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– ARTICLE –

Pohnpei Coring Records: the Natural Distribution of *Cyrtosperma chamissonis*

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ABSTRACT

Dating, pollen, and charcoal particle findings are presented from two mangrove swamp cores recovered from Pohnpei, Eastern Caroline Islands, Micronesia. The cores, from opposite sides of the island, provide continuous sediment sequences dating from the early Holocene. Pollen analysis demonstrates that the giant swamp taro (*Cyrtosperma chamissonis*), an important cultigen on many islands in the Western Pacific, was growing on Pohnpei during prehuman times, indicating that its natural prehuman distribution was far wider than previously suspected. The archaeological implications for the prehuman presence of *C. chamissonis* are discussed. The cores are inconclusive with regard to the timing of initial human settlement and landscape change on Pohnpei, possibly due to their location deep within large coastal mangrove forests where terrestrial pollen types and charcoal from local fires are poorly dispersed.

Keywords: Pohnpei, paleoenvironmental cores, *Cyrtosperma chamissonis*

INTRODUCTION

It is well known that Austronesian colonizers and later migrants to tropical and subtropical Pacific islands introduced many plants of economic and agricultural importance (Hather and Kirch 1991, Kirch 2000: 109, Whistler 1991, Nagata 1985). They sometimes introduced plants of no apparent economic importance, presumably inadvertently (e.g., *Ludwigia octivalvis* – Athens 1997: 269, Fall 2010: 264; and *Oxalis corniculata* and *Digitaria setigera* – Kirch 1985: 46, 291). Many botanical treatises for different islands and archipelagos (e.g. Wagner *et al*. 1990, Stone 1970–71) often specify for each taxon whether it is endemic (evolved in that particular geographic area), native (arriving by natural means), or introduced (by people). With the advent of paleoenvironmental research in the Pacific, wetland and lake coring studies focused on understanding environmental impacts associated with human colonization. It soon became apparent that palynological studies could sometimes provide an independent means of assessing whether certain plants, usually non-cultigens, were native/indigenous, aboriginal introductions, or historic/modern introductions (see Athens and Ward 1991). As explained by Athens and Ward (1991: 19–22) in regard to a Hawai‘i coring project:

> If it can be demonstrated that all of the presumed Polynesian introduced plants were in fact introduced and not indigenous to Hawai‘i, then the presence of these species in the stratigraphic record may serve as an indicator for Polynesian presence in Hawai‘i. A major problem, however, is to verify that … the *non-cultivated* plants are in fact introductions [emphasis added]. In so far as is known, none of the botanists or other investigators attributing Polynesian origins to these plants have any paleontological evidence to support their claims.

That the major *cultivated* plants were introduced was never an issue as it is well established that Austronesian colonizers carried their horticultural traditions across the Pacific (Kirch 1997, 2000: 92, 109–112).

The legacy of this earlier research was to predispose most paleoenvironmental investigators to believe, first, that the presence of major cultigens in their coring records constituted undisputed evidence for human presence in the landscape, and second that the timing of initial human settlement could be determined by the presence of introduced plants in the pollen coring records, be they cultigens or other economically useful plants. While these premises are generally true, we have learned that there can be important exceptions.

This paper is about one such exception. It concerns the cultigen, *Cyrtosperma chamissonis*, an aroid often called swamp taro or giant swamp taro. *C. chamissonis* pollen was originally thought to be an important biomarker for early human presence in the Palau archipelago of western Micronesia since, according to botanists, it did

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not occur naturally in Micronesia (Athens and Ward 2001, and see below). However, recent paleoenvironmental coring on Pohnpei in the Eastern Caroline Islands of Micronesia (Figure 1) now demonstrates that *C. chamissonis* had a far wider pre-human natural distribution than heretofore considered. The use of this pollen as a bio-marker for humans, therefore, must be discontinued. The evidence for this is the subject of this paper.

The Pohnpei paleoenvironmental investigations consisted of the recovery of four wetland cores from near-coastal areas, of which only two of these cores – called Nanitipw-2 and Lewetik-4 – were appropriate for detailed analyses, including sediment analysis, radiocarbon dating, pollen analysis, and charcoal particle counts. The results of these investigations will be presented below.

CYRTOSPERMA CHAMISSONIS AND EARLY HUMAN SETTLEMENT IN THE PACIFIC

Traditionally, *C. chamissonis* has been an important food crop and dietary staple for people on many western Pacific islands, including Palau, Yap, Chuuk, and Kosrae (Hunter-Anderson 1991, Whistler 1991). It is an especially important cultivar on many atolls because of its salt tolerance (Barrau 1961, Hunter-Anderson 1991, Whistler 1991: 59). Whistler (1991: 59), a botanist, believes *C. chamissonis* is 'probably indigenous to New Guinea or elsewhere in Melanesia, but was aboriginally introduced to Micronesia and Polynesia as far east, perhaps, as the Cook Islands.' This is a conclusion echoed by Hay (1988: 433–434), who considered the phytogeography of *C. chamissonis* at length (see also Yen 1991; Smith 1979). Others, however, place the origin of *C. chamissonis* in Indonesia (Massal and Barrau 1956: 7; Plucknett 1977; Sakai 1983: 43).

Paleoenvironmental wetland coring investigations undertaken on the island of Babeldaob in the Republic of Palau in 1996 provided well-documented evidence for the presence of *C. chamissonis* pollen at a time well before humans were believed to have colonized Palau (Athens and Ward 2001). This evidence is from the Ngerchau core, recovered from a fallow taro pondfield near the northeastern coast of Babeldaob Island. The distinctive *C. chamissonis* pollen occurred in three relatively deep intervals dating between 4290 and 4410 calBP (1, 6, and 1 pollen grains, respectively; see Athens and Ward 2001 and 2005: 103). Early *C. chamissonis* pollen was also documented in the Ngardmau core record from northwestern Babeldoab Island, where a single grain was found in a deep interval dating to 4670 calBP (Athens and Stevenson 2011). Although never common in the various Palau core records, *C. chamissonis* has a somewhat more consistent presence after about 2000 calBP.

Because of the depth at which the *C. chamissonis* pollen grains occurred in these cores (between 2.9 and 4.74 m below the present surface in the Ngerchau core, and at 4.18 m in the Ngardmau core), it is unlikely that their pres-

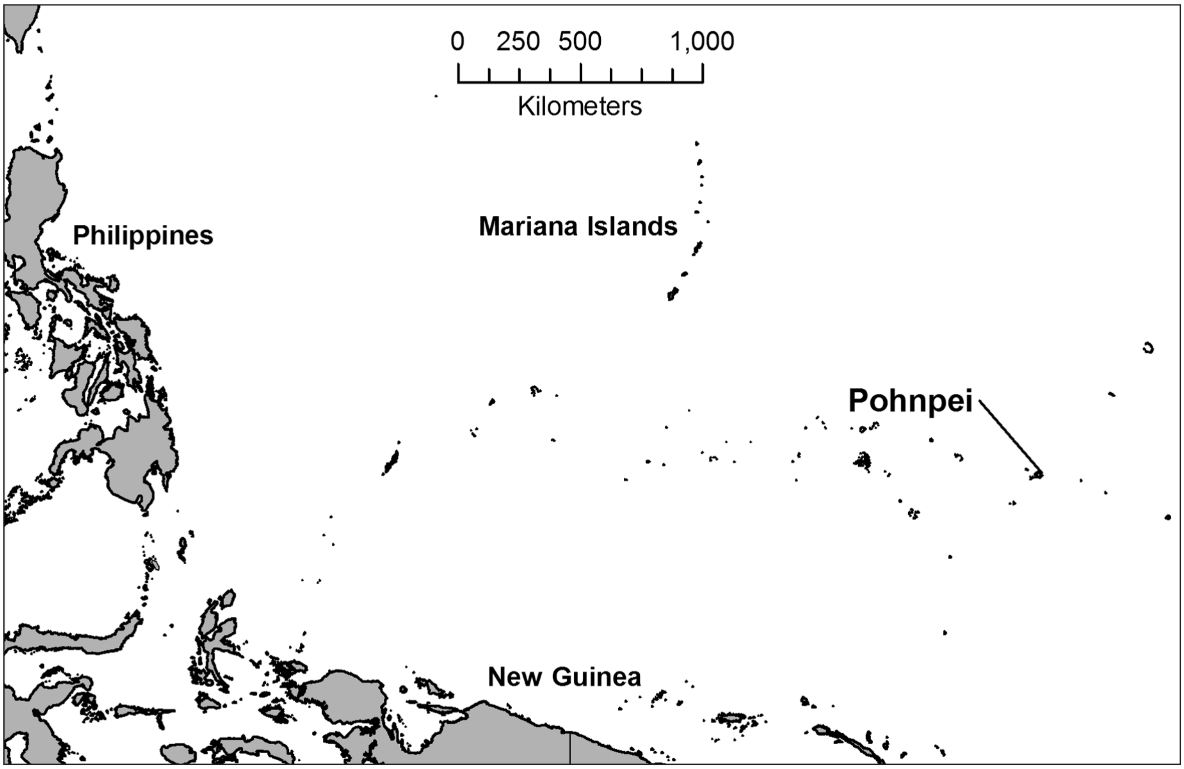

Figure 1. Location of Pohnpei in western Pacific region

ence was the result of downward migration of the pollen grains from late prehistoric, historic, and recent intervals when these wetlands were under cultivation. Nor can it be a result of misleading or poorly dated sequences (see discussion Athens and Ward 2001; Athens and Stevenson 2011). It also cannot be accounted for as a result of the misidentification of *C. chamissonis* pollen.[3] Finally, it cannot be explained as the result of contamination during coring. With respect to the latter, though *C. chamissonis* was growing nearby, the ends of the aluminum core tubes were immediately sealed with plastic caps following extraction from the bore hole, and end samples were never analyzed for pollen as a precaution. Also, for all samples submitted for pollen and dating analyses, the exterior of all samples (where there was contact with the core barrel) was scraped to insure that there could be no residue left on them from the core barrel.

The Palau findings suggested, at face value, that humans must have carried *C. chamissonis* to Palau 1000 years prior to even the earliest Lapita findings in Melanesia, and earlier than the start of the Pre-Latte Period in the Mariana Islands (Athens and Ward 2001).

Kosrae is the only other Micronesian island where prehistoric *C. chamissonis* has been documented. Here 'abundant' *C. chamissonis* pollen was found in an interval dating to 2000–1700 calBP (Athens *et al.* 1996: 843), a time approximately at or immediately following island colonization. Earlier intervals at several sampling locations did not contain *C. chamissonis* pollen, suggesting it may have been absent on Kosrae until introduced by human settlers around 2000 years ago.

POHNPEI ENVIRONMENT AND ARCHAEOLOGY

Pohnpei, with a land area of 334 sq. km, is a relatively isolated tropical Pacific high island in eastern Micronesia at 7° N latitude. The mountains of its rugged interior reach an elevation of 772 m. Plentiful year around rainfall, ranging from about 4000 mm at the driest coastal locations to about 8200 mm at the highest elevations (Landers and Khosrowpanah 2004: 5, 13), promotes luxuriant vegetation growth, which consists primarily of agroforest in the lowlands (especially breadfruit, bananas, coconut, yams, and kava), and native forest in the mountainous uplands (Glassman 1952, MacLean *et al.* 1986, Merlin *et al.* 1992). The coastline of Pohnpei is for the most part obscured by extensive stands of mangrove forest. A barrier reef two to four kilometres offshore almost completely encircles the island, creating a relatively large and protected lagoon with abundant marine resources.

The archaeology of Pohnpei has been studied by various investigators in recent decades, including Athens (1990a, 2007), Ayers (1990), Ayres *et al.* (1981), Bath (1984), Galipaud (2000), Kataoka (1991), and others (see Rainbird 2004 for a recent synthesis). An excellent compendium of the island's ethnohistory is provided by Hanlon (1988). Bascom (1965) and Riesenberg (1968) also provide ethnographies of traditional Pohnpeian society. Detailed oral histories have been prepared by Bernart (1977) and Hadley (1981), and other information is scattered in many sources throughout the literature.

The main point to note about Pohnpei's archaeology is that evidence for initial settlement has been traced back to the first centuries AD[4] (Athens 1990a: 21), consistent with evidence from the closest islands and island groups of Chuuk, Kosrae, and the Marshall Islands (Athens 1990b; Shun and Athens 1990; Shutler *et al.* 1984; Weisler 1999).

PREVIOUS POHNPEI CORING INVESTIGATIONS

The only previous pollen study conducted on Pohnpei concerns recovery and analysis of a mangrove swamp core taken at Nanitipu (Yamanaka and Kikuchi 1995). Radiocarbon determinations on their 6.0 metre peat core are reported for depths at ~105 cm, ~165 cm (depths approximated from illustration on pollen diagram), and 520–550 cm. These samples yielded conventional ages 810 ± 80, 1210 ± 80, and 5080 ± 80 years, respectively. Among the mangrove types, the pollen record displays a considerable dominance of the *Sonneratia* type over the *Rhizophora* type. The ecological significance of this is unclear since both types can occur on the landward, middle part, and seaward sides of large mangrove swamps (Merlin *et al.* 1992: 19, Stemmerman 1981: 97, 102). However, since *S. alba* is the only *Sonneratia* on Pohnpei, and this type can dominate on the seaward edge of mangroves (Glassman 1952: 23), it may be that the coring location was at a relatively low intertidal position during most of the sequence. The significant presence of the *Heritiera* type in the upper part of the core, however, suggests that the Nanitipu coring location may have become closer to the landward edge of

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[3] 'Fosberg *et al.* (1987) list 16 members of the Araceae family in Palau, nine of which are introductions (four of these are probably historic introductions that are used as ornamentals). Pollen of the other seven native species was checked at the generic level in published pollen atlases and none have pollen that remotely resemble that of *Cyrtosperma chamissonis*. However, the pollen of the Palau fossil specimens is identical to a modern reference specimen obtained from Kosrae (Ward, pers. reference collection). *C. hastatum*, related to *C. chamissonis* at the generic level, does not occur in Micronesia' (from Athens and Ward 2005: 104, footnote 9). For Pohnpei, *C. chamissonis* is the only representative of the *Cyrtosperma* genus (Glassman 1952). Fossil pollen identified as *Cyrtosperma* on Pohnpei, therefore, must certainly pertain to the *chamissonis* species.

[4] The earliest archaeological radiocarbon determination, originally reported by Athens 1990a: 21 as 5 BC–AD 240 (1 sigma), has been recalibrated using CALIB 6.0.2 (Stuiver and Reimer 1993), providing a 1 sigma age range of 1740–1870 calBP (AD 80–213).

the swamp with infilling late in the sequence (cf. Stemmermann 1981: 103). As for non-mangrove types, the *Metroxylon* palm was dominant throughout the core, though it gradually declined from the base (about 92%) to the top (about 31%). All other types (except the pteridophytes) had only a minor and/or sporadic occurrence. *C. chamissonis* was not noted, and charcoal particles were evidently not recorded.

Other paleoenvironmental investigations conducted on Pohnpei, though not involving pollen analysis, include studies by Ayres *et al.* (1981: 117–20), Fujimoto and Miyagi (1993), and Matsumoto *et al.* (1986). The Ayres *et al.* (1981) study documented an inland swamp, Leh en Luhk, in Awak valley. Maximum depth of this wetland was determined to be 3.43 m, though sampling could only be taken to a depth of 2.01 m due to difficulty of inserting and extracting the corer. Radiocarbon determinations of 290 ± 120 BC and 570 ± 130 BC were obtained from the LB core at 104–118 cm and 130–142 cm, respectively. A single determination AD 170 ± 110 years also was obtained from the LC core at 96–146 cm (Ayres *et al.* 1981: 119,122; details about the radiocarbon samples, processing, results, and calibration, if any, are not reported and the determinations are presented here as stated in the report). Charcoal 'flecking' is noted for intervals at 55–80 cm and 142–162 cm in the LB core, and 'concentrations of charcoal' were in the LC core at 96–146 cm (same interval as the radiocarbon determination). According to the investigators, the core documents 'slash and burn agricultural practices in the back of the valley as early as AD 315' (Ayres *et al.* 1981: 9). Data supporting this conclusion and the date, however, are not presented, nor is there any discussion of the charcoal that would support its identification as such in order to distinguish it from flecks and fragments of anaerobically blackened wood, which can be common in wetland deposits.

The other two paleoenvironmental studies concerned geomorphological and sea-level change studies in the mangrove swamps of Pohnpei. The investigation of Fujimoto and Miyagi (1993) involved a coring transect through the Lewetik swamp, from the landward side to the shoreward side. The maximum depth of the recovered cores was only three metres. On the basis of several radiocarbon determinations, Fujimoto and Yiyagi (1993: 143) conclude that mangrove peat began to form on top of marine sand or coral about 2000 BP, and for this to have occurred, sea level must have been several metres below its present level.

The study by Matsumoto *et al.* (1986: 104) 'aimed to reconstruct a Holocene transgressive sea-level at Ponape Island, using mangrove peats.' It is similar to the study of Fujimoto and Miyagi. A core was recovered from the Rohi mangrove swamp of south Pohnpei. Peat extended to a depth of about four metres, whereupon it became 'muddier and contain[ed] numerous coral fragments' (Matsumoto *et al.* 1986: 104). On the basis of five radiocarbon determinations, they concluded, 'in the last 5000 years, about 3 m had submerged' (Matsumoto *et al.* 1986: 104).

Following the influence of Bloom (1970), island submergence was the dominant paradigm at the time of the Matsumoto *et al.* (1986) study. However, it is now incontrovertible that a hydro-isostatic mid-Holocene high stand occurred throughout the tropical and subtropical Pacific between roughly 5050 and 2850 calBP, though the exact timing of its onset was somewhat variable in different parts of the Pacific (Dickinson 2001, 2003; Dickinson and Athens 2007: 182). Submergence and peat formation on Pohnpei's coastal fringes, therefore, was probably a process that incorporated both subsidence and highstand effects.

POHNPEI FIELD INVESTIGATIONS

Field investigations on Pohnpei were carried out by the senior author with the assistance of Christophe Descantes and Reddy Lawrence over a six day period from October 29 to November 3, 2002 under permit from the Pohnpei state government and the aegis of its Historic Preservation Office. Initial field investigations involved evaluating a number of promising wetland coring locations identified on a detailed topographic map of the island. Several inland wetland locations were probed, including the Kahmar and Meitik areas in Net Municipality, and the Leh en Luk swamp in the interior of Awak in Uh Municipality (discussed above). Probing was also conducted at several near-coastal locations in wetlands close to the Pilap en Sekereriau and Lehdau Rivers in Madolenihmw. Sediments at these locations all proved to be too shallow for obtaining high resolution cores. However, the probing process did aid in narrowing sampling locations down to four possible sites where cores were eventually taken. Using a GeoCore sampler (Colinvaux *et al.* 1998), cores were obtained at Daueniei (Core 1) in Madolenihmw; Nanitpw-2 (Core 2) and Nanitipw-3 (Core 3), which are both in Net; and Lewetik (Core 4) in Kiti. The latter location is the same swamp where Fujimoto and Miyagi (1983) took their coring transect.

The Daueniei-1 core, located in a former experimental rice field of the 1960s that is now a sedge and grass wetland, reached a depth of five metres of which almost four metres was saprolite. Nanitipw-2, in the middle of a large mangrove swamp, reached 11.0 m. Nanitipw-3, closer to the landward side of the same swamp, reached a depth of six m, of which the lower two metres consisted of saprolite. Lewetik-4, on the landward side of a large mangrove swamp, reached 13.0 m. The cores, in their original sampling tubes, were shipped to the IARII laboratory in Honolulu for analysis and subsampling by the senior author. The second author was responsible for pollen analyses.

Only Nanitipw-2 and Lewetik-4 (hereafter the Nanitipw and Lewetik) cores were subjected to detailed analyses. These two cores, from opposite sides of Pohnpei (Figures 2, 3), provided the best opportunity for obtaining high resolution results. It is unclear if the Nanitipw location is in the same swamp as the Nanitipu core of Yamanaka and

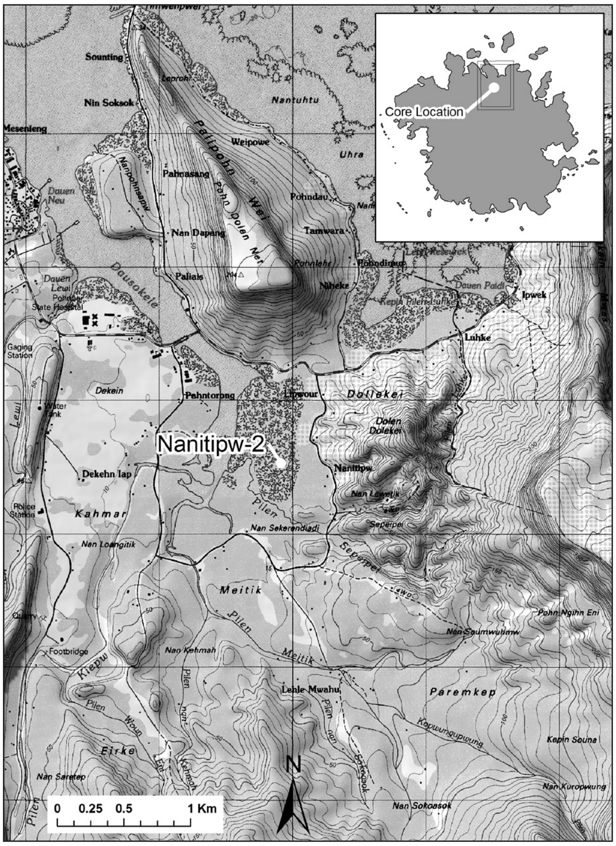

Figure 2. Location of Nanitipw-2 core

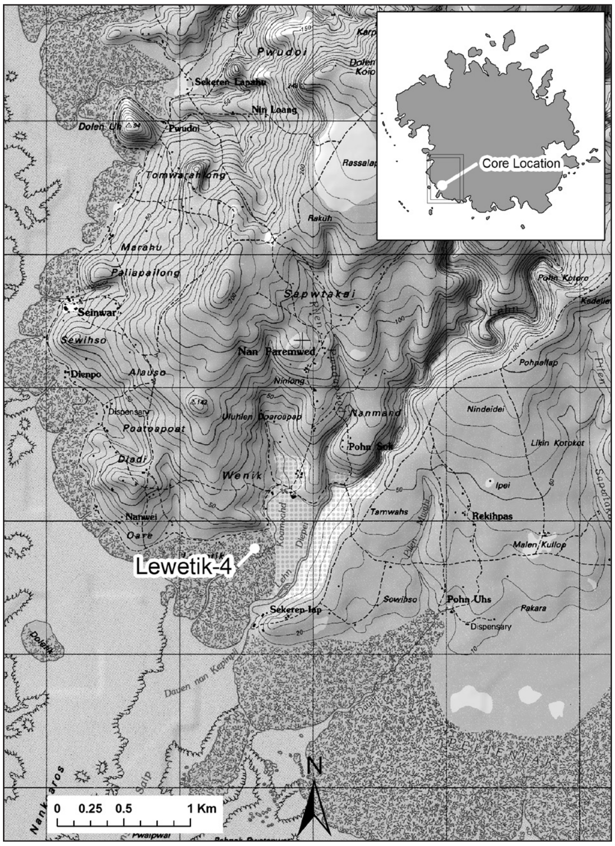

Figure 3. Location of Lewetik-4 cores

Kikuchi (1995) as their report does not provide a map of the location.

NANITIPW AND LEWETIK CORES

Both the Nanitipw and Lewetik cores contained peat and/or black highly organic silt loam or loam sediments typical of mangrove and near-shore lagoonal locations near the mouths of river drainages (Table 1). Minor distinctions between layers in terms of texture and contents were recognized in both cores with the exception that Layer III in the Nanitipw core terminated on what is believed to be old colluvium of the island (Figure 4). This was presumably exposed as an erosional surface when sea level dropped during the last glaciation. In the Lewetik core, basal sediments below mangrove and lagoonal deposits were not reached due to nightfall and the departure of the coring team from the island the next day.

Chronology

Five radiocarbon determinations were obtained from each core (Figure 4; Table 2). For both cores the determinations display a progression of age with depth, with the exception of an inversion of the two uppermost determinations in the Lewetik core. The basal radiocarbon date for the Nanitipw core at the point where lagoonal sediments terminated and alluvial/colluvial sediments began, at a depth of 10.0 m, was 8023–8160 calBP (1 sigma). The basal radiocarbon date for the Lewetik core was 7278–7416 calBP (1 sigma). The age determinations suggest that both cores have complete or nearly complete records of sedimentation since the early Holocene (i.e., there are no suspected unconformities in the two cores).

Calibrated radiocarbon determinations from each core were used to construct depth-age models so that the ages of intervening intervals could be estimated by linear interpolation (Figures 5, 6). Use of interpolated dates, while having the appearance of precise ages, are no more precise than the radiocarbon ages on which they are based, and thus must be considered as statistical approximations. There is no reason to suspect radical changes in deposition rates or unconformities in either core.

For Lewetik, an arbitrary decision was made to accept the more recent (but deeper) of the inverted determinations for graphical display of the age-depth model, though the two dates are close enough in age that the problem is of little consequence for present purposes. As shown in the depth-age graphs, the rate of sediment accumulation slowed between about 7000 and 1500 calBP in the Nanitipw core, and between about 5500 and 2000 calBP in the Lewitik core, and then increased afterwards. A component

Table 1. *Soil description, Nanitpw-2 and Lewetik-4 cores.*

Layer	Nanitipw	Lewetik
I	0–284 cm; 7.5YR 2.5/2 (very dark brown); peat and silt loam with few small rounded basalt pebbles and sparse rounded basalt gravel; slightly increase in clay below 180 cm; abrupt lower boundary.	0–466 cm; 7.5YR 2.5/2 (very dark brown); peat and small amount of silt; coarse to about 100 cm and becomes finer below; silt increases below ca. 400 cm but layer still mainly consists of peat; wood fragments fairly common; possibly abrupt lower boundary but uncertain due to sediment loss at base of core segment.
IIa	284–340 cm; 10YR 3/1 (very dark gray); silt loam; some small pieces of wood, but peaty material greatly reduced; few small rounded basalt pebbles and sparse gravel; diffuse lower boundary.	466–500 cm; 7.5YR 3/1 (very dark gray); pebbles (basalt?) mixed with silt loam, very organic; similar to lower part of I; some marine material present; loss of most sediment in sample tube suggests this layer comprised primarily of clastics; lower boundary not observed.
IIb	340–930 cm; 10YR 3/1 (very dark gray); loam; crab shell present but uncommon; occasional dispersed shells of tiny bivalves and larger delicate bivalves;[1] abrupt lower boundary.	500–1128 cm; 10YR 3/2 (very dark grayish brown); silt loam, organic but little wood; clay content increases with depth; low density of very fine calcareous sand; low density of tiny marine bivalves and larger delicate bivalves;[2] crab shell; clear lower boundary.
IIc	930–1004 cm; 10YR 3/1 (very dark gray); silt loam with ca. 5% fine calcareous sand; some wood fragments; continued presence of bivalves; abrupt lower boundary.	1128–1191 cm; 2.5Y 4/2 (dark grayish brown; loam (basically the same as IIb but with increase of both fine calcareous sand and clay); diffuse lower boundary.
III	1004–1100 cm; 2.5Y 3/2 (very dark grayish brown); sandy loam with rounded basalt gravel and pebbles; marine materials absent; bottom part of core segment missing due to coarse rocky sediment falling out of tube below 1039 cm; lower boundary not observed (further penetration of corer not possible).	1191–1300+ cm; 10Y 4/2 (dark grayish brown); loam; similar to IIc but with more marine small shell fragments; lower boundary not observed (further penetration of corer prevented by darkness).

1. *Tellina perna*, cf. *Iravadiidae* sp., *Lasaeidae* 2. *Nassarius* sp., *Tellinidae*

of this pattern likely relates to the start and termination of the mid-Holocene highstand on Pohnpei.

Pollen Analyses

Pollen analysis and microscopic charcoal particle counts were undertaken for 16 samples in the Nanitipw core and 15 samples in the Lewetik core. Sample distributions are shown in the Figure 4 profiles (the intervals are a little wider in the deeper parts of both cores). Pollen analyses were undertaken using standard acetolysis processing techniques and with approximately 25,000 exotic *Lycopodium* spores added to each sample so that pollen concentrations could be calculated (Bennett and Willis 2001). Charcoal on the pollen slides was also counted as an indicator of fire in the landscape with the concentration of charcoal calculated using the exotic marker method (Bennett and Willis 2001). Only black, opaque angular particles greater than 10 µm were counted as charcoal.

The pollen diagrams (Figures 7 and 8) are percentage diagrams plotted using the program C2 (Juggins 2003) and the individual pollen curves are based on a terrestrial pollen sum that excludes fern spores and aquatic pollen. Pollen recovery was mostly good with between 300 to 600 grains counted for most intervals, though pollen counts in the upper intervals of the Lewetik core were somewhat low. For each slide four transects were counted, and a nominal target of 20 exotic spike pollen was also set. If this target was not reached, then additional transects were counted until a count of 20 exotic pollen grains was achieved. Because of the quantity of *Metroxylon* pollen grains in the 416–418 cm interval in the Nanitipw core, the target rule was relaxed since additional counting would have had almost no effect on the ratios between different types of pollen. Also, the 932–934 cm interval in the Lewetik core was almost devoid of pollen, so the counting effort was discontinued.

As is apparent from the pollen diagrams, the pollen assemblages of both cores are quite similar. *Metroxylon* palm dominates throughout, although it declines in the later part of the cores coincident with the establishment and expansion of *Rhizophora* mangrove forest. Another mangrove type, *Sonneratia*, also tracks the rise in *Rhizophora* pollen. It is apparent that mangrove forests start to develop around 5500 calBP in the Lewetik core, and around 5000 calBP in the Nanitipw core. The category 'other palms', while not producing high pollen counts, also declines in concert with the *Metroxylon*. The other palm pollen types were not identified due to lack of suitable reference pollen, but they probably pertain to both *Clinostigma ponapensis* and *Ptychosperma* spp., which presently are found in uncultivated upland forests (Merlin *et al.*

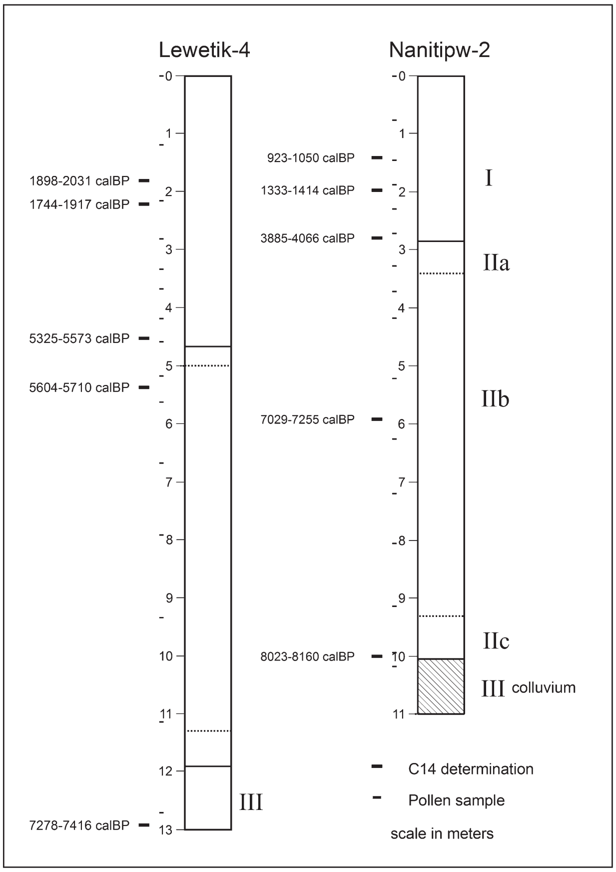

Figure 4. Profiles of Nanitipw-2 and Lewetik-4 cores with locations of pollen samples and radiocarbon determinations. Major layer designations for the Lewetik core follow those of the Nanitipw core.

1992: 66; Glassman 1952: 110–111). Although native palms often decline on Pacific islands with the advent of human settlement (Prebble and Dowe 2008), the decline of the Pohnpei palms appears to have begun well before human settlement. However, this may be simply a artifact of the establishment and progradation of mangrove systems in the late Holocene as indicated by the rise in mangrove pollen. As the mangrove wetlands expanded, the present day location of the Nanitipw and Lewetik coring sites became more distant from dry land. This, with an over arching canopy of mangrove taxa, led to a decreasing representation of native palm pollen at the sites.

Although numerically a small contributor to the pollen assemblages of the two cores, the presence of the coconut palm, *Cocos nucifera*, in multiple intervals of the middle Holocene well prior to human settlement on Pohnpei is of interest. It demonstrates that coconut is a native of Pohnpei rather than aboriginally introduced as is often thought (e.g., Merlin *et al.* 1992: 44). Although presently a common tree in the lowland agroforests of Pohnpei, coconut pollen was absent from surface samples collected at both coring locations. This absence, as suggested above for the decline of the 'other palms' category, appears to confirm that the position of the coring sites deep within mangrove forest is probably a critical factor determining the types of pollen deposited at the coring locations, particularly with respect to the palms.

With one exception – that of *C. chamissonis* – little more can be said about the pollen assemblages. The fern spores, while numerous, are difficult to interpret. With respect to trees and shrubs, if the palms are removed from consideration, the pollen record is quite limited, with only a few grains of different taxa appearing randomly in relatively few intervals, but absent in most. These include Anacardiaceae, *Barringtonia*, *Erythrina*, Euphorbiaceae type, *Ilex*, *Macaranga*, *Pandanus* and Myristicacaeae, the best represented type in the Nanitipw core. Among the herbs, the low counts of Poaceae are mostly confined to the middle regions of the cores; there is no evident increase with the advent of humans. The Liliaceae type, somewhat more common, shows a fairly even distribution throughout the records.

Cyrtosperma chamissonis

The pollen of giant swamp taro, *C. chamissonis*, is conspicuously present in both the Nanitipw and Lewetik cores, with totals of 11 and 14 grains, respectively. In the Nanitipw core, 9 grains were in intervals dating between 7890 and 7220 calBP (these ages and ages mentioned below that are not expressed as ranges are interpolated ages), and two grains in an interval dating to 1310 calBP. In the Lewetik core, three grains were found in an interval dating to 5950 calBP, 10 grains in multiple intervals dating between 5610 and 3590 calBP, and a single grain in an interval dating to 1780 calBP. *C. chamissonis* pollen is distinctive and easily identified as explained in the previous footnote (also see Figure 9). The prehuman presence of this pollen type on Pohnpei is beyond question. The documentation of *C. chamissonis* in the Pohnpei records greatly expands its known natural distribution prior to the advent of humans.

Charcoal Particles

Microscopic charcoal particles, which are distinctive on pollen slides, were counted along with the pollen. A conservative approach was taken in regard to the charcoal counting, given the large amount of black material in the sediment that is not charcoal but believed to arise from either oxidation or iron pyrite staining. The protocol used to categorize charcoal was as follows: black, opaque, angular, greater than 10 µm in size and with visible plant structure. Black particles greater than 10 µm in size but with rounded edges or no plant structure were considered not to be charcoal. While such a procedure may potentially underestimate the actual charcoal content of sediments, the shape of the resulting curves should still be robust. Marker pollen grains were counted along with the charcoal to enable

Table 2. *Radiocarbon determinations, Nanitipw-2 and Lewetik-4 cores.*

Cat. No.	**Lab. No.**	**Provenance**	**Weight g / material**	**Age BP**	**^{13}C/^{12}C ‰**	**Conventional Age BP**	**Calibrated Age BP, 1σ****
Nani-2,140–141	Wk-13639*	Nanitipw, Core 2, Layer I, 140–141 cm bs	2.11 peaty loam	—	–28.2 ± 0.2	1045 ± 46	923–1050
Nani-2,195–198	Beta-215971*	Nanitipw, Core 2, Layer I, 195–198 cm bs	0.90 peaty loam	1550 ± 40	–27.9	1500 ± 40	1333–1414
Nani-2,278–280	Wk-12980*	Nanitipw, Core 2, Layer I, 278–280 cm bs	0.70 / wood (bark; not identifiable)	—	–27.9 ± 0.2	3633 ± 44	3885–4066
Nani-2,591	Wk-12981*	Nanitipw, Core 2, Layer IIb, 591 cm bs	0.25 / wood (not identifiable)	—	–28.3 ± 0.2	6244 ± 49	7029–7255
Nani-2,999–1000	Wk-12982*	Nanitipw, Core 2, Layer IIc, 999–1000 cm bs	0.80 / wood (bark; not identifiable)	—	–28.6 ± 0.2	7271 ± 50	8023–8160
Lewe-4,180–181	Wk-13339*	Core 4, Layer I, 180–181 cm bs	1.73 / peat	—	–27.4 ± 0.2	2014 ± 44	1898–2031
Lewe-4,221	Beta-215970*	Core 4, Layer I, 221 cm bs	0.47 / peat	1940 ± 40	–27.5	1900 ± 40	1744–1917
Lewe-4,449–454	Wk-12585	Core 4, Layer I, 449–454 cm bs	6.11 / wood (mangrove type, prob. *Rhizophora* sp.)	—	–28.6 ± 0.2	4700 ± 48	5325–5573
Lewe-4,536–537	Wk-12586*	Core 4, Layer IIb, 536–537 cm bs	4.01 sediment	—	–28.3 ± 0.2	4933 ± 49	5604–5710
Lewe-4,1290–1291	Wk-12587*	Core 4, Layer III, 1290–1291 cm bs	7.03 sediment	—	–28.5 ± 0.2	6405 ± 55	7278–7416

* AMS procedure used to date sample ** Calibration from Calib Rev. 5.0 computer program (Stuiver and Reimer 1993)

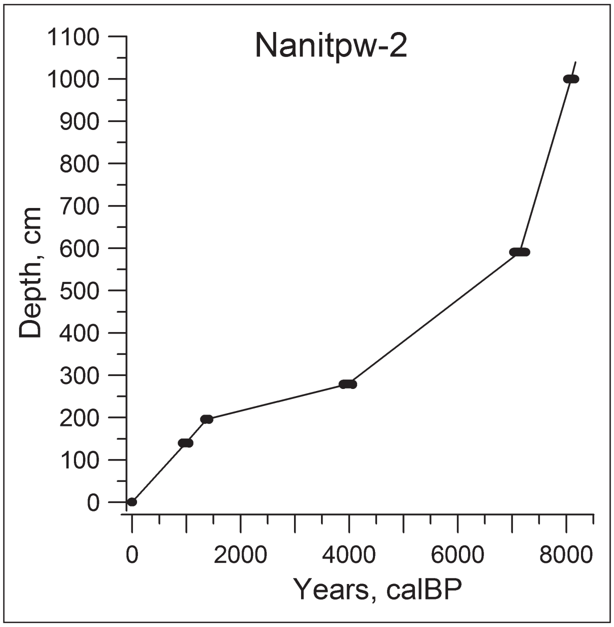

Figure 5. Depth-age graph of radiocarbon determinations for Nanitipw-2 core. Radiocarbon determinations are depicted with 1 sigma calibrated range. The '0' point of the graph is the ground surface.

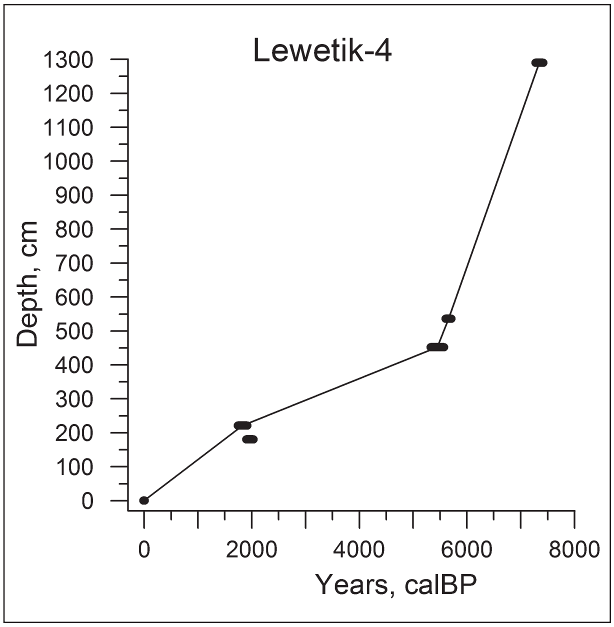

Figure 6. Depth-age graph of radiocarbon determinations for Lewetik-4 core. Radiocarbon determinations are depicted with 1 sigma calibrated range. The '0' point of the graph is the ground surface.

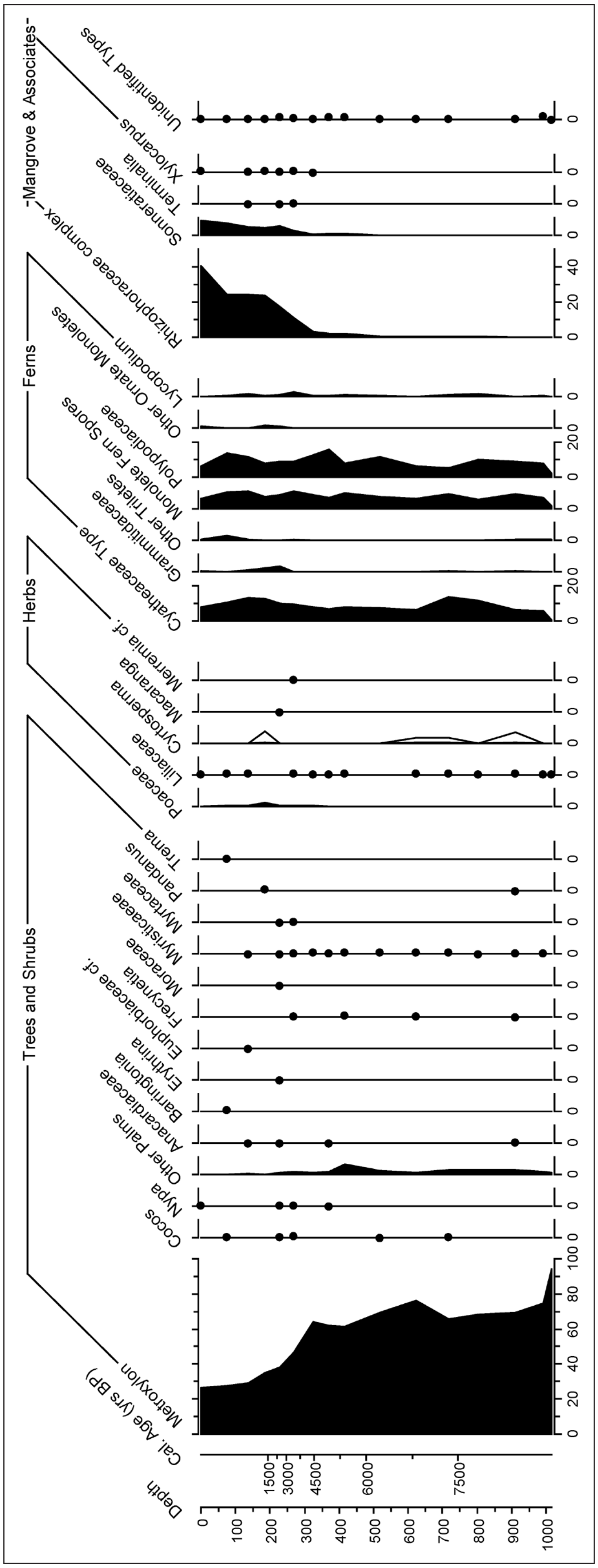

Figure 7. Pollen percentage diagram of Nanitipw-2 core. Curves are based on a terrestrial pollen sum that excludes fern spores and aquatic pollen. Dots have been used for taxa that have values consistently less than 2%. A 10× exaggeration curve is shown for *Cyrtosperma*.

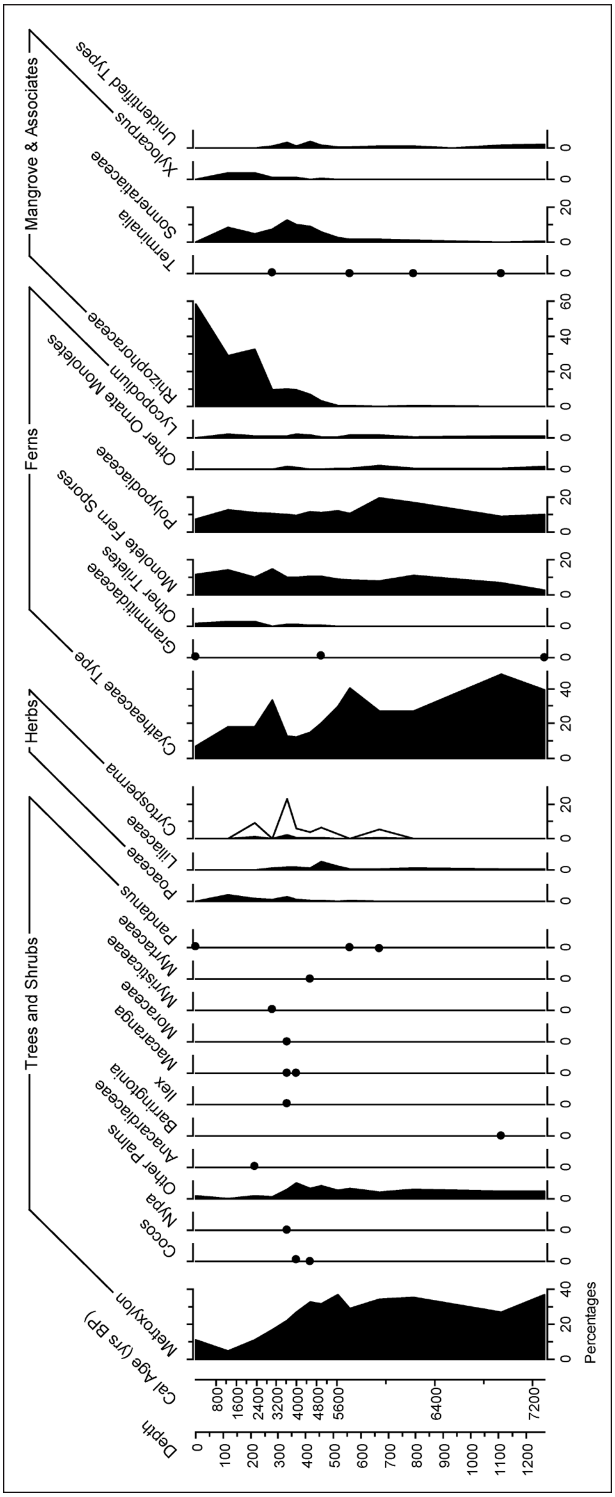

Figure 8. Pollen percentage diagram of Lewetik-4 core. Curves are based on a terrestrial pollen sum that excludes fern spores and aquatic pollen. Dots have been used for taxa that have values consistently less than 2%. A 10× exaggeration curve is shown for *Cyrtosperma*.

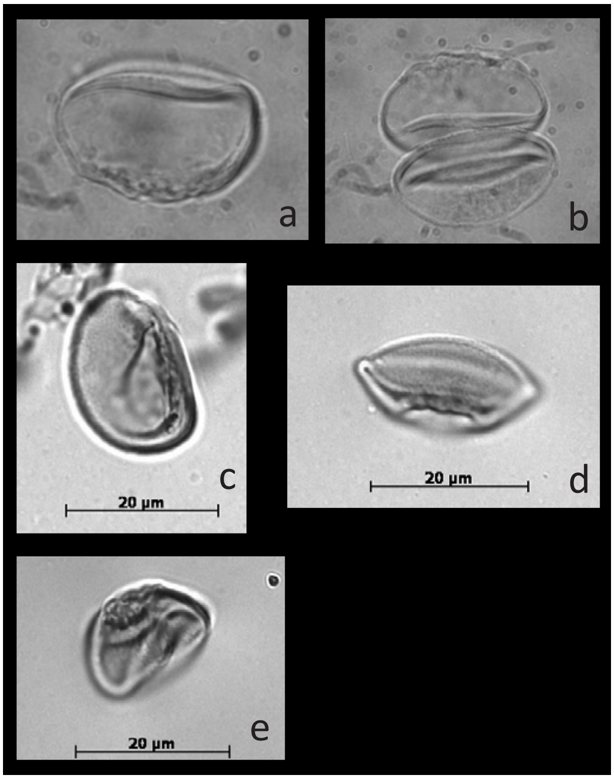

Figure 9. *Cyrtosperma chamissonis* pollen. Photos 'a' and 'b' show reference pollen collected from Kosrae garden by Jerome Ward; the long axis of these grains is about 27 µm; Photos 'c', 'd', and 'e' show fossil pollen from the Nanitipw core at 912 cm (~7900 calBP). The grains in 'c' and 'd' have long axes of 22.4 and 23.3 µm, respectively. The larger size of the reference pollen is due to swelling caused by the mounting medium, glycerine jelly; this sample was collected and mounted about 22 years prior to the Pohnpei core samples.

calculation of particle concentrations.

Almost all charcoal particles in both cores are between 10 and 50 µm, with the majority at the lower limit of identification at 10 µm. Graphs of charcoal densities by interval age are shown for both cores in Figures 10 and 11.

Charcoal particles first appear in the Nanitipw core at 3720 calBP (interpolated and hereafter) and at 4120 calBP in the Lewetik core. Their presence in these cores corresponds roughly to the establishment and growth of mangrove swamps, though the correspondence may be only coincidental. As may be seen in Figures 10 and 11, after several intervals of moderate concentrations, charcoal particles peak at 980 calBP in the Nanitipw core and 2770 calBP in the Lewetik core. These high values then quickly drop, going to zero particles at the surface of the Nanitipw core, and to very low concentrations in the Lewetik core. Notably, it is in the upper two or three samples in each core that larger fragments (ie > 50 um) are more consistently seen.

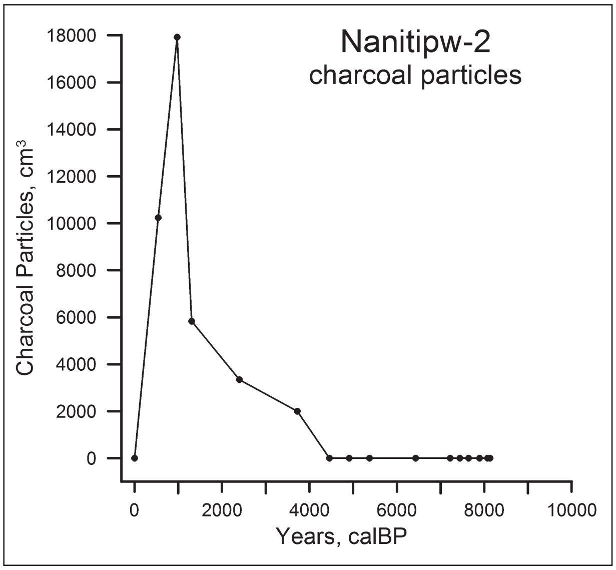

Figure 10. Graph of charcoal particle concentrations in Nanitipw-2 core.

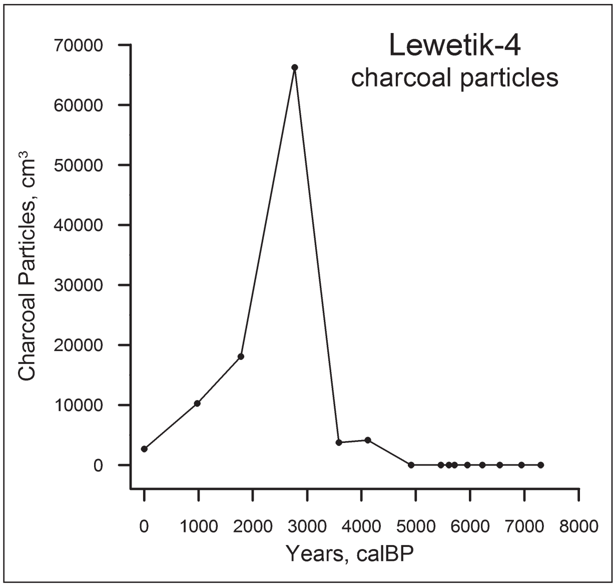

Figure 11. Graph of charcoal particle concentrations in Lewetik-4 core

DISCUSSION AND CONCLUSION

Cyrtosperma chamissonis

Pollen data from the Nanitipw and Lewetik cores are unambiguous in their documentation of the presence of *C. chamissonis* on Pohnpei since the early Holocene. The early part of this time frame places its presence on Pohnpei over 5000 years prior to the likely advent of humans on Pohnpei ca. 2000 years ago as documented by archaeology. This leads to the obvious conclusion that the natural distribution of *C. chamissonis* was far greater than previously realized, extending north and eastward from Melanesia to at least the Eastern Caroline Island of Pohnpei. Paleoenvironmental coring results do not show its presence further east on the high island of Kosrae prior to human settlement (Athens *et al.* 1996) so, barring its lack of documentation on Kosrae due to insufficient sampling, Pohnpei could well mark its easternmost natural distribution.

The vectors for the natural dispersal *C. chamissonis* over broad reaches of the western Pacific are unknown. Since *C. chamissonis* can sometimes produce fertile seeds (Sakai 1983: 46), it can be speculated that birds might have carried these to distant islands in their guts after feeding on the small reddish or orange berries (Hay 1988: 429). The seeds, measuring 5–11 mm (Hay 1988: 432), were probably too large to have become trapped in the feathers of a feeding bird for transport. Rafting of vegetative parts within clumps of soil protected within the root mass of drifting uprooted trees is another possibility since the species is salt tolerant.

Considering these results, therefore, the presence of *C. chamissonis* in paleoenvironmental records of Micronesia cannot be regarded *prima facie* as evidence for the presence of humans. In this respect, the previous conclusion by Athens and Ward (2001: 171–172) that regarded the presence of *C. chamissonis* as the 'smoking gun' for the advent of humans on Palau during the 5th or even 6th millennium must be modified. Because the Pohnpei evidence indicates that the *C. chamissonis* on Palau could be a result of natural prehuman processes of dissemination, it cannot be used as diagnostic of human presence. While other paleoenvironmental evidence – the onset of disturbance indicators in the pollen records – does point to a possible colonization of Palau during the early 5th millennium (Athens and Ward 2005), the presence of *C. chamissonis* no longer has a bearing on this interpretation.

The wider natural distribution of *C. chamissonis* than previously suspected has important implications for initial island colonization in the western Pacific. Its presence on Pohnpei indicates that at least some of these islands would have had available a naturally occurring starch food resource when the initial human colonizers arrived. Thus, many if not most western Pacific islands, already having naturally occurring *C. chamissonis* as well as coconut (*C. nucifera)*, were perhaps not so nutritionally impoverished at the time humans first arrived as might be assumed.

Charcoal Particles

The presence in the Pohnpei cores of charcoal particles at a time well before initial human colonization was unexpected. As noted above, particles begin to appear around 3720 calBP in the Nanitipw core, and about 4120 calBP in the Lewetik core. As the patterns of human settlement are fairly well established throughout the Pacific (see for example Kirch 2000), an origin deriving from anthropogenic activity on Pohnpei at the indicated dates is an unrealistic possibility.

Almost all charcoal particles in both cores were tiny, usually just greater than 10 µm, which is pushing the lower limit of what is identifiable as charcoal. Local fires are usually indicated by charcoal >125 µm, while regional to extra-regional fires are usually defined by the smaller size fractions (Clark 1988; Patterson *et al.* 1987). The overwhelming 10–50 µm charcoal fraction in the Pohnpei cores indicates that the charcoal has a regional or extra-regional source, either from the interior of the island or further afield. However, it is hard to conceive of a regional source of natural fires since such occurrences are virtually precluded by the island's year round high rainfall (Landers and Khosrowpanah 2004). Also, there has been no active volcanism on Pohnpei during the Holocene, so fires caused by local volcanic activity are not a viable explanation. Fires occurring on islands further afield (i.e., extra-regional fires) due to volcanism also seems unlikely. Nevertheless, our coarse sampling intervals preclude us from reaching a definitive conclusion regarding volcanism since we cannot be certain whether the observed particles are the result of punctuated occurrences in the sediment column as would be expected if their origin was the result of distant eruptive events.

Even though strict protocols were adhered to in the counting of the charcoal particles in these sites, the chemical alteration of organic material cannot be discounted based on visual appraisal alone. We raise this issue as the charcoal content of these cores is closely aligned with the development of mangrove forest at each coring location. This in turn raises the question of how suitable or reliable mangrove peats are for documenting human colonization and subsequent landscape change on Pacific islands when the appearance of charcoal on pollen slides is a determining factor. There is, however, a fairly sound means by which to minimize the chance of misinterpretation of what could be regarded as locally generated charcoal (either from naturally caused fires or anthropogenic burning). This is to limit counts to size fractions larger than 125 µm. At this resolution the discrimination of true charcoal particles is relatively straightforward.

Pollen Assemblages

It is also difficult to identify definitively the presence of humans from the Pohnpei pollen data. Often Pacific island cores begin to display an abundance of disturbance indicators such as grasses, Chenopodiaceae/Amaranthaceae, *Gleichenia*, and *Lycopodium cernuum*, and other types with the advent of humans. The appearance and increase of disturbance indicators is almost always coincident with a significant decline in native forests and other plants (e.g. Athens *et al.* 2002, Athens and Ward 2004, Prebble and Dowe 2008).

As previously discussed, the contrary Pohnpei results may be due to the location of the cores deep within coastal mangrove forests, thereby making them too distant to receive more than a trickle of the pollen rain from terrigenous plants. In addition, the limited terrigenous plant pollen that did reach these locations would have been overwhelmed by pollen from mangrove taxa. If the goal is to obtain a record of past human colonization and landscape disturbance, then, given the Nanitipw and Lewetik results, it probably would be more productive to locate future cores in wetlands adjacent to dry habitable areas in the Pohnpei lowlands.

Acknowledgements

We would like to dedicate this paper to the memory of Reddy Lawrence of Pohnpei, who suddenly passed away at an early age shortly after our coring project. Although we owe much of the success of the field effort to his help in moving the project forward, it is our recollections of the pleasant evenings spent with him and his family that we (JSA and CD) will cherish. *Kalangan en komwi*. JSA also wishes to acknowledge and thank his field assistant, Christophe Descantes, for giving a willing hand with the hard and often muddy work. The project was made possible through the generous support of the Wenner-Gren Foundation for Anthropological Research (grant no. 6953), awarded to JSA. In addition, we extend our gratitude to the Institut de Recherche pour le Developpement (IRD), for providing funds for radiocarbon dating. This latter support was facilitated through the kind efforts of Jean-Christophe Galipaud. Jerome Ward provided photographs of the *Cyrtosperma chamissonis* reference pollen. An earlier version of this paper was presented at the 11th Pacific Science Inter-Congress, Tahiti, March 2–6, 2009.

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