

Environmental and climatic considerations: a hypothesis for conflict and the emergence of social complexity in Fijian prehistory

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Abstract

This research utilizes GIS-based environmental analyses in a study of Fijian prehistory. The results suggest that episodic droughts and floods related to the El Niño Southern Oscillation (ENSO) encouraged the development and persistence of competitive strategies in the Sigatoka Valley, located on the island of Viti Levu. These results also suggest the formulation of three modes of habitation/subsistence in Sigatoka Valley prehistory: territorial strongholds, remote refuges, and constructed fortifications on the valley bottom. Archaeological testing indicates that the Sigatoka Valley was initially occupied between Cal BC 20 and Cal AD 80, and fortifications that utilized natural topography were established ca. AD 600, and remained in use throughout the prehistoric period. Resettlement in remote environmental refuges ca. AD 1300–1500 suggest the development of buffering strategies during a period of environmental disturbance (the LCO/LIA transition). The repercussions of increased interaction and population growth on the emergence of social complexity after 500 BP are also hypothesized.

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Archaeological research in the Fiji Islands has focused primarily on the earliest period of occupation, the Lapita (ca. 2800 BP). Less well known are the later periods (2300–1000 BP) that are associated with changes in ceramic styles and settlement patterns, in particular the occurrence of fortified habitation sites atop remote peaks in the interior. Historical and archaeological studies that identify this trend attribute the occurrence of fortifications (and by proxy, competition and conflict) to population growth and the development of exchange networks (Best, 1984; Ladefoged, 1993; Parry, 1977, 1982; Rechtman, 1992), and also the intrusion of migrants from Vanuatu and New Caledonia ca. 1800 and 900 BP (Best, 1984, 2002; Frost, 1974, 1979; Green,

1967). More recently, regional syntheses detail the diversity of ceramic sequences and settlement patterns in the various parts of Fiji, deducing that most regions followed their own developmental trajectories in the formation of interaction networks and acquisition of fortifications (Marshall et al., 2000).

Despite these advances, little attention has been paid to evidence that suggests that ancient Pacific Islanders were broadly affected by seasonal or annual climatic fluctuations that extend into antiquity (but see Finney, 1985; Kirch, 1997; Nunn, 1994; Nunn and Britton, 2001; O'Connell and Allen, 1995; Parry, 1997; and Spriggs, 1997). As has been recognized in other parts of the world, global climatic variations often shaped human history (e.g., robust phenotypes in cooler climates (Pearson, 2000); the transition to agriculture during the Holocene (Richerson et al., 2001); pueblo abandonment related to drought in the American southwest (Dean, 1996); El Niño-related floods and de-centralization of

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Moche political centers in south-coastal Peru (Reycraft, 2000), etc.). The Pacific is no exception. In this case, the analysis of geographical, environmental, and archaeological data from the Sigatoka Valley, Fiji, suggests that spatial variability and episodic climatic perturbances (i.e., the El Niño Southern Oscillation) played a primary role in the development of competitive settlement strategies in prehistory. Changes in subsistence and settlement due to population growth, and also punctuated change caused by a period of environmental disturbance (i.e., the LCO/LIA transition) are also investigated for the region. The results allow for an assessment of pre-existing models of Fijian cultural change, population growth, interaction, and the development of social complexity. Hypotheses supplied by evolutionary ecology provide a series of middle-range theories through which the linkages between human subsistence and settlement strategies, and environmental variability, are evaluated.

Environmental variability, perturbations, and competition

The social and biological sciences offer several theoretical perspectives on the occurrence of competition and conflict amongst human groups. Amid competing theories that privilege proximate causes for warfare (e.g., capturing resources, driving away rivals, and revenge (Chagnon, 1979; Ember and Ember, 1992; Ferguson, 1984; Haas, 1990; LeBlanc, 1999; Otterbein, 1985; Vayda, 1976)), evolutionary ecology assumes that human beings and their social behaviors are the product of evolution, and that all behaviors can be modeled as cost/benefit strategies designed to maximize fitness, or reduce risk (Boyd and Richerson, 1985, pp. 7–12; Smith and Winterhalder, 1992, pp. 39–40). It also posits that the structure and variability of the environment affects the relative success or failure of human endeavors, and it encourages members of populations to behave in either cooperative or competitive ways. Of note, evolutionary ecology-based models of competition and cooperation draw heavily from sociobiological and evolutionary biological models of the formation of groups, the development of social hierarchies, and the establishment of settlement strategies and territoriality. Thus, these models are often able to address issues of subsistence, settlement, and interaction that are commonly encountered in archaeological investigations.

In particular, the writings of Cashdan (1983, 1990), Durham (1976), Dyson-Hudson and Smith (1979), Halstead and O'Shea (1989) Smith (1988), and Boone (1983, 1992) form the core components for an evolutionary ecology perspective on competition and cooperation in human societies. In addition, biological studies of kinship (Alexander, 1974) and territoriality (Brown, 1964; Godfrey, 1987) provide additional

insights relating to aspects of cooperation and competition within families and extended lineages. Computer aided agent-based modeling and biology-derived game theory has also produced individual-based cooperative and competitive models (e.g., Axelrod, 1997). Lastly, environmental studies and the occurrence of warfare have generated several generalizations relating to resource unpredictability and conflict in human societies (Dean, 1988; Dean et al., 1985; Ember and Ember, 1992; Halstead and O'Shea, 1989; Haas and Creamer, 1993; Jones et al., 1999; Kennett and Kennett, 2000; Raab and Larson, 1997). A full discussion of the details of these models is beyond the scope of this paper. However, the following points constitute a set of testable hypotheses for the development of competition in Fijian prehistory:

(1) The distribution of resources in time and space play a pivotal role in the formation of groups, the foraging strategies employed, and the extent to which groups either compete or cooperate with each other. Competitive strategies are beneficial in environments in which the resources are densely distributed and temporally predictable, and the earliest territories are expected to form in relation to these areas (Cashdan, 1983; Dyson-Hudson and Smith, 1979, p. 26).

(2) In environments where resources are scarce and widely scattered, groups are expected to cooperate with each other by employing exchange, information sharing networks, and/or practice some form of mobility (Halstead and O'Shea, 1989). Within groups, individuals and families may persist under a regimen of intense cooperation (Bowles and Gintis, 2003).

(3) Periods of unpredictability in both resource-rich and resource-poor environments tend to intensify competitive and cooperative strategies (Jones et al., 1999; Kennett and Kennett, 2000; Raab and Larson, 1997). Archaeological studies suggest that human groups resort to conflict during longer or extremely severe periods of resource unpredictability, yet also invest in buffering strategies (such as diversified diets, mobility, and exchange) in order to alleviate shortfalls.

(4) If individuals within groups are subject to unpredictable variations in harvest rates, social stratification can develop as a product of individual buffering strategies (i.e., patron and client relationships). In such situations (and if emigration or dispersal to another region is prohibited) social hierarchies may develop and persist (Boone, 1983, 1992).

These hypotheses can be investigated at a variety of scales within the Sigatoka Valley environment. These scales are determined by both the nature of the research questions posed, and also the resolution of both archaeological and paleoenvironmental data. The following analyses evaluate the spatio-temporal variability of the Sigatoka Valley in terms of agricultural productivity and predictability. The results of these analyses allow for the contextualization of the hypotheses mentioned

above, and also suggest how competition and conflict may have developed in Fijian prehistory.

The Sigatoka Valley GIS database

The Sigatoka Valley, a 1700 km² drainage located in the southwestern corner of the island of Viti Levu, provides a large study area that encompasses both the coastal fringe and the remote interior mountains (Fig. 1). The region is known for its well-studied Lapita site located along the sand dunes that lie to the west of the river's mouth (Best, 1987; Birks, 1973; Burley, 1997; Dickinson et al., 1998; Lambert, 1971; Visser, 1994). Previous studies of the valley and its prehistory by Parry (1987) and the author (Field, 1998, 2002, 2003) used aerial photographs to identify nearly 400 habitation sites, 75% of which were fortified. This research integrates this and modern geographic data into a GIS database, which include thematic layers of archaeological sites, topography, soil quality and permeability, and rainfall and stream-flow data.¹ Of note, Spriggs (1985, 1997) suggests that island environments have undergone radical change as a result of human agricultural regimes, and Dickinson et al. (1998), Hope et al. (1999), and Nunn and Kumar (2003) provide evidence of massive erosion in the interior of the Sigatoka Valley, ca. 3000–1500 BP. Presumably this erosion was the result of prehistoric burning and cultivation, however, the areas and vegetation types that were most impacted by this process have yet to be clearly identified.² Therefore, GIS-based environmental analyses in this study utilize modern geographic and environmental data (e.g., Davies, 1992; Fox et al., 1952; Wright and Twyford, 1965). Recent additions to the database consist of thematic layers that track the local and regional effects of seasonal and long-term climatic fluctuations, including predictions relating to the effects of El Niño Southern Oscillation (ENSO), and the transition between the Little Climatic Optimum (LCO), and the Little Ice Age (LIA). Following methods similar to Van West's (1994) study of drought and pueblo abandonment in the American southwest, GIS-based analyses of these data are used to generate a set of expectations for the valley's prehistory, which is tested against a chronology derived from excavations that were conducted between 2001 and 2002.

¹ The geographic information system (GIS) software Idrisi v2.0 and ArcView v3.3, in tandem with a Microsoft Access v9.0 database were used in this research.

² Human-induced vegetation change can be assumed for the Sigatoka Valley; however, palynological data that indicate forest decline are still being assembled within larger studies (e.g., Hope et al., 1999; and Southern, 1986). Thus far, individual studies suggest general forest clearance for Fiji after 3000 BP.

Analysis 1: Agricultural productivity and predictability

The most important premise of the evolutionary ecology hypotheses outlined above is that environmental variation had a marked impact upon the distribution of prehistoric agricultural strategies, and also the rates of productivity and predictability over time. Like other Pacific Island populations, Fijian subsistence was based upon fishing and horticulture, in particular the cultivation of root crops: *dalo* (*Colocasia esculenta*) and the Asian yam, *uvi* (*Dioscorea* spp.) (Barrau, 1965; Kirch, 1994; Kuhlken, 2002).³ These crops require particular environments and techniques of cultivation in order to be produced and differ greatly in terms of their production density and predictability. *Uvi* can be cultivated in most well-drained soils and relies upon rainfall and soil nutrients for large tuber growth. However, *uvi* must be planted at the beginning of the wet season, and allowed to germinate for 7–9 months. Depending upon the quality of the environment and climate, *uvi* will produce between 5 and 15 tons/ha/year, but is susceptible to total loss in the case of cyclone-related floods or droughts that curtail the moisture needed for germination during the wet season. In contrast, *dalo* is a hydrophilic crop, and requires partial submersion in running water in order to produce a large corm. *Dalo* can be planted and harvested year-round, and has prodigious yields of 20+ tons/ha/year. Its cultivation requires the co-occurrence of moisture and silty soils, and production often relies upon the construction of earthworks and irrigation systems that must be maintained. Therefore, *dalo* cultivation is often restricted to small, well-watered tributaries, and requires a substantial investment of physical labor (Kuhlken, 2002). Although for the most part *dalo* is buffered against seasonal droughts, ponds and terraces are vulnerable to flood damage, and total destruction of *dalo* ponds can occur during intense rainfall or cyclone-related floods.

The GIS-generated images in Fig. 2 (diagrams A and B) indicate the extent of land available for cultivation in the valley for all time periods, according to topography (45° slope or less), the relative fertility of soil deposits, and the intensity and length of the dry season (Fox et al., 1952; Wright and Twyford, 1965). Of note, the topography of the landscape limits the amount of land that is arable and markedly divides the northern and southern portions of the valley. Only 40% of the land in the most

³ Other important crops in Fijian agriculture included the giant swamp taro, *via kana* (*Cyrtosperma chamissonis*), and giant taro (*Alocasia macrorrhiza*). Sweet potato (*Ipomoea batatas*), breadfruit (*Artocarpus altilis*), coconut (*Cocos nucifera*), hibiscus leaf (*Hibiscus manihot*), and bananas (*Musa* spp.) were also cultivated in smaller amounts. In the interior, protein was obtained from wild and domesticated pigs (*Sus scrofa*) and modest harvests of riparian fish, mollusks, and crustaceans.

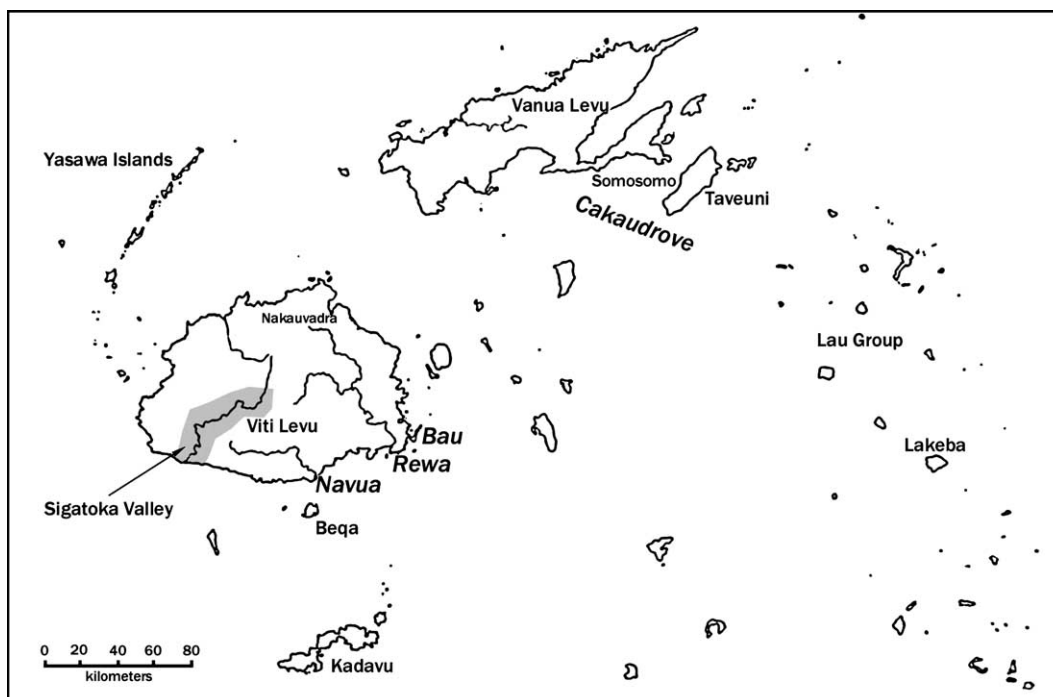


Fig. 1. Regional map of the Fiji Islands showing the location of the Sigatoka Valley. Adapted from Marshall et al. (2000, pp. 2).

northerly portions (the upper valley in Fig. 2A) of the valley are of gentle enough slope to have been cultivated, compared to over 70% of the lower valley, which subsumes the Sigatoka River delta. Moreover, the arable areas of the upper valley are predominantly small and scattered, as opposed to the large contiguous configuration of patches in the delta region. However, the distribution of the most fertile soils and abundant precipitation were the more important factors in pre-historic cultivation. Diagrams A and B indicate that despite its predominantly rugged topography, the middle and upper portions of the valley contain very rich soils, 50–80% of which are of moderate-high nutrient status. These soils also benefit from moderate-weak dry seasons, which suggest that both *uvi* and *dalo* could have been grown with some success during normal rainfall years. However, previous analyses of aerial photographs indicated that irrigated production was restricted to small patches that were widely scattered in the uplands (Field, 2002). In contrast, well-drained alluvial terraces of the lower valley are suited to the cultivation of *uvi* on a grand scale, although only 40% of the soils are of moderate-high quality. These findings suggest that the bulk of the valley's populations (in particular the middle and lower valley populations) were reliant upon the cultivation of *uvi*, a seasonal dryland crop.

In sum, the analysis of topography, soil quality, and dry season intensity suggest that portions of the Sigatoka Valley would have been more amenable to either

wetland or dryland cultivation. Moreover, rainfall patterns and soil quality suggest that portions of the valley would have experienced a higher frequency of fluctuations between the wet and dry season, while other regions remained relatively stable. These data allow for the division of the Sigatoka Valley into three zones that pertain to agricultural production and predictability: (Zone 1) lands suited to dryland cultivation, and which also experienced severe shortfalls due to severe dry seasons; (Zone 2) lands suited to mixed wetland and dryland cultivation, and which also experienced mild shortfalls due to moderate dry seasons; and (Zone 3) lands suited to wetland cultivation, and which also experienced minimal shortfalls due to weak dry seasons. Fig. 3 reveals the geographic extent of these zones. Although this image does not incorporate topographic limitations, it does indicate in general terms how some portions of the valley were more suited to a particular form of cultivation, and less suited to the application of another. Of note, it suggests that the mountainous areas surrounding the valley bottom, as well as much of the upper valley (Zones 2 and 3), would have allowed for a greater variety of cultivation strategies, and also experienced fewer (or less severe) shortfalls related to seasonal dryness. However, gardens in this region would have been smaller, and widely dispersed.

In the short view, the results of these analyses simply suggest that the inhabitants of the valley must have privileged one mode of cultivation over the other.

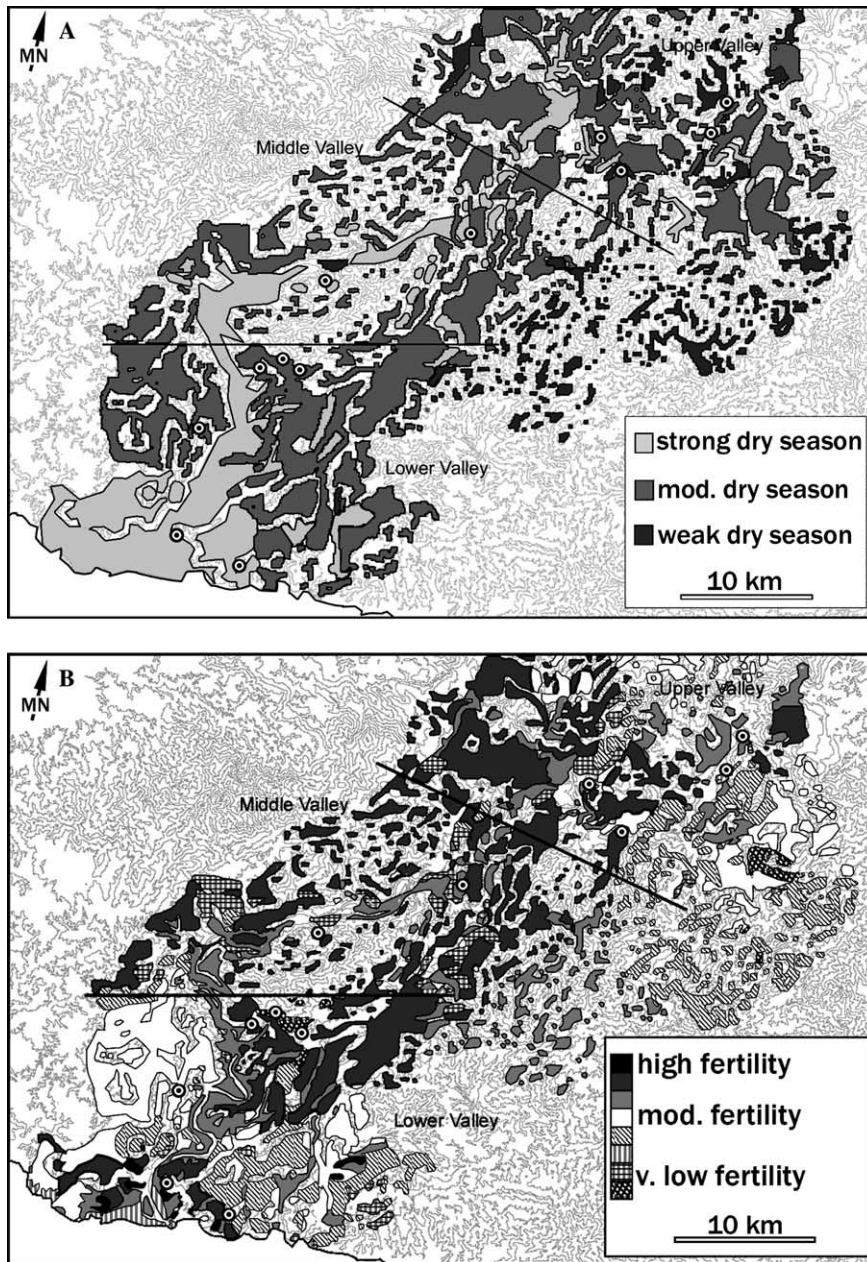


Fig. 2. (A) Intensity of dry season, as determined by annual rainfall and soil permeability. (B) Soil fertility, as determined by nutrient status. In both diagrams, shaded areas reflect topography with $<45^\circ$ slope. Bulls-eye symbols refer to excavated sites discussed in text. Contour interval: 100 m.

However, it also suggests that portions of the Sigatoka Valley were more restricted in terms of cultivation strategies, and more at risk from severe, long-term droughts. In the context of the evolutionary ecology premises outlined in the previous section, these results suggest that all zones could have fostered territorialism, as many areas in both the upper and lower valley could

have fostered the cultivation of both dense and predictable resources. However, episodes of severe environmental fluctuations may have encouraged a general trend towards increased competition and conflict in Zone 1, as this zone was largely restricted to the cultivation of seasonal dryland crops such as *uvi*. The following section evaluates evidence for climatic

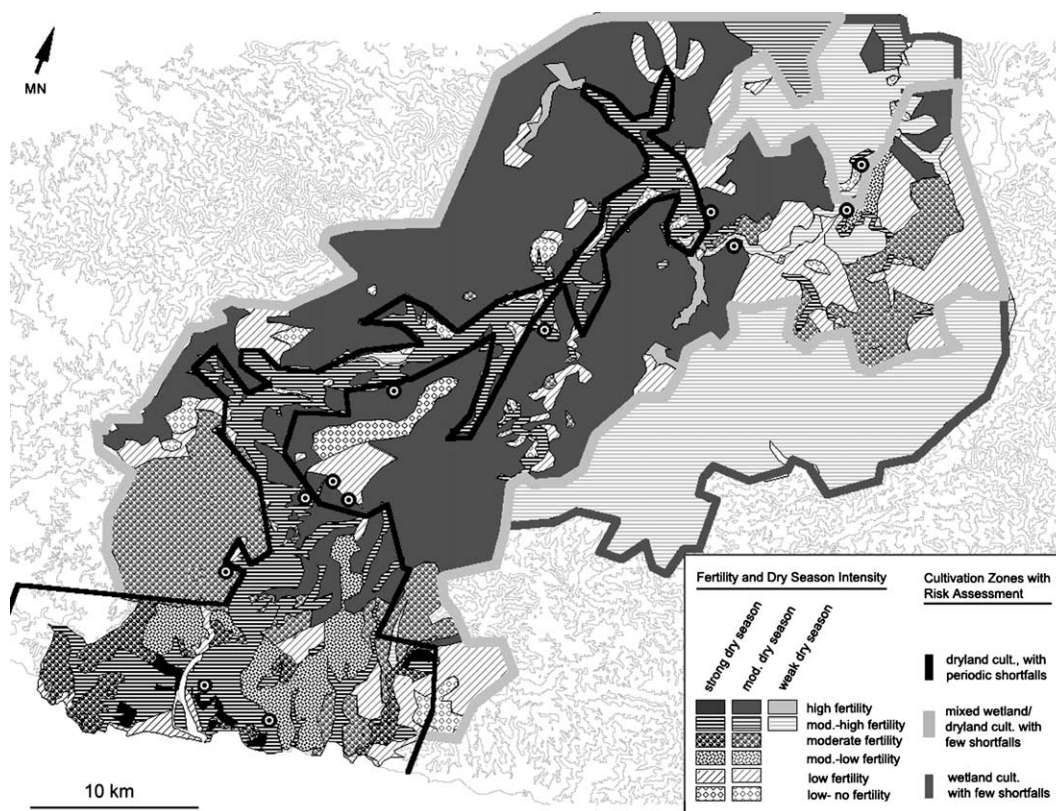


Fig. 3. Environmental zones of the Sigatoka Valley as identified by soil fertility and severity of dry season. Bulls-eye symbols refer to excavated sites discussed in text. Contour interval: 100 m.

perturbances in Fijian prehistory, and predicts the effects of these phenomena on the Sigatoka Valley environment.

Analysis 2: The frequency and amplitude of environmental fluctuations in Fijian prehistory

According to climatologists, the phenomena known as ENSO is brought about by global changes in air pressure and ocean temperatures. The cycle begins when the center of air pressure in the eastern South Pacific collapses, and the wind system incorporated into it slackens or ceases altogether. When this happens, the warm waters of the western Pacific bleed eastward, bringing with them hot and humid air masses. In tandem with this event is the development of a high-pressure climatic cell over Indonesia, which fosters droughts in Australia and South Asia through the disruption of the monsoon system. The climate becomes drier, and the sea temperatures drop in the eastern Pacific (Caviedes, 2001, pp. 8). For climatologists, the difference between the air pressures of the eastern South Pacific and Indonesia cells provide an index of the severity of the El Niño event (the Southern Oscillation Index, or SOI). A low or negative

SOI indicates weak or absent easterly winds, high humidity, and warm ocean conditions—a severe El Niño event, while a high SOI signifies the dominance of easterly winds and cooler sea conditions—a La Niña event. According to climate specialists, ENSO events occur at intervals of 3.5 years, and major events repeat every 5–7 years. Some El Niño and La Niña events are stronger than others, or last for longer periods (Caviedes, 2001, pp. 9; Kiladis and Diaz, 1989; Peel et al., 2002).

Recent research by climatologists (Fiji Meteorological Service, 2003; Nichols and Wong, 1990; Salinger et al., 1995) and geographers (Nunn, 1990) have confirmed that Fiji is strongly affected by climatic perturbances associated with the El Niño Southern Oscillation (ENSO). However, it is important to note that although Fiji is particularly prone to ENSO-related disturbances, nearby Samoa and northern Tonga are not (Salinger et al., 1995). Thus, the effects of ENSO on Fiji (and Fijian prehistory) may not be comparable to the effects of ENSO elsewhere. This is due to the fact that the southwestern Pacific is influenced by both the low pressure system of the eastern Pacific and the high pressure system located over Indonesia. As a result,

the interplay between El Niño and La Niña events produce a unique cycle of rains and droughts that vary across the southwestern Pacific region. Parry's analyses of precipitation records from northern Viti Levu suggest that El Niño years are exceptionally dry—nearly 1000 mm less than average. However, he also notes that the droughts associated with a strong El Niño are preceded and followed by two very different La Niña episodes: wet years with increased rates of cyclones, and drought years. The later La Niña episodes are typified by moderate to extreme droughts, and can last from 2 to 3 years (Parry, 1997, pp. 22–25). These data concur with the recent findings by Salinger et al. (1995) that for the entire archipelago of Fiji, the years that follow the El Niño event (the La Niña years) are the driest. In addition, these data also concur with historic data for cyclones in Fiji, which are more likely to occur under the low-pressure conditions of an El Niño year.

These findings are significant to research of Fijian prehistory, as they suggest that the occurrence of competition and conflict may be related to long and short-term ENSO-based environmental fluctuations. Research performed by Moseley (1997), Caviades (2001), Sandweiss et al. (1996), and Quinn (1992) have identified similar linkages between prehistoric cultural change in South America and ENSO occurrences. These findings also suggest that modern El Niño episodes in Fiji provide an index by which the severity of past ENSO events can be assessed. El Niño events have been recorded for the years of 1938–41, 1950–51, 1957–58, 1965–66, 1974–75, 1982–83, and 1997–98 (Parry, 1997; *pp. 24). According to relief agencies, the 18-month 1997–98 El Niño event resulted in a severe drought throughout the country. During this time rainfall was 22–42% of normal for the rainy season, and national production loss for sugarcane was 50%, with the worst losses on the marginal land near the ocean and on steep slopes. Western Viti Levu (including the Sigatoka Valley) was severely affected, with most of the population receiving food and water rations due to the devastation of local agriculture. In addition, drinking water was depleted, and health problems rose significantly. Economic analyses also suggest that the average income for subsistence farmers dropped from F\$3500 to F\$1500 per annum (a reduction of 42%) due to the effects of the drought (Kaloumaira, 2000).

If modern experience and historical notation serve as any guide, the onset of El Niño in the prehistoric Sigatoka Valley was heralded by a year of heavy rains and floods that soaked the low-lying areas and destroyed root crops (Terry et al., 2001). Full-blown El Niño conditions also introduced a higher frequency of tropical storms and cyclones, which could devastate the countryside with high winds and torrential floods. However, modern ENSO patterns suggest that as El Niño conditions abated, a La Niña-related drought would have

developed, perhaps lasting for several years. As suggested by the economic devastation inflicted on Fiji during the prolonged 1997–98 ENSO episode, prehistoric droughts would have stalled the productivity of the irrigated cultivation of *dalo*, and eventually rendered the more drought-prone areas and soils to near-sterility. This would have been particularly disastrous for the cultivation of *uvi*, which requires soil moisture and rainfall in order to germinate and develop.

The analytic capabilities of the GIS can be used to predict the extent of damage caused by prehistoric ENSO-related droughts and floods. In the case of El Niño-related cyclones and floods, the limits of flood damage were predicted via interviews with modern Sigatoka Valley inhabitants, who pointed out the extent of cyclone-related flood damage (and also the location of villages that were evacuated due to flooding) to the author during the 2001–2002 field season. These interviews identified the 20 m contour line as the upper limit of flooding in the Sigatoka Valley, extending to the 40 m contour in the higher elevation areas of the upper valley. The results of this analysis indicate that the delta portion of the lower valley and the main river channel would have been the most effected, as they are today during flood events (Fig. 4A). The hillier portions of the valley would have been less damaged, and it is likely that irrigated agriculture would have profited from the extra water, especially the areas of the lower and middle valley that are only nominally productive.

Based upon Wright and Twyford's (1965) designations of weak, moderate, and severe desiccation for the Sigatoka Valley soils, the extent and severity of La Niña conditions were also calculated within the Sigatoka Valley GIS database. Fig. 4A indicates that the majority of the lands of the Sigatoka Valley would have experienced at least strong La Niña drought conditions. The severe drought zone predominates in the delta of the lower valley, and extends along the alluvium of the main river channel into the upper valley. These areas would have suffered most, as these soils normally experience a strong dry season, and are composed of well-drained particles. A few areas, such as portions of the upper valley, may have fared better than others during particularly severe ENSO disturbances. Therefore, agricultural productivity in this region would have remained more stable over the long run.

Fig. 4A also overlays the environmental zones identified in the initial geographic/environmental analysis, and the results allow for the formulation of the following conclusions: (1) Zone 1 would have experienced the most severe effects of ENSO-related droughts and floods; (2) Zone 2 would have experienced moderate ENSO-related droughts; and (3) Zone 3 would have been relatively untouched by ENSO-related droughts or floods. In the context of the potential cultivation strategies suggested for the Sigatoka Valley, these conclusions

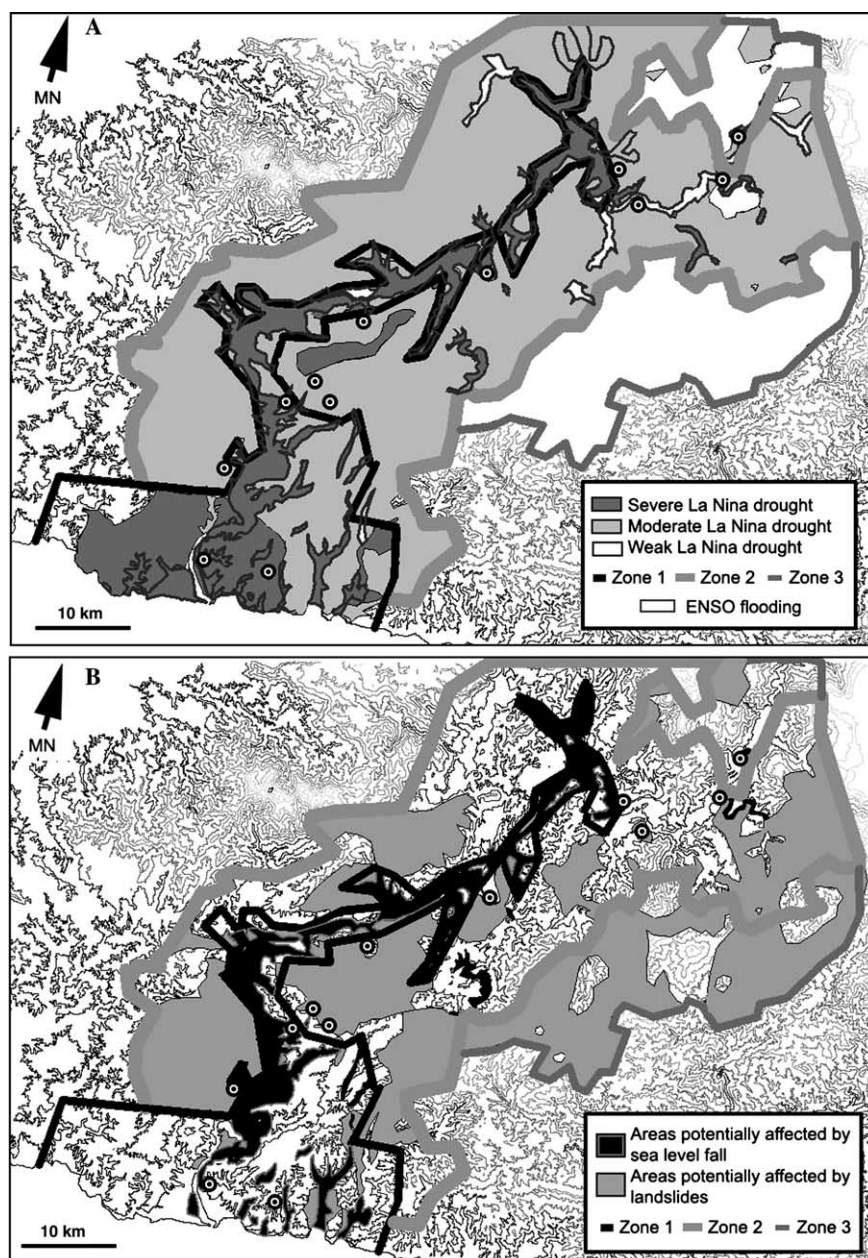


Fig. 4. Comparison of the environmental zones identified by soil/topographic analyses with the extent of damage predicted for ENSO-related disturbances and the LCO/LIA transition. Bulls-eye symbols refer to excavated sites discussed in text. Contour interval: 20, 40, and 100 m.

suggest that *uvi* cultivation in Zone 1 would have experienced the highest frequencies of shortfalls as a result of seasonal and episodic droughts and floods. Contrariwise, Zones 2 and 3 would have allowed for the cultivation of both *dalo* and *uvi*, and experienced lower frequencies of environmental fluctuations. However, the topography of these regions would have limited harvest

sizes, and also forced the dispersal of cultivation to far-flung areas.

In the context of episodic environmental perturbances, evolutionary ecology theory suggests that strategies that included increased frequencies of competition and conflict would have predominated in Zone 1. Zones 2 and 3 would have allowed for increased

stability (i.e., the persistence of territories and fewer instances of conflict). However, the severity and duration of ENSO events, as well as the small size of the Sigatoka Valley, suggests that increased rates of conflict in Zone 1 may well have spilled into the surrounding regions. Overall, the cumulative effects of ENSO for the Sigatoka Valley are suggestive of a situation of episodic environmental unpredictability (perhaps at intervals of 10–12 years), which would have encouraged the development and persistence of competitive strategies in all zones. This premise seems even more likely considering the frequency of severe episodes experienced in Fiji during the last century. If similar cycles persisted in the past, strategies of defense and raiding could have easily been established within the lifespan of a single person.

There is also the potential for punctuated environmental change to have occurred during Fijian prehistory. The following discussion assesses the LCO/LIA transition, which has been proposed as a period of dramatic environmental upheaval ca. 730–525 BP.

Analysis 3: Punctuated climatic change during LCO/LIA transition

Paleoclimatic data from New Zealand caves as well as shell conglomerates in Fijian shorelines indicate that dramatic environmental perturbations may have occurred in the region approximately 700 years ago. These events mark the transition period between the warmer Little Climatic Optimum (1250–700 BP) and cooler Little Ice Age (700–200 BP) (Fagan, 2001). According to recent analyses in Fiji and Niue by Nunn and others (Nunn, 2000a,b, 2003; Nunn and Britton, 2001; Nunn et al., unpublished manuscript), the transition was marked by cooler weather and sea temperatures, and a rapid lowering of sea level by over one meter between 730 and 525 BP. Nunn and Britton (2001, pp. 9–13) propose that a sea level fall of this magnitude over such a brief period would have been devastating for both coastal and interior populations. The fall would have converted embayments to brackish wetlands, and also caused the submersion of groundwater for the interiors of the Fiji Islands. Extensive incising of the riverbeds and streambeds, as well as decreased soil moisture levels in many of the alluvial terraces that supported *uvi* cultivation, may have also resulted in the dramatic reduction of *uvi* yields in the lowlands. Also, the loss of near-shore marine resources due to reef exposure would have impacted coastal populations that relied upon reef fishing and shellfish gathering for a substantial portion of their diet. Nunn and Britton also suggest that the uplands of Fiji may have suffered from periods of torrential rainfall, resulting in erosion and landslides in *dalo*-producing areas.

Although the physical traces of the LCO/LIA transition have yet to be fully assessed for Fiji, the impact of some of the environmental changes predicted by Nunn

and Britton can be calculated within the GIS database. Principally, soil analyses provided by Wright and Twyford (1965) allow for preliminary calculations of the extent of damage produced by a one-meter sea level fall. Alluvial deposits that lie at the lowest elevations (<20 m) in the valley were identified as the most likely candidates for desiccation as a result of sea level fall, river incision, and water table submersion. As detailed in Fig. 4B, the distribution of these soils suggests that the LCO/LIA transition would have had the most impact on the middle and lower portions of the Sigatoka Valley, but perhaps extended into the upper valley as far as the confluence of the Namada river. Fig. 4B also indicates areas that contain extremely steep slopes (45–55° or greater) that would have been prone to landsliding and erosion during torrential rain. These regions were identified by both GIS-based analyses of slope, and also topographic calculations provided by Wright and Twyford (1965). The central parts of the middle valley, and also the most easterly portion of the upper valley, were likely the most impacted by disturbances of this nature, as they receive the most rainfall. These analyses suggest that (1) Zone 1 would have suffered most from sea-level fall during the LCO/LIA transition; (2) Zone 2 would have been affected to a limited degree by the landslides and erosion associated with the LCO/LIA transition; and (3) Zone 3 would have experienced a high/moderate amount of erosion during the LCO/LIA transition.

Archaeological studies of environmental disruptions have documented a variety of human responses (e.g., relocation, increased diet breadth (Reycraft, 2000); physical stress, trauma (Kennett and Kennett, 2000; Lambert, 1994); population aggregation and increased reciprocal exchange (Cordell, 2000)). In accordance with the evolutionary ecology premises outlined above, it is suggested herein that a re-formulation of pre-existing strategies of competition, defense, and raiding may have occurred in order to deal with the extensive nature of the LCO/LIA disturbance. This suggests that the populations of Zone 1 may have initiated alternative buffering strategies, such as the migration to new areas, a focus on more stable resources or environments, or increased levels of interaction, sharing, and exchange.

Summary

The antiquity of the relationship between ENSO and competitive strategies in the Sigatoka Valley is suggested by the ubiquitous presence of fortifications, although the disparities of Zone 1 may have provided the initial impetus for the development of competition in the valley. The proposed effects of the LCO/LIA transition would also have been felt most strongly in Zone 1. In sum, the results of GIS-based analyses of habitation sites, associated subsistence strategies, geography, and the effects of cyclical and punctuated environmental/climatic

change, suggest that the Sigatoka Valley was a dynamic environment which encouraged the application of a variety of subsistence and defense strategies across time and space. However, the absence of chronological data impedes any further analysis. In order to more closely examine the issues relating to competitive strategies in the prehistory of the Sigatoka Valley, the following chapter describes recent archaeological investigations of a sample of sites in the Sigatoka Valley. The resulting chronology provides a means by which strategies of habitation and subsistence can be traced through prehistory, and also used to assess historical developments.

Archaeological investigation in the Sigatoka Valley

Archaeological testing of fortified and non-fortified habitation sites in the Sigatoka Valley provides a means by which the chronology of defense and subsistence may be assessed for Fijian prehistory. Twelve habitation sites were investigated with subsurface excavations during the 2001–2002 field season (Fig. 5). Excavations were focused on determining the initial age of occupation and the duration of subsequent occupations, as well as the age of constructed defensive features that may have been added or refurbished at different times in prehistory. Table 1 provides summary descriptions of each site, and Table 2 lists the results of AMS and ^{14}C dating on 34 samples of charcoal, shell, and human remains. The distribution of calibrated dates according to temporal period is indicated in Fig. 6. These data, along with the

results of environmental analyses described above, suggest three general trends in strategies of habitation and subsistence: (1) the establishment of territorial fortifications and refuges in association with resource variation; (2) relocation to environmental refuges during periods of disturbance; and (3) the emergence of constructed fortifications and undefended production sites as a factor of population growth and/or increased social integration. The following sections discuss each of these trends in turn, and evaluate them according to the expectations outlined in the evolutionary ecology model.

The establishment of territorial fortifications and refuges

The earliest occupation in the Sigatoka Valley occurred at Tatuba Cave between Cal BC 20 and Cal AD 80. The site includes a fortified cave complex situated upon a ridge 60 m above the river, which is studded with 79 associated house-mounds (*yavu*) and terraces. The dating of stratified deposits within the cave indicates a continuous occupation until the historic period, with palisade and rock wall construction dating to as early as AD 1200 (Table 2). GIS-based environmental analyses demonstrate that Tatuba Cave is located within a region that had moderately high soil fertility, and which also experienced a moderate dry season (Figs. 4A and B). In addition, Tatuba Cave had immediate access to small tracts of land suited to dryland cultivation, and was also within a few kilometers of much larger expanses of alluvial terraces suitable for *dalo* cultivation. Of note, the site is located within Zone 2, but a portion of its resource

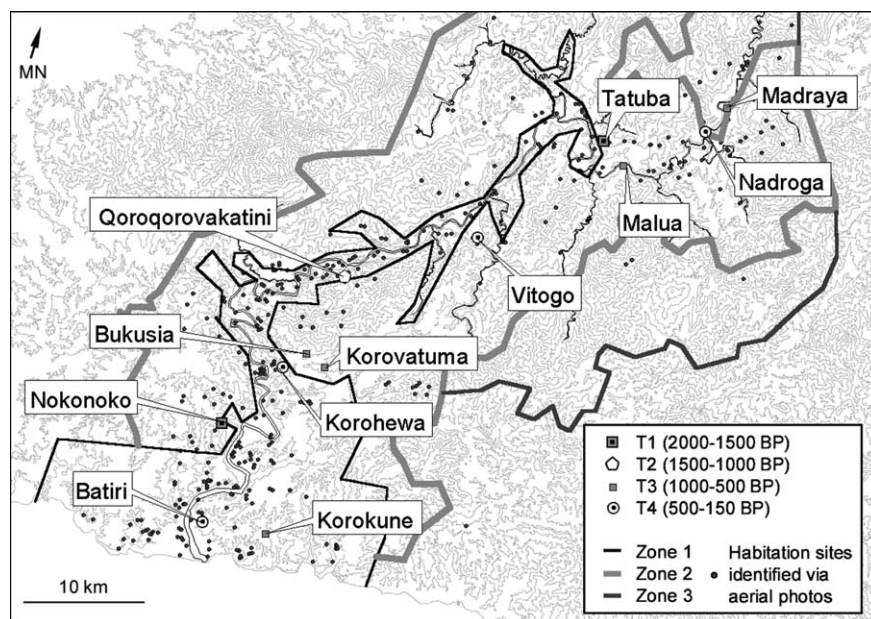


Fig. 5. The location of sites excavated in the Sigatoka Valley in the 2001–2002 season. Symbols indicate inclusion of earliest occupations in temporal periods T1–T4. Sites identified via aerial photo analysis are also shown. Contour interval: 100 m.

Table 1

Topographic, environmental, and archaeological data pertaining to the 12 sites excavated in the 2001–2002 season

District No.	Name	Area (ha)	Elev. (m)	Situation	Zones	Const. def.	Viewshed size (km ²) ^a	No. sites in view ^a	% Slopes >45° ^a	No. agri. feats. 1 km ^a	Total product score ^a	Productive yield ^a	Strategy ^a
1-NKR-031	Madraya	12.5	191	Summit flat	2–3		47.64	25	70	3	54	Med mixed	Defended production
1-NKR-046	Nadroga	1.5	100	River terrace	2–3	Walls	31.98	21	70	1	40	Low Dryland	Defended production
1-NMT-015	Tatuba	25	200	Knoll	2	Walls	92.93	31	83	0	17	Low Dryland	Defensive
2-BMA-011	Vitogo	1.4	35	River flat	2	Ditch	20.21	12	15	0	85	High wetland	Defended production
2-CON-010	Korokune	4.6	184	Summit apex	1	Scarp	177.4	37	72	0	28	Low dryland	Defended production
2-MAV-047	Korovatuma	9	160	Summit apex	2		131.38	39	90	0	10	Low dryland	Defensive
2-MAV-048	Korohewa	1.1	60	River terrace	1		1.98	0	70	4	34	Med mixed	Production
2-MAV-049	Bukusia	37	123	Knoll	2	Walls	34.78	22	80	0	20	Low dryland	Defensive
2-NOK-009	Nokonoko	19.3	200	Ridge	1–2	Ditch	44.6	17	85	0	15	Low dryland	Defensive
2-QMR-007	Qoroqoro.	12.5	200	Ridge	1–2	Walls	58.96	24	98	1	8	Low wetland	Defensive
2-SIG-005	Batiri	3	20	River flat	1	Ditch	34.21	21	0	0	100	High dryland	Defended production
1-NSK-015	Malua	35	100	Promontory	2	Walls	29.92	15	62	1	46	Low dryland	Defended production

^a The size of the viewshed, the number of sites in view, and the percentage of surrounding slopes greater than 45° were part of the analysis of natural and constructed fortifications. The number of agricultural features within 1 km, as well as the slope and quality of surrounding soils was used in the determination of productive yield. Combined, these analyses provide an indication of habitation strategy (purely defensive, defended production, or production sites) (Field, 2002).

Table 2

¹⁴C and AMS dates for the 12 sites excavated in the 2001–2002 season

Sample no.	Provenience (cmbs)	Location	Material	Measured ¹⁴ C age BP	¹³ C/ ¹² C ratio	Calibrated age range probability distributions (1σ) ^a	Calibrated age range probability distributions (2σ) ^a
<i>Tatuba Cave</i>							
Wk-11137	TU1, Ft. 1, 45–55	Cave floor	Wood charcoal	968 ± 52	–28	Cal AD 1020–1160	Cal AD 1000–1220
AA50298	TU1, 50–60	Cave floor	Wood charcoal	1294 ± 40	–25.6	Cal AD 685–780	Cal AD 660–880
AA50294	TU1, 80–90	Cave floor	Wood charcoal	1993 ± 35	–26	Cal BC 20–Cal AD 80	Cal BC 50–Cal AD 130
AA50293	TU 1, 130–140	Cave floor	Human bone	339 ± 40	–20.6	Cal AD 1510–1650	Cal AD 1480–1660
AA50292	TU1, 140–150	Cave floor	Wood charcoal	1802 ± 34	–25.5	Cal AD 210–340	Cal AD 130–380
AA50291 ^b	TU1, 190–200	Cave floor	Wood charcoal	207 ± 31	–28.1	Cal AD 1650–1950	Cal AD 1640–1950
<i>Nokonoko</i>							
AA50287	TU 5, 20–30	Midden	Wood charcoal	1492 ± 43	–26.7	Cal AD 560–645	Cal AD 460–670
AA50283	TU 1, 95–105	Burial mound	Wood charcoal	1311 ± 39	–25	Cal AD 685–775	Cal AD 650–860
AA50284	TU 3, 10–20	Courtyard surface	Riparian shell	674 ± 37	–8.7	Cal AD 1295–1390	Cal AD 1280–1400
AA50288	TU 6, 30–40	yavu	Wood charcoal	212 ± 37	–24.5	Cal AD 1660–1950	Cal AD 1640–1960
AA50299	TU 7, 30–40	yavu	Wood charcoal	185 ± 62	27.4	Cal AD 1660–1950	Cal AD 1650–1960
AA50289	TU 10, 10–20	yavu	Wood charcoal	135 ± 31	–24.9	Cal AD 1690–1920	Cal AD 1670–1960
<i>Qoroqoro</i>							
AA50307	TU1, 90–100	yavu	Wood charcoal	974 ± 43	–29.4	Cal AD 1020–1160	Cal AD 1000–1210
AA50308	TU3, 20–30	Below stone wall	Wood charcoal	182 ± 42	–29.1	Cal AD 1660–1950	Cal AD 1660–1960
Wk-11134	TU4, 50–70	yavu	Wood charcoal	259 ± 99	–28.2	Cal AD 1510–1950	Cal AD 1470–1960
<i>Korovatuma</i>							
AA50301	TU 1, 20–30	yavu	Wood charcoal	188 ± 42	–27.2	1660–1950	1660–1960 Cal AD
AA50300	TU 1, 60–70	yavu	Wood charcoal	527 ± 53	–27.2	Cal AD 1330–1450	Cal AD 1300–1490
AA50310	TU 2, 60	yavu	Wood charcoal	338 ± 46	–26	Cal AD 1510–1650	Cal AD 1460–1670
<i>Bukusia</i>							
AA50303	TU 1, 30–40	yavu	Wood charcoal	189 ± 49	–28.3	Cal AD 1660–1950	Cal AD 1650–1960
AA50304	TU 2, 40–50	Earthen wall	Wood charcoal	259 ± 40	–24.3	Cal AD 1630–1950	Cal AD 1520–1950
Wk-11135	TU 2, 80–90	Earthen wall	Wood charcoal	202 ± 59	–29.6	Cal AD 1650–1950	Cal AD 1640–1960
<i>Malua</i>							
AA50290	TU1, 50–60	yavu	Wood charcoal	159 ± 34	–26.5	Cal AD 1670–1950	Cal AD 1670–1960
AA50295	TU2, 10–20	Rockshelter floor	Wood charcoal	624 ± 33	–26.3	Cal AD 1305–1405	Cal AD 1300–1410
<i>Madraya</i>							
AA50296	TU1, 20–30	yavu	Wood charcoal	398 ± 38	–28.7	Cal AD 1450–1630	Cal AD 1440–1640
<i>Korohewa</i>							
AA50305	TU 1, 60–70	yavu	Wood charcoal	210 ± 39	–27.9	Cal AD 1660–1950	Cal AD 1640–1960
<i>Vitogo</i>							
AA50306	TU1, 20–30	yavu	Wood charcoal	175 ± 40	–25	Cal AD 1670–1950	Cal AD 1660–1960
AA50302	TU1, 60–77	yavu	Wood charcoal	198 ± 63	–24.9	Cal AD 1660–1950	Cal AD 1640–1960
AA50309	TU2, 40–50	Ditch causeway	Wood charcoal	261 ± 46	–25.1	Cal AD 1530–1950	Cal AD 1490–1960
<i>Nadroga</i>							
AA50297	TU1, 50–60	yavu	Wood charcoal	224 ± 50	–24.6	Cal AD 1650–1950	Cal AD 1630–1960

^a All determinations were calibrated using the terrestrial calibration curve of Stuiver et al. (1998), with 27 ± 5 years subtracted from the CRA to account for the southern hemisphere offset in ¹⁴C (McCormac et al., 1998).

^b This date has been discarded from the chronology as likely originated in much later deposits that fell into the bottom of the unit following a wall collapse.

base is located in Zone 1. Although Zone 1 would have been susceptible to flooding and drought during severe ENSO cycles, the region to the north and east of the site was generally buffered against extreme climatic phenomena. Thus, Tatuba Cave meets the expectations of the evolutionary ecology model in that it represents an

early occupation (period T1) in an area that would have been most desirable in terms of productivity, predictability, and aversion to loss. As populations were probably small during the earliest period of occupation, the initial use of the site as a fortification is unlikely. However, it would have provided a natural fortification

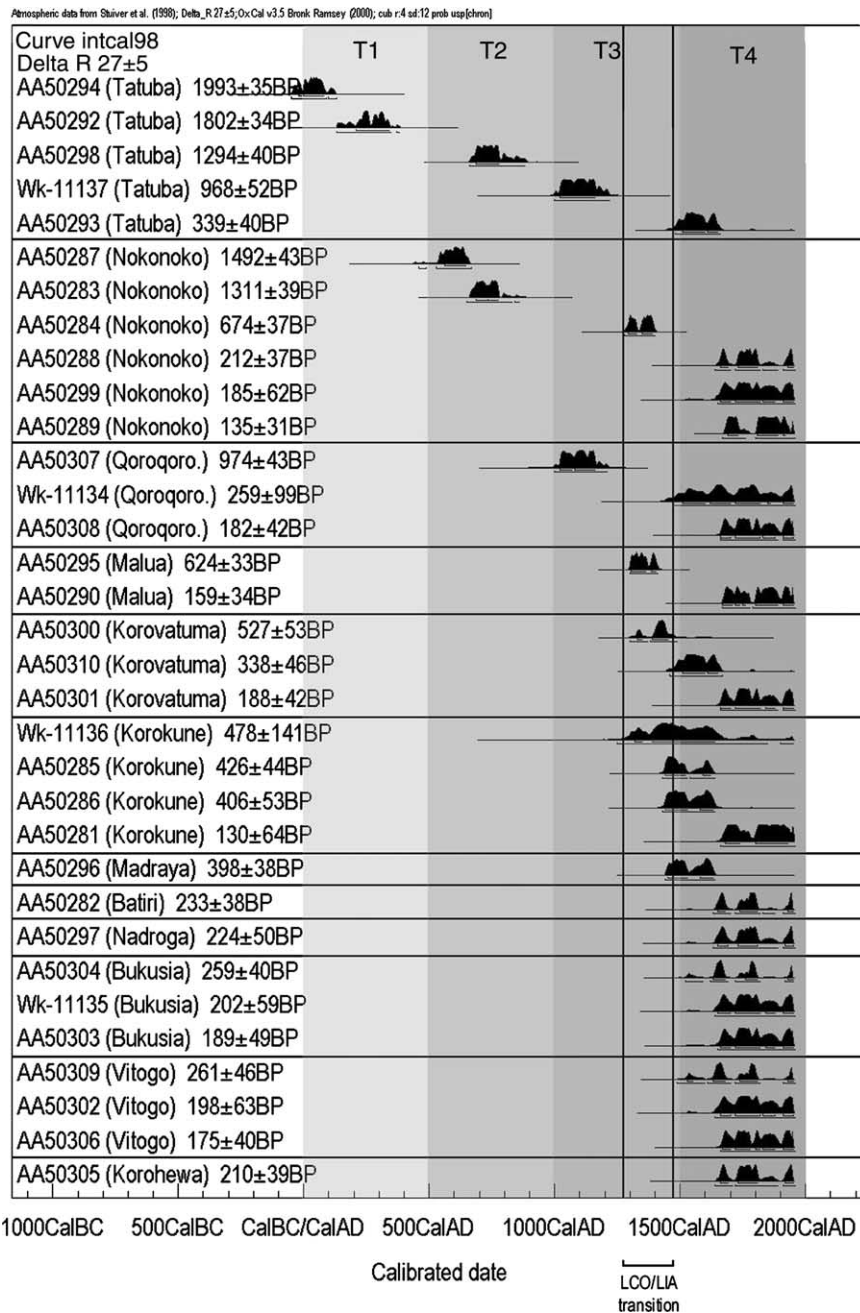


Fig. 6. Calibrated ages for the 2001–2002 Sigatoka Valley excavations. Temporal periods T1–T4 and the position of the LCO/LIA transition are indicated. All determinations were calibrated using the terrestrial calibration curve of Stuiver et al. (1998), with 27 ± 5 years subtracted from the CRA to account for the southern hemisphere offset in ^{14}C (McCormac et al., 1998).

if the need arose. Thus, later occupations at Tatuba Cave may represent the application of a strategy of territorialism associated with dense and predictable resources. The size of the entire Tatuba Cave locale (area, and also number of *yavu* and architectural features) also suggests that the area remained desirable as an occu-

pation site during the following two millennia (T1–T4), and the strategy of territorialism persisted in the region.

Similarly, the sites of Nokonoko and Qoroqoro-vakatini suggest an association between the founding of territorial strongholds and refuges as a response to dense and predictable resources and environmental shortfalls.

Both of these sites consist of remote and naturally defended peaks that are over 240 m above the valley bottom, and contain complex archaeological features and deposits of substantial antiquity. Nokonoko was established as early as the 6th century AD (1492 ± 43 years BP, or period T1) and Qoroqorovakatini was constructed several centuries later (974 ± 43 years BP, or period T2). In the case of Nokonoko, the range of dates from both *yavu* and occupational terraces, and also the deep middens of clamshell and ceramics suggest that the site was occupied throughout the prehistoric period. Thus, this site most closely represents a territorial stronghold that was occupied year-round. In contrast, occupations atop *yavu* at Qoroqorovakatini contained deposits that indicate episodic occupation; hence the site may represent a combination of remote refuge and territorial stronghold.

Environmental analyses indicate that both Nokonoko and Qoroqorovakatini lay on the boundaries of Zones 1 and 2 (Table 1). These sites have limited agricultural resources in their immediate vicinities, as the topography is steep and soils are of poor quality. However, both are within a few kilometers of extensive alluvial terraces, much of which are well drained and suited to *uvi* cultivation. The early presence of these sites in these regions suggests that local resources had achieved 'economic defendability,' (i.e., the benefits of defense outweighed the costs (Boone, 1992; Dyson-Hudson and Smith, 1979)). In addition, the fact that the lands in Zone 1 would have been susceptible to both severe ENSO-related drought and flooding is indicative of the evolutionary ecology expectations for unpredictable environments; the unpredictable nature of shortfalls in such environments encourage the intensification of competitive behaviors (often including physical conflict), resulting in the establishment of territorial strongholds that persist during good times and bad (Bawden and Reyecraft, 2000; Dean, 1996; Tainter and Tainter, 1996). Therefore, the long chronologies of Nokonoko and Qoroqorovakatini reflect the persistence of a territorial and refuge strategy through all temporal periods (T2–T4) relating to environmental limitations and climatic perturbations in Fiji. Of note, occupations at the site of Korokune reflect a similar adherence to the strategy of territorial stronghold, although this site was not established until the third temporal period (Table 2).

Relocation to environmental refuges during periods of disturbance

Four of the 12 excavated sites were established during the third temporal period (1000–500 BP), and also within the period proposed for the transition between the Little Climatic Optimum and Little Ice Age (730–525 BP). The increase in site frequency during this period suggests significant population growth between periods

T1 and T3. Equally important, the location of three newly founded habitations in Zones 2 and 3 suggests the development of a new strategy of habitation and subsistence that is directly related to environmental disturbance. In particular, the environmental conditions surrounding these sites, their topographic positions in remote drainages, and also the presence of faunal material indicating a diversified resource base, are suggestive of a distinctive and new settlement pattern focused on environmental buffering.

Malua, and Korovatuma (and perhaps also Bukusia) are emblematic of this new trend. Both were established between AD 1300 and 1630, and are located atop dramatic outcrops that provided natural defense. The dating of occupations at these sites included *yavu*, and also a defensive wall constructed of earth and rubble (Table 2). The lands surrounding these sites were of moderate quality but extraordinarily rugged (Table 1). Cultivation of *dalo* was certainly possible, but the arable land was restricted to 'pocket gardens,' (i.e., small isolated patches along minor creeks). Neither site had access to the large tracts of alluvial deposits that were available in earlier periods (e.g., Nokonoko, Tatuba Cave, and Qoroqorovakatini). However, environmental analyses place these sites within Zone 2, which indicates that the resource base surrounding these sites would not have been affected by severe drought or a reduction of soil moisture due to sea-level fall predicted for the LCO/LIA transition (Table 1). Unlike significant portions of the valley bottom (Zone 1), cultivation of *dalo* and *uvi* in Zones 2 and 3 would have continued as normal. The timing of the founding of the sites, as well as quality of the surrounding environment, strongly suggest that these new habitations represent a strategy of environmental refuge relating to the effects of the LCO/LIA transition.

It is important to note that these sites vary greatly in size and complexity: the sites of Malua, Bukusia, and Korovatuma each contain a large number of mounds and architectural features, while the site of Madraya is rather modest by comparison (Table 1). This suggests that settlement patterns during the LCO/LIA transition employed both long-term and short-term occupations, and that population density may have varied greatly across the landscape. Moreover, archaeological deposits indicate that subsistence regimes broadened to include tiny riparian snails and fish, and also incorporated marine and riparian foods that were acquired from long distances (e.g., over 40 km). In addition, two of the more ancient sites in the valley, Tatuba Cave and Nokonoko, were refurbished with fortifications and occupations at this time. Cumulatively, these data suggest that the LCO/LIA transition encouraged populations to optimize in new ways: (1) less investment in large but risk-laden agricultural surplus, and increased focus on temporally stable resources; (2) variable patterns of population aggregation and dispersal, perhaps coupled

with mobility; (3) diversification of the resource base; and (4) exchange or travel for non-local food items.

According to Dyson-Hudson and Smith (1979, p. 26) model of resource distribution, the LCO/LIA transition period may represent a period during which pockets of dense resources within Zone 1 became scarce, and much of the region became too unpredictable for seasonal dryland cultivation. Thus, strategies of mobility, exchange, diversification, and storage may have emerged (or increased in frequency) as populations sought to adapt to mountainous environments that were generally of moderate-low production quality, but which were temporally stable (Cashdan, 1990; Halstead and O'Shea, 1989; Rosenberg, 1998). Cooperative strategies, such as the formation of work groups and food sharing between relatives are also expected to increase in frequency. However, it is important to note that competition (as evinced by the use of naturally defended locales and refurbishment of sites with constructed features) also dates to this period. This reflects the continued emphasis on territorial integrity, and perhaps increased rates of conflict between populations that have access to a more stable resource base (such as Tatuba Cave), and populations that resort to mobility or relocation due to shortfalls in their home territories. In this instance, the coarseness of the evolutionary ecology model does not allow for the determination of a more definitive explanation.

Constructed fortifications and undefended production sites

The final phase of Sigatoka Valley prehistory (period T4) witnessed the persistence of previously established strategies (territorial strongholds, remote refuges, and environmental refuges), and also the emergence of a new form of fortification on the valley bottom: villages surrounded by a constructed moat and ditch. The sudden appearance of this kind of fortification suggests the diffusion of new ideas concerning defensive construction, and also an increasingly large population. The sites of Vitogo and Bātiri are a case in point. Excavations of *yavu* and ditch causeways indicate that both of these sites were constructed between 260 and 150 BP and are of the 'ring-ditch' type (i.e., protected with an annular ditch, bank, and palisade) (Tables 1 and 2). Unlike previous centuries, these villages did not make use of any topographical features for defense, but were located within swampy, riparian environments that would have been prime locations for growing *dalo*. The size of annular ditch and bank construction for these sites suggests a significant investment and labor pool: in the case of Bātiri, the ditch was 10 m wide with a circumference of 390 m. This is a marked change from the fortifications of previous centuries, which employed naturally fortified positions that required minimal initial investment, and which also did not require a sizeable population

for defense or construction tasks. Therefore, the restriction of manufactured fortifications to the latest period is almost certainly a factor of population size, and perhaps also related to the transmission of this innovative design throughout Fiji in the late prehistoric period.

The emergence of undefended habitation sites in the valley bottom may also be related to population growth, and perhaps the integration of small communities with larger territorial strongholds. The sites of Nadrogā and Koroheva are representative of this strategy. These habitations were of small size, late age, and were located on the valley bottom. No visible defenses were encountered at Koroheva, and only a modest wall unrelated to defense was present at Nadrogā. The lack of defenses at these sites breaks nearly two millennia of tradition for the Sigatoka Valley; for the first time, villages did not employ topography as the first line of defense against invaders. This omission strongly suggests that these populations were integrated with regional centers, or were protected by another form of defense: armed warriors. Moreover, the presence of undefended habitation sites may be related to cooperative strategies that were established during the LCO/LIA transition. In this case, undefended settlements may have been linked to fortifications maintained by close relatives.

It is also important to note that architecture relating to social divisions (i.e., the extensive retaining walls and division of high conical mounds from lower square mounds at the site of Nadrogā, or the monumental burial mounds of Nokonoko) appear to have only been constructed in the Sigatoka Valley in the latest temporal period. It has been suggested from reference to historical documents that high mounds and spatial divisions within settlements are indicative of Fijian social structure (Best, 1984, pp. 661–662). The fact that these features date to the latest temporal period and are associated with the intensive settlement of the valley bottom suggests that social divisions became more important after 500 BP. This may also suggest that the transition from isolation (habitation on distant mountain peaks) to integration (habitation on the accessible surface of the valley floor) encouraged portions of the population to communicate elite status (Hegmon, 1992; Wobst, 1977). Alternatively, Boone (1992) suggests that social hierarchies emerge as strategies that reduce the variance in individual harvest rates, but only occur if emigration or dispersal to a less populated area is not an option. If populations had grown to the point that emigration in the Sigatoka Valley was no longer possible, the occurrence of elite social strata (i.e., chiefly lineages) may be related to both increased integration and population growth. Archaeological data that are currently available for the Sigatoka Valley can neither confirm nor reject these hypotheses. However, the linkage between constructed fortifications and a larger population size by the latest temporal period seems certain.

Finally, the location of constructed fortifications and undefended production sites was restricted to Zones 1 and 2, in particular the lower elevations and valley bottom. Although these settlements were established after the LCO/LIA transition period, moderate and severe ENSO-related floods and droughts undoubtedly effected the populations of this period. However, these populations may have responded by simply moving to a new locale and constructing a new fortification (or, residing in a regional stronghold for a short duration). Undefended production sites were probably less common, or were occupied for shorter periods.

The emergence of competition in Fijian prehistory: environmental variability, population pressure, and invasion

The results of the analyses described above suggest that populations employed fortifications as both full-time habitations and refuges throughout the much of the prehistoric period. The persistence of this strategy through time and across environmental zones is highly indicative of its utility, and also its general success as a means by which human groups could obtain and maintain access to resources. The preference for naturally defended habitations, especially from 1500 to 500 BP, suggests that populations either lacked the necessary labor to construct artificial fortifications, or had yet to develop (or be exposed to) artificial fortification designs. This is an important point, as it indicates that human groups opted for fortified habitations early on, despite the absence of contemporaneous sites that would signify increasing population pressure.

Of course, this point suggests that between 1500 and 1000 BP (when Nokonoko and Qoroqorovakatini were established as refuges/territorial strongholds), populations were still relatively small in the Sigatoka Valley. The issue of population size as a factor in the emergence of conflict has been discussed in some detail for Fiji. Both Parry (1987) and Rosenthal (1991) suggest that populations in prehistoric Fiji never exceeded the carrying capacity of the local environment. However, census calculations of this sort approximate population size via the measurement of habitation area (e.g., Cook and Treganza, 1950), and even in well-dated archaeological contexts such calculations are often only the most tentative of approximations. In addition, the purely spatial measurement of arable land is a faulty approximation of carrying capacity in that it precludes the most important factor: carrying capacity is always in a state of flux, as landscapes are divided into productive and nonproductive temporal periods and spatial patches, within which the demographics of animal and plant populations are constantly changing (Cashdan, 1992, pp. 237–243; Dewar, 1984, pp. 605–606; Rindos, 1984, pp. 258–284).

It is suggested herein that the presence of fortifications in Fijian prehistory is indicative of human subsistence strategies that were developed to deal with both spatial and temporal resource variation. This suggests that fortifications were constructed in response to the local manifestation of Fiji-wide conditions. When the carrying capacity of a certain locale was either exceeded or at risk, local populations responded by utilizing natural and constructed fortifications in order to maintain access to crucial resources. In the long run, the benefits of fortified habitations (e.g., security, land-tenure) outweighed the costs (e.g., isolation, loss of time/energy for cultivation). Unfortunately, limited excavations of fortified habitation sites often provide only broad indications for particularly severe instances of conflict or environmental stress. Other indicators of subsistence stress may more accurately indicate the severity of shortfalls at different points in prehistory. Research at the site of the Sigatoka Dunes has recorded markers indicative of nutritional deficiency amongst burials from Level 2, which date to ca. AD 550–650 (Visser, 1994; pp. 177). In addition, human remains from sites on Waya (Pietrusewsky et al., 2003), Wakaya (Rechtman, 1992), Lakeba (Best, 1984), and also the sites of Navatu and Vuda on Viti Levu (Gifford, 1951; Degusta, 1999, 2000) have provided several indicators for cannibalism at various times in prehistory.⁴ The ubiquitous nature of cannibalized human remains in midden contexts from throughout Fiji similarly suggests that attitudes of conflict and competition persisted throughout prehistory at frequencies that were independent of regional population sizes.

The Sigatoka Valley data do not suggest that fortifications resulted from clashes between indigenous Fijians and migrants, who presumably arrived from either Vanuatu or New Caledonia ca. 1800 and 900 BP (e.g., Best, 1984, 2002; Frost, 1974). The presence of a variety of items in Fijian material culture (e.g., imported obsidian, incised ceramic design styles, and kava drinking) provide evidence for contacts between Fiji and Vanuatu, and recent debates have focused on the degree to which these contacts have shaped Fijian cultural development (Best, 2002; Clark, 1999). The presence of center-poled house forms and ovoid-shaped ceramics in the upper Sigatoka Valley are suggestive of forms native to both New Caledonia and Vanuatu, however, firmer indicators for a distinct migration of Melanesian migrants in the Sigatoka Valley is not discernable at this time (Field, 2003). Moreover, the analysis of ceramics from the Sigatoka Valley does not indicate the sudden occurrence

⁴ Burials and human remains in midden contexts were recovered from nearly all of the sites excavated in the Sigatoka Valley between 2001 and 2002. These materials have yet to be analyzed for marks or breakage patterns indicative of cannibalism.

of paddle-impressed or incised designs, which are often associated with ceramics from New Caledonia and Vanuatu. Cumulatively, the Sigatoka Valley data suggest that defense and warfare persisted as an indigenous Fijian strategy, rather than an imposed one.

Concluding hypothesis: implications for the emergence of social complexity following the LCO/LIA transition

The trend towards the resettlement of the Sigatoka Valley bottom in the latest temporal period, as well as evidence for social integration, social stratification, and population growth, provides fodder for the formulation of a new hypothesis for Fijian prehistory. Could the environmental and climatic stresses of the LCO/LIA transition also precipitated the emergence of some modes of complexity in parts of the archipelago, most notably the chiefdoms of central Fiji that developed after 500 BP? These chiefdoms are well documented in the historical literature of the 19th century, when European merchants, missionaries, and colonists encountered the confederacies of Rewa, Bau, Navua, and Cakaudrove (Waterhouse, 1866; Wilkes, 1845; Williams and Calvert, 1860). Scholars in the Pacific have long debated the causes associated with the development of complex chiefdoms (e.g., Goldman, 1955; Kirch, 1984; Sahlins, 1958; Williamson, 1924). For the most part, the development of elite aristocracies and a socially stratified society has been explained through neoevolutionary models of population growth, agricultural intensification, and control over limited resources via warfare and tribute systems (e.g., Brookfield, 1972; Kirch, 1984; Sahlins, 1968; Service, 1975; White, 1959). From this perspective, the evolution of chiefdoms in the agriculturally rich river deltas of windward Fiji (and not in the leeward regions) seems to fit the model well. In recent decades Fijian scholars have stressed the role of chiefs in the development of exchange and tribute, and ultimately the development of complexity. Rechtman (1992), and more recently Marshall et al. (2000) suggest that social complexity developed on the heels of chiefly attempts to gain power. Legitimacy, they argue, required an ever-increasing need for material goods that were symbolic of chiefly title. Thus, rising chiefs sought to develop networks that would supply them with exotic and/or chiefly items (e.g., whale's teeth, red feathers, decorated ceramics, etc.), and their ascendancy to power would have further institutionalized these networks and supported additional levels of stratification in the society (Marshall et al., 2000, pp. 92–93).

In light of the chronology for habitation and subsistence in the Sigatoka Valley, why did social complexity necessarily emerge in Fiji after 500 BP? More traditionally, the delay in the development of chiefly states has been explained as a factor of population

growth. For Fiji, scholars such as Palmer (1969a,b) and Parry (1977, 1982) meld the ideas of Boserup (1965) and Brookfield (1972), and suggest that populations did not reach crucial levels until the late prehistoric period, at which point farmers shifted to more intensive modes of production. The higher yields provided by these technologies allowed for the development of the tribute systems, and thus fostered the transition from chiefly class to ruling aristocracy. Alternatively, Marshall et al. suggest that the transition from simple regional exchange hinged upon the establishment of a Tongan outpost at Lakeba ca. 1000 BP. This outpost set in motion a “current or eddy of circulation” that ultimately led to the development of complex chiefly states in central Fiji. Although the enterprise may have started out as a node in Tongan maritime expansion, ultimately the system was appropriated by Fijians and transformed into a tribute system that extended throughout the archipelago (Marshall et al., 2000, pp. 92).

It is suggested herein that emergent social complexity, increased regional interaction, and intra-archipelago exchange may have been further stimulated in Fiji by the upheavals of the LCO/LIA transition. As demonstrated by the changes evident in the Sigatoka Valley, the difficulties experienced by populations during the LCO/LIA transition may have also selected for alternative strategies, such as increased cooperation or interaction between isolated populations, the growth of social hierarchies, or increased mobility. Although it is acknowledged that cool and dry conditions lingered throughout the centuries of the LIA (e.g., Bridgman, 1983; Fagan, 2001), relative environmental stability, despite the harsh conditions, may have allowed for newly emerged social and subsistence systems to flourish between 500 BP and the contact period. Future research that focuses on the history of interaction in Fiji (including the leeward as well as the windward side) may provide evidence that supports this hypothesis.

Conclusion

This research utilized GIS-based environmental analyses and archaeological investigations in a study of Fijian prehistory. The results suggest that environmental factors in Fiji influenced strategies of subsistence and settlement from as early as Cal BC 20. Moreover, the episodic nature of ENSO-related droughts and floods in the Sigatoka Valley encouraged the development and persistence of competitive strategies, in particular the construction of fortified habitations. The founding of environmental refuge sites coincides with the LCO/LIA transition period (ca. 730–525 BP), which is suggestive of the development of strategies that sought to buffer against regional shortfalls. In the latest temporal period (500–150 BP), population growth and innovations in

fortification construction allowed for the resettlement of the valley bottom. Social integration and social hierarchies, as evinced by the proximity of sites and the occurrence of monumental architecture, also developed in the latest temporal period.

Based upon the research presented herein, the application of paleoenvironmental data to archaeological problems reveals itself to be a promising avenue for future research. In particular, further elucidation of the effects of ENSO on prehistoric societies may offer insights into a variety of cultural phenomena, including population growth and demographic change, the development of new technologies or human phenotypic traits, and even modes of cultural elaboration and political development. However it is important to note that the full nature of the ENSO phenomenon has yet to be completely understood, and the projection of oscillation cycles back in time will undoubtedly be altered and refined in future years. It is not impossible that many of the cycles and episodes that archaeologists have used in the evaluation of change may yet be recalibrated according to new measurements of amplitude and frequency.

The analytical capabilities of a GIS, in particular the analysis of landscape topography, is shown in this research to have particular value to spatial analysis, and can be modified to incorporate a temporal aspect. This approach attempts to incorporate all the variables that impact subsistence and habitation. This goes beyond the settlement pattern analyses that typified earlier decades of archaeology, and identifies the region as the object of study. Increasing resolution of the data involved in these kinds of analyses will undoubtedly multiply the analytical potential for archaeological studies.

Finally, evolutionary ecology is identified in this research as both an integrated set of principles that both define and direct research, and also a set of middle-range expectations that can be tested in an archaeological case. Evolutionary ecology is particularly adept at assessing the interaction of individuals and the environment, and determining how and why the selection of particular strategies results in increased fitness for the actor. When placed in an archaeological context, the analysis of human strategies and environmental variables within a framework of evolutionary principles aids in determining not only how change occurs, but also why it occurs. Future research that includes similar methods may well address archaeological problems of increasingly greater scale and complexity.

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References cited

- Alexander, R.D., 1974. The evolution of social behavior. *Annual Review of Ecology and Systematics* 5, 325–383.
- Axelrod, R., 1997. *The Complexity of Cooperation: Agent Based Models of Competition and Collaboration*. Princeton University Press, Princeton, NJ.
- Barrau, J., 1965. L'humide et le sec: an essay on ethnobiological adaptation to contrastive environments in the Indo Pacific area. *Journal of the Polynesian Society* 74, 329–346.
- Bawden, G., Reycraft, R.M., (Eds.), 2000. *Environmental Disaster and the Archaeology of Human Response*. Maxwell Museum of Anthropology, Anthropological Paper No. 7, Albuquerque.
- Best, S., 1984. Lakeba: The Prehistory of a Fijian Island. Unpublished Ph.D. thesis, University of Auckland.
- Best, S., 1987. A preliminary report on the Sigatoka burials. *Domodomo* 3, 2–15.
- Best, S., 2002. *Lapita: A View From the East*. New Zealand Archaeological Association Monograph 24, Auckland.
- Birks, L., 1973. Archaeological Excavations at Sigatoka Dune Site, Fiji. *Bulletin of the Fiji Museum* No. 1. The Fiji Museum, Suva.
- Boone, J.L., 1983. Noble family structure and expansionist warfare in the late middle ages: a socioecological approach. In: Little, M.A., Dyson-Hudson, R. (Eds.), *Rethinking Human Adaptation: Biological and Cultural Models*. Westview Press, Boulder, pp. 79–96.
- Boone, J.L., 1992. Competition, conflict, and the development of social hierarchies. In: Smith, E.A., Winterhalder, B. (Eds.), *Evolutionary Ecology and Human Behavior*. Aldine de Gruyter, New York, pp. 301–337.
- Boserup, E., 1965. *The Conditions of Agricultural Growth: The Economics of Agrarian Change Under Population Pressure*. Allen and Unwin, New York.
- Bowles, S., Gintis, H., 2003. The origins of human cooperation. In: Hammerstein, P. (Ed.), *The Genetic and Cultural Origins of Cooperation*. MIT Press, Boston, pp. 429–443.
- Boyd, R., Richerson, P.J. (Eds.), 1985. *Culture and the Evolutionary Process*. The University of Chicago Press, Chicago.
- Bridgman, H.A., 1983. Could climate change have had an influence on the Polynesian migrations? *Paleogeography, Palaeoclimatology, Palaeoecology* 41, 193–240.
- Brookfield, H.C., 1972. Intensification and disintensification in Pacific agriculture. *Pacific Viewpoint* 13, 30–47.
- Brown, J.L., 1964. The evolution of diversity in avian territorial systems. *Wilson Bulletin* 76, 160–169.

- Burley, D., 1997. Archaeological Research, Sigatoka Dune National Park June 1996. Unpublished Report. Department of Archaeology, Simon Fraser University.
- Cashdan, E., 1983. Territoriality among human foragers: ecological models and an application to four bushman groups. *Current Anthropology* 24, 47–66.
- Cashdan, E. (Ed.), 1990. Risk and Uncertainty in Tribal and Peasant Economies. Westview Press, Boulder.
- Cashdan, E., 1992. Spatial organization and habitat use. In: Smith, E.A., Winterhalder, B. (Eds.), *Ecology, Evolution, and Human Behavior*. Aldine de Gruyter, New York, pp. 237–266.
- Caviedes, C.N., 2001. El Niño in History: Storming Through the Ages. University Press of Florida, Gainesville.
- Chagnon, N., 1979. Mate competition, favoring close kin, and village fissioning among the Yanomamo Indians. In: Chagnon, N., Irons, W. (Eds.), *Evolutionary Biology and Human Social Behavior*. Duxbury, North Scituate, pp. 86–132.
- Clark, G.R., 1999. Post-Lapita Fiji: Cultural Transformation in the Mid-sequence. Unpublished Ph.D. thesis, Australian National University.
- Cook, S.F., Treganza, A., 1950. The quantitative investigation of Indian mounds. *University of California Publications in American Archaeology and Ethnology* XL, 223–262.
- Cordell, L., 2000. Aftermath of chaos in the pueblo southwest. In: Bawden, G., Reyecraft, B. (Eds.), *Environmental Disaster and the Archaeology of Human Response*. Maxwell Museum of Anthropology, Anthropological Paper No. 7, Albuquerque, pp. 179–195.
- Davies, J., 1992. Sigatoka Valley Rural Development Scheme: Groundwater for Irrigation. Mineral Resources Department Hydrogeological Report 3. Ministry of Lands and Mineral Resources, Suva.
- Dean, J.S., 1988. Dendrochronology and paleoenvironmental reconstruction on the Colorado plateau. In: Gummerman, J. (Ed.), *The Anasazi in a Changing Environment*. Cambridge University Press, Cambridge, pp. 119–167.
- Dean, J.S., 1996. Demography, environment and subsistence stress. In: Tainter, J., Tainter, B. (Eds.), *Evolving Complexity and Environmental Risk in the Prehistoric Southwest*. Proceedings Vol. XXIV, Santa Fe Institute Studies in the Sciences of Complexity, Addison-Wesley, Reading, MA, pp. 25–56.
- Dean, J.S., Euler, R.C., Gummerman, G.J., Plog, F., Hevly, R., Karlstrom, T., 1985. Human behavior, demography, and paleoenvironment on the Colorado plateaus. *American Antiquity* 50, 537–554.
- Degusta, D., 1999. Fijian cannibalism: osteological evidence from Navatu. *American Journal of Physical Anthropology* 110, 215–241.
- Degusta, D., 2000. Fijian cannibalism and mortuary ritual: bioarchaeological evidence from Vunda. *Journal of Osteoarchaeology* 10, 76–92.
- Dewar, R.E., 1984. Environmental productivity, population regulation, and carrying capacity. *American Anthropologist* 86, 601–614.
- Dickinson, W.R., Burley, D., Nunn, P., Anderson, A., Hope, G., De Biran, A., Burke, C., Matararaba, S., 1998. Geomorphic and archaeological landscapes of the Sigatoka Dune site, Viti Levu, Fiji: interdisciplinary investigations. *Asian Perspectives* 37, 1–31.
- Durham, W.H., 1976. Resource competition and human aggression, part I: a review of primitive war. *The Quarterly Review of Biology* 51, 385–415.
- Dyson-Hudson, R., Smith, E.A., 1979. Human territoriality: an ecological reassessment. *American Anthropologist* 80, 21–41.
- Ember, C.R., Ember, M., 1992. Resource unpredictability, mistrust, and war. *Journal of Conflict Resolution* 36, 242–262.
- Fagan, B., 2001. *The Little Ice Age: How Climate Made History, 1300–1850*. Basic Books, New York.
- Ferguson, R.B. (Ed.), 1984. *Warfare, Culture and Environment*. Academic Press, Orlando.
- Field, J.S., 1998. Natural and constructed defenses in Fijian fortifications. *Asian Perspectives* 37, 32–58.
- Field, J.S., 2002. GIS-based analyses of agricultural production and habitation in the Sigatoka Valley, Fiji. In: Ladefoged, T.N., Graves, M. (Eds.), *Pacific Landscape: Archaeological Approaches*. Easter Island Foundation Press, Los Osos, pp. 97–124.
- Field, J.S., 2003. The Evolution of Competition and Cooperation in Fijian Prehistory: Archaeological Research in the Sigatoka Valley, Fiji. Unpublished Ph.D. Dissertation, University of Hawai'i, Manoa.
- Fiji Meteorological Service, 2003. Climate. Available from <http://www.met.gov.fj/climate_fiji.html> (Nov. 2003).
- Finney, B., 1985. Anomalous westerlies, el niño, and the colonization of Polynesia. *American Anthropologist* 87, 9–27.
- Fox, J.P., Wright, A., Baumgart, I., Twyford, I., 1952. Report on the Soil Resources of Fiji. Government of Fiji Publishers, Suva.
- Frost, E.L., 1974. Archaeological Excavations of Fortified Sites on Taveuni, Fiji. *Asian and Pacific Archaeology Series No. 6*, University of Hawai'i, Honolulu.
- Frost, E.L., 1979. Fiji. In: Jennings, J. (Ed.), *The Prehistory of Polynesia*. Australian National University Press, Canberra, pp. 61–81.
- Gifford, E.W., 1951. Archaeological excavations in Fiji. *Anthropological Records* 13, 189–288.
- Godfrey, H.C., 1987. The evolution of clutch size in parasitic wasps. *American Naturalist* 129, 221–233.
- Goldman, I., 1955. Status rivalry and cultural evolution in Polynesia. *American Anthropologist* 57, 680–697.
- Green, R.C., 1967. Fortifications in other parts of tropical Polynesia. *New Zealand Archaeological Association Newsletter* 10, 96–113.
- Haas, J. (Ed.), 1990. *The Anthropology of War*. Cambridge University Press, Cambridge.
- Haas, J., Creamer, W., 1993. Stress and warfare among the Kayenta anasazi of the 13th century AD. *Fieldiana: Anthropology*, 88.
- Halstead, P., O'Shea, J. (Eds.), 1989. *Bad Year Economics: Cultural Responses to Risk and Uncertainty*. Cambridge University Press, New York.
- Hegmon, M., 1992. Archaeological research on style. *Annual Review of Anthropology* 21, 517–536.
- Hope, G., O'Dea, D., Southern, W., 1999. Holocene vegetation histories in the western Pacific—alternative records of human impact. In: Galipaud, J.-C., Lilley, I. (Eds.), *Le Pacifique de 5000 à 2000 avant le présent: Suppléments à l'histoire d'une colonisation*. Institut de Recherche Pour le Développement, Paris, pp. 387–406.

- Jones, T.L., Brown, G.M., Raab, L.M., McVickar, J.L., Spaulding, W.G., Kennett, D.J., York, A., Walker, P.L., 1999. Environmental imperatives reconsidered: demographic crises in western North America during the medieval climatic anomaly. *Current Anthropology* 40, 137–170.
- Kaloumaira, A., 2000. Reducing the Impact of Environmental Emergencies Through Early Warning and Preparedness—The case of El Niño-Southern Oscillation (ENSO). South Pacific Applied Geosciences Commission. Available from <http://www.esig.ucar.edu/un/fiji.html> (June 16th, 2003).
- Kennett, D.J., Kennett, J.P., 2000. Competitive and cooperative responses to climatic instability in coastal southern California. *American Antiquity* 65, 379–396.
- Kiladis, G.N., Diaz, H.F., 1989. Global climatic anomalies associated with extremes in the southern oscillation. *Journal of Climate* 2, 1069–1090.
- Kirch, P.V., 1984. *The Evolution of Polynesian Chiefdoms*. Cambridge University Press, Cambridge.
- Kirch, P.V., 1994. *The Wet and the Dry: Irrigation and Agricultural Intensification in Polynesia*. The University of Chicago Press, Chicago.
- Kirch, P.V., 1997. *The Lapita Peoples: Ancestors of the Oceanic World*. Blackwell, Cambridge.
- Kuhlken, R., 2002. Intensive agricultural landscapes of Oceania. *Journal of Cultural Geography* 19, 161–195.
- Ladefoged, T.N., 1993. The impact of resource diversity on the sociopolitical structure of Rotuma: a geographic information system analysis. In: Graves, M.W., Green, R.C. (Eds.), *The Evolution and Organization of Prehistoric Society in Polynesia*, vol. 19. New Zealand Archaeological Association, Auckland, pp. 64–71.
- Lambert, P.M., 1994. *War and Peace on the Western Front: A study of Violent Conflict and its Correlates in Prehistoric Hunter-Gatherer Societies of Coastal Southern California*. Unpublished Ph.D. Dissertation, Dept of Anthropology, UCSB.
- Lambert, R., 1971. Botanical identification of impressions on archaeological potsherds from Sigatoka. *Records of the Fiji Museum* 1, 123–148.
- LeBlanc, S.A., 1999. *Prehistoric Warfare in the American Southwest*. University of Utah Press, Salt Lake City.
- McCormac, F.G., Hogg, A.G., Higham, T.F.G., Lynch-Steiglitz, J., Broeker, W.S., Baille, M.G.L., Palmer, J.G., Xiong, L., Pilcher, J.R., Brown, D., Hooper, S.T., 1998. Temporal variation in the interhemisphere ^{14}C offset. *Geophysical Research Letters* 25, 1321–1324.
- Marshall, Y., Crosby, A., Matararaba, S., Wood, S., 2000. *Sigatoka: The Shifting Sands of Fijian Prehistory*. Oxbow Books, University of Southampton Press.
- Moseley, M.E., 1997. Climate, culture, and punctuated change: new data, new challenges. *Review of Archaeology* 17, 19–27.
- Nichols, N., Wong, K.K., 1990. Dependence of rainfall variability on mean rainfall, latitude, and the southern oscillation. *Journal of Climate* 3, 163–170.
- Nunn, P.D., 1990. Warming of the south pacific since 1880: evidence, causes, and implications. *Journal of Pacific Studies* 12, 35–50.
- Nunn, P.D., 1994. *Oceanic Islands*. Blackwell, Cambridge.
- Nunn, P.D., 2000a. Environmental catastrophe in the pacific islands about AD 1300. *Geoarchaeology* 15, 715–740.
- Nunn, P.D., 2000b. Illuminating sea-level fall around AD 1220–1510 (730–440 cal yr BP) in the pacific islands: implications for environmental change and cultural transformation. *New Zealand Geographer* 56, 46–54.
- Nunn, P.D., 2003. Revising ideas about environmental determinism: human-environment relations in the pacific islands. *Asia Pacific Viewpoint* 44, 63–72.
- Nunn, P.D., Britton, J., 2001. Human-environment relationships in the pacific islands around A.D. 1300. *Environment and History* 7, 3–22.
- Nunn, P.D., Kumar, R., 2003. Alluvial charcoal in the Sigatoka Valley, Viti Levu island, Fiji. *Paleogeography, Paleoclimatology, Paleocology in review*, May 2003.
- Nunn, P.D., Stone, J., Kumar, R., Corroborating the 'AD-1300 sea-level fall' in the south pacific: new dates from Niue and Fiji. Unpublished manuscript.
- O'Connell, J., Allen, J., 1995. Human reactions to the pleistocene-holocene transition in greater australia: a summary. *Antiquity* 69, 855–862.
- Otterbein, K.F., 1985. *Evolution of War: A Cross-Cultural Study*, second ed. Yale University Press, New Haven.
- Palmer, B., 1969a. Ring-ditch fortifications on windward Viti Levu, Fiji. *Archaeology and Physical Anthropology in Oceania* 4, 182–197.
- Palmer, B., 1969b. Fortified sites on ridge junctions, Fiji. *New Zealand Archaeological Association Newsletter* 12, 15–19.
- Parry, J., 1977. Ring-Ditch Fortifications: Ring-Ditch Fortifications in the Rewa Delta, Fiji: Air Photo Interpretation and Analysis. *Bulletin of the Fiji Museum*, No. 3. The Fiji Museum, Suva.
- Parry, J., 1982. Ring-Ditch Fortifications II: Ring-Ditch Fortifications in the Navua Delta, Fiji: Air Photo Interpretation and Analysis. *Bulletin of the Fiji Museum*, No. 7. The Fiji Museum, Suva.
- Parry, J., 1987. *The Sigatoka Valley—Pathways Into Prehistory*. Fiji Museum Bulletin No. 9. The Fiji Museum, Suva.
- Parry, J., 1997. *The North Coast from Bā to Rā: Air Photo Archaeology and Ethnohistory*. Bulletin of the Fiji Museum, Number 10. The Fiji Museum, Suva.
- Peel, M.C., McMahon, T., Finlayson, B., 2002. Variability of annual precipitation and its relationship to the el niño-southern oscillation. *Journal of Climate* 15, 545–551.
- Pearson, O.M., 2000. Activity, climate, and postcranial robusticity: implications for modern human origins and scenarios of adaptive change. *Current Anthropology* 41, 569–608.
- Pietruszewsky, M., Douglas, M., Cochrane, E., Reinke, S., 2003. Cultural modifications in an adolescent earth-oven interment from Fiji: sorting out mortuary practice. Presented at the 67th Annual Meeting of the Society for American Archaeology, Milwaukee, WI.
- Quinn, W.H., 1992. A study of the southern oscillation-related climatic activity for A.D. 622–1900 incorporating Nile River flood data. In: Diaz, H., Markgraf, V. (Eds.), *El Niño. Historical and Paleoclimatic Aspects of the Southern Oscillation*. Cambridge University Press, New York, pp. 119–149.

- Raab, L.M., Larson, D.O., 1997. Medieval climatic anomaly and punctuated cultural evolution in coastal southern California. *American Antiquity* 62, 319–336.
- Rechtman, R., 1992. The Evolution of Socio-political Complexity in the Fiji Islands. Ph.D. Dissertation, University of Michigan.
- Reycraft, R.M., 2000. Long-term human responses to el niño in south coastal Peru, circa A.D. 1400. In: Bawden, G., Reycraft, R. (Eds.), *Environmental Disaster and the Archaeology of Human Response*. Maxwell Museum of Anthropology, Anthropological Papers No. 7. University of New Mexico, Albuquerque, pp. 99–120.
- Richerson, P.J., Boyd, R., Bettinger, R.L., 2001. Was agriculture impossible during the pleistocene but mandatory during the holocene? A climate change hypothesis. *American Antiquity* 66, 387–412.
- Rindos, D., 1984. *The Origins of Agriculture: An Evolutionary Perspective*. Academic Press, New York.
- Rosenberg, M., 1998. Cheating at musical chairs: territoriality and sedentism in an evolutionary context. *Current Anthropology* 39, 653–681.
- Rosenthal, M., 1991. *Realms and Ritual: The Form and Rise of Civitas and Urbs in Southeastern Viti Levu, Fiji*. Ph.D. Dissertation, University of Chicago.
- Sahlins, M., 1958. *Social Stratification in Polynesia*. University of Washington Press, Seattle.
- Sahlins, M., 1968. *Tribesmen*. Prentice Hall, Engle Cliffs.
- Salinger, M.J., Basher, R., Fitzharris, B., Hay, J., Jones, P., McVeigh, J., Schmidely-Leleu, I., 1995. Climate trends in the south-west Pacific. *International Journal of Climatology* 15, 285–302.
- Sandweiss, D.H., Richardson III, J.B., Reitz, E.J., Rollins, H.B., Maasch, K.A., 1996. Geoarchaeological evidence from Peru for a 5000 years B.P. onset of el niño. *Science* 273, 1531–1533.
- Service, E., 1975. *Origins of the State and Civilization: a Process of Cultural Evolution*. Norton, New York.
- Smith, E.A., 1988. Risk and uncertainty in the 'original affluent society': evolutionary ecology of resource-sharing and land tenure. In: Ingold, T., Riches, D., Woodburn, J. (Eds.), *Hunters and Gatherers I: History, Evolution, and Social Change*. Berge, New York, pp. 222–251.
- Smith, E.A., Winterhalder, B., 1992. Natural selection and decision making: some fundamental principles. In: Smith, E.A., Winterhalder, B. (Eds.), *Ecology, Evolution, and Human Behavior*. Aldine de Gruyter, New York, pp. 25–60.
- Southern, W., 1986. *The Later Quaternary Environmental History of Fiji*. PhD thesis, Australian National University, Canberra.
- Spriggs, M., 1985. Prehistoric man-induced landscape enhancement in the Pacific: examples and implications. In: Farrington, I. (Ed.), *Prehistoric Intensive Agriculture in the Tropics*. BAR, Oxford, pp. 409–434.
- Spriggs, M., 1997. Landscape catastrophe and landscape enhancement: are either or both true in the Pacific? In: Kirch, P., Hunt, T. (Eds.), *Historic Ecology in the Pacific Islands: Prehistoric Environment and Landscape Change*. Yale University Press, New Haven, pp. 80–104.
- Stuiver, M., Reimer, P., Bard, E., Beck, J., Burr, G., Hughen, K., Kromer, B., McCormac, G., van der Plicht, J., Spurk, M., 1998. INTCAL98 radiocarbon age calibration, 24000–0 Cal BP. *Radiocarbon* 40, 1041–1083.
- Tainter, J., Tainter B., (Eds.), 1996. *Evolving Complexity and Environmental Risk in the Prehistoric Southwest*. Proceedings vol. XXIV, Santa Fe Institute Studies in the Sciences of Complexity. Addison-Wesley, Reading, MA.
- Terry, J.P., Raj, R., Kostaschuk, R.A., 2001. Links between the southern oscillation index and hydrological hazards on a tropical Pacific island. *Pacific Science* 55, 275–283.
- Van West, C.R., 1994. *Modeling Prehistoric Agricultural Productivity in Southwestern Colorado: a GIS Approach*. WSU Dept. of Anthropology, Report 67, Pullman.
- Vayda, A.P., 1976. Warfare in ecological perspective. *Annual Review of Ecology and Systematics* 5, 183–193.
- Visser, E.P., 1994. *The Prehistoric People from Sigatoka: An Analysis of Skeletal and Dental Traits as Evidence of Adaptation*. Ph.D. Dissertation, University of Otago, Dunedin.
- Waterhouse, J., 1866. *The King and People of Fiji*. Hayman, London.
- White, L., 1959. *The Evolution of Culture: The Development of Civilization to the Fall of Rome*. McGraw-Hill, New York.
- Wilkes, C., 1845. *The Narrative of the United States Exploring Expedition During the Years 1838–1842*, vol. III. Lea and Blanchard, Philadelphia.
- Williamson, R., 1924. *The Social and Political Systems of Central Polynesia*. Cambridge University Press, Cambridge.
- Williams, T., Calvert, J., 1860. *Fiji and the Fijians*. In: Stringer Rowe, G. D. Appleton and Company, New York.
- Wobst, M.H., 1977. Stylistic behavior and information exchange. In: Cleland, C. (Ed.), *For the Director: Research Essays in Honour of James B. Griffin*. University of Michigan, Museum of Anthropology, Anthropology Papers 61. University of Michigan, Ann Arbor, pp. 317–342.
- Wright, A.C., Twyford, I., 1965. *The Soil Resources of the Fiji Islands*. Government of Fiji Publishers, Suva.