2

The Getting of Wisdom: Field and Laboratory Methods

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Figure 2.1. Murujuga subregions initially identified in the heritage inventory methodology (McDonald 2009a).

Representative Landscapes

The project recognised the urgent need for systematic rock art recording and analysis across the National Heritage Place (NHP). The only systematic recording work previously completed in the conservation estate since the NHP listing had been the initial Deep Gorge survey, along with the Burrup rock art field schools (McDonald 2009a; see Table 1.1). A heritage inventory study of the NHP estate identified that a range of representative landscapes across the archipelago needed sampling so that appropriate management strategies could be implemented (McDonald 2009b).

This project targeted the outer islands (OIs) Enderby and Rosemary, central island (CI) West Lewis and northern islands (NIs) Dolphin and Gidley as these were of varying sizes, different geologies and different distances (i.e. with varying accessibility) from the current shoreline in the Holocene (Figure 2.1). To collect comparable data to that which has been collected on the north, central and southern Burrup (NB, CB, SB) over the last 20 years (see Table 1.1), the project targeted survey transects to cover a range of micro-environmental and geological variability in the sampled subregions. The landscapes sampled, people days and nature of the recording trips undertaken throughout the project are shown in Table 2.1.

TRIP	LOCATION	LANDSCAPES	ACTIVITIES	PERSON DAYS: UWA/ INDUSTRY*		MOTIFS RECORDED
April–May 2014	Rosemary Island	OI; Wadjuru Pool, RM08	Excavation (M. Berry's PhD)	50	28	200
July 2014	Murujuga Rockshelter	SB; Burrup	Test excavation during field school	60		
March 2016 men's trip (researchers, TOs, Rangers)	Enderby Island (south camp)	OI; cultural clearance	Cultural clearance by helicopter and boat to SA1, SA2, SA6	10	5	
July 2016	Murujuga Rockshelter	SB; Burrup	Salvage excavation during field school	80		
4–14 April 2016	Enderby Island (south camp)	OI; Areas 1–4	Rock art and stone structure recording	54	46	2,781
2–13 May 2016	Ancient Pools	NB; Areas 1–6	Rock art, stone structure recording	36	34	2,721
4–16 June 2016	Enderby Island	OI; Areas 2, 6	Excavation	61	28	
20 July – 5 August 2016	Rosemary Island (east camp)	OI; Areas 1–3	Rock art and stone structure recording, GPR	62	42	2,926
19 April – 1 May 2017	Rosemary Island (west camp)	OI; Area 5, RM08, Isolated	Rock art and stone structure recording	45	26	1,875
6–16 May 2017	Enderby Island (north camp), Ancient Pools	OI; Areas 6–8	Rock art and stone structure recording; calcium carbonate coring	32	20	2,781
12–23 June 2017	West Lewis Island	CI; Areas 1, 5, Isolated	Historic homestead excavation; rock art and stone structure recording	59	46	1,428
17–28 July 2017	Watering Cove, Old Geos	NB: Burrup sand body, dolerite dyke SB: *Tegillarca* midden	Excavation; limited rock art recording	64	57	332
3–13 May 2018	Rosemary Island, Flying Foam Pearling sites, Dolphin	OI: Areas 3, 5 NI: Areas 1–5	Rock art stone structure recording and visualisation, historic features	50	38	613
Total				*663*	*337*	*14,858*

Table 2.1. Summary of fieldwork locations visited over the course of the Linkage Project showing sample transects, archaeological activities and summaries of motif assemblages recorded.* UWA = researchers, students and traditional owners; GPR – ground penetrating radar. Industry = Rio Tinto Partner Investigator Mulvaney, other Rio Tinto personnel (i.e. Victoria Anderson is included in Rio tally but participated also as a PhD candidate) and volunteers.

In addition to the sampled island locations, annual recording work was achieved on the Burrup during the Rio Tinto–sponsored UWA Rock Art field school (documented in reports to MAC and DPLH, e.g. McDonald and de Koning 2015). This Burrup recording work has documented areas within the NHP both within and outside the zoned conservation estate, i.e. the Murujuga National Park.

Consultation and Cultural Protocols

A Research Management Committee for the Linkage Project included the Murujuga Aboriginal Corporation CEO (mostly Peter Jeffries), Murujuga Land and Sea Unit Manager (until October 2018, Sean McNeair), Lead Chief Investigator Jo McDonald, Partner Investigator Ken Mulvaney and the Research Manager, Joe Dortch. This committee has met regularly: eight times in 2016, four times in 2017 and four times in 2018. Research protocols were developed for the collection and analysis of archaeological materials. A strong relationship with the community has been forged. Between the project's start and end, the project team presented 22 times to the Circle of Elders, the representative body of senior men and women of MAC (Figure 2.2). These presentations described where and why the team was planning to do fieldwork; sought advice on whether this was culturally appropriate, including getting cultural clearance; and (importantly) disseminated fieldwork results.

The project envisaged this as an opportunity to provide MAC Rangers and staff with training in all aspects of rock art and other site recording, excavation and database management. This training was to be directed towards raising the MAC Rangers' capacity to manage, conserve and provide interpretive resources for their own work across Murujuga National Park and the wider land and sea Country, with the new interpretation techniques, to foster new economies around heritage values.

All fieldwork was conducted in close collaboration with local Traditional Owner groups represented by MAC (Figure 2.3). This engagement was facilitated by MAC staff and the Circle of Elders. The Murujuga Land and Sea Unit Rangers participated when their schedule allowed, and the project deployed the MAC vessel *Topaz*, skippered by Ranger Coordinator Sean McNeair. Regular updates on fieldwork results were presented at Circle of Elders meetings. The Elders and Rangers attended conference presentations with the research team in 2016 and 2017 as well as participating in the UWA Research Week activities (in 2017) and other UWA seminars.

The MAC Rangers undergo a program of training certification, and over the life of the project there have been several cycles of new personnel in the coordination and ranger roles. Given the changeover of individual rangers within the Murujuga Land and Sea Unit and Department of Biodiversity, Conservation and Attractions (DBCA) ranger program, the training outcomes have been somewhat hit and miss. The major management outcome of the project has been the generation of new baseline information which can be mobilised into the Murujuga Cultural Heritage Management Plan (MAC 2016), and the new database system which MAC is installing. This has been developed by Environmental Systems Solutions, which also provide back-end support to the CRAR+M database, allowing for the seamless transfer of data between the two databases. The incorporation of digital recording technologies into the recording workflow and employment of a database manager (after the ARC LP funding ceased) through the Rio Tinto–UWA Research Memorandum of Understanding has enabled the completion of the auditing and data uploading as part of the project outputs – also producing opportunities for local and state community heritage displays (e.g. in the Murujuga exhibition of the new WA Museum Boola Bardip).

Rock Art Recording

The fieldwork was undertaken by up to five survey teams, each comprising two or three people, labelled teams A–E. Each team worked independently but in verbal and visual communication with the other teams to ensure full coverage of the survey transects. Each team carried a dedicated camera, GPS, measuring equipment, drawing equipment, a 'Flappy' (an innovative method for identifying team ID and panel numbers in the LightRoom photography workflow) and an iPad to digitally record the specific attributes of panels and motifs (Figure 2.4). Each block and/or platform within a survey area was examined and any surface found to contain rock art was designated as a uniquely identified petroglyph panel. Panel naming included the team letter and the date of its recording and ran sequentially (from -001 to -999) during that particular field campaign within the survey area. Each individual petroglyph was recorded as a 'motif' (i.e. a graphic composition labelled based on its shape characteristics) on that panel, with motifs being numbered sequentially from -01 to -99 on each panel.

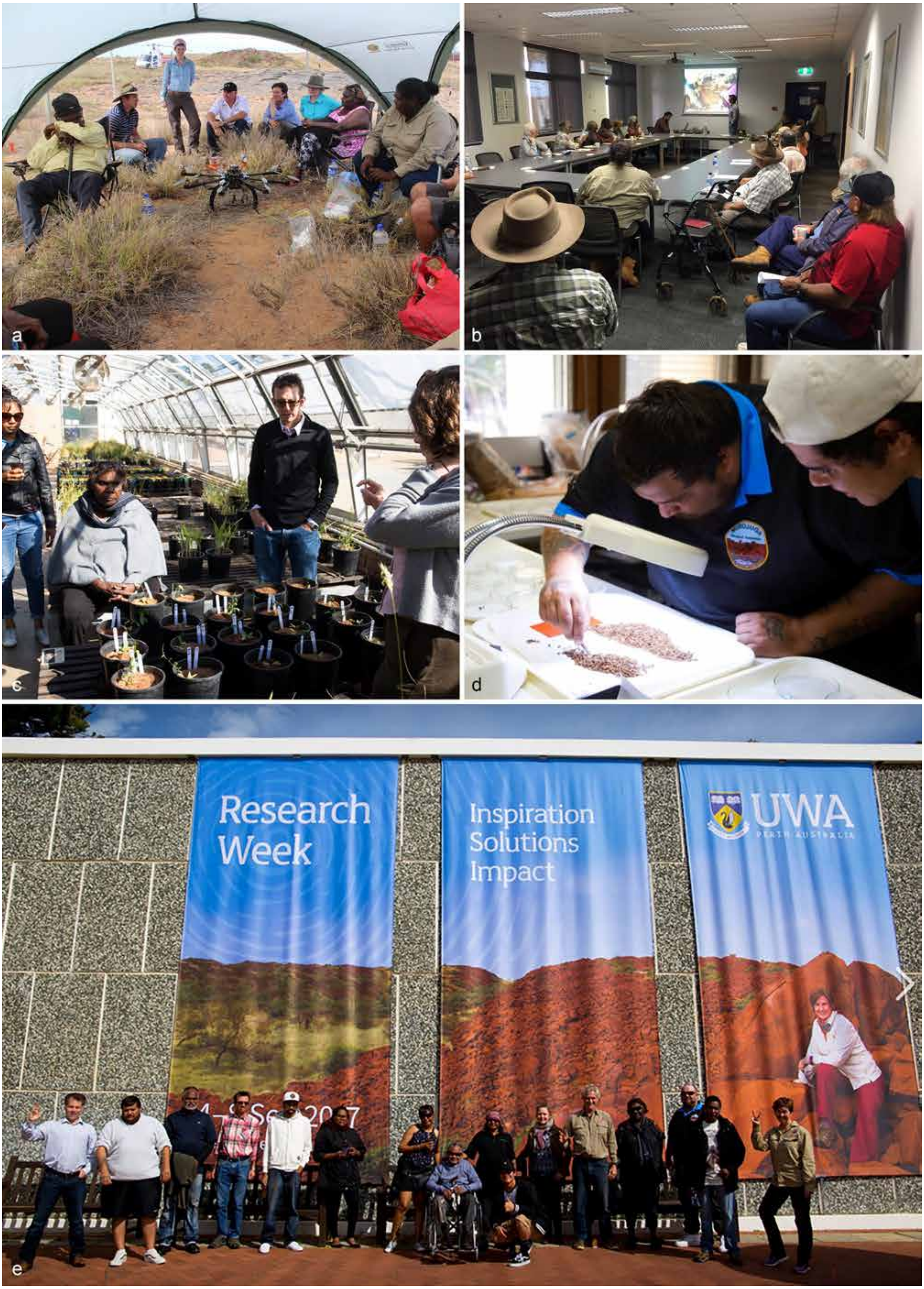

Figure 2.2. Murujuga Aboriginal Corporation's Circle of Elders attended a) on-country meetings as well as b) the project team presenting at Circle of Elders' meetings; (c, d) Elders and Rangers attended Research Week at UWA in 2017, which provided an opportunity for the community to see research experiments in action and the for the Rangers to participate in lab work; (e) Murujuga was the focus of this University of Western Australia 2017 Research Week.

Figure 2.3. The involvement of Murujuga Aboriginal Corporation was vital to the success of the project: (a–c) MAC vessel *Topaz* and MAC Rangers facilitating fieldwork on the islands; (d) MAC Rangers and Elders and Industry representative presenting at an archaeology department seminar in 2016.

An iPad mini running FileMakerPro© recording forms collected information first about the panel: block measurements (length, width and depth), aspect, and surface attributes such as colour, condition and presence/absence of desert varnish.

This process is discussed in more detail in Chapter 3. The location of each panel was recorded using the team's handheld Garmin GPS and downloaded onto Garmin BaseCamp along with csv files to audit. These were crosschecked each evening with the digitally collected panel information. Each team used a Canon DSLR camera to capture every rock art panel and motif in high resolution: most of these had inbuilt GPS location, used as a crosscheck for the handheld GPS information.

Figure 2.4. Recording equipment used during the documentation: (a–b) iPad mini for recording panel and motif details and measuring equipment; (c) sketching on paper; (d) the Flappy.

Motifs were recorded using the taxonomy developed by the authors (e.g. McDonald 2009a; McDonald and Veth 2006, 2009; Mulvaney 2015; and following Vinnicombe 2002). Also recorded were measurements (length, width) and attributes such as superimposition and condition as well as more detailed specific comments. Another variable recorded was contrast state (CS), as an indicator of relative age. With values from CS1 (the same colour as the bedrock) to CS5 (bright/fresh: see Mulvaney 2015 and discussion in Chapter 3), this measure has allowed us to develop a relative chronology.

Towards the end of the project, each recording team also used an iPad Pro running Procreate to make detailed sketches of each image on the panel in the field, replacing the paper component of the recording protocol.

A fieldwork photography workflow evolved over the life of the project and became more streamlined to accommodate the nightly data download. The order of the photographs taken for each panel was:

1. context (a landscape shot showing the location of the panel);
2. panel shot (including the entire extent of the recorded surface);
3. at least one image of each motif engraved on the panel, in the same order as the sketch/digital recorded sequence;
4. picture of the sketch (this was dropped once digital sketches were implemented);
5. aspect from the panel (i.e. at 90 degrees from the panel);
6. a picture of the Flappy with the relevant panel number.

Adobe Lightroom was used to ensure comprehensive and systematic cataloguing of the metadata. This was done at the end of each field day. All images are stored as raw DNG files for archival purposes as well as high-resolution JPEGs to ensure easy access and navigation of files. All imagery was renamed in Lightroom to reflect panel/motif ID, to ensure metadata preservation and to facilitate database uploading.

Post-fieldwork, all images and data collected were audited. Each digital image is linked to its relevant recorded panel and motif entries. All rock art images will be subject to the MAC–CRAR+M Image Clearance Process. This process involves designation of cultural significance of the imagery by a senior male custodian (throughout this project, by MAC CEO Peter Jeffries) working with the CRAR+M Database Manager. This process ensures cultural safety of image repatriation to MAC at the end of all major recording projects. In summary, rock art imagery is designated as 'open' or 'closed' with various levels of cultural significance within the closed categories. This process was incomplete at the end of the project but will be undertaken in a future project by UWA and MAC (Desert to the Sea LP). All data has been uploaded into the CRAR+M database, a web archive that is already accessible to MAC heritage personnel (as well as any other collaborating researchers on their heritage estates), industry partners and researchers at CRAR+M UWA. A shapefile with all panels and all open imagery will be provided to DBCA and Department of Lands, Planning and Heritage (DPLH) for their different management and regulatory purposes.

Stone Structure Recording

The variation in form and density of Murujuga stone structures was recognised along with aspects of the rock art as one of the significant National Heritage values of the NHP. Stone structures include pit features within the rock slopes, heaped stone circular and linear formations, and placed, often chocked, upright stones (see Chapter 4).

Where possible, stone structures were recorded by one of the survey teams when encountered. In areas where particularly high quantities of stone structures were identified, a single team was deployed to focus solely on this site type. Each structure was recorded with a unique code date, team letter and an 'F' (= feature) designation to separate these from rock art (no letter) and 'S' (artefact scatters). As with rock art, structures were numbered sequentially within each survey area. Stone structures were recorded using an iPad mini running FileMaker Pro or a Trimble Nomad with inbuilt Global Navigation Satellite System (GNSS) and ArcPad forms. The recording forms were developed during the Murujuga: Dynamics of the Dreaming Project and allowed for detailed attribute information to be collected while using a simplified typology, developed further by Beckett (2021) during her PhD project. Attributes included structure dimensions (length, width, height or depth), structure shape, construction type and landform context. This information contributed to the development of the more comprehensive typology (Chapter 4). The location of each structure recorded with FileMaker Pro© forms was collected with either a handheld Garmin GPS device or a highly accurate (sub cm) Trimble TSC3. The Trimble TSC3© was a cumbersome piece of equipment so was mainly used in areas where there were densely concentrated stone structures present, such as on Rosemary Island within Area 3 and Area 4. A Canon DSLR camera was used by each team to capture a photographic record of each structure and wherever possible an unmanned aerial vehicle was used to capture the landscape context of these places. Nightly data download was undertaken in Adobe Lightroom or Adobe Bridge. As with rock art, post-fieldwork, all images and data collected were audited and uploaded into the CRAR+M database (see above).

Excavation Procedures

This project aimed to excavate open sites associated with older engraving assemblages across the archipelago, to determine the initial occupation of these landscapes – to provide a firm chronology for Murujuga art production. It had originally been intended to excavate spaced test pits, and to expand these to open area excavation to increase the artefact sample and provide a better understanding of the spatial distribution of assemblages in a variety of occupied landscapes (viz. McDonald 2005; O'Connell 1987). This turned out to be an overly ambitious goal for a three-year project in a landscape where our understanding of the variability in the geomorphic, landscape and archaeological record was limited and where we encountered both extremely deep cultural sequences (i.e. sand bodies over 2 m deep) and very dense cultural assemblages (midden deposits with extremely high densities of shells, artefacts and other cultural remains). Extensive, open-area excavations were well beyond the scope of any three-year cycle, especially given the complex and extensive outcomes of the project which were successfully achieved.

The project focused on archaeological landscapes which are taphonomically unlikely to preserve organics – and minimal charcoal was recovered from most excavations. Where charcoal was recovered, we attempted to provide paired shell and charcoal samples to test the reliability of the shell radiocarbon dates. Unfortunately, this charcoal was generally too fragmentary to survive pre-processing (Fiona Petchey, Waikato, pers. comm., 2016). Many of our Early Holocene sites contain predominantly *Terebralia* spp. shells, and there is no calibration curve available for this species for the north-west coast (cf. Petchey and Ulm 2012).

Standard archaeological excavation techniques were used throughout the project. All excavations of Indigenous sites used usual archaeological and sedimentological descriptions to help understand the site formation processes. All excavated material was screened through 6 mm, 4 mm, 2 mm (and some 1 mm) sieves for maximum recovery. Because of the sandy deposits and arid and remote environment, dry sieving was used on-site. Generally, 2 mm residue was unsorted in the field and returned to the lab for wet sieving and more controlled sorting.

Stratigraphic sections were drawn for each excavated square to maximise recording of relationships between features and stratigraphic units. Sediment samples were collected *in situ* from the north-west corner of each excavation unit. Some of these have been analysed in more detail (e.g. McDonald et al. 2018) and the remainder have been stored with the analysed cultural material. To enable three-dimensional digital recording of all excavated sections, nine photographs were taken at the end of each excavation unit (square base, each of the four baulks and each of the four corners), allowing for a 3D photogrammetric image for the base of each excavation unit (see Figure 2.5). These have also been deployed as 3D visualisations for conference presentations and use in interpretation displays.

Figure 2.5. Visualisation of square EIA-002's western baulk created by using Agisoft Metashape using the end level photographs taken for this square.

A total station was used to record the start and end levels of excavation units in most squares as well as the locations of provenanced finds. The naming of all excavation squares was based on the last three digits from the GPS point at the north-west corner of the excavation square. This was done to enable a seamless expansion around the original square (initially envisaged by our s16 application research methodology) in terms of logical square nomenclature (open area excavation of open sites requires a method which allows for easy analysis of spatial information, for example, through digital imagery and GIS and photogrammetric software). During the project we moved from paper to paperless recording on iPads with the forms replicating digitally the information collected on the paper forms.

Where minimal or no charcoal was encountered, sequences were targeted for optically stimulated luminescence (OSL) dating. Thorough analysis of all excavated finds included identification of faunal and floral remains. Shells were sorted by several students and other volunteers supervised by Joe Dortch. Faunal remains were analysed by Dr Carly Monks, UWA Archaeology Lab Manager.

Historical excavations were undertaken at the West Lewis Island pastoral station and at a stone structure on Enderby Island interpreted previously as a historical burial (EIA08). These are documented in chapters 11 and 6.

Figure 2.6. Excavation in progress at Rosemary Island: (a–c) showing total station and sieving in process; (d) the placement of OSL tubes; (e) the pXRF device being deployed on Angel Island; and (f) Emma Beckett operating a drone to help visualise a rock art site on Rosemary Island.

Economic Shellfish Analysis

Shell was classified into diagnostic and non-diagnostic pieces, and the diagnostic material was identified to taxon (genus or family, but in the case of dominant taxa, to species). Species were identified through UWA Archaeology reference collections and shell guides (e.g. Wells and Bryce 1985). Classified shell in each excavation unit were weighed. *Tegillarca granosa* (formerly *Anadara* cf. *granosa)* and *Terebralia* spp. were abundant enough for counts and measurements to support dietary and palaeo-ecological interpretation (see Chapter 15 for details of this analysis).

Counting and measuring require a brief explanation as these methods vary between shell taxa and according to their state of preservation. Numbers of identifiable specimens (NISP) were not counted because counting shell fragments, estimated to be in the millions, was well beyond the scope of the project. Instead, a smaller value, the minimum number of individuals (MNI), was obtained by counting the most numerous surviving unique structure on shells. MNI is still large enough to provide statistically viable samples.

With *Terebralia*, the base of the shell opening was the most common unique structure, and the number of intact openings indicated the MNI for a given stratigraphic unit (Figure 2.7b).

For *Tegillarca*, intact umbo and hinge structures were classified as 'left' or 'right' and the largest group in either side category then gave the MNI for each unit counted. Due to fragmentation typical of open archaeological midden sites, particularly in landscapes like Murujuga, a single measurement was usually all that was feasible for each species. *Tegillarca* valves were measured at their longest point, from left to right apices of the valve, parallel with the hinge (Figure 2.7c, d). Due to fragmentation of many shells, the measured population in each species is only a subset of the MNI, which in turn represents a subset of the total identified weight.

Figure 2.7. Shell morphologies and definitions: (a) complete *Telescopium* spp. showing key features; (b) *Terebralia* spp. showing fragmentary archaeological specimens with their measurable apertures; (c) intact *Tegillarca granosa* valves and (d) archaeological examples showing diagnostic features; (e) whole *Dentalium* scaphopod (*Laevidentalium lubricatum*) showing diagnostic parts (after Jeff Wright, Queensland Museum); and (f) *Dentalium* necklace (WAM A00635).

Dentalium or scaphopod (i.e. tusk shell) pieces have been found within a number of sites across the archipelago (see Figure 2.7e). Some of these were analysed and measured by Wade Goldwyer, who identified a bead manufacturing site at the centre of Enderby Island (Goldwyer 2018). His analysis identified that the dominant scaphopod species to be made into beads at Enderby 10 was *Laevidentalium lubricatum*.

Calorific content and human effort

We were interested in the human effort required to have collected the shellfish at the various sites that were excavated. Our most detailed analysis of this was undertaken at Old Geos (on the southern Burrup), where the midden comprised predominantly *Tegillarca granosa*. Betty Meehan (1982) describes the amount of (live weight) meat represented per individual *Anadara (Tegillarca granosa)* as 6 g. Live weight is taken as shell plus meat, typically 15 g for the sizes measured (Mirzaei et al. 2015). Daily calorific intake is 2,200 kcal/day for an adult. Calorific content can be calculated by using a figure of 80 kcal per 100 g of shellfish meat (following Meehan 1982: 143; McDonald 1992: 43; see also Bailey 1975; Faulkner 2009; Lambrides and Weisler 2016; Shawcross 1968).

Meehan's ethnoarchaeological observations from the Northern Territory reveal that women collected an average of 3 kg of shellfish per person per hour (Meehan 1982). By calculating the total live weight of shellfish in any square, we can estimate the person hours required to collect the sample within the excavated square. Where we know the surface dimension of the midden, we have been able to project the collection hours required to have contributed to the shellfish remains across the site (not counting transportation to the site). These analyses have been completed on Enderby Island (Chapter 6) and at Old Geos (Chapter 15).

Flaked Stone Artefact Analysis

All artefact recording was completed in the Archaeology Laboratory at the University of Western Australia. Metric measurements were taken with digital callipers. Artefact weight was measured in grams to two decimal places using digital scales. A unique identification number was recorded for each artefact. All collected data was entered into Excel spreadsheets. Separate spreadsheets were created for each site. All recorded data is stored in the CRAR+M database. Several laboratory volunteers and Honours students were involved in the initial sorting of the excavated 2 mm residue material, which was brought back to the UWA lab for sorting, following permission being granted by the MAC Circle of Elders. All artefact assemblages were analysed by Wendy Reynen, who analysed the Murujuga Rockshelter assemblage for her PhD (Reynen 2018). This included those assemblages which had been either partially or fully analysed by PhD or Honours candidates throughout the project. By having a single lithic specialist analyse/audit all assemblages, we have achieved a consistency in both classification and reliability/comparability of the excavated material.

The debitage component of each assemblage (2 mm sieve assemblage) typically comprises artefacts with a maximum dimension less than 10 mm. Material type was the only attribute recorded for <10 mm artefacts. The debitage component was not included in artefact type and assemblage reduction characterisation.

The stone tool analysis used multiple attributes as described in Clarkson and O'Connor (2013) to identify technological change and raw material use which may reflect changes in mobility and provisioning (e.g. Kuhn 1994), risk investment (Hiscock 1984, 1988, 2002) and subsistence procurement and maintenance across time and space (Andrefsky 2009). Based on these analyses, stone artefacts can be interpreted to provide insights into how these different sites in the landscape functioned in the past.

Stone artefact discard

Stone artefact discard at all sites was calculated per cubic metre and per kilogram of sediment. Discard rates can be affected by factors relating to types of activity, site function, sediment deposition and composition, post-depositional processes, and technological systems (e.g. Hiscock 1984; Hiscock 1988; Kuhn and Clark 2015:10). These factors were examined before interpreting and comparing site occupations. Marked variation in deposit composition (i.e. proportion of rocks/shell) between and within sites can result in wildly varying density comparisons per kilogram sediment. For instance, the Old Geos earlier deposit is within an extremely rocky matrix, with a very low proportion of sediment remaining when the rock component is removed. When compared to sites with less rocky components (e.g. the sand sheet deposit at EIA02-998997), artefact density per kilogram sediment at Old Geos is significantly much higher. Comparing artefact density per cubic metre together with discard per kilogram sediment reduces issues resulting from variations in depositional histories within and between sites. Care has been taken to modify our approach depending on the relevant site's depositional processes.

Some of the factors affecting artefact discard can be resolved through comparison of raw artefact and minimum number of flake (MNF) counts and the proportion of small (<1 cm) artefacts. These approaches test for fragmentation and compare lithic discard rates to discard rates of other cultural materials, such as charcoal, dietary shell and faunal remains (Hiscock 1984, 2002). The MNF includes only those flakes with remnant platforms (complete, proximal and longitudinally broken flakes) to account for fragmentation (Hiscock 2002).

Assemblage composition

Lithic material identification at all sites was determined through either portable X-ray fluorescence (pXRF) analysis of representative stone artefacts or direct comparison with artefacts at nearby sites which had been subject to pXRF (see below). Raw materials were separated to control for variation in the mechanical properties of different raw materials and the nature of the source material on patterns of artefact manufacture, use and discard (e.g. Amick and Mauldin 1997; Ditchfield 2016; MacDonald 2008). The frequency and proportion of raw materials was calculated for each site by analytical unit.

All artefacts larger than 10 mm were classified as one of the following artefact types: complete flake, broken flake, core/core fragment or tool (see usewear/residue section later). Broken flakes were recorded as either distally, proximally or longitudinally broken, or as a flake fragment (type unidentifiable but with remnant ventral and dorsal present). Within the tool class, the presence of formal tool types such as backed artefacts was also noted. The frequency and proportion of artefact classes was calculated for each site by raw material and analytical unit.

Assemblage reduction

Reducing stone nodules to produce tools is a key part of past Aboriginal technology in Australia. Recorded attributes on complete flakes and cores were quantified to assess reduction intensity.

Cortex is often linked with reduction and, theoretically, the amount of cortex remaining on dorsal surfaces should reduce as reduction progresses (Shott 1996). However, the cortex-reduction relationship assumes that nodules are fully cortical prior to initial reduction. This is not always the case, especially in landscapes such as the Dampier Archipelago, where many stone source outcrops become increasingly non-cortical as quarrying progresses over multiple series of extraction events. For this reason, cortex proportions were assessed in the context of other reduction attributes. Proportions of cortex were visually estimated to the nearest ten per cent. Cortex type was additionally recorded as riverine (water-worn) if applicable.

Because the dorsal surface of a flake retains the previous core surface, it can be used to reconstruct the reduction strategy used to reduce cores and produce tools (Bradbury and Carr 1995; Holdaway and Stern 2004: 143; Shott 1994). Dorsal scars are formed through the removal of flakes from a core. As core reduction proceeds, the number of flake scars on cores and dorsal flake surfaces generally increases. The Scar Density Index (SDI) is used here as an objective and comparative measure of reduction rather than flake scar count to account for size (number of dorsal scars can decrease with size) by dividing the number of dorsal flake scars by the logarithm of surface area (maximum length x maximum width, Braun 2006; Clarkson 2013). SDI was calculated for cores in the same manner but using a three-dimensional surface area, which is calculated by entering the maximum length, width and thickness semi-axes into an equation for the surface area of an ellipsoid:

$$S = 4\pi \left[\frac{\mathrm{ap\,bp} + \mathrm{ap\,cp} + \mathrm{bp\,cp}}{3}\right]^{1/\mathrm{p}}$$

where a, b and c are the respective semi-axes for maximum length, width and thickness, and p is 1.6075 (Thomsen 2004). Changes in core reduction intensity can also be inferred by counting the number of rotations (platforms) on cores.

Other reduction attributes quantified include flake size (weight and surface area), shape (elongation ratio) and the proportion of flakes with flaked platforms. The presence of two or more flake scars indicates prior flake removals. Flakes with flaked platforms are often removed during late stages of core reduction after cores are rotated (Andrefsky 2005: 94; Hiscock 1988: 372). The orientation of scars on dorsal flake surfaces was also recorded if flake scar orientation was identifiable through the direction of initiations, terminations or force lines. This provides an indication of whether the core that the flake was removed from had been rotated.

Overhang removal refers to consistent small fractures (<5 mm) along the edge of a platform created from brushing a hammerstone along a core platform to remove fractures or overhangs (Flenniken and White 1985; Hiscock 1988). Overhang removal can indicate a degree of preparation before flaking and potentially aids in control over the flaking process as knappers adjust core platforms to prepare them for blows. This technique can also increase platform angle and platform strength (Clarkson and O'Connor 2013: 160). The presence or absence of overhang removal was noted for all flakes and cores retaining complete platforms.

These results of these analyses are documented in each of the excavation chapters.

Geochemical sourcing to identify lithic materials (pXRF)

> The predominant rock types on the peninsula and the eastern islands are granophyre (a fine-grained igneous rock composed of quartz and alkali feldspar with a distinctive intergrowth texture) and gabbro (an intrusive rock composed of feldspar and pyroxene; the intrusive equivalent of basalt lava). On the outer islands basaltic lava is the main bedrock type with lesser exposures of sedimentary rocks derived from basaltic volcanoes, and some gabbro. (Donaldson 2011a: 1)

The dominant exposed Precambrian rock types across Murujuga include gabbro, granophyric rhyodacite (known as the Gidley granophyre: Donaldson 2011a; Fairweather 2019), andesitic basalt, granite, and quench gabbro (Figure 2.8), all Neoarchaean in age (Donaldson 2011b: 8). Previous researchers have focused on the different qualities provided by these volcanic substrates for different rock art forms (Bednarik 2011; Donaldson 2011a; Mulvaney 2015; and see discussion in Chapter 3); others have investigated raw material qualities and resultant quarrying behaviour and stone tool manufacture preferences (Veth 1982), while still others have investigated the hardness and weathering properties of these basal geologies (Pillans and Fifield 2013). Until this project there had been no previous geochemical analyses completed of Murujuga lithic assemblages (cf. McDonald et al. 2021), although the various qualities of the basal materials have long been recognised (Veth 1982; Vinnicombe 1987). Throughout the project we have been interested in sourcing different materials to understand mobility (e.g. Berry 2018; Blunt 2019) as well as the effects that the geochemical properties may have had on stone tool manufacture.

Geochemical sourcing of the analysed assemblage was undertaken by John Fairweather, who also mapped the surface geology of Rosemary Island for his Honours thesis (Fairweather 2019). Fairweather undertook additional geochemical studies of the assemblages analysed at the UWA lab (this monograph) and at Nganjarli (McDonald et al. 2021). The provenance analysis, using non-destructive pXRF, was conducted using the Niton XL3t GOLDD+ pXRF device. Each analysis was 60 seconds using TestAll Bulk mode. Each 60-second analysis cycled through four filters (15 seconds for each filter) – high range, main range, low range and light range – with energy levels between 6 and 50 kV. The standards used were 99.995 SiO_2 (pure silica standard) and NIST 2709a (soil and sediment standard). Each standard is analysed before each session and the results are compared against a control dataset (defined by the National Institute of Standards and Technology, which is printed out and kept with the pXRF). This ensures the pXRF is reproducing accurate and present geochemical analyses.

Representative samples from seven artefact assemblages from across the archipelago were analysed to understand their geochemical signatures. Samples derived from two sites on Enderby Island (EIA02, EIA04), two from Rosemary Island (RIA01, WP1), Watering Cove (WC), Nganjarli open sites and quarry, and the West Lewis (WLA01) rock shelter (Figure 2.9 and Figure 2.10). The analysed artefact samples were plotted and compared to the geochemistry of known rock types to determine the artefact source (Figure 2.10). The rock-type-zones shown in Figure 2.9 (i.e. granophyric rhyodacite, gabbro, volcaniclastic siltstone or andesitic basalt) are based on outcrop sample analyses from the peninsula as well as from Enderby, Rosemary and Dolphin islands (Fairweather 2019). The rock-type-zones represent areas on a Ti/Zr element plot where the analysed rock types have plotted previously, forming a comparable map for the artefact analyses. Artefacts which fall within an identified rock-type-zone are interpreted as being composed of that rock type. To display the artefact rock-type-zones, the zircon vs titanium (Zr vs Ti) plot is favoured as more robust and reliable. This is because zircon and titanium are largely immobile elements, meaning they have a lower reactivity when in a stable crystal lattice, thus reducing the effect that weathering and alteration has on the analyses. Comparing the artefact's rock type to where known outcrops are mapped aids in determining where those artefacts were sourced.

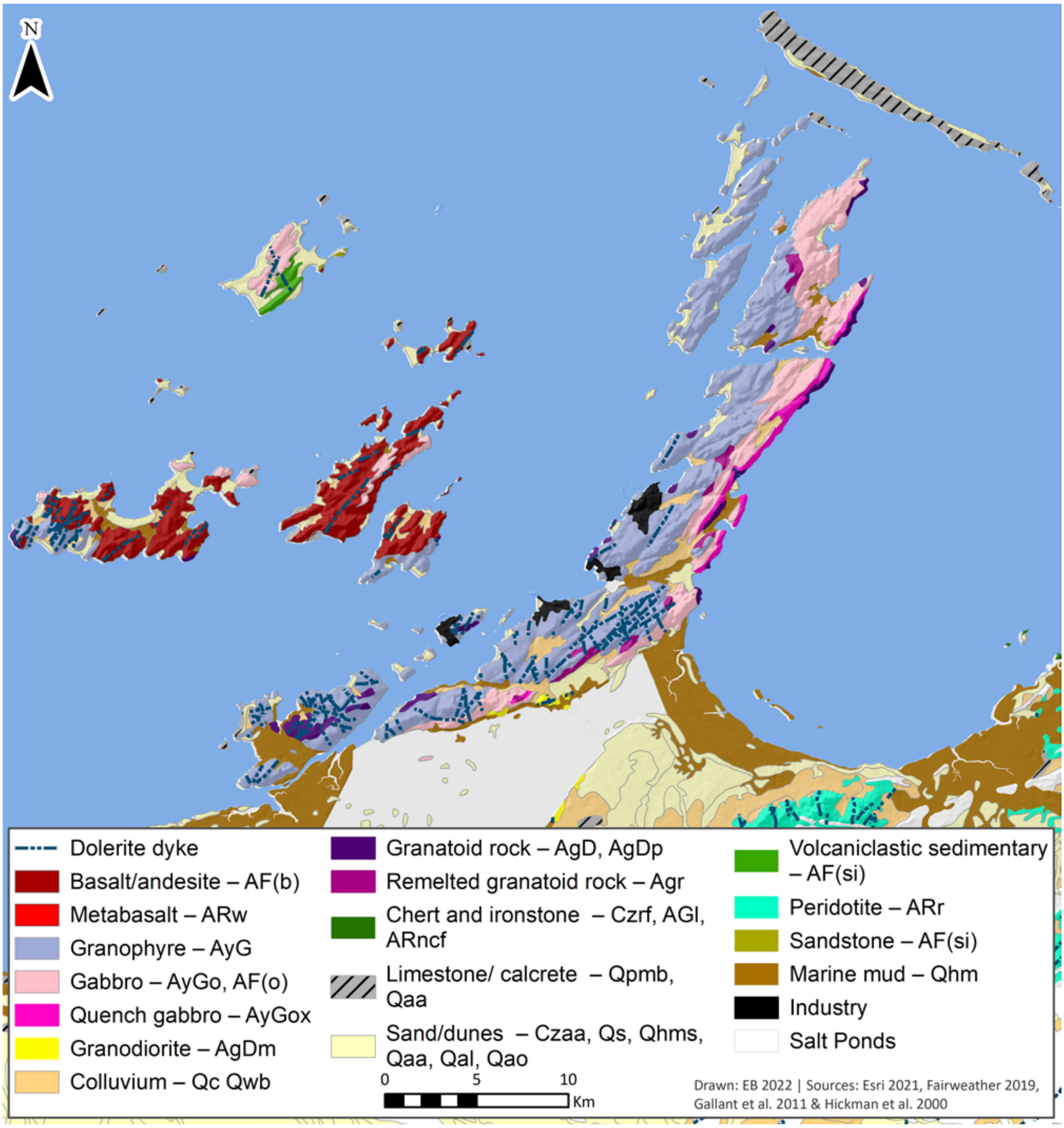

Figure 2.8. Geological map for the Dampier Archipelago (drawn by Emma Beckett based on the identified sources).

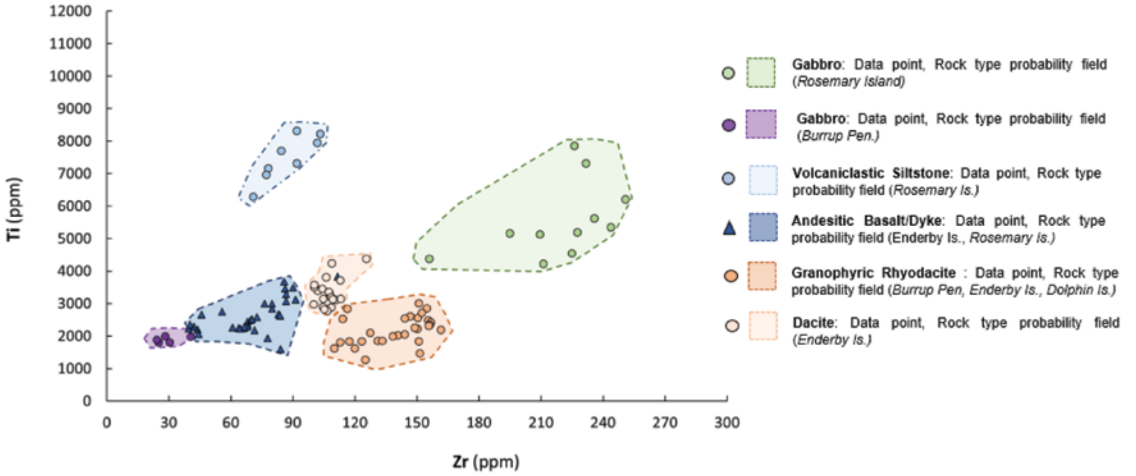

Figure 2.9. Geochemical results of the analysis of geological outcrop and artefact assemblages from across the analysed sites showing the groupings according to major rock types (based on Ti and Zr) (datapoint n = 116).

Most analysed artefacts plot within the granophyric rhyodacite field or andesitic basalt fields (Figure 2.9) as these are major rock types in the archipelago (Figure 2.8). The artefacts from Nganjarli and Enderby Island (EIA04), are identified as granophyric rhyodacite, and are found within 1–2 km of an outcrop of this material. Granophyric rhyodacite exists in both stated locations, with the latter having a more intermediate composition (dacite). Nganjarli is within the inner geological region of the Dampier Archipelago, where the exposed rock is entirely dominated by the rocks of the Gidley Granophyre intrusion (c. 2725 Ma), whereas the middle to outer islands (e.g. West Lewis and Enderby) host a mix of rock types, mostly granophyric and andesitic (Figure 2.9).

Many artefacts plot within the andesitic basalt probability field, in particular artefacts from Enderby and Nganjarli and, to a lesser extent, Watering Cove. This rock type field also includes artefacts that derived from outcropping dykes, which explains the many andesitic artefacts from Nganjarli, but due to a paucity of dyke geochemical data we have not been able to define a doleritic dyke field. The sourcing of the artefacts within this field is more complicated as these rocks show more internal variability across multiple islands.

The artefacts from Rosemary Island plot within the two identified Rosemary Island rock types and are definitely locally sourced from the island (volcaniclastic siltstone and Rosemary Island gabbro). Three artefacts derive from this island's dolerite dyke and these plot within the andesitic basalt field.

A relatively small proportion of the analysed artefacts show no correlation with any outcropping rock type, indicating these artefacts derive from rock types which have not yet been analysed (or could be errors in the analyses).

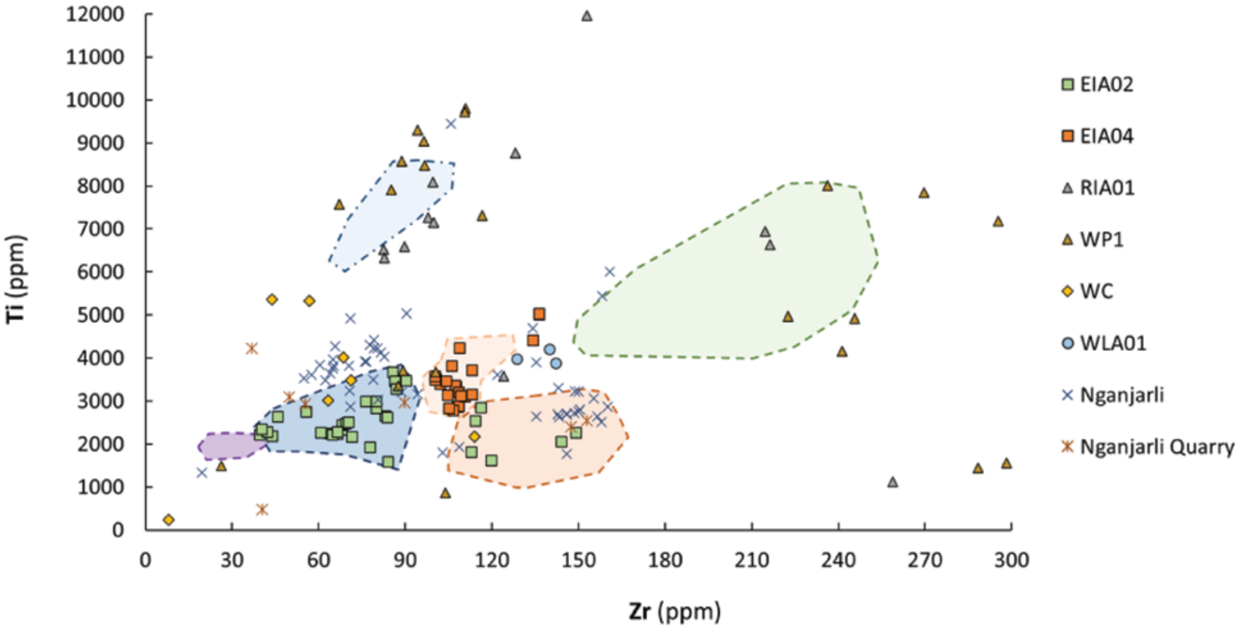

Figure 2.10. The analysed artefact assemblages showing their basal geochemical identifications (based on Ti/Zr ratios) (n = 167).

Usewear and residue analysis

During an artefact's life as a tool, during handling, and in storage, the edges and surfaces of the artefact can be modified in several ways that are collectively referred to as usewear (Fullagar 2014: 208). The different types of modification, or usewear, include bevelling, edge rounding, polish, shallow edge scarring, smoothing and striations, and in some cases can be used to identify the types of activity by which an artefact has been used (Fullagar 2014: 220–226). It is important to recognise that wear on artefacts does not always relate to the artefact's use: for example, usewear on an artefact with a morphological design suggestive of an arrowhead is more likely to be interpreted as evidence for hunting activity (Akerman et al. 2002). Weathering (on the surface and *in situ*) can also alter or, in some cases, entirely remove evidence of usewear on artefact surfaces (Fullagar 2014: 208). For these reasons, usewear studies are often paired with residue analysis to provide additional lines of evidence for how an artefact may have been used.

Extracting residues that adhere to artefacts can provide evidence of the types of material(s) that the artefact encountered during its use (Briuer 1976). Two methods are used for extracting residues: ultrasonication, which offers little control over the sample area and may damage residues; and pipette extraction, a highly targeted approach that minimises the risk of damaging any residues present on the artefact. While residue analysis is a powerful method for understanding how artefacts may have been used, it requires an intimate knowledge of plant cellular structures and blood cell morphology to positively identify the extracted resources. Furthermore, identifying residues related to use rather than post-depositional processes can also be problematic (Rots et al. 2016). For this research, methylene blue was used to stain plant fibres for positive identification, and its effectiveness for this application has been widely demonstrated (Rots et al. 2016: 10). In cases where plant fibres were morphologically distinct, the types of plant they might belong to was narrowed down using various lines of evidence (CSIRO 1998; Dashek and Miglani 2017; Department of Agriculture, Water and Environment 2019). To identify the presence of blood, Matheson and Veall (2014) demonstrated the efficacy of using Siemens Multistix™; however, they also recognised that in rare cases, heavy concentrations of metals in sediments can cause a false positive. To eliminate this possibility, 20 µl of distilled water mixed with sediment from bulk sample bags was applied to five Siemens Multistix™. No positive reactions were recorded.

Artefacts were identified by Wendy Reynen for usewear and residue analysis according to signs of macroscopic edge-wear. Usewear and residues were then documented, extracted and evaluated by Zane Blunt, who analysed several of the project's assemblages for residues during his Honours research (Blunt 2019).

To minimise the risk of contamination in the lab, artefacts were handled with gloves during usewear and residue analysis, and microscope stages were cleaned with rubbing alcohol after each artefact was inspected. The artefacts were first inspected for signs of usewear and residues at low-magnification (up to 16x) using a Leica M205C. The artefacts were then inspected at up to 100x magnification using a Nikon Eclipse LV100ND. All signs of usewear and residues were photographed and stored on Microsoft Onedrive for future analysis with the artefact number, site number and location/type of usewear noted in the file name. All photographed artefacts, with their associated residues, are stored in the CRAR+M database.

Artefacts that showed signs of use and potential for residue analysis were sampled using a mechanical pipette with a nylon disposable tip using 10–20 µl of distilled water. The water was applied to the areas with usewear, gently agitated using the pipette tip, and left to rest for one minute. The liquid was then extracted back into the pipette tip, approximately 5 µl was applied to a Siemens Multistix blood test, and the remaining liquid was ejected onto a glass microscope slide and sealed with a glass slide cover. The blood was tested after one minute and the result recorded into a Microsoft Excel spreadsheet. Extracted residues were examined and photographed using a Nike Eclipse LV100nd transmitted light microscope. In the case of possible starch cells, aqueous iodine was applied and left for one minute before the results were photographed. Where plant fibres were more likely, 5 µl of methylene blue (0.001%) was then applied to the residue liquid and left to rest for five minutes. Residues were then examined for positive adhesions to plant fibres, and all positive identifications were photographed and stored for future analysis. All stored photographs have the artefact number, site number, and location of the residue lift and residue type noted in the file name. All results were also recorded into a Microsoft Excel spreadsheet, which is similarly stored in the CRAR+M database. The results of these analyses are documented in each of the excavation chapters.

Dating the Occupation Sequences – Bayesian Analyses

The archaeological sequences have been dated using AMS radiocarbon determinations based on any available organic materials recovered from the excavation, usually shell, and occasionally charcoal recovered from hearths. In sites where no organic remains were encountered, or where there were deep, relatively intact sand bodies (Wadjuru Pool, Enderby sand sheet), OSL dating has been used. Other midden sites with minimal shell remains in their earlier layers (e.g. Old Geos and Fig Tree) also had OSL samples analysed. The results of these analyses are presented in each relevant excavation chapter, while Chapter 17 summarises these results and undertakes a Bayesian analysis of the combined dated Murujuga sequences. The ANSTO and the Waikato University radiocarbon labs were used for the radiocarbon results. A variety of OSL labs were used (Adelaide, Oxford, Sheffield, Denmark) as there were significant waiting times given all labs have high demand. Permissions were received from the MAC Circle of Elders to send all soil samples overseas for dating analyses. All results are provided in the Supplementary Information Dating Appendix.

Bayesian analysis was used to model the chronology for each site analysed during this project. Sequence depositional models were used throughout (Bronk Ramsey 2008, 2009a). In each model, dates were entered into the model in order of their depth organised by at least one, but often multiple, phases. These were defined by the chrono-stratigraphy and artefact analyses. The use of phases to order the dates within the stratigraphic or analytical units is important because, in Bayesian analysis, phases assume that age determinations are uniformly distributed with no order (Bronk Ramsey 1998). This is appropriate for Murujuga given we cannot assume a lack of intra-strata movement for most sites analysed during this research project. Phases were also separated by boundaries which represent the chronological 'beginning' and 'end' of each analytical unit. We used two boundary designs to model the Murujuga chronologies: continuous and sequential. Continuous boundaries are used to represent unbroken transitions from one analytical unit to the next, while sequential boundaries can be used to represent a discontinuity between analytical units (see Bronk Ramsey 2009a). If the 'deposit surface' boundary was close to 0 cal. BP, it was constrained with a uniform distribution between 0 and 100 cal. BP to stop the model from producing dates into the future. To assess the likelihood of any modelled dates being outliers, a General t-type Outlier Model was inset into each model (Bronk Ramsey 2009b). All dates were assigned a prior outlier probability of 0.05. This was also supported by an Agreement Index which indicates the 'goodness-of-fit' for individual dates and, more generally, the whole model using a 60% threshold value (Bronk Ramsey 1998). Models were calibrated using SHCal20 for charcoal (Hogg et al. 2020) and Marine20 (Heaton et al. 2020) with a 109 ± 25 marine reservoir value for shell (Veth et al. 2017). Modelled dates were rounded following conventions in Stuiver and Polach (1977).

Permits and Compliance

The excavation methodologies used throughout the project were stipulated in the research designs accompanying the Section 16 permits granted to conduct research on Aboriginal heritage sites (no. 556, granted by the former Department of Aboriginal Affairs 14/3/2014; no. 575, granted by DPLH 22/5/2017). These Section 16 permits were executed in accordance with their conditions, as reported at the conclusions of the 2018 field seasons (McDonald and Dortch 2018).

Field camping on the islands complied with conservation and safety regulations as stipulated in the CALM Act Regulation 4 permits (CE004391 31/3/2014; PILCALMR4-001/2016, granted by the former Department of Parks and Wildlife 29/2/2016; PILCALMR4-010/2016, granted by DBCA 5/4/2017; PILCALMR4-009/2018, granted by DBCA 3/4/2018). No vegetation was cleared, and tents, shelters and rubbish were all removed on the completion of the trip. No wildlife was harmed; and only archaeological and fossil materials were collected as per the relevant permits (Regulation 4 pertaining to the *Wildlife Conservation Act 1950* and *Conservation and Land Management Act 2002*; Section 16 of the *Aboriginal Heritage Act 1972*).

Tertiary Training

The project has proved a fertile training ground for undergraduate and postgraduate students at the University of Western Australia (see Chapter 1). Despite not having an ARC PhD candidate budget, four PhD dissertations have been focused fully or partially on the project's various outputs. Meg Berry completed her dissertation on several of the Rosemary Island excavations and the rock art assemblages that she recorded during her fieldwork on Rosemary Island (Berry 2018). Wendy Reynen analysed the Murujuga Rockshelter assemblage as part of her PhD dissertation on Pilbara ice-age rockshelters (Reynen 2018). Emma Beckett completed her PhD on the Murujuga stone features (Beckett 2021), while Victoria Anderson is enrolled part-time and will complete her dissertation on the Holocene transition and fishing technologies across the archipelago in 2023. The associated extensive field program provided extraordinary opportunities and eight Honours dissertations have also been produced over the life of the project on a set of diverse topics (Blunt 2019; Burcham 2019; de Koning 2014; Fairweather 2019; Goldwyer 2018; Morrison 2019; Stewart 2016; Woods 2018), the results of which are incorporated in the chapters of this monograph.

References

Akerman, K., Fullagar, R. and A. van Gijn. 2002. Weapons and wunan: production, function and exchange of Kimberley points. *Australian Aboriginal Studies* 1: 13–42.

Amick, D. S. and R. P. Mauldin. 1997. Effects of raw material on flake breakage patterns. *Lithic Technology* 22(1): 18–32. https://doi.org/10.1080/01977261.1997.11754531

Andrefsky, W. 2005. *Lithics: Macroscopic Approaches to Analysis*. New York: Cambridge University Press.

Andrefsky, W. 2009. The analysis of stone tool procurement, production, and maintenance. *Journal of Archaeological Research* 17: 65–103. https://doi.org/10.1007/s10814-008-9026-2

Bailey, G. N. 1975. The role of molluscs in coastal economies: the results of midden analysis in Australia. *Journal of Archaeological Science* 2(1): 45–62. https://doi.org/10.1016/0305-4403(75)90045-X

Beckett, E. 2021. Contextualising Murujuga Stone Structures: Dampier Archipelago. Unpublished PhD thesis, Centre for Rock Art Research + Management, and Archaeology, University of Western Australia.

Bednarik, R. G. 2011. Inherited vs recent accretions (comment). *Rock Art Research* 28(1): 7–8.

Berry, M. 2018. Murujuga Desert, Tide, and Dreaming: Understanding Early Rock Art Production and Lifeways in Northwest Australia. Unpublished PhD thesis, University of Western Australia.

Blunt, Z. 2019. Sea level rise and islandisation: how did the reconfiguration of Murujuga's Holocene landscape influence Indigenous people's occupation and resource exploitation on Enderby and Rosemary islands? Unpublished BA (Hons) thesis, Archaeology and CRAR + M, University of Western Australia.

Bradbury, A. P. and P. J. Carr. 1995. Flake typologies and alternative approaches: an experimental assessment. *Lithic Technology* 20(2): 100–115. https://www.jstor.org/stable/23273168

Braun, D. R. 2006. The Ecology of Oldowan Technology: Perspectives from Koobi Fora and Kanjera South. Unpublished PhD thesis, The State University of New Jersey.

Briuer, F. L. 1976. New clues to stone tool function: plant and animal residues. *American Antiquity* 41(4): 478–484. https://doi.org/10.2307/279013

Bronk Ramsey, C. 1998. Probability and dating. *Radiocarbon* 40: 461–474.

Bronk Ramsey, C. 2008. Deposition models for chronological records. *Quaternary Science Reviews* 27: 42–60. https://doi.org/10.1016/j.quascirev.2007.01.019

Bronk Ramsey, C. 2009a. Bayesian analysis of radiocarbon dates. *Radiocarbon* 51: 337–360. https://doi.org/10.1017/S0033822200033865

Bronk Ramsey C. 2009b. Dealing with outliers and offsets in radiocarbon dating. *Radiocarbon* 51: 1023–1045. https://doi.org/10.1017/S0033822200034093

Burcham, A. 2019. *A 'share in the place': the isolated frontier settlement of West Lewis Island, Dampier Archipelago, Western Australia*. Unpublished BA (Hons) thesis, Archaeology and CRAR + M, University of Western Australia.

Clarkson, C. 2013. Measuring core reduction using 3D flake scar density: a test case of changing core reduction at Klasies River Mouth, South Africa. *Journal of Archaeological Science* 40(12): 4348–4357. https://doi.org/10.1016/j.jas.2013.06.007

Clarkson, C. and S. O'Connor. 2013. An introduction to stone artefact analysis. *Archaeology in Practice: A Student Guide to Archaeological Analyses*, eds J. Balme and A. Paterson, 2nd edn. New York: Blackwell.

CSIRO. 1998. *Flora of Australia, Volume 48: Ferns, Gymnosperms and Allied Groups*. Melbourne: ABRS/CSIRO Australia. https://www.awe.gov.au/science-research/abrs/publications/flora-of-australia/vol48

Dashek, W. V. and G. S. Miglani. 2017. *Plant Cells and their Organelles*. Chichester: Wiley Blackwell.

de Koning, S. 2014. Thatharruga: a stylistic analysis of turtle engravings on the Dampier Archipelago. Unpublished BA (Hons) thesis, CRAR + M, University of Western Australia.

Department of Agriculture, Water and Environment. 2019. *Flora of Australia*. Australian Government. https://profiles.ala.org.au/opus/foa

Ditchfield, K. 2016. The influence of raw material size on stone artefact assemblage formation: an example from Bone Cave, south-western Tasmania. *Quaternary International* 422: 29–43. https://doi.org/10.1016/j.quaint.2016.03.013

Donaldson, M. 2011a. Understanding the rocks: rock art and the geology of Murujuga (Burrup Peninsula) [with comments]. *Rock Art Research: The Journal of the Australian Rock Art Research Association* 28(1): 35–43. https://search.informit.org/doi/abs/10.3316/informit.265664199623302

Donaldson, M. 2011b. Geological processes and semantics (a reply). *Rock Art Research* 28(1): 8–9.

Fairweather, J. 2019. Geological and geochemical characterisation of the Archean Fortescue Group, Rosemary Island, and associated archaeological material from the Dampier Archipelago, Western Australia. Unpublished Geology Honours thesis, University of Western Australia.

Faulkner, P. 2009. Focused, intense and long-term: evidence for granular ark (*Anadara granosa*) exploitation from late Holocene shell mounds of Blue Mud Bay, northern Australia. *Journal of Archaeological Science* 36(3): 821–834. https://doi.org/10.1016/j.jas.2008.11.005

Flenniken, J. J. and J. P. White. 1985. Australian flaked stone tools: an Australian perspective. *Records of the Australian Museum* 36: 131–161.

Fullagar, R. 2014. Residues and usewear. *Archaeology in Practice: A Student Guide to Archaeological Analyses*, eds J. Balme and A. Paterson, 2nd edn, pp. 207–234. Oxford: Blackwell Publishing.

Gallant, J. C., T. I. Dowling, A. M. Read, N. Wilson, P. Tickle and C. Inskeep. 2011. SRTM-derived 1 Second Digital Elevation Models Version 1.0. Canberra: Geoscience Australia.

Goldwyer, W. 2018. An archaeological investigation of Late Holocene shell bead manufacture, Dampier Archipelago, north-western Australia. Unpublished BA (Hons) thesis, CRAR + M, University of Western Australia.

Heaton, T., P. Köhler, M. Butzin, E. Bard, R. Reimer, W. Austin, C. Bronk Ramsey, P. M. Grootes, K. A. Hughen, B. Kromer, P. J. Reimer, J. Adkins, A. Burke, M. S. Cook, J. Olsen and L. C. Skinner. 2020. Marine20 – the marine radiocarbon age calibration curve (0–55,000 cal BP). *Radiocarbon* 62: 779–820. https://doi.org/10.1017/RDC.2020.68

Hickman, A. H. and C. A. Strong. 2000. *Dampier-Barrow Island, WA. Sheet SF 50-2 and part sheet SF 50-1* (2nd edn). *1:250000 Geological Series*. Perth: Western Australia Geological Survey.

Hiscock, P. 1984. A preliminary report on the stone artefacts from Colless Creek Cave, northwest Queensland. *Queensland Archaeological Research* 1: 120–151. http://hdl.handle.net/1885/41368

Hiscock, P. 1988. Prehistoric settlement patterns and artefact manufacture at Lawn Hill, northwest Queensland. Unpublished PhD thesis, University of Queensland.

Hiscock, P. 2002. Quantifying the size of artefact assemblages. *Journal of Archaeological Science* 29(3): 251–258. https://doi.org/10.1006/jasc.2001.0705

Hogg, A. G., T. J. Heaton, Q. Hua, J. G. Palmer, C. S. Turney, J. Southon, A. Bayliss, P. G. Blackwell, G. Boswijk, C. B. Ramsey and C. Pearson. 2020. SHCal20 southern hemisphere calibration, 0–55,000 years cal BP. *Radiocarbon* 62: 759–778. https://doi.org/10.1017/RDC.2020.59

Holdaway, S. J. and N. Stern. 2004. *A Record in Stone: The Study of Australia's Flaked Stone Artefacts*. Canberra: Aboriginal Studies Press.

Kuhn, S. L. 1994. A formal approach to the design and assembly of mobile toolkits. *American Antiquity* 59: 426–442. https://doi.org/10.2307/282456

Kuhn, S. L. and A. E. Clark. 2015. Artifact densities and assemblage formation: evidence from Tabun Cave. *Journal of Anthropological Archaeology* 38: 8–16. https://doi.org/10.1016/j.jaa.2014.09.002

Lambrides, A. B. and Weisler, M. I. 2016. Pacific islands ichthyoarchaeology: implications for the development of prehistoric fishing studies and global sustainability. *Journal of Archaeological Research* 24 (3): 275–324. https://doi.org/10.1007/s10814-016-9090-y

MAC (Murujuga Aboriginal Corporation). 2016. *Murujuga Cultural Management Plan: Ngaayinthari Gumawarni Ngurrangga – We All Come Together on This Country*. Karratha: MAC.

MacDonald, D. H. 2008. The role of lithic raw material availability and quality in determining tool kit size, tool function, and degree of retouch: a case study from Skink Rockshelter (46NI445), West Virginia. *Lithic Technology: Measures of Production, Use, and Curation*, ed. W. Andrefsky, pp. 216–232. New York: Cambridge University Press.

McDonald, J. 1992. The Great Mackerel rockshelter excavation: women in the archaeological record? *Australian Archaeology* 35: 32–50. https://doi.org/10.1080/03122417.1992.11681467

McDonald, J. 2005. Salvage Excavation of Six Sites along Caddies, Second Ponds, Smalls and Cattai Creeks. Jo McDonald Cultural Heritage Management Pty Ltd. Melbourne: Australian Association of Consulting

Archaeologists Inc., Monograph Series, 1.

McDonald, J. 2009a. Archaeological survey of Deep Gorge on the Burrup Peninsula (Murujuga) Dampier Archipelago WA. Jo McDonald Cultural Heritage Management Pty Ltd. Unpublished report to the Western Australian Department of Indigenous Affairs.

McDonald, J. 2009b. Heritage inventory methodology report Dampier Archipelago. Jo McDonald Cultural Heritage Management Pty Ltd. Unpublished report to Western Australian Department of Indigenous Affairs.

McDonald, J. and S. de Koning. 2015. Report on Field Schools held at Queen Victoria Valley Burrup Peninsula July 2013 and 2014. Report to Murujuga Aboriginal Corporation and the Department of Environment and Heritage.

McDonald, J. and J. Dortch. 2018. Dampier Archipelago Archaeological Investigations – 2015–2018. Murujuga: Dynamics of the Dreaming: Australian Research Council Linkage Project LP140100393. Summary report to Murujuga Aboriginal Corporation, Department of Planning, Lands and Heritage, Department of Biodiversity, Conservation and Attractions.

McDonald, J. and P. Veth. 2006. A Study of the Distribution of Rock Art and Stone Structures on the Dampier Archipelago. Jo McDonald Cultural Heritage Management Pty Ltd. Unpublished report to Heritage Division, Department of Environment and Heritage, Canberra: Australian Government.

McDonald, J. J. and P. Veth. 2009. Dampier Archipelago petroglyphs: archaeology, scientific values and National Heritage Listing. *Archaeology in Oceania* 44(S1): 49–69.

McDonald, J., W. Reynen, K. Ditchfield, J. Dortch, M. Leopold, B. Stephenson, T. Whitley, I. Ward and P. Veth. 2018. Murujuga Rockshelter: first evidence for Pleistocene occupation on the Burrup Peninsula. Quaternary Science Reviews 193: 266–287. https://doi.org/10.1016/j.quascirev.2018.06.002

McDonald, J., K. Mulvaney, E. Beckett, J. Fairweather, P. Morrison, S. de Koning, J. Dortch and P. Jeffries. 2021. Seeing and managing rock art at Nganjarli: a tourist destination in Murujuga National Park, Western Australia. *Australian Archaeology*, 87(3): 268–293. https://doi.org/10.1080/03122417.2021.1978915

Matheson, C. and M. Veall. 2014. Presumptive blood test using Hemastix with EDTA in archaeology. *Journal of Archaeological Science* 41: 230–241. https://doi.org/10.1016/j.jas.2013.08.018

Meehan, B. 1982. *Shell Bed to Shell Midden*. Canberra: Australian Institute of Aboriginal Studies.

Morrison, P. 2019. *The geoarchaeology of a submerged Aboriginal site in the intertidal zone of Dolphin Island, Murujuga*. Unpublished BA (Hons) thesis, CRAR + M, University of Western Australia.

Mulvaney, K. 2015. *Murujuga Marni: Rock Art of the Macropod Hunters and Mollusc Harvesters*. Perth: UWA Publishing.

O'Connell, J. F. 1987. Alyawara site structure and its archaeological implications. *American Antiquity* 52: 74–108. https://doi.org/10.2307/281061

Petchey, F. and S. Ulm. 2012. Marine reservoir variation in the Bismarck region: an evaluation of spatial and temporal change in ΔR and R over the last 3000 years. *Radiocarbon* 54(1): 45–58. https://doi.org/10.2458/azu_js_rc.v54i1.13050

Pillans, B. and L. K. Fifield, 2013. Erosion rates and weathering history of rock surfaces associated with Aboriginal rock art engravings (petroglyphs) on Burrup Peninsula, Western Australia, from cosmogenic nuclide measurements. *Quaternary Science Reviews* 69: 98–106. https://doi.org/10.1016/j.quascirev.2013.03.001

Reynen, W. H. 2018. Rockshelters and Human Mobility during the Last Glacial Maximum in the Pilbara Uplands, North-western Australia. Unpublished PhD thesis, University of Western Australia. https://doi.org/10.26182/5ca6a03b9c51f

Rots, V., E. Hayes, D. Cnuts, L. Christian and R. Fullagar. 2016. Making sense of residues on flaked stone artefacts: learning from blind tests. *PLoS One* 11(3): e0150437. https://doi.org/10.1371/journal.pone.0150437

Shawcross, W. 1968. An investigation of prehistoric diet and economy on a coastal site at Galatea Bay, New Zealand. *Proceedings of the Prehistoric Society* 33: 107–131). https://doi.org/10.1017/S0079497X00014079

Shott, M. 1994. Size and form in the analysis of flake debris: review and recent approaches. *Journal of Archaeological Method and Theory* 1: 69–110. https://doi.org/10.1007/BF02229424

Shott, M. 1996. An exegesis of the curation concept. *Journal of Anthropological Research* 52(3): 259–280. https://doi.org/10.1086/jar.52.3.3630085

Stewart, R. 2016. An approach with style: a stylistic analysis of macropod rock art on Murujuga (Burrup Peninsula), Western Australia. Unpublished BA (Hons) thesis, CRAR + M, UWA.

Stuiver, M. and H. A. Polach. 1977. Discussion reporting of 14C data. *Radiocarbon* 19: 355–363. https://doi.org/10.1017/S0033822200003672

Thomsen, K. 2004. Surface area of an ellipsoid. *Numericana* [website] <http://www.numericana.com/answer/ellipsoid.htm> retrieved 2 January 2018.

Veth, P. 1982. Testing the behavioural model: the use of open site data. Unpublished Honours thesis, University of Western Australia.

Veth, P., I. Ward, T. Manne, S. Ulm, K. Ditchfield, J. Dortch, F. Hook, F. Petchey, A. Hogg, D. Questiaux, M. Demuro, L. Arnold, N. Spooner, V. Levchenko, J. Skippington, C. Byrne, M. Basgall, D. Zeanah, D. Belton, P. Helmholz, S. Bajkan, R. Bailey, C. Placzek and P. Kendrick. 2017. Early human occupation of a maritime desert, Barrow Island, North-West Australia. *Quaternary Science Reviews* 168: 19–29. https://doi.org/10.1016/j.quascirev.2017.05.002

Vinnicombe, P. 1987. *Dampier Archaeological project: Resource Document, Survey and Salvage of Aboriginal Sites, Burrup Peninsula, Western Australia*. Perth: Department of Aboriginal Sites, WA Museum.

Vinnicombe, P. 2002. Petroglyphs of the Dampier Archipelago: background to development and descriptive analysis. *Rock Art Research: The Journal of the Australian Rock Art Research Association* 19(1): 3–27.

Wells, F. E. and C. W. Bryce. 1986. *Seashells of Western Australia*. Perth: Western Australian Museum.

Woods, T. 2018. Tool-stone activity in Murujuga: an archaeological analysis of Holocene raw material variation and mobility in the Dampier Archipelago, Western Australia. Unpublished BA (Hons) thesis, Archaeology and CRAR + M, University of Western Australia.

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