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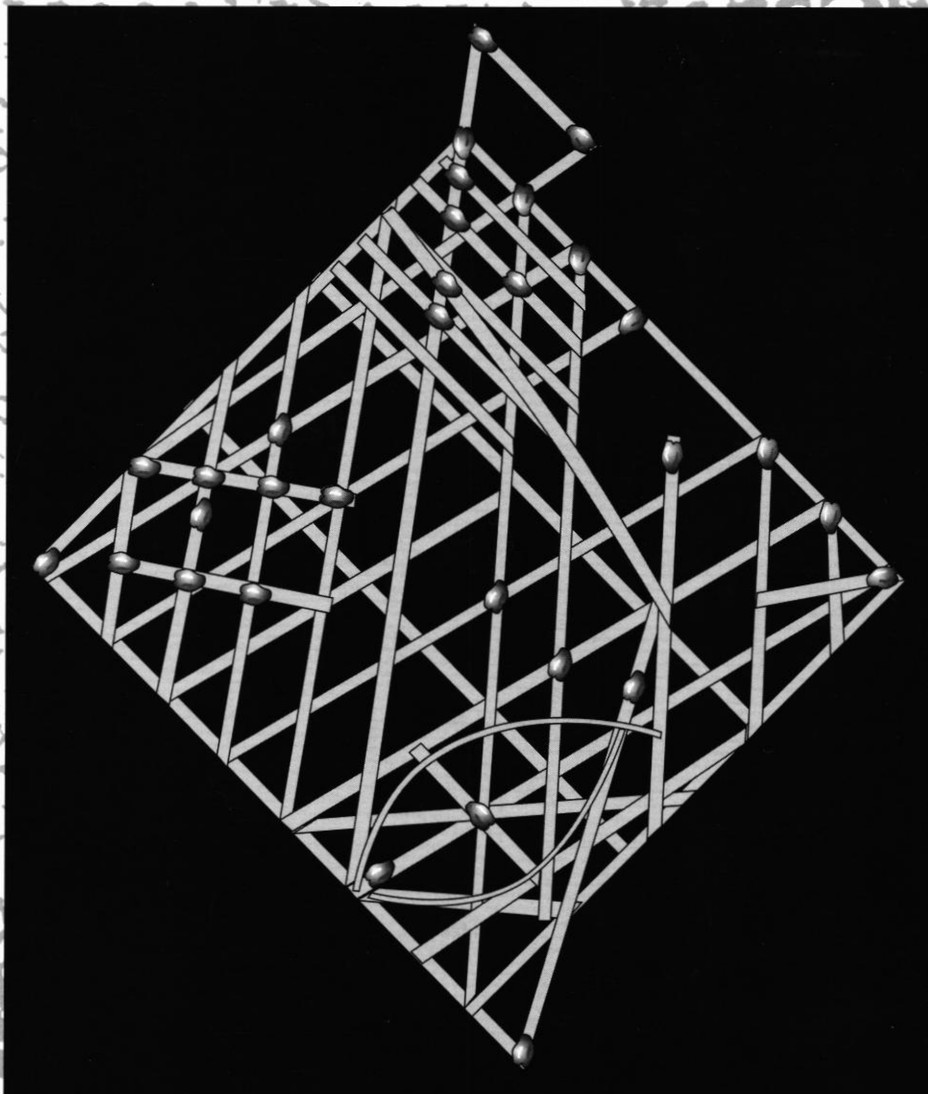

PREHISTORIC LONG-DISTANCE INTERACTION IN OCEANIA: AN INTERDISCIPLINARY APPROACH

Edited by Marshall I. Weisler

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NEW ZEALAND ARCHAEOLOGICAL ASSOCIATION MONOGRAPH

INTERACTIONS WITHIN AND BEYOND THE SAMOAN ARCHIPELAGO: EVIDENCE FROM BASALTIC ROCK GEOCHEMISTRY

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The islands of Samoa are critically important for understanding the prehistory of the central Pacific. It is well known that prehistoric Samoans had long-term socioeconomic interactions with the inhabitants of Tonga and Fiji (Davidson 1977). Indeed, Kaeppler (1978) has argued that Fiji-Tonga-Samoa constituted a large social system with extensive inter-island relations, although each island group retained a distinctive culture. Central to these relations were exchanges of valued goods that included spouses, fine mats, bark cloth, wooden bowls, red feathers and more. Much about these important exchanges cannot be gleaned from the archaeological record. But by concentrating on valued non-perishable resources, archaeologists can broadly outline the network of inter-island contacts over space and time.

In the Fiji-West Polynesia region, arguably the most important of the non-perishable materials was fine-grained basaltic rock. This material was used for the manufacture of adzes, which were the most widely used stone tools in Oceania. Other tools of basaltic rock were also employed, though these were predominantly informal flake tools. Basaltic rock with desirable flaking qualities is not evenly distributed throughout the region, thus making it a valued item of exchange.

In this paper we summarise archaeological and geochemical studies of basaltic rock and its exploitation sites. Special attention is given to the role of Tutuila, in American Samoa, because Tutuila was a major source of fine-grained basaltic rock. Following a review of Samoan geology, we briefly describe the known basaltic-rock exploitation sites in Samoa, then summarise recent geochemical studies of rock samples from Tutuila and the central Pacific. We conclude by outlining some implications of those data for understanding prehistoric interactions within the Samoan group and between Samoa and other archipelagoes.

GEOGRAPHY AND GEOLOGY OF SAMOA

The islands of the Samoan archipelago stretch along a submarine ridge for some 370 km, east-west. The islands are on the Pacific Plate about 120 km north of the southeast-northwest extension of the Tonga Trench. The western islands - Savai'i, Apolima, Manono and 'Upolu - compose

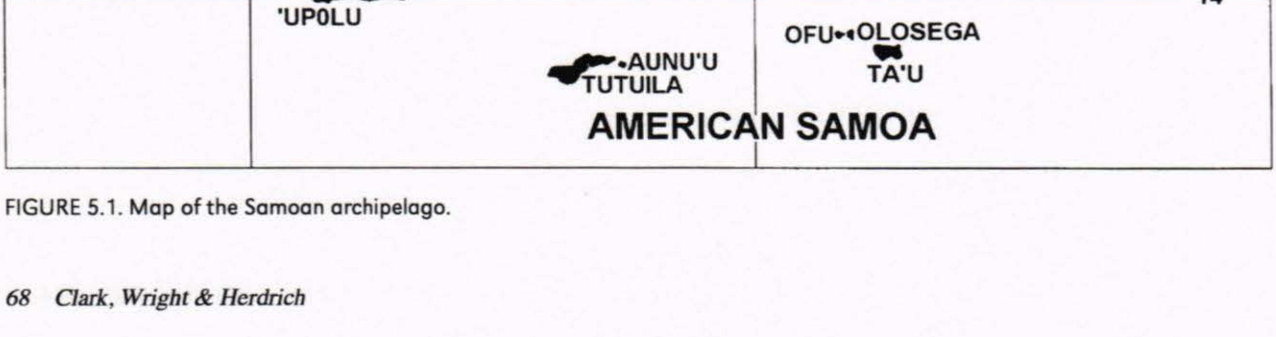


FIGURE 5.1. Map of the Samoan archipelago.

the nation of Western Samoa, while the eastern islands - Tutuila, 'Aunu'u, Ofu, Olosega and Ta'u - fall into the Territory of American Samoa (Fig. 5.1). The formal political separation of these two groups is a product of Western colonialism at the turn of the century, although the three eastern-most islands, known as Manu'a, have a long tradition of somewhat distinct sociopolitical identity.

The Samoan chain consists of a series of basaltic shield volcanoes that probably reflect a hot-spot origin (Duncan 1985). The shield-building lavas are predominantly olivine basalts and hawaiites (MacDonald 1968), and are mostly alkalic in composition, high in Ti (titanium) and large-ion lithophile elements (LILE) (Wright 1986). The subaerial volcanism goes back several million years and proceeded from west to east (Natland and Turner 1985). The Manu'a group appeared most recently and has experienced volcanic eruption in historic times (Stearns 1944).

Some of the islands have been substantially affected by post-erosional volcanism. This is particularly so for Savai'i, where most of the pre-existing shield volcanoes have been covered by recent eruptions, the last of which was early this century (Hawkins and Natland 1975; Stearns 1944; Wright 1986). On 'Upolu, Tutuila and Manu'a, the shield-building sequence remains exposed, including highly alkalic post-caldera lavas erupted from the older, large calderas (Macdonald 1944; McDougall 1985; Natland 1980; Natland and Turner 1985; Stearns 1944; Stice and McCoy 1968).

Tutuila is the largest island of American Samoa, though it is much smaller than Savai'i and 'Upolu. It is long (31.9 km east-west), narrow (from 9.8 to 1.6 km), and rugged, with steep slopes and small coastal valleys. A series of ridges form an island spine from which numerous smaller ridges radiate. Peaks are scattered along the ridge tops, with the highest peak, Matafao, at 653 m a.s.l. (metres above sea level). A large area of comparatively flat ground, the Tafuna Plain, projects to the south on the western side of the island.

Half a century ago, Stearns (1944) presented a comprehensive study of Samoan geology. In that work he characterised Tutuila as having developed from the coalescence of four major shield-volcanic centres: from west to east, Taputapu, Pago, Alofau and Olomoana. The Tafuna Plain was added much later, perhaps in the Holocene, along with the post-erosional Leone Volcanic Series. More recently, on the basis of a suite of potassium-argon dates, McDougall (1985) has suggested that the Alofau Volcanic Series may be only an eastern-flank formation of the Pago Volcano rather than the product of a distinct volcano. Also, while the Pago volcanism may have been slightly earlier, the satellite Taputapu and Olomoana Volcanoes were active at the same time as Pago, with Olomoana a little earlier than Taputapu. For geochemical reasons, however, we will continue to treat the Alofau Volcanic Series as distinct from Pago, and all five volcanic zones are illustrated in Figure 5.2.

Activity at the shield volcanoes of Tutuila ceased around a million years ago and substantial erosion has

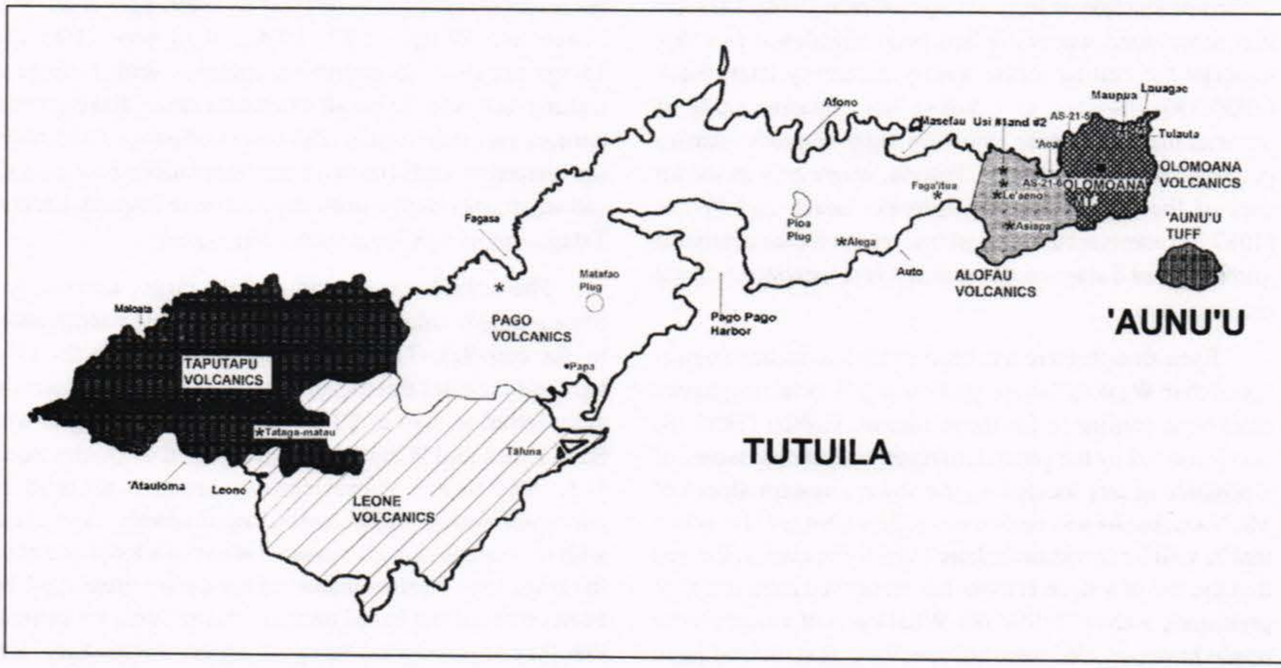


FIGURE 5.2. Map of Tutuila Island showing the volcanic series defined by Stearns (1944) and the various sites discussed in the text.

affected the island since. The large, central, Pago caldera may have spanned some nine kilometres at the time it was formed. Stearns (1944) has postulated that in succeeding millennia the caldera was partially filled with tuffs and lavas, and was breached by the ocean on the south and east, thus forming the large Pago Pago Bay.

BASALTIC ROCK EXPLOITATION SITES

The term 'basaltic rock' refers here to a large class of materials produced from volcanic activity. In Samoa, basaltic-rock artefacts actually range in composition from basalt to hawaiite, though the term basalt is generally used by archaeologists in reference to all those materials. 'Resource exploitation sites' are places where valued resources were collected. Such sites are usually referred to as quarries and will be so referred here regardless of the nature of the raw material source and the means of extraction.

Despite the importance of basaltic rock to prehistoric Samoans, there is scant ethnohistorical information about the sources of the raw material. Undoubtedly this was due to the fact that metal replaced stone fairly quickly in the historic period. This was especially so in those areas with the most intensive European and American contact, which were precisely the areas where observations were commonly made. The earliest European visitors to Samoa provided no reference to stone tools. The missionary Heath did report in 1840 that on Tutuila was "found the hard stone...of which the Polynesian adzes and other tools were made previously to the introduction of iron" (cited in Green 1974a:141). By that time, stone apparently had been abandoned as a raw material for cutting tools. Nearly a century later, Buck (1930:330) observed that during his extensive study of Samoan material culture, inquiries regarding rock quarries produced responses only on Tutuila, where he was shown part of the Tataga-matau complex. Leach and Witter (1987:34) comment that at least one reason for the continued knowledge of Tataga-matau is that it is referred to in a local oral tradition.

Even though there has been extensive archaeological research in Western Samoa, particularly 'Upolu, no quarries have been confirmed for those islands. Golson (1969:18) was informed by the general manager of Samoan Estates of a possible quarry located on the lower, western slopes of Mt. Vaea, but he was unable to locate such a site. He added that "a visit by Davidson in June 1964 to the quarry, showed that the use of a stone crusher has destroyed most traces of prehistoric activity" (1969:18). What traces of a quarry those might have included were not specified. It is interesting to note that six geological samples from Mt. Vaea were included in the extensive geochemical analysis of Best *et al.* (1992), and while those samples showed some variation, none clustered with any of the many artefacts analysed from throughout Samoa as well as other islands in the central Pacific. If a quarry did exist at Mt. Vaea - and that is questionable - it was at a location with quite different geochemical characteristics than the areas tested, or it was a quarry for limited local use.

The scarcity of basaltic-rock quarry sites in Samoa led Green (1974a:141) to state that, "quarry sites, it would appear, are not well known and therefore presumably not a common feature of the Samoan landscape". Subsequent work in Western Samoa gave no reason to alter that assessment. It has recently become apparent, however, that this condition does not hold for Tutuila in American Samoa. From the time of Buck's (1930) early work until the latter part of the 1980s, Tataga-matau, in western Tutuila, was the only documented basaltic-rock quarry in Samoa. Over the last few years several new quarry sites have been found in Tutuila as a result of surveys by Clark and Herdrich (1993). Because of the importance of quarry sites, and their comparative rarity in the central Pacific, each of the Tutuila sites is described briefly below.

Tataga-matau

This large quarry inland of Leone has long been known as a major source of high-quality hawaiite, and may well be the largest basaltic-rock quarry in the central Pacific. Tataga-matau has been described in some detail, and from the recent investigations (Best *et al.* 1989; Best *et al.* 1992; Leach and Witter 1987, 1990), it is now clear that Tataga-matau is an enormous complex with a range of features that include basalt extraction areas, flaking areas, terraces (some industrial and others possibly residential), star-shaped mounds (*tia' ave*), earthen platforms, stone walls and alignments, depressions and defensive features. In short, Tataga-matau was more than a large quarry.

The actual quarry loci, while large, constitute a comparatively small portion of the total area encompassed by the complex. The largest quarry zone is on the ridge tops and includes three quarry areas. These upper quarries are referred to here as TTM-U1-3, corresponding to what Best, Leach and Witter (1989) designated as Quarry Areas 1-3. Additional stoneworking areas - marked by concentrations of flakes, cores, and preforms - associated with the quarries are also present at various locations along the ridge tops. Measurements of the quarry areas have not been provided but based on map illustrations, we estimate that they cover several thousand square metres each. Best *et al.* (1992) also refer to two Leafu (waterfall and stream) 'subsources' at the southwestern base of the ridge complex. These were identified on the basis of two clusters of artefacts and geological samples that were distinguishable from the TTM-U sources, but differentiated from one another by high versus low titanium. A Leafu hill-slope quarry was eventually identified that Best *et al.* (1992:67) suggest is associated with the high-titanium geological samples from the waterfall area. While no geochemical data have been reported on materials directly from the Leafu Quarry (TTM-L), we will follow Best and colleagues and use the two high-titanium geological samples - but only the geological samples - to characterise that quarry. The second, low-titanium subsource remains hypothetical.

It does not appear that outcrop quarrying was involved at the ridge top quarry sites. At TTM-U1, where the archaeological investigations have been concentrated, "the chief extraction techniques were a combination of surface block selection and the separation of basalt boulders from the clay subsoil mantling the spur", the latter process sometimes involving major earth moving (Best *et al.* 1989:68-69).

Fagasā quarries

Beyond Tataga-matau, the largest quarry is at Fagasā, on the north coast of central Tutuila. This, too, is a large complex of at least two quarry areas, workshops, multiple terraces and deep pits. The main quarry at Fagasā (site AS-26-10, or Fagasā 1) covers an area of approximately 27,000 m^2. It begins at the valley floor and extends up a ridge spur. In the area just below the ridge are relatively dense scatters of flakes and tools in various stages of manufacture. Also present are three grinding stones which were used in the final stage of adze production. Farther up the ridge spur are two stone walls, the upper-most of which has projections similar to those found on *tia'ave* (see Herdrich 1991). Just above the second wall the ridge spur flattens to a long and wide terrace that is completely covered with a dense layer of flakes and tool preforms. Toward the back of this terrace is a rectangular house foundation. To the north of, and further back from, the foundation is a depression from which, it appears, rock has been extracted. From there the ridge begins to slope steeply upwards, with flakes covering the slope. The ridge then levels off at a second large terrace that has a dense layer of flakes and four pits, between 1.0 and 1.5 m deep and 8-10 m across, that we interpret as extraction pits. All of the pits contained large flakes and chunks. A dense layer of flakes is also found on the north slope of the ridge spur. The flakes can be found from the extraction pits all the way down to the valley floor, fanning out to the northwest. Just above the extraction pits is a third, large terrace with a lighter scattering of flakes and an old house foundation.

About 200 m up Fagasā Valley from the main quarry is a second, smaller quarry (AS-26-11, Fagasā 2). This quarry is located on the beginning approach of the main ridge spur and extends up and around the east side of the spur. The density of flakes is low compared to the main quarry, and the quarry covers an area of approximately 525 m^2. In the opposite direction from the main quarry, about 100 m toward Fagasā Bay, is a workshop area marked by a dense scatter of flakes and some stone tools (AS-26-8, Fagasā 3). This scatter rests on a slightly elevated area that may be an old beach berm. Two grinding stones were found in the immediate area of this scatter. Also, basaltic-rock flakes, tools and occasional grinding stones, are scattered throughout Fagasā village.

Alega quarries

A smaller complex of quarries and associated industrial terraces is located at the small valley of Alega on the south coast. Along with a set of prehistoric and historic residential sites scattered over Alega Valley and the surrounding slopes, three hawaiite quarries have been identified and described (Clark 1993). The quarries are situated on the steep slopes (*ca* 35°) that surround the valley and are marked by concentrations of flakes, shatter, preforms and core pieces.

The first of the Alega quarry sites (AS-23-22, or Alega 1) is at an elevation range of 64 to 76 m a.s.l. Artefacts are distributed over the surface covering an area of about 123 m^2. A second quarry area (AS-23-23, Alega 2) is a short distance to the west but is distinctly separated from the latter site. Lithic debris covers an area of about 495 m^2 at 46 to 73 m a.s.l. The third quarry (AS-23-29, Alega 3), at 40 to 50 m a.s.l., covers about 250 m^2. Alega 1 and 2 are several metres below a long basalt outcrop. There are no signs that the outcrop itself was directly quarried but it was undoubtedly the source of the exploited rocks scattered over the slope. Those rocks, as well as those over the slope at Alega 3, have flat surfaces and angular edges produced by natural weathering and cleavage plains.

Along with the three quarry sites, flaking activity areas and abundant hawaiite debitage and tools are scattered throughout the valley floor. The Alega sites and artefacts indicate that hawaiite exploitation and tool manufacturing were major activities in the valley. While adzes were the predominant tool of intent, some formal flake tools - notably graters/scrapers - were also produced.

Faga'itua quarry

In the summer of 1995, Herdrich observed abundant basaltic rock flakes and adzes scattered through the village of Faga'itua. He suspected that a quarry existed in the area but was unable to conduct a survey. He did, however, show some local residents examples of basaltic-rock artefacts, and on a subsequent visit to Faga'itua he was informed by William Robert Malepeai, age twelve, of a large area covered with such artefacts. A check of the location revealed the largest quarry yet known for eastern Tutuila.

Faga'itua quarry is just inland of the western edge of Faga'itua Village. The dense collection of flakes and preforms that mark the site are scattered over the steep slope on the east side of Palapala Ridge, from the bottom of a small stream drainage to the top (or nearly so) of the ridge. The full dimensions of the sites are still unknown, but the preliminary estimate is that it covers at least some 12,000-16,000 m^2. The middle of the site is at 440 m a.s.l.

The Faga'itua site is clearly a large and, presumably, important quarry. The actual scope of quarry activities at Faga'itua cannot be determined until the ridge slopes surrounding Faga'itua and neighbouring villages have been surveyed. Unfortunately, rock samples from this site could not be included in our geochemical study.

Asiapa quarry

Farther east in Tutuila, on the southeast ridge-top leading to Asiapa peak, at 239 to 255 m a.s.l., is Asiapa Quarry (AS-22-31) (Clark 1989). This site consists of three loci of flakes and whole and fragmentary preforms. A *tia' ave* is just above the quarry, on the southwest crest of the peak. Running atop the ridge, through the site and beyond, is an old path.

The debris of the lowest quarry locus is scattered amidst a collection of large boulders, some up to 2 m across. Though flakes are scattered over a large area, there is a particularly heavy concentration of approximately 20 m^2. Adjacent to that concentration is a shallow depression and a low pile of soil and rock that may be from the extraction of angular-fractured rock. A short distance (less than nine metres) up the ridge-top is the middle locality, which has the heaviest concentration of lithics. Debris extends across the ridge-top and a short distance down both side slopes, covering an area of approximately 205 m^2. About 16 m farther up the ridge is the third locality, where large flakes and a small number of preforms cover about 104 m^2. At all three localities the basalt source appears to have been the angular boulders scattered over the ridge-top.

Le'aeno quarries

Le'aeno mountain marks the juncture of three sociopolitical units (now counties) - Sua, East Vaifanua, and Sa'ole - and is the highest point on the eastern end of Tutuila (290 m a.s.l.). Associated with this summit area is a site complex consisting of three quarries, two defensive sites and four *tia' ave* . When the Le'aeno mountain sites are taken as a whole, we see a large complex with parallels to Tataga-matau, although not as large, especially in the extent of quarry activities, which, in fact, were minor.

At Le'aeno are two peaks separated by about 155 m and each the focus of a defensive site. The fortifications incorporate the extremely steep side slopes with added defensive features. From the primary peak to the secondary peak are large ditches and terraces with high, steep, fronts. Atop the secondary peak are two *tia 'ave* one on each side of the crest. Two ridges radiate off that peak, one to the northeast, Sua, and one to the north, Usi.

A short distance down the northwest side of Sua ridge is Le'aeno quarry (AS-21-110) at 233 m a.s.l. This small quarry is marked by a concentration of large basalt flakes and some preforms over an area of about 50 m^2. In the area of heaviest concentration, the ground surface is completely covered with debitage, although the accumulation is not thick. The lithic concentration is near the precipitous northwest edge of the ridge-top, and a portion of the quarry area may have been lost through slumping. Beyond the quarry is a narrow defensive terrace with a massive front embankment, sloping at about 45° and faced by large boulders stacked 3 to 4 m high. Farther down the ridge is a group of large, low terraces.

Usi ridge is not as wide as Sua ridge but has two small exploitation sites. The first of these, Usi 1 (AS-23-12), at 250 m a.s.l., consists of four small concentrations of flakes and crude or broken preforms, separated by several metres, that cover a total of some 70 m^2. The first concentration is about 10 m^2 in size and the second about 15 m^2. The third and fourth concentrations each cover about 10 m^2 and are on the rear of a *tia' ave.* About 21 m farther down the ridge is Usi 2 (AS-23-14), a short distance from the end of another *tia 'ave* and at an elevation of 246 m. Lithic debris covers 300 m^2 along the narrow ridge-top and down the west slope. The east side of the ridge is sharply defined by a precipice. A concentration of large flakes is along the precipice and part of the site may have slumped away.

At the Usi and Le'aeno quarries, the rock exploited was naturally fracturing, angular boulders. At the Usi quarries the hawaiite does not seem to be as fine-grained as the hawaiite from the other quarries on the island.

Lau'agae quarry

At Cape Matatula, at the extreme northeast tip of Tutuila, is Lau'agae ridge. On the southern peak of the ridge (about 62 m a.s.l.) and extending down the southwest slope is Lau'agae quarry (AS-21-100), which consists of 12 separate loci over an area of roughly 10,000 m^2. These loci range in size from 6 to 250 m^2. The lithic material at this site consists primarily of flakes, but includes cores and broken and whole adze preforms.

The quarry was first reported by Clark and Herdrich (1993; Clark 1989) who found the first locus on the peak. This thick carpet of lithic debris is disturbed on the east by a U.S. military bunker. In addition, two *tia' ave* lie a short distance to the northeast, and there are some traces of residential remains in the vicinity. Recently, Moore and Kennedy (1995) discovered 11 other quarry loci, and a few military features, scattered down the southwest slope of the peak. It appears that naturally fractured, angular rocks scattered down the slope were utilised.

Gould, Honor and Reinhardt (1985:6) claimed that "one of the largest basalt quarries and lithic or adze manufacturing sites in all of Polynesia" existed at the Tulauta site, which is immediately inland of the coastal village of Tula (AS-21-1) and west of Lau'agae. Brophy (1986) (a.k.a. Reinhardt) later reported the existence of a large basalt quarry at nearby Maupua that probably produced adzes for exchange beyond Tutuila. However, Tulauta is a residential, not a quarry, site, albeit one with abundant hawaiite debitage and tools, and the artefacts at Tulauta are no more abundant than at other residential valley sites on Tutuila (e.g., Leone, 'Aoa, Alega, Maloata). Moreover, subsequent surveys of the Maupua area have failed to locate a prehistoric quarry (Clark and Herdrich 1993; Kennedy 1988). Instead, the broken rock at Maupua is debris from recent mechanised quarry operations. The most likely source of the Tulauta hawaiite is Lau'agae Quarry.

Possible quarry areas

Other quarries may be indicated by the abundance of basaltic rock artefacts at non-quarry sites. In the Nu'u'uli area of central Tutuila, a reconnaissance of an inland stretch of Papa Stream revealed at least 28 grinding facets used in the manufacture of adzes, basaltic rock flakes and a small hammerstone in the stream bed (AS-26-12). A reconnaissance of the lower portion of Atauloma Stream at Afao Village, western Tutuila, revealed another concentration of grinding facets on boulders (AS-34-16). In a stretch of approximately 40 m, beginning at the stream mouth, there are at least 51 grinding facets (some of these are multiple facets on a single large boulder).

At both sites the large number of facets suggests intensive adze production. The fact that comparatively few basaltic flakes were observed in the stream beds indicates that the adzes were simply being ground in the stream with very little flaking in the immediate vicinity. Consequently, it is quite likely that quarries existed nearby, perhaps on a ridge above the upper course of Papa Stream and on the slopes around the small valley at Afao.

The large quantity of basaltic rock debitage, tools and grinding facets recovered from Maloata Valley, on the north coast, has lead Ayres to suggest that a quarry probably exists in the vicinity of that valley (Ayres, cited in Best *et al.* 1992; see also Ayres and Eisler 1987).

Jeff Fentress, an archaeologist with the American Samoa Power Authority, has informed us of a notable abundance of flakes, preforms and polished adzes on the surface at Auto Village, near the western point of Faga'itua Bay. Based on the type and quantity of material in Auto, we suspect that there is another quarry, possibly fairly large, on slopes around the village.

Summary

At all of the eastern Tutuila quarries, the raw material exploited was angular chunks of basaltic rock naturally fractured from large boulders or outcrops. The lithic debris at these sites consists predominantly of large waste flakes with cortex commonly present, indicating early reduction of exposed raw material. Crudely-shaped preforms are typically present, although they are not abundant and they are frequently broken. Finished, ground tools are absent from the quarry sites, as are grinding stones. We infer that the primary activity at the quarries was preliminary extraction of suitable hawaiite and initial shaping of preforms, which were then carried to residential areas or nearby terraces for final reduction and polishing. Residential areas near the quarries have produced abundant debitage and tools.

A similar pattern seems to hold for the larger quarries of Tataga-matau and Fagasā in western and central Tutuila, respectively, although some digging for the extraction of suitable rock chunks also occurred at both of those locations. There may have been further reduction of the tool blanks on the ridge terraces at Tataga-matau and Fagasā complexes. At the same time, at both locations the residential areas of the associated valley floors contain highly abundant flake material. At Leone, below Tataga-matau, grinding facets are particularly abundant, both in the upper reaches of Leafu Stream and at areas along the coast.

Given the nature of the small quarry sites in eastern Tutuila, the often poor ground visibility, the location of some quarries on steep slopes, and the many ridges and slopes not surveyed on Tutuila, there are undoubtedly many other quarry sites not yet found. Most of these are probably small to moderate in size, but large quarries may also exist, as suggested by the large complex at Fagasā that was not known until a few years ago. We further note that much of Tutuila, especially in the central and western districts, is archaeologically unknown. We surmise that basalt exploitation sites on Tutuila were fairly common on the landscape.

The quarries at Tataga-matau, Fagasā and Faga'itua are so large that export of these fine-grained hawaiites seems almost certain. Even moderate-sized quarry areas such as Alega and Lau'agae appear too large to have produced tools only for local use. The small quarries may have been exploited primarily for local use, although export of some of those materials cannot be ruled out. Given the quantity of quarries on Tutuila and the results of recent sourcing studies (Walter and Sheppard 1996; Best *et al.* 1992; Weisler 1993a), purely intra-island exchange seems highly unlikely. In short, Tutuila was a major 'industrial' centre, producing basaltic rock adzes (or possibly preforms) for inter-island export.

GEOCHEMISTRY

We conducted geochemical analysis of 26 basaltic rock samples from 15 sites. These samples and sites represent four of the geologic volcanic regions of Tutuila; only the Leone Volcanic Series is not represented. Seventeen samples came from eight quarries: one sample came from Lau'agae quarry in the Olomoana Volcanic Series; Asiapa, Le'aeno and Usi 1 each provided one sample from the Alofau Series; from Alega, in the Pago Series, two samples were analysed, one from Alega 1 and one from Alega 3; ten samples were analysed from Fagasā, also in the Pago Series; and one sample came from the bed of Leafu Stream below Tataga-matau in the Taputapu Volcanic Series. Of the Fagasā samples, five came from the two ridge-spur quarries, three from the coastal workshop, one from a lithic scatter and another found in the village.

Nine samples from non-quarry sites were also analysed. One sample came from the Maupua outcrop in the Olomoana Volcanic Series. Three samples are artefacts from a residential site in 'Aoa valley (AS-21-5), and an additional artefact sample came from a nearby residential site (AS-21-6), both sites in the Olomoana group. One sample each came from the tool finishing sites at Papa Stream at Nu'u'uli (AS-26-5) in the Pago Series and Atauloma Stream at Afao (AS-34-16) in the Taputapu Series. Excavation at a site (AS-34-44) in Leone Valley, which fronts the main ridge of Tataga-matau in the Taputapu Series, also produced a sample flake. A final archaeological sample was collected from the surface on Ofu Island.

Samples were analysed for major and trace elements by x-ray fluorescence at Michigan State University and the XRAL company. For techniques, precision and accuracy data for the MSU samples, refer to Flood *et al.* (1989); for the XRAL samples, those data are available from the company.[1]

To the extent possible, our data were compared with those of the Tutuila samples reported by Best *et al.* (1992), the nine Tataga-matau samples reported by Weisler (1993a), and three recent samples from Lau'agae reported by Moore and Kennedy (1995)[2]. Our data and the ranges of data from other investigators are presented in Tables 5.1-5.5. Certainly there are inter-laboratory biases to contend with, but the comparisons of data on rocks from the same sources indicate substantial agreement. In our analysis of the data, TiO_2, FeO* (total iron calculated as ferrous iron), CaO, K_2O and P_2O_5 were of particular use in discriminating between sources, at least partly because they were apparently consistent across labs (see also, Chapter 10, this volume).

	TTM-L Best *et al.* (1992) n=2	TUT-II.11 Afao village AS-34-16	TUT-II.13 Leone valley AS-34-44
SiO_2	45.52-46.45	45.6	45.6
TiO_2	4.53-4.82	4.56	4.85
Al_2O_3	15.36-15.52	15.1	15.4
FeO*	12.64-12.95	12.89	13.33
MnO	0.18	0.17	0.17
MgO	5.70-5.79	5.28	5.52
CaO	8.17-8.21	8.24	8.29
Na_2O	3.28-3.32	3.03	2.79
K_2O	1.19-1.39	1.23	1.16
P_2O_5	0.59-0.61	0.62	0.63
Ba	264	290	280
Rb	31	20	40
Sr	604	580	570
La	35	34.5	31.5

TABLE 5.1. Basalt/hawaiite data for the Tutuila Volcanic Series. Taputapu: TTM-L. The TTM-L range comes from geological samples that fall in that geochemical group, i.e., A8 and A9 from Best *et al.* (1992).

	TTM-UI Best *et al.* (1992) n=14	TTM-U2 n=8	TTM-U3 n=7	TUT-II.1 Tataga-matau AS-34-10	TTM-U1 Weisler (1993a) n=7	TTM-U3 Weisler (1993a) n=1
SiO_2	47.88-48.56	47.27-48.05	48.15-48.86	48.33	49.56-50.56	49.32
TiO_2	3.36-3.54	3.52-3.56	3.28-3.44	3.36	3.38-3.43	3.65
Al_2O_3	15.43-15.81	15.41-15.74	15.54-15.77	15.66	15.35-15.62	13.86
FeO*	12.03-12.45	12.17-12.54	11.80-12.32	12.51	12.34-12.9	12.4
MnO	0.14-0.19	0.13-0.20	0.17-0.19	0.19	0.17-0.18	0.17
MgO	4.59-5.07	4.86-5.06	4.61-4.91	4.80	4.55-4.77	7.06
CaO	7.38-7.77	7.45-7.67	7.42-7.61	7.46	7.56-7.7	7.8
Na_2O	3.44-3.89	3.38-3.69	3.59-3.88	3.64	3.96-4.09	3.45
K_2O	1.51-1.64	1.47-1.53	1.55-1.61	1.53	1.54-1.62	1.79
P_2O_5	0.76-0.80	0.73-0.77	0.78-0.80	0.81	0.79-0.81	0.71
	(n=5)	(n=5)	(n=5)	(n=5)	(n=5)	(n=5)
Ba	297-330	309-320	309-333	454	268-302	331
Rb	38-45	34-44	38-45	59	42-45	50
Sr	710-720	707-712	708-721	783	698-708	693
La	43-48	42-46	42-44	41.9	13-50	43

TABLE 5.2. Basalt/hawaiite data for the Tutuila Volcanic Series. Taputapu: TTM-U.

	TUT-II.2 AS-22-31 Asiapa	Best *et al.* (1992) Sample 8 Asiapa	TUT-II.3 AS-21-100 Le'aeno	TUT-II.6 AS-23-12 Usi 1	Best *et al.* (1992) Sample 6 Usi 1*	TUT-II.16 Adze butt Alofau	TUT-II.9 Ofu
SiO_2	50.24	48.86	47.80	45.90	45.90	47.49	47.40
TiO_2	2.94	2.89	3.71	4.38	4.26	3.78	4.21
Al_2O_3	16.01	15.46	16.09	15.00	15.55	15.65	15.30
FeO*	11.58	11.15	12.74	13.25	12.59	13.10	12.18
MnO	0.18	0.16	0.18	0.20	0.19	0.18	0.16
MgO	4.11	4.05	4.84	4.96	5.41	5.02	4.45
CaO	7.26	7.15	7.71	7.81	7.83	7.74	7.81
Na_2O	3.99	3.62	3.65	3.09	3.23	3.46	3.27
K_2O	1.77	1.74	1.61	1.38	1.35	1.54	1.31
P_2O_5	1.25	1.20	0.76	0.66	0.64	0.74	0.66
Ba	386	(426)	331	290	–	–	320
Rb	–	(41)	33	40	–	–	30
Sr	806	(755)	842	570	–	–	730
La	49	(49)	37	33	–	–	34

*See endnote 5.

TABLE 5.3. Basalt/hawaiite data for the Tutuila Volcanic Series. Pago: Fagasā, Alofao: Asiapa, Le'aeno and Usi.

Quarries

The compositions of the known quarries of Tutuila define a single broad differentiation trend, from the least differentiated (TTM-L) through intermediate compositions (TTM-U, Fagasā and the Olomoana quarries) to the most differentiated (at Asiapa) (Figs 5.3-5.5). Although the quarry samples fall into fairly well-defined groups that define a single fractionation trend on all applicable plots of major and trace elements, there is considerable overlap in quarries, even some that are widely separated geographically (Figs 5.3-5.5).

The Tataga-matau subsources, TTM-U and TTM-L, do show significant differences, and can easily be

	H1 AS-26-10 Fagasā	H2 AS-26-10 Fagasā	H3 AS-26-10 Fagasā	H4 AS-26-10 Fagasā	H5 Find Spot Fagasā	H6 AS-26-11 Fagasā	H7 AS-26-11 Fagasā
SiO_2	48.9	48.8	48.7	47.0	47.7	46.6	48.2
TiO_2	3.19	3.16	3.16	3.25	3.23	3.53	3.47
Al_2O_3	15.9	15.8	15.9	16.2	15.9	16.0	15.7
FeO*	11.91	11.82	11.82	12.18	12.00	12.53	12.36
MnO	0.19	0.18	0.18	0.18	0.19	0.18	0.18
MgO	4.45	4.42	4.31	4.34	4.34	3.23	4.73
CaO	7.21	7.17	7.19	6.81	7.03	7.06	7.48
Na_2O	3.71	3.69	3.68	3.36	3.61	3.23	3.53
K_2O	1.70	1.69	1.73	1.64	1.76	1.51	1.57
P_2O_5	0.84	0.82	0.82	0.88	0.89	0.80	0.77
Ba	360	350	360	350	410	350	340
Rb	60	50	50	60	60	50	40
Sr	640	650	630	610	620	590	630
La	46	45	45	45	46	40	45
	H8 AS-26-8 Fagasā	**H9 AS-26-8 Fagasā**	**H10 AS-26-8 Fagasā**	**TUT-II.7 AS-23-24 Alega 1**	**TUT-II.8 AS-23-26 Alega 3**	**TUT-II.10 AS-26-5 Nu'u'uli**	
SiO_2	48.8	48.9	49.1	49.8	48.9	52.8	
TiO_2	3.15	3.16	3.16	3.16	3.12	2.03	
Al_2O_3	15.8	15.9	15.9	15.5	15.2	16.3	
FeO*	11.82	11.91	11.84	12.09	11.91	9.25	
MnO	0.19	0.18	0.19	0.18	0.17	0.17	
MgO	4.53	4.51	4.45	4.07	4.02	3.23	
CaO	7.24	7.25	7.30	7.39	7.24	6.10	
Na_2O	3.82	3.80	3.77	3.56	3.50	4.20	
K_2O	1.66	1.69	1.71	1.61	1.62	2.20	
P_2O_5	0.82	0.82	0.82	0.84	0.83	1.25	
Ba	390	350	390	380	340	520	
Rb	40	30	50	50	60	80	
Sr	670	650	650	660	660	850	
La	47	45	47	44	44	62	

TABLE 5.4. Basalt/hawaiite data for the Tutuila Volcanic Series. Pago: Fagasā, Alega and Nu'u'uli.

distinguished on all plots. However, the three areas within TTM-U are harder to separate: U1 overlaps with both U2 and U3, though U2 and U3 show some separation from each other on most plots. It should also be noted that TTM-L is defined by only two geological samples, perhaps producing a falsely tight field.

The Lau'agae quarry and the Maupua outcrop in the Olomoana Volcanic series are virtually indistinguishable. More importantly, they cluster fairly tightly with the Le'aeno quarry in the Alofau series, and overlap with the TTM-U group (Taputapu series) on some plots (e.g., Fig. 5.4).

The quarries in the Alofau Volcanic series show wide variation on all plots, spanning most of the differentiation trend defined by all Tutuila quarries. Asiapa is the most differentiated quarry on Tutuila (Figs 5.3 and 5.4), and may fall off the differentiation trend because of unexpectedly high P_2O_5 content (this result is consistent across labs). Le'aeno quarry plots with the main TTM-U-Olomoana portion of the trend (see above), and the Usi quarries plot between Olomoana and the least-differentiated TTM-L groups.

The Pago quarries (Fagasā and Alega) form a group overlapping at the less-fractionated end with TTM-U (though not Olomoana), and extending toward more differentiated compositions. Alega samples cluster tightly with the bulk of the Fagasā samples.

	TUT-II.4	Best *et al.* (1992)	Kennedy (1988)	TUT-II.5	Best *et al.* (1992)	TUT-II.12	TUT-II.14	TUT-11.15
	AS-21-100	n=1	n=3		2 samples	AS-21-5	AS-21-5	AS-21-5
	Lau'agae	Lau'agae	Lau'agae	Maupua	Maupua		2/60	2/254
SiO_2	47.95	47.98	47.89-48.06	47.82	47.12-47.48	46.9	44.77	46.47
TiO2	3.82	3.87	3.70-3.74	3.81	3.79-3.80	3.77	4.62	4.16
Al_2O_3	15.96	16.23	15.98-16.05	16.00	15.97-16.10	15.4	12.38	15.63
FeO*	12.51	12.11	12.58-12.63	12.63	12.17-12.50	12.71	13.71	13.23
MnO	0.16	0.14	0.16	0.16	0.13-0.19	0.18	0.17	0.17
MgO	4.89	5.08	4.94-4.97	4.99	4.95-5.06	4.70	11.25	5.41
CaO	7.71	7.73	7.69-7.75	7.73	7.60-7.73	7.66	8.56	7.97
Na_2O	3.63	3.62	3.33-3.38	3.59	3.52-3.55	3.2	1.80	3.32
K_2O	1.51	1.45	1.48-1.49	1.53	1.47-1.49	1.50	.90	1.34
P_2O_5	0.73	0.71	0.72-0.73	0.73	0.69-0.72	0.73	0.60	0.66
Ba	333	–	–	313	–	330	237	259
Rb	45	–	–	43	–	50	<16	28
Sr	821	–	–	786	–	620	531	–
La	39	–	–	38	–	39	33	32

TABLE 5.5. Basalt/hawaiite data for the Tutuila Volcanic Series. Olomoana.

Non-quarry samples

Samples from the excavation site in Leone and the tool finishing site in Afao resemble TTM-L quarry samples on all plots. Certainly the Afao flake could have come from TTM-L, but that is not as confident an association as with the Leone flake because of logistics. Afao is separated from TTM-L by over 3.5 km and three villages. That is a surprising geographic and political distance over which to transport quantities of preforms for finishing at the unusually abundant grinding facets at this small village. Given the geochemical data, it is conceivable that a locally exploited quarry exits in the immediate vicinity of Afao - which, as with TTM-L, is in the Taputapu Volcanics - that geochemically clusters with TTM-L.

The flake from the tool finishing area in Papa Stream at Nu'u'uli is something quite different. Material from this site apparently comes from an unknown source - presumably a quarry, given the volume of adze finishing suggested by the quantity of grinding facets - in a highly differentiated rock. The Nu'u'uli sample is the most differentiated sample studied, and forms the fractionated endpoint on all plots.

The archaeological samples from neighbouring residential sites AS-21-5 and AS-21-6 do not appear to have come from the same quarry. Flake TUT-II.12 (21-5) resembles material from the Olomoana quarries on all plots, while II.14 (21-5) was generally less fractionated than TTM-L, forming the least differentiated endpoint on most plots. Flake II.15 (21-6) plotted between the Olomoana and TTM-L groups on all plots, usually clustering with the Usi quarries and the archaeological sample from Ofu. The Ofu sample does not resemble any of Weisler's (1993a) geological samples from Ofu (all from dykes), and probably came from Tutuila.

We conclude from these data that we can confidently attribute far-flung artefacts to Tutuila, as opposed to Western Samoa or other Pacific island groups, on the basis of distinctive geochemical trends (Fig. 5.6; Natland 1980), but much more care should be exercised in assigning artefacts to specific quarries. It is premature to attribute artefacts from distant sites to Tataga-matau or any other specific quarry based on their geochemical similarity to quarry rock. The more differentiated TTM-U compositions overlap significantly with the Fagasā quarry field, and, to a lesser extent, the less fractionated TTM-U samples fall within the field defined by the Olomoana quarries. (Fagasā and Olomoana, however, are reliably distinct from each other.) TTM-U may also be confused with Le'aeno quarry in the Alofau group. To illustrate the potential problem with artefact-quarry associations, Best *et al.* (1992:65) report that an adze from Ma'uke, Cook Islands, (sample RW-M) clusters with TTM-U1 samples and thus "can be firmly assigned to the quarry". However, when the Fagasā quarries are brought into the picture, we find that that adze might also be from Fagasā.[3]

TTM-L, on the other hand, appears to be consistently distinct from the Olomoana-TTM-U-Fagasā cluster, and shows up in excavation and tool-finishing sites in Leone

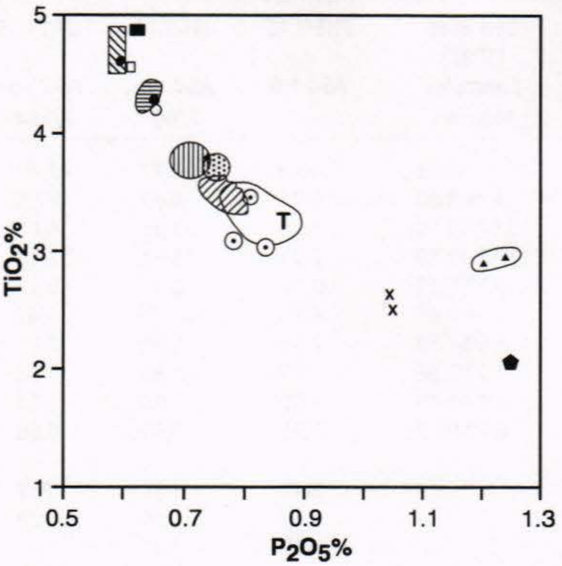


FIGURE 5.3. Plot of TiO_2 vs P_2O_7 for artefacts and quarry samples. Quarries are grouped with their volcanic units (Stearns 1944), except for those in the Alofau group (Le'aeno, Usi and Asiapa), which show such variability that they have been plotted separately.

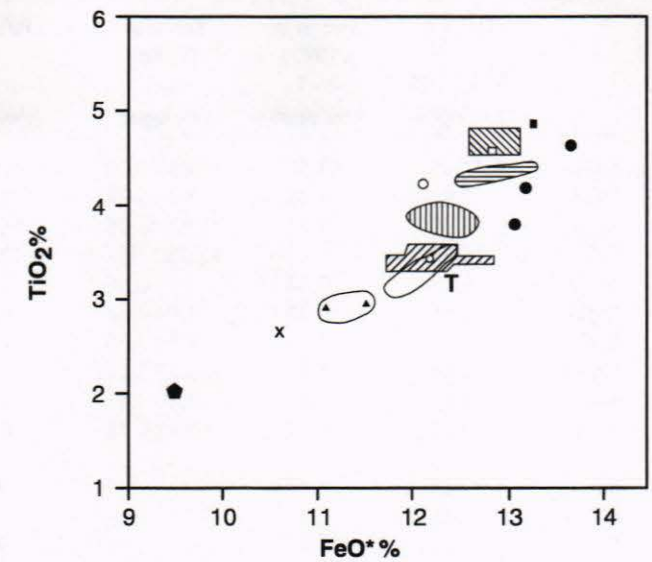


FIGURE 5.5. Plot of TiO_2 vs FeO* (total iron calculated as ferrous iron) for artefacts and quarry samples.

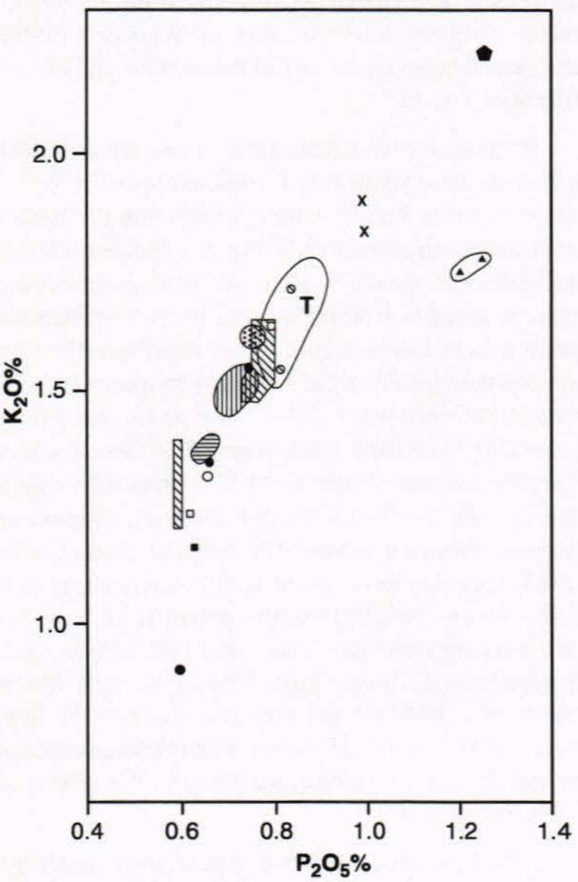
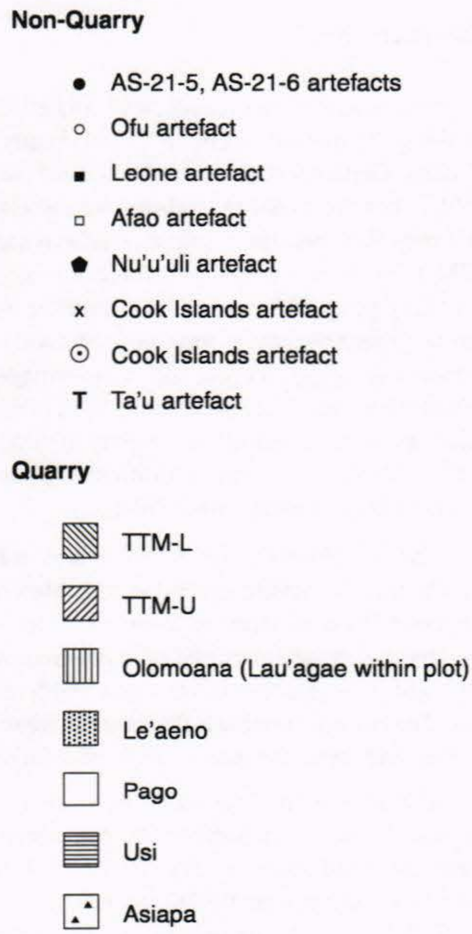


FIGURE 5.4. Plot of K_2O vs P_2O_5 for artefacts and quarry samples.



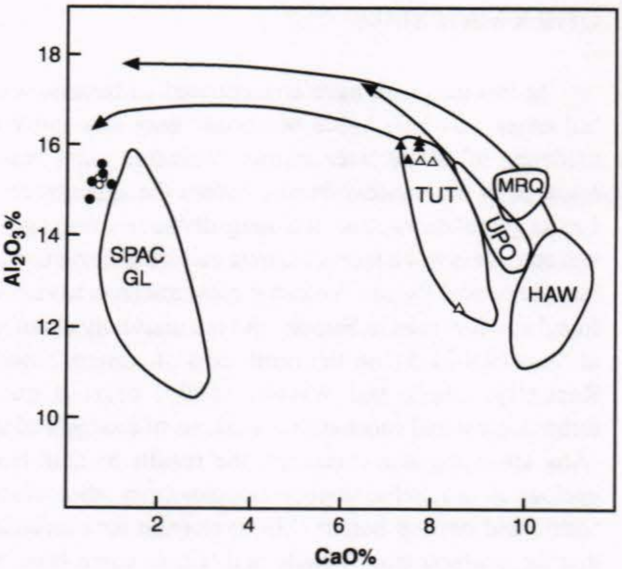


FIGURE 5.6. Plot of Al_2O_3 vs CaO for geological samples from Tutuila (TUT), 'Upolu (UPO), the Marquesas (MRQ) and Hawaii (HAW), after Natland (1980). Also plotted are volcanic glass analyses from other Pacific islands (SPAC GL; Duerdon *et al.* 1987), basaltic artefacts from Tutuila and 'Upolu (triangles) and volcanic glass from Tutuila and 'Upolu (circles; Clark and Wright 1995). This plot shows the distinct differentiation trends of these islands, which enable us to distinguish them as possible source materials.

and possibly Afao. However, TTM-L is defined on the basis of only two geological samples, and may 'spread out' geochemically as more samples are analysed. If it does, it may prove impossible to distinguish - on the basis of TiO_2, P_2O_5 and CaO - from the Usi quarries in the Alofau group, as well as possible undiscovered quarries within a broadly contemporaneous flow in the same area.

Asiapa quarry forms a distinct group on most plots. Best *et al.* (1992:82) show Asiapa quarry samples clustering with two adzes, one from the Outer Reef Islands and one from Ma'uke, Cook Islands (samples REEF-51 and RW-F, respectively), but we find the differences to be significant and would *not* suggest a quarry-artefact link based on these data.

Finally, two artefacts are still looking for quarries: flakes from the tool finishing site at Nu'u'uli have a unique composition, more differentiated than any known quarry; and an archaeological sample from residential site AS-21-5 (TUT-II.14) matches no known quarry unless TTM-L has more variability than is presently documented.

QUARRY CHRONOLOGIES

The chronology of quarry utilisation on Tutuila can be only vaguely outlined. Best and colleagues claim that by 2,200 years ago, adzes were being produced from both the upper (TTM-U) and Leafu (TTM-L) sources at Tataga-matau. This age is based on dated artefacts that cluster with each of those sources. Best *et al.* (1992:66) report a flake from Ta'u that dates to 2330 ± 50 bp[4] (Hunt and Kirch 1988) and clusters with low titanium Leafu samples. However, this date is on shell, but shell dates from Samoa have been inconsistent (e.g., dates of Jennings and Holmer 1980) and there is no documented delta-R value for this region to allow for accurate correction. Furthermore, a low-titanium quarry at Leafu is hypothetical and has not been identified archaeologically. An adze from Sasoa'a, 'Upolu, that Best *et al.* (1992:65) claim clusters with TTM-U is from a layer that produced a radiocarbon determination of 1840 ± 100 bp (Green 1974a:113). Unfortunately, that date was determined by the Gakushuin lab, and Gakushuin dates from the time of that assay are notoriously unreliable (Kirch 1984:73; Spriggs 1989:604; Spriggs and Anderson 1993:207). Consequently, the dates for both artefacts are questionable. More importantly, however, when compared with geochemical data for quarries presented here, the composition of the Ta'u flake is more consistent with Fagasā. Moreover, if, for the reasons outlined above, we are unable confidently to associate a specific artefact with a specific quarry, then neither the Ta'u nor the Sasoa'a artefact can be used to infer a date for Tataga-matau regardless of the reliability of their dates.

Any efforts to date a quarry should be based on dates produced from that quarry. Leach and Witter (1990:81) suggest that "the major industrial phase" at Tataga-matau was the fourteenth to sixteenth centuries, although there was tool manufacturing at the ridge-top quarries both before and after that phase. For Tataga-matau, excavations of ridge-top sites have produced eight radiocarbon dates (Best *et al.* 1989). The earliest of these may predate quarry operations and has a large standard deviation: 906 ± 157 bp. Two others are less than 250 bp. The remaining five dates consistently indicate an age of about 600 to 300 years BP. Those dates relate to the modification of the ridge-top, and while utilisation of the hawaiite may have occurred prior to that, direct evidence of such early use is not available.

Beyond Tataga-matau, chronological data on quarry exploitation is almost non-existent. Only Alega has yielded any suggestion of age. Evidence from a workshop terrace lead Clark (1993) to suggest that the onset of intensive quarrying at Alega was sometime in the fourteenth century A.D., which is consistent with the evidence for Tataga-matau.

At best, one can say that if indeed the artefact dates mentioned above are in the ball park, then some quarry or quarries on Tutuila were supplying basalt to other islands in the archipelago over 2000 years ago. The geochemical data provided by Best *et al.* (1992) indicate that Tutuila basalts eventually were traded/exchanged well beyond the Samoan Archipelago. By 900 years ago, adzes from Tutuila quarries were in Fiji. Within the last few centuries, and possibly a millennium ago, Tutuila basaltic artefacts were reaching the Tokelaus. Data from Best *et al.* (1992) are supplemented by those of Sheppard *et al.* (Chapter 6) suggesting that within the last 600 years or so, Tutuila hawaiite had reached the Cook Islands. By 300 BP, Tutuilan adzes were in Tonga (Best *et al.* 1992), though a much earlier date for initial exchanges between Tonga and Samoa would seem highly likely. Basalt tools from Tutuila even reached as far afield as Taumako, in the Southeast Solomons, and Tuvalu, although the ages of those tools are unknown.

The cessation of quarry activities in Samoa probably occurred early in the historic period. In the early years of European contact, Samoans were not interested in metal as an exchange item. As late as 1787, La Pérouse (1799) reported that the islanders of Tutuila were interested only in beads and ignored metal. Following upon the hostilities that erupted between La Pérouse and the Samoans on Tutuila, intensive Western contacts with Samoa were delayed until the early 1830s and the establishment of a Christian mission station by John Williams. While there are no early ethnohistorical references to stone tools, Green (1974b:254) cites missionary reports from the mid 1830s indicating that metal tools had already replaced stone, a fact reinforced by Heath's comment cited above.

We think it likely that the quarries were abandoned sometime prior to the 1830s, perhaps between about 1790 and 1810. The size of the major Tutuila quarries clearly seem too large for purely local use, and the geochemical studies demonstrate the export of Tutuila basalt and/or tools to other islands. Given the documented inter-island connections, Tonga and Fiji are likely to have been important consumers of Tutuila basaltic artefacts. Western interactions - explorers and traders - in those island groups intensified several decades earlier than in Samoa. Metal was a common item of exchange by sandalwood traders by the first decade of the 1800s in Fiji and Tonga (e.g., Im Thurn and Wharton 1925; Martin 1981). In fact, Mariner, who reached Tonga in 1806, described Tongan adzes as made of metal, with no mention of stone tools (Martin 1981:359). Given this condition, it would not be surprising to find that basaltic-rock adzes had ceased to be an important item of inter-archipelagic exchange by the about the turn of the 19th century. Correspondingly, the basaltic rock quarries of Tutuila probably substantially reduced, if not virtually ceased, operation at about the same time. This would explain the lack of references to stone tools by the post-1830 European visitors.

OTHER MATERIALS

In this paper we have concentrated on basaltic rock, but other non-perishable materials may also provide evidence of island interactions. Volcanic glass was a resource in the western Pacific before the appearance of Lapita populations, and the long-distance exchange of volcanic glass was a facet of Lapita culture that was carried into the central Pacific. Volcanic glass artefacts have been found at a few sites in Samoa, and are unusually abundant at 'Aoa (AS-21-5), on the north cost of eastern Tutuila. Recently, Clark and Wright (1995) carried out a technological and geochemical analysis of a sample of the 'Aoa artefacts, and compared the results to data from geological and archaeological samples from other islands within and beyond Samoa. Major element data indicated that the artefacts from Tutuila and 'Upolu came from the same source island, and that island is almost certainly Tutuila.

The 'Aoa volcanic glass artefacts come from an early and a late component and range in age from about 3000 years to perhaps 400 years (Clark and Michlovic 1996). However, these artefacts are much more abundant in the early component, which is the first millennium B.C. In later centuries, the use of volcanic glass decreased while the use of basaltic tools increased substantially. In addition, 'Upolu samples from Vailele 4 sourced to Tutuila are on the order of 2000-1500 years old.

Three small pieces of pink to rose-coloured siliceous material, probably chert, have been found at two sites in 'Upolu and one on Tutuila. A single flake from 'Aoa dates to about 2764-2195 BP (2 s) (Clark and Michlovic 1996). On 'Upolu, a flake from Sasoa'a (SU-Sa-3) dates to about 1986-1530 BP (2 s) (Green 1974a:149), and a flake from Leuluasi (SU-Le-12) is probably one to two thousand years old (Davidson and Fagan 1974:89). Siliceous material of this type almost certainly comes from beyond Samoa, perhaps Fiji or Futuna.

Another potentially important material for interaction studies is pottery. Petrographic analyses by Dickinson (1974, 1976, 1993, pers. comm. 1994) of sherds from sites on 'Upolu, Ofu and Tutuila provided no evidence of pottery transport between Samoa and any other island groups. However, Petchey's (1995) recent temper analysis of additional sherds from the Lapita site at Mulifanua, 'Upolu, indicates that one sherd came from Tonga or Fiji. We note also that Leach and Green (1989) described an adze from Mulifanua with macroscopic characteristics suggestive of Tongan origin. Also, Green, Best and Richards (1988) reported a surface collected adze from Luatuanu'u, 'Upolu, that they view as an early (Lapita) type unknown from

Samoa. Furthermore, they observed that it is from a material that macroscopically is unlike Samoan basaltic rocks, and comparison with other adzes suggests that it most likely came from Fiji. Petchey (1995:54) reports a recent date for Mulifanua at cal. 2358 BP, which is surprisingly later than an earlier assessment of cal. 2950 BP, and also later than one would expect based on ceramic typology. Clay characterisations by Hunt and Erkelens (1993) suggest that some sherds from To'aga, Ofu are exotic to the island. These imported sherds date between 3000 and 1500 years ago.

CONCLUSION

The archaeological data summarised in this paper illustrate that basaltic-rock quarries are common on the island of Tutuila although uncommon on other islands in Samoa. These quarries are quite variable in size and production capacity, yet two factors seem to hold constant: (1) the raw material is of better flaking quality - which largely means more hawaiitic than basaltic - than in other areas; and (2) the raw material occurs in easily exploitable and workable form, i.e. naturally fracturing, angular chunks. While the first inhabitants of Samoa, beginning some three millennia ago, utilised basaltic rock for tools, the most intensive production of this material came in the last millennium on Tutuila.

The geochemical study indicates that there are ranges in the elemental composition of basaltic-rock quarries on Tutuila. Furthermore, in many instances these ranges overlap, even with quarries in different volcanic series. Given these overlaps, together with the realisation that there are many undiscovered quarries on the island, attempts to assign artefacts from non-quarry sites to specific quarries on the basis of oxides is premature. Instead, artefact geochemistry is best used to identify the island of origin and to eliminate unsuitable source possibilities. Consequently, the statements of Best *et al.* (1992) regarding the quarry sources of numerous artefacts throughout the central Pacific should be regarded as hypotheses, not facts. At the same time, the work of Best and colleagues marks a major achievement in geochemical studies of artefacts and source areas, and their compiled data provide a firm foundation on which future studies can build.[5]

Archaeological and geochemical data demonstrate that the quarries of Tutuila were major suppliers of basaltic-rock artefacts, either as preforms or finished adzes, to other islands within the archipelago and, eventually, to neighbouring archipelagoes. From the evidence at hand, we propose the following descriptive model of island interactions.

Kirch (1988) has suggested that the initial migrants to the West Polynesia-Fiji region engaged in long-distance regional relations that were maintained, in part, by exchange activities. From the archaeological evidence in Samoa, if such a network existed, it was weakly maintained and is indicated only by the presence of a few pieces of chert. Such a system quickly broke down, probably as local populations interacted more with one another than with distant populations. A substantially reduced remnant of the regional system was retained through the first millennium BC in the form of intra-archipelagic networks. In Samoa such a network is evidenced by the distribution of volcanic glass from Tutuila and possibly by the exchange of pottery. By about 2000 years ago, perhaps a little more, hawaiites from Tutuila were also exchange goods in the intra-archipelagic system. It is not known what goods were coming into Tutuila in exchange.

Approximately a millennium later, the network of interactions expanded to become inter-archipelagic, encompassing a large area of the central Pacific. By this time, volcanic glass had apparently lost value and may not have been a trade commodity. Basaltic-rock artefacts were the primary exchange item moving out of Tutuila, but the goods coming in are again unknown. During the inter-archipelagic phase of interactions, the larger quarries of Tutuila were expanded and production intensified. And while those quarries were probably the major suppliers of basaltic rock, smaller quarries are also likely to have produced some export material. Shortly after the introduction of metal into the region, the value of basaltic rock dropped dramatically. Around the beginning of the 19th century, export production from the Tutuila quarries largely ceased.

In conclusion, this study highlights the need for further investigations. First, archaeological data relating to chronology, quarrying process, tool-making technology and relationship to nearby sites (e.g., *tia' ave* , terraces and defensive features) is sorely needed at quarries representing the range in site sizes. Second, additional quarries should be sought throughout Samoa, especially on Tutuila. Systematic surveys of sample areas in central and western Tutuila would be highly informative. As part of those surveys, the areas around Nu'u'uli, Afao and Maloata should be carefully examined, and the upper Leafu area should be searched for the hypothesised low-titanium quarry. Finally, geochemical characterisations from multiple samples should be made for each quarry (Weisler 1993c; Chapter 10). Specifically, TTM-L should be directly and more thoroughly characterised, as it may form a distinctly identifiable source.

By combining geochemical with archaeological studies of non-perishable materials, we can develop a better picture of the geographic extent and timing of inter-island interactions. While recent studies of this type have made advances in this area, there is still much to learn about the total pattern and process of short- and long-distance island interactions.

NOTES

1. The address for XRAL is as follows: XRAL Activation Services Inc., 3915 Research Park Drive, Suite A12, Ann Arbor, Michigan 48108 USA.

2. This analysis was carried out by John Sinton, University of Hawaii (see Chapter 10).

3. The Fagasā sample (TUT9) included in Best *et al.* (1992) is from an analysis by Natland a number of years ago and may not be strictly comparable. In any case, it is a basalt from the coastal flows, not at the quarries. Geochemically, it matches none of the actual quarry samples that we collected.

4. Dates reported here as 'bp' ages are uncalibrated while those listed as 'BP' are calibrated according to CALIB 3.03 (Stuiver and Reimer 1993).

5. While the article of Best *et al.* (1992) is an important contribution, there are a number of small errors that should be corrected. The East Tutuila Sa'ilele Quarry, site AS-23-11, is actually Usi #1, site AS-23-12. Site AS-21-6 is from the village of Fa'alefu and is not near Maupua. For sample TUT 9 they report a measurement for Fe_2O_3T but it is really a measure of FeO*, and samples UPO 2 and UPO 3 have iron totals that may also be calculated as FeO* (original data from Natland 1975).

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