Tutuila range, as was indicated in the original plot (Best 1989:404). The situation, however, is not as simple as that suggested by the original work. At the high-titanium end of the scale, some of the adzes fall between this grouping and that containing the east Tutuila quarries, indicating that eventually there may be considerable overlap between some of these and the samples from the base of Tataga Matau, and that differentiation on the basis of major elements alone may not be enough. The low-titanium cluster is attributed to the area around the base of Tataga Matau on the strength of one flake, collected from the Leafu stream bed. Although this flake does not group with the low titanium adzes in the cluster analysis (cluster 1c), it is highly probable, based on both the presence of the 1c subcluster in the greater Tataga Matau group (cluster 1) and the geochemical continuity between the flake and the adzes (which is expressed in Figure 7), that the adzes come from an as yet poorly sampled low titanium area at the base of Tataga Matau. Six adzes fall into the Tataga Matau quarry cluster: one from east Tutuila, two from Taumako, one from Tokelau, one from Western Samoa and one from the Southern Cooks. One other late adze (TO6-109), from Tonga, is on the periphery of the cluster. Some of the remaining adzes group with the East Tutuila quarries sampled by Clark. Two Cook Islands samples (RW-H and RW-K) which fall in the top right hand part of the plot are very different from any Samoan basalts.

Some adzes were omitted from this plot. Another early Tongan adze, T06-20, found in Horizon 1 at site T06, grouped with the two Easter Island samples. This was one of the rare occasions when the amounts of the three elements used were very different but their ratios were the same. A better idea of their relationship is shown by the cluster analysis (Table 1). Archaeological probability should also be a warning factor: two dates from Horizon I, 2380±51 B.P. and 2350±200 B.P. are almost 700 years earlier than the known settlement date for Easter Island.

One of the Hawai'ian adze samples (AN 29) fell close to the Pitcairn cluster (also see Best 1989:403). This had been taken from an adze in the Auckland War Memorial Museum collection, which subsequent inquiry determined had been catalogued in 1981; the artefact had earlier been one of the museum's unprovenanced items.

Cook Islands samples with an LOI figure of 0.99% or more were omitted from the plot on the grounds of their extreme variability in the three elements plotted. Some samples from the Southern Cooks are heavily weathered based on their loss on ignition figures; this is seemingly a characteristic of these low-silica rocks (see Palacz and Saunders 1986, Table 1). Weathering will substantially alter the values for iron and, thus, interfere with the ratios used in the analysis. All five of the samples omitted plotted just above the Samoan groups; a phosphorus figure of 0.05% less would have put all of these in with the Samoan basalts. It may be that such a regular distribution results from Samoan artefacts exposed to a Southern Cooks weathering regime for a similar length of time.

Tataga Matau and Associated Adzes

Trends in the chemistry between the stoneworking areas exploited within Tataga Matau itself are evident (Fig. 6). Category 1 represents stoneworking area 1, category 2 stoneworking area 2 on the quarry itself and small exposures on the top of the site and down the south-east ridge, and category 3

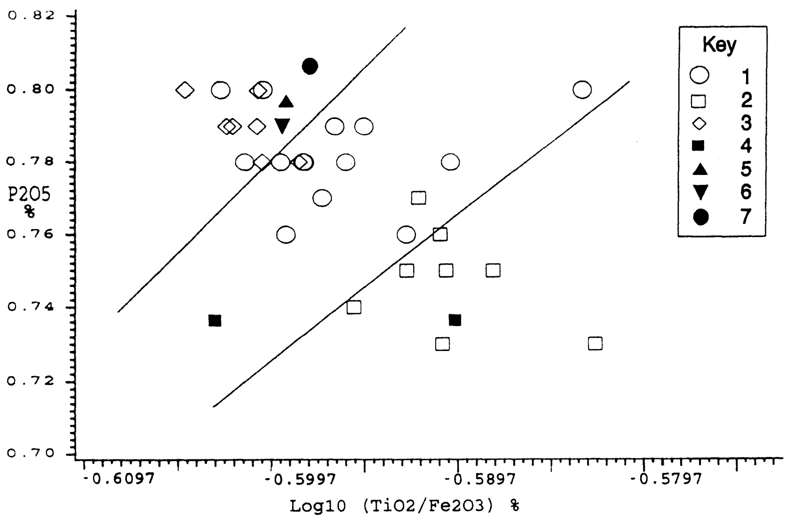

Figure 6. 1 = Area 1, 2 = Area 2, 3=Area 3, 4 = Adzes Taumako Kahula and Kongo (Tau-48, Tau-54), 5 = Adze Tokelau Atafu (7-A2), 6 = Adze Western Samoa (SA-3, SU-9, Layer 5) 7 = Adze Southern Cook Islands (RW-M).

stoneworking area 3. When five adzes (two from Taumako, one from Tokelau, one from the Southern Cooks and an early one from Western Samoa) are added to the plot, there are indications as to where on the site they may have been manufactured. The sixth adze (from east Tutuila) falls in area two.

Trace Element Data

The association between some of the adzes and the Tataga Matau and Leafu sources, as suggested by the major element analysis, was further examined by comparison of the trace elements. Fifteen samples were processed from the Tataga Matau quarry itself, five from each of the three main flaking areas, and another five from the Leafu subsource. Four of the six adzes that, on major elements, plotted with the main quarry were analysed (the Cook Islands specimen could not be run due to the lack of an appropriate sample remaining after analysis for majors) and the high-titanium Cook Islands flake and the low titanium San Cristobal adze were also analysed. Trace element data from the two West Samoan Mt Vaea geological samples which plotted

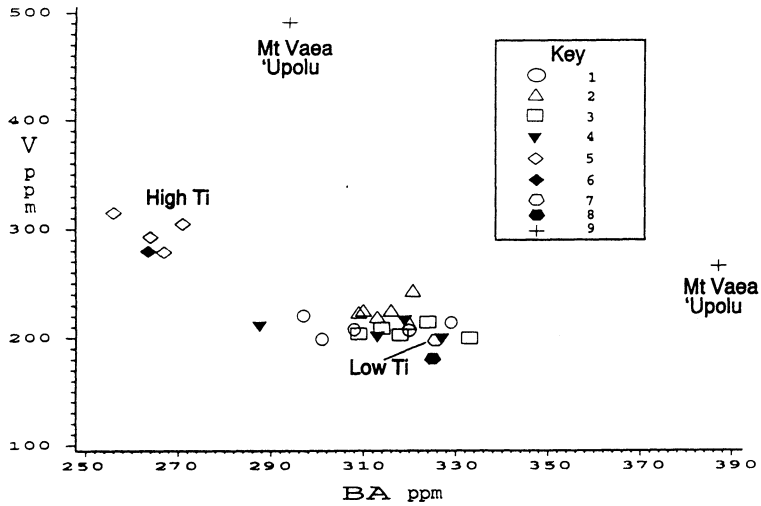

Figure 7. Tataga Matau Plot of Vanadium by Barium: 1 = Area 1, 2 = Area 2, 3 = Area 3, 4 = Adzes (Main Quarry): Tokelau (TOK-A2); Taumako (Tau-54, Tau-48); 'Upolu (53) 5 = Base of Hill (high titanium), 6 = Adze Southern Cooks (high titanium) 7 = Tataga Matau Leafu Stream (?) Sinoto collection (low titanium), 8 = Adze San Cristobal (low titanium) 9= Mt Vaea Western Samoa Geological samples.

with the high and low titanium groups on major elements are also included. Of the remaining eight archaeological samples from outside Samoa, some are considered suspect as the loss on ignition was more than 1 per cent, while others are on adzes that plotted between groups on major elements; these assume much the same position in this analysis. All samples are included in Table 2, and the last eight are omitted from Figure 7. Barium and vanadium were found to be the most useful elements for discriminating between major quarry areas. The three samples showing very high nickel and chromium values were cored at the same time using a different drill-cooling method. It is highly likely that these levels reflect contamination from the steel drill, possibly from overheating.

Examination of the trace element data shows a high level of similarity between the quarry samples and the archaeological adzes, confirming the results obtained from majors alone. The main quarry area is, again, a relatively tight cluster with the high-titanium samples forming a separate group. The adzes and flakes which grouped with these two sources on majors are again linked on the trace elements. On the elements chosen, the two low-titanium samples are indistinguishable from the main quarry group but do plot close together. The two Mt Vaea samples are shown to be distinct from the Tataga Matau rock, indicating that none of the adzes sampled so far can be traced to this supposed source.

Oceanic Island Basalt Sources

The final run consists of all sampled Oceanic basalt sources (Fig. 8). It is clear that, even at this end of the scale, the three elements are capable of distinguishing between most sources, although the boundaries of some, even with the small samples available for analysis, tend to merge. One Hawai'ian source sample, from Polulu (Haw An 52), differed so greatly from all other samples that it would have affected the scale of the plot had it been included. Again, all Cook Islands samples were omitted.

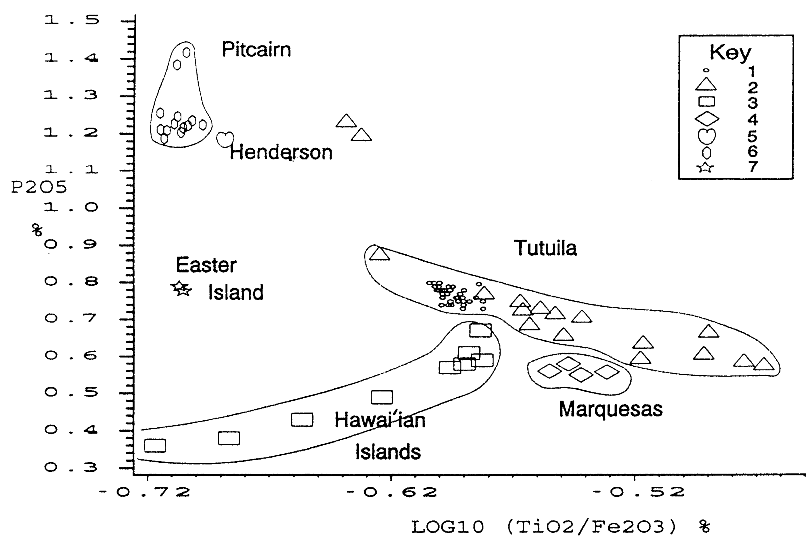

Figure 8. Oceanic Island Basalts: 1 = Tataga Matau quarry, 2 = Tataga Matau Base and East Tutuila quarries, 3 = Hawai'ian islands, 4 = Marquesas, 5 = Henderson, 6 = Pitcairn, 7 = Easter Island.

DISCUSSION

The three major elements selected for graphically displaying the results appear to be sensitive to even quite small changes in the magma composition, and able to differentiate not only between island groups, but also between different areas on one island, and possibly between different stoneworking areas on the one quarry complex not more than 100 metres apart. Trace elements, where used, have tended to confirm relationships suggested by the above.

These results should be regard with some caution, however; sample sizes for all quarries other than Tataga Matau are lamentably small, and, even for the Tataga Matau quarry, are insufficient to make any but the most general statements about intrasite variation. With the inevitable discovery of more quarries in the Pacific, especially on Tutuila (and probably Western Samoa), and with extensive sampling, more sophisticated methods of distinguishing between sources, and of attributing artefacts to these, will probably be needed.

The single flake from a rock outcrop at Ti'avea, on the south-east point of 'Upolu, which plots on major elements (trace element analysis is forthcoming) with the Tutuila group of quarries, is the only indication that some of the adzes sampled may have a source outside Tutuila itself. That such sources exist is certain, as is indicated by the Mulifanua adze; it is their importance relative to the Tutuila quarries through time that has yet to be discovered.

It seems unlikely, however, that a source other than Tutuila could have produced most of the adzes of Samoan typology that have been a feature of this work. That being so, the position of the hilltop quarry named Tataga Matau as the pre-eminent producer of Samoan adzes, as suggested by Buck (1930:330), Green (in Green and Davidson, 1974:141) and Leach (in Leach and Witter 1987:51) must be questioned. Only five of the 36 adzes or flakes sourced to Tutuila can be attributed to this hilltop quarry. In addition, Tataga Matau has also assumed added importance because of its description as a fortified quarry (Leach and Witter 1987:51; Leach and Witter in Best, Leach and Witter 1989:10; Leach and Witter 1990:80), and the suggestion that the stone within the fort and quarry complex is of superior quality to that outside it (i.e., Leach and Witter in Best, Leach and Witter 1989:69). The first of these assumptions can no longer be realistically sustained, and the second requires extensive systematic sampling and testing in order to be substantiated.

USE OF THE TATAGA MATAU QUARRY

Five radiocarbon dates were obtained from the excavations. Only two of these can be taken to refer to the earliest period of intensive use of the site. One of these, NZ-7598, from close to the base of square 1, marks the start of terrace construction on the ridge above stoneworking area 1. The conventional age was 602±50 B.P. The other came from Pit 1, sited in front of one of the terraces in stoneworking area 1 (PI on map), where charcoal in a post or stake hole gave a date of 906±157 B.P. (N.Z.7593). Two other dates were obtained from the same terrace of 580±63 B.P. (N.Z.7954) and 580±110 B.P. (N.Z.A374). It is, thus, by no means clear when the spur was first used to any extent; the very large Standard Deviation of the earliest date renders it of limited use, but it seems unlikely that much modification of the slope took place before about 1000 B.P., and possibly much later.

Of the six adzes that can be firmly assigned to the quarry, all but one probably fall within the allowed time-depth. The Tokelau specimen comes from the upper layer in a site on Atafu, the northernmost atoll in the group (Best 1988). The earliest date for the site was 1000±100 B.P. (NZ 7462); this adze, although in a layer subject to recent disturbance, is likely to date considerably later than that, possibly in the last few hundred years. Of the six other Tokelau adzes sampled, from all three atolls in the group, three fall in the two clusters representing material from around the base of Tataga Matau, and three are in or close to the eastern Tutuila scatter. At least two of the former come from the lower layers of the excavations, quite possibly earlier than the proposed date of *c*.600 B.P. marking the extensive use of the quarry.

The Cook Islands adze fragment was excavated in layer 4 at Anai'o on Mau'ke; this layer was dated to about A.D. 1300-1400 (Walter 1990:351).

The two Taumako adzes, from Kahula and Kongo, were surface finds, as was the east Tutuila adze from AS-21-b. The adze from Western Samoa is the only one of the five older than the earlier quarry date; this specimen was found in layer 5 square I4 in site SU-SA-3, 'Upolu. This layer was dated by the excavator to 1840±100 B.P. (GAK 1441, in Green 1974:113). Given that this adze was not intrusive (and some disturbance in the layer was noted by the excavator, although he regards any movement of artefacts to have been up rather than down, R. Green, personal communication), then it appears that the scree slope and subsources on Tataga Matau itself were used, probably *en passant,* before the spurs and ridges were modified to their present form. This is consistent with the recovery of a sherd and obsidian from excavations at the summit. Five of the other six adzes from Western Samoa, including one from the same layer and square as 17/927 (17/928), plot with or near either the high or low titanium Leafu clusters from just outside the quarry.

The Tongan adze on the edge of the cluster was found in the lower part of horizon 3 at site T06. This was thought by the excavator to be late in the sequence, possibly within the last 300 years (Poulsen 1967:363 and Tables 20 and 33).

All of the Lauan adzes sampled fall into the two Leafu high and low titanium groups, as does the Taveuni specimen. As mentioned above, most of these, if not all, probably arrived in Fiji about 900 years ago. An adze flake from an excavation at Ta'ū village (site AS-11-51) in the Manu'a group fits with the low-titanium cluster. A date for this site is given as 2330±50 B.P. (Beta19741), calibrated at one S.D. to A.D. 0-128 (Hunt and Kirch 1988:167, 168).

Samoan look-alike adzes have been reported from various other island groups. For Tikopia, both Firth (1959:153) and Kirch and Yen (1982:223, 226) describe adzes of fine-grained grey or black basalt typologically identical to adzes from Samoa and other West Polynesian groups (these were, unfortunately, not located for sampling). Kirch and Yen were able to date the arrival of these adzes through chips from similar tools found during excavations, and put the event at some time after about 750 B.P. A possible Samoan (or east Polynesian) connection for five adzes excavated at the early Fijian sites of Sigatoka and Yanuca was made by the excavators (Birks and Birks 1968:114), although at least some of these do not appear to be made from a fine-grained basalt.

In the Cook Islands a cache of six adzes with reversed triangular cross-section and made from a fine-grained black basalt were found at Avarua on Rarotonga. The find spot was excavated in 1972 by Bellwood, and the adzes were said to probably come from a site dated to between 500 and 700 B.P. (Bellwood 1979:348). This cache is interesting in that a local tradition tells of a Samoan chief, Karika, founding a settlement on the island about 650 B.P. One of the adzes was unusual for a Samoan origin in that it had an incipient tang, and recently a local source of basalt, known in oral traditions, has been sampled, the Black Rock quarry, which, as its name suggests, polishes to a similar colour (R. Walter, personal communication). However, the findings from this study indicate that at least one and most probably four flakes from the Anai'o site on Mau'ke, all dated to between about A.D. 1300 to 1400, came from quarries on Tutuila. Taking typology and legend into account also, this must suggest that the cache itself probably did too.

It would seem that, at present, there is little evidence for adzes from Samoa reaching other distant island groups before about 900 years ago. Any oral traditions regarding such movements, as for the Pukapuka legend where "returning Pukapukan navigators brought back to the atoll stone from which adzes were made" (Beaglehole and Beaglehole 1938:164), and also the tale of Punamai and Punaloa, who travel from Atafu in Tokelau to Tutuila (and specifically the Leone quarry) for adze material (Herman 1970: 94-5) probably refer to events within the last few hundred years. Since at least 12 of the sampled adzes do not come from the stoneworking areas on Tataga Matau itself but from somewhere just outside the site (as in the case of all the Lauan adzes), they may well predate the use of those sources. It is also likely that, even within the life span of the fortification, adzes were being produced from outside the fortified or terraced areas and yet somewhere close by. What is certain, however, is that in the more than 2,000 years before the fort, adzes were being produced mainly from this other area or areas.

THE EARLY LEONE SUBSOURCE LEAFU (THE WATERFALL AND STREAM)

The early source may, in fact, be two distinct subsources, although probably very close to each other. These are the high and low titanium groups, consisting mainly of adzes, but also containing three archaeological flakes and two geological samples. Two of these flakes were collected by Sinoto in 1961-2, and almost certainly come from somewhere along the base of the hill close to the stream and waterfall below the quarry I spur. One of these was the single low-titanium specimen. One other flake was collected by Leach from the base of the slope some 60 metres downstream from the waterfall. Two geological samples were also collected by Leach: one from the rock at the waterfall itself, and one from the steep slope on the south side of quarry I spur.

Thus, there seems no doubt that at least one of the early Leone subsources is located at the base of quarry spur I. Given the discovery of the ethnographic and "fortified" sources on the hill itself, this area by the creek was not examined in the 1988 season. During the search for Tataga Matau in 1985, however, Leach described what is very probably the early quarrying area. She found cores, flakes, and preforms on the wooded slope on the south side of quarry spur I, and noted, in the sides of a narrow watercourse running down between this and the access spur further to the south, that there were flakes "... several feet below the ground surface, and [that] the debris is probably piled very deep at the foot of the slope" (Leach and Witter 1985:28). She interpreted this hill-slope flaking debris as material that had eroded down from the terraced stoneworking areas along the top of the spur. It now seems more likely, considering the chemical analyses and the fact that prodigious erosion would have been necessary to bring very much worked stone from the top of the spur to the base (and there is no evidence of this process along the spur top), that this deposit is a separate stoneworking area and subsource in its own right.

Since this present paper was written, further field work by one of us (S.B.) has established that the hill-slope itself is indeed a major quarry area, with preforms, and flakes ranging in size from 10 to 200 mm dia., extending over an area equivalent to that of quarry 2 on the fortification. This worked scree slope lies under a 5-10 m high basalt face, which seems likely to be a continuation of the high-titanium basalt exposed at the waterfall.

The spur end itself, immediately below the terraces where Leach excavated trenches 5 and 6 and just above the waterfall, was not sampled (although this has now been accomplished), and it may be that this is also part of the same basalt outcrop.

Quarrying and working must also have taken place at the base of the slope itself and at the waterfall exposure. Debris from all stages of manufacture has been recorded at these locations, and at the base of the slope the landowner had found a hammerstone which Leach describes as for use in the first stage of production, that of obtaining primary flakes from natural blocks (Leach and Witter 1985:28). Flakes are eroding out of the creek bank at this location (from at least 1 m below ground level), and it is certain that the small river flat, some 10 m wide and 60 m long, lying between the creek and the base of the hill-slope, contains many hundreds of tonnes of flaking debris, most of this in situ material. Boulders with grinding facets are also found in this vicinity.

Although Figure 1 shows the proposed Leafu subsource to be on both sides of the creek, this assumption is now thought to be incorrect, as little evidence for stoneworking has been found on the west side. It may also be premature to restrict this early source to the location described above, as the lateral distribution of the basalt flow characterised by high titanium has not been determined. Flaking debris is known from at least one other hill-slope adjacent to the rear of the Leone flats, and also occurs in all or most of the side-creeks running into these, and along the shores of Leone Bay itself (D. Herdrich, personal communication).

The same conditions apply to the location of the proposed low-titanium subsource. The 2500-1900-year-old flake from Manu'a tentatively assigned to this subsource suggests it was exploited early in the sequence.

SUMMARY

Adzes of Samoan typology, made from a fine dark basalt, and found in an area ranging from the Lau Island in Fiji north to Tokelau and west to the Outer Eastern Solomons, have been shown to have originated in Samoa. Some of these can be further assigned to the Leone area of Tutuila, and within this both to a very large fortification dating to between 600 and 900 years ago, and to an unmodified location or locations at the base of the hill itself, associated with the Leafu waterfall and stream. This hillbase subsource is thought to have been exploited before the fortification was built, and probably produced adzes, for the local people at least, from the time of earliest settlement some 3,000 years ago. By 2,200 years ago, adzes from both the Leafu subsource and, possibly at times, those on the hill were reaching Western Samoa.

A procedure for sourcing basalt adzes in the mid-Oceanic region of the Pacific has been set out progressing from initial macroscopic identification to thin-section petrographic work and finally to geochemical analysis. Simple plots using the three major elements titanium, iron and phosphorus have served to distinguish between island groups, between islands in the same group, between different locations on one island, and even possibly between different areas in one quarry. Many of these distinctions will need to be verified by the use of larger samples. It would, however, appear that it is the variation within a magma source, due mainly to crystal fractionation, that can help the archaeologist in the finer aspects of tracing a basalt to a specific source.

The finding that a loss on ignition value of more than 1 per cent appears to indicate a degree of weathering which affects the geochemical characteristics of the rock was unexpected, and should be of use in the future preparation of samples.

The results of the sourcing programme, together with the archaeology of the site, have enabled its importance as an adze quarry through time to be assessed (Fig. 9). If the single example from Mulifanua is representative, local rocks may have supplemented the adze kit for each settlement in the initial period of colonisation. By the middle of the first millennium B.C. it would seem that the basalt outcroppings at the waterfall and on the hill behind the back of the Leone river valley were reaching 'Upolu at least. While this

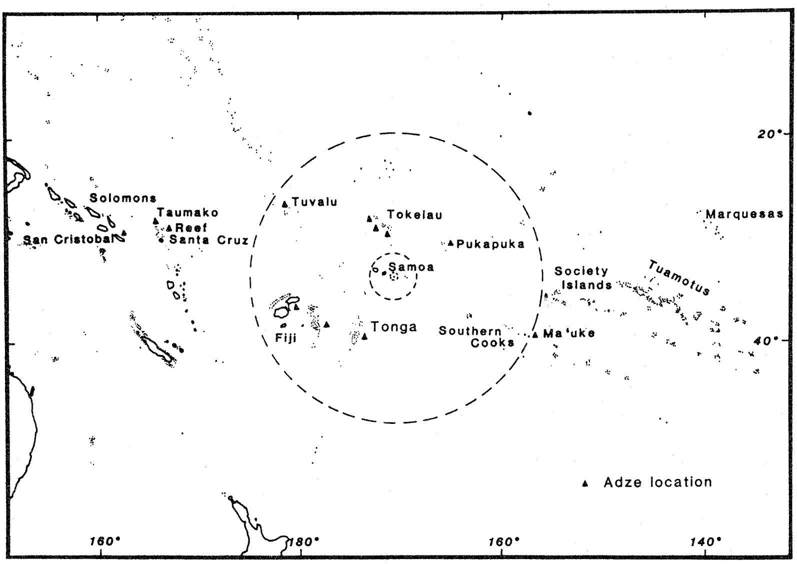

Figure 9. Distribution of Tatagmatau adzes over the life of the quarry.

may be a result of its superior qualities within Tutuila, it may equally well derive from the fact that the Leone flats, probably then, as now, the largest on the island, were a preferred place for settlement on Tutuila, with the movement of adzes merely part and parcel of the workings of a dominant social system.

At some time the Tutuila adze material moved further out into the Pacific, although the chronology and mechanism of this event or events remains to be discovered. While this may have occurred early in the prehistory of the area, the archaeological evidence suggests that it either began about 900 years ago or at least at that time assumed a more important role. At this time, or perhaps a few hundred years later, the exploitation of the Tataga Matau source changed with the construction of a very large fort on the ridge and spurs above and behind the quarry. While at least one of us (R.G.) agrees with Leach and Witter that the fortification was built to exploit and guard the basalt source on the hill, another (S.B.) believes the construction of the site relates to some other stimulus, with the stone from the two spur stoneworking areas a by-product of terrace construction, and the third (unmodified) stoneworking area used simply because it had become more readily accessible.

Some six smaller quarry sites have now been located in East Tutuila, a number which will probably increase with further surveys in that area (Clarke 1989). There is no reason to think that a similar concentration of basalt sources does not exist between these and Tataga Matau. Two large quarries have recently been discovered in this area, and another is suspected to exist. One of the former, at Fagasā on the north coast of Tutuila, south-west of Pago Pago, has been surveyed and found to be up to 80 per cent of the total exploited area on the Tataga Matau fort and quarry complex (Best, in prep.). The others are the Alega Quarry or quarries investigated by Clarke (personal communication)east of Pago Pago on the south coast, and a predicted source in the vicinity of the Maloata site on the north-west tip of the island, excavated by Bill Ayres (personal communication).

At the present stage of analysis, however, more than half the archaeological adzes fall into the Leafu subsources, especially those adzes that may predate the fortification. It is interesting to note that all the Fijian adzes come from the Leone source complex, while 'Upolu and Tokelau have adzes from all exploited areas on Tutuila that have been geochemically analysed. While this may be a function of their relative closeness and varied kinship ties which gave them access to multiple sources, or suggest that the Fiji connection was of short duration and from the Leone area, it may also be an indication that the other and minor sources were late.

At present, there is no securely dated early adze sourced to the East Tutuila quarries, while there is such evidence for the Leone basalt source complex.

Any competitor to the inland Leone rock in the early period of Samoa's prehistory should be in a location with comparable ease of access, either on the coast or at the rear of a stream. The size of these early quarries, even that at Leone, may not be very great, considering the presumed smaller populations of those times.

The search for such early sources might take two approaches. The first would be detailed site surveys, covering not only ridges but also valleys and their side slopes, and the coastal strip. If such a site does exist, one of the strongest pointers to it would be the tools it produced. Considerable collections of Samoan adzes now exist (there are two collections totalling 1,200 in New Zealand alone; Richards 1990), and some programme to study these should be attempted, with the aim, using information already obtained from this study, of conducting most of the work with macroscopic or nondestructive methods. Any resultant groupings should hold information on the importance of the known quarries through time, and also indicate where any unknown source might be.

The history of adze manufacture in Samoa is intricately enmeshed with many other aspects of the culture: with population size, technology, warfare, interacting local social systems and the movement of people to and from distant lands. This preliminary study indicates that it may be possible to throw light on some of these through further examination of the stone resources of the Samoan group.

APPENDIX: Sample provenance data.

SAMPLE NO.	DESCRIPTION	LOCATION
13-17, 39-42, 43-46	Archaeological flake, surface	Tataga Matau Quarry, stoneworking Area #1.
47	Archaeological flake, surface	Tataga Matau Quarry, Terrace ditch east of starmound.
30-38	Archaeological flake, surface	Tataga Matau Quarry, stoneworking Area # 2
23-29	Archaeological flake, surface	Tataga Matau Quarry, stoneworking Area #3.
18-22	Archaeological flake, surface	Tataga Matau, from foot of Ololua crater (market garden) spur.
9-12	Archaeological flake, surface	Tataga Matau, from west running spur off centre of site, middle terrace.
2	Geological sample from excavated cobble	Tataga Matau, from trench 7 (ext) on starmound terrace.

A7	Geological sample A	Tataga Matau, from upper quarry face, stoneworking Area # 1.
A8	Geological sample B	Tataga Matau, from lower slope between spurs, Quarry stone-working Area #1.
A9	Geological sample C	Tataga Matau, from exposure at waterfall, base of hill.
A10	Archaeological flake, surface collected	Tataga Matau, from base of hill.
A11	Archaeological flake surface collected	Tataga Matau, from somewhere in Olulua crater, (collr. H.L.).
A12	Archaeological flake surface collected	Tataga Matau, from Quarry stoneworking Area #1.
AN40	Archaeological flake surface collected	Tataga Matau, probably from Le Afu streambed, Leone-i-uta (Sinoto coll.)
AN 41	Archaeological flake	Tataga Matau, probably from Le Afu streambed, Leone (Sinoto coll.)
ST 25	Geological sample	From west of Leone, on south coast road, near Faga'one Point.
ST 26	Geological sample	Taputapu volcanics c. 100 m of ST 25.
ST 22	Geological sample	From west of Leone, on south coast road near Asili Point.
TUT 9	Geological sample	Pago volcan\ics From N.E. shore of Fagasā Bay.
6/1	Adze butt	East Tutuila, Site AS-21-6
II-2	Archaeological flake	East Tutuila, Asiapa Quarry (AS-22-31)
8	Archaeological flake	East Tutuila, Asiapa Quarry (AS-22-31)
II-3	Archaeological flake	East Tutuila, Laeano Quarry (AS-21-110)
II-4	Archaeological flake	East Tutuila, Lauagae Quarry (AS-21-100)
7	Archaeological flake	East Tutuila, Lauagae Quarry (AS-21-100)
II-5	Geological sample	East Tutuila, Mapua basalt outcrop sample. Near site AS-21-6
1	Geological sample	East Tutuila, Mapua basalt outcrop sample. Near site AS-21-6
4	Geological sample	East Tutuila, Mapua basalt outcrop sample. Near site AS-21-6
2/60	Archaeological flake	East Tutuila, Site AS-21-5
2/254	Archaeological flake	East Tutuila, Site AS-21-5

6	Archaeological flake	East Tutuila, Sa'ilele Quarry (AS-23-11).
6c	Archaeological flake	Manu'a Islands, Ta'ū village site (As-11-51).
53	Adze (exc.) (17/927)	Western Samoa, Site SA-3, SU-9, Layer 5, Sq. I-4.
55	Adze (exc.) (17/928)	Western Samoa, Site SA-3, SU-9, Layer 5, Sq. I-4.
8c	Adze	Western Samoa, 'Upolu Mulifaunua dredge tailings.
3c	Geological sample	Western Samoa, 'Upolu Ti'avea (Tai) (Rhys Richards).
A16/26	Adze Surface Coll. (A16/260)	Western Samoa, Savai'i, Fagae'e.
A12/17	Adze Surface Coll. (12/17)	Western Samoa, 'Upolu Luatuanu'u.
A16/16	Adze Surface Coll. (A16/167)	Western Samoa, Savai'i, Sasina.
A16/27	Adze Surface Coll. (A16/277)	Western Samoa, Savai'i, Sala'ilua.
3	Geological sample	Western Samoa, Mt Vaea (Moamoa) (H. Leach).
5	Geological sample	Western Samoa, Mt Vaea (Alamagato) (H. Leach).
UPO 1	Geological sample	Western Samoa, Mt Vaea basalt (Natland and Turner 1985)
UPO 2	Geological sample	Western Samoa, Mt Vaea basalt (Natland and Turner 1985)
UPO 3	Geological sample	Western Samoa, Mt Vaea basalt (Natland and Turner 1985)
UPO 4	Geological sample	Western Samoa, Mt. Vaea basalt (Natland and Turner 1985)
AN 10	Archaeological adze Surface collection	Fiji, Lau Group, Lakeba, Site 47
AN 11	Surface collection	Fiji, Lau Group, Lakeba, Site 47
AN 12	Archaeological adze exc.	Fiji, Lau Group, Lakeba, Site 47
AN 14	Archaeological adze, Surface collection	Fiji, Lau Group, Namuka, Site Na-1.
AN 15	Archaeological adze, Surface collection	Fiji, Lau Group, Kabara, Site Ka-1.
AN 16	Archaeological adze exc.	Fiji, Lau Group, Vanua Balavu, Site area Rasea
AN 17	Adze, ?Surface coll.	Fiji, Taveuni, Site area Ura.
AN 18	Adze, Surface coll.	Fiji, Lau Group, Moce, Site MO-6.

AN-19	Adze, Surface coll.	Fiji, Lau Group, Fulaga site, FU-18.
TO6-170	Adze, exc. (TO6-170)	Tonga, Site TO-6, Horizon 1.
TO6-20	Adze, exc. (TO6-20)	Tonga, Site TO-6, Horizon 1.
TO6-10	Adze, exc. (TO6-109)	Tonga, Site TO-6, Horizon 3.
TUV 26	Archaeological flake	Tuvalu, Site Temei, Layer IIa Depth 90.
TUV 27	Archaeological flake	Tuvalu, Site Temei.
TAU 48	Adze, Surface coll. (78-77)	Taumako, Kahula
TAU 49	Adze, exc. (A138)	Taumako, Kahula, Sq. L51, 10th level.
TAU 52	Adze, exc. (A172)	Taumako, Kahula, Sq. I52, 9th level.
TAU 54	Adze, Surface coll. (78-76)	Taumako, Kongo
RE-50	Adze, Surface coll. (D30317)	Nupani Island.
RE-51	Adze, Surface coll. (D30318)	Nupani Island.
BB-8-4-4(A)	Adze, Surface coll.	Na Mugha Village (BB8-4), San Cristobal.
TOK-A1	Adze, Surface coll. (R1)	Tokelau, Nukunonu Island.
TOK-A2	Adze, exc.	Tokelau, Atafu Island, 7-A2.
TOK-A3	Adze, exc.	Tokelau, Atafu Island, 5-C1.
TOK-A4	Adze, exc.	Tokelau, Atafu Island, 6-A2.
TOK-A5	Adze, exc.	Tokelau, Fakaofo Island, I-E.
TOK-A6	Adze, exc.	Tokelau, Fakaofo Island, 2-1.
TOK-A7	Adze, exc.	Tokelau, Fakaofo Island, 3-G2.
B8809	Adze, surface	Pukapuka
PIT-1	Flake, exc.	Pitcairn 640173 Tedside
PIT-2	Flake, exc.	Pitcairn Bill's Gdn SQ1 Layer 2
PIT-3	Flake, exc.	Pitcairn 640036 75/2E Bot. Char. Lens
PIT-4	Geol. Sample	Pitcairn Misc. surface
PIT-5	Flake, exc.	Pitcairn Bill's Gdn. SQ1 Layer 2
PIT-6	Flake, exc.	Pitcairn Bill's Gdn. SQ 1 Layer 2
PIT-7	Flake, exc.	Pitcairn 640173 Tedside
PIT-8	Flake, exc.	Pitcairn 640173 Tedside
PIT-9	Flake, exc.	Pitcairn 640173 Tedside
PIT-10	Flake, exc.	Pitcairn 640173 Tedside
AN-20	Flake, exc.	Pitcairn, Auckland Museum

AN-21	Flake, exc.	Pitcairn, Auckland Museum
AN-4 8	Flake, HEN-1-TP3-140	Henderson Island
AN-26	Flake, 31686.1	Hawai'i, Auckland Museum
AN-52	Flake, Ha-Q2-4	Hawai'i, Pololu Quarry
AN-53	Flake, Kh-Q1-1	Kahoolawe, Puu Moiwi Quarry
AN-54	Flake, Ha-Q1-1	Hawai'i, Mauna Kea Quarry
AN-55	Flake, Ha-Q1-3	Hawai'i, Mauna Kea Quarry
AN-56	Flake, Ha-Q1-5	Hawai'i, Mauna Kea Quarry
AN-65	Flake, Ha-Q1-2	Hawai'i, Mauna Kea Quarry
AN-66	Flake, Ha-Q1-4	Hawai'i, Mauna Kea Quarry
AN-49	?, Mo-Q3-5	Molokai
AN-50	Flake, Mo-Q2-15	Molokai, Moomomi Quarry
AN-57	Flake, Ma-Q1-2	Maui, Haleakala Quarry
AN-58	Flake, Oa-Q1-1	Oahu, Waiahole Quarry
AN-51	Flake, Oa-Q2-1	Oahu, Kailua Workshop/Quarry
AN-42	Flake	Marquesas, Eiao
AN-43	Flake, Tma-271	Marquesas, Maupiti
AN-45	Flake, MuHI-M74-51	Marquesas, Hane
AN-46	Flake, MH-21-90	Marquesas, Hiva Oa
AN-47	Flake, MN-1-K-14	Marquesas, Nukuhiva
AN-44	Flake, TR-785	Raiatea, Vaitopatapata
RW-A	Adze, Surface	Cooks, Atiu, Areora
RW-B	Geological	Cooks, Ma'uke, Te Rua o te Toki (source site)
RW-C	Adze, Surface	Cooks, Ma'uke, Makatea
RW-D	Adze, Surface	Cooks, Ma'uke, Areora
RW-E	Adze, exc.	Cooks, Ma'uke, Anai'o, layer 4, Flaking Area 1.
RW-F	Adze, exc.	Cooks, Ma'uke, Anai'o, layer 4, Flaking Area 5.
RW-G	Core, exc.	Cooks, Ma'uke, Anai'o, layer 4, Flaking Area 1.
RW-H	Adze, Surface	Cooks, Rarotonga, Arai-te-Tonga
RW-I	Adze, Surface	Cooks, Mangaia
RW-J	Adze, Surface	Cooks, Mitiaro
RW-K	Adze, Surface	Cooks, Ma'uke, Araki
RW-L	Adze, Surface	Cooks, Rarotonga, Arai-te-Tonga
RW-M	Adze flake, exc.	Cooks, Ma'uke, Anaio, layer 4, Area B.
RW-N	Adze, Surface	Cooks, Aitutaki, Vaipae
RW-O	Adze, Surface	Cooks, Mangaia
COOKS-1	Adze Flake, exc.	Cooks, Ma'uke, Anaio, layer 4, Area B.
COOKS-2	Adze Flake, exc.	Cooks, Ma'uke, Anaio, layer 4, Area B.

COOKS-3	Adze Flake, exc.	Cooks, Ma'uke, Anaio, layer 4, Area B.
COOKS-4	Adze Flake, exc.	Cooks, Ma'uke, Anaio, layer 4, Area B.

ACKNOWLEDGMENTS

We thank the following for providing research grants: National Geographic Society Committee for Research and Exploration #375088; University of Auckland Research Fund 403.166; Department of Anthropology, University of Auckland.

We should like to thank the following individuals for providing adze and flake samples: Yosihiko H. Sinoto, Department of Anthropology, and Toni Han Collections Manager, B. P. Bishop Museum; Jeffrey T. Clark, Department of Sociology/Anthropology, North Dakota State University; Jack Golson, Department of Prehistory, Australian National University; H. Leach and Richard Walter, Department of Anthropology, University of Otago; Jun Takayama, Tezukayama University; Foss Leach, Foss Enterprises, Wellington; Pat Kirch, Department of Anthropology, University of California at Berkeley; Terry Hunt, Department of Anthropology, University of Hawai'i; Rhys Richards, Department of Foreign Affairs, Wellington.

Phillipa Black, Department of Geology, University of Auckland, kindly provided thin-section analysis of the Tataga Matau basalt. Elizabeth Wright, Department of Geological Science, University of Illinois, provided valuable criticism of the elemental data presentation. We should also like to thank Bill Ayres, Department of Anthropology, University of Oregon, for information on the location of a newly discovered quarry on Tutuila, and Tom Dye for providing informa-tion on Tongan material. Ian Smith, Department of Geology, University of Auckland, provided the initial series of XRF analyses. Dave Simmons, former ethnologist at the Auckland War Memorial Museum, permitted sampling of adzes held in the museum. Jan Duncan (Department of Anthropology, University of Auckland) prepared Figures 1 3.

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——— and J. T. Clark, n.d. Geochemical Analysis of Materials Found in and around Archaeological Sites on Tutuila, American Samoa.

CLUSTER	TYPE	LOCATION	SAMPLE	SiO_2	TiO_2	Al_2O_3	Fe_2O_3T	MnO	MgO	CaO	Na_2O	K_2O	P_2O_5	LOI
1A	F	TTM-A1	13	47.93	3.48	15.75	13.79	0.17	4.81	7.38	3.44	1.64	0.78	0.15
1A	F	TTM-A1	15	48.19	3.44	15.62	13.56	0.17	4.94	7.52	3.56	1.56	0.78	0.02
1A	F	TTM-A1	40	48.20	3.42	15.63	13.65	0.16	4.96	7.53	3.48	1.56	0.78	0
1A	F	TTM-A2	32	47.78	3.53	15.67	13.81	0.17	5.06	7.63	3.60	1.47	0.75	-0.03
1A	F	TTM-A2	31	47.98	3.56	15.56	13.78	0.16	4.90	7.66	3.57	1.51	0.75	0.01
1A	F	TTM-A2	38	47.83	3.54	15.41	13.94	0.16	4.90	7.58	3.69	1.49	0.74	-0.32
1A	A	TAUMAKO-KONGO	TAU-48	47.62	3.41	15.27	13.66	0.16	4.96	7.50	3.72	1.51	0.74	0.51
1A	A	W-SAMOA	53	48.38	3.31	15.60	13.15	0.16	4.87	7.39	3.80	1.54	0.79	-0.05
1A	A	FIJI-LAU	AN14	47.85	3.37	15.40	13.83	0.18	4.63	7.52	4.07	1.45	0.89	0.27
1A	A	FIJI-LAU	AN15	47.73	3.32	15.44	13.56	0.17	4.76	7.44	3.99	1.50	0.88	0.57
1A	A	FIJI-LAU	AN18	48.61	3.36	15.52	13.90	0.16	4.79	7.49	4.05	1.49	0.87	-0.03
1A	F	TTM-A2	33	47.27	3.54	15.48	13.53	0.18	4.87	7.59	3.38	1.48	0.73	0.07
1A	A	TAUMAKO-KAHULA	TAU-54	47.43	3.51	15.11	13.65	0.18	4.96	7.56	3.68	1.49	0.74	0.28
1A	F	TTM-MKT-GDN	22	47.35	3.51	15.30	13.95	0.17	4.75	7.41	3.65	1.49	0.74	0.63
1A	F	TTM-WEST-SPUR	10	48.08	3.63	15.48	14.17	0.18	4.68	7.62	3.46	1.49	0.77	0.12
1A	F	TTM-A1	14	48.38	3.45	15.54	13.70	0.18	4.96	7.57	3.60	1.51	0.76	-0.35
1A	F	TTM-A3	27	48.22	3.44	15.65	13.70	0.18	4.88	7.56	3.66	1.55	0.78	-0.24
1A	F	TTM-MKT-GDN	18	47.94	3.48	15.52	13.64	0.18	4.83	7.44	3.65	1.53	0.76	0.11
1A	F	TTM-A1	16	48.51	3.36	15.68	13.45	0.18	4.78	7.55	3.82	1.57	0.80	-0.38
1A	F	TTM-A3	25	48.15	3.35	15.61	13.35	0.18	4.91	7.48	3.87	1.57	0.79	-0.17
1A	F	TTM-A3	26	48.23	3.36	15.54	13.38	0.18	4.90	7.42	3.59	1.61	0.80	-0.06
1A	G	TTM-A1	A7	48.28	3.45	15.55	13.38	0.18	4.59	7.66	3.89	1.58	0.80	0.37
1A	F	TTM-A1	A12	48.27	3.50	15.43	13.4	0.18	4.71	7.63	3.89	1.56	0.8	0.43
1A	F	TTM-A1	45	48.31	3.43	15.81	13.49	0.19	4.90	7.65	3.81	1.53	0.79	-0.35
1A	F	TTM-A3	28	48.25	3.39	15.70	13.63	0.19	4.85	7.49	3.75	1.57	0.80	-0.23
1A	F	TTM-A3	29	48.47	3.37	15.62	13.47	0.19	4.71	7.51	3.88	1.57	0.79	-0.36
1A	A	TOKELAU-ATAFU	TOK-A2	48.30	3.43	15.68	13.62	0.19	4.93	7.75	3.82	1.65	0.80	-0.31
1A	F	TTM-A1	17	48.56	3.37	15.61	13.42	0.17	4.80	7.55	3.76	1.57	0.80	-0.34
1A	F	TTM-MKT-GDN	19	47.97	3.55	15.67	13.57	0.19	4.87	7.68	3.69	1.47	0.75	0.02
1A	F	TTM-A3	23	48.86	3.40	15.71	13.48	0.17	4.61	7.61	3.63	1.57	0.78	-0.44

Table 1. Data on major and minor elements (XRF) for Pacific Basalts. Type = sample type (F = archaeological flake, G=geological sample, A= archaeological adze). LOI = loss on ignition.

CLUSTER	TYPE	LOCATION	SAMPLE	SiO_2	TiO_2	Al_2O_3	Fe_2O_3T	MnO	MgO	CaO	Na_2O	K_2O	P_2O_5	LOI
1A	F	TTM-A3	24	48.54	3.28	15.77	13.12	0.18	4.78	7.42	3.69	1.61	0.79	0.11
1A	F	TUTUILA-LE AFU	AN40	48.58	3.34	15.49	14.08	0.19	4.79	7.55	3.68	1.60	0.88	-0.1
1A	F	MANUA	6C	48.38	3.28	15.65	13.74	0.20	4.70	7.70	3.97	1.66	0.87	-0.14
1A	F	TTM-EAST-STAR-MOUND	47	47.64	3.53	15.42	13.74	0.20	5.16	7.54	3.52	1.49	0.74	0.27
1A	F	TTM-A2	37	48.05	3.56	15.43	13.86	0.20	4.94	7.57	3.66	1.48	0.75	-0.07
1A	F	TTM-WEST-SPUR	11	47.75	3.55	15.41	13.99	0.19	4.85	7.59	3.59	1.50	0.75	0.06
1A	F	TTM-WEST-SPUR	12	47.51	3.56	15.51	14.03	0.20	4.77	7.54	3.76	1.48	0.75	0.14
1A	F	MAUKE-4	RW-M	47.92	3.43	15.53	13.57	0.21	4.77	7.74	3.91	1.54	0.81	0.01
1B	F	TTM-CRATER	A11	47.90	3.62	15.50	13.35	0.18	4.76	7.63	3.57	1.64	0.77	0.0
1B	A	E-TUTUILA-AS-21-6	6/1	47.49	3.78	15.65	14.56	0.18	5.02	7.74	3.46	1.54	0.74	
1B	A	TOKELAU-FAKAOFO	TOK-A6	47.92	4.09	15.77	13.23	0.18	5.01	7.90	3.33	1.70	0.75	0.14
1B	F	E-TUTUILA-LAEANO-Q-AS-21-110	II.3	47.80	3.71	16.09	14.16	0.18	4.84	7.71	3.65	1.61	0.76	
1B	F	E-TUTUILA-LAUAGAE-Q-AS-21-100	II.4	47.95	3.82	15.96	13.90	0.16	4.89	7.71	3.63	1.51	0.73	
1B	G	E-TUTUILA-MAPUA	II.5	47.82	3.81	16.00	14.03	0.16	4.99	7.73	3.59	1.53	0.73	
1B	G	E-TUTUILA-MAPUA	1	47.48	3.80	15.97	13.90	0.19	5.06	7.73	3.55	1.49	0.69	-0.41
1B	F	E-TUTUILA-AS-21-5	2/254	46.47	4.16	15.63	14.70	0.17	5.41	7.97	3.32	1.34	0.66	
1B	G	W-SAMOA-UPOLU	3C	47.98	4.00	15.77	13.59	0.17	4.94	7.83	3.69	1.45	0.68	-0.40
1B	A	TOKELAU-ATAFU	TOK-A4	47.42	3.81	15.92	13.54	0.16	4.99	7.85	3.75	1.45	0.73	-0.42
1B	A	TOKELAU-FAKAOFO	TOK-A7	47.48	4.05	15.68	13.54	0.16	4.75	7.81	3.51	1.40	0.73	0.07
1C	A	W-SAMOA-SAVAI'I	A16/167	48.90	3.10	15.70	13.32	0.18	4.56	7.21	4.38	1.60	0.97	0.39
1C	A	FIJI-LAU	AN16	48.75	3.05	16.01	13.06	0.18	4.67	7.08	4.27	1.63	0.94	0.37
1C	A	W-SAMOA-SAVAI'I	A16/277	49.64	3.22	15.47	13.33	0.18	4.51	7.51	4.01	1.72	0.90	-0.54
1C	A	TONGA-TO6-3	TO6-109	49.16	3.23	15.63	13.00	0.19	4.52	7.58	4.01	1.59	0.83	-0.15
1C	A	TOKELAU-NUKUNONU	TOK-A1	48.51	3.10	16.40	12.71	0.18	4.63	7.39	3.96	1.71	0.85	0.0
1C	A	SAN CRISTOBAL-NA-MUGHA	BB-8-4(a)	48.73	3.25	16.14	13.75	0.17	4.58	7.27	4.12	1.66	.86	0.12
1C	F	TUVALU-TEMEI	TUV-27	49.03	2.87	15.74	13.00	0.20	4.52	7.25	4.27	1.77	1.08	-0.05

CLUSTER	TYPE	LOCATION	SAMPLE	SiO_2	TiO_2	Al_2O_3	Fe_2O_3T	MnO	MgO	CaO	Na_2O	K_2O	P_2O_5	LOI
O	A	PUKAPUKA	B8809	47.49	3.38	15.34	15.26	0.18	4.91	7.73	3.77	1.49	0.79	0.0
1D	F	TTM-A1	41	47.88	3.54	15.46	13.85	0.14	4.92	7.77	3.47	1.56	0.76	-0.08
1D	F	TTM-A2	34	47.89	3.56	15.68	13.87	0.14	4.95	7.67	3.52	1.51	0.76	-0.09
1D	F	TTM-A2	30	47.80	3.53	15.74	13.79	0.15	4.92	7.61	3.60	1.49	0.77	0.02
1D	F	TTM-WEST-SPUR	9	47.72	3.62	15.62	13.93	0.15	4.96	7.69	3.26	1.51	0.76	0.03
1D	F	TTM-A1	42	48.23	3.43	15.50	13.56	0.14	4.84	7.54	3.66	1.55	0.77	0.09
1D	F	TTM-A1	46	48.47	3.41	15.65	13.46	0.14	5.07	7.60	3.53	1.53	0.79	-0.2
1D	F	TTM-A1	43	48.33	3.40	15.76	13.51	0.15	4.95	7.59	3.89	1.55	0.78	-0.25
1D	F	TTM-A1	44	48.14	3.42	15.73	13.55	0.15	4.84	7.52	3.68	1.52	0.78	-0.1
1D	F	TTM-A2	36	47.73	3.52	15.64	13.71	0.13	4.86	7.45	3.61	1.53	0.73	0.32
1D	F	TTM-MKT-GDN	21	47.79	3.49	15.33	13.78	0.13	4.94	7.56	3.69	1.46	0.74	0.14
1D	F	E-TUTUILA-LAUAGAE-Q-AS-21-100	7	47.98	3.87	16.23	13.47	0.14	5.08	7.73	3.62	1.45	0.71	-0.34
1D	G	TTM-TRENCH 7 (EXT)	2	47.58	3.59	15.93	13.10	0.14	4.55	7.29	3.36	1.49	0.78	0.88
1D	G	E-TUTUILA-MAPUA	4	47.12	3.79	16.10	13.53	0.13	4.95	7.60	3.52	1.47	0.72	0.31
1D	F	TTM-MKT-GDN	20	48.02	3.42	15.55	13.58	0.13	4.94	7.50	3.69	2.06	0.77	-0.49
OUT	F	TTM-A2	35	45.61	3.68	15.90	14.27	0.13	4.63	6.96	2.99	1.42	0.84	1.75
OUT	F	TTM-A1	39	47.96	3.49	15.73	13.58	0.24	4.83	7.51	3.80	1.51	0.78	-0.03
2	G	TTM-A1-LOWER	A8	45.52	4.82	15.36	14.40	0.18	5.79	8.21	3.28	1.19	0.59	0.71
2	F	TTM-BASE-HILL	A10	45.82	4.82	15.25	14.13	0.17	5.82	8.26	3.30	1.22	0.58	0.98
2	A	TAUMAKO-KAHULA	TAU-49	45.22	4.51	15.33	13.93	0.17	5.87	8.11	3.13	1.22	0.57	0.59
2	F	TUTUILA-LE AFU	AN41	45.86	4.78	15.53	14.77	0.17	5.64	8.48	3.14	1.24	0.67	-0.3
2	A	TOKELAU-ATAFU	TOK-A3	45.59	4.65	15.71	14.35	0.18	5.85	8.46	3.21	1.28	0.64	-0.1
2	A	W-SAMOA-UPOLU	12/17	45.31	4.58	15.33	14.46	0.19	5.67	8.09	3.67	1.22	0.69	0.34
2	G	TTM-WATER-FALL	A9	46.45	4.53	15.52	14.06	0.18	5.70	8.17	3.32	1.39	0.61	0.36
2	F	E-TUTUILA-SA'ILELE-Q	6	45.90	4.26	15.55	14.00	0.19	5.41	7.83	3.23	1.35	0.64	0.48
2	F	MAUKE-ANAIO	COOKS1	46.41	4.51	15.27	14.31	0.22	5.90	8.35	3.43	1.23	0.59	0.31
2	A	FIJI-LAU	AN19	46.42	4.82	15.65	14.94	0.21	5.70	8.51	3.52	1.26	0.67	-0.03
2	A	FIJI-TAVEUNI	AN17	46.41	4.79	15.72	14.63	0.13	5.94	8.38	3.53	1.21	0.66	-0.55

CLUSTER	TYPE	LOCATION	SAMPLE	SiO_2	TiO_2	Al_2O_3	Fe_2O_3T	MnO	MgO	CaO	Na_2O	K_2O	P_2O_5	LOI
2	A	TAUMAKO-KAHULA	TAU-52	46.26	4.17	15.57	14.07	0.15	5.41	7.94	3.19	1.34	0.64	0.45
O	G	MOOMOMI-Q	AN50	44.57	4.11	15.66	15.73	0.19	6.04	8.41	3.35	0.90	0.67	0
O	G	W-SAMOA-MT-VAEA	5	45.56	4.56	14.33	14.11	0.20	5.33	9.48	3.19	1.20	0.62	0.45
3	F	MARQUESAS-EIAO	AN42	46.74	3.83	15.09	13.50	0.17	6.52	9.37	3.11	1.01	0.58	-0.1
3	F	MARQUESAS-HANE	AN45	46.56	3.79	14.97	13.60	0.18	6.44	9.45	3.07	1.01	0.56	-0.1
3	F	MARQUESAS-NUKUHIVA	AN47	47.07	3.83	15.17	13.34	0.18	6.23	9.35	3.26	1.04	0.55	-0.3
O	G	W-SAMOA-MT-VAEA	3	45.34	3.15	15.69	13.06	0.20	6.31	8.73	3.64	1.29	0.77	0.73
4	F	E-TUTUILA-ASIAPA-Q	II.2	50.24	2.94	16.01	12.87	0.18	4.11	7.26	3.99	1.77	1.25	
4	A	NUPANI	REEF-51	50.08	2.76	15.79	12.11	0.17	4.35	7.21	4.09	1.80	1.17	-0.09
4	F	E-TUTUILA-ASIAPA-Q	8	48.86	2.89	15.46	12.40	0.16	4.05	7.15	3.62	1.74	1.20	0.08
4	A	MAUKE-4	RW-F	49.45	2.73	16.61	11.91	0.20	4.19	7.13	4.55	1.88	1.00	0.05
5	F	PITCAIRN-AUCK-MUS	AN20	49.46	2.72	15.32	13.68	0.22	3.66	7.07	4.51	1.88	1.45	-0.01
5	F	PITCAIRN	PIT-1	49.94	2.64	15.58	13.42	0.22	3.54	7.15	4.79	2.03	1.21	-0.43
5	F	PITCAIRN	PIT-2	49.93	2.67	15.47	13.49	0.22	3.50	7.19	4.66	2.01	1.23	-0.34
5	F	PITCAIRN	PIT-7	50.04	2.68	15.54	13.46	0.22	3.73	7.18	4.58	1.96	1.24	-0.41
5	F	PITCAIRN	PIT-3	49.89	2.64	15.35	13.45	0.23	3.60	7.16	4.81	2.14	1.25	-0.31
5	F	PITCAIRN	PIT-8	49.89	2.65	15.31	13.44	0.20	3.55	7.06	4.75	2.00	1.22	0.1
5	F	PITCAIRN-AUCK-MUS	AN21	50.93	2.71	15.57	13.78	0.23	3.46	7.09	4.67	2.03	1.39	-0.42
5	F	PITCAIRN	PIT-4	49.59	2.60	15.39	13.39	0.24	3.54	7.03	4.78	2.04	1.21	-0.29
5	F	PITCAIRN	PIT-9	50.13	2.62	15.40	13.58	0.25	3.55	7.07	4.80	2.02	1.21	-0.42
5	F	PITCAIRN	PIT-10	49.57	2.64	15.45	13.50	0.25	3.61	7.07	4.65	1.99	1.23	-0.13
5	F	PITCAIRN	PIT-5	49.86	2.65	15.50	13.20	0.25	3.48	7.12	4.69	2.00	1.23	-0.43
5	F	PITCAIRN	PIT-6	49.21	2.61	15.28	13.48	0.25	3.61	7.01	4.61	1.93	1.19	0.22
O	G	HAWAII-POLOLU-Q	AN52	49.49	2.44	16.64	11.90	0.23	3.71	6.62	5.13	1.86	1.97	0.2
O	F	HENDERSON	AN48	50.93	2.35	16.31	11.25	0.20	2.87	6.74	4.97	2.42	1.17	0.4
6	F	EASTER-AUCK	SB5	50.90	2.66	14.89	13.44	0.23	3.29	7.24	4.15	1.19	0.77	0.96
6	A	EASTER-AUCK	SB6	51.03	2.64	14.73	13.44	0.33	3.22	7.18	4.11	1.25	0.79	0.67
7	A	W-SAMOA -MULIFANUA-DREDGE	8C	42.94	3.82	14.98	14.20	0.21	6.65	9.77	4.27	2.05	0.64	0.10

CLUSTER	TYPE	LOCATION	SAMPLE	SiO_2	TiO_2	Al_2O_3	Fe_2O_3T	MnO	MgO	CaO	Na_2O	K_2O	P_2O_5	LOI
7	F	MANGAIA	RW-I	42.18	4.57	14.50	14.80	0.24	5.21	9.48	3.55	1.97	0.83	1.77
8	F	RAROTONGA	RW-H	43.60	4.51	15.68	12.44	0.18	5.14	10.12	3.74	2.27	0.98	0.73
8	F	AITUTAKI	RW-N	44.98	3.77	15.65	12.87	0.20	4.74	9.61	3.33	2.39	0.85	0.99
8	F	RAROTONGA	RW-L	43.35	3.88	15.11	12.81	0.21	5.24	10.73	2.63	2.73	0.84	1.77
8	F	MAUKE	RW-K	42.74	4.34	14.53	13.63	0.20	5.07	11.14	3.33	2.42	1.12	0.55
8	A	MAUKE	RW-D	42.25	3.42	15.10	14.46	0.20	5.35	11.21	4.05	1.23	0.60	1.2
8	F	MITIARO	RW-J	43.07	3.78	16.30	12.92	0.21	5.58	10.28	3.43	1.21	0.50	2.28
8A	F	MAUKE	COOKS2	44.13	3.69	16.35	13.31	0.22	5.41	10.11	4.02	1.14	0.49	1.16
8A		MAUKE	COOKS3	43.73	3.7	16.29	13.53	0.21	5.45	10.35	3.98	1.04	0.49	1.16
8A		MAUKE	COOKS4	44.12	3.75	16.55	13.13	0.18	4.91	10.62	3.73	0.86	0.5	1.61
O	F	MANGAIA	RW-O	46.00	3.67	16.31	11.36	0.26	4.61	9.34	3.90	1.79	0.74	1.7
9	G	TUTUILA-LEONE-WEST	ST25	47.40	3.91	12.90	14.32	0.15	8.70	8.84	3.03	0.80	0.56	
9	G	TUTUILA-LEONE-EAST	ST26	47.70	3.86	12.60	13.45	0.14	8.20	8.72	2.90	0.95	0.54	
10	A	W-SAMOA	55	46.22	4.34	13.64	13.60	0.14	7.61	8.66	3.20	1.23	0.65	-0.12
10	F	TUVALU-TEMEI	TUV-26	46.13	4.29	13.46	14.00	0.16	7.54	8.88	3.24	1.28	0.67	-0.41
10	A	W-SAMOA-SAVAI'I	A16/260	47.29	4.23	13.54	13.70	0.17	8.03	8.94	3.18	1.13	0.62	-0.54
10	A	FIJI-LAU	AN11	47.20	4.68	13.70	13.79	0.20	6.82	8.72	3.15	0.99	0.58	0.07
10	A	FIJI-LAU	AN12	46.90	4.60	13.94	13.41	0.16	6.41	8.51	3.29	1.02	0.61	0.42
10	A	TOKELAU-FAKAOFO	TOK-A5	47.63	4.74	14.09	13.72	0.17	6.76	9.06	2.82	1.03	0.56	-0.41
O	F	E-TUTUILA-AS-21-5	AS/21/5	44.77	4.62	12.38	13.71	0.17	11.25	8.56	1.80	0.90	0.60	
11	G	W-SAMOA-MT-VAEA	UPO1	47.80	4.04	13.90	13.71	0.17	5.60	10.39	3.08	0.80	0.47	
11	G	W-SAMOA-MT-VAEA	UPO4	48.40	4.11	13.80	13.00	0.15	4.60	10.11	2.63	1.04	0.46	
0	F	MARQUESAS-HIVA-OA	AN46	48.20	3.67	14.28	12.50	0.17	5.64	9.54	3.00	1.75	0.57	0.2
12	G	HAWAII-MAUNA-KEA-Q	AN55	47.92	3.99	13.32	15.45	0.23	4.88	9.44	3.13	1.20	0.61	-0.4
12	G	HAWAII-MAUNA-KEA-Q	AN65	47.94	3.93	13.37	15.28	0.22	4.98	9.47	3.00	1.16	0.58	-0.51
12	A	HAWAII-AUCK-MUS	AN26	48.46	4.00	13.55	15.30	0.21	5.04	9.38	3.43	1.12	0.59	-0.08
12	G	HAWAII-MAUNA-KEA-Q	AN66	46.66	3.98	13.09	15.69	0.21	5.01	9.71	3.08	1.14	0.57	0.1
12		HAWAII-MAUNA-KEA-Q	AN56	47.87	3.60	13.73	15.14	0.21	5.42	10.01	2.74	0.99	0.49	-0.5

CLUSTER	TYPE	LOCATION	SAMPLE	SiO_2	TiO_2	Al_2O_3	Fe_2O_3T	MnO	MgO	CaO	Na_2O	K_2O	P_2O_5	LOI
13	A	MAUKE-4	RW-G	41.11	4.23	14.31	17.14	0.27	6.31	8.18	4.30	1.69	1.21	0.75
13	A	MAUKE-4	RW-E	41.46	4.24	14.50	16.93	0.26	6.39	8.14	4.76	1.67	1.20	0.29
O	G	TUTUILA-FAGASA	TUT9	46.20	4.09	13.70	12.01	0.15	9.50	9.35	2.99	1.05	0.33	
14	G	W-SAMOA-MT-VAEA	UPO2	47.20	3.12	13.20	12.95	0.15	8.20	11.43	2.57	0.52	0.35	
14	G	W-SAMOA-MT-VAEA	UPO3	48.80	3.37	14.00	12.96	0.15	6.40	10.75	2.63	0.69	0.38	
15	G	KAHOOLAWE-PUU-MOI.-Q	AN53	51.84	2.95	13.68	13.38	0.19	4.69	8.65	3.11	0.81	0.43	-0.1
15	G	MOLOKAI	AN49	50.14	2.67	13.81	12.97	0.17	5.85	9.59	2.26	0.57	0.38	0.8
16	G	OAHU-WAIAHOLE-Q	AN58	52.54	2.16	13.71	11.25	0.16	6.47	9.16	2.59	0.74	0.36	0.7
16	G	OAHU-KAILUA-Q	AN51	52.89	2.13	13.66	11.44	0.16	5.67	9.45	2.85	0.40	0.33	0.8
O	A	TONGA-TO6-1	TO6-170	49.82	2.50	16.63	10.43	0.21	3.94	7.57	4.54	1.34	0.68	1.83
17	A	TONGA-TO6-1	TO6-20	52.95	1.92	16.92	9.60	0.22	3.06	6.17	5.20	1.52	0.89	0.92
O	G	MAUI-HALEAKALA-Q	AN57	51.13	2.00	17.46	10.54	0.25	2.46	6.31	6.26	2.25	0.93	0.2
TRIMMED FROM THE CLUSTER ANALYSIS														
	G	TUTUILA-LEONE-WEST	ST22	46.10	3.47	10.80	13.69	0.15	12.30	9.29	2.70	0.89	0.40	
	A	NUPANI	REEF-50	40.49	2.89	12.89	11.13	0.18	4.30	13.33	3.00	1.23	0.64	9.07
	F	ATIU	RW-A	47.70	2.48	18.34	9.55	0.18	2.67	7.50	5.72	2.39	0.83	2.1
	F	MAUKE	RW-C	41.83	3.83	17.20	12.30	0.19	3.58	8.78	4.50	1.85	1.30	2.9
		ATUTAKI	SB1	39.61	2.54	11.37	12.68	0.21	12.46	12.16	4.36	1.71	1.15	1.79
	A	COOKS	ANT70	50.73	1.00	19.98	6.46	0.25	0.85	4.77	8.34	5.42	0.26	2.43
	A	COOKS	ANT71	52.50	0.72	21.13	5.24	0.24	0.25	2.96	9.59	5.24	0.16	1.65
	A	FIJI-LAU	AN10	46.07	3.16	14.53	13.01	0.19	4.54	7.18	3.83	1.40	0.98	5.24
	?	MARQUESAS-MAUPITI	AN43	43.10	3.56	15.32	13.39	0.19	4.77	10.39	3.95	1.87	0.76	2.9
	F	RAIATEA	AN44	44.63	4.34	14.65	12.97	0.17	5.14	11.14	2.86	1.69	0.73	1.6
	G	HAWAII-MAUNA-KEA-Q	AN54	30.33	2.38	8.59	9.97	0.13	3.41	6.39	1.82	0.68	0.34	35.6

Sample	Nb	Zr	Y	Sr	Rb	Th	Pb	As	Zn	Cu	Ni	Cr	V	Ba	La
42	45	406	48	716	42	0	0	0	192	12	0	0	208	308	48
17	42	406	50	720	38	5	4	0	191	8	0	0	214	330	45
43	44	394	48	711	39	0	6	0	194	0	0	0	199	301	45
15	44	406	50	710	44	0	0	0	195	7	0	0	221	297	43
44	43	412	50	717	45	0	0	0	193	10	0	0	207	320	45
33	43	395	48	707	44	0	5	0	180	9	0	0	214	320	43
38	43	395	49	712	34	0	5	0	192	11	0	7	220	313	43
34	42	399	48	712	39	4	5	0	189	0	0	0	226	310	46
37	42	403	47	709	43	0	0	6	190	7	0	0	226	316	42
30	42	387	45	707	39	6	6	0	196	7	0	0	224	309	43
26	43	417	50	713	43	0	0	0	195	12	0	0	215	324	44
29	45	405	49	708	38	5	6	0	192	8	0	7	204	309	42
24	44	419	52	713	45	4	9	0	187	0	0	0	200	333	44
25	44	407	48	709	45	0	0	7	198	10	0	0	203	318	43
23	44	407	50	721	41	4	5	0	190	15	6	0	209	314	44
A10	37	333	43	599	29	0	0	0	159	22	38	6	315	256	32
A8	37	347	41	604	31	5	6	0	150	22	43	0	293	264	35
AN41	40	350	43	622	28	0	6	0	549	26	41	0	305	271	34
AN40	44	424	51	742	50	0	8	0	197	0	0	0	197	326	44
A9	39	365	45	618	36	0	0	6	156	36	27	7	279	267	33
5	41	343	38	518	33	0	8	0	143	78	53	40	491	294	38
3	50	240	32	796	32	0	7	0	130	48	60	115	266	387	48
53	44	412	50	708	44	0	9	0	192	0	0	0	199	327	48
TAU48	42	371	46	735	42	15	8	0	184	8	0	0	216	319	44
TAU52	36	351	42	594	33	0	9	0	153	10	13	22	248	269	32
TAU54	40	380	46	686	40	4	13	9	170	105	319	758	214	286	45
TOK(A2)	43	408	47	719	40	7	10	0	187	15	10	0	201	313	44
TO6(109	45	391	48	742	39	4	7	5	257	7	0	0	197	354	46
A2(TO6-170)	33	186	39	413	27	0	8	0	96	12	0	0	208	380	28
BB-8-4-4A	44	445	50	668	45	0	5	6	157	65	260	664	184	325	53
B8809	41	395	45	714	42	5	5	5	173	67	345	828	219	281	44
II-2	48	451	55	755	41	0	0	0	193	23	17	0	153	426	49
COOKS1	39	347	42	598	27	0	9	0	159	42	54	0	279	264	36
COOKS2	63	241	33	717	20	6	5	0	110	34	19	0	248	370	48
COOKS3	63	239	32	708	17	4	7		116	37	23	0	272	372	52
COOKS4	63	245	34	734	13	0	5		115	39	24	0	285	372	48

Table 2. Trace element data (XRF) on Tataga Matau quarry and associated archaeological samples