Disruption of coastal societies in the Pacific Islands from rapid sea-level fall about AD 1300: new evidence from northern Viti Levu Island, Fiji

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Abstract

This paper reports preliminary findings of a study in northern Viti Levu Island (Fiji) intended to test the model of the AD 1300 Event. This holds that around AD 1250-1350, during the transition between the Medieval Warm Period and the Little Ice Age, there was a rapid climate-driven sea-level fall of 70-80 cm which created a food crisis for coastal dwellers throughout the tropical Pacific Islands and led to conflict and the abandonment of open coastal settlements in favour of those in more defensible locations. Two main areas were targeted – the Ba River Valley and adjoining Vatia Peninsula (plus offshore islands) – and inland/offshore sites in defensible locations, particularly in caves, ridge-top rockshelters, and isolated hilltops, were surveyed and test excavations made. Results show that while some of these sites were established during the AD 1300 Event, most were established shortly afterwards, which is exactly what the model predicts. It is concluded that prehistoric populations in Fiji (and similar island groups) were affected by the food crisis during the AD 1300 Event and did respond in ways that profoundly and enduringly altered contemporary trajectories of societal evolution.

This study has great implications for the preservation of the record of prehistoric settlement in Fiji (and other tropical Pacific Island groups) because as a consequence of this climate-forced migration from coasts to inland/upland sites, large amounts of sediment were released from island interiors and carried to their coasts where they buried earlier settlements or redistributed their material signature. Since European arrival in such places around 150 years ago, a second wave of coastal sedimentation, largely driven by plantation agriculture development had similar effects. The current rise of sea level around Pacific Island coasts is the latest in a series of (largely human) threats to the preservation of their cultural heritage.

Introduction

There is compelling evidence from across the tropical Pacific Islands and elsewhere of societal collapse 600-700 years ago (Nunn 2007a, 2007b; Nunn et al. 2007). This evidence is mostly from contrasting the "time of plenty" that characterized many island societies during the Medieval Warm Period (ca. AD 750-1250) and the "time of less" which obtained in most of the ensuing Little Ice Age (ca. AD 1350-1800). In many island societies, a food crisis during the transition period (The AD 1300 Event – ca. AD 1250-1350) evidently led to conflict which is most widely manifested in the archaeological record by the contrast between open coastal settlements during the Medieval Warm Period and fortified inland upland settlements during the Little Ice Age.

One possible cause of this widespread and fundamental change in Pacific Island societies is a climate-driven sea-level fall of 70-80 cm which occurred during the AD 1300 Event. By exposing coral-reef surfaces, reducing water movement in nearshore lagoons, and lowering coastal water tables, it is estimated that this sea-level fall brought about an 80% decrease in coastal food resources within the hundred years of the AD 1300 Event. For long-established coastal populations dependent on marine foods, it is understandable how such a situation would lead to conflict and the abandonment of coastal settlements in favour of others in fortifiable locations.

While there is a plethora of data in support of this model from both Pacific Islands and the continental rim of the Pacific (Nunn 2007a) and it has attracted independent support from elsewhere in the Pacific Basin (e.g. Whyte et al. 2005; Carson 2008; Mann et al. 2009), it has also attracted criticism from several scientists who regard it as either too general or involving incorrect interpretations of particular data sets (Allen 2006; Hope et al. 2009). It is indeed true that many corroborative data were collected for different purposes and could be argued as being unable to properly test the model. For this reason, a major project funded by the Vetlesen Foundation is underway in northern Viti Levu Island, Fiji, to gather data to test the model in a hitherto archaeologically-unknown area. This paper describes the preliminary results.

The environmental changes that accompanied the AD 1300 Event model (coastal sedimentation, floodplain aggradation, shallow seafloor emergence) brought about major changes to the habitability of the coastal zone that had been occupied by people for millennia previously. In particular, these changes have obscured, typically by burial or re-distribution of artefacts, the evidence of these earlier cultures in these areas. Thus in the prehistory of Fiji, for example, there are major gaps in our understanding owing to an absence of contemporary sites.

Environmental change poses similar threats today. In island groups like Fiji, especially over the past 150 years with the wholesale transformation of island

landuse associated with colonization and globalization, there have been in places rapid coastal sedimentation and increased nearshore sediment mobilization, and in other places shoreline erosion attributable to vegetation clearance and sea-level rise. Many such island coasts, where the richest legacy of prehistoric settlement is generally found, are rapidly developing, particularly experiencing conversion from benign natural conditions to more dynamic revenue-generating conditions including tourism, mining and the spread of urban areas. National legislation to ensure the preservation of tangible cultural heritage in the face of such developments is largely impotent to prevent these in small developing economies such as most in the Pacific Islands (Ratunabuabua 2005; Thomas and Teaero 2010).

Study Area

The Fiji Islands comprise a large and dispersed archipelago (Figure 1), the importance of which to an understanding of Pacific prehistory is manifest (Clark and Anderson 2009a). Like many oceanic (rather than continent-peripheral) islands, Fiji provides a model system for understanding interactions between biota (including humans) and the environment. With specific regard to understanding the effects of climate-driven environmental changes on human-societal behaviour, important studies have been carried out in Fiji on both its early settlers (Nunn 2009) and on populations during the AD 1300 Event (Kumar et al. 2006). It seems clear that coastal settlement dominated in most parts of the Pacific Islands (including Fiji) until about the 15th century. The subsequent changes, both those during the early part of the Little Ice Age and those of post-colonial times, have resulted in geomorphic change in such coastal areas which renders a complete understanding of their settlement history almost impossible.

The largest island in Fiji is named Viti Levu and most evidence shows that until about 600 years ago, its inhabitants were clustered – as most are today – along its coasts. In the historical context, this is consistent with lifestyles based around nearshore marine subsistence yet also incorporating, increasingly during the Medieval Warm Period, some peri-coastal agriculture, often of *taro* (*Colocasia esculenta*) cultivation on irrigated terraces (Hashimoto 1990; Parry 1994; Kuhlken 1994; Kuhlken and Crosby 1999; Kumar et al. 2006). There is only little evidence for true inland occupation and there is discussion about whether this represents sustained or transitory occupations, perhaps temporary refuges from local conflicts or overnight stops *en route* from one coast to the other (Best 1984; Field 2004; Nunn and Kumar 2004a).

While the south coast of Viti Levu Island has been well studied, most would agree that the north coast of Viti Levu and its hinterland have received disproportionately little interest from archaeologists and others concerned with pre-modern human-environment interactions. This project focused on the Ba River Valley and adjoining Vatia Peninsula (Figure 2) where almost nothing was known about prehistory aside

from a few former coastal (or near-coastal) settlement sites being identified and briefly described (Parry 1997). The only exception to this is the Lapita site at Natunuku, described by Davidson et al. (1990) and Clark and Anderson (2009b), which represents one of the earliest settlements in this part of Fiji but is not relevant to any discussion of the past millennium.

Research Aims and Methods

In many other parts of the tropical Pacific Islands (and elsewhere), there is evidence for profound changes in human lifeways around (or shortly after) AD 1300. These include

- changes in settlement pattern (from coasts to inland/upland/offshore locations),
- changes in subsistence (decrease in marine dietary inputs, increase in terrestrial), and
- increased evidence for conflict (including skeletal trauma).

In addition, a whole series of environmental proxies for such change exist including

- land-use transformation in interior parts of large islands (suggesting their permanent human occupation),
- increased charcoal (from burning) inputs to river sediments,
- changed rates and patterns of deltaic sedimentation (indicating increased downstream anthropogenic sediment loads), and
- the emergence of shallow-water coral reefs, often creating new land available for human use.

All such indicators were sought in the Ba Valley and Vatia Peninsula. Given that the terrain was similar to that of the Sigatoka Valley (in southern Viti Levu Island) where such studies had been carried out (Field 2004; Nunn and Kumar 2004b; Kumar et al. 2006), there was an expectation that in the Ba Valley and Vatia Peninsula there would be a number of fortified hilltop and rockshelter sites that had been established shortly after the AD 1300 Event. Also, given that there is a sizeable delta at the mouth of the Ba River, as there is at the mouth of the Sigatoka River, there was also the expectation that there may be some sedimentary indicators of increasing inland settlement after AD 1300 in this delta and offshore islands. As elsewhere in the Pacific Islands at this time (Nunn 2007a), increased river-mouth (and deltaic) sedimentation would have extended shorelines and created offshore islands and shoals where none existed before.

While there was a concerted effort to identify likely sites using aerial photographs (and Google Earth) before fieldwork commenced, informants on the ground provided the most valuable information in this regard. And naturally the distribution of informants was governed largely by the road network, a situation that led to no

information for many large areas of the Ba catchment. For these areas, several forays were made to likely spots and a limited amount of additional information obtained.

Elderly informants, long resident in particular places, were asked about upland settlement sites. Many sites identified through this method were associated with oral histories recalling the movements of particular clans from upland fortified sites to their present lowland ones. This movement commonly occurred in Fiji with the arrival of European missionaries in the mid-19th century, a time that saw population decimation from the introduction of alien diseases and the widespread reduction of conflict (McNeill 1994; Denoon 1995) .

Site surveys were undertaken in most such places visited, supplemented by augering (38 holes) and test-pit excavation (total of 17 m^2 to date). Where suitable samples were found, these were sent for radiocarbon dating. Traditional protocols were followed in obtaining access to these sites and specific permission was sought before carrying out excavations. The entire project is sanctioned by the Fiji Museum through the issue of permits.

The survey in the Ba Delta and offshore islands was informed by aerial photo survey and several key locations identified. Coring at these was carried out using a (maximum) six-metre long, 4-cm diameter, hand corer with a sediment sampler attachment.

Preliminary Results – Human Lifeway Change

Four sites inland from the Ba coast have been satisfactorily dated thus far in the project. They are Naqara, Nayavutu, Tubabaka and Vatusososo, all of which are cave/rockshelter sites in the northeast part of the catchment. In addition, three sites have been dated on the Vatia Peninsula: the cave at Matanigaga, the hillfort of Vatutaqiri, and the offshore island of Vatia Lailai (see Figure 2). There follows a brief description of each site together with the results of radiocarbon dating.

Naqara (in Fijian, *the cave*) is approximately 350 m above sea level and is the furthest inland site described in this paper, being almost 20 km from the coast at Natunuku. The cave is cut in volcanic conglomerate with large chambers in its finer-grained least well-consolidated facies. Potsherds and edible shell remains (predominantly the marine-shell species *Anadara* and *Gafrarium*) were abundant on the surface. The cave has two entrances, both of which are narrow because of boulders that have fallen down from above. One auger hole inside the cave exposed a 60-cm thick cultural deposit. Radiocarbon dates from the base of the cultural sequence (Table 1) suggest the cave was occupied as early as AD 1480.

Nayavutu (or Qara) is around 5 km from the sea at Natunuku, some 180 m above sea level, but this still represents a four-hour walk one way: a fact that led the local

people to wonder at the remains of edible marine shells found in the cave. The cave entrance is obscured behind a barrier of fallen slabs of volcanic conglomerate and represents the erosion (by groundwater) of a soft layer within this formation. This means that the cave itself, while extensive (approximately 30 m^2), is mostly low; in only a few parts did its height exceed 1.8 m. Test excavations showed the cultural layer to be 80-90 cm in thickness in parts. Radiocarbon dates (see Table 1) suggest that the cave may have been occupied first during the AD 1300 Event (AD 1270) with more intensive use thereafter, its occupants apparently consuming more marine-shell species (principally *Anadara* and *Gafrarium*) than freshwater ones (such as *Septaria*).

Tubabaka is a rockshelter site close to the divide between the Ba catchment and that to the east. It lies about 370 m above sea level. The rockshelter is formed from an overhang of lava beneath which less well-consolidated materials have been eroded. Pottery fragments and the remains of edible shells (both freshwater and marine), suggesting an intensive occupation of this site, are visible on the steep approach to the rockshelter as well as on its floor. This interpretation is supported by the size of the shelter, part of which is shown in Figure 3. One pit (1 x 2 m) was dug and bedrock reached at 74 cm. Radiocarbon dates from the bottom of the sequence (see Table 1) show that the rockshelter was first occupied during the AD 1300 Event (at least by AD 1295).

Vatusososo is a cave about 7 m in length and 4-8 m wide about 270 m above sea level. It shows signs of possible fortification both within and around the entrance, mostly in the forms of stone piles that may be collapsed walls. The cave is cut in volcanic conglomerate and the walls are built from the boulders derived from this conglomerate that are scattered down the slopes below the cave entrance. Abundant pottery fragments and edible shellfish remains (especially marine species) were found at the surface and in two 1 m^2 pits that were dug. Radiocarbon dates suggest this cave was occupied as early as AD 1480 (see Table 1).

On the Vatia Peninsula, only one cave was found, some 180 m above sea level. This is at **Matanigaga** and is cut into volcanic conglomerates overlain by denser layers including some lavas. It is accessible through a narrow entrance but then opens up into a single chamber about 6 m in diameter and 10 m high. Pottery sherds and the remains of edible shells were found on the surface within this chamber. A single pit (1 m^2) was excavated and the base of the cultural deposit reached at almost 1 m depth where bedrock was encountered. Radiocarbon dates suggest cultural deposits began accumulating as early as AD 1440 (Table 1).

Vatutaqiri is only about 250 m from the shore of the Vatia Peninsula but is constructed around a hilltop (named Vatuvatuva) some 400 m above sea level (Figure 4). It is still being investigated but is regarded as unusual in that there are multiple rings of sizeable stone walls surrounding the central residential/ceremonial

areas. One radiocarbon date from a test excavation suggests that it may have been occupied comparatively recently, perhaps as early as AD 1720 (see Table 1).

Approximately 150 m across the ocean from the coast at the northeast extremity of the Vatia Peninsula lies the 3 km^2 island of **Vatia Lailai**. While no trace of fortified sites were found in its high interior, an excavation in the extensive coastal flat on its southwest side revealed signs of occupation. Dating of a single *Anadara* shell suggests that the island was occupied as early as AD 1510 (see Table 1).

For each of the inland sites described, the AD 1300 Event model implies that they were established (or at least permanently occupied) during or shortly after this event (Figure 5) as a consequence of a profound and enduring food crisis affecting the coastal settlements where people had lived in earlier times. This food crisis led to conflict which in turn led people to seek defensible sites to occupy. All the sites described from the inland parts of the Ba Valley (including Vatia Lailai) can be regarded as being in defensible locations. The fact that the radiocarbon ages for the earliest occupation of these sites all fall within or just after the AD 1300 Event (as shown in Figure 5) suggest that the model proposed may be applicable to this part of Fiji.

Preliminary Results – Environmental Proxies

The Ba Delta and the uninhabited offshore island of Tavuca (Figure 6) were also targeted in this study. Six cores were taken from the Delta but radiocarbon dates show that the bulk of the sediments recovered significantly predated the last millennium. For this reason, the Ba Delta is not therefore considered further in this paper, although it is worth noting that it is likely to have expanded significantly during and shortly after the AD 1300 Event as a result of increased terrigenous sediment inputs associated with the increase of inland settlement and associated land clearance (Nunn 2005). In this interpretation, it can simply be concluded that the sediment cores were not taken in those parts of the Ba Delta where last-millennium sedimentation had been dominant. In fact, to judge from the existence of a submerged delta (shown in Figure 6), it seems probable that last-millennium sediments associated with the upsurge in inland settlement after AD 1300 are mostly below the sea surface. The observation that this situation is quite different to that in the Sigatoka River Delta can be explained by the fact that this is a wave-dominated delta while the Ba Delta is a river-dominated delta; one where outward growth is not inhibited, on account of its leeward location, by onshore winds or currents.

There is a different story with the offshore island Tavuca where a single core recovered a 1.9 metre sediment column that began accumulating only after the AD 1300 Event (see Table 1). This result is highly significant because it implies that before this Event, when sea level was relatively high, the island of Tavuca was an offshore coral reef. Then when sea level fell during the AD 1300 Event, this reef was abruptly exposed, its surface parts died and became a focus for sediment

accumulation. In this, the last-millennium history proposed for Tavuca is similar to that inferred for atolls in various parts of Micronesia (Bikini and Kapingamarangi) and elsewhere (Nunn 2007a).

Tentative model for last-millennium settlement change

While there are still more data to be processed and interpreted, there is enough evidence from the synthesis presented above to suppose that the AD 1300 Event model proposed by Nunn (2007a, 2007b) can explain the observed settlement pattern changes in this part of Fiji. A three-stage sequence is proposed.

In **Stage 1** (2700 BC to AD 1250), most people in this part of Fiji occupied the coast (Figure 7A), largely because of their high dependence on marine foods which was supplemented by agriculture along the fertile coastal lowlands. As elsewhere, the evidence for this is largely inferential rather than empirical. For although there is a well-known early-period site at Natunuku (established ca. 2700 cal BP) where there is abundant evidence pointing to the importance of marine foraging in human diets (Davidson et al. 1990), no other sites are known. Yet by default, because there is no great number of inland sites occupied during this period – at least not permanently – it is almost certain that people continued to live along the coast as their ancestors had done at Natunuku throughout this period.

Evidence from elsewhere in the region suggests that, in spite of several prolonged droughts, the last 300 years or so of Stage 1 – the Medieval Warm Period – was largely a time of plenty (Nunn et al. 2007). There is evidence that, despite perhaps growing populations, most coastal communities were able to supply themselves with enough food to live comparatively easily. In support of this, there is little material evidence of conflict (warfare) in the tropical Pacific Islands during the Medieval Warm Period and, in the Ba Valley and Vatia Peninsula, no evidence of sustained occupation of defensive sites.

The reasons why more settlements are not known from Stage 1 is partly because there have been no systematic search for these but also because subsequent coastal sedimentation, especially from the large Ba River, has effectively obscured all trace of many of these settlements. This is of particular concern on the larger islands of the Pacific where sediment loads of large rivers have increased markedly in the past few hundred years as a result of changing land-use in their upper parts (Nunn 2005; Nunn and Heorake 2009).

In **Stage 2** (AD 1250-1350), a rapid cooling led to a rapid sea-level fall of 70-80 cm throughout the tropical Pacific (Figure 7B). This is what I and co-authors have referred to as the AD 1300 Event (Nunn 2007a, 2007b; Nunn et al. 2007) and is inferred to have caused in the study area (as elsewhere in the region) a food crisis for coastal people resulting from three main factors. These are the exposure of the most productive parts of offshore coral reefs, the reduction in the rate and

effectiveness of water circulation in nearshore (reef-bounded) lagoons, and the lowering of water tables in coastal lowlands. Depending on the antecedent population density and the diversity of the subsistence base, the response of coastal people in this area to the food crisis may have been a few years or a few decades. The former is considered likeliest, not only because there are radiocarbon ages from Nayavutu and Tubabaka implying occupation during (not after) the AD 1300 Event (see Table 1), but also because the Ba coast is on the leeward side of Viti Levu Island where coral reefs and associated marine ecosystems are generally less bioproductive than along the island's windward coasts.

It is therefore envisaged that during Stage 2, conflict erupted among the coastal dwellers of this area as a result of the food crisis. In response to the conflict, people abandoned coastal settlements and moved inland, upslope and offshore in search of more defensible locations. While this undoubtedly required a major change in subsistence, particularly a greater dependence on terrestrial foods, it is interesting that marine shellfish are found at all the inland sites investigated, even Naqara almost 20 km inland. Of course, it is unclear how important these highly-visible foods were in the subsistence of such people but it does signal a continuing their use of marine foods.

In Stage 2, it is likely that familial groups of people moved inland in search of appropriate sites. As in the Sigatoka Valley to the south (Kumar et al. 2006), inland caves and rockshelters appear to have been favoured, which is understandable given that they provide shelter, a refuge for vulnerable group members, a storage area for foods and other material goods (especially pots), and commonly an adjacent lookout position from which approaching aggressors might be readily seen. The latter point is especially true in the Ba Valley and Vatia Peninsula where the upland vegetation is (and would have been throughout the last millennium) a grassland-savanna (*talasiga*) which allows views of vast tracts of terrain.

In **Stage 3** (AD 1350-1850), it is likely that settlement in the area studied was almost exclusively non-coastal (Figure 7C). From the evidence of fortification post-dating the AD 1300 Event, it can be inferred – as elsewhere in the region at this time (Nunn 2007a) – that conflict became even more embedded among the people of the study area. This conclusion is supported by a wealth of other fortified sites in the area, especially on the Vatia Peninsula which Parry (1997: 119) regarded as having the "largest concentration of hill fortifications" in northern Viti Levu.

That this situation endured until the arrival in the mid-19th century of Europeans, who provide the earliest written descriptions of such places, seems clear. For example, behind Viti Levu Bay in the northeast of the island in 1870 could be seen

> "in the distance the houses of the mountaineers, perched curiously on the apex of rocky pinnacles, a position singularly secure from invasion ... Walking around the base of the bay in a northeasterly

> direction we came to a thickly populated town on the crest of a hill, east of which could be seen another native village, built on an immense rock. The natives who were all clustered together on a little plateau in front of the town received us very nervously ..." (Britton 1870: 55).

Yet it also seems clear that by the end of Stage 3, there was increased interaction with the coast. Several near-coastal settlements like Vatutaqiri were prodigiously fortified (see Figure 4) yet located where there was ready access to marine foods, especially shallow-water shellfish. Other fortified (ring-ditch) villages were established in the Ba Delta where mangroves were used as defences (Calvert 1849; Parry 1997). From written reports elsewhere, it is clear that by the time of European contact, interior villages had established links with near-coastal ones, the latter supplying fish to the former as a form of tribute.

The idea of a reduction in conflict towards the end of Stage 3 is similar to that elsewhere on tropical Pacific Islands where it is explained as a recovery of the food-resource base (Nunn 2007a). It should be noted that because of the massive reductions in indigenous populations in such areas shortly after European arrival, it is sometimes difficult to relate contemporary descriptions of such places to the situation that obtained before European arrival.

Conclusions

There is compelling evidence from the part of northern Viti Levu Island (Fiji) studied that sea-level fall during the AD 1300 Event led to a food crisis which, in turn, led to conflict and caused coastal people to move to live inland. This is an excellent example of how external forcing of coastal livelihoods invokes societal changes that are prolonged and profound.

Yet it is also clear that in this case the process of societal change itself initiated environmental changes that contributed significantly to the disappearance of many earlier-period coastal sites. Moving inland, people changed the natural vegetation, especially through burning, and increased upland sediment inputs to river systems. This sediment accumulated around the river mouths, where it buried and mobilized earlier settlement sites, and covered much of the new land (including offshore reef platforms) that had emerged as a result of sea-level fall.

This in turn explains some of the focus on early-period (particularly Lapita-era) settlement in Pacific Island groups like Fiji. For the Lapita people were largely marine foragers who had little interest (at least at first in Fiji and Tonga) in agriculture, so eschewed river deltas and lowland river valleys in favour of coastal sites that adjoined broad productive coral reefs (Nunn 2007c; Burley and Dickinson 2001). So today, Lapita settlement sites are comparatively easy to find in many island groups because they were located in less-dynamic coastal settings (Nunn and

Heorake 2009). In contrast, later-period sites in many island groups are often difficult to locate and challenging to convincingly reconstruct because they were often located in more dynamic coastal settings, a reflection of the desire of their inhabitants to exploit fertile alluvial soils for agriculture (Clark and Anderson 2009).

In the past 150 years or so, sediment inputs to Pacific Island coasts have generally increased as a result of comparatively rapid changes to island landscapes resulting from their conversion during colonial times. This is well seen in many parts of Fiji where plantation crops replaced native forest and other ecosystems resulting in sharply increased upland sediment loss (Cochrane 1969; Clarke and Morrison 1987; Nunn 1990).

Today many Pacific Island coasts are comparatively dynamic, particularly those which regularly experience the effects of storm surges (from hurricanes) or long-range tsunami. With sea-level rise over the past few decades, most sandy shorelines in this region have been experiencing erosion which is threatening much of the coastal cultural heritage in the region. In addition the demands of development are accentuating the loss of this cultural heritage to an extent that future generations of Pacific Islanders will inevitably bemoan.

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References

Allen MS (2006) New ideas about Late Holocene climate variability in the central Pacific. Current Anthropology 47:521-535

Best S (1984) Lakeba: the prehistory of a Fijian island. Unpublished Ph.D. dissertation, University of Auckland

Britton H (1870) Fiji in 1870, being the Letters of “The Argus” special correspondent. Samuel Mullen, Melbourne

Burley DV, Dickinson WR (2001) Origin and significance of a founding settlement in Polynesia. National Academy of Sciences, Proceedings 98:11829-11831

Calvert J (1849) Fiji and the Fijians, and Missionary Labour among the Cannibals. Volume 2. Woolmer, London

Carson MT (2008) Correlation of environmental and cultural chronology in New Caledonia. Geoarchaeology 23:695-714

Clark G, Anderson A (eds) (2009a) The Early Prehistory of Fiji. ANU E Press (Terra Australis 31), Canberra

Clark G., Anderson A (2009b) Fieldwork in northern Viti Levu and Mago Island. In: Clark G, Anderson A (eds) The Early Prehistory of Fiji. ANU E Press (Terra Australis 31), Canberra, pp 121-152

Clarke WC, Morrison J (1987) Land mismanagement and the development imperative in Fiji. In: Blaikie P, Brookfield H (eds) Land Degradation and Society. Methuen, New York, pp 76-85

Cochrane GR (1969) Problems of vegetation change in western Viti Levu, Fiji. In: Gale F, Lawton GH (eds) Settlement and Encounter. Oxford University Press, Oxford, pp 115-147

Davidson J, Hinds E, Holdaway S, Leach F (1990) The Lapita site at Natunuku, Fiji. New Zealand Journal of Archaeology 12:121-155

Denoon D (1995) Pacific Island depopulation: natural or un-natural history? In: Bryder L, Dow DA (eds) New Countries and Old Medicine: Proceedings of an International Conference on the History of Medicine and Health, Auckland, 1994. Pyramid Press, Auckland, pp 324-339

Field JS (2004) The evolution of competition and cooperation in Fijian prehistory: Archaeological research in the Sigatoka Valley. Unpublished PhD dissertation, University of Hawai‘i, Manoa

Hashimoto S (1990) Irrigated cultivation of taro in the Sigatoka Valley, Fiji. Essays of the Faculty of Letters of Kansai University 39:1-19

Hope G, Stevenson J, Southern W (2009) Vegetation histories from the Fijian Islands: alternative records of human impact. In: Clark G, Anderson A (eds) The Early Prehistory of Fiji. ANU E Press (Terra Australis 31), Canberra, pp 63-86

Kuhlken RT (1994) Agricultural Terracing in the Fiji Islands. (2 volumes). Unpublished PhD dissertation, The Louisiana State University and Agricultural and Mechanical College

Kuhlken R, Crosby A (1999) Agricultural terracing at Nakauvadra, Viti Levu: a late prehistoric irrigated agrosystem in Fiji. Asian Perspectives 38:62-89

Kumar R, Nunn PD, Field JE, de Biran A (2006. Human responses to climate change around AD 1300: a case study of the Sigatoka Valley, Viti Levu Island, Fiji. Quaternary International 151:133-143

Mann ME, Zhang ZH, Rutherford S, Bradley RS, Hughes MK, Shindell D, Ammann C, Faluvegi G, Ni FB (2009) Global signatures and dynamical origins of the Little Ice Age and Medieval Climate Anomaly. Science 326:1256-1260

McNeill JR (1994) Of Rats and Men: A Synoptic Environmental History of the Island Pacific. Journal of World History 5:299–350

Nunn PD (1990) Recent environmental changes on Pacific islands. The Geographical Journal 156:125-140

Nunn PD (2005) Reconstructing tropical paleoshorelines using archaeological data: examples from the Fiji Archipelago, southwest Pacific. Journal of Coastal Research Special Issue 42:15-25

Nunn PD (2007a) Climate, Environment and Society in the Pacific during the Last Millennium. Elsevier, Amsterdam

Nunn PD (2007b) The AD 1300 Event in the Pacific Basin. The Geographical Review 97:1-23

Nunn PD (2007c) Echoes from a distance: progress report on research into the Lapita occupation of the Rove Peninsula, southwest Viti Levu Island, Fiji. In: Bedford S, Sand C, Connaughton S (eds) *Oceanic Explorations: Lapita and Western Pacific Settlement*. Australian National University (Terra Australis 26), Canberra, pp 163-176

Nunn PD (2009) Geographical influences on settlement-location choices by initial colonizers: a case study of the Fiji Islands. Geographical Research 47:306-319

Nunn PD, Heorake TA (2009) Understanding the place properly: palaeogeography of selected Lapita sites in the western tropical Pacific Islands and its implications. In: Sheppard PJ, Thomas T, Summerhayes GR (eds) Lapita: Ancestors and Descendants. New Zealand Archaeological Association, Monograph 28, Auckland, pp 235-254

Nunn PD, Kumar R (2004a) New scientific evidence for exploitation and settlement of coastal hinterlands in Fiji around AD 785. Domodomo (Scholarly Journal of the Fiji Museum) 17:21-24

Nunn PD, Kumar R (2004b) Alluvial charcoal in the Sigatoka Valley, Viti Levu island, Fiji. Palaeogeography, Palaeoclimatology, Palaeoecology 214:153-162

Nunn PD, Hunter-Anderson R, Carson MT, Thomas F, Ulm S, Rowland M (2007) Times of plenty, times of less: chronologies of last-millennium societal disruption in the Pacific Basin. Human Ecology: An Interdisciplinary Journal 35:385-401

Parry JT (1994) Aerial photography and pre-European agriculture and fishing in Fiji. In: Morrison J, Geraghty P, Crowl L (eds) Science of Pacific Island Peoples. Institute of Pacific Studies, The University of the South Pacific, Suva. Volume II, pp 155-180

Parry JT (1997) The North Coast of Viti Levu: Ba to Ra. Air Photo Archaeology and Ethnohistory. Fiji Museum, Suva

Petchey F, Anderson A, Hogg A, Zondervan A (2008) The marine reservoir effect in the Southern Ocean: an evaluation of extant and new ΔR values and their application to archaeological chronologies. Journal of the Royal Society of New Zealand 38:243-262

Ratunabuabua M (2005) What role for culture in the sustainable development of SIDS? Unpublished paper, International (UN) Meeting to Review the Implementation of the Programme of Action for the Sustainable Development of Small Island Developing States, Mauritius, 10-14 January 2005

Thomas F, Teaero T (2010) Learning about the past today to map future routes: historic preservation and education in Kiribati. In: Nabobo-Baba U, Koya CF, Teaero T (eds) Education for Sustainable Development, Volume 1 – Continuity and Survival in the Pacific. School of Education, The University of the South Pacific, Suva. pp 26-45.

Whyte ALH, Marshall SJ, Chambers GK (2005) Human evolution in Polynesia. Human Biology 77:157-177

Captions for Figures

Figure 1. The principal islands of Fiji showing the location of the Ba Valley in northern Viti Levu Island, where this study is focused, and the Sigatoka Valley in the southern part of the island, where similar research has been carried out (Kumar et al. 2006).

Figure 2. The Ba Valley, Vatia Peninsula and the offshore islands of Tavuca and Vatia Lailai where research was conducted. The Ba River catchment is delimited by a solid line, the Ba Delta (see also Figure 4) is shown by darker shading, and the names of the last-millennium settlement sites reported in this study are underlined. Other settlement sites were studied in other parts of the Ba River catchment.

Figure 3. Views of the main part of the Tubabaka Rockshelter. The excavation in the right of the main picture is also shown in the inset.

Figure 4. Sketch of the fortified hilltop of Vatutaqiri (after Parry 1997) with photos to show the nature and scale of fortifications. Parry regarded the highest (northernmost) part of the site as having a ceremonial function while the lower enclosed and semi-enclosed compounds were for chiefly families.

Figure 5. Radiocarbon dates for selected last-millennium settlement sites in the Ba Valley and adjoining areas (see Table 1). Note that all settlements dated can be plausibly regarded as having been established either during or in the aftermath of the AD 1300 Event. as postulated originally.

Figure 6. The emergent and submerged parts of the Ba Delta, the location of offshore reefs, and Tavuca Island from which a dated core suggests the island originated only during or after the AD 1300 Event, plausibly as a result of the associated sea-level fall.

Figure 7. Plausible model for the development of settlement in the Ba Valley and Vatia Peninsula over the last millennium. Note that all settlements are represented by squares of the same size, securely-dated settlements by filled squares, likely settlements by unfilled squares.

Stage 1 (ca. AD 1200) shows the inferred situation during the Medieval Warm Period, all permanent settlement being tethered to the coast. Note that owing to the higher sea level, the emergent part of the Ba Delta is smaller than today.

Stage 2 (ca. AD 1300) shows the likely situation during the AD 1300 Event when the people of the area were responding to the food crisis driven by sea-level fall. Inland sites had already been established at

Nayavutu and Tubabaka and probably on high points elsewhere in the valley. Note that owing to the lower sea level, the emergent part of the Ba Delta was larger than today.

Stage 3 (ca. AD 1700) shows the likely situation towards the end of the Little Ice Age when populations in the area had probably increased and many more defensive settlements existed. These include all those investigated in this study. Note that owing to a slightly higher sea level, the front of the emergent Ba Delta has been cut back to approximately its present position.

Caption for Table

Table 1. Selected radiocarbon dates from the Ba Valley, Vatia Peninsula and offshore islands. Ages calibrated using OxCal (version 3.10) and, for marine shell, a ΔR value of 11±25 years (Petchey et al. 2008); 95.4% probability given.

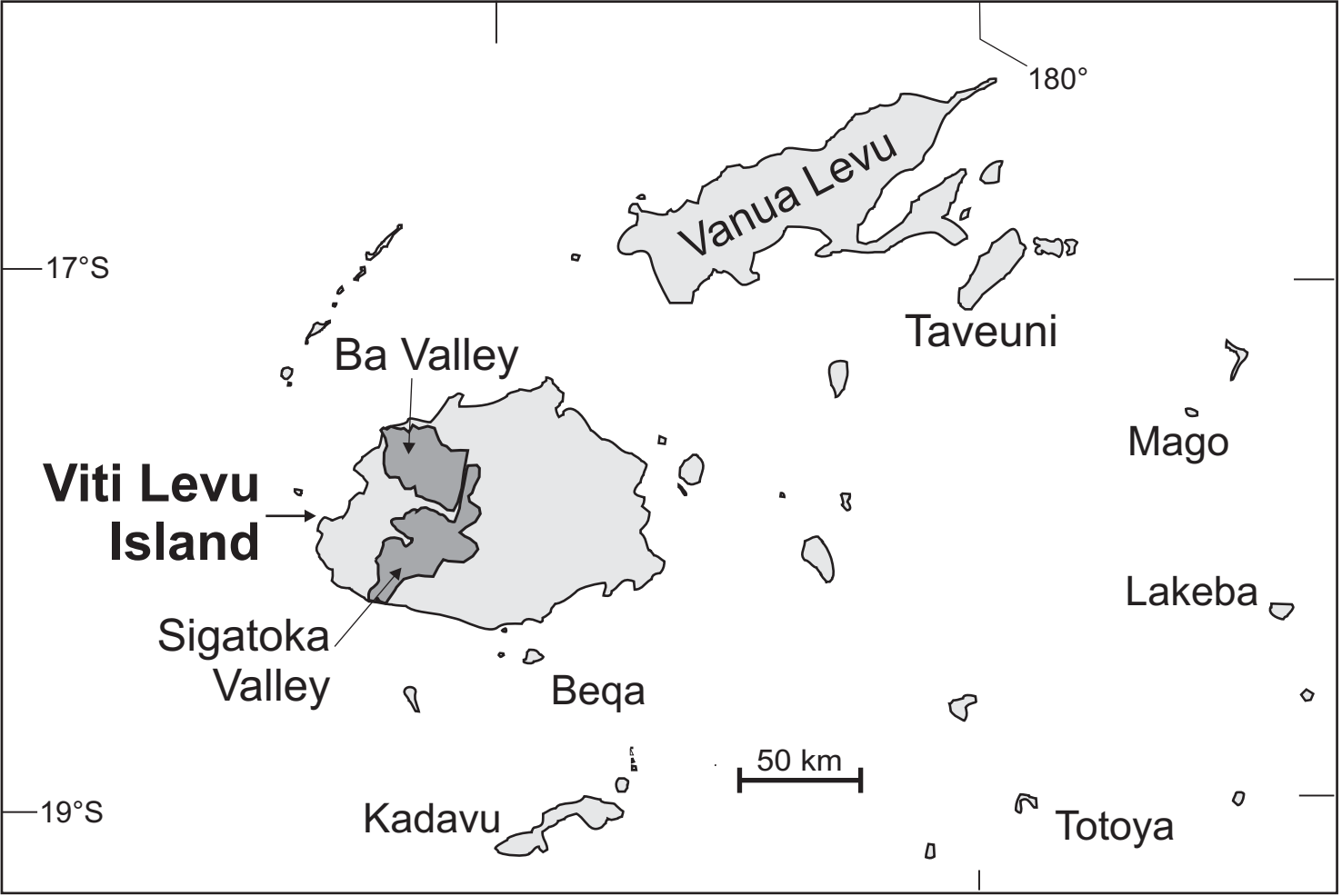

180°
Vanua Levu
17°S
Taveuni
Ba Valley
Mago
Viti Levu
Island
Lakeba
Sigatoka
Valley
Beqa
50 km
19°S
Kadavu
Totoya

Figure 1

Figure 2

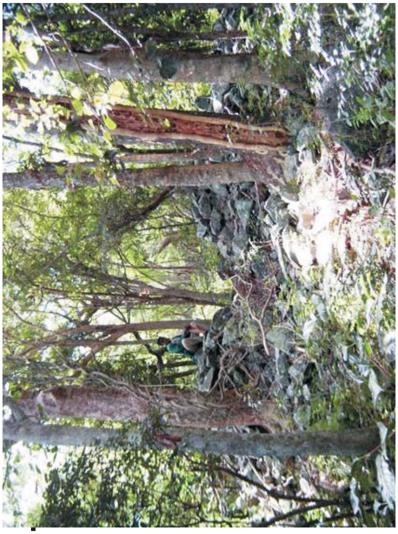

177°45´E
South Pacific Ocean
Tavuca Island
Vatuvatuva
Vatia Lailai Island
Vatia Peninsula
Mataniguagua Cave
Ba Delta (mangrove swamp)
Ba River mouth
Natunuku
Nayavutu Cave
Votua
Nailaga
Elevuka Creek
Navisa Creek
Tubabaka
Namosau Creek
Ba Town
Vatusososo Cave
Nadarivatu (peak)
Koro-o
1060 m
Nasolo
Soweri
Naqara
Nadrau Creek
BA RIVER
Nalotawa
Toge
Navala
1160 m
Waisali Creek
Savatu Creek
Koro
Nakara River
17°45´S
Viti Levu Island
Bukuya
Talawase Creek
0
5
km

Figure 3

Figure 4.

B.

C.



A.

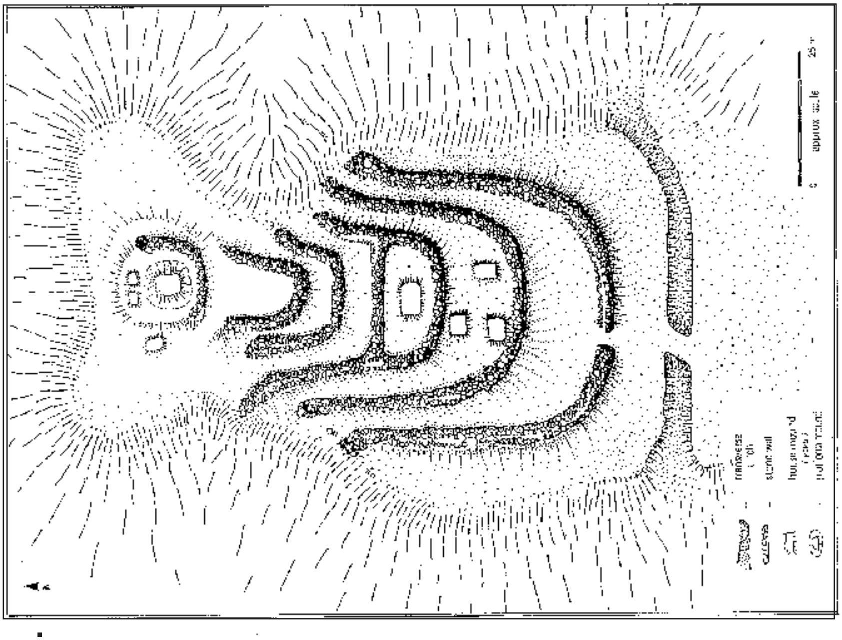
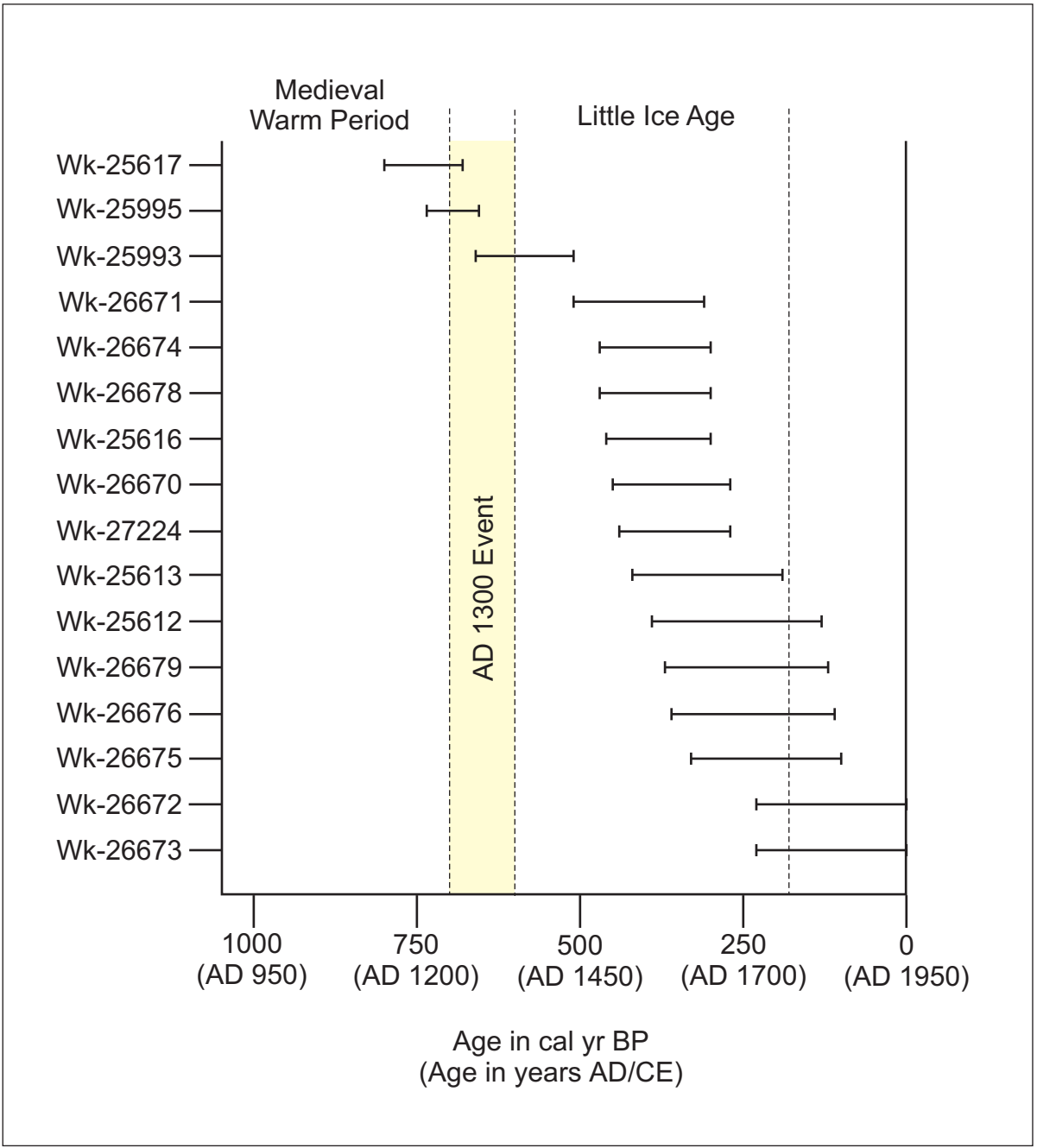


Figure 5


Medieval
Warm Period
Little Ice Age
AD 1300 Event
Wk-25617
Wk-25995
Wk-25993
Wk-26671
Wk-26674
Wk-26678
Wk-25616
Wk-26670
Wk-27224
Wk-25613
Wk-25612
Wk-26679
Wk-26676
Wk-26675
Wk-26672
Wk-26673
1000
(AD 950)
750
(AD 1200)
500
(AD 1450)
250
(AD 1700)
0
(AD 1950)
Age in cal yr BP
(Age in years AD/CE)

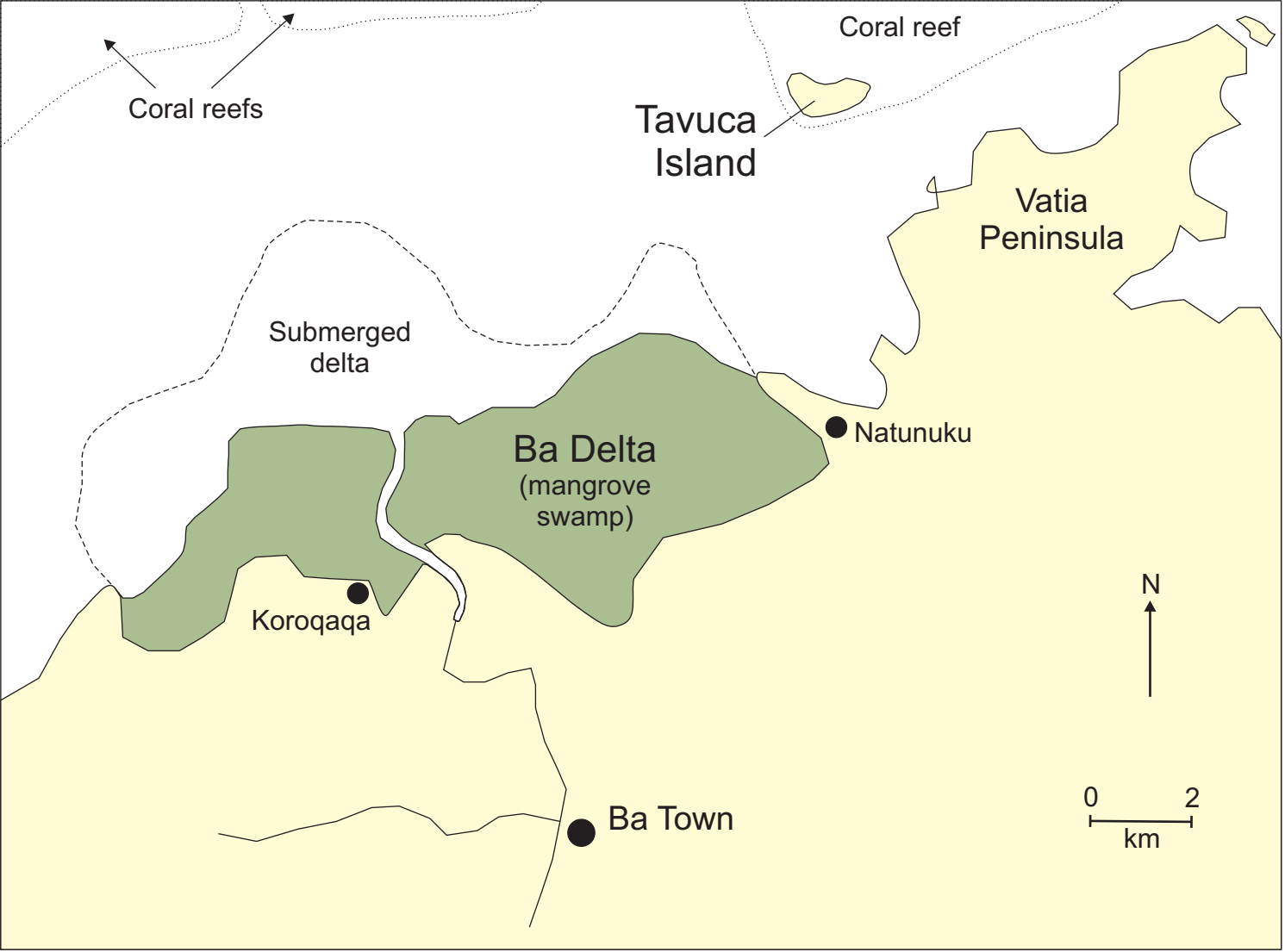

Coral reef
Coral reefs
Tavuca
Island
Vatia
Peninsula
Submerged
delta
Ba Delta
(mangrove
swamp)
Natunuku
Koroqaqa
N
Ba Town
0
2
km

Figure 6

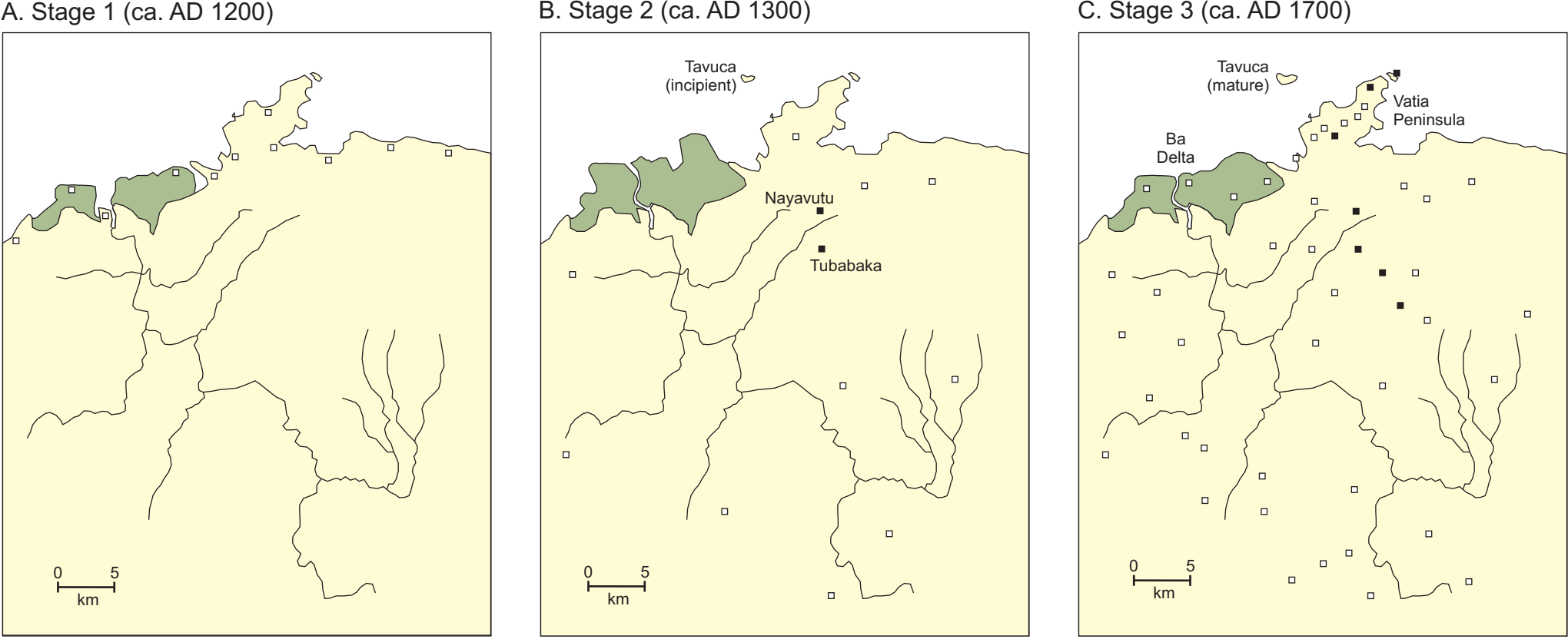

A. Stage 1 (ca. AD 1200)
0
5
km
B. Stage 2 (ca. AD 1300)
Tavuca
(incipient)
Nayavutu
Tubabaka
0
5
km
C. Stage 3 (ca. AD 1700)
Tavuca
(mature)
Vatia
Peninsula
Ba
Delta
0
5
km

Figure 7

Table 1. Selected radiocarbon dates from the Ba Valley, Vatia Peninsula and offshore islands. Ages calibrated using OxCal (version 3.10) and, for marine shell, a ΔR value of 11+/-26 years (Petchey et al., 2008); 95.4% probability given.

Site	*Sample*	*Laboratory number*	*Sample material*	*Depth (cm)*	*$d^{13}C$*	*Conventional radiocarbon age (BP)*	*Calibrated radiocarbon age (cal BP)*	*Calendar age*
BA VALLEY								
Naqara	Naqara Cave (N1)	Wk-26673	marine shell (*Gafrarium* sp.)	50	-0.1+0.2	502±30	230-0	AD 1720-1950
	Naqara Cave (N2)	Wk-26674	charcoal	62	-24.2+0.2	307±30	470-300	AD 1480-1650
Nayavutu	Nayavutu-80 (6767)	Wk-25612	marine shell (*Gafrarium tumidum*)	80	0.0±0.2	629±33	390-130	AD 1560-1820
	Nayavutu-80a (6777)	Wk-25616	charcoal	80	-24.0±0.2	342±30	460-300	AD 1490-1650
	Nayavutu-90 (6768)	Wk-25613	marine shell (*Anadara* sp.)	90	-0.6±0.2	660±31	420-190	AD 1530-1760
	Nayavutu -90a (6778)	Wk-25617	freshwater shell (*Septaria* sp.)	90	-5.4±0.2	884±31	800-680	AD 1150-1270
Tubabaka	Tubabaka (T60)	Wk-25995	freshwater shell (*Batissa* sp.)	70	-8.5±0.2	747±34	735-655	AD 1215-1295
	Tubabaka (T1)	Wk-26675	marine shell (*Anadara* sp.)	55	-1.3+0.2	609+30	330-100	AD 1620-1850
Vatusososo	Vatusososo (K1)	Wk-26676	marine shell (*Anadara* sp.)	75	-1.2+0.2	616±30	360-110	AD 1590-1840
	Vatusososo (K2)	Wk-26678	charcoal	75	-26.6+0.2	320±30	470-300	AD 1480-1650
	Vatusososo (K2a)	Wk-26679	marine shell (*Anadara* sp.)	75	-0.5+0.2	624±31	370-120	AD 1580-1830

VATIA PENINSULA								
Matanigaga	Matanigaga (M1)	Wk-26670	marine shell (*Anadara* sp.)	85	-2.1+0.2	720±30	450-270	AD 1500-1680
	Matanigaga (M2)	Wk-26671	charcoal	95	-25.6+0.2	374±30	510-310	AD 1440-1640
Vatutaqiri	Vatutaqiri (V1)	Wk-26672	marine shell (*Gafrarium* sp.)	55	0.5±0.2	476±30	230-0	AD 1720-1950
OFFSHORE ISLANDS								
Tavuca Island	Tavuca (Tav-1a)	Wk-25993	marine shell (*Turbo cinereus*)	170	3.7±0.2	1016±34	660-510	AD 1290-1440
Vatia Lailai Island	Vatia Lailai (V2)	Wk-27224	marine shell (*Anadara* sp.)	65	0.6±0.2	712±30	440-270	AD 1510-1680