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5.5 PREHISTORIC MAN-INDUCED DEGRADATION OF
THE LAKEBA LANDSCAPE: EVIDENCE FROM TWO
INLAND SWAMPS

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I - INTRODUCTION AND METHODS

INTRODUCTION

Much of the island of Lakeba supports a pyrophytic vegetation cover dominated by ferns growing on very impoverished and often eroded soils. This soil-vegetation complex, known as *talasiga*, is generally considered to be anthropogenic and to have resulted from the degradation of forested land through clearance and burning for shifting cultivation. For this to have been so, the extensive transformation of the forest to *talasiga* must have taken place in the last 3000 years or so, the time span that recent archaeological investigations have shown the island to have been occupied (S. Best, personal communication). However Latham (this volume) has argued that disturbed habitats probably existed before human arrival and that the *talasiga* might well be a natural formation which has since become more widespread (see also UNESCO/UNFPA Project 1977, p. 59-61).

In order to test hypotheses concerning the origin of the *talasiga* complex and implications for prehistoric man-induced degradation of the landscape M. Latham and M. Brookfield collected cores from a number of inland and near-coastal swamps in diverse ecological settings with the aim of constructing a vegetation history for the island through pollen analysis¹. The cores consist largely of inorganic sediment with a small percentage of microscopic organic debris, mainly cuticles, fungal spores and carbonized plant remains. On the basis of preliminary studies of two of them, J. Flenley and J. Guppy of the Australian National University concluded that since they contained very little well preserved pollen, detailed pollen analysis was not warranted.

A number of radiocarbon dates were obtained from one of the inland swamps (Waitabu) and their depth/age distribution showed that at least 1 m of sediment had accumulated in the last 1000 years and, less certainly, 6.5 m in the last 2000 years (Latham, this volume). As the contributing catchment for this swamp is small in area these rates of accumulation of sediment suggested the possibility that accelerated soil erosion had occurred on the surrounding slopes within the time span of man's occupation of the island, presumably as a result of his interference with the vegetation cover. Recent work in the New Guinea Highlands has provided evidence in the form of accelerated deposition of inorganic sediments in swamps for accelerated rates of soil erosion in the contributing catchments over the last 9000 years, and these in turn have been attributed to forest clearance for shifting agriculture (Golson and Hughes, 1976; Harris and Hughes, 1968; Hope, in press).

In order to test the hypothesis that prehistoric man's activities on Lakeba had resulted in accelerated erosion through disturbance of the vegetation cover, two sites were selected for study. A thorough investigation was made of their sediments and, through radiocarbon dating, of their histories of accumulation. The role of fire in transforming the vegetation cover was assessed through detailed studies of the carbonized particle contents of the

¹ Hughes and Hope were not involved in the field stage of the research. During discussions in Canberra between M. Brookfield and members of the Department of Biogeography and Geomorphology, Australian National University, it was suggested that the form of analysis employed here might yield valuable results, even though the cores were unsuitable for pollen analysis. Hughes and Hope were brought in at this stage.

sediments. The accumulation of carbonized particles is taken to reflect the burning of vegetation on or near the site with the incompletely combusted material being washed in by local runoff.

The two inland swamps cored by the project team were selected for this study as in both cases the sediment and carbonized material in them must have been entirely derived from small local catchments (Latham, this volume, Fig. 6.2). The Waitabu swamp covers an area of 3.4 ha and its very steeply sloping contributing catchment, 45.6 ha in area, is largely vegetated with closed regrowth forest. The Nabuni swamp is even smaller, 1.9 ha, and its more gently sloping catchment, 27.5 ha in area, is covered with *talasiga*. The outlets of both swamps are constricted either by bedrock or, more likely, by colluvial-alluvial deposits whose formation predates the arrival of man (Latham, this volume).

METHOD

Fieldwork

The cores were collected by M. Latham and M. Brookfield in November 1976. A D-section corer was used to recover the top 50 cm of the Waitabu core and the remainder of this core and the whole of the Nabuni core were collected in 50 cm sections with a Hiller-borer. The Waitabu core could not be extended down below 650 cm because of a lack of extension rods, and coring of the Nabuni swamp was not continued below 450 cm because of the extremely compact nature of the substratum.

Laboratory

The cores were opened and examined in the sedimentary laboratory in the Department of Biogeography and Geomorphology, RSPacS, at the Australian National University. Most of the sections were still moist and in good condition, however some of those from the Waitabu core that had previously been opened and sampled for pollen analysis and radiocarbon dating had completely dried out and had crumbled.

Detailed descriptions of the sediments, especially of their structure, moist Munsell colour and field texture, were then made after which the cores were cut up for further analyses as follows:

Radiocarbon dating: Three samples from each core were submitted to Geochron Laboratories, U.S.A., for radiocarbon dating.

Bulk chemistry: Six samples from the Waitabu core and five from the Nabuni core were chemically analyzed by ORSTOM in the laboratory in Noumea. The samples were prepared for analysis by digesting them at high temperature in concentrated nitric acid (HNO_3) and perchloric acid (HClO_3). This digestion dissolves all but the unweathered rock fragments and minerals.

Grain-size analyses: The grain-size distribution of three samples from each core were determined using the hydrometer method for the silt and clay fractions and dry sieving for the sand. The grain-size used was that of Wentworth (Folk 1968:25) in which clay is that fraction finer than 4μ , silt $4-63\mu$ and sand $63-2000\mu$. The field textures were then checked against these detailed analyses.

Mineralogy: Two samples from the Waitabu core were impregnated with resin,

thin sectioned and their mineralogy was described in detail by A. Watchman, A.N.U. His descriptions were augmented by microscopic examination of the sand and silt fractions from a number of samples from both cores.

Organic carbon: The organic carbon contents of 38 samples from the Waitabu core, and 22 from the Nabuni core, were determined by combustion using a LECO automatic carbon analyzer.

Carbonized particles: The concentration of carbonized particles in 31 samples from the Waitabu core and eight from the Nabuni core were determined as follows. A standard volume of sediment was extracted from each sample (2 ml) and treated with hydrofluoric acid (HFO and zinc bromide ($ZnBr_2$) heavy liquid flotation to extract all the contained organic material. Most of the non-carbonized organic material was then removed by oxidation with concentrated nitric acid (HNO_3) over 24 hours. The remaining organic material, which consisted of fine carbonized particles and residual non-carbonized organic debris was suspended in silicone oil. A proportion of this suspension was then examined under a microscope. All black or blackened particles with a maximum dimension of 3-10 μ , and all particles larger than 10 μ which were clearly derived from plant remains and which were carbonized to some extent, were counted.

II - COMPOSITION AND STRATIGRAPHY OF THE SWAMP DEPOSITS

WAITABU SWAMP

The sediment is essentially composed of clay minerals and silt- and sand-sized angular to sub-rounded kaolinized feldspar grains, iron oxide-rich nodules and charcoal specks with minor amounts of fresh, angular plagioclase, fragments of fresh volcanic rock, opaque iron-oxides and charred plant stems and seeds. The sediment is generally mineralogically homogeneous throughout the core. The medium to very coarse sand-sized feldspar grains and iron oxide-rich nodules were usually so soft as to be readily crushed in the fingers or smeared with a trowel.

The bulk chemistry of the deposit proved to be homogeneous throughout and as there were no apparent trends with depth the analyzes are presented in a summarized form in Table 5.1. The high silica/alumina ratio suggests the presence of well-ordered clays of the montmorillonite family in addition to clays of the kaolinite family.

The textures of the sediment do not show marked variations except that there is a small but steady increase in sand with depth at the expense of clay such that whereas in the top 550 cm the textures are generally sandy silty clay, below this they are silty sandy clays. The bulk of the clay is extremely fine. The coarse sand grades, which give the deposit a 'gritty' feel, consist largely of kaolinized feldspar grains and iron oxide rich nodules in roughly equal proportions.

Fine plant material, humates and charcoal make up the organic component of the deposit which is low throughout, 0.5 to 2.5 per cent (Fig. 5.1). Macroscopic specks of charcoal were observed throughout the core and in general where charcoal was observed to be concentrated locally so also were the highest organic carbon contents.

The concentration of carbonized particles is extremely high throughout

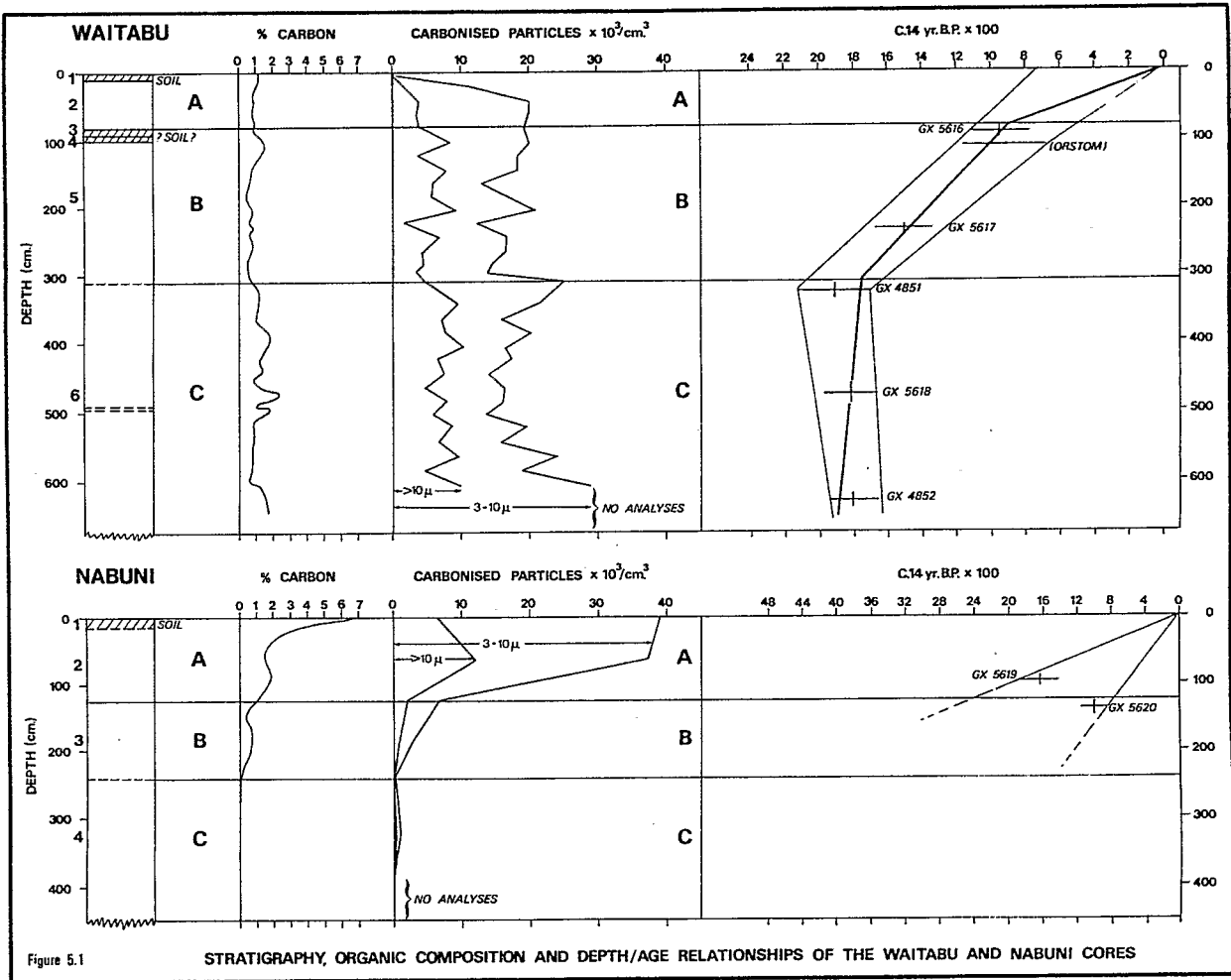


Figure 5.1 STRATIGRAPHY, ORGANIC COMPOSITION AND DEPTH/AGE RELATIONSHIPS OF THE WAITABU AND NABUNI CORES

TABLE 5.1: BULK CHEMISTRY OF SAMPLES FROM THE WAITABU
AND NABUNI SWAMP CORES

	WAITABU (6 samples) % by wt.	NABUNI (5 samples) % by wt.
Loss on ignition at 1100°C	13.3 - 14.0	11.9 - 15.7
Residue following acid digestion	3.2 - 5.4	0.6 - 1.7
Silica SiO ₂	39.3 - 41.4	41.1 - 44.5
Alumina Al ₂ O ₃	27.2 - 30.4	26.4 - 31.7
Iron oxide Fe ₂ O ₃	9.6 - 12.2	5.1 - 17.2
Titanium oxide TiO ₂	1.2 - 1.4	1.0 - 1.5
Magnesium oxide MnO ₂	0.4 - 0.6	0.5 - 2.0
Total Phosphorus	0.15 - 0.26	0.02 - 0.04
Trace amounts of oxides of manganese, calcium, magnesium, potassium and sodium also present		
SiO ₂ /Al ₂ O ₃	2.3 - 2.6	2.3 - 2.9
pH	3.9 - 5.3	4.5 - 5.5

all but the top 20 cm of the core (Fig. 5.1). There is little correlation between the minor variations in the concentration of carbonized particles and those in the organic carbon curve.

Monolete fern spores are noticeable in many horizons through the deposits, together with occasional trilete spores and grass pollen. The frequencies are too low to say more than that ferns appear to have played a role in the local vegetation on the site throughout the history of the deposit. Fern spores are typically highly over-represented in most lowland tropical vegetation communities.

Colour does not appear to be related to organic content; for example, the very dark to dark greyish-brown colour of much of the sediment cannot be accounted for by the presence of humus, as the total organic carbon content of most of those parts of the core is less than one per cent

The sediment appears to be essentially homogeneous in terms of mineralogy, chemistry, texture and organic content, and accordingly the following stratigraphic divisions are based almost wholly on differences in colour and structure.

1. 0-10 cm Friable dark brown (10YR3/3) to brown (10YR4/6) slightly mottled soil. This grades sharply over 2 cm into
2. 10-82 cm dark greyish-brown (10YR4/2) to brown (10YR4/3) structureless sandy silty clay with brown (10YR4/6) to reddish-brown (5YR4/6) iron oxide-rich nodules and yellow kaolinized feldspar grains. This unit in turn gives way over 1-2 cm to

3. 82-92 cm dark brown (10YR3/3) sandy silty clay with a blocky structure and numerous reddish-brown iron oxide-rich nodules.
4. 92-97 cm This unit has the same characteristics as the overlying unit except that it is distinctly very dark greyish-brown (10YR3/2) in colour. It gives way abruptly to
5. 97-310 cm brown (10YR4/2), dark yellowish brown (10YR4/4) and dark to very dark greyish-brown (10YR4/2 to 3/2) structureless sandy silty clays with brown to reddish brown iron oxide-rich nodules and yellow kaolinized feldspar grains. The air-dry colour of this unit is generally greyish brown (10YR5/2).
6. 310-650 cm This unit has the same characteristics as the overlying unit except that its moist colour is dark greyish brown (10YR4/2) and its air-dry colour is light grey (10YR6/1). The sediment is increasingly sandy with depth and below about 550 cm its texture is silty sandy clay. Within this unit is a lens of distinctly brown coloured (10YR4/4) sediment at 490-93 cm.

NABUNI SWAMP

The mineralogy of the sediment in this swamp is essentially the same as that of the material from Waitabu with the notable exception that the coarse sand-sized 'grits' of iron oxide-rich material so characteristic of the Waitabu core are absent from this core. Again the bulk chemistry of the deposit proved to be homogeneous with depth and was generally similar to that of the Waitabu material. One noteworthy difference is the low phosphorus content compared with that of the Waitabu deposit (Table 5.1).

The texture of the sediment varied greatly with depth, there being a marked increase in sand, and decrease in clay, with depth. Again the bulk of the clay is extremely fine.

The organic carbon content of the deposit decreases markedly with depth from about 6.0 per cent near the surface to less than 0.1 per cent below 240 cm. The amount of visible charcoal also decreased with depth and none was observed in that part of the core from below 240 cm. The concentration of carbonized particles is extremely high in the upper part of the core but decreases markedly with depth to very low concentrations below 240 cm. There is a close relationship between the organic carbon content and the concentration of carbonized particles. Fern spores were present in the top 100 cm but were not seen below 125 cm.

Thus in contrast to the Waitabu deposit, the textural and organic composition of the Nabuni deposit shows considerable variations with depth and accordingly the following stratigraphic units were defined in terms of these characteristics as well as those of colour

1. 0-15 cm Slightly friable dark brown (7.5YR4/1) soil with diffuse dark brown (7.5YR4/2) mottles and an organic carbon content of about 6.0 per cent. This unit gives way sharply to
2. 15-125 cm Structureless sandy silty clay, dark brown (7.5YR4/1) down to 65 cm, changing gradually below this to dark greyish-brown (10YR4/2) and then below 80 cm to very dark grey

- (10YR3/1). This unit contains abundant amounts of sand-sized grains of yellow, kaolinized feldspar and charcoal. The organic carbon content decreases down from about 4.0 per cent at the top to as little as 1.5 per cent towards its base. Below 120 cm the sediment becomes transitional in colour between that of the overlying clay and the underlying silt. This unit gives way over 1-2 cm to
3. 125-240 cm silt with a sand content that steadily increases with depth such that the texture changes down from sandy clayey silt at the top to clayey sandy silt at its base. Down to 155 cm the colour is dark brown (10YR3/3) with up to 50 per cent diffuse mottles ranging in colour from dark yellowish-brown (10YR4/6) to dark reddish-brown (5YR3/4). Below this and down to 200 cm the sediment is dark reddish-brown (5YR3/3) with diffuse yellowish-red (5YR4/6) mottles. The basal 40 cm of the unit is dark reddish-brown (5YR3/4). Yellow kaolinized feldspar grains are abundant throughout but the amount of organic carbon (including visible charcoal) decreases steadily with depth from about 0.9 per cent at the top to 0.1 per cent at this base. This unit merges over a few cm into
4. 240-450 cm charcoal-free clayey silty sand which becomes increasingly sandy with depth. The colour of this unit ranges from 2.5 to 5YR3/4 (dark reddish-brown) above 200 cm to 2.5YR3/4 (dark reddish-brown) below that depth. Again kaolinized feldspar grains occur throughout but at a much lower concentration than above. The organic carbon content of this is extremely low (0.02-0.05 per cent).

III - AGE AND HISTORY OF THE SWAMP DEPOSITS

RADIOCARBON DATES

Six radiocarbon dates were obtained for the Waitabu deposits (Table 5.2) and these demonstrate an excellent depth/age relationship. A depth/age curve was fitted visually to the distribution and an envelope indicating the likely age limits of the deposit was drawn so that it encompassed the outer limits set by \pm one standard deviation of each of the dates (Fig. 5.1). The core covers the time span from 1900 yr BP until the present and therefore provides a record of events that does not extend back before the arrival of man on the island.

Only two of the three samples submitted from the Nabuni core proved dateable (Table 5.2) and as these give an inverted depth/age relationship it was possible only to fit a broad envelope to indicate the likely age limits of the upper 125 cm of the core (2400-800 yr BP -- see Fig. 5.1) and, much less certainly, the upper 240 cm (1500-4800 yr BP).

The sediments in the swamps are derived from soil and regolith washed in from the surrounding slopes. At both sites the mineralogy and chemistry of the deposits is essentially the same as those of the soils mantling the surrounding slopes and there is no evidence that the sediments have undergone significant post-depositional alteration other than changes in the state of oxidation of the iron oxides. Difference in mineralogy and chemistry between the sites is taken to reflect local variations in geology, topography and weathering and erosional history. For example the larger proportion of un-

TABLE 5.2: RADIOCARBON DATES FROM THE WAITABU AND NABUNI SWAMP CORES

DEPTH (cm)	AGE (C-14 y BP) AND ERROR (± 1 S.D.)	LAB. NO.	SUBMITTED BY	COMMENT
<u>WAITABU</u>				
82-100	945 \pm 170	GX 5616	P.J. Hughes	C-13 corrected. Uncorrected age 920 y BP.
100	920 \pm 240	-	M. Latham	Wood collected from wall of pit dug precisely at the spot the core collected from.
225-240	1505 \pm 165	GX 5617	P.J. Hughes	C-13 corrected. Uncorrected age 1455 y BP.
315-335	1910 \pm 210	GX 4851	M. Brookfield	Not corrected for C-13.
460-490	1820 \pm 150	GX 5618	P.J. Hughes	C-13 corrected. Uncorrected age also 1820 y BP.
618-638	1805 \pm 140	GX 4852	M. Brookfield	Not corrected for C-13.
<u>NABUNI</u>				
90-105	1645 \pm 205	GX 5619	P.J. Hughes	C-13 corrected. Uncorrected age 1610 y BP.
125-150	1005 \pm 145	GX 5620	P.J. Hughes	C-13 corrected. Uncorrected age 965 y BP.
210-240	Not dateable	GX 5621	P.J. Hughes	Sample too small to be dated.
Note all GX dates on organic mud containing finely divided charcoal.				

weathered rock and minerals in the Waitabu deposit is likely to be because fresh rock crops out or lies closer to the surface of the Waitabu catchment more frequently than in the Nabuni catchment.

The soils and regolith mantling the catchments have formed through deep weathering of the iron-rich volcanic parent rock and are characterized by their reddish-colour which is largely due to the presence of 'oxidized' iron oxides (Soils of ferrallitic evolution - Latham, this volume). The marked colour differences between these soils and some of the sediments in the swamps are explained in terms of differences in the state of oxidation of these oxides resulting from differences in the depositional and post-depositional conditions under which the sediments have accumulated.

WAITABU

The sediment consists largely of silt and clay that must have been deposited under still or sluggish water conditions. The presence throughout of fern spores which must have grown on the site suggests that the environment of deposition was swampy rather than open water lacustrine.

The accumulation of this deposit is interpreted as having taken place in three stages. The lowest 3.4 m (level C) was deposited at the extremely rapid average rate of 230 cm/100 years between about 1900 and 1750 years ago. The presence of some fern spores, possibly from wetland taxa, suggests however that the rate of deposition was never too high to preclude plants from growing on the site. The grey colour of this part of the core is due to the reduced state of the iron oxides and this suggests that it has never been subject to extensive drying out since it was deposited. However the abundant spores and hyphae, presumably from soil fungi, indicate that the swamp surface was aerated at least some of the time.

From about 1750 yr BP the average rate of accumulation decreased to about 27 cm/100 years and this was maintained until about 900 years ago. The bulk of the sediment laid down over this time span (level B) is brown to greyish-brown and this suggests that the iron oxides are less reduced than those below. This in turn may reflect deposition under drier conditions and/or a drier post depositional environment. The dark brown colour and blocky structure of the top 10-15 cm of this unit suggests that from about 900 years ago there may have been a pause in deposition, allowing the formation of a poorly developed soil. Alternatively it is possible that the soil-like character of this material resulted from gardening of the swamp at that time.

Whatever the significance of the upper part of level B, over the next 900 years deposition continued at an even slower average rate of 9 cm/100 years. The lower part of this deposit (level A) is predominately grey in colour, again suggesting accumulation under wet conditions. The upper 10 cm of the deposit has been incorporated into a recent taro garden.

NABUNI

The character of the basal material (level C) is essentially the same as that of the soils on the surrounding slopes and its sandy texture and reddish colour attest to its origin as a colluvial-alluvial deposit laid down in a dryland environment which has never been subject to long periods of waterlogging. The lower metre or so becomes increasingly compact with depth and the possibility is admitted that this material is the remnant of

TABLE 5.3: RATES OF EROSION FROM THE WAITABU AND NABUNI CATCHMENTS

	THICKNESS OF SEDIMENT IN SWAMP (cm)	TIME SPAN (yr BP)	RATIO OF AREA OF SWAMP/	THICKNESS OF SOIL ERODED FROM CATCHMENT	RATES OF EROSION (cm/1000 yr)	MEAN EROSION INDEX (t/km ² /yr)
<u>WAITABU</u>						
Level A	82	0 - 900	0.075	6	7	105
Level B	228	900 - 1750	0.075	17	20	300
Level C	340	1750 - 1900	0.075	26	173	2595
				Total	49	
<u>NABUNI</u>						
Level A	125	0 - 800	0.069	9	4-10	60-150
Level B		or 0 - 2400				
Level B	115		0.069	8		
				Total	17	

Mean erosion index calculated as in Latham (this volume, Table 2.4).

an *in situ* weathering profile overlain by colluvial-alluvial sediments.

The sediment in the central segment of the core, between 240 and 125 cm (level B), gradually changes in colour upwards from reddish-brown to brown, and this, along with the increase in silt and clay up the core, suggests deposition took place in an increasingly still or sluggish water environment. No fern spores or other plant microfossils were observed in levels C and B and their absence is attributed to biochemical oxidation rather than that they were never present. Biochemical oxidation proceeds most rapidly in well drained, aerated conditions. These conditions clearly would have prevailed in level C but for them to have existed during the accumulation of level B means that the swamp that is inferred to have begun to form during this period was subject to periodic extensive drying out.

The clayey texture, grey colour, presence of fern spores and relatively high organic content of the upper 125 cm of the deposit (level A) all indicate that accumulation took place in still or sluggish water in a swampy environment and that the sediment has never been subject to extensive post-depositional drying. This level accumulated in the last 800 to 2400 years at an average rate of between 16 and 5 cm/100 years. The upper 15 cm of the deposit has been incorporated into a recent taro garden.

IV - DISCUSSION

EROSION AND BURNING

The amounts and rates of soil erosion from the catchments were calculated as shown in Table 5.3. The assumption was made that the stratigraphies and depth/age relationships established for the cores reflect the histories of accumulation of the swamps as a whole. The calculations also depend on the assumption that the area of deposition remained the same through time. However, it is likely that the surface areas of the swamps increased as they accumulated; if so the rates of erosion estimated for the lower levels are over estimated. On the other hand the calculated amounts and rates of erosion as they stand must be *minima* as they do not take into account the losses downstream in suspension or solution that must have occurred.

The concentrations of carbonized particles in these swamps reflect the frequencies of burning, nature of fuel and fire, efficiency of transport and dilution by other sediment (Singh *et al.* in press). Hence whilst fluctuations in these curves must be interpreted with caution, when they are used in conjunction with known rates of accumulation and erosion major changes in fire regime can be detected.

At Waitabu, in the 150 years between 1900 and 1750 yr BP a minimum thickness of 26 cm of soil was eroded from the catchment at an average rate of 173 cm/1000 years or 2600 t/km²/year. This is an extremely high rate of erosion (cf. Latham, this volume) and if the whole catchment had been so affected virtually all the topsoil could have been removed in this short period.

During this period of extremely rapid erosion and accumulation of sediment in the swamp the concentrations of carbonized particles remained steadily very high and this can only be interpreted as meaning that this massive erosion was accompanied by massive regular burning of the vegetation on and around the site. The presence of fern spores throughout the core at

this time suggests that despite massive erosion, accumulation and burning, some vegetation cover was maintained on and around the site. This vegetation, presumably at least partially composed of rhizomatous taxa, including ferns and sedges, would have acted as an efficient sediment trap.

The stratigraphy and depth/age and carbonized particles curves all indicate that this regime of massive erosion and burning was well established at 1900 yr BP and must therefore have been initiated before that time.

Between 1750 and 900 yr BP the average rate of soil erosion, 20 cm/100 years or 300 t/km²/year, was only one-tenth of that before 1750 yr BP. This rate was nevertheless high compared with recorded rates in other tropical regions (Latham, this volume) and a further 17 cm of soil was lost from the catchment during this 850 year period. As the ratio of carbonized particles did not change significantly after 1750 yr BP the total amount of burning must have decreased proportionately with the decrease in erosion. However, the concentration of carbonized particles remained steadily high throughout this period, indicating that the vegetation on and around the site continued to be regularly burned.

Over the last 900 years the rate of erosion declined even further to an average of 7 cm/100 years or 105 t/km²/year and a further 6 cm of soil was lost from the catchment. This rate falls at the upper end of the range of rates given by Latham (this volume) for other tropical regions and is considered to be high for tropical environments.

Initially the ratio of carbonized particles to sediment remained similar to that in the lower levels, suggesting a decrease in the incidence of burning proportional to that in erosion. However late in the depositional history of the swamp the concentration of carbonized particles began to fall markedly (Fig. 5.1) and as there is no evidence for a compensating increase in sediment accumulation this trend is taken to reflect a real and pronounced decrease in the incidence of burning.

The history of erosion and burning in the Nabuni catchment is more speculative than that of Waitabu because of the less satisfactory chronology.

The occurrence of low frequencies of carbonized particles throughout the basal 2 m or so of the core (level C) suggests that erosion and accumulation of this colluvial-alluvial material was accompanied by some burning. There is no way of assessing whether or not the formation of this part of the deposit pre-dates the arrival of man on the island, and thus whether burning was natural or anthropogenic. However, as its character and topographic setting is like that of the extensive valley-bottom colluvial-alluvial deposits described by Latham (this volume) we conclude that this material also has the same origin and age (possibly mid-Quaternary) and that it did not accumulate within the time span of human occupation of the island.

The environment of deposition during the next phase of accumulation (level B) was one of increasingly wet conditions. The concentration of carbonized particles increased over this time span and provides for the first time unequivocal evidence for heavy burning. Extrapolation of the depth/age envelope suggests that the accumulation of this level may well have commenced within the time span of human occupation of the island.

The rate of erosion over the time span represented by the uppermost

level (A) was probably between 4 and 10 cm/1000 years or 60 and 150 t/km²/year, and the thickness of soil lost from the catchment by erosion was about 9 cm. Thus the erosion regime over the last 800 to 2400 years was similar to that which prevailed in the Waitabu catchment over the last 900 years. The concentration of carbonized particles during this phase of erosion and deposition was extremely high and this suggests high levels of burning relative to erosion.

Whatever the explanation for the inversion of the dates from this swamp, their close depth proximity indicates that during at least the upper part of level B the rates of erosion and accumulation were as slow, if not slower, than those of level A. Thus in marked contrast to Waitabu there is no evidence for an early phase of extremely rapid erosion and deposition within the time span of human occupation of the island.

HUMAN IMPACT ON THE LANDSCAPE

The very high rates of accumulation of carbonized particles throughout the Waitabu swamp, especially before 1750 yr BP, undoubtedly reflects heavy, regular anthropogenic burning of the vegetation in the swamp and its catchment. Over the last 2000 years at least 50 cm of soil has been lost from the catchment, more than half of it in a 150 year period between 1900 and 1750 yr BP. The pattern of erosion and burning during this early stage of accumulation suggests strongly that massive erosion and burning regimes must have been well established by 2000 yr BP.

Such accelerated erosion could only have come about through extensive clearance of the forest mantle on the steep slopes of the catchment, either by felling or fire or both. A likely explanation for this degree of disturbance in the forest is that it was cleared and burned for shifting cultivation. Clearance would have exposed the soil and greatly increased its susceptibility to rainsplash erosion, slope wash and gullyng (Golson and Hughes, 1975; see also Bayliss-Smith, 1977, p. 69). Accelerated erosion would have been facilitated by the extremely high runoff that occurs when severe hurricanes strike the island. Such events may well have occurred several times per century (Bayliss-Smith, 1977, p. 67-70). Erosion of this magnitude must have led to severe degradation of the soils and would account for the widespread truncation of soil profiles noted widely in catchments partially or wholly forested as well as those only under *talasiga* (see Latham, this volume).

Clearance and burning of the forest and consequent erosion and impoverishment of the soils must have resulted in long term change in the composition of the vegetation in the catchment, although the presence today of regrowth forest shows that degradation of the landscape never led to the complete removal of the forest.

The decline in rates of erosion and incidence of burning after 1750 yr BP and especially after 900 yr BP, can be explained in terms of the response of the catchment to the following factors:

1. The intensity of human use of, and interference with, the vegetation and soils resulted in the land becoming less attractive for cultivation.
2. The progressive removal of soil and regolith at rates which far exceed the rate at which weathering of the substrata could produce

more regolith and soil would have rapidly diminished the reserves of easily-erodible material.

The sharp decrease in incidence of burning late in the history of accumulation of the swamp might reflect the cessation of human interference with the catchment in fairly recent times. This is an interesting correlation with evidence of late prehistoric and historic movement of population towards the coast (M. Brookfield, this volume) and a possible absolute decline in numbers since, say, 1800 AD. This decrease in burning would have favoured the regeneration of forest and the establishment of the secondary forest which exists today probably dates from that recent time.

Like Waitabu, the Nabuni swamp shows evidence for anthropogenic burning and erosion in its catchment extending back well beyond 1000 years. About 2.4 m of sediment accumulated in the time span of human occupation and this represents a loss of soil of at least 17 cm. Differences in the erosion and burning histories of the two catchments can be explained in terms of differences in their original vegetation and soil covers (and consequent influences in land use) and topography.

The vegetation cover of the Nabuni catchment in pre-human times is taken to have been woodland with a substorey that included ferns. The basis of this contention is twofold. Firstly the phosphorus content of the Nabuni deposit is very low throughout (0.02 - 0.04%) compared with that of the Waitabu deposit (0.15 - 0.26%) and this suggests that the soils in the Nabuni catchment were already much poorer in phosphorus and therefore were unlikely to have supported a close forest such as that now established in the Waitabu catchment. Secondly, the presence of carbonized particles in the lowermost pre-human colluvial-alluvial deposit probably reflects burning at the time of accumulation and this in turn supports the possibility that the vegetation was susceptible to fire. The accumulation of this colluvial-alluvial deposit must have led to a severe degradation of the soils at that time through truncation of the soil profiles by erosion.

The open vegetation and severely truncated soils might well have been similar to those of the present day *talasiga* complex. Whatever the precise nature of the landscape at that time, it probably would not have been a productive environment for shifting agriculture and this may explain the small amount of man-induced soil erosion compared with the forested Waitabu catchment. The tendency for low rates of erosion due to low intensity of the use of the land would have been enhanced by the more gentle topography of the catchment and the lack of easily-erodible soil.

On the other hand this vegetation cover would have been highly susceptible to anthropogenic burning, and this would explain the high ratio of burning to erosion exhibited in the carbonized particle curve late in the history of accumulation.

CONCLUSION

1. In both catchments there is evidence for anthropogenic burning which in the case of the Waitabu catchment began before 2000 yr BP and in the Nabuni catchment well before 1000 yr BP.
2. There is evidence in both catchments for man-induced erosion at rates which are high by tropical standards and which in the case of Waitabu were extremely high early in the history of accumulation of the swamp.

3. Major differences between the burning and erosion regimes in the two catchments have been explained in terms of differences in their original vegetation and soils and the consequent influence of these on land use.
4. These findings have implications for the interpretation of *talasiga* as anthropogenic. First, despite the almost catastrophic erosion and burning that occurred over the last 2000 years in the Waitabu catchment, the vegetation was not irreversibly or completely transformed to *talasiga*; indeed in fairly recent times, with diminished erosion and a marked decline in burning, closed secondary forest has been able to regenerate. Second, a case has been argued that when the island was first inhabited the Nabuni catchment had a vegetation/soil complex that may well have resembled the modern day *talasiga*. Thus although human settlement of the island undoubtedly resulted in severe degradation of the landscape, it may not have irreversibly transformed the vegetation to the extent postulated by earlier workers (e.g. Twyford and Wright, 1975).

This example illustrates that vegetation should never be allocated to strict 'natural' or 'anthropogenic' categories in the absence of firm vegetation histories. Many of the controversies over the status of grasslands or shrublands have subsequently been resolved by showing that man has been responsible for extensions in range of these communities rather than their creation (e.g. Hope and Hughes, 1976; Hope, in press).

5. Finally, the evidence of the swamps themselves, especially Nabuni, suggests that their formation on a large scale may only have begun with the arrival of man and the consequent onset of vegetation disturbance, especially forest clearance, and accelerated erosion. It is envisaged that following clearance, massive amounts of plant debris, especially branches and tree trunks together with leaf litter, were washed into the valley bottoms along with large quantities of soil. Transport of such debris would have been facilitated by severe hurricanes. Flood debris could then have choked the already constricted outlets of these swamps -- and many of the other similar swamps on the island -- leading to ponding of sediment-charged runoff for sufficient time for the sediment to settle out and accumulate. These swampy valley floors would have provided an ideal environment for wetland taro cultivation from early times and it is possible that prehistoric man, purposely or accidentally, encouraged their development through the instigation of water control ditching systems such as those described by M. Brookfield (this volume).

ACKNOWLEDGEMENTS

As described elsewhere in this volume, this task involved wider interdisciplinary and inter-institutional co-operation than any other part of the Fiji project. Financial support for the analyses and for the radio-carbon dates was provided initially by the project budget, but was later supplemented by grants from ORSTOM and from the University of Melbourne. A. Watchman carried out the mineralogical analyses, and we are grateful to the Department of Biogeography and Geomorphology, Australian National University, for storage of the cores and use of laboratory facilities.

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THE UNESCO/UNFPA POPULATION AND
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ISLAND REPORTS

NO. 5

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Editor:
H. C. Brookfield

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GENERAL NOTE

The 'Island Reports' of the UNESCO/UNFPA Population and Environment Project in the Eastern Islands of Fiji are supplementary reports to the General Reports of the Project. Being on specific topics of more restricted scope than the General Reports, they are produced in only a limited edition. Subject to the general approval of the editor they are the responsibility of the authors concerned. The views presented in these Reports are not necessarily those of UNESCO and UNFPA.

The series replaces the 'Project Working Papers', which were preliminary statements published before the General Reports of the project were in draft. One of the Project Working Papers is reproduced in this series, being of a definitive nature; the others, of which only small stocks now remain, are not republished. However, a statement of the formerly-proposed numbers of Project Working Papers, as advertized in our General Report No. 1, is appended to each Report to facilitate cross-reference.

There are five issues of these 'Island Reports', as follows:

1. The hurricane hazard: natural disasters and small populations
2. Koro in the 1970s (reprinted from Project Working Paper No. 7)
3. Land, population and production in Taveuni District
4. The small islands and the reefs
5. Lakeba: environmental change, population dynamics and resource use

The series has been edited in Melbourne, by the former Chief Technical Adviser of the project, assisted by Tyna Charles. It is published for UNESCO at the Socpac Printery, Australian National University, Canberra. The series is not for sale, and is distributed by UNESCO and for UNESCO by the Australian National Commission for UNESCO to individuals and institutions in Fiji and elsewhere. A limited number of additional copies is available from UNESCO, Paris, and from the Department of Geography, University of Melbourne, on payment of a nominal charge to cover handling costs and postage. All enquiries should be addressed either to the Division of Ecological Sciences, UNESCO, or to the Secretary, Department of Geography, University of Melbourne, Parkville, 3052, Australia.

NOTE

In the first general report of the project (Population, resources and development in the eastern islands of Fiji: information for decision-making, Canberra (Australian National University, Development Studies Centre, for UNESCO, 1977), the papers in this 'Island Report' are announced as follows:

			5.0
			5.1
			5.2
5.1	(M. Brookfield)	:	Not announced
5.2	(Latham)	:	Project Working Paper No. 17
5.3	(McLean)	:	Project Working Paper No. 17
5.4	(Salvat et al)	:	Not announced
5.5	(Hughes et al)	:	Not announced
5.6	(Latham)	:	Project Working Paper No. 17
5.7	(M. Brookfield)	:	Project Working Paper No. 18 & 19
5.8	(Bedford/Brookfield)	:	Project Working Paper No. 20
5.9	(H. Brookfield)	:	Not announced

Titles also differ from those announced in the General Report.

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A NOTE ON PRONUNCIATION AND SPELLING

The standard Fijian spelling is used through this Island Report as in all reports of the project. It departs from normal English usage in the following:

b is pronounced mb as in lumber
 c is pronounced th as in this
 d is pronounced nd as in hand
 g is pronounced ng as in ring
 q is pronounced ngg as in singer (i.e. with greater stress)

There are differences in practice between hard and soft use of these consonants, and the pre-nasalization of 'b' and 'd' ranges from very slight to very strong, but these differences are not reflected in the spelling of the word.

Thus in this report:

LAKEBA is pronounced LAKEMBA
 TUBOU is pronounced TUMBOW
 YADRANA is pronounced YANDRANA
 NASAQALAU is pronounced NASANGGALAU
 KEDEKEDE is pronounced KENDE-KENDE
 YAQONA is pronounced YANGGONA

The stress in Fijian words of two syllables is either on the first syllable, or equal between both syllables. In longer words it is usually placed on the second syllable.

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