THE IMPACT OF CYCLONIC SURGE ON ARCHAEOLOGICAL SITES IN TONGA

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In the Pacific Islands, it has long been observed that sites situated on shorelines may be particularly threatened by erosion by the sea. This paper assesses the impact of excessive wave action on archaeological sites generated by cyclones or tsunamis. The case study is based on observations made during seven months of archaeological fieldwork on Tongatapu.

Covering some 245 square kilometres, Tongatapu is the largest island in the Tongan group. It is a coral limestone block with a gently rolling topography, there being only a few knolls and small hills to provide relief. The island rises to a maximum height of some 65 m along the southeastern coast, and has a fringing reef on the west, south and east, sometimes approaching the base of the cliffs, but more commonly situated some 50 to 60 m offshore. The northern shore, however, dips gently into the sea and is protected by a fringing reef, patch reefs and sand cays. On the fringe of the reef are a number of small islands, mainly emerged sand cays, some of which will be the focus of this report. Due to their exposed position, these islands are obviously prone to destruction by waves generated by cyclones and tsunamis (Gabites 1979, Krishna 1984, Bird 1976:28-31).

Whereas tropical storms (sustained wind speeds between 34 and 63 knots) and hurricanes (sustained wind speeds greater than 64 knots) occur frequently in the Tongan Group, with an average of one per 1.8 years (Kerr 1976; Lewis 1978), tsunamis are apparently a comparatively rare feature on Tongatapu (see Soloviev and Go 1984, Lewis 1978). Volcanic eruptions have been noted during the historical period (Lewis 1979), especially those associated with the notoriously appearing and disappearing islands created by submarine vents, such as Metis Shoal and Falcon Island (Lewis 1978), but none of these eruptions have caused waves or surges of any size.

THE CASE STUDY

Due to two excellent publications we are well informed about the physical state of some of the smaller islets off the northern coast of Tongatapu (Figure 1). In 1969 D.R. Stoddart (1975) undertook detailed mapping of some sand cays off Tongatapu. After Cyclone Isaac some of these islets were revisited by C. Woodroffe (1983), who undertook an assessment of the damage to the shoreline caused by the cyclone. This paper draws heavily on these two studies, since they supply an excellent basis for assessing the damage to archaeological sites caused by tidal wave action.

During the 1985|86 field season of the Tongan Dark Ages Research Programme (TDARP) some of the offshore islets were surveyed and the archaeological sites mapped (Spennemann 1986).

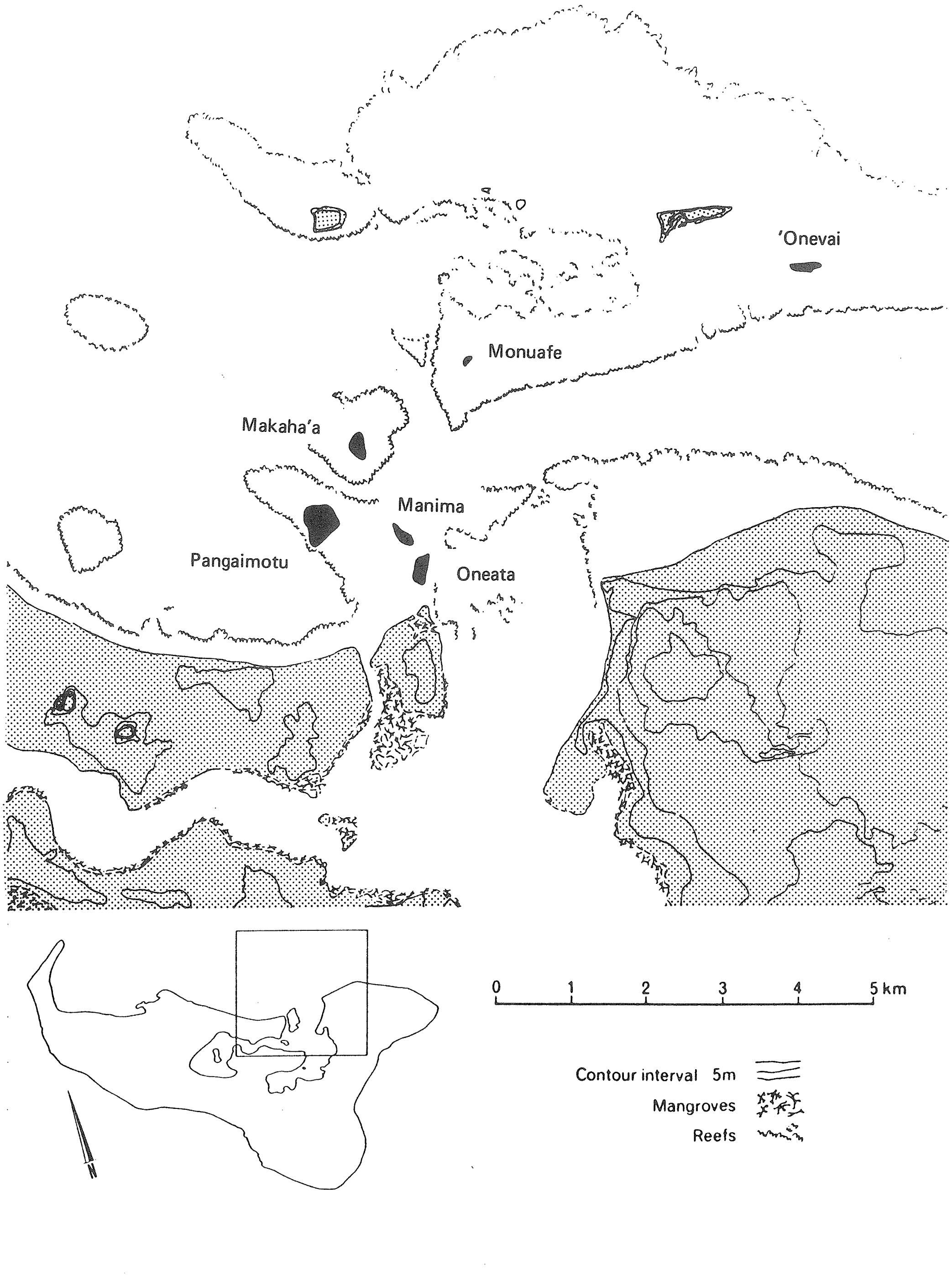

Figure 1. Map of the north-eastern part of Tongatapu, Tongan Islands, showing locations discussed in the text.

Cyclone Isaac

Tropical Cyclone Isaac, which hit Tonga on March 3, 1982, was undoubtedly one of the worst storms which Tonga has experienced this century. It claimed six lives and caused enormous devastation to buildings and crops. The cyclone developed about 160 km northeast of Western Samoa and travelled southwest at an average speed of 12 knots, travelling directly over the Ha'apai Group and passing some 53 km northwest of Tongatapu. Wind direction appears to have changed during the passage of the storm and trees fell in all directions. In Nuku'alofa a peak gust of 92 knots was measured (Reddy 1982), and more than 120 mm of rainfall fell on Tongatapu.

Tides in Tonga are semi-diurnal; the tidal range is about 1.20 m at springs and 0.70 m at neaps (Belz 1984; Woodroffe 1983). Cyclone Isaac coincided with a high spring tide of 1.2 m at Nuku'alofa. Since no tide gauge was in operation at the time of the storm, no exact record of the height of the storm surge is available. Extensive flooding of coastal areas on the northern coast and the fact that Nuku'alofa was entirely under water testify that the water was several meters above the high-tide level (for a more detailed assessment of damage see Oliver and Reardon 1982).

The worst flooding occurred in the low-lying areas of Sopu, the western part of Nuku'alofa, where the seawall enclosing an area of reclaimed mud flat (Straatmans 1954) was breached by the storm and renewed tidal inundation in the area meant the loss of several hectares of grassland. The tidal surge at Sopu was approximately 2.0 to 2.5 m above high tide level (I. Helu pers.comm). Much of the storm surge associated with Cyclone Isaac must have been buffered by the great width of reef flat along this coast and therefore its impact was not enormous.

The situation, however, was different on the small, low-lying sand cays off the northern shore of Tongatapu. These islands are either directly at or very near the reefs (Figure 1). Three of these islands are now discussed in more detail; Pangaimotu, Makaha'a and Monuafe.

Pangaimotu (Figure 2)

Pangaimotu is the largest of the sand cays off Tongatapu and the closest to Nuku'alofa. In some places the depth of water between it and Tongatapu is less than 1.5 m, which at low tide allows access on foot. The island is roughly triangular, 680 m long N-S and up to 500 m wide, with an area of 22.3 ha. The shores are aggrading except at the extreme eastern and western points: beachrock outcrops only occur at the latter, at the foot of the beach. Today the island is covered with coconut palm woodland surrounded by a thicket of broadleaf trees.

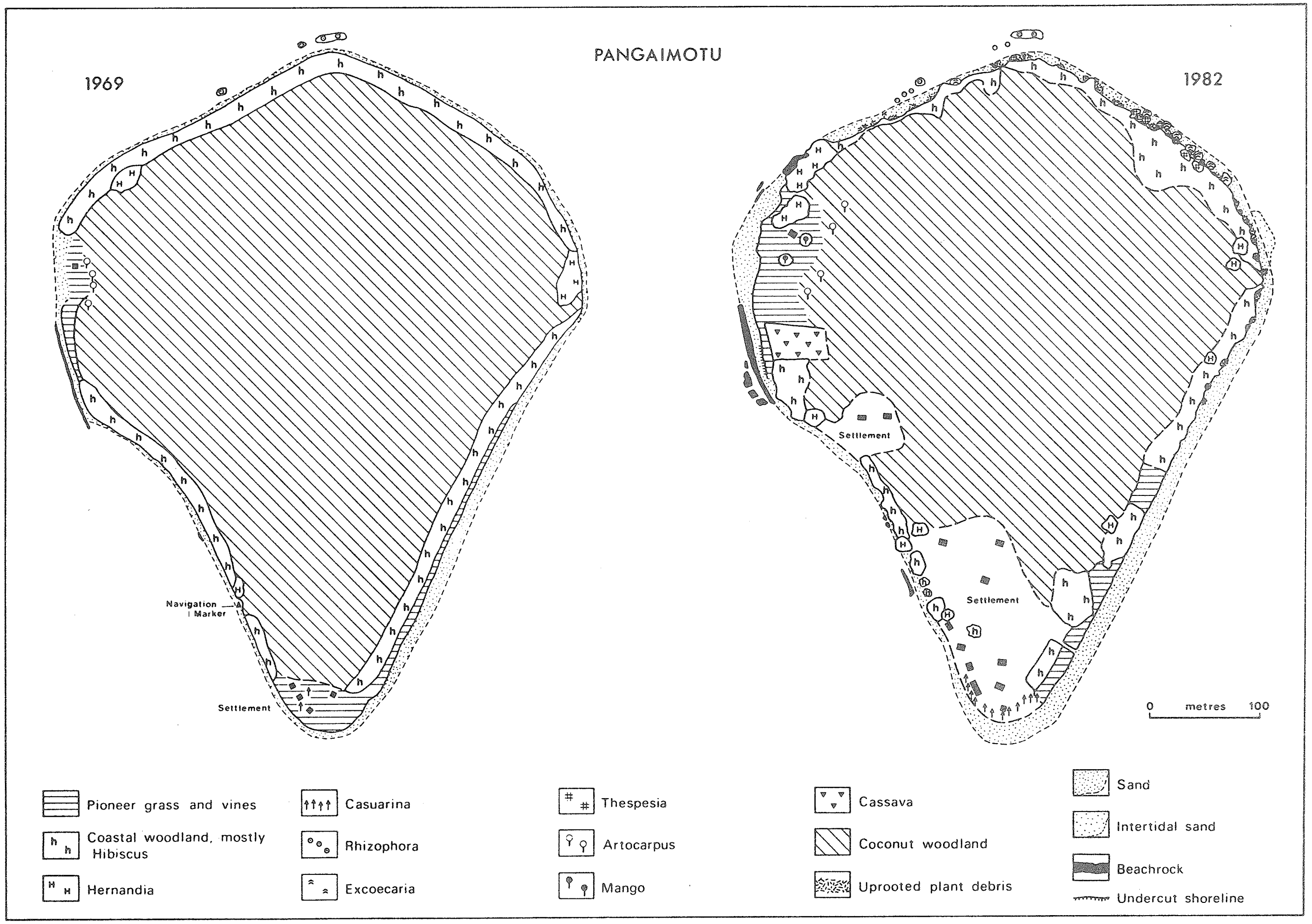

Figure 2. Map of Pangaimotu Island, Tonga. Left: state in 1969. Right: state in 1982. Reprinted from Woodroffe 1983, Fig. 9, with permission of the author and the University of Hawaii Press.

According to the current tenant of Pangaimotu, a surge caused by Cyclone Isaac swept the entire (southern?) part of the island. This surge was more than 1 m above normal high water level and flooded an electric generator erected 0.8 m above ground "in the middle of the island" (E. Emberson, pers.comm.).

According to Woodroffe, the impact of Cyclone Isaac was most apparent along the northeast and east shore where there was a discontinuous tangle of plant debris, along with several fallen coconut palms. Comparing the 1982 and 1969 surveys, there appears to have been about 10-11 m of retreat along this coast in 13 years. Obviously not all of this need have resulted from Cyclone Isaac: indeed, Stoddart recorded (1975:5) that erosion was taking place at the eastern point of the island. However, the retreat of land around some trees left on the foreshore implies that at least 8 m of erosion did occur during the cyclone.

The only extensive outcrop of beachrock is to the west of the island. Woodroffe (1983) mentions it as extending 95 m along the shore and up to 6 m wide, with further degraded outcrops to seaward. The archaeological survey of 1985/6 showed the outcrops to be 135 m long and up to 15 m wide at low tide (at high tide they are completely water covered). This beachrock outcrop has been used as a quarry for stone slabs used in the construction of langi (McKern 1929; Spennemann in press).

The first archaeological work on Pangaimotu was undertaken by William C. McKern in 1920/21. He noted the quarry on the west side of the island (McKern 1929:5) and excavated one "kitchen midden" (ibid. 102-103) and one burial mound subsequently used as a habitation site with earth-ovens (ibid. 104-106). The skeletal remains from this mound were analysed by the present author and showed severe cut marks resulting most likely from blows with metal knives or bayonets.

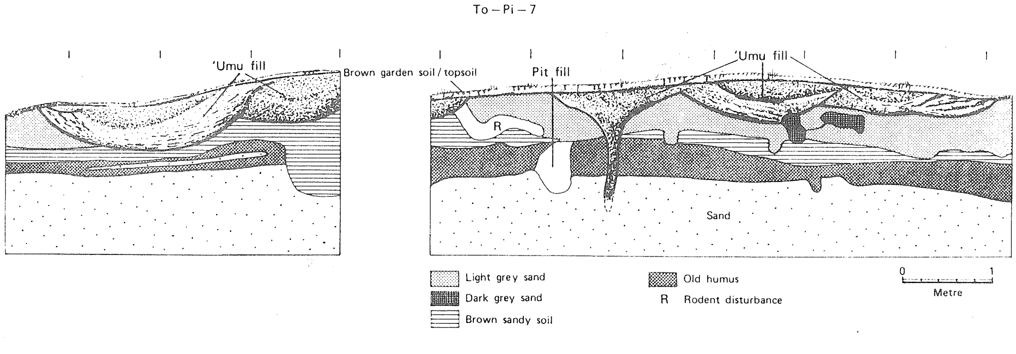

Figure 3. Pangaimotu I., Tongatapu, Tonga. Drawing of cleaned, exposed profile, site To-Pi-7.

During the 1985/86 field season Pangaimotu was surveyed. Due to heavy coverage of the interior with bush and thicket some sites will certainly have been overlooked. A group of eight mounds, the only mounds on the island, was seen at the western tip of the island, directly above the outcrop of beachrock. One mound, site TO-Pi-7, was affected by wave-generated erosion. The exposed profile of this mound was cleared and drawn (Figure 3). The correlation between the mounds mapped during this survey and the mounds excavated by Mckern could not be established beyond doubt, but it seems as if the "kitchen midden" which Mckern excavated has been completely washed away.

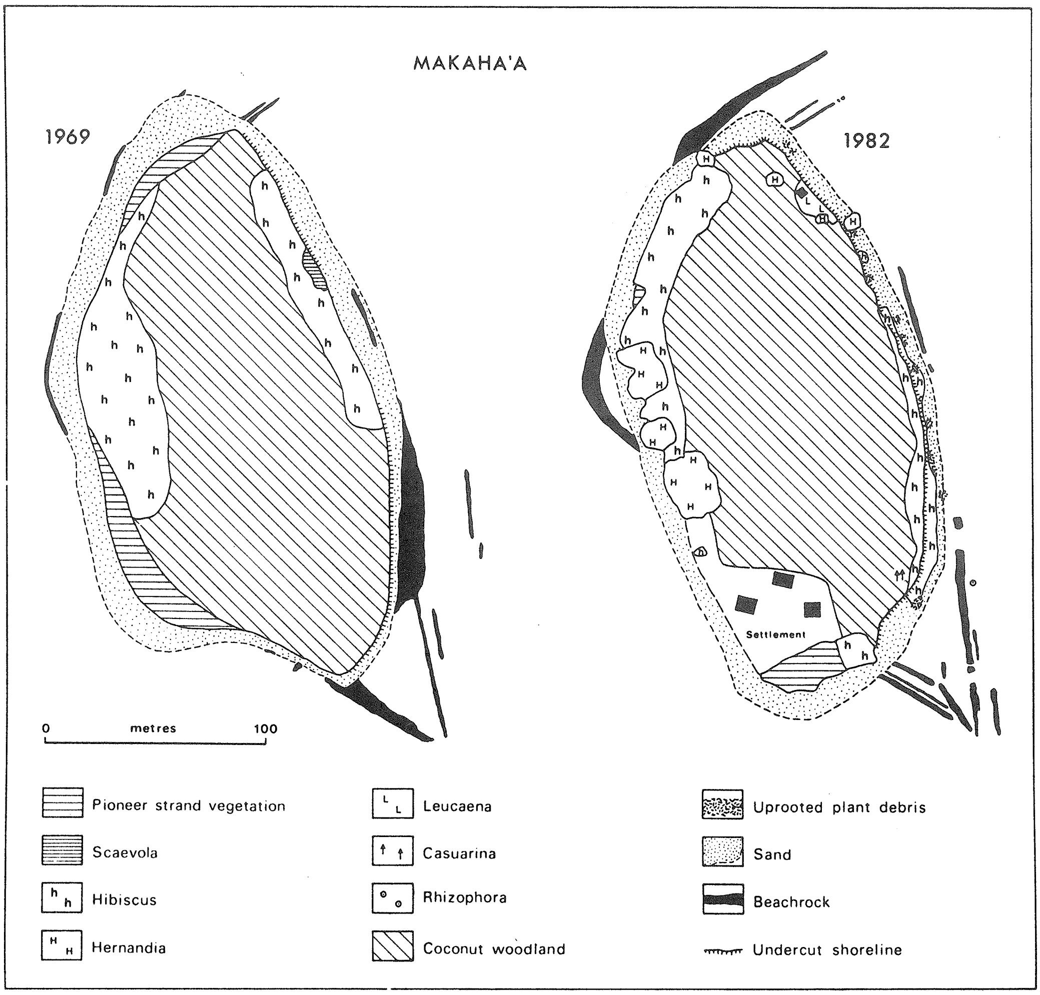

Figure 4. Map of Makaha'a Island, Tonga. Left: state in 1969. Right: state in 1982. Reprinted from Woodroffe 1983, Fig. 10, with permission of the author and the University of Hawaii Press.

Makaha'a

Makaha'a (Figure 4) is a small oval sand cay, 310 m long and 170 m in greatest width, on the eastern side of a reef patch isolated from the Tongatapu fringing reefs by a narrow channel about 10 m deep. It is approached through a gap in the encircling reef at its northeast point.

The island has aggrading sand beaches on its west and northwest sides and flat ('umu-)stone spreads fronting eroded sand cliffs on its eastern side. These cliffs are 1.5-2 m high along most of the eastern shore, rising to 3 m in the southeast. Beachrock is extensively exposed, especially in the southeast, and the island is clearly migrating towards the northwest. The eastern cliff is cut in sand, exposing coconut tree roots, and is marked by fallen coconut plams and some large fallen Hernandia.

The vegetation is primarily an open coconut palm woodland with a varied undergrowth of low trees. In his assessment of the island after Cyclone Isaac, C. Woodroffe (1983) stated:

> Makaha'a shows several marked changes from 1969 to 1982. The patterns of beachrock mapped in the two surveys are broadly similar and serve as a reference for the rest of the island. An area of settlement with three buildings has grown up on sand which has aggraded to the southwest of the island since the earlier study. An undercut shoreline was observed along the eastern shore in 1982, rising from 1.4 m at the south to 2 m to the southeast, and being approximately 1 m high on the eastern shore. However, along much of the central part of this eastern shore the cliff is covered by growth of Hibiscus presently extending 3 to 4 m to seaward and showing little or no evidence of disturbance resulting from Cyclone Isaac. It would appear that the present undercutting predates the recent storm. To the southeast where the sand cliff is not protected by growth of Hibiscus, some retreat appears to have occurred; coconut woodland is exposed on the coast and coconuts are undermined. In these areas retreat of 20 m or more has occurred since 1969, and there was various plant debris.

The first archaeological survey to take place on Makaha'a was conducted in 1957 by Jack Golson. He noted a stone-lined burial mound on the east side of the island, which was badly eroding (see Figure 5), with more than half of the site already washed into the sea. He also noted a burial vault, just visible in the profile. His excavation proved that the mound consisted of two construction phases, an earlier house or settlement mound and a later use as a burial mound (Golson 1957). This re-use of house mounds has been observed in other excavations as well (Spennemann, unpubl. fieldnotes).

On the occasion of the 1986 survey of Makaha'a no trace of the stone lining could be seen and the burial vault mentioned by Golson was standing in the middle of the beach (Figure 5), some 2 to 3 m in front of the present sand cliff. Only a small part (approx. 1 m) of the earth mound is still visible. Since 1957 at least 5 m of shoreline has been eroded here.

A large coastal midden was encountered along the southeast coast of Makaha'a, showing a 2–3 m high steep scarp caused by wave erosion. This midden is degrading very quickly. Woodroffe (see above) reckons that at this place the shoreline has retreated 20 m or more since 1969.

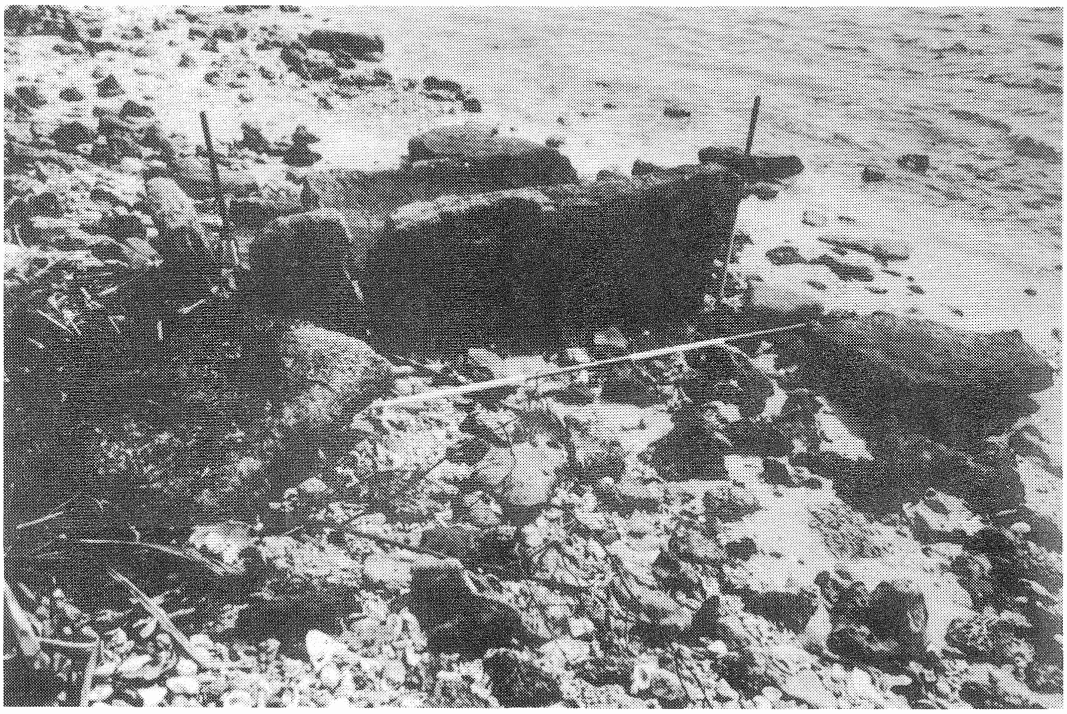

Figure 5. Burial chamber at low tide. Site TO-Bi-1, Makaha'a, Tongatapu, Tonga. At low tide as seen from the south-west.

Monuafe (Figure 6)

Monuafe was mapped by W. Wilson (1799) as Monooaffai, and appears on the maps as much larger in relation to the other islands than it does today. However, this could be an inaccuracy of the map caused by a mistake in drawing.

The island is an excellent example of an almost completely destroyed sand cay. In 1982, it was 176 m long and 56 m wide. It lies to the northeast of a deep channel separating it from Makaha'a. There are outcrops of beachrock to the north and east (Figure 6), indicating that the island was more extensive at the time of beachrock

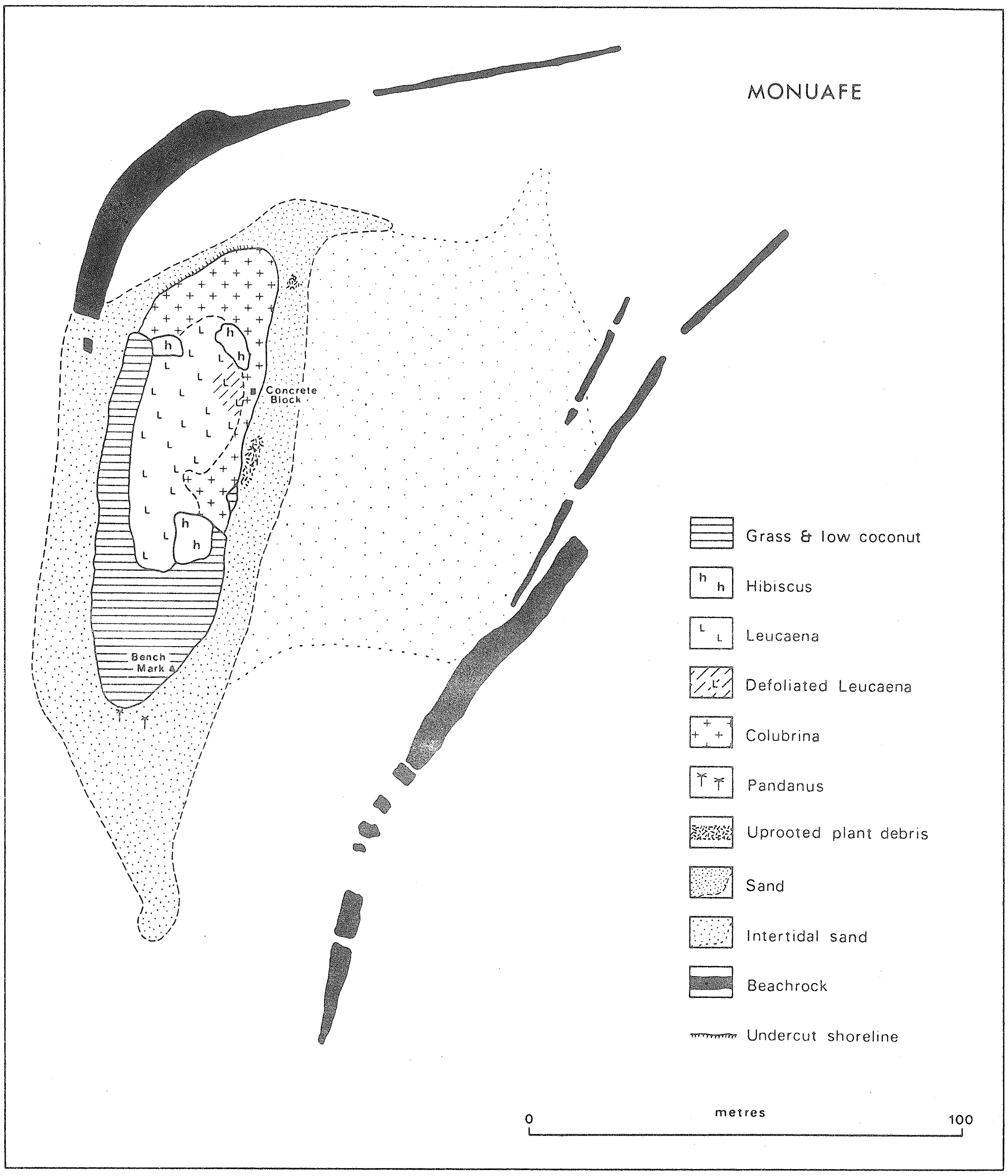

Figure 6. Map of Monuafe Island, Tonga; state in 1982. Reprinted from Woodroffe 1983, Fig. 11, with permission of the author and the University of Hawaii Press.

formation. An expanse of intertidal sand, exposed at low tide and up to 70 m wide, separates the vegetated island from a discontinuous line of beachrock to the east.

The vegetation of Monuafe is not well developed and is composed largely of grass and scrub up to 3 m high. Grass covers much of the west and south of the island, and a few recently planted coconut palms occur.

Little evidence of storm damage was observed by Woodroffe, partly because the scrub has little woody vegetation which might be preserved, in contrast to the tangle of uprooted plants on the islands to the south. The only undercutting of the shoreline has been in the north of the island where a sand cliff up to 70 cm high can be traced for 30 m along the shore at the point where the beach is narrowest, and beachrock is found at the base of the beach. The large intertidal flat to the east results from recession of the island, but there is no indication as to whether this occurred during the cyclone or whether it predates the storm.

During the archaeological survey in 1986 an erosion edge was clearly visible at both the eastern and western shores. Considerable parts of the northern shore must have been washed away in very recent times, since a concrete trigonometric point, dated 20 January 1983, was found intact in position 4 m out in the shallow water. Another trigonometric point, from the 1956 survey, originally sunk 0.5 m deep, was found lying loose on the island. Whether the latter was uprooted by human or by natural action could not be determined.

Some potsherds were found at the southern and western sides of the island, in completely reworked beach deposits. Two of these sherds show an incised decoration characteristic of the later Fijian wares.

DISCUSSION

The destructive effect of wave-generated erosion on archaeological sites can be observed not only on the islands described in the text, but also on other islets such as 'Onevao, Manima and Oneata and in sites along the northeastern shore of the Tongatapu mainland. In some instances (e.g. Manima and 'Onevao) entire sites have been washed away. All that remains are scatters of oven stones, stone adze fragments and (sometimes) pottery.

The uneven distribution of observable shoreline retreat, especially on Makaha'a, suggests that day-to-day erosion plays the most damaging role in site destruction. Occasional storm surges, however, are able to wash away entire sites on a single occasion and form therefore the most destructive element.

The destructive effects of cyclonic storm surges and the mud and sand masses carried by them must have had their effects throughout prehistory. At times one effect was the archaeological preservation under the mudflows of the village destroyed by them. A good example is the site of Vaito'otia-Fa'ahia on Huahine in the Society Islands (Sinoto 1983a, 1983b). At Anuta (Kirch 1982) a cyclonic storm surge apparently capped a prehistoric settlement with a roughly 0.5 m thick layer of sand, producing a hiatus in the occupation.

In Fiji cyclones frequently expose hitherto unknown archaeological deposits along the shoreline, so that monitoring the effects of cyclonic storm surges can be used as a surveying technique (F.Clunie, pers.comm).

On the other hand, storm surges and tsunamis have destroyed entire archaeological assemblages on the Siassi Islands of Papua New Guinea (Lilley 1986) and elsewhere in Melanesia, and have been re-working coastal shell-middens in Australia (Hughes & Sullivan 1974) and in the Andaman Islands (Cooper 1985).

CONCLUSIONS

Surges generated by cyclones or tsunamis, as well as day-to-day wave action, are major factors influencing the forms of the shorelines of small low-lying islands. From an archaeological viewpoint, abnormally strong wave action on the shoreline offers advantages and disadvantages. While wave action may expose hitherto unknown archaeological sites, however, the negative impact of sites being washed away is greater.

Archaeological sites located on low-lying, exposed islands are highly threatened by wave-generated erosion, through both occasional storm surges and day-to-day wave action.

In order to preserve the National Cultural Heritage as well as the World Cultural Heritage the protection of such sites is of importance. Since the conservation of these coastlines is rendered impossible because of the horrendous coasts involved, most of the threatened sites should be test-excavated as soon as possible in order to recover information. Further, more detailed excavations should follow, wherever and whenever necessary.

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