Age of a charcoal band in fluvial sediments, Keiyasi, Sigatoka Valley, Fiji: possible indicator of a severe drought throughout the Southwest Pacific 4500-5000 years ago

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Abstract

A ^{14}C date for a charcoal band near the base of the High (10 m) Terrace in the middle Sigatoka Valley (western Viti Levu Island, Fiji) shows that this terrace accumulated mostly within the past 4-5000 years showing it to be a Holocene rather than a Pleistocene (Last Interglacial) landform as previously thought. The charcoal band also indicates that there was extensive, perhaps catastrophic, burning of forests and perhaps an associated local extirpation/extinction of forest taxa. The notion that humans may have been responsible for the forest burning represented by this charcoal band is rejected on account of its age predating known human arrival by at least one thousand years. Attention is drawn to the contemporaneity of this charcoal band and those found in Bonatoa Bog (southeast Viti Levu Island) and in New Caledonia, some 1300 km southwest of Fiji, suggesting that catastrophic forest burning during this period may have been widespread and a regionwide response to a period of prolonged aridity 4500-5000 years ago, possibly associated with a unusually severe El Niño event.

Key waords: *Charcoal, fluvial sediment, holocene, fire*

1 Introduction

There is little quantitative information available about the ages of sedimentary valley fills in the interior parts of Pacific Islands yet such information is needed to inform models of environmental change and human impact, about which there is considerable ongoing debate (Kirch and Hunt, 1997; Nunn, 1999a). One reason for the absence of such information is that there is normally little within these fills that can be dated. This paper reports on a unique site in the middle Sigatoka Valley on Fiji's main island of Viti Levu, from which a band of charcoal was recently dated and which provides a remarkable insight into valley history.

The burning event which this charcoal band represents may have been catastrophic and may have affected much of Fiji and other island groups in the southwest Pacific. Unlike similar finds in Australia, where humans are known to have resided for much longer than Fiji, this charcoal band almost certainly predates human arrival and is considered a result of a natural fire or fires. Such events offer a unique opportunity to better understand long-term natural environmental change and climatic events that could lead to widespread vegetation change and the extinction or extirpation of island biodiversity.

2 The study site

The Sigatoka River (Figure 1) drains an area of some 1452 km^2 and has a mean annual discharge of some 15 m^3/s at Namoka where the catchment area is 1333 km^2 (JICA Study Team, 1997) and 44 m^3/s at the river mouth (Ryland, 1981). Although it flows largely through the drier leeward side of Viti Levu Island, its headwaters rise in the wetter part, in consequence of which it has never been known to dry up.

From Namoli downstream, the Sigatoka Valley has broad areas of valley floor, marked by a number of aggradational terraces reaching in some places 20-25 m above channel bankfull level. Most of the higher river terraces are wholly erosional; their general form and significance were discussed by Nunn (1998). The numbers of low aggradational terraces appear to vary but this may be solely a reflection of post-formation erosion and reworking of the sediments by the river, particularly during flood stages, when new sub-levels are excavated within the main levels. Earlier work suggested that the aggradational terrace remnants constituted the remains of a valley floor approximately 10 m above sea level (Houtz, 1960, 1963) which was thought by Parry (1987) to be the Last Interglacial terrace (approximately 125,000 years old). Parry also identified a lower terrace throughout the middle and lower valley representing a valley floor graded to a level 2-3 m above sea level; he implied that this had formed during the Holocene sea-level high, some 4000 years ago in Fiji (Nunn and Peltier, 2001).

Both the High Terrace (10 m) and the Low Terrace (2-3 m), as Parry (1987) termed them, are visible throughout most of the middle and lower parts of the valley. There is an excellent exposure of the High Terrace on the left bank of the river 2 km south of Keiyasi (Keiasi) Village, 150 m north of the confluence with Saweta Creek (grid reference: 938997, Sheet M28, 1:50,000 topographic map series 31). The site is located on the outside of a broad meander bend

and was well-exposed in September 2000 by recent bank collapse (Plate 1).

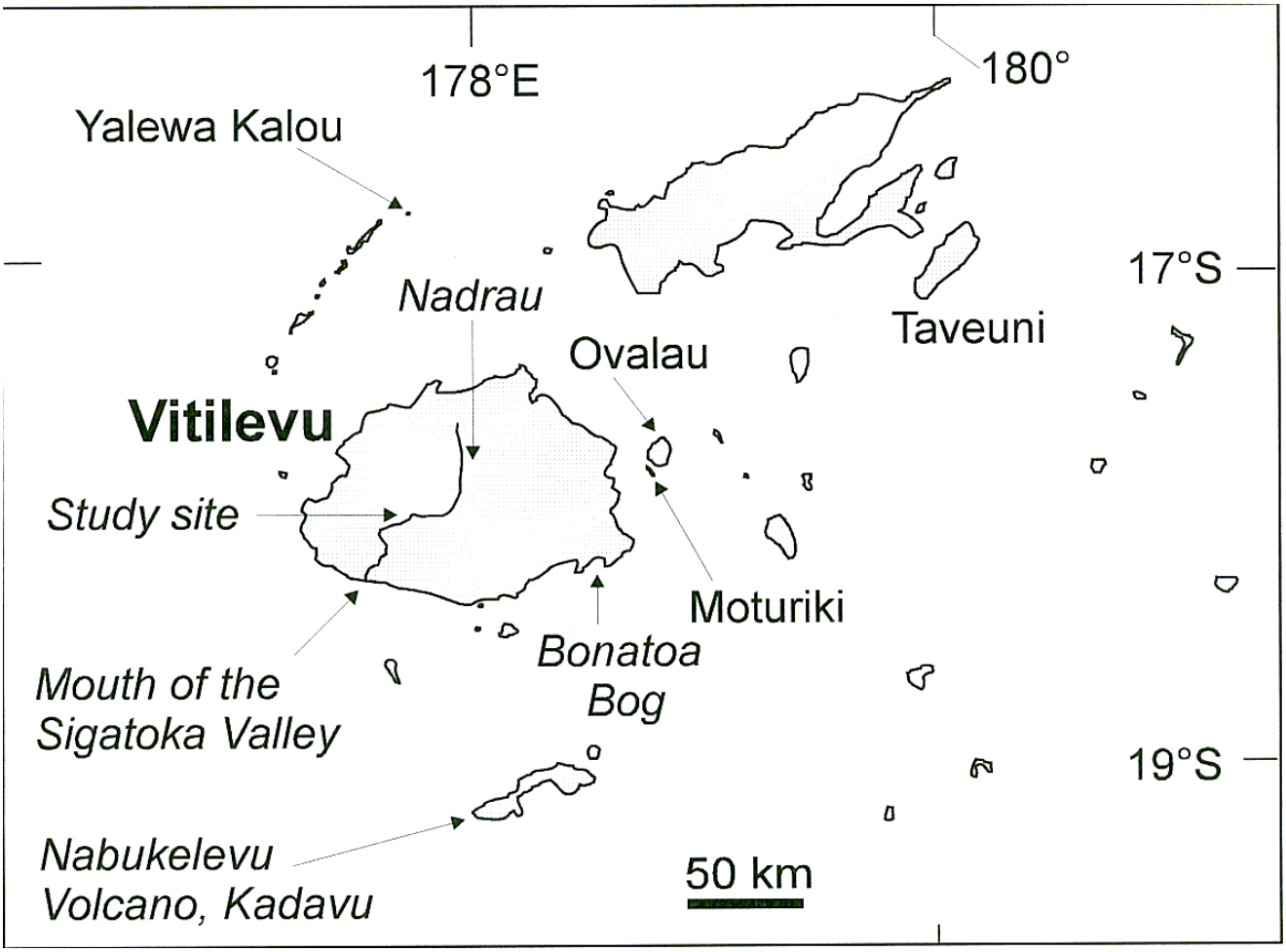

Figure 1. The locaton of the study site and other key places mentioned in the text

Close examination of the sedimentary composition of the section showed that, close to its base, beneath 6 m of undifferentiated medium-coarse sand capped by a thin (~10 cm) layer of soil, there was a 10-14 cm thick black charcoal-rich layer of medium-coarse sand (Plate 2). From its distinctiveness and continuity along at least 30 m of the river bank, it is likely to have been deposited within a short period of time, probably shortly after a catastrophic burning event. The charcoal is envisaged as having been deposited following heavy rain which carried ash from watersheds that had been extensively burned and were thus devoid of vegetation cover, organic material and humus, which normally reduce erosion, absorb water and slow surface runoff. The charcoal was sampled and sent for ^{14}C dating.

3 Results and Discussion

There was not enough charcoal in the original sample for it to be dated in the normal fashion, so it had to be dated using Accelerator Mass Spectrometry (AMS) dating, a technique used specifically for measuring radioactive isotopes in small samples. The sample was submitted to the University of Waikato (New Zealand) Radiocarbon Dating Laboratory (Wk-8806) and AMS measurement was carried out at the Institute of Geological and Nuclear Sciences in Wellington (NZA 12539). The resulting date is 4630 $\pm$ 60 BP which, when calibrated using OxCal (version 3beta2) and CALIB IntCal98.14c with a δR value of 24 $\pm$ 3 ^{14}C years, gives a range of 5600-5050 cal yr BP (3650-3100 BC).

Charcoal dates are difficult to interpret because charcoal can remain on the ground for a long time before it is washed into an area such as the valley bottom where it was found during this study. Even assuming that the charcoal lay on the ground before being deposited in the valley for a century, which seems improbably long, the error between the calibrated age range and the actual time when forest burning took place could be no more than 400 years.

Assuming this, perhaps overly conservative, estimate to be the case, the actual age range for the forest burning event is 5600-4650 cal yr BP (3650-2700 BC) which is well before the first unmistakable indication of the first human presence in Fiji about 2900 cal yr BP (950 BC: Anderson and Clark, 1999). There are non-archaeological indicators of environmental change predating this time that

some authorities have thought should be attributed to humans. One example is the accumulation of charcoal 5458-4436 cal yr BP at Bonatoa Bog in coastal southeast Viti Levu (Southern, 1986; calibration by Spriggs, 1996) which may be linked to the hiatus in reef-surface growth 4870-3840 cal yr BP off Ovalau and Moturiki islands (Nunn, 2000a).

Plate 1. The main exposed section through the High Terrace at the study site. The charcoal band is just above the observers' feet.

The involvement of humans in the forest burning event in the Sigatoka Valley is rejected here because it is highly unlikely that humans were in Fiji at the time. Even if they had been present, they would most likely (like the first-known humans in Fiji) have been coastal dwellers who had no reason to settle so far inland. A cautionary note should be sounded here. Some of the earliest settlers on Aneityum Island in Vanuatu settled inland because the valley floors were too swampy (Spriggs, 1981), but there is at present no evidence of any comparable situation in Fiji.

It is more plausible to suppose that the forest burning event recorded by the charcoal band at the Keiyasi site was a result of a natural, perhaps catastrophic forest fire or a series of fires, perhaps lightning or volcano ignited, during a major drought. We envisage that an extended period of drying out followed a long wetter period during which tropical forests and woody vegetation were dominant. The slow drying out of the forest cover would have turned it into a veritable "tinder box" of biomass. If an El Niño event was superimposed on an existing prolonged dry

period, the aridity could have been exacerbated further still, leading to the makings of a catastrophic forest fire. We picture an analogous situation to that which occurred recently in Borneo, where droughts exacerbated by a severe El Niño provided the conditions necessary for massive forest fires that destroyed a large portion of this large island's remaining forests (Brown and Lomolino, 1998). The charcoal band in the Sigatoka Valley is likely to have been deposited by surface runoff following heavy rain at the end of such a drought.

Plate 2. The charcoal band.

The fact that this forest burning event is almost exactly coincident with that recorded in Bonatoa Bog (see above), suggests that it may have been a widespread event within Viti Levu Island, that it could have affected an extensive area of the island, burning considerable areas of tropical lowland rainforest, including riparian forest, grassland and savanna. It may also be a sign of a more widespread, regional event because a high influx of charcoal occurred 4650-4350 cal yr BP in cores from Saint Louis Lac (Lake) on the main island of New Caledonia. It has been suggested that this was a product of a single, naturally caused forest fire coincident with an exceptionally dry period (Stevenson and Dodson, 1995). Other possibly linked events include the significant catchment disturbance on Mangaia, Cook Islands, 6580-5750 cal yr BP which was likely to have been associated with a major El Niño (Ellison, 1994), and the pre-human forest burning episodes 5800 BP and 3800 BP in South Island, New Zealand (Burrows and Russell, 1990).

Based on palynological evidence from the Nadrau Plateau in the centre of Viti Levu island and an area climatically similar to the Keiyasi site, Southern (1986) reports the virtual disappearance of common forest taxa after about 2090 BP and their almost permanent replacement by pioneer species in the families Poaceae (grasses) and Urticaceae, and the genera *Bischofia*, *Omalanthus*, *Parasponia* and/or *Celtis* which indicate a dramatic change in the dryland vegetation. She notes that the increased abundance of carbonised particles at about the same time as the reduction in forest elements suggests that fire played a part in the changes. Although Southern links this burning to humans, this could not possibly have been the case with the charcoal deposit which is the object of this study. If such devastating fires could occur in the absence of humans, perhaps it is premature to assign to

human impact all such fires which occurred after humans are known to have colonised a particular island.

Although we have no supporting palynological evidence from the Keiyasi site, we suggest that the catastrophic fire(s) which the charcoal band is believed to represent could have been associated with a major local, and possibly more widespread extirpation/extinction event, and the transformation of forest and woodlands into today's familiar grassland-savanna (*talasiga*) landscape with scattered pioneer species, such as *Bischofia javanica* and *Alphitonia zizyphoides*, remaining in grassland areas and forest only in the wetter ravines.

Another question relates to the cause(s) of the fire. Lightning strikes can undoubtedly cause fires in forests and these fires will spread rapidly and widely where there is a lot of available, exceptionally dry, biomass. In Fiji there is also the possibility that fires were caused by volcanic eruptions. Within the past 5000 years, volcanoes have been active on the islands Taveuni (Dr Shane Cronin, 1998, personal communication), 152 km northwest of Viti Levu, and Kadavu (Nunn, 1999b), 91 km south of Viti Levu. The distances between these volcanoes and Viti Levu are probably too great to admit volcanic eruptions as a possible cause of this fire, particularly given that these eruptions were probably not particularly explosive or of large magnitude (Dr Shane Cronin, 1998, personal communication). There is a remote possibility that the volcano of Yalewa Kalou, a small island 73 km north of Viti Levu, was active during the last few thousand years but, as yet, there is insufficient known about its recent eruptive history (Rodda, 1983).

4 Implications

The presence of a Holocene charcoal layer close to the base of the 10 m aggradational terrace in the Sigatoka Valley clearly shows that it could not be of Last Interglacial (pre-Holocene) age as Parry (1987) supposed. Rather it must now be assumed that the accumulation of this persistent terrace occurred only within the last four thousand years or so.

Although it is difficult to draw conclusions from the study of just one terrace section, it is plausible to suppose that most of the sediment above the charcoal layer accumulated recently – perhaps only within the last 800 years or so – when coastal-dwelling humans first moved up the Sigatoka Valley and began having an impact on the landscape (Dickinson et al., 1998). A comparable situation has been found at the Sigatoka Sand Dunes, just west of the river mouth, where the main phase of dune accumulation began only some 7-800 years ago, perhaps as a result of people moving inland (and clearing forest) in response to the fall in sea level and attendant rapid decline of the nearshore resource base around AD 1300 (Nunn, 2000b; Nunn and Britton, 2001).

Having demonstrated that the Higher (10 m) Terrace is of Holocene rather than earlier age, the question then arises as to what age the Lower (2-3 m) Terrace is. The only other sea-level high stage following the high stand around 4000 years BP occurred around AD 1300 (Nunn, 2000c). It is possible that the Lower Terrace was formed in the Sigatoka Valley during the Little Climatic Optimum (approximately 1200-650 cal yr BP) and then became abandoned when sea level fell and the river channel responded by downcutting during the "AD 1300 event" (around 650 cal yr BP).

5 Conclusions

This research has provided evidence suggesting that there may have been widespread catastrophic fires, associated with periods of extended drought, that led to a dramatic change in the natural vegetation of forested areas and aided the spread of the grassland-savanna that characterises most drier areas of Fiji today. Such events may have been region wide and brought about extinctions affecting not only plants but the indigenous animal communities that depended on forests.

This research has also demonstrated that the low-level aggradational fills of the Sigatoka Valley are probably younger than hitherto supposed, implying that we need to re-examine our assumptions about the rates of geomorphological processes operating in this and similar tropical Pacific Island environments.

Further research is needed to confirm this suggestion, and the Sigatoka Valley is a good place to continue this because of both the well-dated sequence at the mouth of the river but also because of the area's comparatively high visibility and its long, relatively well-studied history of human occupation. By linking data on charcoal bands with palynological and palaeontological data from time periods before and after their deposition, it could be possible – like studies of comparable deposits before and after the great end-Cretaceous (K-T boundary) event 64.5 million years ago (Spicer, 1989; Cox and Moore, 2000) – to show clearly how major extinction events have affected the vegetation and resident biodiversity in the Pacific Islands.

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