3. Archaeobotany in the Wallacea region and beyond

Chapter 3 describes existing archaeobotanical information for Island Southeast Asia relevant to this study. Information from adjacent areas of Mainland Southeast Asia, eastern Asia and New Guinea is also discussed, especially when it helps in understanding the data gathered in this project.

Recovering, identifying and interpreting plant remains from archaeological sites – most of what archaeobotany is about – has the potential to elucidate the history of relations between communities and their surrounding environments. Over the last few years, the study of archaeobotany has developed from being a set of methodologies and techniques, aimed at essentially providing archaeologists with an additional tool for palaeoeconomic and palaeoenvironmental reconstructions, to becoming a discipline in its own right with a proper philosophy of knowledge that seeks to comprehend those relations through time in a more holistic way.

Different plants and different parts of plants preserve differentially in the archaeological record, and the discipline has today various methods to tackle this problem. Some of those methods, such as pollen analysis or the analysis of macro charcoal remains, go a long way back in archaeology to the second half of the nineteenth and first half of the twentieth centuries (Renfrew 1973:1-6; Pearsall 2000). Others, such as phytolith and diatom studies, the isotopic analysis of human bones, or the use of entomology to research past climate change and vegetation, are more recent approaches that also allow for the recovery of information on past human-plant interactions (Wilkinson and Stevens 2003).

The wide range of disciplinary approaches in archaeobotany today, its global scale, and the long history of some of its applications, have produced a significant amount of information. Since a comprehensive description of that work is beyond the scope of this research, it is necessary to narrow the background information down, both within the geographic area of interest and in its relevance for the present study. Paz recently presented a listing of archaeological projects in Island Southeast Asia, within which archaeobotanical work had been undertaken (Paz 2001:52-58). As the present study aims at detailing the history of plant food production in East Timor, relevant archaeobotanical data on food plants from excavated sites are also given here. This will be done in a more comprehensive way for the whole of Island

Southeast Asia. As to the nearby regions, description will focus on food plants of interest to the current research. The methods of recovery, analysis and identification of plant remains from the sites described, as well as the methods through which identifications were obtained – macrobotanical analysis of charred, waterlogged or desiccated remains, pollen, phytolith, diatoms or other – are also referred to.

East Timor has long been at the crossroads between two major botanical "worlds": Southeast Asia and the Australasian region. Since many plants used as food resources there are expected to have originated in either Asia or New Guinea, these will be used as the main geographic boundaries. The staples introduced from Europe, the Americas or elsewhere after the first European contacts in the sixteenth century, are obvious exceptions to this pattern. Historical and archaeobotanical information for those introductions, where available, is also given.

3.1 Archaeobotany in Wallacea: Glover sets the tone

It is a matter of fortune that recovery of plant remains from archaeological sites in the Wallacean part of Island Southeast Asia began properly in East Timor, with Ian Glover's doctoral research in the 1960s (Glover 1972). Before that, information on plant material that resulted from archaeological work was sporadic and poorly documented, such as the remains of *Aleurites moluccana* reported by Bühler at Nikiniki (Sarasin 1936:9). As Paz aptly noted (2001:54), Glover pioneered the application of archaeobotanical methods in this region, initially in the 1960s in East Timor (Glover 1972, 1979, 1986), and later in the 1970s in South Sulawesi (Glover 1977, 1979).

As outlined in the previous chapter, Glover's investigations in East Timor involved a program of excavations in different caves and rockshelters. For the first time in Island Southeast Asia, systematic recovery of plant macrofossil remains was undertaken, using a system of double dry-sieving through 3 and 6 millimetres mesh sieves (Glover 1972: 65). The use of such large meshes and the fact that no flotation method was applied, probably accounts for only larger fragments being retrieved.

Tables 3.1, 3.2, 3.3 and 3.4 in appendix 9 list the plant remains and their identification status from the 4 major sites excavated by Glover (Bui Ceri Uato, Lie Siri, Uai Bobo 1, and Uai Bobo 2). These identifications were obtained by Douglas Yen, P. van Royen and H. St. John, from the Bishop Museum in Hawaii (Glover 1986: 229-230). The corresponding radiocarbon dates are given once more in association with the identifications, in order to provide an easier reading of the latter. The “mid-point in years BP” column represents Glover’s estimated antiquity of excavated horizons, based on the available radiocarbon dates, the “depth of deposit and the time period over which it has accumulated” (Glover 1986:29).

In 1969, together with Mulvaney and Soejono (1970), Glover undertook his first field survey in the Maros District of South Sulawesi, in Indonesia (Glover 1976, 1977, 1979). This Australian-Indonesian project located and test excavated several sites; however, detailed information is only available for three of them. Tables 3.5 and 3.6 with identified species from two of them (Batu Ejaya 2 and Ulu Leang 1) are given in appendix 10.

Leang Burung 1 was excavated by Mulvaney and Soejono that year (1970:169-171). The archaeological plant remains recovered from this site were analysed by Paz (2004) and are discussed in the following section. Batu Ejaya 2 was also excavated in 1969 by Mulvaney & Soejono (1970a, 1970b), and the archaeobotanical assemblage recovered has been analysed by McConnell, who described it as essentially modern in age (Di Lello 1997:175).

Ulu Leang 1 was initially excavated by Glover in 1969, and is of particular significance (Glover 1976, 1977). The 1973 excavation season, the second from a total of three at Ulu Leang 1, is noteworthy since this was the first time in Island Southeast Asia that a flotation procedure (together with wet-sieving) was used for the specific purpose of recovering archaeological plant remains (Glover 1979:19). The method used involved a froth flotation unit (Glover 1976:118). The provisional list of plant remains[1] was identified at the Herbarium of the Royal Botanic Gardens, Kew, in England. Evidence of rice (*Oryza sativa*) was identified by T.T. Chang, from the International Rice Research Institute in the Philippines (Glover 1979:24).

Ulu Leang’s occupation spans from around 11,000 to 3500 years ago, but no indication is given as to when within the sequence the plant remains appear. Rice remains (in the form of carbonised grains and husks) from a hearth at Ulu Leang 1 were initially thought to be dated from approximately 6000 BP, based on an overlying radiocarbon date within that range. However, another date of about 2000 BP from close to the hearth suggests some level of disturbance not previously observed (Glover 1979:24; Glover and Higham 1996:437).

The 1979 publication of Ulu Leang 1 is also significant, as it was the first time that a SEM photograph of an archaeological plant specimen (the silica skeleton of a hull from *Oryza sativa*)

[1] According to Glover, plant remains from Ulu Leang 1 and Leang Burung 2 were later sent to the Rijksherbarium, in Holland, from where they seem to have disappeared (Glover pers. comm.).

was ever published for this part of the world (Glover 1979:23). Unfortunately, none of the other determinations, from this or the sites in East Timor, are supported by SEM evidence. This should be a common procedure for positive identifications of archaeological plant specimens, although it has not always been done in Southeast Asia.

Glover's later work in South Sulawesi, in 1975, included the excavation of another cave site, Leang Burung 2. In this case, however, only dry-sieving was used and no analysis of the recovered archaeobotanical assemblage was undertaken (Glover 1981; but see footnote from previous page).

As Glover (1979:11) noted, the suggestion by Sauer (1952) that Southeast Asia could be the place of origin for some of the world's earliest agriculture, triggered a debate that led archaeologists in this region (Glover himself included) to devote more attention to the recovery of plant remains from archaeological sites. Apart from Glover's excavations and Gorman's pioneer work in Thailand (referred to below), the 1970s also saw several archaeologists in the Philippines recovering archaeobotanical assemblages from their excavations. A list of these was recently given by Paz and includes the sites of Mangahan in Zambales, Kalatagan in Batangas, and Ille cave in El Nido, Palawan. Unfortunately, none of these assemblages were ever analysed (Paz 2001:53).

Between 1979 and 1981, researchers working within the Tanjay archaeological project test excavated a few sites on the island of Negros in the Philippines (Hutterer and Macdonald 1982:174). At one of these sites, Edjek, four sediment samples from a hearth dated to about 595 ± 80 BP (678 – 507 cal BP) were floated, using a kitchen strainer with a 2 millimetre mesh sieve (Hutterer and Macdonald 1981:220). Identifications of *Cocos nucifera* and a monocot (possibly bamboo or a palm), done by Hoffman, were obtained using a low-powered (10 to 30 magnification) microscope. A small grass seed was identified as possible *Oryza* sp., although preservation was not good enough for a positive identification (Hutterer and Macdonald 1981:221). Also within this project, modern plant specimens were recovered and a reference collection initiated (Hoffman and Lucagbo 1982). However, as noted by Paz (2001:52), there was no follow up and collected specimens were never processed.

In the late 1970s, the Victoria Archaeological Survey undertook several field seasons on Panay Island, in the Philippines. The recovery of plant remains and other small cultural materials from archaeological sites there was in the initial research design, and all excavated sediment was dry-sieved using 1 and 2 millimetre mesh sieves (Coutts 1983:10). Flotation was initiated with the purpose of recovering seeds and other charred material; however, after analysing about 10 per cent of floated samples, results were negative and the process was abandoned (Coutts 1983:19). A small ethnobotanical study was also undertaken within this project, and a list of modern edible plants from around the site is given as an appendix to the final 1983 publication (Coutts 1983:189-191).

In 1981, Bodner initiated her doctoral dissertation on the evolution of agriculture in central Bontoc (Luzon), in the Philippines (Bodner 1986). The investigation of two sites there, Lubuk and Bekes, involved excavations and dry-sieving of all sediment through 6.35 millimetre mesh sieves, as well as the recovery of 12 and 44 10-litre soil samples from each site, respectively. This was done for flotation purposes, and additional samples were recovered for pollen and phytolith analysis (Bodner 1986:236). After being floated (using a 0.42 millimetre mesh), the recovered assemblages were dried and screened through a 2 millimetre sieve, with separation of the larger fragments into wood and non-wood fractions done with the use of a bifocal low-powered microscope (Bodner 1986:300). Macrobotanical remains of non-wood fragments from both sites were identified by Yen within different degrees of confidence, and include various seeds, fruits, legumes, and cereals. These are given in tables 3.7 and 3.8 in appendix 10.

The main occupational layer at Lubuk was dated to 450 ± 50 BP (552 – 426 cal BP), and most plant identifications come from within this layer. The only occupation layer at Bekes was dated to 1390 ± 60 BP (1404 – 1226 cal BP). Both Lubuk and Bekes document a stage of agricultural development in Central Bontoc, from approximately 600 to 1400 AD. Rice is not present in either of the two archaeobotanical assemblages (a small rice fragment recovered was considered a modern intrusion), and evidence for its presence in the phytolith record is elusive. According to Bodner, “oral tradition, ritual practices, and lexical data from nearby groups suggest a pre-rice agricultural economy based on the dry cultivation of millet, sorghum, Job’s tears, grain legumes, and root crops, and the pond-field cultivation of taro” (Bodner 1986:466).

An ethnobotanical survey around these sites involved the collection of plant vouchers from 200 modern specimens. Despite this, wood charcoal was not identified, as the modern material for comparative purposes was never processed (Bodner 1986:300). Analysis of phytoliths at both sites was also conducted and is discussed below.

In 1988, Bacus initiated fieldwork in Negros Island, in the Philippines, where two sites Unto and Yap were excavated (Bacus 1996, 1997). All sediment from these two sites was dry-sieved through 6.35 millimetre mesh sieves, and flotation and phytolith samples were recovered from every feature or cultural layer (Bacus 1997:111). The recovered samples for archaeobotanical analysis were later analysed by Paz (2001) as part of his own doctoral dissertation, and are presented in appendix 13.

The sites of Osmeña Park and Santiago Church are located in the town of Tanjay, Negros Islands (Philippines). They span from the early first millennium AD to the mid- second millennium AD. Santiago Church was excavated by Junker between 1981 and 1986 (Junker 1993:150). Junker reports that fine screening and flotation of sediments from all excavated features at Santiago Church were undertaken. Few charred plant materials were recovered, and the author believes this was due to post-depositional taphonomic factors (Junker 1993:182, 183). In 1995, excavations were undertaken at Osmeña Park, and a new suite of macrobotanical remains was recovered.

Charred plant materials from both sites were analysed by Gunn within her doctoral dissertation. These include 148 flotation samples from the 1995 Osmeña Park excavation, as well as 70 flotation samples from the 1985-86 excavation at Santiago Church (Gunn 1997:231). Tables 3.9 and 3.10 in appendix 11 present the identified seeds from both sites. These were only obtained at family and genus levels, and based mainly on Martin and Barkley (1961). No scale of confidence is given.

The Utti Batue site, in Luwu, South Sulawesi (Indonesia), was test-excavated in 1997 by Bulbeck *et al.* (2007). It was occupied between approximately AD 1400 and AD 1600, and most excavated spits contained significant amounts of charred macrobotanical remains. Apart from fragments of *Canarium* sp. and *Cocos nucifera* nutshells, however, no other identifications were attempted (Bulbeck et al. 2007:127). According to Bulbeck (pers. comm.), Utti Batue was waterlogged and water had to be continually pumped out. Sieving was difficult and plant remains were recovered by hand during the excavation.

Apart from macrobotanical remains directly recovered from archaeological sites, the analysis of pottery may also result in the identification of relevant food plants. Such is the case with rice, which does not always preserve in the excavated sediment matrix but is sometimes embedded in pottery as temper. In this region, two examples came from excavations in the Philippines: Andarayan, in northern Luzon, and the Unto site previously referred to.

Andarayan, in the Cagayan Valley, was excavated by Shutler in 1978. Snow *et al*. (1986:5) reported several carbonized inclusions of rice husks and stem parts in earthenware, one of which was AMS dated to 3400 ± 125 uncal BP (3933 – 3380 cal BP). Another conventional radiocarbon date from the same layer returned a 3240 ± 160 uncal BP (3874 – 3062 cal BP) determination (Snow *et al*. 1986:3). At Unto, in Negros Island, rice was tentatively identified by Ford, from the University of Michigan, in the form of husk impressions in earthenware sherds (Bacus1997:128). These were recovered from layers dated to approximately 2000 uncal BP (Bacus 1997:114).

In 1992 a team from the University of Hawaii located and surveyed Labarisi Cave (Buru Island) and Batususu Rockshelter (Ambon Island), both located in Maluku, Indonesia (Stark and Latinis 1992). Information recovered from both sites was used in Stark's PhD dissertation (Stark 1995). At Batususu Rockshelter remains of *Canarium indicum* nutshell were identified in layers dated to ca. 850 BP, while in layers from ca. 350 BP from Labarisi Cave plant remains identified included *C. indicum*, *C. lamii*, *Pangium edule* and *Diospyros* sp. (Stark and Latinis 1996:60-61).

Information on food plants in this part of Island Southeast Asia also includes that obtained through phytoliths, diatoms, and starch grains, as well as the analysis of pollen on sediment samples from cultural and non-cultural sites. The study of phytoliths, in particular, has made substantial progress in the last few years, whether through extensive, quantitative studies (Pearsall, in Bodner 1986), or quick scans in order to detect the range and presence/absence of diagnostic taxa (Bowdery 1999; Bowdery pers. comm.). Its use in archaeology has gone beyond addressing vegetation and climate change, to incorporate dietary and food production issues. Chapter 9 will address the importance of phytolith analysis in identifying plant species that are less frequent or do not preserve in macrobotanical assemblages in East Timor.

Phytolith analysis on recovered soil samples from Lubuk and Bekes was conducted by Pearsall, and revealed the possible presence of some cereal types at both sites. However, the identification of rice phytoliths remains uncertain, and Pearsall considers that "there is no evidence to support the presence of rice at the sites" (Pearsall, in Bodner 1986:574).

Bowdery (pers. comm.) has analysed phytoliths in sediment samples from archaeological sites in several Indonesian islands. At Golo, in Gebe Island, Bowdery determined an intermittent occupation throughout approximately the last 30,000 years by analysing changes in vegetation through time. At Banda Naira, in Maluku, high percentages of *Myristica fragrans* phytoliths suggest that orchards of nutmeg were well established there before the arrival of the first European colonizers. And at the Utti Batue site, in South Sulawesi, phytolith analysis confirmed that *Metroxylon sagu* was part of the landscape during the site's period of occupation (ca. 1400 to 1600 AD). Bulbeck had also suggested that sago was the main food resource at this site (Bulbeck *et al.* 2007:137).

Palynological research in this region and in the rest of Island and Mainland Southeast Asia has focused on non-cultural sites, and aimed particularly at palaenvironmental reconstructions (see Maloney 1996 for a Southeast Asian bibliography; Maloney 1992 and Gremmen 1987 for reviews). One possible reason for this focus has to do with preservation: ancient pollen preserves better in open sites and such archaeological sites are not so common in the region. Caves and rockshelters are the predominant sites investigated in Island Southeast Asia, and pollen does not always preserve well in caves, especially if they are located in dry or semi-dry environments (Dimbleby 1985:130; but see Burney and Burney 1993 and Navarro *et al*. 2001). An example of pollen investigations from an archaeological site in this region is the work carried out by Nishimura at Cebu City, in the island of Cebu, Philippines. (Nishimura 1992 unpublished PhD cited in Gunn 1997:74).

The recovery, analysis, and identification of plant remains from archaeological sites in the Wallacean part of Island Southeast Asia have not always been carried out in a systematic manner. Despite Glover's initial effort, only a few investigations since then contemplated an archaeobotanical component in their research design. Even if sediment samples were wet or dry-sieved, and flotation methods were employed, recovered assemblages have not always been analysed or comprehensively published. In this region, it is still often the case that it takes an archaeobotanist to do the job – at least systematically –including recovering, sorting, identifying, interpreting, and publishing plant assemblages from archaeological contexts. This is precisely what Paz has been doing in northern Wallacea for the past 10 years, and the following section deals with his work in more detail.

3.1.1 The works of Victor Paz

Paz is the first local trained archaeobotanist in Island Southeast Asia, and he has pioneered the application of modern archaeobotanical criteria in the region. As part of his doctoral dissertation, Paz (2001) excavated a few sites in the northern Philippines and analysed macrobotanical plant remains recovered by other archaeologists working in this region, using archaeobotany to address the issue of Austronesian origins and dispersal. Looking for a "botanical indicator of human movement" (Paz 1999:152) in northern Wallacea, and assuming that the domesticated yam *Dioscorea alata* originated in Mainland Southeast Asia and is a human translocation into Island Southeast Asia, Paz's work aimed at identifying and dating this species in the archaeological record (Paz 2005:114). Paz also looked at whether there was a direct correlation between the first introduced pottery in northern Wallacea and cereal agriculture (Paz 2001:49-50), in order to investigate processes of cultural transformation within the Neolithic in the region

The sites directly investigated by Paz and those excavated by others whose macrobotanical remains were given to him for analysis are located in the northern Wallacea region and span the last 4000 years or so. A list of those sites is given below, with a short description of the archaeobotanical work carried out at each of them. In those cases found relevant to the current study, tables of identified species are also given. The determination system and different levels of confidence used by Paz (2005:71) to identify plant remains are referred to in chapter 5 (and given in appendices 19 and 20), and have also been adopted in the current study.

The 1998 excavations at the Racuaydi settlement site, in the Batanes (Philippines), were directed by Paz, and flotation and wet-sieving were undertaken (Paz 2001:185). Although no radiocarbon dates are available, the site's occupation is thought to have spanned from the 10th century AD to the 17/18th century AD (Paz 2001:188-189). A suite of seeds, nut fragments, and non-domesticated tuber remains was determined and these are presented in table 3.11 in appendix 13. No evidence of rice or any other cereals was found, although taphonomic conditions were considered conducive to their preservation (Paz 2001:189).

Ivana Holiday Camp is another open-air site located in the Batanes whose excavation was conducted by Paz. Again no rice remains were found, and the few significant plants recovered came from layer 9. These were described as "fragments of hard seed-shell, fragmented seeds of cereal type, waterlogged wood and a large waterlogged seed" (Paz 2001:195). The only radiocarbon date available for Ivana Holiday Camp also came from this layer, with a determination range of 1880 – 1620 cal BP (Paz 2001:199). Paz reported that no flotation or wet-sieving was done during excavations at this site. This was due to time constraints and because dry-sieving proved to be an adequate method for recovering the few preserved plant remains (Paz 2001:195). This was also the only site at which analysis of phytoliths from recovered samples was attempted, although with poor results: no evidence of rice, scarce evidence of a palm species, Cyperaceae, and grass-type phytoliths, also within the same radiocarbon dated layer (Paz 2001:196).

The Mabangog cave site, in the Cagayan Province of Luzon (Philippines), was jointly excavated in 1997 by Hidefumi Ogawa, from Tokyo University, and a team of the National Museum of the Philippines (Ogawa 1998). Manually floated samples were collected from each layer excavated in squares 8 and 17. These were dried and stored, and later loaned to Paz for analysis (Paz

2001:200). Different types of macrobotanical remains were recovered from both squares, although square 8 contained many untransformed seeds through the entire sequence. Those seeds were interpreted as the result of vertical displacement caused by post-depositional disturbances (Paz 2001:205).

The only available (AMS) radiocarbon date for this site is from layer 2 in square 10, just above bedrock. It gave an age determination of 7790 ± 40 uncal BP (8637 – 8455 cal BP) (Paz 2001:204). This date comes from a pottery layer and is much earlier than those from similar layers in the neighbouring Magapit shell middens, indeed than any pottery site in Island Southeast Asia, and both Ogawa and Paz are cautious about accepting this as the age of the site. Paz suggests that the presence in the same layer (but in square 17) of *Phyllanthus amarus*, a species of probable South American origins, either indicates that the deposit has suffered from some degree of disturbance, or that the species is native to Southeast Asia (Paz 2001:204). Paz also notes that although no food plants were identified, analysis of the archaeobotanical assemblage from Mabangog was important as a way to crosscheck the site's stratigraphic integrity (Paz 2001:205). A list of all plant species identified at Mabangog is given in table 3.12 in appendix 12.

The Capiña and Miguel Supnet shell middens, also located in the Cagayan Province of Luzon, were excavated in 1998 by Tsang, from the Academia Sinica in Taipei. Archaeobotanical samples were directly recovered by Paz from both sites (Paz 2001:204). At Capiña, 50 litres of sediment per context were sampled through manual flotation and wet-sieving (Paz 2001:207, 208), in a process very similar to that used in the present study. Because the method aimed specifically at recovering evidence of charred parenchyma and rice, the total amount of charred plant remains recovered was not significant (Paz 2001:209). Two radiocarbon determinations were obtained at Capiña, dating its earliest occupation to approximately 5890 – 4870 cal BP (Paz 2001:212). A list of identified macrobotanical remains from this site, including the few parenchyma fragments (all smaller than 4 millimetres), is presented in table 3.13 in appendix 13. Other unidentified fragments of parenchyma and nutshell were also recovered at Capiña but are not listed.

As Paz points out, the sampling and recovery strategies used at Miguel Supnet shell midden benefited from the experience accumulated from the previous work at Capiña (Paz 2001:212). Again 50 litres of sediment per context were collected, but this time from the profiles of two squares left open after the excavation had finished (Paz 2001:212). Flotation of all these samples was also undertaken; however, the resulting light fractions were sorted a first time at the University of the Philippines, and a second time at the Pitt-Rivers laboratory, at Cambridge University, using a bifocal epiluminescent microscope (Paz 2001:212). The samples were described as rich in macrobotanical remains, with many plant types identified to different levels of confidence, including seeds, nuts, and root crops. Paz notes that parenchyma fragments were recovered from most sampled layers (Paz 2001:213). No evidence of rice or any other cereals was found at the Supnet shell midden, and Paz believes this is not related to taphonomic processes since preservation of charred plant remains at this site is significant, both in quantity and diversity (Paz 2001:217). Although most samples analysed are bracketed by several radiocarbon determinations, ranging from 6210 to 4510 cal BP, they also contained untransformed seeds, which suggests that some level of contamination occurred (Paz 2001:217). A list of identified macrobotanical remains is presented in table 3.14 in appendix 13. Paz's original table with identifications from this site (Paz 2001:215,216) presents various unidentified seeds and their general shape, as well as unidentified nutshells, however these are not included in the table given here.

In 1998, the National Museum of the Philippines undertook excavations at the Angono rockshelter, in southern Luzon, where Paz had the chance to collect a total of 82 litres of sediment from two squares (Paz 2001:221). Despite the considerable size of the samples subjected to manual flotation and wet-sieving, this site produced no archaeobotanical remains (Paz 2001:222).

The sites of Yap and Unto, in the island of Negros (Philippines), were excavated by Bacus between 1987 and 1997, within a broader research framework that involved investigating the development of complex societies in the Visayas. Fieldwork there resulted in the identification of more than 70 archaeological sites (Bacus 1997, 1999). The recovery of sediment samples through flotation was undertaken by Bacus and her team in the field, and later processed by Paz.

Yap was interpreted as an elite centre, whose occupation spanned from the 11th century A.D to the 15th/16th century AD (Bacus 1999:71). Four consistent radiocarbon dates were reported (Bacus 1996b) and these are given in appendix 13 together with the table of plant remains identified by Paz. Twenty-four samples (between 350 millilitres and 5 litres in size) from five different archaeological features were subject to manual flotation, and macrobotanical remains recovered with the use of a tea strainer (Paz 2001:226). Thirteen species in twelve different plant families were identified at Yap with different levels of confidence, and these are given in table 3.15 (appendix 13). Other unidentified seeds and nutshell fragments were also recovered (Paz 2001:227-228). No evidence of parenchyma, rice, or any other cereal macro remains was found at this site (Paz 2001:227-228). Since Bacus (1999:68) reported rice inclusions in local earthenware dated to the 11th century AD, Paz suggests that the absence of rice from the macrobotanical assemblage may not be the result of taphonomic processes or the size of recovered samples. Other smaller and more fragile seeds were recovered, and Paz believes that the absence of rice may instead reflect low consumption, and the fact that that it was not being domesticated or cultivated at Yap during this period (Paz 2001:230).

The Unto site, excavated within the same research framework, was interpreted as having had a secondary role, interacting with elite sites such as Yap (Bacus 1996, 1997 and 1999). At this site, 56 sediment samples were collected from 17 different archaeological features and layers through a similar flotation process, each sample varying between 10 and 0.5 litres of volume (Paz 2001:234). Paz identified 11 species within nine different botanical families to different confidence levels, including seeds, legumes, the periderm of a possible fruit, and parenchyma fragments (table 3.16 in appendix 13). Other unidentified seeds and nutshell fragments were also recovered (Paz 2001:236-237) but are not listed. A few contexts had untransformed seeds, possibly resulting from some level of disturbance. As with Yap, despite rice husk inclusions in pottery being reported (Bacus 1999:128), no macrobotanical remains of this species were found. Paz suggests that the same reasons invoked for Yap worked for its absence at Unto: low consumption and no domestication or cultivation (Paz 2001:237).

Madai 1 is part of a cave system with the same name, located in Sabah (Borneo). It is the only site among those investigated by Paz that is not located in the Wallacean region. However, it was decided to include it in this section as part of Paz's comprehensive archaeobotanical study. Between 1979 and 1980, excavations at three different loci within the cave system (Madai 1, 2, and 3) were undertaken by a team led by Bellwood and colleagues from the Sabah Museum (Bellwood 1988). Based on the radiometric sequence obtained, the Madai 1 periodisation spans the last 8000 years, with 13 archaeological layers distributed in four different periods (Bellwood 1988:102).

Archaeobotanical studies on this site started with Harris' attempt to extract plant residues from pottery. A preliminary report suggested the presence on some sherds of fatty acids from palm oil, coconut, nutmeg and cinnamon, as well as wood resin (Bellwood 1988:231). Unfortunately, this work has not been continued. The archaeobotanical assemblage analysed by Paz only refers to two periods of the site's occupation (Paz 2001:244). These were defined by Bellwood as the upper middle group, spanning from around 2200 to 1500 uncal BP, and the late group, from 500 uncal BP to the present (Bellwood 1988:108).

Paz analysed five different samples that had previously been dry-sieved and floated (Bellwood 1988:102), sorting the assemblage through sieves of 4, 2, and 1 millimetre meshes, and using a bi-focal epiluminescent low-powered microscope (Paz 2001:240). Paz reports that Madai 1 contained the largest amount of wood charcoal from all sites analysed. However, due to the lack of a comprehensive reference collection, no further work beyond sub-sampling (using a riffle box) and general quantification was attempted (Paz 2001:241).

Remains of parenchyma were identified, suggesting consumption of non-domesticated tubers (Paz 2001:245), as well as fruit fragments (including *Dracontomelon dao*, and possibly *Artocarpus* sp.), and other unidentified seeds. Paz also suggests that fruit remains of cf. Moraceae and cf. Fabaceae families, described as "distorted beyond identification" (Paz 2001:242), probably represented consumption of non-domesticated resources, as he was not able to match them confidently with any of the modern reference material (Paz 2001:245). No evidence of rice was found at this site, and again Paz believes that is not due to any taphonomic processes, but to the fact that the Madai 1 inhabitants were not producing it (Paz 2001:244, 245). Table 3.17 in appendix 13 presents all identified charred plant materials from this site.

Leang Burung 1 is a site already referred to, located in the Maros region, in Sulawesi (Indonesia), and excavated by a team led by Mulvaney and Soejono (1970, 1970b). Paz was given 35 samples that were dry-sieved from two excavation areas: trench A and trench B. Some of these materials had been previously analysed by Kathleen McConnell at the ANU (McConnell, in appendix to Di Lello 1997).

Samples were sorted through 2, 1, and 0.5 millimetre mesh sieves, and separated into different categories, including wood (which was not analysed), parenchyma, seeds, and nut fragments (Paz 2001:249). Seven genera and four species were identified, some of them (such as some of the tubers) to higher levels of confidence, and others to lower (the possible Pandanaceae). The legumes of the Fabaceae family present in various contexts were interpreted as non-domesticated or cultivated, as they did not match any of the domesticated specimens in the reference collection (Paz 2001:254, 255). No evidence of rice or any other cereal was found within the Leang Burung 1 macrobotanical assemblage (Paz 2001:253; Paz 2004).

According to Paz, identified charred materials from trench A (inside the shelter) are dated to between 3000 and 2000 BP while materials from square B (outside the shelter) are dated to between 5500 and 3500 BP (Paz 2004:191)[2]. ANU-391 corresponds to a date of 2820 ± 210 uncal BP (3444 – 2451 cal BP) obtained from samples recovered at 270 centimetres below surface in squares A3 (spit 16) and square A4 (spit15) (Mulvaney and Soejono 1970:171; see Ellen and Glover 1974:376 for a correction). Bulbeck *et al*. obtained five additional radiocarbon dates on collagen and apatite samples for this area, which presumably date a later phase of use between ca. 2000 and 1000 BP (Bulbeck *et al*. 2000:78). ANU-390 corresponds to a date of 3420 ± 400 uncal BP (4713 – 2761 cal BP) obtained from samples recovered at 150 centimetres below surface in square B3 (Mulvaney and Soejono 1970:171; Ellen and Glover 1974:376). Two other radiocarbon determinations for square B overlap with this one: ANU-1264, on charcoal, with a date of 4880 ± 480 uncal PB (6673 – 4383 cal BP); and ANU-6175, on apatite, with a date of 4610 ± 220 uncal BP (5759 – 4807 cal BP) (Bulbeck *et al*. 2000:78).

Tables 3.18 and 3.19 in appendix 13 list all identified charred plant materials in trenches A and B from Leang Burung 1. Paz's original tables (Paz 2001:252 and Paz 2004:198,199) present other unidentified charred plant materials, not listed.

More recently Paz and Carlos have analysed macrobotanical remains from Callao Cave, in Luzon (Philippines), in layers dated to 3650 – 3470 cal BP and identified seeds of *Boehmeria* cf. *platanifolia*, as well as parenchymatous tissues and charred remains of fruits, seeds and wood. Parr also conducted phytolith analysis on sediment samples from the same layers and identified remains of Poaceae, Cyperaceae, *Bambusa* sp. and Arecaceae (poss. *Cocos nucifera*) (Mijares 2006:135-137). Other caves investigated by Mijares in this region included Dalan Serkot Cave (3900 – 3690 cal BP) and Eme Cave (2010 – 1690 cal BP). At both these sites Paz and Carlos identified charred parenchymatous tissues and mineralised *Boehmeria* cf. *platanifolia* seeds (Mijares 2007:130-134).

The work carried out by Paz in Island Southeast Asia is original in more than one way. The whole project's research design focused on the recovery, identification, and interpretation of charred plant remains in order to address specific questions posed by the archaeological record. It also aimed at developing some key archaeobotanical methodologies. It involved, for example, the use of both morphological and anatomical criteria in the identification of charred

[2] According to Ian Glover, who was present during excavations at Leang Burung 1, this site had been previously disturbed, which could explain some discrepancies in the radiocarbon record (Glover pers. comm.).

parenchymatous tissues of roots and tubers. This was done using epiluminescent bi-focal and SEM microscopes, following a methodology initially developed by Hather (1991, 1994, and 2000). Moreover, Paz introduced relevant quantitative methods, by measuring features that may be diagnostic in the analysis and identification of specific plant species (Paz 2001:87-88).

In those sites excavated by Paz, comprehensive recovery techniques for macrobotanical remains were used, with manual/bucket flotation of at least 50 litres of sediment per archaeological context and wet-sieving (Paz 2001:54). He notes that of all the assemblages from sites he did not excavate, only Leang Burung 1, excavated by Mulvaney and Soejono (1970), was not floated and only subject to dry-sieving (Paz 2001:55). Paz also developed a regional collection of modern plant specimens from around the sites he excavated. He suggested that in the absence of a comprehensive collection of modern materials, matching the archaeological specimens with these should start from the archaeobotanical assemblages themselves and any local ethnobotanical data (Paz 2001:57). As previously referred to, this methodology has been adopted to some extent in the present study and will be described in the following chapter.

Paz experimented with the charring process of some modern reference specimens, examining both the condition of the samples (fresh or sun-dried), and the matrix used (sand, wood ash, or no matrix) (Paz 2001:85, 86). The results obtained and additional information given by the author (Paz pers. comm.), suggest that samples previously dried in a wood ash matrix allow for the best preservation of cellular tissue. This is so because it presumably replicates better the common charring process that specimens undergo archaeologically (Paz 2001:87). This charring practice of modern specimens was followed in the current research, and is also described in chapter 5.

There are various useful facets of the archaeological and archaeobotanical work that Paz has developed in the last decade. Not least, the focus on designing a research project where archaeobotany is seen as a direct line of investigation of the archaeological record, both as a methodological and empirical key tool, is of paramount value.

3.1.2 A short note on the ETAP project

Neither the excavations undertaken within the ETAP nor the more recent ones have had a major archaeobotanical component in their research design (O’Connor pers. comm.). Despite that, plant remains have been recovered from some of the archaeological sites investigated and were incorporated in the present study.

Since the ETAP begun, wet-sieving through a less than 2 millimetre mesh sieve has been the general practice (O'Connor *et al*. 2002:47; O'Connor 2007:528), and flotation was carried out at most sites (O'Connor 2007:529; O'Connor and Spriggs, pers. comm.). The flotation method usually involved filling plastic buckets with sediment and water, and the recovery of buoyant charred plant material done with a tea strainer (O'Connor and Spriggs, pers. comm.).

Very few of these sites investigated by ETAP (or later by O'Connor) in East Timor contained significant amounts of macrobotanical remains. From those where charred plant materials were recovered and are part of this study (Lene Hara, Telupunu, Macha Kuru 1 and 2, and Jerimalai), only Telupunu has a significant assemblage. Telupunu is also, together with BCUM and Glover's four main analysed sites, the only one in East Timor where charred plant remains are preserved throughout most of the stratigraphic sequence. As we shall see, in all other sites analysed charcoal is essentially preserved only in the uppermost layers. The specific methods used in the sites from which charred plant assemblages were recovered and that are part of this study, together with results from the analysis undertaken, are presented in the following chapters.

3.2 The rest of Island Southeast Asia

The part of Island Southeast Asia that belongs to the Sunda continental shelf has not seen as much archaeobotanical work as the Wallacea region. In reality, most existing information comes from analysis of plant remains in pottery sherds and from palynological studies.

Archaeological research on the use of plant materials in Taiwan has not been systematic and has focused mostly on tracing the origins of agriculture, especially rice. This may have in part resulted from early suggestions that Taiwan, as the putative centre of early Austronesian dispersal, could also responsible for the introduction of cereal agriculture into Island Southeast Asia. (see Bellwood 1980 for initial suggestion and also Bellwood 1978:422 on Austronesian dispersal and the origins of agriculture). Despite the amount of archaeological work carried out there in few years, very few archaeobotanical materials have so far been reported (Bellwood 2005). Until recently, in fact, claims for the presence of cereal agriculture in Taiwan around 3000 BC came mostly from indirect proxies, through pollen records and particular artefacts in archaeological assemblages (Bellwood 2006, 2005, 1995; Lin *et al*. 2007). However, the discovery of the open-air sites located within the Tainan Science-Based Industrial Park, in southwest Taiwan, have revived the discussion. At Nan-kuan-li, a few charred remains of *Oryza sativa*, together with remains of *Picrasma quassioides* and *Celtis sinensis* have been found in archaeological layers dated by radiocarbon to a period between 3000 and 2500 BC. In another *locus* of the same site designated Nan-kuan-li East, thousands of carbonised remains of millet, tentatively identified as *Setaria italica* were also recovered and dated to the same period (Tsang 2005:70-71). These finds represent the first direct macrobotanical evidence for cereal agriculture in Taiwan at this period in time.

The limestone cave of Gua Sireh, in Sarawak, was excavated in 1989 by Bellwood and Datan. Despite an initial phase of occupation in the Pleistocene, about 20,000 years ago, most of the deposit was built up during the mid- to late-Holocene (Datan and Bellwood 1991:394). A total of 21 pottery sherds with rice inclusions were found at this site, located in every archaeological level containing evidence of pottery (Bellwood and Datan 1991:387). Identification of rice remains was done by Gill Thompson at the ANU, and two of those remains were directly AMS dated. One rice husk in a pottery sherd from layer 3 (in square 89A), returned a 1480 ± 260 uncal BP (1953 – 906 cal BP) determination, and a whole rice grain in another sherd returned a date of 3850 ± 260 uncal BP (4891 – 3563 cal BP). Regarding the earliest date, the authors suggest that "together with ANU 7049 [3990 ± 230 uncal BP, 5052 – 3826 cal BP] and ANU 7045 [5290 ± 80 uncal BP, 6218 – 5916 cal BP] it makes a presence of rice in Gua Sireh at circa 4300 BP a certainty" (Bellwood and Datan 1991:393), although ANU 7045 is obviously very young. At the time of publication, Bellwood and Datan pointed out that it was not possible to say whether rice was grown locally or if the pottery had been brought into the site. New finds of charred rice husks used as pottery temper from Gua Sireh, however, confirmed initial suggestions that rice was present at this site around that early period in time (Doherty *et al*. 2000; but see Spriggs 1989:590-598).

Evidence of rice remains in pottery sherds has also been found in many other archaeological sites in Sarawak. Using a low-powered microscope (with 10 x 30 magnification), Doherty *et al*. were able to identify the presence of rice (or husk moulds) in pottery from 35 archaeological sites, ranging from 4000-3000 BP to 400 BP. According to the amount of rice found in each sherd, this was interpreted as either temper (large amounts), or used for cultural reasons or found there by accident (small amounts) (Doherty *et al*. 2000).

Amongst these finds by Doherty *et al*., one is of possible significant importance. At the West Mouth of Niah Cave, one rice husk mould has been identified in a sherd associated with a burial. This burial was dated to 4990 ± 90 BP (5913 – 5589 cal BP). The original determination was obtained on human bone, and although this was considered to have enough collagen to yield a reliable date (Brooks *et al*. 1977:28), there is no pottery of this age anywhere in Island Southeast Asia. Because the find was a mould and not an actual grain, it was not possible to obtain a direct date. Doherty *et al*. suggest that if this early date can be verified, it "pre-dates the Austronesian migrations into Southeast Asia which are generally considered responsible for the introduction of rice farming in Sarawak" (Doherty *et al*. 2000:150).

The recent reexcavation of the Niah site stands out in this part of Island Southeast Asia, in the sense that different archaeobotanical approaches have been used as direct and independent lines of investigation. A sediment column held evidence of pollen in layers dating to the Late Pleistocene, allowing for a local palaeoenvironmental reconstruction (Barker *et al*. 2007:255, Hunt *et al*. 2007, Hunt and Rushworth 2005). Besides pollen, other archaeobotanical materials included starch grains (Barton 2005), stable carbon isotopes of tooth enamel (Krigbaum 2005), and charred macro plant remains (Paz 2005). Identified starch grains from Pleistocene and early Holocene layers at Niah suggest consumption of wild tubers (*Alocasia* sp., possibly *Cyrtosperma merkusii*, and *Dioscorea* sp., possibly *D. alata*) and C*aryota mitis* or *Eugeissona* sp. palms (Barton 2005). Analysis of charred plant materials from the Hell Trench (in the West Mouth of Niah), whose occupation ranges from approximately 46,000 to 34,0000 years ago, included additional species. Identifications were done by Paz and comprise fragments of cf. *Colocasia* elim. *esculenta*, elim. Araceae, possibly Araceae, cf. *Dioscorea hispida*, prob. Moraceae (breadfruit family), *Pangium edule*, Fabaceae, Urticaceae and Apiaceae (Barker *et al*. 2007; Paz 2005).

Despite the above-mentioned research, most palynological investigation in Island Southeast Asia has focused on palaeoenvironmental reconstructions. Maloney conducted extensive palynological research both in Island and Mainland Southeast Asia, mostly of forest coverage and human impact on it (Maloney 1982, 1985, 1988 and 1992, amongst others). Two additional examples of palynological studies on food plants, both on and off archaeological sites are represented by Maloney's work on the origins of rice production in Sumatra, and his work on dating the human use of *Canarium* sp. (Maloney 1996c).

3.3 Mainland Southeast Asia and southern China

These two geographical areas have been grouped together, despite the fact that there may be differences in their individual histories of plant management throughout the Holocene. Since the last approximately 10,000 years, however, they would have represented the physical southern limits of what today is Mainland East and Southeast Asia. Any move East or South beyond there and into Island Southeast Asia would have thus involved a sea crossing of some kind. On the other hand, and based on the existing archaeobotanical evidence regarding cereal agriculture (i.e. rice and millets), they both seem to represent areas of spread rather than of origin (Bellwood 2005:127; but see Weber & Fuller in press).

The pioneer work of Chester Gorman marks the first use of modern archaeobotanical procedures in Mainland Southeast Asia. Gorman conducted fieldwork in Thailand in the 1960s and the 1970s aiming, amongst other things, at locating "Hoabinhian" cultural sites and at examining the hypothesis that this could have been a region of plant and animal domestications in the past (Gorman 1970:80). Gorman located and excavated several caves and rockshelters in Northwest Thailand. At Spirit Cave, a sequence was revealed dating back to the early Holocene (Gorman 1969, 1970, 1971). Dry-sieving of all excavated sediment with a 1 millimetre mesh sieve (Gorman 1970:92) was specifically used to test the hypothesis of a Southeast Asian centre for plant domestication (Sauer 1952 and 1969). It allowed for the recovery of a suite of charred plant remains dating back approximately to the last 10,000 years[3]. Most identifications were obtained by Yen and van Royen at the Bishop Museum in Hawaii (Gorman 1969:673). The samples came from cultural level 1, described as "Hoabinhian" based on its lithic component and grouping excavation layers 4, 3, 2a and 2. They are bracketed by a 9180 ± 360 uncal BP date (11,319 – 9466 cal BP) just below the surface of layer 4, and two dates of 8550 ± 200 uncal BP (10,163 – 9091 cal BP) from layer 2 and 8750 ± 140 uncal BP (10,182 – 9530 cal BP) from layer 2a. Later excavation at this site resulted in the identification of a further suite of species. These remains, however, have no associated radiocarbon dates and we can only presume that they are as old as the ones previously documented. All plant identifications from Spirit Cave are listed in table 3.20 in appendix 14.

Gorman pointed out that these identifications were only tentative, and because plants are subject to genetic changes through time, they "obviated the use of binomials" (Gorman

[3] According to Jean Kennedy, Gorman had a froth flotation machine at Spirit Cave but it never worked properly (Kennedy pers. comm.).

1969:673). However, a relevant point to retain from this study is the suggestion that along with most identified trees (that Gorman thinks were wild or possibly tended), the presence of several legumes point to a "very early use of domesticated plants" (Gorman 1969:163) in Mainland Southeast Asia. Yen, however, believes there is a much weaker argument for that if *Pisum* and *Vicia* spp. are interpreted as misidentifications (Yen 1977:594). The possible importance of the tree remains identified at Spirit Cave will be addressed in the final chapter.

As Yen noted, reactions to identifications of plant materials from Spirit Cave varied from caution (Flannery 1973:285) to open criticism (Harlan and de Wet 1973). Despite that, further work by Gorman in northwest Thailand resulted in the identification of similar assemblages, although of a younger age. Excavation of other sites there included Banyan Valley Cave (dated 5450 BP to 1250 BP) and Tham Pa Chan (dated 7450 BP to 5450 BP). The archaeobotanical assemblages from these sites, recovered through sieving, were also identified by Yen (1977) and are presented in tables 3.21 and 3.22 in appendix 13. The initial suggestion that rice could have been domesticated at Banyan Valley from a wild variety (Yen 1977:593) has now been dismissed (Higham and Lu 1998:872). Based on personal observations, Chang (1976:431) had already suggested that the rice remains from this site were more closely related to wild or weed races than to domesticated forms. An updated report on the results from Banyan Valley has meanwhile been published (Reynolds 1992).

Ban Chiang, in Northeast Thailand, was initially test-excavated in 1967 by the Thai Fine Arts Department. Later, in 1974 and 1975, a "multi-discipline, multi-national" team led by Gorman and Charoenwongsa (1976:16) initiated larger-scale excavations there. Although nothing is mentioned regarding the methods of recovering charred plant remains, Higham, who took part in the excavations, notes that all sediment was screened (Higham 1989:109)[4]. Yen was responsible for the identification of charred rice grains and husks, used as temper in pottery sherds recovered from this site, the earliest of which could date back to the mid-second millennium BC (Yen 1982:54). As Yen himself points out, the discovery of impressions of rice used as temper in pottery at Non Nok Tha, also in Northeast Thailand, excavated by Bayard and dated by this researcher back to about 5450 BP (Bayard 1970:135), was significant at the time as it helped trigger the debate about the origins of domesticated plants in this region (Yen 1982:51). However, Chang (1976:431) again suggested that the rice remains from Non Nok Tha

[4] According to Jean Kennedy who participated in excavations at Ban Chiang for 7 months, there was also a froth flotation machine at this site that did not work. According to Kennedy, most but not all sediment at this site was screened (Kennedy pers. comm.).

were more closely related to wild or weed races than to domesticated forms, and this site has since been ascribed a date between 3450 – 2950 BP (Higham 1996:31). After Gorman's death in 1981, work on the collections from Ban Chiang was continued by White, who had previously conducted ecological work in this region (White 1982).

Between 1977 and 1979, the Hoabinhian Research Project of Silpakorn University in Bangkok, led by Pookajorn, identified 3 cave sites near the village of Ban Kao, in Western Thailand. Small amounts of carbonised and calcified plant remains were recovered from these sites through dry-sieving. The identified macrobotanical remains, which are said to have come from layers spanning between 11,000 and 2500 BP (cf. Pyramarn 1989:282), are given in table 3.23 in appendix 15.

Between 1979 and 1980, the Khorat Basin Archaeological Project, involving the University of Hawaii and the Thai Fine Arts Department, conducted archaeological surveys near the town of Phimai, in northeastern Thailand. Two open sites were excavated: Non Ban Kham and Ban Tamyae (Welch 1983; Welch and McNeill 1988/89). Dry-sieving (with a 6 millimetre mesh sieve) and flotation (of 3-5 litre soil samples) were undertaken but very few plant remains recovered (Welch & McNeill 1988/89:103). Rice chaff and chaff impressions on pottery suggest this cereal was available and it was an important dietary element from around 1000 BP. However, as the authors themselves note, there is no proof that this was domesticated rice (Welch and McNeill 1988/89:115; see also Fuller *et al*. 2007, below).

In the early 1980s Higham and Kijngam conducted archaeological excavations at several sites on the Khorat Plateau of Northeast Thailand, including Ban Na Di, Non Kao Noi, Ban Muang Phruk, Ban Chiang Hian, Non Noi, and Ban Kho Noi (Higham and Kijngam 1984 i, ii and iii). According to the authors, the methodology for recovering plant remains from these sites involved dry-sieving one sample from each archaeological layer through a 1 millimetre mesh sieve (Higham and Kijngam 1984 i:23). At Ban Na Di, in particular, flotation was utilised in order to recover macrobotanical rice remains (Higham 1989:133), and these were reported by Chang & Loresto (1984 ii:384-385). They were interpreted as cultivated and are present throughout the site's stratigraphic sequence, dating back to approximately 3450 BP (Higham and Kijngam 1984 i:32).

The Lang Rongrien rockshelter, in south western Thailand, was first excavated in 1983. Although macrobotanical remains were recovered through dry-sieving (with 0.5 millimetre mesh sieves) and flotation, these were never fully analysed and published (Anderson 1990:8).

As the most comprehensive example of an archaeobotanical investigation in Thailand, Thompson's (1996) work at Khok Phanom Di remains an important case study for any apprentice archaeobotanist in the region. Thompson (1992) conducted her doctoral dissertation based on the 1985 field season at Khok Phanom Di, where recovery of plant remains was described as "an integral part of the excavation" (Thompson 1996:13). A mechanical system of flotation was employed, and charred and mineralised plant remains were also recovered directly from the excavation and through dry-sieving. These were then compared to a significant modern collection of reference specimens, which was gathered from around the site.

Thompson's work at Khok Phanom Di was admittedly focused on the recovery and identification of rice remains, and the initial suggestion that it might have been domesticated there in the 7th millennium BP (Thompson 1996:7). In 1985 Maloney had recovered two pollen cores from around this site. Samples from these cores were analysed by Kealhofer and Piperno, who suggested the existence of rice phytoliths in layers dated to 7000-8000 years ago (Thompson 1996:236). In his own research, Maloney also suggested that cultural burning (and possibly agriculture) was initiated around Khok Phanom Di approximately 7000 years ago (Maloney in Higham and Bannanurag 1991:93-94).

Thompson conducted analysis on the abundant wood charcoal assemblage from Khok Phanom Di, aiming to "estimate the relative density of charcoals through the profile, and to examine temporal changes in taxonomic composition" (Thompson 1996:37). Although a few taxa were identified, Thompson suggests that the results obtained allow limited palaeoenvironmental inferences (Thompson 1996:71). Work on seeds and other plant parts from this site was also conducted and a table (3.24) with ubiquity indices for identified seed classes is given in appendix 16.

Thompson's work set out to prove that archaeological plant remains did preserve in open sites in the Asian humid tropics. Although rice is said to be the only food plant at Khok Phanom Di, remains of it were only found in the form of husks used as pottery temper, as well as a few grains preserved in coprolites and "quantities of finely fragmented, ashed rice chaff" (Thompson 1996:155). They were all dated to approximately 4000 years ago (ANU 5483: 3430 ± 80, 3879 – 3478 cal BP). Khok Phanom Di has meanwhile been reinterpreted as a hunter-gatherer complex (Higham and Thosarat 2004).

Higham has conducted several other excavations across Thailand, including one at Nong Nor in the Gulf of Siam in 1991-93, which revealed a single occupational phase around 4500 BP.

Despite flotation and the good preservation of wood, no evidence of rice (as macro remains or used as pottery temper) was ever found at this site (Boyd *et al*. 1998). During excavations at Ban Lum Khao, in 1995 and 1996, mechanical flotation is said to have been employed and plant materials recovered by Thompson. However, no details of this work have been published (Higham and Thosarat 2004:2). And in 1997 and 1998, further work was undertaken at the Iron Age sites of Noen U-Loke and Non Muang Kao (the latter excavated by O'Reilly). Despite nothing being mentioned regarding the recovery of plant materials, pollen investigations carried out by Boyd around these sites resulted in the identification of several plant family taxa, including some described as having "significant arboricultural members", including *Artocarpus*, *Canarium*, *Syzygium*, *Terminalia*, *Ficus*, and the Bombacaceae and Palmae families (Higham *et al*. 2007:52).

During 1995 and 1996, the Lower Mekong Archaeological Project, established between the University of Hawaii and the Royal University of Fine Arts, in Cambodia, was responsible for fieldwork work and test excavations at Angkor Borei (Stark *et al*. 1999; Griffin, Ledgerwood and Phoeurn 1999). Angkor Borei is a pre-Angkorian site dated to about 2500 years BP. Although dry-sieving was regularly employed during excavations, no information on archaeological plant remains as yet been published. The project also involves a palaeoenvironmental component, which among other things aims at investigating the use of ancient canals and at reconstructing palaeovegetation around the site (Bishop *et al.* 2003).

More recently, archaeobotanical investigations by Viet in Vietnam led to the identification of plant remains in contexts dating to the final Pleistocene and early Holocene. Viet identified remains of *Juglans* sp., *Castanopsis* sp., and *Canarium* sp. from five sites, spanning from ca. 19,000 BP to 8000 BP (Viet pers. comm., paper presented at the 18th congress of the Indo-Pacific Prehistory Association, held in the Philippines in 2006).

As Paz noted, despite Gorman's initial efforts, the recovery of plant remains from archaeological sites in this region did not become a systematic practice after that pioneering example (Paz 2001:59). In many cases, recovery of macrobotanical remains from archaeological contexts did take place, but frequently there was no follow up and little is known regarding the role of plants in the subsistence economies of sites investigated. Pollen analyses and phytolith studies are also growing in number in this region, although mostly focusing on palaeoenvironmental reconstructions rather than palaeodietary issues. Two exceptions involved the use of phytoliths and diatoms to investigate early agricultural practices, especially the identification of phytoliths from rice (Kealhofer and Piperno 1994) and other crops (Kealhofer 2002).

Further north, across Vietnam and along the coast into the monsoonal region of southwestern China, the recovery of plant remains from archaeological sites has also seen developments in the last couple of decades. In the latest edition of his seminal archaeological work on Chinese archaeology, Chang noted that the application of proper recovery methods (including flotation) to sites in southern China would certainly produce similar results to the ones obtained by Gorman at Spirit Cave (Chang 1986:105). Until then, however, few sites investigated in that region had provided any archaeobotanical information.

More recent archaeological reviews for this area with information on sites, dates and finds are provided by Higham (1996), Glover & Higham (1996), and Higham & Lu (1998, which cites some of the original reports in Chinese). A few documents originally published in Chinese have also been made available on line at http://http-server.carleton.ca/~bgordon/Rice/ (see note on following page).

As Higham noted, early finds of cereal agriculture further north, in the Yellow and the Yangzi River Valleys, have triggered the debate about early centres of plant domestication in other parts of China (Higham 1996; but see Meacham 1984/85 for a different interpretation). That in part was responsible for most of the archaeobotanical practice in this region to focus on trying to identify early evidence for rice domestication, and considerably less effort has been made in documenting other crops and plant remains. The paucity of available archaeobotanical information within these investigations (including detailed methods of recovery and results), however, is not proportional to the amount of research that has been undertaken. Even evidence for rice agriculture in the earliest Neolithic sites in southern China, as Bellwood puts it, "is currently very fugitive" (Bellwood 2005:127).

3.4 East Asia in a nutshell

The region under analysis here is where domesticated rice (*Oryza sativa*) and millets (*Setaria italica* and *Panicum miliaceum*), amongst other important crops, originated. The focal area for the domestication process of these crops is between the Yellow and the Yangzi River basins, in southeastern China. At face value, relevance of this centre of plant domestication for the present study lies in the fact that both domesticated rice and foxtail millet (and possibly broomcorn millet) were brought into Island Southeast Asia at some point in prehistory. In the case of foxtail millet and rice, these crops became quite important food staples in parts of this region and remain so today (especially rice, in most of the Philippines and parts of Indonesia). However, and as we shall see, the archaeobotany of this part of the world is not just made of rice and millets, and that is of significant relevance for the present study.

"East Asia in a nutshell" may sound like a paradox: in the last three decades, this region has seen a considerable amount of archaeobotanical work (especially when compared with the areas previously described, and New Guinea), including the systematic and extensive adoption of sieving and flotation processes to many archaeological sites. The resulting archaeobotanical litreature is prolific but part of it has only been published in Chinese. K.C. Chang (1986) provided a synthesis in English of the archaeology of China but that is now more than 20 years old. More recently Glover and Higham (1996), Underhill (1997), Crawford and Shen (1998), Higham and Lu (1998), Gordon (1999)[5], Lu (1999), Higham (2005), Bellwood (2005:111-127), Lu (2006), Stark (2006), Fuller *et al*. (2007), and Fuller *et al*. (in press), have provided updated summaries especially focusing on agricultural beginnings and dispersals. The following account is taken from these sources, as well as from other recently published archaeobotanical data. The considerable amount of published literature prevents a detailed description and only the more significant aspects are highlighted.

At the end of the Pleistocene, the general climatic amelioration in this part of the world saw the proliferation of more permanent open-air settlements across two of the main river basins running from West to East across south-central China. In central China, these sites developed around the Yellow River valley and are associated with the development of agriculture based mainly on the domestication of *Setaria italica* (Lu 1999; Lu 2006). Information from pollen analysis suggests a markedly warmer climate around 11,000 BC, followed by a cooler episode from 10,800 to 9600 BC, known as the Younger Dryas. During the Final Pleistocene, and when cooler conditions prevailed, hunter-gatherers would have foraged resources including many grasses, herbaceous plants, and trees. One of the grasses native to this area, *Setaria viridis*, is well established as the progenitor of *S. italica*, the domesticated foxtail millet (Lu 1998:902).

[5] This report is part of a National Geographic Society funded project, involving collaboration between the Canadian Museum of Civilization and Chinese archaeologists, and together with other papers originally published in Chinese and translated to English is available at http://http-server.carleton.ca/~bgordon/Rice/.

Exactly when domestication of *S. italica* took place remains, archaeobotanically speaking, elusive. It has been suggested that grinding slabs found at the Xiachuan site and dated to 20,000 to 13,000 BP, may have been used for processing gathered grass seeds, including *S. viridis* (Lu 1998:904). Claims for domesticated *S. italica* in archaeological contexts, based on the identification of archaeobotanical remains, are however much more recent. They include those from the Cishan site, in Hebei province, said to be dated to approximately 7950 to 7650 cal BP (Lu 1998, 1999), and those from Xinglonggou, in Eastern Inner Mongolia, dated to ca. 7950 cal BP (Zhao 2005, in Fuller *et al*. 2007:326). By approximately 5800 cal BP *S. italica* was being cultivated in central China, together with rice (Nasu *et al*. 2007).

As for *Oryza sativa*, despite earlier claims for its domestication in various parts of China, Mainland Southeast Asia and even South Asia, it now seems more likely that this actually took place in the middle ranges of the Yangzi River valley, possibly extending north to the Huai River valley. This region lies at the northern limits of wild rice today. Despite expected changes in its natural range caused by climatic fluctuations through time, wild rice would have at some point in the past been available to hunter-gatherer communities (Higham 2005:240). The palaeoenvironmental record for this region also suggests a cooler climate until about 14,950 BP, with brief periods of amelioration from then on and until ca. 12,750 BP, and more stable warmer conditions from approximately 9950 BP onwards.

Various sites have been excavated in this region, from where macrobotanical evidence of rice, in the form of charred rice husks and grains, as well as chaff used as temper in pottery, was collected. Both wet-sieving and flotation methods have been extensively used. In a few of these sites, very early radiocarbon dates associated with the presence of rice prompted suggestions that rice domestication was a fairly old phenomenon. At Shanghan, for example, chaff used as temper in pottery was directly radiocarbon dated to ca. 10,000 cal BP (Jiang & Liu 2006), and at Bashidang, in Lixian Province, 15,000 grains of rice both with husk and whole grains were excavated from an archaeological layer dated to about 8000 BP (Pei 1998). This evidence, together with that from the nearby site of Pengtoushan and dated to about the same period, have been interpreted as domesticated rice.

Despite these claims for early rice domestication, a recent revision of these and other published data suggests that the picture could have been somewhat different. The review provided by Fuller *et al*. (2007) on the overall process of rice domestication in eastern China claims that: a) modern genetic studies indicate separate domestication events for each of the two rice subspecies brought into cultivation (*indica* and *japonica*); and b), a recent morphometric revision of length-to-width ratios of both wild and domesticated *Oryza* spp. suggests that unless wild species can be excluded, traditional identification ratios will not work (Fuller *et al*. 2007:316, based on Harvey's unpublished doctoral thesis). Grounded on these genetic and archaeobotanical criteria, Fuller *et al*. call for a systematic revision of early identifications and imply, based on available data, that most rice remains previously identified as domesticated at Shangshan and later sites may in reality be from wild specimens. As such, it is argued that the domestication process of rice in this region may have taken longer than initially predicted. A stage of "wild food production" is suggested, recovering Harris' (1989) concept of a stage between cultivation and fully developed agriculture. This intermediate stage is argued for the Hemudu phase, around 6950 BP with fully domesticated rice only present at about 5950 BP, at Longqiuzhuang (Fuller *et al*. 2007:325).

Most importantly, Fuller *et al*. also note that while the debate in this region was centred on rice domestication and the early presence of rice remains in archaeological sites, a different but complementary kind of archaeobotanical evidence has been "mainly ignored" (Fuller *et al*. 2007:326). At Tian Luo Shan, a site of the Hemudu culture, substantial quantities of nuts (mainly acorns and water chestnuts), together with other plant remains, clearly outnumber the evidence of rice. The authors suggest that this may have also been the case at Hemudu and additional early sites, where recovered nuts and other plant remains were poorly reported. Despite asserting that further research is needed, the suggestion is that these types of plant remains – and not rice – were the main food staples used by people at those sites (Fuller *et al*. 2007:328).

A later paper by Liu *et al*. (2007) reassessed Fuller *et al*.'s argument outlined above, maintaining that existing archaeobotanical evidence does support an earlier rice domestication process in China. The specific arguments used by Liu *et al*. will not be detailed here. Suffice to say that in their paper, Liu *et al*. (2007) present a short review of previous investigations dealing with the use of wild plant resources in China and suggest that these works should be reassessed. As Fuller *et al*. (2007) pointed out, the search for rice (and millet) origins in eastern China has obscured the presence and possible significance of other plant remains. Apart from those already mentioned, many other sites there have yielded plant remains of different sorts than rice or millet. At Cishan, for example, remains of *Celtis* seeds, walnuts, and hazelnuts were found together with foxtail millet, suggesting that tree crops were an important resource alongside domesticated cereals (Higham 2005:239). At Bashidang, wetland plants such as water caltrop and lotus root were probably cultivated alongside rice (Pei 1998:883). The overall picture that should be retained and will be further discussed in the final chapter is that despite the importance of cereal agriculture, this is a region where many tree and fruit crops have long been utilised and were probably cultivated or domesticated.

3.4.1 Evidence of rice in archaeological cave sites

This section briefly reviews evidence for the presence of rice in archaeological cave sites. It follows a much-debated archaeological issue as to how representative caves and rockshelters are in terms of past human occupation and activity patterns. In East Timor as in the rest of Southeast Asia, caves and rockshelters comprise the majority of sites that compose the existing archaeological corpus for most of prehistory (Paz 2005). Glover conducted extensive fieldwork there but failed to find evidence of early open-air sites (Glover 1986). Despite changes in subsistence systems that may have occurred, Glover did not believe that these changes were represented in the nature of cave use, at least not in the ones he excavated. The assumption, based on numbers of stone artefacts, pottery sherds and his own observations, was that caves and rockshelters had a temporary, short-lived, and specific type of use. This use was especially related to "hunting and collecting aspects of life" (Glover 1986:207), before and after the introduction of agriculture. As such, these excavated contexts represented a biased sample of human activities.

Assuming this line of argument is correct, one of the obvious things one would expect is that cereal agriculture – a specific economic activity implying a certain level of sedentism – would not be represented in cave sites at all. And that the absence of archaeobotanical remains to confirm its existence would not necessarily prove it was not being practiced. It would simply mean that we should not expect evidence of its presence in caves, rockshelters and similar site types.

However, from a purely archaeobotanical perspective, rice remains do preserve in archaeological caves and rockshelters. As previously described, rice remains were documented in cave sites in Southeast Asia, including Banyan Valley Cave in Mainland Southeast Asia and Ulu Leang 1 in Island Southeast Asia, and in almost all types of archaeological sites in China, from caves to open settlements. Macrobotanical remains of different parts of the plant have also been shown to preserve. Citing a study by Zhimin (1999), Paz notes that from a list of 117 archaeological sites in China with evidence of rice, 43 had hull remains, 61 had grain, 11 had grain and hull, and for 12, identification was based on stalk remains (Paz 2001:269-270). So preservation across a wide region and through various forms does not seem to be an issue.

Within the many sites investigated in south and southeastern China, several are cave sites and contain archaeobotanical evidence for the presence of rice. This was not necessarily cultivated, as with the case of Wangdong and Xianrendong, in the southern Chinese province of Jiangxi, occupied from the late Pleistocene (Macneish 1995; summarised in Underhill 1997:138). Incidentally, these finds are associated with some of the earliest evidence of pottery. The presence of pottery does not necessarily imply agriculture, as pottery is present in East Asia well before any full agricultural system was in place (Rice 1999; Yasuda 2002). Based on that same line of evidence, Fuller *et al*. point out that sedentary hunter-gatherers also seem to have preceded agriculture in this part of China (Fuller *et al*. 2007:325). This leaves us with sedentism, pottery, cave sites, and rice – and, incidentally, no agriculture.

In a recent paper, Pannell and O'Connor revisited the arguments concerning cave uses in East Timor and elsewhere, presenting contemporary examples of caves having a central role in both fully agricultural and hunter-gatherer communities. The authors argue that caves are frequently used and revisited and, at least in one, evidence of contemporary agricultural activities was documented (Pannell and O'Connor 2005:200). Instead of discussing whether caves and rockshelters were being used as temporary or permanent shelters, the authors suggest, based on the ethnographic record, that both caves and open sites were part of a more flexible pattern of site use. We shall return to this issue in chapter 9, when discussing the use of pottery and other indirect proxies as indicators of agriculture.

3.5 Near Oceania

The importance of the New Guinea region to the present study has to do with the possibility that some plant species native or domesticated there may have been introduced to Timor at some point in the past. Relations between these two areas are not just documented by the presence in East Timor of a phylum of languages of Papuan origin (Capell 1943/44, 1943/44b, 1944/45; Pawley 2005, 2007); they now have archaeological support dating back to approximately 10,000 cal BP (O'Connor 2006).

Archaeobotanical investigation in New Guinea has seen significant progress in the last few decades, based on a diverse range of evidence and aiming at both palaeoenvironmental and palaeodietary reconstruction. The island of New Guinea was archaeologically confirmed as a possible centre of plant domestication after pioneer investigations there by Golson (1976, 1977, 1985, and 1989). Further ethnobotanical and archaeobotanical work developed subsequently has led to the identification of a suite of tree and tuber crops which presumably have New Guinean origins. To the East, the impact of some of these crops in Pacific agricultural systems has been extensively surveyed (e.g. Massal and Barrau 1956; Barrau 1958; Yen 1974, 1982, 1993; Kirch 1989, 2000). However, to the West and especially regarding the possible human translocation of New Guinean crops to Timor and other islands in Southeast Asia, further research is needed.

Due to the amount of data currently existing, a detailed account of archaeobotanical investigations in this area is a difficult exercise. Many works focus specifically on the impact of New Guinean crops in Pacific subsistence systems within the last 3500 years and those will not be discussed, unless they serve to illustrate the use of specific crops of relevance to this study. Latinis (2000:52-53) provides a list of all arboreal botanical remains recovered from sites in New Guinea and Near Oceania, as well as those from Wallacea. Suggestions of a New Guinean origin for some crops initially thought to have originated in Southeast Asia will be further discussed in this thesis.

Archaeological work in the New Guinea Highlands was initiated by Bulmer (1975) in 1959. However, investigation of early agricultural systems there commenced with Golson's pioneer multidisciplinary work at the Kuk site and palynological research in the Wahgi Valley and elsewhere. The importance of these early lines of evidence for investigating claims for an independent agricultural focus of agricultural have recently been addressed by Denham (2003) in the course of his doctoral research. Suggestions that New Guinea could have been a centre of plant domestication (Yen 1982b; Golson 1989) relied on evidence of bush clearance for gardening, suggested at Kuk from approximately 9000 BP (Golson 1977: 612), and six different phases of use identified at this site. The most distinctive archaeological features at Kuk were ditch systems managing water levels within the swamp so that it could be used for agricultural purposes.

The use of wet-sieving and flotation techniques at Kuk allowed for the recovery of a suite of seed and wood remains (Powell 1982), and phytolith analysis was also conducted (Wilson 1985). Despite that, no direct evidence for agricultural use of particular plant types was found, as many species were present at Kuk before the agricultural phases (Powell 1982). Nonetheless, the assumption was still that the excavated early palaeochannels and correlated features were used in association with some important economic species recorded ethnographically, including *Colocasia* taro, *Dioscorea* yams, *Pandanus* trees, Australimusa bananas, and sugarcane (Golson 1985:308-309; Golson 1991:89). Trees with edible nuts, vines with edible fruits, and edible foliage and fungi were also suggested as possible dietary components of the early Kuk community (Golson 1991:87).

The somewhat fragmentary nature of Golson's results, particularly concerning the limited archaeobotanical evidence, led some archaeologists to cast doubt on the notion of a New Guinean independent agricultural centre (e.g. Smith 1995; Harris 1995, 1996; Bayliss-Smith 1996; Spriggs 1996). At the same time, it also triggered a new set of multidisciplinary investigations, initiated by Denham at the same Kuk site in the 1990s. In the course of his doctoral research, Denham (2002) made strong claims for an independent focus of agriculture in the New Guinea Highlands, revising the chronology and adding important information regarding the nature of specific crops utilised at the site since the terminal Pleistocene (Denham 2003). Denham's new chronology confirmed and extended the existence of agricultural practices in the wetland margins of the Kuk site that were well established before the arrival of Southeast Asian influences in New Guinea around 3500 cal BP (Denham *et al*. 2003:190). The new microfossil (pollen, microcharcoal, phytoliths and diatoms) data also confirmed the existence of *Colocasia esculenta* and *Musa* spp. (of the Eumusa section) in early Holocene contexts (Denham *et al*. 2003:191). Based on Powell's (1982) previous work on charred macrobotanical remains and the new archaeobotanical lines of evidence, a list of edible plants associated with the earliest phases at Kuk was provided (Denham *et al*. 2003: table S3 online support material).

Denham's results question previous assumptions that agriculture in the New Guinea Highlands had been an introduction from lowland areas (Golson 1991:82). Instead, Denham suggests that "agricultural practices arose in the Highland of New Guinea during the early to mid-Holocene through the transformation of pre-existing plant exploitation strategies" (Denham *et al*. 2004:240; see also Denham and Barton 2006 and Denham 2007). This claim may cast light on previous archaeobotanical finds in New Guinea, some of which are detailed below.

In earlier excavations by Bulmer at Yuku, finds of Pandanus in late Pleistocene, and of bamboo and sugarcane in early- to mid-Holocene contexts had been claimed (Bulmer 1975:30-31; although see Bulmer 2005:393 where it is stated that identification of archaeological specimens was done by local informants only). Further claims for an early use of *Pandanus* spp. in New Guinea include Christensen's excavations in the Manim Valley in the 1970s. Having located more than 80 sites in this region, Christensen conducted excavations at four: Manim, Kamapuk, Etpiti, and Tugeri. All the sediment from these excavations was subject to flotation, and charred plant materials recovered (Christensen 1975:29). Seeds of *Pandanus* sp.

described as “mountain Pandanus” (nut or *karuka* type) were said to be the predominant type of macrobotanical remains in the earlier deposits at Manim (dated to between 7002 – 6396 cal BP and 11,763 – 10,387 cal BP) and it was suggested that these were being seasonally harvested (Christensen 1975:35). Further identifications of this plant genus from the Kamapuk site, in layers dating to approximately 2500 BP, were obtained by Donoghue (1989:103-104).

The importance that wild *Pandanus* spp. may have had in attracting early population groups into highland areas of New Guinea was first suggested by White *et al*. (1970). However, as Fairbairn *et al*. noted, evidence for the presence of *Pandanus* spp. in the Highlands still post-dates the first signs of human presence there, which leaves unanswered the question as to whether these are local species (Fairbairn *et al*. 2006:379). The complex taxonomy of this genus and the existing archaeobotanical evidence of its presence in sites have recently been summarised (Kennedy and Clarke 2004), and will be further discussed.

Additional claims of early arboriculture in New Guinea include the work in the 1980s by Swadling *et al*. at the Dongan shell midden, in the Sepik-Ramu area of the northern coast. Identification of a suite of waterlogged (and a few charred) plant remains, dated to approximately 5500 BP, was undertaken by Yen and McEldowney (Swadling *et al*. 1991:109-112, in appendix). The list of identified species within different levels of confidence is given in table 3.25 in appendix 16. As the cohesiveness of some elements in this suite of plants was doubtful (cf. Spriggs 1996), an archaeobotanical reassessment and direct AMS dating on some of its elements were carried out. This allowed for the validation of some of the previous identifications, and the establishment that both *Areca catechu* and *Metroxylon sagu* were modern intrusions (Fairbairn and Swadling 2005:378). The new AMS radiocarbon date directly obtained on a *Canarium* sp. nutshell fragment extended the site’s occupation (and therefore the threshold of plant use) to 5960 ± 44 BP or 6895 – 6673 cal BP (Fairbairn and Swadling 2005:380).

Ongoing archaeobotanical work by Fairbairn in the coastal northern New Guinea sites of Taora and Lachitu has led to the identification of yet another suite of plant remains from mid-Holocene contexts. Fairbairn’s work followed the original research at these sites by Gorecki *et al*. (1991; see also Gorecki 1993), involving new excavations and the recovery of charred plant materials through flotation (Fairbairn 2005:493). Preliminary identifications at Taora include *Canarium indicum*, *Elaeocarpus* sp., *Ficus* sp., possible *Pangium* sp., *Cocos nucifera*, *Pandanus* sp., and *Terminalia* cf. *catappa*. All these plant remains came from well-sealed contexts bracketed by two radiocarbon dates of 6375 – 5965 cal BP and 7421 – 6599 cal BP (Fairbairn

2005:493). Large fragments of *Canarium indicum* were also identified at Lachitu, in layers dated to 6233 – 5881 cal BP (Fairbairn 2005:494). Work is ongoing, including identifications of other fruit and nut taxa, as well as root parenchyma.

Other archaeobotanical work in New Guinea has involved the identification of exocarp fragments and seeds of *Benincasa hispida*, from the Kana archaeological site (Matthews 2003). This site was excavated in 1993-94 and 1996-97 by Muke and Mandui within a rescue archaeological intervention, and the plant remains directly dated to 2950-2000 cal BP (Muke and Mandui 2003). Exocarp remains of prehistoric gourd recovered by Golson and a small team from the ANU at Manton, a site in the upper Wahgi Valley in New Guinea, previously identified as *Lagenaria siceraria* have now also been reinterpreted as *Benincasa hispida* (Golson 2002:7).

Relatively little archaeobotanical work has been carried out in the Indonesian part of New Guinea. Excavations conducted by Pasveer at Kria Cave, located on the Bird's Head of Papua New Guinea, involved the recovery of a small assemblage of charred plant materials. Dry-sieving of one sample per excavated spit, with a 2 millimetre mesh sieve and no flotation, was the method employed (Pasveer 2004:21). The recovered materials, bracketed by mid-Holocene radiocarbon dates, were analysed by McConnell who tentatively identified them as fruit remains of the Elaeocarpaceae family (McConnell 2004:403). Seeds of *Celtis* and *Musa* spp. (the latter from top layers) were also recovered from Toé Cave and identified by Lyn Craven from the Australian National Herbarium (Pasveer 2004:65).

Between 1995 and 1997 a joint Australian-Indonesian project was responsible for research in the Aru Islands, which have only been separated from New Guinea since 11,500 cal BP (Veth *et al*. 2004; O'Connor *et al*. 2006b). Various sites were identified and excavated during three years of fieldwork in Aru, with macro plant remains recovered from several archaeological contexts through dry- or wet-sieving with a less than 2 millimetre mesh sieve. Preservation of charred plant remains at all sites was generally poor. Apart from mineralised seeds of *Celtis philippinensis*, no other plant remains were identified (O'Connor *et al*. 2006c). Likewise, pollen did not preserve well in any of the excavated sites. However, a pollen core from a swampy area in close proximity to one of the archaeological sites resulted in a useful palaeoenvironmental record (Hope and Aplin 2006). This indirect proxy also provided the only possible palaeodietary information for Aru, as the increase in charcoal counts around 4400 to 3600 cal BP was interpreted to be the result of vegetation clearance by fire. However, as the authors also note, there was “nothing registered in the pollen record to demonstrate that this increased clearing is related to agriculture" (O’Connor *et al*. 2006e:311).

The islands immediately to the East of New Guinea have also seen significant archaeobotanical work undertaken in the last decades. At sites such as Talepakemalai (Kirch 1987), Apalo (Hayes 1992), Buang Merabak (Rosenfeld 1997), and Pamwak (Frederickson *et al*. 1993; Spriggs 1997), archaeological plant remains were recovered and identified, extending plant use in this region to the late Pleistocene. As these sites are not entirely relevant to the origins of plant management and agriculture in the region under study, detailed information on their assemblages is not given here.

Extensive palynological research has also been carried out in New Guinea, although mostly focused on palaeoenvironmental reconstruction. Investigations by Haberle (1995), however, demonstrated that pollen morphology of both cultivated *Pandanus* and *Colocasia* types are distinguishable, allowing tracking of these human translocated species chronologically. At the same time, the use of starch residues on stone artefacts has proved to be an alternative to the lack of preservation of macrobotanical plant remains in older contexts, as the work by Loy *et al*. (1992) has shown. The use of these and other archaeobotanical and palaeobotanical methods to investigate early human-plant relations is well developed in this region. More recent research on phytoliths to investigate both wild and domesticated species (Kealhofer *et al*. 1999; Lentfer and Green 2004; Denham *et al*. 2003; Denham *et al*. 2004 ; Ball *et al*. 2006), as well as the development of methodologies for starch residue analyses (e.g. Barton *et al*. 1998; Torrence *et al*. 2004; Fullagar *et al*. 2006; Denham and Barton 2006), and biomolecular and genetic studies (e.g. Lebot *et al*. 1998; Lebot 1999; Lebot *et al*. 2004; Allaby 2007), offer good perspectives for a better understating of the history of plant management practices in this part of the world.