

# Excavation of Pit-Agriculture Landscape on Majuro Atoll, Marshall Islands, and Its Implications

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## Abstract

Coral atolls have been considered the most precarious landforms thus having an extremely severe environment for human settlements in the Oceanic realm. It appears that atoll islets of foraminiferal sand and coral shingle accumulated on reef flats are considerably weaker than high islands with regard to sea-level change and climatic fluctuation, but there also seems to be variety to their vulnerability. In fact our excavation on Laura, the largest and widest islet in Majuro atoll, Marshall Islands, has revealed that its earliest colonization surprisingly dated back to 2,000 BP, and agricultural pits for cultivation of aroid species – probably *Cyrtosperma* – were constructed some centuries later at the least, while a smaller islet shows a much younger age of 360 BP. The long-lasting landscape of pit agriculture comprising remarkable undulation and rich vegetation, which appears to be the richest and most diverse part of the present atoll environment, can be viewed as a symbol indicating the islets are in good condition in aspects of both land formation and human subsistence. Here, we will discuss this landscape as a historical product invented through the entanglement between two agencies, nature and human. Understanding this will be also helpful in framing policies regarding anticipated sea-level rising in the future.

**Key words:** archaeological excavation, Oceanic atolls, pit agriculture, prehistoric human settlements

## 1. Introduction

In the trade wind zone are scattered a number of coral atolls, the most precarious landforms of the central Pacific realm. Their islets of foraminiferal sand and coral shingle accumulated on reef flats are often no more than 2-3 meters in elevation and a few hundred meters wide. A storm surge easily inundates such low and flat islets. There is no running surface water either, and thus some atolls frequently suffer from droughts. The atoll environment appears to be extremely severe for any human settlement.

Near the center of larger islets, however, exist remarkable banks that are several meters higher than the surrounding flat and low surface. There are now houses or graveyards on these banks. Each of them

encircles an agricultural pit dug into the water table of the freshwater lens. The pit is infilled with soils containing much humus which have been developed by the deliberate addition of vegetable compost to provide a nutrient-rich layer. *Colocasia* and/or *Cyrtosperma* tubers, the latter prevailing in the Eastern Micronesia, are planted in this wet ground (Fig.1).

When *Cyrtosperma* is fully grown, it measures more than 3 meters in height and produces tubers weighing 20-30 kg. While it takes 9 months to a few years to harvest the tubers, they have the highest carbohydrate content per unit among the aroid tubers. *Cyrtosperma* also withstands a high level of water or even flooding, provided that it does not result in an inflow of sea water. The species is thus more adaptable to a water table fluctuating with tidal change

(Lambert, 1982). This characteristics may be one reason *Cyrtosperma* is the main aroid grown in the atolls of Micronesia.

Tall trees of Chinese lantern (*Hernandia sonora*), Pacific rosewood (*Cordia subcordata*) and fish-poison tree (*Barringtonia speciosa*), as well as coconut and breadfruit trees, grow on the banks of the *Cyrtosperma* pits and shade the inside of the pits so as to prevent the moisture of the hydromorphic terrain from evaporating. These elements appear to provide the richest landscape, as a whole, in contrast with the prevailing image of atoll environments. However, the landscape has just begun to be scrutinized as a historical product (*e.g.*, Weisler, 1999a). The present article is thus intended to examine what agencies invented the landscape of agricultural pits on the basis of archaeological evidence from our excavation in 2003 on Laura islet in Majuro Atoll, the Marshall Islands.

## 2. Excavation of Laura, Majuro Atoll

Micronesia encompasses about 2,100 islands, most of which lie between the equator and 20 degrees N latitude. The Marshall Islands, lying along its eastern margin, consists of 29 atolls and five small coral islands, which are spread over approximately 2 million km<sup>2</sup> of ocean (Fig.2). These islands come in two, nearly parallel chains: the Ralik (sunset) group in the west and the Ratak (sunrise) group in the east. They are aligned in a NW-SE direction and extend over a distance of nearly 1,200 km between 4 to 12 degrees N latitude, and also form substantial links in a scarcely broken chain of island groups along with Kiribati and Tuvalu Islands.

Majuro Atoll is situated at 7 degrees N latitude and 171 degrees E longitude, in the southern part of the Marshall Islands (Fig.3). This atoll consists of more than 60 islets on reef flats encircling a large lagoon



Fig. 1 *Cyrtosperma* agricultural pit (a) and its spoil bank (b) in Laura, Majuro Atoll.

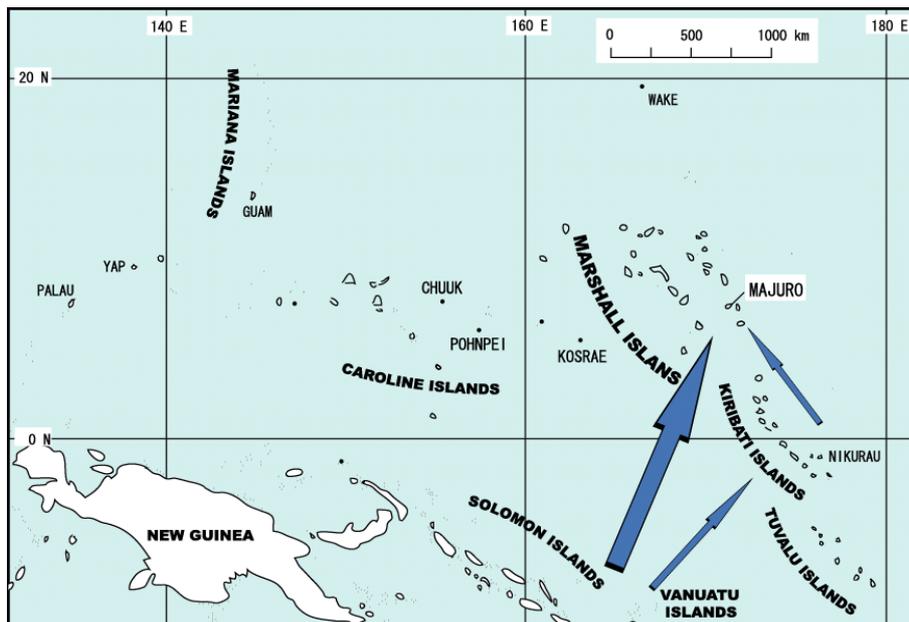


Fig. 2 Map of Eastern Micronesia and estimated colonization routes to the Marshall Islands.

measuring 41 km by 11 km with the long axis extending east to west. The total land area is just less than 10 km<sup>2</sup>. The Marshall Government organizations are allocated on its eastern islets, named Djarrit, Uliga and Delap, at present.

Majuro is the first atoll in the Marshall Islands to have been systematically excavated by the archaeologists of the Bishop Museum, who not only collected plenty of artefacts, adding up to 4,122, but also reported the first evidence of human settlement on atolls ca. 2,000 BP, which was excavated from Laura, the westernmost islet of Majuro (Riley, 1987). Our field research in 2002 and 2003 also focused on this islet. Passing westward from the eastern islets through the long and narrow islet of Long Island, one arrives at Laura with a land area of 1.2 km<sup>2</sup>. This islet is crescentic in shape, measuring approximately 1,200 m at the widest point between shorelines, lagoonward and

oceanward (Fig.4).

Two transect lines were selected in the vicinity of widest point, one in each research year, to survey the topographic profile: MJ-Lr1 in 2002 and MJ-Lr-2 mainly in 2003. For archaeological and geomorphological purposes, ten sites were excavated along these lines, of which, a site lying at the center of Laura (MJ-Lr2-8) is the focus of our examination here. This site is on a heap located between two *Cyrtosperma* agricultural pits (Fig.5). The top is 261 cm high above the present mean sea level and the bottom of the pits, 28 cm. It appears to be a remarkable undulation in comparison with the general landform of low, flat islets (Fig.6). A two by four meter trench was excavated to an approximate depth of 150 cm and intact stratified deposits were encountered there, which came roughly in three strata excluding the surface humus as follows (Fig.7):

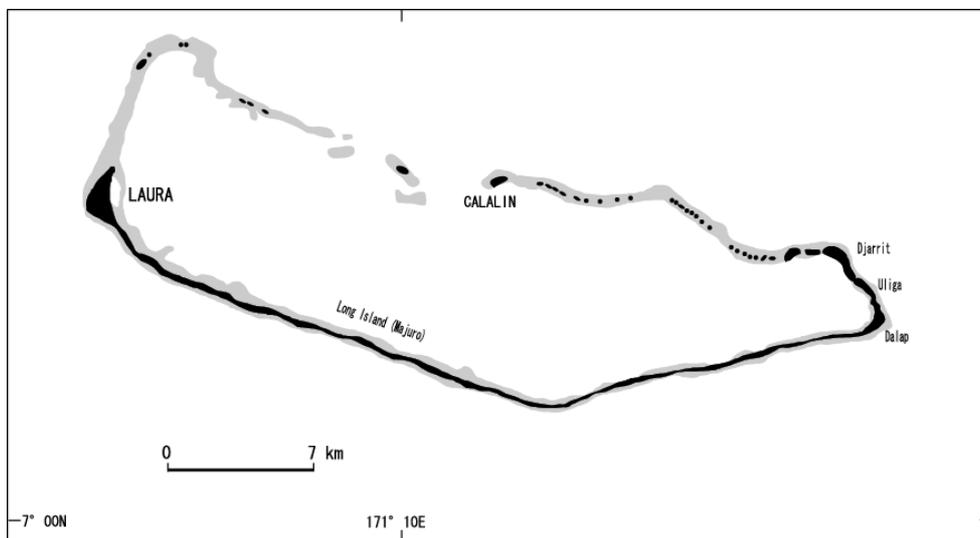


Fig. 3 Majuro Atoll in the Marshall Islands and location of Laura Islet.

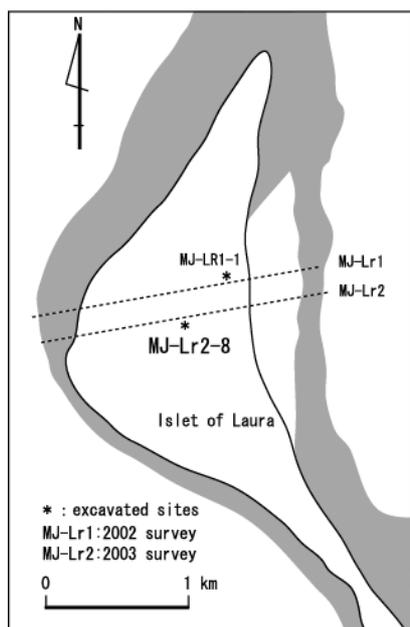


Fig. 4 Excavated sites on Laura Islet.

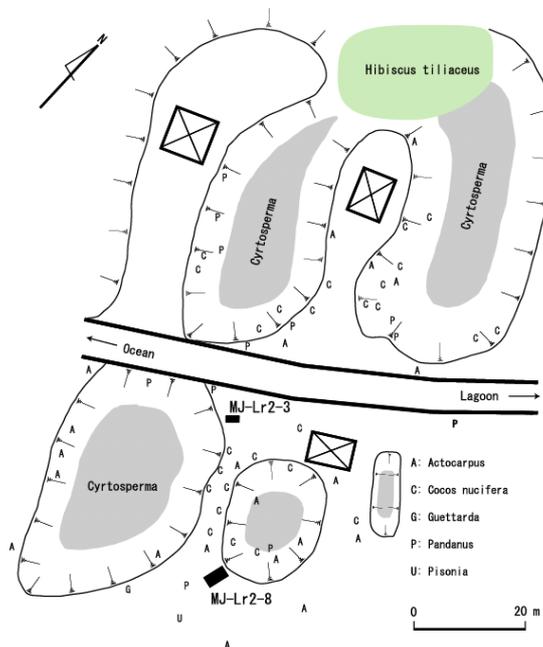


Fig. 5 Location of sites MJ-Lr2-8 and 2-3.

- (i) the lowest stratum (Layer 7) contains very pale brown sand (Mansell's color, 10YR7/3) that is almost horizontally accumulated, and thus should be the natural sediment. Its skeletal components consist of sand-size fragments of coral, coralline

algae, mollusks and abundant tests of foraminifera. The samples were collected from the same stratum at site MJ-Lr2-3 lying at the foot of heap, from which two ages of 2,380 BP were obtained (Table 1);

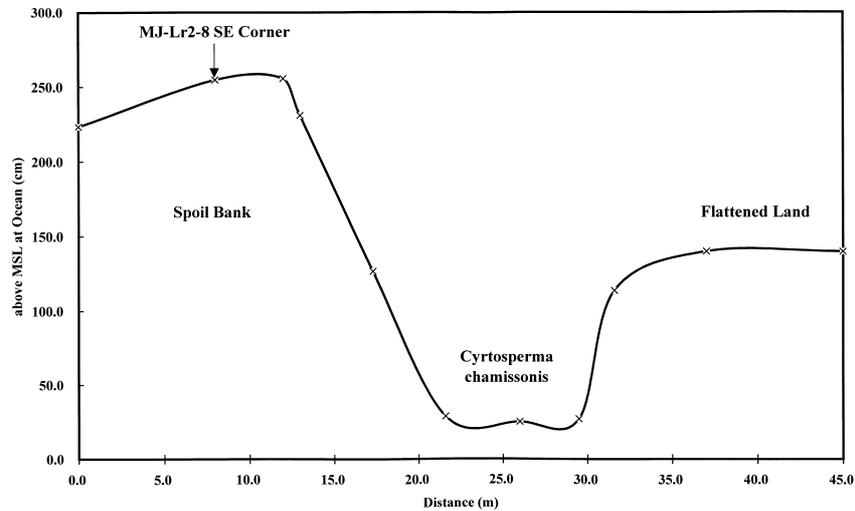


Fig. 6 Undulation of pit agriculture at site MJ-Lr2-8.

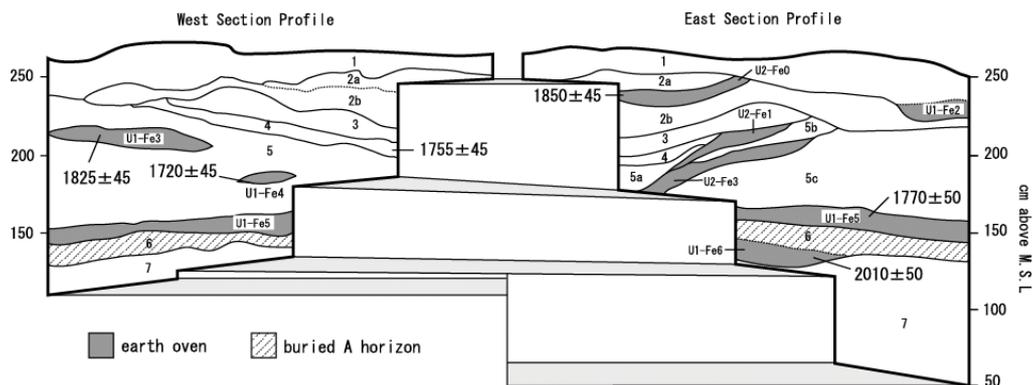


Fig. 7 Stratigraphy of site MJ-Lr2-8.

Table 1 Radiocarbon ages (AMS) from sites MJ-Lr2-8 and 2-3.

Lab. Code	Material	Provenience (Site, Layer or Feature)	$\delta^{13}\text{C}$ (‰)	$^{14}\text{C}$ age (yrBP $\pm 1\sigma$ )	Cal. Year (1 $\sigma$ )
Beta-191711 (AMS)	foraminifera ( <i>Calcarina</i> spp.)	Layer 3 (upper) at MJ-Lr2-3, equivalent to 1st Stratum, Layer 7 at MJ-Lr2-8		2,380 $\pm 40$	
Beta-191714 (AMS)	foraminifera ( <i>Calcarina</i> spp.)	Layer 3 (lower) at MJ-Lr2-3, equivalent to 1st Stratum, Layer 7 at MJ-Lr2-8		2,380 $\pm 40$	
PLD-2790 (AMS)	wooden charcoal (monocoty ledon)	2nd Stratum, Unit 1 / Feature 6 (Eastern section profile)	-27.8	2,010 $\pm 50$	cal. BC 50 - cal. AD 60 (99.4%)
PLD-2785 (AMS)	wooden charcoal ( <i>Cordia</i> spp.)	3rd Stratum, Unit 2 / Feature 0 (Eastern section profile)	-25.8	1,850 $\pm 45$	cal. AD 125 - 235 (97.0%)
PLD-2786 (AMS)	wooden charcoal ( <i>Pandanus</i> spp.)	3rd Stratum, Layer 4 (Western section profile)	-28.1	1,755 $\pm 45$	cal. AD 230 - 345 (94.6%)
PLD-2787 (AMS)	wooden charcoal ( <i>Cocos</i> spp.)	3rd Stratum, Unit 1 / Feature 3 (Western section profile)	-26.3	1,825 $\pm 45$	cal. AD 130 - 240 (100%)
PLD-2788 (AMS)	charred phalange of fruit ( <i>Pandanus</i> spp.)	3rd Stratum, Unit 1 / Feature 4 (Western section profile)	-25.4	1,720 $\pm 45$	cal. AD 255 - 300 (41.4%) cal. AD 320 - 385 (58.6%)
PLD-2789 (AMS)	wooden charcoal ( <i>Cordia</i> spp.)	3rd Stratum, Unit 1 / Feature 5 (Eastern section profile)	-25.7	1,770 $\pm 50$	cal. AD 215 - 340 (91.9%)

- (ii) the second stratum (Layer 6), lying just on top of the natural stratum, contains dark gray sand (10YR4/1) and charcoal flecks. It appears to be the earliest buried A horizon. From a shallow pit of an earth oven (U.1-Fe.6) on the eastern profile, a lot of burned coral pebbles and charred flecks of probable monocotyledon trunk and coconut endocarp were retrieved, which dated to 2,010 BP;
- (iii) the third stratum (Layer 2 to U1/Fe5) consists of gray sand (10YR4/1-6/1) layers and earth ovens containing burned coral pebbles and charcoal flecks. The components of these layers bear a resemblance to those of soil in the adjacent pits. The layers also tend to descend to one of these pits. These characteristics support the possibility that the heap consists mainly of spoils dug up from the pit. From the ovens as well as the spoil layers, dolphin vertebrae and turtle remains were retrieved along with bones of pelagic, benthic and reef fishes (Fig.8). We also obtained five radiocarbon ages associated with these ovens from charred flecks of Pacific rosewood and Chinese lantern. They intriguingly fall within a narrow interval around 1,800 BP.

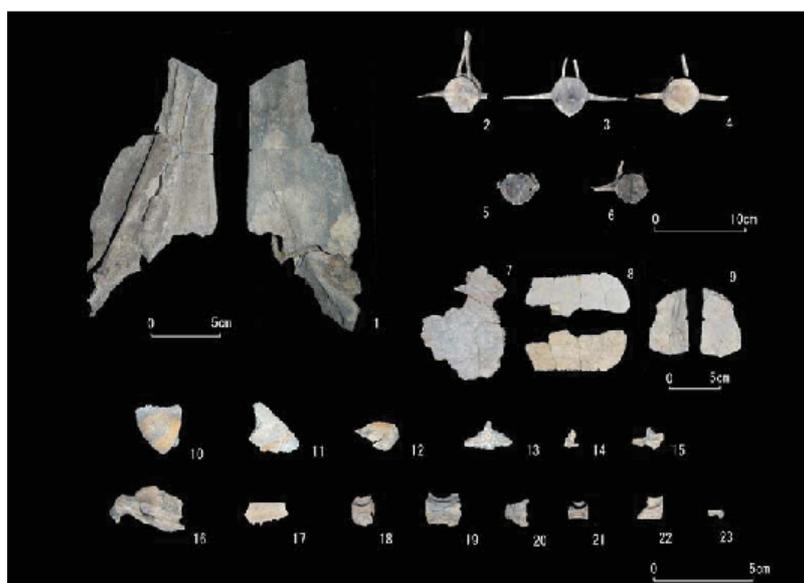
Recent archaeological studies of the Marshall Islands in Eastern Micronesia have revealed that the prehistoric human settlements on several atolls date back to the early period of the first millennium AD (Beardsley, 1993; Dye, 1987; Streck, 1990; Weisler,

1999a, 1999b, 2001)<sup>[1]</sup>. The earliest age from site MJ-Lr2-8,  $2,010 \pm 50$  BP (PID-2790, AMS), falls within this range. The preceding evidence from Laura reported by the Bishop Museum (Riley, 1987) and Weisler (2000) also show a range of 1,800-2,000 BP. It is, thus, almost certain that a group of Oceanic islanders arrived at Majuro Atoll around the first century AD, while other ages reported from Micronesia and Polynesia suggest a later range of 1,000-500 BP for initial settlements on atolls.

This time difference between the Marshalls and other atolls must be elucidated in detail from the viewpoints of geomorphology relating to atoll formation and cultural history with regard to human colonization, but two aspects should be here noted that:

(a) surprisingly the age of 2,000 BP is almost equivalent to the estimated end of the mid-Holocene highstand of the sea level within the central Pacific. The first settlers in the Marshall Islands would have landed on islets newly occurring above the late Holocene sea level. What is interesting is that they would have been one of the first groups to have confronted the strange environment of remote atolls. Recent geomorphological studies on atolls would be relevant to an examination of this topic;

(b) although the majority of atolls were previously thought to have been temporally occupied at first and settled later than high islands that would have been



**Fig. 8** Remains of sea mammals and fishbones from site MJ-Lr2-8.

1. *Peponocephala electra* / left premaxilla and maxilla (left: ventral, right: dorsal);
- 2-6. Delphinidae gen. Indet / lumber or caudal vertebrae; 7. Cheloniidae gen. Indet / plastron;
8. Cheloniidae gen. Indet / carapace; coastal scute (upper: dorsal, lower: ventral);
9. Cheloniidae gen. Indet / left parietal (left: ventral, right: dorsal); 10. Scaridae gen. indet / left dentary; 11. *Cetoscarus bicolor* / right premaxilla; 12. *Cetoscarus bicolor* / right dentary;
13. Labridae gen. indet / low pharyngeal; 14. *Epinephelus* sp. / right premaxilla;
15. Serranidae gen. indet / right maxilla; 16. Scombridae gen. indet / right quadrate;
17. Scombridae gen. indet / right premaxilla; 18-20. Scombridae gen. indet / caudal vertebrae;
- 21-22. *Katsuwonus pelamis* / caudal vertebrae; 23. Carangidae gen. indet / caudal vertebra.

preferred as human habitation (Goodenough, 1957: 152; see also Alkire, 1978:20), Oceanic islanders appear to have colonized the Marshall Islands during as early a phase as the high islands such as Kosrae, Pohnpei and Chuuk in Central Micronesia. This suggests that the first settlers on the Marshall atolls would have transported knowledge or lore, including agronomic ones for cultivating aroids in wet edaphic soil, which were helpful to their subsistence in the atoll environment.

Both aspects are closely related to each other but they will be discussed separately for convenience in the following section.

### 3. Early Settlement on Laura Relating to Its Geomorphological Formation

In the mid-Holocene period the paleoreef had up-grown to the highstand sea level over the bedrock of Pleistocene limestone. It probably started to emerge sometime after *ca.* 2,000 years ago (Tracey & Ladd, 1974; Buddemeier *et al.*, 1975), and was fully exposed when the subsequent decline of the sea level first carried its high-tide level below the mid-Holocene low-tide level. This 'cross-over' date is estimated around 1,100 AD for the Marshall Islands (Dickinson, 2003). The archaeological evidence, however, indicates that wave build-up sediment may have rapidly formed subaerial cores of some islets even though the Holocene paleoreef flat still lay within the tidal range and so it was overtopped by sea water at high tide.

We collected sand samples from the natural stratum at site MJ-Lr2-3 that was equivalent to the lowest one (Layer 7) at site MJ-Lr2-8. It contained many tests of large benthic foraminifera, mostly *Calcarina* spp. Its availability had recently been illustrated for radiometric dating in a geomorphological study on coral sand sedimentation (Yamano *et al.*, 2001; Yamano *et al.*, 2002). Our samples of *Calcarina* preserving fresh spicules, which suggest that they were transported and accumulated immediately after their production in the vicinity of the reef edge, yielded two

ages of  $2,380 \pm 40$  BP (Table 1): one associated with the upper part of the natural stratum just below the earliest A horizon (Beta-191711) and the second with the lower part just above the water table (Beta-191714). While the ages have not been corrected for the marine reservoir effect yet, they appear to support the possibility that the core of Laura quickly occurred just before the arrival of Oceanic islanders in Marshall Island waters.

The physical variety of the islets should be, however, considered with reference to the timings of their emergence and their geomorphological stability. While it has been pointed out that coral islets quickly emerged after a relative fall in the late Holocene sea level (Schofield, 1977; Scoffin, 1993; Yamano *et al.*, 2000; Woodroffe & Morrison, 2001), it seems unrealistic to suppose that every islet was synchronously formed, as the production of foraminifera and the sedimentary process are probably constrained by local conditions (*e.g.*, Marshall & Jacobson, 1985:16).

This is also suggested by the present variation of islets in shape and size that is observable even in one atoll. An islet with a shorter perimeter becomes more circular and broader than one having an equal size with a longer perimeter. In a graph showing the distribution of sizes and widths of Majuro islets (Fig.9), Laura is located at the uppermost right hand corner. This means it is the largest and broadest islet in this atoll. The present Laura accounts for 18% of the total land area, while more than 80% of the islets are less than  $0.2 \text{ km}^2$  in area. Laura is the very islet associated with the earliest human settlement back to *ca.* 2,000 BP, while a smaller islet, Calalin, shows a much younger age of 360 BP (Riley, 1987:242).

The core of Laura was probably one of the few atoll islets first occurring in Oceania during the Holocene period, and it must have been one of first atoll islets for Oceanic islanders to discover. According to our archaeological evidence, coconut and/or pandanus trees appear to have already been grown in its landscape at *ca.* 2,000 BP.

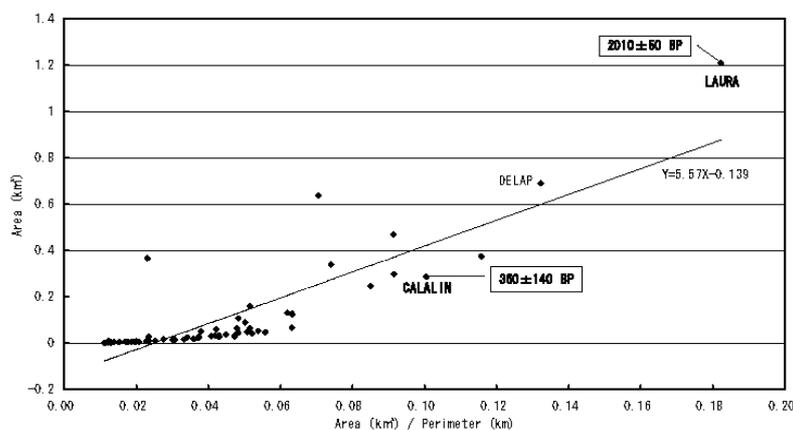


Fig. 9 Diversity of present Majuro islets in size and shape.

#### 4. Prehistoric Invention of Pit Agriculture Landscape

As already described, the third stratum in the trench of MJ-Lr2-8 is interposed with earth ovens that tend to descend in the same way as the spoil layers, except for the lowest oven (U1/Fe5), which is the largest one more than 2 meters in diameter. It can be, thus, speculated that the lowest oven was made before the excavation of the adjoining agricultural pit began, and the rest of ovens were used in the process which created the spoils piled up around the pit.

Of interest is, however, that the five radiocarbon ages associated with these ovens including the lowest and uppermost ones fall within a narrow interval of around 1,800 BP (Table 1). These ages imply that the spoil bank was formed not gradually but over a short period. The most reliable age is  $1,720 \pm 45$  BP (PLD-2788) obtained from a charred phalange of pandanus fruit, short-lived organic matter. It is thus very plausible that the people on Laura not only widely explored the marine resources (Najima & Yamaguchi, 2004) but also constructed the undulation of agricultural pit and spoil bank as early as some centuries after the earliest evidence of human colonization.

The charcoal samples also tell us about the past vegetation although partially. The wood charcoals from the third stratum were identified as those of Pacific rosewood (*Cordia* spp.) and Chinese lantern (*Hernandia* spp.) as well as pandanus and coconut trees (Fig.10). These vegetable matters, in particular those from Chinese lantern, have been described as green fertilizers in some ethnographies of Oceanic

atoll societies. For instance, the leaves stripped by hand from Chinese lantern are tramped in planting beds of agricultural pits in Pukapuka Atoll of the Northern Cook Islands (Beaglehole & Beaglehole, 1938:89).

Our archaeological evidence indicates that the pit agriculture landscape, consisting mainly of remarkable undulation and rich vegetation, was artificially constructed around 1,800 BP and probably has been maintained until the present without any destruction by subsequent natural catastrophes or human activities. What agencies would be associated with the invention of this long-lasting landscape of pit agriculture on an atoll islet? We would have to consider the hydrogeologic and culture-historical factors at least.

##### 4.1 Hydrogeologic characteristics of Laura

Because the freshwater sits atop saline water permeating the porous underground of the islets, its quality and volume is affected by tidal and seasonal fluctuations in the water table that cause diffusion between fresh and saline water. Its magnitude is inversely proportional to the width and size of the islets (Tracey *et al.*, 1961).

The permeability of underground sediments is more crucial to the fluctuation of water lenses. According to a hydrogeologic investigation, the near-surface lithological framework beneath Laura comes in two primary hydrologic units (Anthony *et al.*, 1989). The lower represents a lagoonward-dipping unit that was sub-aerially exposed and leached during a Pleistocene glacial lowstand sea level. The upper unit is 'an uncemented grainstone composed of a heterogeneous

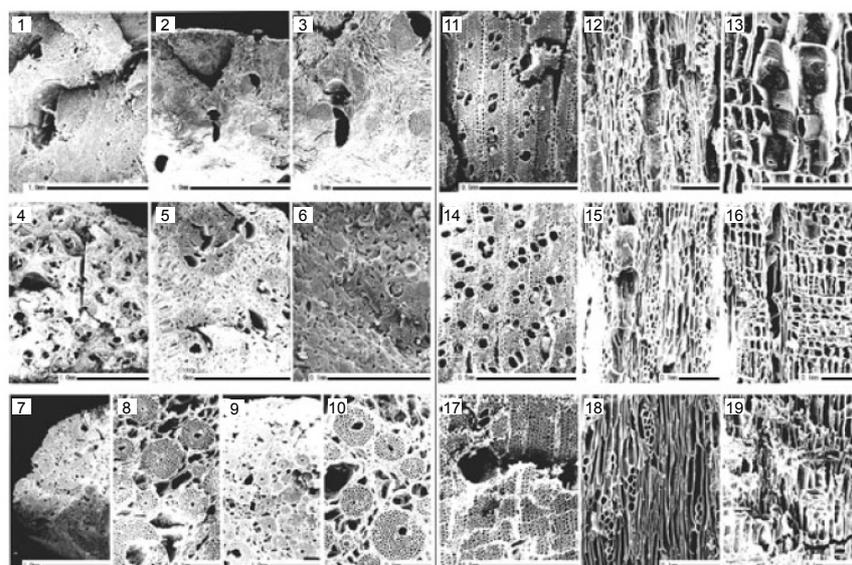


Fig. 10 Identified charred woods from site MJ-Lr2-8.

1: *Pandanus* nut (cross grain); 2: *Pandanus* nut? (cut end); 3: enlarged no.2 (cut end); 4: Monocotyledon (cut end); 5: Monocotyledon (cut end); 6: *Cocos* nut? (cut end); 7: *Cocos* trunk? (cut end); 8: enlarged no.7 (cut end); 9: *Cocos* trunk? (cut end); 10: enlarged no.9 (cut end); 11: *Cordia* (cut end); 12: *Cordia* (cross grain); 13: *Cordia* (straight grain); 14: *Cordia* (cut end); 15: *Cordia* (cross grain); 16: *Cordia* (straight grain); 17: *Hernandia* (cut end); 18: *Hernandia* (cross grain); 19: *Hernandia* (straight grain).

mixture of moderately well-sorted, foraminifera sand and fragments of coralline algae' (ibid.:1068), while its lower part contains a relatively higher abundance of silt. This unconsolidated unit is markedly less permeable than the leached Pleistocene limestone and the coral sequence of the Holocene reef that are more porous or have cavities (Marshall & Jacobson, 1985; Anthony *et al.*, 1989).

Drillholes on Laura have revealed that the upper unit of fine sand was *ca.* 25 m thick on the lagoonward edge and 16 m even inland. The sand's lower permeability and its thickness and width would prevent saline water from moving upward or inward into the freshwater lens. While the sedimentary process remain a matter of geomorphological speculation, it is probably the accumulation of this foraminifera sand, along with rich precipitation averaging *ca.* 3,500 mm in annual rainfall, which provides Laura the comparatively larger freshwater lens that has sustained its vegetation and in particular the growth of *Cyrtosperma* in the agricultural pits.

#### 4.2 Transported knowledge of manipulating hydromorphic terrain

The fortuitous hydrogeologic conditions are not, however, sufficient for pit agriculture landscape to have been invented on Laura. The people would have needed knowledge on how to manipulate hydromorphic terrain in such a subtle way.

As with most languages in the Caroline and Kiribati islands, all of those spoken throughout the Marshall Islands belong to Nuclear Micronesian, one of the Proto-Oceanic subgroups that are closely correlated with the eastward expansion of the Lapita cultural complex occurring around 3,500 BP in the vicinity of the Bismarck Archipelago. Archaeological excavations on three high islands in central Micronesia – Chuuk, Pohnpei and Kosrae – have revealed sand-tempered plain-ware potsherds relating to the period around 2,000 BP. Their attributes in form and technology have been pointed out to bear a resemblance to the late Lapita Plain Ware pottery tradition that extended from the Bismarcks westwards as far as the Reef-Santa Cruz Islands eastwards after 2,500 BP (*e.g.*, Athens, 1990:29).

Both linguistic and archaeological evidences, therefore, strongly indicate that the Marshall Islands would have been colonized not from the west but the south, probably somewhere from the southeast Solomon-Vanuatu region (Intoh, 1997:22; Kirch, 2000:175). A recent archaeological excavation on Nikunau, a reef island in the Kiribati, has also revealed two early earth ovens dating approximately to 2,000 BP (Di Piazza, 1999). This evidence might suggest direct or indirect colonization of the Marshalls from the south (see Fig.2). At any rate, Oceanic islanders moved northward from Melanesia and they consequently discovered around 2,000 BP the just emerged islets of remote atolls in Eastern Micronesia

as well as high islands in Central Micronesia. There is little doubt that Laura was one of these islets.

Although it would be worthwhile to study whether the Lapita people had practiced irrigation in Melanesia, they probably cultivated both species of taro – *Colocasia* and *Cyrtosperma* – at least 'in naturally swampy swales behind the beach terraces where they made their homes' (Kirch, 1997:211; see also Kirch & Lepofsky, 1993)<sup>[2]</sup>. It would thus be plausible that one of their groups transported to Laura the idea of cultivating swamp taro on hydromorphic terrain, from which the later landscape modification would have been derived for their deliberate exploitation of rich freshwater resources.

### 5. Conclusions – Prehistoric Interaction between Natural and Human Agencies –

Our excavation on Laura, Majuro Atoll, in the Marshall Islands, has revealed that its earliest colonization dates back to 2,000 BP and the agricultural pit was constructed some centuries later. The earliest colonists on Laura would have been one of first groups who could discovered atoll islets in Oceania, as their subaerial landform would have emerged after the relative fall of the late Holocene sea level, the timing of which is surprisingly estimated around 2,000 BP. Beneath Laura, however, had accumulated low-permeable thick sediments of foraminiferal sand, extending down more than 16 m. These lagoonal facies have advanced the occurrence and the enlargement of the freshwater lens, which would have been a crucial condition for human subsistence.

The people on Laura may have cultivated wet taro, probably *Cyrtosperma*, in low-lying natural swamps on the basis of their own knowledge transported from the late Lapita cultural tradition. At least some centuries later, they deliberately constructed agricultural pits to explore the rich freshwater resource and probably planted on the spoil banks tall trees of Pacific rosewood (*Cordia* spp.) and Chinese lantern (*Hernandia* spp.) as well as pandanus and coconut trees, the organic matters of which would have been also used as green fertilizers. The comprehensive interpretation which is obvious from the synthesis of various evidences is that the pit agriculture landscape, which we can see on Laura at present, is the historical product of interaction or entanglement between agencies both natural and human.

What is interesting is also that this landscape has existed for a long time, more than 1,800 years. This fact appears to bear out the relative stability of Laura against natural catastrophes. It appears that atoll islets are considerably weaker than high islands with regard to rising sea level and climatic fluctuation, but there is also variety to their vulnerability. A report that some 4,000 residents living in the city relocated themselves to Laura when storm surges from Hurricane Alice inundated the eastern part of Majuro in 1979

(Spennemann, 1998) also seems to suggest this. The present pit agriculture landscape, comprising remarkable undulation and rich vegetation, can therefore be viewed as a historical indication of islets with good conditions in aspects of both land formation and human subsistence.

## Notes

- [1] The earliest radiocarbon age from the Bikini Atoll is 3,450±60 BP (Streck, 1990). Judging from the timing of the relative sea-level fall in the mid-Holocene and the formative process of subaerial landforms on which the Oceanic islanders settled, however, the age is highly dubious and seems to be from long-lived organic matter or old material from driftlogs (e.g. Kirch & Weisler, 1994:292).
- [2] The topic on the origin and development of Oceanic irrigation systems seems to be related to a semantic aspect of 'irrigation.' If this term embraces all forms of 'wetland' agriculture from the use of naturally swampy areas to true systems of irrigation such as a pondfield (Spriggs, 1990:175), our evidence from Laura supports the view that the Lapita people would have had knowledge of 'irrigation.'

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