Holocene vegetation histories in the Western Pacific: alternative records of human impact

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The Indo-Pacific Pollen Database

Until recently, pollen data has been collected and analysed in isolation, the richness of the results allowing only a summary of the percentage data to be presented as a pollen diagram. Although the original data, in the form of the actual pollen identifications and counts, together with stratigraphic information, is usually preserved, comparisons between sites, or re-interpretation based on new chronologies or ecological information, has rarely been possible. A worldwide effort is being made to collect the original data (pollen counts, dates) in integrated databases for all dated pollen sites (Webb *et al.* 1993, Markgraf *et al.* 1996). This Global Pollen Database, though incomplete, can already be accessed from the National Ocean and Atmosphere Centre in Boulder Colorado. (http://www.ngdc.noaa.gov/paleo/paleo.html) A browser, (SITESEER), provides a nested map of several world regions in which individual sites can be zoomed and details of publications, chronology and the pollen diagram for each entered site can be extracted.

As part of this effort the Australian National University is coordinating a database of vegetation history sites from tropical India to Hawaii, south to the Antarctic and across to Easter Island. The project has identified about 630 records in this huge area, the bulk of which are concentrated in southeastern Australia, New Zealand and India. The development of data analysis programs such as TILIA and PSIMPOL (Grimm 1988, Bennett 1994), for actual pollen count data frees the user from the particular calculation methods of the authors of the individual sites, and allows the reliability of the chronology to be assessed and modified. Statistical sub-routines (eg Grimm 1987) help to identify periods of major change providing an aid to zonation. The statistics can be run on different ecolological groups (eg forest trees or swamp taxa) for example to help detect if changes in wetland succession are responsible for apparent changes to the dryland pollen reaching the site. Data on particular plant taxa can be assembled from several sites, creating a tool for investigating the spread of a pollen analytically visible taxon (which, unfortunately, many economic plants are not).

These developments will soon allow individual users to browse data in the Pacific, with simple pollen diagrams being automatically produced from the stored data. Diagrams can be presented on both stratigraphic or a chronological time scale. The latter are more speculative, as they rely on a single interpretation based on available dates, but they readily allow comparisons. New techniques for creating chronological models with confidence limits (Bennett 1994) are a great advance on simple linear models between available radiocarbon dates. Pollen data has hitherto been inaccessible to many users, not least because much data has never been published, for example the seven pollen diagrams from Fiji prepared by Southern (1986). A comprehensive analysis of the available data from the western Pacific would be premature, as in many cases only summary diagrams have been produced, with relatively low chronological resolution and precision. Another difficulty is the high level of unknown pollen types which is compounded by the relatively unknown ecology of many of the source plants. This has limited the use that archaeologists can make of pollen diagrams, but set against that is a rapid increase in site numbers and the reliability of chronologies.

Fifty-one pollen sites have been located in the area from Yap Island in the northwest, lowland New Guinea, Micronesia, island Melanesia and Polynesia, as well as Hawaii and Easter Island on the criteria of an existing pollen diagram and dates, whether published or not. Western Pacific sites are shown on Figure 1 and brief details are given as an appendix to this paper. Data for Australia, and for several sites in progress on Palau Is., Norfolk Is., Efate Is., New Caledonia, Viti Levu, Vanua Levu, Lau Is., and Hawaii have not been included. Also excluded are sites which do not have data in the later Holocene such as three Pleistocene sites on the Plaine des Lacs, New Caledonia (Hope 1996a, Hope and Pask in press) and the Wainisavulevu section from upland Viti Levu (Southern 1986). Numerous upland sites in New Guinea have also been omitted although the archaeological implications of these are summarised by Haberle (1994) and Hope and Golson (1995).

Four types of site history

The aim of this paper is a modest one; to classify the Holocene pollen records into four categories and comment on the utility of each group, with examples from the western

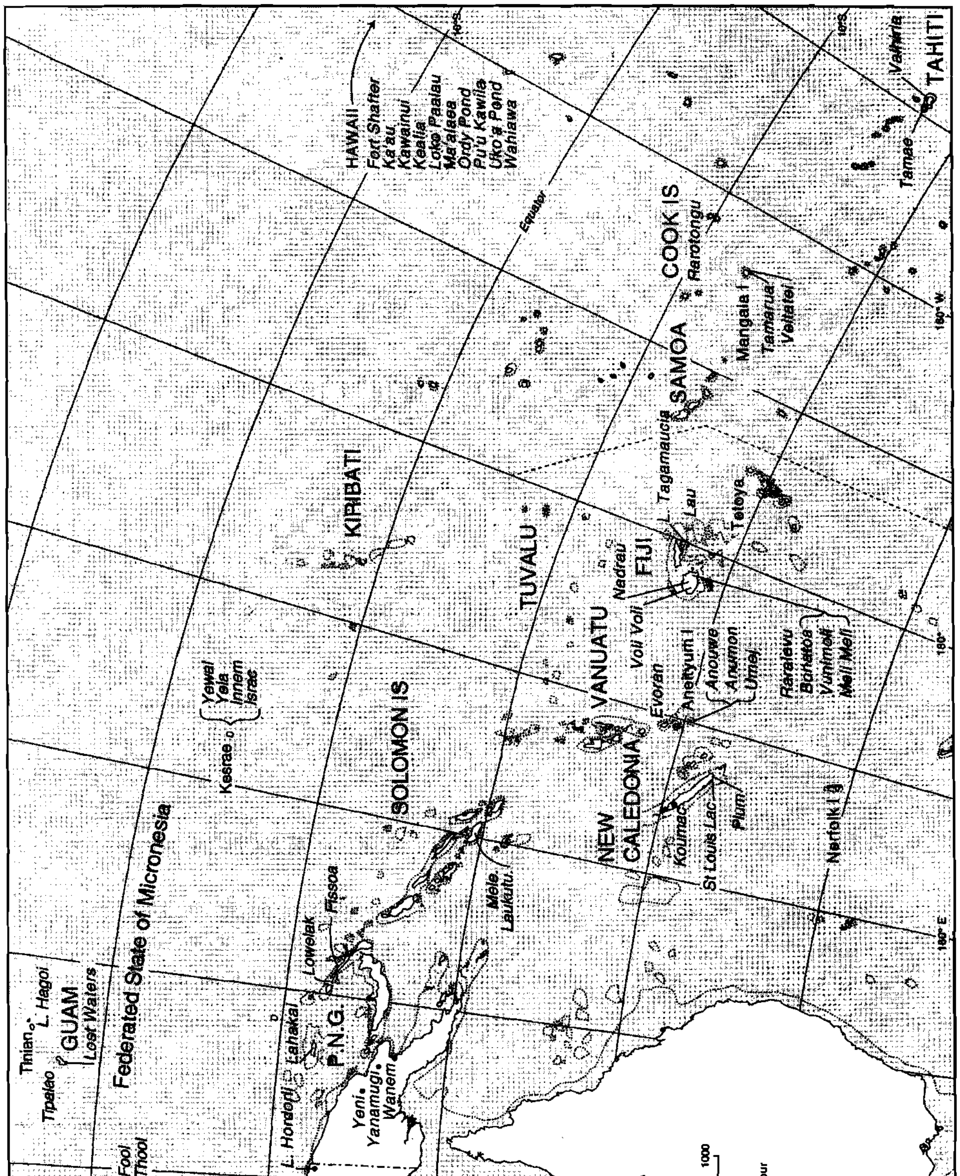


Figure 1
Location of Holocene pollen records in the western Pacific.

Pacific. Can pollen diagrams from swamps and lakes provide an alternate archaeological record that shows earliest disturbance? The answer is a firm "maybe". Criteria for assessing pollen diagrams for anthropogenic influences have been discussed by Haberle (1994) for New Guinea. These include evidence for primary forest decline and secondary forest increase, grasslands replacing forest, plant introductions and silviculture and substantial and sustained changes in finely divided carbonised particles that are presumed to be records of fires. Associated sedimentary change, such as an increase in slope debris and B horizon soil inputs or a change in swamp hydrology may help build a case. However a range of possible non-anthropogenic causes must be considered before an hypothesis for anthropogenic causes can be sustained. While isolated and short lived change in the past is often equivocal at our present state of knowledge, much more convincing cases can be made if a presently disturbed location is traced back through time to locate the initiation and process of settlement in the record.

Long pre-human records

An advantage of Pacific work is that many records extend back over the Holocene, a time of relatively homogenous climatic conditions although affected by sea level change and coastal adjustment. This provides non-coastal records of the natural vegetation over thousands of years against which modern vegetation can be compared. Lake Hordorli, at 780 m on the northern side of Irian Jaya, in fact extends back to an estimated 60,000 years (Hope and Tulip 1994, Hope 1996b). No fires are recorded for 50,000 years in the humid lower montane forest. The appearance of charcoal, at 11,200 yr BP, and consistent low to moderate levels in every sample since that time to the surface, is a clear indication of human influence. It establishes that the fire regime is almost certainly anthropogenic in this locality. For more seasonal localities this cannot be assumed. On New Caledonia fire has been a component of the forest in the Pleistocene and early Holocene (Hope 1996a, b, Stevenson 1997), sometimes associated with considerable erosion. On other Pacific islands fire prior to the archaeologically established human arrivals seems to be a rare event. Mid-Holocene peat sequences at Voli Voli and the Navua delta in Fiji and at Anouwe and Umej on Aneityum Island, Vanuatu, lack fire in their immediate catchments. Ellison (1994) records occasional fires on Mangaia Island, Cook Islands, in pre-human times. All these sites commence as estuaries about 6000 years ago and contain infills adjacent to attractive areas for early settlement.

While archaeologists might not seem to have much use for the pre-arrival parts of pollen diagrams, they will become increasingly important as the accuracy of pollen identification improves. The spread of the economic plants throughout the Pacific will eventually be investigated (using phytoliths, macrocharcoal and macrofossils as well as pollen) by locating the natural ranges. The indigenous vegetation is one of the resources available to initial colonists. The continuing search for a sparse pre-ceramic human presence may also look to these records.

Holocene records with no human impact

Sites with no discernable human inputs tell us where humans are not interested in living. Often the deposition site itself is little liked by its human neighbors (eg mangrove forest or large swamps) and human impact signals will be muted, even if settlement is nearby. Lake Tagamaucia, at 780 m on Taveuni Island, Fiji provides a 13,000 year record in which very little change attributable to human disturbance can be seen. Southern (1986) notes however that the ratio of secondary to primary forest trees is at its highest over the last 2800 years of the record. This may possibly reflect forest clearance on the windward slopes, but could as easily be due to changed cyclone frequency or other climatic or tectonic changes. What is clear is that humans have chosen not to clear the forest and burn around the lake at any stage. This commendable spirit of nature conservation by early Fijians might have been reinforced by the 12,000 mm rainfall and incessant drizzle which has stunted the forest to a few metres height, and which would certainly prevent crops from maturing or fires from doing more than smoulder sullenly. Such records are currently rather rare, most probably because palynologists have deliberately targeted sites with a potential to provide human histories. Very late evidence for clearance also suggests that some sites are unsuitable for detecting early human colonisation. For example in New Guinea the great highland valley floors are cleared by 6 -9 000 yr BP. But sites in neighboring marginal environments to the Wahgi Valley, such as Yeni, at 540 m, or Sirunki, at 2 500 m, record impact after 3500 years, and presumably reflect more gradual colonisation of marginal sites.

Human impact records

In many cases pollen diagrams document the appearance of a changed fire regime, with associated forest clearance and grassland expansion, that almost certainly represents human activity. One of the most convincing cases is Plum Swamp, southern New Caledonia, presented by Stevenson (1997), where reliable dating and a clear and permanent change in charcoal inputs about 3000 years ago heralds the widespread clearance of the forest. Poor soils and a seasonal climate increase the sensitivity of a site to recording early settlement, as even small clearings regenerate slowly, and small fires may spread to burn substantial areas. The diagrams from Easter Island and several from Hawaii (eg Logo Paaia) also provide unequivocal evidence for dramatic floristic change within the last thousand years.

An infilled estuarine embayment 500 m south of Koumac (Fig. 2) provides a record that illustrates the difficulties of interpreting preliminary studies. The clay samples were collected in 10 cm spits by Marc Latham and Daniel Frimagacci in 1980, who obtained three carbon dates that suggest that a relatively complete column of sediment exists. Six samples yield pollen and there is a clear increase in charcoal, decline in forest and jump

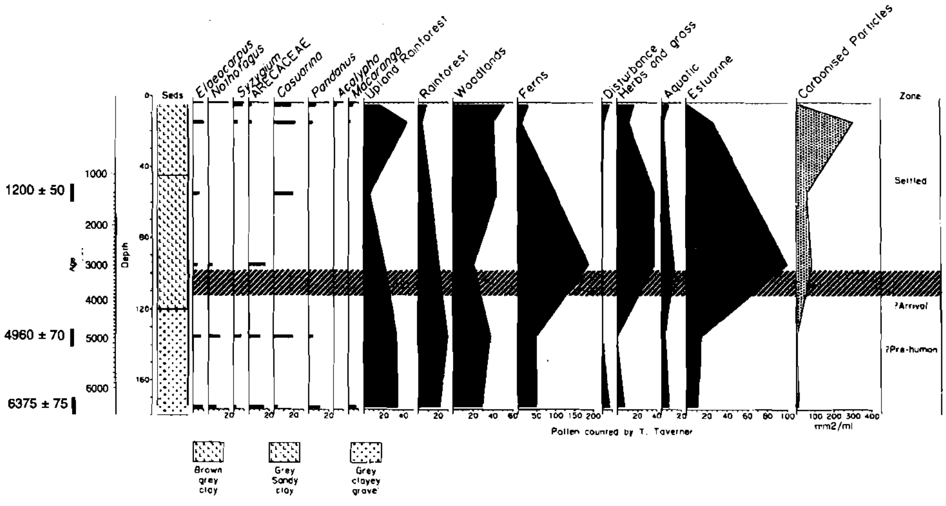


Figure 2
Summary pollen diagram from Koumac, Northwestern New Caledonia, dates from M. Latham, pers. communication. Pollen sum is non-swamp taxa.

in fern spores from the 90-100 cm sample upwards. An age model based on the available dates places the 95 cm level at 3000 yr BP, but of course the event is not located more precisely than 5000-2900 yr BP. A complication is an increase in a large pored pollen type which is tentatively allocated to Rhizophoraceae, and hence may be a mangrove. This type (and other estuarine types) also increase at the 90-100 cm level perhaps representing a change from an open estuary to a mangrove forest that then subsequently declines to the modern open salt flat as sedimentation infills the basin. Such an environmental change may mask human effects on the immediate catchment. Nonetheless, the site has a potential for detailed work and a precise fixing of the time of increased burning, using AMS dating of the organic component. Resolution of the taxonomy will also allow much better environmental determinations.

Lower quality diagrams such as Koumac and Voli Voli Lagoon, Fiji also indicate massive changes in vegetation and sedimentation within brackets of dates that are consistent with abrupt change around 3000 yr BP. But there are definite problems with accepting a conclusion of blitzkreig or sudden anthropogenic environmental change from abrupt changes in sediment cores. Archaeologists have been surprised by claims for apparent anthropogenic change on the Rewa Delta, eastern Viti Levu around 4,000 years ago. Other cases include persuasive evidence for human arrival from makatea dammed lagoons on Mangaia Island, Cook Islands and from Anouwe Swamp, Aneityum Is, Vanuatu. Anderson (1994, 1995) has pointed out that at least three major influences can interfere with the common assumption of continuous sedimentation between dated levels. Firstly, there may be truncation of the section by fire or other erosion. Here prehuman sediments will be overlain by significantly younger sediments possibly reflecting the stabilisation of a settled area after a long period of adjustment. Secondly, the erosion of catchments can release old carbon which is incorporated in the younger sediments, causing older dates than the pollen spectrum actual age. Finally occupation may cause mixing of horizons and changes in the area from which pollen is being derived, suggesting widespread change. These difficulties can be overcome by detailed dating, including AMS dates on individual plant or charcoal fragments. Duplicated sections from the same basin can also establish if a change is local or more widespread, especially if combined with pollen transport studies.

In the cases mentioned above, the core from Bonatoa Bog is largely inorganic silts below peats in the Rewa River estuary of eastern Viti Levu (Southern 1986). A basal date of 4360±180 yr BP (ANU 3816) at 390 cm, lies within a zone of well developed dryland forest and sago swamp with significant levels of fine charcoal (Fig. 3). There is a significant decline of sago and increase in grasses and sedges around 290 cm, associated with peat growth, forest decline and decreasing charcoal. Charcoal increases again about 240 cm. Southern regards the charcoal as being of likely anthropogenic origin. A modern age was obtained on peats at 290 cm and one of 2290±75 yr BP (ANU 3813) at 240 cm. This chronology makes it difficult to guess the real age at 300 cm where the sediment changes from clay to peat, nor to assess the reliability of the basal date. The human impact on vegetation is equivocal until after 2500 years ago, but there is charcoal at the older dated level. The site thus could represent early exploitation of

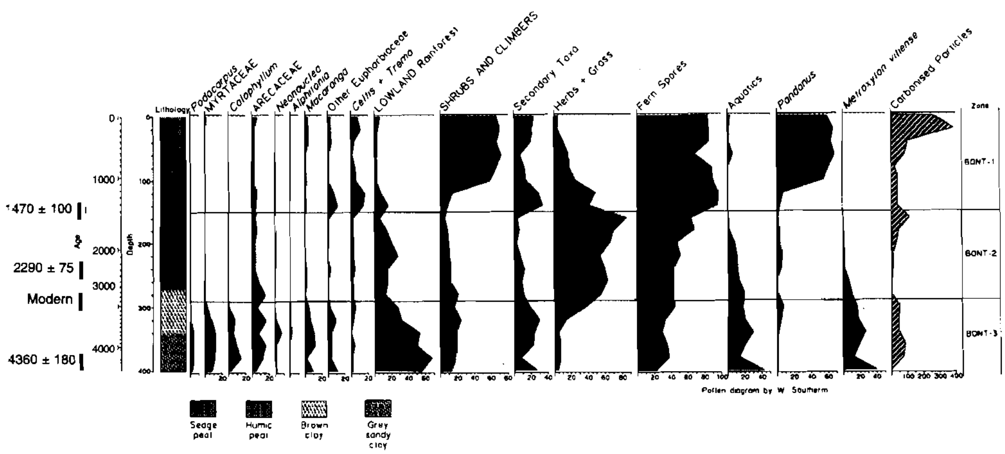


Figure 3
Summary pollen diagram from Bonatoa Bog, Rewa Delta, Viti Levu.

the delta, but in the absence of independant records for such settlement, the chronology must be regarded as unproven.

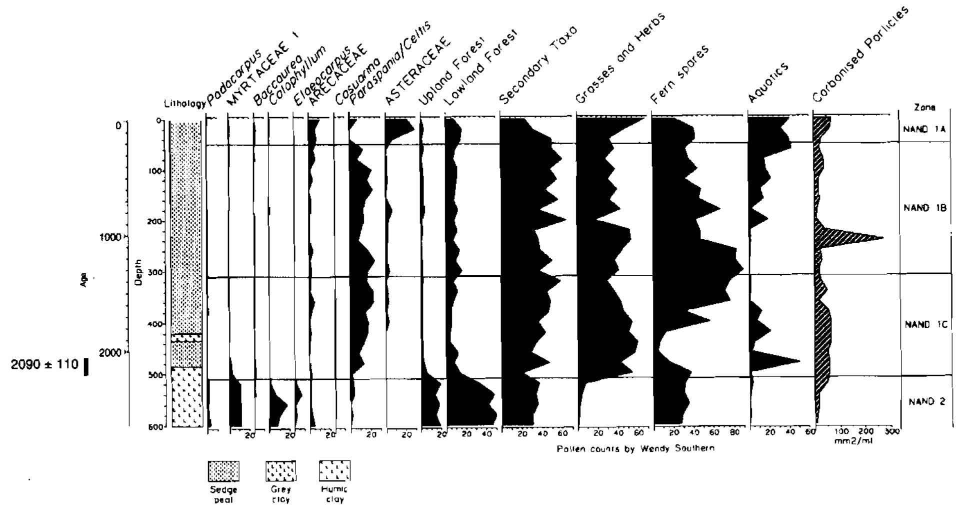
Anderson (1994) suggests that the time of occupation of Mangaia Island might also be much younger than the dated levels in Veitatei VT6, which lie immediately below the level at which fire consistently increases (Ellison 1994). He notes that pollen analysts are used to presenting a simple chronological model, based on mean sedimentation between dated levels. Such chronologies need to be treated with caution where the bulk of the sediment is formed in carbonate rich waters, and where the watertable is controlled by sea level in an emergent island.

At Anouwe swamp, Vanuatu, Hope and Spriggs (1982) assume a continuous infill sequence on the margin of the swamp from 5000 yr BP to about 1500 yr BP, with settlement showing up after 3000 yr BP. Several new cores from more central parts of the swamp provide a series of dates that indicate that there is a hiatus between organic rich estuarine sediments more than 4000 years old, and younger peats less than 2000 years old. Pollen in the younger peats shows that substantial deforestation had already taken place, but the time of onset cannot be fixed. Part of the swamp is buried by inorganic muds stripped from slopes. While these are probably post-3000 years of age, the peats below the contact are 4000-5000 years old and provide only maximum ages for the overlying sediments.

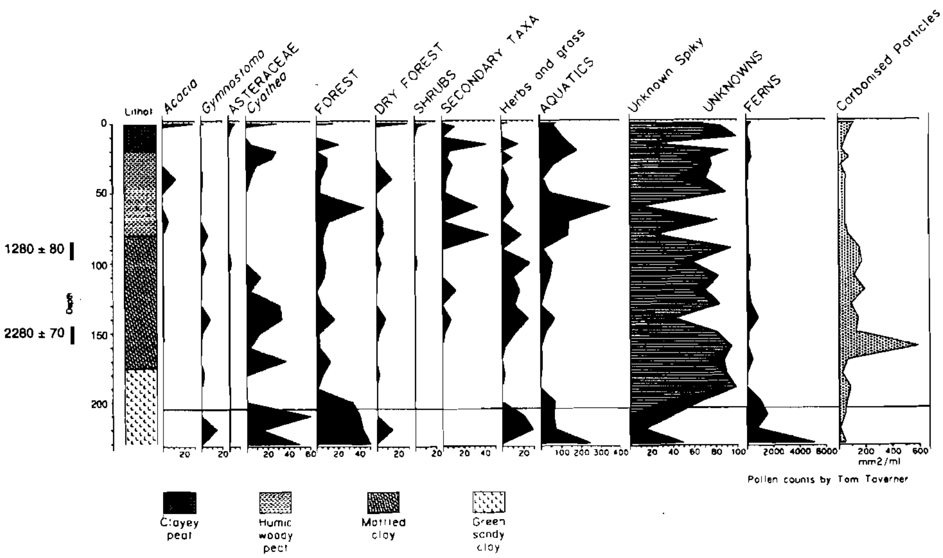
These examples show that each site needs to be assessed independently from others, and that the evidence should be treated cautiously until sufficient dates have been assessed.

Anthropogenic sites

A class of sites, about 25-30 % of the total listed, consist of peat swamps within settled or disturbed catchments. When these are cored, they typically consist of a depth of clay overlain by up to several metres of peat. Both clay and peat contain charcoal, and the pollen diagrams show clear evidence from the base for forest disturbance and clearance. There is a good case for supposing that some of these sites are anthropogenic, accidentally caused by forest clearance that increases the water yield and supplies sediment to impede drainage. For example Nadrau Swamp in central Viti Levu (Fig. 4) infills a broad valley with up to 6 m of sedge peat over the past 2000 years (Southern 1986). The basal age of the swamp provides a useful estimate for levee building across the outlet drainage. This levee may have been created by initial clearance and slope erosion, since the swamp records significant levels of fire throughout. At Yeni Swamp on the Papua New Guinea mainland Gillieson *et al.* (1987) noted the presence of garden ditches beneath the peat, demonstrating the encroachment of peat onto gardens established after forest clearance. Other prominent examples are Mele Swamp on Guadacanal, Lowelak Swamp on the northeast coast of New Ireland, PNG, and Anumon Swamp on Aneityum Island, Vanuatu. Within an area, a study of several deposits could provide a record of the forest clearance process from the basal dates.



▌Figure 4
Summary pollen diagram from Nadrau Swamp, 760m altitude,Viti Levu.



▌Figure 5
Summary pollen diagram from Evoran Pond, Erromango Island, Vanuatu.

While the initiation or increase in swamp areas may be an unintentional result of clearance, swamps can be a valuable resource by providing a permanent source of fresh water, wildfowl habitat and a new range of plant resources such as sago palm and stems. At Evoran, in northwestern Erromango Island, Vanuatu, there is no apparent natural cause for the existence of shallow lagoons at several points in a relict valley. Cores established that up to 1,5 m of peat overlies a similar thickness of organic muds and a pollen diagram was prepared from one site, Evoran Pond (Fig. 5). Dated sediment shows that this pond is 2000 years old, and that high levels of burning are evident throughout. The vegetation is disturbed, and shows an expansion of forest in the later stages. The pond may even have been constructed by earth works across the valley, to provide water and possible taro habitat. Stevenson (1997) notes the occurrence of terraces around Lac St Louis, New Caledonia, although the swamp has a natural origin.

Discussion

Pollen analysis and Quaternary stratigraphy are complex fields with their own specialist taphonomic concerns and potential errors. They cannot provide an automatic answer to archaeological questions, but they have a high potential to contribute. In general, the technique is suited to the humid Pacific because it seems that people have been the main cause of deforestation and the spread of grasslands and Talasiga. The site records suggest that clearance soon after 3000 yr BP was fairly common, but not universal. The variety of natural response can largely be ascribed to the complexity of the landscapes and local climate as well as their remoteness from settlement. Many sites (eg Lowelak, New Ireland, Naudrala* and Nandrau, Viti Levu, Fiji, Anlinpece*, Anidirai*, Anumon* and Evoran, Vanuatu and possibly Mele and Laukutu on Guadacanal Is.), initiate peat formation with clearance of the forest and subsequent burning. At Kingston Common*, Norfolk Is., Anouwe Swamp, Aneityum Is., Vanuatu, and Voli Voli, Natunuku*, Mago Is.*, Kaibu Is.* and Yacata Is.*, Fiji, some peat bogs are buried by overburden with a simultaneous increase in charcoal.

Evidence for occasional fires extends back into the Pleistocene, so presumably cannot be ascribed to human agency, but the post-settlement fire regime can be differentiated

* These sites are still in progress so are not listed in the site lists.

as a major human marker. Most problems experienced by archaeologists in assessing these data sources are due to insufficient resolution of both pollen and time. Careful dating is needed to accurately find the time of initiation of these regimes, and this must usually follow the preparation of pollen data to accurately locate the initial impact levels. The lack of precise chronologies diminishes the contribution that sedimentary sequence studies have so far made to archaeological reconstructions.

Acknowledgements

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Bibliographie

ANDERSON (A.), 1994 — Palaeoenvironmental evidence of island colonisation: a response. *Antiquity* 68: 845-847.

ANDERSON (A.), 1995 — Current approaches in East polynesian colonisation research. *Journal of the Polynesian Society* 104: 110-132.

BENNETT (K.), 1994 — Confidence intervals for age estimates and deposition times in late-Quaternary sediment sequences. *The Homocene* 4: 337-348.

ELLISON (J.C.), 1994 — Palaeo-lake and Swamp Stratigraphic Records of Holocene Vegetation and Sea-level changes, Mangaia, Cook Islands. *Pacific Science* 48: 1-15.

GRIMM (E.), 1987 — CONISS: a Fortran 77 program for stratigraphically constrained cluster analysis by the method of incremental sum of squares. *Computer Geoscience* 13: 13-33.

GRIMM (E.), 1988 — "Data analysis and display". *In* Huntley (B.), Webb (T.) eds: *Vegetation History*, Kluwer *Dordrecht Academic*: 43-76.

GILLIESON (D.), GORECKI (P.), HEAD (J.), HOPE (G.S.), 1987 — "Soil erosion and agricultural history in the central highlands of Papua New Guinea". *In* Gardiner (V.) Wiley (J.) ed.: 507-522

HABERLE (S.), 1994 — "Anthropogenic indicators in pollen diagrams: problems and prospects for late Quaternary palynology in New Guinea". *In* Hather (J.) ed.: London, Routledge: 172-201.

HOPE (G.S.), 1996a. — "History of New Guinea and New Caledonia". *In* Veblen (T. T.) Hill (R. S.), Read (J.) eds: Yale Univ. Press: 257-270.

HOPE (G.S.), 1996b. — "Quaternary change and historical biogeography of Pacific Islands". *In* Keast (A.), Miller (S. E.) eds: Amsterdam, SPB Publishing: 165-190.

HOPE (G. S.), GOLSON (J.), 1995 — "Late Quaternary change in the mountains of New Guinea". *In* Allen (F. J.), O'Connell (J.F.) eds: 69 (265): 818-830.

HOPE (G.S.), & PASK (J.), — (in press). *Pleistocene vegetation change on the Plaine des Lacs, New Caledonia.*

KIRCH (P.V.), ELLISON (J.), 1994 — Palaeoenvironmental evidence for human colonisation of remote Oceanic islands. 68: 310-321.

MARKGRAF (V.), ANDERSON (L.), KELTNER (J.), GRIMM (E.), 1996 — Boulder, World Data Center - A for Paleoclimatology Publication 4.

SOUTHERN (W.), 1986 — *The Late Quaternary Environmental History of Fiji.* PhD thesis, Australian National University, Canberra.

STEVENSON (J.), 1997 — *Human impact from the palaeoenvironmental record on New Caledonia.* The Pacific from 5000 to 2000 BP. Eds: Galipaud (J.-C.) and Lilley (I.), Noumea Orstom, 251-258.

WEBB (R.S.), OVERPECK (J.T.), ANDERSON (D.M.), BAUER (B.A.), ENGLAND (M.K.), GROSS (W.S.), MEYERS (E.A.), WOROBEC (M.M.), 1993 — World Data Center-A for Paleoclimatology at the NOAA Paleoclimatology Program, Boulder, Colorado.

Annexe

Database of Pollen Sites covering the late Holocene in the Western Pacific.

Sites are arranged from west to east, by country

KEY: COUNTRY.

SITE. LOCATION. LAT (+ N). LONG (+E). ALTITUDE (m). AGE RANGE (ka). Paper 1. Paper 2.

Indonesia.

Lake Hordorli. Cyclops Mts, Irian Jaya. -02°32'. 140°33'. 780m. 0 - 50ka. Hope, G. and Tulip, J. 1994. A long vegetation history from Irian Jaya, Indonesia. Palaeogeography, Palaeoclimatology, Palaeoecology 109, 385-398. Hope, G. S. 1996. History of Nothofagus in New Guinea and New Caledonia, in Veblen, T. T. Hill, R. S. and Read, J. (eds.) The Ecology and Biogeography of Nothofagus Forest, pp. 257-270. New Haven, Yale.

Papua New Guinea.

Yeni. Ruti Flats, Jimi Valley. Papua New Guinea. -05°21. 0'. 144°16. 7'. 540m. 0-1, 2. 5-5. 5ka. Gillieson, D., Gorecki, P., Head. J and Hope, G. S. 1987. Soil erosion and agricultural history in the central highlands of Papua New Guinea. Pp. 507-522 in Gardiner, V. (ed.) International Geomorphology. J. Wiley, London. Gillieson, D., Hope, G. S. & Luly, J. 1989. Environmental change in the Jimi valley. in Gorecki, P. and Gillieson, D. eds.) A Crack in the Spine, pp 105-122. Div Anthropology, James Cook Univ, Townsville.

Lake Yanamugi. Markham Valley. -06°24'. 146°17'. 180m. 0-3ka. Garrett Jones, S. E. 1979. Holocene vegetation and lake sedimentation in the Markham Valley, Papua New Guinea. Unpubl. PhD Thesis, ANU Canberra.

Lake Wanum. Near Lae. -06°38'. 146°47'. 35m. 0-9ka. Garrett Jones, S. E. 1979. Holocene vegetation and lake sedimentation in the Markham Valley, Papua New Guinea. Unpubl. PhD Thesis, ANU Canberra.

Lahakai Swamp. Manus Island. -02°08'. 147°14'. 85m. 0-5. 4ka. Southern, W. Unpublished. The Vegetation History of Lahakai Swamp, Manus Island, Papua New Guinea; a Preliminary Report.

Fissoa River. New Ireland. -02°87'. 151° 9'. 2m. 0-2. 5ka. Hope G. S. and Ogden R. 1988. Unpublished file.

Lowelak Swamp. New Ireland. -02° 56'. 151° 25'. 30m. 0-2. 4ka. Hope G. S. and Ogden R. 1988. Unpublished file.

Federated States of Micronesia.

Fool Swamp. Southern Yap. 09°29. 1'. 138°05. 2'. 4m. 0 -5. 5ka. Dodson, J. R. & Intoh, M. (in press). Prehistory and palaeoecology of Yap, Federated States of Micronesia. Quaternary International.

Thool Swamp. Tamil Is, Yap. 09°32. 7'. 138°11. 0'. 4m. 0 -2. 6ka. Dodson, J. R. & Intoh, M. (In press). Prehistory and palaeoecology of Yap, Federated States of Micronesia. Quaternary International.

Mariana Is.

Tipalao Marsh, Orote Peninsula, Guam. 13°27'. 144° 38'. 1.5m. 1.9 - 6.2ka. Athens, J. S. and Ward, J. V. 1995. Paleoenvironment of the Orote Peninsula, Guam. Micronesica 28, 51-76.

Lost Water Marsh, Guam. 13°27'. 144° 38'. 1. 5m. 0 - 2.2ka. Ward, J. V. 1994. Unpublished report.

Lake Hagoi. Tinian Island. 14°58'. 145° 38'. 1m. 0-9ka. Athens, S.J. and Ward, J.V. 1998. Palaeoenvironment and prehistoric landscape change: a sediment core record from Lake Hagoi, Tinian, CNMI. Unpublished report, Dept U.S. Navy, Honolulu.

Innem B. Kosrae Is. 05°19. 7'. 163° 00. 3'. 2m. 0 -5. 2ka. Ward, J. V. 1988. Palynology of Kosrae, Eastern Caroline Islands: Recoveries from pollen rain and Holocene deposits. Review of Palaeobotany and Palynology 55, 247-271.

Israc, Kosrae Is. 05°16. 3'. 162° 55. 7'. 4. 0 -1. 2. Ward, J. V. 1988. Palynology of Kosrae, Eastern Caroline Islands: Recoveries from pollen rain and Holocene deposits. Review of Palaeobotany and Palynology 55, 247-271.

Yela, Kosrae Is. 05°19. 5'. 162° 57. 1'. 0. 5m. 0 -3. 5ka. Ward, J. V. 1988. Palynology of Kosrae, Eastern Caroline Islands: Recoveries from pollen rain and Holocene deposits. Review of Palaeobotany and Palynology 55, 247-271.

Yewal, Kosrae Is. 05°17'. 162° 58. 5'. 5m. 0 - 4ka. Ward, J. V. 1988. Palynology of Kosrae, Eastern Caroline Islands: Recoveries from pollen rain and Holocene deposits. Review of Palaeobotany and Palynology 55, 247-271.

Norfolk Island.

Kingston Common, Norfolk Is. -29°02' 167°59'. 2.1m. 0.5-6ka. Macphail, M.K. and Hope, G. S.1997. Palynological report, Core Site KCA, Kingston Swamp, Norfolk Island. Unpublished report to Australian Heritage Commission.

Solomon Islands.

Laukutu Swamp. Guadacanal Is. -9° 30'. 160° 05'. 20m. 0 -3. 5ka. Haberle, S. 1996. Explanations for palaeoecological changes on the northern plains of Guadacanal, Solomon Islands: the last 3200 years. The Holocene 6, 333-338. Powell, J. M. 1976. Pollen, plant communities and prehistory in the Solomon Islands. In R. C. Green and M. M. Cresswell (eds), Southeast Solomon Islands Cultural History: a preliminary survey. Wellington, Roy. Soc. New Zealand.

Mele Swamp. Guadacanal Is. -9° 30'. 160° 05'. 20m. 0 -2. 8ka. Haberle, S. 1996. Explanations for palaeoecological changes on the northern plains of Guadacanal, Solomon Islands: the last 3200 years. The Holocene 6, 333-338. Powell, J. M. 1976. Pollen, plant communities and prehistory in the Solomon Islands. In R. C. Green and M. M. Cresswell (eds), Southeast Solomon Islands Cultural History: a preliminary survey. Wellington, Roy. Soc. New Zealand.

New Caledonia.

Koumac. Northeastern Grande Terre. -20° 39'. 164° 17'. 0. 5m. 0 - 6. 5ka. Hope, G. S. and Latham M. Unpublished file. Hope, G., O'Dea, D. and Southern W. 1997. Holocene vegetation histories in the Western Pacific - alternative records of human impact. This volume.

Saint Louis Lac, east of Noumea, Grande Terre. -22° 31'. 166° 31'. 5m. 0-6.6ka. Stevenson, J. and Dodson, J. R. 1995. Palaeoenvironmental evidence for human settlement on New Caledonia. Archaeology in Oceania 30, 36-41. Stevenson J., 1997. Human impact from the palaeoenvironmental record on New Caledonia This volume.

Plum Swamp. South coast of Grande Terre. -22° 16'. 166° 37'. 40m. 0-22ka. Stevenson J., 1997. Human impact from the palaeoenvironmental record on New Caledonia This volume.

Vanuatu.

Evoran Pond. Erromango. -18° 45. 68'. 169° 0. 07'. 190m. 0 -2. 5ka. Hope, G. S. 1996. A reconnaissance survey of potential sites for pollen analysis on Aneityum Island, sou-

thern Vanuatu. Unpublished report to the Vanuatu Cultural Centre, Vanuatu. Hope, G., O'Dea, D. and Southern W. 1997. Holocene vegetation histories in the Western Pacific - alternative records of human impact. This volume.

Anouwe 1 & 2. Aneityum Is. Vanuatu. -20° 14. 03'. 169° 46. 9'. 4m. 0 -5. 5ka. Hope, G. S. and Spriggs, M. J. T. 1982. A preliminary pollen sequence from Aneityum Island, southern Vanuatu. Indo-Pacific Prehistory Association Bulletin, 3: 88-94. Hope, G. S. 1996. A reconnaissance survey of potential sites for pollen analysis on Aneityum Island, southern Vanuatu. Unpublished report to the Vanuatu Cultual Centre, Vanuatu.

Anumon Swamp. Aneityum Is. Vanuatu. -20° 09. 46'. 169° 49. 39'. 45m. 2. 9-5. 0ka. Hope, G. S. 1996. A reconnaissance survey of potential sites for pollen analysis on Aneityum Island, southern Vanuatu. Unpublished report to the Vanuatu Cultual Centre, Vanuatu.

Umej, Aneityum Is. Vanuatu. -20° 14. 94'. 169° 50. 94'. 2m. 0 -5. 5ka. Hope, G. S. 1996. A reconnaissance survey of potential sites for pollen analysis on Aneityum Island, southern Vanuatu. Unpublished report to the Vanuatu Cultual Centre, Vanuatu.

Fiji.

Voli Voli Lagoon. Sigatoka Delta, southern Viti Levu, . -18° 09. 5'. 177° 29. 1'. 2m. 0-5ka. Hope, G. S and Anderson, A. 1996. A reconnaissance survey of Holocene deposits on Viti Levu and Vanua Levu, Fiji. Unpublished report to the National Museum, Fiji. Dickinson, W.R., Burley, D.V., Nunn, P.D., Anderson, A., Hope, G., Biran, A.De, Burke C. and Mataraba, S. 1998. Geomorphic and Archaeological Landscapes of the Sigatoka Dunes Site, Viti Levu, Fiji: Interdisciplinary Investigations. Asian Perspectives 31, 1-31.

Doge-Doge Swamp, Sigatoka river valley, southern Viti Levu. -18° 06' 177° 33.52'. 8m. 0-2.2ka. Hope,G.S and Anderson, A. (1995) A Reconnaissance Survey of Holocene deposits on Viti Levu and Vanua Levu , Fiji. Unpub. Dickinson, W.R., Burley, D.V., Nunn, P.D., Anderson, A., Hope, G., Biran, A.De, Burke C. and Matararaba, S. 1998. Geomorphic and Archaeological Landscapes of the Sigatoka Dunes Site, Viti Levu, Fiji: Interdisciplinary Investigations. Asian Perspectives 31, 1-31.

Navatu, Raki Raki, Viti Levu. -18° 04' 178°32' 4m. 0-4.4ka. Unpublished diagram Melimeli Swamp. Navua Delta, eastern Viti Levu. -18° 19'. 178° 00'. 1m. 0-4. 5ka. Southern, W. 1986. The Late Quaternary Environmental History of Fiji. Unpublished PhD thesis, Australian National University, Canberra.

Vunimoli Swamp. Navua Delta, eastern Viti Levu. -18° 25'. 178° 02'. 1m. 0-2. 7ka. Southern, W. 1986. The Late Quaternary Environmental History of Fiji. Unpublished PhD thesis, Australian National University, Canberra. Hope, G. S & Anderson, A. 1995. A Reconnaissance Survey of Holocene deposits on Viti Levu and Vanua Levu, Fiji. Unpub.

Bonatoa Bog. Rewa Delta, eastern Viti Levu. -18° 04'. 178° 32'. 4m. 0-4. 4ka. Southern, W. 1986. The Late Quaternary Environmental History of Fiji. Unpublished PhD thesis, Australian National University, Canberra. Hope, G., O'Dea, D. and Southern W. 1997. Holocene vegetation histories in the Western Pacific - alternative records of human impact. This volume.

Raralevu. Rewa Delta, eastern Viti Levu. -17° 55'. 178° 30'. 1m. 0-2. 1ka. Southern, W. 1986. The Late Quaternary Environmental History of Fiji. Unpublished PhD thesis, Australian National University, Canberra.

Nadrau Swamp. Viti Levu. -17° 45'. 177° 53'. 0-2. 1. Southern, W. 1986. The Late Quaternary Environmental History of Fiji. Unpublished PhD thesis, Australian National University, Canberra. Hope, G., O'Dea, D. and Southern W. 1997. Holocene vegetation histories in the Western Pacific - alternative records of human impact. This volume.

Lake Tagamaucia, Taveuni Island, -16°49'. -179°56'. 820m. 0-14. 3ka. Southern, W. 1986. The Late Quaternary Environmental History of Fiji. Unpublished PhD thesis, Australian National University, Canberra. Hope, G. S. 1996. Quaternary change and historical biogeography of Pacific Islands. In A. Keast & S. E. Miller (eds) The Origin and Evolution of Pacific Island Biotas, New Guinea to Eastern Polynesia: Patterns and Process. Amsterdam, SPB Publishing. pp. 165-190.

Soleve Cakadrove -17 15.591 -179 29.35 20-7 Clark G. and Hope, G.S. 1997. Preliminary report on archaeological and palaeoenvironmental investigations in northern Lau (Mago, Yacata-Kaibu and Vatuvara), Fiji. Unpublished report to National Museum, Fiji. 28pp.

Yacata, Cakadrove. -17° 15.6' -179° 30.41'. 2m. 0-6.5ka. Clark G. and Hope, G.S. 1997. Preliminary report on archaeological and palaeoenvironmental investigations in northern Lau (Mago, Yacata-Kaibu and Vatuvara), Fiji. Unpublished report to National Museum, Fiji. 28pp

Coastal sites. Totoya Is. -18° 52'. -179° 40'. 1m. 0-2. 4ka. Cole, A. 1996. Unpublished PhD thesis, Massey University, New Zealand.

Cook Islands.

Tamarua(W) TM7. Mangaia Is. -21° 54'. -157° 58'. 0m. 0-7. 5ka. Ellison, J. C. 1994. Palaeo-lake and Swamp Stratigraphic Records of Holocene Vegetation and Sea-level changes, Mangaia, Cook Islands. Pacific Science 48, 1-15. Kirch P. V. and Ellison, J. 1994. Palaeoenvironmental evidence for human colonisation of remote Oceanic islands. Antiquity 68, 310-321.

Veitatei VT6. Mangaia Is. -21° 54'. -157° 58'. 0m. 0-3. 8ka. Ellison, J. C. 1994. Palaeo-lake and Swamp Stratigraphic Records of Holocene Vegetation and Sea-level changes, Mangaia, Cook Islands. Pacific Science 48, 1-15. Kirch P. V. and Ellison, J. 1994. Palaeoenvironmental evidence for human colonisation of remote Oceanic islands. Antiquity 68, 310-321.

Tonga.

Tongatapu. -21° 00'. -175° 00'. 0. 5m. Ellison, J. C. 1989. Pollen analysis of mangrove sediments as a sea-level indicator: Assessment from Tongatapu, Tonga. Palaeogeography, Palaeoclimatology, Palaeoecology 74, 327-341.

French Polynesia.

Lac Taemae. Moorea, Society Islands. -17° 29'. -149° 48'. 2. 5m. 0-1. 6ka. Parkes, A. and Flenley, J. R. (editors) 1990. Hull University Expedition 1985 Final Report. University of Hull, School of Geography and Earth Resources. Miscellaneous series, No. 37.

Lac Vaihiria. Tahiti, Society Islands. -17° 40. 9'. -149° 25. 0'. 473m. 0-1. 3ka. Parkes, A, Teller, J. T. and Flenley, J. R. 1992. Late Quaternary environmental history of the Lake Vaihiria drainage basin, Tahiti, French Polynesia. Journal of Biogeography 19, 431 - 447. Parkes, A and Flenley, J. R. (editors) (1990. Hull University Moorea Expedition 1985 Final Report. University of Hull, School of Geography and Earth Resources. Miscellaneous series, No. 37.

USA-Hawaii.

Wahiawa Bog (Kanaele swamp). Kauai Is. 22° 29'. -159° 33'. 652m. 0-35ka. J. Ward & L. Cranwell. Unpublished data.

Pu'u Kawila. Kohala Mts, Hawaii Is. 20° 06'. -155° 46'. 1300m. Hotchkiss, S. C. 1996. Last Glacial and Holocene Pollen Records from Oahu and North Kohala, Hawaii. Abstracts IX Int. Pollen Conf., Houston

Ma'alaea. Maui Is. 20° 42'. -156° 36'. 5m. 0 - 0. 4ka, ? - 7ka. J. V. Ward 1994. Unpublished report.

Barbers Point. Southwest O'ahu Is. 21° 20. 5'. -158° 07. 5'. 0. 5m. 0 - 1. 5ka. J. Ward Unpublished data.

Fort Shafter flats. O'ahu Is. 21° 20'. -157° 57'. 3m. 0. 9-3ka. Athens, J. S., Ward, J. V. and Wickler, S. 1992. Late Holocene lowland vegetation, O`ahu, Hawai`i. New Zealand Journal of Archaeology, 14, 9-34.

Ka'au Crater. O'ahu, 21° 25'. -157° 47'. 450m. 0 - 20ka. Hotchkiss, S. C.

1996. Last Glacial and Holocene Pollen Records from O'ahu and North Kohala,

Hawaii. Abstracts IX Int. Pollen Conf., Houston.

Kawainui Marsh. O'ahu Is. 21° 25. 3'. -157° 45. 0'. 1. 5. 0-3. 5. Athens, J. S., Ward, J. V. and Wickler, S. 1992. Late Holocene lowland vegetation, O`ahu, Hawai`i. New Zealand Journal of Archaeology 14, 9-34.

Loko Paaiau, Pearl Harbour, O'ahu Is. 21° 20'. -157° 57'. 1m. 0-8ka. J. Ward and C. Hotton. Unpublished data.

Nimitz Highway. O'ahu Is. 21° 25'. -157° 48'. 400m. J. Ward Unpublished data.

Uko'a Pond. Northern O'ahu Is. 21° 31'. -158° 15'. 2m. 0 - 7ka. J. V. Ward 1995. Unpublished report.

Chile.

Rano Arol. Easter Island. -27° 05. 2'. -109° 24. 0'. 425m. 0 -38ka. Flenley, J. R. and King, S. M. 1984. Late Quaternary pollen records from Easter Island. Nature, Lond., 307, 47-50. Flenley, J. R., King, A. S. M., Teller, J. T., Prentice, M. E., Jackson, J. and Chew, C. 1991. The Late Quaternary vegetional and climatic history of Easter Island. Journal of Quaternary Science 6, 85-115.

Rano Kao. Easter Island. -27° 11'. -109° 26'. 110. 0-1. 5. Flenley, J. R. and King, S. M. 1984. Late Quaternary pollen records from Easter Island. Nature, Lond., 307, 47-50. Flenley, J. R., King, A. S. M., Teller, J. T., Prentice, M. E., Jackson, J. and Chew, C. 1991. The Late Quaternary vegetional and climatic history of Easter Island. Journal of Quaternary Science 6, 85-115. Flenley, J. R. 1988. Palynological evidence for land use-changes in South-East Asia, Journal of Biogeography 15, 185-197

Rano Raraku bore3. Easter Island. -27° 08'. -109° 17'. 75. 6. 8-35. 5. Flenley, J. R. and King, S. M. 1984. Late Quaternary pollen records from Easter Island. Nature, Lond., 307, 47-50. Flenley, J. R., King, A. S. M., Teller, J. T., Prentice, M. E., Jackson, J. and Chew, C. 1991. The Late Quaternary vegetional and climatic history of Easter Island. Journal of Quaternary Science 6, 85-115.