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Abstract

Rainforests are often described as the world's last virgin landscapes; however hunter-gatherers may have been modifying these environments for over 50,000 years. Despite this, the antiquity of early tropical forest exploitation by hunter-gathers and the transition to farming are still poorly understood. Today globalization drives deforestation of rainforests at an unprecedented rate. The forest, the lives of its present-day inhabitants, and the archaeological evidence for their history are unlikely to survive for much longer in their present form. The 'Cultured Rainforest Project', an interdisciplinary project involving anthropologists, archaeologists and palaeoecologists, was set up in 2007 to investigate the long-term and present-day interactions between people and the rainforest in the Kelabit Highlands of central Borneo, so as to better understand past and present agricultural and hunter-gatherer lifestyles and landscapes. This paper examines the environmental evidence used to investigate initial signs of plant exploitation and the transition to agriculture, as well as to understand the wider significance of past plants in a changing cultural landscape. Results have shown that two pronounced cultural waves of human-plant interactions took place in the Kelabit Highlands during the late Holocene; although tentative marks may be present on the landscape ca.7000-6000 years ago. The first pronounced wave of human-plant interaction begins from at least 3000 cal. BP. It seems to correspond with the appearance of stone mounds and open-air sites recorded in the archaeological record. The sago palm *Eugeissona* plays an important role during this period. A second wave of cultural activity, particularly in the last 450 years, is recorded in the southern Kelabit Highlands and is marked by rice becoming important. This may be linked to the construction of a wide range of different megaliths and earthworks, due to its inferred association

with wealth and status in prehistoric and historic periods. It is perhaps also linked to a rise in trade between the coastal regions and highlands.

1 Introduction

Tropical rainforests contain a wealth of resources for health, construction, food and commodities. Rainforests are often described as the world's last virgin landscapes (e.g. Willis et al., 2004); however, from the perspective of the pervasive reach of people today, it may seem natural that modern humans (*Homo sapiens*) have throughout their history altered and manipulated tropical forests, to gain maximum benefit from economically useful plants. Indeed recent work (e.g. Barker et al., 2007; Hunt et al., 2007, 2012; Hope, 2009; Summerhayes et al., 2010; Barker and Janowski, 2011; Barton and Denham, 2011) suggests that people may have been exploiting rainforest environments in Southeast Asia and Melanesia for over 50,000 years. This is far removed from previous assumptions e both scientific and popular e that tropical forests were, in the past, pristine environments, relatively untouched by humans (e.g. Bailey et al., 1989; Balee, 1989; Bailey and Headland, 1991). At Niah Cave in lowland Sarawak the earliest evidence of plant exploitation dates from at least 45,000 years ago and evidence for rainforest manipulation by fire might extend back to 53,000 years (Hunt et al., 2007, 2012). People gained the necessary knowledge and skills to be able to detoxify and render digestible, poisonous or acidic tubers, rhizomes and nuts (Barker, 2005; Barton, 2005; Barton and Paz, 2007; Barker et al., 2007; Barton and Denham, 2011). There is no evidence for cultivation or the active management of plants other than what appears to be forest burning, which would have created ecological space for desirable plants. According to Barton and Denham (2011) it certainly demonstrates an early stage in the long history of people-plant interaction.

One of the main problems with attempting to identify early signs of plant manipulation and the transition to agriculture in tropical forests is the very limited number of sites that have been investigated, and the even more restricted number of sites investigated using modern multidisciplinary methods. Compared with more temperate regions of the world, the number of archaeological and palaeoecological sites investigated within tropical rainforests is significantly small. This is partly due to rapid decomposition and poor preservation of organic material in oxic tropical environments, which restricts the availability of plant remains and pollen on non-waterlogged sites. It is also due to the rich ground cover in tropical forests, making the search for archaeological sites difficult.

The site at Niah is the only site with evidence of plant-people interactions during the Pleistocene so far investigated in Borneo. Other potential Pleistocene sites occur in Borneo (Sabah: Majid et al., 1998; Kalimantan: Plagnes et al., 2003; Arifin, 2004; Chazine, 2005a,b; Gunadi, 2006; Chazine and Ferrié, 2008; Plutniak, 2014), although research has not yet identified the role of plants at any of these sites.

Information relating to human-plant interactions during the Holocene remains almost equally scarce. During the 1990s more than 100 cave sites were identified in East Kalimantan. The sites date from the early to the late Holocene (Plagnes et al., 2003; Chazine, 2005a,b; Chazine and Ferrié, 2008; Ricaut et al., 2011; Plutniak, 2014) but none as yet have been investigated for plant remains. What has been suggested to be very early Holocene management of vegetation involving massive burning, several sago species including the non-native *Metroxylon* and very abundant phytoliths of wild rice (phytolith data-unpub.) was recorded from a deep borehole at Loagan Bunut in the lowlands of Sarawak, from ~11,200 BP (Barker and Janowski, 2011; Hunt and Premathilake, 2012). The development of an early arboriculture may be indicated; but this is as yet an isolated point which requires corroboration from other locations.

Other evidence for potential human-vegetation associations have been suggested by Hunt and Rushworth (2005) within the catchment of the Sungai Niah. Hunt and Rushworth (2005) report clearance close to the Niah caves, which is associated with rice-type pollen and open swampy environments from ~7400 cal. BP. Morphological similarities however, exist between some grass species and rice types, which are not distinctive under a light microscope (Ah-Lee et al., 2004; Datta and Chatturvedi, 2011). Chacornac-Rault (2005) provides evidence which may corroborate these findings. Chacornac-Rault (2005) identified *Oryza* phytoliths, associated with other useful plants (such as *Arenga*) ~7000 cal. BP at Bugel smaller Lake (Punung Karst), Java. According to Chacornac-Rault and Sémah (2004), and mentioned in Sémah and Sémah (2012), a significant increase in the occurrence of these plants suggests some form of management.

After 4000 cal. BP, evidence for subsistence practices and rice usage becomes more prominent in Borneo, particularly along the coastal regions of Sarawak. Krigbaum (2003) suggests that early food production during the Neolithic in Borneo likely involved endemic plants and fruits, and potentially non-native items such as domesticated rice. Based on isotope analysis on teeth, Krigbaum (2003) identified potential forest culture and some form of systematic food production at Niah Cave and Gua Sireh, but closed forest subsistence further inland at Lubang Angin, around 4000 cal. BP. Broadly contemporary are rice-tempered pottery and rice embedded in potsherds (Datan and Bellwood, 1991; Beavitt et al., 1996; Doherty et al., 1998, 2000). None of this evidence, however, is located in the Central Highlands. There is also a marked lack of research on early food production in the other states on Borneo. The development and spread of vegeculture and arboriculture in tropical rainforests and the transition to rice farming is a subject still very poorly known and very difficult to comprehend due to the limited research undertaken (e.g. Barton and Denham, 2011; Barton, 2012; Hunt and Rabett, 2014).

The 'Cultured Rainforest Project', (CRF), an interdisciplinary project involving anthropologists, archaeologists and palaeoecologists, was started in 2007 to investigate the long term and present day interactions between people and the rainforest in the Kelabit Highlands of Central Borneo, to better understand past and present agricultural and huntergatherer lifestyles and landscapes (Barker et al., 2008, 2009 and; Lloyd-Smith et al., 2010). The focus of this paper is to examine environmental evidence from the Kelabit Highlands that identifies initial signs of plant exploitation and the transition to agriculture, as well as the wider significance of plants in the changing cultural landscape.

2 Regional setting

The Kelabit Highlands (Fig. 1) rise between 1000 and 3500 m above sea level and cover an area of 5400 km^2. They are situated mainly in Sarawak, but part lies in Kalimantan. The headwaters of a number of rivers lie here, including the Baram and Kerayan (Janowski, 2005). The Kelabit Highlands lie largely in the domain of Lower Montane Forest, with peaks in the Upper Montane Forest zone. The Lower Montane forest lacks many of the characteristic taxa of the Lowland forests of Borneo, such as most of the Dipterocarps, and has generally-lower biodiversity. Instead, in undisturbed locations, Fagaceae (*Lithocarpus* and *Quercus*) are prominent, along with taxa which in the lowlands are confined to bog habitats, such as *Palaquium*, *Shorea*, *Durio*, *Sygyzium* and *Calophyllum*. Also very prominent are *Rhododendron* spp., particularly on *kerangas* vegetation (very acid tolerant vegetation growing on well-drained substrates such as old river terraces). The Upper Montane forest is particularly marked by the gymnosperm *Phyllocladus* and members of the Theaceae, but Rhododendron and members of the Fagaceae are also important.

Two main human groups live in the Kelabit Highlands today: the Kelabit and the Penan. The Kelabit are rice growers and live in longhouses. They assert that they have always eaten rice, underlining the cultural centrality of rice as a staple. Rice is eaten at every Kelabit meal. It is profoundly embedded in the Kelabit sense of self and is fundamental to Kelabit society. To be successful in rice-growing is traditionally the basis of kinship, hierarchy and the relationship with the spirit world (Janowski, 1995, 2003, 2004, 2005, 2007; Janowski and Langub, 2011). It has been argued that in the more distant past, before the Kelabit adopted rice agriculture, they are very likely to have used sago (Barton, 2012).

The Penan were originally semi-nomadic and rely mainly on hunting and gathering. They are divided into two groupings, Eastern and Western, with the Baram catchment being inhabited by the Eastern Penan. The Eastern Penan of the Baram include settled, semi-settled and still quasi-nomadic people who live in small groups based on nuclear families. Among the quasi-nomadic Penan, each group has its own hunting and foraging area within the forest. These areas have relatively defined boundaries, which follow streams, watersheds, mountain ridges and landmarks (Kedit, 1982). The Penan prefer not to grow rice, although in recent times many Penan have settled in villages, mainly due to the reduced area of forest available to them because of logging, and some now grow their own rice and other crops like manioc and maize (Janowski and Langub, 2011; Janowski et al., 2014). For the nomadic Penan, sago palms provide the main source of carbohydrate. Four types of sago palm are utilized by the Penan, of which hill sago *Eugeissona utilis* is the most important, but *Caryota* spp. the most preferred (Kedit, 1982; Brosius, 1986, 1991).

Although they conceive of their relationship with the environment differently, both the Kelabit and the Penan draw heavily on wild resources from the forest, particularly bushmeat and wild fruits, and both manipulate their environment to increase the production of foods which they value. The Penan propagate sago by clearing space, planting seeds and removing encroaching weeds. The Kelabit plant rice either on cleared hillslopes (dry rice) or in constructed padi fields on alluvial terrain (wet rice). The Kelabit also maintain vegetable plots and orchards close to their long-houses. Kelabit informants told us that in the past, when the average residence time at any particular longhouse location was around five years, the Kelabit would plant fruit trees such as durians around the old longhouse site before moving on to the next. In due course (probably 60-100 years), the group would return to the old longhouse site, which was now surrounded by mature fruit trees, and rebuild the longhouse. The Kelabit also maintain large areas of secondary forest as ‘women's forest’. Here the women would extract plant foods and medicines and other resources such as rotan (rattan) palms for basket making, resins for waterproofing pottery, poisons for blowpipe darts and fishing, leaves for plates and thatching and so on. In the recent past the ‘women's forest’ was also a source for dammar resin which was exchanged with Chinese traders for large ceramic pots, beads and iron objects. Some areas of primary forest were explicitly maintained as such to provide hunting areas and to safeguard water supply.

The Kelabit Highlands contain abundant cultural marks and megalithic monuments, which were first surveyed by Tom Harrisson in the late 1950s (Harrisson, 1958), in the broader Apad Uat highland area by Schneeberger (1979) and more recently along the upper reaches of the Bahau River, in the Pujungan district of North Kalimantan by Arifin and Sellato (2003) and in the Kelabit Highlands by Hitchner (2009). Some archaeological excavations were carried out in the Kelabit Highlands by Tom Harrison in the 1950s and 1960s, and notes of these excavations can be found in the Sarawak Museum in Kuching; but the archaeological reports were never published.

3 Materials and methods

3.1 Brief description of archaeological and anthropological methodologies

While this paper focuses primarily on the environmental results from the Kelabit Highlands, we will provide a brief overview of the anthropological and archaeological work. This will be done in order to place the palaeoenvironmental interpretations into a broader context, so as to better understand the long-term record of people-plant interactions.

During the CRF project anthropologists gathered information on present-day and past forest life as people remembered or conceived it; on the practical and cosmological aspects of people's relationship with the natural environment, including through legends, genealogies and settlement histories; on how crafted and heirloom objects are being used today and were used in everyday life as grave goods, in cemeteries in the recent past; and on the domestication of forest plants (Barker and Janowski, 2011; Janowski and Langub, 2011; Janowski and Barton, 2012; Ewart, 2013; Janowski, 2014a,b,c).

Archaeological survey and test excavation focused on the southern Kelabit Highlands. Sites included rock shelters; settlement sites (current, remembered in folklore, and known sites but dating to a time beyond oral histories), megaliths, dragon jar cemeteries and earthworks (Barker et al., 2008, 2009; Lloyd-Smith et al., 2010, 2013). Radiocarbon ages were obtained from the Chrono Centre at Queen's University Belfast and Beta Analytic, Miami, Florida.

3.2 Palaeoecological materials and methodologies

Seven sites were selected from the northern and southern Kelabit Highlands for multidisciplinary palaeoecological analysis. The choice was constrained by the geomorphology of the region. Detailed methodologies for the palaeoecological investigations can be found in Jones et al. (2013a,b, 2014). The only peat bog we could locate in the region was cored (core Ba). The bog is located adjacent to the airport and about 2 km from the main village of Bario, the centre for the main rice-growing area in the Highlands. No archaeology is recorded in the vicinity of this site, although Bario is close to the villages of Pa'Derung, Pa'Umor, Pa'Ukat and Pa'Lungan which contain several megalithic structures including menhirs, stone mounds (perupun), dolmen, and carved rocks. Many of the rock carvings depict images of head hunters. The number of notches carved alongside these images represent the number of heads taken (ITTO and SFD, 2009).

Four sites were selected from around the village of Pa'Dalih (cores CO1, PDH 212, PDH 223 and PDH 210), all from abandoned and silted-up river channels selected because peat bogs and lakes were not available. Today many former river channels are used for rice cultivation in the Kelabit Highlands. The sites selected were not currently in use for rice cultivation but were adjacent to rice fields currently being used. All the core sites at Pa'Dalih are located in very close proximity to archaeological sites (within 1 km radius). Archaeological sites include Batuh Liban Pa'Dalih (a type of chamber tomb, carved out of rock, ITTO and SFD, 2009), four Batuh Nangan (individual stone cysts and slabs) and Perupun Pa' Rabiung (stone mound). One site was selected from a palaeochannel at the side of a rice field in undisturbed sediments at Pa'Buda (core BPG). This site was located within 2 km of an abandoned settlement site at Long Kelit, one large and one small perupun (stone mounds), a standing stone jar burial at Menatuh Long Kelit Fig. 10, and within 2 km of Perupun Payeh Telipa (core PPT). At PPT, sediments were extracted adjacent to a stone mound, but results for this site are yet to be finalised.

4 Palaeoecological evidence from the Kelabit Highlands

Table 1 represents the Holocene radiocarbon ages for four of the investigated sites (Ba, PDH 212, PDH 223 and BPG). Two of the cores examined (PDH 212 and Ba) extend into the Pleistocene and their bases are older than 50,000 cal. BP. The Pleistocene results can be seen in Jones et al. (2014). Most of the Holocene pollen and palynomorph results are discussed in detail in Jones et al. (2013a,b). A synthesis of the different data sets are provided below. The significance of the results in terms of early plant exploitation, the transition to agriculture, and the association of plants with the cultural landscape are then examined in detail in the discussion.

The earliest palaeoecological evidence for potential human activity dates ~6200 years ago at Pa'Buda (BPG) (Jones et al., 2013b). Most of the material sampled by the BPG core appears to have accumulated extremely rapidly following a major fire event, which probably took place around 6200 cal. BP. The fire event is followed by an atypical regeneration sequence largely lacking the normal sequence of regeneration indicators such as Poaceae, herb species and pioneer species *Macaranga*, *Mallotus*, *Ficus*, and *Syzygium* (Slik et al., 2003, 2008; Cole et al., 2015). Instead, there is a rise in palm pollen; and brief peaks in pollen of the fruit tree *Callicarpa*. The sago palm *Caryota* is present in the BPG record but occurs prior to the burning event. Pollen of the families Sapotaceae and Sapindaceae, which include many fruit trees also rise, but it should be noted that these families also include non-edible species (Fig. 2). An increase in large scabrate Poaceae pollen in the top 15 cm of the core most likely reflects the development of the modern rice field on the site. This site is challenging, not least because pollen counts in the rapidly-accumulated sediments are rather low, the pollen of Sapotaceae and Sapindaceae could not be identified to species so it is uncertain that they were taxa that produce edible fruits, and because there is no modern ecological work on regeneration sequences in the lower montane rainforests of the Kelabit Highlands. The BPG record is so far the only site of this antiquity in the Kelabit Highlands. At Perupun Payeh Telipa (PPT), close to

Pa'Dalih, *Eugeissona* pollen grains first appear after a radiocarbon age of 5300-4900 cal. BP and might correspond to incipient arboricultural practices ca.4000 cal. BP. Unfortunately the analysis of this site is not yet fully completed; but a detailed interpretation of the results will be forthcoming. Discontinuities in the Ba and PDH 212 records make it extremely difficult to determine other potential anthropogenic signals prior to 3000 cal. BP. Two sites in the southern Kelabit Highlands, at Pa'Dalih (PDH 212, described in Jones et al., 2013b; and PDH 223, described in Jones et al., 2013a) show likely human-environmental interactions from 3000 cal. BP and 2300 cal. BP, associated with clearance episodes and then arboriculture, particularly from 2300 cal. BP. The signal appears later in the northern highlands at Bario, from 300 cal. BP.

At PDH 212 an increase in disturbance indicators occurs from ~3000 cal. BP. Disturbance indicators are higher than during the Pleistocene but species diversity tends to be lower. Echinate palm phytoliths appear at ~2800 cal. BP and continue to be present for the remainder of the record with an increase at 460-310 cal. BP. *Eugeissona* pollen appears ~2000 cal. BP (Fig. 3), although counts are not consistent. *Eugeissona* pollen rises after ~1000-600 cal. BP. *Oryza* bulliforms and large scabrate Poaceae become more frequent after ca. 450-250 years (Fig. 8) and at the same palm phytoliths increase. The *Oryza* bulliforms from the sediments later than 450-250 cal. BP are completely different from most *Oryza* type phytoliths appearing lower down the core in shape, size and appearance. It should be made clear that it is impossible to separate bulliform phytoliths from domesticated and wild rice types based on measurement criteria alone. This is due to a wide overlap in measurements. However, if notable changes in bulliform shape, size and appearance take place over a specific time frame, particularly if we trace this signal backwards from a known rice source, it might be possible to link these changes to the presence of domesticated rice (with caution) (Figs. 6 and 7).

In PDH 223 *Eugeissona* pollen grains appear from ~2300 cal. BP and show a pronounced and consistent representation until 1800 cal. BP. In the same interval, disturbance indicators are also strongly represented. In addition to *Eugeissona*, rice phytoliths comparable with those from domesticated rice, including two bulliform types and one double peaked glume phytoliths (see Jones et al., 2013a), appear between 2000 and 1800 cal. BP. Despite the occasional appearance of cf. *sativa* types around 2000-1800 cal. BP, *Oryza* phytoliths only become frequent in the top 15 cm of the core.

At Bario in the northern Kelabit Highlands, human-environmental associations appear much later, although perhaps older sediments are missing due to an erosional hiatus. *Eugeissona* pollen grains and the edible fern *Stenochlaena* are present and Palmae phytoliths are abundant after 1300 cal. BP (Fig. 5), and remain consistently present until present day. A progressive increase in Palmae phytoliths and decline in *Eugeissona* pollen occurs in the top of the core.

5 Landscape archaeology

Interdisciplinary research can contribute considerably to our understanding of complex interactions between people and the rainforest in the Central Highlands of Borneo, both in the present, in the recent past and in the more distant past. The construction of megalithic monuments has been until quite recently a significant part of the cultural landscape. According to Ewart (2009) the erection of large stone monuments in the Kelabit Highlands and the cutting of clearings (*Kawang* on ridgetops) and ditches (*Nabang* by rivers), was often associated with Kelabit funerary rites and was practised until 1950. Megaliths were also constructed to honour people, for rites of passage, protection of possessions, boundary markers, to show strength: some have associations with myths and legends (Hitchner, 2009. See Table 3). During the CRF project the purpose and antiquity of selected sites within the Kelabit Highlands were investigated in more detail. The ages of these CRF sites are represented in Table 2.

The earliest radiocarbon date from an archaeological context (a buried soil horizon at the riverside location of Ruma Ma'on Daka, Long Kelit) of 3770 ± 40 BP or 2310e2030 cal BP (Beta-237849) (Table 2) is most likely the result of re-worked charcoal as the other finds from this area date to the last fewhundred years (Lloyd-Smith et al., 2010: 60). The earliest secure date has been obtained on cremated human bone retrieved from a previous excavation of a stone mound in the northern Kelabit Highlands, which produced a date of 2026-1826 BP or BC 76 - AD 124 (Beta-280504; Lloyd-Smith, 2012); from the southern Kelabit Highlands the earliest secure date (1620 ± 40 BP or AD 340-550; Beta 237850) is from the settlement site of Taa Payo.

6 Early indications of human-plant relationships

The main focus of this paper has been to examine the antiquity of arboriculture, vegeculture, early agriculture and the role of plants within the cultural landscape of the Kelabit Highlands. This becomes more complex the further back in time we go. Forest plants have been and still are an essential part of the everyday lives of both the Kelabit and Penan people (Christensen, 2002; Barker and Janowski, 2011). Both the Kelabit and Penan have been managing plants for at the least as long as they can remember. Forest plants were and still are frequently moved from a wild environment to a more domesticated setting and vice versa (Barker et al., 2009). Therefore what is cultivated and what is wild can often be blurred. Nevertheless, when passing through the forests in the Kelabit Highlands, one cannot help but notice the clusters of economically useful plants, many of which are being managed today or have been in the recent past. This includes banana plants, various fruit trees, bamboos and *Eugeissona* palms (Author, pers.obs). The palaeoecological signal from these taxa might be expected to be be stronger than if the taxa occurred naturally.

The first potential sign of human-environmental interactions in the Central Highlands of Borneo dates to ~6200 cal. BP, as suggested by a burning event, atypical regeneration, rise in palm trees and brief rise in fruit trees at Pa'Buda (Fig. 2). As noted above, this evidence is relatively insubstantial and so far this is an isolated occurrence at this date.

One important issue with the record from Pa'Buda is that *Eugeissona*, the main genus of sago palm used today by the Penan, (Kedit, 1982; Brosius, 1993; Koizumi, 2005), was not identified at Pa'Buda, while it is recorded in later sites at Perupun Payeh Telipa, Bario and Pa'Dalih. Apart from *Eugeissona utilis*, which is the main palm managed in the Kelabit Highlands today, a number of other palms are widely processed for sago in Borneo, including *Arenga* spp., *Caryota* spp. and other species of *Eugeissona* (Barton, 2012: 98) so perhaps other palms were being used. Indeed, *Caryota* is presentin the Pa'Buda record (see Jones et al., 2013b: Fig. 5b), but it occurs prior to the main burning event. An important characteristic of *Eugeissona utilis* is that it will thrive and sucker through careful management, a process the Penan refer to as *molong* (which means to ‘care for’ or ‘look after’) (Brosius, 1986; Langub, 2007). Other palms utilized by the Penan do not sucker and will die after being felled, therefore for the groups interviewed by Janowski and Langub (2011) it is not worthwhile to harvest them. A further issue with the BPG results is that no burning events are recorded after 6200 cal BP, which might be expected if people were actively managing the environment.

Thus, if people were present in the Kelabit Highlands 7000 years ago, then the traces left behind on the landscape seem to be barely if not indistinguishable from the natural record. These results highlight the need for caution when making interpretations associated with arboriculture (see Sémah and Sémah, 2012). Natural disturbance should not necessarily be ruled out at Pa'Buda. In fact a number of authors report climatic drying during this period in island southeast Asia, which perhaps initiated natural forest fires. On the island of Borneo in south Kalimantan Sieffermann et al. (2000) report a period of relative dryness between 6500 and 2000 BP. In western Java, Stuijts (1993) observed a relatively dry period between 8000 and 6000 BP, and in central Java at Ambarawa, Sémah et al. (2004) recorded a period of decreased precipitation between 7000 and 5000 cal BP. Cole et al. (2015) on the other hand suggest relatively wet and warm conditions between 7000 and 4000 cal BP in Sarawak; although a brief change in vegetation can be observed in the CPL pollen diagram ca. 6200 cal BP. The change is shown by a sharp drop in the peat swamp forest taxa *Rhizophora*, and by small increases in pioneer taxa Syzigium, *Pometia*, *Macaranga* and *Elaeocarpus* and micro-charcoal.

7 Sago

At PPT (Perupun Payeh Telipa) the record of *Eugeissona* may extend back to ca. 4000 cal. BP, although interpretation of the analysed results has yet to be completed. The potential PPT age would be closer to the earliest known archaeological date from the Kelabit Highlands at Ruma' Ma'on Dakha (ca. 3770 cal. BP: Table 2).Due to hiatuses in the sediment record at Bario and Pa'Dalih there is a gap in palaeoecological knowledge at these sites spanning most of the early and mid-Holocene, which means no further evidence is as yet available until ca. 3000 cal. BP. A more secure signal of likely human plant interactions is indicated by a rise in disturbance indicators in the southern highlands at Pa'Dalih from ca. 3000 cal. BP (Fig. 3). Higher counts of herb taxa and spores but lower species diversity when compared to the Pleistocene at PDH 212, suggest anthropogenic-related disturbance rather than natural. This evidence is further supported by the appearance of *Eugeissona* pollen and palm phytoliths at Pa'Dalih (PDH 212) between 2800 and 2300 cal. BP (Figs. 4 and 8). The palaeoecological investigations support the possibility of palm management, perhaps as part of an arboricultural or swidden system by at least 2800 cal. BP in association with archaeological material including settlement sites, stone mounds (*perupun*), megaliths and open air sites (Barker et al., 2008, 2009; Lloyd-Smith et al., 2010, 2013). *Eugeissona* pollen is also present at ~2000 cal. BP (Fig. 3), although counts are not consistent, and significant increases in both pollen and palm phytoliths, do not occur until after 1000 cal. BP.

At PDH 223 (Fig. 4) following a distinct rise in disturbance indicators, *Eugeissona* pollen grains show a pronounced representation from 2300 cal. BP until 1800 cal. BP; whilst in the northern Kelabit Highlands at Bario both *Eugeissona* pollen and palm phytoliths appear from 1200 cal. BP until modern day (Fig. 5). Such a strong contrast between the Pleistocene-mid Holocene (lack of *Eugeissona*), and the late Holocene (pronounced and consistent representation of *Eugeissona*) is strongly suggestive of management of this sago palm. In addition, the natural habitat of *Eugeissona* *utilis* today appears to be ridge tops and scarps within the steeply dissected terrain of the highland mountain areas (see also Puri, 1997). High frequencies of pollen appearing in the inter-montane swamps around Bario and the valleys in and around Pa'Dalih, is suggestive of a human translocation - possibly vegetative - from the ridges to gardens or fields located adjacent to human settlements. It is interesting that *Stenochlaena* also appears at the same time *Eugeissona* appears at Bario, and also remains consistent until present day. *Stenochlaena palustris* is an edible fern. This is perhaps a further indication of people actively managing the surrounding vegetation. Isolated grains of *Eugeissona* only appear once in the long Pleistocene record at Bario, and twice in the long Pleistocene record of Pa'Dalih (PDH 212). It is not present in the earlier Holocene at Pa'Buda, or at Pa'Dalih or Bario until the later Holocene. The appearance of *Eugeissona* in the highlands during the late Holocene contrasts with the position in the Borneo lowlands, where *Eugeissona* appears to be present from the earliest Holocene, suggesting that this species may have been imported into the Kelabit Highlands (Hunt and Premathilake, 2012). This theory at present remains purely speculative as evidence is limited. Perhaps in future work more sites, examining both the distribution of *Eugeissona* through time, in the lowlands and highlands, could be analysed to test this hypothesis further.

The timing of *Eugeissona* appearance in the southern Kelabit Highlands, comes slightly before the first contextually secure archaeological C14 date (ca. 2030-1830 BP) obtained from cremated bone at a stone mound from the village of Pa'Lungan (Lloyd-Smith, 2012, Table 2). Pa'Lungan is located ca 28 km north from the archaeological and palaeoecological sites at Pa'Dalih and 10 km north of Bario. Interestingly two other sites close to Pa'Dalih also produce similar ages. This includes a settlement underlying a megalithic stone jar cemetery ca 1240 cal. BP and a stone wall enclosure at Ruma Ma'on Taa Payo (Fig. 9), ca.1640 cal BP (Lloyd- Smith et al., 2010).

Based on anthropological data we know that in the recent past many of the megalithic structures were associated with death and commemoration, and their construction was usually organised by people of wealth and status (Ewart, 2009; Hitchner, 2009; ITTO and SFD, 2009). One way to have gained status was perhaps through head hunting; wealth however has been associated with the ability to produce food (rice) (Janowski, 1988, 1995, 2004; Janowski and Barton, 2012; Hitchner, 2009). In the more distant past perhaps wealth was associated with the production of other food staples such as sago.

After 1500 cal. BP there is a large gap in the archaeological record in the southern Kelabit Highlands until 400e600 cal. BP. There is also a gap in the palaeoecological record at Pa'Dalih PDH 223 where *Eugeissona* pollen disappears after 1800 cal. BP (at site PDH 223, Fig. 4), palm phytoliths also decline after 2700 cal. BP until 460 cal. BP, at PDH 212. In the northern Kelabit Highlands the pattern is different. Eugeissona and palm phytoliths appear at 1200 cal. BP and continue until relatively recently. This demonstrates that people were still present and influencing the landscape in the highlands during the archaeological gap. Perhaps the later occurrence of sago in Bario might suggest people were moving around the landscape and relocating to different areas. Further investigations from different settlement locations within and beyond the Kelabit Highlands may help to answer this question during future work.

At Pa'Dalih in more recent times, both palm phytoliths and *Eugeissona* show a pronounced rise, after 1000 cal. BP (phytoliths) and at about 460-310 cal. BP (*Eugeissona* pollen) in the PDH 212 record (Fig.

8). The increases are likely associated with increasingly intensive agricultural practices, since they also coincide with a rise in rice-type phytoliths. No increase occurs in the PDH 223 record during this period.

At Bario (Fig. 5) there is a progressive increase in palm phytoliths and decline in *Eugeissona* pollen in the top of the Ba core. This perhaps represents forest clearance and in-wash of phytoliths rather than an increase in palm cultivation in more modern times and may be indicative of more intensive forms of agriculture (e.g. rice cultivation or even pineapple cultivation, which is common on the surrounding hills today).

8 Rice

The earliest confirmed evidence for rice usage in Borneo comes from coastal lowland sites dating to ca. 4300 cal. BP at the cave of Gua Sireh (Datan and Bellwood, 1991) and ca. 5400e5900 cal. BP at the Great Cave of Niah (Doherty et al., 2000). These sites contained rice tempered or rice embedded in pottery. Potential earlier rice usage is also reported in Barker and Janowski (2011), in which phytoliths of probably-wild rice, many of which are burnt, were found to be abundant in the Loagan Bunut cores from 11,200 cal. BP, although more evidence is needed to verify this. Doherty et al. (1998) report the identification of 38 sites in Sarawak, associated with rice inclusions in pottery, including Gua Sireh. Some sherds were also recovered from Neolithic burial sites, but it is not until the 10th Century AD that widespread rice appears along the coasts of Sarawak. One of the main problems with Doherty's data however, is the lack of radio carbon dates. Until the CRF project no evidence had been found of early rice occurring further inland.

The recent palaeoecological work from the Kelabit Highlands has shown an appearance of sporadic rice phytoliths, which might be an indication of experimental or small scale rice cultivation from 2000 to 1800 cal. BP, but evidence is limited to only one double peaked phytolith and two bulliform types. This is not enough evidence to argue with absolute certainty for rice cultivation. More investigations are needed in the area. Bulliform types cannot be statistically separated into wild and domesticated types, although morphological features were similar to bulliforms identified in the modern sediments close to current cultivation sites of domestic rice.

In the recent past until the 2000s, swidden cultivation was the predominant form of cultivation in the Kelabit Highlands, and swidden fields were used for no more than one year or occasionally two years at a time. Taro/yams/cassava, fruit trees and other crops would often be planted after the rice and then the field would be left to fallow (with respect to rice growing) for 10 or 20 years during which time it would become covered in what can be described as enriched (from a human point of view) secondary forest. The same pattern occurred elsewhere in Borneo (Sellato, 1994). Indigenous groups would shift location from time to time around a wider territory to make new swidden fields, as the lands around a village ceased to become productive, although they continued to return to previous fields where other useful plants had been planted. Even wet rice fields were often shifted after 2-5 years of use, as they were until the 1960s in the Bario area in the northern Highlands. One of the limitations of this research has been that sites were selected in close proximity to current settlement sites and where known wet rice agriculture had been practiced; these sites are perhaps younger than swidden farming. Dry sites were not investigated but may hold potential for future work despite their possible problems of preservation and soil bioturbation. The practice of shifting cultivation however, could make rice agriculture difficult to detect in the palaeoecological record, since fields were only made for a brief period at a time, before being relocated.

Despite a potential date of 2000-800 cal. BP for experimental forms of rice cultivation, rice may not have become a food staple in this region until the historic period, within the last ~450 years (Barton, 2012; Jones et al., 2013a,b). Growing significant quantities of rice requires tools to clear land for fields, and its very rarity in earlier times may have contributed to its high status. Increasing trade, predominantly with Chinese merchants, would have been a major factor influencing the adoption of rice cultivation in the Kelabit Highlands, particularly during the emergence of Islam (Ewart, 2009), and later during the establishment of the Brunei sultanate, where a more systematic governance and trade would have developed along the coastal regions of western Borneo. On the neighbouring island of Java rice was being used as a payment method in the 14th century (Hirth and Rockhill, 1911; Pigeaud, 1960-1963). Perhaps the perception of wealth gained by successful rice cultivation in the coastal regions of western Borneo, initiated an attractive alternative to vegecultural and arboricultural practices in the Kelabit Highlands, particularly with the arrival of metal tools from the coast, which allowed for the expansion of dry fields on hill slopes and flat areas which are naturally covered with big trees. In the southern Kelabit Highlands sago management also seems to have increased during the same time period as suggested from the PDH 212 results (Fig. 8), perhaps another indication of the arrival of metal tools. Excavations undertaken by Tom Harrison from the largest megaliths in the Kelabit Highlands, described in Harrisson (1970), produced Siamese pottery sherds dating to the 13th-14th Century AD. He also reports that identical sherds are present in Ming levels of the Kota Batu site at coastal Brunei Bay, which clearly demonstrates the hinterland was supplied with trade goods from Brunei Bay after the establishment of an Iron Age.

The establishment of rice fields in the southern Kelabit Highlands and rise in palm management at PDH 212 is followed by an explosion of megalithic activity and is thus representative of a second wave of cultural change. This megalithic activity is recorded not only in the sites excavated by Tom Harrisson (Harrisson, 1970) but also in the archaeological sites excavated by the CRF project (Table 2). For example at Ruma Ma'on Ra'an Berangan (filled post hole at abandoned settlement site), Meantuh long Kelit (Fig. 10) (single stone jar burial) and by the presence of numerous Chinese dragon jar burial sites. Before the Second World War, high status amongst the Kelabit was deeply connected with rice cultivation (see Janowski,1995,1988, 2003 etc.). Effective leadershipwas based on successful rice cultivation, ensuring that all members of a longhouse community had enough rice to eat. Leadership was further proved by holding great rice feasts known as irau and by creating marks on the landscape through megalithic construction (Janowski, 2003; Hitchner, 2009). According to Hitchner (2009) megaliths were often constructed by large numbers of people both from within the village or from other villages. Irau were held essentially to pay for the labour necessary to construct the megaliths as attendees were expected to participate. Normally only the wealthiest aristocrats could afford to pay for Irau. The construction of megaliths is therefore generally associated with wealth and status. Similar megalithic structures have also been reported by Arifin and Sellato (2003), Schneeberger (1979), Baier (1987), and Baier (1992), with more than 100 archaeological sites (Arifin and Sellato, 2003) recorded along the upper reaches of the Bahau River and its tributaries in Kalimantan. Unfortunately no dating or palaeoecological analysis have been undertaken at these sites.

Up until the mid-2000s the Kelabit grew rice in both wet and dry fields, depending on the type of soil and terrain available. There was a huge increase in wet rice cultivation from the 1960s onwards; nowadays the Kelabit have abandoned dry swidden cultivation and rely entirely on permanent wet cultivation (Janowski, 1988, 2003) (Figs. 11 and 12).

9 Conclusion

Within the tropical highlands of central Borneo communities of nomadic hunter-gatherers and agriculturalists have developed a unique cultural relationship with their environment. The purpose of this paper has been to examine the environmental evidence for initial signs of plant exploitation and the transition to agriculture, within the Kelabit Highlands of Sarawak, as well as to understand the wider significance of past plants in a changing cultural landscape. A multi-disciplinary approach has been an essential part of the 'Cultured Rainforest Project'. By understanding how the people living in the Kelabit Highlands relate to their landscape today we have been able to gradually go back in time to connect the present and recent past with the more distant past.

Tentative evidence of human environment interactions is first recorded ca. 6200 cal. BP; however the evidence is insubstantial and isolated. Perhaps low energy forest clearance or minor arboricultural practices was taking place during this period, although a climatic event should not be ruled out either. After 6000 cal. BP gaps in the environmental record present further difficulty in interpreting potential human signatures until the later Holocene. The first secure evidence of human activity in the Kelabit Highlands takes place from ~3000 cal. BP. This seems to be part of a pronounced cultural phase associated with megalithic construction. A further pronounced phase is recorded from ~450 cal. BP.

Particularly within the southern Kelabit Highlands evidence has shown that forests have been modified or re-worked to some extent for at least 3000 years. The palaeoecological investigations support the possibility of palm management, perhaps as part of an arboricultural system, by possibly as early as ~4000 cal. BP and certainly by 2800-2300 cal. BP. What initiated this change from predominantly hunter-gathering to arboriculture remains a question for future work. For unknown reasons megalithic construction ceases after 1500 cal. BP; however people remain present in the region particularly at Bario in the northern Kelabit Highlands. Here *Eugeissona* management emerges around 1200 cal. BP and remains until the recent historic period. This may simply signify that people were moving around the landscape.

After 600 cal. BP, although particularly from 450 cal. BP a second wave of cultural activity takes place, which was perhaps initiated by increasing trade with the coast and the arrival of metal tools. The wave in cultural activity is represented by the establishment of rice agriculture, increased palm management, by an explosion in megalithic activity, and by the appearance of Chinese ceramics.

Few other areas in Borneo contain records comparable with the archaeology, anthropology and palaeoecology in the Kelabit Highlands. What these results show is that there is a wealth of information still to be uncovered about the early and later development, pattern and spread of vegecultures in Borneo and island SE Asia and their cultural significance. This relates not only to the sago palm but also to other potential food plants, which have not been investigated during this project.

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Table 1: C14 and calibrated ages for the palaeoecological results discussed in this paper: Bario (Ba), Pa'Dalih (PDH 212 and PDH 223) and Pa'Buda (BPG).G).

UBA no	Site code	Depth (cm)	C14 age BP	+/	Cal BP (2 sig)	Material
UBA-15637	Ba	29-31	1433	23	1297-1366	Peat
UBA-9995	Ba	32.5-33	2428	42	2352-2543	Charcoal
UBA-10000	Ba	47-49	1719	25	1558-1699	Wood
UBA-10001	Ba	59-65	4841	29	5483-5645	Wood
UBA-10002	Ba	78-80	25,598	104	30,756-30,219	Wood
UBA-9310	Ba	114-118	29,981	109	34,939-34,497	Wood
UBA-9311	Ba	160-162	26,042	90	31,066-30,517	Wood
UBA-10003	Ba	258-260	40,397	436	45,017-43,453	Wood
UBA-9312	Ba	286-292	44,583	345	49,006-46,479	Wood
UBA-10584	PDH 212	31	43	17	242-0	Charcoal
UBA-12735	PDH 212	95-97	329	23	309-464	Wood
UBA-10585	PDH 212	193-194	2655	23	2744-2838	Charcoal

UBA-13654	PDH 212	255-257	32,670	177	37,936-36,612	Wood
UBA-12738	PDH 212	345-347	47,501	514	Too old	Charcoal
UBA-12741	PDH 212	425-427	50,321	552	Too old	Wood
UBA-12586	PDH 212	449.5-451	47,468	611	Too old	Charcoal
UBA-8130	BPG	89	5692	43	6398-6631	Charcoal
UBA-9305	BPG	152-154	6177	23	7005-7163	Charcoal
UBA-9308	BPG	156-158	5396	27	6124-6283	Charcoal
UBA-9309	BPG	170-172	5495	24	6218-6388	Charcoal
UBA-9306	BPG	192-194	5633	23	6322-6479	Charcoal
UBA-10593	PDH 223	144-146	1751	19	1604-1715	Charcoal
UBA-10594	PDH 223	178-182	1867	18	1734-1868	Charcoal
UBA-10595	PDH 223	275-278	2308	18	2322-2352	Charcoal

Table 2

C14 ages from the archaeological sites of the CRF (Barker et al., 2009; Lloyd-Smith et al., 2010, 2012).

Site	Context	Material	Lab number	Cal BP age (2 sigma)	Cal BC/AD age (2 sigma)
Ruma Ma'on Dakha	Possible buried soil horizon from an earlier phase of occupation	Charcoal	Beta-237849	3770 ± 40 BP	BC 2310-2030
Perupun Raya Pa'Lungan	Inside of the stone mound at 60-90 cm	Cremated bone	Beta-280504	2026-1826 BP	BC 76-AD 124
Long Diit stone jar cemetery	Underneath packing stones of a foundation trench	Charcoal	UBA-12420	1238 ± 22 BP	AD 760-873
Ruma Ma'on Taa Payo (Stone wall enclosure)	Buried feature (ditch) filled by a stone wall	Charcoal	Beta 237850	1620 ± 40 BP	AD 340-550
Ruma Ma'on Ra'an Berangan	Fill of a post hole at a ridge top settlement	Charcoal	Beta 237854	400 ± 40 BP	AD 1430-1640
Menatuh Long Kelit	Packing fill in foundation trench of standing stone jar	Charcoal	Beta-237848	240 ± 40 BP	AD 1510-1960

Table 3: Main megalithic types found in the Kelabit Highlands (based on the work on the work by Hitchner, 2009 and ITTO and SFD, 2009).

Types	Description	Purpose or association
Batuh Sinuped/Senuped	Menhirs/Stone markers ranging from <1m to 2.5 m, usually rectangular, wider than they are thick with a triangular top	Rite of passage into manhood, Boundary markers To show strength
Batuh Narit	Carved stones	Associated with Myths, Honour, to commemorate death, to depict events
Batuh Nawi	Stone burial urns, carved from solid rock	Used for warriors or notables in secondary burial
Batuh Nangan	Supported stones or dolmens, which range in size: Large slabs on upright stones	Burials, Honour & Name changing ceremonies
Perupun	Stone rock piles	Commissioned by childless people, usually men, for the purpose of burying their valuables before their deaths
Binatuh/Belanai	Chinese Dragon jar burials	To bury the dead- Secondary burial
Nabang	Large ceremonial trenches	To guide spirits of the dead into the afterlife and to commemorate dead ancestors
Kawang	Cutting a large ceremonial clearing in virgin forest on a mountain ridge	To commemorate events

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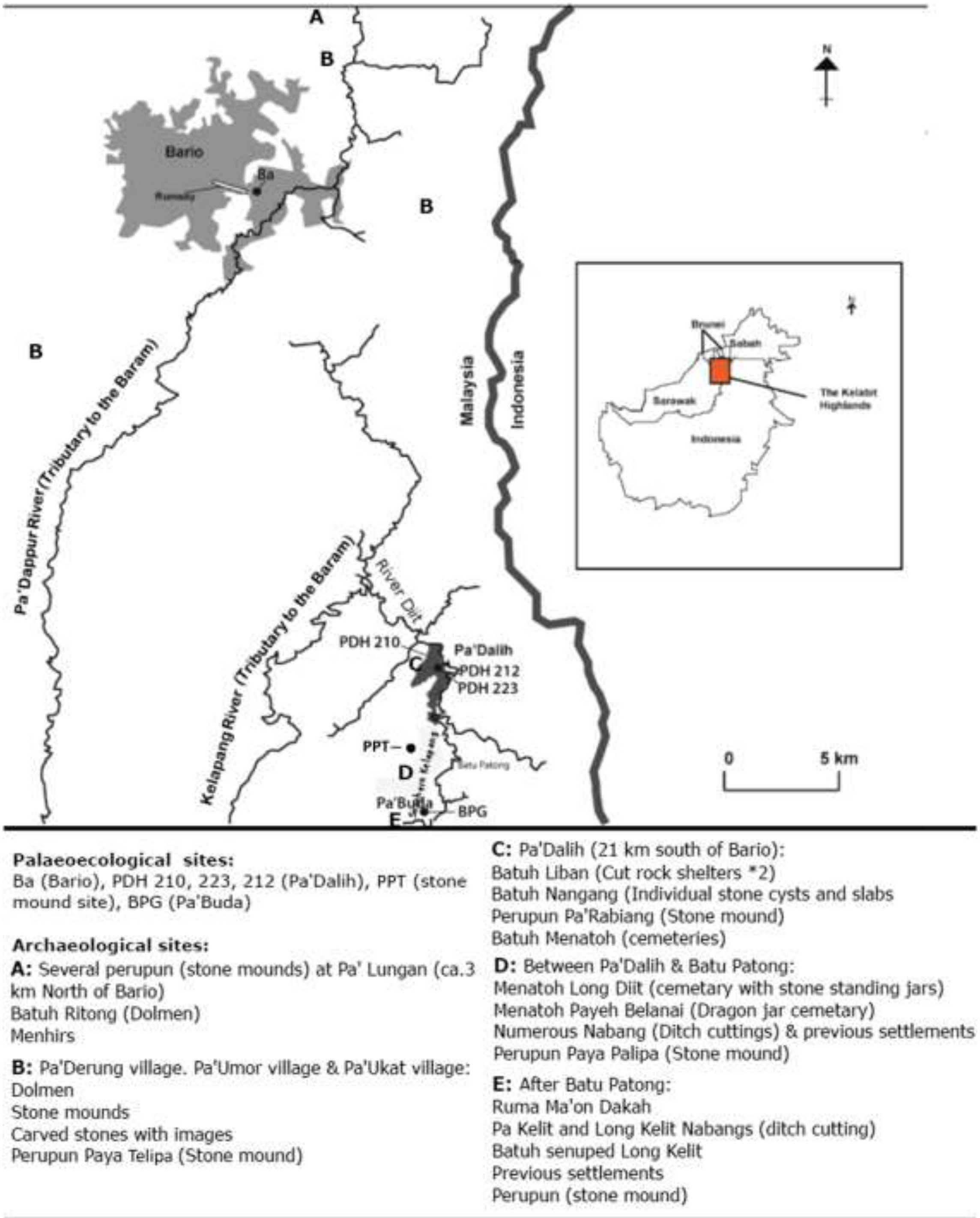

Fig. 1. Map of Kelabit Highlands: Sites where palaeoecological analysis was undertaken and a list of archaeological features within a 3 km radius of these sites.

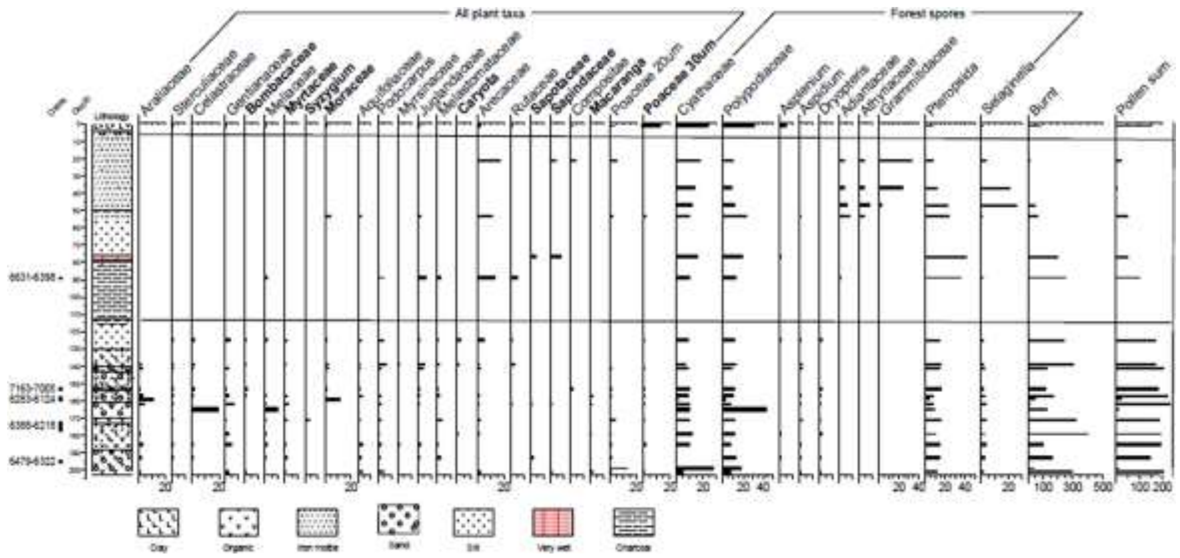

Fig. 2. Pa'Buda-Core BPG, Sediment profile, palm and fruit tree pollen, and a pollen count summary (Adapted from Jones et al., 2013b).

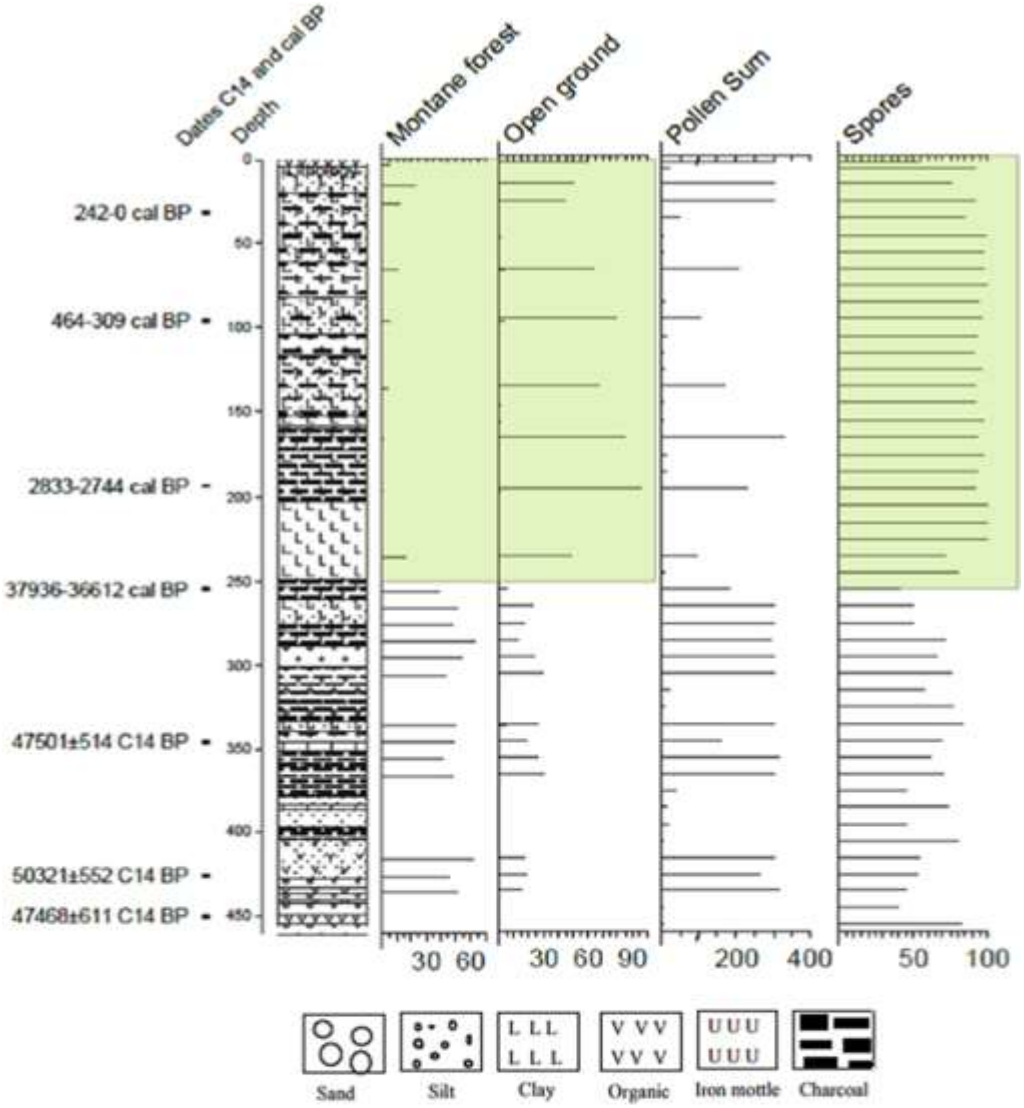

Fig. 3. Pa'Dalih-PDH 212. This pollen summary highlights the difference in vegetation distribution between the Pleistocene and Holocene. The results demonstrate an increase in disturbance indicators and spores, and a decline in tree taxa after 3000 cal. BP, highlighted by the box (Adapted from Jones et al., 2013b).

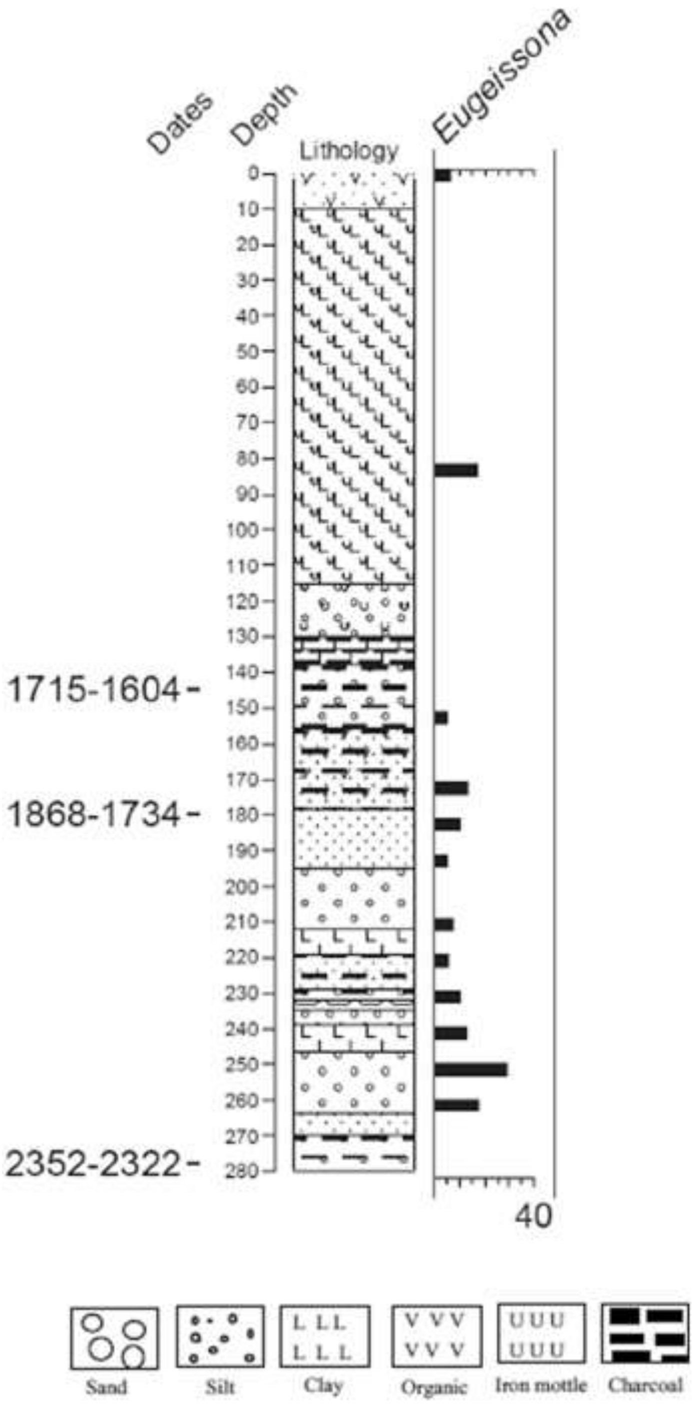

Fig. 4. Pa'Dalih-PDH 223-*Eugeissona* pollen results (See Jones et al., 2013a).

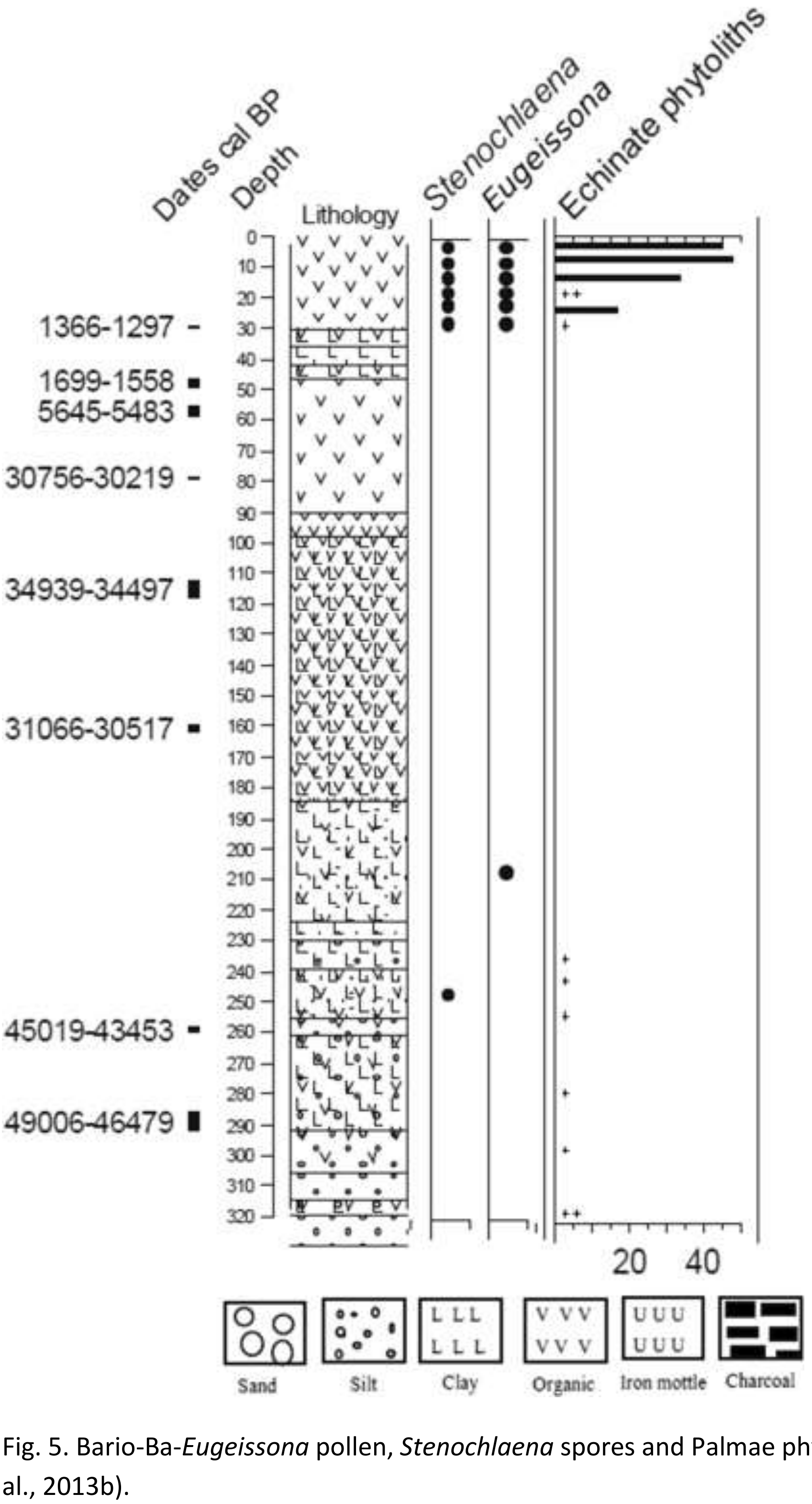

Fig. 5. Bario-Ba-*Eugeissona* pollen, *Stenochlaena* spores and Palmae phytolith results (See Jones et al., 2013b).

Fig. 6. Eugeissona pollen images.

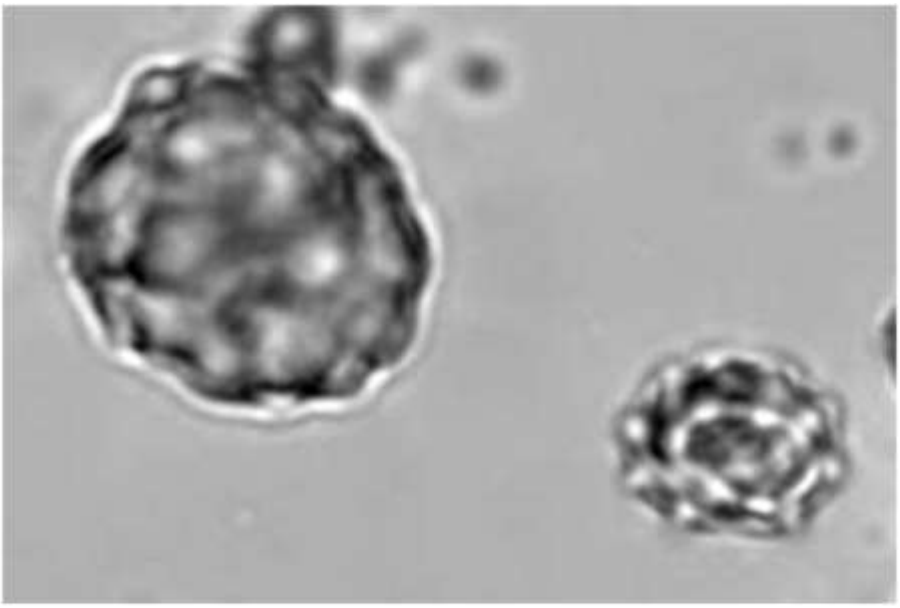

Fig. 7. Palmae phytolith images.

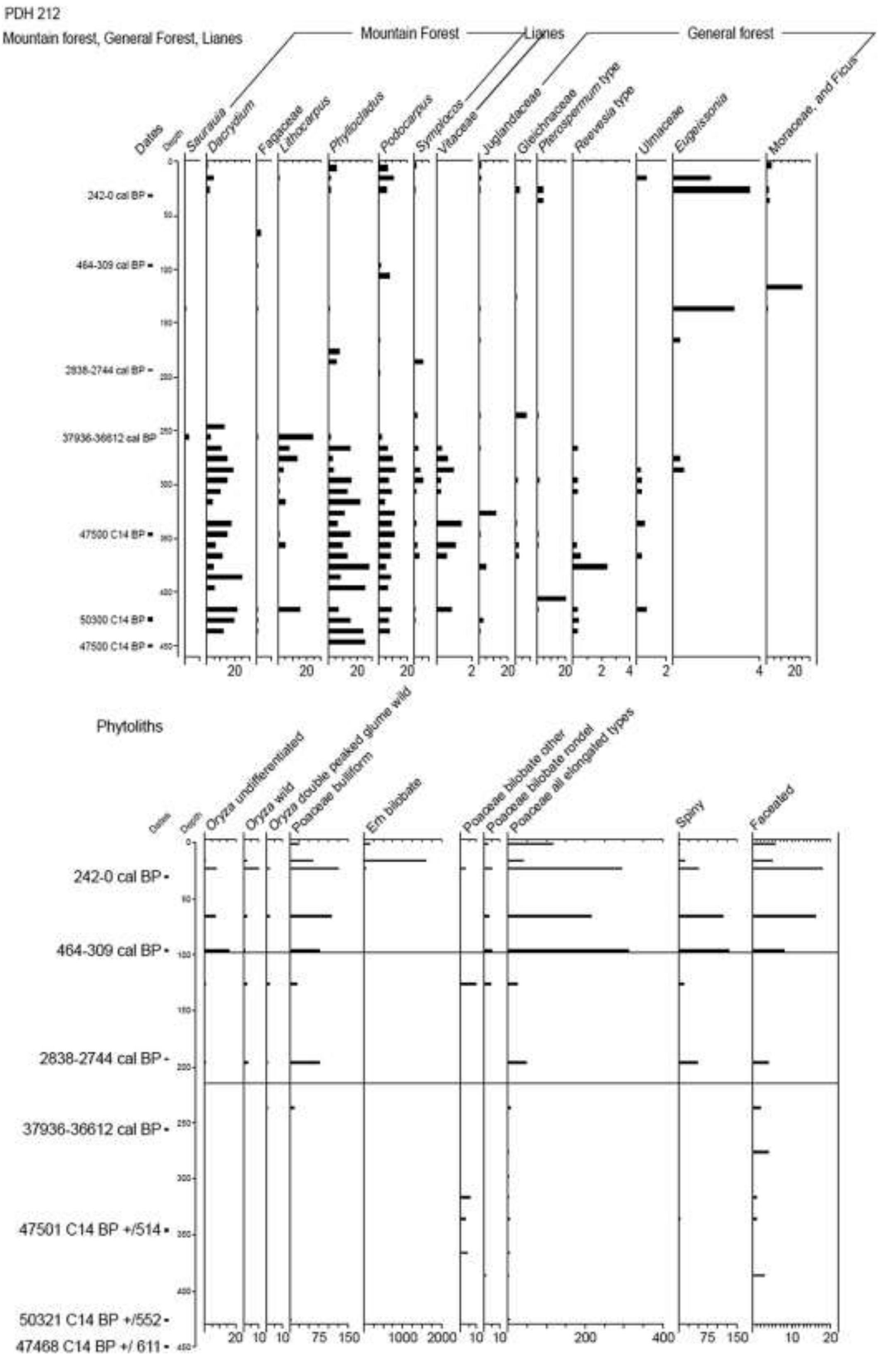

Fig. 8. cf. Forest pollen summary, including *Eugeissona* and Phytolith results for PDH 212.

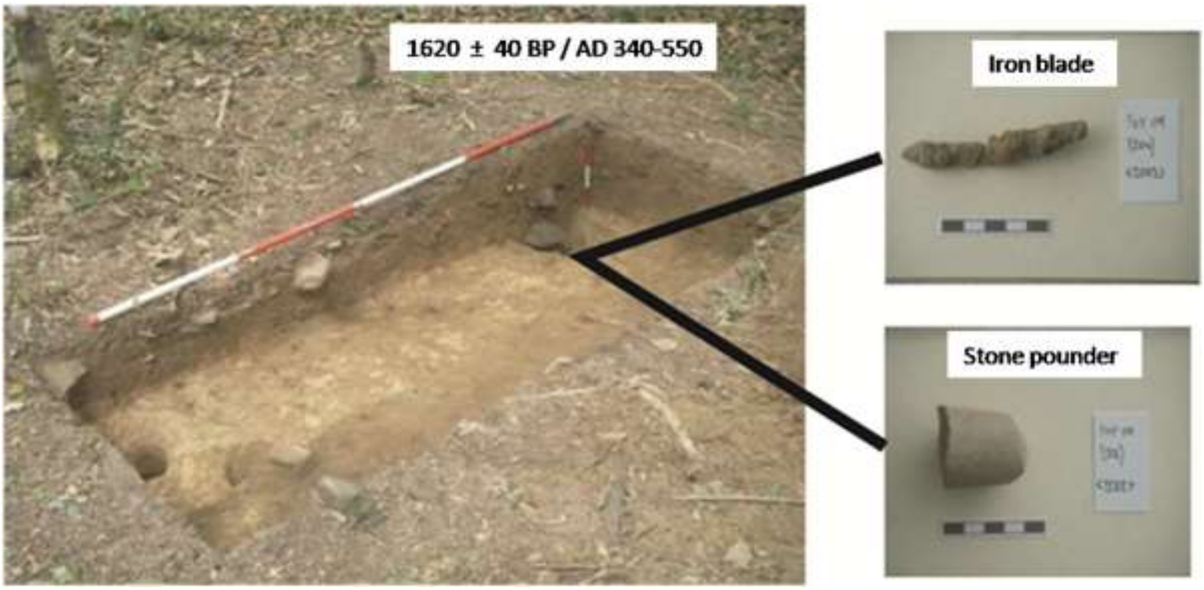

Fig. 9. Archaeological site of Ruma Ma'on Taa Payo: buried ditch feature. Feature contained a stone pounder, an iron blade and glass beads. There was palm starch on one end of the stone pounder and it may have been used to process sago.

Fig. 11. Abandoned rice fields in Bario, from the recent past.

Fig. 12. Present day rice fields in Bario.

Fig. 13. Archaeological site of Menatuh Long Kelit. Stone burial site which contained charred rice fragments.