

ARCHAEOBOTANY IN AUSTRALIA AND NEW GUINEA:

Practice, Potential and Prospects

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Abstract

Archaeobotany is the study of plant remains from archaeological contexts. Despite Australasian research being at the forefront of several methodological innovations over the last three decades, archaeobotany is now a relatively peripheral concern to most archaeological projects in Australia and New Guinea. In this paper, many practicing archaeobotanists working in these regions argue for a more central role for archaeobotany in standard archaeological practice. An overview of archaeobotanical techniques and applications is presented, the potential for archaeobotany to address key historical research questions is indicated, and initiatives designed to promote archaeobotany and improve current practices are outlined.

Introduction

The study of plant remains from archaeological contexts, or archaeobotany, is a subdiscipline of archaeology that has come to increasing prominence over the last three decades across the globe. Australian archaeology has been at the forefront of several developments in archaeobotany, particularly the use of plant microfossil applications to address archaeological problems, including residue analysis (Loy 1994), phytoliths (Wilson 1985) and starch grain analysis (Barton and White 1993; Loy *et al.* 1992). Despite ground-breaking work and consolidation in several areas of macrofossil and microfossil research (consider Beck *et al.* 1989; Bowdery 1998; Hart and Wallis 2003; Torrence and Barton 2006), as well as the importance of plants in primary production and as a resource, archaeobotany has been a relatively peripheral concern for most archaeological projects (academic and consultancy) in Australia and New Guinea.

At a December 2007 meeting at the University of Queensland, archaeobotanists who work in Australia and Papua New Guinea decided to take a more active role in showcasing the potential contributions of archaeobotany. The primary goal is to make the field a more central concern of archaeological practice in this region, as it is in many other countries across the globe. As a first step we offer an overview of archaeobotanical practice in the region, consider its potential to address key historical research questions, and outline initiatives designed to promote archaeobotany and improve current practices.

The call to bring archaeobotany to the core of archaeological practice should not be considered radical. Plants have always been a fundamental component of human economy as they contribute materials for food, medicine, clothing, shelter, tools and other uses. In the continental area of Australia and Papua New Guinea, the specialised use of floristic resources is evident from the late Pleistocene to the recent past. Recorded transformations include major technological innovations such as the advent of seed-grinding, detoxification, arboriculture and agriculture in various parts of Sahul. These technological innovations would doubtless have had an impact on social systems and economies of the time, not to mention material culture associated with subsistence technology. In archaeological practice, it is already unacceptable to leave stone tools or faunal remains at an archaeological site unsampled or unstudied, and it should no longer be acceptable to leave the investigation of plant use unexplored either at the site or in the laboratory. No balanced understanding of human-environment interactions in the past can be expected when there

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is so little information on interactions with plants; relationships that are fundamental to human life.

Archaeobotany: An Overview

Archaeobotanists use a range of techniques to study plant remains from various perspectives. Techniques can be coarsely grouped according to the scale of the samples: macrofossil, microfossil and molecular.

Macrofossils

The study of plant macrofossils is perhaps the most familiar type of archaeobotanical method. Plant remains are collected in the field, whether by direct excavation, sieving of excavated material, or flotation of bulk samples (Fairbairn 2005a; Pearsall 2000). These plant remains tend to be charred and of hardy materials, usually seeds, wood and the hard pit stones of fruits and kernels of nuts, although they occasionally include soft tissues preserved through charring, desiccation, freezing or waterlogging. Macrofossil assemblages, comprising intact and fragmented materials, are sorted and identified to genus or species level where possible using voucher specimens in comparative reference collections. Macrobotanical analysis is invaluable at occupation sites in order to understand food processing and palaeodiet, and is also important more broadly to understand human adaptation, human movements, environmental and plant management, and vegetation history (Crawford 2008; Pearsall 2000), as well as site taphonomy. Additionally, the analysis and identification of charcoal can inform the selection of samples for radiocarbon dating (i.e. to avoid 'old wood') and the interpretation of vegetation history (Smith *et al.* 1995).

The analysis of archaeological parenchyma – the soft parenchymatous tissue of plants – was conceived as a technique to identify root crops that were formerly 'invisible' archaeobotanically at archaeological sites (Hather 1993, 2000). The technique is generally considered macrobotanical, although it can also be microbotanical depending on the size and fragmentation of plant remains. Despite its potential, especially for understanding traditional plant exploitation in Australia and New Guinea, the analysis of archaeological parenchyma has not been widely adopted, relevant reference collections have not been established, training has been limited and, consequently, the technique has been eclipsed by others, principally phytolith and starch grain analyses (see below). At present, the analysis of archaeological parenchyma occurs as an incidental activity accompanying other forms of archaeobotany.

In Australia, macrobotanical research has been limited by poor preservation and, perhaps more importantly, by inadequate field sampling strategies. Charred material, mainly wood charcoal, is very common at most sites, but has been rarely analysed beyond occurrence and dating (although see Boyd *et al.* 2000; Dolby 1995; Hope 1988; Smith *et al.* 1995). Early applications of macrofossil research included Beaton's (1982; followed by Beck 1992) investigations of cycad use by Aboriginal people and Clarke's (1989) contribution to archaeological research in Kakadu National Park. Following an apparent hiatus (although see McConnell and O'Connor 1997), recent investigations have shed light on complex plant management practices from seed remains in the Kimberley (Atchison *et al.* 2005) and semi-arid New South Wales (Fullagar *et al.* 2008), and nuts and charcoal

preserved in the wet tropics of northeast Queensland (see Cosgrove *et al.* 2007), and the diets of urban dwellers following European settlement (Fairbairn 2007), as well as included re-evaluations of previous work (Asmussen 2005).

In Papua New Guinea, macrobotanical research has not been systematically applied at most sites, although it has been a feature of multidisciplinary investigations of early agriculture at wetlands in the highlands since the 1960s (e.g. Powell 1970, 1982) and has figured in studies of key Lapita sites (Lepofsky *et al.* 1998; Matthews and Gosden 1997). Given the relative paucity of archaeobotanical information for New Guinea and Melanesia, but the known development of agriculture (Golson 2007) and arboriculture (Yen 1996) in this region, most published archaeobotanical studies are of considerable significance, such as those for Pleistocene occupation at Kosipe in highland New Guinea (Fairbairn *et al.* 2006), and for Holocene sites in lowland New Guinea (Swadling *et al.* 1991; cf. Fairbairn and Swadling 2005) and Island Melanesia (Gosden and Webb 1994; Lepofsky *et al.* 1998; Matthews and Gosden 1997). However, major lacunae remain; for example, archaeobotanical studies have shed very little light on the distribution, dispersal and domestication of several food plants – including bananas, sugarcane, taro and yams – within the New Guinea region, in comparison with genetic and molecular analyses (e.g. Lebot 1999). Contributory factors certainly include the lack of analysis and limited publication, for various reasons, of several archaeobotanical assemblages, including those from Kuk Swamp (although see Denham 2003:Appendix G1), Manim 2 (Christensen 1975; cf. Donoghue 1989), Seraba/Kowekau (Gorecki 1993; cf. Yen 1996), and of Lapita sites in Island Melanesia. Often, only selected and more-easily-identified components of assemblages are analysed, while other components – especially wood and charcoal – are left unexamined.

Macrobotanical analyses at archaeological sites in Australia and New Guinea have often been complemented by ethnographic accounts of plant use (e.g. Gott 1983, 1999), and engagement with Indigenous people who share traditional knowledge about plant use (see Atchison *et al.* 2005 and Cosgrove *et al.* 2007 for recent Australian examples). In this part of the world, as elsewhere, archaeological research has often been enriched by an engagement with anthropology and ethnobotany.

Microfossils

Over the last three decades, several microfossil techniques have been applied to archaeological problems, most significantly the analysis of pollen, phytoliths and starch grains. Techniques have been applied to bulk samples of soil, sediment and feature fill and to residues extracted from wooden, stone or ceramic artefacts and teeth.

Palynology employs a relatively well-known set of techniques for the extraction of pollen and spores, and their identification to family, genus or species level (Faegri and Iversen 1989). Palynology, in conjunction with micro-charcoal counts, has been the primary tool of palaeoecological reconstruction, by providing a record of how vegetation has changed through time and by allowing inferences to be made about the contribution of people's activities to environmental change. Such palaeoecological reconstructions have been based on samples from archaeological sites (Dimbleby 1985) and also from complementary off-site

locations that situate archaeological remains and the human processes they represent within broader environmental contexts, or within broader environmental archaeological investigations (Evans and O'Connor 1999).

A major focus of palynology in Australia has been the study of the impacts of Aboriginal people on the environment, principally through the use of fire to manage the landscape and increase resource density, both of animals (Bowman *et al.* 2001) and plants (Gott 2005; Jones 1969). Other research foci include the effects of initial colonisation on the environment (Kershaw *et al.* 2006), with potential implications for megafaunal extinction (Miller *et al.* 2005), although these interpretations are much debated due to varying chronologies for the colonisation of Australia (e.g. O'Connell and Allen 2007). Regional chronologies for Pleistocene or Holocene burning and vegetation change have been established for the Lake Condah region of southwestern Victoria (Builth *et al.* 2008), Sydney Basin (Black *et al.* 2008), Atherton Tablelands of northeastern Queensland (Kershaw *et al.* 2007), Torres Strait (Rowe 2006a), and elsewhere. Additionally, high-resolution records have been used to understand climatic and anthropogenic drivers of environmental change over the last 1000 years (Haberle *et al.* 2006).

Palynology in New Guinea has been used to reconstruct the human role in vegetation history (Haberle 1994, 2007; Hope 1980, 1998), especially with respect to human colonisation of new environments and the emergence of agriculture and its subsequent transformation and diffusion (Denham and Haberle 2008; Powell 1982). The approach has complemented archaeological investigations in New Guinea to a much greater extent than in Australia, in terms of both on-site (e.g. several wetland sites in the highlands of New Guinea: Denham *et al.* 2003; Powell 1970) and off-site (e.g. Kosipe: Hope 1982; Hope and Golson 1995) applications. The presence and proportion of diagnostic vegetation communities have been identified, including secondary growth, anthropogenic grasslands and weedy species (Haberle 1994), as well as economically significant plants (e.g. taro, *Colocasia esculenta*: Garrett-Jones 1979; Haberle 1995).

Phytoliths are another type of plant microfossil. They are siliceous, or occasionally calcareous concretions that form in the intra- and inter-cellular spaces of plants (Piperno 2006). After the decay of a plant or plant part, phytoliths may be incorporated through various taphonomic processes into archaeological and palaeoecological deposits (Wallis 2000a, 2000b). Unlike pollen, there is not necessarily a single phytolith morphotype that is characteristic of a particular plant taxon; rather, some plant species produce numerous phytolith morphotypes whereas others produce none. In some cases, a combination of phytolith morphologies is diagnostic of a specific genus or species, for example in some grasses, which are difficult to distinguish using pollen. Of great significance for archaeology and palaeoecology, phytoliths are often preserved in depositional settings where macrobotanical remains and pollen have decayed. Consequently phytolith analysis has great potential for application in the arid, semi-arid, monsoonal and wet, subtropical and tropical regions of Sahul.

In archaeology, phytoliths have been used to identify plants to the family level, and less often to the genus and species levels. They have successfully been used to chart the chronological transformation or dispersal of plants undergoing domestication

(Piperno and Pearsall 1998; Piperno and Stothert 2003); track vegetation changes resulting from human interference in ecosystems (Boyd *et al.* 2005; Lentfer *et al.* 2002; Lentfer and Torrence 2007); and to study tool uses (Fullagar 1993; Kealhofer *et al.* 1999).

A pioneering study at Kuk Swamp sought to identify and discriminate banana (*Musa* spp.) phytoliths and infer vegetation history during the Holocene (Wilson 1985; also see Fujiwara *et al.* 1985 for a comparable example from Australia). Wilson's work laid a foundation for the discrimination of bananas using phytoliths in New Guinea (Bowdery 1999; Denham *et al.* 2003; Horrocks *et al.* 2008), the Torres Strait (Parr and Carter 2003), Island Melanesia (Lentfer and Green 2004), and elsewhere (e.g. Mbida *et al.* 2001). Studies of vegetation history based on phytoliths have greatly augmented the interpretation of several archaeological sites in arid Australia – principally Puritjarra (Bowdery 1998) and Carpenter's Gap (Wallis 2000a, 2001), and the wet tropics of New Guinea – principally Kuk (Denham *et al.* 2004) and sites on the Willaumez Peninsula, New Britain (Boyd *et al.* 2005; Lentfer 2003; Lentfer and Torrence 2007; Parr 2003; Parr *et al.* 2001). Like pollen and macrofossils, phytoliths of introduced plants, particularly exotic cereals, have served as chronological markers of European settlement and resultant environmental change in Australia (Lentfer *et al.* 1997). Additionally, experimental work has confirmed the potential of carbon secured within the silica casing of phytoliths for radiocarbon dating (Parr and Sullivan 2005).

The analysis of starch grains, or granules, is a more recent addition to the suite of microfossil techniques used by archaeobotanists to detect and identify plant remains. Starch grains are microscopic components derived from various plant parts; they are mainly located in storage organs such as tubers, nuts and trunk pith, but may also include metabolic starch that is formed in photosynthetic (green) leaves and stems (Field 2008; Torrence and Barton 2006). Starch is entrained in archaeological deposits, sediments and soils after a plant dies or a plant part decays (i.e. decaying food remains), although the taphonomy and geochemistry of starch preservation in the burial environment is poorly known (Barton and Matthews 2006; Haslam 2004). As with pollen and phytoliths, diagnostic starch grains can augment vegetation and land-use histories (Lentfer *et al.* 2002; Therin *et al.* 1999), identify specific plant species (e.g. Barton 2005; Dickau *et al.* 2007; Horrocks and Nunn 2007) and chart domesticatory relationships through time (e.g. Piperno and Holst 1998), with the latter two applications predominating. More recently, the direct radiocarbon dating of starch has established an important advance in documenting the initial use and expansion of maize in South America (Zarillo *et al.* 2008).

Some of the earliest and most innovative archaeological applications of starch grain analysis occurred in Australian laboratories that used starch in the interpretation of tool use (Barton and White 1993; Fullagar 1993; Loy 1994; Loy *et al.* 1992) and hafting (Bowdery 2001), and pioneered its study in the reconstruction of vegetation history (Lentfer *et al.* 2002; Therin *et al.* 1999). This work has continued (see Torrence and Barton 2006) with recent studies revealing food processing using Pleistocene-aged grinding stones at Cuddie Springs (Fullagar *et al.* 2008), at an early agricultural site in the highlands of New Guinea (Fullagar *et al.* 2006), in the tropical rainforests of northeastern

Queensland (Cosgrove *et al.* 2007), and in the western Pacific (Crowther 2005; Horrocks and Bedford 2005). The need for broader applications is considerable given that flaked stone tools of Pleistocene age in Australia and New Guinea are likely to have been used to exploit plants as much as, and if not more than, animals (Fullagar 1986, 1992; Hayden 1977; White and Thomas 1972). Stone tools dominate archaeological assemblages in Australia and yet knowledge of plant exploitation in these regions, particularly during the Pleistocene, is extremely limited (Denham *et al.* in press). Studies have begun to investigate and demonstrate the survival of starch residues on archaeological and ethnographic artefacts held in museum, university and private collections (Barton 2007; Field *et al.* in press; Fullagar *et al.* 2006; Nugent 2006).

Resins, a plant exudate, are known to have been used by Aboriginal Australian people as a sealant, adhesive and fixative for hafting, namely to attach a handle to a stone tool. The resin was heated, sometimes reinforced with beeswax, ash, fine sand or plant fibres, and fashioned into place (see Parr 2002). As a residue on artefacts, resin is relatively long-lasting in the archaeological record. The identification of archaeological resins provides valuable information on the manufacture and function of hafted tools, as well as the role of specific resins within exchange and social relationships. For example, many archaeologists believe that Australian backed artefacts, called microliths elsewhere in the world, required hafting and evidence derived from resins suggests this was often the case (e.g. Boot 1993; Robertson 2005; Therin 2000). Several methods have been employed to assist in identifying archaeological resins, including visual appearance of the raw material (Boot 1993), gas-liquid chromatography and thin-layer chromatography (Bowden and Reynolds 1982; Parr 1999), ascending paper chromatography (Boot 1993), high performance liquid chromatography (Welch 1997), and starch analysis (Parr 2002).

Molecular

The principal molecular technique of potential archaeobotanical relevance in the Australian region is the analysis of ancient DNA (aDNA). Analysis of aDNA has yielded significant results over the last 10–15 years (Willerslev and Cooper 2005), especially for understanding plant domestication (e.g. Allaby *et al.* 1994; Jaenicke-Després *et al.* 2003). The extraction of ancient DNA from plants (Gugerli *et al.* 2005; Schlumbaum *et al.* 2008), however, is relatively difficult and has yet to be successful for Australian or New Guinean samples. The preservation of DNA for long periods of time in a condition suitable for analysis requires very particular circumstances. If suitable archaeobotanical materials can be found for aDNA analysis, then there is great potential for using this approach to investigate the exploitation, management and human transport of plants in Australia and New Guinea.

Further chemical and physico-chemical methods can be used to analyse a great variety of biomolecules that can be recovered from archaeobotanical remains. The biomolecules can include proteins, fatty acids, terpenes, phenols, oils, waxes, nucleic acids and biomarkers. Biomarkers are chemical compounds that are found in a specific plant source and examples include: caffeine, theobromine and xanthine to identify the presence of cacao (Hall *et al.* 1988); tartaric acid to identify the presence of wine (McGovern *et al.* 1996); and, the tetrahydropyridine alkaloids

arecoline, arecaidine, guvacine and guvacoline to identify betel nut (Oxenham *et al.* 2002). Techniques used to analyse biomolecules, either singularly or in combination, include spectroscopy, chromatography and electrophoresis:

- raman spectroscopy and infrared spectroscopy to chemically characterise a variety of plant materials, particularly archaeological resins (de Faria *et al.* 2004);
- nuclear magnetic resonance spectroscopy to identify resins and wood (Maccotta *et al.* 2005);
- mass spectroscopy detection of archaeological plant residues and resin identification (Evans and Donahue 2005; Oudemans *et al.* 2007);
- gas chromatography to analyse plant residues and oils on ceramic vessels (e.g. Evershed *et al.* 2003); and
- gas chromatography-mass spectrometry to identify date palm, palm oil and resins, tobacco in pipe residue, and biomarkers of wine in residues from ceramic vessels (Copley *et al.* 2001; Guasch-Jane *et al.* 2006).

As the technology and application of these analyses improve, they will contribute greatly to our ability to interpret plant use in the past.

Potential Opportunities

Archaeobotanical techniques have considerable potential to contribute in major ways to several key areas of archaeological enquiry, particularly when used in combination with other subfields of archaeology. Some of the most high-profile opportunities are noted below.

Human Adaptation to Environmental Change

Current debates on human responses to environmental change, including climatic factors, are couched in long-term historical frameworks (e.g. Diamond 2005). Without a more detailed understanding of human–environment interactions through time, including how people adapted to and transformed the faunal, floral and inanimate components of their environment, the evidence from Sahul will continue to have little new information to contribute to global debates. The Sahulian evidence will remain locked into generalised frameworks of human behaviour and environmental change, including highly speculative debates on extinctions, resource exploitation and burning, with limited understanding of social processes. Without the kinds of detail provided by archaeobotany, the frames of reference for these debates will remain more firmly rooted in assumptions from the present than in evidence from the past.

Colonisation of Sahul

Without more archaeobotanical information, our understanding of how people colonised Sahul and adapted to the diverse continent will remain extremely limited. Most information regarding the Pleistocene occupation of Australia is derived from faunal and lithic assemblages, supplemented by some physical anthropology; comparable archaeobotanical information is extremely sparse (Denham *et al.* in press). Plants are likely to have contributed significantly to diets and have facilitated adaptation to environmental zones across the continent from initial colonisation. Although research has been hindered by

poor macrobotanical preservation and field sampling, there is enormous scope for phytolith applications (e.g. Wallis 2000a) and for the analysis of residues from previously excavated lithic assemblages (e.g. Fullagar *et al.* 2006).

Interpreting Environmental Management

Archaeobotany provides highly specific information that can complement palaeoecological records and potentially enable greater interpretative resolution for understanding how people have contributed to environmental change in the past. For example, Cosgrove *et al.*'s (2007) recent macrobotanical findings from the tropical rainforests of Queensland provide detailed and nuanced understandings of what people were doing in the landscape during the late Holocene (following Horsfall 1987), practices that are only recorded in gross terms through palaeoecology (Turney *et al.* 2001) and interpretations of archaeological dates (Turney and Hobbs 2006). Cosgrove *et al.*'s (2007) finding that the increased intensity of rainforest occupation during the last 2000 years was facilitated, in part, by the adoption and intensification of toxic nut processing is unexpected and adds depth to often one-dimensional conceptions of human agency in palaeoecological reconstructions. Additionally, a comparison of contemporary vegetation in the east Kimberley with the late Holocene archaeobotanical record indicates the significant role of Aboriginal customary land management in maintaining culturally important plant food resources (Atchison 2009). These important results highlight the need for detailed work to uncover the complexities of human-environment interactions in the past.

Emergence and Transformation of Agriculture and Arboriculture in New Guinea

Claims for early agricultural emergence and the development of arboriculture in New Guinea are based on relatively few well-published archaeobotanical studies, when compared to similar histories elsewhere in the world. The detailed studies undertaken to date are derived from a few sites or regions and, even though they provide robust information, they constitute only a loose historical framework (Denham 2007; Fairbairn 2005b; Golson 1977, 2007). The early dates for agriculture in the highlands raise questions concerning the development of subsistence strategies in the lowlands, where the locations, timing and transformation of early domesticatory relationships and cultivation are especially under-researched. Only through the systematic application of archaeobotanical techniques to previously excavated collections and at newly excavated sites can the history of plant exploitation in New Guinea and neighbouring Island Melanesia be fully understood.

Aboriginal Diets and Health

Isotopic and palaeopathological research has shed some light on general constituents to the diet and health of Aboriginal populations in the past (e.g. Pate 1997, 1998; Webb 1995; see Larsen 2000). As in other spheres, there is missing detail on exactly what foods people ate, how people obtained food, the range and proportions of foods consumed, the effects of diet on human health, and how these all transformed through time. Such concerns are not of arcane relevance. Questions such as, 'why did people increasingly process toxic plants for food in some areas of Australia?' can lead to a deeper understanding of traditional

diets and inform current initiatives to improve Aboriginal health (O'Dea 1992; O'Dea and Spargo 1982).

Archaeobotanical Initiatives and Proposals

A working group, titled 'Archaeobotany in New Guinea and Australia' (ANGA), has been established to promote, develop initiatives and provide a point of contact for archaeobotany in the region. Several initiatives have already been proposed and are beginning to be implemented by the ANGA working group to overcome the relative marginalisation of archaeobotany within mainstream archaeological practice in Australia and New Guinea. Any feedback, additional suggestions and participation are most welcome.

Redefinition of Standard and Acceptable Archaeological Practice

If archaeobotany is to be at the core of archaeological practice, it needs to be a standard aspect of most field projects, whether academic or consultancy, as it is in the United Kingdom (English Heritage 2002) and some parts of Europe and North America (Holloway 1997). This point is well-illustrated by several projects in the Sahulian region that have taken archaeobotany seriously and that have each yielded findings of global import. These include the multidisciplinary investigations at Kuk Swamp in the 1970s directed by Jack Golson and from the 1990s directed by Tim Denham, research ongoing in the West New Britain Project since the early 1990s led by Robin Torrence and Bill Boyd, as well as the aforementioned investigations of plant exploitation in the monsoonal savanna of the Kimberley (Atchison *et al.* 2005) and the tropical rainforests of northeastern Queensland (Cosgrove *et al.* 2007). The success of these projects derives from the integration of archaeobotany at the initial stages of planning.

The nature of archaeological investigations, especially those involving excavation, should be determined through consultation with an archaeobotanist before the fieldwork occurs, preferably at the planning stages so that sufficient resources – people, time, money and equipment – can be allocated. Archaeobotanists should be present in the field, undertake their own sampling, processing and analysis in accordance with standard protocols, and be trusted to integrate their research and findings into the aims of the archaeological project as a whole.

Too often, the role of archaeobotany has been a *post facto*, or post-excavation, afterthought. Archaeobotanists have not usually been involved in the planning or fieldwork. Habitually they are given samples after fieldwork has been completed with a specific set of predetermined analyses and questions in mind, or a separate reinvestigation of a site has occurred in order to obtain samples for a specific archaeobotanical project. Although highly valuable information may have been garnered, without proper planning and consultation there is a lingering sense of 'what if ...?' had the project been devised and implemented with archaeobotany as a core concern, along with stone tools, faunal remains and such like.

Members of the ANGA working group are actively promoting archaeobotany in several ways:

- hold their own annual meeting at each Australian Archaeological Association Annual Conference, comprising an open session showcasing recent work to the whole

archaeological community and a more specialised workshop on archaeobotany;

- the proactive promotion of archaeobotany in academic arenas inside and outside archaeology, including earth and environmental science meetings and public-oriented publications;
- provide education within the discipline to improve current practices, through courses taught at universities and through collaborations with colleagues; and,
- work with Aboriginal communities and academic reference groups in regard to plant processing and land management.

The group has also initiated specific projects to address the immediate needs of the archaeobotanical community in Australia.

Curation of Archaeobotanical, Ethnographic and Reference Collections

Linked to a realignment of archaeobotany within the discipline is a need to take the curation of collections seriously. Three main kinds of collection are important: archaeobotanical assemblages recovered from excavations; historical and ethnographic collections; and modern collections of reference materials. Samples, whether macrobotanical assemblages or microfossil slides and extractions, require proper handling, storage and access protocols so that they are not lost in one-off studies and reports, and are available to other researchers in the future. Many ethnographic collections have never been examined in order to identify the materials from which traditional artefacts were made. The potential value of ethnographic collections to archaeobotany has received little attention. Finally, although modern plant collections in biological research institutions (herbaria) are extensive, separate reference collections are needed to allow destructive analysis of reference samples for certain kinds of comparison with archaeobotanical samples.

Many collections that have taken years to assemble languish in inadequate store rooms after a student has finished a project or a specialist has retired; others have already been lost. Yet these collections are sorely needed by, and can serve as a foundation for other researchers. Given the lack of adequate facilities and resource allocation at most universities and contract organisations, there is an urgent need for a national archaeobotanical repository at which archaeobotanical and reference collections can be deposited once a study or line of research has been completed. Members of the ANGA working group are currently negotiating with several state and national herbaria with a view to establishing a national archaeobotanical repository, which can also store archaeobotanical collections from Papua New Guinea under arrangement with and permission from the Papua New Guinea National Museum and Art Gallery.

Knowledge Dissemination and Online Database

ANGA is working to establish a database for Australia and New Guinea with the following components (also see Barker 2000; Rowe 2006b; Rowe *et al.* 2007):

- metadata for archaeobotanical projects in the region;
- detailed data on archaeobotanical materials at each site, including accession lists with associated information and graphics (where possible); and

- detailed data of reference materials, including database records and graphics.

The database is intended to encourage data sharing and to preserve data in online repositories, information that is often locked away in theses, personal archives, storerooms and garages. Although considerable effort will be needed to establish the database, it will then only require diligence to ensure its continuing development and currency. The database will be accessible through the *Archaeobotany Net* website (<http://archaeobotany.ning.com>), which is being developed to provide an archaeobotany network for the Asia-Pacific region. The open access website will provide information about archaeobotany generally and support links to ANGA, and will be a forum for posting information, queries and communication among working group members, as well as other interested people.

Career Development and Resource Rationalisation

A more central role for archaeobotany in archaeological practice in the Australia and New Guinea region will encourage specialist retention. At present, postgraduate students who have trained and conducted research in a sphere of archaeobotany have limited opportunity for employment in their field. A few are able to find full-time employment as archaeobotanists, notably as postdoctoral fellows and occasionally as lecturers, although the former often lack continuity of employment. Most take generalist positions in either academic or commercial sectors, because their skills are usually viewed as too specialised and restricted. However, if the role of plants as a fundamental aspect of the occupation of Sahul from colonisation onwards is accepted, and if the ability of archaeobotany to address fundamental questions concerning the human condition is appreciated, then the scope of this field and the potential for specialist retention and development are much greater than currently acknowledged.

Furthermore, rationalisation is required to maximise resources, especially given the fiscal constraints within the university sector and the investment needed to assemble and curate reference collections. Why train specialists and fund facilities if there is no long-term vision within the discipline for continuity of employment and use? Furthermore, why train more people in the same field if there are already trained specialists who are not utilised? How can we maximise effective use of available resources within the discipline as a whole? Given the limitations of public funding generally, and particularly in terms of archaeobotany, it makes sense to rationalise the distribution of resources, training and specialisations among universities, and to develop stronger partnerships with the commercial sector. Cross-organisational communication, rationalisation and partnership are essential for archaeobotanists working in Australia and New Guinea; ANGA will provide a forum and the advocacy for these things to happen.

Looking to the Future

In this appraisal, a more central role for archaeobotany in standard archaeological practice across Australia and New Guinea is advocated. A range of macrofossil, microfossil and molecular techniques are reviewed, together with a consideration of their application to archaeological problems in Australia and

New Guinea. The potential of archaeobotany to contribute to key multidisciplinary research fields is highlighted. Several initiatives designed to promote archaeobotany, rationalise resources and improve current practice are outlined.

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References

- Allaby, R.G., M.K. Jones and T.A. Brown 1994 DNA in charred wheat grains from the Iron Age hillfort at Danebury, England. *Antiquity* 68:126-132.
- Asmussen, B. 2005 Dangerous Harvest Revisited: Taphonomy, Methodology and Intensification in the Central Queensland Highlands, Australia. Unpublished PhD thesis, Australian National University, Canberra.
- Atchison, J. 2009 Human impacts on *Persoonia falcata*: Perspectives on post-contact vegetation change in the Keep River region, Australia, from contemporary vegetation surveys. *Vegetation History and Archaeobotany* 18(2):147-157.
- Atchison, J., L. Head and R. Fullagar 2005 Archaeobotany of fruit seed processing in a monsoon savanna environment: Evidence from the Keep River region, Northern Territory, Australia. *Journal of Archaeological Science* 32:167-181.
- Barker, J.A. 2000 Towards an Archaeobotanical Reference Bank: A Pilot Study for the Construction of an Identification Tool for Macroscopic Plant Remains from Archaeological Deposits. Unpublished BArch (Hons) thesis, Department of Archaeology, Flinders University, Adelaide.
- Barton, H. 2005 The case for rainforest foragers: The starch record at Niah Cave, Sarawak. *Asian Perspectives* 44:56-72.
- Barton, H. 2007 Starch residues on museum artefacts: Implications for determining tool use. *Journal of Archaeological Science* 34:1752-1762.
- Barton, H. and P.J. Matthews 2006 Taphonomy. In R. Torrence and H. Barton (eds), *Ancient Starch Research*, pp.75-94. Walnut Creek, CA: Left Coast Press.
- Barton, H. and J.P. White 1993 Use of stone and shell artifacts at Balof 2, New Ireland, Papua New Guinea. *Asian Perspectives* 32:169-181.
- Beaton, J.M. 1982 Fire and water: Aspects of Australian Aboriginal management of cycads. *Archaeology in Oceania* 17(1):51-58.
- Beck, W. 1992 Aboriginal preparation of *Cycas* seeds in Australia. *Economic Botany* 46:133-147.
- Beck, W., A. Clarke and L. Head (eds) 1989 *Plants in Australian Archaeology*. Tempus 1. St Lucia, QLD: Anthropology Museum, University of Queensland.
- Black, M.P., S.D. Mooney and V. Attenbrow 2008 Implications of a 14 200 year contiguous fire record for understanding human-climate relationships at Goochs Swamp, New South Wales, Australia. *The Holocene* 18:437-447.
- Boot, P. 1993 Analysis of resins and other plant residues on stone artefacts from Graman New South Wales. In B. Fankhauser and J. R. Bird (eds), *Archaeometry: Current Australasian Research*, pp.3-12. Occasional Papers in Prehistory 22. Canberra: Department of Prehistory Research School of Pacific Studies, Australian National University.
- Bowden, B.F. and B. Reynolds 1982 The chromatographic analysis of ethnographic resins. *Australian Institute of Aboriginal Studies Newsletter* 17:41-42.
- Bowdery, D. 1998 *Phytolith Analysis Applied to Pleistocene-Holocene Archaeological Sites in the Australian Arid Zone*. BAR International Monograph Series 695. Oxford: Hadrian Books.
- Bowdery, D. 1999 Phytoliths from tropical sediments: Reports from Southeast Asia and Papua New Guinea. *Bulletin of the Indo-Pacific Prehistory Association* 18:159-168.
- Bowdery, D. 2001 Phytolith and starch data from an obsidian tool excavated at Bitokara, New Britain Province, Papua New Guinea: A 3400 year old hafting technique? In J.D. Meunier and F. Colin (eds), *Phytoliths: Applications in Earth Sciences and Human History*, pp.225-237. Lisse: AA Balkema Publishers.
- Bowman, D.M.J.S., M. Garde and A. Saulwick 2001 *Kunj-ken makka man-wurrk* (fire is for kangaroos) landscape burning in central Arnhem Land seen through an ethnographic lens. In A. Anderson, I. Lilley and S. O'Connor (eds), *Histories of Old Ages: Essays in Honour of Rhys Jones*, pp.61-78. Canberra: Pandanus Books.
- Boyd, W.E., J.P. Collins and J. Bell 2000 The accumulation of charcoal within a midden at Cape Byron, northern New South Wales, during the last millennium. *Australian Archaeology* 51:21-27.
- Boyd, W.E., C.J. Lentfer and J. Parr 2005 Interactions between human activity, volcanic eruptions and vegetation during the Holocene at Garua and Numundo, West New Britain, PNG. *Quaternary Research* 64:384-398.
- Builth, H., A.P. Kershaw, C. White, A. Roach, L. Hartney, M. McKenzie, T. Lewis and G. Jacobsen 2008 Environmental and cultural change on the Mount Eccles lava-flow landscapes of southwest Victoria, Australia. *The Holocene* 18:413-424.
- Christensen, O.A. 1975 Hunters and horticulturalists: A preliminary report of the 1972-4 excavations in the Manim Valley, Papua New Guinea. *Mankind* 10:24-36.
- Clarke, A. 1989 Macroscopic plant remains. In W. Beck, A. Clarke and L. Head (eds), *Plants in Australian Archaeology*, pp.54-89. Tempus 1. St Lucia, QLD: Anthropology Museum, University of Queensland.
- Copley, M.S., P.J. Rose, A. Clapman, D.N. Edwards, M.C. Horton and R.P. Evershed 2001 Processing palm fruits in the Nile Valley: Biomolecular evidence from Qasr Ibrim. *Antiquity* 75:538-542.
- Cosgrove, R., J. Field and Å. Ferrier 2007 The archaeology of Australia's tropical rainforests. *Palaeogeography, Palaeoclimatology, Palaeoecology* 251:150-173.
- Crawford, G.W. 2008 Macroremains analysis. In D.M. Pearsall (ed.), *Encyclopaedia of Archaeology*, pp.1593-1598. New York: Academic Press.
- Crowther, A. 2005 Starch residues on undecorated Lapita pottery from Anir, New Ireland. *Archaeology in Oceania* 40(2):62-66.
- de Faria, D.L., H.G. Edwards, M.C. Afonso, R.H. Brody and J.L. Morais 2004 Raman spectroscopic analysis of a tembete: A resin archaeological artefact in need of conservation. *Spectrochimica Acta Part A: Molecular and Biomolecular Spectroscopy* 60:1505-1513.
- Denham, T.P. 2003 The Kuk Morass: Multi-Disciplinary Evidence of Early to Mid Holocene Plant Exploitation at Kuk Swamp, Wahgi Valley, Papua New Guinea. Unpublished PhD thesis, Australian National University, Canberra.

- Denham, T.P. 2007 Thinking about plant exploitation in New Guinea: Towards a contingent interpretation of agriculture. In T.P. Denham, J. Iriarte and L. Vrydaghs (eds), *Rethinking Agriculture: Archaeological and Ethnoarchaeological Perspectives*, pp.78-108. Walnut Creek, CA: Left Coast Press.
- Denham, T.P. 2008 Traditional forms of plant exploitation in Australia and New Guinea: The search for common ground. *Vegetation History and Archaeobotany* 17:245-248.
- Denham, T.P. and S.G. Haberle 2008 Agriculture emergence and transformation in the Upper Wahgi valley during the Holocene: Theory, method and practice. *The Holocene* 18:481-496.
- Denham, T.P., R. Fullagar and L. Head in press Plant exploitation on Sahul: From colonisation to the emergence of regional specialisation during the Holocene. *Quaternary International*.
- Denham, T.P., S.G. Haberle and C. Lentfer 2004 New evidence and interpretations for early agriculture in Highland New Guinea. *Antiquity* 78:839-857.
- Denham, T.P., S.G. Haberle, C. Lentfer, R. Fullagar, J. Field, M. Therin, N. Porch and B. Winsborough 2003 Origins of agriculture at Kuk Swamp in the Highlands of New Guinea. *Science* 301:189-193.
- Diamond, J. 2005 *Collapse: How Societies Choose to Fail or Survive*. Melbourne: Penguin.
- Dickau, R., A.J. Ranere and R.G. Cooke 2007 Starch grain evidence for the preceramic dispersals of maize and root crops into tropical dry and humid forests of Panama. *Proceedings of the National Academy of Sciences of the United States of America* 104:3651-3656.
- Dimbleby, G.W. 1985 *The Palynology of Archaeological Sites*. London: Academic Press.
- Dolby, N. 1995 A Unique Perspective: Charcoal, Environment and Fuel Use at the Pleistocene Archaeological Site of Nunamira, Southwest Tasmania. Unpublished BA (Hons) thesis, Department of Archaeology, La Trobe University, Bundoora.
- Donoghue, D. 1989 Carbonised plant fossils. In W. Beck, A. Clarke and L. Head (eds), *Plants in Australian Archaeology*, pp.90-100. Tempus 1. St Lucia, QLD: Anthropology Museum, University of Queensland.
- English Heritage 2002 *Environmental Archaeology*. Swindon: English Heritage.
- Evans, A.A. and R.E. Donahue 2005 The elemental chemistry of lithic microwear: An experiment. *Journal of Archaeological Science* 32:1733-1740.
- Evans J.G. and T. O'Connor 1999 *Environmental Archaeology: Principles and Methods*. Stroud: Sutton Publishing.
- Evershed, R.P., S.N. Dudd, V.R. Anderson-Stojanovic and E.R. Gebhard 2003 New chemical evidence for the use of combed ware pottery vessels as beehives in Ancient Greece. *Journal of Archaeological Science* 30:1-12.
- Faegri, K. and J. Iversen 1989 *Textbook of Pollen Analysis*. New York: Hafner Press.
- Fairbairn, A. 2005a *Simple Bucket Flotation and Wet Sieving in the Wet Tropics*. Palaeoworks Technical Report 4. Canberra: Research School of Pacific and Asian Studies, Australian National University.
- Fairbairn, A. 2005b An archaeobotanical perspective on plant-use practices in lowland northern New Guinea. *World Archaeology* 37:487-502.
- Fairbairn, A. 2007 Seeds from the slums: Archaeobotanical investigations at Mountain Street, Ultimo, Sydney, New South Wales. *Australian Archaeology* 64:1-8.
- Fairbairn, A. and P. Swadling 2005 Re-dating mid-Holocene betelnut (*Areca catechu* L.) and other plant use at Dongan, Papua New Guinea. *Radiocarbon* 47:377-382.
- Fairbairn, A.S., G.S. Hope and G.R. Summerhayes 2006 Pleistocene occupation of New Guinea's highland and subalpine environments. *World Archaeology* 38:371-386.
- Field, J. 2008 Analysis of botanical remains: Starch grain analysis. In D. Pearsall (ed.), *Encyclopaedia of Archaeology*, pp.2078-2082. New York: Academic Press.
- Field, J., R. Cosgrove, R. Fullagar and B. Lance in press Starch residues on grinding stones in private collections: A study of morahs from the tropical rainforests of NE Queensland. In M. Haslam, G. Robertson, S. Nugent, A. Crowther and L. Kirkwood (eds), *Archaeological Science under a Microscope: Studies in Residue and Ancient DNA Analysis in Honour of Tom Loy*. Terra Australis. Canberra: ANU E Press.
- Fujiwara, H., R. Jones and S. Brockwell 1985 Plant opal (phytoliths) in Kakadu archaeological sites: A preliminary report. In R. Jones (ed.), *Archaeological Research in Kakadu National Park*, pp.155-164. Special Publication 13. Canberra: Australian National Parks and Wildlife Service.
- Fullagar, R. 1986 Use-Wear and Residues on Stone Tools: Functional Analysis and its Application to Two Southeastern Australian Archaeological Assemblages. Unpublished PhD thesis, La Trobe University, Bundoora.
- Fullagar, R. 1992 Lithically Lapita: Functional analysis of flaked stone assemblages from West New Britain Province, Papua New Guinea. In J.-C. Galipaud (ed.), *Poterie Lapita et Peuplement. Actes du Colloque Lapita, Noumea, Janvier 1992*, pp.135-143. Noumea: ORSTOM.
- Fullagar, R. 1993 Taphonomy and tool use: A role for phytoliths in usewear and residue analysis. In B. Frankhauser and J.R. Bird (eds), *Archaeometry: Current Australasian Research*, pp.21-37. Occasional Papers in Prehistory 22. Canberra: Department of Prehistory, Research School of Pacific Studies, Australian National University.
- Fullagar, R., J. Field, T.P. Denham and C. Lentfer 2006 Early and mid-Holocene processing of taro (*Colocasia esculenta*) and yam (*Dioscorea* sp.) at Kuk Swamp in the Highlands of Papua New Guinea. *Journal of Archaeological Science* 33:595-614.
- Fullagar, R., J. Field and L. Kealhofer 2008 Grinding stones and seeds of change: Starch and phytoliths as evidence of plant food processing. In Y.M. Rowan and J. R. Ebeling (eds), *New Approaches to Old Stones: Recent Studies of Ground Stone Artifacts*, pp.159-172. London: Equinox Publishing.
- Garrett-Jones, S. 1979 Evidence for Changes in Holocene Vegetation and Lake Sedimentation in the Markham Valley, Papua New Guinea. Unpublished PhD thesis, Australian National University, Canberra.
- Golson, J. 1977 No room at the top: Agricultural intensification in the New Guinea Highlands. In J. Allen, J. Golson and R. Jones (eds), *Sunda and Sahul: Prehistoric Studies in Southeast Asia, Melanesia and Australia*, pp.601-638. London: Academic Press.
- Golson, J. 2007 Unravelling the story of early plant exploitation in Highland Papua New Guinea. In T.P. Denham, J. Iriarte and L. Vrydaghs (eds), *Rethinking Agriculture: Archaeological and Ethnoarchaeological Perspectives*, pp.109-125. Walnut Creek, CA: Left Coast Press.
- Gorecki, P. 1993 The Sepik River people of Papua New Guinea: Culture and catastrophes. In American Museum of Natural History, *People of the Stone Age: Hunter-Gatherers and Early Farmers*, pp.154-155. San Francisco: Harper.
- Gosden, C. and J. Webb 1994 The creation of a Papua New Guinea landscape: Archaeological and geomorphological evidence. *Journal of Field Archaeology* 21:29-51.
- Gott, B. 1983 Murnong – *Microseris scapigera*: A study of a staple food of Victorian Aborigines. *Australian Aboriginal Studies* 2:2-17.
- Gott, B. 1999 Cumbungi, *Typha* species: A staple Aboriginal food in southern Australia. *Australian Aboriginal Studies* 1:33-50.
- Gott, B. 2005 Aboriginal fire management in south-eastern Australia: Aims and frequency. *Journal of Biogeography* 32:1203-1208.
- Guasch-Jane, M.R., C. Andres-Lacueva, O. Jauregui and R.M. Lamuela-Raventos 2006 First evidence of white wine in ancient Egypt from Tutankhamun's tomb. *Journal of Archaeological Science* 33:1075-1080.
- Gugerli, F., L. Parducci and R.J. Petit 2005 Ancient plant DNA: Review and prospects. *New Phytologist* 166:409-418.
- Haberle, S.G. 1994 Anthropogenic indicators in pollen diagrams: Problems and prospects for late Quaternary palynology in New Guinea. In J.G. Hather (ed.), *Tropical Archaeobotany: Applications and New Developments*, pp.172-201. London: Routledge.

- Haberle, S.G. 1995 Identification of cultivated *Pandanus* and *Colocasia* in pollen records and the implications for the study of early agriculture in New Guinea. *Vegetation History and Archaeobotany* 4:195-210.
- Haberle, S.G. 2007 Prehistoric human impact on rainforest biodiversity in highland New Guinea. *Philosophical Transactions of the Royal Society (B)* 362:219-228.
- Haberle, S.G., J. Tibby, S. Dimitriadis and H. Heijnis 2006 The impact of European occupation on terrestrial and aquatic ecosystem dynamics in an Australian tropical rain forest. *Journal of Ecology* 94:987-1002.
- Hall, G.D., M.S. Tarka, W.J. Hurst, D. Stuart and R.E.W. Adams 1988 Cacao residues in ancient Maya vessels from Rio Azul, Guatemala. *American Antiquity* 55:138.
- Hart, D.M. and L.A. Wallis (eds) 2003 *Phytolith and Starch Research in the Australian-Pacific-Asian Regions: The State of the Art*. Terra Australis 19. Canberra: Pandanus Books.
- Haslam, M. 2004 The decomposition of starch grains in soils: Implications for archaeological residue analyses. *Journal of Archaeological Science* 31:1715-1734.
- Hather, J. 1993 *An Archaeobotanical Guide to Root and Tuber Identification, Volume 1 Europe and Southwest Asia*. Oxbow Monograph 28. Oxford: Oxbow Books.
- Hather, J. 2000 *Archaeological Parenchyma*. London: Archetype Publications Ltd.
- Hayden, B. 1977 Stone tool functions in the Western Desert. In R.V.S. Wright (ed.), *Stone Tools as Cultural Markers: Change, Evolution and Complexity*, pp.178-188. Canberra: Australian Institute of Aboriginal Studies.
- Holloway, R.G. 1997 Excavation and recovery of botanical materials from archaeological sites. In T.R. Hester, H.J. Shafer and K.L. Feder (eds), *Field Methods in Archaeology*, pp.283-297. Mountain View: Mayfield Publishing.
- Hope, G.S. 1980 Historical influences on the New Guinea flora. In P. van Royen (ed.), *Alpine Flora of New Guinea*, pp.223-248. Vaduz: Cramer Verlag.
- Hope, G.S. 1982 Pollen from archaeological sites: A comparison of swamp and open site pollen spectra at Kosipe Mission, Papua New Guinea. In W. Ambrose and P. Duerden (eds), *Archaeometry: An Australasian Perspective*, pp.211-219. Canberra: Research School of Pacific and Asian Studies, Australian National University.
- Hope, G.S. (ed.) 1988. *Identifying Wood Charcoal Remains as Palaeo Evidence for Regions of Central and Northeast Australia*. Canberra: Research School of Pacific and Asian Studies, Australian National University.
- Hope, G.S. 1998 Early fire and forest change in the Baliem Valley, Irian Jaya, Indonesia. *Journal of Biogeography* 25:453-461.
- Hope, G.S. and J. Golson 1995 Late Quaternary change in the mountains of New Guinea. *Antiquity* 69:818-830.
- Horrocks, M. and S. Bedford 2005 Microfossil analysis of Lapita deposits in Vanuatu reveal introduced Araceae. *Archaeology in Oceania* 40(2):67-74.
- Horrocks, M. and P.D. Nunn 2007 Evidence for introduced taro (*Colocasia esculenta*) and lesser yam (*Dioscorea esculenta*) in Lapita-era (c. 3050-2500 cal. yr BP) deposits from Bourewa, southwest Viti Levu Island, Fiji. *Journal of Archaeological Science* 34:739-748.
- Horrocks, M., S. Bulmer and R.O. Gardner 2008 Plant microfossils in prehistoric archaeological deposits from Yuku rock shelter, Western Highlands, Papua New Guinea. *Journal of Archaeological Science* 35:290-301.
- Horsfall, N. 1987 Living in the Rainforest: The Prehistoric Occupation of North Queensland's Humid Tropics. Unpublished PhD thesis, James Cook University, Townsville.
- Jaenicke-Després, V., E.S. Buckler, B.D. Smith, M.T.P. Gilbert, A. Cooper, J. Doebley and S. Pääbo 2003 Early allelic selection in maize as revealed by ancient DNA. *Science* 302:1206-1208.
- Jones, R. 1969 Fire-stick farming. *Australian Natural History* 16:224-228.
- Kealhofer, L., R. Torrence and R. Fullagar 1999 Integrating phytoliths within use-wear/residue studies of stone tools. *Journal of Archaeological Science* 26:527-546.
- Kershaw, A.P., S. van der Kaars, P. Moss, B. Opdyke, F. Guichard, S. Rule and C. Turney 2006 Environmental change and the arrival of people in the Australian region. *Before Farming* 1:Article 2.
- Kershaw, A.P., S.C. Bretherton and S. van der Kaars 2007 A complete pollen record of the last 230 ka from Lynch's Crater, north-eastern Australia. *Palaeogeography, Palaeoclimatology, Palaeoecology* 251:23-45.
- Larsen, C.S. 2000 Dietary reconstruction and nutritional assessment of past peoples: The bioanthropological record. In K. Kiple and K. Ornelas (eds), *The Cambridge World History of Food*, pp.13-34. Cambridge: Cambridge University Press.
- Lebot, V. 1999 Biomolecular evidence for plant domestication in Sahul. *Genetic Resources and Crop Evolution* 46:619-628.
- Lentfer, C. 2003 Plants, People and Landscapes in Prehistoric Papua New Guinea: A Compendium of Phytolith (and Starch) Analyses. Unpublished PhD thesis, Southern Cross University, Lismore.
- Lentfer, C.J. and R.C. Green 2004 Phytoliths and the evidence for banana cultivation at the Lapita Reber-Rakival site on Watom Island, Papua New Guinea. In V. Attenbrow and R. Fullagar (eds), *A Pacific Odyssey: Archaeology and Anthropology in the Western Pacific: Papers in Honour of Jim Specht*, pp.75-88. Records of the Australian Museum 29. Sydney: Australian Museum.
- Lentfer, C. and R. Torrence 2007 Holocene volcanic activity, vegetation succession, and ancient human land use: Unravelling the interactions on Garua Island, Papua New Guinea. *Review of Palaeobotany and Palynology* 143:83-105.
- Lentfer, C.J., D. Gojak and W.E. Boyd 1997 Hope Farm Windmill: Phytolith analysis of cereals in early colonial Australia. *Journal of Archaeological Science* 24:841-856.
- Lentfer, C.J., M. Therin and R. Torrence 2002 Starch grains and environmental reconstruction: A modern test case from West New Britain, Papua New Guinea. *Journal of Archaeological Science* 29:687-698.
- Lepofsky, D., P.V. Kirch and K.P. Lertzman 1998 Metric analysis of prehistoric morphological change in cultivated fruits and nuts: An example from Island Melanesia. *Journal of Archaeological Science* 25:1001-1014.
- Loy, T. 1994 Methods in the analysis of starch residues on prehistoric stone tools. In J.G. Hather (ed.), *Tropical Archaeobotany: Applications and New Developments*, pp.86-114. London: Routledge.
- Loy, T., M. Spriggs and S. Wickler 1992 Direct evidence for human use of plants 28,000 years ago: Starch residues on stone artefacts from northern Solomon Islands. *Antiquity* 66:898-912.
- Maccotta, A., P. Fantazzini, C. Garavaglia, I.D. Donato, P. Perzia, M. Brai and F. Morreale 2005 Preliminary 1H NMR study on archaeological waterlogged wood. *Annali di Chimica* 95:117-124.
- Matthews, P.J. and C. Gosden 1997 Plant remains from waterlogged sites in the Arawe Islands, West New Britain Province, Papua New Guinea: Implications for the history of plant use and domestication. *Economic Botany* 51:121-133.
- Mbida, C.M., H. Doutrelepon, L. Vrydaghs, R.J. Swennen, H. Beeckman, E. de Langhe and P. de Maret 2001 First archaeological evidence of banana cultivation in central Africa during the third millennium before present. *Vegetation History and Archaeobotany* 10:1-6.
- McConnell, K. and S. O'Connor 1997 40,000 year record of food plants in the southern Kimberley ranges, Western Australia. *Australian Archaeology* 45:20-31.
- McGovern, P.E., D.L. Glusker and L.J. Exner 1996 Neolithic resinated wine. *Nature* 381:480-481.
- Miller, G.H., M.L. Fogel, J.W. Magee, M.K. Gagan, S.J. Clarke and B.J. Johnson 2005 Ecosystem collapse in Pleistocene Australia and a human role in megafaunal extinction. *Science* 309:287-290.
- Nugent, S. 2006 Applying use-wear and residue analyses to digging sticks. *Memoirs of the Queensland Museum, Cultural Heritage Series* 4:89-105.

- O'Connell, J.F. and J. Allen 2007 Pre-LGM Sahul (Pleistocene Australia-New Guinea) and the archaeology of early modern human. In P. Mellars, K. Boyle, O. Bar-Yosef and C. Stringer (eds), *Rethinking the Human Revolution*, pp.395-410. Cambridge: McDonald Institute for Archaeological Research.
- O'Dea, K. 1992 Diabetes in Australian Aborigines: Impact of the western diet and lifestyle. *Journal of Internal Medicine* 232:103-117.
- O'Dea, K. and R.M. Spargo 1982 Metabolic adaptation to a low carbohydrate-high protein ("traditional") diet in Australian Aborigines. *Diabetologia* 23:494-498.
- Oudemans, T.F.M., G.B. Eijkel and J.J. Boon 2007 Identifying biomolecular origins of solid organic residues preserved in Iron Age pottery using DTMS and MVA. *Journal of Archaeological Science* 34:173-193.
- Oxtenham, M.F., C. Locher, N.L. Cuong and N.K. Thuy 2002 Identification of *Areca catechu* (betel nut) residues on the dentitions of Bronze Age inhabitants of Nui Nap, northern Vietnam. *Journal of Archaeological Science* 29:909-915.
- Parr, J.F. 1999 Once, twice maybe, but not three times: Reheating *Xanthorrhoea australis* resin - Not viable. *Australian Archaeology* 49:23-27.
- Parr, J.F. 2002 The identification of *Xanthorrhoea* resins by starch morphology: Prospects for archaeological and taxonomic applications. *Economic Botany* 56:260-270.
- Parr, J. 2003 A Study of Landscapes in Numundo Region of West New Britain, Papua New Guinea, as Indicated by Fossil Phytolith Analysis. Unpublished PhD thesis, Southern Cross University, Lismore.
- Parr, J. and M. Carter 2003 Phytolith and starch analysis of sediment samples from two archaeological sites on Dauar Island, Torres Strait, northeastern Australia. *Vegetation History and Archaeobotany* 12:131-141.
- Parr, J., C.J. Lentfer and W.E. Boyd 2001 Spatial analysis of fossil phytolith assemblages at an archaeological site in West New Britain, Papua New Guinea. In G.R. Clark, A.J. Anderson and T. Vunidilo (eds), *The Archaeology of Lapita Dispersal in Oceania*, pp.125-134. Canberra: Pandanus Books.
- Parr, J. and L.A. Sullivan 2005 Soil carbon sequestration in phytoliths. *Soil Biology and Biochemistry* 37:117-124.
- Pate, F.D. 1997 Bone collagen and paleodiet: Reconstructing prehistoric subsistence-settlement systems in Australia. *Journal of Anthropological Archaeology* 16:103-120.
- Pate, F.D. 1998 Stable carbon and nitrogen isotope evidence for prehistoric hunter-gatherer diet in the lower Murray River Basin, South Australia. *Archaeology in Oceania* 33(2):92-99.
- Pearsall, D.M. 2000 *Paleoethnobotany: A Handbook of Procedures*. 2nd ed. London: Academic Press.
- Piperno, D.R. 2006 *Phytoliths: A Comprehensive Guide for Archaeologists and Paleoecologists*. Lanham: AltaMira.
- Piperno, D.R. and I. Holst 1998 The presence of starch grains on prehistoric stone tools from the humid neotropics: Indications of early tuber use and agriculture in Panama. *Journal of Archaeological Science* 25:765-777.
- Piperno, D.R. and D.M. Pearsall 1998 *The Origins of Agriculture in the Lowland Neotropics*. San Diego: Academic Press.
- Piperno, D.R. and K.E. Stothert 2003 Phytolith evidence for early Holocene *Cucurbita* domestication in Southwest Ecuador. *Science* 299:1054-1057.
- Powell, J.M. 1970 The Impact of Man on the Vegetation of the Mount Hagen Region, New Guinea. Unpublished PhD thesis, Australian National University, Canberra.
- Powell, J.M. 1982 The history of plant use and man's impact on the vegetation. In J.L. Gressitt (ed.), *Biogeography and Ecology of New Guinea*, pp.207-227. Vol. 1. The Hague: Junk.
- Robertson, G. 2005 Backed Artefact Use in Eastern Australia: A Residue and Use-Wear Analysis. Unpublished PhD thesis, University of Queensland, Brisbane.
- Rowe, C. 2006a Landscapes in western Torres Strait history. In B. David, B. Barker and I.J. McNiven (eds), *The Social Archaeology of Australian Aboriginal Societies*, pp.270-286. Canberra: Aboriginal Studies Press.
- Rowe, C. 2006b *The Australasian Pollen and Spore Atlas User Document*. PalaeoWorks Technical Report 8. Canberra: Australian National University.
- Rowe, C., S. Haberle, G. Hope, S. Hungerford and M. Buchhorn 2007 The Australasian Pollen and Spore Atlas: A new online relational database. *Quaternary International* 167-168(Supplement):355.
- Schlumbaum, A., M. Tensen and V. Jaenicke-Despres 2008 Ancient plant DNA in archaeobotany. *Vegetation History and Archaeobotany* 17:233-244.
- Smith, M.A., L. Vellen and J. Pask 1995 Vegetation history from archaeological charcoals in central Australia: The late Quaternary record from Puritjarra rock shelter. *Vegetation History and Archaeobotany* 4:171-177.
- Swadling, P., N. Araho and B. Ivuyo 1991 Settlements associated with the inland Sepik-Ramu Sea. *Bulletin of the Indo-Pacific Prehistory Association* 11:92-110.
- Therin, M. 2000 Residue and use-wear analysis. In L. Haglund (ed.), *Salvage Excavation: Site SG5, Aboriginal Rock Shelter Site*. Vol 1. Unpublished report to Ulan Coal Mines Ltd.
- Therin, M., R. Fullagar and R. Torrence 1999 Starch in sediments: A new approach to the study of subsistence and land use in Papua New Guinea. In C. Gosden and J. Hather (eds), *The Prehistory of Food*, pp.438-462. London: Routledge.
- Torrence, R. and H. Barton (eds) 2006 *Ancient Starch Research*. Walnut Creek, CA: Left Coast Press.
- Turney, C.S.M. and D. Hobbs 2006 ENSO influence on Holocene Aboriginal populations in Queensland, Australia. *Journal of Archaeological Science* 33:1744-1748.
- Turney, C.S.M., A.P. Kershaw, P. Moss, M.I. Bird, L.K. Fifield, R.G. Cresswell, G.M. Santos, M.L. di Tada, P.A. Hausladen and Y. Zhou 2001 Redating the onset of burning at Lynch's Crater (north Queensland): Implications for human settlement in Australia. *Journal of Quaternary Science* 16:767-771.
- Wallis, L.A. 2000a Phytoliths, Late Quaternary Environments and Archaeology in Tropical Semi-Arid Northwest Australia. Unpublished PhD thesis, Australian National University, Canberra.
- Wallis, L.A. 2000b Phytolith analysis at Carpenter's Gap 1: A preliminary consideration of assemblage formation processes. In T. Denham and S. Blau (eds), *Proceedings of the Second National Archaeology Students Conference 1999*, pp.55-64. Canberra: Australian National University.
- Wallis, L.A. 2001 Environmental history of northwest Australia based on phytoliths evidence at Carpenter's Gap 1. *Quaternary International* 83-85:103-117.
- Webb, S.G. 1995 *Palaeopathology of Aboriginal Australians: Health and Disease across a Hunter-Gatherer Continent*. Melbourne: Cambridge University Press.
- Welch, M. 1997 Characterization of *Xanthorrhoea* Resins by HPLC for Botanical, Archaeological and Forensic Purposes. Unpublished BSc (Hons) thesis, University of Technology, Sydney.
- White, J.P. and D.H. Thomas 1972 What mean these stones? Ethnotaxonomic models and archaeological interpretations in the New Guinea Highlands. In D.L. Clarke (ed.), *Models in Archaeology*, pp.275-308. London: Methuen.
- Willerslev, E. and A. Cooper 2005 Ancient DNA. *Proceedings of the Royal Society B* 272:3-16.
- Wilson, S.M. 1985 Phytolith evidence from Kuk, an early agricultural site in New Guinea. *Archaeology in Oceania* 20(3):90-97.
- Yen, D. 1996 Melanesian aborigiculture: Historical perspectives with emphasis on the genus *Canarium*. In M.L. Stevens, R.M. Bourke and B.R. Evans (eds), *South Pacific Indigenous Nuts*, pp.36-44. Canberra: Australian Centre for International Agricultural Research.
- Zarrillo, S., D.M. Pearsall, J.S. Raymond, M.A. Tisdale and D.J. Quon 2008 Directly dated starch residues document early formative maize (*Zea mays* L.) in tropical Ecuador. *Proceedings of the National Academy of Sciences of the United States of America* 105:5006-5011.