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APPLYING USE-WEAR AND RESIDUE ANALYSES TO DIGGING STICKS

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Use-wear and residue analysis techniques were used to examine 12 Aboriginal Australian post-contact wooden digging sticks to ascertain if they retain traces of their use. All but one of the artefacts originate from northern Australia. The analyses included simulation of digging stick manufacture and low-magnification microscopic examination of tool surfaces. Hydrated extracts were tested for the presence of blood proteins and placed on microslides for high-magnification microscopic examination. Although no blood residues were detected, residues indicative of contact with soil and plants, including phytoliths, starch granules and plant tissue, were identified. Multivariate analysis indicates that some complex-shaped marks are possibly indicative of use-wear. In light of ethnographic documentation and museum records, the presence of residues and possible use-wear indicators strongly suggests that 10 of the digging sticks were used to procure plant foods. The results demonstrate that use-wear and residue analyses can be applied to wooden artefacts to add information of value to museum collections. □ *Australian Aboriginal material culture, microscopy, ethnography, wooden artefacts, starch granules, use-wear, residues.*

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Undoubtedly one of the most important of the first tools made by hominids were straight, sharpened wooden digging sticks, serving as weapons to obtain burrowing animals and implements for gathering plant foods (Oswalt, 1973: 170). Wooden tools and tools with wooden components continued to be used throughout prehistory to the present (Coles et al., 1978: 2). As wood is perishable, stone dominates the archaeological record and therefore also archaeological research. Wood does survive, however, in certain environments such as extreme cold or dry. A great deal can be learned about past subsistence and economic life where wood has survived under such conditions (Coles et al., 1978: 1). Coutts (1977), for example, replicated stone and steel adze manufacture and use, and identified tools used to manufacture wood chips from six archaeological sites at Southport in New Zealand. In Australia, wood is the source of most Aboriginal material culture, yet the study of this raw material is one of 'the most neglected areas of research on Aboriginal material culture' (Kamminga, 1988: 26). Although Fullagar et al. (1999) microscopically examined a variety of ethnographic and archaeological artefacts from northern Australia (made of various materials), they were unable to identify residues on the wooden digging sticks and spearheads in the sample (Fullagar et al., 1999: 22). This paper reports on the first systematic functional analysis

of wooden digging sticks using use-wear and residue analysis techniques (Nugent, 2001). These techniques are usually applied to ancient stone and bone tool research, thus this research was exploratory in nature. Nevertheless, results from the examination of ethnographic artefacts provide guidelines for analysis of archaeological wooden implements.

ETHNOGRAPHIC BACKGROUND

Wooden digging sticks or 'yam sticks' employed by Aboriginal Australians are of various sizes, generally made from heavy hardwood such as *Acacia aneura* (mulga), and have either spatulate or acicular end shapes (e.g. Brokensha, 1975: 53; Hardwick, 1977: 38; Memmott, 1979: 112; Roth, 1904: 24; Thomson, 1964: 407). The entire digging stick manufacturing process for any particular Aboriginal group is unclear with sources noting that wood was generally worked when green and hardened by charring or the application of lizard fat. The ends were then ground with stone tools or rubbed on whetstones (e.g. Brokensha, 1975: 53; Finlayson, 1935: 79; Kamminga, 1988: 28; Roth, 1904: 10, 24; Thomson, 1964: 420; Tindale, 1972: 245-6; White, 1915: 728). Thomson (1964: 409, 1975: 100) notes that Pintubi men repaired damaged digging sticks by re-charring and grinding the blades on sandstone. The introduction of metal to Australia as early as the 17th Century (Chaseling,

TABLE 1. Museum catalogue information and description of digging stick sample.

Catalogue No.	Origin & Year Acquired	Dimensions	Description	Recorded Use
Queensland Museum				
QE10059	Mornington Is Qld 1975	630 x 31mm	Pale outer and dark heartwood Ends concave with broken tips	-
QE10123-1	Mornington Is Qld 1976	420 x 30mm	Pale wood with scratches and splits Acicular ends but one more round with flattened damaged tip	Dig roots Stun small game Women fighting
QE10123-2	Mornington Is Qld 1976	610 x 30mm	Notched and scratched brown wood One slightly spatulate and one acicular end	-
QE16/1117	Mornington Is Qld 1916	1252 x 17mm	Dark patchy wood Acicular but rounded ends Gooji' and 'Mornington Is' on shaft	-
QE10007	Edward River Qld, 1975	1450 x 38mm	Brown wood slightly curved shaft One end blunt with nicks and other pointed and ochre decorated	Dig yams roots lilies Women fighting
QE5034	Normanton area Qld Unknown	1684 x 33mm	Dark heavy wood with scratches and splits on dented shaft One blunt and one acicular end	-
QE3632	Torrens Creek Qld Unknown	-	Dark heavy wood with splits on shaft One blunt acicular and one chisel-shaped end	-
QE10171	Aurukun Qld 1976	708mm long	Brown wood with splits on shaft One slightly blunt acicular end and one end roughly chopped off	Dig roots Stun game Women fighting
The University of Queensland Anthropology Museum				
22909	Port Keats NT 1978	1060 x 31mm	Red ochre decorated notched bent shaft One long wedged and one blunt end	Gather tubers burrow- ing animals
24253	Wellesley Is Qld 1979	-	Mottled heavy smooth wood Both ends acicular and damaged Made of <i>Terminalia</i> species	Dig wells roots and nuts Women fighting
9982	Unknown 1960s	-	Dark bent wood with splits on shaft One acicular and slightly flattened and one roughly chopped end	-
25350	Utopia Station NT 1983	1050 x 30mm	Very rough notched wood with splits on shaft One blade-shaped and one end blunt Made of <i>Eucalyptus gamophylla</i>	Dig yams

1957: 90) began to alter the digging stick manufacturing process. At Utopia Station (Northern Territory) in the early 1980s, for example, Devitt (1988: 186) found that the women also used metal crowbars for digging, while wooden digging sticks were improvised tools, chopped hastily during foraging trips and discarded at the end of the day.

A variety of uses for digging sticks have been recorded. As domestic tools, for example, digging sticks were used to turn cooking food and shift ashes in the fire (Roth, 1897: 105). In the Victoria Desert, the blunt end of a digging stick was used as a pestle to grind the bark of mallee roots (Helms, 1896: 258-9). In southwest Western Australia, they were used to dig graves, holes in which to place *Xanthorrhoea arborea* stems that were used as hut supports, and pits to trap kangaroos (Hammond, 1933: 37; Thomas, 1906: 70). Wells were also dug with digging sticks in north Queensland (Memmott, 1979;

Roth, 1901: 8), the arid interior and southwest Western Australia (Hammond, 1933: 37; Helms, 1896: 254; White, 1915: 729). Digging sticks were and still are primarily used to procure food, especially roots, tubers, bush onions and bulrush stems, and also small animals such as frogs, snakes, lizards, goannas, rabbits, kangaroo mice, bandicoots and echidna (Basedow, 1904: 15, 18; Curr, 1883: 255; Devitt, 1988: 30-1; Finlayson, 1935: 79; Grey, 1841: 291-2; Lawrence, 1969: 51, 64-5, 74, 76-7, 118, 204-5, 206, 212; Low, 1991; Roth, 1897: 92-4; Sweeney, 1946-47: 291, 295-296). If traces of use in the form of organic remains and use-wear can be found on bone and stone (Loy, 1993b; Semenov, 1964), the same should hold true for wood. This hypothesis was tested empirically by determining if any artefact in a sample of digging sticks had been used as a food-procuring tool, as indicated by residues remaining on the surface in association with possible use-wear marks.

TABLE 2. Methods and materials for replication of digging stick manufacture.

No.	Species & Dimensions	End	Method of Manufacture	End Shape	References
1	<i>Acacia aneura</i> 730 x 26.9mm	A	Charred Bark scraped off with quartzite tool End shaped with quartzite tool and ground with sandstone tool Worked towards body	Wedge	Thomson 1964:420 J Bradley 1999 UQ pers comm M Cause 1999 Qld Forestry Research Inst pers comm T Loy 1999 UQ pers comm
		B	Charred Bark scraped off with quartzite tool End shaped with tomahawk Worked towards body for shaft and away from body to chop point	Acicular	
2	<i>Eucalyptus tereticornis</i> 550 x 19.2mm	A	Charred Bark scraped off with machete End shaped with tomahawk and ground with file Worked towards body with machete and away from body shaping end	Acicular	Brokensha 1975:53 J Bradley 1999 UQ pers comm W Harris 1999 Qld Herbarium pers comm
		B	Charred Bark scraped off with machete End shaped with tomahawk and ground with rasp Worked away from body	Acicular	
3	<i>Acacia aneura</i> 630 x 11.1mm	A	Charred Bark scraped off End shaped with tomahawk and ground with file Worked away from body	Wedge	Brokensha 1975:53 M Cause 1999 Qld Forestry Research Inst pers comm J Devitt 1999 pers comm L Satterthwait 1999 UQ pers comm
		B	Charred Bark scraped off End shaped with tomahawk and ground with rasp Worked away from body	Wedge	
4	<i>Eucalyptus tereticornis</i> 370 x 19.4mm	A	Charred Bark scraped off and end shaped with butchering knife Worked towards body	Acicular	J Bradley 1999 UQ pers comm W Harris 1999 Qld Herbarium pers comm
5	<i>Eucalyptus tereticornis</i> 430 x 21.3mm	A	Not charred Bark scraped off and end shaped with butchering knife Worked towards body	Acicular	J Bradley 1999 UQ pers comm W Harris 1999 Qld Herbarium pers comm

MATERIALS AND METHODS

Mutually informative use-wear and residue analyses were used to examine each digging stick as if it were an individual archaeological site (Barton et al., 1998: 1234; Fullagar, 1998: 14; Haslam, 1999: 13; Kealhofer et al., 1999: 528; Loy, 1993a: 44). The ensuing data was compared between the artefacts in the sample and with ethnographic documentation.

In addition to a macroscopic examination to observe variations in artisanship and other factors contributing to the recognition of variety within the sample (Loy, 1993b: 57), the major components of the strategy devised to obtain comparable information were the selection of locations for analysis, and both low- and high-magnification microscopy. When examining stone and bone artefacts some residues can be observed during low-magnification microscopy,

but high-magnification microscopy is indispensable in detecting residues that are identifiable by morphology and histology. An issue considered pertinent to the legitimacy of any findings during this research was contamination. Contamination occurs when residues are transferred through contact of artefacts with other materials and the environment. When dealing with archaeological material, for example, soil samples from associated strata should be analysed to determine the residues present as these can contaminate artefacts (Barton et al., 1998; Kealhofer et al., 1999: 527; Loy, 1994: 96). While no soil samples could be analysed in this research, all possible measures to control for further contamination were undertaken, including wearing non-powdered gloves during analyses and monitoring for airborne starch and phytoliths on microslides, placed in both museum digging stick holding bays and the Archaeological Residue Laboratory

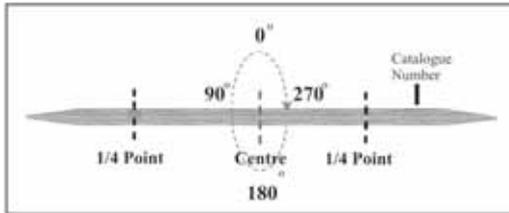


FIG. 1. Locations for analysis on digging sticks (image courtesy of Yvonne Silanesu).

(School of Social Science, The University of Queensland).

SAMPLING. *Research Sample and Replicas.* Thirty-six Aboriginal Australian ethnographic wooden artefacts that are classified as digging sticks from the Queensland Museum and The University of Queensland Anthropology Museum were selected for the research sample. Owing to time constraints, only 12 digging sticks were examined (Table 1). With the aim of producing some manufacture marks comparable with those observed on the research sample, and guided by the available but limited ethnographic documentation on digging stick manufacture, five experimental implements were made but not used (Table 2). The *Acacia aneura* wood was provided and identified by M. Cause (Queensland Forestry Research Institute), and the *Eucalyptus tereticornis* was identified by W. Harris (Queensland Herbarium).

Selection of Locations for Analysis. Semenov (1964: 22) recommends microscopic examination of the entire artefact when undertaking use-wear analysis. However, digging sticks are large artefacts and analysis involving high-magnification microscopy is extremely time-consuming (Dunnell, 1978: 53; Odell & Odell-Vereecken, 1980: 88). A strategy was required that would permit the analyses to be completed within the imposed research time limitations and the systematic examination of each digging stick in a comparable way. Therefore, a sample of locations for analysis was systematically chosen, but with the first location for analysis selected by choice, not randomly (Drennan, 1996: 245-7; Lazerwitz, 1968: 295). Rotating clockwise, four analytical locations at 0°, 90°, 180° and 270° were chosen at the centre, quarter points and ends of each artefact, each zero degree being aligned with the museum catalogue number inked on the surface (Fig. 1). Thus for each artefact, there were 20 locations for the application of use-wear

TABLE 3. Nominated terms for observed marks.

Terms	Definitive Aspects of Observed Marks
Scratch	Scratches are fine or very fine linear or tapered and can be curved and/or broken The base shape of a scratch can be curved or flat
Channel	Channels are wider scratches
Scrape	Scrapes are scratches or channels that have complex bases
Groove	Grooves are scratches or channels that have angular bases
Gouge	The overall shapes of gouges can be ovate crescent-shaped or elliptical
Chop	Chops are varied in overall shape and have bases that are angular or complex
Hole	Holes are irregular in shape
Bruise	Bruises are flat and discoloured
Ridge	Ridges are raised strips that have curved or angular bases

and residue analyses. The five replicas were similarly assigned locations for analysis.

LOW-MAGNIFICATION MICROSCOPY. A Wild stereo-binocular (6-30.6x) microscope, equipped with a graticule eyepiece for measuring, and mounted with an Olympus® DP10 camera set at the highest resolution of 3.2 million pixels was used for low-magnification examination of each location. The area examined at each location was the field of view at 6x magnification. Potential residues and contaminants, indications of charring and the presence of sediment (soil particles) were recorded and photographed, and shiny patches and damage to the ends noted. Observed marks (including those that extended beyond the field of view on the sample and replicas), possibly indicative of use-wear or manufacture, were defined, photographed and counted. The presence of sediment was considered indicative of the digging sticks having been in soil and although difficult to quantify, was described as 'thinly scattered', 'thickly scattered' or 'caked'. 'Ultrapure' water was then applied to the sample artefact surfaces for residue removal for the Ames Hemastix® (Bayer Corp, USA) tests, dry-mounted microslide preparation and high-magnification microscopic examination.

Classification of Marks. To begin to formulate a method for meaningfully differentiating the diverse array of marks observed on the digging sticks and replicas (Coles & Orme, 1985: 25), a classification scheme for the types of marks was devised. Seven of the chosen terms – 'scratch', 'channel', 'scrape', 'groove', 'gouge', 'chop' and 'hole' differentiate incisive marks, a raised

TABLE 4. Variables and attributes used to define observed marks.

Variable	Attributes
Angle	Horizontal or parallel to the artefact length axis Vertical or parallel to the artefact diameter axis Angled
Shape	Linear, tapered, ovate, elliptical, crescent, irregular, broken, curved
Width	Very fine or > .0032 but < .032mm Fine or = .032 but < .16mm Wide or = .16 but < 1mm Very wide or ≥ 1mm Varied
Length	Very short or < .32mm Short or = .32 but < 1mm Long or = 1 but < 5mm Very long or = 5 but < 10mm Extremely long or ≥ 10mm
Depth	Flat, shallow, moderate, deep, varying, not applicable
Base Shape	Flat, curved, angular, complex, indistinguishable, not observed

mark was termed a 'ridge' and a flat mark a 'bruise' (Table 3). Each mark type observed was more accurately defined by a set of linked attributes pertaining to the variables – angle or position of the mark on the artefact, its shape, width and length (measured in mm), depth and base shape (Table 4). Marks often displayed more than one shape attribute, for example, 'linear scratches' could be 'curved' and/or 'broken'. Marks that appeared broken were the result of the undulating surface of the wood or marks that crossed.

Based on the proposition that a digging stick used to procure food would have a greater number and variety of marks than an unused artefact, all of the observed marks were tallied for each analytical location and converted to segmented bar graphs for comparison. For this paper, the marks have been tallied for the four locations on five transects around each artefact and plotted as three-dimensional column graphs. An attempt was also made to distinguish use-wear from manufacture marks. The sets of attributes defining the different types of marks observed were subjected to a multivariate analysis (non-parametric multidimensional scaling) using DataDesk® (Data Description Inc., NY) that was undertaken by Dr Tom Loy (School of Social Science, The University of Queensland).

Hemastix® Tests. The Ames Hemastix® (Bayer Corp., USA) presumptive colourimetric test detects the presence of blood proteins which would indicate possible use of a tool for animal procurement or processing. Positive Hemastix®

results can also indicate the presence of bacterial and vegetable peroxidases, copper ions, manganese dioxide (MnO_2) and chlorophyll (Custer et al., 1988; Loy, 1993a: 62). Heating the residue to 100°C destroys bacterial and vegetable peroxidases and the reaction to manganese, copper and chlorophyll can be reduced with the addition of 0.5 molar sodium-EDTA (ethylenediaminetetraacetic sodium salt) to the residual solution (Loy, 1993a: 62, 1993b: 49). However, in the case of digging sticks, chlorophyll may be an authentic residue, indicative of contact with plants while digging. Due to the shape and dry absorbent nature of some of the wood, Loy's (1997: 37-39) Hemastix Protocol was modified by increasing the amount of water from 50iL to 60iL, and reducing the length of time water was agitated on the tool surface from 10 to 5 minutes. Loy's (1997) protocol does not include heating of residues. The Hemastix tests on extracted residual solutions, including those with the addition of sodium-EDTA were graded according to the provided colour chart and the results tabulated.

HIGH-MAGNIFICATION MICROSCOPY. Microslides of extracted residues were examined under transmitted Köhler illumination using an Olympus® BX60 (50x-1000x) microscope that was mounted with a DP10 camera and fitted with a rotating polarising analyser, measuring graticule eyepiece, and movable (X-Y) stage. While attempts were made to identify all residues on the microslides, specific residues were searched for on the basis that they are indicative of contact between the artefact and soil. These residues were opal phytoliths, fungal tissue, and faecal and uric acid spherulites. Spherulites often have a permanent dark extinction cross and can be mistaken for starch granules (Canti, 1998). Many saprotrophic fungi utilise cellulose in seasoned or dead wood (Ingold & Hudson, 1993: 145), so the presence of fungal tissue was only noted when identified with other soil constituents. On a tool surface, the presence of large storage starch granules, generally >5µm in diameter in association with plant tissue is generally accepted as indicative of tuberous plant processing (Haslam, 1999: 58; Haslam, 2004: 1723; Loy, 1994: 101). The additional presence of raphides can also indicate tuberous plant processing (Loy et al., 1992: 898-901; Sakai, 1979). Therefore starch granules, raphides and diagnostic plant tissue components were also specifically targeted. The identification of detected residues was based on their morphology



FIG. 2. Acicular, slightly wedged end of digging stick #25350 (image courtesy of Jenny Davis, Anthropology Museum, University of Queensland).

and optical properties and reliant on comparative literature (e.g. Banks & Greenwood, 1975; Canti, 1997, 1998; Griffin, 1994; Pearsall, 2000; Raven et al., 1999; Reichert, 1913; Weier et al., 1982), reference microslides and the Residue Laboratory Microscopy Guide. Except for starch granules, the presence or absence of all residues identified was noted. Starch granules, including damaged or gelatinised granules, that occurred singly and in clusters of various sizes, were photographed, measured and counted except when they exceeded 100. Starch granule counts were graded 0, 1-10, 11-50, 51-100 and >100.

RESULTS AND DISCUSSION

MACROSCOPIC ANALYSIS. As briefly described in Table 1, most of the digging sticks are damaged with scratches, splits and/or flattened tips. There is a range in tool size and variation in end shape morphology, including chisel-shaped, spatulate, acicular and blunt, and combinations of these. Variation was also noticed in artisanship. For example, digging stick #25350 has a roughly chopped blunt end and shaft with protruding notches. The other end is acicular and slightly wedged (Fig. 2). However, #QE10007 is smoothly finished, has one ochre-decorated acicular end and one blunt end carved with rows of nicks – perhaps for use as a handgrip. For such a small sample of artefacts, a great variety of individual artisanship was observed. The only indication of any universal pattern to digging stick manufacture, as suggested by Brokensha (1975: 53) and Roth (1904: 24), was the use of a relatively straight shaft of wood, at least one end of which was sharpened.

LOW-MAGNIFICATION MICROSCOPY. The degree of end damage was more evident under low-magnification microscopy. Artefacts #22909, #24253, and #9982 display flattened tips with the wood at the edge curled back to form a lip, possibly suggesting damage caused through use, although upright museum storage could also have a similar effect. Other forms of damage, possibly attributable to use-wear, are jagged splinters and pitting. Frayed and dried wood fibres and fine splitting were observed, but such phenomena can also occur when wood dries out (Kamminga, 1988: 27). Apart from artefacts #QE10059, #QE10123-1 and #QE10123-2, extremely shiny patches (e.g. Fig. 3) were observed on at least one end of each digging stick in the sample. These shiny patches often exhibit numerous marks. Any other sheen observed on the shafts was relatively dull, and could not be described as the ‘glass finish’ caused by a combination of constant use and impregnated oil and sweat that, according to Thomson (1964: 408), defines prolonged use. Varying thicknesses of soil sediment were observed on the entire



FIG. 3. Shiny patch at location 20, artefact #QE10007.

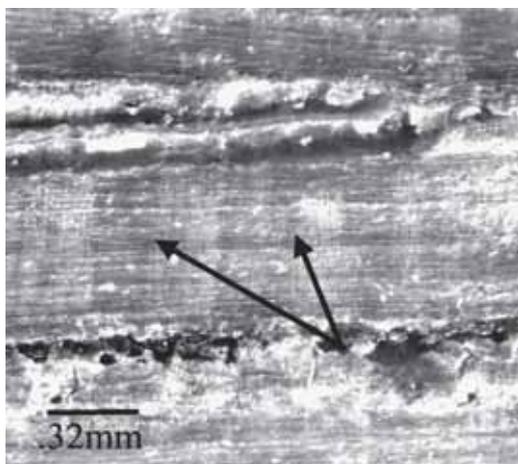


FIG. 4. Bruises at location 1, artefact #24253.

sample. Shiny black flecks of charcoal and charred patches were observed on all of the simulated artefacts except the fifth replica that had not been charred. The same evidence of charring was also observed on all of the sample artefacts. Indications of charring were expected given that digging sticks could be charred during manufacture and/or repair, and were commonly used to turn food in a fire.

Classified Marks. Four hundred and nineteen mark types were identified during low-magnification examination. Eighty-nine of 106 marks observed on the replicas were defined with the same set of attributes as those on the research sample. Marks defined as bruises (Fig. 4) were observed on artefacts #QE3632, #QE10171, #22909, #9982, #25350 and the fourth replica that was made using a butchering knife. Artefact #25350, collected by Devitt from Utopia Station, is an improvised digging stick chopped with a steel axe (Devitt, 1988). While it is conceivable that digging sticks bruise when used as levers to remove plant roots (White, 1915: 729), it is also possible that metal manufacturing tools bruise wood.

Multivariate Statistical Analysis. The most commonly occurring attributes were those defining 'scratches', that is, marks that were linear, fine, long, shallow and with curved bases. Of the six variables, angle, shape and width ranked the highest in a principal components analysis, but shape was the only one displaying a bivariate distribution of its attributes. In a three-dimensional cloud plot, the simple shape attributes (linear, elliptical, crescent-shaped and

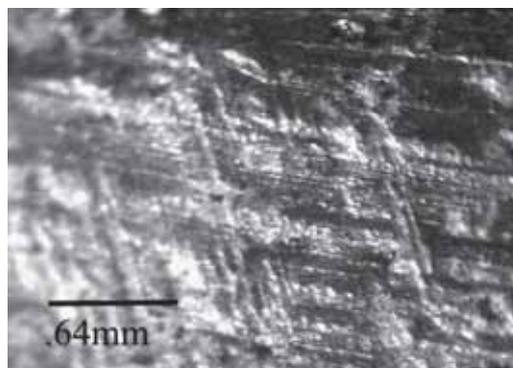


FIG. 5. Broken linear scratches at location 18, artefact #24253.

tapered) were clearly separate from the complex shapes (comprising more than one attribute such as curved linear, broken tapered or curved broken linear). Histograms showing the occurrence of simple- and complex-shaped marks similarly illustrated that the majority of marks observed on the sample and replicas were simple linear marks or 'scratches'. Examination of the occurrence of complex-shaped marks on the histograms revealed there were more of these marks observed on digging sticks #QE16/1117, #QE10007, #QE5034, #QE3632, #QE10171, #22909, #24253, #9982 and #25350 than on #QE10059, #QE10123-1, #QE10123-2 and the replicas. Examination of a tally of the different complex mark types observed at the 20 locations on each tool revealed that generally, there was greater variety towards the ends and/or at the ends of each artefact.

During different tasks, there is variation in the angles of inclination of the working parts of any tool, whether bone, stone or wooden, resulting in a diverse range of use-wear marks, some curved, some parallel, some continuous and some interrupted or intersecting (Semenov, 1964: 17, 21). During food procurement, digging sticks were stabbed into the soil, and used as levers and probes (Devitt, 1988: 184; Helms, 1896: 254). The working parts of a digging stick would be positioned at different angles during these actions, resulting in different types of marks. One would imagine that on a used digging stick, such marks would intersect and be superimposed on one another. Furthermore, applying the attributes chosen in this research, these marks would be defined by various shape attributes and thus complex-shaped. Therefore, it is possible that some of the complex-shaped marks observed

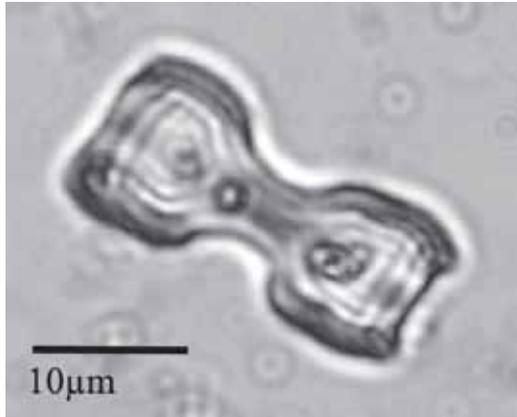
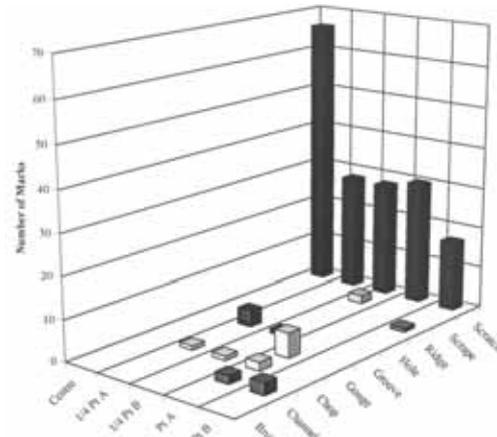


FIG. 6. Phytolith from location 9, artefact #9982.

(e.g. Fig. 5) are use-wear marks. However, it is also possible that complex marks were created during the repair of working ends and any of the enumerable digging stick uses.

Hemastix® Tests. Positive Ames Hemastix® (Bayer Corp, USA) results were obtained on some locations for artefacts #QE16/1117, #QE10007, #QE5034 and #9982. However, in all cases, applications of sodium EDTA and repetition of the Hemastix test resulted in negative results, indicating the possible presence of chlorophyll, vegetable peroxidases and/or manganese dioxide. The lack of any possible blood residue was unexpected given the ethnographic reports of Aborigines using digging sticks to procure burrowing animals. Unfortunately, it is not known whether blood residues survive for extended periods of time on any wood, let alone wood used in monsoonal tropical soils. If blood did survive on any of the digging sticks it is also possible that any quantities of myoglobin or haemoglobin present on the artefacts are below the Hemastix threshold of sensitivity. Alternatively, the skin of burrowing animals need not necessarily have been broken during procurement (L. Satterthwait, 2000, The University of Queensland, pers. comm.).

HIGH-MAGNIFICATION MICROSCOPY.
Contamination. Establishing the presence or absence of any residues on the contamination-control microslides was necessary prior to attempting to evaluate residues identified from the sample. Only small non-diagnostic cellulose fragments were detected on the two microslides from the Queensland Museum. However, in



Residues	Centre	1/4 Pt A	1/4 Pt B	Pt A	Pt B
Starch	b	b	b	b	b
Damaged Starch	p	-	-	-	-
Plant Tissue	pl	-	pl, r	pl	pl
Soil Contents	ts	ts	ts, f	ts	ts, ph, s

FIG. 7. Corresponding residues and marks observed on artefact #QE10007 (Queensland Museum).

Key: Starch granule numbers: a = 0, b = 1-10, c = 11-50, d = 51-100, e = >100; p = Present, - = Absent; Plant tissue: pl = Plant tissue (may include amorphous plant tissue, bordered pits, annulars, helical wall thickenings, sieve areas); r = Raphides, d = Druse, sc = Seed casing;

Soil contents: ts = Thin sediment, tks = Thick sediment, c = Caked sediment, ph = Phytoliths, s = Spherulites, f = Fungi, co = Coccolith.

addition to cellulose, five starch granules (average diameter 12.6µm) were observed on the microslides from the Anthropology Museum, and nine granules, one of which appeared damaged (average diameter 18.4µm), were identified on the microslide from the Residue Laboratory. Therefore, the presence of less than 10 starch granules on microslides from the research sample was only noted if the granules were detected in association with other plant tissue components.

Identified Residues. Apart from minimal soil sediment and amorphous cellulose fragments, no residues indicative of contact with plant matter were detected in solutions extracted from artefacts #QE10059 and #QE10123-1. In addition to soil sediment, inorganic phytoliths (e.g. Fig. 6), the majority being morphologically similar to grass phytoliths (Pearsall, 2000: 366), fungal hyphae and spores and/or a variety of spherulitic forms were identified on various microslides for #QE10007 (Fig. 7), #QE5034

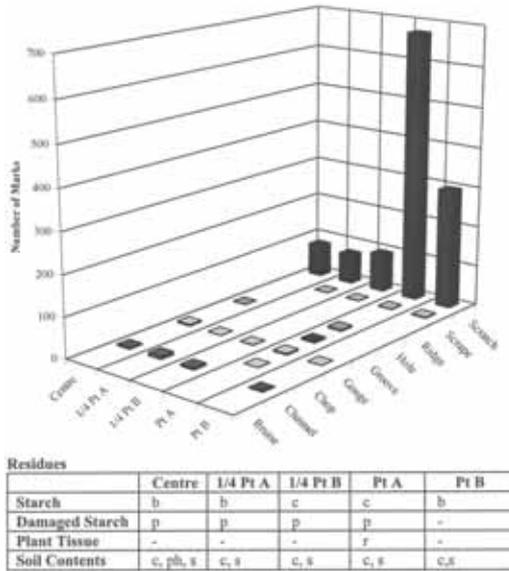


FIG. 8. Corresponding residues and marks observed on artefact #QE5034 (Queensland Museum). Key as in Fig. 7.

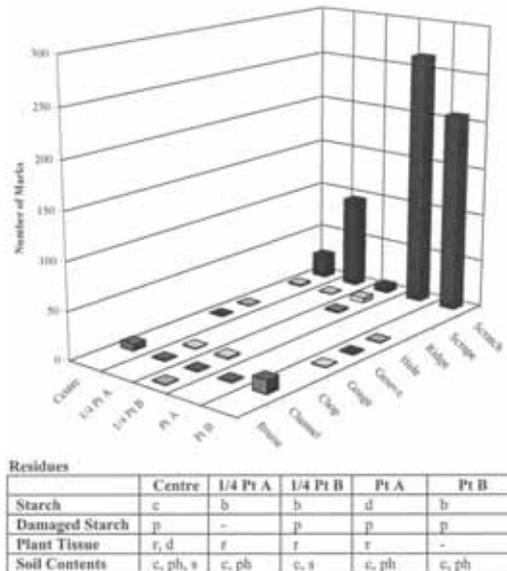


FIG. 9. Corresponding residues and marks observed on artefact #QE3632 (Queensland Museum). Key as in Fig. 7.

(Fig. 8), #QE3632 (Fig. 9), QE10171 (Fig. 10), #22909 (Fig. 11), #24253 (Fig. 12), #9982 (Fig. 13) and #25350 (Fig. 14), indicating contact between these artefacts and soil. While a diverse array of organic plant residues was also identified on many of the microslides from these artefacts, only soil sediment and starch granules were identified on #QE10123-2 (Fig. 15) and #QE16/1117 (Fig. 16). The starch granules vary in shape and size (Figs 17-18) with some of the smaller granules probably being transitory, that is, temporary granules that are produced by chloroplasts in leaves and green stems (Haslam, 2004: 1722). However, the majority of granules observed on the artefacts are $>5\mu\text{m}$ in diameter. Coincident with the greatest number of clusters and individual granules, the largest granule size variation ($2\text{--}32\mu\text{m}$ diameter) occurs on microslides from artefact #9982. Compound granules were only observed in extracts from digging sticks #QE3632, #QE10171, and #22909 whereas damaged and/or gelatinised granules, identified by their swollen appearance and varying degrees of loss of the extinction cross (Banks & Greenwood, 1975: 265), occur sporadically on all 10 artefacts. Other identified plant tissue components comprise raphides (e.g. Fig. 19), tracheids (principal water conducting cells in the plant xylem) and tracheary elements

including annular (ringlike) and helical (spiral) wall thickenings (thickenings deposited in the primary xylem of roots, stems and leaves that permit organ stretching) and bordered pits (pits in the secondary cell walls that overarch membrane-covered gaps in the primary cell walls). Sieve areas (clusters of pores that occur fairly regularly in the plant phloem through which food is conducted) were also identified (Raven et al., 1999: 64, 576-580).

Six residues were identified in addition to those specifically targeted. These residues were: fabric fibres, possibly from the curatorial use of cotton gloves; a druse (cluster of radiating crystals of calcium oxalate trihydrate, sometimes found in association with raphides) (Sakai, 1979: 271); a seed casing; an insect egg; a coccolith (calcite disc formed by uni-cellular marine algae) (Canti, 1998: 442); and a downy feather barbule. The coccolith, from artefact #24253, is probably a sand constituent because this digging stick is from the sandy Wellesley Islands (either Mornington or Bentinck Island). Similarly, the seed casing and druse are likely indicators of contact between an artefact and soil or plant material. The insect egg, on the other hand, may be a soil constituent or could have been laid on the artefact at any time, including during storage in the controlled environment of a museum. As

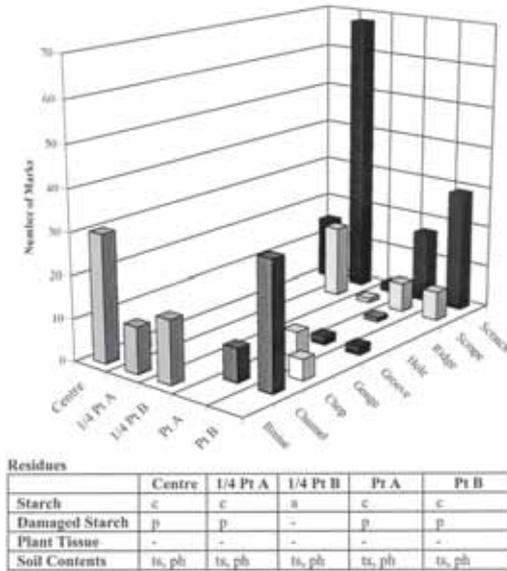


FIG. 10. Corresponding residues and marks observed on artefact #QE10171 (Queensland Museum). Key as in Fig. 7.

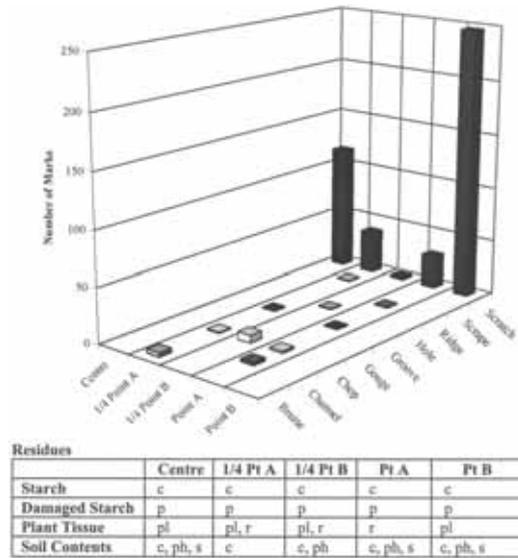


FIG. 11. Corresponding residues and marks observed on artefact #22909 (Anthropology Museum). Key as in Fig. 7.

museums often house feathered artefacts, the feather barbule could also be a contaminant. The egg, feather and fabric fibres were therefore not considered indicative of digging stick use. Possible collagen fibrils were also detected on two microslides from #25350. However, their identification could not be confirmed due to the lack of any associated animal tissue or hair and the negative Hemastix® results.

THE CO-OCCURRENCE OF RESIDUES AND USE-WEAR INDICATORS. As this research was based on the premise that residue and use-wear analyses are mutually informative (Barton et al., 1998: 1234; Fullagar, 1998: 14; Kealhofer et al., 1999: 538), both residues and marks indicative of use should have been observed on a digging stick that had been used for digging purposes. More importantly, the distribution of the residues on the artefacts should logically have corresponded with an increase in the number and variety of observed marks. Such a correspondence would support the suggestion that a greater number and variety of marks is indicative of use-wear and minimise the chances of incorrect inferences being made due to the presence of possible contaminant residues or an increase of mark numbers produced through manufacturing processes.

When used to dig for food, a digging stick was usually held near the lower end with one hand and then plunged into the soil (Devitt, 1988: 187). Both hands would be used and move up the shaft as digging continued and the hole deepened. Occasionally, digging continued unsuccessfully for several hours resulting in ‘a confusion of excavated soil and holes’ (Devitt, 1988: 195). Devitt’s (1988) account gives the distinct impression that a well-used digging stick would have residues, especially soil constituents, over its entire surface as a result of flying soil spread by moving hands. Arguably, less used digging sticks would exhibit residues where they were held and/or on the working end/s. Logically, such manipulations would also abrade existing residues and previously created use-wear and manufacture marks while adding new residues and a greater variety of marks to the surface.

Residues were identified from nearly all of the locations examined on artefacts #QE5034 (Fig. 8), #QE3632 (Fig. 9), #22909 (Fig. 11), #24253 (Fig. 12), #9982 (Fig. 13) and #25350 (Fig. 14). These digging sticks also exhibit the greatest residue variety. Residue distribution on the other four artefacts indicates they have been used less for digging or perhaps for other purposes. A wide variety of residues were identified for #QE10007 (Fig. 7) but mostly from the middle and ends.

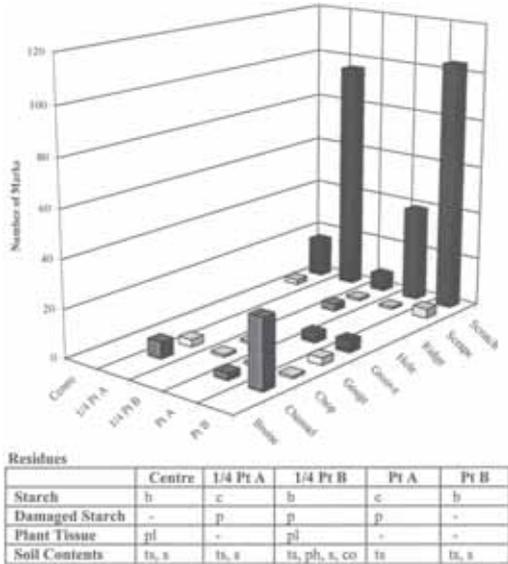


FIG. 12. Corresponding residues and marks observed on artefact #24253 (Anthropology Museum). Key as in Fig. 7.

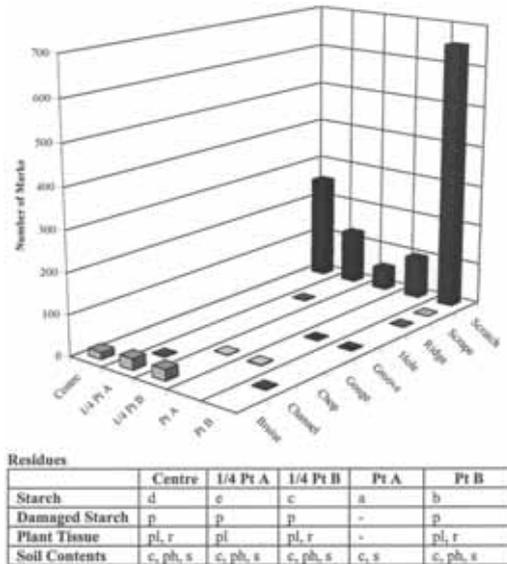


FIG. 13. Corresponding residues and marks observed on artefact #9982 (Anthropology Museum). Key as in Fig. 7.

Similarly but with less variety, #QE10171 (Fig. 10) has residues at the middle and ends. The least variety of residues was identified at one quarter point and at one or both ends of #QE10123-2 (Fig. 15) and #QE16/1117 (Fig. 16).

There is a generally strong correspondence between the distribution of greater mark numbers and/or mark variety and the frequency of occurrence of residues on the digging sticks. Most of the artefacts have more residues and more marks, including a greater variety of mark types at the quarter points and at one or both ends, although #QE5034 (Fig. 8), #QE3632 (Fig. 9), #22909 (Fig. 11) and #9982 (Fig. 13), in addition to having the most marks overall, exhibit more marks and/or mark variety at their centre, further suggesting they were well-used tools. Similar to #QE10171 (Fig. 10), there is an increase in the number of marks at the same locations where residues were extracted from #QE10123-2 (Fig.15). There is an increase in mark variety with residues at the ends of #QE10007 (Fig. 7) but more scratches at the centre where residues were also extracted. Although mark numbers decrease at both ends of #QE16/1117 (Fig. 16), there is more mark variety towards and at the end where starch granules were extracted. The improvised tool #25350 (Fig. 14) has a variety of residues and five mark types but exhibits

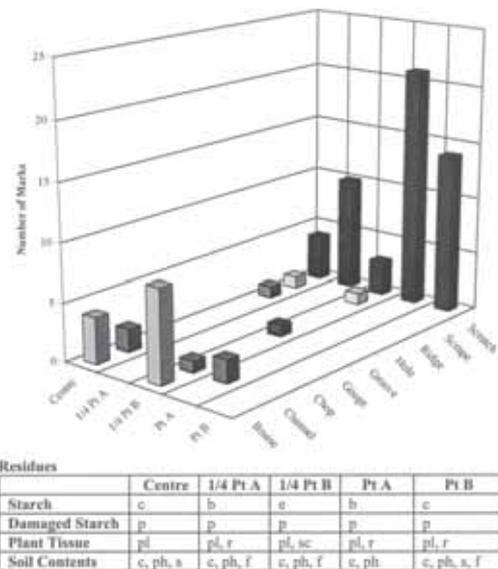


FIG. 14. Corresponding residues and marks observed on artefact #25350 (Anthropology Museum). Key as in Fig. 7.

comparatively few marks with only some variation in mark distribution, evidence indicative of its use for a short period of time (Devitt, 1988: 186). Digging stick QE10123-1,

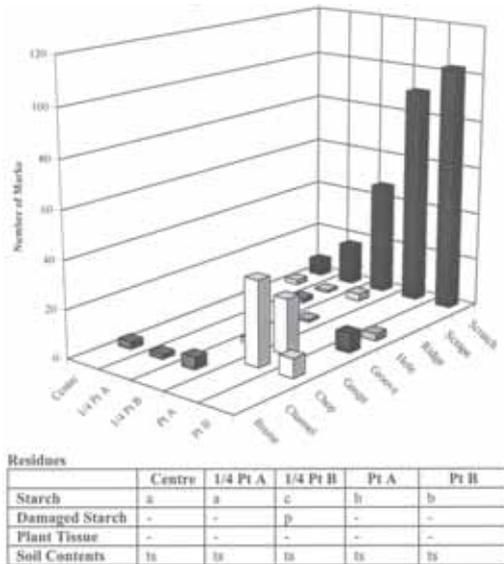


FIG. 15. Corresponding residues and marks observed on artefact #QE10123-2 (Queensland Museum). Key as in Fig. 7.

which exhibits no residues other than a thin scattering of soil sediment, has less mark quantities than #25350, little variation in mark distribution, and only three mark types (Fig. 20). No residues were identified for #QE10059 either, although the ends of this artefact do exhibit mark variety and numbers (Fig. 21), probably from having been worked into concave points.

According to Fullagar (2005, Sydney University, pers. comm.), Aboriginal women in the East Kimberley region dig adjacent to a tuber and it is removed complete without damage from the digging implement. Therefore, the quantity of starch granules and plant tissue observed on the slides requires explanation. At Keep River in north-western Australia the tops of the retrieved yams were broken off and replaced in the hole, taking two seasons to reproduce. Such holes were regularly revisited over many years (Head et al., 2002: 180-181). The quantity of starch from the base of the yam tops and plant debris in the soil resulting from such activity is unknown, but presumably there would be an increase over time, a phenomenon that might explain the presence of starch and plant material on some of the digging sticks, should no contact have been made between the artefacts and tubers. It is also likely that a quantity of starch and plant material is

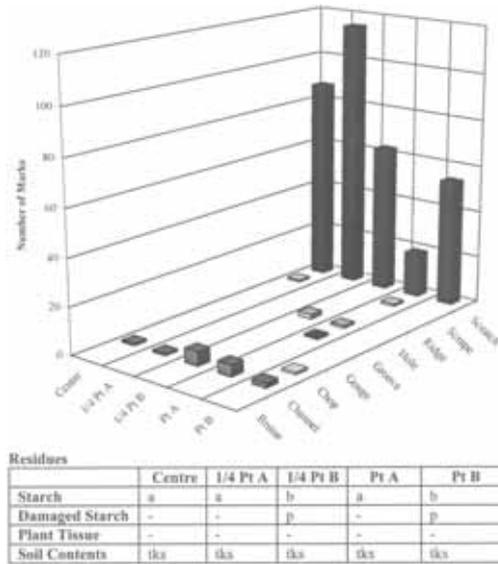


FIG. 16. Corresponding residues and marks observed on artefact #QE16/1117 (Queensland Museum). Key as in Fig. 7.

transferred from the plants to the digging stick by the forager's hands during such an activity.

Based on the presence of residues, especially starch granules $>5\mu\text{m}$ in diameter, and also soil constituents, mark variety and/or quantity, and the presence of more complex marks (summarised in Table 5), the inference can be made that 10 of the digging sticks examined, #QE10123-2, #QE16/1117, #QE10007, #QE5034, #QE3632, #QE10171, #22909, #24253, #9982, and #25350, have been used to procure plant foods. Arguably, #QE5034 #QE3632, #22909 and #9982 had been used the most. The presence of starch granules and plant tissues without the presence of chlorophyll on #22909, #24253 and #25350, suggests the plants procured with these digging sticks were probably roots and tubers. The presence of raphides on #22909 and #25350 provides further evidence supporting this suggestion. One might also suggest that the residues and mark numbers and/or mark variety observed on the blunt ends of #QE10007, #QE5034, QE10171 and #22909 are indicative of some form of plant processing.

In light of the available ethnographic information concerning #25350, the suggestion is also made that 'caked' sediment is not necessarily a reliable indicator of prolonged digging stick use. As already noted, this tool was

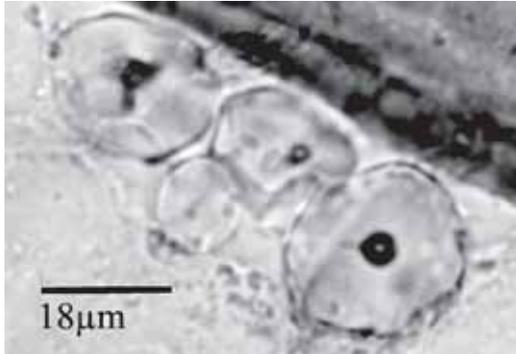


FIG. 17. Starch granules from location 1, artefact #QE16/1117, part-polarised.

hastily manufactured at the beginning of the day (Devitt, 1988: 186) and is, therefore, likely to have been moist with sap when first used, in which case, any soil particles would have rapidly adhered to its surface. In addition, the presence of charring on #25350 requires explanation. Devitt (1988: 186) does not mention charring during improvised digging stick manufacture. However, during foraging trips, the women of Utopia Station stopped to light fires and make tea and, more importantly, 'whenever possible, animals were cooked in the bush' (Devitt, 1988: 92, 119, 200). Therefore, it is possible that #25350 had also been used to turn food in a fire, the charring, plant tissue and presence of probable gelatinised starch granules observed on this artefact indicating vegetable food rather than animal food. The possible gelatinised starch granules and evidence of charring observed on the end/s of #QE16/1117, #QE5034, QE3632, QE10171, #22909, #24253 and #9982 may also be indicative of turning starchy food in a fire.

CONCLUSION

The results demonstrate that mutually informative use-wear and residue analysis techniques, in hand with ethnographic documentation and museum records, can be used to determine traces of digging stick use. The presence of starch granules, soil and/or plant residues in tandem with a greater number and/or variety of marks, strongly suggests that ten digging sticks had been used for plant food-procurement. Such evidence is of considerable benefit to the Queensland Museum and the University of Queensland Anthropology Museum, providing additional information for displays and public and scholarly inquiries, and

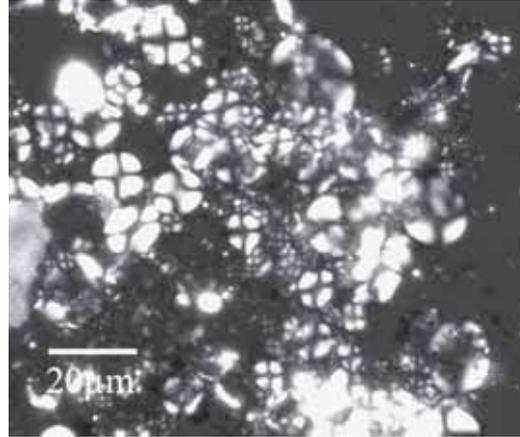


FIG. 18. Starch granules from location 6, artefact #9982, cross-polarised.

thus adding value to their collections (Ambrose & Paine, 1993: 156-7; Rothschild & Cantwell, 1981: 3).

Further analyses of a similar nature on a larger sample of digging sticks would undoubtedly address the more obvious limitations of this study. Although the preservation qualities of blood and animal tissues on wood is not known, the detection of such residues, indicative of animal-procurement, possibly only requires the study of a larger sample and increase in the time taken to agitate water prior to the Ames Hemastix® (Bayer Corp, USA) tests and microslide preparation. Wet-mounted rather than dry-mounted microslides would permit the application of the biological stain Congo Red that stains gelatinised, but not ungelatinised starch



FIG. 19. Raphide from location 5, artefact #25350, plane-polarised.

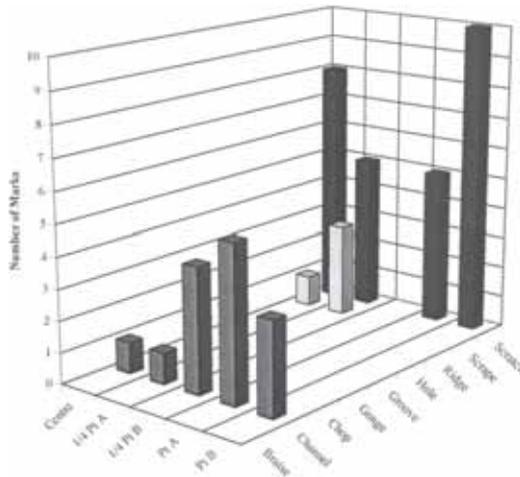


FIG. 20. Marks observed on artefact #QE10123-1 (Queensland Museum).

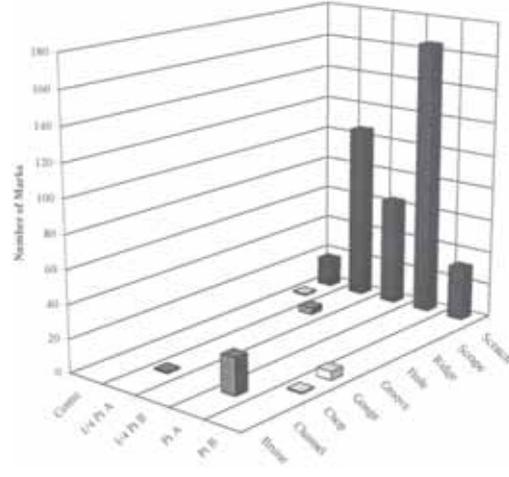


FIG. 21. Marks observed on artefact #QE10059 (Queensland Museum).

granules (Lamb & Loy, 2005; Loy, 1994: 92). Such a test would determine whether the starch granules observed on artefact #25350, for example, were gelatinised by heating or damaged through friction. The identification to genus or species level, confirming that the plant tissues derived from food plants and negating any possibility they derived from other sources such as medicinal plants, was beyond the scope of this research. However, such information would be available with the development of a comprehensive reference collection (Hall et al., 1989: 141; Loy, 1994: 100; Piperno & Holst, 1998).

Owing to the morphology of digging sticks and the numerous ways they might be used during any task, replication experiments of digging stick use would be extremely time-consuming. However, taking into account such variables as wood type and end shape, duration of use and soil type (Kammaing, 1982: 19-22), replicating the initial action of stabbing into the soil would be useful. Such experimentation would possibly establish which, if any, types of complex marks are produced at this stage of use, and might assist in determining the causes of pitting, holes and flattened tips, and whether the observed shiny patches are the result of soil abrasion.

In view of the results, the application of a systematic use-wear and residue analyses to archaeological wooden artefacts to determine their past use is feasible, although obviously, the choice of the locations for analysis would depend on artefact morphology. In addition to the

analytical procedures presented above, such research would not only require thorough study of the relevant archaeological site documentation and comparative ethnographic literature, but also consideration of additional variables such as how well the artefacts are preserved and the preservational matrix from which they were excavated (Barton et al., 1998; Loy, 1997: 33; Loy, 1994: 96; Taylor, 1981: 7-8). Clearly more use-wear and residue analyses research of wooden artefacts, whether ethnographic or archaeological, is required for the study reported here has barely 'scratched the surface'.

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TABLE 5. Summary of correspondence of residues and use-wear indicators. ts = thin scatter; tks = thick scatter; c = caked; * = present; - = absent; pc = possible chlorophyll; d = damaged or gelatinised granule.

Artefact	Sediment	Shiny Patch	Blood	Starch	Raphide	Phytolith	Plant Tissue	Spherulite	Fungi	Druse	Coccolith	Seed Casing	Mark Variety or Numbers	More Complex Marks
Queensland Museum														
QE10059	ts	-	-	-	-	-	-	-	-	-	-	-	*	-
QE10123-1	ts	-	-	-	-	-	-	-	-	-	-	-	-	-
QE10123-2	ts	-	-	*d	-	-	-	-	-	-	-	-	*	-
QE16/1117	tks	*	pc	*d	-	-	-	-	-	-	-	-	*	*
QE10007	tks	*	pc	*d	*	*	*	*	*	-	-	-	*	*
QE5034	c	*	pc	*d	*	*	-	*	-	-	-	-	*	*
QE3632	c	*	-	*d	*	*	-	*	-	*	-	-	*	*
QE10171	ts	*	-	*d	-	*	-	-	-	-	-	-	*	*
Anthropology Museum														
22909	c	*	-	*d	*	*	*	*	-	-	-	-	*	*
24253	ts	*	-	*d	-	*	*	*	-	-	*	-	*	*
9982	c	*	pc	*d	*	*	*	*	-	-	-	-	*	*
25350	c	*	-	*d	*	*	*	*	*	-	-	*	-	*

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