Reference: Wesley, D., Litster, M., Moffat, I., O'Connor, S., 2018, Indigenous built structures and anthropogenic impacts on the stratigraphy of Northern Australian rockshelters: insights from Malarakk 1, north western Arnhem Land, *Australian Archaeology*, 48: 3-18.

Title: Indigenous built structures and anthropogenic impacts on the stratigraphy of Northern Australian rockshelters: insights from Malarakk 1, north western Arnhem Land

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Malarakk 1 is currently the northernmost excavated rockshelter on the Australian mainland, located in the Wellington Range in north western Arnhem Land. The site contains a rich late Holocene deposit, with extensive contact rock art, stone artefacts, shell, bone, contact materials, ancestral human remains, and other cultural material. Excavation of the Malarakk 1 rockshelter and analysis of its sediments revealed many impacts on site formation processes within the deposit. We attribute the disturbance to possible erosion or sediment deposition during periods of intense rainfall and also to the construction of timber structures within the site. This is supported by modern and historical observations and is the focus of this paper. The extent of the disturbance to Malarakk 1 provides a cautionary tale for other excavations in the region that may be affected by similar Indigenous site occupation, as these anthropogenic activities enhance the risk of further impacts arising from biological and geomorphological processes that can impinge on the stratigraphic integrity of the cultural deposits.

Introduction

Whilst modern and historical observations inform us that wooden structures—such as burial platforms and scaffolding for rock art painting—were constructed in rockshelters of the Northern Territory, there has been little explicit discussion of the material traces of these structures, or the impacts such construction events might have had on the deeper archaeological record. This paper reports on the broader implications of post-holes found during the excavation of Malarakk 1, a rockshelter located in north western Arnhem Land, best known for its culture contact rock art associated with the Macassan trepang-fishing (bêche-de-mer) trade and European colonisation (Chaloupka 1974, 1993, 1996; May et al. 2010, 2013; Wesley 2013) (Figures 1 and 2). Recently, Malarakk 1 has become the subject of detailed research, including archaeological excavation conducted by two of the authors in 2009 (DW and SO), a discussion of the contact rock art by May et al. (2010, 2013) and Wesley et al. (2012), isotope analysis of Indigenous ancestral remains (Theden-Ringl et al. 2011) and contact period glass and stone beads recovered from the excavation (Wesley and Litster 2015).

The 2009 investigation involved the excavation of three squares—G25, H25 and K25—which revealed extensive evidence of culture contact and late Holocene deposits overlying basal cultural deposits with an accelerator mass spectrometry (AMS) radiocarbon age of 34,790–36,204 cal. BP (NZA32453, Square G25). The excavation also exposed disturbance of the cultural deposit within Squares G25 and H25, including the presence of visible post-hole features and changes in sediment grain size, magnetic susceptibility and inverted radiocarbon dates, raising important issues that should be considered when examining the structural integrity of cultural deposits in this and other Arnhem Land rockshelter sites.

Informed by the direct-historical approach to analogy (Lyman and O'Brien 2001), multiple lines of evidence including field notes, traditional knowledge, and photography, support our interpretation of wooden structures at Malarrak 1. Photographs taken by Axel Poignant (1952) at the shelter in 1952 illustrate partial remains of a burial platform and several human skulls on the shelter floor (National Library of Australia Series PIC5936/Album 6/294-318). The human skeletal remains appear to be half-buried in the surface sediments and were located in the northeastern end of the shelter. Lazarus Lamilami (1974), the senior Maung traditional owner, also recalled bones being placed in the Malarrak 1 rockshelter when he was a boy. Furthermore, in 1974 a story of a disabled artist was recounted to rock art expert George Chaloupka by George Winunguj (George Chaloupka pers. comm. 2008). Platforms were erected near the shelter walls enabling the artist to produce paintings. These accounts provide strong evidence for the construction of at least two types of wooden platform structures at Malarrak 1 during the contact era, which we argue had a role in disturbing the archaeological stratigraphy of the shelter.

Figure 1. Map of Arnhem Land indicating the location of Malarrak 1.

Figure 2. Malarrak 1 (A) facing south showing Square K25. (B) aerial view (photographed by: Daryl Wesley).

Figure 3. Examples of Indigenous architecture. (A) TPH 1742—Wet season camp of Makani, a Mildjingi, at Gaatji, Arnhem Land, 1937. Photographed by Donald Thomson. Courtesy of the Thomson Family and Museums Victoria. Source: Museums Victoria. (B) TPH 1734—Sleeping platform with fire place below to repel mosquitos in the wet season, Cape Stewart,

Arnhem Land, 1937, Photographed by Donald Thomson. Courtesy Thomson Family and Museums Victoria. Source: Museums Victoria. (C) PH0111/0100—Aboriginal camp in Palmerston (Darwin), NT Library, Photographed by Paul Foelsche # Northern Territory Library. (D) Aboriginal camp in Palmerston (Darwin), PH0111/0118 NT Library, Photographed by Paul Foelsche # Northern Territory Library.

Built structures in rockshelters

Aboriginal shelters and structures in open settings are well known and have been documented since the earliest encounters by European explorers, with many types of ‘humpies’ and ‘wurleys’ recorded across Australia (Broome 2005; Clarke 2003; Memmott 2007; Robins 1981; Welch 2008; Wiseman et al. 1996). Structures identified by Memmott (2007:10) as ‘classical Indigenous ethno-architecture’ were made primarily from organic materials such as wooden posts, bark, branches, and rope. The earliest documentation of such structures in the Northern Territory are found in the records of Paul Foelsche (1831–1914), who photographed examples around Darwin in 1890 (Figure 3). Additionally, stone structures from open site contexts have also been seen in the archaeological record, such as the features on High Clifty Island and Rankin Island off the northwest coast of the Kimberley (O’Connor 1987; O’Connor et al. 2007), the ovoid habitation structures on Rosemary Island, Western Australia (McDonald and Berry 2017), Aboriginal stone huts along the Georgina River (Wallis et al. 2017), and the semi-circular, C-shaped or U-shaped huts at Lake Condah (Clarke 1994; McNiven et al. 2017).

Published literature pertaining to the archaeology of built structures in northern Australian rockshelters concerns stone features (see Brown 1987; Wallis and Matthews 2016), while, organic structures have received little attention in the literature (except Bowdler 1971; Megaw and Wright 1966, for New South Wales), perhaps owing to their susceptibility to weathering and the role of the tropical climate in accelerating decay. Under these circumstances, post-hole remains often provide the only evidence for their prior existence, and they are consequently difficult to interpret (Gabucio et al. 2017). This situation is contrasted with those reported further afield, such as in Niah Cave in Sarawak, c. 2,500 years BP (Barker 2005) and at Bui Ceri Uato and the nearby Bui Ceri Uato Mane rockshelters in Timor-Leste (Glover 1986; Oliveira 2008). Post-holes have been reported also at the rockshelter site of Vampiros 1, in Panama, which have been ostensibly linked to activities associated with the fish preparation, such as drying beds (Carvajal-Contreras et al. 2008). McNiven et al. (2010) discuss the post-hole evidence of a Himaiyu stilt structure in Papua New Guinea. Scheffler (2002, 2008) documented the impact of post-holes on stratigraphic units (SUs) in the Honduran rockshelter site El Gigante. Post-holes have been interpreted as evidence of prehistoric pens in rockshelters and caves in Iberia (Díaz et al. 2014); and, in eastern Kentucky, Classen (2011) links remnant post-holes and material culture in the Newt Kash rockshelter to oral histories, suggesting these places might have functioned as retreats for women during menstruation, birthing, and sickness.

The under-reporting in Australia is interesting given the diversity of structures known to have featured prominently as significant components of the Indigenous built environment in Arnhem Land as documented by Donald Thomson and Axel Poignant (Memmott 2007; Poignant and Poignant 1996; Thomson and Peterson 2003; Wiseman et al. 1996). These features can still be observed in parts of Arnhem Land, such as the remains of the burial platform at Djulirri in the Wellington Range, and metal and paperbark structures in western Arnhem Land rockshelters (Daryl Wesley pers. obs). The size, scale and use of structures in tropical Northern Territory open contexts can be seen in Figure 3. Such structures would have been built in rockshelters to

enhance protection from the elements in the shelter, provide bedding, and to assist with managing biting insects.

The research context

Investigations of rockshelter sites in the ‘Top End’ of the Northern Territory have been concentrated in western Arnhem Land and Kakadu National Park. Fifteen rockshelter excavations in the western Arnhem Land region have been published, with several of the same shelters investigated multiple times. Of these sites, nine have Pleistocene–Holocene transition occupation, and six have Pleistocene dates extending beyond the Last Glacial Maximum (Allen and Barton 1989; Clarkson et al. 2015, 2017; David et al. 2011, 2012, 2017; Jones 1985; Schrire 1982; Shine et al. 2013). Recently published optically stimulated luminescence (OSL) dating results from the sediments from Madjedbebe (Malakunanja II) in Kakadu National Park indicate that Indigenous people were potentially present in the region at around 65 ka, with conservative calculations of 59.3 ka (Clarkson et al. 2017).

Malarrak 1 is located in the Wellington Range of north western Arnhem Land approximately 12 km south of the coast (Figure 1), within the traditional lands of the Manganowal (Maung speaking) Aboriginal clan group. Manganowal Traditional Owners refer to this area as the Namunidjbuk Estate, which is a remote locality serviced by the small Waruwi (South Goulburn Island) and Gunbalanya communities.

Geologically, the area is dominated by the Mamadawerre Formation (part of the larger Kombolgie Formation) which consists of crossbedded medium to very coarse grained quartzose sandstone generally outcropping as tors, platforms, and escarpment features (Needham 1984; Senior and Smart 1976; Sweet et al. 1999). The massif outlier that contains the Malarrak 1 rockshelter is formed by the basal unit of the Mamadawerre Sandstone Formation which is estimated to have formed 1,810 million years ago (Sweet et al. 1999). This unit consists of a poorly sorted, medium to coarse grained quartz sandstone with pebble or granular bands with a polymictic quartz pebble to boulder conglomerate as its base (Sweet et al. 1999).

Environmental attributes of the Wellington Range region are typical of the coastal biogeographic Arnhem Land zone which is dominated by coastal plains with eucalypt woodlands, monsoon vine forests and coastal mangrove communities (Woinarski and Baker 2002). The topography of the area is low and gently undulating, except for the strongly dissected plateau and outliers. North of the Wellington Range are discontinuous low coastal cliffs and vegetated laterite escarpment areas which break the sand sheet surface areas. Tidal flats and mangrove-lined channels are found along the coastal zones (Senior and Smart 1976). Vegetation surrounding the Malarrak 1 site is savannah open woodland and is dominated by *Eucalyptus miniata* (Darwin woolly butt) and *Eucalyptus tetradonta* (stringybark) with a *Sorghum* sp. grassland understorey.

Malarrak 1: 2009 investigations

Malarrak 1 was formed by a major semi-vertical fracturing event from the outcropping bedrock, with the fallen boulders lying upright and creating a barrier. The rockshelter faces north and is 29.6 m in length by 7 m in width with an approximate height to the ceiling at the drip-line of 15 m (Figure 4). The main rock art panel is approximately 19.4 m in length and the secondary panel is 10.2 m. The site contains a range of archaeological features typical of

western Arnhem Land rockshelters, including rock paintings (May et al. 2010, 2013), fragments of human skeletal remains, grinding hollows, stone artefacts, faunal remains, shell, wooden artefacts, and introduced contact period artefacts.

Monsoon vine forest vegetation grows around the shelter and provides a protective canopy. Owing to the conglomerate nature of the sandstone, the scree slope consists of a high proportion of quartz cobbles and sandstone gravel. During the 2009 investigations two major water channels were observed to flow through the site during the wet season; the first flows into the shelter down the sandstone walls and then out to the northern slope over the pebble scree.

A second water flow channel was noted emerging from the eastern end of the shelter (Figure 4). Prior to excavation, it appeared that the most intact area of the deposit would be between the fallen sandstone boulders and the rear shelter wall, as the surface lacked visible erosion from precipitation and water flows. Approximately 30 cm of deposit was eroding in places along the drip-line. This erosion was mostly attributed to disturbance from feral animals (pigs and buffalo) followed by wet season sheet flows. Furthermore, a star picket fence had previously been erected in the site to provide a barrier to feral pigs but was removed in 2009 owing to disrepair and its contribution to erosion.

Figure 4. Site plan of Malarrak 1.

Methods

The excavation of Malarrak 1 consisted of three 1_1 m squares on a north-oriented alpha numeric grid (see Figure 4). Squares G25 and H25 were chosen to test the archaeological deposit. After finding significant disruption of sediments in G25 and H25 in the form of post-holes, K25 was excavated in efforts to probe for non-disrupted sediments. This paper will discuss the results from these three squares. Square G25 consisted of 24 excavation units (XUs) to a total depth of 47.5 cm; H25 consisted of 21 XUs to a total depth of m; and K25 consisted of 7 XUs and reached a total depth of 21.8 cm.

Each XU was 2 cm deep. Importantly, excavating at this resolution enabled the post-hole features to be clearly identified. During the excavation, we undertook sediment descriptions, Munsell colour identification of sediments, pH testing of each XU, end unit sketches and photographs followed by a stratigraphic drawing of pit walls at the conclusion of excavation. Artefacts identified in situ, and charcoal samples for radiocarbon dating were bagged separately and recorded three dimensionally with X, Y, Z measurements (cm), using a total station.

Sediments were then screened through 6mm and 3mm sieves for further sorting of cultural materials in a laboratory. Average and column sediment bulk samples were taken from each XU to provide material for geoarchaeological analysis. Bulk samples weighing on average 250 g were collected from a 10_10 cm area forming a continuous column in the south-east corner of each excavation square. An average bulk sample of approximately 250 g was taken from aggregated sediment prior to sieving.

Resources were focussed on Square G25 for investigating issues of stratigraphic integrity and sediment disruption, owing to the early detection of post-holes in the field, better representation of all SUs in the square, and the multiple radiocarbon age determination inversions. Squares H25 and K25 were excluded from further sediment analysis for multiple reasons; it was obvious that H25 was significantly disrupted by a single large posthole, which did not become apparent until the end of XU 19 due to the intermixing of the yellow-brown SUIV sediments into the upper dark grey and grey sediments. Therefore, this disruption was not able to be quarantined in the same manner as those from G25. Other factors included sloping bedrock and the associated limited representation of SUIII and IV sediments. Square K25 proved to be unaffected by post-hole activity and intrusion of contact artefacts at depth and also contained only seven XUs with no SUII sediments and limited representation of SUIV.

Particle size analysis was conducted on G25 bulk sample sediments to scrutinise distributions and changes in the archaeological deposit that were not visible in the stratigraphic profile of the excavation. For Square G25, sediment was analysed for mean grain size using laser diffraction particle size analysis conducted with the Malvern Mastersizer 2000, fitted with a 2,000 hydro mu dispersion unit. For particle size, 5 g of sediment was weighed into a 50ml centrifuge tube with 5ml of 30% hydrogen peroxide added, followed by 5ml 5% sodium hexametaphosphate to disaggregate the clay particles. A further 10 ml of milli-q water was added. Shaking occurred after the addition of each and samples were left to stand overnight. Samples were transferred to the dispersion unit with a pipette and 30 s of ultrasonics was applied before analysis. Volume specific magnetic susceptibility was measured on 24 ten millilitre samples at low frequency (0.46 kHz) on a Bartington Instruments MS2B dual-frequency scanner. Sediment samples were prepared for Loss on Ignition (LOI) by oven drying at 105 _C for 24 h and then placed in a desiccator to be weighed for pre-ignition sample weight. Samples were then placed in an unheated furnace in which the temperature was gradually increased to a final 550 _C. The samples were then left for 3.5 h and removed from the oven to cool. After cooling, samples were removed from the desiccator and weighed for their post-ignition weight.

Charcoal was collected in situ and from bulk samples. Four charcoal samples were initially submitted to Rafter GNS Science for dating from Square G25 to establish an overall site chronology (Table 1). Further charcoal samples were submitted to the Australian National University Radiocarbon Laboratory and Direct AMS (Table 1). Dates were calibrated using OxCal 4.3.2 (Bronk Ramsey 2013) using the SHCal curve (Hogg et al. 2013). Cultural materials from the site were sorted from the 6 and 3mm residues and identified into flaked stone artefacts, non-flaked stone artefacts (hammerstones and grinding stones), faunal remains (bone and shell), post-contact artefacts (glass, metal, ceramics), organic material and ochre. Stone artefacts were counted and weighed. Mollusc taxa were identified and quantified by the minimum number of individuals (MNI), number of individual specimens (NISP), and weight (g). All other cultural material was weighed (g).

Results

Stratigraphy and sediments

SUs from the Malarrak 1 excavation are described in detail in Table 2 and the east wall of G25, H25 and K25 are illustrated in Figure 5. Upper SUs SUI, II and III are distinguished by their high charcoal content and a very dark grey to grey colour. SUI and II had generally alkaline pH levels of 9 and 8.5. The pH level for SUIII was neutral between 7.5 and 6.5 with SUIV sediment trending into more acidic pH levels of 5–6. These results are consistent with pH values from other Arnhem Land rockshelter sediments (Jones (ed.) 1985; Schrire 1982; Shine et al. 2013), which generally decrease with depth. LOI in G25 illustrates a decrease of organic matter throughout the deposit with the highest organic content in SUI to SUIII. There is a peak LOI value in XU5. Organic content is very low in the acidic sediments of SUIV, presumably due to poor preservation rather than non-deposition. Magnetic susceptibility values are significantly greater in SUIV sediments in G25 with spikes in XUs 14, 21, and 22. Magnetic susceptibility values are generally even throughout SUI, II, and III. Magnetic susceptibility and LOI values are relatively higher in XU11 where a stratigraphic change occurs.

Sediment analysis in G25 has revealed the presence of four possible sedimentary disconformities occurring in the Malarrak 1 deposit indicated by sudden changes in particle size and changes in LOI and magnetic susceptibility values (Figure 6). Disconformity indicates a break in a geological sedimentary sequence, but it has also been used to describe stratigraphic breaks or changes in archaeological sediments (cf. Bowler et al. 1970:44–45; McNiven et al. 2012:283). This study has adopted the use of the term disconformity to describe phases of sedimentary changes at Malarrak 1 identified in the particle size analysis of G25 sediments that are not necessarily recognisable from the excavated sections of the trench. This may reflect a period of erosion or non-deposition and reflects a change in depositional energy, process or sediment source. These are labelled as ‘Disconformity 1–4’ in Figure 6.

Disconformity 1 is located within SUI at a depth of approximately 10 cm. It is characterised by a small peak in LOI values, no obvious change in Low-Frequency Magnetic Susceptibility values and a dramatic increase in mean grain size with more than 60% of grains being larger than 125 μ m (fine sand) and more than 20% being larger than coarse sand. Disconformity 1 is interpreted to occur at 10 cm total depth but the anomalous grain size values occur over approximately 8 cm total depth (from 16 cm to 8 cm). Disconformity 2 occurs within SUIII at approximately 22 cm total depth and is characterised by no obvious change in LOI values, a small increase in LF magnetic susceptibility values and a moderate increase in overall grain size with more than 40% of grains being larger than 125 μ m (fine sand). Post-holes began to be observed in this unit during excavation. Disconformity 3 occurs within SUIV at approximately 28 cm total depth and is characterised by a small increase in LOI values, a large discrete increase in LF magnetic susceptibility values and an increase in grain size with more than 40% of grains being coarser than 125 μ m (fine sand) compared to 15% in surrounding sediments. Disconformity 4 occurs within SUIV at a total depth of approximately 42 cm and is characterised by no change in LOI values, a large discrete increase in LF magnetic susceptibility values and a moderate increase in grain size with approximately 20% being coarser than 125 μ m (fine sand).

Table 1. Radiocarbon results from Malarrak 1, G25, H25 and K25 (Calibration using Oxcal v4.3.2; 95% probability, 95.4–50% mean confidence).

Sample	Sample	$\delta^{13}\text{C}$	^{14}C Years BP	PMC	Depth (cm)	XU	Years Cal BP	% certainty within 95.4% probability	Comments
Malarrak 1 G25 XU6	S-ANU-21412	–35	65 ± 30	99.18 ± 0.35	15.1	6	73 to 5	52.7%	Charcoal fragment from bulk column sample from a defined sediment change at top of XU6
Malarrak 1 G25 XU6/3	NZA32470	–27	417 ± 20	94.26 ± 0.21	15.7	6	500 to 441	69.1%	In situ sample taken from a concentration of charcoal that was interpreted as a hearth concentration
Malarrak 1 G25 XU10	S-ANU 21413	–32	905 ± 40	89.32 ± 0.43	23.9	10	820 to 681	82.3%	Charcoal fragment from bulk column sample
Malarrak 1 G25 XU11	NZA32455	–26	654 ± 20	91.53 ± 0.2	24.5	11	649 to 585	71.6%	In situ sample from the south east quadrat
Malarrak 1 G25 XU16	S-ANU 21414	–31	955 ± 30	88.76 ± 0.3	31.5	16	914 to 749	95.4%	Charcoal fragment from bulk column sample
Malarrak 1 G25 XU19/12	NZA32454	–27	114 ± 15	97.89 ± 0.21	38.8	19	72 to 18	53.3%	In situ charcoal fragment
Malarrak 1 G25 XU19	S-ANU 21416	–31	425 ± 30	94.81 ± 0.34	40	19	505 to 437	64.4%	Charcoal fragment from bulk column sample
Malarrak 1 G25 XU24/1	NZA32453	–25	31,620 ± 350	1.94 ± 0.08	47.3	24	36,204 to 34,790	95.4%	In situ end of excavation charcoal fragment
Malarrak 1 G25 XU24	S-ANU 21417	–33	420 ± 40	94.908 ± 0.45	47.5	24	506 to 426	54.2%	Charcoal fragment from bulk column sample; end of excavation
Malarrak 1 H25 XU6	D-AMS-020962	NA	503 ± 34	93.93 ± 0.40	7.2	6	535 to 472	95.4%	In situ charcoal sample (<i>Eucalyptus</i> sp.)
Malarrak 1 H25 XU20	D-AMS-020963	NA	402 ± 24	95.12 ± 0.29	29.4	20	435 to 325	49.4%	In situ charcoal sample (<i>Eucalyptus</i> sp.)
Malarrak 1 K25 XU7/4	D-AMS-020964	NA	2,542 ± 39	72.87 ± 0.35	14.8	7	2,743 to 2,426	93.8%	In situ charcoal sample (unidentified angiosperm) from rich 10 cm diameter lens.

Table 2. Stratigraphic units at Malarrak 1.

Stratigraphic unit	Munsell	Colour	pH	Description	Taphonomic Comments
I	7.5YR 3/1	Very dark grey	8–9	Very dark grey charcoal rich unit. Consists of coarse sands to very fine grain sands and silt. Well sorted sediment with highly fragmented shell throughout.	Highly fragmented shell interspersed throughout. XU2 had leaves and macropod faeces. High level of bio-turbation in upper XUs.
II	7.5YR 4/1	Dark grey	8.5	Compacted dark grey sediments consisting of silts, very fine to mostly fine grain sands. Some quartz cobbles and gravel interspersed. Well sorted sediment, prone to dusting. Concentrations of charcoal with silty ashy lenses.	Some small roots (>100 g) and root-lets found in this layer. No insect burrows are apparent. Change from SUII to SUIV begins in XU8.
III	7.5YR 5/1	Grey	6.5–7.5	Discrete loosely compacted, mostly silt and very fine-grained sand sediment. Very ash and charcoal rich and appears as a narrow lens in the southern half of the square and is visible in the southern profile.	The unit appeared to be intact with no obvious taphonomic features.
IV	10YR 4/3	Brown	5.5–6	A dark yellow brown to brown, hard compact sand and gravel sediment. High proportion of quartz gravel and pebble rich sediment. Coarse to very fine grain sands with silt and clay. Friable sandstone fragments interspersed. The sediment has increasing proportions of quartz cobbles and gravel towards the base of this unit. Desiccating sandstone rock forms the base of the unit.	This unit has been extensively contaminated by materials from upper units from posthole digging into the sediments. Despite the attempt to remove the posthole features at XU15, there was no certainty that contamination of sediments and cultural materials had not occurred around the post-hole features.

Post-holes

Seven post-hole features were excavated from G25 and one from H25 which are listed in Table 3. These post-hole features ranged in diameter from approximately 30 cm to 10 cm with a mean diameter of 16 cm. Features F7 and F8 were the largest of the post-holes and also the deepest. Figure 7 illustrates the size, scale, and the downward intrusion into SUIV of the post-holes in both H25 and G25. The large post-hole in H25 was not clearly visible until XU19 was excavated. Conversely, in G25 discolouration in the sediment began to be uncovered in the NE quadrat by XU12 indicating anomalous features. These G25 features with nondescript boundaries became well defined during the excavation of the sediments through the transition from SUIII to SUIV (XU12–14). After the removal of two further XUs, the uniformity of the size and depth of the features revealed these were likely to be post-holes, with seven identified in G25 after excavating XU14 (Table 3; Figure 7). The texture and compactness of the post holes in both squares differed significantly to the surrounding compacted brown sediments of SUIV. The sediment colour inside the post-hole features was dark greyish brown (10YR 4/2) and outside the post-hole areas a distinctive dark yellowish brown (10YR 4/4) (Figure 4). These features were infilled with loosely compacted, poorly sorted sediments with sandstone gravel, quartz pebbles and very fine-grained sediment. The sediments were interspersed with varying densities of stone artefacts, charcoal, and shell fragments.

Post-holes should be considered as a separate archaeological SU and a by-product of people living within the rockshelter; the presence of such features was therefore dealt with by treating each as a separate feature (Harris 1999). In excavating XU15 for G25 and XU19 for H25 a decision was made to remove each of the features and follow the loosely compacted sediment interspersed with fragments of shell and charcoal. The inclusion of these shell fragments indicates the post-holes were packed with more recent sediments (*sensu* McNiven et al. 2010:4). The post-hole Feature 3 in Square H25 had clearly been dug into the desiccating sandstone bedrock requiring some force to dislodge the quartz cobbles and gravel from the sandstone matrix when digging the footing hole.

Radiocarbon dating

Table 1 presents all 12 radiocarbon dates from Malarrak 1. Nine dates were obtained from G25, two from H25 and one from K25. Squares G25 and H25 contained radiocarbon inversions. G25 returned an old date, 34,790–36,204 cal. BP (NZA32453) from XU24; however, a charcoal sample from XU19 in G25 was dated from 5–73 cal. BP. Given the considerable discrepancy between these two dates an attempt was made to replicate the initial age determinations with a further five charcoal samples from the column sediment sample located in the southeast corner of G25. As this column sample was removed during the excavation, the risk of contamination of charcoal falling from the wall above this column sample was considered low. The column sample area of G25 appeared to be robust in terms of stratigraphic integrity and was located away from the post-hole features uncovered in the northern half of the square, no evidence of post-holes or cuts through SUII into SUIV was evident and it was located away from a hearth depression. However, as shown in Table 1, these dates contributed even further to the inversion anomalies of the radiocarbon age determinations throughout the cultural deposit. The charcoal fragment dated to 36,204–34,790 cal. BP was removed in situ from the pebble sediments at the base of XU24. At the time of the excavation, the other three in situ charcoal samples seemed to be taken from stable features in the sediment. Two charcoal samples, which were identified as *Eucalyptus* sp. were dated from H25, one from XU6 and one in XU20, with the near basal date obtained from charcoal in XU20 being younger (435–325 years cal. BP) than that from

XU6, which was dated 535–472 years cal. BP. The basal layers from XU7 Square K25 were dated 2,743–2,426 cal. BP.

Figure 5. Stratigraphic sections for the East Wall of Squares G25, H25 and K25.

Cultural materials

The cultural materials from Malarrak 1 (see Figure 8) include 10,756 stone artefacts (flakes, cores, retouched flakes, edge-ground axe fragments, grinding stones and hammerstones manufactured on mostly quartz, quartzite, silcrete, chert, kaolinite claystone, metasandstone and dolerite), charcoal, burnt earth, glass (sherds, flaked artefacts, beads), ochre (haematite and red, yellow and white kaolinite claystone fragments), metals (corroded tin fragments, three iron spear prongs, iron adzing tool), invertebrate faunal remains (*Melo* sp., *Ellobium aurisjudae*, *Cassidula angulifera*, *Nerita balteata*, *Cerithidea anticipata*, *Telescopium telescopium*, *Terebralia* spp., *Marcia hiantina*, *Tapes conspersus*, *Chicoreus capucinus*, *Velesunio* sp., *Tegillarca* [*Anadara*] *granosa*, *Atactodea striata* and *Geloina erosa*), vertebrate faunal remains of small mammals and reptiles (fragmentary and largely undiagnostic), a human molar, small quantities of beeswax, wood fragments and seeds.

In Square G25, 3,384 stone artefacts were recovered (3.7 kg), with very low densities found in XU8–12. Shell, bone and charcoal were found to the lowest levels of the square, with the largest quantities found in the uppermost XUs. Square G25 also contained a total of 10.9 kg of marine shell. Shell peaked in XUs 3 and 4, with very low densities interspersed through XU9–24. Likewise, the bone was found in higher quantities in XU1–7, with very marginal densities found in XU9 to the bedrock. Charcoal peaked in XUs 3 and 4, with lower densities found from XU9 to the base of the site. A total of 103 g of ochre was found throughout the square with the highest densities found in the lower spits from XU17–22. Contact artefacts (metals, glass sherds, glass artefacts and glass beads) were found in low quantities from XU1–8 and a singular fragment of earthenware in XU11.

A further 3,298 stone artefacts were recovered from H25 (2.7 kg), with peaks in the lower spits in XUs 16 and 17. Shell was found from XU1–18, with higher proportions found from XU1–14 totalling 1.7 kg. A total of 200.99 g of highly fragmented bone was found from XU1–20, with peaks at XU11, XU13, and XU14. Charcoal was found throughout the square, with high densities in XU15 and 16. Ochre was found in small quantities throughout the excavation, with a peak at XU11. Contact artefacts were found from XU1–17 in small quantities.

Square K25 contained a dense shell matrix compared to G25 and H25 producing a total of 13.2 kg of shell, alongside a total of 4,074 stone artefacts (6.4 kg), with peaks in XU6 and 7. Small amounts of bone (421.66 g) and charcoal (213.33 g) were found, with peaks at around XU4 and 5. Ochre was found in small quantities in XUs 2, 4 and 7. Contact artefacts were found only in XU2.

Figure 6. Sediment analysis from Square G25 (Loss on Ignition, magnetic susceptibility, particle size analysis).

Table 3. Post-hole features at Malarrak 1.

Square and feature #	Length	Width	XU Start	Total observed depth of post-hole (cm)	Comments
G25 F3	11	5	15	9	Circular feature with loosely compacted and poorly sorted fine to very fine grained sediment, charcoal rich.
G25 F4	13	13	12	5	Loosely compacted and poorly sorted fine to very fine-grained sediment, charcoal rich.
G25 F5	11	10	12	14	Loosely compacted and poorly sorted gravel and very fine-grained sediment, charcoal rich with some stone artefacts.
G25 F6	14	10	12	10.4	Circular feature with, loosely compacted and poorly sorted gravel and very fine-grained sediment, charcoal rich.
G25 F7	24	20	12	20	Large circular feature with loosely compacted and poorly sorted gravel and very fine-grained sediment, interspersed with charcoal and shell fragments, containing some stone artefacts.
G25 F8	30	17	12	24.8	Large circular feature with loosely compacted and poorly sorted gravel and very fine-grained sediment, with stone artefacts, interspersed with charcoal and shell fragments.
G25 F9	12	10	12	8	Dark grey poorly sorted fine-grained sediment with charcoal, artefacts and shell fragments.
H25 F3	25	17	19	19.4	A deep circular feature with loosely compacted sediment with charcoal, complete <i>T. granosa</i> shells, shell fragments, and stone artefacts. Dug into the desiccated sandstone bedrock

Figure 7. Photographs illustrating post-hole features. (a) Square H25, view south showing post-hole feature F3. (b) End of XU14 (G25). (c) End of XU15—removal of posthole features (G25). Photographed by: Daryl Wesley.

Discussion

The depositional environment of rockshelters has been an important topic in Australian archaeology with Hughes (1983) making an extensive contribution to understanding the geomorphic context of sediments. A variety of site formation and post depositional processes that affect Australian archaeological sites has been variously investigated (Hewitt and Allen 2010; O'Connor et al. 1999; Ward and Larcombe 2003). More recent studies have examined sediment accumulation and subsequent post-depositional effects from wet-dry tropical monsoon climates in northern Australian sandstone dominated environments (Ward 2003; Ward and Larcombe 2003; Ward et al. 2006). These studies have demonstrated that post-depositional disturbance is particularly likely in unconsolidated sandy deposits, such as in Malarrak 1 (Hiscock and Kershaw 1992; Ward 2003; Ward and Larcombe 2003; Ward et al. 2006). Gregory (1998) noted in her study of archaeological sites in the Victoria River region of the Northern Territory that humans, animals, plants, wind, fire, and water action all provide the basis for substantial post-depositional disturbance. Additionally, Walthall (1998) has identified the fact that rockshelter sediments are at a particularly higher level of risk from post-depositional modification from fluvial action owing to the constrained nature of the space.

Geoarchaeological research has demonstrated that site developmental history requires more information than just field archaeological descriptions such as colour, pH and sediment texture (Hassan 1978, 1979; Stein and Farrand 2001; Walthall 1998). Hassan (1978, 1979) demonstrated that geophysical, geochemical and morphological properties of sediments could potentially provide a thorough understanding of site formation processes. Holliday (2004) describes in detail modern approaches of geoarchaeological analytical techniques (e.g. magnetic susceptibility to determine anthropogenic enhancement of sediments through burning, particle shape analysis to provide insights into sediment provenance and depositional conditions, LOI to quantify the charcoal and carbonate content), that are necessary to formulate archaeological interpretations from site sediments.

Furthermore, Ward et al. (2016) have shown that the use of 'SU groupings' of an archaeological deposit may assist in overcoming anomalies caused by the disruption of post-holes to site sediments and may still provide meaningful data for interpretation. It is with these methods in mind, in particular, sudden changes in grain size or magnetic susceptibility, that we present an analysis of the sediments and cultural materials from excavations at Malarrak 1.

We attribute Disconformity 1 to the effect of water flow during a period of intense rainfall and Disconformities 2–4 to the effects of post-hole digging (Figure 6). The critical distinguishing features were the larger and thicker increase in grain size and the lack of magnetic susceptibility response in Disconformity 1, compared to a more modest grain size increase and enhanced magnetic susceptibility in 2–4. The sudden increases in mean grain size associated with the disconformities may have occurred when water flow transported coarser grained sediments into the site and winnowed finergrained particles (Hj}ulstrom 1939). We suggest that these flood deposits will generally have an erosive base, coarser grain size, no increase in LF magnetic susceptibility and may have a discrete distribution within the shelter if the flow is channelised. We consider it particularly likely that a period of fluvial activity in the shelter will result in enhancement of the magnetic properties of the sediment, although this could occur as a post-depositional process. We suggest that sediments introduced through post-hole digging at Malarrak 1 will usually be coarser in grain size, and accompanied by an increase in LF magnetic susceptibility but not an increase in LOI. We were unable to ground truth this conceptual model with sediments from the visible post-holes as they were not archived for

analysis during excavation, but suggest this as a productive field of enquiry for future researchers.

The process of digging the post-holes, packing them and then the subsequent infill after posts have decayed, been consumed by termites (Werner and Prior 2007; Werner et al. 2008), or physically removed or burnt, combined to significantly affect site formation processes at Malarrak 1. The Honduran site of El Gigante is another site where post-holes were observed (Scheffler 2002, 2008). A particular stratum (Stratum III) would often be 'pinched out' of the sequence owing to such intrusions from above (Scheffler 2002). Scheffler (2002) found a pit feature extended down into pre-cultural depths as well as post-holes which contained cigarette butts, recently imported botanical remains and other refuse. Although Malarrak 1 did not have such modern refuse in the lower layers, the intrusion from the processes of digging and repacking postholes and later destruction of timbers from termites or removal by people, distributed both large and small fragments of shell from the upper shell matrix into the lower units of both H25 and G25 which was the best indicator of vertical movement of recent cultural materials. Like El Gigante, the visible post-holes at Malarrak 1 were irregular in size ranging from 10 to 30 cm in diameter (Figure 7). Evidence of introduced materials such as small glass flakes and corroded metal fragments were also found in the lower XUs of H25. The timing of posthole disturbance at Malarrak 1 is likely to have been in the last 1,000 years given that the inverted radiocarbon dates cluster within this time period. The observation of debris from burial platforms and evidence from Traditional Owners support a late date for when most of the post-holes may have been dug into the lower sediments (Wesley et al. 2016). Some of these post-holes must have been excavated during the culture contact period owing to the presence of downward movement of glass and metal artefacts.

Furthermore, the infilling of the post-holes must have played a large role in the penetration of younger charcoal into the lower sediments not only by vertical dispersal processes, but also laterally through hydrological processes and insect activity. It is for this reason that we strongly recommend that charcoal used for radiocarbon dating is located far from post-holes. Movement of charcoal is also known to be exacerbated by insect inhabitation in sediments (Hewitt and Allen 2010). According to Ward and Larcombe (2003) northern Australian termites, which can be introduced via posts, can completely rework sandy sediments to depths of 25 cm.

The distribution profiles of archaeological materials from G25, H25 and K25 as shown in Figure 8 are significantly different. An explanation for such differing profiles co-located in the same area of a rockshelter is attributable to the impact from the eight post-holes. The disconformities align with either pronounced increased or decreased distribution of cultural materials in G25. Distribution of G25 stone artefacts decrease in XUs 11 and 21 which coincide with Disconformity 2 and 4, whereas G25 stone artefact numbers peak in XU11 which corresponds with Disconformity 3. Furthermore, a decrease in contact artefacts in XU4 is concomitant with Disconformity 1. Disconformity 2 appears to have caused the most significant disruption across all classes of cultural materials in G25. This lack of uniformity of cultural material distribution associated with each disconformity suggests there are different site formation and post-depositional processes altering sediment particle size distribution, but in the absence of sediment analysis from the interpreted post hole structures, it is difficult to draw detailed conclusions about the specific reason for these alterations. No post-holes were visible in Square K25, which contained a dense shell matrix consisting of 11,881 individual shells and shell fragments (NISP). The unimodal distribution of most of the cultural materials in this square (see Figure 8) contrasts to that of G25 and H25, indicating less anthropogenic disturbance compared to the other two squares. Furthermore, the presence of large sandstone

boulders, the relatively shallow deposit and the absence of post-hole features indicate that it is an unlikely location for structure building.

Despite the taphonomic and post-depositional processes that have impacted the archaeology of Malarrak 1, some conclusions can be made on the Indigenous occupation of the site. There was an economic focus on marine resources over the last 3,000 years even though suitable coastal environments are located over 8 km to the northeast. The species present include mainly those from mangrove habitats, such as *T. telescopium*, *Terebralia* spp., *C. anguilifera*, *E. aurisjudae*, *N. balteata*, *C. capucinus* and *G. erosa*, all of which would have been sourced from Anuru Bay, with very minor contributions from freshwater habitats (*Velesunio* sp.), and sandy muddy substrates (*T. granosa*). The stone artefact assemblage reveals a reliance on local raw materials including the abundant quartz, claystone, and dolerite outcrops with exotic raw materials such as chert and quartzite providing further support for the wide-ranging trade and exchange networks of western Arnhem Land. Artefact types including retouched flakes, edge-ground axes, hammerstones, and grinding stones illustrate a diversity of activities undertaken at Malarrak 1 for processing local resources and the production and maintenance of stone artefacts. The extensive contact assemblage consisting of glass, metal and rock art imagery demonstrates Indigenous interaction with Macassans at the nearby Anuru Bay trepang processing site, nineteenth century European military outposts on the Coburg Peninsula and later mission settlements on South Goulburn Island. The presence of the 36,204–34,790 cal. BP basal date also provides a tantalising glimpse of the potential Pleistocene occupation of the site.

Figure 8. Cultural materials from Squares G25, H25 and K25 (stone artefacts, shell, bone, charcoal, ochre and contact artefacts).

Conclusion

The excavation of Malarrak 1 has added further evidence to the antiquity of occupation of northern Australia and has revealed an abundant and diverse artefact assemblage. Significantly, the site illustrates how an anthropogenic modification to cultural sediments can have a considerable impact on an archaeological deposit. By comparing contemporary local information associated with Malarrak 1 with the archaeological evidence from the excavation, we argue that former building activities in the rockshelter have impacted on the ability to reliably date the cultural deposits in Squares G25 and H25 and interpret the archaeological sequence. Despite these issues, the presence of these structures also highlights how little they have been investigated in excavations of rockshelters to date. The anthropogenic and taphonomic factors identified at Malarrak 1 clearly demonstrate the need for caution when interpreting archaeological deposits in similar rockshelter contexts in northern Australia but also suggest a productive new field of enquiry for Australian archaeology.

Acknowledgements

The authors would like to thank Traditional Owners Ronald Lamilami and his family of the Manganowal clan for their support, guidance and enthusiasm throughout fieldwork from 2008 to 2010. Fieldwork was undertaken by DW and SO as part of the Baijini, Macassans, Balanda, and Bininj: Defining the Indigenous Past of Arnhem Land through Culture Contact Linkage Project. Rock art of Malarrak 1 was recorded by the Picturing Change Project [DP0877463]. The authors would like to thank CartoGIS for production of the map used in this publication. Grateful thanks for the Australian National University (ANU) volunteers as well as volunteers from Flinders University, the University of Queensland, Heritage Conservation Branch, Department of Natural Resources, Environment, Arts, and Sport and others from abroad. Thanks are also due to Katherine Seikel and Melissa Hetherington for laboratory supervision. The North Australia Research Unit (ANU) in Darwin supported the project with a base of operations for the fieldwork in the Northern Territory. The authors would like to acknowledge the Thomson Family, Museums Victoria, and Northern Territory Library, Department of Tourism and Culture for the use of images in this publication. The authors would like to thank Patrick De Dekker for comments relevant to the research and Jessica Reeves for providing palaeoclimate data in addition to three anonymous reviewers who provided very constructive feedback on the submitted manuscript. All errors contained within are our own.

Disclosure statement

No potential conflict of interest was reported by the authors.

Funding

This work was funded by the Australian Research Council Linkage Project program [LP0882985] with contributions from the Linkage Partners Bushfires Council NT and the Department of Sustainability, Environment Heritage and Water. Daryl Wesley was also supported by Australian Research Council fellowship DE170101447 'People, Animals and Ochre'. Ian Moffat was supported by Australian Research Council fellowship DP160100703 'The Drumbeat of Human Evolution: Climate Proxies from Rockshelter Sediments'.

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