

Technological organisation and points in the southern Kimberley

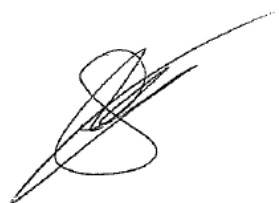
Tim Ryan Maloney

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Declaration

This thesis is my own original work. Contributions by co-authors to papers are listed before each chapter in authorship declarations.

A handwritten signature in black ink, consisting of a series of loops and a long, sweeping horizontal stroke extending to the right.

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Abstract

The anthropogenic manipulation of stone is ubiquitous in every part of the world, throughout human prehistory. The durability of stone technologies creates an enduring material link between the tool maker and the archaeologist, particularly in Australia, where stone tools are a dominant component of the extant archaeological record, and as such, provide fundamental access to our understanding of the technology and lifeways of Australia's Indigenous ancestors. This research, which is part of the ARC Linkage project: Lifeways of the First Australians, analyses stone artefacts from excavated and surface assemblages in the southern Kimberley region. This thesis by compilation focuses on the technological development of points, which are a distinctive, Holocene component of the Australian lithic suite, in order to test a series of hypotheses, which are presented in a collection of published manuscripts, and unpublished manuscripts currently being reviewed.

Lithic artefacts are produced by reduction. When a stone is worked into a tool, it reduces in size, with some fragments resulting in usable pieces, others in debitage. The process of reduction forms the basic premise for this thesis, where reduction is quantified by a morphological methodology outlined in Chapters 1 and 2, and applied to a number of assemblages in order to reconstruct the life history of stone tools from the Kimberley region (Chapters 3 – 7). Chapter 3 presents a robust chronology for point technology in the Kimberley region, where direct percussion points first appear in the archaeological record between 6,000 and 5,000 years ago, and Kimberley Points appear within the last 1,000 years. Chapter 4 provides detailed examination of a large, excavated point assemblage from the Mt Behn rock shelter. This analysis demonstrates that points were produced within a reduction continuum, where changes in reduction intensity and artefact morphology were sensitive to environmental change during the mid to late Holocene. Chapter 5 presents analyses of multiple surface assemblages across the Kimberley, where backing technology is shown to be a regular component of point technologies. The presence of the Kimberley Backed Point challenges the existing model of spatial distributions of backing in Australia. Chapter 6 presents a remarkable point from Carpenters Gap 1, which was recovered with sizable portions of adhering hafting resin, an organic resin which was directly dated. This artefact provides the most compelling evidence for hafting technology used in the mid to late Holocene, and reveals that people were hafting small, lightly reduced points with both mastic and binding. Chapter 7 employs a novel approach to model the level of pedagogy, or teaching and learning, present in two different point reduction sequences. This manuscript demonstrates that pedagogy can be gleaned from stone artefact assemblages, and shows that Kimberley Points represent a shift towards a greater emphasis on a formal pedagogy within the last millennium of Kimberley prehistory. Finally, this thesis culminates in Chapter

8, which presents a summary of the conclusions and discussions offered throughout the manuscripts, and recommends areas of research for further investigation.

A note on page numbers and formatting

This is a PhD thesis by compilation, or publication. Published papers retain the original format of the journal, including the page numbers. In addition to the page numbers associated with these journal publications, continuous page numbers are maintained throughout the thesis, located in the bottom right corner of each page. These page numbers are the only page numbers used for non-published pages of the thesis.

Title page.....	I
Declaration.....	II
Acknowledgements.....	III
Abstract.....	V
A Note on Page Numbers.....	VI
Contents.....	VII
List of Tables.....	XII
List of Figures.....	XIV

Chapter 1. Introduction.....	1
1.1 The Reduction Process of Stone Artefacts.....	3
<i>1.1.1 Stone artefact life histories.....</i>	<i>4</i>
1.2 The Underlying Causes of Variation.....	6
<i>1.2.1 The currencies of technological organisation.....</i>	<i>6</i>
<i>1.2.2 Overall strategies of technological organisation.....</i>	<i>8</i>
<i>1.2.3 Raw material availability.....</i>	<i>9</i>
<i>1.2.4 Evolutionary approaches and the inheritability of technology.....</i>	<i>10</i>
<i>1.2.5 The design of technology.....</i>	<i>11</i>
1.3 The Archaeology of the Kimberley.....	11
<i>1.3.1 The observation of types in Australian Archaeology.....</i>	<i>12</i>
<i>1.3.2 Simple technology and a bimodal prehistory.....</i>	<i>13</i>
<i>1.3.3 The recognition of point reduction and the vestiges of typology.....</i>	<i>17</i>
<i>1.3.4 Point technology in the recent past.....</i>	<i>22</i>
<i>1.3.5 The underlying cause of point technology.....</i>	<i>25</i>
<i>The diffusion hypothesis.....</i>	<i>25</i>
<i>The hafting hypothesis.....</i>	<i>26</i>
<i>A technological responses to environmental change.....</i>	<i>28</i>
<i>Social signalling and demography.....</i>	<i>32</i>

<i>Summary of existing point hypotheses</i>	34
1.4 Research Questions and Hypotheses	34
1.4.1 <i>How old is point technology in the Kimberley?</i>	35
1.4.2 <i>Is the typological model for points valid in the Kimberley?</i>	36
1.4.3 <i>What are the underlying causes of point technology?</i>	36
1.4.4 <i>What are the spatial distributions of point and backing technologies?</i>	37
1.4.5 <i>Were points hafted?</i>	38
1.4.6 <i>Why did Kimberley people make Kimberley Points?</i>	38
1.5 The Study Area and Samples	39
1.5.1 <i>Rock shelter excavations</i>	39
1.5.2 <i>Surface collections</i>	42
1.5.3 <i>Raw material availability</i>	42
Introduction References.....	46
 Chapter 2. Methods	 67
2.1 Stone Artefact Analyses	67
2.1.1 <i>Identifying stone artefacts</i>	67
<i>Flaked lithic artefacts</i>	67
<i>Edge ground and grinding artefacts</i>	72
2.1.2 <i>Quantifying core morphology</i>	73
2.1.3 <i>Quantifying core reduction</i>	74
2.1.4 <i>Quantifying flake morphology</i>	75
2.1.5 <i>Quantifying reduction from flakes</i>	79
<i>Diagnostic impact fractures</i>	83
2.1.6 <i>Indices and measures of flake morphology</i>	83
2.1.7 <i>Blank selection</i>	89
2.1.8 <i>Qualitative retouch variables</i>	91
2.1.9 <i>Quantifying retouch intensity</i>	93
<i>The Index of Invasiveness</i>	93
<i>The Average Geometric Index of Unifacial Reduction</i>	94
<i>Percentage of Retouched Perimeter</i>	95

<i>The Number of Retouched Segments</i>	96
<i>Edge Curvature Index</i>	96
<i>Initial to Terminal Mass Comparison [I/TMC]</i>	97
2.1.10 <i>Pressure flaking</i>	97
2.1.11 <i>Practical geology for lithics analysis</i>	99
2.2 Excavation Methods	101
2.3 Radio Carbon Dating	105
Methodology References.....	106

Chapter 3. New dates for point technology in the Kimberley

3.1 Authorship declaration.....	111
3.2 Maloney T, O'Connor S, Balme J 2014 New dates for point technology in the Kimberley. <i>Archaeology in Oceania</i> , 49(3):137–147.....	(137)112

Chapter 4. Point reduction continuums and changing technological investment in the Mid Holocene record of the southern Kimberley, northern Australia

4.1 Authorship declaration.....	123
4.2 Maloney T, O'Connor S, Balme J In Review. Point reduction continuums and changing technological investment in the Mid Holocene record of the southern Kimberley, northern Australia. <i>Archaeology in Oceania</i>	124

Chapter 5. Backed points in the Kimberley: Revisiting the north-south division for backed artefact production in Australia

5.1 Authorship declaration.....	166
---------------------------------	-----

5.2 Maloney T, O'Connor S 2014 Backed points in the Kimberley: Revisiting the north-south division for backed artefact production in Australia. <i>Australian Archaeology</i> , 79:146-155.....	(146)167
---	----------

Chapter 6. Directly dated resin hafted stone technology in Australia: Points as composite tools in the mid Holocene

6.1 Authorship declaration.....	177
6.2 Maloney T, Wood R, O'Connor S, Whitau R Accepted. Directly dated resin hafted stone technology in Australia: Points as composite tools in the mid Holocene. <i>Australian Archaeology</i> , December 2015.....	178

Chapter 7. Teaching and learning lithic technology: A case study of Kimberley Points

7.1 Authorship declaration.....	195
7.2 Maloney T In Review. Teaching and learning lithic technology: A case study of Kimberley Points. <i>Journal of Archaeological Method and Theory</i>	196

Chapter 8. Australian lithic technology: evolution, dispersion and connectivity.

8.1 Authorship declaration.....	237
8.2 Hiscock P, Maloney T Australian lithic technology: evolution, dispersion and connectivity.....	238

Chapter 9. Conclusions.....260

9.1 How old is point technology in the Kimberley?.....	260
9.2 Is the typological model for point variability valid?.....	260
9.3 The underlying causes of point technology.....	261
9.4 What are the spatial distributions of point and backing technologies?.....	264
9.5 Were points in the mid Holocene hafted, if so, how?.....	264

9.6 Why did Kimberley people make Kimberley Points?.....	265
9.7 Summary.....	266
Conclusion References.....	267

Appendices.....270

A) O'Connor S, Maloney T, Vannieuwenhuyse D, Balme B, Wood R 2014 Occupation at Carpenter's Gap 3, Windjana Gorge, Kimberley, Western Australia. <i>Australian Archaeology</i> , 78:10–23.....	271
B) O'Connor S, Hiscock P, Balme J, Maloney T In Review. World's earliest edge-ground axe production is coincident with human colonization of Australia and exemplifies the emergence of novelty during the global dispersion of humans. <i>Journal of Human Evolution</i>	285
C) Maloney T, Vannieuwenhuyse D, O'Connor D, Balme J, Fyfe J In Reveiw. Re-examination of a Holocene rock shelter in the southern Kimberley, north Western Australia. <i>Australian Archaeology</i>	296
D) Australian National University thesis by compilation procedure.....	309
E) List of Recorded Variables.....	311
F) Maloney T 2013 I/TMC experimental examination. Unpublished Report.....	315
G) Maloney T, Marwick B Elliptical Fourier Analysis Unravels a Palimpsest of Point Technology. Poster given at the Society for American Archaeology annual conference in 2014.....	331
H) Analysed assemblages not included in published manuscripts.....	338

List of Tables

Chapter 1

Table 1. Frequency of reported points from Kimberley excavations.....	18
--	-----------

Table 2. Frequency of reported points from Northern Territory excavations.....	19
---	-----------

Chapter 2

Table 1. Identification of rock types in the study area	101
--	------------

Chapter 3

Table 1. Existing published radiocarbon dates associated with direct percussion points and pressure-flaked points in the Kimberley. Conventional radiocarbon ages were calibrated and calendar age ranges determined using OxCal v.4.2 (Bronk Ramsey 2009a) against SHCal04 (McCormac et al. 2004). Marine samples were calibrated using marine Curve 09 (Reimer et al. 2009).....	(140)115
---	-----------------

Table 2. OSR and TL dates associated with direct percussion points and pressure-flaked points in the Kimberley. Note that no laboratory codes were provided with the OCR dates given by Harrison and Frink (2000).....	(141)116
---	-----------------

Table 3. Radiocarbon dates from recent excavations in Bunuba country associated with direct percussion points and pressure-flaked points. Conventional Radiocarbon Ages were calibrated and calendar age ranges determined using OxCal v.4.2 (Bronk Ramsey 2009a) against SHCal04 (McCormac et al. 2004). Marine samples were calibrated using marine Curve 09 (Reimer et al. 2009).....	(143)118
---	-----------------

Chapter 4

Table 1. Radiocarbon dates obtained from Mt Behn deposit.....	130
--	------------

Table 2. Technological classes identified from excavation squares 1 and 2.....	133
---	------------

Table 3. Raw material frequency and percentage of unifacial, bifacial, and backed points of the total sample of points.....	135
--	------------

Table 4. Frequency and percentage of quartz cortex type observed on points.....	135
--	------------

Table 5. Statistical analysis for point platform variables against Index of Invasiveness.....	135
--	------------

Table 6. Statistical analyses for point platform variables against retouch intensity, using sub sample of Index of Invasiveness values below 0.25.....	136
---	------------

Table 7. Statistical analyses of bifacial and unifacial point retouch versus linear dimensions and morphological indices.....	137
--	------------

Table 8. Qualitative cross-sectional shape frequencies distributed over quartiles of Index of Invasiveness values recorded only on complete points.....	139
--	------------

Table 9. Statistical analyses of Index of Invasiveness against width to thickness ratios taken at three landmarks along the percussion axis of points.....	140
---	------------

Table 10. Placement and order of retouch for complete points distributed across quartiles of the Index of Invasiveness. These observations were recorded only on complete points (n = 109) and points with small distal breaks, where retouch order was clear (n = 6).....	141
---	------------

Table 11. Associated time period of points relative to stratigraphic units per quadrant.....	143
---	------------

Table 12. Frequencies of retouched flakes and total number of artefacts (TNA) per associated time period.....	144
--	------------

Table 13. Time periods showing divisions of the Index of Invasiveness and the order of retouch for complete points. These observations were recorded only on complete points ($n = 109$) and points with small distal breaks, where retouch order was clear ($n = 6$).....	147
---	------------

Chapter 5

Table 1. Technological classes observed in the analysed assemblages.....	(149)170
---	-----------------

Table 2. ANOVA results: 3D scanned platform area measurements for points with Index of Invasiveness values below 0.3 against point type. Note: backed point platform surface area is not significantly different to other point morphologies.....	(151)172
--	-----------------

Table 3. ANOVA results for comparison of retouched edge angle and edge angle of backed points with other point morphologies.....	(152)173
---	-----------------

Table 4. Analysis of variance results for the Average Geometric Index of Unifacial Reduction against the average retouched edge angle.....	(153)174
---	-----------------

Table 5. Linear regression results for Average Retouched Edge Angle against the Average Geometric Index of Unifacial Reduction.....	(153)174
--	-----------------

Table 6. The placement and order of retouch for complete backed points in the analysed assemblages.....	(153)174
--	-----------------

Chapter 6

Table 1. Table 1. Radiocarbon dates from CG1, square A1. Calibrated in OxCal v.4.2 (Ramsey et al. 2009) against SHCal 13 (Hogg et al. 2013).....	185
---	------------

Chapter 7

Table 1. Stone artefact frequency in Mandanari sample. Bracketed numbers represent subtotals.....	205
--	------------

Table 2. Raw material frequency in Mandanari sample. Bracketed numbers represent subtotals.....	206
--	------------

Table 3. Stone artefact frequency in Wanalirri assemblage. Bracketed numbers represent subtotals.....	206
--	------------

Table 4. Raw material frequency in Wanalirri assemblage. Bracketed numbers represent subtotals.....	207
--	------------

Table 5. Biface production stages.....	213
---	------------

Table 6. ANOVA results for comparison of Index of Invasiveness and cross section ratios.....	214
---	------------

Table 7. ANOVA results comparing direct percussion point retouch intensity (Index of Invasiveness) with width to thickness ratios.....	215
---	------------

Table 8. Retouch order observed on complete direct percussion points, and 5 broken points where retouch order was observable.....	215
--	------------

Table 9. Pearson's Chi square test of direct percussion unifacial versus bifacial point platform attributes.....	216
---	------------

List of Figures

Chapter 1

Figure 1.1 Map of Australian continent showing Kimberley region (yellow), Pleistocene coastlines, and early Pleistocene sites discussed in the following text.....	2
Figure 1.2 Teleological and evolutionary sequence models.....	6
Figure 1.3 Artefact types of the small tool tradition.....	13
Figure 1.4 Varied depictions of spatial distributions of backing and point technology.....	16
Figure 1.5 Map of northern Australia showing excavated sites where assemblages of points were recovered.....	21
Figure 1.6 A Range of pressure flaked bifaces from the Kimberley.....	24
Figure 1.7 Distribution of Kimberley Points, showing isolated observations and manufacturing areas.....	24
Figure 1.8 One of several bowers constructed inside the Mt Behn shelter.....	41
Figure 1.9 Proximity of excavated sites in Bunuba and Ungummi country to the Lennard River and Windjana Gorge. Aerial photograph facing north east modified from Playford et al. (2009:234).....	41
Figure 1.10 Proximity of sites in Bunuba and Ungummi country to the Lennard River and Windjana Gorge. Aerial photograph facing west modified from Playford et al. (2009:234).....	42
Figure 1.11 Proximity of sites in Bunuba country around McSherrys Gap. Aerial photograph facing north west modified from Playford et al. (2009:336).....	42
Figure 1.12 Locations of survey tracks, sites analysed, and those sites analysed but not included in published manuscripts. The limestone range extends diagonally, with the Canning Basin to the south, and the Kimberley Block to the north.....	43

Chapter 2

Figure 2.1 Conchoidal surface attributes on flakes produced by hertzian fracture.....	68
Figure 2.2 Initiation of hertzian, bending, shearing, and bipolar fracture.....	66
Figure 2.3 Modes of fracture termination.....	69
Figure 2.4 Mutually exclusive artefact categories: Cores, flakes, retouched flakes, and flaked pieces. The positive conchoidal surface is present only on flakes and retouched flakes, and the negative surface only on cores and retouched flakes.....	70
Figure 2.5 Identification of pitted surfaces on hammer stone after repeated blows.....	71
Figure 2.6 Basic orientation of pressure flaking and force using pressure flaking tool.....	71
Figure 2.7 Ethnographically observed pressure flaking method the Kimberley.....	72
Figure 2.8 Identification of striations on edge ground surfaces.....	73
Figure 2.9 Two different cores used to illustrate the recording of core rotations.....	75
Figure 2.10 Length measurements recorded on flakes and retouched flakes.....	76
Figure 2.11. Width measurements recorded on flakes and retouched flakes, perpendicular to the length.....	77
Figure 2.12 External and internal platform angle measurements, viewed from the lateral margin of a flake. A) Depicts the angle between platform and dominant dorsal surface, while B) depicts the angle between the platform and overhang removal scars.....	78

Figure 2.13 Identifying flake fragments and breakage patterns.....	79
Figure 2.14 Primary, secondary, and tertiary flakes removed from core.....	80
Figure 2.15 Method for quantifying the percentage of cortex.....	81
Figure 2.16 Examples of cortex observed on dorsal surfaces of flakes.....	81
Figure 2.17 Platform surfaces observed of flakes, showing the corresponding change in core morphology.....	82
Figure 2.18 Variation in Platform surfaces and platform preparation.....	83
Figure 2.19 Landmarks where thickness measurements, transverse and longitudinal cross sections.....	84
Figure 2.20 Qualitative cross sectional shapes.....	84
Figure 2.21 Production of 3D laser scanned cross section shapes.....	85
Figure 2.22 Calculation of elongation Index.....	86
Figure 2.23 Marginal angle calculation for four different morphologies A) Parallel margins which return values of 0; B) Expanding margins which return values below 0; C) Contracting margins which return values above 0; D) False indication of parallel margins for ovate morphology.....	87
Figure 2.24 Parallel index calculated on four different flake and retouched flake morphologies.....	87
Figure 2.25 Distal parallel index calculated on four different flake and retouched flake morphologies.....	88
Figure 2.26 Proximal edge curvature index.....	89
Figure 2.27 Platform surface measurements using digital callipers.....	90
Figure 2.28 Figure 2.28 Measuring platform surface area with a Next Engine 3D laser scanner. A) Completed scan after fusing data points; B) Dorsal and ventral surfaces of artefact after editing all unwanted data points using the trim function; C) Trimmed artefact showing only the platform surface; D) The calculation of platform surface area in inches squared.....	91
Figure 2.29 Recycling of older tools recognised by differential weathering of fresh retouch scars superimposed onto older scar surfaces.....	92
Figure 2.30 Index of Invasiveness.....	94
Figure 2.31 Average Geometric Index of Unifacial Reduction [AGIUR].....	95
Figure 2.32 Percentage of perimeter retouched.....	95
Figure 2.33 Calculation of edge curvature index.....	97
Figure 2.34 Example of serrate, denticulate, and dentate margins on pressure flaked bifaces...	98
Figure 2.35 Quantification of marginal serrations on pressure flaked bifaces.....	99
Figure 2.36 Excavation recording form.....	103
Chapter 3	
Figure 1. A map of north-western Australia, showing the locations of sites mentioned in text (map by Kay Dancey).....	(139)114
Figure 2. (a) A crystal quartz pressure-flaked point from CG3 (photograph Noel Tan). (b) A crystal quartz pressure-flaked point from Windjana Gorge 1 (photograph Noel Tan).....	(139)114

Figure 3. A pressure-flaked point (Kimberley Dentate point, after Akerman & Bindon 1995), recovered from the Mount Behn excavation (photograph Noel Tan).....(144)**119**

Figure 4. Proximal and distal portions of a pressure-flaked point (Kimberley Dentate point) from Mount Behn. The distal point fragment matches the alignment of negative scars and ridges on the proximal portion. The proximal piece has been rejuvenated after the break and shows that the platform surface is still intact.....(145)**120**

Chapter 4

Figure 1. Northern Australia showing location of Mt Behn and other sites mentioned in text....**125**

Figure 2. A) Bifacial preform made on crystal quartz, technically a core, illustrating invasive scars produced by direct percussion. B) Kimberley Point made on crystal quartz, with pressure flaking scars and marginal serrations, from scree slope in front of Mt Behn. Unifacial and bifacial points from Mt. Behn excavation, showing varying retouch intensities and remnant platform surfaces.....**126**

Figure 3. Mt Behn shelter surface and cross-sections, shaded area shows the extent of the deposit (CAD: Dorcas Vannieuwenhuyse).....**128**

Figure 4. Stratigraphic sections of 2012 excavation squares 1 and 2 (CAD: Dorcas Vannieuwenhuyse).....**129**

Figure 5. Mass plotted against the percentage of perimeter retouched on complete points, showing the overlap in retouch intensity between unifacial and bifacial points.....**138**

Figure 6. Central tendency of complete points using maximum length, excluding all distal breaks.....**138**

Figure 7. The quartile divisions of the Index of Invasiveness used to illustrate the location of retouch across segments of the dorsal and ventral surfaces, on points where retouch order was recorded. Percentages are calculated by dividing the number of segments with retouch, by the number of points within each quartile division of the Index of Invasiveness. 0 values are given for marginal segments when an invasive score is present.....**142**

Figure 8. Total number of artefacts discarded per thousand years, where the duration of each time period is divided by 1000.....**145**

Figure 9. Discard of points per thousand years, where the duration of each time period is divided by 1000.....**145**

Figure 10. Mid with to thickness ratios of points relative to time period.....**146**

Figure 11. Other retouched flakes as a percentage of overall discard relative to time period...**149**

Figure 12. Unifacial retouch intensity, recorded on other retouched flakes, relative to associated time period.....**149**

Figure 13. Summary of changing point retouch strategies and reduction intensity. The stratigraphic units with associated time periods are used to illustrate technological change through time.....**151**

Chapter 5

Figure 1. Northern Australia showing sites mentioned in text and backed artefact distribution line (after Hiscock 2007:148, Figure 8.3).....(147)**168**

Figure 2. Three complete backed points from Widgingarri Shelters 1 and 2 (modified from O'Connor 1999).....(148)**169**

Figure 3. 3D laser scanned image of backed point from ME3, illustrating multiple points along percussion axis where cross-section shapes were calculated.....	(150)	171
Figure 4. Scatter plots showing marginal angle against length to thickness ratio for LR9, LR12 and ME3 samples. Backed points were selected from the same pool of flakes, with similar size and shape characteristics. The blank flake morphology for backed points, and indeed all point morphologies, are typically those flakes with either parallel or contracting margins and with length to thickness ratios between 2 and 12.....	(151)	172
Figure 5. Average retouched edge angle for the Widgingarri points.....	(152)	173
Figure 6. Average retouched edge angle for the LR9 points.....	(152)	173
Figure 7. Backed point from ME3 showing cross-section shapes at multiple points obtained from 3D laser scanned images. The backed retouch margin shows that retouch scars initiated from the ventral surface extend along the left dorsal margin. The medial to distal left margin shows bidirectional scars with small step terminating scars indicative of anvil-rested percussion. The inset image highlights the retouched section, with observation of bipolar anvil-rested percussion.....	(152)	173

Chapter 6

Figure 1. Map of north Western Australia showing site location.....	179
Figure 2. Point from CG1 showing transverse scar across midsection, impressions formed by binding materials, and small pieces of plant, probably spinifex chaff, in the resin (photograph by Tim Maloney).....	183
Figure 3. Hypothetical hafting arrangement and impact forces, based on specimen observations.....	184

Chapter 7

Figure 1 Examples of pressure flaked bifaces A) Bottle glass Kimberley Point with serrate margins B) Crystal quartz Kimberley Point with serrate margins, from Carpenters Gap 3 (Maloney et al. 2014:139 fig. 3) C) Quartzite Kimberley Point with serrate margins D) Quartzite Kimberley Point with serrate margins D) Chert Dentate Kimberley Point with dentate and serrate margins.....	201
Figure 2 Map of northern Australia showing approximate boundary of Kimberley Point distribution, including isolated observations and manufacturing areas	201
Figure 3 Orientation of pressure flaker during Kimberley Point pressure flaking.....	203
Figure 4 Point reduction continuum from Mt Behn showing a diversity of retouch strategies and recycling within the point reduction continuum (Maloney et al. In Review).....	204
Figure 5 Biface production stages 1 and 2 A) Tabular piece of white/pink quartzite, lacking any ventral surface B) Large white/pink quartzite flake C) Tabular piece with no platform or ventral surface, with early bifacial reduction D) Highlight of the early stages of bifacial reduction on tabular piece.....	209
Figure 6 Biface production stage 2 A) Ventral and dorsal surface, as well as platform initiation point are evident, with bifacial scars extending across the margins B) Invasive flake scars have removed the flake platform surface, although partial ventral surface remains.....	209
Figure 7 Production stage 3 bifaces with biconvex cross sections and invasive flake scars.....	210

Figure 8 Production stage 2 failures, with step terminating scar build ups towards the centre of the biface.....	211
Figure 9 Biface width against length showing biface production phases and outlying nature of stage 2.....	211
Figure 10 Broken biface fragments with transverse snaps.....	212
Figure 11 The pressure flaking biface production stages 4 and 5 A) Red quartzite biface with pressure flaking scars B) Outline of unambiguous pressure flaking scars C) Dentate Kimberley Point with transverse snap removing distal portion.....	212
Figure 12 Decreasing length of bifaces across 5 production stages from Mandanari.....	213
Figure 13 Decreasing mass of bifaces across 5 production stages from Mandanari.....	213
Figure 14 The two bifaces from Wanalirri A) Quartzite biface with step termination build ups B) Biface with early stages of pressure flaking C) Outline of unambiguous pressure flaking scars...	214
Figure 15 Direct percussion points showing retouched perimeter length on dorsal and ventral surfaces A) Invasive unifacial retouch B) Marginal unifacial retouch C) Unifacial to bifacial retouch D) Backing.....	216
Figure 16 Points with marginal serrations.....	217
Figure 17 Examples of cores A) Quartzite single platform, unidirectional core B) Chert multiplatform, multidirectional core.....	218
Figure 18 Large blades (aka Leilira) found at both Mandanari and Wanalirri.....	219
Figure 19 Percussion tools recovered at Wanalirri: A) and B) Hammer stones C) Edge ground tip of bone tool, showing rounded margins with intersecting striations D) Bone pressure flake.....	219
Figure 20 Total surface area of direct percussion points and bifaces.....	220
Figure 21 Comparing the length of the descriptions of regularities between direct percussion points and biface reduction.....	222
Figure 22 Theoretical contrast of effective complexity and raw material costs, with reference to levels of pedagogy and rates of innovation.....	225

Chapter 8

- Figure 1** Three categories of artefact: A = Bifacial point from Arnhem Land, B = Backed artefacts from southern Australia, C = Axe from eastern Australia (Illustrations by Peter Hiscock and Chris Clarkson).....**240**
- Figure 2** Model of the extension-Abundance continuum after Hiscock (2006). A = Continuum of possible artefact forms that play off reduction potential against production cost/rate. B = Plot of backed artefacts, bifacial points, and axes on the continuum using proxies for reduction potential (specimen weight) and production rate (number of specimens per kilogram). Dots indicate the central tendency (arithmetic mean) of each class, and an ellipse indicates variation exists (standard deviation).....**244**
- Figure 3** Distribution of backed artefacts, bifacial points and ground-edge axes across the current Australian mainland (from Hiscock 2008, 2014a; Morwood and Trezise 1989). Late Holocene distributions (c. 3-1,000 bp) are more accurately established than early Holocene distributions (c. 8-5,000 bp).....**246**
- Figure 4** Idealized images of possible backed artefact hafting positions, inspired by McCarthy's (1976) illustration but excluding those options which are unlikely given existing usewear and residue evidence (after Hiscock in press).....**248**

Chapter 1: Introduction

1. Introduction

The ancestors of contemporary Indigenous nations occupied Australia for at least 50,000 years (Hiscock 2008:44). Groups across this island continent utilise, and have utilised, a diverse array of organic materials, which seldom endure in the archaeological record as either finished products or raw materials. Stone artefacts, which are both durable and abundant, provide archaeologists with a means of reconstructing the lifeways of Aboriginal people over time and space, often in the complete absence of other material evidence. Lithic technologies are the primary vestiges of prehistoric lifeways in Australia, and their analysis is an essential component of Australian archaeology.

This thesis focuses on Holocene point technology in the Kimberley region of Western Australia. The archaeology of the Holocene in Australia has long been recognised as a period of dynamic change in stone technology, particularly the mid to late Holocene (5,000 to 1,000 years ago) (Allen & Barton 1989:15-20, 131-7). Point technologies found during this period have a long history of varied interpretation. To many, stone points are defined simply by converging margins (e.g. Flenniken & White 1985; Holdaway & Stern 2004:154). However, since retouch intensity changes the morphology of points in response to an array of social and ecological factors, analysis of points with retouched converging margins offers unique insight into the role this technology played in people's lifeways. The Kimberley region of northern Australia (Figure 1.1) is home to some of the most spectacular and diverse point technologies in the world, yet this area, and these artefacts, are under-explored.

In parts of Australia, stone artefact analyses are in need of major revision, especially where typological methods have been used to assess the meaning of artefact variability, rather than quantified reduction methods. The Kimberley region of Western Australia is a prime example. While archaeologists have revised their thinking about technological change in parts of the Northern Territory and Queensland (Clarkson 2008; Hiscock 1994a, 1994b; Hiscock & Veth 1991), the technological history of the Kimberley region is still largely embedded in outdated typological models of technological change. The major assumptions from previous studies regarding point technology, such as typology, spatial boundaries, temporal patterns, hafting techniques, use as spear heads, and morphological variability are clarified by the analyses provided in this thesis.

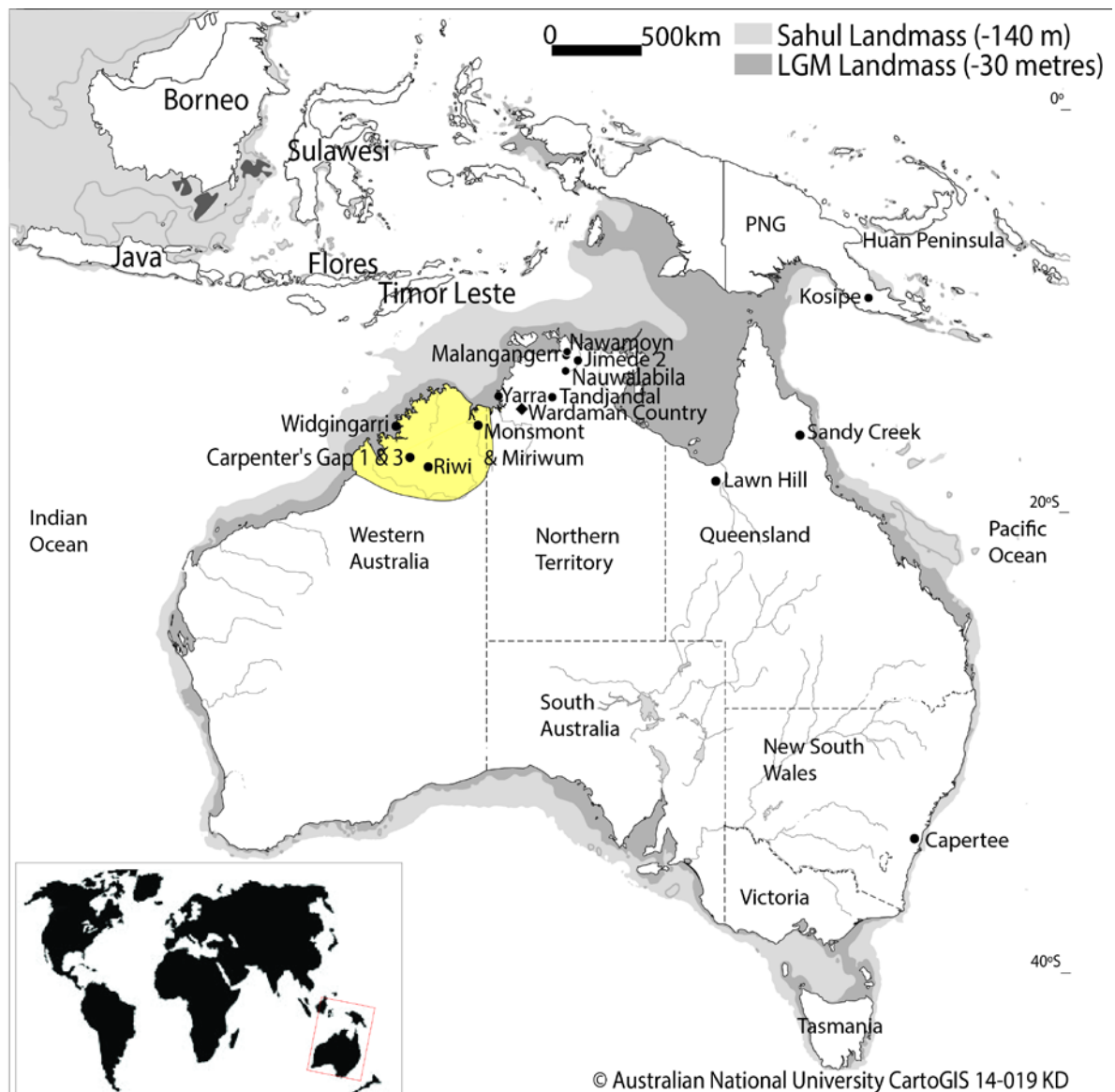


Figure 1.1 Map of Australian continent showing Kimberley region (yellow), Pleistocene coastlines, and early Pleistocene sites discussed in the following text.¹

¹Note: All figures are produced by the author unless otherwise stated.

This dissertation is presented via a series of published and in review manuscripts, forming a thesis by compilation, rather than the traditional thesis structure. The format followed here is governed by the Australian National University thesis by compilation guide (Appendix D). This first chapter begins with a description of reduction sequence analysis, and then provides a theoretical base for interpreting stone artefacts as archaeological data, followed by a background to the archaeology of the Kimberley region. Chapter 1 concludes with an overview of the study area, the sites and the samples analysed. Thus the chapter outlines the research questions which are addressed by the research papers, which comprise the body of the thesis. In the following chapter, the stone artefact analysis methodology is explicitly outlined, since manuscripts cannot accommodate such detailed

explanations of artefact measurements, indices, and observations. The first published manuscript, Chapter 3, provides a robust temporal model for point technologies in the Kimberley, using new excavation data, critical literature review, and Indigenous oral history (Maloney et al. 2014). The second paper, Chapter 4, presents an analysis of the retouched flake assemblage from the excavated site of Mt Behn (Maloney et al. In Review). These data are used to reconstruct point reduction sequences over the last 5,200 years, and assess competing models for the explanations underlying the development of point technology. Chapter 5 uses data from previous excavations and new analysis of surface collections to demonstrate that backing technology was widely practiced throughout the Kimberley region, and casts serious doubt on the validity of long held spatial boundaries for backed artefacts in Australia (Maloney & O'Connor 2014). In Chapter 6, one remarkable point from Carpenters Gap 3 is presented, which provides the most conclusive evidence for the hafting technology used in the mid to late Holocene, and is directly dated using the remnants of adhering resin (Maloney et al. In Review). Chapter 7, uses surface assemblage data from the central Kimberley to contrast the reduction sequences of two different point technologies (Maloney In Review). This paper introduces effective complexity as a novel method for quantifying the likely role of pedagogy in the past, and argues that technological change within the last millennium is most likely to have been accompanied by changing social relationships, which were previously detected. The final manuscript, given as chapter 8, explores social contexts of stone technologies as a means of modelling connectivity across the Australian continent. The body of this thesis is these six manuscripts. Chapter 9 concludes the thesis, with a summary of the research and recommendations for future study. A series of appendices are also included which contain data relevant to the case studies and analysis conducted during this research program.

1.1 The Reduction Process of Stone Artefacts

All flaked stone artefacts are created within a reduction sequence where stone is reduced into usable units, or tools, using percussion (for a history of this approach see Shott 2003). As the reduction process continues, units of stone become increasingly smaller, and irreversibly modified. Because lithic artefacts are produced by reduction, reduction analysis is an essential, unavoidable practice for stone artefact analysts. This thesis quantifies reduction processes to reconstruct how stone artefacts were made, and then uses these data to model and test why such strategies were followed. The methods of this quantification are explicitly outlined in the following methodology chapter, although it is useful here to introduce some basic terminology and briefly describe why typology is no longer regarded as useful for describing artefact variability.

Since all lithic artefacts are part of a reduction sequence, the term reduction is here used to refer to all aspects of stone artefacts. Retouch intensity only refers to the reduction of

retouched flakes. Production can here refer to either the creation of flakes, or the staged manufacturing of specific tools in anticipation of use. The reduction thesis approach has not been the dominant approach to stone tool analysis in the history of Australian archaeology, or the study area itself. In recent decades, experimentation and verification have led to the widespread adoption, within Australia, of the approach adopted in this thesis.

Two methodologies have dominated stone artefact analyses: The typological and the reduction sequence approach. The typological approach identifies shared traits of discarded artefacts, and conceives of these types as mutually exclusive products, often thought to relate to intended use and design. Since most stone technologies cannot be observed in use, it is the size and shape, or morphology, which suggests this use to typologists. Typological approaches thus assume that the observed morphology of artefacts is the intentional design that people manufactured and used in the past. This approach has been useful in compartmentalising complex phenomena from the archaeological record into easily recognised units, and will no doubt remain a much discussed method in many regions. As an analytical approach to stone artefacts; however, typology is fundamentally flawed. The majority of modern day analysts now see stone tool typology as an essentialist construct which falsely views observed artefacts as discrete products of their makers' design, and in doing so, either discounts or downplays the process by which stone artefacts are created, used, reshaped and discarded – the reduction process (Shott et al. 2007:204-205). The reduction sequence approach quantifies the process by which stone tools were created, without typological assumptions. The importance of recognising reduction, and its effect on observed artefact morphologies during their systemic use, has forced archaeologists to consider the artefact's life history.

1.1.1 Stone artefact life histories

Artefact life histories begin with initial production in the systemic context, and end with analysis by the archaeologist (Andrefsky 2008:6; Schiffer 1972:158, 1976:46). This life history can include production, use, modification, maintenance, reconfiguration, discard, recycling, alternate use and modification, another discard, and occasionally archaeological recovery. While methods such as the *chaîne opératoire* (Böeda 1995; Leroi-Gourhan 1964; Shott 2003) are capable of reconstructing these life histories, and essentially focus in the same underlying process (Shott 2003); metric recording of morphological variability and quantification of retouch intensity is here considered a more fitting approach for the archaeological data. Morphological variability within reduction sequences beckons the comparison of discarded morphology with the genesis or blank morphology, which is readily achievable in point assemblages. The first focus on the difference between discarded tool morphology and blank form was introduced by Binford (1973) as the curation concept.

Curation attempts to define the relationship between the realized and maximum utility of stone tools (Shott 1996). There has been extensive discourse on the subject of curation in North American and European studies (Andrefsky 2009; Bamforth 1986; Bettinger 1987; Binford 1973; Kuhn 1994; Nelson 1991; Shott 1986, 1996). The dialogue surrounding curation essentially confounds aspects of artefact life history. This confusion is exemplified by researchers' definitions of terms such as utility (Kuhn 1994:430-432), use life utility (Elston 1992:41), length of service (Andrefsky 2009:72), number of uses (Schiffer 1976:54), remnant use life (DeBoer 1983:26), and reduction potential (Macgregor 2005); which essentially represent parts of the same overall process, with varied archaeological phenomena. All of these variables are encompassed by the term artefact life history, which is employed throughout this thesis, following various other researchers (Andrefsky 2009:70-71; Blades 2008:137; Nash 1996:96; Odell 1996:75; Shott 1986:24; 1996:267; Quinn et al. 2008:151).

Due to the inherent nature of reduction, the life history of stone artefacts is reconstructed using sequential models. The incomplete record that archaeologists use to infer behaviour means that sequential models are often partial theoretical constructs, which position observed artefact morphologies within a reduction continuum. A complete or absolute sequential model is only possible by refitting (e.g. Hofman & Enloe 1991), so when this is not possible, which is often the case, sequence models must use observable data to reconstruct artefact life history. Two sequence models utilised for this application are the teleological and evolutionary models (Figure 1.2), which provide a means to conceptualise and order the reduction process. Teleological sequence models interpret variation as a set of internally determined actions that follow one from another, leading to predetermined goals (Bleed 2001). Different morphologies are a result of planning, rather than a response to situational constraints, which makes teleological sequence models best suited to reduction sequences with observable design. Evolutionary sequence models, by contrast, describe morphologies that are produced by selected interaction between conditions and variables (Bleed 2001:121), where a multiplicity of situations can occur that cause morphological variability (Figure 1.2). Because evolutionary sequence models are not unilinear, they are generally applied to reduction sequences that are not associated with specific or specialised morphologies, but rather with reduction sequences that exhibit high morphological variability. Both teleological and evolutionary sequence models are utilised in this thesis where appropriate. These models ultimately form the basis for inferring why such reduction sequences were followed—in other words, for the underlying causes of stone artefact variability.

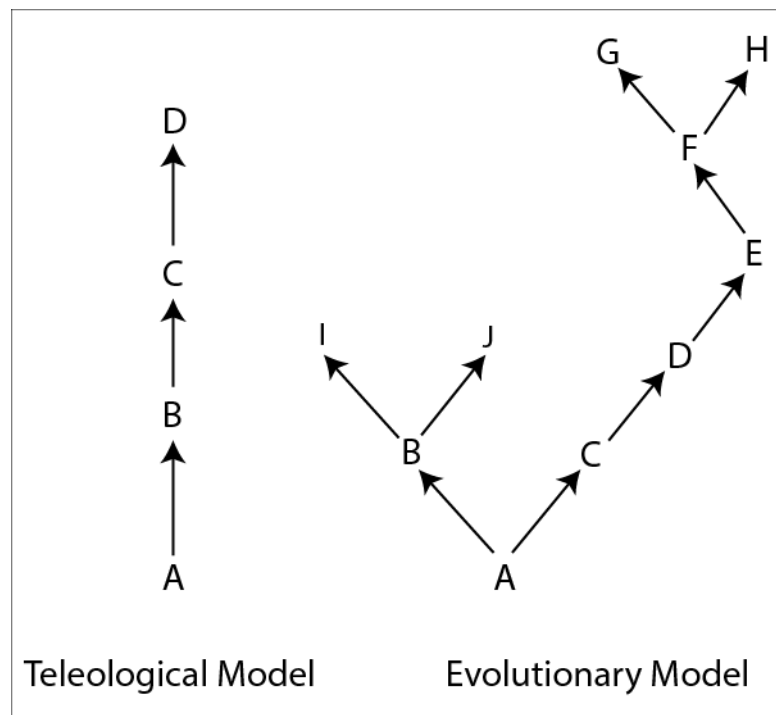


Figure 1.2 Teleological and evolutionary sequence models.

1.2 The Underlying Causes of Variation

While the reduction sequence approach has often been employed to test and refute typologies (e.g. Brumm & McLaren 2011; Dibble 1984; Hiscock & Attenbrow 2003; Hiscock & Veth 2001; Odell 2000:286-287), archaeologists are now primarily concerned with explaining why these reduction sequences were followed. Technologies are often conceived as adaptive problem solving strategies. Stone tool technology is adaptable to both subsistence and social tasks, but is also subject to evolutionary forces. The body of theory explaining these underlying causes in the systemic contexts of tool use is technological organisation, which is now briefly discussed.

1.2.1 The currencies of technological organisation

...[humans] must eat to live at all... (Childe 1951:61)

Like all forms of life, humans are dependent on ecological resources, such as food and water. While some feel that this core premise detracts from the complex nature of human culture, the structure of ecology in which humans existed provides a compelling means to model human behaviors, such as subsistence patterns. These subsistence patterns are organized around the variation in time and space of desired resources, and technology has a closely embedded relationship with those subsistence practices (Kuhn 1995; Torrence 1989:58). The residual nature of stone technology provides great potential to link technology to past subsistence. While every aspect of human subsistence does not follow a

uniformly optimal pattern, the distribution of resources undoubtedly relates to the way people organize their lifeways, and also their technology (Nelson 1991:58).

Technological organization is the structuring of technology around subsistence and settlement patterns, often described in terms of costs and benefits, or investments and returns. The cost, or investment, of various strategies and actions is often contrasted with the predicted benefit or return (Bamforth 1986, 1991; Bamforth & Bleed 1997; Bleed 1986; Kuhn 1994, 1995). Popular currencies discussed by archaeologists associated with stone technology, include time, energy, and risk (Bleed 1986; Kuhn 1995; Torrence 1983, 1989).

Theory regarding the investment of time into technology has produced seminal research on the technological organisation of stone tool using societies (Smith 1987; Torrence 1983, 1989). In one such landmark paper, Torrence (1983) discussed time stress, through the allocation of time to technological activities around a range of exclusive activities. This theory suggests that people invest greater time into their technology during periods of economic stress, and in doing so, recuperate that time cost with greater economic return from more capable technology. Time stress was later discussed in terms of foraging risk (Torrence 1989:60), described below. Further theoretical exploration of time costs by Mackay and Marwick (2011:121), suggested that units of time enter technological organisation at three major intervals. First, in the magnitude of procurement episodes, where time varies according to the units of stone, second, in the frequency of these procurement episodes, and finally, in the time spent during manufacture and maintenance. These divisions of time investment can surely overlap (Nelson 1991:64), but they provide a useful theoretical method of compartmentalising time investment within a technological organisation strategy.

Time invested or spent on teaching and learning has not been a popular inquiry of technological organisation. Nonetheless, most researchers are convinced that mastering any complex lithic technology requires years of practice (Bamforth & Finlay 2008; Howe et al. 1998; Nunn 2006; Stout 2002), and in most instances, these complexities are not achievable via observation and imitation alone (Tehrani & Riede 2008:318). Therefore, people clearly spent time learning, practicing, and teaching stone reduction techniques. Complex technologies require not only greater time invested by teachers and learners, but also the social group (Hiscock 2014:35; Shennan & Steele 1999). It is the social group that bears the cost of educating students in technology, students who will presumably produce sub-optimal results for some time (Hiscock 2014). How these factors of time manifest in the archaeological record is poorly understood and worthy of greater interest.

A far better explored theory of technological organisation is foraging risk. For hunter gatherer populations, foraging risk is the probability and severity of failure in subsistence

(Bamforth & Bleed 1997:112-113; Torrence 1989:59; Winterhalder et al. 1999:302). This probability and severity can relate to dietary needs and access to fresh water (Torrence 1989:58-59), or the capture or encounter of dangerous animals (Ellis 1997), but most pragmatically is used to refer to overall subsistence viability. Strategies of technological organization can dampen the spatial and temporal distribution of resources, and so are often explained as risk minimization strategies. Risk minimization technologies often emphasize extendibility, standardization, multifunctionality, and adaptability in foraging contexts. While many researchers interested in risk minimization theory have pursued this ecological focus, there are also social means of reducing risk. For example, Weissner's studies (1982:172-173; 1983) outlined four social strategies for reducing subsistence risk: the prevention of loss, the transfer of loss, storing of resources, and the pooling of resources. Here foraging risk is reduced by securing subsistence resources through storage or tribute relationships. Both socially and ecologically focused foraging risk theories involve dietary needs, needs which have promoted discussion of energy as a currency of technological organization.

Energy can refer to the energy expended in labor, as well as the absorption of energy, or failure to do so (Bleed 1986; Torrence 1989:58). Optimal foraging theory implies that minimal expenditure with greater return would be emphasized; however, as resources fluctuate through time and space, energy expenditure levels must change to suit. Direct measures of energy return are unlikely to ever be modeled in direct association with stone tools. As a currency of technological organization, energy instead has the benefit of correlation with the physical transport of stone tools and other technologies, in terms of mass. Energy expended in the transport of cores and tools is directly proportional to mass, allowing the cost of carrying alternate masses of stone to be theoretically contrasted. Kuhn (1994:435) found that the best, or optimal, overall strategy in these terms, is the carrying of many small tools within a size range between 1.5 and 3 times the minimum usable size, determined using gross measures of tool size. These data show that in contrast to the expectations of risk minimization technologies, it may be unrealistic to expect multifunctionality as an important technological concern, since there is simply more 'payoff' to packing several smaller and more functionally specialized implements (Kuhn 1994). Kuhn (1994:427) described mobile tool kits as tools that 'mobile individuals keep with them most or all of time, implements that are subject to virtually continuous transport'.

1.2.2 Overall strategies of technological organization

It is unrealistic to expect uniform patterning in technological organization as time, energy, and risk are responded to with massive technological diversity. It is equally unrealistic to expect uniform patterns of curated or expedient stone tools to account for all formal variation (Nelson 1991:62). Expedient technology refers to implements used immediately

and, curated technologies refers to those used for extended periods and tasks. Expedient and curated technologies can be interwoven in the archaeological record, and so cannot be reliably theorized as mutually exclusive strategies. For example, high risk situations could incorporate both expedient and curated technologies, dependent on the situation within day to day foraging. Theory of technological organization tested by archaeological data must be able to cope with this phenomenon, and recognize the role stone tool assemblages played in wider aspects of technological organization. One resolution of these issues is to model the overall strategies of technological organization beyond the contrast of expediency and curation, and hypothesize what role stone tool assemblages played in wider patterns of technological strategies.

One such approach to modelling stone artefacts within the wider notion of technological organization was offered by Hiscock (2006:81), who contrasted an extension strategy with an abundance strategy. The extension strategy maximizes the use life of tools, where such tools facilitate extensive resharpening, minimizing the need for frequent replacement. This strategy allows a small number of highly extendible and adaptable tools to be carried. The abundance strategy focuses on maximizing the number of tools produced per unit of stone. In this strategy, large quantities of suitable tools are produced which can be used interchangeably, but do not facilitate the greater rates of recycling and maintenance of the extension strategy. Hiscock's (2006) abundance and extendibility strategies partly resolve the analytical issues identified by Kuhn (1994), surrounding the benefit of multifunctionality in tools according to mass and reduction levels. An abundance or extendibility strategy can be better suited to local conditions, and supersedes the rudimentary expectations of maintainability and multifunctionality being correlated to contrasts of expedient or curated technologies. Nelson (1991:70) also distinguished between tool flexibility, where forms change to achieve multifunctional demands, and versatility, where tools maintain regularity in form while meeting multifunctional demands (see Shott 1986:19 for minor differences). Thus maintainability means more than just extension of use life, when considered within a wider technological strategy. Different strategies, whether focusing on abundance or extendibility (Hiscock 2006), or the differing application of flexibility and versatility (Nelson 1991), are ultimately suited to local conditions. Some environments and social systems will favor some technologies at the expense of others (Bleed & Bleed 1987:189; Torrence 1989:59), so the role tools play in the overall strategy must be considered. Perhaps most pertinent to the adoption of various strategies is the availability of raw materials.

1.2.3 Raw material availability

As an underlying cause of stone tool variability, the abundance and quality of raw materials could be the central factor in determining different technological strategies (Andresky 1994; Bamforth 1986). Contrary to the tenets of Binford's (1979:35) technological organisation

theory – where curated and expedient technologies are used respectively in logistical and residential mobility patterns – the availability of stone is a more proximate constraint on any given reduction sequence. For example, highly mobile populations would not necessarily produce curated or extendable tools, if good quality raw materials were readily accessible at needed locations (Andrefsky 1994:23). Conversely, if sedentary populations did not have access to suitable lithic raw materials, the production of expedient tools would not necessarily be a common practice (Andrefsky 1994:23). In recognising these challenges to modelling the underlying causes of stone artefact variability, raw material availability also presents one great benefit to the archaeologist: In many contexts the raw material availability of a given study area can be reasonably reconstructed from modern geological data and observations of knapping quality. By observing the abundance and quality of raw materials within a study area, it is possible to theorise how these variables affected the reduction of stone, although any cultural taboos surrounding access are unlikely to be appreciated.

The distribution of suitable stone does not necessarily correlate with the active need for stone tools in social and ecological tasks; therefore, material must often be transported. Transportation of stone away from their abundant source has evoked a distance decay principle, which holds that the further away from the source, the more there is a need to conserve and maintain stone technology. This relationship can be described as a decaying exponential (Goodale et al. 2008), which encourages people to keep existing tools usable for longer, when access to replacement material is limited, or unknown. Raw material diversity scales on the other hand, are an exponentially decreasing function of raw material quality. Diversity is highest when quality is lowest (Goodale et al. 2008:323). One implication of this is that high quality materials are focused on when available, and a wider range of materials are procured when availability is lower. Raw material availability must therefore be reasonably well understood if archaeologists are to use stone artefact variability to inform on past human lifeways.

1.2.4 Evolutionary approaches and the inheritability of technology

The preceding discussion of technological organisation theory has a clear focus on economic rationale, even in social aspects of foraging risk, perhaps at the expense of discerning the origins of these strategies in terms of evolutionary forces. Descent with modification, the core principle of evolution (Darwin 1859), is increasingly being applied to stone artefact variation (Eerkens & Lipo 2007; Kempe et al. 2012; O'Brien et al. 2012; Schillinger et al. 2014a, 2014b; Waguespack et al. 2009). All people inherit not only genetic traits, but cultural traits via social learning. Cultural traits are inherited through a common descent, whereby information is passed on through individuals and social groups. The transmission of this information is subject to evolutionary forces, where the information can be modified via error or innovation, before being passed on (Eerkens & Lipo 2007:245-246), a concept

referred to as cultural transmission theory [CTT]. CTT can be used to model common artefact morphologies, and the innovation of novel technologies. People continually acquire, modify, and pass on modified information, hence, the CTT process is fundamentally based on the interaction of both individual experimentation and innovation, as well as social learning and replication (Eerkens & Lipo 2007:242; see Sterenly 2012).

1.2.5 Design of technology

The sequences by which stone is reduced into tools requires some level of planning. Planning can be considered in terms of the immediate configuration of stone units to be reduced (Moore 2013), or in some instances, higher levels of planning or design will be required to produce complex technologies, or be able to budget stone for prolonged use (Hiscock 2014). Artefact design has been one focus of human behavioural ecology (e.g. Bettinger et al. 2006; Bright et al. 2002; Ugan et al. 2003), where rather than predicting functional designs from discarded tool morphology, the design of technology is considered within ecological frameworks. Nelson (1991:66), for example, describes five design variables of stone tools: Reliability, maintainability, transportability, flexibility, and versatility.

Design of artefact form is most often recognised by a series of structured actions geared to produce a specific morphology, such as pressure flaked bifaces (Wilson & Andrefsky 2008). To identify design stages associated with specific forms, archaeologists must essentially do the opposite of what many reduction sequence analyses seek to do, by demonstrating regular, repeated, and deliberate manufacturing stages within a reduction sequence. This means that different artefact morphologies must be shown to not occur through edge maintenance and the gradually increasing extent of reduction, but rather have both discrete manufacturing and use stages.

The preceding review of the underlying causes of stone artefact variation provides a theoretic base for interpreting the data presented in the following chapters. The following section provides background on the archaeology of Australia and the Kimberley region specifically.

1.3 The Archaeology of the Kimberley

...If humans are variably responsive to these factors, the relative success and stability of their adaption will also vary... (Binford 1978:453)

The factors that Binford refers to in the quote above are ecological, and ecological models of Australian prehistory have a long and active history within Australian archaeology (Gould 1967; see Veth et al. 2000). Australian environments and ecological resources underwent major change during the Holocene, and humans are expected to have adjusted their

behaviours in adaptation to these changes. This hypothesis is tested in this thesis. The following establishes the background to this research, which reflects how Australian archaeologists began and continue to debate ecological models, particularly those engaging with the mid Holocene period.

The following section briefly discusses the research history of the Australian archaeological record. The typological context of stone tools in Australian prehistory is first reviewed, which provides the background to the historical interpretations of point technology. It is shown that while the validity of unifacial and bifacial point typologies have been debunked in some areas, there is a lingering typology in the Kimberley region. Additionally, the report of backed points in this region raises further issues surrounding point typology. Following this, alternative explanations for Holocene artefact variability are reviewed, including diffusion, hafting, demographic, and ecological models.

1.3.1 The observation of types in Australian prehistory

Typology was the founding approach to Australian stone artefact analyses (Etheridge 1890, 1891; Kenyon & Stirling 1900; Smyth 1876). The later exhaustive typological systems developed by McCarthy (1948, 1949, 1958, 1963, 1964, 1967; McCarthy et al. 1946), provided the basis for many typological assumptions of research conducted in the past few decades (Hiscock & Attenbrow 2003:240). Typology provided the 'evidence' used for the first Australian prehistoric sequence models (Hale & Tindale 1930; McCarthy & Noone 1946; Mulvaney 1969; Mulvaney & Joyce 1965). The presence or absence of the most prolific types, including backed artefacts, unifacial and bifacial points, adze tulas, and edge ground axes (Figure 1.3) were used to create a three phase temporal model (Lampert 1971; Mulvaney 1969). The earliest and longest phase was recognised by the total absence of regular types, labelled the core tool and scraper tradition (Bowler et al. 1970). The following phase was recognised by the abundance of these types, and became known as the small tool tradition (Gould 1969:235, 1977:89-90). The final phase, marked by the decline or absence of these types, was later described as the lesser tool tradition (Campbell 1982:62). More exhaustive reviews of the history of Australian stone tool analysis are available (Fullagar 2004; Hiscock 1983; Hiscock & Clarkson 2000; Holdaway 1995; Mulvaney 1977), although it is the interpretation of these artefact types that has occupied the most attention of Australian archaeologists. This influence is expressed in the continued grappling with a technological history, essentially revolving around the interpretation of these small tool tradition typologies.



Figure 1.3 Artefact types of the small tool tradition.

1.3.2 Simple technology and a bimodal prehistory

Archaeologists have depicted Pleistocene technology as synchronically and diachronically stable (Lampert 1971; McNiven 2000; Mellars 2006; Moore 2013; Jones 1977; Shawcross 1998). This premise mostly extends from the perceived lack of regular typologies in Pleistocene lithic assemblages, but also the lack of comprehensive studies of Pleistocene technologies, which is further compounded by the small sample sizes in most Pleistocene-aged assemblages (Allen 1996:148).

The widespread innovation of edge ground axe technology following colonisation, found at sites such as Malangangerr, Nawamoy, Nauwalabila, Sandy Creek, Nawarla Gabarnmang, Widinggarri, Carpenter's Gap 3 and Miriwun (Figure 1.1), provides counter evidence to the widely held notion of simple technology (Bird et al. 2005:1065; Dortch 1977; Geneste et al. 2012:5; Jones & Johnson 1985:216; Morwood & Trezise 1989:81; O'Connor 1990:194, 246-251; O'Connor et al. 2014; Roberts et al. 1993; Schrire 1982:84, 107, 118, 143). Edge ground

axe technology involves procuring volcanic materials susceptible to grinding and bifacial reduction, as well as transport to suitable grinding locations. While no organic evidence has been recovered, waisted edge ground axes recovered by Schrire (1982) in Arnhem Land, and the waisted axes from Kosipe and the Huon Peninsula in the northern part of Pleistocene Sahul (Anderson & Summerhayes 2008; Groube et al. 1986; Summerhayes et al. 2010) (Figure 1.1), strongly suggest that this early technology was hafted.

Despite this evidence of Pleistocene technological complexity, the concept of simple and unchanging Pleistocene technology, reflected in both the lack of typological regularity until the Holocene, and the comparison of Australian assemblages with those from the European Palaeolithic (Akerman 1852:171; Balme & O'Connor 2015), is perpetuated by some researchers (Mellars 2006:798; Moore 2013:1-3). The more recent studies discussing this apparent simplicity (Mellars 2006; Moore 2013), ignore the implications of complex artefact life histories in the Pleistocene (Hiscock & Attenbrow 2003), the presence of backed artefacts and thumbnail scrapers in the Pleistocene (Cosgrove et al. 1990:71; Slack et al. 2004), the world's earliest evidence of edge ground axe technology (Geneste et al. 2012), pigment art from Pleistocene contexts (O'Connor 1995:59; Roberts et al. 1990, Roberts et al. 1994), and Pleistocene shell beads (Balme & Morse 2006; Balme & O'Connor In Press). Because of the focus on typology; however, there has been a deeply embedded notion that Australian prehistory has only one major phase of technological change (Mellars 2006).

Temporal change in stone artefacts across Australia has consistently been modelled within an older and younger, or underlying and overlying, stone tool industry (e.g. Bowdler & O'Connor 1991; Cundy 1990:28; Holdaway 1995; Dortch 1977), which Dortch (1977:129) for example, identified as the only major event in the prehistory of Western Australia. The signal for this temporal change was the presence of any elements of the small tool tradition. The notion that technological change was a temporally unanimous and interconnected event is no longer tenable. Small numbers of backed artefacts have been reported in early Holocene and late Pleistocene sites (Hiscock & Attenbrow 1998, 2004; Slack et al. 2004:135-136), although these are found more numerous between 4,000 and 2,000 years ago. The retouched flakes, which archaeologists often recognise as thumbnail scrapers, are also known to have developed during the Last Glacial Maximum [LGM] in Tasmania (Cosgrove et al. 1990:71). Points from the Northern Territory have been dated to as early as 6,000 years ago (Hiscock 1999:98; Jones & Johnson 1985:206), and are found more numerous between 3,000 and 1,500 years ago. In the Kimberley, several sites have produced early points dated to between 6,000 and 5,000 years before present (O'Connor 1995, 1999: 73, 103; O'Connor et al. 2008), although most points from the region are reported with dates between 3,500 and more recent times (Dortch 1977:109-111; Fullagar et al. 1996:764; Harrison 2004:4; Harrison & Frink 2000:10-11; Veitch 1999:342; Ward et al. 2006:8, 13). While the early dates no doubt have their critics due to problems such as the vertical

movement of small objects in deposits, there have been no credible refutations that explain all of the early examples. It appears that the development of these diverse retouched tools began earlier than previously thought. Contra to earlier models, temporal variation across Australia and within regions is also highly variable.

There is; however, a demonstrated pattern of proliferation around the mid to late Holocene. It now seems most likely that the early observation of backed artefacts and points represents low rates of production, unlikely to be detected by archaeology, and the mid to late Holocene period in which these tools were more frequently manufactured is more visible in the record (Hiscock & O'Connor 2006:2).

In addition to this improved chronology, researchers have demonstrated gradual change in stone technology before the earliest observed types (Clarkson 2007; Clarkson & David 1995; Hiscock & Attenbrow 2003). For example, Clarkson and David (1995:40) demonstrated that blade production gradually developed in Wardaman Country from the late Pleistocene, and that these early blade technologies were an antecedent, or even prerequisite, to the technological developments that occurred in the mid to late Holocene. Clearly there is no synchronous arrival or development of what was termed the small tool tradition.

While the temporal unity of the small tool tradition has gradually been broken down with these new studies, the spatial distribution of these technologies is still poorly understood. Most archaeologists accept that backed artefacts are restricted to eastern and southern Australia, while bifacial points are restricted to the northern portion of the continent (Flood 1995:222, Fig. 15.1; Hiscock 2001:56-58, 2014; Hiscock & Hughes 1980; McCarthy 1976:95; Morwood 1989:44; Mulvaney 1969:123; Pearce 1974:301-302; Smith & Cundy 1985). This trend encouraged researchers to argue that a northern limit could be applied to the distribution of backing in Australia, found below 20 degrees south latitude (McCarthy 1977:255; Smith & Cundy 1985:35). Bifacial points have also been reported as far south as Brisbane, at sites such as Platypus rock shelter and Cooloola (McNiven 1993). Several researchers have since produced varied distribution boundaries (Allen 1996:150, Fig. 2; Clarkson 2007:4; Hiscock 1994a:274, 2007:149; Smith & Cundy 1985:34), with the most prominently cited boundaries illustrated in Figure 1.4. These boundaries have constantly been reworked to accommodate new data, while ignoring more isolated exceptions to the rule (see Allen 1996:150, Fig. 2), which raises the question of the value of applying any such spatial boundary to these technologies (Davidson 1983:34).

In considering these spatial boundaries, particularly for backing, there are several exceptions to the rule that require clarification. For example, backed artefacts termed Kimberley backed points, have been reported by Dortch (1977:117) and O'Connor (1999:72, 73) in the Kimberley region. Akerman et al. (2002:28) mention the presence of backed points in the Keep River sites, although no data are provided by Fullagar et al. (1996) or

Ward (2004) on these reported backed tools. In the Northern Territory and northern Queensland, several researchers have reported either isolated backed artefacts, or forms of backing retouch on points and scrapers (Akerman 1998; Allen 1996:150; Brayshaw 1977:281; Flood 1970:47; Hiscock & Hughes 1980:93; Kamminga 1977:208–211; Lamb 1996; Morwood 1989:18, Table 7, 29, Table 11, 39, Table 15; Schrire 1982:40). Little attention has been given to these artefacts as part of the broader spectrum of point technology from northern Australia or to the relationships with backed artefacts from elsewhere in Australia.

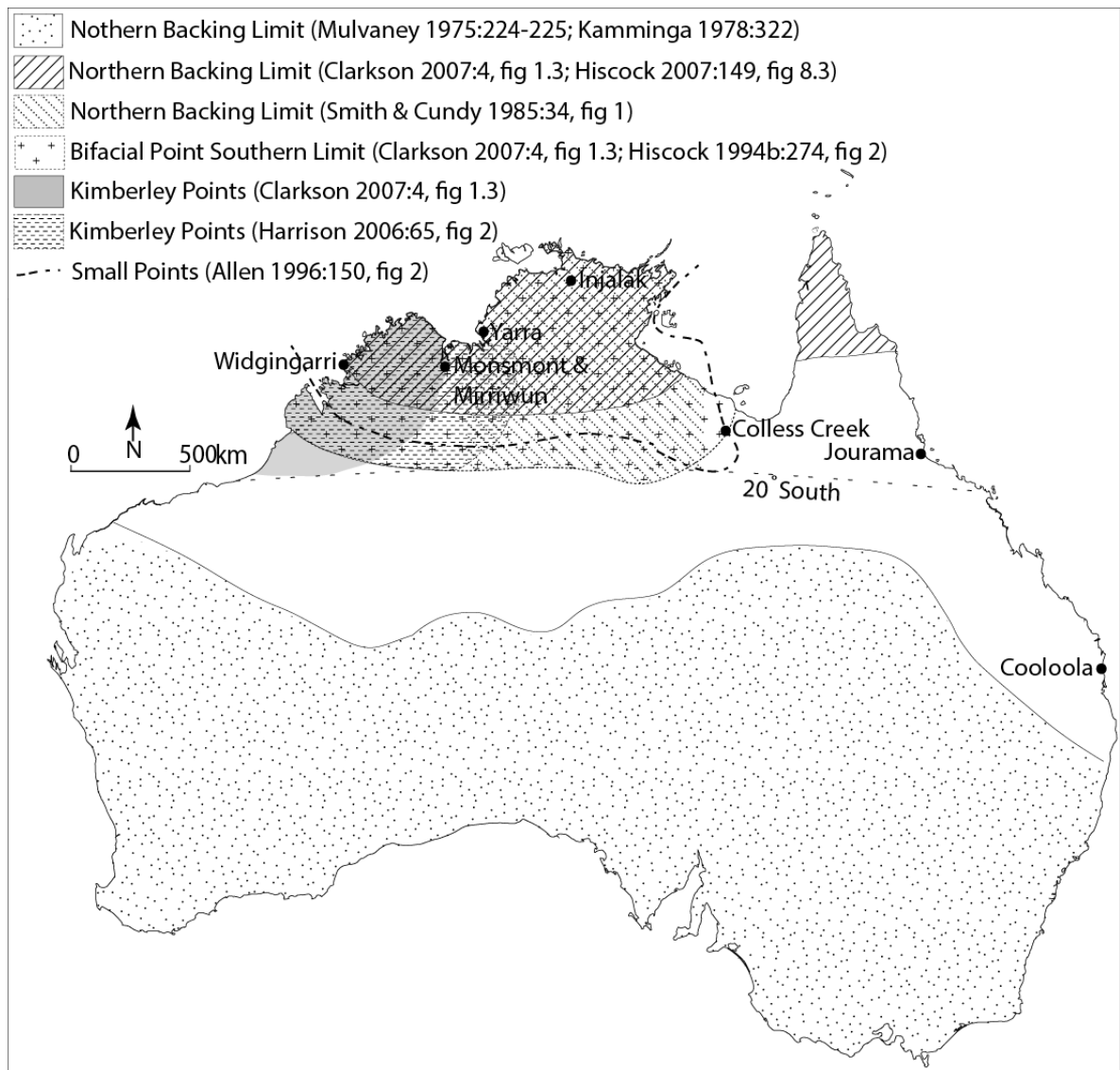


Figure 1.4 Varied depictions of spatial distributions of backing and point technology.

1.3.3 The recognition of point reduction and the vestiges of typology

In northern Australia, archaeologists are beginning to delineate a complex life history for points, yet despite researchers calling for an abandonment of typological validation testing (Clarkson 2008:287), these technologies are still understood from typological models in the Kimberley. Points in northern Australia were both unifacially and bifacially retouched to varying degrees, which were interpreted as mutually exclusive types since the earliest observations (Davidson 1935:160-162). This typological model of point variability has not been tested in the Kimberley region with reduction sequence analyses.

In application, the categorical division of these point types has been ad hoc, totally lacking any explicit or systematic framework. These qualitative retouch observations are problematic, as evinced in several studies of points from the Kimberley, where points with bifacial retouch are interpreted as part of unifacial point technology (Blundell 1975:250; Flenniken & White 1985:148; Mulvaney 1975:219; O'Connor 1999:72, Fig. 5.13, no. 2), or an intermediate category independent of either type (Dortch 1977:113; Flood 1970:41). There appears to be consensus that bifacial retouch applied to the bulbar surface of points, is nonetheless, a retouch strategy associated with unifacial point technology, and so independent of 'true' bifacial points (Flenniken & White 1985:148; Mulvaney 1975:219). This assumption is probably partly built on an analogy to the Pirri points found mostly in southern and central Australia (Campbell 1960; see Akerman et al. 2002:14). Others have suggested that cross sectional shape controls the application of unifacial or bifacial retouch on northern points (Flenniken & White 1985:148; O'Connor 1999:76).

The accepted model of point variability was that unifacial and bifacial points represented mutually exclusive designs. This bipartite division of unifacial and bifacial points, which Hiscock (1994a) referred to as the divergent model, not only impedes analyses that test for continuous morphological change (Clarkson 2007:102), but prevents the extrapolation of point life history, by polarising point types as end products. It is this divergent model for point variability that has been advanced in the Kimberley, yet samples sizes were very small and no statistical testing was carried out to verify this model.

Excavation of sites in the Kimberley region, listed in Table 1, uncovered samples of less than 50 points, and most less than 10 (Table 1). The 42 points from the Widgingarri shelters comprise the largest excavated assemblage of points from well dated contexts in the region (O'Connor 1999:64-78). The larger numbers reported by Dortch and Zlatnik (nd), have not been included in the analyses presented in Chapter 3, since they are problematic to associate with stratigraphic context and radiocarbon dating. In contrast, excavated sites from the Northern Territory have uncovered much larger point assemblages (Table 2), which no doubt contributes to the insightful depictions of point life history in these areas. Clarkson's (2006:99) study of points from Wardaman Country in the Northern Territory

included 456 complete points from four excavated rock shelter sites [Nimji (aka Ingaladdi), Garnawala 2, Jagoliya, and Gordolya]. Based on the figures provided by Flood (1970:34), Yarrar shelter recovered at least 1,273 points and point fragments (see Hiscock 1994a:75, table 2 for different figures). Likewise, Hiscock's (1994a:77, 79) reanalysis of the Jimede 2 assemblage included 187 points, and his samples from Lawn Hill included 35 points from surface sites (1988:571; 1994a:79), with 190 additional points recorded during survey (1988:593, Table 7.10). The data given in Tables 1 and 2 indicate that the percentage of points as a portion of the overall assemblage is consistently low; however, the greater frequency of points in studies from the Northern Territory has certainly helped promote the reduction continuum model, probably by capturing more variation in discarded point morphology.

Table 1. Frequency of reported points from Kimberley excavations

Kimberley sites			
Site	Data	Points	% of assemblage
Kununarra	Dortch & Zlatnik nd:69	284	-
Monsmont	Dortch & Zlatnik nd:50	117	-
Miriwun	Dortch & Zlatnik nd:37-38	83	-
Pincombe Range	Personal observations	<50	<0.5%
Widgingarri 1	O'Connor 1999:34, 64-65, Table 4.5	42	0.45%
Lennard River 9	Blundell 1975:346, Table 30, 727, Table 97	39	2.71%
Kununarra Arched Shelter	Bradshaw 1986:239, Table 108, 234 Table 106	38	0.28%
Wilinyjibari	Harrison 2004:4, Table 1	30	-
High Clifty	O'Connor 1999:102, Table 6.5, 104, Table 6.7	25	1.17%
Pilchowskis Crossing	Bradshaw 1986:239, Table 108, 234 Table 106	24	1.05%
Mount Elizabeth 2	Blundell 1975:319, 698-701, Table 81-83	19	10.38%
The Grotto	Bradshaw 1986:239, Table 108, 234 Table 106	18	0.13%
Lennard River 12	Blundell 1975:346, Table 30, 744-748, Table 106-107	12	1.85%
Ngurini	Veitch 1999:211, Table 8.6, 234, Table 8.16	11	0.1%
Goorurarmum	Ward et al. 2006:15	9	-
Lennard River 2	Blundell 1975:346, Table 30, 710, Table 88	8	9.41%
Karlinga	Ward et al. 2006:15	8	-
Thompsons Cave	Bradshaw 1986:239, Table 108, 234 Table 106	6	6.66%
Lennard River 3	Blundell 1975:346, Table 30, 714, Table 90	5	3.4%
Windjana Water Tank Shelter	O'Connor et al. 2008:79, Table 5	4	0.95%
Wundalal	Veitch 1999:269, Table 9.5, 286, Table 9.11	4	0.18%
Moochalabara	Bradshaw 1986:239, Table 108, 234 Table 106	2	0.12%
Bangorona	Veitch 1999:307, Table 10.5, 324, Table 10.14	2	0.15%
Lennard River 10	Blundell 1975:346, Table 30, 736-737, Tables 102-103	1	0.3%

Table 2. Frequency of reported points from Northern Territory excavations

Northern Territory Sites			
Site	Data	Points	% of assemblage
Yarra	Flood 1970:34, 38, Table 1 [based on minimum of 43,000 flakes] Hiscock 1994a:75, Table 2	2708 – Flood 735 – Hiscock	<6.29% 1.7%
Nimji	Clarkson 2007:66, 195-196, Table B.4 - B.5	794	1.28
Garnawala	Clarkson 2007:66-77, 202-203, Tables C.4 – C.5	202	1.79
Ngarradj Warde Djobkeng	Allen & Barton 1989:56, Tables 28, 29, 30	140	1.2%
Jimede 2	Hiscock 2011:76 Schrire 1982:197	102	<1%
Jagoliya	Clarkson 2007:208-214, Tables D.7 – D.10	99	1.14
Tandandjal Cave	Macintosh 1951:197-198	~71	-
Scotch Creek	Smith & Brockwell 1994:94, Table 3 – 4 Based on minimal TNA	50	0.14%
Nauwalabila 1	Jones & Johnson 1985:192, Table 9.5, 200, Table 9.8	45	0.33%
Jinmium	Fullagar et al. 1996:760-761, Table 3 – 6	43	0.32%
Gordolya	Clarkson 2007:216-221, Table E.3 -E.13	15	0.44
Native Well 1	Morwood 1981:29, Table 11	14	0.14%
Native Well 2	Morwood 1981:39, Table 15	13	0.33%
South Alligator Wetlands	Brockwell 1989:26 - 30, Tables 4.5 – 4.11	7	0.029%
Anbangbang 1	Jones & Johnson 1985:55 Table 4.7, 56 Table 4.8	1	0.11%
Spirit Cave	Jones & Johnson 1985:71	1	0.14%
Turtle Rock	Morwood 1989:18, Table 7,	1	0.02%
Punipunil & Granilpil	Ward 2004	No data	-
Yiboio	Jones & Johnson 1985:72	-	-
Ki'na	Meehan et al. 1985:117	-	-

Several of the larger samples of points from the Northern Territory (Figure 1.5) have been subject to quantified reduction sequence analyses, analyses which have demonstrated that unifacial and bifacial points are part of an underlying reduction continuum. The first Australian archaeologist to recognise that unifacial and bifacial point types could be better explained by varying degrees of reduction was Macintosh (1951:200), who analysed the Tandandjal Cave assemblage in the Northern Territory. The most prolific proponent of the point reduction continuum model has been Hiscock (1988, 1994a, 1994b, 2006, 2009, 2011), who also analysed assemblages from the Northern Territory and northern Queensland. Hiscock (1994b; 2006:77-78) demonstrated a single ramified reduction sequence for points at Lawn Hill and Jimede 2, where unifacial points were transformed into bifacial points, and sometimes recycled into other non-pointy tools, such as the bifacial ovals identified by Schrire (1982) (see Hiscock 2009:84-85, Fig. 6.3). Variation in retouch intensity was affected primarily by blank morphology, the distance from replacement

material, and unique variants of artefact use life (Hiscock 2009, 2011). These factors were responsible for the varied levels of retouch intensity observed on points, and there was no credible evidence that traditional point types were end products within this sequence. The continuum model has since found empirical support across the Northern Territory (Clarkson 2006, 2007, 2008; Cundy 1990; Maloney 2010; Roddam 1997), which has led researchers to call for a regional comparison of point assemblages (Clarkson 2006:105; Hiscock 1994a:82), particularly from the Kimberley, where prior to the analysis presented in Chapter 4 the typological model was untested with reduction based methods.

Studies of point technology from the Kimberley region (Figure 1.5), have rejected the point reduction continuum model (Akerman et al. 2002:15; Blundell 1975:393; Flenniken & White 1985:148; O'Connor 1999:76). One Kimberley researcher, Blundell (1975:288), entertained the possibility of a continuum between unifacial and bifacial point types, but argued in support of mutually exclusive point types after observing bifacial points being reduced from cobbles and unifacial points being reduced from blades (Blundell 1975:89, 275, 288). Archaeologists working in the Kimberley have not found any evidence that compellingly demonstrates the transformation of unifacial points into bifacial points. O'Connor (1999:76-77) for example, concluded that bifacial points could not have been the end product of a reduction sequence from unifacial points in the Widgingarri assemblages, since firstly, unifacial and bifacial points were not contemporaneous in the excavated sample, and secondly, the cross sectional shape of point types indicated technological divergence.

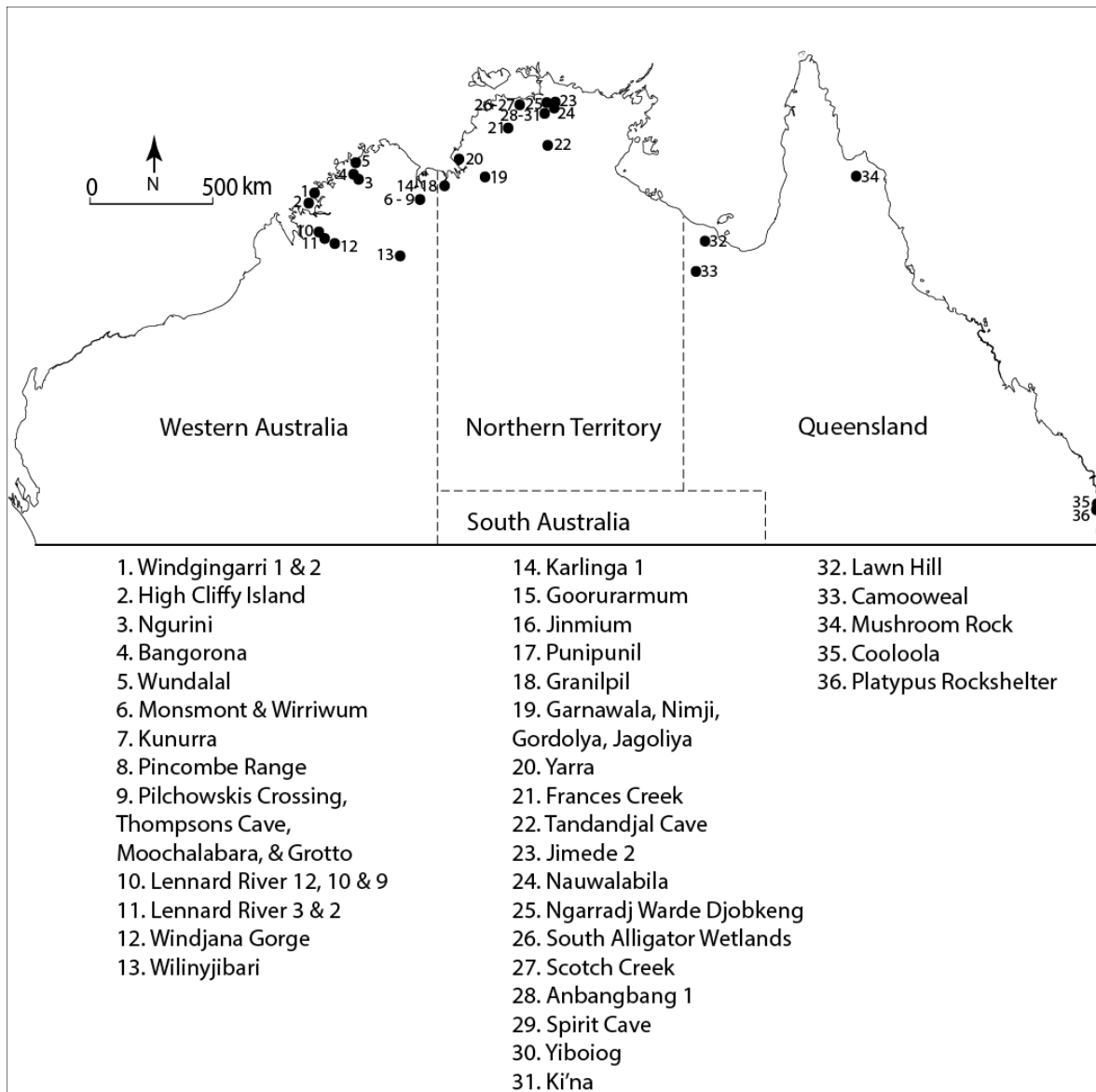


Figure 1.5 Map of northern Australia showing excavated sites where assemblages of points were recovered.

Cross sectional shape does not appear to control the application of bifacial retouch in the Northern Territory point assemblages. Instead, Hiscock (1994a) quantified the spread of retouch across point surfaces from Jimede 2 and Lawn Hill, to show that most points followed a pattern of marginal unifacial retouch and were gradually transformed into bifacial points with increasing retouch intensity. In Wardaman Country, Clarkson (2006, 2007) demonstrated a similar pattern, but used the segments of the Index of Invasiveness (Clarkson 2002) to illustrate the spread of retouch across points in finer detail (later replicated by Hiscock 2006). These studies quantified the spread of retouch independent of point typology, which not only shows the folly of the types, but illuminates a more complex relationship between retouch intensity and changing point morphology.

The life history of points in the Northern Territory during the mid to late Holocene was far more dynamic than the typological model had revealed. Instead of producing two discrete morphologies, people produced standardised blanks, and gradually maintained the margins and distal tip of points, through a long and vibrant life history. At Lawn Hill, the extent of reduction on points was largely determined by the distance away from replacement material, seeing lightly retouched points reduced into heavily reduced, often bifacial points. Bifacial retouch provided a way to keep points usable for longer, rather than producing specific functional forms, with the consequence that the constantly changing morphology of these Northern Territory points is related to maintenance rather than functional design (Clarkson 2007:110, 139, 141). From these studies there are emerging regional trends in the retouching patterns of point technologies.

In the Wardaman assemblages, for example, Clarkson (2007) found that points typically begin being retouched on the dorsal face first, with an initial focus on the distal right margin (2007:104, 109). As retouch intensity increases, the distribution of retouch on points becomes increasingly likely to become bifacial, with the first stages of bifacial retouch typically being added to proximal portions of points (2007:104, 109). Clarkson suggested that this pattern of proximal trimming was related to point hafting. This retouch pattern is not dissimilar to that demonstrated in the Jimede 2 and Lawn Hill assemblages by Hiscock (1994a:77-80, 2006, 2009:84, 2011:78). Proximal thinning of the Jimede 2 points; however, was not found to be related to increasing retouch intensity, or the curvature of the point butt (Hiscock 2009:77). Maloney (2010) showed that points from Frances Creek surface collections followed a similar retouch pattern to these regional trends (2010:91-95), where the first stages of bifacial retouch were added to the proximal portion of points, with the proximal curvature gradually increasing (Maloney 2010:96-97).

Further differences in point life history include methods of recycling. In Wardaman Country, recycling took the form of burinate retouch following transverse snaps, and rejuvenation of pointed morphologies, while those from Jimede 2 were heavily reduced into bifacial forms that totally lack the pointed shape (Hiscock 2009:84-85, Fig. 6.3). Instances of burinate recycling following transverse snaps were also reported by Dortch and Zlatnik (nd:44) in the upper units of Miriwun in the Kimberley. Unfortunately, the intricate details of point life history in the Kimberley are unknown, since most research in this region has focused on point technology in the recent past (Akerman et al. 2002).

1.3.4 Point technology in the recent past

Within the recent past several new point technologies emerged, including the Wanji biface in parts of the Northern Territory (Akerman & Bindon 1995:90-191), the production of large Leilira blades (Akerman 2007), metal shovel nose spears (Cundy 1989), and pressure flaked bifaces. The Kimberley region is exceptional as the only region of Australia where people

produced pressure flaked bifaces, known to Australian archaeologists as Kimberley Points or Dentate Kimberley Points (Figure 1.7) [note: this thesis uses the term Kimberley Point synonymously with pressure flaked biface, and independently of bifacial points produced by direct percussion]. Small samples of bifaces have been reported from other areas, such as Camooweal (Barkly 1979; McCarthy 1976; Moore 2003a, 2003b; Rainey 1991); however, nowhere else in Australia did pressure flaking become as prolific as in the Kimberley.

Kimberley Points are pressure flaked bifaces with distinct marginal serrations (Figure 1.6) produced within the Kimberley region of northern Western Australia. The dating of Kimberley Points is far less clear than the antiquity of mid Holocene points, largely due to their infrequent recovery from datable archaeological contexts. While pressure flaking is likely to have been occasionally used in earlier technologies (Flenniken & White 1985:148), there is undoubtedly a proliferation of pressure flaking techniques associated with Kimberley Points, although there is no convincing data to suggest precisely when this technology developed.

The first attempts at dating Kimberley points used their observation in recent Aboriginal society, to suggest a historical antiquity (Davidson & McCarthy 1957:447, 450; McCarthy 1976:44; White & O'Connell 1982:112). Akerman and Bindon (1995) and Akerman et al. (2002) advanced a prehistoric age for Kimberley Points, as well as suggesting the Dentate Kimberley Point was older, although they could not provide an age estimate due to the lack of radiocarbon dating. More recently, Newman and Moore (2013:2615) suggested that pressure flaking was present in the Kimberley from 4,500 years ago, citing Bowdler and O'Connor (1991). Rainsbury (2014:51) suggested a date of 2,800 years, citing Veitch (1996). Kimberley Points have been reported within contexts ranging from 3,000 years to modern times (Dortch 1977:109; Harrison 2004:4; Harrison & Frink 2000:11; O'Connor 1995:59; 1999:71, 76; O'Connor et al. 2008; Ward 2004:2; Ward et al. 2006:18). Harrison's (Harrison 2004:5; Harrison & Frink 2000:13) suggested age of 1,400 years, and O'Connor's (1990) suggestion of 1,000 years, both rely on debitage analysis that has elsewhere been refuted as a reliable indicator of pressure flaking (Ammerman & Andrefsky 1982; Andrefsky 1986, 2005:119). Indigenous oral histories and mythologies are consistent in suggesting that Kimberley Points were produced after the creation of the direct percussion points (see Akerman et al. 2002:15-17; Harrison 2006:73; Tindale 1985:1, 26-27). The development of Kimberley Points appears to postdate the earlier direct percussion points, perhaps within the recent past, but certainly prior to European contact (Akerman & Bindon 1995:97-98). Evidence pertaining to the dating of direct percussion points and Kimberley Points in the study is presented in Chapter 3.

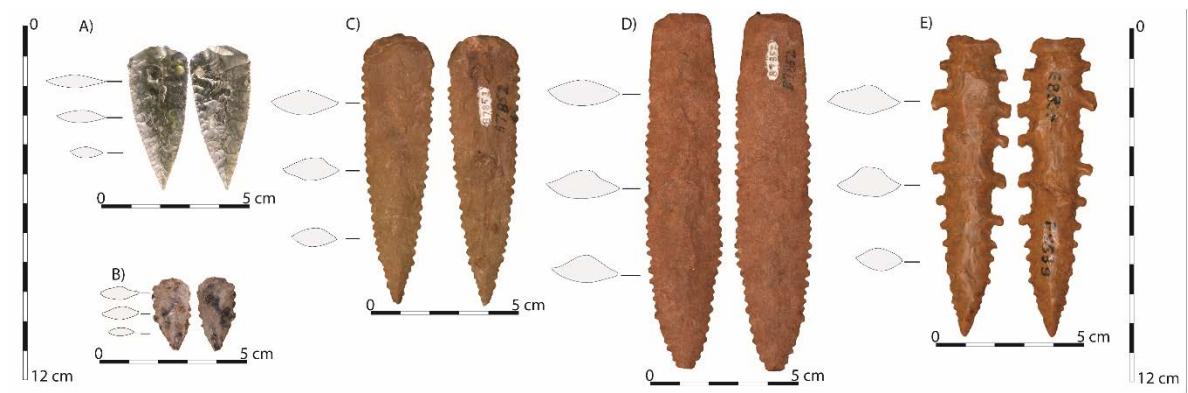


Figure 1.6 A range of pressure flaked bifaces from the Kimberley

Manufacture and distribution of Kimberley Points was initially confined to the Kimberley region, although trade resulted in a much wider distribution, and Kimberley Points were highly prized trade objects. Isolated observations of pressure flaked bifaces have been reported from the Tennant Creek area (Spencer 1928:17 Fig. 147), the Alligator Rivers (Akerman et al. 2002:22), Central Desert regions (Gould 1980:141-143; Spencer 1928: 510-511; Spencer & Gillen 1904:675-676), the Gibson Desert region (Akerman et al. 2002:18), the Western Desert (Tindale 1985:12), and even as far east as central Queensland (Akerman & Stanton 1994:17), and the Gulf of Carpentaria (Davidson & McCarthy 1957:450). Manufacture outside of the Kimberley occurred in historical times, such as in Wardaman Country (Davidson 1935:170), Rottnest Island prison off the coast of Perth (Harrison 2002:361-363), and Barrow Island (pers. comm. Phillipa Hunter). On Rottnest and Barrow Islands the manufacture of Kimberley points relates to the forced translocation of Kimberley men. These distributions are illustrated in Figure 1.7.

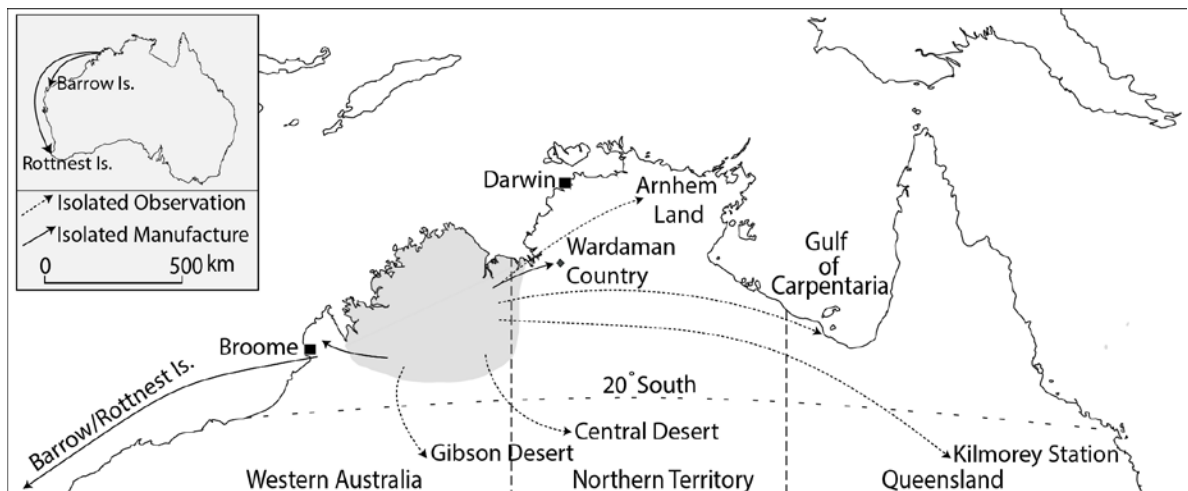


Figure 1.7 Distribution of Kimberley Points, showing isolated observations and manufacturing areas.

A rich ethnographic record exists from the early 19th century, which occasionally recounts parts of the manufacture of Kimberley Points, and observations of the role this technology played in Aboriginal societies at the time (Balfour 1903, 1951:274; Basedow 1925:367-370; Elkin 1928:110-113; Indriess 1937:59-62; Kaberry 1939:16, 165; Lommel [1954] 1997:6; Love 1917:25-26, 1936:93-95; Mitchell 1949:64; Petri [1954] 2011; Porteus 1931:112; Spencer 1928; Tindale 1985:8-11). Production models have now been outlined by several researchers (Akerman & Bindon 1995:94-95; Akerman et al. 2002:18-20; Love 1936:93-95; Moore 2000, 2015), all drawing heavily on these ethnographic observations. Europeans began collecting Kimberley Points in the 19th and 20th centuries when these items were part of an elaborate Indigenous trade network extending across the entire north-west region (Akerman et al. 2002; Blundell 1975:403; Redmond 2012). During this time, Kimberley Points began to be produced directly for a European market, and production is likely to have proliferated when trade for European commodities such as flour, tobacco, and new raw materials, was incorporated into Aboriginal subsistence (Harrison 2002:358, 364). During the latter half of the 20th century, Kimberley Points were commissioned by archaeologists such as Tindale (1985). Today, these bifaces are only produced and used for ceremonial activity, often sourced from a single expert knapper living in Tasmania.

1.3.5 The underlying cause of point technology

From the preceding archaeological background and existing studies of point technologies, four main hypotheses serve as explanations of point technology. Each hypothesis will now be summarised. This section draws together the historic approaches to explaining Holocene technologies, with the theory surrounding the underlying causes of stone tool variability.

The diffusion hypothesis

The implied temporal and spatial unity of the small tool tradition promoted the hypothesis of an introduction from overseas, either by immigration of a new population, or introduction following contact with a new population (Allen & Barton 1989:119; Bowdler 1981, 1994; Bowdler & O'Connor 1991; Davidson & McCarthy 1957:393, 451; Dortch 1977:123; Evans & Jones 1997; Layton 1997:378; McConvell 1996; Mulvaney 1969:164). Researchers hypothesised that points and backed artefacts formed part of a package of introduced material culture, emphasising the coincident timing of these artefacts with the arrival of the dingo (Bowdler & O'Connor 1991; Dortch 1977:123; Flood 2001; Olsen & Glover 2004). The exact circumstances in which people did bring dogs to Australia will likely remain unresolved (Bellwood 2013:116); however, dating of the dingo and the development of points and backed artefacts has partially been resolved. The general consensus currently supports an antiquity of between 4,000 and 3,500 years ago for the arrival of the dingo, based on the recovery of dingo remains from dated Australian archaeological deposits (McBryde 1982; Milham & Thompson 1976; Mulvaney et al.

1964:498-507), and direct dating of dog bone from Timor Leste (Gonzalez 2013; Spriggs et al. 2003). DNA evidence may suggest an earlier date for the dingo, between 4,600 and 18,300 years ago (Oskarsson et al. 2013). Regardless, on current evidence the dingo has no temporal correlation with the development of backed artefacts or points (Bellwood 2013:116, 199; Brown 2013), since, as previously discussed, the earliest observed backed artefacts date to the late Pleistocene and early Holocene (Hiscock & Attenbrow 1998, 2004; Slack et al. 2004:135-136), with the earliest points dating to between 7,000 and 5,000 cal BP (Hiscock 1999; Jones 1985:291; Jones & Johnson 1985; O'Connor et al. 2008).

Given the expansion of seafaring populations during the mid to late Holocene throughout Melanesia, the Pacific, and Island South East Asia (Bellwood 2007:234; Bellwood & Hiscock 2013; Bowdler 1994), it is highly likely that cultures were in regular contact; however, the diffusion hypothesis for points and backed artefacts arriving in the mid to late Holocene is no longer tenable.

The hafting hypothesis

A shift, or innovation, in hafting techniques has also been hypothesised as an explanation for the development of points and backed artefacts (Jones 1979:456-457; Mulvaney 1969:153). Hafting has since been incorporated into ecological models (Clarkson 2007:155, 2008:302; Hiscock 1994b:278) and social signalling models (Johnson 1979:144), the latter are discussed in the following section. The evidence used to support the presence of hafting has had to be extrapolated from stone tool morphology, due to the rare recovery of organic hafting technologies. Qualities that resemble modern projectiles, such as a pointed shape and a small size, and observations of proximal thinning, have frequently been used as evidence of hafting in Australian points and backed artefacts (Allen & Barton 1989:121; Banning 2002:155; Clarkson 2007:155, 2008:302; Clarkson & David 1995:22; Davidson 1935:150; Flood 2004:225; Hiscock 1994b:277; Hiscock & Veth 1991:342; Holdaway & Stern 2004:266; Kamminga 1982:81; McCarthy 1967:40; Mulvaney 1969; Mulvaney & Joyce 1965; Mulvaney & Kamminga 1999:237). Even models that demonstrate the dynamism of changing point morphology retain an emphasis on the effectiveness of points as projectile tips (Clarkson 2006:104).

The recovery of organic hafting agents and shafts from the archaeological record is emphatically rare, which renders all conclusions of hafted spear heads as speculative, since they are based on a suggestive tool morphology (Brindley 2011). This assumption is embodied in the interpretations of Flenniken and White (1985:147-148), who clearly anticipate both a pointed morphology and projectile function as the central requirement of point technologies:

...The simplest type of point...was the unmodified 'pointed' true blade or linear flake...It required no modification in order to function successfully as a lethal

projectile point...If a flake or blade did not meet the knapper's concept of a 'point', modification by percussion and/or pressure was required... (Flenniken & White 1985:147-148)

While this statement is fraught with functional assumption, and attempts at deciphering the mindset of the knapper, the important detail here is the focus on an intended pointed morphology being indicative of a projectile function. Australian researchers have since refuted this simple mono-function for both points and backed artefacts (Brindley & Clarkson 2015; Hiscock 2006:78; Robertson et al. 2009:249, 297; Wallis & O'Connor 1998), and notably, it has been demonstrated that the pointed morphology is often transformed, losing the converging margins (Clarkson 2006; Hiscock 2006:77-78). The pointed shape is not solely indicative of hafted projectile use in the mid to late Holocene, given the dearth of recovered resins, and low frequency of diagnostic impact fractures in recent studies. Brindley and Clarkson (2015) and Brindley (2010) uses diagnostic impact fractures from experimental and archaeological data to argue that points were rarely used as projectiles. Furthermore, they suggest that projectile use was more likely to occur early in point life histories (Brindley & Clarkson 2015). The use of lightly retouched points as projectiles, particularly the more steeply angled unifacial points, could be argued to refute a long history of assuming adzing functions for such unifacial points (Davidson & McCarthy 1957:408; Dortch 1977:117; O'Connor 1999:74).

The assumed projectile function has also been used in social explanations of points. One such explanation suggested that points, and backed artefacts, were functionally superfluous as hafted projectiles, following a logic that spears were both effective, and ethnographically observed using a wooden tip (Peterson 1971; Veitch 1999:354; Walters 1989:219; White & O'Connell 1982:124-125). The major flaw in this explanation lies in the assumption that points and backed artefacts were manufactured as spear heads at all. While spears are undoubtedly useful without stone armatures, this explanation overlooks the complex and varied nature of point life history, and the limitations of ethnographic analogy (Binford 1972:86). Even experimental studies that have attempted to quantify the benefits of wood versus stone projectiles cannot accurately account for the multifunctional benefits of tools such as points, outside of a hafted projectile function (Elston & Brantingham 2002:104-105; Waguespack et al. 2009). The few studies that showcase hafting resins on backed artefacts were able to confirm that multiple hafting arrangements were employed (Boot 1993 Tables 8-11; Robertson et al. 2009:249, 297), with projectile tips or barbs being employed much less frequently, even rarely.

The importance of hafting has been central to attempts at explaining the proliferation of points and backed artefacts across so many areas during the mid to late Holocene. One explanation for increased production is an increase in conflict and warfare. The greater frequency of points between approximately 3,500 and 2,000 at Scotch Creek in the

Northern Territory for example, has been suggested to result from increased cultural interaction, causing competition and conflict following changes to estuarine environments (Smith 1995:40; Smith & Brockwell 1994:102). Others have pursued similar lines of argument for backed artefacts (Flood 1995:236), although there is only one, albeit one stellar, example of backed artefacts recovered in unambiguous conflict contexts (McDonald et al. 2007). Several researchers have also presented rock art images, purported to show lithic projectile use (Taçon & Chippindale 1994:15; Walsh 1994; Walsh & Morwood 1999). Ethnographic examples of Kimberley people using hafted points as fighting weapons, among other functions (Akerman et al. 2002:21), suggests that in the recent past these points were indeed used in conflict. However, extending these observations to points from the mid Holocene is far too presumptuous.

While many points were probably hafted as composite tools at some stage during their life history, the recovery rates of organic hafting agents and shafts will continue to inhibit a clear understanding of this aspect of the technology. Highlighting this rarity in the Kimberley, Wallis and O'Connor's (1998:10) residue analysis of points from Widgingarri yielded only two of 42 points with possible microscopic traces of hafting resin. The only other reported observations of hafting technology are associated with more recent Kimberley Points (Akerman 1978; Akerman et al. 2002), Leilira blades (Akerman 2007), or adze tulas (Tindale 1965).

These more recent forms of hafting technology are better informed with the benefit of ethnographic observation and collection (Akerman 1978:486; Akerman et al. 2002:21-22; Bindon & Lofgren 1982:119, Fig. 6; Newman & Moore 2013:2614, Fig. 1). Allen and Akerman (2015) and Akerman et al. (2002:20-21), have suggested that distributions of shaft materials, such as phragmite reed, could be responsible for changes in stone points. However, while this component of technology was surely an important factor in technological organisation, it also implies that all points were hafted in some similar fashion to those more recent examples. Perhaps the first great challenge to understanding point hafting in the mid to late Holocene, is the acceptance that recent Kimberley Points are markedly different from earlier points, so it is inappropriate to assume that the hafting arrangement would also be identical. Chapter 6 demonstrates this by reference to a partial point from CG1 which preserves hafting resin and impressions of the binding material used.

A technological response to environmental change

...an ingenious suggestion, but not a well demonstrated one... (White 2011:69)

The ingenious suggestion referred to above has also been described as the adaptive, utilitarian, ecological, or risk minimisation model, which advocates that backed artefacts and points were developed as a technological response to environmental change. Despite ecological models having a long history in Australian archaeology (e.g. Gould 1967, 1977,

1991; Hayden 1976; O'Connell 1977; see Veth et al. 2000 for review), it was not until Hiscock's (1994a, 1994b) revision of Holocene technologies that environmental change was considered a major driver of technological change. Hiscock (1994b) proposed that with the onset of climate change around the mid Holocene, people became increasingly mobile in response to less productive and less predictable environments. If environmental change made the distribution of resources such as fresh water, edible plant species, and game animals less dense, people would be forced to increase the territorial range they occupied (Kuhn 2012:76). The risk reduction model suggests people produced technologies that could provide greater economic return and reduce foraging risk. This model has gained increasing support following the analysis of point assemblages in the Northern Territory and northern Queensland (Hiscock 2002, 2006, 2009, 2011; Clarkson 2006, 2007, 2008).

The extension of point use life is thought to offset part of this foraging risk, by increasing the likelihood that foragers would have an adaptable and ready tool kit to exploit resources when they were encountered (Hiscock 2006:81; Veth et al. 2011:12). This technology reduced the frequency at which replacement raw material was needed, which would be advantageous when foraging in less familiar regions, where replacement raw material is not at hand, or access is unassured. Standardisation of point technologies has been argued to provide an additional benefit, by facilitating regular blanks, consistent morphologies for hafting, and predictable morphological transformations during maintenance (Clarkson 2007:150, 155, 160; Hiscock 1994b:278). The cost of this standardization, particularly in producing regular blank morphologies, has been suggested as being recouped by the extension of point use life (Clarkson 2008:302). A range of social factors are also embedded into these risk minimization models, discussed in the following section; however, it is first necessary to expand on why foraging risk is thought to have increased during the mid Holocene.

The temporal correlation of risk reducing technologies with predicted changes in ecological resources relies on environmental proxy data. Many researchers have used proxy records of El Nino-Southern Oscillation [ENSO] strength, or intensification, to model likely changes in ecological resources, particularly focussing on the impacts of increased aridity and periodicity of rainfall (Clarkson 2006, 2007, 2008; Clarkson & Wallis 2003; Hiscock 1994a, 1994b, 2006; Veth 1995, 2005; Veth et al. 2011; Williams et al. 2010). Intensification of ENSO moves the inter-tropical convergence zone to the north, which acts to reduce monsoonal rainfall, overall rainfall, and the predictability of rainfall. There is a widely recognised pattern of intensified ENSO occurring around 5,000 BP, with locally varying peaks and troughs in this intensity between 5,000 and 2,000 BP (Conroy et al. 2008; Denniston et al. 2013; Donders et al. 2007; Donders et al. 2008; Gagan et al. 2004; Moy et al. 2002; Rein et al. 2005; Rodbell et al. 1999; Schulmeister 1999), and an equally widespread decline in ENSO intensity within the last 2,000 years (Donders et al. 2007; Gagan

et al. 2004; Lees et al. 1990), or 1,000 years (Denniston et al. 2013; McGowan et al. 2012; Haberle pers. comm). Other proxy records, such as effective precipitation, likewise indicate increased aridity occurring after 5,000 cal BP (Shulmeister & Lees 1995), causing patchy fresh water abundance. The altered distribution and abundance of fresh water implied by these records has immediate foraging risks regarding peoples day to day access to fresh water, but would have also promoted longer term change in the distribution of edible plant species, and game animals. Hiscock (2006:88) noted that the onset of a dominant ENSO pattern after 5,000 cal BP would have not only made ecological resources less abundant, but less predictable. This implies that the distribution of resources became patchier, causing people to forage in larger areas, across larger ranges and increasingly in less familiar areas.

There have now been several convincing demonstrations of temporal correlation between environmental change and technological change in Australia (Clarkson 2006, 2007, 2008; Hiscock 2002, 2006; Hiscock & Attenbrow 2005; Mackay 2005; Marwick 2002; Veth et al. 2011). One example, with a major focus on points, is Clarkson's (2007:130-142) model of technological change throughout the Holocene in Wardaman Country. This study provides a compelling case for a strong correlation between environmental change, and changes in stone tool reduction. He argues that climate change increased foraging risk after around 5,000 cal BP, peaked in severity between 3,000 and 1,500 cal BP and declined within the last 1,500 years. During times of intensified ENSO, there was likely an increased foraging risk. People were likely highly mobile, making access to replacement raw material more limited, so the observed correlation with high levels of reduction intensity during this time, reflect attempts at extending the use life of standardised technologies (Clarkson 2008:302). The more recent phase which saw the decline in predicted foraging risks and corresponding decline in reduction intensities could be widely related to reduced foraging risk and a correspondingly reduced need of these technologies across Australia (Torrence 1989:65). Yet it must be recognised that the effect of climate change was not uniform across northern Australia, or the Australian continent, therefore technological responses should not be expected to also be uniform.

In light of this variability, Veth et al. (2000:60) cautioned that potentially undermining ecological explanations of technology is the applicability of proxy records to local conditions. They suggested an acute need for investigation of local responses to local environmental change. This leads to the imposing question:

...if the proximate cause of these Holocene technological changes is largely or partially the same...[ENSO]...what is the reason that different mechanisms of change occurred for different tool classes? (Veth et al. 2011:120)

One answer to this quandary is that the effect of climate change on Holocene people's subsistence in northern Australia could not have been unimodal. It has been argued that for

areas in Queensland, climate change may have had positive effects on local resource abundance (Turby & Hobbs 2006), such as in the Whitsunday Islands where no response to environmental change was detected by Genever et al. (2003:141). Hiscock (2006:87) suggested that in some areas, drastic and large scale geomorphological change in terrain and vegetation occurred, while in other areas more subtle alterations to the distribution of plant and animal resources occurred. It is plausible that environmental change in the mid to late Holocene could have had both positive and negative effects on resources, so clearly local proxy records are essential for testable hypotheses of ecological explanations of technology.

One local study from the Kimberley did not find compelling evidence for a correlation between environmental change and the presence of points in the Mitchell Plateau area; although it was suggested that points offered a functional improvement to hunting gear (Veitch 1999:36). Veitch (1999:363-365, 370) argued that intensification and possible population increase, based on increases in archaeological materials in the deposits (Lourandos & Ross 1994), provided a more compelling local correlation with point technology. Very small samples of points ($n = 17$); however, coupled with a lack of information on local ecological change during the mid to late Holocene, make this study a poor test of the risk minimisation model for points in the Kimberley. In order to satisfy what is probably the only major issue within the risk reduction model – local scale adjustments of technology to local scale resource change (White 2011:68) – the Kimberley region's Holocene environmental records must be examined.

Localised records of climatic variability in the Kimberley region provide general correlation with the Holocene climate change model, seeing the onset of aridity around 5,000 years ago or slightly earlier, and subsequent peaks in aridity between 4,000 and 1,500 cal BP, and a return to wetter conditions resembling the modern climate within the last 1,000 years. Stratigraphy from Geegully Creek, a tributary of the Fitzroy River, has been interpreted as indicating that the monsoon regime was less intense prior to 6,500 BP (Wyrwoll et al. 1992; see Semeniuk 1995). Pollen records from Black Springs in the northwest Kimberley were used by McGowan et al. (2012) to argue that the region underwent rapid environmental change, beginning about 5,750 years ago, when the region transitioned from a tropical humid climate with an intense and predictable summer monsoon, to a much drier climate where the summer monsoon was absent or intermittent (McGowan et al. 2012:3). The authors provide evidence for slight climate amelioration and a switch back to a more active monsoon between 4,600 and 4,200 years ago; followed by increasingly dry conditions between 3,200 and 2,700 years ago, and then a period of extreme aridity between 2,400 and 1,300 years ago (McGowan et al. 2012:2-4). Following this arid phase, they show that modern summer monsoon systems were established within the last 1,000 years. Oxygen isotope records from cave KNI-51 in the Ningbing Range indicate Indonesian Australian

Summer Monsoon [IASM] strengthened in the early to mid Holocene, producing increased rainfall (Denniston et al. 2013). This IASM strengthening was followed by a significant decrease in monsoon strength beginning about 4,000 cal BP, with peak aridity detected between 1,500 and 1,200 years. These data also indicate a return to wetter conditions within the last millennium, albeit with small-scale variability (Denniston et al. 2013). A recent pollen core in the Mitchell Falls area provides further support for the timing of these climate reconstructions, with the onset of aridity occurring after 6,000 cal BP; although, possibly indicating that the current monsoon pattern was not established until 500 years ago in this area (Haberle pers. comm.). The phytolith and macro botanical studies from Carpenters Gap 1 (McConnell & O'Connor 1997:29; Wallis 2001:106) unfortunately do not have the temporal clarity to inform on mid to late Holocene vegetation, at least not to the same level as these previous studies, and instead assess the Holocene units as a single phase. What remains to be tested is the correlation of Holocene technology in the Kimberley with further local, and the previously discussed regional, environmental proxy data. Risk reduction models have certainly not been adequately assessed for point technology in the Kimberley, but the social explanations of technologies during this time also provide compelling grounds for examination.

Social signalling and demography

Risk reduction models have never discounted social drivers of change (e.g. Clarkson 2007:167; 2008:311-312; Hiscock 1994b:277, 2002:169, 2006:86-87, 2008:160; Kuhn 2012:76), although some Australian researchers have suggested that social explanations have been neglected (Bowdler 2011; White 2011). The social responses to reducing foraging risk observed by Weissner (1982, 1983), have seen analogous use in the risk reduction models for points in Australia (Clarkson 2007:156, 2008:311-312; Hiscock 1994b:277) and other social dynamics such as gender division, have been linked to changes in point technology (Allen 1996:152).

Nonetheless, many researchers have questioned how risk minimisation explanations could be applied to such wide observations of technologies across diverse environments, as implied by Hiscock (1994b), particularly for backed artefacts (Layton 1997:378; Mulvaney & Kamminga 1999:267; Veth et al. 2011; White 2011:68). It must be acknowledged that all forms of foraging and learning by humans are inherently social (Stern 2012). The decisions to make certain tools across the Australian continent were ultimately products of social learning (Kuhn 2011:70); thus, social interaction is implicit in all technological strategies, regardless of the emphasis that archaeologists have placed on social factors, contra to Bowdler's claims of risk minimisation confetti (2011:70).

Social drivers of change in the mid to late Holocene do not preclude the risk minimisation explanation (Kuhn 2011:70). For example, in discussion of highly mobile strategies, Kuhn

(2012:76) argues that there would be a greater probability of intergroup contact, which would necessarily incorporate social signalling. In the Australian Holocene context, Hiscock (2006:86) suggested that increased mobility would have required 'radical revision of inter-group social and political agreements'. The role that stone technology played in these social contexts is unclear, yet has featured prominently in discussion of point technology from the mid to late Holocene.

Points, particularly if hafted, may have provided people with a means of signalling individual and group identities. A leading proponent of social explanations for point technology in Australia is Moore (2013, 2015), who challenges the veracity of risk reduction arguments. Instead he argues that population increase during the mid to late Holocene was more likely the major driver of technological change, with larger populations leading to altered land use strategies. In response to increased interaction, cultural groups developed more elaborate information systems, which included points as signalling items (Moore 2013:145; see White 2011:68-69 for similar arguments regarding backed artefacts). Predictions of population size, crucial to this model, use frequencies of radiocarbon dates as proxy data for population density (Williams et al. 2010; Williams 2013; see also Shennan et al. 2013). Attenbrow and Hiscock (2015) have recently critically assessed this technique, finding major flaws in the use of charcoal dates as human population proxies. According to Williams (2013), populations in Australia increased from approximately 12,000 years ago, with three major pulses and plateaus between 8,300 – 6,600; 4,400 – 3,700; and 1,600 – 400 years ago, with the peak occurring around 500 years ago. Smith et al. (2008:400) also suggest populations were rising throughout the Holocene; however, they argue that the arid zone experienced a widespread population collapse around 3,000 years ago. These assumptions of population density suggest that any technological change during the Holocene could be argued as occurring against the back drop of increasing social interaction.

Moore (2015) further develops this demographic model for the recent past, arguing that population pressure, in the form of increased interaction within the landscape and competition for resources, is responsible for the development of Kimberley Points. Predominantly using historical accounts, he argues that pressure flaked bifaces observed in archaeological contexts, served a social function of individual skill or prestige displays, which became more frequent in recent times. He suggests that Kimberley Points served simultaneously to reinforce clan solidarity, and signal difference between groups that produced and traded these valued items, and those that received them. The mid Holocene development of points arising to fill a similar function of signalling appears less robust than the case for Kimberley Points in this sense, yet there is empirical evidence for a likely social role of earlier points, based on the standardisation of point form and increased mobility of populations during the mid to late Holocene. The standardisation of the early points is plausible evidence to support a market exchange value (Clark 1987). Interacting mobile

groups could have exchanged points and blanks in varied levels of reduction, and assumingly varied market values.

Summary of existing point hypotheses

Reflecting on the opening comment of this section from Binford (1978:453); variable conditions across the huge expanse of Australia, both environmental and social, will surely produce variable reactions – this is the archaeological record. Favouring social versus ecological drivers of change in the Holocene, in such a mutually exclusive fashion as archaeologists have (Bowdler 2011; Kuhn 2011; Shott 2011; Veth 2011; White 2011) diminishes the reality of diversity in the record. Rather than broad scale uniform explanations, this thesis addresses several succinct research questions surrounding the development of point technology in the Kimberley. It gives equal weight to social and ecological factors as possible explanations for the development of point technology and tests the appropriateness of these models using the assemblages and environmental proxy data from the study area.

1.4 Research Questions

The following section outlines the specific research questions addressed by the manuscripts in this thesis. But firstly, why are point technologies such valuable archaeological data, and can they answer these following questions? After all, despite their prominence in Australian archaeological literature, points constitute only a small portion of all assemblages, ranging from between 0.02 to 6% of artefacts (Tables 1 & 2). While some would argue that the focus on retouched flakes detracts from the possibility and significance of people using non-retouched flakes (Holdaway 1995), the use of tools is best analysed within the domain of use wear, residue analysis, and experimentation. Retouched artefacts provide a means of reconstructing tool life history and the interaction of reduction intensity with changes in social and ecological factors through time and space. This aspect of the research design was summarized by Andrefsky (2009:88) who stated:

...it might be best to use the most reliable information we have from a stone tool assemblage, even if it represents but a fraction of the assemblage as opposed to using a greater proportion of the assemblage to make unreliable interpretations... (Andrefsky 2009:88).

The research questions posed below cannot be adequately answered by studying the many thousand flakes and flaked pieces, mostly left out of the manuscripts. The data presented here provide one means of examining blank production, blank standardisation, raw material procurement, and a myriad of other possibilities, but their use or function is a task for residue and use wear analysis. Points provide the ability to reconstruct the transport and modification of tools across the landscape in quantified values. Following this premise,

Hiscock suggested 'one of the best examples of material conservation and recycling is the production and progressive modification of stone points' (2009:84). Points as archaeological data are well suited to testing hypotheses of technological organisation in the Kimberley from the mid to late Holocene to contemporary times. Additionally, much of Australian prehistory is built on stone typologies, and consequently there are already existing hypotheses that can be directly addressed by these data.

1.4.1 How old is point technology in the Kimberley?

In order to understand the factors that enabled and initiated point production in the Kimberley, their chronology must be resolved. Points in the Northern Territory first appear sometime between 7,000 and 5,000 years ago, and proliferate between 3,500 and 2,000 years ago (Hiscock 1999:98; Jones 1985:296). In the Kimberley, some researchers have identified points in similarly early contexts (O'Connor et al. 2008), but most have been associated with dates after 3,500 cal BP (Bradshaw 1986; Fullagar et al. 1996:764; Veitch 1999:324, 234, 286; Ward et al. 2006:14-16, 18, Table 3). Data that can inform on the timing of the earliest points in the Kimberley region is patchy, and questions remain about the validity of the claims for early dates, and what temporal correlations these could have with similar early claims from the Northern Territory. The dating of Kimberley Points is further confounded by their infrequent recovery from datable contexts. As previously discussed, there are a range of claims for the antiquity of these pressure flake bifaces, and thus a poor temporal understanding of point technology in the Kimberley, despite the great importance to wider themes of Australia's archaeology.

To decipher how old point technology in the Kimberley really is, analysis of existing assemblages, as well as new excavations were conducted. By targeting excavations with known point assemblages, and excavating new sites with well controlled units and in situ point collection, points were able to be precisely associated with either radiocarbon dating samples, or directly dated by attached resin. In Chapter 3 (Maloney et al. 2014), a re-examination of existing data, Indigenous oral histories, and new radiocarbon dates, provides a clear and testable chronology for point technology in the Kimberley. This manuscript demonstrates that points are first widely archeologically visible around 5,500 years ago in the southern Kimberley. Relatively more points are found between 3,500 and 1,500 years ago, likely to represent proliferation. This study also reveals that Kimberley Points are first archaeologically visible around 1,000 years ago, and direct percussion points continued to be manufactured during this time.

1.4.2 Is the typological model for points valid in the Kimberley?

Several studies have demonstrated that a reduction continuum model best explains point variability in other parts of northern Australia, and yet this model has been rejected in the Kimberley, regardless of the total absence of similar reduction sequences analyses. The lingering questions of typological validity in the Kimberley are extinguished in this thesis. In Chapter 4 (Maloney et al. In Review), the Mt Behn assemblage is used to demonstrate how a reduction continuum best explains point variability from the mid to late Holocene. In contrast to the typological model for points, Chapter 4 reconstructs point life history from the Mt Behn assemblage, and demonstrates that a diversity of retouch strategies were followed, including: The transition from unifacial to bifacial retouch via multiple pathways, backed points, and recycling into radically different tools. This reduction continuum model is also supported by surface collection data from the Wanalirri and Mandanari sites analysed in Chapter 7 (Maloney In Review).

While the typological validity of unifacial and bifacial points is refuted in this thesis, the backed points analysed in Chapter 5 (Maloney & O'Connor 2014) represent a technological divergence. The points are shown to be technologically discrete, since they are produced with bipolar anvil rested retouch and are not part of the reduction continuum between unifacial and bifacial points.

1.4.3 What are the underlying causes of point technology?

The underlying causes of point technology have been the subject of vigorous debate. The drivers of this technology in the Kimberley have already been the subject of research (Moore 2013; O'Connor 1999; Veitch 1996, 1999), yet it is still unclear how each of the discussed models holds against point assemblage data from the mid to late Holocene. Technological organisation theory, local and regional environmental proxy data, and the role of pedagogy in these technological changes are yet to be prominently engaged with point assemblage data from the Kimberley.

In Chapter 4 (Maloney et al. In Review), the Mt Behn data are used to assess these models, where it is argued that a technological response to increased foraging risk is a more compelling explanation than social signalling alone. Environmental proxy data from localised and regional studies indicate an onset of aridity after 6,000 years ago, followed by peaks in aridity between 3,000 and 1,000 years ago, before declining within the last 1,000 years. The timing of changes in point technology show remarkable correlation with these trends. The life history reconstructed from these points strongly supports an overall subsistence strategy of risk minimisation as the underlying cause, involving standardisation, maintainability, and use life extension of points, rather than social signalling alone. As

standardised items, potentially hafted, points were undoubtedly socially valuable, but this is inadequate as an overall explanation of the underlying causes of point technology. It is argued that pressure flaked bifaces developed after the need for a highly maintainable, risk reducing technology diminished within the last millennium, and the value of elaborate and highly skilled technologies increased.

Chapter 8 explores the social aspects of stone technology, focusing on directionality and scale in social connectivity. This analysis focusses on three kinds of artefacts (points, backed artefacts, and edge ground axes), their production, distribution, history, and evolutionary context. It is argued that during the proliferation of these tools, Aboriginal societies are very likely to have been interacting over large scale areas throughout the continent.

An external introduction of point technology is rejected by these data, without denying the likelihood of many migrations and contacts with overseas populations. Analysis of the CG3 assemblage in Appendix A (O'Connor et al. 2014) demonstrates morphological change in flakes during the early Holocene, where flakes were gradually becoming more elongate, more efficient (in terms of raw material economy), and approximating the morphology of flakes later used as blanks in point reduction. These data support the arguments of Clarkson and David (1995), where the production of regular flakes resembling blades was already well established by the terminal Pleistocene.

1.4.4 What are the spatial distributions of point and backing technologies?

The spatial distribution of point and backing technologies in northern Australia is not well understood. Two point technologies are recognised as unique to the Kimberley region – the Kimberley backed point, and pressure flaked bifaces.

In Chapter 5 (Maloney & O'Connor 2014), the Kimberley backed point is shown to be a discrete form of backing within the spectrum of point technology. These backed points were made on the same blanks, although typically smaller, as other points that were immobilised on an anvil, and retouched with bipolar techniques. The backed margin was maintained rather than unintentionally accumulated, indicating a specialised point morphology. Unlike the backed artefacts from elsewhere in Australia, which have been interpreted as an abundance strategy (Hiscock 2006), backed points probably represent a specific, but unknown function, within the greater extension strategy of point technology. The backed point is also reported in Chapter 4 (Maloney et al. In Review), and Chapter 7 (Maloney In Review). The current spatial distribution of point and backing technologies are further discussed in Chapter 8 by Hiscock and Maloney (In Review). All future studies of backing technology in Australia must consider these data, since the accepted north/south division of backing technology is not an accurate picture of spatial distribution.

Kimberley Points have been the subject of much discussion and debate, although this has largely surrounded their role in recent Aboriginal society. The huge spatial extension of these artefacts as trade items, and the movement of the highly skilled artisans in recent times, is discussed in Chapter 7 (Maloney In Review).

1.4.5 Were points hafted?

The exact nature of hafting arrangements for points in the mid to late Holocene, if any at all, remains elusive. Until now, the decidedly rare recovery of any organic hafting technology, in the form of binding agents or shafts, has forced archaeologists to estimate hafting technology from tool morphology and ethnographic analogy. In Chapter 6 (Maloney et al. 2015), the nature of point hafting technology during the mid to late Holocene is informed from a single remarkable point, recovered from CG1. This artefact reveals that spinifex resin was most likely manufactured as hafting mastic, and also incorporated some form of binding material was also incorporated, overlying the mastic joint. This point also indicates that small, lightly retouched unifacial points were hafted, implying that bifacial thinning was not a requirement for hafting. This point, and others from this period, could have plausibly served as hafted projectiles, or hand held composite tools for any number of tasks. The significance of this rare find is discussed within the context of risk minimisation, and social signalling models for point technology in the mid to late Holocene, in Chapter 6.

1.4.6 Why did Kimberley people make Kimberley Points?

This study also builds on existing interpretations of Kimberley Points as social tools of prestige and trade, by introducing novel insight into pedagogical environments. What these pressure flaked bifaces represent outside of aesthetically pleasing and culturally significant trade items from the recent past, has been understudied. In Chapter 7 (Maloney In Review) it is demonstrated that archaeological stone tool assemblages can be used to quantify, and make general contrasts of, the effective complexity of technologies. The implication of these findings is that complex technology, measured by the length of the description of regularities, also signals enhanced teaching and learning. Conversely, less complex technology signals less formal teaching and learning environments. Comparison is made between the reduction sequences of direct percussion points, and the production of pressure flaked bifaces. This research argues that Kimberley Points not only represent enhanced social interactions, supporting the observations of many Kimberley Aboriginal people, and many other researchers (Akerman & Bindon 1995:96-97; Akerman et al. 2002; Davidson 1935:179-181; Harrison 2002, 2004, 2006; Moore 2015); but also signal intensified pedagogical investments by social groups within the last millennium.

The differences in tool morphology resulting from these reduction sequences are further assessed using Elliptical Fourier Analysis in Appendix G. This study uses variation in the shape of tools to delineate the morphological difference between the reduction of direct percussion points, and the production of pressure flaked bifaces.

1.5 The Study Area and Samples

To answer these questions, several excavated and surface assemblages were analysed from throughout the Kimberley, which are described in the following section. Analysed assemblages derive from Worrora, Ngarajin, Ungummi, Bunuba, and Gooniyandi country. Bunuba and Gooniyandi country in the southern Kimberley were the focus of field work conducted between 2011 and 2013, as part of the 'Lifeways of the first Australians' ARC project (Linkage Grant LP100200415). Analyses were also carried out on excavated and surface assemblages, collected by Blundell (1975); each within Ungummi country, and the southern portion of Ngarajin country; and assemblages excavated by O'Connor (1990, 1995, 1999), from Worrora and Bunuba country. Site plans for those sites not previously published are illustrated in Appendix H. Additionally, many sites were recorded and surface assemblages analysed in situ during survey, as well as several assemblages from the Blundell collections (1975), that were not included in the published manuscripts. These data are also summarised in Appendix H.

The rock shelter excavations, and surface assemblage data, are now briefly described, followed by a description of raw material availability in these areas.

1.5.1 Rock shelter excavations

Previous excavation of rock shelter sites within the Napier Range by O'Connor (1995), and O'Connor et al. (2008), provided unanalysed samples of lithic artefacts containing points from dated contexts which had good organic preservation. The assemblage from Carpenter's Gap 3 [CG3], a large limestone rock shelter complex, which was excavated in 1994 and 2012, was analysed for this study. The 1994 excavation was discontinued without reaching bedrock. The 2012 excavation continued the original excavation square to bed rock, uncovering a larger Pleistocene sample of stone artefacts. The excavation of an additional, adjacent square recovered points from units dated to the mid to late Holocene. The lithic assemblage from CG3 is reported in Appendix A (O'Connor et al. 2014), and radiocarbon dates associated with points from the site are discussed in Chapter 3 (Maloney et al. 2014).

The other existing assemblage is from Carpenters Gap 1 [CG1], a large limestone rock shelter with unanalysed assemblages (O'Connor 1995). The analysed sample from this site included all lithic artefacts from square A2, as well as points from other squares. Points from

this site are reported in Chapter 3 (Maloney et al. 2014), and Chapter 6 (Maloney et al. 2015). Analysis of both Carpenters Gap sites revealed edge ground flakes, which, by association with radiocarbon dates, are shown to be the oldest evidence for edge ground axe technology in the world (Appendix B, O'Connor et al. In Review).

The retouched flake assemblage from Widgingarri Shelters 1 and 2 (O'Connor 1999) was also reanalysed, to reassess the morphological variability of points; particularly the reported backed points (1999:72-74). Data from this analysis are presented in Chapter 4 (Maloney & O'Connor 2014).

Two new rock shelters were excavated in 2012, in the Napier Range area of Bunuba country. Survey during the 2011 field season prioritised these rock shelter sites for excavation since they were likely to have deep deposits rich in stone artefacts, with good organic preservation. The first site excavated was the Windjana Gorge Water Tank Shelter (WGWTS). The Bunuba name for this site is Djuru, meaning outlying or projecting rock (June Oscar & Dillon Andrews pers. comm. 2012). This excavation is adjacent to a small test pit excavation (50 x 50cm²) conducted in an adjacent chamber of the outlier in 1994 (O'Connor et al. 2008), which produced a small sample of points. A report on the newly excavated archaeological assemblage is given in Appendix C (Maloney et al. In Review), and the recovered points are discussed in Chapter 3 (Maloney et al. 2014).

The second site excavated in 2012, known as Mt Behn, is a large limestone rock shelter with surface artefacts, and a densely painted rock art panel. Several bowers constructed by the male bird *Chlamydera nuchalis* were observed within the shelter, built of thousands of stone artefacts including several quartz points (Figure 1.8). Use of stone artefacts in bower construction by these birds is not uncommon (Solomon et al. 1986). Combined with the surface artefacts on the talus approach to the shelter (Appendix H), these bowers provided a good indication that there would be a sizable point assemblage in the Mt Behn deposit. This assemblage is analysed in Chapter 4 (Maloney et al. In Review), and used to construct the point chronology of Chapter 3 (Maloney et al. 2014). Like the Widgingarri assemblage sample, only the retouched flakes from the Mt Behn rock shelter were analysed, in order to focus on point technologies and other tools.



Figure 1.8 One of several bowers constructed inside the Mt Behn shelter.

These four excavated sites are all within the Oscar Napier Range, and in close proximity to the Lennard River and Windjana Gorge (Figure 1.9). All surface collections, and excavated sites are shown in Figures 1.9 to 1.11 [Figures modified from Playford et al. 2009:234,336], which illustrates the proximity of sites to one another in the landscape.

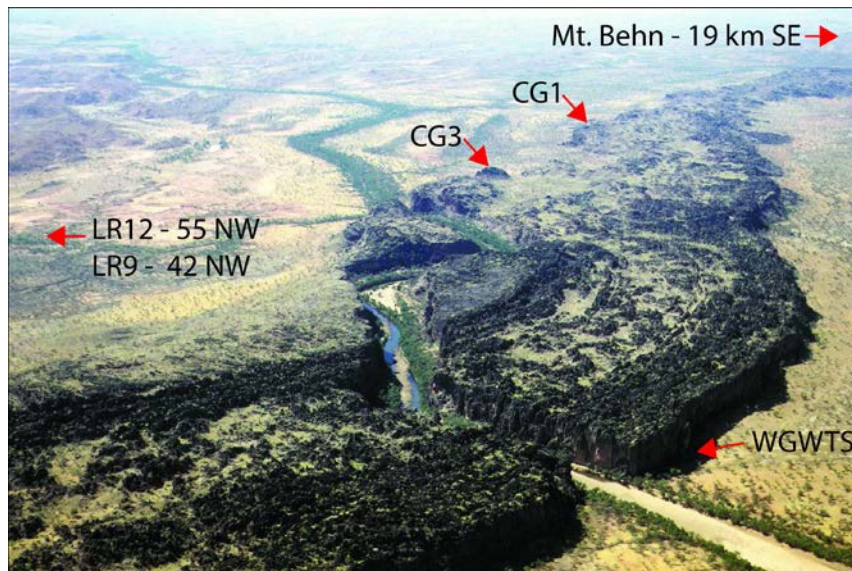


Figure 1.9 Proximity of excavated sites in Bunuba and Ungummi country to the Lennard River and Windjana Gorge, aerial photograph facing north east modified from Playford et al. (2009:234).

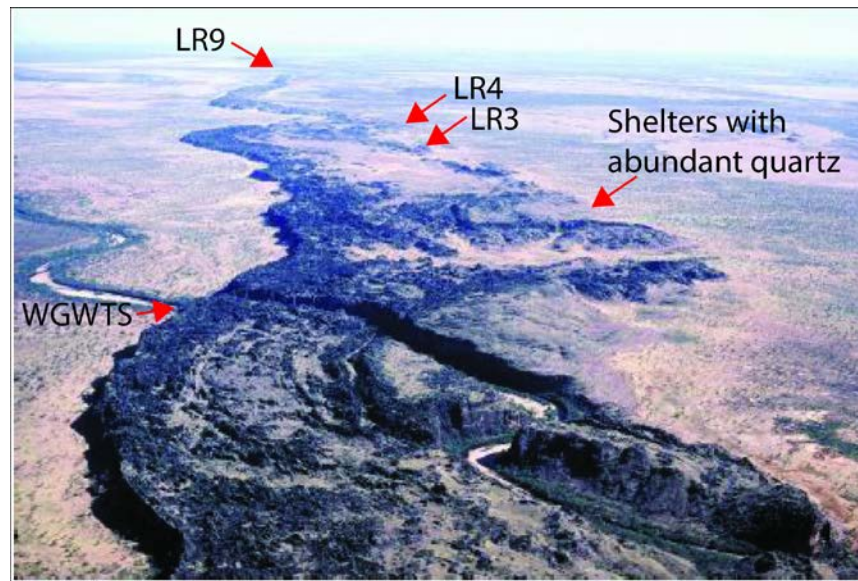


Figure 1.10 Proximity of sites in Bunuba and Ungummi country to the Lennard River and Windjana Gorge, aerial photograph facing west modified from Playford et al. (2009:234).

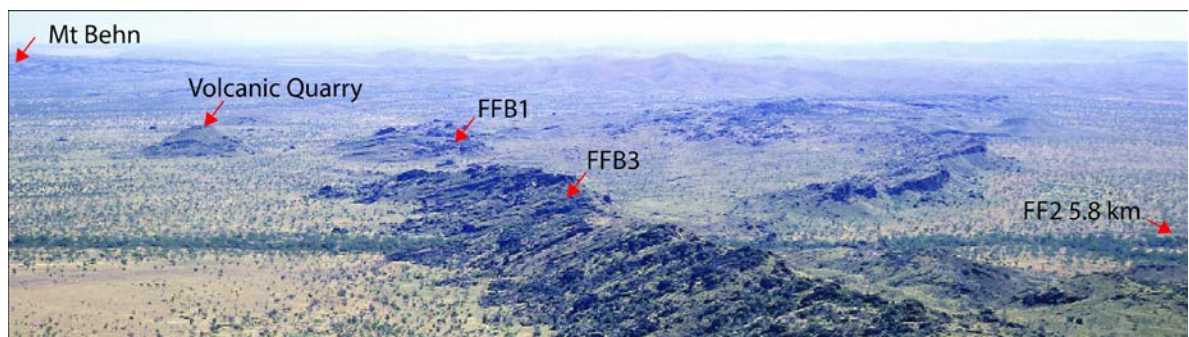


Figure 1.11 Proximity of sites in Bunuba country around McSherrys Gap, aerial photograph facing north west modified from Playford et al. (2009:336).

1.5.2 Surface collections

Surface assemblages from Ungummi and Ngarajin country were also analysed, from collections conducted by Blundell (1975), including Lennard River 12, 9, 5, 4, 3; and Mount Elizabeth 3 and 2 (Figure 1.12). The latter two sites are referred to by their Ngarajin names, Manadanari and Wanalirri, as recorded by Blundell (1975). These surface assemblages are analysed in Chapter 5 (Maloney & O'Connor 2014), and Chapter 7 (Maloney In Review). These data are also used in the Elliptical Fourier Analysis methodology, reported in Appendix G.

1.5.3 Raw material availability

A model of the distribution and quality of raw materials can be constructed for each site within the area illustrated in Figure 1.12. The geology of these areas presented two primary

challenges, faced by all stone tool using societies: Firstly, suitable or desirable raw material is not ubiquitous in the landscape, and secondly, these sources of stone will not always occur where and when they are required (Mackay 2009:105). To understand these challenges in the study area, geological surveys conducted by Playford et al. (2009) and Veevers & Wells (1961), as well as surveys conducted by the author (Figure 1.13), provide a suitable model of raw material availability. Outcrops of stone were recorded and collected, some samples of which were knapped and collected separately. The same clarity of raw material data is not available for the Wanalirri, Mandanari, Lennard River, or Widgingarri sites; although, the original publications do provide some account of local raw material availability. Regional descriptions of raw material availability are provided by Akerman and Bindon (1995:93), Akerman et al. (2002:17), and Blundell (1975:597-599). Akerman (1980) also provides a spatial division of the Kimberley into four zones, according to lithic and organic raw materials used for technologies in the recent past.

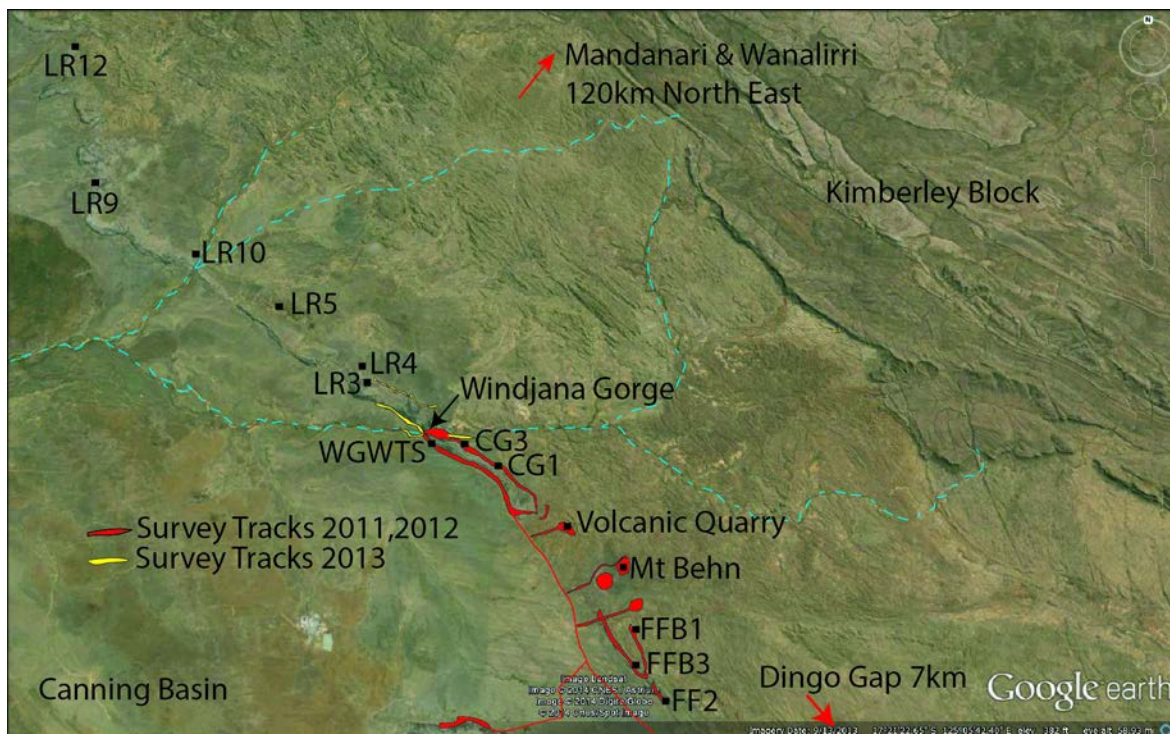


Figure 1.12 Locations of survey tracks, sites analysed, and those sites analysed but not included in published manuscripts. The limestone range extends diagonally, with the Canning Basin to the south, and the Kimberley Block to the north.

The Napier Range, encompassing the Lennard River, Carpenters Gap 1 and 3, Windjana Gorge Water Tank Shelter, Mt Behn, and Fairfield sites, is a Devonian-aged limestone reef system (see Playford et al. 2009 for regional geological history). The range extends approximately 350km in a northwest to southeast direction, in places 50km wide, and rising up to 100m above the surrounding plain in the study area (Playford et al. 2009:8). To the

south of the range is the Canning Basin, and to the North is the Kimberley Block (Figure 1.13).

The Upper Devonian rock in the Napier Range includes conglomerates susceptible to conchoidal fracture, others to grinding. Conglomerate bands close to the study area include the Barramundi and Behn conglomerates (Upper Devonian), and the Pillara conglomerate further to the south east (Middle and Upper Devonian). The erosion of conglomerates from scarps has produced sheets of quartzite cobbles (Playford et al. 2009:125-127), within a kilometer of both Mt Behn and the Carpenter's Gap sites. Occasional and thin conglomerate bands, which contain quartzite cobbles, are also found between limestone reef masses throughout the range. While both sources of quartzite have been exploited for tool making, and are locally abundant, they are of low knapping quality. Also found throughout the range are mineral fragments such as quartz, occurring between reef masses (Veevers & Wells 1961:41). In the Windjana Gorge area, the Napier formation consists of fore-reef sediments deposited against the bioherms and back reef biostromes of the Pillara formation (Veevers & Wells 1961:41). These uplifted reef formations have produced a local abundance of crystal quartz in the Lennard River gravels, and occasional distribution as water rolled cobbles or formed crystals, in many of the creeks and gullies emerging from the range. Crystal quartz cobbles occasionally occur within conglomerate bands. Formed crystal quartz occurs in greater abundance within and around the Mt Behn site, where intact crystals were procured from eroding gullies adjacent to the site, or quarried from mineral outcrops in between reef masses. The crystal quartz found here is not as locally abundant as quartzite, but is of exceptionally high knapping quality. These mineral outcrops are the dominantly exploited materials in the study area, from Windjana Gorge to the Fair Field area. Quartz seams or dykes have also produced a high local abundance of milky-white to red quartz in this area, of poor knapping quality, which was only occasionally exploited. This material is found in virtually every part of the landscape shown in Figure 1.3, with notable sources of abundance immediately in front of CG1, the Dingo Gap area, and close to two smaller shelters to the north east of Windjana Gorge (Figure 1.11). Both tabular nodules and water rolled white quartz cobbles can be found in river gravels.

The limestone range area surrounding the Carpenters Gap sites, Mt Behn, and McSherrys Gap (Figure 1.13) has no locally abundant source of chert or chalcedony. Chert cobbles are a very rare component of the conglomerate bands, and the eroded conglomerate sheets close to the sites. The very rare chert cobbles found in the Lennard River gravels were of small size, and very poor knapping quality. Sources of high quality chert are known to occur 40km to the north west at Lennard River 9, and near Riwi 180km to the south east in the Laidlaw Range, and other sources may be available. Chalcedony, particularly a white semitransparent material, also occurs in abundance towards Riwi; although, this chalcedony was not found during the raw material survey around the Oscar-Napier Range. This material

is a regionally well-known source of high knapping quality, mostly restricted to Gooniyandi country (Akerman pers. comm; Mervyn Street pers. comm.). While hornfels and tuff (possible indurated mudstone) were identified as very small components of archaeological assemblages, no local sources were identified.

Calcareous sandstone conglomerate occurs in several isolated bands throughout the study area, with prominent formulations within Windjana Gorge (Playford et al. 2009:342, 362). CG1 is in immediate proximity to such a fine-grained sandstone formation, the sandstone seams interbedded within the limestone at CG1 have been extensively used for grinding and petroglyphic art. Similar, albeit smaller, outcrops of sandstone are located within 1km of Mt Behn.

Volcanic rock occurs within the conglomerate distributions (Playford et al. 2009:128, 349), although these sources were largely unsuitable for knapping and edge grinding, due to their friable texture. Two isolated outcrops of basalt were identified as axe quarries. The first is located around 12km east of the Carpenter's Gap area, which has been totally destroyed by modern quarrying (possible the abandoned Narlarla zinc mine); although, large chunks of blasted volcanic rock remains. The other volcanic quarry is around 140km to the south east in Gooniyandi Country.

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Chapter 2: Methods

The papers that form the body of this thesis could not accommodate a detailed outline of methods. Firstly, the methods used to quantify artefact morphology and reduction are described and illustrated in this chapter. Secondly, the excavation methods are described for the newly excavated sites. Finally, the methods for selection of samples for radiocarbon dating are described.

2.1 Stone Artefact Analysis

My analysis follows what is often referred to as the technological approach (see Hiscock 2007). This approach uses morphometric measurements of artefact size and shape to provide the central means of quantifying artefact morphology. These variables are recorded using digital callipers, a goniometer, a digital balance, and a Next Engine 3D laser scanner. Additionally, multiple reduction indices are used as a means of quantifying reduction in assemblages. All of these procedures are described below.

2.1.1 Identifying stone artefacts

Flaked lithic artefacts

Stone artefacts are the most ubiquitous cultural material in the archaeological record, and identification of stone artefacts is fundamental to Palaeolithic studies. Stone is constantly fracturing in the natural world through a range of geomorphologic processes, some of which produce geofacts that resemble stone artefacts. Understanding of the mechanical fracturing properties that occur via the reduction of stone by humans allows us to reliably distinguish artefacts from naturally fractured rock. The fracture studies conducted by Cotterell and Kamminga (1979, 1986, 1987, 1990) provide a robust framework for identifying these processes and distinguishing human from natural fracture. Human manipulation of stone through flaking (or knapping) can produce three main fracture types: Hertzian, bending, and bipolar. These fractures occur when force is directed onto the surface of the parent material with an indenter, such as a hammer stone, and material is removed.

The most prolific type of human induced fracture is hertzian. Hertzian fracture invariably produces conchoidal surfaces. The conchoidal surface is recognised by a series of characteristic surface features such as: a hertzian cone (or bulb of force), enlèvement scar, ring crack, fissure lines, compression waves, and an initiation surface or platform (Figure 2.1). The hertzian fracture process is initiated by force entering the material at the impact point with the indenter, or point of force application [PFA], and begins to form a hertzian cone (Cotterell & Kamminga 1987:686) (Figure 2.2). This force initiates multiple concentric fractures, however; one dominant fracture will initiate the hertzian cone. Crabtree (1975:24) notes that a partial bulb or cone of force is produced, since the indenter will regularly meet the parent material close to an edge. This semi-spherical bulb is formed by the force travelling away from the PFA towards the nucleus of the

parent material, and encountering outward bending pressure, which then forces the fracture back towards the plain of the fracture initiation (Cotterell & Kamminga 1987:687) (Figure 2.2). The force then travels through the parent material towards the free face of the core until the fracture terminates (Figure 2.2).

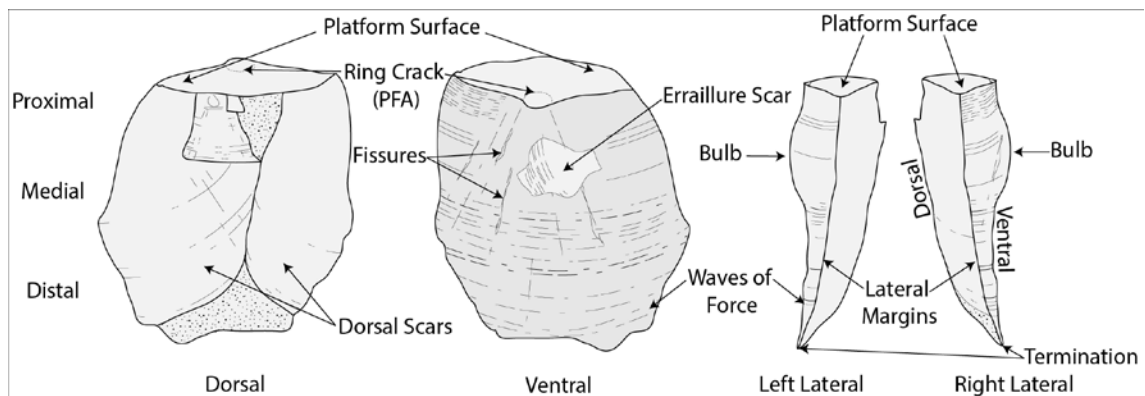


Figure 2.1 Conchoidal surface attributes on flakes produced by hertzian fracture.

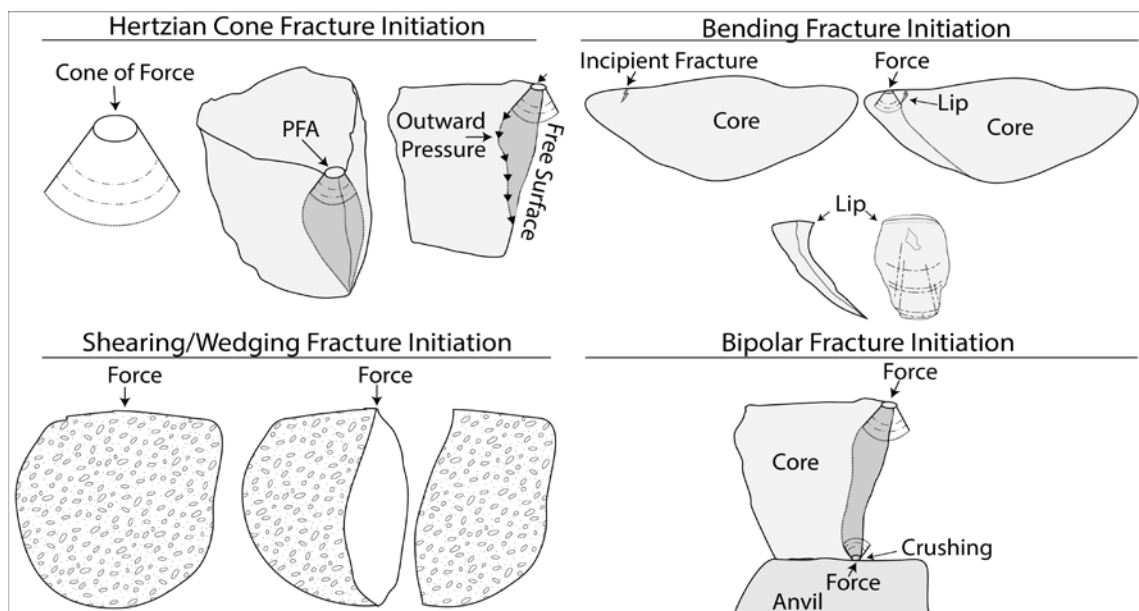


Figure 2.2 Initiation of hertzian, bending, shearing, and bipolar fracture.

Bending fractures are identified by the lack of a bulb of percussion, and the presence of a pronounced lip on the proximal ventral surface (Figure 2.2). This fracture type can be caused by incipient fractures close to the edge of the parent material, which initiates the bending force and encloses the cone of force inside the proximal portion of the flake (Figure 2.2). Some analysts have associated bending fractures, particularly the combination of a diffuse bulb and pronounced ventral lip, with soft hammer percussion (Crabtree 1972:74); however, other replicative studies demonstrate that this is not universally reliable (Driscoll & Garcia-Rojas 2014; Patterson & Sollberger 1978; Pelcin 1997; Redman 1998).

Bipolar fractures occur when an anvil is employed to immobilize the parent material, and so produces an additional PFA (Figure 2.2). The additional PFA creates a bidirectional fracture where scars have two initiation points. Crushing caused by the anvil resting at the additional initiation point is an indication of bipolar fracture. Bipolar fractures are complex and do not always produce landmarks that are as readily identifiable as the other mentioned fracture types. Bipolar fractures in this study are recognised by the combination of bidirectional scars with crushing at the initiation points.

Each fracture initiation will terminate in modes or morphological patterns, which are termed by archaeologists: Feather, step, hinge, and outpasse (or plunging) terminations (Figure 2.3). Feather terminations are recognised by the relatively thin tapering of the flake, which viewed laterally has a wedge like shape. Hinge terminations are created by force abruptly moving towards the free face, which produces a curved or lipped termination surface. Step terminations are caused by a more abrupt shift in force towards the free face, where force leaves at right angles to the fracture plain, producing the abrupt step. Outpasse terminations occur when the force travels beneath the parent material before terminating, creating a prominent termination at a different angle to the main flake percussion axis.

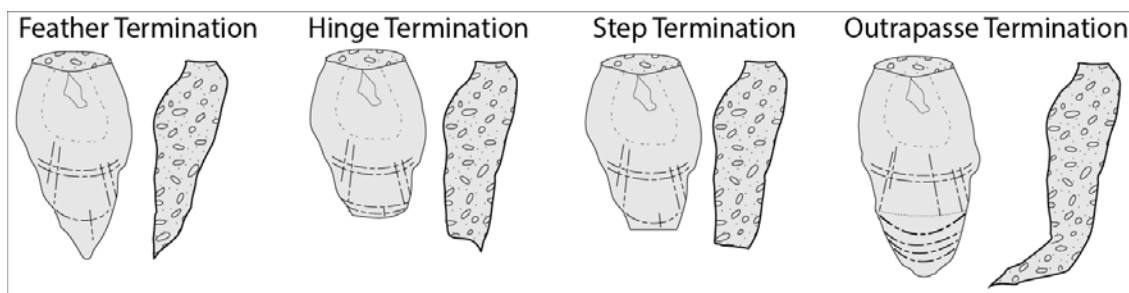


Figure 2.3 Modes of fracture termination.

These fracturing processes produce four mutually exclusive categories of artefacts: Cores, flakes, flaked pieces, and retouched flakes. Since both a positive and a negative fracture surface is produced, with readily identifiable traits, these surfaces provide the means of discriminating each of the four artefact types. The positive features of the conchoidal fracture surface can only be observed on the ventral surface of flakes. The negative features are present only on scar surfaces created by the removal of flakes from cores or retouched flakes (Figure 2.4). Cores retain one or more negative scars, and completely lack a ventral surface. Retouched flakes display negative scars truncating the ventral surface of the flake, indicating that additional flakes were removed from the flake margins, after the parent flake was produced. These scars can be initiated from the ventral surface and propagate onto the dorsal surface, and vice versa.

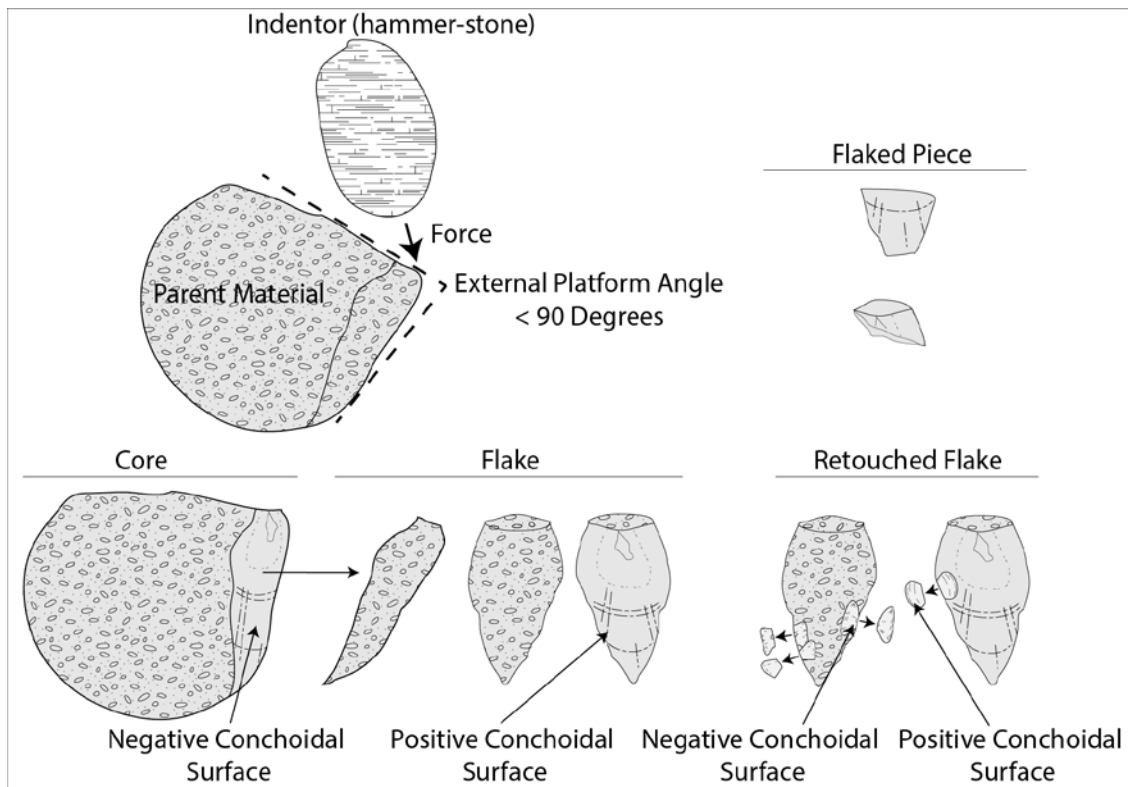


Figure 2.4 Mutually exclusive artefact categories: Cores, flakes, retouched flakes, and flaked pieces. The positive conchoidal surface is present only on flakes and retouched flakes, and the negative surface only on cores and retouched flakes.

A crucial, yet variably defined category of stone artefact is the flaked piece. Different studies have used variable criteria for identifying flaked pieces (Andrefsky 2005:83-84; Hiscock 1988:322; 2007:204; Holdaway & Stern 2004:115-118). This study recognises flaked pieces as stone artefacts that cannot be placed into the previous three categories, yet retain partial conchoidal fracture surfaces that are anomalous in the geomorphological context. The flaked piece is an arbitrary category, which serves to prevent observations of ambiguous flaked stone artefacts from being falsely included into the previous three categories (Hiscock 2007). Flaked pieces are recognised only by the observation of partial conchoidal surfaces and the lack of other features, regardless of raw material types. Exotic raw materials that lack human induced fracture qualities, but which are also anomalous in the geomorphological context, are identified as manuports.

An artefact category more difficult to identify is the indentor. The indentor is the object that imparts force to the parent material. An indentor tool may be hard, such as a hammer stone, or relatively soft such as bone, wood, or antler. Hammer stones can be identified by pitted surfaces after repeated blows, as shown in Figure 2.5.



Figure 2.5 Identification of pitted surfaces on hammer stone after repeated blows.

Pressure flaking is another technique of flake removal performed with a different indenter. Pressure flaking involves a different form of force application, where the fine point of a pressure flaking tool, such as antler, bone, metal, or wood, is placed on the edge of the parent material, and force is loaded onto that precise location to remove a flake. Andrefsky (2005:12) notes that force is both pushing down and into the point of applied force (Figure 2.6). Different techniques of pressure flaking have developed around the world, and people in the Kimberley region were observed during the 19th century using a technique that included an anvil, and paperbark insulation, where the manufacturer held the pressure flaking tool with the palm of the hand facing up (Basedow 1925:367-370; Elkin 1928:110-113; Idriess 1937:59-62; Love 1917:74-75; Tindale 1985:19-21, plate 1.1 to 1.5) (Figure 2.7).

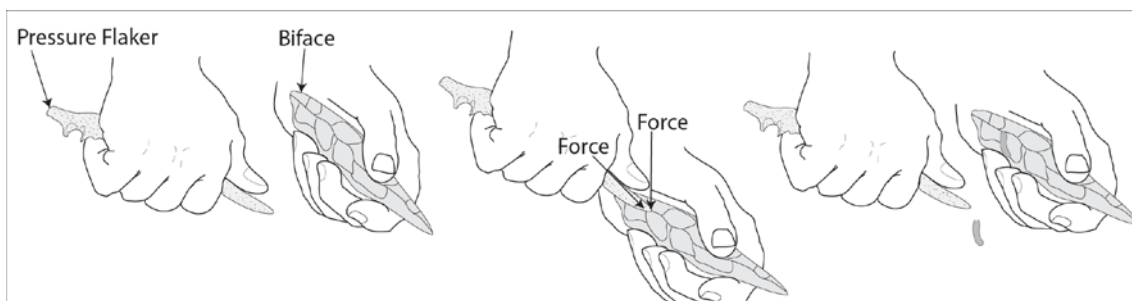


Figure 2.6 Basic orientation of pressure flaking and force using pressure flaking tool.

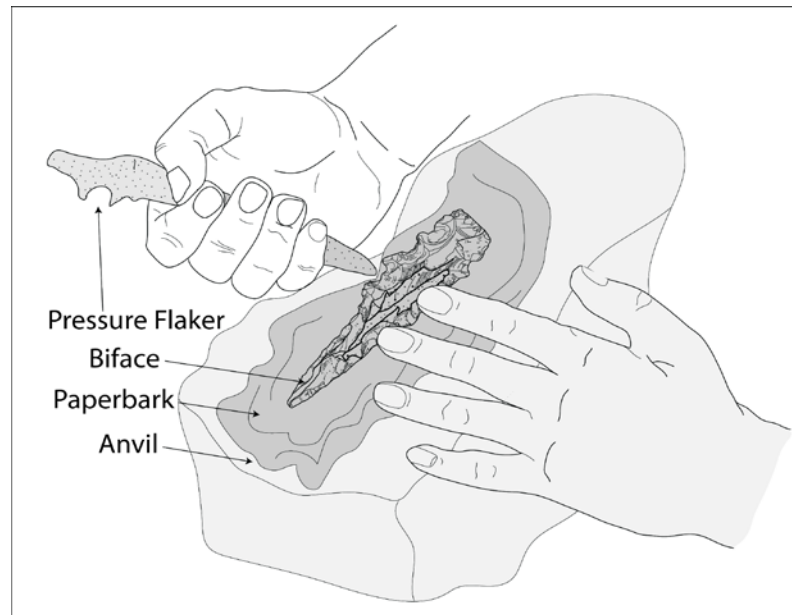


Figure 2.7 Ethnographically observed pressure flaking method the Kimberley.

Indirect percussion involves an additional medium in the application of force. For example, a punch between the hammer stone and parent material can be used, which controls the force application more precisely (Andrefsky 2005:12). While this technique has been observed in many parts of the world, such as the European Upper Palaeolithic (e.g. Newcomer 1975), it is hitherto absent from the Australian archaeological record (Flenniken & White 1985:149).

Edge ground and grinding artefacts

In addition to flaking or knapping, stone artefacts are also produced by grinding and polishing against another hard surface. In this study microscopy is used to identify edge ground surfaces using magnification between 20x and 200x. Multiple and intersecting striations that penetrate polished lithic surfaces are used as the criteria to recognise edge ground surfaces (Figure 2.8). These striations must be independent of the raw material grain structure. Other forms of grinding technology employ materials such as sandstone to process organic material, while removing very little lithic material (Smith 1985; 1986). This can result in similar striations and polished surfaces, as well as individually cut sand grains within the mineral composition of rock. Sandstone grindstone fragments were recognised only by striations, polished surfaces, and cut grains.

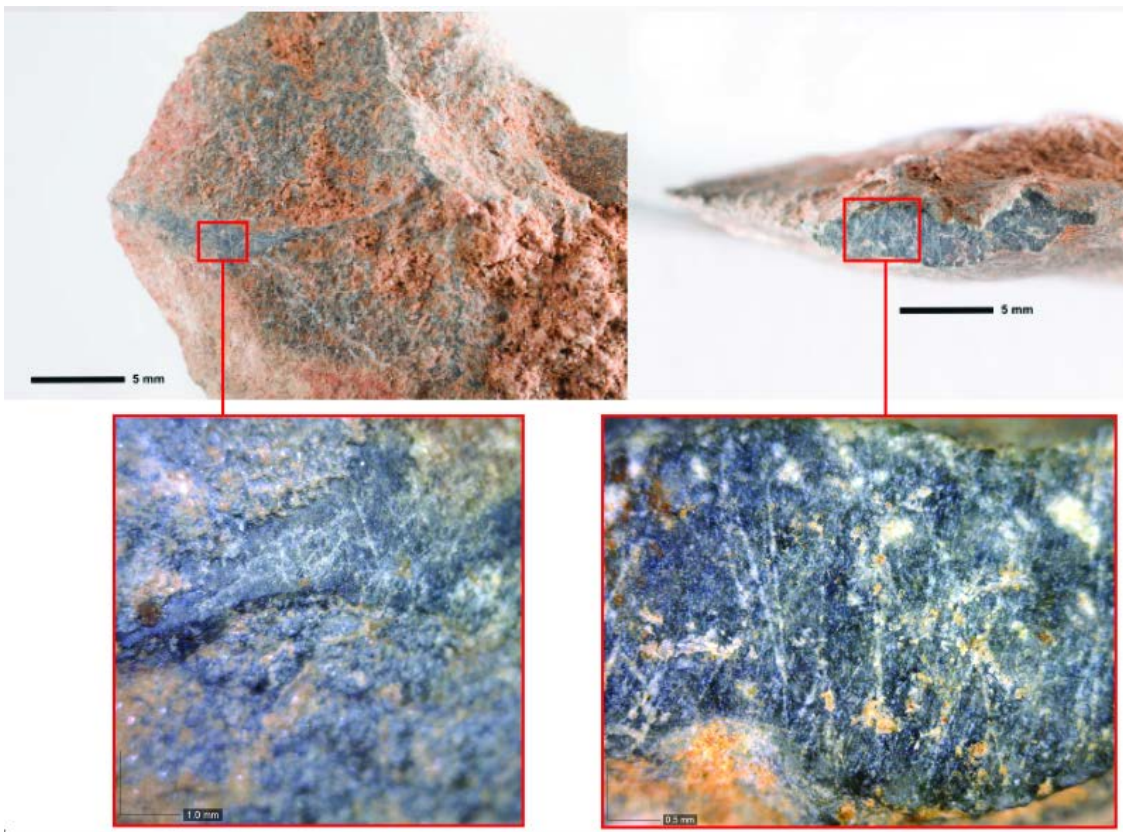


Figure 2.8 Identification of striations on edge ground surfaces.

2.1.2 Quantifying core morphology

Reduction begins with cores (Hiscock 2006), since they are the first flaked lithic artefact created in a reduction sequence. Core morphology provides vital insight into the nature of core use life. This section describes the recording of core morphology.

The morphologies of cores present some difficulty in consistently measuring size, since reduction can drastically alter core morphology (Andrefsky 2005:144). Unlike flakes, with landmarks such as the PFA and termination, cores lack regular landmarks. Core length, width, and thickness are often measured (Burke & Smith 2004:215) based on the dominant flaking pattern or morphology, which is really only applicable for a limited range of core morphologies. If such a dominant flaking pattern is no longer evident on a core, then measuring core length, width, and thickness is problematic.

As a resolution to this problem, this study uses the maximum linear dimension [MLD] shown by Andrefsky (2007) to be a valid and more replicable measurement of core size. The MLD is measured using a single linear calliper measurement, taken between the two most distant points on each core. This value is multiplied by core mass to give an index of core size (Andrefsky 2007). A Next Engine 3D laser scanner was also used to record a complete 3D model of cores, which does not require landmarks. The Next Engine HD Pro software records the total surface area, which is then converted to square millimetres.

Other metrical attributes that were recorded using digital callipers include the length and width of the largest remaining complete scar, which was recorded from the negative PFA to termination. These values allow the calculation of approximate elongation (length divided by width), and ventral area (length multiplied by width). The perimeter of the largest remaining platform was calculated by the addition of linear measurements across the circumference of the platform surface. The maximum lineal dimension across the largest remaining platform provides a general measure of platform size. The mass of all cores was recorded in grams using a high quality digital balance to two decimal places.

The average platform angle of cores was calculated using a goniometer, where the angle between the platform surface and the length of the negative flake scar was averaged for all scars with a platform.

In addition to quantified measures of core morphology, a range of qualitative attributes were recorded on cores. The flaking direction was recorded as unidirectional, bidirectional, or multidirectional, based on the orientation of flake scar directions. The number of platforms was counted and used to describe cores as single or multiplatform. Platform types were also recorded and are described in the following flake methodology section. The presence of crushing was also recorded on core platform surfaces as a means of identifying bipolar reduction.

2.1.3 Quantifying core reduction

The difficulty in reliably recording core morphology stems from the dynamic reduction processes that change during core use life. In order to continually remove flakes, cores are rotated, and flakes struck from a new platform. The frequency of these rotations is observable on all discarded cores, and used as a method of quantifying core reduction (Clarkson & O'Connor 2006:174). The number of core rotations is always one unit less than the number of flake scar directions. For example, if a core has had any number of flakes removed from one platform only, it has zero rotations. If a core has two flaking directions, it has been rotated once (Figure 2.9). Other observations of core reduction included a count of the total number of flake scars, and the frequency of step and hinge terminations.

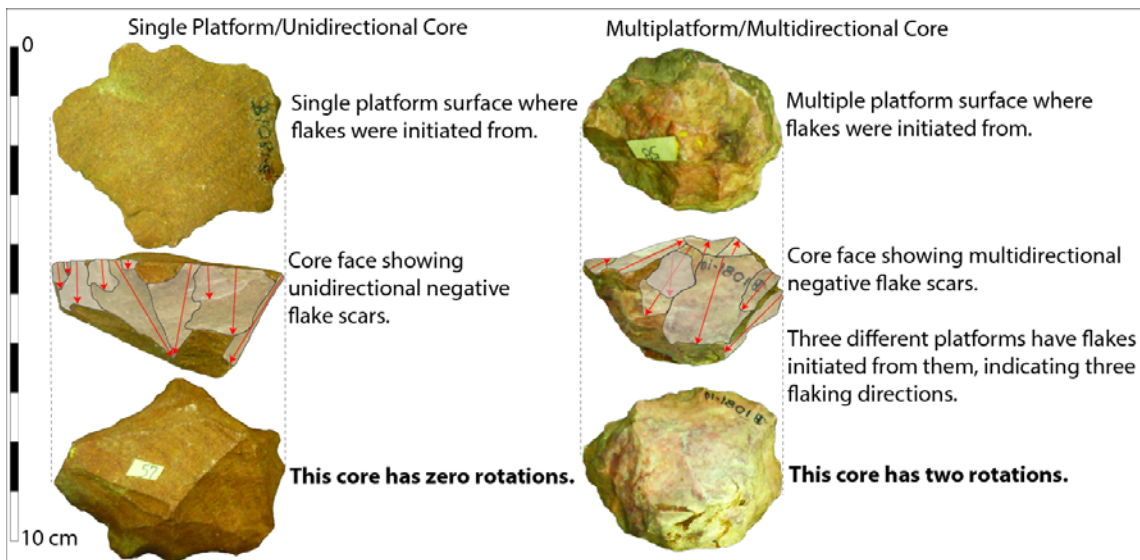


Figure 2.9 Two different cores illustrate the recording of core rotations.

2.1.4 Quantifying flake morphology

As discussed in chapter 1, quantifying the size and shape of flakes and retouched flakes is crucial to quantifying artefact variability. To quantify the morphology of flakes, a range of linear measurements were recorded using digital callipers and a Next Engine 3D laser scanner. This section describes all recordings and observations of flakes and retouched flake morphology.

Length was measured in three different ways on all complete and retouched flakes (Figure 2.10), including maximum linear dimension [MLD], box length, and percussion length. Measuring flake MLD follows the same procedure as core MLD. Flake box length was measured as the maximum lineal distance parallel to percussion axis and/or margins. Percussion length was measured from the PFA, directly to the flake termination. Each length measurement is useful for different situations. For example, while percussion length is preferable for length comparison, box length provides a means of recording retouched flake length when the PFA is obliterated by retouch.

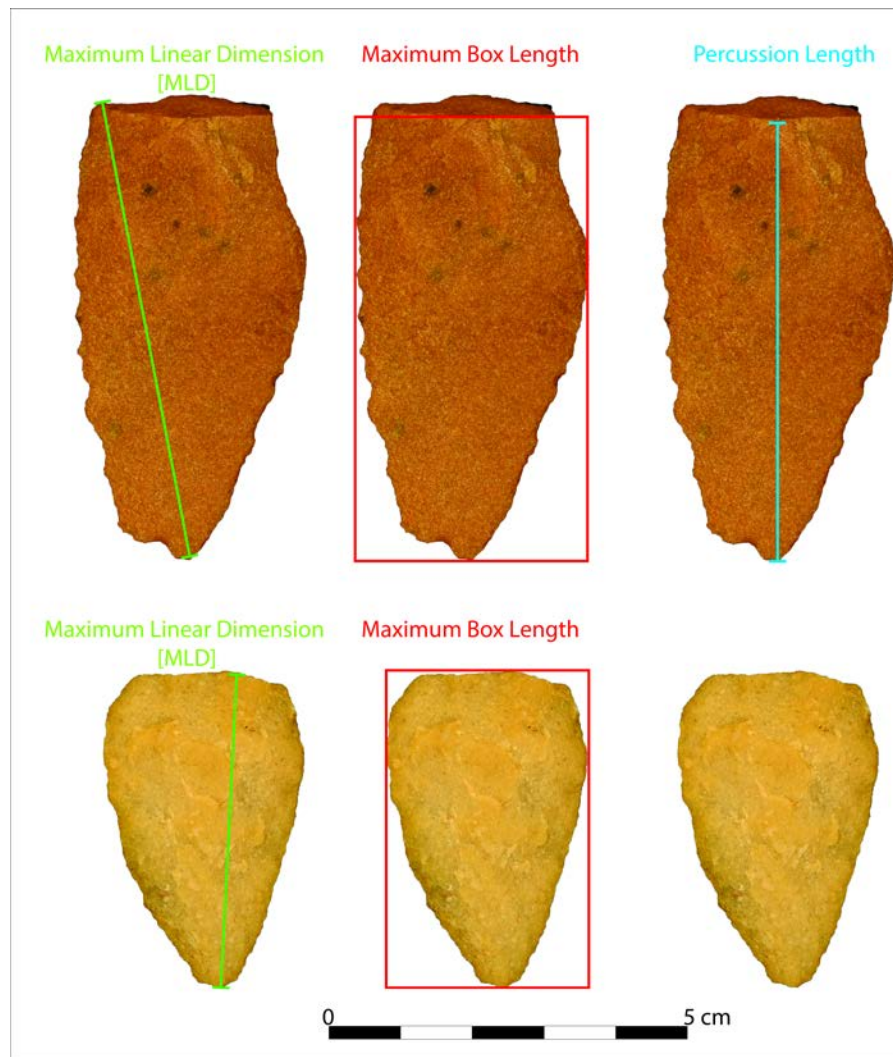


Figure 2.10 Length measurements recorded on flakes and retouched flakes.

Width is measured between the margins, across the ventral surface at three points: The midpoint of length (mid width), the proximal half (proximal width), and distal half (distal width) (Figure 2.11). The proximal and distal width measurements were recorded at one quarter and three quarters of box length. Maximum width was measured as the greatest possible distance between flake margins, perpendicular to length.

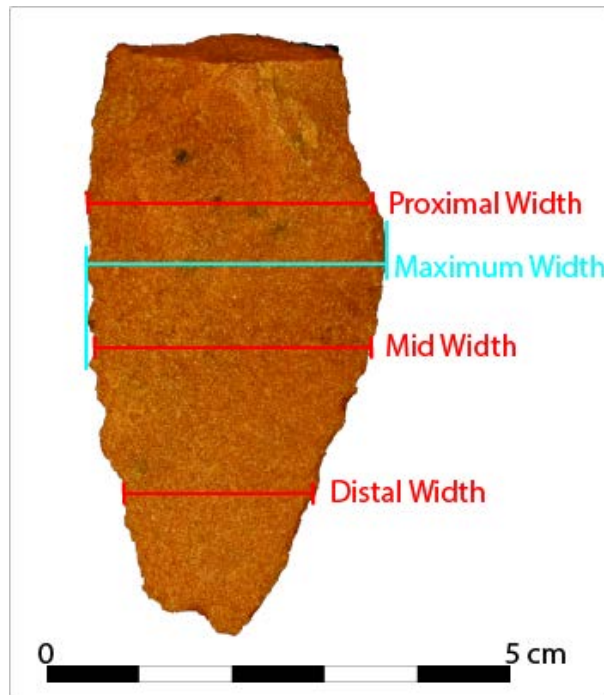


Figure 2.11 Width measurements recorded on flakes and retouched flakes, perpendicular to the length.

Thickness measurements were recorded at three points between the ventral and dorsal surface, at the intersection of length with mid, proximal, and distal width. These values are described as proximal thickness, mid thickness, and distal thickness, respectively.

The external and internal platform angles were measured with a goniometer in degrees (see Dibble & Bennard 1980:858-859). These angles were recorded between the platform and dorsal surface, focusing on the dominant dorsal morphology and avoiding the angle created by overhang removal scars (Figure 2.12). Internal platform angle [IPA] was also calculated between the platform surface and dominant angle of the ventral surface.

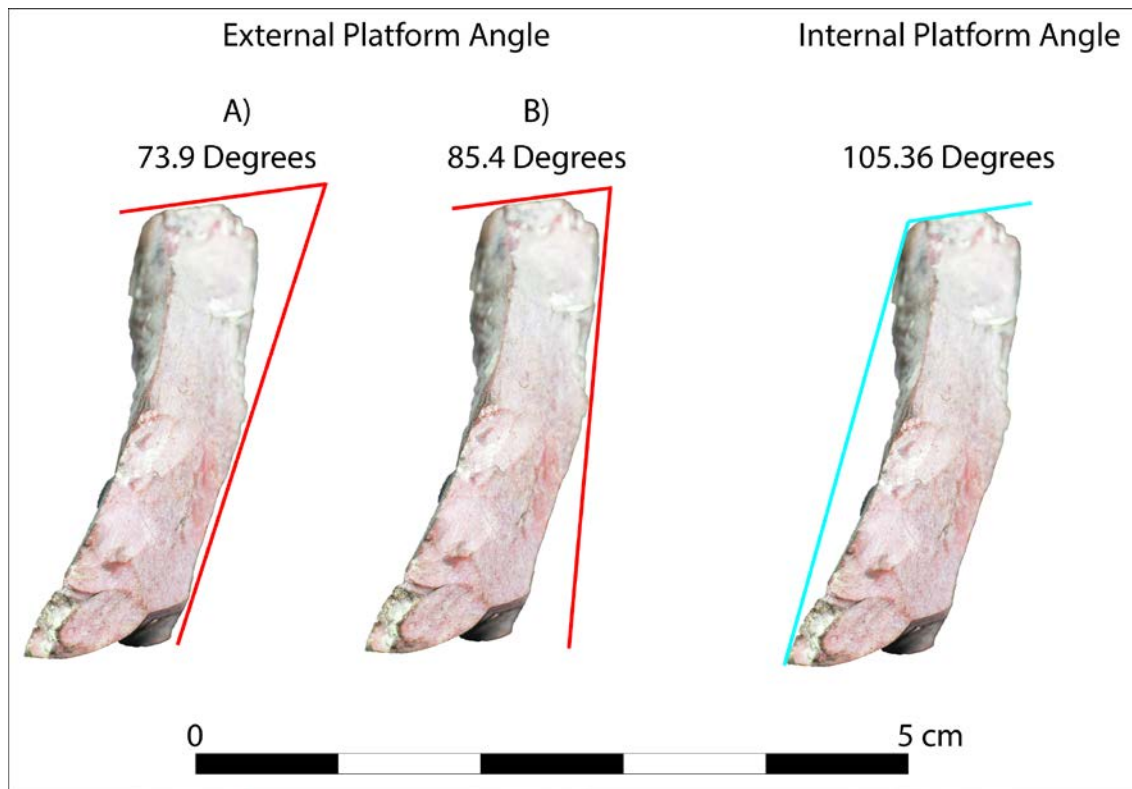


Figure 2.12 External and internal platform angle measurements, viewed from the lateral margin of a flake. A) Depicts the angle between platform and dominant dorsal surface, while B) depicts the angle between the platform and overhang removal scars.

Average edge angles were calculated for all complete flakes, retouched flakes, and bifaces using a goniometer. The goniometer cannot realistically measure the nonlinear margins of artefacts to any greater precision than 5°, so mean values were calculated for both retouched edges and non-retouched edges. The average edge angle was taken at six points along the margins of complete flakes, regardless of retouch. These points are the mid sections of three sections on each margin, calculated by dividing length into thirds. The average retouched edge angle was taken at multiple points along the retouched margins within each segment.

Breakage occurs in most assemblages via the knapping process, use, maintenance, and post depositional processes. Broken flakes can be categorised by their remaining portion when enough of the ventral surface remains (Figure 2.13). Longitudinal cone splits occur when the fracture propagates through the bulb of percussion, splitting the flake in half along the percussion axis. Transverse snaps occur when a fracture propagates through the flake perpendicular to the fracture plane. Marginal breaks refer to smaller breaks restricted to flake margins, and lack a PFA initiation that would constitute a retouch scar. The distinction between transverse snaps and step terminations is problematic on many raw materials. Where possible, a fracture direction indicated by waves of forces and fissure lines can be used to delineate between a step termination, which follows the percussion axis direction, and a transverse snap, which truncates the percussion

direction. In some instances, transverse snaps can also be distinguished by the observation of a lip where the fracture terminates.

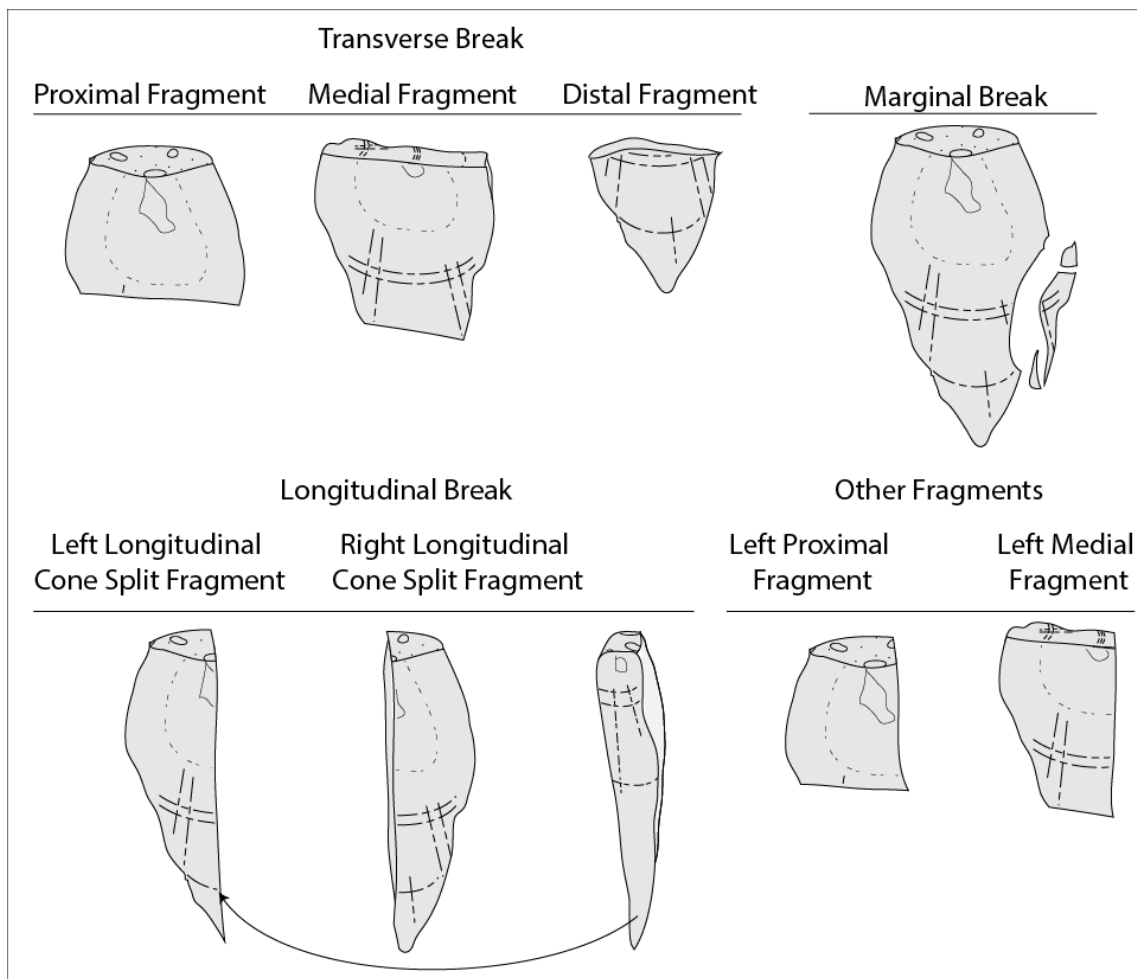


Figure 2.13 Identifying flake fragments and breakage patterns.

Given these breakage patterns, archaeologists have developed various methods to count the minimum number of flakes (Andrefsky 1998: 87-88; Sullivan & Rozen 1985), in an effort to include the frequency of broken flakes into the total count of an assemblage. Here I use Hiscock's (2002) minimum number of flakes [MNF] equation. The MNF is calculated by tallying the number of complete flakes, the higher number of either proximal or distal fragments, and the highest count of left, or right longitudinal fragments (Hiscock 2002:254). This count does not include medial fragments or flaked pieces due to the likelihood of multiple counts for these fragment types.

2.1.5 Quantifying reduction from flakes

Flakes can be ordered into a reduction sequence using observations of the dorsal surface. When initially sourced, many lithic materials will retain cortex: The weathered exterior surface of rock. Geological processes such as chemical and physical weathering create an outer cortical layer discrete from the internal rock. The presence and quantity of cortex can be used to quantify reduction in flakes (Jeremie & Vacher 1992; Marwick 2008; Nishimura 2005). Three qualitative groups of flakes will be typically produced:

Primary flakes, which retain cortex over the entire dorsal surface; secondary flakes, which retain partial cortex; and tertiary flakes, which completely lack cortex. The greater the level of core reduction, the higher the proportion of noncortical flakes there will be in an assemblage (Dibble et al. 2005). Figure 2.14 illustrates the difference between these three flake categories, and how they are logically ordered in a reduction sequence.

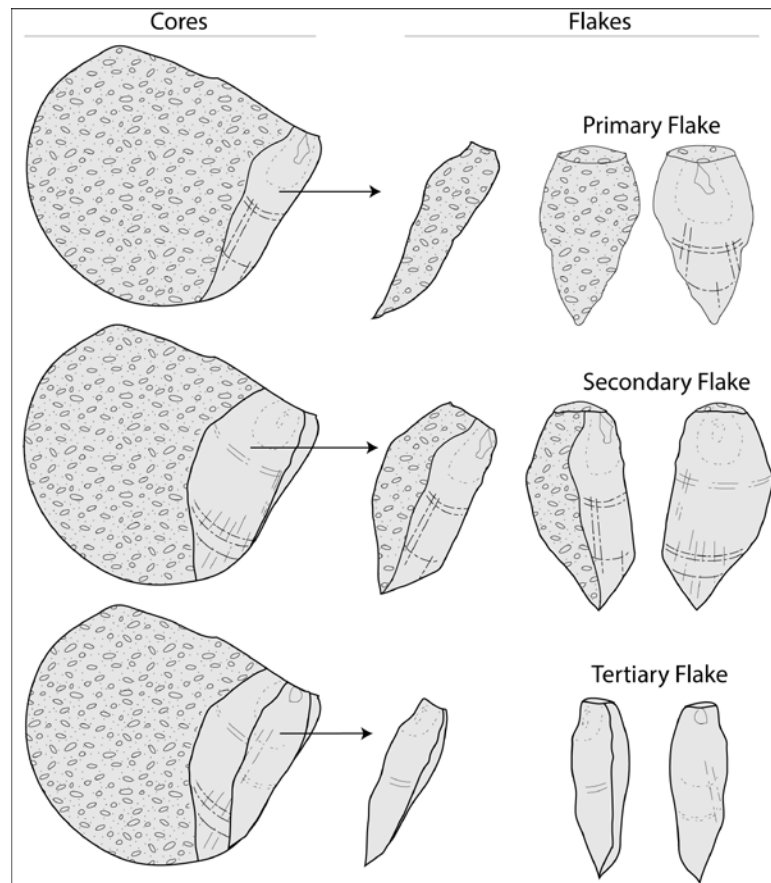


Figure 2.14 Primary, secondary, and tertiary flakes removed from core.

The quantification of cortex on the dorsal surfaces of flakes is best suited to the early stages of reduction (Marwick 2008:1194). Cortex is here quantified using a quadrant system that estimates a percentage of cortex covering the dorsal surface. Each flake is divided into four segments and given a score of 1 for the presence of cortex, or 0 for the absence. The score is totalled, divided by 4, and multiplied by 100 to give a percentage (Figure 2.15). In this way, quantifying cortex coverage removes error from estimating an overall percentage without a relative scale.

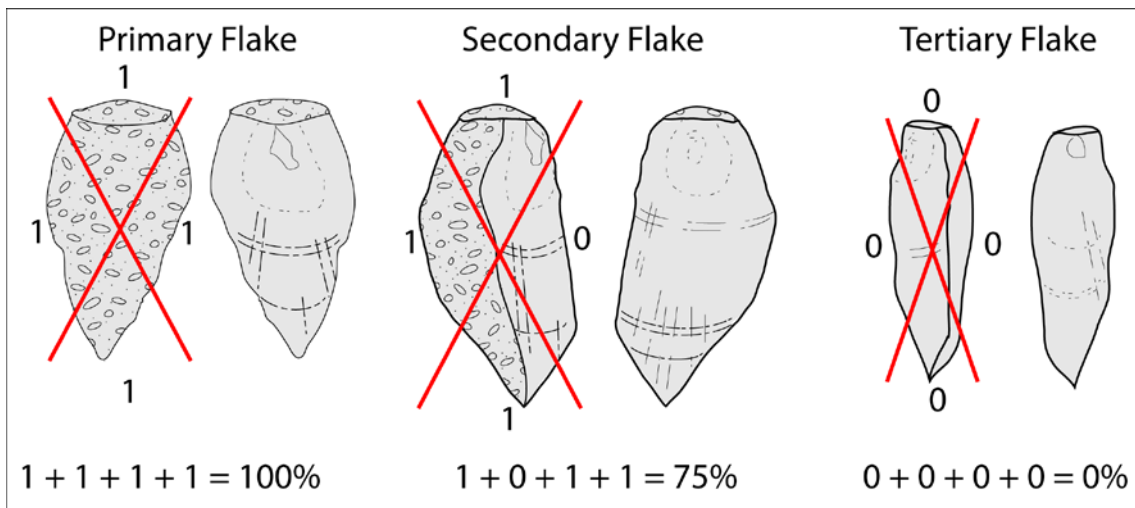


Figure 2.15 Method for quantifying the percentage of cortex.

Five classes of cortex were observed on the stone selected for reduction in this study. Water worn cortex occurs on rock that has been transported via water bodies. This process creates a smooth and rounded cortical surface. Weathered cortex occurs via chemical and physical weathering, through exposure to the elements. Weathered cortical surfaces can have a characteristic colour difference to the internal rock surface, or form porous and pitted surfaces. Tabular cortex occurs when rock formations such as dykes or seams form angular rock deposits, and will be weathered with distinct colour and texture differences. Crystal quartz cortex is recognised by the observation of formed crystal surfaces, which is often only represented by remnant crystal structures on the dorsal surface. Figure 2.16 illustrates several examples of cortex types on the dorsal surfaces of flakes from the study area.

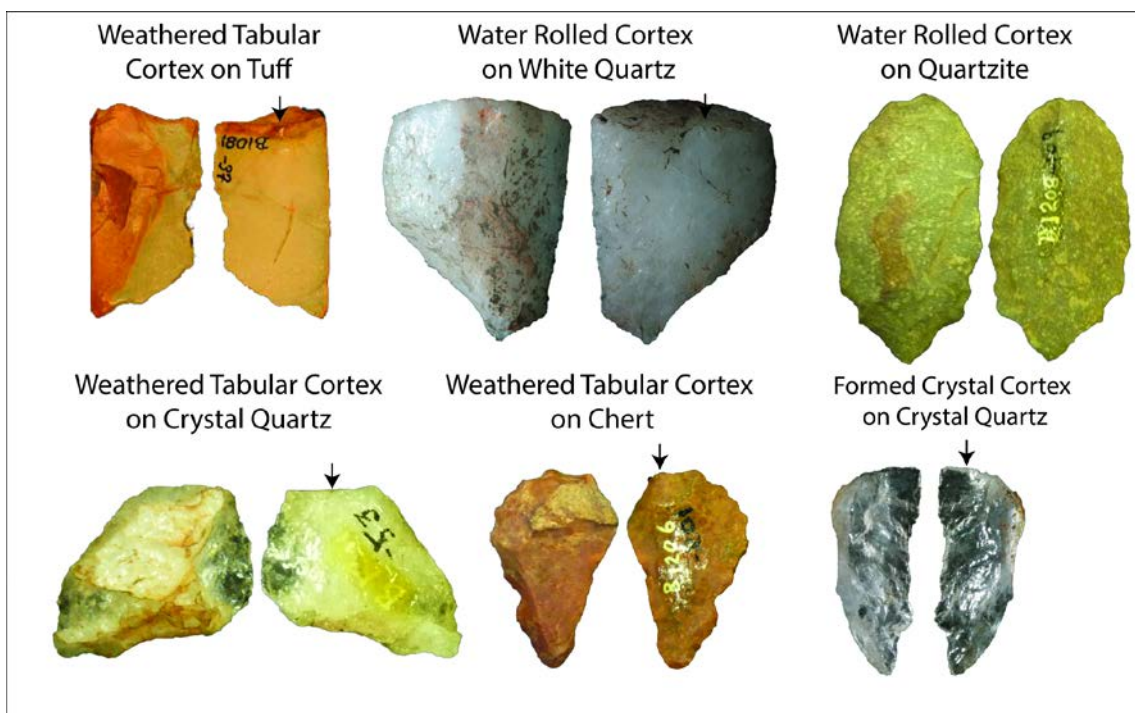


Figure 2.16 Examples of cortex observed on dorsal surfaces of flakes.

The flake platform surface also has a direct link to core reduction at the time of flake production. In the earliest stages of core reduction, flake platform surfaces will be cortical, which means that the platform surface is completely covered with cortex. As core reduction continues, and cortex is removed, flake platforms will reflect the altered surfaces. Plain platform surfaces are recognised by a single non-cortical surface, created by a single scar on the core platform surface. As core reduction continues, and more flakes are removed, core platforms will retain multiple flake scars, termed flaked platforms. The frequency of separate flake scars is counted. Crushing can form on platform surfaces after multiple blows from the indenter, and can also be the result of bipolar reduction. Crushed platforms are recognised by multiple cascading scars. Focalised platforms are those with a platform size approximating the size of the ring crack (Figure 2.17).

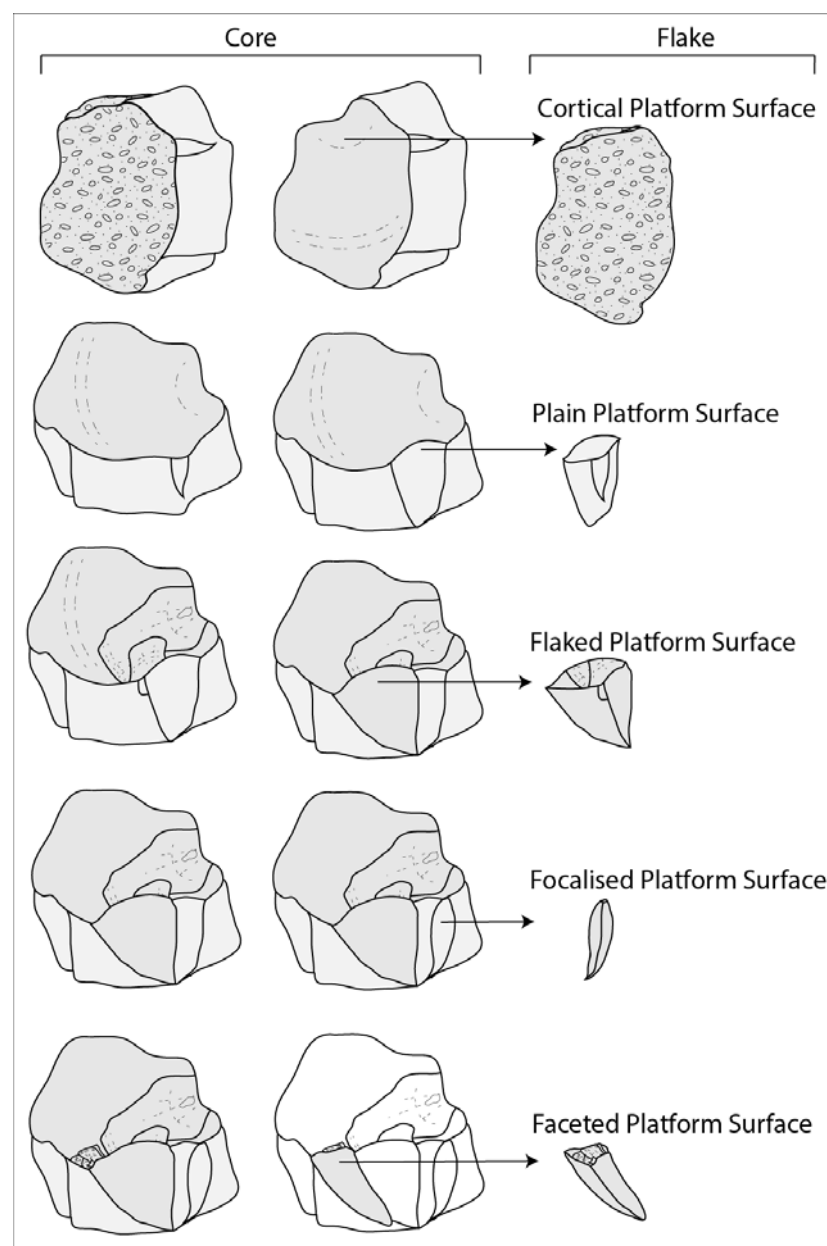


Figure 2.17 Platform surfaces observed of flakes, showing the corresponding change in core morphology.

The external platform angle [EPA] must be controlled to remove flakes, with the EPA being less than 90 degrees. To achieve such an EPA, it is often necessary to prepare the platform surface before flake production. Platform preparation refers to technological actions in anticipation of flake removal which assist the fracturing process by controlling the EPA and/or isolating an intended initiation point. Overhang removal is where small flakes are removed from the platform edge to increase the EPA (Figure 2.18). Overhang removal is recognised by small scars on the dorsal surface, initiated from the flake platform surface. When the platform angle is too high, adjustments can be made by removing scars onto the platform surface, forming faceting scars (Figure 2.18).

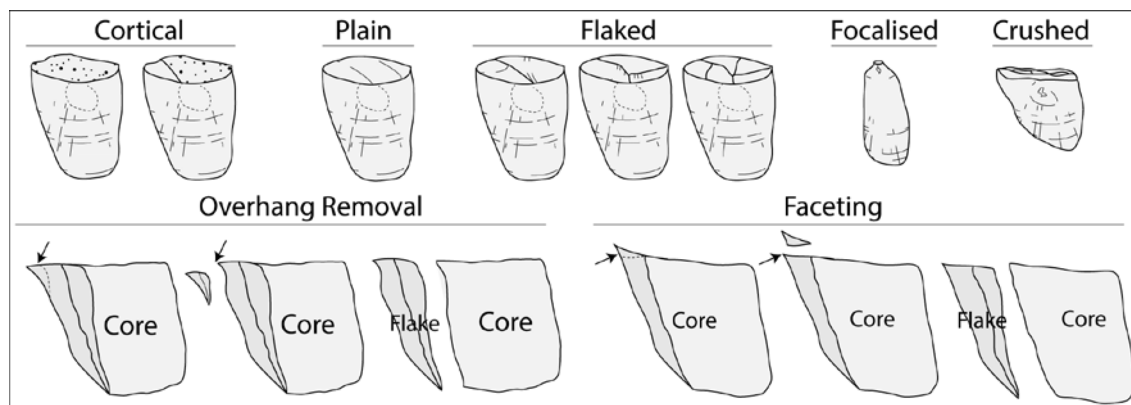


Figure 2.18 Variation in Platform surfaces and platform preparation.

Diagnostic impact fractures

Diagnostic impact fractures [DIF] are fractures that form from impact damage when tools are used as projectiles. DIF are the only attempts at recording use wear on artefacts in this study. While the likelihood of a projectile function can be estimated from these observations, they do not provide irrefutable evidence (Fischer et al. 1984). Experimental reproduction by Brindley (2011), and Brindley and Clarkson (2015), is used as the basis for recognising and evaluating DIF on points.

Fractures initiated from the distal portion of points were recorded as either unifacial or bifacial spin offs; bending initiated scars with step or hinge terminations; or burinate scars. Unifacial and bifacial spin off scars were recognised by scars initiated from the distal tip, which propagate onto the point surfaces. Bending initiated scars, with either step or hinge terminations, were identified by the lack of a negative bulb at the initiation. Burinate scars, which propagate along the margins, are also recognised as a possible DIF, although burinate scars can also be initiated from transverse snaps during recycling. Burinate scars initiated from a converging point tip were recognised as DIF.

2.1.6 Indices and measures of flake morphology

The morphological variability of flakes, particularly retouched flakes, is of great interest to reduction sequence analyses. To quantify the morphology of flakes and retouched flakes, and make meaningful comparisons, a range of shape indices were calculated such

as width to thickness ratios, elongation indices, marginal expansion values and edge curvature indices. These indices allow reconstruction of morphological change during artefact use life.

Width and thickness measurements are used to calculate transverse cross section ratios. Each width measurement is divided by the corresponding thickness (Figure 2.19) to provide a quantified value for the relationship between flake width and thickness. A longitudinal cross section is also calculated, where box length is divided by the thickness at mid-point. These values are sensitive to retouch variation, and provide a useful approximation of cross sectional shape.

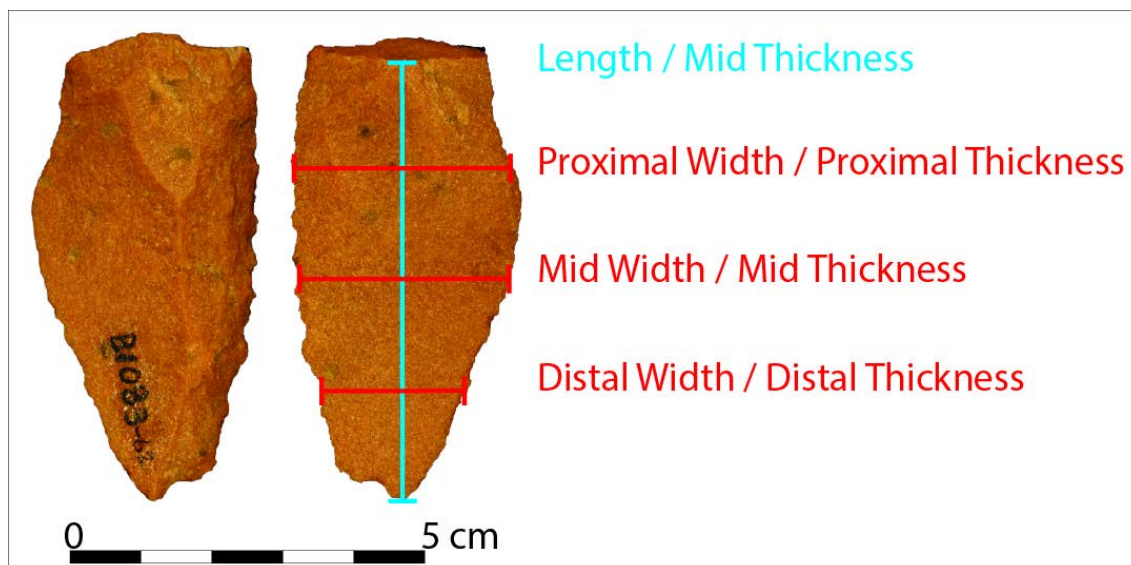


Figure 2.19 Landmarks where thickness measurements are taken, and transverse and longitudinal cross sections.

The 3D models of each flake were also manipulated to produce images of the exact transverse cross section at nominated points along flake length. Artefact scans were edited using the Next Engine HD pro software trim function, where the artefact meta data are deleted or trimmed to retain only the exact cross section at a given transect. This image is then exported, to scale, for illustration against artefact morphology (Figure 2.20). Cross sectional shapes were also recorded using reference to the relationship between the ventral and dorsal surfaces (Figure 2.21).

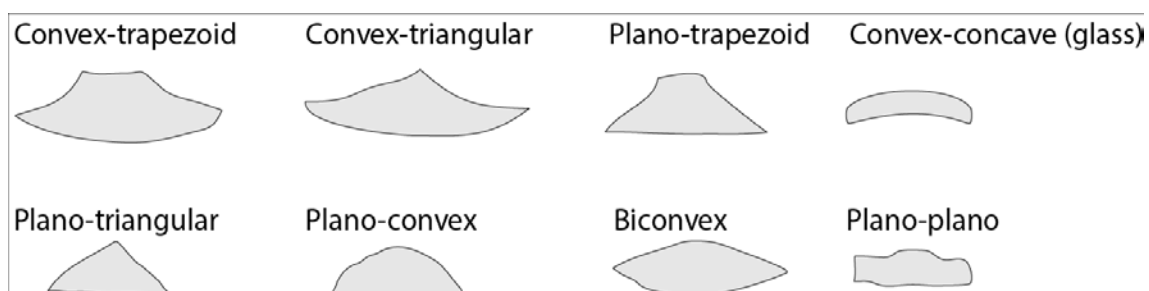


Figure 2.20 Qualitative cross sectional shapes.

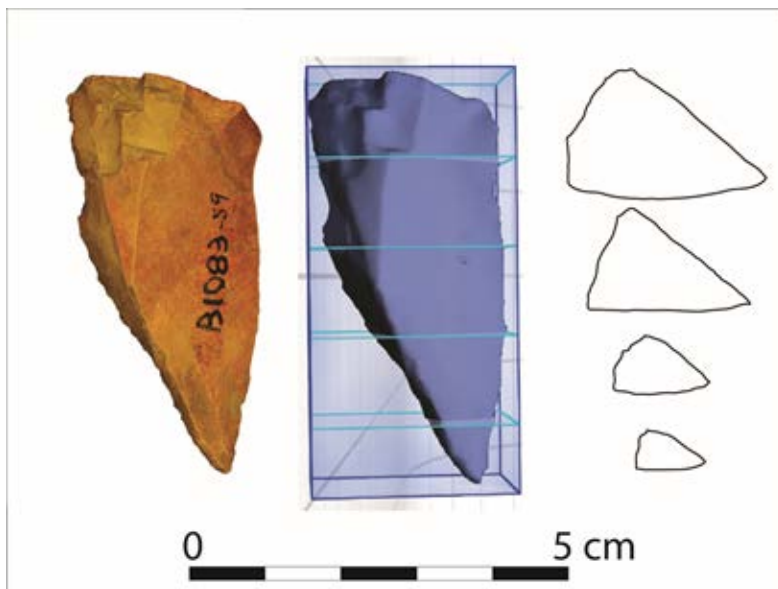


Figure 2.21 Production of 3D laser scanned cross section shapes.

Flake edge relative to mass, expressed in millimetres over grams, is used to track changes in the conversion of core mass into potential working edge (Mackay 2008). If a large amount of core mass is removed for a relatively small amount of workable flake margin, then the use of core mass in terms of potential working edge is less efficient than removing smaller and thinner flakes (Mackay 2008:615). This index is calculated by multiplying flake lateral perimeter length by mass. The lateral perimeter length is calculated by the addition of linear measurements taken along the flake margins, including the ventral platform margin (see Braun 2005; Mackay 2008 for alternatives).

Several indices were calculated that quantify the elongation and marginal shape of flakes and retouched flakes. The elongation index is calculated by the division of length by width; therefore this index is dependent on the width and length measurements employed. Figure 2.22 illustrates the calculation of elongation indices on different flake morphologies, using different length and width measurements. Elongation is here calculated using the box length and mid width, which allows for the inclusion of retouched flakes where the platform landmarks used to measure percussion length have been obliterated by retouch. The marginal angle index quantifies the expansion or contraction of flake margins in degrees (Clarkson 2007:38-39). This index uses the difference between proximal and distal width measurements, relative to length, to give a positive or negative value in degrees (Figure 2.23). Values of 0 indicate parallel margins, positive values indicate contracting margins, and negative values indicate expanding margins. Figure 2.23 illustrates four examples of variation in marginal angle: A) illustrates parallel margins which return values of 0; B) illustrates expanding flake margins which return values below 0; and C) illustrates contracting margins which return values above 0. The final illustration in Figure 2.24, (D), illustrates how this index can falsely indicate parallel margins for ovate morphologies. In this latter instance, the difference in proximal and distal width measurements would indicate a marginal angle value close to 0, while the actual margins clearly expand and contract in either direction.

The parallel index is calculated by dividing the width at the mid-point of maximum length, by the width of the platform (Davidson 2003:56) (Figure 2.24). Values of 1 indicate parallel proximal margins, values greater than 1 indicate diverging proximal margins, and values less than 1 indicate converging proximal margins. The parallel index only contrasts the expansion or contraction of flake margins between the platform and proximal half of flakes. Figure 2.24 illustrates variation in this index on four different flake morphologies. The distal parallel index is calculated by dividing the mid width by distal width. Figure 2.25 illustrates variation in this index on four different flake morphologies.

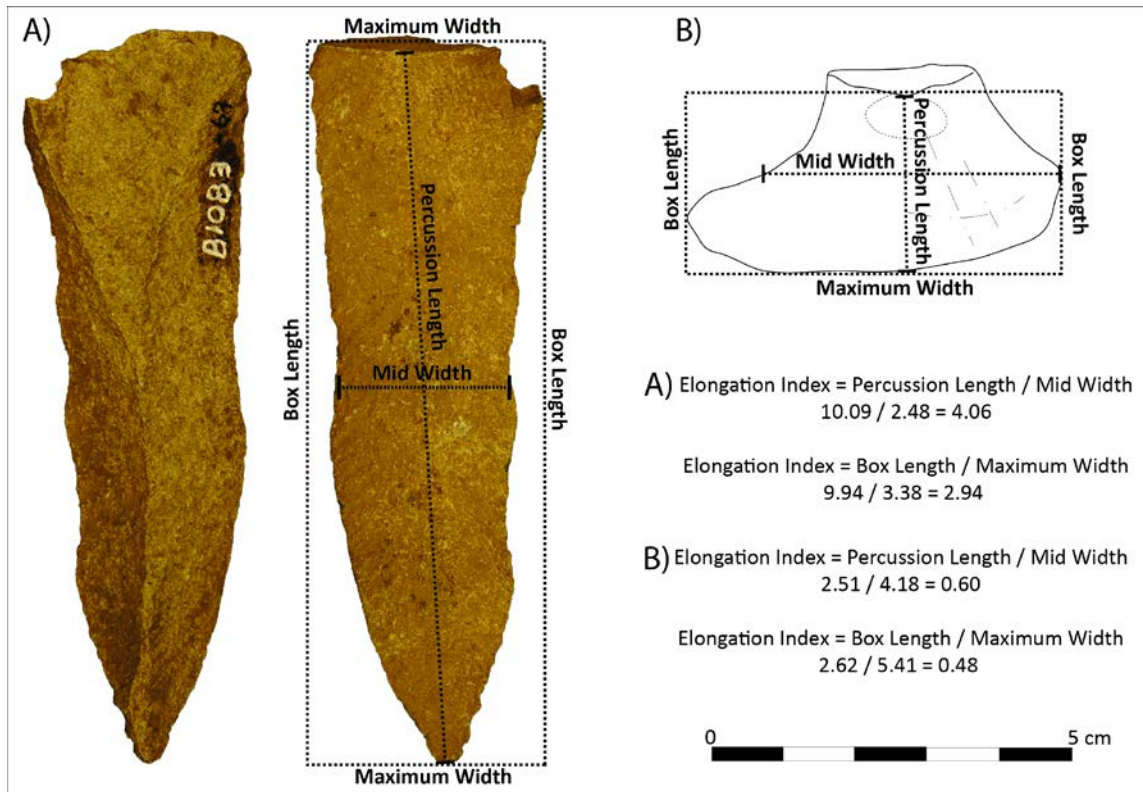


Figure 2.22 Calculation of elongation Index.

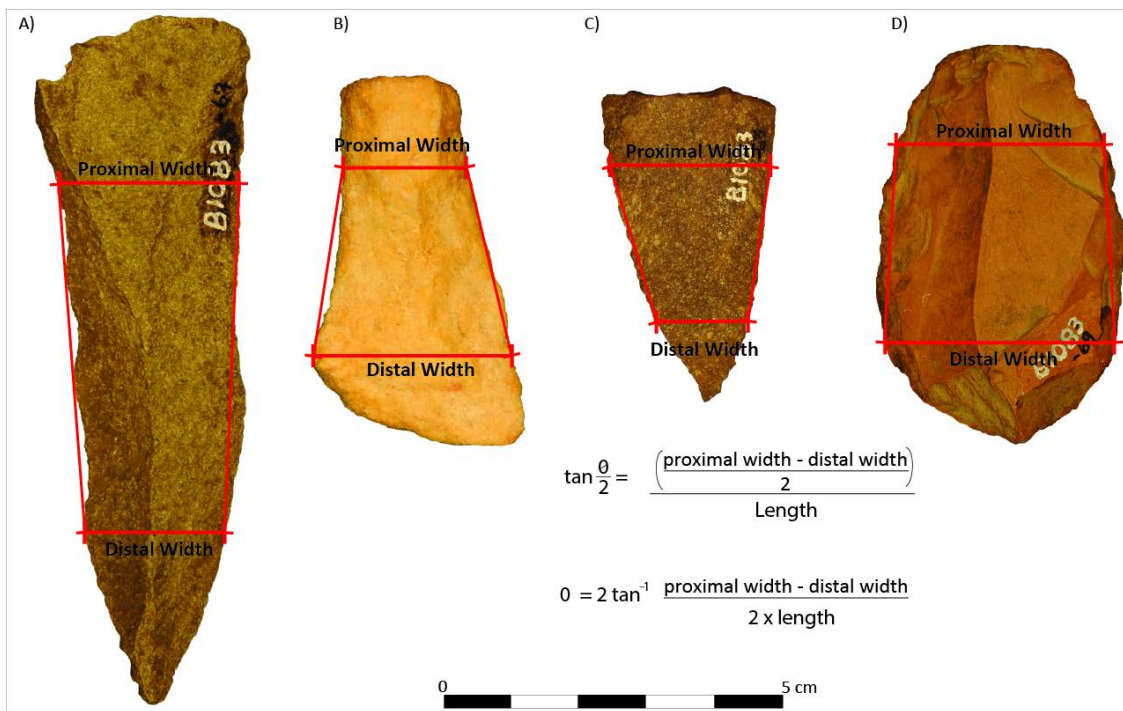


Figure 2.23 Marginal angle calculation for four different morphologies A) Parallel margins which return values of 0; B) Expanding margins which return values below 0; C) Contracting margins which return values above 0; D) False indication of parallel margins for ovate morphology.

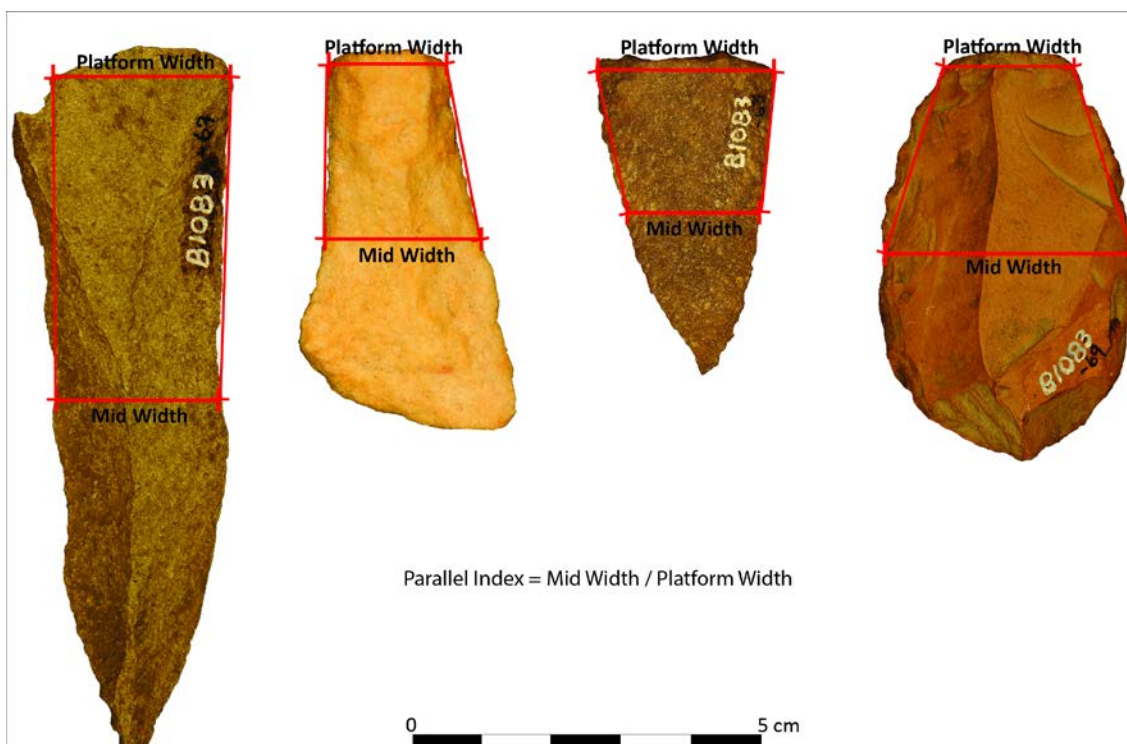


Figure 2.24 Parallel index calculated on four different flake and retouched flake morphologies.

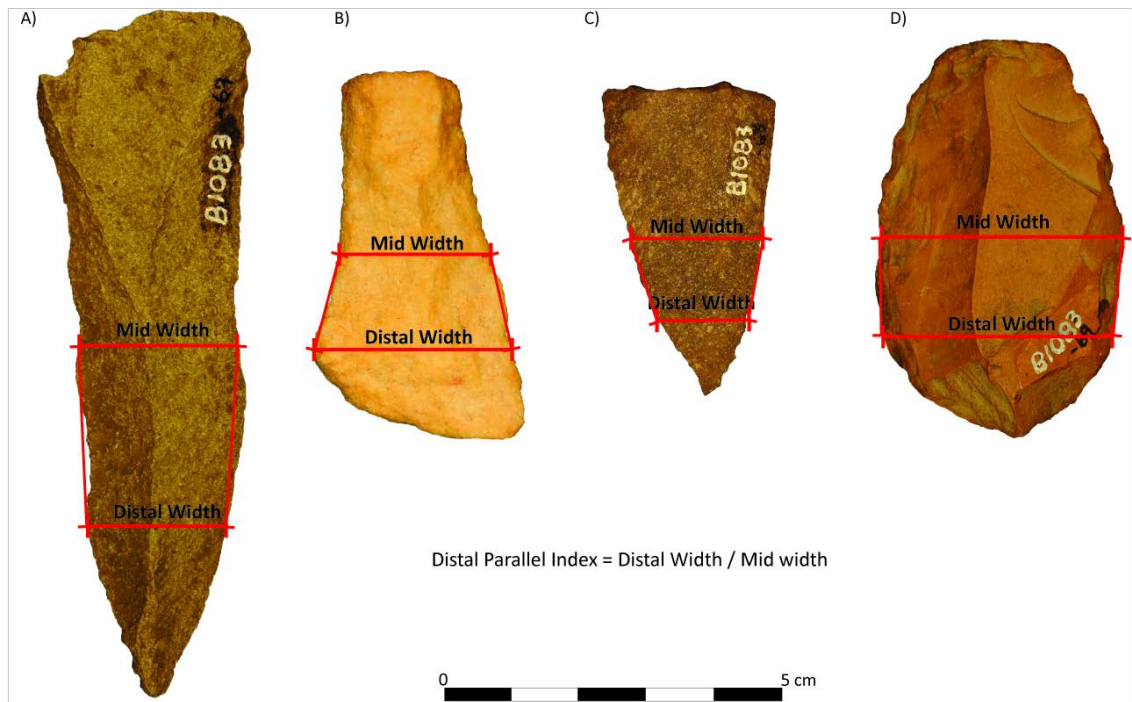


Figure 2.25 Distal parallel index calculated on four different flake and retouched flake morphologies.

The modification of the proximal portion of points (or butts) is of particular interest, since proximal modification is often discussed in relation to the hafting of points (Clarkson 2007:104). The proximal curvature index was calculated for all points with proximal retouch, that is, retouch on the point margins between proximal width and the platform, or non-pointed end. This index uses two linear measurements. The proximal width measurement is taken across the lateral margins at the maximum width where retouch begins to contract towards the proximal, or non-pointed end. Proximal width is divided by the proximal radius, taken as the perpendicular distance from the proximal width to the most proximal margin (Figure 2.26). Qualitative recordings were also made, referring to the proximal portion of points as either generally square or round; however, these variables are liable to overlap and are only used as a general reference to shape.

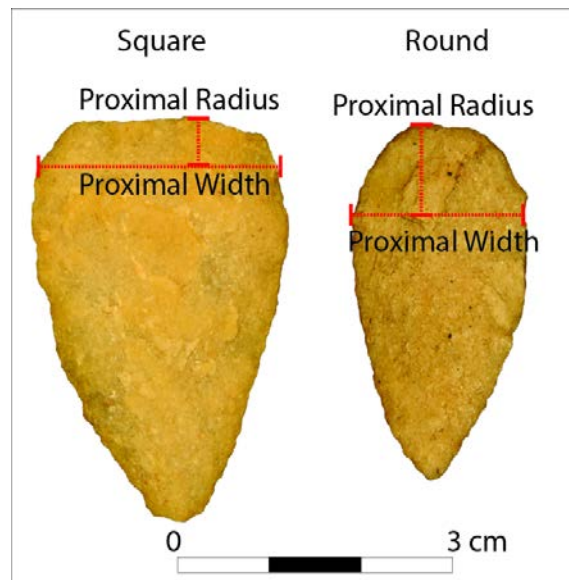


Figure 2.26 Proximal edge curvature index.

The 3D laser scanned images of each artefact were also analysed using elliptical Fourier analysis [EFA]. EFA analyses the variation in shape outline of artefacts using programs constructed with R statistical software. The variation in shape outline between flakes, retouched flakes and bifaces when orientated along the same axis was assessed with principal components analysis. The harmonics or sensitivity of shape outline variation can be adjusted to suit different morphologies. Appendix H outlines this methodology and its application.

2.1.7 Blank selection

The term 'blank' is used to identify the morphology of flakes which were selected for further modification. Extrapolating the morphology of blank flakes is complex, but it provides an indication of the level and importance of standardization. Identifying the blank morphology also provides a means of assessing the departure in morphology of retouched flakes from their original blank.

Platform area has well established relationships with flake mass (Clarkson & Hiscock 2011; Dibble & Pelcin 1995; Dibble & Rolland 1992; Muller & Clarkson 2014), and so provides a powerful means of contrasting retouched flakes with blanks, and different retouched flakes themselves. Provided the platform surface was present, intact, and not truncated by retouch, several linear platform surface measurements were recorded, including width, thickness, and approximate area (thickness times width). As illustrated in Figure 2.27, two thickness measurements were recorded, including the thickness at the PFA and maximum thickness, both taken perpendicular to width.

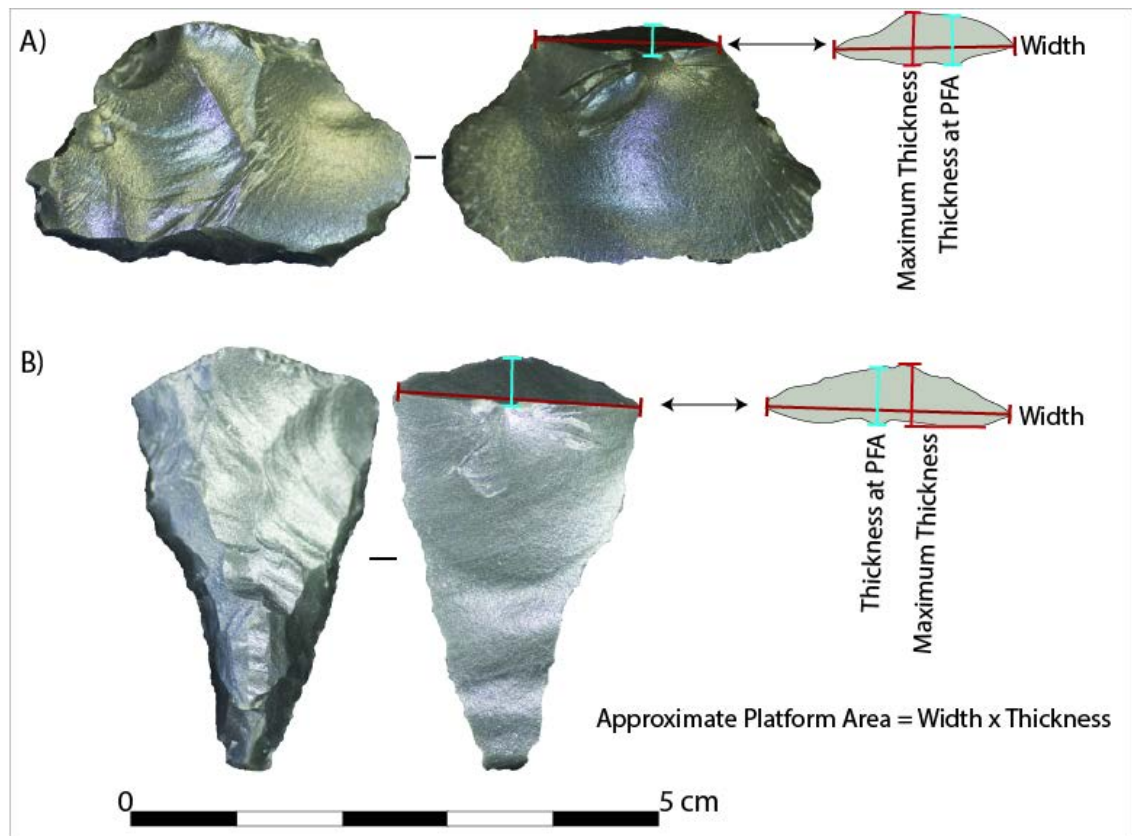


Figure 2.27 Platform surface measurements using digital callipers.

Approximate platform area is calculated by multiplying the width and thickness measurements, which will overestimate area by assuming a rectilinear shape. This assumption undermined many of the early attempts at modelling flake mass based on platform area (see Appendix G). The Next Engine 3D laser scanner was employed to record platform surface areas and overcome these inaccuracies. Platform area was measured with the laser scanner and converted to millimeters² (following Clarkson & Hiscock 2011). This process involved setting each flake or retouched flake on the scanning clamp, performing the scan in high resolution, fusing the scanned data, and editing the unwanted data points to include only the exact platform surface area. This precise surface area was calculated using the Next Engine software surface area function. The given value is in inches squared, and was converted to millimeters squared. Figure 2.28 illustrates the transformation of 3D data following these steps. The 3D laser scanned surface area is used as the primary metric to contrast blank forms and make comparisons of retouched flakes; however, where scanning was not possible due to translucency (see Appendix G), the linear platform measurements were used. In order to identify the early stages of use life in retouched flakes, prior to drastic modification, retouched flakes were sub-sampled using Index of Invasiveness values of less than 0.3 (Clarkson 2007:109).

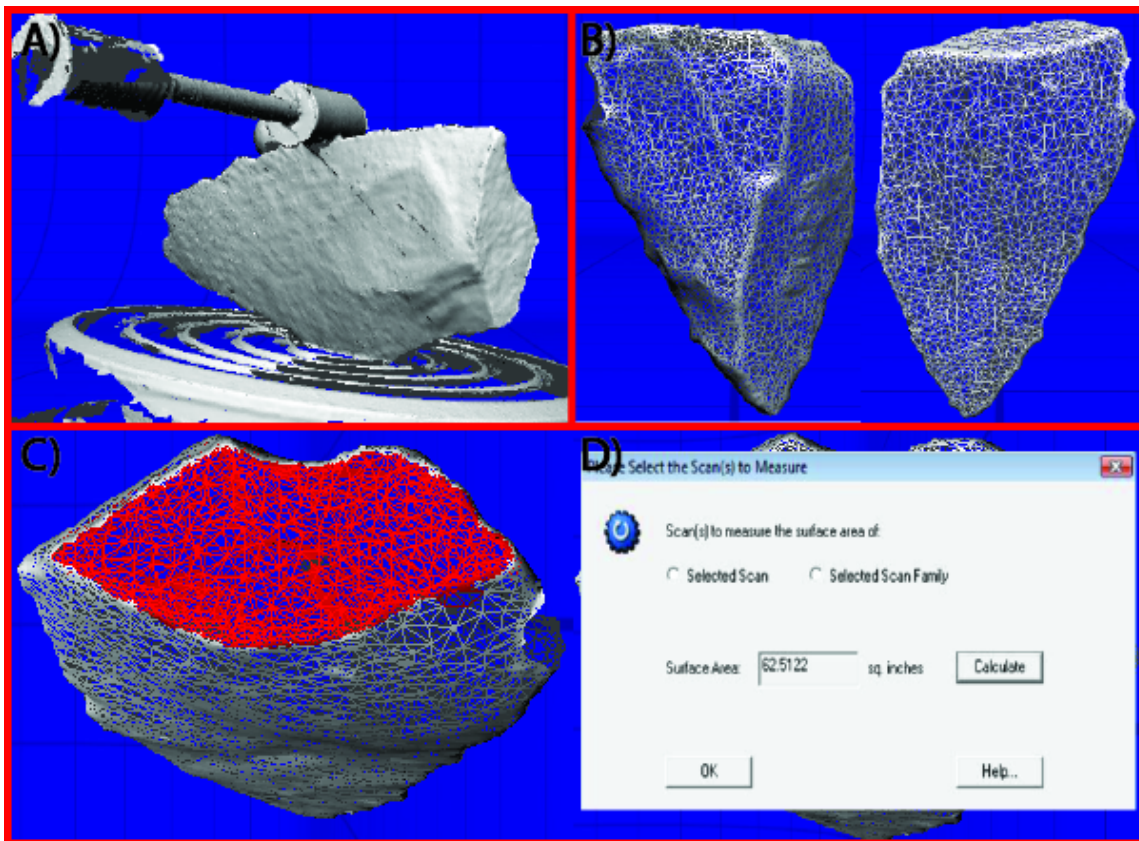


Figure 2.28 Measuring platform surface area with a Next Engine 3D laser scanner. A) Completed scan after fusing data points; B) Dorsal and ventral surfaces of artefact after editing all unwanted data points using the trim function; C) Trimmed artefact showing only the platform surface; D) The calculation of platform surface area in inches squared.

2.1.8 Qualitative retouch variables

Retouch can be distinguished as unifacial, initiated from one surface, or bifacial, initiated from two overlapping surfaces. As discussed in Chapter 3 (Maloney et al. In Review) these variables were used by earlier researchers to characterise and model point variability in Australia (Hiscock 1994), and so are strictly recorded as mutually exclusive observations, to avoid the overlapping of retouch types. Retouch can be either unifacial or bifacial; no intermediate qualitative categories are used. Retouch scars are also referred to as either marginal, restricted to flake margins, or invasive, where the scar invades the dorsal or ventral surfaces. These qualitative terms use the Index of Invasiveness scores of 0.5 and 1 to designate between marginal or invasive.

Burinate retouch refers to scars that propagate along the flake margins. Unlike unifacial and bifacial retouch scars, which are initiated from the flake margins and propagate onto the flake surfaces, burinate retouch propagates along the margins. Burinate retouch has been identified as a method of recycling broken points following transverse snaps, where burinate spalls (flakes) are initiated from the transverse snap (Clarkson 2007:112-

115) (Figure 2.29). The number of burinate scars was counted, as well as the number of burinate flake directions or rotations.

Retouch which truncates a break surface is also a signal of recycling. For a recycled artefact to be labelled as such, retouch scars must truncate the break surface. Retouch scars superimposed onto older, weathered surfaces, which show clear differentiation between fresh and older scars are also used to discern recycling (Figure 2.29).

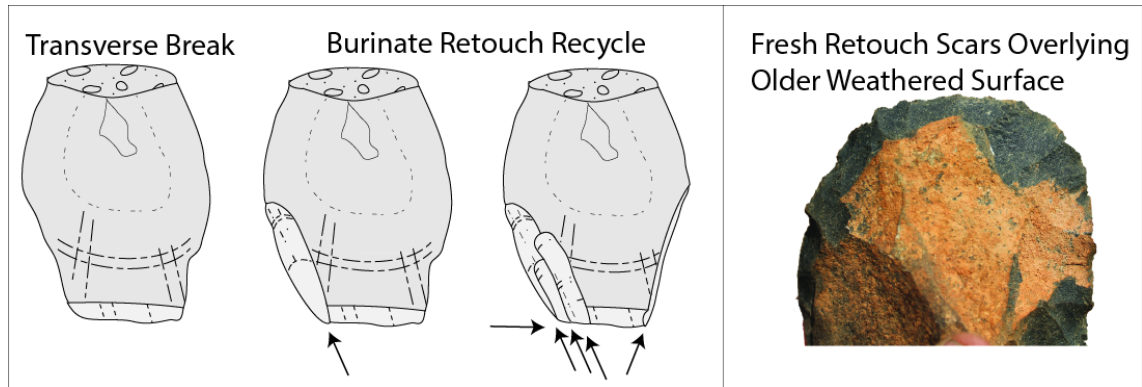


Figure 2.29 Recycling of older tools recognised by differential weathering of fresh retouch scars superimposed onto older scar surfaces.

There are numerous, variable definitions for identifying backing retouch. Andrefsky (2005:169) describes backing as an intentionally dulled edge produced by retouch, abrasion, or grinding, in preparation for hafting. Holdaway and Stern (2004:159, 259) define backing as abrupt unidirectional, or bidirectional retouch, normally found on one lateral margin, and most often initiated from the ventral surface. Hiscock (2006:78) defines backing retouch as ‘near ninety degree retouch retouched along one or more margins that was often accomplished with the use of bipolar techniques on an anvil’. The analyses here follow Hiscock (2006:78) in recognising backing as steep angled retouch approaching 90°, forming a blunted retouched margin. Bipolar anvil-rested retouch was recognised, independently, by bidirectional scars accompanying evidence of crushing in the form of multiple small step terminating scars (Cotterell & Kamminga 1987:689). The identification of anvil rested retouch is complicated by the variability in a flake’s cross section however; which can prevent bidirectional anvil contact from producing two initiation points. Flenniken and White (1985:143-144) pointed out that there are three modes of anvil rested retouch. The first occurs when the anvil is used to immobilise small flakes, preventing anvil contact on the surface opposite the retouch initiation, and resulting in steep angled unifacial scars. The second mode of backing occurs when dorsal ridges prevent the one surface from making anvil contact, and results in one edge being backed, and the opposite edge being rounded. In this instance, crushing on the dorsal ridges provides some confirmation of anvil-resting (Hiscock & Attenbrow 2005a:39). In the third mode described by Flenniken and White (1985:143–144), anvil contact does occur, and force is directed onto the backed margin from both the mobile percussor and stationary anvil (Cotterell & Kamminga 1987:689).

The sequence in which flakes were removed from retouched flakes is reconstructed using observations of the order of retouch. The order of retouch was recorded as either ventrally initiated, where retouch scars propagate onto the dorsal surface, or dorsally initiated, where retouch scars propagate onto the ventral surface. When retouch scars initiated from one surface impact existing scars initiated from the opposite surface, the latter surface was the last to be retouched. Using this premise, retouch order was recorded as either dorsal only, dorsal last, ventral only, or ventral last. There are also two possible ambiguous retouch orders on complete retouched flakes. First, when no ventral surface can be identified, such as when retouch obliterates the ventral surface traits. Second, when alternate bifacial retouch occurs and the original retouch order is obscured by the rotation of the retouched flake.

2.1.9 Quantifying retouch intensity

Several methods of quantifying retouch intensity are used in this study, each verified in experimental and archaeological contexts to be both valid and robust (Hiscock & Tabrett 2010). Indices include the Index of Invasiveness (Clarkson 2002), Kuhn's Geometric Index of Unifacial Reduction [GIUR] (Kuhn 1990), the percentage of retouched perimeter (Hiscock & Attenbrow 2005b), and the number of retouched segments (Hiscock & Attenbrow 2005b).

The Index of Invasiveness

The Index of Invasiveness (Clarkson 2002) quantifies the intensity of retouch using the extent to which scars spread across the dorsal and ventral surfaces of both unifacial and bifacial retouched flakes. Each retouched flake is conceptually divided into 16 segments, with 8 on the dorsal surface, and 8 on the ventral. Each segment can receive a score of 0 (no retouch), 0.5 (marginal retouch scar/s are present, but do not extend beyond a quarter of flake width in that segment), or 1 (invasive retouch scar/s extend more than a quarter of flake width in that segment). These values are tallied and divided by the total number of segments (16) to give a value between 0 and 1. Figure 2.30 illustrates the Index of Invasiveness calculation for a retouched flake. This index is fast to calculate, can be applied to any complete retouched flake or biface, and is capable of dealing with both unifacial and bifacial retouch. Hiscock and Tabrett (2010) demonstrated that this reduction index supersedes many others in inferential strength. The index is; however, less sensitive to retouch variation in assemblages dominated by marginal, steep angled, and step terminating retouch (Clarkson 2007:35). The Index of Invasiveness was recorded on all complete retouched flakes, as well as bifaces.

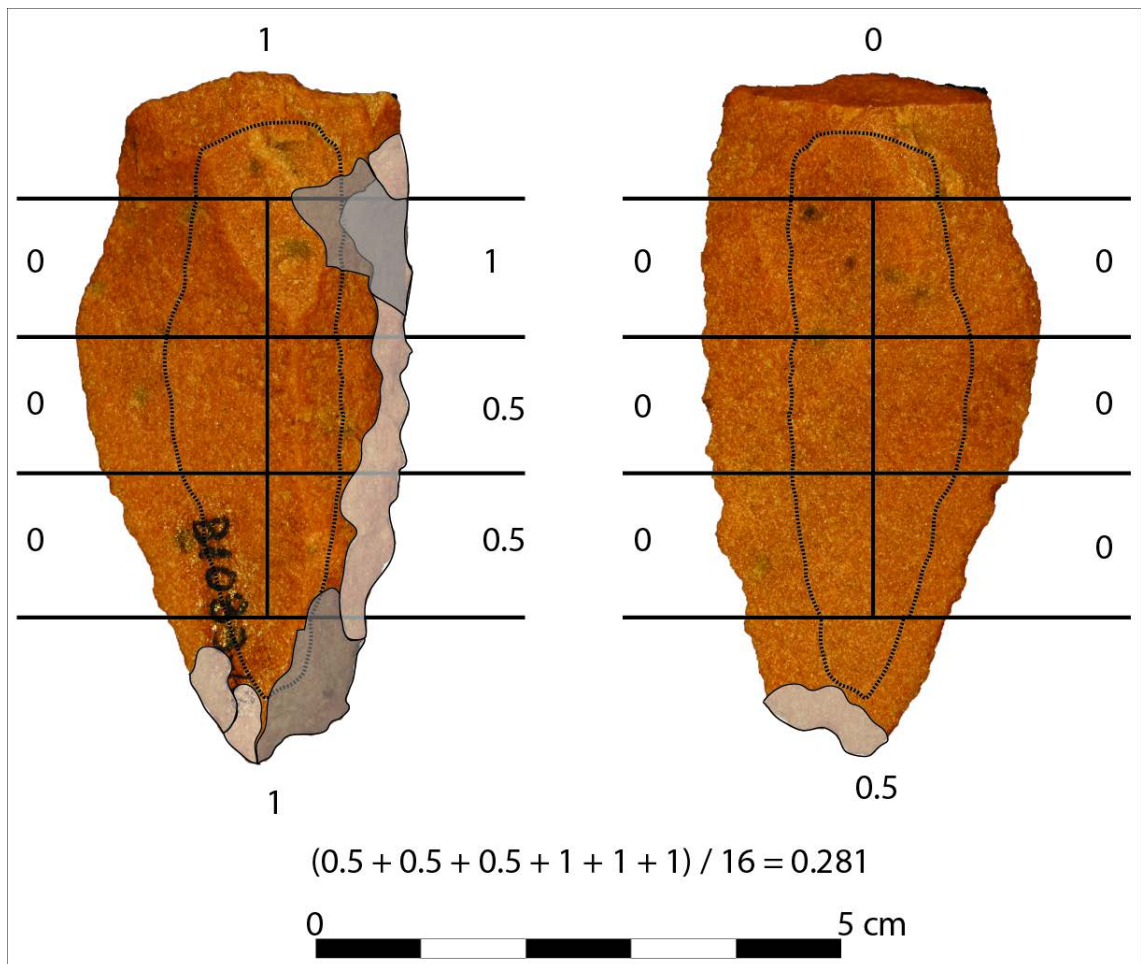


Figure 2.30 Index of Invasiveness.

The Average Geometric Index of Unifacial Reduction

Kuhn's (1990) Geometric Index of Unifacial Reduction [GIUR] calculates the relative difference between retouch scar height, expressed as 't', and retouched flake thickness, expressed as 'T'. This index is widely used, but suited only to unifacial retouch. The weakness of the GIUR is the 'flat flake problem', where flake thickness (T) varies little (Dibble 1995; Eren & Sampson 2009; Shott 2005), and so retouch scar height does not increase. Experimental and archaeological data demonstrate that with recognition of these cross sectional shapes, the index is a powerful technique for quantifying unifacial retouch. Following Hiscock and Attenbrow (2003, 2005a, 2005b) the GIUR is averaged over the length of the retouched margin, using six segments, to give a value between 0 and 1, and is referred to as the AGIUR. The box length was used to divide each retouched flake into three segments per margin, and the maximum scar height within each segment (t) was divided by the maximum thickness along that transverse plane (T). Figure 2.31 illustrates the AGIUR index. Since bifacial retouch alters the t/T relationship, this index was only recorded on complete unifacial retouched flakes.

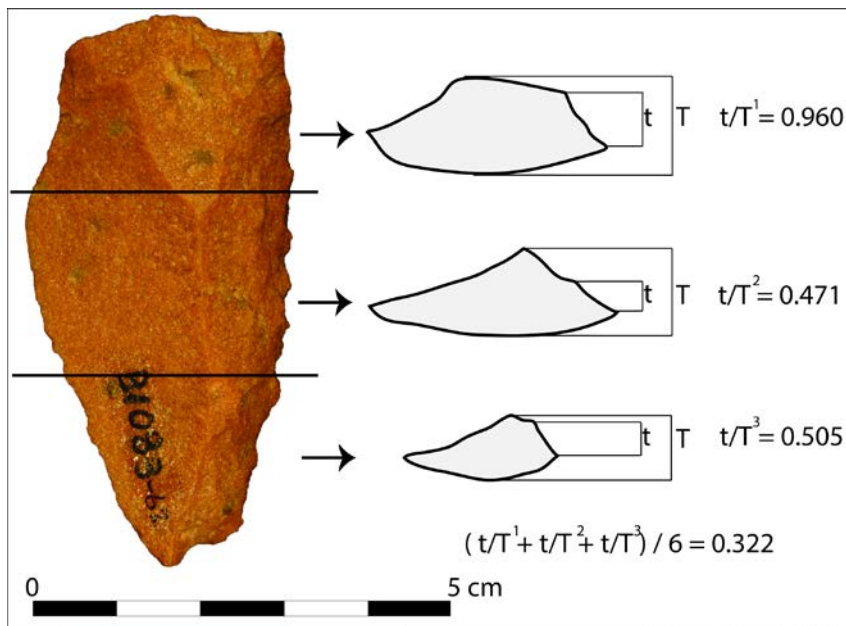


Figure 2.31 Average Geometric Index of Unifacial Reduction [AGIUR].

Percentage of Retouched Perimeter

To quantify the spread of retouch across flake margins, the length of retouched margin in millimetres is divided by the total lateral margin length, and multiplied by 100 to give a percentage value (Figure 2.32). These variables were recorded using a series of linear calliper measurements on retouched flake margins.

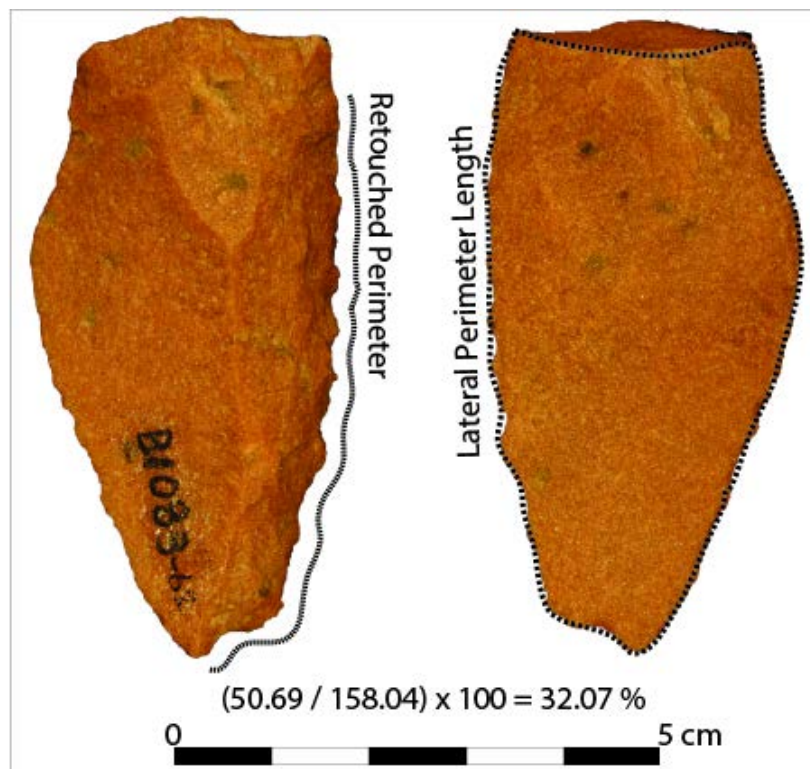


Figure 2.32 Percentage of perimeter retouched.

The Number of Retouched Segments

Both the Index of Invasiveness (Clarkson 2002) and AGIUR (Kuhn 1990) conceptually divide each retouched flake into segments. These indices therefore provide a further quantification of marginal retouch. The number of retouched segments has been successfully employed by Hiscock and Attenbrow (2005b) to quantify reduction in backed artefacts where other indices are less sensitive to increasing retouch intensity. The number of segments retouched out of the 16 Index of Invasiveness segments was recorded for all complete retouched flakes and bifaces.

The Index of Invasiveness segments are also used to quantify the spread of retouch within reduction sequences relative to the order of retouch. Each segment was recorded in the same clockwise order on each surface allowing the spread of retouch to be quantified relative to these segments. Percentages of segments with marginal or invasive retouch are used to convey these retouch order patterns. Percentage values for each segment, including both marginal and invasive segments, are calculated by dividing the individual segments with retouch scores by the number of retouched flakes within quartile divisions of the Index of Invasiveness (0 – 0.25, 0.25 – 0.5, 0.5 – 0.75, 0.75 – 1). These data can then be used to illustrate the spread of retouch within these divisions following Hiscock (2011:78) and Clarkson (2005:25). Marginal segments associated with inner invasive values are left blank to highlight the frequency of invasive retouch on those point segments.

Edge Curvature Index

The spread of retouch will also create convex or concave retouched margins, which can vary during artefact use life. The edge curvature index quantifies this variation by dividing the diameter of the retouched margin by the maximum depth of the retouched diameter (Brumm & McLaren 2011:189; Clarkson 2007:48-49; Hiscock & Attenbrow 2003, 2005b) (Figure 2.33). Increasingly convex retouched margins are captured by positive values, while increasingly concave retouched margins are captured by negative values.

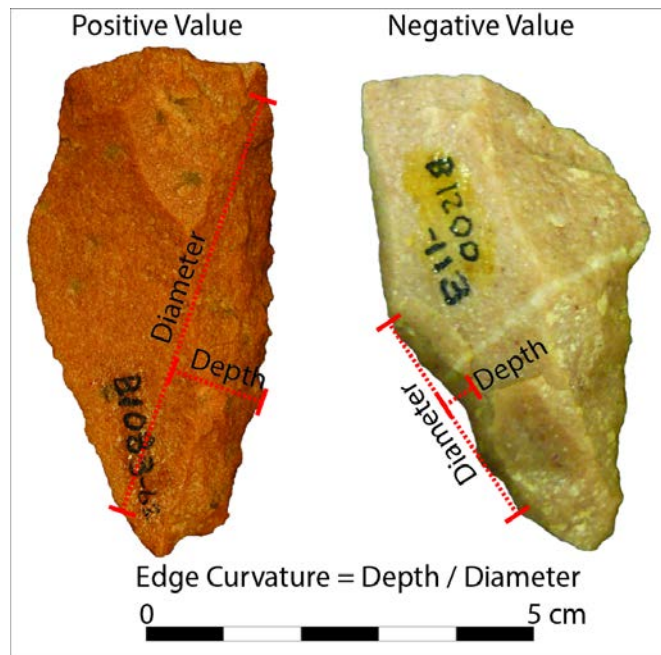


Figure 2.33 Calculation of edge curvature index.

Initial to Terminal Mass Comparison

The initial to terminal mass comparison [I/TMC] proposed by Clarkson and Hiscock (2011), and tested by Muller and Clarkson (2014), was conducted for the retouched flakes and flakes with intact platform surfaces. The I/TMC works on the correlation between platform area and flake mass, which, with the accuracy of 3D laser scanning drastically improves the strength of the relationship. This method requires multi regression analyses of sub populations within assemblages, such as platform type, EPA divisions, and termination types (see Appendix G). Using the I/TMC, the mass lost from retouched flakes is estimated by comparing the retouched flakes' platform surface area, with the estimated initial mass, derived from the non-retouched flakes' platform surface area regression line. The estimated initial mass of retouched flakes, predicted by this regression, is subtracted from the known terminal mass of the retouched flakes. The given estimated mass lost can then be quantified as a percentage of the initial mass (Hiscock & Tabrett 2010:553).

The performed experimental test of I/TMC (Appendix G) indicated that this technique is not as versatile as the other reduction indices. While sample sizes used in this experimental study are probably too small to provide a definitive answer to the questions surrounding the value of this technique, it was determined that I/TMC lacks the empirical backing of the other reduction indices, and so was not included in the main analyses presented.

2.1.10 Pressure flaking

The importance of pressure flaked bifaces to the prehistory of the study area, described in Chapter 1, emphasises the importance of analysing pressure flaking. It has been

suggested that there are no reliable mutually exclusive criteria for distinguishing pressure flakes as discrete components of an archaeological assemblage (Andrefsky 2005:118). Using attributes such as flake morphology or platform characteristics to identify pressure flakes is often unreliable, since the same attributes have been shown to result from hard hammer or direct percussion in other modes of reduction (Ammerman & Andrefsky 1982; Andrefsky 1986, 2005:119). So while many attributes used in the attempted recognition of pressure flakes are recorded in this study, such as focalised platforms and transverse parallel initiations, no attempts are made to use these criteria for the recognition of pressuring flaking. Identifying pressure flaking scars themselves can be more reliable. Negative scars with relatively small, focalised initiations, and parallel margins are evident on pressure-flaked points (Mourre et al. 2010:660-661, Fig 1 and 2); providing a means of identifying pressure flaked scars (Figure 2.34).

Marginal serrations or lateral projections provide another feasible means of identifying pressure flaking, since projections observed on bifaces are invariably produced by pressure flaking. Akerman and Bindon (1995:89) outline three modes of marginal serrations: Serrate, denticulate, and dentate (Figure 2.34). Serrate margins are extremely small or fine projections, usually triangular in outline, and separated from each other by equally fine notches. Denticulate margins are regularly spaced projections separated by notches that are of similar or narrower width than the projections. Dentate projections are separated by notches that are wider than the projections. Variation between these serration types is illustrated in Figure 2.34.

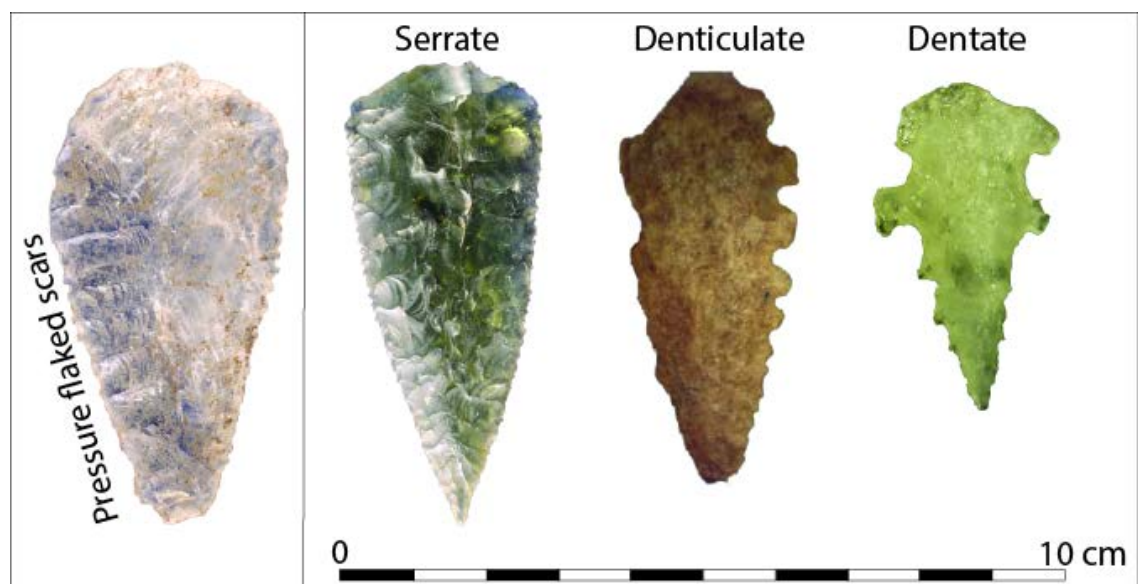


Figure 2.34 Example of serrate, denticulate, and dentate margins on pressure flaked bifaces.

The nature of variation between marginal serrations was quantified by a series of novel indices, designed to capture metric variation. These measures were not included in the main thesis chapters, due to the consistently low sample size of pressure flaked bifaces

in the assemblages. The total number of serrations were counted and used to calculate the number of serrations per millimetre of biface edge, and the percentage of biface perimeter with serrations. The average length of each serration was measured as the maximum lateral projection between the adjacent notches for each serration (Figure 2.35). This measurement was calculated for the largest projections with each of the 16 segments of the biface, following the Index of Invasiveness segments. The average distance between each projection was also calculated, by measuring the distance between the centres of each serration, which was divided by the total number of serrations (Figure 2.35).

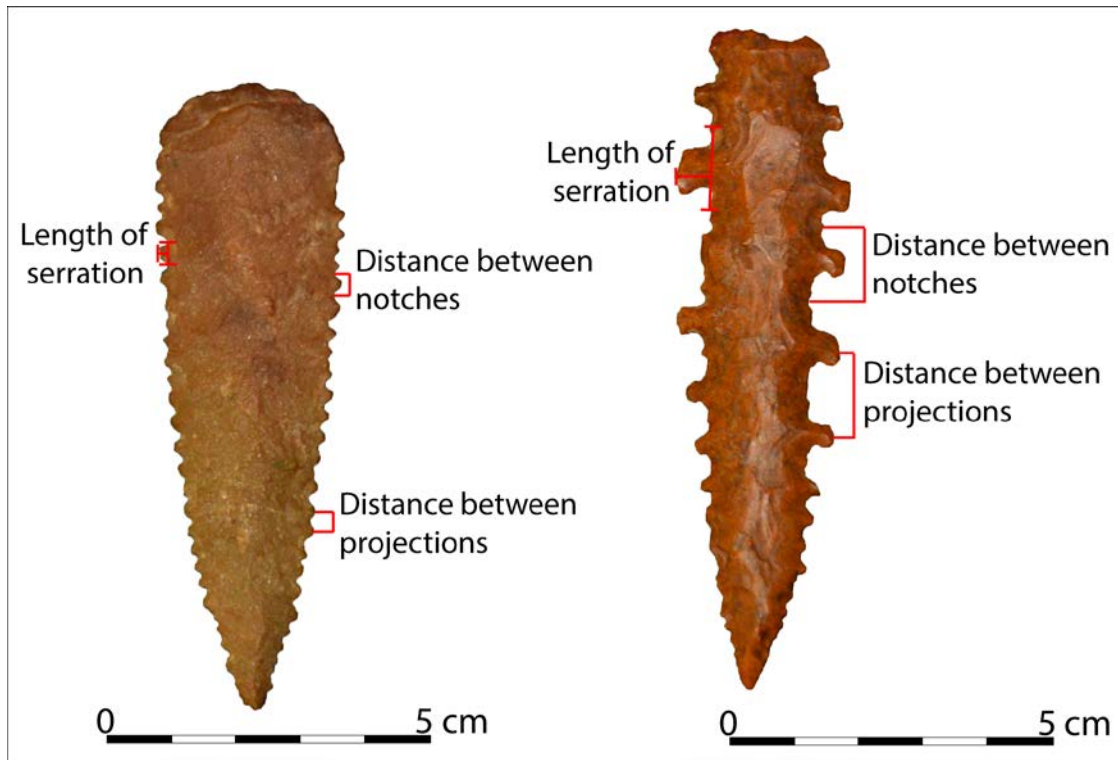


Figure 2.35 Quantification of marginal serrations on pressure flaked bifaces.

2.1.11 Practical geology for stone artefact analysis

Macroscopic elements and microscopic identification of structure were employed to determine geological origin and allocate artefacts to a rock type. No thin sections or polarized light analyses were conducted on any of the materials; rather, macroscopically observed traits (Table 1), and some microscopic identification of traits, were used to place rock types into broad groups. These broad groups provide a means of comparing the raw materials selected for artefact manufacture, and are not meant to be an exhaustive geological description.

The first distinction made between rock types is their relative formation process. Igneous rocks are formed by cooling and consolidation of magma. Sedimentary rocks are formed by the deposition of mineral particles transported by flowing water, wind, or ice. Metamorphic rocks are either igneous or sedimentary rocks that have been since altered through high pressure and/or temperature (Skinner et al. 1999:118).

These three formation processes will create unique mineral structures and other properties observable at low magnification. A qualitative measure of grain size was developed, to reliably record the mean size of constituent particles within the rock. Grain size was recorded relative to a millimetre scale, where very fine represented invisible grain sizes; fine smaller than 1mm; fine to medium around 1mm; medium above 1mm, and coarse up to 5mm. The mineral composition or texture is also used in definitions of rock. The texture and mineral composition were also described, the latter referring to the mineral components observed, such as feldspar, quartz, or mica. Coarse to medium grained igneous rocks including gabbro, granite, and diorite can be examined for ratios of quartz, feldspar, and olivine minerals. For example, basalt and andesite are finer grained extrusive igneous rocks, recognised by the lack of quartz and olivine minerals. The lustre of rock surfaces was also used to distinguish rock types. The reflective properties of rock surfaces will generally fall into either metallic or non-metallic lustre. The non-metallic lustres can be further divided into vitreous, resinous, pearly, or greasy (Skinner et al. 1999:121). The hardness of rock types is often used in identification of geological samples, although as all of the rocks selected for reduction are hard and brittle, many rock types can be easily eliminated, such as mica or chalk. The use of a hardness test, such as the Moh relative hardness scale, was not used on archaeological specimens. The combination of these practical geological observations are listed in Table 1 according to the main raw material types of the study area.

Table 1. Identification of rock types in the study area.

Rock Type	Formation Process	Outcrops	Grain Size	Lustre	Colour
Crystal Quartz	Mineral	Formed crystal; or water rolled cobble within gravels	Very Fine/ Invisible (<1mm)	Vitreous	Translucent
White Quartz	Mineral	Vein/dyke; or water rolled cobble in either limestone conglomerate, or eroded into gravels	Very Fine/ Invisible (<1mm)	Greasy	White to pink/red
Chert	Metamorphic	Seams within & between limestone reef masses; or eroded into gravels as cobbles	Very fine/ invisible to fine (~ 1mm)	Greasy to vitreous	Highly variable: Reds, browns, creams, & greens
Quartzite	Metamorphic	Conglomerate bands throughout limestone; or eroded cobbles into fluvial fans & river gravels	Fine to medium (~1mm to >1mm)	Pearly	Pink, purple, red, & orange
Basalt	Volcanic	Extrusive igneous outcrops; very occasional river cobbles; or conglomerate components	Fine to medium (~1mm to >1mm)	Greasy	Dark green/grey to black
Tuff	Volcanic/Sedimentary	Deposited volcanic ash; very occasional river cobble	Very fine/ invisible to fine (~ 1mm)	Greasy	Grey to black
Hornfels	Metamorphic	Occasional river cobble	Very fine/ invisible to fine (~ 1mm)	Greasy	Blue to green
Chalcedony	Metamorphic	Sheets between reef masses; or water rolled cobbles in gravel	Very Fine/ Invisible (<1mm)	Greasy to vitreous	White to semi transparent

2.2 Excavation Methods

Excavation squares or test pits at each site were initially 1 meter square, and later adjoined by additional 1 meter square pits. The recording of excavation information at each site used the form illustrated in Figure 2.36. Arbitrary excavation units [EU] of 2cm were employed at each site. At CG3 5cm were used due to the small quantity of cultural material being recovered and the cemented nature of the deposit, which made it difficult to control 2cm removals (O'Connor et al. 2014:11). Within each EU, horizontal quadrants of 50 x 50cm were removed separately, ordered: A, B, C, and D, with A originating from the south-west corner. All recovered materials were associated within a single vertical EU, and a single horizontal quadrant. Where cultural or sedimentary features were identified, these features were removed separately within the arbitrary vertical and horizontal units. Sediments were described during, and at the completion of all EU. Texture, sorting, and compaction were described following Burke and Smith

(2004:132-135). Sediment colour was described using the Munsell colour chart and was conducted on the main body of sediment within each EU as well as the unique features. At the completion of each EU, all features, rocks, and sediment changes were measured and drawn to scale on page two of the recording form (Figure 2.36). Photographs were taken as aerial shots of both the completion of each EU, and the features as they emerged. Stratigraphic sections were drawn for each wall at the completion of the excavation before backfilling, by Dorcas Vannieuwenhuysen. Sections were also sampled for micro-stratigraphy analysis.

Metrics such as sediment volume (litres), and weight in grams (g) were recorded, for each quadrant and EU. All sediment was dry sieved through nested screens. The excavation of Windjana Water Tank Shelter and Mount Behn used screen sizes of 3mm and 1.5mm. The excavation of CG1 employed screen sizes of 6mm and 3mm, and the CG3 excavation used 6 and 3mm sieves during the 1993 field season, and 5 and 1.5mm sieves during the 2012 season.

In situ recording of materials, such as charcoal, shell, bone, and lithic artefacts, used horizontal X and Y coordinates originating from the south-west corner, and Z measurements, or depth, were recorded using a dumpy.

Large rocks with no cultural modification were weighed and discarded. Sorting of the recovered material into categories of bone, wood, shell, organics, charcoal and artefacts took place at the site after sieving. Each material was bagged separately.

Bulk sediment samples of approximately 200g were taken from every EU, at the north east corner. Sediment samples were also taken from features during excavation. Micro-stratigraphy samples were taken from the sections at each excavation. Mount Behn was the only excavation subjected to froth flotation sampling, consisting of approximately 200 - 300g of sediment from the north west corner of Square 2.

EXCAVATION DATA SHEET: LIFEWAYS PROJECT 2013



**Australian
National
University**

Copyright
Barham Brugsman
& Associates

DATE

SITE NAME

SITE LOCATION/AREA

LATITUDE

LONGITUDE

EXCAVATORS	SQUARE #	Dumpy H	Bearing	Datum	SPIT #	INTERVAL

EXCAVATION PLAN

U
C
L

ORIGIN (0,0)

START LEVELS (cm)

ORIGIN (0,0)

END LEVELS (cm)

ORIGIN (0,0)

N

MAIN SEDIMENT DESCRIPTION

	Page	W/C	Munsell Colour	pH
Texture:				
Sorting:				
Compaction:				
Inclusions (%):				

FEATURE DESCRIPTIONS

EXCAVATION COMMENTS

Charcoal ☐ Lithics ☐ Bone ☐ Shell FW ☐ Marine Shell ☐ Beads ☐ Ochre ☐ Seeds ☐ Wood ☐

DISTURBANCE OBSERVED

Photo # log:	Sediment / Feature samples	CLAYEY SAND - SILTY SAND - COARSE SAND - MEDIUM SAND - FINE SAND - CLAYEY SILT - SILT - SANDY SILT - CLAY - SANDY CLAY - SILTY CLAY
		WELL SORTED MODERATELY SORTED POORLY SORTED VERY POORLY SORTED
		   

Camera:

FEATURE PLAN FOR SQUARE / SPLIT LEVEL

100
90
80
70
60
50
40
30
20
10
0

(0,0)

ORIGIN (E,N)

0102030405060708090100

centimetres

A

B

C

D

N

EXCAVATION CONTEXT

ORIGIN (SUB)

Were insitu samples taken from within feature?

Feature Context/Order

Quad	Mass (kg)	Vol	Rocks Discard	6mm	1.5mm
A					
B					
C					
D					
X					
X					
X					
X					

insitu Objects	Info - sediment	x	y	z	TSR

Figure 2.36 Excavation recording form.

2.3 Radiocarbon Dating

Radiocarbon samples were taken in situ during excavation, as well as from the sections at completion of the excavation and after drawing identified significant changes in the profile. While samples selected for radiocarbon dating were comprised of bone, wood, resin, freshwater shell, marine shell, and charcoal, the latter was primarily used. Samples were dated either at Direct AMS the Accelerator Mass Spectrometry Lab in Seattle, USA, The Australian National University Radiocarbon Dating Facility in Canberra, Australia, or The University of Waikato Radiocarbon Laboratory in Otago, New Zealand. Radiocarbon dates were calibrated using OxCal version 24 (Bronk-Ramsey 2009). Prior to the 2013 terrestrial and marine curves (Hogg et al. 2013), dates were calibrated using the 2004 terrestrial and marine curves (McCormac et al. 2004; Reimer et al. 2009).

Radiocarbon dates were associated directly with cultural material by proximity of artefacts to the dated units (Maloney et al. 2014; In Review) (Chapter 3 and 4), or the construction of age depth models (O'Connor et al. 2014) (Appendix A), or generalised periods within strata (Maloney et al. In Review) (Chapter 4). Direct dating of artefacts included marine shell beads (Maloney et al. In Review) (Chapter 4, Appendix D), and the resin adhering to one stone artefact (Maloney et al. In Review) (Chapter 6).

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Chapter 3

New dates for point Technology in the Kimberley. *Archaeology in Oceania*, 49:137–147.

Authors: Tim Maloney, Sue O'Connor and Jane Balme

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Formulation of arguments in manuscript. Composed the overall question, background research, site description, discussion, and conclusion of this research paper and wrote the major part of the paper. Analysis of lithic artefacts. Submission and calibration of new radio carbon dates, and calibration of all previously published dates.



Signed:

Tim Maloney

Refinement of arguments in manuscript. Australian Research Council Linkage Grant (LP100200415) CI, coordination of fieldwork and excavations at Mount Behn, Carpenters Gap 3 and Windjana Water Tank Shelter. As Project CI contributed to the topic development and editorial supervision for the research paper. Assisted with formulation of arguments in the manuscript and wrote sections of the manuscript.

Signed:

Professor Sue O'Connor



Refinement of arguments in manuscript. Australian Research Council Linkage Grant (LP100200415) CI, coordination of fieldwork and excavations at Mount Behn, Carpenters Gap 3 and Windjana Water Tank Shelter. As Project CI contributed to the topic development and editorial supervision for the research paper. Assisted with formulation of arguments in the manuscript and wrote sections of the manuscript.

Signed: 

Professor Jane Balme



New dates for point technology in the Kimberley

TIM MALONEY, SUE O'CONNOR and JANE BALME

TM, SO'C: *The Australian National University*; JB: *University of Western Australia*

ABSTRACT

New data from Bunuba country in the southern Kimberley provide more robust dates for point technology in the Kimberley than have been previously available. Direct percussion points have been recovered from three sites in the southern Kimberley associated with radiocarbon dates of ~5000 calBP, whereas the earliest pressure-flaked points are consistently associated with dates within the past 1000 years. This suggests that pressure-flaked point technology postdates the earliest occurrence of direct percussion points by ~4000 years in this region.

Keywords: Kimberley, point technology, pressure flaking, dating, Holocene Australia.

Correspondence: Tim Maloney, Department of Archaeology and Natural History, College of Asia and the Pacific, The Australian National University, Coombs building, 9 Fellows Road, Acton ACT 2601, Australia.
Email: tim.maloney@anu.edu.au

INTRODUCTION

Although direct percussion and pressure-flaked points from the Kimberley region are abundant in museum holdings and displays, they are predominantly from surface collections in shelters and open sites, and are poorly documented from well-dated contexts. Previous research indicates that pressure-flaked point production postdates the earliest appearance of direct percussion points (Dortch 1977; Harrison 2004; O'Connor 1999); however, poorly dated contexts and confusion over nomenclature have made it difficult to determine the relationship between these artefact classes and their temporal separation. In order to examine the implications of these changes in terms of technological restructuring, it is first necessary to understand the temporal framework for production. Here, we review previous studies relating to the chronology of stone point production in the broader Kimberley region, and then describe the points and dating contexts from our new excavations in the southern Kimberley.

Point technology in the Kimberley has been described with a range of *ad hoc* classifications. For example, the term “Kimberley Point” has occasionally been used to describe any retouched artefact made on an elongate flake with converging margins, regardless of retouch attributes (e.g. Veitch 1996: 70–2, 74, 76, 77, 79; see Veitch 1999: 356). Akerman and Bindon (1995), however, use the term “Kimberley Point” specifically to describe points produced by pressure flaking exhibiting “denticulate” or “serrated” margins. On the other hand, these authors distinguished a Kimberley Dentate point (Akerman and Bindon

1995:93–4), where the notches separating the teeth are wider than the teeth. In order to avoid the confusion that can arise from the application of different typologies, here we follow Harrison (2004: 2) in recognising a class of retouched points produced by direct percussion, as distinct from those produced by pressure flaking.

THE MANUFACTURE OF POINTS

Direct percussion points

Point morphologies in parts of the Northern Territory and northern Queensland have been convincingly shown to be part of a dynamic reduction continuum, where the heuristic classifications of unifacial and bifacial points are best explained as a consequence of variation in blank morphology and retouch intensity (see Clarkson 2006: 103–4; Clarkson 2007: 101–12, 160; Hiscock 1994: 77–80; Hiscock 2006: 77–8; Hiscock 2009: 84–5; Macintosh 1951: 200; Maloney 2010: 89–103; Smith & Cundy 1985: 34). However, there were major changes in technological production following the initial introduction of points. Clarkson (2006: 104) showed that, following the introduction of point technology in Wardaman country approximately 3000 years ago, bifacial point discard peaked at around 2000 calBP, after which time points began gradually receiving less overall retouch, with a peak in unifacial point production evident at c.1500 calBP. Clarkson (2007: 104) also observed an overall decline in retouched point production within the past 1000 years, in favour of the manufacture of large unretouched blades that Davidson (1935: 167) notes were hafted without

modification. Davidson (1935: 168) specifically comments that the Wardaman were only just adopting pressure-flaked points during his time there in 1930, and notes that their attempts at making them lacked expertise (Davidson 1935: 170). Wardaman technology was clearly subject to major transformations in the immediate pre-contact to contact periods.

Although Blundell (1975: 288) entertained the possibility of a reduction continuum between unifacial and bifacial points, researchers have largely rejected a sequential model to explain variability in point morphology in the Kimberley (Akerman & Bindon 1995; Akerman *et al.* 2002: 15; Blundell 1975; Dortch 1977; Flenniken & White 1985: 148; O'Connor 1999: 76). O'Connor (1999: 76) based her classification of points from Widgingarri Shelters 1 and 2, in the west Kimberley, on the distribution of retouch along margins and across the dorsal and ventral surfaces. She specifically concluded that bifacial points were not the end product of a reduction sequence from unifacial points (O'Connor 1999: 76) at Widgingarri. This conclusion was based on an argument about the sequence of flake removals during point manufacture and the fact that unifacial and bifacial points do not co-occur in the lower levels at these shelters, bifacial points being later (O'Connor 1999: 76–7). Dortch (1977: 113) defined an “intermediate” category between unifacial and bifacial point morphologies from the Ord Valley in the east Kimberley, which he described as only partly flaked on the bulbar surface after retouch was applied to the dorsal surface.

Pressure-flaked points

The manufacture of pressure-flaked points has been widely observed ethnographically throughout the Kimberley (Akerman 1978; Balfour 1903, 1951; Basedow 1925: 367–70; Elkin 1948: 110–13; Idriess 1937: 59–62; Love 1917: 25–6; Love 1936: 93–5; Mitchell 1949: 64; Petri 1954; Spencer 1928; Tindale 1985: 8–11 – and see also Davidson 1935 for observations of pressure-flaked points in Wardaman country in the Northern Territory). Akerman *et al.* (2002: 18–19) review these ethnographic observations. The observations consistently reveal a staged production process, where the pressure-flaked point is an exclusive end product, with some evidence of curation (Akerman *et al.* 2002: 30). In other words, retouching events are not reactions to immediate technological requirements, but staged around the production of a specific morphology in anticipation of use. The staged production of these pressure-flaked points involves blank selection from flakes, blades or large tabular pieces (see Akerman & Bindon 1995: 94; Akerman *et al.* 2002: 19; Moore 2000: 7). The selected blanks are initially retouched with direct percussion to create an ovate bifacial morphology to further facilitate pressure flaking. This bifacial preform (after Akerman & Bindon 1995: 94; Akerman *et al.* 2002: 19) is biconvex in cross-section, invasively flaked usually across all of the surfaces and the resultant finished artefact has commonly lost any evidence

of a ventral or initiation surface. Pressure flaking, with a range of indenters including hard wood, bone and metal (post-contact), is then used to further reduce the artefact into a thin (relative to thickness), elongated or ovate biface (Akerman *et al.* 2002: 19; Love 1936: 93–5). Additional fine pressure flaking produces serrate, denticulate or dentate projections along the margins. Crests or ridges may be found on the distal portion of the point, where retouch scars terminate and meet from opposing margins (Akerman *et al.* 2002: 19–20).

THE CHRONOLOGY OF POINT PRODUCTION: THE ARCHAEOLOGICAL EVIDENCE

Dating the earliest presence of pressure-flaked points in the Kimberley archaeological record has been a challenge for archaeologists. This is largely due to the paucity of unambiguous pressure-flaked points in stratified sites. Because of this, identification of debitage thought to be produced exclusively from pressure flaking has been used as a proxy for the presence of pressure-flaked technology (e.g. Harrison 2004: 5; Harrison & Frink 2000: 13). Outside of Australia, archaeologists have sought to identify unique flakes produced from pressure flaking (e.g. Sappington 1991: 70). However, using size attributes, flake shape or platform characteristics to identify flakes produced from pressure flaking is problematic, as the same attributes have been shown to result from hard hammer or direct percussion in other modes of bifacial reduction (Andrefsky 1986, 2005: 119), as well as during core reduction (Ammerman & Andrefsky 1982). Negative scars originating from very small, isolated initiations in line with parallel flake scars may be evident on some pressure-flaked points (e.g. the experimental reproductions of the bifacial points from Still Bay, South Africa; Mourre *et al.* 2010: 660–1, figures 1 and 2). However, in the assemblages reported here the raw materials simply did not exhibit the collateral pressure-flaking scars and small isolated initiations observed by other researchers (Akerman & Bindon 1995: 94; Moore 2000: 7). Accordingly, the methodology adopted here does not use debitage or negative scars to identify pressure flaking but, rather, recognises points with serrate, denticulate or dentate margins as definitive evidence of this technology. It is acknowledged that while this approach is robust, it is also conservative, as some pressure-flaked points and unfinished artefacts that lack these projections will be overlooked. All presented radiocarbon age determinations are given to 2σ .

In 1991, Bowdler and O'Connor (1991: 61) argued that point technology in the Kimberley, was most likely no older than 4500 BP (calibrated age range of 5430 to 5030 Wk- 1398) based on a marine shell sample associated with the lowest excavated point in Widgingarri shelter 2, as well as other dates from the region (Bradshaw 1986: 35; Dortch 1977: 109; O'Connor 1990, 1999). Their argument pertained specifically to direct percussion points and not to the introduction of pressure-flaking techniques by 4500

Figure 1. A map of north-western Australia, showing the locations of sites mentioned in text (map by Kay Dancey).

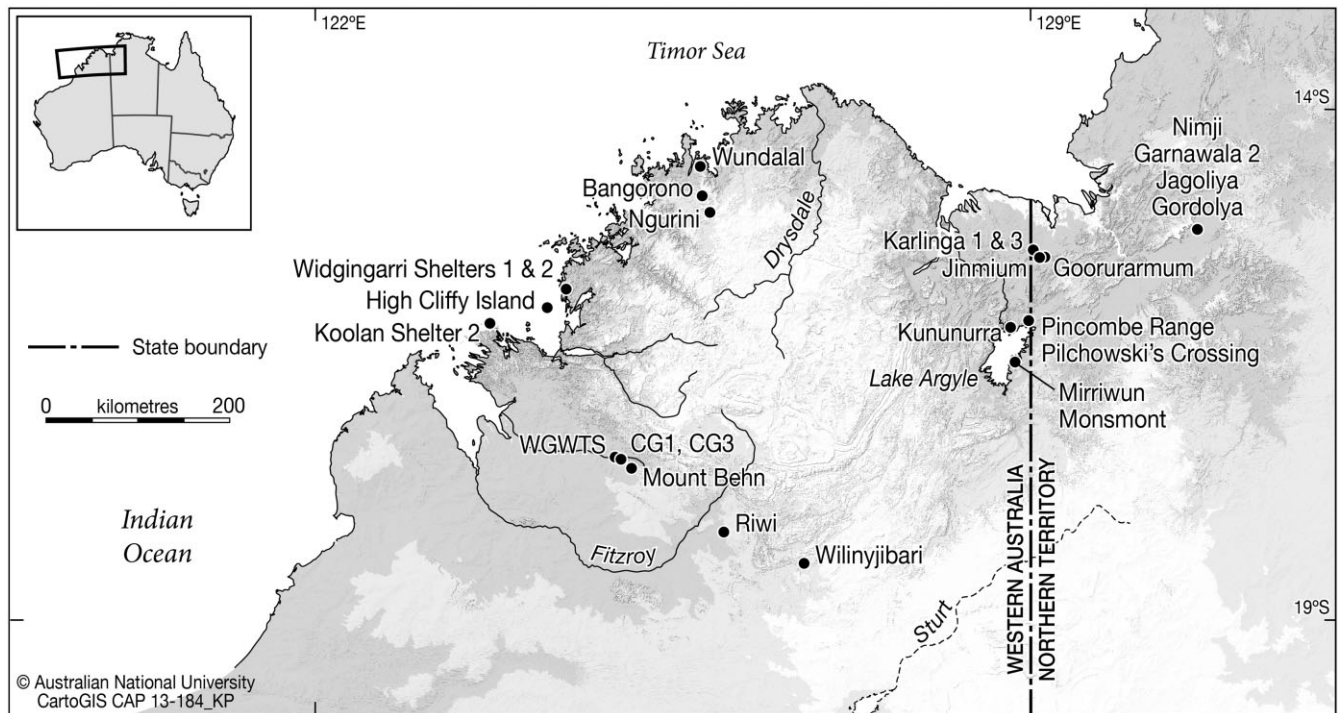
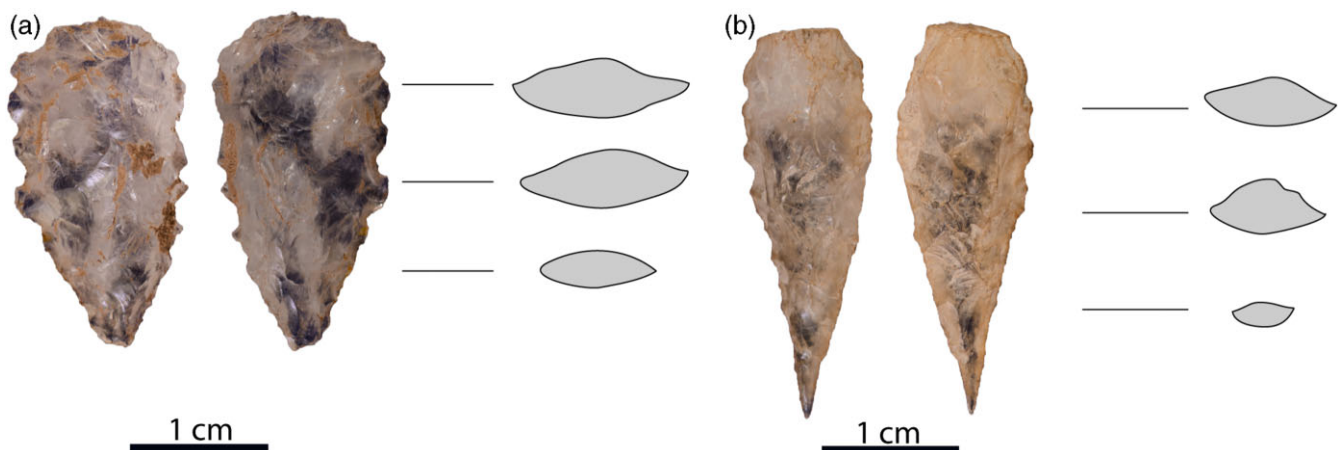


Figure 2. (a) A crystal quartz pressure-flaked point from CG3 (photograph Noel Tan). (b) A crystal quartz pressure-flaked point from Windjana Gorge 1 (photograph Noel Tan).



BP, as was recently suggested by Newman and Moore (2013: 2615). While it is recognised that using isolated occurrences of rare artefacts in shelters with sandy deposits may be problematic because artefacts may move vertically, our review of the dates across the Kimberley region further consolidates the results presented in Bowdler and O'Connor's (1991: 61) earlier review. The review also suggests remarkable consistency in the respective timing of the appearance of direct percussion and pressure-flaked points across the region (Tables 1 and 2).

The oldest dates for direct percussion points in the Kimberley derive from the southern Kimberley, where

O'Connor *et al.* (2008) identified several such points from Windjana Gorge Water Tank Shelter in Windjana Gorge National Park (Figure 1). The oldest was recovered from Spit 17, beneath a unit with a carbon date of 5575 to 5081 calBP (NZA 18654 AMS) (O'Connor *et al.* 2008: 76, 79). It was also suggested that another point recovered from a 2 cm excavation unit with an associated radiocarbon date of 966 to 805 calBP (NZA 22269), was probably produced with pressure flaking, based on negative scars. The excavation unit directly below this produced a radiocarbon date of 1589 to 1416 calBP (NZA 22269). The only other pressure-flaked point identified from this excavation was in the upper unit and is made of European glass. In the same

Table 1. Existing published radiocarbon dates associated with direct percussion points and pressure-flaked points in the Kimberley. Conventional radiocarbon ages were calibrated and calendar age ranges determined using OxCal v.4.2 (Bronk Ramsey 2009a) against SHCal04 (McCormac *et al.* 2004). Marine samples were calibrated using marine Curve 09 (Reimer *et al.* 2009).

Researcher	Site	Calibration curve	Material	Laboratory number	$\delta^{13}\text{C}$ (‰)	% Modern	^{14}C age (years BP)	Age (calBP 2 σ)
Direct percussion points								
O'Connor <i>et al.</i> 2008	Windjana Gorge Water Tank Shelter	ShCal 04	<i>Celtis</i> seed	NZA 18654	-14.74	55.46	4684 $\pm$ 40	5575 to 5081
O'Connor 1999	Widgingarri 2	Marine 09	Marine shell	Wk- 1398	+2.2	82.9	4970 $\pm$ 60	5430 to 5030
O'Connor 1999	High Clifty Island	Marine 09	Marine shell	Wk 1096	+4.4	na	3210 $\pm$ 110	3251 to 2720
O'Connor 1999	Widgingarri 1	Marine 09	Marine shell	Wk 1490	+2.6	80.9	1700 $\pm$ 90	1372 to 980
Bradshaw 1986: 35	Pilchowski's Crossing	ShCal 04	Charcoal	Not given	na	na	3640 $\pm$ 110	4230-3585
Dortch 1977: 109	Kununurra	ShCal 04	Charcoal	SUA - 56	na	na	3110 $\pm$ 85	3446 to 3001
Dortch 1977: 109	Mirriwun	ShCal 04	Charcoal	SUA 142	na	na	2980 $\pm$ 95	3348 to 2850
Dortch 1977: 109	Pincombe Range	ShCal 04	Charcoal	GaK 1767	na	na	3560 $\pm$ 100	4084 to 3485
Dortch 1977: 110	Pincombe Range	ShCal 04	Charcoal	GaK 1767	na	na	3560 $\pm$ 100	4084 to 3485
Dortch 1977: 110	Pincombe Range	ShCal 04	Charcoal	GaK 1768	na	na	2660 $\pm$ 90	2877 to 2363
Harrison 2004: 4; Harrison and Frink 2000: 10	Wilinyjbari	ShCal 04	Charcoal	Wk 6645	-24.2	na	2100 $\pm$ 140	2345 to 1704
Fullagar <i>et al.</i> 1996: 757	Jinnium	ShCal 04	Charcoal	Beta 83636	na	na	2920 $\pm$ 70	3212 to 2794
Veitch 1999: 387	Ngurini	ShCal 04	Charcoal	Wk 1615	na	na	2820 $\pm$ 90	3158 to 2737
Veitch 1999: 387	Wundalal	ShCal 04	Charcoal	Wk 1616	na	na	3560 $\pm$ 110	4086 to 3483
Veitch 1999: 387	Bangorono	ShCal 04	Charcoal	Wk 1617	na	na	1510 $\pm$ 70	1523 to 1271
Ward <i>et al.</i> 2006: 18	Karlinga 3	ShCal 04	Charcoal	Wk 19789	-24.7	na	3619 $\pm$ 122	4236 to 3558
Pressure-flaked points								
O'Connor <i>et al.</i> 2008	Windjana Gorge Water Tank Shelter	ShCal 04	Charcoal	NZA 22269	-26.2	na	1058 $\pm$ 30	966 to 805
O'Connor <i>et al.</i> 2008	Windjana Gorge Water Tank Shelter	ShCal 04	Charcoal	NZA 22269	-26.84	na	1164 $\pm$ 35	1589 to 1416
O'Connor 1990	Widgingarri 1	Marine 09	Marine shell	Wk 1397	+1.6	na	1510 $\pm$ 50	1148 to 893
O'Connor 1999	Carpenters Gap 1	ShCal 04	Charcoal	Wk 3075	-25.8	na	650 $\pm$ 90	721 to 499
Dortch 1977: 109	Kununurra	ShCal 04	Charcoal	SUA 55	na	na	1940 $\pm$ 80	2002 to 1608
Dortch 1977: 109	Kununurra	ShCal 04	Charcoal	SUA 54	na	na	1030 $\pm$ 80	1055 to 734
Dortch 1977: 109	Monsmont	ShCal 04	Charcoal	SUA 57	na	na	1730 $\pm$ 80	1810 to 1395
Dortch 1977: 109	Monsmont	ShCal 04	Charcoal	ANU 1130	na	na	1420 $\pm$ 70	1408 to 1091
Dortch 1977: 109	Monsmont	ShCal 04	Charcoal	ANU 1129	na	na	1480 $\pm$ 90	1533 to 1172
Ward 2004: 2; Ward <i>et al.</i> 2006: 18	Karlinga 1	ShCal 04	Charcoal	Wk 10783	-26.3	na	484 $\pm$ 45	549 to 331
Ward 2004: 2; Ward <i>et al.</i> 2006: 18	Karlinga 1	ShCal 04	Charcoal	Wk 10784	-25.8	na	917 $\pm$ 76	925 to 625

Table 2. OSR and TL dates associated with direct percussion points and pressure-flaked points in the Kimberley. Note that no laboratory codes were provided with the OCR dates given by Harrison and Frink (2000).

Researcher	Method	Site	Code	Date	Temperature (°C)
Direct percussion points					
Fullagar <i>et al.</i> 1996: 757	TL	Jinmium	W1755	2900 ± 400	325
Fullagar <i>et al.</i> 1996: 757	TL	Jinmium	W1755	3200 ± 400	375
Harrison and Frink 2000: 11	OCR	Wilinyjbari	3628	2289 ± 68	Not given
Pressure-flaked points					
Harrison 2004: 4; Harrison and Frink 2000: 11	OCR	Wilinyjbari	3621	1398 ± 41	Not given
Harrison 2004: 4; Harrison and Frink 2000: 11	OCR	Wilinyjbari	3622	1088 ± 32	Not given

study area at Carpenter's Gap 1 (CG1), O'Connor (1995: 59) recovered a distal fragment of a pressure-flaked point. The underlying spit has a calibrated age range of 721 to 499 calBP (Wk 3075).

The antiquity of direct percussion points in the southern Kimberley seems to be in close agreement with the timing of their appearance in the coastal western Kimberley. Here, O'Connor (1999) excavated 42 points from Widgingarri 1 and Widgingarri 2 and 13 from High Cliffy Shelter (O'Connor 1999: 73, 103), described as "bifacial points, unifacial points and triangular shaped blades or flakes with laterally retouched margins" (1999: 69). Like McCarthy (1967: 42) and Dortch (1977: 116, 117), O'Connor (1999: 72) identified a "backed point" variant, distinguished by steep 90 degree retouch – usually along one margin. However, while Dortch (1977: 117) argued that backed points from the east Kimberley were produced with direct percussion, O'Connor (1999: 72) observed evidence for bipolar anvil rested retouch on those from the Widgingarri shelters. O'Connor (1999: 77, 103) concluded that both the early Widgingarri and High Cliffy Island points exhibit little standardisation in shape and size. This is in contrast to some of those seen on the surface of sites in the region, which include examples made on larger flakes with apparent evidence of pressure flaking. The oldest direct percussion point was recovered from Widgingarri 2 and is associated with a radiocarbon date of 5430 to 5030 calBP (Wk 1398). Only one example from the excavated assemblages is unambiguously pressure flaked, and this was recovered from the uppermost excavation unit of Widgingarri 2. This artefact is a proximal portion exhibiting serrated and dentate margins, clearly a result of pressure flaking prior to its transverse break and discard (see O'Connor 1999: 74, figure 5.14). A radiocarbon date on marine shell underlying this point returned a calibrated age range of 1148 to 893 calBP (Wk 1397) and this provides a maximum age for pressure-flaked points at this site (see O'Connor 1999: 71, 76).

Further north, Veitch (1999: 342) argued that direct percussion points first appear in the Mitchell Plateau (Figure 1) between 3000 and 3500 years ago, based on calibrated age ranges of 3158 to 2737 calBP (Wk 1615)

and 4086 to 3483 calBP (Wk 1616), associated with the lowest direct percussion points from two excavated sites, Ngurini and Wundalai. The points from Veitch's excavations were classified by him as "Kimberley Points" (Veitch 1996: 70–2, 74, 76, 77, 79), but he reported the retouch as either unifacial or bifacial, on one or two margins, and he recognised that these points lacked evidence of pressure flaking (see Veitch 1999: 356). Veitch's excavation at a third site, Bangorono, recovered two direct percussion points, both with bifacial retouch on two margins, from spits above a basal unit with an age range of 1523 to 1271 calBP (Wk 1617). The uppermost excavation unit may also contain a bifacial preform (Veitch 1999: 359, figure 11.3); however, no absolute dates are associated with this unit.

In the Wilinyjbari rock shelter in the south-east Kimberley, the earliest observed direct percussion points are associated with an OCR carbon date of 2289 ± 68 years BP, immediately above which is a radiocarbon date of 2345 to 1704 calBP (Wk 6645) (Harrison 2004: 4; see Harrison & Frink 2000: 10–11). The latter date was associated with one unifacial and one bifacial point, both made on short "blade flakes", and neither exhibits evidence of pressure flaking (Harrison 2004: 4). The pressure-flaked points from the site are associated with OCR dates of 1389 ± 41 years BP and 1088 ± 32 years BP (Harrison 2004: 5; Harrison & Frink 2000: 11). They lack serrate, denticulate or dentate margins – with the exception of one fragment with a single projection (Harrison 2004: figure 2d). The flake scars were identified as produced from pressure flaking due to the small initiations and parallel scars. On the basis of these data and evidence from surface sites in the region, Harrison (2002: 359; see also Harrison 2004: 6–7) argued that pressure-flaked Kimberley Points were present in the archaeological record from around 1400 to 1000 years BP.

In the Keep River region of the north-eastern Kimberley at Jinmium shelter, Fullagar *et al.* (1996: 764) reported radiocarbon dates of 3212 to 2794 calBP (Beta 83636) directly below the lowest observed direct percussion point. They suggested a date of ~3000 years BP for the appearance of point technology at the site and cite thermoluminescence (TL) dates of 2900 ± 400 years BP

(325°C) and 3200 ± 400 years BP (375°C) from units below the lowest point as supporting evidence (Fullagar *et al.* 1996: 763–4). Ward (2004) reported several OSL, TL and radiocarbon dates from a series of other excavated open sites and rock shelters in the Keep River region. Although it is difficult to ascertain precisely where the reported points occur in the sequences presented by Ward (2004: 2) and whether the author is referring to direct percussion points or pressure-flaked points, she notes that “Kimberley points” were observed at the Karlinga 1 site between 925 to 625 calBP and 549 to 331 calBP (Ward 2004: 2, figure 2; Ward *et al.* 2006: 18). Direct percussion points were recovered between a radiocarbon age of 4236 to 3558 calBP (Wk 10789) and a TL date of 2100 ± 200 years BP (Ward *et al.* 2006: 8,13) at the Kalinga 3 site.

Also in the north-east Kimberley but in the Ord River region, Dortch (1977: 109, table 1) reported a “denticulate piece” from the Kununurra rock shelter with an associated date of 2002 to 1608 calBP (SUA 55), although it is unclear whether this piece is pressure flaked. The earliest direct percussion points were found above a unit with an age range of 3446 to 3001 calBP (SUA 56) at Kununurra rock shelter (Dortch 1977: 111). Monsmont rock shelter, in the same region, produced three dates with age ranges of 1810 to 1395 calBP (SUA 57), 1408 to 1091 calBP (ANU 1130) and 1533 to 1172 calBP (ANU 1129) (Dortch 1977: 109, table 1). These dates are inverted and show decreasing age with increasing depth, but all flaked points at Monsmont occur within or above these dated units.

Dortch (1977: 110) also reported two dates associated with direct percussion points (“early phase industry”), from an unpublished excavation by Ian Crawford in the Pincombe Range, not far from the Ord River. These dates are also inverted, but range between 4084 to 3485 calBP (GaK 1767) and 2877 to 2363 calBP (GaK 1768). Examination of these artefacts indicated that the points from units immediately overlying the dated units were all produced by direct percussion (Maloney pers. obs.). Numerous pressure-flaked points were recovered from units closer to the surface of the site, but there are no published dates for the upper units. Bifacial preforms were also observed in upper units containing European glass artefacts. Newman and Moore (2013: 2615) have suggested that preform manufacture associated with pressure flaking occurred sometime later than the earliest occurrence of pressure flaking on small blades and flakes.

Kimberley oral history on the chronology of points

Interestingly, several accounts from people in the Kimberley region also suggest a temporal separation of direct percussion and pressure-flaked points. For example, Tindale (1985: 1, 26–7) recorded accounts of stories from Kitja and Djaru men, suggesting that pressure-flaked points were preceded by unifacial points with direct percussion retouch. Upon inspection of an assemblage with Tindale, these men identified pressure-flaked points as from early days “when white men shot at us with guns” (Tindale 1985: 26). They described the “unifacially

hammer dressed points” as not being used by people, but instead they ascribed them to a bird-like ancestor being that lived in the country before Djaru people (Tindale 1985: 26). Akerman *et al.* (2002: 15–17) similarly recount an Umede-Worora man’s recollection of the story of the creation of the first stone spearheads by the culture hero Wodoi. These were simple pointed flakes and blades with coarse-toothed or steep edges (2002: 16) that were later improved by humans with invasive pressure flaking (2002: 17). According to this same source, prior to the invention of stone points for spearheads, people used simple wooden spears (Akerman *et al.* 2002: 15). Miriung people from the east Kimberley attributed the introduction of pressure flaking and direct percussion unifacial points to two different beings and recognise a separate being as responsible for the creation of the Kimberley Dentate point (Akerman *et al.* 2002: 17). Akerman and Bindon (1995) also note Miriung people from the east Kimberley recalling stories of the introduction of direct percussion and the later presence of pressure-flaked points. Harrison (2006: 73) provides accounts of Lamboo people being aware of a temporal separation between prehistoric and historical points, which may indicate that historical-period points were more regular in symmetry and invasiveness of retouch. Maloney has discussed point technology with a Gooniyandi elder, who also distinguishes older points as those that lack the “teeth” found on pressure-flaked points.

In summary, it is apparent from the body of excavated sites and Kimberley oral history that there is substantial temporal separation between the earliest direct percussion points and the first firm date for the appearance of pressure-flaked points. Results from recent excavations in the south-west Kimberley further support this pattern.

NEW DATES FROM BUNUBA COUNTRY IN THE SOUTHERN KIMBERLEY

In 2012, direct percussion points and pressure-flaked points were recovered from excavations carried out by the “Lifeways of the First Australians” team at three sites in Bunuba country: Carpenter’s Gap 3 (CG3), Mount Behn 1 (MB1) and Windjana Gorge 1 (WG1), in a separate chamber but the same outcrop as Water Tank Shelter [DIA 12588]). Earlier excavations at CG3 by O’Connor also recovered points and, in addition to the 2012 points, a total of nine direct percussion points and one pressure-flaked point have been recovered from the site. A total of 125 direct percussion points and one pressure-flaked point were recovered from the MB1 excavation and two direct percussion points and one pressure-flaked point were found at WG1. The dates associated with both types of points from the three sites are shown in Table 3.

The earliest observed direct percussion points are from CG3, where they occur directly above excavation unit 10 with an age range of 5602 to 5333 calBP (OZF325) (O’Connor *et al.* 2014: 17). These points exhibit marginal retouch, with some observation of invasive and bifacial retouch. None of these scars are indicative of pressure

Table 3. Radiocarbon dates from recent excavations in Bunuba country associated with direct percussion points and pressure-flaked points. Conventional Radiocarbon Ages were calibrated and calendar age ranges determined using OxCal v4.2 (Bronk Ramsey 2009a) against SHCal04 (McCormac *et al.* 2004). Marine samples were calibrated using marine Curve 09 (Reimer *et al.* 2009).

Site	Unit	Curve	Material	Laboratory number	$\delta^{13}\text{C}$ (‰)	% Modern	^{14}C age (years BP)	Age (CalBP 2 σ)
Direct percussion points								
Carpenters Gap 3	10	ShCal 04	<i>Celtis</i> seed	OZF325	-15.3	55.16	4780 $\pm$ 40	5602 to 5333
Mount Behn 1 SQ1	9	Marine 09	<i>Dentalium</i> shell	S-ANU 33030	-7	63.12	3695 $\pm$ 40	3608 to 3103
Mount Behn 1 SQ1	10	Marine 09	<i>Dentalium</i> shell	S-ANU 33031	-6	62.67	3755 $\pm$ 40	3680 to 3195
Mount Behn 1 SQ1	11	Marine 09	<i>Dentalium</i> shell	S-ANU 33032	-6	66.21	3310 $\pm$ 40	3159 to 2691
Mount Behn 1 SQ1	12	Marine 09	<i>Dentalium</i> shell	S-ANU 33033	-4	53.28	5060 $\pm$ 40	5390 to 4855
Mount Behn 1 SQ2	10	ShCal 04	Charcoal	S-ANU 32513	-32	73.62	2460 $\pm$ 35	2699 to 2343
Mount Behn 1 SQ2	15	ShCal 04	Charcoal	S-ANU 32632	-26	70.80	2775 $\pm$ 35	2921 to 2752
Pressure-flaked points								
Carpenters Gap 3	6	ShCal 04	<i>Celtis</i> seed	S-ANU 32506	-23	92.77	600 $\pm$ 30	631 to 519
Windjana Gorge Water Tank Shelter	18	ShCal 04	Charcoal	D-AMS 001670	-31	87.56	1067 $\pm$ 25	968 to 822
Windjana Gorge Water Tank Shelter	18	ShCal 04	Charcoal	D-AMS 001671	-18.8	87.32	1089 $\pm$ 26	1049 to 916
Mount Behn 1 SQ2	3	ShCal 04	Charcoal	S-ANU 32631	-25	96.76	265 $\pm$ 35	439 to 146

flaking. A single pressure-flaked point from the adjacent square at this site was recovered from excavation unit 6, with a date of 631 to 519 calBP (S-ANU 32506). It is a Kimberley Point (after Akerman & Bindon 1995: 91–2), made on translucent quartz with serrations along both margins (Figure 2A). This is in agreement with finds from nearby shelter CG1, where a pressure-flaked point was recovered above a unit dating to 721 to 499 calBP (Wk 3075) (O'Connor 1995).

From the 2012 excavation of WG1, direct percussion points occur only in unit 2, dated to within the past 1000 years. However, as noted above, O'Connor's earlier excavation of the adjoining Water Tank Shelter produced dates of 5575 to 5081 calBP (NZA 18654). A single pressure-flaked point from WG1 (Figure 2B) has two overlapping dates from charcoal samples collected *in situ* within a 2 cm spit of the same 50 cm $\times$ 50 cm quadrant. These dates are 968 to 822 calBP (D-AMS 001670) and 1049 to 916 calBP (D-AMS 001671), and are the oldest and most dependable dates from recent excavations for pressure flaking in the study area.

At MB1, a total of 125 direct percussion points were recovered from two adjacent excavation squares. The lowest, recovered from SQ1 excavation unit 12, was from the same unit and 50 cm $\times$ 50 cm quadrant as a marine shellfish sample with an age range of 5390 to 4855 calBP (S-ANU 33033). The majority of points were recovered from within units dated to between 3608 to 3103 calBP (ANU – 33030) and 2699 to 2343 calBP (S-ANU 32513). For example, three complete and two broken direct percussion points were found in excavation unit 9, with an age range of 3608 to 3103 calBP (S-ANU 33030). Four direct percussion points were recovered from excavation unit 10, with an age range of 3680 to 3195 calBP (S-ANU 33031). Excavation unit 11, dating to 3159 to 2691 calBP (S-ANU 33032), contained a single direct percussion point.

At MB1 SQ2, the earliest direct percussion point was in excavation unit 14, immediately above unit 15, dated to 2921 to 2752 calBP (S-ANU 32632). A total of 18 complete and one broken direct percussion points were recovered between units 14 and unit 10, dated to 2699 to 2343 years BP (S-ANU 32513). A single pressure-flaked point that conforms to Akerman *et al.*'s (2002: 14) description of a Kimberley Dentate point (Figure 3) was obtained from the same 2 cm spit and 50 cm $\times$ 50 cm quadrant as a charcoal sample collected *in situ* and dated to 439 to 146 calBP (S-ANU 32631). The large size and regularity of these dentate projections are unlikely to have been produced with direct percussion, and further evidence of this is provided by the observation of smaller serrate projections inside notches, such as those on the left medial and distal margin. The point has lost its distal tip, but retains the lateral projections that unambiguously evidence pressure flaking. The broken distal tip was recovered less than 4 cm above the proximal section of the point in the adjacent quadrant. The two parts can only be directly conjoined on a small surface of the left distal margin, as

Figure 3. A pressure-flaked point (Kimberley Dentate point, after Akerman & Bindon 1995), recovered from the Mount Behn excavation (photograph Noel Tan).



subsequent to breakage retouching over the break to form a new distal tip rejuvenated the proximal section. Matching flake scars, particularly one on the left distal margin that crosses the break surface, as well as grain structure close to the break, provide proof of the prior association of these two pieces. Both specimens are illustrated in Figure 4.

Notably, direct percussion points continued to be produced after the appearance of pressure-flaked points. Both the WG1 and MB1 shelters contained direct percussion points from units dated to within the past 1000 years BP, a trend observed in other dated sites (Dortch 1977; O'Connor 1990, 1999; Ward 2004).

DISCUSSION AND CONCLUSIONS

Three examples of direct percussion points dating earlier than 5000 calBP and four pressure-flaked points from contexts dated within the past 1000 years are present in three excavated sites in the southern Kimberley. Our review of the literature demonstrates that pressure-flaked points consistently postdate direct percussion points by more than 4000 years in excavated sites throughout the Kimberley. Although direct percussion points occur significantly earlier in the southern and western Kimberley than in the north or the east, points that are as old as the southern Kimberley examples have been reported from stratified sites in the Northern Territory (see Jones & Johnson 1985: 206).

At this stage, it is difficult to know whether regional variation in the timing of the appearance of point technology is an artefact of sampling, or a result of differences in the spread and rate of uptake of new

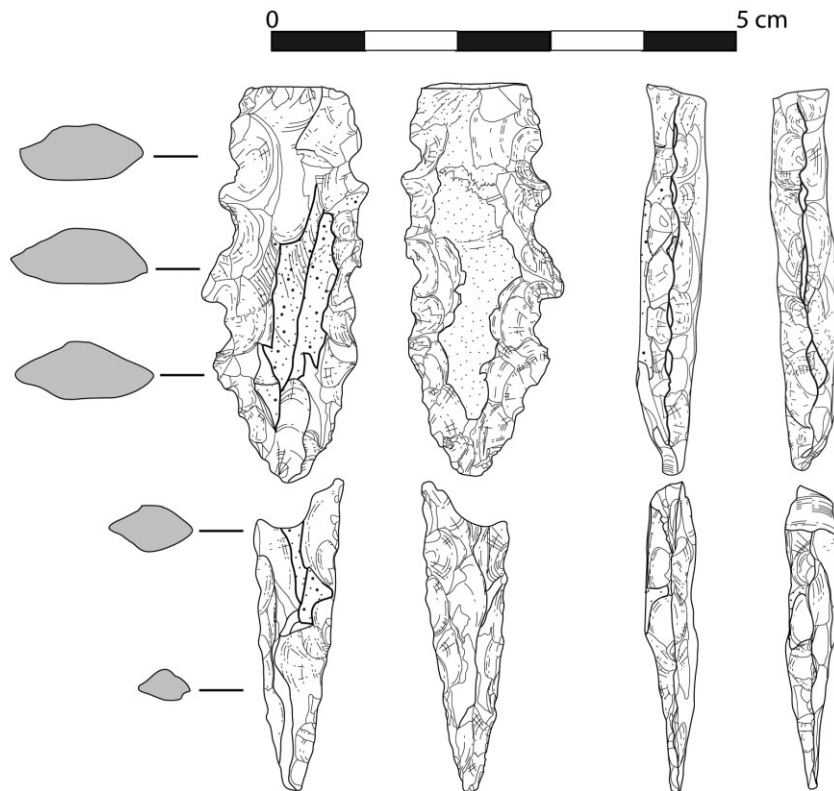
technologies. Hiscock (1993: 177) argued that sample size must be investigated to determine the relationship between vertical movement, dates and isolated occurrences of rare technological types, such as points. He further stressed the need for sample size analyses in any investigation into the earliest observations of new technologies and argued that the recovery of a rare type in a deposit reflects only the first instance of discard within the boundaries of the excavated area (Hiscock 1993: 175). Hiscock and Attenbrow's (1998: 170) claim for the early Holocene appearance of bipolar backed artefacts in Australia is based on only two artefacts, dated by association (see also Hiscock & Attenbrow 2004). They argue that there is no *a priori* reason why the uptake of new technology will be uniform through time and space, and that the inception of any new technology may occur thousands of years before its spread and proliferation result in a widespread signature in the archaeological record. In this sense, it is not unlikely that the temporal patterning of pressure flaking across the Kimberley, as presented here, is the proliferation of this new technology and earlier evidence of this technology may yet be recovered with increased sample sizes.

While we believe it is unlikely, there is also the possibility that the artefacts associated with the older dates have been subject to vertical downward movement in the shelter deposits. The ultimate test of these alternatives will be achieved by direct dating of mastic or binders on the artefacts themselves. Those in the southern Kimberley sites discussed here have been examined, but no residual mastic remains. Future excavations in other regions of the Kimberley are needed to refine the dating and gain a better understanding of regional variability in point production.

The context of tool production, maintenance and use of these technologies is beyond the scope of this paper. How similar the underlying causes of morphological variation in point technologies were throughout the Holocene, will remain a tempting question for Australian archaeology. For example, it is unclear exactly what degree of ecological, environmental or population change has driven the development of and changes to point technology in the Kimberley.

It would appear that lithic production in the Kimberley has undergone a major change within the past 1000 years. The timing of the introduction of pressure flaking was earlier in the southern Kimberley than in the Northern Territory, where this technology was being taken up as late as the 1930s. On the basis of the ethnographic and archaeological accounts, it would appear that pressure flaking moves from south to north. However, there are parallels between the Kimberley and the Northern Territory, with both regions having evidence for the adoption of new types of projectiles about 1000 BP. In Wardaman country in the Northern Territory, people were also clearly adopting different technologies during this time, such as increased production of large hafted blades occurring during the past 1000 years (see Clarkson 2007: 104; Davidson 1935: 168–70). Although we have only

Figure 4. Proximal and distal portions of a pressure-flaked point (Kimberley Dentate point) from Mount Behn. The distal point fragment matches the alignment of negative scars and ridges on the proximal portion. The proximal piece has been rejuvenated after the break and shows that the platform surface is still intact.



dealt with the chronology here, investigating these changes in association with other archaeological and environmental evidence for economic and social change should be a priority for the future.

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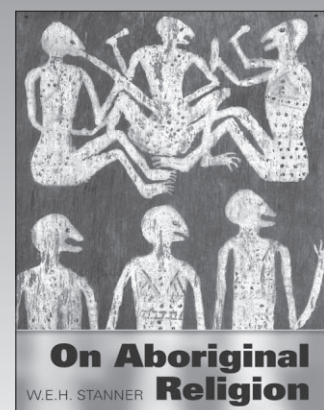
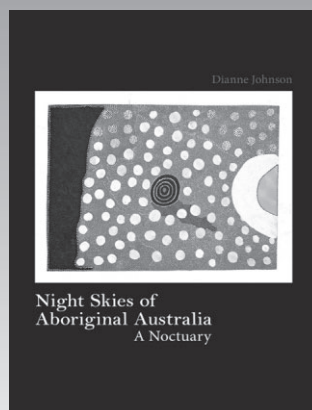
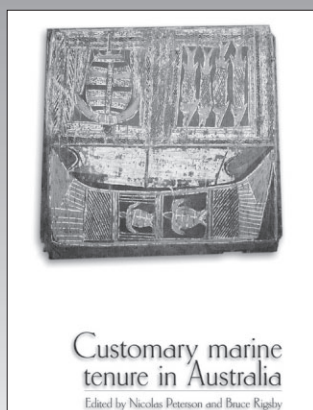
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Chapter 4

Point reduction continuums and changing technological investment in the Kimberley. *Archaeology in Oceania*.

Authors: Tim Maloney, Sue O'Connor and Jane Balme.

Publication: *Archaeology in Oceania*

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Formulation of arguments in manuscript. Composed the overall question, background research, site description, discussion, and conclusion of this research paper. Conducted all lithic artefact analysis and statistical tests. Coordinated excavation of Mount Behn site and analysis of materials. Submission and calibration of radio carbon dates.

Signed:



Tim Maloney

Formulation and review of arguments in manuscript. Responsible for writing sections of the paper. Australian Research Council Linkage Grant (LP100200415) CI.

Signed: 

Professor Sue O'Connor

Formulation and review of arguments in manuscript. Responsible for writing sections of the paper. Australian Research Council Linkage Grant (LP100200415) CI.

Signed:

Professor Jane Balme



Point reduction continuums and changing technological investment in the Holocene record of the southern Kimberley, northern Australia.

TIM MALONEY

Department of Archaeology and Natural History, College of Asia and the Pacific, Australian National University

SUE O'CONNOR

Department of Archaeology and Natural History, College of Asia and the Pacific, Australian National University

JANE BALME

Archaeology, School of Social Sciences, University of Western Australia

Abstract

Recent excavation of a rock shelter in the southern Kimberley region of northern Western Australia has produced a sample of 137 stone points, both unifacial and bifacial, dating between 5500 and modern times. This research demonstrates, for the first time, that the morphology of mid to late Holocene points in the Kimberley was the consequence of a reduction continuum involving multiple retouching strategies. Point technology was a highly adaptable and maintainable technology, and as such, it was a technology that was most likely employed in a variety of tasks. Reduction sequence data support a development of points around 5400 years BP. This development was followed by a diversification in retouch strategies between 3790 and 1747 years BP in what seems most likely to be an effort to extend implement use life. Pressure flaked bifaces were adopted within the last 1000 years. The changing nature of reduction intensity, morphological diversity, and technological investment are discussed within the context of existing explanations for Holocene technological change in the Kimberley and elsewhere in Australia. While the documented technological change occurred during an overall Holocene population increase, we argue in favour of heightened foraging risk as a compelling explanation for the development of point technology and incorporate changing social systems into this model.

Key words: Reduction Continuum, Holocene, Kimberley, Points, Risk, Mobility

Correspondence: Tim Maloney, Department of Archaeology and Natural History, College of Asia and the Pacific, The Australian National University, Coombs building 9 Fellows Road Acton, ACT 2601. Email tim.maloney@anu.edu.au phone: +61250309

Introduction

Australian archaeologists have debated the meaning of morphological variation in stone point technologies for close to a century (Clarkson 2007:102-110; Davidson 1935:160-162; Flood 1970; Hiscock 1994a; Macintosh 1951; McCarthy & Setzler 1962; Schrire 1982:246). In the last decade Hiscock (1994a, 2006, 2009, 2011) and Clarkson (2006, 2007) have used technological criteria to examine the morphological variation of point form in assemblages from the Northern Territory, Australia, and have demonstrated a reduction continuum from unifacial to bifacial forms. Their findings have prompted a reconsideration of the relationship between point form and reduction in the neighbouring Kimberley archaeological record, where the point reduction continuum has been rejected (Akerman et al. 2002:15; Blundell 1975:393; Flenniken & White 1985:148; O'Connor 1999:76). Although Blundell (1975:288) entertained the possibility of a continuum, other researchers have not found compelling evidence to demonstrate the transformation of unifacial points into bifacial points. This research uses morphometric and reduction sequence analyses to examine the relationship between unifacial and bifacial points from a recently excavated rock shelter, Mt Behn¹, in the southern Kimberley (Figure 1). The analysis focuses only on retouched flakes, comprising points and other retouched flakes, in order to decipher the systemic technological strategies employed and critique explanations for the underlying causes of point technology in the southern Kimberley. The results of this study are used to discuss the underlying causes of point technology and technological change from the mid to late Holocene in northern Australia.

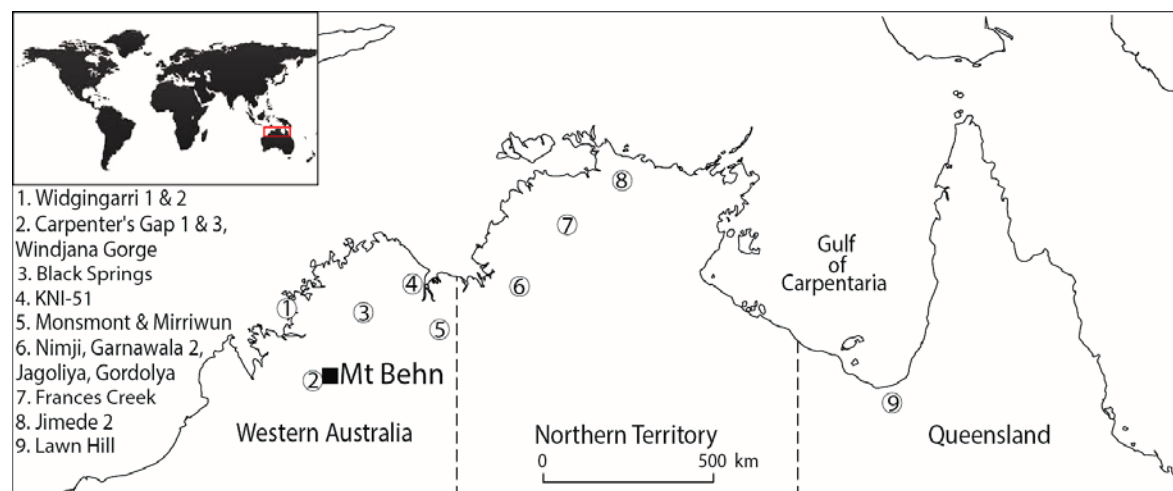


Figure 1. Northern Australia showing location of Mt Behn and other sites mentioned in text.

¹ Previously referred to as Mount Behn 1 (MB1) by Maloney et al. (2014)

Point reduction

Until recently, the archaeological understanding of Holocene point technology in northern Australia was largely founded on typological approaches, which rest on speculations about function and ethnographic analogies. This typological mode of analysis categorically divides unifacial and bifacial points (e.g. Flenniken & White 1985; Flood 1970:9; Schrire 1982). One implication is that these categories, or types (see Figure 2), exist as mutually exclusive entities and are the functional or desired end products of fixed designs. This bipartite division, which Hiscock (1994a) referred to as the 'divergent model', both impedes the analytical power of analyses that test for continuous morphological change (Clarkson 2007:102), and hinders the reconstruction of artefact life history.

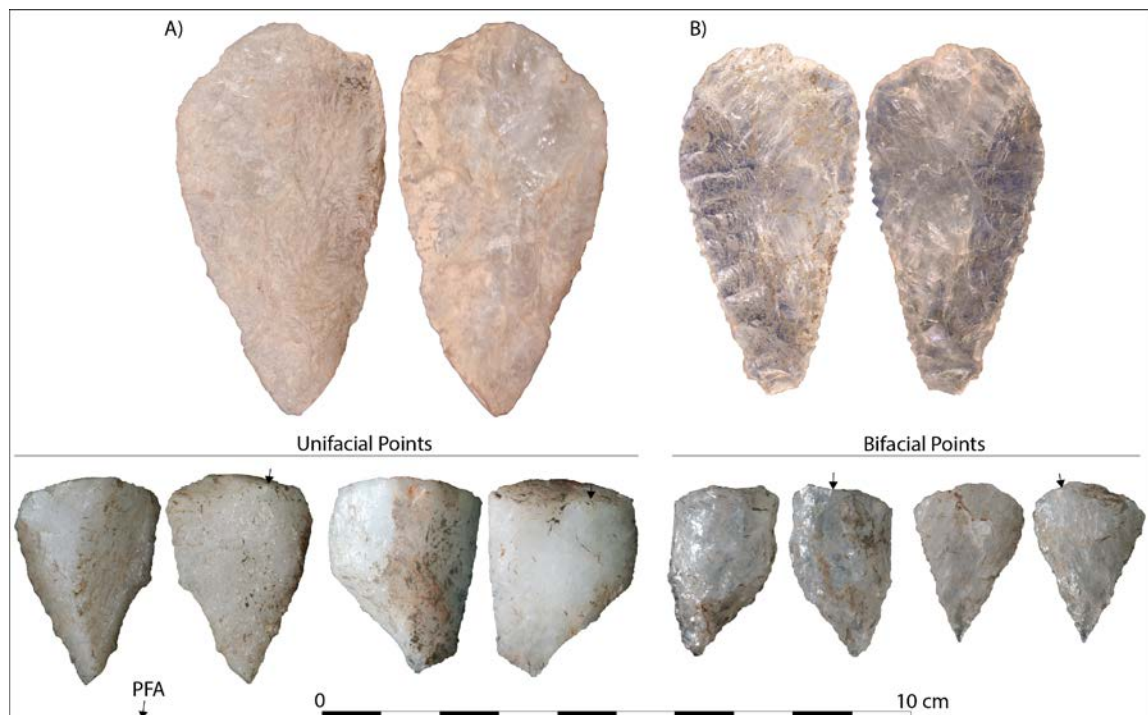


Figure 2. A) Bifacial preform made on crystal quartz, technically a core, illustrating invasive scars produced by direct percussion. B) Kimberley Point made on crystal quartz, with pressure flaking scars and marginal serrations, from scree slope in front of Mt Behn. Unifacial and bifacial points from Mt. Behn excavation, showing varying retouch intensities and remnant platform surfaces.

Alternatively, the sequential approach, which is applied here, quantifies retouch intensity independent of typology and models artefact life history relative to reduction. This approach is not new to Australian archaeology (e.g. Macintosh 1951:200) however, as Hiscock (1994a:74) notes, it was the divergent or typological approach that gained early endorsement. In recent years a growing number of point studies from across northern Australia have advocated the sequential reduction model (Clarkson 2006:103-104,

2007:101-112,160; Hiscock 1994a:77-80, 2006:77-78, 2009:84-85; Maloney 2010:89-103; Smith & Cundy 1985:34).

Perhaps a significant reason for the rejection of a point reduction continuum in the Kimberley has been the interpretation of Kimberley Point reduction sequences (Akerman & Bindon 1995). Kimberley Points are pressure flaked bifaces with marginal serrations, produced as functional hafted projectiles, trade items, and prestige goods (see Akerman 2008; Harrison 2002, 2006). Maloney et al. (2014) demonstrate that these pressure flaked bifaces were widely produced only within the last 1000 years BP, whereas direct percussion unifacial and bifacial points were first produced around 5000 years ago. The manufacture of Kimberley Points has been widely observed ethnographically (see Akerman et al. 2002:18-19; Love 1936:93-95) and archaeologically (Moore 2015) as a staged production process, with gross morphological difference to the earlier direct percussion points.

A paramount feature of Kimberley Point reduction not shared with the points examined in the studies by Clarkson (2007) or Hiscock (1994a), is the staged reduction of bifaces that may not have been reduced from flake blanks (see Akerman et al. 2002:19; Moore 2015) or have involved maintenance retouch during their use life. The blank morphologies, or bifacial preforms, reach maximum retouch intensity values prior to marginal pressure flaking, as they are invasively flaked to thin the bifaces (see Moore 2000, 2015). These early stages of Kimberley Point reduction are often technically cores, as they lack any ventral surface and are produced by a reduction process that is radically different from unifacial and bifacial points made on flakes. Figure 2A illustrates a bifacial preform from surface collections within 3 km of the Mt Behn site and Figure 2B illustrates a Kimberley Point found outside the Mt Behn shelter. Both examples are produced from crystal quartz. Notably, bifaces used in Kimberley Point production begin use life as much larger units than points reduced from flakes.

A further problem besetting earlier Kimberley studies is that the small number of points recovered from stratified contexts is inadequate to convincingly support either the divergent or sequential models. For instance, the 42 mostly unifacial points from Widgingarri Shelters 1 and 2, comprise one of the largest collection of points from dated contexts in the region (O'Connor 1999:64-78). The only other sizeable dated point assemblages are those from Monsmont (n = 117) and Miriwun (n = 83) rock shelters in the Ord Valley (Dortch 1977; Dortch & Zlatnik nd:38, 50) and the 86 points analysed by Bradshaw from five sites in the east Kimberley (1986:239, Table 108). Other dated stratified Kimberley sites have produced consistently small samples (Harrison 2004:4-5; Fullagar et al. 1996:764; Maloney et al. 2014; O'Connor et al. 2014:17; Veitch 1996; Ward et al. 2006:8, 13). It is likely that the prevalence of the divergent typological models of point variation in the Kimberley is in part a result of the small sample sizes that are incapable of capturing the continuum. In contrast, Clarkson's (2006:99) study of points from Wardaman country in the

Northern Territory included 456 complete points from four shelter sites and Hiscock's (1994a:77, 79) reanalysis of the Jimede 2 assemblage included 187 points.

The Mt Behn site

The Mt Behn site is an outlying limestone rock shelter approximately eight kilometres to the north east of the Napier Range. The shelter extends about 40 m in length, varying between 1 to 10 m deep and 1.5 to 1 m in height (Figure 3). Although there is no nearby permanent freshwater source, a small pool to the immediate east of the shelter fills in the wet season and occasionally retains water late into the dry season. Excavations at Mt Behn in 2012 recovered abundant cultural material including 54294 stone artefacts and a variety of organic remains.

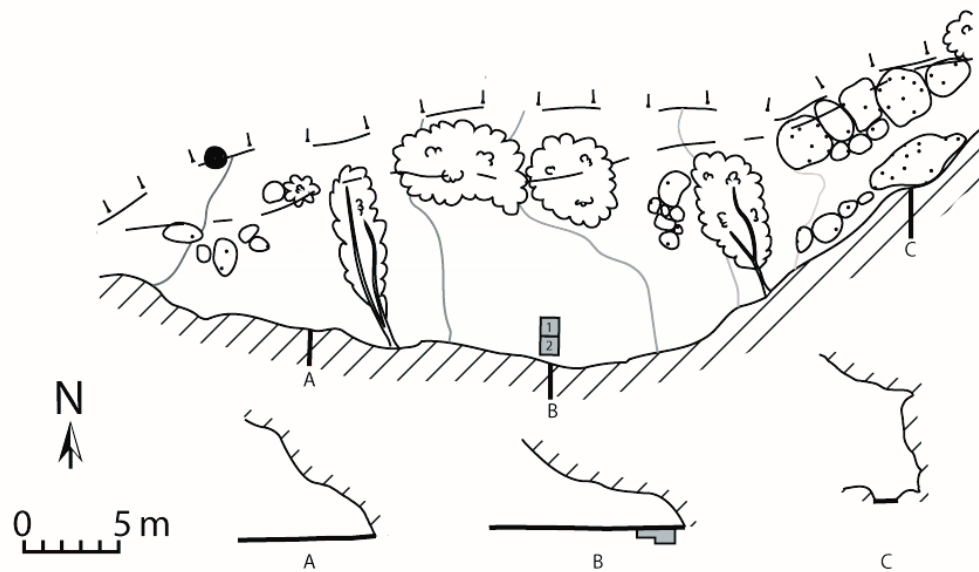


Figure 3. Mt Behn shelter surface and cross-sections, shaded area shows the extent of the deposit (CAD: Dorcas Vannieuwenhuyse).

Excavation, stratigraphy and chronology

Two adjoining 1 x 1 m squares (1 and 2) were placed centrally in an area where the deposit appeared to have greatest depth and away from the drip line and large trees. Each square was divided into 50 cm quadrants that were removed separately in 2 cm units. Where possible, excavation units followed stratigraphic changes and features. This allowed cultural materials to be recorded within stratigraphic layers as well as excavation units. All sediments were dry sieved through nested 3 mm and 1.5 mm screens.

Seven stratigraphic layers were identified in the excavation, marked by changes in colour, texture, and compaction (Figure 4). Stratigraphic layers 6 and 7 are the remnants of decayed bedrock and are culturally sterile. Stratigraphic layer 5 is only visible on the southern and

eastern walls. A sharp transition between layers 4 and 6 is visible on the western wall and is presumably a sign of the removal of older sediment. Several hearths and charcoals lenses were identified during the excavation and are visible in the sections (Figure 4).

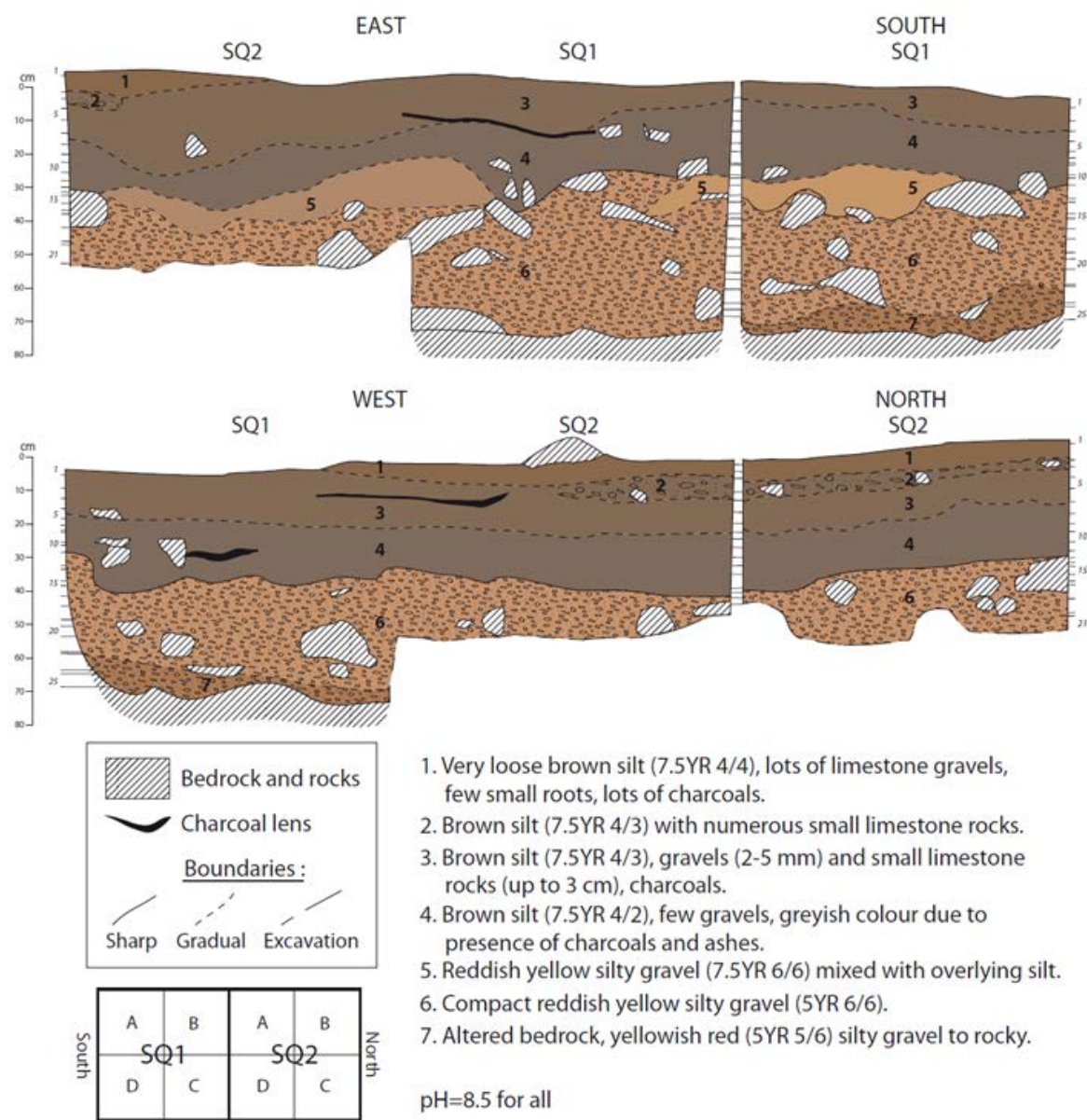


Figure 4. Stratigraphic sections of 2012 excavation squares 1 and 2 (CAD: Dorcas Vannieuwenhuyse).

Sixteen radiocarbon dating samples were obtained from the excavated deposit (Table 1). All radiocarbon samples were calibrated using Ox Cal 4, with charcoal samples calibrated using the southern hemisphere curve [SHCal13] (Hogg et al. 2013) and marine shell samples calibrated using the marine curve [Marine13] (Reimer et al. 2013), with a delta R correction of $\Delta R = 54 \pm 37$. The stratigraphic layers shown in Figure 4 were used with the calibrated age ranges in Table 1 to identify the time periods represented by each layer. No dates were obtained from stratigraphic layer 1 and this layer was amalgamated with stratigraphic layer

2, and assigned a time period of 439 calBP to present. Stratigraphic layer 3 is associated with dates ranging from 2602 to 1747 calBP. It is likely that the transition from stratigraphic layer 3 to 2 includes the last 1000 years, given the lack of evidence for a removal of sediment such as a sharp boundary. Stratigraphic layer 4 is associated with dates ranging from 3790 to 2349 calBP. Stratigraphic layer 5 has a single date calibrating from 5510 to 5240 calBP (ANU – 33033) and is assigned as ranging from 5510 to the upper range from stratigraphic layer 4 of 3790 calBP. The lowest point was recovered from the same quadrant and EU as the dated sample from stratigraphic layer 5. This supports Maloney et al. (2014) who found that points developed in the southern Kimberley by at least 5000 BP, although at Mt Behn they appear to be slightly earlier, around 5400 BP. Stratigraphic layer 6 contained a single fragment of charcoal collected in situ that was dated from 2736 to 2380 calBP (ANU – 32511) however, aside from this charcoal, this stratigraphic layer is completely sterile and the dated charcoal likely moved vertically downward.

Table 1. Radiocarbon dates obtained from Mt Behn deposit.

Lab. code	Sq	EU	Q	Average DBS (m)	Insitu Depth (m)	Strat. Layer	Curve	Material	d ¹³ C	C14 Age	Age calBP 2 sigma 95.4
ANU-33026	1	4	A	0.075		3	Marine13	Scaphopoda	-4	2740±35	2602-2270
ANU-33027	1	6	A	0.131		3	Marine13	Scaphopoda	-7	2505±35	2273-1958
ANU-32507	1	7	A	0.152		3	SHCal13	Celtis		1955±30	1930-1785 (88.7%) 1773-1747 (6.7%)
ANU-33029	1	8	C	0.167		3	Marine13	Scaphopoda	9	2225±40	1891-1608
ANU-33106	1	8	C	0.167		4	Marine13	Scaphopoda	-6	2995±35	2843-2567
ANU-33030	1	9	A	0.185		4	Marine13	Scaphopoda	-7	3695±40	3685-3399
ANU-33031	1	10	B	0.214		4	Marine13	Scaphopoda	-6	3755±40	3790-3468
ANU-33032	1	11	B	0.24		4	Marine13	Scaphopoda	-6	3310±40	3239-2911
ANU-33033	1	12	D	0.255		5	Marine13	Scaphopoda	-4	5060±40	5510-5240
ANU-32631	2	3	D	0.069	0.065	2	SHCal13	Charcoal	-31	265±35	439-401 (4.8%) 390-379 (0.8%) 328-262 (44.5%) 223-146 (45.2%)
ANU-32514	2	4	A	0.099		2	SHCal13	Charcoal	-32	135±25	258-233 (17.0%) 145-... (78.4%)
ANU-32509	2	5	C	0.124	0.12	3	SHCal13	Charcoal	-22	2020±35	2008-1867 (92.1%) 1854-1838 (3.3%)
ANU-32513	2	10	A	0.259		4	SHCal13	Charcoal	-32	2460±35	2700-2632 (17.8%) 2618-2585 (6.7%) 2575-2563 (1.2%) 2541-2349 (69.7%)
ANU-32632	2	15	B	0.367		4	SHCal13	Charcoal	-7	2775±35	2925-2756
ANU-32512	2	16	A	0.389	0.39	4	SHCal13	Charcoal	-25	2715±45	2875-2735
ANU-32511	2	20	D	0.49		6	SHCal13	Charcoal	-26	2530±30	2736-2427 (94.2%) 2393-2380 (1.2%)

* Some of these dates are reported in Maloney et al. (2014:143, Table 3) where they are calibrated using ShCal04 (McCormac et al. 2014) and Marine 09 calibration curves (Reimer et al. 2009).

Methods

All retouched flakes recovered from the site were analysed to model both the reduction sequence of, and overall technological investment into, retouched flakes. Points are here identified by their converging retouched margins, following Hiscock (2009:84; 2011:76). The other retouched flakes lack converging margins, and are referred to simply as other retouched flakes. Burinate retouch is recognised by multiple negative scars that remove flakes or spalls along the margin, rather than away from them (Clarkson 2007:112). The term complete, refers to retouched flakes with intact margins, lacking transverse, longitudinal, or marginal breaks. Recycled artefacts are recognised by the superimposition of retouch scars over break surfaces. While these categories can be seen as essentially typological tenants, in that attributes are used to group these archaeological phenomena, the variation in these retouched flake categories are technologically discrete.

We acknowledge that the unretouched flakes excluded from our study could have been used, some perhaps even for similar functions to the points. However, as we are interested primarily in retouch intensity variation, unretouched artefacts are not relevant to the current study. Without observation of tool use, residue and use wear analyses, the unretouched flakes' use life will remain unresolved. The focus on retouched flakes is justified because retouch intensity provides information on technological practices, particularly as they relate to current models for the underlying causes of point technology (Hiscock 1994a; Moore 2011).

Point and other retouched flake morphologies, were recorded using a series of linear measurements and indices of shape, following Clarkson (2006:99-103; 2007:101-111). Where the platform of points is unmodified, it provides a morphological link to the original blank morphology. Therefore, measurements of platform surfaces such as thickness, width, area, and external platform angle [EPA], were used to make comparisons between point types and retouch intensity. To further tease out the earlier stages of point reduction, points with Index of Invasiveness (Clarkson 2002a) values of less than 0.25 were identified as analogues of blank morphology prior to extensive modification (after Clarkson 2006:102).

Quantified measures of retouch intensity were employed to test typological validity, to provide an assessment of morphological change, and to gauge levels of technological investment. Indices deemed suitable for the assemblage following Hiscock and Tabrett (2010), were only recorded on complete retouched flakes. The Index of Invasiveness (Clarkson 2002a) is well suited to quantifying the spread of both unifacial and bifacial retouch and was recorded for all complete retouched flakes. The number of retouched segments ($n = 16$) which are recorded for this index, were also used as a measure of the distribution of retouch. The Average Geometric Index of Unifacial Reduction [AGIUR] (Hiscock & Clarkson 2005; Kuhn 1990) is only recorded for unifacial retouch, and is well

suitable to the point assemblage, because of the predominance of either plano-triangular or convex triangular cross-sections. The Percentage of Perimeter Retouched, and the Edge Curvature Index (Clarkson 2002b:82, Fig. 3) were also used.

The location of retouch scars has been central to classification of point technologies and time ordering through superimposition of retouch scars has revealed complex artefact life histories (Hiscock 1994a:78-79). Ventrally initiated retouch, with scars propagating onto the dorsal surface are here referred to as dorsal retouch. Dorsally initiated retouch, with scars propagating onto the ventral surface are here referred to as ventral retouch. In bifacial retouch, where scars initiated from one surface truncate retouch scars initiated from the opposite surface, the latter surface was the last to be retouched. Using this premise, the retouch order of points was recorded as dorsal only, dorsal last, ventral only, or ventral last. The order of retouch can be ambiguous in two situations. First, in bifacial points where the retouch initiation surfaces were rotated multiple times, the original order of retouch could be obliterated. Second, retouch order can be ambiguous where bifacial retouch prevents unambiguous identification of the ventral surface altogether.

To further tease out retouch strategies, the order of retouch was analysed within quartile divisions of the Index of Invasiveness (Clarkson 2007:102). These divisions represent arbitrary stages of variation in retouch intensity. Additionally, backing retouch was identified following Maloney and O'Connor (2014:150), with retouched edge angle, bidirectional scars, and crushing used as evidence for bipolar anvil-rested retouch.

All statistics were calculated using the SPSS version 2.2 package.

Results

The Mt Behn excavation recovered a total of 54294 stone artefacts. The analysed sample contained 264 complete and broken retouched flakes, including 109 complete points, 28 broken points, 99 complete other retouched flakes, and 27 broken other retouched flakes. A single pressure flaked biface was also recovered. Technological classes analysed are listed in Table 2. All points are reduced from flakes and are not reduced from cores or bifacial preforms.

Table 2. Technological classes identified from excavation squares 1 and 2.

Technological Class															
	EU	Points Total	Bifacial Points	Unifacial Points	Dentate Kimberley Point	Backed points	Other Retouched Flakes	Burrinate	Adze Tula	Broken Point	Broken Other Retouched Flake	Edge Ground Adze	Edge Ground Axe	Grind Stone Fragment	Recycling After Break (points)
Square 1	1	4	2	1			3		1	1					1
	2	4	2	1			3			1	1			3	
	3	3		1	1		1			1	1				
	4	2	2				3				1				
	5	2		1			3			1	2				
	6	6	2	2		2	1				1				
	7	7		3		2	2			2					
	8	3		1		1	1			1	1				
	9	6		4			1			2					
	10	6	1	3		1				1					
	11	5	1	3			2			1	1				
	12	1		1											
	Total	49	10	21	1	6	20		1	11	8			3	1
Square 2	1	7		7			10	2						1	5
	2	6		3		1	7	1	1	2				1	2
	3	3		3			9				2			1	3
	4	3	1	1			8			1	5			1	3
	5	6	3	3			3				2			1	
	6	11	1	8			6			2			1		
	7	8	3	4			4	1		1	2			1	
	8	11	2	6			6	1		3	1				1
	9	12	2	6			7	2		4				1	
	10	9	1	4		1	5			3	4	1			1
	11	4		3			4			1	2				
	12	1		1			3	1							
	13	4		3		1	4								
	14	3		3			3				1				
	Total	88	13	55		3	79	8	1	17	19	1	1	4	7

Retouched flakes (points = 0.25%, other retouched flakes = 0.23%) constitute only a small component of the overall stone artefact assemblage, however, this is not unusual for Australian archaeological sites (e.g. Holdaway 1995:784; O'Connor 1999:34, 64-65, Table 4.5; Smith 2006:377, Table 3). Points in particular appear to make up very small components of assemblages across northern Australia. For example, Clarkson's (2007) analysis of points from four sites throughout Wardaman Country, included percentages of points between 0.44%, at Gordolya, and 1.79% at Garnawala (2007:66-77, App B-E). Likewise, Hiscock's reanalysis of nine squares from Jimede 2, included 102 points and a further 119 other

retouched flakes (2011:76) which, based on the overall total given by Schrire (1982:197), must represent less than 1% of the assemblage. Similarly, points recovered from Widgingarri Shelter 2 represent 0.45% of the assemblage (O'Connor 1999:64-65, Table 5.8). The small percentage of points within the Mt Behn assemblage is therefore not unusual for northern Australia and probably reflects both low frequencies of point production and discard relative to debitage, and the use of 1.5 mm sieves which capture more debitage. The samples analyzed by Hiscock (2011) were collected with 6.35 mm sieves (Schrire 1982:192), and the mentioned sites analyzed by Clarkson (2007) were collected using either 6.6 mm or 3 mm sieves (Clarkson 2007:55, 69).

Raw material

Points are most commonly reduced from locally available crystal quartz (Table 3). This high quality material is relatively rare and appears as either formed crystals in the limestone conglomerate or tabular pieces in the adjacent creek beds. Crystal quartz also occurs in the Lennard River gravel beds as water rolled cobbles approximately 18 km to the west of the Mt Behn site. The remaining cortex on all quartz points indicates that the reduction of local crystal quartz was favoured, rather than the water rolled cobble sources (Table 4). Although white vein quartz is locally abundant, occurring in eroding seams, it was not heavily exploited (Table 3). The quartzite points were most likely collected from cobble sheets derived from the Mt Behn conglomerate (Playford et al. 2009:143) to the immediate north of the site. This quartzite is of moderate to poor quality. Hornfels, chert, and chalcedony are high quality materials but used rarely for point production at the site (Table 3). No local sources for these materials are presently known but they may occur as occasional nodules in the conglomerate bands in the Napier limestone. Chert is known to outcrop abundantly in seams 60 km to the north west near Blundell's (1975:218) LR9 site, and about 160 km to the south west near Riwi (Balme 2000), although there has been little survey in this area and closer sources may exist. No significant difference in retouch intensity (Index of Invasiveness) was detected between complete retouched flakes made on non-crystal quartz materials ($n = 35$) and the dominant material ($U = 1075.000$, $p = 0.614$), indicating that retouch intensity did not favour exotic materials.

Table 3. Raw material frequency and percentage of unifacial, bifacial, and backed points of the total sample of points.

Raw Material	Crystal Quartz	Quartzite	White Vein Quartz	Hornfels	Chert	Chalcedony
Total Frequency of Points	102	16	10	6	2	1
Total Percentage of Points	74.5	11.7	7.3	4.4	1.5	0.7
Frequency Relative to Type	Crystal Quartz	Quartzite	White Vein Quartz	Hornfels	Chert	Chalcedony
Unifacial	64	14	9	3	2	1
Bifacial	29	2	1	2		
Backed	9					
Kimberley Dentate Point				1		

Table 4. Frequency and percentage of quartz cortex type observed on points.

Quartz Cortex Type	Intact Formed Crystal	Tabular/Angular	Weathered	Water Rolled
Frequency	4	33	9	2
Percentage	2.9	24.1	6.6	1.5

Blank selection

There is no difference in blank morphology between traditional point types, unifacial and bifacial. Multiple platform measurements, used as a proxy for blank morphology, revealed no statistically significant difference in retouch intensity (Table 5). When values of the Index of Invasiveness below 0.25 are sub-sampled, there is again no statistically significant difference between platform variables and retouch intensity (Table 6). These tests indicate that all points begin use life from the same pool of flakes or blanks, which typologically resemble the ‘lancet’ described by Clarkson (2007) or the macro blades described by Moore (2015).

Table 5. Statistical analysis for point platform variables against Index of Invasiveness.

ANOVA – Platform Variables vs. Index of Invasiveness (n = 104)		F	df	p
Platform Width		1.131	21	0.336
Platform Thickness		1.335	22	0.176
Chi Square Test – Platform Variables vs. Index of Invasiveness (n = 104)		χ^2	df	p
Platform Area		2121.000	2100	0.369
External Platform Angle		183.784	242	0.998
Internal Platform Angle		254.277	242	0.281
Number of Scars on Platform		114.460	132	0.862
Shapiro-Wilk – Test of Normality		W	df	p
Platform Width		0.993	100	0.885
Platform Thickness		0.986	100	0.399
Platform Area		0.960	100	0.004
External Platform Angle		0.965	100	0.010
Internal Platform Angle		0.897	100	<0.001
Number of Scars on Platform		0.884	100	<0.001

Table 6. Statistical analyses for point platform variables against retouch intensity, using sub sample of Index of Invasiveness values below 0.25.

ANOVA – Platform Variables vs. Index of Invasiveness (n = 104)	F	df	p
Platform Width	0.874	73	0.553
Platform Thickness	1.107	74	0.371
Platform Area	0.904	73	0.527
External Platform Angle	0.603	72	0.790
Chi Square Test	χ	df	p
Platform Variables vs. Index of Invasiveness (n = 104)			
Internal Platform Angle	71.218	90	0.928
Number of Scars on Platform	46.335	54	0.761
Shapiro-Wilk – Test of Normality	W	df	P
Platform Width	0.988	68	0.739
Platform Thickness	0.978	68	0.283
Platform Area	0.962	68	0.037
External Platform Angle	0.959	68	0.025
Internal Platform Angle	0.863	68	<0.001
Number of Scars on Platform	0.866	68	<0.001

Changing morphology and retouch intensity

There is a complete overlap between unifacial and bifacial points in both morphology and retouch intensity, indicating that an underlying reduction continuum is responsible for point morphologies. The range of morphological measures reveals no significant difference between unifacial and bifacial points (Table 7). Figure 5 illustrates the overlap in the percentage of perimeter retouch between unifacial and bifacial points, where mass generally declines with increasing retouch. Bifacial retouch occasionally begins in the early stages of point reduction and many unifacial points were discarded with invasive scars covering the entirety of only one surface (n = 21). Figure 6 illustrates the central tendencies of mean point length, where bifacial points are generally smaller than unifacial points, suggesting that increasing retouch intensity reduced point dimensions, probably controlled by size of the original blank.

Table 7. Statistical analyses of bifacial and unifacial point retouch versus linear dimensions and morphological indices.

Chi Squared Test	χ	df	p
Bifacial / Unifacial Retouch vs. Linear Dimensions and indices			
Mass	113.718	122	0.691
Maximum Length	107.635	109	0.519
Distal Thickness	106.534	101	0.334
Elongation Index	59.000	58	0.439
Proximal Width to Thickness Ratio	111.000	110	0.455
ANOVA	F	df	p
Bifacial / Unifacial Retouch vs. Linear Dimensions and indices			
Percussion Length	1.486	111	0.226
Distal Width	0.841	110	0.361
Mid-Width	1.553	110	0.215
Proximal Width	2.036	112	0.156
Proximal Thickness	0.007	112	0.934
Mid-Thickness	0.303	111	0.583
Mid-Width to Thickness Ratio	2.264	110	0.135
Distal Width to Thickness Ratio	0.115	110	0.735
Shapiro-Wilk – Test of Normality	W	df	p
Mass	0.868	59	<0.001
Percussion Length	0.963	59	0.072
Maximum Length	0.951	59	0.019
Distal Width	0.971	59	0.166
Mid-Width	0.966	59	0.101
Proximal Width	0.967	59	0.111
Proximal Thickness	0.966	59	0.098
Mid-Thickness	0.980	59	0.429
Distal Thickness	0.959	59	0.046
Elongation Index	0.884	59	<0.001
Mid-Width to Thickness Ratio	0.978	59	0.366
Proximal Width to Thickness Ratio	0.880	59	<0.001
Distal Width to Thickness Ratio	0.981	59	0.490

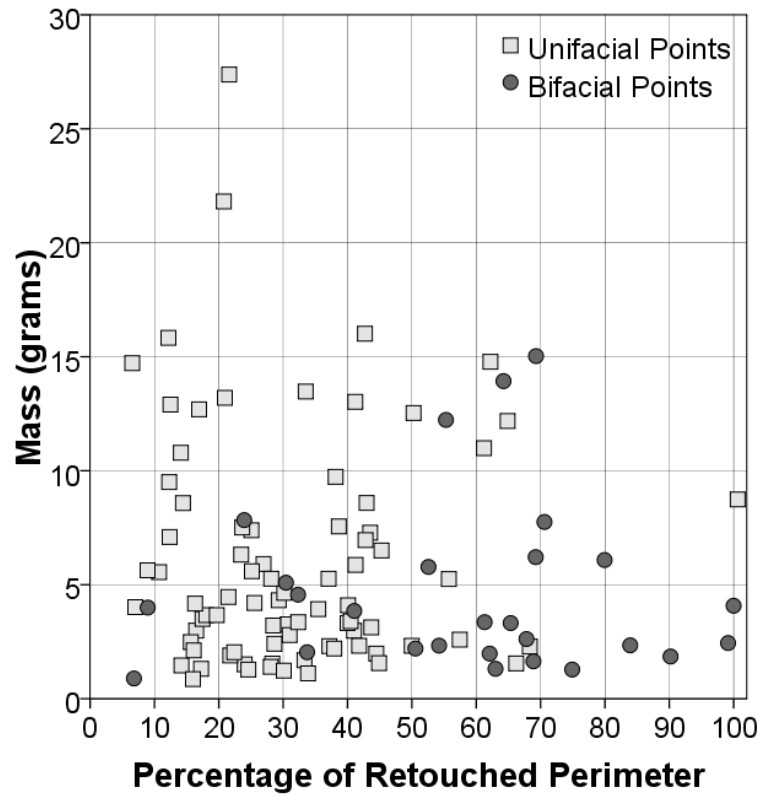


Figure 5. Mass plotted against the percentage of perimeter retouched on complete points, showing the overlap in retouch intensity between unifacial and bifacial points.

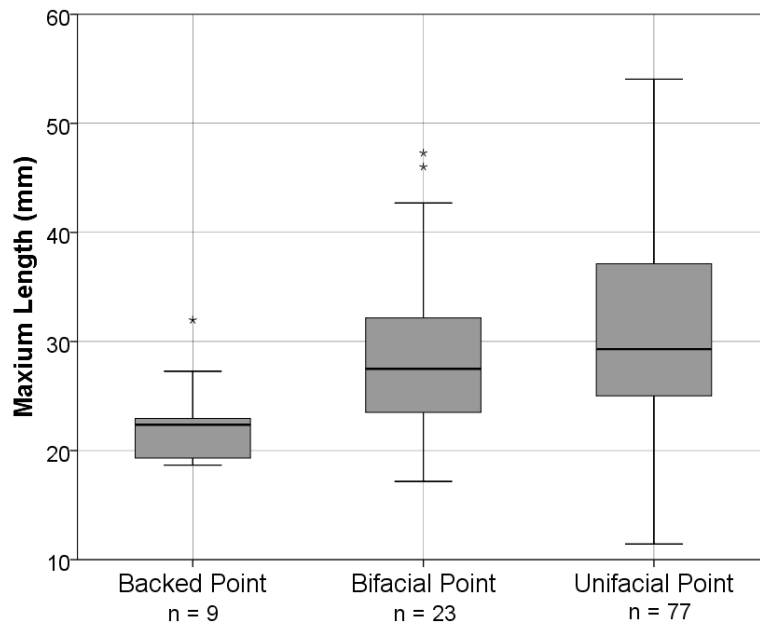


Figure 6. Central tendency of complete points using maximum length, excluding all distal breaks.

The retouched edge curvature index, calculated for points, reveals that increasing retouch intensity gradually produced more convexity on the retouched margins ($W = 0.109$, $p = 0.005$; ANOVA $F = 1.930$, $df = 99$, $p = 0.018$). Negative values of this index, which detect concave retouched margins, are rare ($n = 2$). However, increasing retouch intensity does not support an increasing likelihood of proximal thinning, and neither is proximal retouch associated with high retouch intensity values. Only six of the 137 points were observed with proximal trimming and ranged in Index of Invasiveness values from 0.19 to 1.

While points were reduced from the same select group of flakes, the other retouched flakes were produced on a wider morphological range, proving to be significantly different from the point blanks, based on platform thickness for example ($W = 0.988$, $p = 0.067$; $\chi^2 = 249.206$, $df = 195$, $p = 0.005$). Overall, the other retouched flakes were only lightly retouched before discard, with comparatively low mean values of AGIUR and Index of Invasiveness (0.24 and 0.16 respectively). The percentage of perimeter retouched and the edge curvature index indicates that as marginal retouch expanded, it became increasingly curved and convex ($W = 0.810$, $p = <0.001$; ANOVA - $df = 16$, $f = 1.976$, $p = 0.029$). None of these retouched flakes were reduced into notched morphologies, such as those found by Clarkson (2008:298, Fig. 13.8 C).

Point cross-section morphology

Table 8 summarises the cross-section morphologies of points, relative to quartile divisions of the Index of Invasiveness. Width to thickness ratios taken at three points along the percussion axis, do not appear to be greatly affected by retouch intensity (Table 9), suggesting that increasing frequency of invasive retouch did not drastically thin bifacial points and that it is not exclusively associated with biconvex cross sections.

Table 8. Qualitative cross-sectional shape frequencies distributed over quartiles of Index of Invasiveness values recorded only on complete points.

Cross Section Shape	0 – 0.25	0.25 – 0.5	0.5 – 0.75	0.75 – 1	Total
Plano Triangular	41	1	1		43
Plano Convex	4	4	4	2	14
Plano Trapezoid	18		1		19
Biconvex	3	2	2	5	12
Convex Triangular	7	2	2	1	12
Convex Trapezoid	3	1			4
Bi - Triangular	1				1
Ambiguous			1	3	4
Total	77	10	11	11	109

Table 9. Statistical analyses of Index of Invasiveness against width to thickness ratios taken at three landmarks along the percussion axis of points.

ANOVA – Index of Invasiveness vs.	F	df	p
Mid Width to Thickness	0.653	25	0.886
Distal Width to Thickness	1.036	25	0.434
Chi-square Test – Index of Invasiveness vs.	χ^2	df	p
Proximal Width to Thickness Ratio	2750.000	2725	0.364
Shapiro-Wilk – Test of Normality	W	df	p
Mid-Width to Thickness Ratio	0.978	59	0.366
Proximal Width to Thickness Ratio	0.880	59	<0.001
Distal Width to Thickness Ratio	0.981	59	0.490

Edge angles and backing

Nine backed points were recovered with average retouched edge angles between 82 and 90 degrees. Bipolar anvil-rested retouch was observed on seven of the nine backed points. The backed point retouched edge angle is significantly different from all other point morphologies ($W = 0.974$, $p = 0.033$; $\chi^2 = 94.745$, $df = 36$, $p = <0.001$). The average edge angle of backed points, which excludes retouched edge angle measures, exhibits no significant difference from other point morphologies ($W = 0.989$, $p = 0.479$; ANOVA $df = 1$, $f = 0.884$, $p = 0.349$). This test suggests that prior to backing, the blanks were not drastically different in edge angle. The smaller size of backed points, relative to other point morphologies (Figure 6), combined with the observation that backing occurs only in the early stages of point reduction, suggests that the backed points may have been selectively made on blanks with shorter lengths.

Like the findings of Maloney and O'Connor (2014), the Mt Behn backed points appear to be a specialised point morphology. As unifacial retouch intensity increases on points, the average retouched edge angle shows no correspondingly increase ($W = 0.974$, $p = 0.033$; $\chi^2 = 2001.375$, $df = 1950$, $p = 0.204$) suggesting that the backed margins are not the unintentional product of unifacial retouch reducing width to thickness ratios. Moreover, there is no significant difference between the AGIUR values of backed points and other unifacial points ($W = 0.872$, $p = 0.096$; ANOVA $df = 1$, $F = 0.076$, $p = 0.783$).

Multiple point retouch strategies

Quantifying the order and spread of retouch on points within the reduction continuum, reveals a diverse range of retouch strategies. The order of retouch was observable on 115 points, consisting of 109 complete points, and a further six with minor distal breaks that allowed reliable identification of retouch order. Table 10 lists the order of retouch divided into quarters of the Index of Invasiveness.

Table 10. Placement and order of retouch for complete points distributed across quartiles of the Index of Invasiveness. These observations were recorded only on complete points (n = 109) and points with small distal breaks, where retouch order was clear (n = 6).

Retouch Order	0 – 0.25		0.25 – 0.5		0.5 – 0.75		0.75 - 1		Total	
	n	%	n	%	n	%	n	%	n	%
Dorsal Only	66	86.5	12	52	0	0	0	0	78	100
Ventral Last	5	7	3	13	5	50	3	37.5	16	100
Ventral Only	2	3	2	9	0	0	0	0	4	100
Dorsal Last	1	1.5	2	9	4	40	2	25	9	100
Unambiguous Bifacial	1	1.5	2	4	1	10	3	37.5	8	100
Total	75	100	22	100	10	100	8	100	115	100

The early stages of point reduction (Index of Invasiveness values between 0 and 0.25) were the most commonly discarded at the site, with more than half of all points exhibiting only dorsal retouch (n = 77). Retouch was initially unifacial and concentrated on the dorsal right medial and distal margins. These points collectively lack invasive scars, despite bifacial retouch being occasionally instigated at this stage (n = 7, 10%). All of the backed points are within this early stage of reduction.

As retouch intensity increases (Index of Invasiveness values between 0.25 and 0.5), points received dorsal retouch in 52 % (n = 12) of cases. In 90 % of cases, retouch expanded around the entire perimeter of the point. The likelihood of bifacial retouch increases, with 39 % of cases exhibiting bifacial retouch. Invasive retouch is mostly restricted to the first surface retouched, typically applied to the ventral right medial and distal margin, which in most cases is typically the same margin first retouched on the opposite surface.

In the next stage of point reduction (Index of Invasiveness values between 0.5 and 0.75) all points exhibit bifacial retouch. Invasive scars partially cover the dorsal and ventral surfaces, but lack the dominantly invasive scars found in the later stages of point reduction. Five cases exhibit ventral last retouch and four dorsal last retouch, which indicates that bifacial retouch followed two strategies, probably dependent on individual morphology and life history.

In the last stage of point reduction (Index of Invasiveness values between 0.75 and 1) the dorsal and ventral surfaces were covered by invasive retouch. Of the eight cases representing this final stage of reduction, three exhibit ventral last retouch, two dorsal last retouch, and three had bifacial retouch that continued to such an extent that recognition of the retouch order was impossible.

Figure 7 illustrates this distribution of retouch across the surface of points within the quartile divisions, where a dominant retouch strategy can be seen. The percentage values given in Figure 7 are calculated by dividing the individual segments with retouch scores, by the number of points within each quartile division of the Index of Invasiveness. The blank

marginal segments associated with inner invasive values, are used to highlight the frequency of invasive retouch on point segments.

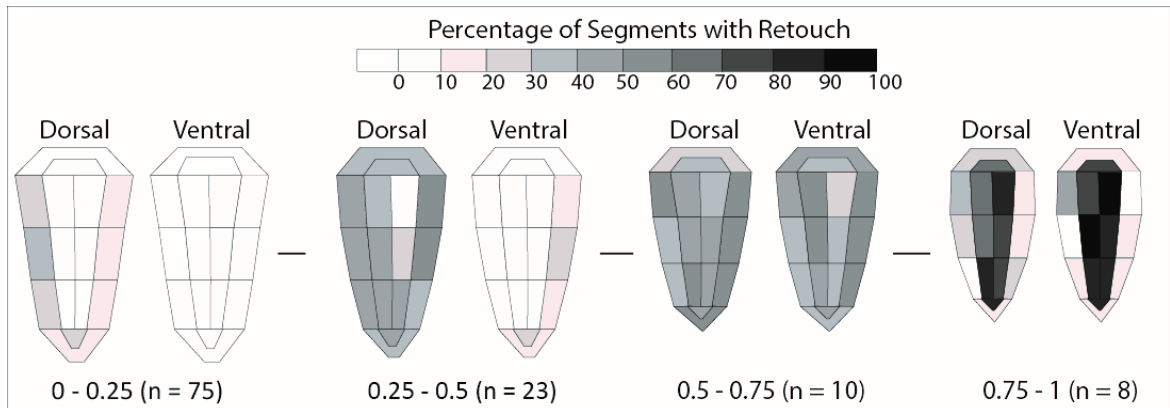


Figure 7. The quartile divisions of the Index of Invasiveness used to illustrate the location of retouch across segments of the dorsal and ventral surfaces, on points where retouch order was recorded. Percentages are calculated by dividing the number of segments with retouch, by the number of points within each quartile division of the Index of Invasiveness. 0 values are given for marginal segments when an invasive score is present.

In summary, the point reduction continuum evident in the Mt Behn assemblage reveals a pattern of retouching poorly reconciled by the traditional typological division. The majority of points began modification as unifacial points with retouch across one margin. The spread of retouch was gradual and initially concentrated on the point margins. Points that were continually retouched could potentially have followed multiple reduction pathways. Invasive bifacial flaking focuses on maintaining margins, rather than on thinning points. The life history of points within this reduction continuum can now be assessed for changes through time.

Technological change model

Temporal context

All retouched flakes were allocated an associated time period, based on the calibrated radiocarbon dates within each stratigraphic layer (Table 11). The quadrant and EU that each artefact was recovered in is associated precisely with one of the five cultural layers producing four time periods as indicated in the table. This chronology neither represents a precise age/depth model, particularly given the error ranges of radiocarbon dating, nor does it represent sediment accumulation rates. In instances where excavation units cross cut stratigraphic layers, points were recovered in situ and were able to be precisely associated with a single time period.

Table 11. Associated time period of points relative to stratigraphic units per quadrant.

Square 1 Point Frequency *insitu					Associated Stratigraphic Layer				Associated Age Range Years calBP
EU	A	B	C	D	A	B	C	D	
1	2	0	0	2	1	1	3	3	0 - 439
2	1	2	1	0	1	1	3	3	
3	1	1	0	0	2	3	3	3	
4	0	1	0	1	3	3	3	4	1747 - 2602
5	1	0	1	0	3	3	3	4	
6	1	2	0	4	3	3	4	4	
7	2	0	4	1	3	3	4	4	
8	2	0	0	1	3,4	4	4	4	
9	2	3	1*	1	4	4	5	4	
10	1	4	0	0	4	4	5	4	
11	0	4*	0	1	4	4	5	5	2349 - 3790
12	0	0	0	1	4	4	5	5	3790 - 5510
13	0	0	0	0	6	6	6	5,6	
14	0	0	0	0	6	6	6	6	Sterile
15	0	0	0	0	6	6	6	6	
16	0	0	0	0	6	6	6	6	
17	0	0	0	0	6	6	6	6	
18	0	0	0	0	6	6	6	6	
19	0	0	0	0	6	6	6	6	
Square 2 Point Frequency *insitu					Associated Stratigraphic Layer				Associated Age Range Years calBP
EU	A	B	C	D	A	B	C	D	
1	2	2	3	0	3	3	1	3	0 - 439
2	1	5	0	0	3	3	1	3	
3	1	1	0	1	3	3	2,3	3	
4	0	1	2	0	3,4	3	3	3	1747 - 2602
5	0	2	2	2	4	3	3	3	
6	3	3	2	3	4	3	3	3	
7	2	3	3	0	4	3,4	3	3,4	
8	4*	1	2*	4*	4	4	4	4	
9	3	2	2	5*	4	4	4	5	2349 - 3790
10	2	6	1	0	4	4	4	5	3790 - 5510
11	3	0	0	1	4	4	4	5	
12	0	0	1	0	4	4	4	5	
13	2	0	0	2	4	4,6	4,5	5	
14	1	2	0	0	4	4,6	4,5	5	
15	0	0	0	0	4	4,6	5	5	
16	0	0	0	0	6	6	6	5	
17	0	0	0	0	6	6	6	5,6	3790 - 5510
18	0	0	0	0	6	6	6	6	
19	0	0	0	0	6	6	6	6	
20	0	0	0	0	6	6	6	6	Sterile
21	0	0	0	0	6	6	6	6	

Table 12 lists the total number of artefacts and percentage of this total of, points, and other retouched flakes within the four identified time periods. While the relative percentage of points is generally very low, several trends are apparent. Notably, within the earliest period, between about 5510 and 3790 calBP years, more points were discarded as a percentage of overall discard than in any subsequent period. In the following period, between about 3790 and 2349 calBP, the relative frequency of points was at its lowest, and between 2602 and 1747 calBP, proportionally more points were discarded.

Table 12. Frequencies of retouched flakes and total number of artefacts (TNA) per associated time period.

Time Period years calBP	Total Number Artefacts [TNA]	Points & Point Fragments	Other Retouched Flakes	% of Points Relative to TNA	% of Other Retouched Flakes Relative to TNA
439 – 0	4625	9	14	0.22	0.26
2602 – 1747	17503	56	60	0.31	0.27
3790 – 2349	27425	57	40	0.21	0.11
5510 – 3790	4103	15	12	0.37	0.22

The numbers of discarded artefacts per thousand years for each time period (Figure 8) suggest that the most intensive occupation period at the site is represented by the two middle time periods, with the highest discard rate occurring between 2602 and 1747 calBP. Moreover, the numbers of points discarded per thousand years (Figure 9), suggests that this same period saw the greatest number of points discarded. The number of points within each time period, is statistically significant ($W = 0.893$, $p = 0.398$; $t = 7.272$, $df = 3$, $p = 0.005$), suggesting that point discard is not simply a reflection of sample size.

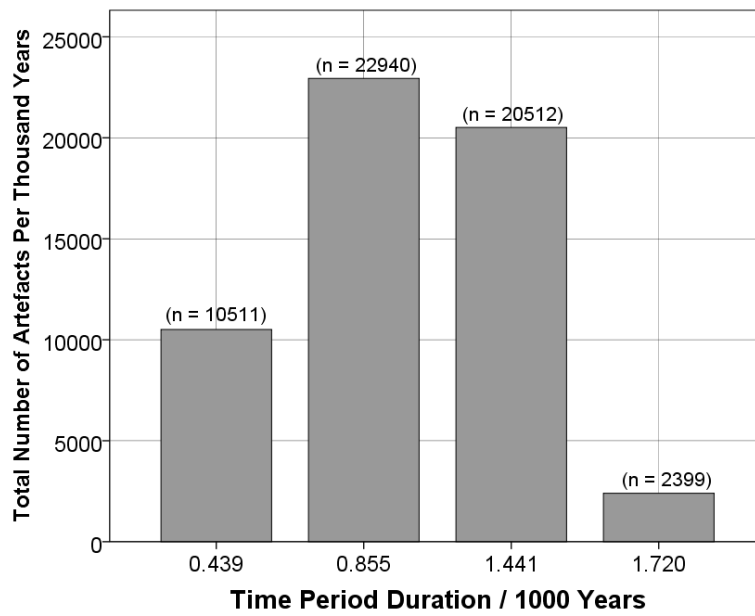


Figure 8. Total number of artefacts discarded per thousand years, where the duration of each time period is divided by 1000.

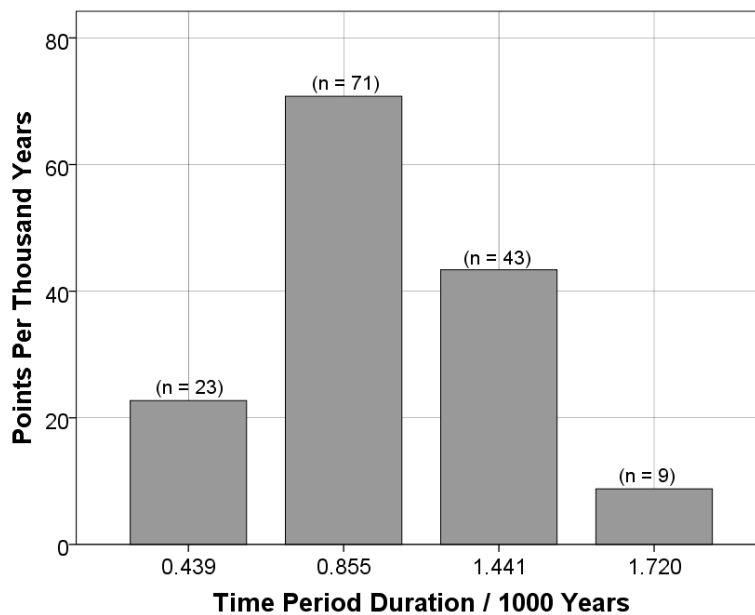


Figure 9. Discard of points per thousand years, where the duration of each time period is divided by 1000.

Morphological change through time

Morphological change in points over time, saw the mean value of width to thickness ratios shift from 3.2 to 2.7, between 5510 calBP and 1608 calBP, and then rise again to 3.0, during the last 439 years (Figure 10). A gradual reduction in the width to thickness ratios of all points was observed, with the exception of the last 439 years (Figure 10). This gradual decline in cross-sectional ratio values occurred irrespective of retouch intensity (Index of Invasiveness), ($\chi = 143.153$, $df = 125$, $p = 0.127$). The relative thickness of points changed throughout the site's occupation, perhaps to deal with changing functions and tasks, or as a consequence of greater efforts to reduce points. A host of other morphological measures did not significantly change though time, suggesting that point standardisation was emphasised.

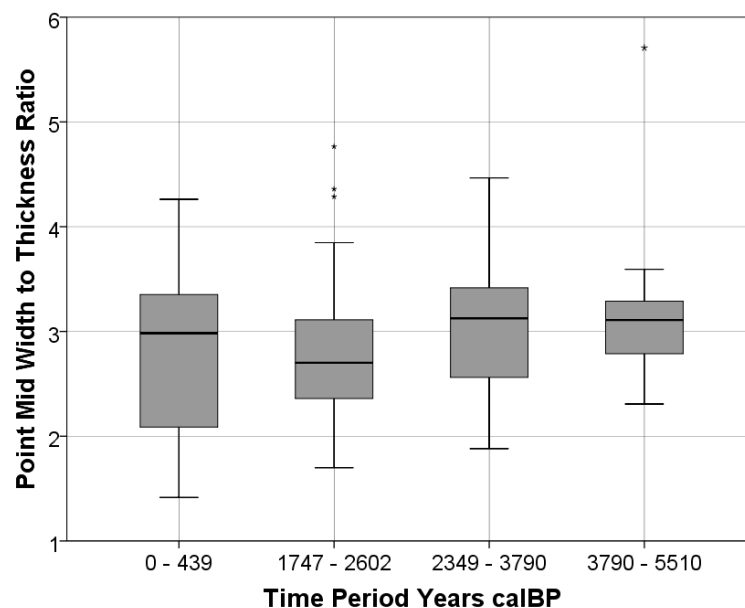


Figure 10. Mid with to thickness ratios of points relative to time period.

Diversification of point retouch strategies over time provides further evidence for change. Table 13 lists changing retouch strategies represented by the order of retouch on complete points, within the associated time periods. It should be noted that Table 13 and the following discussion of retouch order, only include data for points where retouch order is observable.

Table 13. Time periods showing divisions of the Index of Invasiveness and the order of retouch for complete points. These observations were recorded only on complete points (n = 109) and points with small distal breaks, where retouch order was clear (n = 6).

439 - 0 years (Complete Points n = 9)										
Retouch Order	0 – 0.25		0.25 – 0.5		0.5 – 0.75		0.75 – 1		Total	
	n	%	n	%	n	%	n	%	n	%
Dorsal Only	2	50							2	25
Ventral Last	1	25			1	100			2	25
Ventral Only										
Dorsal Last	1	25	1	50					2	25
Ambiguous Bifacial			1	50			2	100	3	25
Total	4	100	2	100	1	100	2	100	9	100
2602 - 1747 years (Complete Points n = 46)										
Retouch Order	0 – 0.25		0.25 – 0.5		0.5 – 0.75		0.75 – 1		Total	
	n	%	n	%	n	%	n	%	n	%
Dorsal Only	21	77	6	60					27	58.7
Ventral Last	4	15	1	10	4	66.6	2	66.6	11	24.3
Ventral Only	1	4	1	10					2	
Dorsal Last					2	33.3			2	4.3
Ambiguous Bifacial	1	4	2	20			1	33.3	4	8.7
Total	27	100	10	100	6	100	3	100	46	100
3790 - 2349 years (Complete Points n = 50)										
Retouch Order	0 – 0.25		0.25 – 0.5		0.5 – 0.75		0.75 – 1		Total	
	n	%	n	%	n	%	n	%	n	%
Dorsal Only	34	97	4	50					38	76
Ventral Last			1	12.5			1	25	2	4
Ventral Only	1	3	1	12.5					2	4
Dorsal Last			1	12.5	2	33.3	2	50	5	10
Ambiguous Bifacial			1	12.5	1	66.7	1	25	3	6
Total	35	100	8	100	3	100	4	100	50	100
5510 - 3790 years (Complete Points n = 10)										
Retouch Order	0 – 0.25		0.25 – 0.5		0.5 – 0.75		0.75 – 1		Total	
	n	%	n	%	n	%	n	%	n	%
Dorsal Only	6	100	2	66.6					8	80
Ventral Last			1	33.3					1	10
Ventral Only										
Dorsal Last										
Ambiguous Bifacial							1	100	1	10
Total	6	100	3	100			1	100	10	100

The 15 points recovered from the time period between 5510 and 3790 calBP, are mostly unifacial (n = 8) and retouched on the dorsal face only. Of the two complete bifacial points, one was retouched on the ventral surface after marginal dorsal retouch, while the other has an ambiguous bifacial retouch order. The five broken points within this layer showed no signs of recycling or rejuvenation. Relatively few of the other complete retouched flakes (n = 9) were discarded during this period although those that were have the highest retouch intensity for this technological class at the site (AGIUR = 0.32).

The time period dated to between 3790 and 2349 calBP, contains points that are also mostly unifacial with dorsal only retouch ($n = 34$); however, a greater diversity of retouch strategies is represented than in the earliest time period. Bifacial retouch was occasionally employed in the early stages of point use life ($n = 4$) and multiple strategies were followed (Table 13). The first recycled points ($n = 2$) having rejuvenated pointed distal tips following a transverse snap were also recorded in this time period. Unifacial to bifacial retouch transitions were more likely to have ventral only retouch, superimposed by dorsal last retouch. Seven backed points were recovered within this period, where alternate bipolar anvil resting obscured the retouch order. Other complete retouched flakes ($n = 30$) convey relatively less retouch intensity ($AGIUR = 0.30$) than the earliest time period, although these other retouched flakes represent a much smaller component of overall discard (Table 12). While this period is associated with the greatest number of points and artefacts, the percentage of points relative to overall discard is at its lowest value (Table 12). This low rate of point discard indicates that observed retouch strategy diversification is unlikely to be a function of sample size.

The time period dated to between 2602 and 1747 calBP contained 46 complete points, and marks an expansion in both retouch strategy diversification and use life extension. Points were mostly discarded with unifacial retouch on the dorsal surface only ($n = 27$), although proportionally more bifacial points are evident ($n = 17$). These bifacial points indicate that a ventral last retouch order ($n = 11$) was the most common strategy, with dorsal last retouch only identified in two cases. Bifacial retouch was occasionally instigated in the early stages of reduction ($n = 3$), and the ambiguous bifacial retouch orders ($n = 4$) indicate that after significant modification, alternate bifacial reduction continued. Unifacial to bifacial retouch transitions were more likely to be dorsal only retouch, superimposed by ventral last retouch, which is the opposite of the previous period (Table 13). Two backed points were recovered within this period. Burinate retouch superimposed over a transverse break, which drastically changed the distal point morphology, is present. Other forms of point recycling following transverse snaps ($n = 4$), mark the highest rate of point recycling in the site. Other complete retouched flakes ($n = 48$) have relatively less retouch intensity than the previous periods ($AGIUR = 0.22$) while representing an increased portion of overall discard. This period is also marked by greater technological diversity, with the recovery of an edge ground axe and adze, each respectively associated with radiocarbon dates of 2699 to 2343 calBP 95.4 % (ANU – 32513) and 2148 to 1659 calBP 95.4 % (ANU – 33027). The only examples of sandstone grindstone fragments ($n = 7$) were also found during this period. Overall, the time period between 2602 and 1747 calBP, saw more technological diversity than those layers proceeding and preceding.

Eight complete points were discarded within the most recent time period, which, while being allocated an associated age of 439 years to present, probably represents the last

millennium. Bifacial point (n = 6) retouch orders were equally likely to follow a ventral last or dorsal last strategy, including the only observation of a pressure flaked biface (see Maloney et al. 2014, Fig. 4). No backed or recycled points were identified in this period. Other complete retouched flakes (n = 12) continue the trend of decreasing retouch intensity (AGIUR = 0.12), while representing a similarly high relative portion of overall discard (Figures 11 & 12).

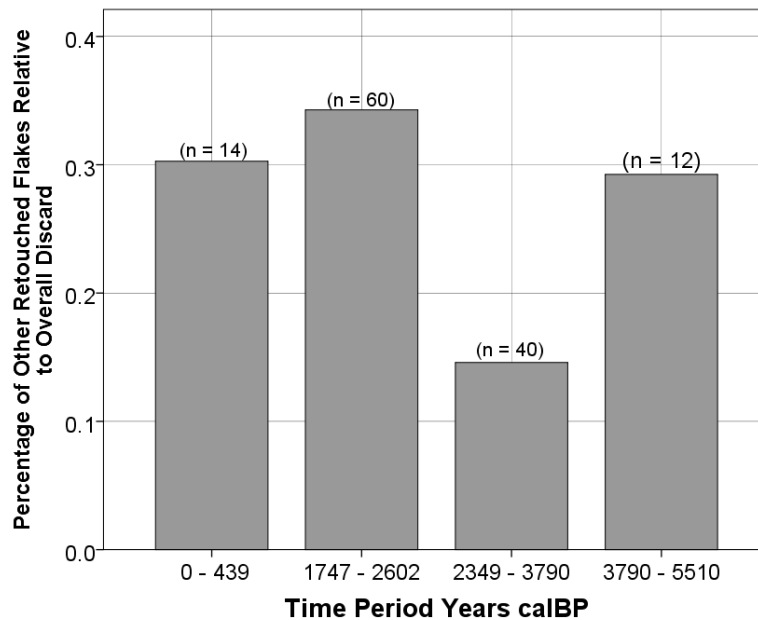


Figure 11. Other retouched flakes as a percentage of overall discard relative to time period.

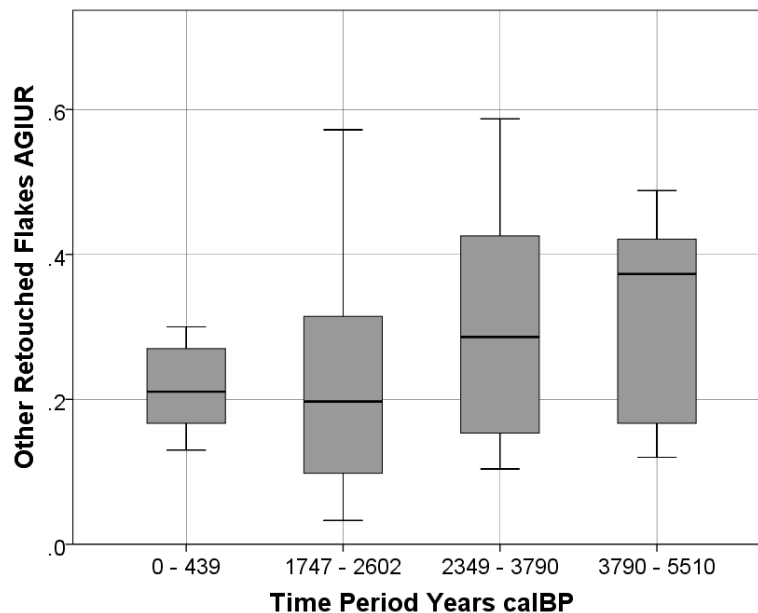


Figure 12. Unifacial retouch intensity, recorded on other retouched flakes, relative to associated time period.

The Mt Behn point assemblage displays multiple retouch strategies within a single reduction continuum throughout these time periods. This reduction continuum produced both unifacial and bifacial points, with the latter following multiple retouch orders. Backing retouch was exclusively conducted early in artefact use life and backed points were only observed during time periods between 3790 and 2349 calBP, and 2602 and 1747 calBP. The retouch intensity of the other retouched flakes declined over the 4 time periods ($W = 0.729$, $p = <0.001$; $\chi = 107.727$, $df = 17$, $p = <0.001$). The discard frequency of these other retouched flakes increases at the same time that retouch intensity decreases. This trend could reflect a declining technological investment into the use life extension of these implements, when greater use life extension was being emphasised in the more standardised point technology.

Statistical tests reveal that the changes in retouch observed on points and other retouched flakes are unlikely to be a result of artefact accumulation or varied occupation intensity. The time periods used to assess change through time, generalised as they may be, indicate that the discard rate of points and other retouched flakes was greatest between 2602 and 1747 years calBP. Most notably, this same period saw the greatest effort to extend the use life of points, with heightened retouch intensity, the greatest diversity in retouch strategies and recycling, as well the appearance of grinding technologies (although we caution that edge ground axes are certainly much older than this in the Kimberley region, see O'Connor et al. 2014). The changes observed in the point assemblage throughout the identified time periods are summarised in Figure 13.

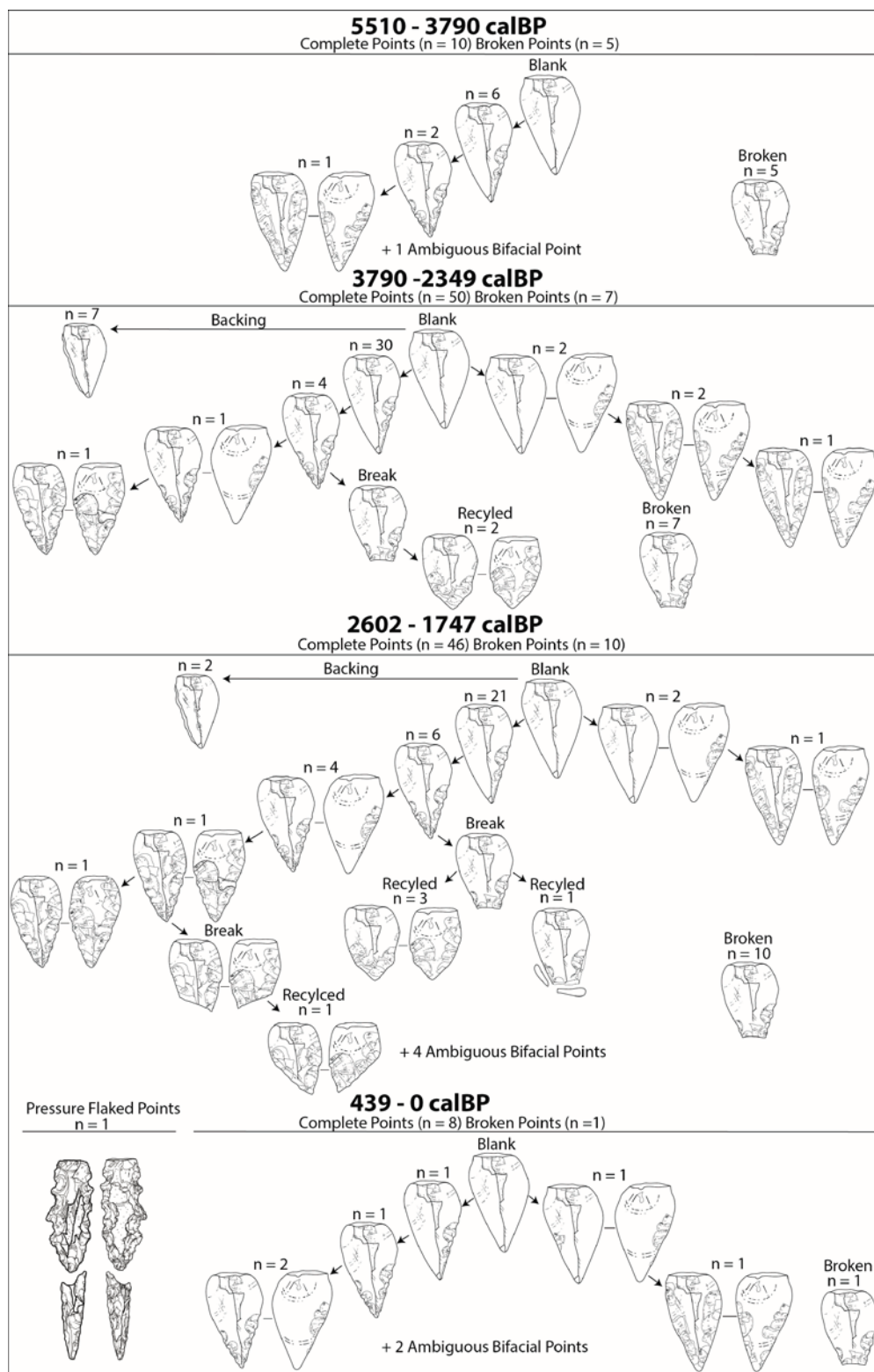


Figure 13. Summary of changing point retouch strategies and reduction intensity. The stratigraphic units with associated time periods are used to illustrate technological change through time.

Discussion: Explanations for mid Holocene changes in lithic technology in Australia

The analyses presented here demonstrate that point reduction sequences in the Kimberley region have parallels with those from parts of the Northern Territory and northern Queensland. An underlying reduction continuum for unifacial and bifacial points during the mid to late Holocene is now demonstrated across the north. Within this reduction continuum regional patterns are now emerging. For example, in the Wardaman assemblages, Clarkson (2007) found that points typically begin being retouched on the dorsal face first, with an initial focus on the distal right margin (2007:104, 109). As retouch intensity increases, the distribution of retouch is increasingly likely to become bifacial, with the first stages of bifacial retouch typically added to proximal portions of points (2007:104, 109). This retouch pattern is not dissimilar to that demonstrated in the Jimede 2 and Lawn Hill assemblages by Hiscock (1994a:77-80, 2006, 2009:84, 2011:78). However, proximal thinning of the Jimede 2 points was not found to relate to increasing retouch intensity, or the curvature of the point butt (Hiscock 2009:77). Maloney (2010) showed that points from Frances Creek in the Northern Territory followed a similar retouch pattern to these regional trends (2010:91-97). Regional differences in point life history include methods of recycling. In Wardaman Country, recycling took the form of burinate retouch following transverse snaps, and rejuvenation of pointed morphologies, while those from Jimede 2 were heavily reduced into bifacial forms that totally lack the pointed shape (Hiscock 2009:84-85, Fig. 6.3). Instances of burinate recycling following transverse snaps were also reported by Dortch and Zlatnik (nd:44) in the upper units of Miriwun rock shelter in the Kimberley. On current evidence it appears that the heavily reduced bifacial forms reported by Hiscock (2009:84-85), may be restricted to Arnhem Land and as far west as Frances Creek (Maloney 2010), although are apparently absent in the Victoria River district and the Kimberley.

The following discussion concerns the role of point technology and its appearance in the Kimberley during the mid Holocene to late Holocene. The major explanations for the underlying causes of point technology are now assessed with referenced to the Mt Behn data.

Owing to the pointed distal end and elongation of many point morphologies, as well as ethnographic observation of some stone points in hunting, researchers in Australia have largely assumed points were primarily made for use as hafted projectiles (Allen & Akerman 2015; Banning 2002:155; Davidson 1935:150; Holdaway & Stern 2004:266; Kamminga 1982:81; McCarthy 1967:40; Mulvaney & Kamminga 1999:237). An alternative interpretation sees points as adaptable, multifunctional tools, including, but not limited to, hafted projectiles (Hiscock 1994a:78; 1994b:277-278, 286; 2006:78). The only residue analysis so far conducted on points from the Kimberley indicates their use for working plant materials (Wallis & O'Connor 1998). There is also some ethnographic support for the use of

points in resin hafts as hand held tools (Akerman 2007; Blundell 1975:383). Thus we suggest that points were adaptable tools most likely used in a variety of tasks. This multipurpose nature of points is supported by the morphological diversity found in the Mt Behn assemblage.

External diffusion models

Early researchers suggested that points, along with the backed artefacts found elsewhere in Australia, formed a package of introduced technology, via a diffusion of ideas or technological transfer, noting the coincidence in the timing of their initial appearance with the arrival of the dingo in Australia (e.g. Bowdler & O'Connor 1991; Dortch 1977:123; Olsen & Glover 2004). This view has largely fallen out of favour in recent years (although see Bellwood 2013:116, 199 for a recent revival). There is also poor temporal correlation for the appearance of backed artefacts and points across Australia, since small numbers of backed artefacts have been reported in early Holocene and late Pleistocene contexts in south east (Hiscock & Attenbrow 2004) and north east Australia (Slack et al. 2004:135-136), strongly supporting *in situ* development. Furthermore, the recognition of gradual change in artefact assemblages prior to the advent of points in the Northern Territory (Clarkson & David 1995) and the Kimberley (O'Connor et al. 2014:17) provide supporting evidence that point technology was an internally generated innovation.

Environmental change and risk minimisation models

Currently, the most discussed explanation for the development of point technology is the risk minimisation model. This model has been advanced in the Northern Territory and northern Queensland, where points appear to be a technological response to increased foraging risk brought on by environmental change (Hiscock 1994a, 1994b, 2002, 2006, 2009, 2011; Clarkson 2006, 2007, 2008). Foraging risk is the probability and severity of failure to gain resources (Bamforth & Bleed 1997:112-113; Torrence 1983; 1989:59). Mobile foragers are theoretically better equipped to offset this risk when using highly transportable, adaptable, and standardised technologies. The extension of point use life could offset foraging risk by increasing the likelihood that foragers would have an adaptable and ready tool kit to exploit a range of resources as they were encountered, rather than having to reschedule activities to source raw material (Veth et al. 2011:12). Standardisation has also been argued to provide an additional benefit, by increasing reliability, particularly in hafting (Clarkson 2007:150, 155, 160; Hiscock 1994b:278). The cost of this standardization, has been suggested to be recouped by the advantages gained by extending implement use life (Clarkson 2008:302). By initiating change in lithic technology, to make more adaptable, maintainable and standardised tools with a longer use life, hunter-gatherers are argued to have offset foraging risk in the mid to late Holocene (Hiscock 1994a; Veth et al. 2011).

Change in the frequency and intensity of ENSO has been argued as underpinning environmental stresses on Indigenous populations (Williams et al. 2010) and this, in turn, has been central to technological change models. For example, Clarkson's (2007:130-142) model of technological change throughout the Holocene suggests that records of climate variation associated with ENSO, are temporally correlated with changes in stone artefact reduction. He argues that resource pressures increased from around 5000 BP, peaked in severity between 3000 and 1500 BP and declined within the last 1000 years. During times of resource pressure when people are thought to have been highly mobile, access to replacement raw materials was limited and so the observed levels of high reduction intensity reflect attempts at extending artefact use life (Clarkson 2008:302). Environmental change as a driver for technological change was also advocated by Hiscock (1994a:280; 1994b:273) to explain much of the technological change observed in Holocene Australia, including the efflorescence of points. This model can be seen as equally applicable to the southern Kimberley region and tracks well with the climate evidence for this region.

McGowan et al. (2012) have recently presented proxy climate data extrapolated from pollen records at Black Springs in the northwest Kimberley. These authors argue that the Kimberley region underwent rapid environmental change beginning about 6000 years ago, after which it begins to transition from a tropical humid climate with an intense and predictable summer monsoon, to a much drier climate where the summer monsoon was absent or intermittent (2012:3). Black Spring became a dry swamp environment 5750 years ago. Evidence for slight climate amelioration and a switch back to a more active monsoon was detected between 4600 and 4200 years BP, but was followed by increasingly dry conditions between 3200 and 2700 and then extreme aridity between 2400 and 1300 years ago (McGowan et al. 2012:2-4). It was only after this that modern summer monsoon systems were established. This general pattern of Holocene climatic variability is also documented in oxygen isotope records in stalagmites from cave KNI-51 in the Ningbing Range about 550 km to the north east of the study area (Denniston et al. 2013). These records indicate Indonesian Australian Summer Monsoon (IASM) strengthening in the early to mid-Holocene, with increased rainfall. This IASM strengthening was followed by a significant decrease in monsoon strength beginning about 4000 years ago, with peak aridity occurring between 1500 and 1200 years ago. The last millennium saw a return to wetter conditions, albeit with small-scale variability (Denniston et al. 2013). A recent pollen core to the north of Mt Behn in the Mitchell Falls area also provides support for these climate reconstructions, although it indicates that the current monsoon pattern was not established until later, about 500 years ago (Haberle pers. comm.).

It is conceivable that climate variability or stochasticity of climate, coupled with increasing aridity, led to increases in mobility, which in turn favoured equipping with more adaptable tools whose use life could be extended by retouch. This variability of climate likely made

resource distribution less predictable for foragers. If, as Hiscock (1994b:278) suggests, points were a favourable technological innovation for people foraging in less familiar environments and with smaller mobile groups, then both the timing and change in reduction at Mt Behn shows correlation with environmental change. The production of standardised point forms, where use life could be extended, reduces the frequency of encountering foraging situations when technology was not ready or suitable.

The Mt Behn data provide evidence of a shift in technological organisation from around 5400 calBP with the initial appearance of points. This innovation is followed by an increase in point production as a component of the overall assemblage coupled with an increase in retouch intensity. The increase in point production, retouch intensity and use life extension at Mt Behn, coincides closely with increased aridity as modelled by McGowan et al. (2012), Denniston et al. (2013) and Haberle (pers. comm.). The time period between 2602 to 1747 calBP at Mt Behn, has the greatest technological diversity and number of points per thousand years. Attempts at extending point use life are also more prevalent during this period, as indicated by the recycling of points and the shift in point retouch strategy towards mostly ventral last retouch orders, which suggests an emphasis on gradual point reduction and maintainability. The other retouched flakes were also at their highest discard levels during this period, although retouch intensity on these technologies had declined. This decline probably represents an emphasis on extending the use life of points, a more standardised tool, and comparatively less technological investment into the other retouched flakes. The period identified by McGowan et al. (2012:4) as particularly arid, between 2400 and 1300 calBP, shows a striking temporal correlation with the artefact changes observed between 2602 and 1747 calBP at Mt Behn. After 1000 BP, points continued to be produced but with a reduced effort to extend use life. The production of elaborate pressure flaked bifaces begins during this phase. Maloney et al. (2014) have demonstrated a wide regional pattern for the adoption of these pressure flaked bifaces within the last 1000 years. Akerman and Bindon (1995:94-98) suggest that the 'fragility' of the more elaborate pressure flaked points, such as Dentate Kimberley Points, indicate trade and exchange as their primary function. The return to wetter conditions in the last millennium is inversely correlated with both retouch intensity and diversity of point retouch strategies. Thus it would seem logical that these specialised point forms developed when the need for maintainable and adaptable tools diminished, and a more socially valuable item emerged.

Points provided people with a standardised technology that could be used in a multitude of tasks with a long use life. The continual maintenance of point morphology meant that people could be equipped with a ready tool kit during foraging activities. Points being maintainable and adaptable, also allow for their use life to be extended when replacement material was not available, such as forays away from the Mt Behn area. The effort to

gradually modify points and recycle broken ones implies that use life extension was an important part of this lithic technology. As has been suggested elsewhere (Clarkson 2008:302), the cost of standardisation was probably recouped by this use life extension. In these ways points can be seen as contributing to a risk reduction strategy by a mobile population.

The general correlation between environmental change and technological change appears wide spread in northern Australia and well supported by the Mt Behn data, but it is not without opponents.

Population change and social signalling models

While, risk reduction models have never discounted social drivers of change (Clarkson 2007:167; 2008:311-312; Hiscock 1994b:277, 2002:169, 2006:86-87, 2008:160; Kuhn 2012:76), other researchers have advocated social factors as providing a more potent underlying cause for the appearance of points. At a broad level, population size has been shown to be strongly correlated with technological innovation (Shennan 2001:15), suggesting that increases in population precede periods of rapid technological evolution (Henrich 2004:209). Moore (2011) has suggested that population levels may be the primary factor driving change in lithic technology in Australia, where larger populations led to altered land use strategies. Cultural groups are argued to have responded by developing more elaborate information systems, including points, as symbolic items to enhance intergroup identity (Moore 2011:145; see also White 2011:68-69). If radiocarbon dates are accepted as a proxy for population density, a concept not free of critics (Attenbrow & Hiscock 2015), populations in Australia, overall appear to have increased from approximately 12000 BP, with peaks in the late Holocene (Williams 2013; Williams et al. 2015:6, Table 1; Smith et al. 2008). Williams et al. (2015) suggest that demographic data could support the risk minimisation model, where greater investment into technology was likely used to improve subsistence, but they also argue that mobility did not increase during this period. Instead, they suggest populations began expanding around 2000 BP, following declining ENSO frequency. This population increase is argued to be the result of internal 'social, demographic and economic conditions, rather than environmental conditions' (Williams et al. 2015:11).

The population data presented by Williams et al. (2015:6, Table 1) does not show a compelling correlation between the known development of point technology around 5400 BP and notable change in the modelled population density. Furthermore, point technology developed following a period of apparent population decline at approximately 5500 calBP, according to Williams (2013:5), and also proliferated during a period of population decline

between 2600 and 2200 calBP (2013:5). This trend is the opposite of that expected if increasing populations encouraged social signalling via stone point technology.

What makes the risk minimisation model compelling is the consistent temporal correlation between proxy records for the onset of aridity across the north, and similar patterns of technological change. The point assemblage documented here is part of a reduction sequence where the morphology was prone to drastic change with maintenance. It is difficult to attribute signalling to these artefacts which occur over much of northern Australia at about the same time and show a high degree of inter assemblage variability. If signalling rather than maintainability and use life extension was a major influence on the development of point technology in the mid Holocene, why did people produce such a diversity of point morphologies? The benefits of carrying a few highly adaptable points for a mobile population, is more easily reconciled with the evidence than social signalling.

There is a stronger case for population increase influencing technological change within the last millennium. For example, Moore (2015) argues that pressure flaked bifaces best reflect social signalling, because their manufacture requires great technical skill and that manufacturing knowledge was held exclusively by initiated men of high rank. These bifaces served simultaneously to reinforce clan solidarity and to signal difference between groups that produced and traded these valued items and those that received them (Moore 2015). As these bifaces appear to develop around 1000 calBP (Maloney et al. 2014), in this case it can be reasonably argued that increasing population resulted in technological innovation and that pressure flaked bifaces, crucially lack the emphasis on extendibility found in earlier points.

Conclusion

The above discussion has demonstrated that contrary to the arguments advanced by earlier researchers, the unifacial and bifacial points that appear in the mid Holocene in the Kimberley are produced and discarded within a reduction continuum. We have also suggested that the risk reduction explanation of point technologies better explains the introduction of points in the Kimberley from about 5400 years ago than social signalling, which seems more likely to be linked to the development of the elaborate pressure flaked bifaces within the last 1000 years. We do not discount that points, particularly if considered as part of a composite technology, would have operated within a broader system of communication between groups and individuals. However, the way in which this may have involved non-pressure flaked forms of point technology is not currently clear. Perhaps standardisation of point form provided an exchange commodity between social groups

The search for an overall explanation of Holocene technological change should logically evaluate potential ecological and social drivers of change, as we have done, to better weigh

the evidence against explanatory models. It is hoped that in the future local and regional scale environmental records will provide resolution on the timing and severity of aridity in the mid to late Holocene and the return of monsoon strengthening in the last millennium, and enable possible correlations with technological change to be tested and refined.

Finally, it is worth stressing that contrary to the views expressed in McGowan et al. (2012:1), the Mt Behn data give no indication that Aboriginal cultures in the Kimberley ‘experienced catastrophic upheaval due to rapid natural climate variability’. In this paper the authors assert that as a result of the severity of mid to late Holocene aridity Indigenous populations in the Kimberley actually ‘collapsed’. They make this pronouncement without reference to any of the regional archaeological sequences, but rather on the basis of some widely contested dates for Kimberley rock art styles. McGowan et al. (2012) argue that population collapse is demonstrated by a hiatus between the production of Gwion Gwion-style paintings, to which they assign a *terminus ante quem* age of between 7000 to 5000 years, and the beginning of the Wanjina art phase, which they suggest commenced 3800 years ago. This hiatus is put down to the ‘demise of the Gwion artists’ (McGowan et al. 2012:4). In the Mt Behn site over 50000 stone artefacts were recovered from a 2 x 2 m test pit with a chronology spanning the last 5400 years. While this is not the place to discuss the veracity of the dates for these painting styles or problems with the reasoning underlying this proposition, we think it is important to point out that Mt Behn and the many other archaeological sites in the Kimberley demonstrate that Indigenous cultures persisted and flourished throughout the mid to late Holocene regardless of increasing aridity. The Mt Behn site provides an example of how technology was adapted to meet these changing conditions.

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Chapter 5

Backed points in the Kimberley: Revisiting the north-south division for backed artefact production in Australia. *Australian Archaeology*, 79:146-155.

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Tim Maloney



Formulation of arguments in manuscript. Excavation of Widgingarri Shelters and original analysis of the point assemblages from these sites. Responsible for writing minor sections of the paper. Australian Research Council Linkage Grant (LP100200415) CI.

Signed:

Professor Sue O'Connor



Backed points in the Kimberley:

Revisiting the north-south division for backed artefact production in Australia

Tim Maloney and Sue O'Connor

Department of Archaeology and Natural History, College of Asia and the Pacific, The Australian National University, Canberra ACT 0200, Australia <tim.maloney@anu.edu.au> <sue.oconnor@anu.edu.au>

Abstract

Dortch (1977:117) first identified the 'Kimberley backed point' from the east Kimberley as an asymmetrical point form with steep-angled backing retouch along one dorsal margin. O'Connor (1999) subsequently recorded backed points as a component of the mid- to late Holocene assemblages in sites from the coastal west Kimberley. However, the distribution and morphology of backed point technology, and the relationship of backed points to other forms of point technology, has not been assessed for the broader Kimberley region. Here we use morphological analysis and measures of retouch intensity to examine the differences between backed points and other forms of point technology. We use three assemblages from the south Kimberley and reassess two assemblages from the west Kimberley, and argue that backed points are a discrete and specialised reduction trajectory of point technology which were produced throughout the Kimberley region. Although produced from the same pool of flake blanks as other point forms, the backed variant focused on the production of a maintainable blunted margin with a steep-angled retouched edge of between 75 and 90°.

Introduction

Backed artefacts have been central to academic discussions of Australian artefact assemblages for close to a century (see Hiscock 2014). These kinds of artefacts occur widely across the central and southern portions of the continent and include a variety of symmetrical and asymmetrical forms. These have been variously described as backed microliths, backed blades, geometric microliths, Bondi points and eloueras, and, although morphologically variable, they share a common feature: backing retouch.

Although backed artefacts were reported from the Kimberley as early as 1977 (Dortch 1977), little attention has been given to these artefacts as part of the broader spectrum of point forms in the Kimberley, or to the relationships between the Kimberley backed artefacts and those from elsewhere in Australia. For example, a backed flake/blade variant, the elouera, has been reported from the Oenpelli region of the Northern Territory (NT) (Kamminga 1977:208–211; Schrire 1982:40). Schrire (1982:40) suggested that these artefacts, which she termed 'Oenpelli polished flakes', were a functional group resembling the Currarong elouera identified by Lampert (1977:48) from the Illawarra region of eastern Australia. Like the Kimberley backed points, many of the NT backed artefacts have steep-angled retouched margins and irregular morphology, and are argued to have been hafted adzes employed in the working of plant material (Kamminga 1977:208–211; see also Akerman 1998).

Despite the early recognition of backed artefact forms in the Kimberley and NT there has long been debate about whether there was a northern boundary beyond which backing technology was absent from the lithic repertoire and, if so, where this boundary lay (e.g. Flood 1995:222,

Figure 15.1; Hiscock 2001:56–58, 2014; Hiscock and Hughes 1980; Mulvaney 1969:123, 1985; Pearce 1974:301–302; Smith and Cundy 1985). A better understanding of Kimberley backed tools is essential for understanding the spatial variation in lithic technologies across Australia and for assessing the reality of a north-south division for backing technology. Here we assess 11 complete and four partial backed points from five assemblages in the south and west Kimberley on technological and morphological grounds to determine if they can be classed as backed artefacts.

Kimberley Backed Points: The Historical Context

The Kimberley backed point was originally identified by Dortch (1977:117) following the salvage excavation of sites in the Ord River catchment prior to their flooding for the Ord Dam. The excavation of Miriwun and Monsmont rockshelters (Figure 1) established a temporal framework for the appearance of point technology in the east Kimberley. At the time, these sites also provided the first records of new technologies in the Holocene archaeological record of the region. Dortch (1977) argued that the appearance of points represented a major technological change which occurred around the mid-Holocene, and related this to the mid- to late Holocene appearance of the 'Australian Small Tool Tradition' in southern Australia. The Ord assemblages contained a range of point forms (Dortch 1977), and the backed points were a distinctive but proportionally small component of the overall assemblages. Backed points were noted as respectively representing 2.3% and 3.7% of the formal tool types identified from the surface and sub-surface contexts at Miriwun (Dortch 1977:121, Table 4). No quantitative data was presented for the other Ord sites.

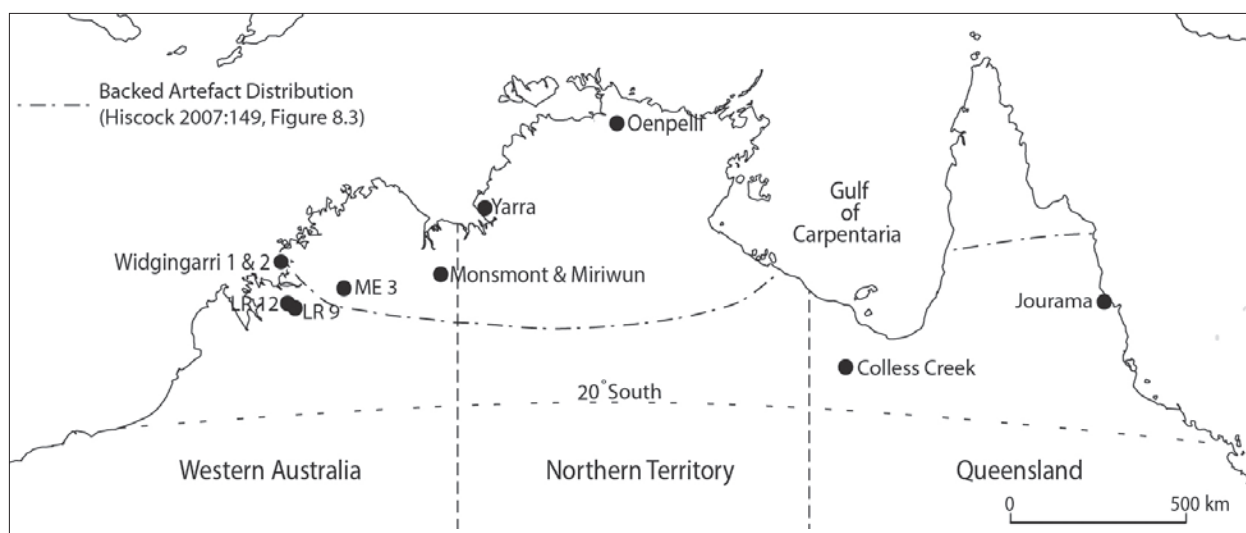


Figure 1 Northern Australia showing sites mentioned in text and backed artefact distribution line (after Hiscock 2007:148, Figure 8.3).

Dortch (1977:117) described the morphology of the east Kimberley backed points as larger, thicker and broader than those known from eastern and southern Australia. Their retouched margins were produced with direct percussion, with no observation of bipolar anvil-rested retouch. Furthermore, the backing retouch was described as 'generally semi-abrupt instead of abrupt' and, unlike many eastern Australian backed artefacts, did not appear to expand around proximal margins and remove or truncate the platform or 'butt' (Dortch 1977:117). Despite these contrasts, several illustrated specimens were noted as being morphologically similar to geometric microliths and Bondi points (Dortch 1977:116, Figures 5.6, 5.12 and 5.13). A single specimen was described with the platform surface truncated by backing retouch (Dortch 1977:116, Figure 5.13). Additional technological observations made by Dortch (1977:117) included crushing along the proximal edge of backed surfaces, which led him to suggest that the Kimberley backed points were likely used in adzing activities.

O'Connor (1999) subsequently identified a range of point forms, including marginally retouched, bifacial and unifacial points, as well as four complete and three fragments of backed points at Widgingarri Shelters 1 and 2 in the coastal west Kimberley. Backing retouch on these artefacts was argued to have been produced with bipolar anvil-rested percussion (O'Connor 1999:72, 73, Figure 5.13[3]) on the four complete specimens, described by O'Connor (1999:72) as 'double backing'. The retouched margins were otherwise primarily unidirectional, with scars initiated from the ventral surface. The retouch edge angle was abrupt; between 80–90°, with the maximum retouch scar height approaching the maximum flake thickness (see O'Connor 1999:69, Table 5.13); this is evidenced by the illustrated cross-sections (O'Connor 1999:73, Figure 5.13 and 74, Figure 5.14). On one specimen, retouch expanded around the perimeter and truncated the platform surface (O'Connor 1999:74, Figure 5.14[3]). No evidence suggested that these backed points were made on relatively thicker flakes than the other point technologies in the assemblages (O'Connor 1999:72). Importantly, O'Connor argued that the backed points were not the discard stage of other point technologies but rather a discrete form of point produced for a distinct purpose. Although O'Connor (1999) did not comment specifically

on the function of these artefacts, residue analysis on the Widgingarri points indicated that the majority were used for processing plant materials (Wallis and O'Connor 1998). The four backed points were no exception and were all found to contain visual residues of starch, whilst three were observed with cellulose residues and one with ochre (Wallis and O'Connor 1998:160, Table 2).

Both Dortch's (1977:117) and O'Connor's (1999:72) observations of backed points suggested they occurred in low frequencies, could generally be described as morphologically larger than the asymmetrical and symmetrical forms in central, eastern and southern Australia, and were consistently associated with a range of other unifacial and bifacial point technologies. Neither researcher discussed the relationship of the Kimberley forms with NT eloueras.

Hiscock and Hughes (1980:93) included Dortch's (1977:177) observation of the Kimberley backed points in their reassessment of the spatial distribution of backed artefacts in Australia. They noted that 'on morphological criteria we have little doubt that a number of the artefacts illustrated by Dortch (1977:116, Figures 5.6–5.13) are technically 'backed blades' (Hiscock and Hughes 1980:93). They also drew on evidence for steep-angled retouch observed on points recovered from Flood's excavation of Yarra shelter in the NT (see Flood 1970:47, Figures 6B and 6C), and a single point from the excavation of the Jourama site in northeast Queensland (Qld) (Brayshaw 1977:281). They concluded that if all these artefacts, as well as the backed artefacts from Colless Creek in northern Qld (Hiscock and Hughes 1980), were accepted as 'backed blades', it would 'drastically alter the concept of an abrupt northern boundary in the distribution of backed blades' (Hiscock and Hughes 1980:93).

Smith and Cundy (1985:35) argued that a northern limit could be applied to the distribution of backing in Australia, with Kimberley backed points interpreted as remote from the other forms of backing technology. Owing to the lack of 'blunting' retouch and the high morphological variability of the backed points in the east Kimberley in Dortch's (1977) data, Smith and Cundy suggested that backed points were best described as a 'variety of asymmetrical point with steep retouch' (1985:35). A similar view had been expressed by White and O'Connell (1982:113), who suggested that backed points were 'probably varieties of abruptly trimmed points'.

Subsequently, Hiscock (2001) pointed out that the distribution model for backed artefacts proposed by Smith and Cundy (1985) was flawed, as it was based on small sample sizes. The sample to the north of the line demarcating the boundary of backing technology included a mere 92 artefacts, and was thus unlikely to include rare artefact forms such as backed artefacts (Hiscock 2001:57). There can now be little doubt that the backed points illustrated by O'Connor (1999) do have blunting retouch produced with bipolar anvil-rested percussion. Three complete backed points from the Widgingarri excavations are illustrated in Figure 2, where the cross-sectional shape is shown at multiple points and the backed margin is shown with bidirectional retouch scars and marginal step terminations.

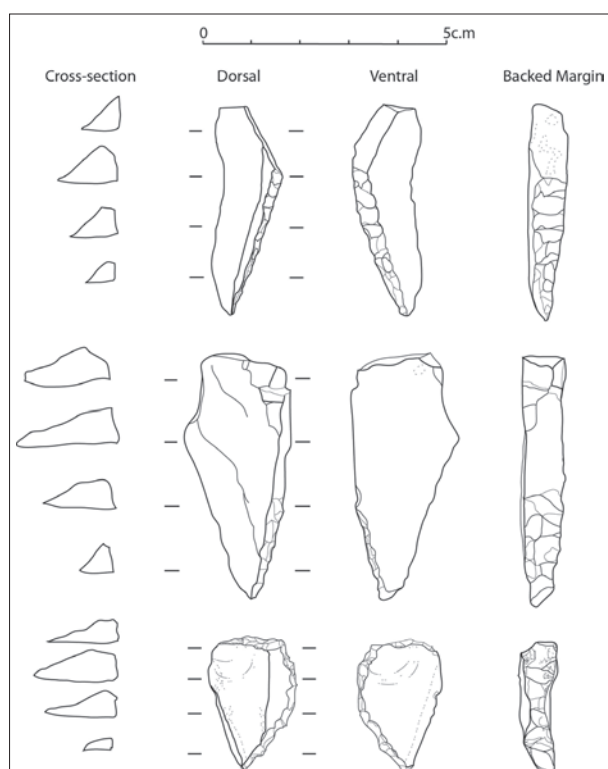


Figure 2 Three complete backed points from Widgingarri Shelters 1 and 2 (modified from O'Connor 1999).

The South and West Kimberley Samples

To assess the divergence of the northern backed point technology, two assemblages from the Napier Ranges in the south Kimberley, and one from the Mount Elizabeth region in the southeast Kimberley, were analysed, and the point assemblages from the Widgingarri 1 and 2 excavations in the west Kimberley were re-analysed. The locations of these sites are shown in Figure 1. Three of the assemblages, Lennard River 12 (LR12), Lennard River 9 (LR9) and Mount Elizabeth 3 (ME3), were collected and excavated by Blundell (1975:218–221, 232–236). Blundell collected the total surface assemblage from all three rockshelters and excavated in the two Lennard River rockshelters. Although she noted that both excavated and surface collections were 'screened', she did not elaborate on this methodology nor the screen size (Blundell 1975:227). The Widgingarri Shelter 1 and 2 assemblages were derived solely from excavation. O'Connor (1999:53–54) excavated five adjoining 1 x 1 m squares in Shelter 1 and a 2 x 1 m pit in Shelter 2; all excavated material was screened through nested 6 and 3 mm sieves.

The Blundell collections were subsampled for this analysis. Our sample from LR12 included all artefacts from the 1 x 1 m excavation, as well as all retouched flakes from the floor of the cave (an area of approximately 110 square metres). A single backed point was identified in this sample, representing <1% of the assemblage. Our LR9 sample included all of the material from a single 1 x 1 m test pit (of the three Blundell excavated). From her LR9 surface assemblage we analysed all artefacts from a 2 x 2 m area, as well as all retouched artefacts from the remaining surface assemblage (approximately 72 square metres in total area) (Blundell 1975:218–221). Four backed points were recovered from this sample, representing <1% of the assemblage. The ME3 assemblage is a surface collection from a small sandstone rockshelter to the north of the Napier Range sites on Mt Elizabeth Station (Blundell 1975:198). No excavations were conducted at this shelter. Our sample from ME3 comprised the entire surface collection assemblage. Blundell provides no information about the size of the area collected at this shelter. Two complete and one broken backed point were recovered from this collection. Point technology dominates the formal tools represented in these assemblages and includes a range of marginally retouched and invasively flaked direct percussion points, as well as pressure flaked points, such as Kimberley points and dentate Kimberley points (after Akerman and Bindon 1995). The backed points in each sample represent <2% of all the retouched flakes. Other lithic artefacts found include flakes, cores, burren retouched flakes, edge ground adzes and axes, portable grindstones and large blades (leilira). Amorphous retouched flakes are found in every sample and lack backing retouch. The technological classes observed in the analysed assemblages are listed in Table 1. A total of 11 complete and four broken backed points were identified in the assemblages from the five sites.

Methodology

Here we test the proposition that Kimberly backed points were a discrete and specialised reduction trajectory of point technology. We argue that if Kimberley backed points were a real technological divergence from other point reduction trajectories, representing a deliberate attempt to create and maintain a steep retouched edge angle, then several phenomena can be predicted and empirically tested.

Firstly, if backed points are made on different flake or blank morphologies than other points, then it would suggest technological divergence in the earliest stages of artefact use life. Hiscock (2006:79) argued that backing technology in Australia may have been assisted by the production of standardised blanks; however, it did not depend on this strategy. He suggested they 'were made on any flake with an appropriate cross-section and one straight or gently undulating margin of sufficient length' (Hiscock 2006:78).

Secondly, backed points could equally diverge from other point technologies during their manufacture and use life. For example, if backed points were simply a discard stage in a reduction continuum of laterally retouched or bifacial points and the 'backed margin' was a result of a gradual build up of unwanted steep angle scars, the backed margin would logically occur in the later or discard stage of point reduction and the backed point would display retouch on the dorsal or ventral face of the margin opposed to the backed margin.

To test these propositions, quantitative and qualitative variables were recorded for retouched artefacts in each

Assemblage	LR12		LR9		ME3		Widgingarri 1 and 2 (Formal Tools)	
Technological Class	n	% of Sample	n	% of Sample	n	% of Sample	n	% of Sample
Flakes	285	40.42	529	34.15	33	23.50	0	0
Retouched Flakes	39	5.53	43	2.80	3	2.12	0	0
Blades	29	4.10	39	2.51	17	12.10	0	0
Unifacial Points	26	3.68	42	2.71	13	9.21	27	64.28
Backed Points	1	0.15	4	0.25	2	1.41	4	9.72
Broken Backed Points	0	0	0	0	1	0.70	3	7.14
Bifacial Points	28	3.97	25	1.62	10	7.10	7	16.66
Pressure Flaked Points	1	0.15	1	0.06	3	2.12	0	0
Bifacial Preforms	10	1.41	1	0.06	14	9.92	0	0
Tulas	0	0	0	0	0	0	1	2.38
Cores	5	0.70	19	1.25	14	9.92	0	0
Bipolar Flakes	5	0.70	3	0.18	1	0.70	0	0
Edge Ground Flakes	7	0.99	11	0.71	0	0	0	0
Burrens	1	0.15	3	0.18	0	0	0	0
Hammerstones	7	0.99	2	0.14	0	0	0	0
Broken Flakes	95	13.47	291	18.80	6	4.25	0	0
Broken Retouched Flakes	12	1.70	26	1.68	9	6.39	0	0
Pot Lid / Heat Shatter	1	0.15	3	0.18	0	0	0	0
Broken Points	35	4.96	40	2.60	7	4.97	0	0
Broken Pressure Flaked Points	2	0.28	1	0.06	1	0.70	0	0
Flaked Pieces	115	16.35	465	30.00	7	4.97	0	0
Grindstone Fragments	1	0.15	1	0.06	0	0	0	0
Total	705	100	1549	100	141	100	42	100

Table 1 Technological classes observed in the analysed assemblages.

assemblage. Blank selection, edge angles, cross-section shape, retouch intensity and retouch characteristics, as well as morphological variation, were assessed, because they directly relate to different aspects of the reduction sequence and allow the identification of any technological divergence present within the assemblages.

Two types of statistical tests were calculated using SPSS. The first, analysis of variance (ANOVA), provided regression analysis and one way analysis of variance for one dependent variable by one or more factors or variables (Hiscock and Attenbrow 2005a:37). This test was used for comparisons of retouch intensity, edge angles and other metric measurements of artefact morphologies. The data analysed were deemed to be appropriate for ANOVA tests due to the normality or symmetry in each sample as gauged by graphical representation and normal quantile-quantile plots. The second test, linear regression analysis, is an evaluation of the strength of covariation between two variables. Linear regression was used for comparison of retouch intensity and edge angle, which have been shown to be in positive correlation (Hiscock and Attenbrow 2005b:51); however, we were interested in testing the strength of this correlation in the early stages of point use life.

Blank Selection

Determining the blank flakes selected for retouching reveals both the level and importance of standardisation. We were interested primarily in determining the blank morphology

of backed points and determining whether a unique morphology was being selected or whether backed points were made from the same pool of flakes as other types of points in the assemblage.

The remaining platform surface presents a viable link to the unmodified size of all discarded retouched artefacts. Provided the platform is intact and not truncated by retouch, this surface area measurement can be used to obtain a proxy for the size of the original blank. The recent application of 3D laser scanning has improved the accuracy of platform surface area measurements (Clarkson and Hiscock 2011). Platform area was here measured with a Next Engine 3D laser scanner and converted to mm² (see Shott and Trail 2012 for a methodological description of 3D laser scanning for lithic artefacts).

Additionally, to identify the early stages of use life prior to extensive modification, only the platform area of points with Index of Invasiveness values less than 0.3 were selected in each assemblage. Clarkson (2007:109) used this methodology in an analysis of blank selection on point assemblages from the NT. Clarkson (2007:38, 108, Figure 6.17) further used graphical techniques to illustrate the early stages of point reduction against the larger sample of variation in all other flakes.

Edge Angles and Cross-Section Shape

Two edge angle calculations were made for each complete retouched artefact. Edge angles were measured using a

goniometer in degrees (see Dibble and Bennard 1980:858–859). This device cannot realistically measure the nonlinear retouched margins of artefacts to any greater precision than 5°, hence, mean values were calculated for both retouched edges and non-retouched edges. The average edge angle was taken at six points along the margins of complete artefacts, regardless of retouch. The average retouched edge angle was taken at multiple points along only the retouched margins.

The cross-section shape was quantified by width to thickness ratios that were calculated at three points on each complete artefact's percussion length. Caliper measurements of width at the midpoint, proximal quartile and distal quartile of percussion length, were divided by the thickness at these points. Additionally, 3D laser scanned images were able to be manipulated to provide more precise cross-section shapes at four points along the percussion axis of backed points. Each 3D image was edited to retain only the cross-section shape at these points, which was then converted to line drawings. An example of this is given in Figure 3, where the cross-section shape was taken at four points along the percussion axis of a backed point from ME3. Qualitative observations were also recorded for each artefact as generally representing either plano-triangular, convex triangular, convex trapezoid or plano-trapezoidal cross-sections.

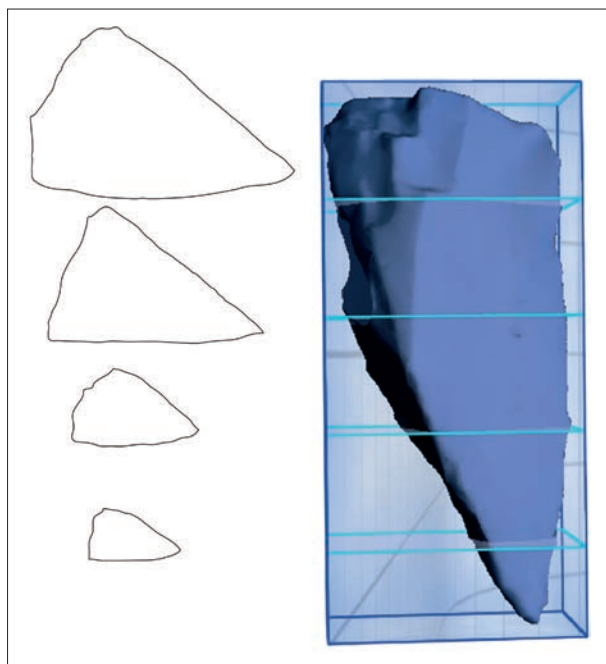


Figure 3 3D laser scanned image of backed point from ME3, illustrating multiple points along percussion axis where cross-section shapes were calculated.

Retouch Characteristics and Intensity

A range of definitions for backing are available. Andrefsky (2005:169) described backing simply as an intentionally dulled edge produced by retouch, abrasion or grinding, in preparation for hafting. Holdaway and Stern (2004:159, 259) stated that backing is 'abrupt unidirectional or bidirectional retouch, normally found on one lateral margin', most often initiated from the ventral surface. Hiscock stated that backed artefacts are 'flakes with near ninety degree retouch retouched along one or more margins that was often accomplished with the use of bipolar techniques on an anvil' (2006:78). Here, we follow Hiscock (2006:78) in defining

backing as steep angled retouch approaching 90°, which forms a blunted retouched margin which was likely produced by anvil-resting of the flake. Bipolar anvil-rested retouch was recognised by bidirectional scars with evidence of crushing, such as multiple small step terminating scars (see Cotterell and Kamminga 1987:689). We emphasise, however, that the observation of anvil-rested retouch is complicated by variability in flake morphology. Cross-section shape may prevent anvil contact. For example, Flenniken and White (1985:143–144) pointed out that there are three modes of anvil-rested retouch. The first occurs when the anvil is used to immobilise small flakes and prevents anvil contact on the surface opposite the fracture initiation. This form of backing results in steep angled unifacial scars only. The second mode of backing occurs when dorsal ridges or arises prevent the opposite surface from making anvil contact and results in one edge being backed and the opposite edge being rounded. In this instance, crushing on the dorsal ridges may provide some confirmation of anvil-resting (Hiscock and Attenbrow 2005:39). In the third mode (Flenniken and White 1985:143–144), anvil contact does occur and force is produced on the backed margin from both the mobile percussor and the stationary anvil (see also Cotterell and Kamminga 1987:689). Flenniken and White (1985:144) referred to the resultant margin as 'squared off'.

The order of retouch was recorded as ventrally initiated, with retouch scars propagating onto the dorsal surface, or, dorsally initiated, with retouch scars propagating onto the ventral surface. When retouch scars initiated from one surface impact existing scars initiated from the opposite surface, the latter surface was the last to be retouched. Using this premise, retouch order was recorded as either dorsal only, dorsal last, ventral only or ventral last.

As many of the points in the analysed assemblages have retouch on only one face, the Average Geometric Index of Unifacial Reduction (AGIUR) (Kuhn 1990; see Hiscock and Clarkson 2005a, 2005b, 2009) was employed to assess the retouch intensity of unifacially retouched points. The AGIUR calculates the relative difference between retouch scar height and retouched flake thickness using caliper measurements and averages these values across six zones.

The Index of Invasiveness (Clarkson 2002) calculates the intensity of retouch by estimating the frequency of retouch scars initiated from lateral margins and the extent that scars 'invade' or spread across the retouched flake surface. A retouched flake is conceptually divided into 16 segments, with eight on each of the dorsal and ventral surfaces. Each segment can receive a value of 0 (no retouch), 0.5 (marginal retouch scar/s are present but do not extend beyond a quarter of flake width at that point) or 1 (invasive retouch scar/s extend more than a quarter of flake width). These values are then tallied and divided by the total number of segments to give a value between 0 and 1.

Morphology

A range of quantitative measures was recorded with calipers to characterise the general shape of complete points, including percussion length, and multiple width and thickness calculations. These measurements were then used to calculate other indices, such as marginal angle (Clarkson 2007:38, 39, Figure 3.7), and length to thickness and width to thickness ratios.

Results

Blank Selection

Backed points were made on the same pool of blank flakes as the other direct percussion points. No specialised blank form was selected for backed point manufacture. The 3D laser scanned platform surface areas for the backed points are not significantly different to those for unifacial and bifacial points with intact platforms (Table 2). The fact that the morphology of early stage points and backed points is drawn from the same pool of flakes, with similar size and shape characteristics, is further evidence to support this. Figure 4 illustrates these phenomena, where the backed points from the LR9, LR12 and ME3 assemblage are shown to overlap with the other point morphologies from the assemblage. The blank flake morphology for backed points, and indeed all point morphologies, are typically those flakes with either parallel or contracting margins, with length to thickness ratios between 2 and 12.

Assemblage - ANOVA	df	f	p
LR9 (n = 71)	1	0.005	0.945
LR12 (n = 55)	1	0.245	0.630
ME3 (n = 25)	1	0.110	0.744
Widgingarri 1 and 2 (n = 16)	1	0.067	0.800

Table 2 ANOVA results: 3D scanned platform area measurements for points with Index of Invasiveness values below 0.3 against point type. Note: backed point platform surface area is not significantly different to other point morphologies.

Edge Angle and Cross-Sectional Shape

The retouched edge angle of backed points varied from 75–90°. Figures 5 and 6 contrast the average retouched edge angle of backed points with other point morphologies from the LR9 and Widgingarri assemblages, where backed point sample sizes allowed for meaningful graphical representation of these data. The retouched edge angle of backed points was found to be significantly different to other point morphologies in three of the analysed assemblages. ANOVA results are given in Table 3, though we caution that these results may be affected by the small sample size, despite determining that ANOVA tests were appropriate based on quantile-quantile plots. The average edge angle, which included the non-retouched margin, was not found to be significantly different in each sample. This indicates that margins of backed points were altered to such an extent that the high retouch angles were significantly different to the retouched margins of other points and were likely very similar in edge angle prior to this modification.

The cross-section shapes of backed points were either plano-triangular or slightly convex-triangular. Figure 7 shows the cross-section shape at four positions along the percussion axis of a backed point from ME3. Retouch edge angles are shown to be from 80–90° and retouch scar height approaches the maximum thickness of the flake. The backed retouch margin shows retouch scars initiated from the ventral surface and along the left dorsal margin, as well as several scars initiated from the opposite dorsal surface on the distal margin. The inset image of Figure 7 highlights these bidirectional scars on the left distal margin, with evidence of multiple smaller step terminating scars

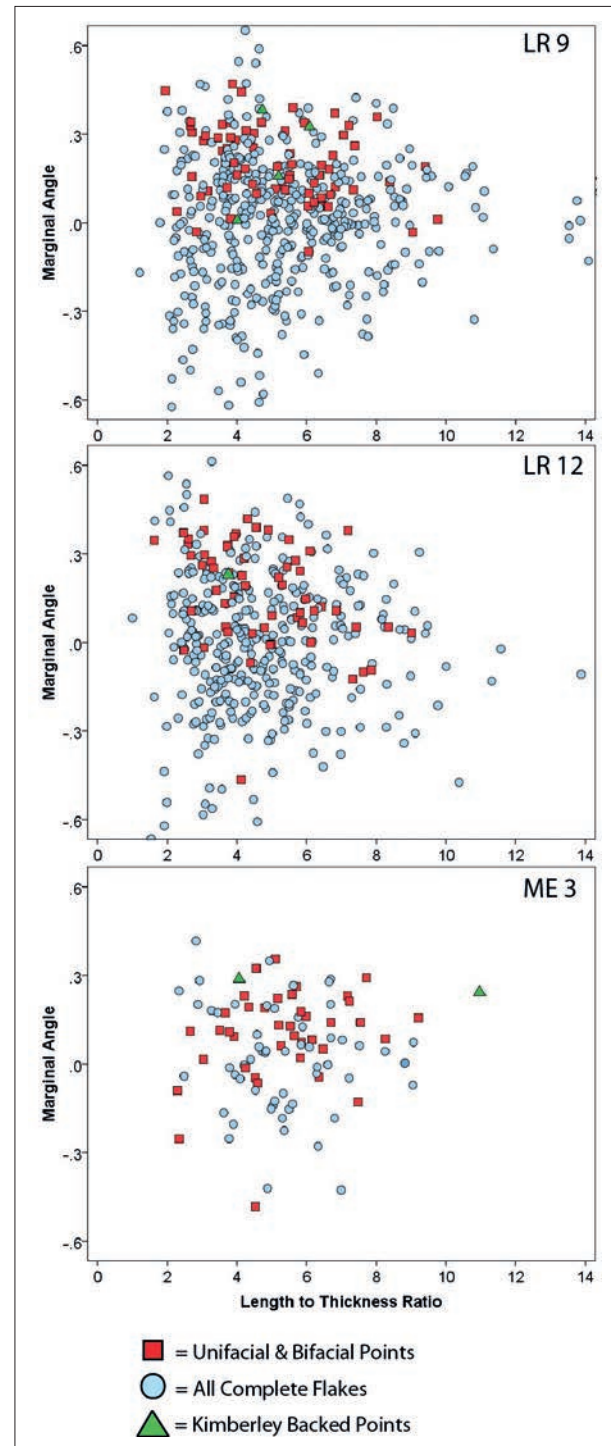


Figure 4 Scatter plots showing marginal angle against length to thickness ratio for LR9, LR12 and ME3 samples. Backed points were selected from the same pool of flakes, with similar size and shape characteristics. The blank flake morphology for backed points, and indeed all point morphologies, are typically those flakes with either parallel or contracting margins and with length to thickness ratios between 2 and 12.

or crushing. The superimposition of multiple scars on this anvil-rested margin suggests the morphology was likely maintained along the length of the retouched margin, rather than modified.

Width to thickness ratios also indicate that backing was highly unlikely to be a result of the gradual buildup of steep-angled retouch scars. As the width to thickness ratios were reduced with increasing unifacial retouch, the

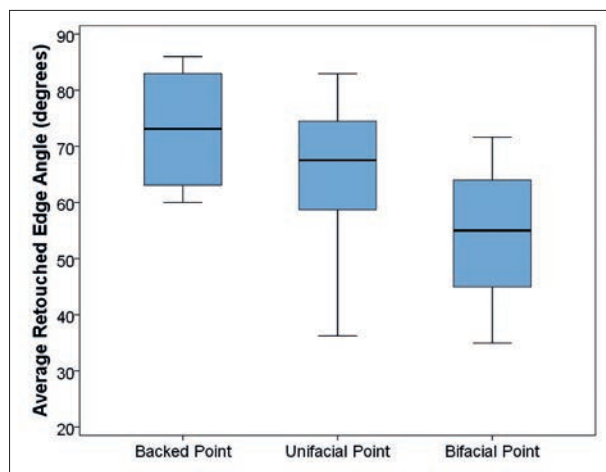


Figure 5 Average retouched edge angle for the Widgingarri points.

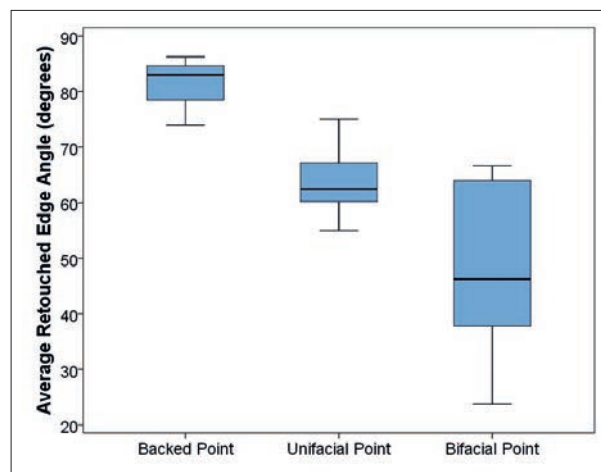


Figure 6 Average retouched edge angle for the LR9 points.

Assemblage	LR12 (n = 55)			LR9 (n = 71)			ME3 (n = 25)			Widgingarri 1 and 2 (n = 50)		
ANOVA	df	f	p	df	f	p	df	f	p	df	f	p
Retouched Edge Angle	1	9.028	0.003	1	0.027	0.869	1	6.232	0.016	1	8.836	0.007

Table 3 ANOVA results for comparison of retouched edge angle and edge angle of backed points with other point morphologies.

average retouched edge angle did not always significantly increase. To explore this relationship, Index of Invasiveness values below 0.3 were selected in each assemblage as an additional proxy for blank flake morphologies. As the width of points is reduced relative to thickness at each position on the percussion axis, the average edge angle showed three statistically significant increases from the three calculations from each assemblage. Table 4 lists ANOVA results for width to thickness ratios taken at three points along the percussion axis against the average morphologies' retouched edge angle. The majority of cases show no significant relationship between average edge angle and cross-section shape.

Unifacial retouch was also found to have little effect on the average retouched edge angle. As unifacial retouch

intensity increased, the average retouched edge angle did not. These data contrast with results presented by Hiscock and Attenbrow (2005b:51) and provide further support for the backed margin being the end product of a deliberate technological strategy, as opposed to a consequence of increasing retouch frequency and a corresponding increase in retouched edge angle. Linear regression results for this trend are given for each assemblage in Table 5.

The backed margin therefore cannot be explained as a by-product of increasing unifacial reduction reducing the width to thickness ratios as retouch scar heights approach the maximum flake thickness. Backing retouched edge angles from 75–90° were produced earlier in artefacts' use lives.

Retouch Characteristics and Intensity

The backed margin was formed in the early stages of reduction. Bipolar anvil-rested retouch was identified on four of the 15 backed points (see Table 6). Scar superimposition shows multiple steep-angled scars on the backed margin, with 'cascades' of small step scars (Cotterell and Kamminga 1987:689). The other backed points are likely to have been retouched with anvil-rested percussion, as evidenced by minor crushing and the steep-angled scars; however, dorsal ridges prevented anvil contact from forming bidirectional scars. Bipolar retouch was not observed in any other retouched flake morphology in the analysed assemblages, which strongly suggests a divergent technological strategy was being used to produce the backed points. Bipolar flakes and cores were also observed in the LR9 and LR12, as well as ME3, assemblages.

The order of retouch for backed points was dominated by ventrally initiated retouch, with no observation of bifacial or invasive retouch truncating a backed margin. The only instances to the contrary were the observations of bipolar retouch from a bidirectional platform, where additional scars follow the same steep angle as previous scars. Backed points are the result of a unique retouch strategy. It is therefore reasonable to suggest that backed margins were likely to be maintained.

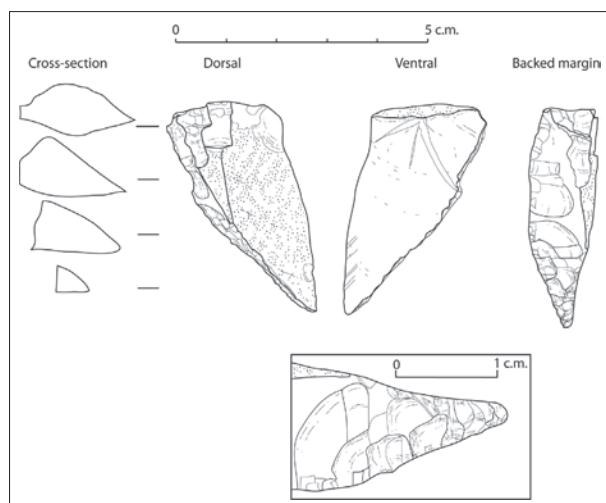


Figure 7 Backed point from ME3 showing cross-section shapes at multiple points obtained from 3D laser scanned images. The backed retouch margin shows that retouch scars initiated from the ventral surface extend along the left dorsal margin. The medial to distal left margin shows bidirectional scars with small step terminating scars indicative of anvil-rested percussion. The inset image highlights the retouched section, with observation of bipolar anvil-rested percussion.

Assemblage	LR12 (n = 27)			LR9 (n = 45)			ME3 (n = 15)			Widgingarri 1 and 2 (n = 13)		
ANOVA	df	f	p	df	f	p	df	f	p	df	f	p
Proximal Width: Thickness	32	2.371	0.019	34	3.207	0.002	15	50.379	0.110	-	-	-
Mid-Width: Thickness	32	0.591	0.914	34	3.887	<0.001	15	1.968	0.513	12	5.572	0.162
Distal Width: Thickness	32	2.217	0.636	34	0.680	0.852	15	0.774	0.726	-	-	-

Table 4 Analysis of variance results for the Average Geometric Index of Unifacial Reduction against the average retouched edge angle.

Linear Regression	r	r ²	df	f	p
Average Retouched Edge Angle vs AGIUR					
LR12 (n = 27)	0.031	0.001	1	0.034	0.856
LR9 (n = 45)	0.116	0.014	1	0.700	0.407
ME3 (n = 15)	0.337	0.113	1	1.534	0.239
Widgingarri 1 and 2 (n = 13)	0.166	0.028	1	0.226	0.647

Table 5 Linear regression results for Average Retouched Edge Angle against the Average Geometric Index of Unifacial Reduction.

The frequency of retouch order and placement for backed points in the analysed assemblage is given in Table 6. Backing only occurs in the lower retouch intensity values for all point technologies, with no remnant backed margins observed on later stage point morphologies. These data demonstrate that backed points were not the discard stage in point reduction continuums.

Discussion

There is no evidence that backed points in the Kimberley were produced from small blades and flakes that were similar in size to backed artefacts produced elsewhere in Australia. On the contrary, Kimberley backed points were made from the same pool of flakes as other point technologies. The greatest divide between backing technologies in the Kimberley and those from the central and southern portions of the Australian continent is the relative frequency of backed artefacts within the total retouched artefacts in the assemblages. The Kimberley backed points occur in low frequencies relative to other point forms, and it is thus reasonable to argue that backing retouch was not a high priority for stone tool makers in the Kimberley.

In contrast to the observations by Hiscock (2009:85)—that bipolar reduction was associated with the end of reduction sequences—bipolar, anvil-rested retouch was not a strategy to extend the use life of individual artefacts in the Kimberley samples. We suggest that the bipolar anvil-rested retouch observed on the Kimberley backed sample is likely to be a technological strategy to increase the predictability of steep

flake removals, rather than to extend an individual artefact's use life.

Because backed points are a unique retouching strategy within the broader range of point reduction in the Kimberley, it is possible that backing represents a technological response to a specialised functional requirement. In answer to the form and function question posed by Hiscock and Attenbrow (2005b:46), 'how can implements be designed for, and be efficient in, a specific use if their morphology is continuously changing?', we argue that the backed margin was deliberately produced. The backed morphology does not continuously change and therefore is likely to be related to an efficient and specific use. Just what this use was will remain elusive until further residue analysis is conducted, particularly as the only residue analysis undertaken to date (Wallis and O'Connor 2003) revealed no difference in observed residues between backed and other points from the Widgingarri 1 and 2 assemblages.

Hiscock (2006:80–83) contrasted backed artefacts with northern Australian point technologies using a framework that compared the abundance of production versus the extendibility of those products. Backed artefacts were identified as part of an abundance strategy, with high production rates and low reduction potential. Therefore, backed artefacts represent an extreme form of raw material conservation per unit. These artefacts were contrasted with edge ground axes, which had comparatively low frequencies of production but greater reduction potential. Point technologies typical in northern Australia were modelled as the median of these two theoretical references. The Kimberley backed points do not, however, fit in the abundance strategy described by Hiscock (2006), as they were produced in low frequencies.

Australian archaeologists have suggested that ENSO-forced climate changes in the mid-Holocene may have underpinned changes in technology at this time, as people adapted their tool-kits to offset the severity of subsistence risks associated with both increased aridity and the periodicity of environmental change. Hiscock (1994, 2002, 2006, 2009:90) has argued that, after the mid-Holocene, people invested more time and energy in producing maintainable and portable tool-kits in order to reduce both the severity and probability of risks associated with subsistence failure. Highly reduced

Assemblage	Dorsal Only	Ventral Last	Bipolar Retouch	Plano-Triangular	Convex-Triangular
LR12 (n = 1)	1			1	
LR9 (n = 4)	3	1	1	2	2
ME3 (n = 3)	2		1		2
Widgingarri 1 and 2 (n = 4)	1	3	4	3	1
Total (n = 12)	7	5	4	6	5

Table 6 The placement and order of retouch for complete backed points in the analysed assemblages.

forms of flaked lithic artefacts were also detected by Clarkson (2006:104) in the mid-Holocene archaeological record of northwest Australia, which he argued were a response to higher subsistence risks associated with environmental fluctuations. McGowan et al. (2013) recently presented data from Black Springs which indicate that the Kimberley region underwent rapid environmental change beginning about 6000 years ago, when it transitioned from a tropical humid climate with an intense and predictable summer monsoon to a much drier climate with a summer monsoon either absent or intermittent. Evidence for slight climatic amelioration and a switch back to a more active monsoon was detected in the Black Springs record for a brief period between 4600 and 4200 cal. BP, but was followed by another period of extreme aridity peaking between ca 2400 and 1300 years ago. In this scenario the backed point may represent one component of a suite of technologies that developed in the Kimberley in the mid-Holocene to offset subsistence risk in the face of unpredictable rainfall and resources. The backed form may have been selectively used for tasks requiring an abrupt margin, as well as a stout point capable of penetration that reduced the risk of breaking or altering other point forms in the technological suite and simultaneously provided a transportable source of small sharp flakes. However, until a larger sample of backed points is examined and further residue studies are carried out, this will remain a testable hypothesis.

Conclusion

Backing technology has now been documented in assemblages from the east (Dortch 1977:117), west (O'Connor 1999:72) and south Kimberley regions. Data presented here demonstrate that backing retouch was highly unlikely to be either the discarded manufacturing stages in unifacial and bifacial point reduction continuums or the result of unwanted or unintentional build-ups of steep-angled retouch. Rather, backed points were made from the same pool of blank flakes as other point technologies and received specialised retouching, such as bipolar anvil-rested percussion, in order to create and maintain the backed margin. Backed point technology in the Kimberley region, therefore, appears to constitute a unique reduction trajectory within the broader range of point reduction continuums.

The only observations of retouch truncating backed margins were additional bipolar, anvil-rested retouch, with no observation of remnant backed margins on more intensely reduced point forms. This suggests that, whilst Dortch (1977:117) did not observe this form of point reduction, it was practiced in the west and south Kimberley. We suggest that some points received additional bipolar retouch during their use life to rejuvenate or maintain the backed margin.

The proposed northern boundary for backed artefact manufacture has gradually been broken down, with increasing sample sizes and studies of lithic artefact technology identifying backed artefacts in northern Qld (Davidson 1983:34; Hiscock and Hughes 1980) and the Kimberley (Dortch 1977:117; O'Connor 1999:72). Backing technology has been observed throughout the Kimberley region and potentially represents a regional response to a particular technological requirement rather than an extension of the range of any of the backed industries found elsewhere in Australia. Although backed artefacts were a small component of overall retouched assemblages

in the Kimberley, our data and review of the literature clearly demonstrate that they are widely distributed north of the 20° south latitude (contra Smith and Cundy 1985). Further analysis of museum collections could bolster the sample size of Kimberley backed points, enabling more robust technological comparison with backed industries elsewhere and better information about their use life. Future attempts at mapping the distribution of backing as a technological strategy within Australia should include Kimberley backed points.

Acknowledgements

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Chapter 6

Direct dating of resin hafted stone technology in Australia. *Australian Archaeology*.

Authors: Tim Maloney, Rachel Wood, Sue O'Connor and Rose Whitau.

Publication: Australian Archaeology

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Formulation of arguments in manuscript. Composed the overall question, background research, site description, discussion, and conclusion of this research paper. Identification and analysis of reported artefact.

Signed:



Tim Maloney

Dating of resin sample from reported specimen. Wrote the section describing the dating methods and contributed to the arguments and writing of the manuscript.

Signed: 

Dr. Rachel Wood

Australian Research Council Linkage Grant (LP100200415) CI. Contributed to the arguments and writing of the manuscript. Original excavation of Carpenters Gap 1 site. Wrote sections of the manuscript.

Signed: 

Professor Sue O'Connor

Contributed to the arguments and writing of the manuscript. Wrote sections of the manuscript.



Signed: Rose Whitau

Direct dating of resin hafted point technology in Australia

Tim Maloney¹, Rachel Wood², Sue O'Connor¹ and Rose Whitau¹

1. Department of Archaeology and Natural History, College of Asia and the Pacific, Australian National University ACT 0200, Australia.

2. Radiocarbon Facility, Research School of Earth Sciences, ANU College of Physical and Mathematical Science, The Australian National University ACT 0200, Australia.

<Tim.maloney@anu.edu.au, Rachel.wood@anu.edu.au, sue.oconnor@anu.edu.au, rose.whitau@anu.edu.au>

Abstract

The rare recovery of hafting technology from archaeological deposits around the world prevents a clear picture of Palaeolithic hafting arrangements. Without the recovery of hafted stone tools, our understanding of this technology is limited to extrapolation from artefact morphology and ethnographic analogy – such is the case in Australia. Here we present a direct date of 3160–2954 cal. BP, obtained from resin on a stone point recovered from the Carpenters Gap 1 rockshelter in northern Western Australia. This artefact fits the description of point technology in Australia, being a retouched flake with converging margins, and provides the first direct date on a stone tool from the Australian continent. The hafting arrangement of points during the mid to late Holocene is archaeologically visible for the first time in Australia. This point was hafted using resin adhesive as well as wound binding material. This rare artefact is used to discuss the current interpretations of technological change in the Holocene record of Australia and the direct dating process.

Introduction

Excavation at Carpenters Gap 1 (CG1), a site with exceptional organic preservation in the southern Kimberley, Western Australia (WA) (McConnell and O'Connor 1997, 1999; O'Connor 1995; Wallis 2001) (Figure 1) recovered a distal point fragment with a sizable portion of adhering resin with imprints of an organic binder. This paper presents the results of direct dating of the resin and a description of the imprints and stone artefact. This is the first Australian stone tool to be directly dated using adhering resin and demonstrates how this method can be used to provide reliable ages for a range of Australian composite tools, as well as assist us to better understand hafting technology.

Unifacial and bifacial points first appear in parts of Australia in the mid-Holocene (Hiscock 2008:158; Maloney et al. 2014), although the dating of the appearance of these tools (and other hafted tools) has not been without contention. Points are widely identified as retouched flakes with converging margins (Hiscock 2006:76; Holdaway and Stern 2004:266). Dating the appearance of this technology has conventionally relied on dating organics in associated excavation units. In sandy deposits; however, the assumption of association is problematic as bioturbation and other disturbance can lead to vertical movement of objects up and down the profile (e.g. O'Connor et al. 2002; Richardson 1992). Direct dating of resin has the potential to provide reliable ages for the diversity of hafted tools that appear across Australia in the Holocene. The impressions preserved in the resin of the CG1 point also provide evidence of the methods involved in its hafting, indicating the use of organic binders as well as mastic.

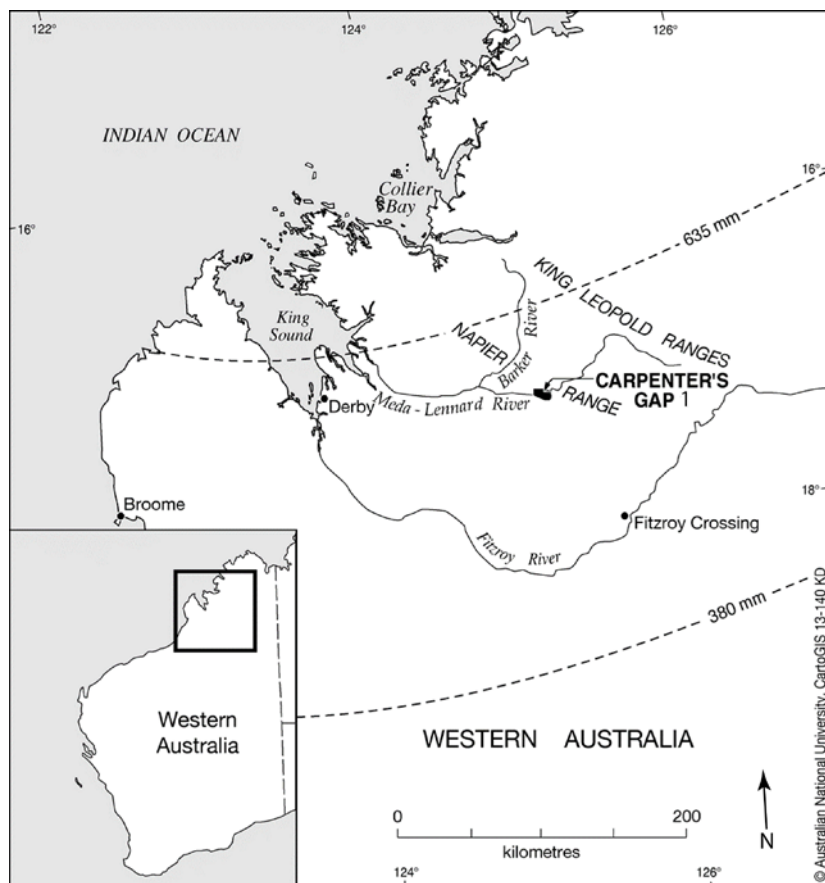


Figure 1 Map of north Western Australia showing site location.

The process of hafting was a crucial technological development in human evolution. The expansion of hominid populations resulted in the adaptation of hafting technologies to a myriad of environmental, social and economic conditions across the globe. A vital component of the toolkit (Shea 2006), hafted technology is still employed by some hunter-gatherer groups today (Weedman 2006). Despite the ubiquity of hafting technology, direct evidence of hafting in the archaeological record is rare, limiting our understanding of how this technology was adapted to novel conditions.

Archaeologically, there are three elements that can provide evidence of hafting: the tool itself, the haft and the binding agent. The earliest evidence for hafting technology is based on diagnostic impact fractures on tools, such as those fractures found on points excavated from the Kathu Pan 1 site in South Africa and dated by association to 500,000 years (Wilkins et al. 2012:943). The earliest spear shafts were recovered from the Schöningen site in Germany (Thieme 1997), dated to 400,000 years; however, no lithic projectiles were recovered, prompting the authors to conclude that the spears were fashioned entirely from wood. The earliest organic evidence of compound hafting matrix was identified on Middle Stone Age tools, dated to 70,000 years, from Sibudu Cave in South Africa (Wadley et al. 2009:9590). Birch tar residues have been recovered on stone tools from several European Palaeolithic sites (Boëda et al. 1996; Mazza et al. 2006; Pawlik and Thissen 2011:1707), including a birch tar piece with impressions of a stone tool, a wooden artefact and fingerprints (Grünberg 2002; Hedges et al. 1998; Koller et al. 2001).

Recovery of early hafting technology throughout Asia has been rare and few studies demonstrate composite tool use before the terminal Pleistocene. In Timor Leste, the butt end of a bone projectile from Matja Kuru 2 (MK2) has been dated to ca 32,000 cal. BP,

by association with radiocarbon dates of marine shell (O'Connor et al. 2014a:110–111). This artefact preserves evidence of a complex hafting mechanism, which employed an organic fibre wrapped around a mastic on the bilaterally notched butt. At Niah Cave in Borneo several bone and stingray spine points, with traces of hafting resin and fibrous binding, have been dated to the terminal Pleistocene, based on association with charcoal radiocarbon dates (Barton et al. 2009:1708–1709). Hafting of backed artefacts using resinous mastic was practiced in the late Pleistocene at Jwalapuram Locality 9, in India (Clarkson et al. 2009:334, 339); however, only a few of the recovered artefacts retained resin, inhibiting a convincing interpretation of the composite arrangement (Clarkson et al. 2009:339). The only other direct evidence for early hafting comes from northern China where use wear analysis on adzes and projectile points indicates that these artefacts were used in composite tools from around 10,000 years ago (Zhang et al. 2009).

The earliest colonisers of Sahul, who employed complex seafaring technology (Balme and O'Connor 2015), are likely to have been adept at fibre processing and resin manufacture and use. On encountering new environments these early settlers developed new hafting technology and made edge-ground and waisted axes, since whole axes and flakes detached from them have been recovered from the earliest levels of some of the oldest sites in northern Australia (Clarkson et al. 2015:59; Geneste et al. 2012:2; O'Connor 1999:175; O'Connor et al. 2014b:18; Schrire 1982:84, 106–107). McConnell and O'Connor (1997:24–27), suggested that the abundance of resinous spinifex culms in the Pleistocene assemblage at CG1 may indicate early resin production for hafting. Prior to the CG1 point discussed here, the only direct dates obtained from manufactured resin in Australia have been reported from surface assemblages in the Pilbara, WA (Veitch et al. 2005:60, Table 1), where two spinifex balls were dated to within the last 1000 years. Despite the continuing dearth of physical evidence, hafting remains central to explanations of technological change in Australia.

The mid-Holocene has long been recognised as a period of dynamic technological and social change across the continent of Australia, with either new forms of stone tools or the proliferation of existing stone technologies becoming widespread. The majority of evidence for hafting technology has been extrapolated from tool morphology. A generally small size, pointed termination, elongation and proximal thinning of many tools have led some archaeologists to argue that hafting was a central technological requirement of these tools (e.g. Allen and Barton 1989:121; Clarkson 2007:155, 2008:302; Clarkson and David 1995:22; Flood 2004:225; Hiscock 1994b:277; Mulvaney 1969:153; Mulvaney and Joyce 1965). Innovation in hafting techniques was hypothesised as an overall explanation for new stone tools across the continent during the mid-Holocene (Jones 1979:456–457; Mulvaney 1969:153). The implied hafting of points and backed artefacts was also used to argue for increased conflict (Flood 1995:236; Smith 1995:40; Smith and Brockwell 1994:102). Recent explanations of the development of points and backed artefacts, tend to either support a technological response to foraging risk (Clarkson 2007:155; Hiscock 1994b:277; 2011), and/or a social response to demographic changes (Moore 2013; White 2011). Hafting features prominently in both scenarios. The foraging risk model argues that points as standardised implements, allowed continuous hafting and rejuvenation within the same costly, pre-designed hafting arrangement (Clarkson 2007:155, 2008:302; Hiscock 1994b:278). Social signalling explanations on the other hand, suggest that points were hafted as highly visible symbols of identity and social status (Moore 2013:145).

Points are a likely candidate for hafting as projectiles, due to their shape, although it is also apparent that points were used for a range of functions both with and without other hafting arrangements. Limited resin recovery has hitherto prohibited reconstruction of hafting arrangements. For example, the only residue analysis of points thus far carried out yielded two of 42 points with possible traces of hafting resin but no dating of the resin was attempted (Wallis and O'Connor 1998:10). Additionally, while hafting is largely inferred from the morphology, the pointed shape was not always maintained (Clarkson 2007:112, 114, 117; Hiscock 2009:84–85; Maloney and O'Connor 2014). Macrofracture analysis of points from the Northern Territory reveals that mid-Holocene points may have rarely been used as hafted projectiles (Brindley and Clarkson 2015). Conversely, a few studies that showcase hafting resins on backed artefacts were able to confirm that multiple hafting arrangements were employed (Boot 1993:5, Tables 8–11; Brown 1987:49; Robertson et al. 2009:249, 297) with projectile tips or barbs utilised less frequently (McDonald et al. 2007).

Without overextending the application of ethnographic analogy (Binford 1972:86), more recent and museum curated examples of stone tool hafting can be informative. In northern Australia, ethnographic observation and collection has provided useful insights into recent forms of point hafting technology (Akerman 1978:486; Akerman et al. 2002:21–22; Hardman 1888:64–64; Kaberry 1939:14; Newman and Moore 2013). For example, Akerman (1978:486) described the ethnographic hafting of Kimberley points, which are present in archaeological deposits around 1000 cal. BP (Maloney et al. 2014). Other forms of point and blade hafting described by Newman and Moore (2013:2615, Fig. 1), Spencer and Gillen (1899:652), Graham and Thorley (1996:78–79), Bindon and Lofgren (1982:119, Fig. 6), and McCarthy et al. (1946:32), demonstrate that in recent times, multiple hafting arrangements were used. Ethnographers such as Roth (1897, 1904) provide accounts of hafting a range of stone tools, including what would not be recognised as formal tools (see Khan 1993). There are also examples handles created from mastic and binding, with no incorporated shaft (Neman and Moore 2013:2615, Fig. 2), and large blades hafted as knives (Akerman 2007).

Sources of Resin in Australia

Ethnographically, resins were observed being extracted from a range of plant species across Australia (Aiston 1929:45; Boot 1993:5; Latz 1995:341; Maiden 1975; Parr 1999:23; Richardson 1988:58). In the Kimberley, resin was extracted from *Triodia pungens* (spinifex), the roots of *Erythrophleum chlorostachys* (ironwood), *Callitris columellaris* (native cypress pine) (Akerman pers. comm. 2014). Other sources of resin include native bee hives (*Trigona* sp.) (Akerman pers. comm. 2014) and ant nests (Akerman 1980:246; Latz 1995:290; Lowe and Pike 2009; Spencer 1896:69–71), probably produced by *Iridomyrmex rostrinatus* (Butler 1966), which is possible a more recent technological development (Pitman 2010:89–91). Again, more recently, burnt battery cases and tar from sealed roads were used in hafting technologies (Akerman 1980:246). In north Queensland, the young roots of the ironwood tree *Erythrophleum labouchei* were processed for resin production (Khan 1993:87). In the same area, Roth (1897) noted dry lumps of gum, gathered from the brown cedar or mackay cedar tree *Canarium australasicum*, which were used for joining spear shafts (see Khan 1993:130).

Spinifex resin, a thermoplastic adhesive, is the most prolific source of plant resin in Australia (Pitman 2010; Pitman and Wallis 2012). The threshing of spinifex, in order to extract the resin, was practiced across much of the continent where resinous spinifex

occurred (Binford 1984; Brokensha 1975; Cleland 1966; De Graaf 1967; Gould 1970; Pitman 2010:31–39; Roth 1904; Sheridan 1979; Tindale 1965). Spinifex grass was threshed on a hard surface, and the resulting resin-chaff mixture was collected in a container (Binford 1984:161–171; Gould 1970:39–40; Latz 1995:66,290). This mixture was then winnowed, which frees scales of resin from the leaf bases. The mixture was then heated using a variety of techniques (Pitman 2010:36) and metamorphosed into a homogenous cake of resin (Cleland 1957, 1966:122, 146–147; Roth 1897:101–102, 1904:13).

Inclusions of chaff in resin are a reasonable visual indicator that the resin source was spinifex grass (Pitman 2010:102; Sheridan 1979:67). Other inclusions, such as sediment grains, ash, charcoal, saliva, animal fat and blood are also possible. Ochre and bird feather decorations are present on recent Kimberley points, variable covering the shaft and mastic (Akerman et al. 2002:23–24; Newman and Moore 2013:2616, Fig. 3), and have been detected on at least one mid-Holocene point (Wallis and O'Connor 1998:160, Table 2).

The CG1 Hafted Point

The hafted stone tool illustrated in Figure 2 meets the descriptive criteria for point technology, based on several observations. Firstly, the distal portion of the tool can be observed projecting from the resin, with an intact feather termination and partial ventral surface, confirming that the tool is technically a broken retouched flake (Hiscock 2007:203). Secondly, retouch scars initiated uniaxially from the ventral surface are present on the left distal margin, which combined with the unretouched right margin, have created converging margins. The marginal angle (approximately 63°) is within the morphological range of other retouched flakes described as points, such as those found throughout the Kimberley (Dortch 1977:166, Fig. 5; O'Connor 1999:73–74, Fig. 5.13, Fig. 5.14; O'Connor et al. 2008:79–80, Fig 4.) and in Wardaman Country (Clarkson 2006:102). Prior to breaking, the point was probably very similar to those recovered from the nearby Windjana Gorge Water Tank Shelter (O'Connor et al. 2008:79–80, Fig. 4) and Carpenters Gap 3 (O'Connor et al. 2014b:21, Fig. 10), being less than 4 cm in length and not particularly elongate. None of the retouch scars are covered by the resin, so it is possible that the tool was hafted with no retouch, and later modified.

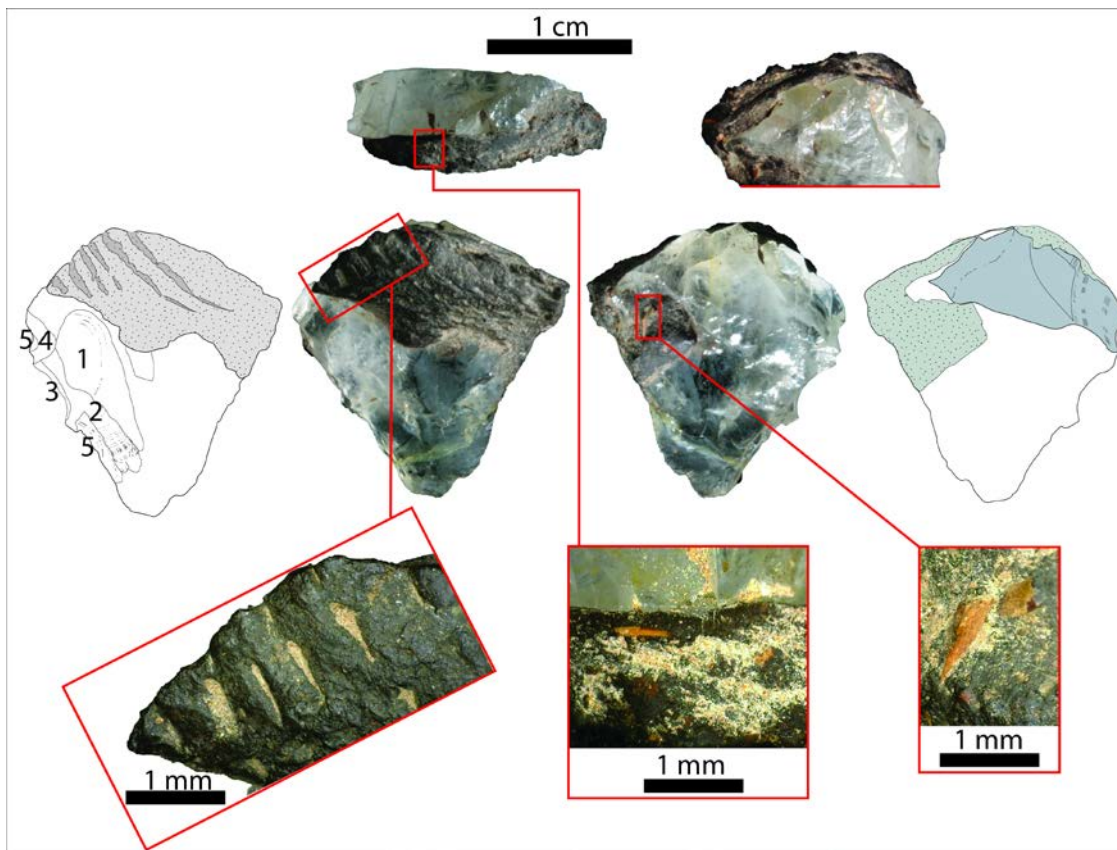


Figure 2 Point from CG1 showing transverse scar across midsection, impressions formed by binding materials, and small pieces of plant, probably spinifex chaff, in the resin (photograph by Tim Maloney).

The resin adhering to the dorsal surface of the point has been impressed, resulting in several clearly visible parallel lines on the proximal left surface (Figure 2). Each impression is approximately 0.3 mm wide, with the deepest penetration of the resin observed closest to the proximal edge. These impressions continue diagonally across the surface of the resin, with reduced penetration towards the right distal portion. These impressions were produced by a thin, fibrous material, which further bound the tool to the haft. The binding material covered around half of the remaining resin, and presumably continued over the shaft portion. The impressions do not intersect.

There are small pieces of plant material within the resin (Figure 2), which provide reasonable evidence that the resin was produced from spinifex chaff. Additional inclusions of small black and red flecks, around 1 mm², are possibly charcoal and ochre (Figure 2).

A negative flake scar initiated from the left medial margin propagates through the mid-section of the point and truncates the resin (Figure 2). This flake scar terminates before reaching the opposite margin (Figure 2), where resin can be seen covering part of the right margin. This small amount of resin is therefore covering a surface that predates the mid-section break and indicates that the right margin was contracting towards a probable platform surface. The implication of this observation is that the proximal portion is unlikely to have been much larger than the remaining distal portion, leading to the estimated shape of the proximal portion used in Figure 3. It is possible that this scar was caused from projectile impact, given the resemblance to transverse scars observed on other hafted points (Ahler 1992:45, Fig. 11; Lombard 2005:225; Lombard et al. 2004). No other diagnostic impact fractures are evident. This fracture is perhaps

less likely to have been caused during manufacture, following Ahler (1992:42, 56, Fig. 8), who demonstrated that transverse snaps observed on manufacturing failures, will typically intersect or truncate retouch scars. This is not the case on the CG1 point. It is also possible that this break occurred while the tool was hafted for a non-projectile function, such as a cutting tool or drill. Given the nature of the material, crystal quartz, it is equally plausible that an incipient fracture plain propagated this transverse fracture.

The observed resin did not encapsulate the pointed distal tip. This distal portion of the tool was the only observed part to have been modified. Therefore, we can be certain that the point was hafted to utilise the acutely angled tip with converging margins, and potentially facilitated drilling, cutting, and projectile functions. This assumption, in conjunction with the binding impressions and the mid-section break, was used to produce the hypothetical hafting arrangement illustrated in Figure 3. Figure 3 also shows how the binding agent may have increased resistance across the mid-section of the point, initiating the break (following Fauvelle et al. 2012:2807, Fig. 5).

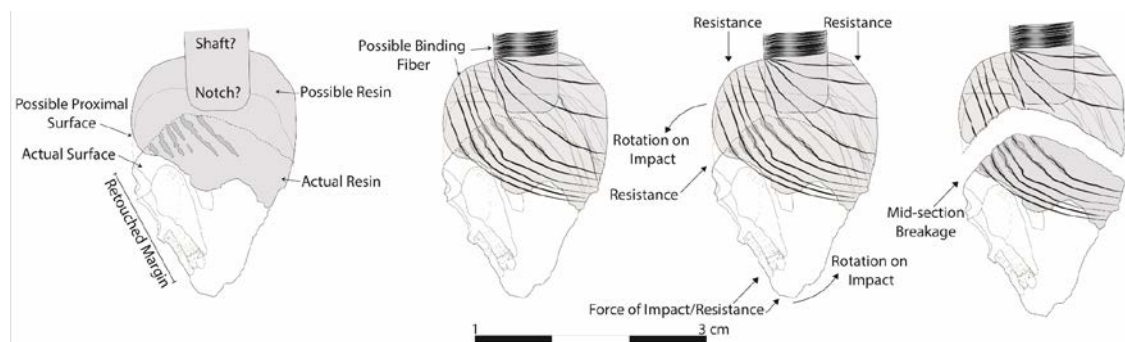


Figure 3 Hypothetical hafting arrangement and impact forces, based on specimen observations.

Dating

The excavation units (EU) surrounding the point were formed between 3632 and 2850 cal. BP, based on multiple radiocarbon dates from charcoal (Table 1). Charcoal was dated at the ANU lab in the 1990s (laboratory code ANU) and the resin directly dated more recently (laboratory code SANU). All dates have been calibrated in OxCal version 4.2 (Bronk Ramsey 2009), using the SHCal13 curve (Hogg et al. 2013), with ranges given at 95.4% probability.

The CG1 point was recovered in Unit 8c, a layer rich in organic matter including paper bark and other plant materials, and which was removed separately from the surrounding sedimentary units. This unit produced a date of 3632–3365 cal. BP (ANU-10030). The EU immediately above this, EU 8, dates to 3441–3076 cal. BP (ANU-10029). A hearth feature (EU 8b) truncating EU 8 dates to 3209–2927 cal. BP (ANU-11421). It is possible that the point comes from the interface of Units 8b and 8c. EU 9, which produced a date of 3557–3165 cal. BP (ANU-11460), is adjacent to, or immediately underlying, 8c. EU 10 produced a date of 3463–3164 cal. BP (ANU-11462).

Table 1 Radiocarbon dates from CG1, square A1. Calibrated in OxCal v.4.2 (Ramsey et al. 2009) against SHCal 13 (Hogg et al. 2013).

Lab No.	EU	Material	Methods	$\delta^{13}\text{C}$ (‰, VPDB)	Radiocarbon date (BP)	Calibrated age (cal BP, 95.4% probability range)
ANU-11421	8b	Charcoal	Conventional	-	2960±40	3209–3191 (1.7%) 3185–2927 (93.7%)
ANU-10029	8	Charcoal	Acid wash, Conventional	-24.0±2.0 ²	3110±60	3441–3431 (0.7%) 3402–3076 (94.7%)
SANU-39039	8c	Resin on point	Acid-Base-Acid, AMS (see text)	-18±2.0 ¹	2950±25	3160–2954
ANU-10030	8c	Charcoal	Acid wash, Conventional	-24.0±2.0 ²	3300±60	3632–3365
ANU-11460	9	Charcoal	Acid-Base-Acid, Conventional	-24.0 ± 2.0	3180±70	3557–3531 (1.9%) 3510–3165 (93.5%)
ANU-11462	10	Charcoal	Acid-Base-Acid, Conventional	-25.6±0.1	3160±60	3463–3164

The resin sample produced a calibrated age range of 3160–2954 cal. BP (SANU-39030) (Table 1). A 5.4 mg piece of resin, free from visible inclusions, was taken from the right ventral margin with a scalpel. This sample was subjected to a very gentle acid-base-acid pre-treatment to remove likely contaminants: HCl (0.1 M, 30 minutes, room temperature [RT]), NaOH (0.1 M, 45 minutes, RT), HCl (0.1 M, 30 minutes, RT), with three washes in ultrapure MilliQTM water between each treatment. The base wash appeared to dissolve the resin, but also caused the dark resin to turn a pale cream colour, and highlighted an unidentified black fleck, possibly some form of charred material. The treatment decreased the sample weight to 1.32 mg (24% yield). The freeze-dried product, excluding the black fleck, was combusted in an evacuated quartz tube in the presence of silver foil and CuO wire at 900°C for 6 hours. The CO₂ was then collected and purified cryogenically before reduction to graphite with H₂ over an iron catalyst for measurement in a NEC Single Stage AMS (Fallon et al. 2010). The sample contained only 16% C, calculated volumetrically during cryogenic collection. The graphite weight was correspondingly low (0.21 g), but is within the range of sample weights routinely dated at the ANU.

Resins are rarely radiocarbon dated, and the ability of this specific pretreatment method to remove contamination added in the burial environment from a sample is not conclusively established. However, resins often give ages in agreement with other material types. For example, a radiocarbon date on resin of pine origin from a late 4th century Roman shipwreck was in agreement with a coin embedded in the resin (Beck et al. 1994). Resin on a microlith from Border Cave (OxA-X-2418-47, 35750 ± 500 BP) gave an age in accordance with others from the same context on other materials without any pretreatment (D’Errico et al. 2012). In contrast to this Pleistocene example, large amounts (>1 %) of contamination are required to shift the Holocene-aged date from CG1 outside of its reported error.

A second problem may relate to the inbuilt age of the resin. As spinifex resin can be collected from ant nests, it could have an inbuilt age either from inclusion of old material, such as old wood charcoal brought into the nest, or from the use of resin from old ant mounds. On its own, the date should be treated as a maximum age for the hafting event. However, given the broad agreement between the dated resin and charcoal from surrounding contexts, it is unlikely to substantially overestimate the age of the hafting event.

Discussion

The CG1 point is the first directly dated hafted stone tool from the Australian archaeological record, providing the most conclusive evidence for mid-Holocene point hafting methods. The direct dating showcases the potential to effectively date small samples of resin found on stone tools (5.4 mg), which in turn will provide better understanding of the chronology of hafting technology.

The hafting arrangement of the CG1 point can be reconstructed from fibre impressions preserved in the resin, and analysis of the mid-section break. The impressions indicate that the hafting of this point incorporated some form of binding over the top of the mastic, unlike ethnographic examples (Akerman 1978:486; Tindale 1985:16, Fig. 1.10), where fibres were either wound onto the shaft before the application of mastic, or avoided entirely. Measurements of the impressions show that the fibre was likely fine strands of sinew or plant, less than 0.3 mm in diameter, that were wound around the resin. The resin itself was likely a spinifex product, given the observation of probable chaff, implying other technological actions; including spinifex threshing, and metamorphosis into resin through heating. The CG1 point's mid-section break was probably initiated by resistance created by the fibrous haft at the mid-section, and possibly produced by a projectile impact. It is also possible that applied pressure to the distal end was caused in any number of other functions, such as cutting or drilling, and produced a similar breakage. We would like to stress firstly, that while the CG1 point is an evocative example of projectile technology, it could have very likely had other functions throughout its use life, and secondly, this hafting arrangement cannot be used as a standard for the hafting of all mid to late Holocene points.

What this hafting arrangement can reveal within current explanatory models of point technology is limited, although worthy of some discussion. Points first appear in the Kimberley by at least 5,200 cal. BP (Maloney et al. 2014). Rejuvenation of broken points is more likely to occur when access to replacement materials is scarce (Andrefsky 2010; Hiscock 1988), such as forays away from the CG1 site, into areas where suitable point producing material was less available. Andrefsky (2010:18) noted that the archaeological recovery of points with impact damage, suggests people could afford to discard the point fragment and replace it with a new point. The discard of the CG1 point, could therefore relate to relatively low pressures on point rejuvenation at the time. Alternatively, its discard in proximity to locally available crystal quartz sources, could simply indicate that raw material availability made rejuvenation of small points unnecessary.

Because the CG1 point is small in size, was only lightly modified and was discarded without rejuvenation, it seems unlikely that this artefact attained high symbolic value and information exchange potential (Moore 2013:145). The small size of this point makes recognition of retouch only possible by close examination, which suggests that retouch was unlikely to be a requirement of social signalling via point technologies. Rather, retouch of pointed forms, with undoubted potential as social signals, was more likely focused on working edge and tip maintenance.

Conclusion

The life history of points in Australia during the mid-Holocene is beginning to be better understood with reduction-based analyses and experimental use wear. The central role of hafting in the explanatory models of technological change surrounding point

technology in the Australian record can only be expounded by the recovery of rare artefacts such as the CG1 point reported here. The dating and analysis of the mastic on the CG1 point demonstrates the huge potential of this method for elucidating the timing and nature of this technology throughout the world. Complexities of dating residues on stone tools involve the ability to remove contamination added in the burial environment, but more particularly the unknown inbuilt age. For these reasons, the direct date of resin should be treated as a maximum age for the hafting event.

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Chapter 7

Detecting pedagogy in prehistory using stone artefacts: A case study from north Western Australia. *Journal of Archaeological Method and Theory*.

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Formulation of arguments in manuscript. Composed the overall question, background research, site description, discussion, and conclusion of this research paper. All lithics analysis and statistical tests.

Signed:

A handwritten signature in black ink, appearing to be 'T. Maloney', enclosed in a thin black rectangular border.

Tim Maloney

Detecting pedagogy in prehistory using stone artefacts: A case study from north Western Australia

Tim Ryan Maloney

Department of Archaeology and Natural History, College of Asia and the Pacific, The Australian National University, Coombs building 9 Fellows Road Acton, ACT 2601, Australia.

<tim.maloney@anu.edu.au> (+ 0261250309)

Abstract

Social learning is a fundamental aspect of all human societies, and is arguably a central facet of human evolution. While the prehistoric contexts of social learning have proven problematic to reconstruct, stone tools from archaeological assemblages can provide a viable means to examine such pedagogical processes. Stone technology is a suitable medium for investigating social learning processes for two reasons: Firstly, stone technology is ubiquitous across human history, and secondly, the inheritable nature of social learning associated with technology and its production, maintenance, and innovation. I employ the effective complexity of two stone tool reduction sequences from the Kimberley region of northern Western Australia, to contrast the different styles of pedagogy that might be inferred from, and associated with, both of these technologies. This study demonstrates that archaeologists can use effective complexity, constructed from reduction sequences, to model levels of pedagogical investment by past societies.

Keywords: Pedagogy; cultural transmission; biface; reduction; stone tools.

Introduction

Social learning is a fundamental aspect of all human societies, and is arguably a central facet of human evolution (Csibra and Gergely 2011; Gergely and Csibra 2006; Semaw 2000; Sterenly 2012). While the prehistoric contexts of social learning have proven problematic to reconstruct, stone tools from archaeological assemblages can provide a viable means to examine such pedagogical processes. Two factors assert the viability of stone technology as a means to addressing this goal: Firstly, the ubiquitous nature of stone technology across human history, and secondly, the inheritable nature of social learning associated with technology and its production, maintenance, and innovation.

Archaeologists have successfully modelled units of time, energy, and foraging risk from variation in stone artefacts, leading to models of technological organisation and subsistence practices (e.g. Bleed 1986; Kuhn 1995; Torrence 1983, 1989). More complex stone tools often require great skill, and imply enhanced investment of time and energy into technological pedagogy; however, outside of the theoretical distinction between abstract knowledge and physical abilities (e.g. Bloch 1991; Keller and Keller 1996; Pelegrin 1990), ethnographic observations (Moore 2015; Stout 2002), and general reference to apprenticeship or novice knapping (Apel 2001; Fischer 1989, 1990; Greenfield et al. 2000; Hiscock 2014; Mackay and Marwick 2011:121; Pigeot 1990) pedagogical contexts are rarely reconstructed from archaeological data. Neurological studies have revealed how learning developments occur in modern populations in

experimental contexts (Stout and Chaminade 2007), yet archaeologists do not have the benefit of extracting these data from stone tool assemblages. Contemporary Indigenous populations, such as the first Australians, have had numerous anthropological studies record knowledge transfer in the recent past (e.g. Berndt and Berndt 1964:132-133; Kaberry 1939:227-234; Love 2009[1936]:113-114; Peterson 1997:181-184), but none of these allow for specific conclusions to be drawn regarding social learning practice from archaeological data such as stone tools (see Holdaway and Allen 2013). Even archaeological studies focused on skill in stone tool production have placed minimal emphasis on the agency of teaching (Findaly 2008; Olausson 2008).

The inference of greater and lesser skill is nonetheless often documented in assemblage analyses (Pelegrin 1990). Studies have used assemblage variation to identify novice knapping activity areas within sites (Assaf et al. 2015; Grimm 2000), and even child knappers (Högberg 2008). Skill level is a crucial aspect of pedagogical inquiry, and one returned to shortly, however; identification of skill is highly subjective (Findley 2008:85), and will not elucidate the pedagogical contexts of ancient tool markers. Despite the continued study of skill in knapping, archaeologists do not have a feasible technique for quantifying the level of expertise required for different lithic technologies. Modern replicative studies may not reveal much more than levels of skill acquired after much practice, so there is both a lack of, and great value in, a method of analysis that can reveal pedagogy, not just skill. I propose to compare levels of investment in teaching and learning, between two different reduction sequences present in the Kimberley region of northern Western Australia, using effective complexity (Gell-Mann and Lloyd 2003). In this case, effective complexity is the length of the description of regularities within the learning of a technology. It is demonstrated that a shift in pedagogical contexts is detectable in these stone artefact assemblages.

Pedagogy in prehistory

No one is born with great knapping skill, as noted by Shelley (1990:187). Individuals within societies using stone technology would logically have some elementary knowledge of stone reduction (Bamforth and Finlay 2008:3). This most basic level of technological knowledge equates to the design space described by Moore (2010:17-18; 2011:703-704), and is certainly not exclusive to the *Homo* line (Davidson and McGrew 2005:798-800; Roffman et al. 2012; Toth et al. 1993). Other primate species lack the imitative abilities of *Homo*, and appear to only pass on behaviours that have short term pay offs (Tehrani and Riede 2008:318; Whiten 2005). It is only humans that have produced complex stone tools, with dynamic life histories requiring planning and cognition beyond this rudimentary utility. Most archaeological sites associated with *Homo sapiens* have documented the discard of stone tools, many of which were finely crafted, throughout a dynamic life history of reduction, use, maintenance, and recycling. It is these finely crafted and complex tools that strongly suggest greater skill levels and imply greater investments into the teaching and learning process.

Complex technologies require a greater time investment by individuals, both teachers and learners, as well as indirect investment by the social group (Hiscock 2014; Shennan and Steele 1999). Many researchers are convinced that mastering any complex lithic

technology requires years of practice (Bamforth and Finlay 2008; Howe et al. 1998; Nunn 2006; Olausson 2008; Pelegrin 1990; Stout 2002), since complex tools cannot be replicated with only observation and imitation (Tehrani and Riede 2008:318). For example, Stout (2002) provides an informative case study of teaching and learning in Irian Jaya, where he observed apprentices learning to knap adzes from around 12 years of age and potentially spending a further decade before reaching the highest recognised production skill level (Stout 2002:333). The social group takes on the cost of these novice individuals spending time learning and practicing the manufacture of such technologies, since instead of making foraging, or social contributions directly, students are learning manufacturing practices and producing suboptimal products, with minimal return (Hiscock 2014). The transfer of knowledge may immediately conjure ideas of descent; however, it is only relatively recently that evolutionary perspectives on contextual pedagogy have been directly applied to stone artefact assemblages (reference to this recent application).

Descent with modification, a core principle of evolution (Darwin 1859), is increasingly being applied to stone artefact assemblage variation (Eerkens and Lipo 2007; Kempe et al. 2012; O'Brien et al. 2012; Schillinger et al. 2014b; Waguespack et al. 2009). All people inherit genetic traits from their parents, and also cultural traits from their social group, via social learning. Cultural traits are inherited through a common descent, whereby information is passed on through individuals. The transmission of this information is subject to evolutionary forces, where the information can be modified before being passed on (Eerkens and Lipo 2007:245-246); a concept referred to as cultural transmission theory [CTT]. CTT can be used to account for common artefact morphologies and the innovation of novel technologies. Modification leading to such novelty can occur through both error and innovation. People continually acquire, modify, and pass on modified information, so the process is fundamentally based on the interaction of both individual experimentation and innovation, as well as social learning and replication (Eerkens and Lipo 2007:242). While the products of this transmission are readily identifiable across the globe, the context of these transmissions in the past is not well known.

A spectrum of teacher-student relationships must have existed throughout prehistory, and it would be superficial to assume that these would resemble modern practices. There are; however, several guiding principles that can facilitate accurate modelling of prehistoric pedagogy. The two main principles of social learning theory, outlined by Tehrani and Riede (2008:318), are imitation and emulation, the former occurs where observers copy a specific set of actions enacted by a role model to accomplish some task, and the latter where an observer focuses only on the outcomes of those actions.

Information is likely to be transmitted more accurately by the authoritative credibility of a recognised expert, or when information is regarded as private or non-public (Eerkens and Lipo 2007:249; Rowlands 1993; Sperber and Hirschfield 2004; Sterenly 2012:136). It is expected that complex technologies depend on social learning, as opposed to individual learning, especially when the cost of experimentation is high (Bettinger and Eerkens 1997, 1999). Highly repetitive information, where the cost of experimentation is

low, is more likely to materialise with less error than information that is less common (Eerkens and Lipo 2007:248; Sperber and Hirschfield 2004; Sterenly 2012:136).

Modern replicative studies provide further guidelines for modes of error transfer that can be applied to archaeological data. Eerkens and Lipo (2007:248) point out that verbal instruction alone results in higher error rates, and visual instruction alone results in slightly lower error rates. The combination of the two was found to be the least prone to error transfer (2007:248). Schillinger et al. (2014a:1) conducted material reproduction experiments, and found that less copying error occurred when people had manufactured immediately after viewing the target morphology, rather than from long term memory. This study also found that copying error rates were lower when a manufacturer compounds or amalgamates components for a technology (Schillinger et al. 2014a:1).

In light of these theoretical and modern replicative studies, it is reasonable to conclude that if a technology is common, and hence more public, the skills would likely be learnt without a formal teaching and learning relationship. Conversely, if a technology is less common, and more private, a socially exclusive teaching and learning environment is probably the standard. The teacher and implied expert of some craft or technology has to alter their behaviour to suit the teaching process, rather than normal production and use. The teacher(s) of complex technologies change their behaviours in order to promote learning (Caro and Hauser 1992; Gregeley and Csibra 2006; Tehrani and Riede 2008:320). For example, the archaeological record may contain artefacts where both master and apprentice have worked on the same piece, a phenomenon termed scaffolding (Crown 2001:462; Greenfield et al. 2000; Stout 2002). Scaffolding is a procedural system of teaching and learning that is probably essential to craft and tool making, since it builds upon the relevant skills. Greater amounts of scaffolding are associated with greater complexity and vice versa.

The recognition of skill in the archaeological record is highly subjective. Symmetry and regularity, which could often be an output of high skill (Whittaker 1994:191), can also be the result of edge maintenance gradually producing such morphologies, rather than intentional production of a symmetrical morphology. The identification of skill on individual stone artefacts has used the frequency of aberrant flake terminations such as steps and hinges (Assaf et al. 2015; Bamforth and Findlay 2008:6; Grimm 2000:54; Finlay 2008:83-84; Shelley 1990:198) caused by unsuccessful blows creating incipient fractures (Hiscock 2014:33), as well as low length to width ratios (Fischer 1989, 1990; Stout 2002; 2005). Identification of skill using these 'classic elements' (Finlay 2008:84), can also be affected primarily by raw material quality, regardless of skill level. So poorly knapped artefacts being indicative of novice knappers (e.g. Finlay 1997:207; 2008:82, 85; Högberg 2008:117), may be fundamentally flawed. In this way, raw material economy and availability must be accounted for if poorly knapped artefacts are used as measure of skill (Findlay 2008:70), particularly if apprentices or novices use different materials to other more skilled knappers (e.g. Högberg 2008:127-128). Olausson (2008:34) raises doubts on whether archaeological assemblages can reveal the nature of skill acquisition by individual knappers at all. It must be considered that in many assemblages, the archaeologist is analysing the unwanted waist of reduction, or exhausted tools that people discarded (Davidson and Noble 1993:365). So determining skill from these data is not

only very complex, but is often based on perceptions and methods that may not be universally applicable.

Another problem in using identified skill to explore pedagogical contexts in the archaeological record is the fact that experts will also produce errors, and novices will also produce successful tools (Assaf et al. 2015:14; Buonsanto and Peretto 2013:187). Regardless, these more or less skilled products do not provide a means of identifying the nature of pedagogy beyond such artefacts being found in distinct activity areas within sites (Assaf et al. 2015) or landscapes (Moore 2015). Despite several studies identifying novice and expert knapping products (e.g. Fischer 1990; Grimm 2000; Karlin and Julien 1994; Pigeot 1990), there remains no technique to quantify of the level of teaching required, or the level of pedagogical investment, for different archaeological technologies.

A credible alternative is to measure the complexity of technology. One such novel application of this method uses the length of the descriptions of regularities, which Gell-Mann and Lloyd (2003:387) term effective complexity. The length of the description of regularities refers to how many factors or cues need to be relayed to the learner, by the teacher. Complex technologies require a longer description of the associated regularities than simple ones. This premise finds strong support from cognitive psychology data analysed by Gergeley and Csibra (2006), who show that copying behaviours of children are improved when the teacher or parent uses pedagogical cues. These researchers argue that such cues, or regularities, which provide a structured correction mechanism, are a prerequisite for complex skills and behaviours (Gergeley and Csibra 2006:239). Effective complexity therefore includes some level of teaching, rather than focusing on manifest individual abilities and practices. Rather than a quantification of units of complexity, effective complexity attempts to identify the non-random and essential components of a teaching system that must be conveyed in order to produce, activate, or create. Effective complexity is used in this study to make general contrast of lithic reduction sequences, from more simple, to more complex. It is inferred from these contrasts of effective complexity that the case study reduction sequences represent different levels of investment into teaching and learning.

Case study background: Point technology in the Kimberley

A case study from the Kimberley region of northern Western Australian is used to contrast the effective complexity of two stone artefact reduction sequences: pressure flaked bifaces and direct percussion points. Each technology is described below.

Pressure flaked bifaces/Kimberley Points

Kimberley Points are the only Australian stone tool reduction sequence to involve systematic pressure flaking. Kimberley Points are pressure flaked bifaces with marginal serrations (Figure 1) produced within the Kimberley region of northern Western Australia (Figure 2). The terms Kimberley Point and Kimberley Dentate Point (after Akerman and Bindon 1995) both shown in Figure 1, are here synonymous with pressure flaked biface. Pressure flaked bifaces were first widely produced around 1,000 cal BP (Maloney et al. 2014). Manufacture was initially endemic to the Kimberley region, although finished

points were widely traded into regions across the north of the continent¹. Figure 2 illustrates this distribution.

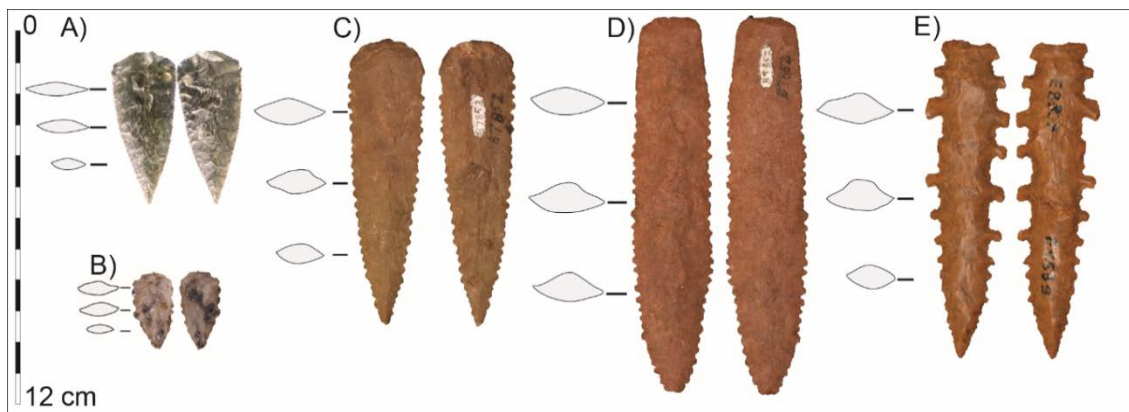


Fig 1 Examples of pressure flaked bifaces A) Bottle glass Kimberley Point with serrate margins B) Crystal quartz Kimberley Point with serrate margins, from Carpenters Gap 3 (Maloney et al. 2014:139 fig. 3) C) Quartzite Kimberley Point with serrate margins D) Quartzite Kimberley Point with serrate margins E) Chert Dentate Kimberley Point with dentate and serrate margins

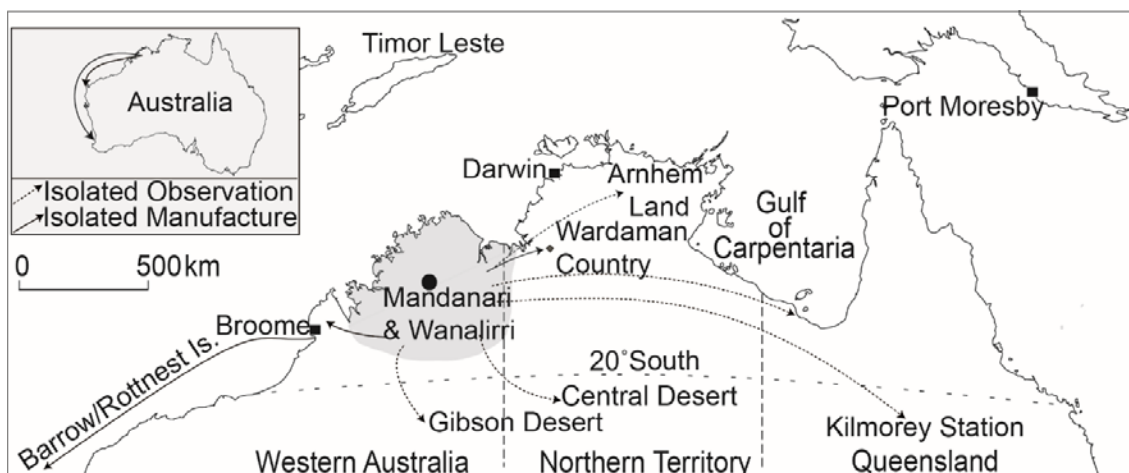


Fig 2 Map of northern Australia showing approximate boundary of Kimberley Point distribution, including isolated observations and manufacturing areas

¹ Kimberley Points have been observed in parts of the Northern Territory such Wardaman Country (Davidson 1935:170), Port Keats (Falkenberg 1968:19, 24; cited in Akerman 2008:75), the Tennant Creek area (Spencer 1928:17 fig 147), the Alligator Rivers (Akerman et al. 2002:22), Central Desert regions (Gould 1980:141-143; Spencer 1928:510-511; Spencer and Gillen 1904:675-676), the Gibson Desert region (Akerman et al. 2002:18), the Western Desert (Tindale 1985:12), and even as far east as central Queensland (Akerman and Stanton 1994:17), and the Gulf of Carpentaria (Davidson and McCarthy 1957:450). Manufacture outside the Kimberley region occurred in Wardaman country within the last 300 years (Clarkson 2007:157; Davidson 1935:170), Rottnest Island prison off the coast of Perth in the 20th Century (Harrison 2002:361-363), the Dampier Peninsula in the 20th Century (Akerman pers. comm.), and Barrow Island, probably during the pearling Industry in the mid-20th century (Hunter pers. comm.).

Kimberley Points are a highly significant cultural item in certain contemporary Aboriginal societies. Many Indigenous people retain stories and memories of these points, with oral histories providing several chronologies and mythologies associated with these artefacts (Akerman et al. 2002:15-17; Harrison 2006:73; Tindale 1985:1, 26-27), which

archaeologists have used to temporally separate pressure flaked bifaces from earlier point technologies, in conjunction with radiocarbon dating (Maloney et al. 2014:142). Until recently, manufacture and morphological variability of these artefacts was largely inferred from ethnographic and historical data. Europeans began occupying large tracts of inland country after 1885 AD (Harrison 2006:63), one consequence of which is a rich ethnographic record from the late 19th century, which occasionally recounts the manufacture of Kimberley Points, and some observation of the role this technology played in Aboriginal societies (Balfour 1903, 1951:274; Basedow 1925:367-370; Elkin 1948:110-113; Indriess 1937:59-62; Kaberry 1939:16, 165; Love 1917:25-26, 2009 [1936]:93-95; Mitchell 1949:64; Petri 1954; Spencer 1928; Tindale 1985:8-11). Kimberley Points were collected in the 19th and 20th century, when these items were part of an elaborate Indigenous trade network called *Wunan*, which extends across the entire north-west region (Akerman et al. 2002; Blundell 1975:403; Blundell and Woolagoodja 2005:129; Redmond 2012). During the early 20th century, Kimberley Points were also produced for a non-Indigenous market, and production rates likely proliferated when trade for European commodities, such as flour, tobacco, and new raw materials, were adopted by Aboriginal societies (Harrison 2002:358, 364). During the latter half of the 20th century, Kimberley Points were collected for museums (see Akerman 2008; Harrison 2006). Today, these bifaces continue to be used in ceremonial practices, and cultural exchanges.

Ethnographic observations and more recent archaeological studies (Akerman and Bindon 1995:94-95; Akerman et al. 2002:18-20; Moore 2000, 2015) reveal a staged manufacturing process for Kimberley Points. This involves regulated design stages and biface morphologies, geared to the production of a specialised end product – the pressure flaked biface. These were occasionally made from flakes, but large tabular pieces of stone (later glass and ceramics), which are technically cores, are often described as the blanks (Akerman and Bindon 1995; Akerman et al. 2002; Moore 2015). A bifacial preform was initially produced by direct percussion flaking, creating a relatively thin and ovate shaped biface (Akerman and Bindon 1995:94; Akerman et al. 2002:19). This production stage was crucial to facilitating further pressure flaking, which later removed more regular and invasive flakes with greater control of force. Pressure flaking was accomplished with multiple tools manufactured from wood, bone, and later metal (see Love 2009 [1936]:93-95), in conjunction with stone anvils and paper bark layers to immobilise and insulate the biface during pressure flaking. The final production stage saw finer pressure flaking produce serrate, denticulate, or dentate margins (Figure 1). The technique of pressure flaking that developed in the Kimberley is unlike those found in the Americas (e.g. Crabtree 1966); and involved a unique orientation of the pressure flaker (Figure 3).

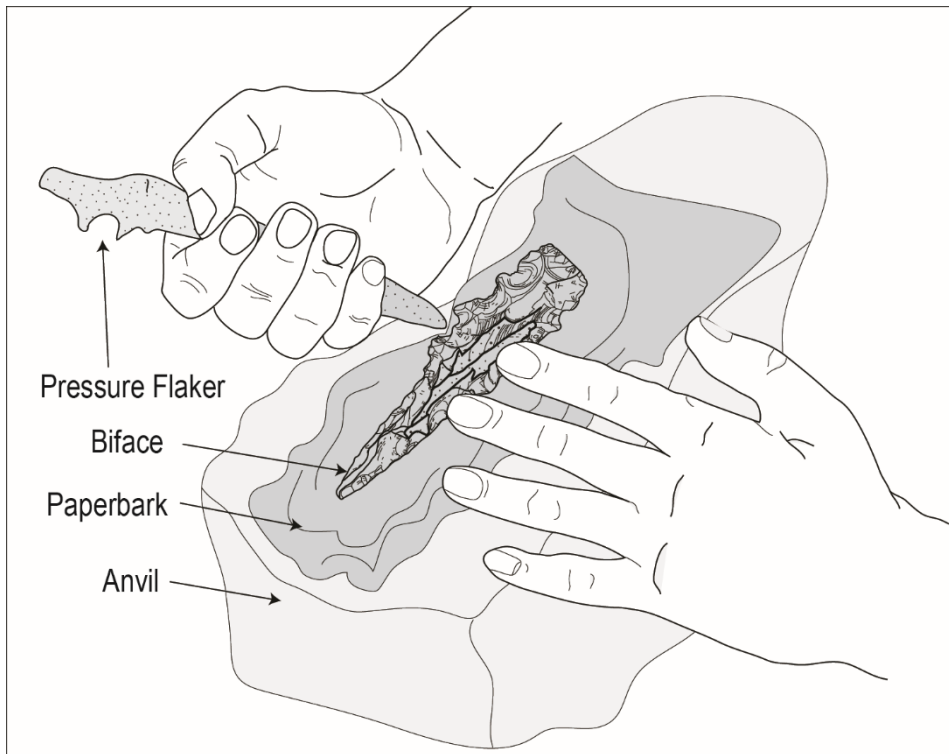


Fig 3 Orientation of pressure flaker during Kimberley Point pressure flaking

Ethnographic data further reveal contexts of pedagogy from the recent past, where pressure flaking was a socially exclusive skill that carried prestige (Akerman 2008; Harrison 2002:364; Moore 2015). Ethnographic images have often captured a teacher and student relationship, associated with this technology (Love 2009:93 [1936]; Tindale 1985:19). Similar to the conclusions of Apel (2008:109) on Danish bifacial daggers, Moore argues that biface production in the Kimberley was socially exclusive. He argues that the bifacial thinning or preform production stages were conducted in private, and the pressure flaking stages were conducted before an audience, instilling social prestige upon the producers. In support of this model, Moore (2015) discusses an ethnographic account by Davidson (1935:170) from Wardaman Country in the Northern Territory (Figure 2), where the production of thinned bifaces, which enabled pressure flaking, was unknown to the Wardaman. Ethnographic accounts also support biface production skill being non-uniformly distributed within, and across Kimberley social groups (e.g. Lommel 1997:6 [1952]; Petri 2011:32 [1954]; Porteus 1931:112; Spencer 1928:511; Tindale 1985:11). Internal social group skill variation was observed by Kaberry (1939:16, 165) and Akerman (1978:489; 1979:149-150). There is therefore a strong case for Moore's (2015) argument in recent Kimberley society, with some exceptions. For example, Akerman (2008:72) notes that while men would pressure flake within a camp site, they would more often move to a more isolated location to conduct pressure flaking, and further notes that the necessity for good lighting in pressure flaking meant that rock shelters were seldom appropriate for this task. Whether biface production stages were unanimously socially exclusive across the Kimberley is an engaging and testable hypothesis; regardless, it is apparent that in the recent past, Kimberley Point production relied on a formal pedagogy with scaffolding.

Direct percussion points

Unlike pressure flaked bifaces, direct percussion points are invariably reduced from flakes, and typically exhibit a wide range of retouch intensities and morphologies (Figure 4). Direct percussion points are found across many areas of northern Australia during the mid to late Holocene (Figure 2) (Clarkson 2006; Dortch 1977; Flood 1970; Hiscock 1994a; Maloney et al. 2014). In the Kimberley, these points first appear around 5,000 cal BP, proliferate between 3,000 and 1,500 years ago and continue to be manufactured after the development of pressure flaked bifaces within the last millennium (Maloney et al. 2014).

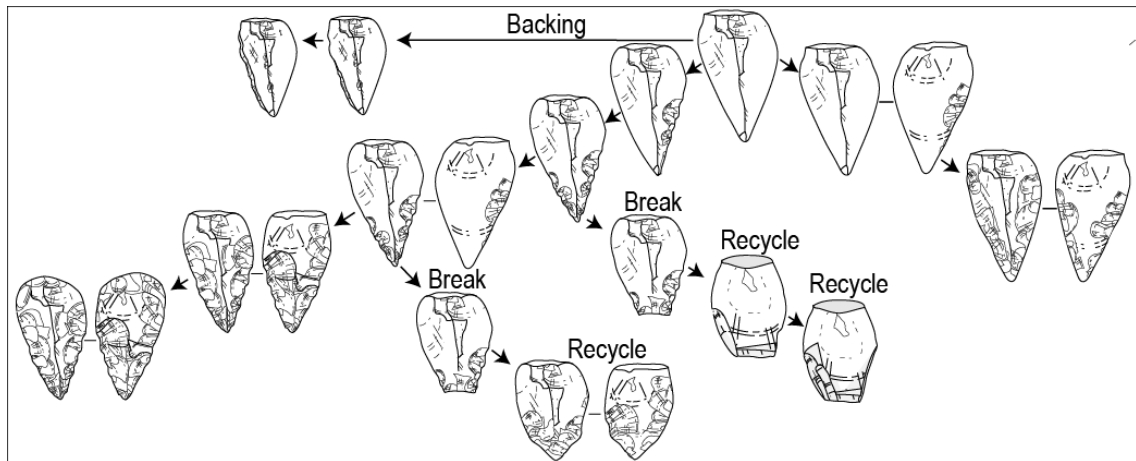


Fig 4 Point reduction continuum from Mt Behn showing a diversity of retouch strategies and recycling within the point reduction continuum (Maloney et al. In Review)

Direct percussion points within this distribution exhibit unifacial and bifacial retouch, which resulted in a typological interpretation of mutually exclusive, discontinuous designs for each type of retouch (see Hiscock 1994a). This typological model for direct percussion points has been dismantled in parts of northern Australia, where a reduction continuum model provides a far more convincing explanation of morphological variability (Clarkson 2006:103-104, 2007:101-112, 160; Hiscock 1994a:77-80, 2006:77-78, 2009:84-85; Macintosh 1951:200; Maloney 2010:89-103; Maloney et al. In Review; Roddam 1997; Smith and Cundy 1995:34). The reduction continuum model posits that a single ramified reduction process existed between various lightly retouch points, often unifacial, and more heavily reduced bifacial points. There is no rigid or finished tool design evident in these studies, although there were occasional discrete forms of backing (Maloney and O'Connor 2014). Overall, direct percussion points display gradual morphological change, likely a result of maintaining or extending the usability of these tools for a wide range of tasks. Many researchers are now convinced that direct percussion points were a technological strategy that helped to reduce foraging risk during the mid Holocene (Clarkson 2006, 2007, 2008; Hiscock 1994a, 1994b, 2009, 2011; Maloney et al. In Review). Other explanations posit social drivers of change linked to population increase as a more pertinent factor (Moore 2011, 2013).

The two reduction sequences previously described provide a testing ground for effective complexity as a gauge of the likely educational processes associated these stone technologies. Pressure flaked bifaces are complex and require great skill. Direct percussion points are less complex, probably require less skill, and exhibit great

morphological diversity. While direct percussion points are found in relatively large samples in excavations and surface collections, pressure flaked bifaces are far less common in archaeological contexts.

Case study samples

Pressure flaked bifaces, although often noted in surface collections (O'Connor 1999:71), are seldom recovered from excavated deposits (Maloney et al. 2014:137); therefore, surface collections provide the largest available samples for these reduction sequences.

Two rock shelter surface assemblages, which were originally collected by Blundell (1975) from Ngarinyin country in the central Kimberley region (Figure 2), were sampled for this study. The Ngarinyin names for these sites are Mandanari and Wanalirri (Blundell 1975:197-198). While the 'total surface assemblage' was collected at each site, the lack of artefacts smaller than 10 mm probably suggests a size bias. Collections were sieved, although the screen size is not provided (Blundell 1975:227). Individual artefacts were not plotted within the sites, and so cannot facilitate the analysis of spatial difference in activity areas, such as that demonstrated by Assaf et al. (2015). In the absence of radiocarbon dates, Blundell (1975:201, 305) estimated the antiquity of these two sites to range from the late prehistoric to early historic periods. Artefacts from these sites cannot be reliably dated, but will be discussed later with reference to recent dating of point industries from the wider region (Maloney et al. 2014).

The original surface collection at Mandanari recovered 178 lithic pieces (Blundell 1975:198), and reanalysis of this sample identified 138 flaked stone artefacts. The remaining 40 specimens are excluded from this analysis due to the lack of unambiguous conchoidal fracture evidence. The technological classes and raw material frequencies for Mandanari are listed in Tables 1 and 2.

Table 1 Stone artefact frequency in Mandanari sample. Bracketed numbers represent subtotals

Stone Artefacts	n	% of Sample
Biface	24	14.5
Dentate Kimberley Point	1	0.7
Core	11	10
Direct Percussion Point	27	19.5
- (Unifacial Point)	(13)	(10)
- (Bifacial Point)	(5)	(5.8)
- (Backed Point)	(2)	(1.4)
- (Broken Point)	(7)	(5)
Retouched Flake	4	(3)
Broken Retouched Flake	3	2
Flake	50	36
Broken Flake	6	4.5
Flaked Piece	7	5.8
Tabular Piece	5	1.4
Total	138	100

Table 2 Raw material frequency in Mandanari sample. Bracketed numbers represent subtotals

Raw Material	n	% of Sample
Quartzite	104	75.3
- <i>White/Pink</i>	(59)	(42.5)
- <i>Purple</i>	(5)	(3.6)
- <i>Red</i>	(11)	(8)
- <i>Purple/grey</i>	(17)	(12.3)
- <i>Orange</i>	(11)	(8)
- <i>Mottled</i>	(1)	(0.7)
Chert	6	4.4
Hornfels	2	1.5
Tuff	7	5
White Vein Quartz	4	3
Crystal Quartz	1	0.7
Mudstone	7	5
FGS	2	1.5
Glass	5	3.6
Total	138	100

The second analysed site, Wanalirri, included 46 stone artefacts, which was the total of Blundell's surface collection (Blundell 1975:192). Additionally, a single test pit reached bed rock at 30 cm below the surface, and recovered an additional sample of 183 artefacts, of which, only the first and upper most unit was recorded in the analysed sample (n = 43). This unit is the only one from the excavation containing points and bifaces. A combined total of 89 stone artefacts make up the analysed sample from Wanalirri. The technological classes and raw material frequencies are listed in Tables 3 and 4. Several Europeans are known to have visited this site and removed artefacts².

Table 3 Stone artefact frequency in Wanalirri assemblage. Bracketed numbers represent subtotals

Wanalirri		
Stone Artefacts	n	% of Sample
Biface	2	2.3
Core	5	5.6
Direct Percussion Point	39	43.8
(Unifacial Point)	(14)	(15.8)
(Bifacial Point)	(8)	(9)
(Broken Point)	(17)	(19)
Flake	24	27
Broken Flake	19	21.3
Total	89	100

² Ngarajin people recalled a German anthropologist visiting Wanalirri during the Second World War, which Blundell (1975:193) suggested was Lommel (Lommel 1997 [1952]; see Akerman 2014:23). Ian Crawford, the Western Australian Museums' first archaeology curator, also visited this site in the early 1960's (Crawford 1968:40-42, 107-109). It is very plausible that both visitors removed Kimberley Points.

Table 4 Raw material frequency in Wanalirri assemblage. Bracketed numbers represent subtotals

Raw Material Type	n	% of Sample
Quartzite	84	94.4
- <i>White/Pink</i>	(34)	(38.2)
- <i>Purple</i>	(20)	(16.8)
- <i>Red</i>	(11)	(12.3)
- <i>White/grey</i>	(19)	(21.3)
Chert	3	3.4
Crystal Quartz	1	1.1
Hornfels	1	1.1
Total	89	100

Methods

Other studies pursuing pedagogical models from stone artefact data have followed a chaîne opératoire approach, with an emphasis on refitting (e.g. Piegeot 1990; Fischer 1989; Tehrani and Riede 2008:322-324), which was not a viable approach to these smaller samples. Instead, this study quantifies morphological variability and employs reduction indices. To quantify morphological variability within each reduction sequence, a range of linear measurements were recorded with digital callipers and 3D laser scanning. These included multiple length, width, and thickness measurements. In the absence of a flake initiation point, biface length was measured as the longest axis parallel to lateral margins, and width measurements were taken perpendicular to this axis. Cross-sectional shape was quantified by width to thickness ratios, calculated at three points along length. A Next Engine 3D laser scanner was employed to record 3D models of artefacts. These models were used to calculate total surface area of each complete artefact, and the platform surface area of flakes and direct percussion points (following Clarkson and Hiscock 2011). Cross section shape images were also produced using these 3D models (following Maloney and O'Connor 2014:150). These cross section images accompany high resolution photographs of bifaces to convey the morphological change in cross section morphology associated with biface thinning.

Bifaces reduced from tabular pieces, instead of flakes, are identified by the absence of a positive ventral surface, and the presence of bifacial negative scars. While these artefacts are technically cores (Hiscock 2007), they are morphologically distinct from other cores, since they exhibit biconvex cross sections, and low average platform angle. This morphological distinction is tested with the variation in biface average edge angle, and the average core platform angle, measured with a goniometer.

The identification of biface production stages uses Moore's (2015) biface production phases, developed through analysis of open sites from the north-west Kimberley. In following Moore's (2015) biface production phases, I prefer the term stage, which emphasises production in anticipation of use (Andrefsky 2009), and the progression through discrete cues. The discrete elements of each production stage are:

Production Stage 1: Production of large blanks directly from bedrock edges or cobbles.

Production Stage 2: Thinning and initial shaping of blanks with direct percussion.

Production Stage 3: Invasive thinning decreases relative thickness.

Production Stage 4: Thinning with invasive collateral pressure flaking.

Production Stage 5: Additional pressure flaking to produce marginal serrations.

Biface thinning is often analysed with a debitage analysis approach (Crabtree 1972), which attempts to identify unique flakes and percussor types. Such debitage analyses are not well suited to sites with multiple reduction sequences (Andrefsky 2009:83). The identification of percussor type from flake morphology in the analysed assemblages would be valuable, but is not feasible, and recent experimental studies raise serious doubts on the recognition of hard hammer percussors (Driscoll and García-Rojas 2014:140). Identification of flakes produced from pressure flaking in the archaeological record is also problematic in many cases (Andrefsky 1983, 1986, 2005:119, 123; Ammerman and Andrefsky 1982; Maloney et al. 2014:138; Sappington 1991:70). Akerman (2008:72) notes that pressure the flaking of Kimberley Points consistently results in shattered flakes. Negative scars originating from small, isolated initiations aligned with parallel flake scars are evident on experimental reproduction of pressure flaked points (e.g. Mourre et al. 2010:660-661 fig. 1 and 2), and so provide one means of identifying pressure flaking. While some Kimberley Points will retain these flake scars (Figure 1 A and C), many do not (Figure 1 B, D and E). Only scars that resemble the aforementioned pressure flaked scar morphology are recognised as reliable signals of pressure flaking. Fine lateral projections, either serrate, denticulate, or dentate, are also used as a feasible signal of pressure flaking (following Maloney et al. 2014:138).

The effective complexity of these reduction sequences is modelled using the observed and demonstrated technological actions to represent the description of regularities. Statistical analyses run with SPSS version 24 software, included one way ANOVA, Chi square, T-test, and multi-regression analyses.

Results

Biface Production

Biface production is a major component of discarded technology in the Mandanari assemblage. The 24 complete bifaces allow the production stages to be teased out. The blank morphologies were typically large tabular pieces of white/pink quartzite (Figure 5 A), or occasionally large flakes ($n = 3$) (Figure 5 B, Figure 6 A and B). These blank morphologies are defined as production stage 1. Bifacial removal of invasive flakes with direct percussion, which begins to thin the cross section, is defined as production stage 2 (Figure 5 C and D).

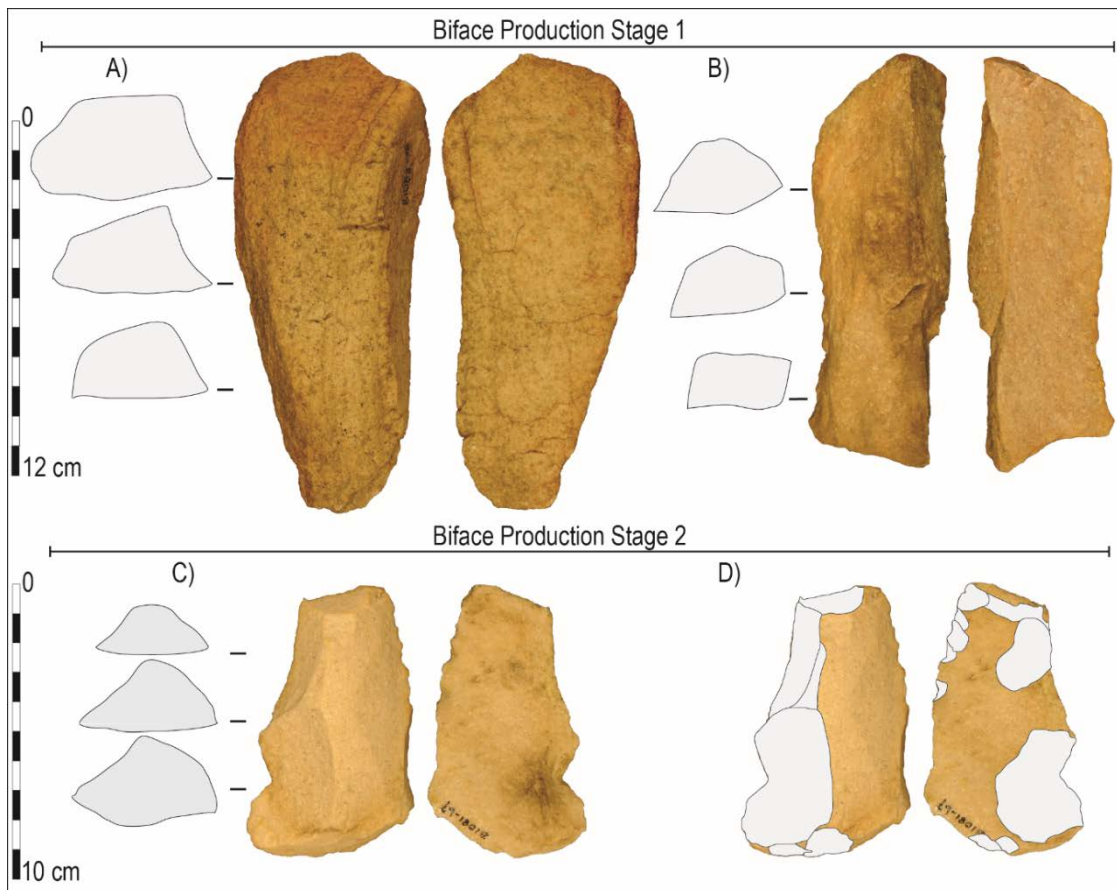


Fig 5 Biface production stages 1 and 2 A) Tabular piece of white/pink quartzite, lacking any ventral surface B) Large white/pink quartzite flake C) Tabular piece with no platform or ventral surface, with early bifacial reduction D) Highlight of the early stages of bifacial reduction on tabular piece

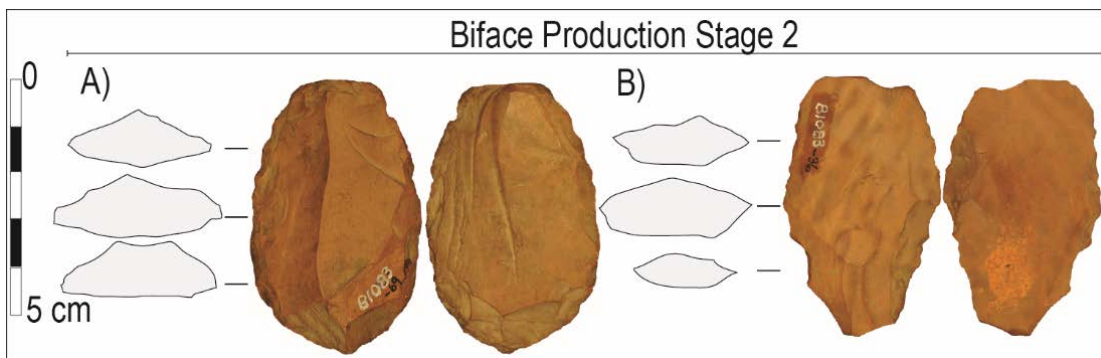


Fig 6 Biface production stage 2 A) Ventral and dorsal surface, as well as platform initiation point are evident, with bifacial scars extending across the margins B) Invasive flake scars have removed the flake platform surface, although partial ventral surface remains

Where bifacial thinning continues, and width to thickness ratios are reduced, the morphology resembles the bifacial preform identified by Akerman and Bindon (1995:94). Figure 7 illustrates examples of bifaces with relatively thin biconvex cross sections; these scars are invasive and terminate as either feathers, or very slight hinges and steps. Evidence for pressure flaking is totally absent. This morphology is identified as biface production stage 3.

Production stage 3 is the most error prone. Failed attempts at producing the stage 3 morphology are here defined as stage 2 failures, as the relatively thin cross section and invasive flaking of stage 3 is not accomplished. Figure 8 illustrates examples of these stage 2 failures in the Mandanari assemblage, where multiple bifacial flakes have been removed, forming a stepped biconvex cross-section, without invasive scars breaching the centreline of the biface. Accumulations of step terminating flakes perpetuated a build-up of mass towards the centre of the biface, while reducing biface width. The inability to thin bifaces at stage 2 created increased relative thickness, also reducing length without reducing width. Figure 9 illustrates biface length against width, from the Mandanari assemblage, conveying a linear trend of biface elongation throughout the production stages. Notably, production stage 2 bifaces, including the failures, outlie the otherwise linear trend of biface elongation. In fact, analysing biface elongation throughout these production stages with linear regression analyses, stage 2 is significantly different ($r = 0.729$, $r^2 = 0.531$, $df = 1$, $f = 24.897$, $p = <0.001$). Crushing on all stage 2 failure bifaces indicates repeated blows that likely caused incipient fractures. Breakage patterns provide further support for stage 2 being error prone. For example, Figure 10 illustrates three examples where transverse snaps occurred before invasive bifacial thinning formed a biconvex cross section. Negative scars initiated at these transverse snaps probably indicate breakage during manufacture (Ahler 1992:42, 56 fig 8).

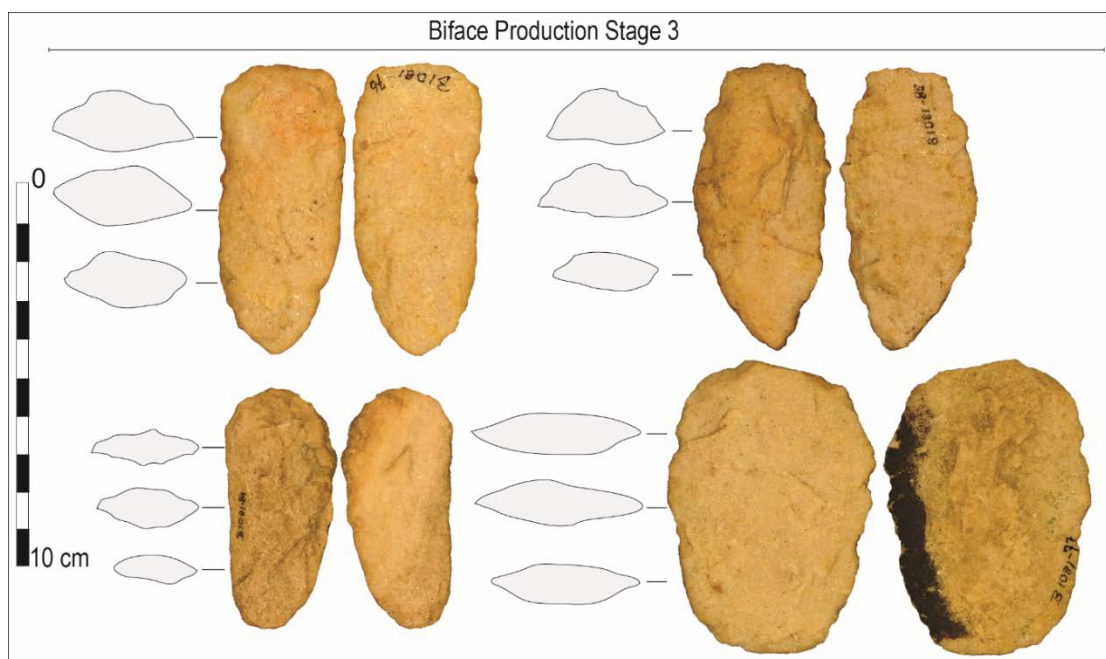


Fig 7 Production stage 3 bifaces with biconvex cross sections and invasive flake scars

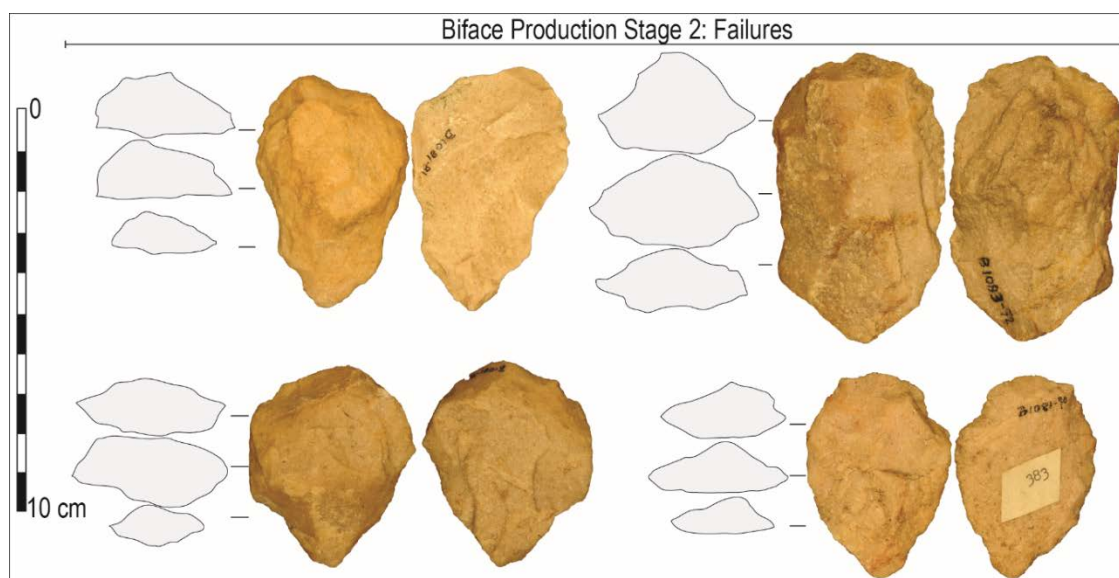


Fig 8 Production stage 2 failures, with step terminating scar build ups towards the centre of the biface

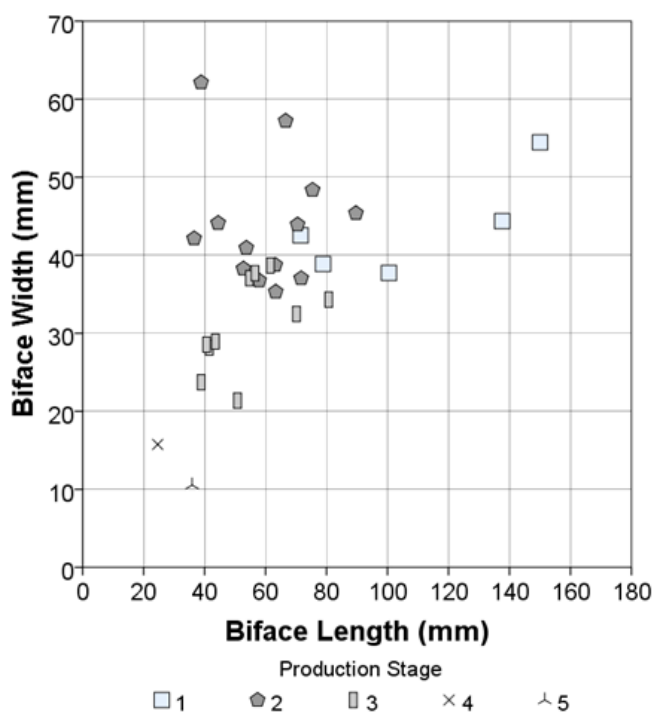


Fig 9 Biface width against length showing biface production phases and outlying nature of stage 2

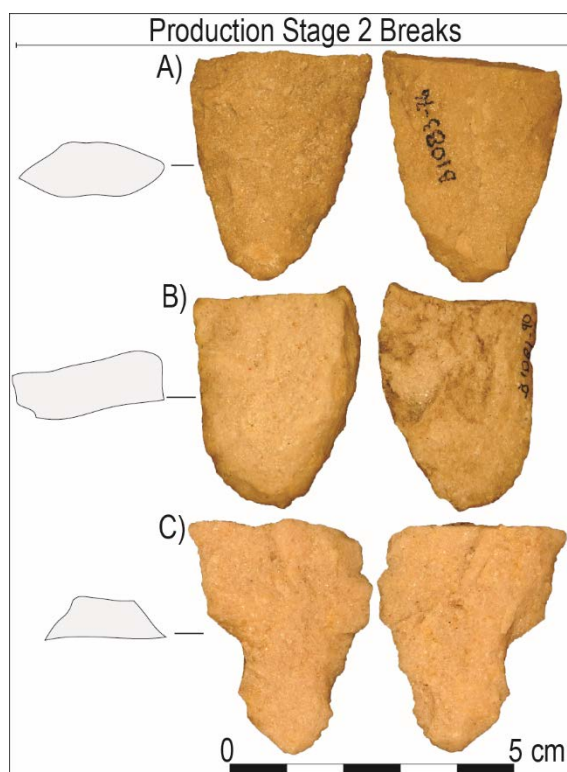


Fig 10 Broken biface fragments with transverse snaps

When such failures did not occur, collateral pressure flaking removed more controlled invasive flakes (production stage 4), followed by the production of marginal serrations (production stage 5). These production stages are represented by only two pressure flaked bifaces in the Mandanari assemblage (Figure 11). A single pressure flaked biface made on red quartzite was recovered, exhibiting unambiguous pressure flaking scars without marginal serrations (Figure 11 A and B). Only one pressure flaked biface with marginal serrations was recovered: A Kimberley Dentate Point with a transverse snap removing the tip (Figure 11 C). A negative scar truncated by this transverse snap suggests that breakage possibly occurred during manufacture (Ahler 1992:42, 56 fig 8). Pressure flaking most probably involved the use of an anvil and insulation, such as paper bark, to facilitate this fine control of pressure flaking and prevent breakage, although none of these materials were noted by Blundell (1975).

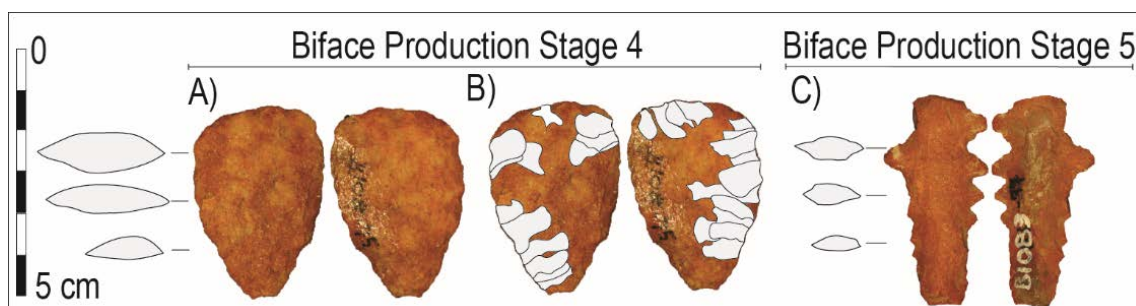


Fig 11 The pressure flaking biface production stages 4 and 5 A) Red quartzite biface with pressure flaking scars B) Outline of unambiguous pressure flaking scars C) Dentate Kimberley Point with transverse snap removing distal portion

The frequency of the five biface production stages in the Mandanari assemblage is listed in Table 5. There are two identified blank morphologies: Large tabular pieces and large

flakes, which indicate that there are at least two major reduction pathways for the initiation of biface reduction, represented by stages 1, 1a, 2 and 2a. Trends within these sequential production stages include a stepwise decrease in length and mass, as shown in Figures 12 and 13. There is also a correlation between the intensity of bifacial reduction, measured using the Index of Invasiveness (Clarkson 2002), and increasing biconvexity in cross sections, measured by width to thickness ratios (Table 6).

Table 5 Biface production stages

Stage	Description	Cases
1	Blank morphologies of tabular pieces	4
1a	Blank morphologies of large flakes	1
2	Bifacial reduction of tabular piece forming initial biconvex cross section	12
2a	Bifacial reduction of large flake forming initial biconvex cross section	2
3	Bifacial reduction thins biface	9
4	Pressure flaking used to thin biface	1
5	Pressure flaking used to form marginal serrations	1

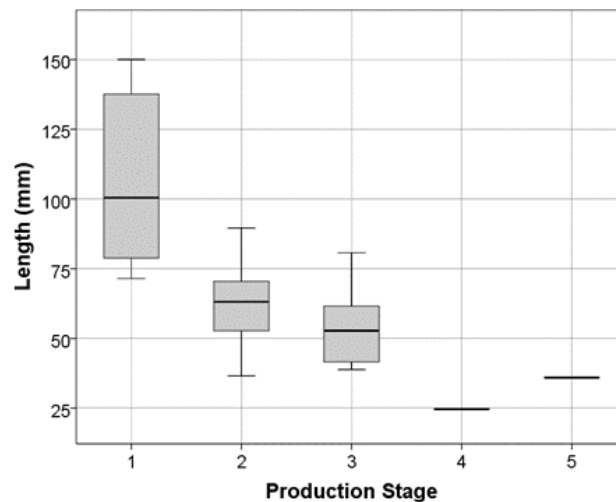


Fig 12 Decreasing length of bifaces across 5 production stages from Mandanari

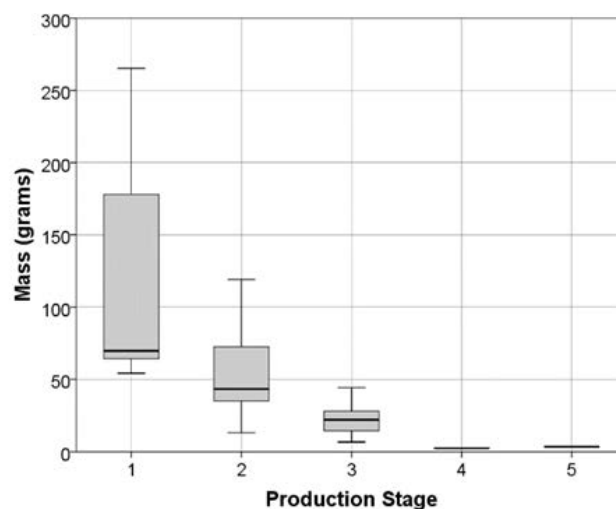


Fig 13 Decreasing mass of bifaces across 5 production stages from Mandanari

Table 6 ANOVA results for comparison of Index of Invasiveness and cross section ratios

Biface Cross Section (n = 24)	df	F	p
Proximal Width to Thickness	14	7.000	0.021
Mid Width to Thickness	14	3.478	0.088
Distal Width to Thickness	14	6.886	0.022

The Wanalirri assemblage contained two bifaces. Both are made on fine grained white to pink quartzite, and neither display any trace of a ventral surface. One biface represents production stage 2, with a thinned biconvex cross-section, although several step terminating scars created a buildup of mass towards the center of the biface (Figure 14 A). The second biface represents production stage 4, where collateral pressure flaking further thinned the biface, after a biconvex cross section was produced (Figure 14 B and C).

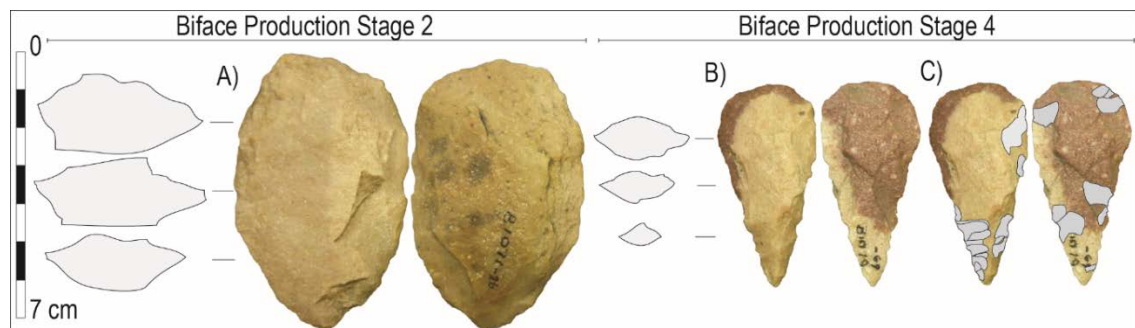


Fig 14 The two bifaces from Wanalirri A) Quartzite biface with step termination build ups B) Biface with early stages of pressure flaking C) Outline of unambiguous pressure flaking scars

Direct Percussion Points

The Mandanari sample contained a total of 20 complete, and 7 broken direct percussion points, and the Wanalirri sample contained 22 complete, and 17 broken direct percussion points, all reduced from flakes. None of these direct percussion points were observed with any evidence for pressure flaking. The complete bifacial points made on flakes with direct percussion each retained remnant platform surfaces, even in instances where retouch spread to the platform. In contrast to the biface reduction stages, increasing retouch intensity, measured using the Index of Invasiveness (Clarkson 2002), did not significantly thin the cross section of direct percussion points in either assemblage (Table 7). The distal width to thickness ratio of points in the Wanalirri assemblage is one exception to this trend, perhaps indicating an emphasis on reducing the distal portion of points at this site.

Table 7 ANOVA results comparing direct percussion point retouch intensity (Index of Invasiveness) with width to thickness ratios

Mandanari direct percussion points (n = 20)			
Direct Percussion Point Cross Section (n = 20)	df	F	p
Proximal Width to Thickness	10	2.116	0.166
Mid Width to Thickness	10	0.994	0.520
Distal Width to Thickness	10	0.802	0.637
Wanalirri direct percussion points (n = 22)			
Direct Percussion Point Cross Section (n = 22)	df	F	p
Proximal Width to Thickness	15	0.638	0.771
Mid Width to Thickness	15	2.727	0.137
Distal Width to Thickness	15	13.769	0.004

The order and placement of retouch in these direct percussion points demonstrates a gradual spread of retouch, without regular stages. Table 8 lists the order of retouch observed on complete direct percussion points, which shows that while a diversity of retouch strategies were followed; bifacial retouch was typically added to the ventral surface subsequent to unifacial retouch on the dorsal surface. A single case was observed in the Mandanari assemblage where bifacial retouch was applied subsequent to the ventral surface being retouched. One of the 2 ambiguous retouch order observations in this assemblage is a backed point, with bipolar anvil rested retouch, and the other exhibits alternate bifacial flaking obscuring the original retouch order. Of the 13 discarded bifacial points in the Wanalirri assemblage, 6 exhibited ventral last retouch orders, 2 dorsal last retouch orders, and 7 with alternate bifacial retouching.

Table 8 Retouch order observed on complete direct percussion points, and 5 broken points where retouch order was observable

Mandanari complete direct percussion point retouch order (n = 20)					
Retouch Order	Dorsal Only (unifacial)	Ventral Last (bifacial)	Ventral Only (unifacial)	Dorsal Last (bifacial)	Ambiguous (bifacial)
Frequency	14	3	0	1	2
% of Points	70	15	0	5	10
Wanalirri complete direct percussion point retouch order (n = 22)					
Frequency	7	6	2	0	7
% of Points	31.8	27.3	9.1	0	31.8

Direct percussion points, whether unifacial, bifacial, or backed, were made from the same pool of standardized flakes. No significant difference in platform characteristics was detected between the two traditional point typologies in either assemblage (Table 9), demonstrating that a reduction continuum is responsible for retouch variation. In the Mandanari assemblage, there was also no significant difference between the unretouched flakes' 3D scanned platform area (n = 35), and the early stages of direct percussion point reduction (n = 13), using a subset of Index of Invasiveness scores below 0.3 ($r = 0.125$, $r^2 = 0.016$, $df = 1$, $f = 0.174$, $p = 0.685$). This test indicates that all direct percussion points were reduced from similar flakes in terms of mass and platform morphology. This test

was not possible for the Wanalirri direct percussion points due to smaller sample size of complete platforms. Figure 15 illustrates a range of retouch strategies evident within the point reduction continuum at Mandanari.

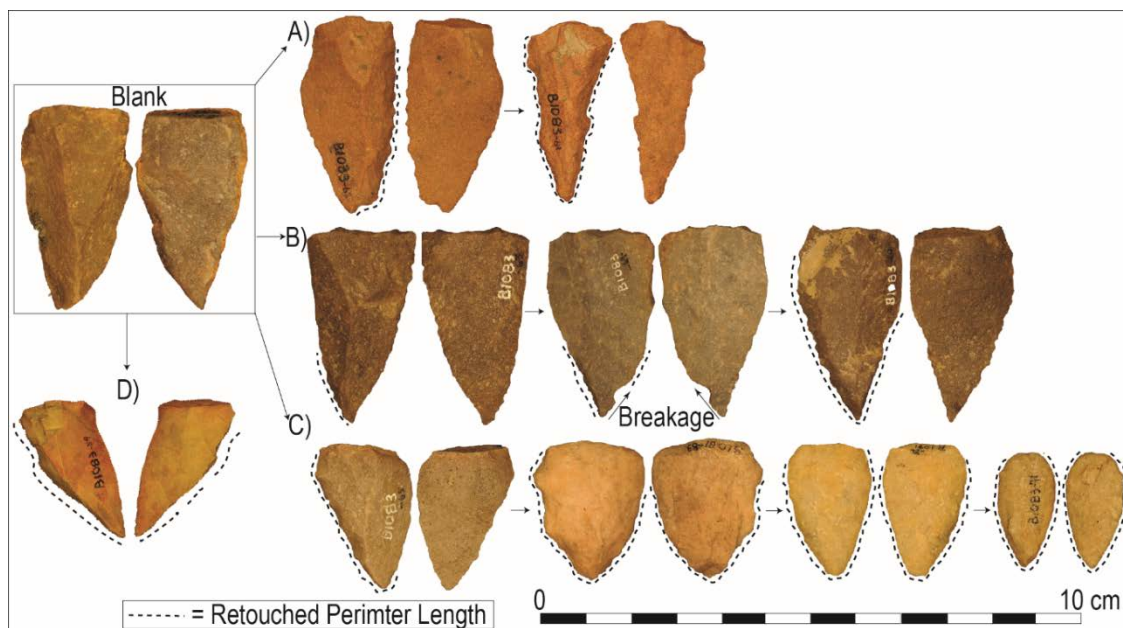


Fig 15 Direct percussion points showing retouched perimeter length on dorsal and ventral surfaces A) Invasive unifacial retouch B) Marginal unifacial retouch C) Unifacial to bifacial retouch D) Backing

Table 9 Pearson's Chi square test of direct percussion unifacial versus bifacial point platform attributes

Mandanari direct percussion points			
Pearson's Chi square test: Unifacial verses bifacial point	χ	df	p
3D laser scanned platform area (mm ²)	11.000	10	0.358
Platform thickness	52.970	48	0.288
Platform width	66.000	57	0.194
Platform Area [length x width] (mm ²)	66.000	56	0.277
External Platform Angle	29.194	21	0.109
Wanalirri direct percussion points			
Platform thickness	47.401	48	0.497
Platform width	48.000	47	0.432
Platform Area [length x width] (mm ²)	47.000	46	0.431
External Platform Angle	8.878	11	0.633

Two silcrete points, less than 4 cm in length, were recovered from Mandanari with marginal serrations (Figure 16). Notches, between 1 and 2 mm, separate fine serrations of about 1 mm in width along both margins. No invasive retouch had preceded this probably marginal pressure flaking, making these artefacts the only cases of pressure flaking outside of the biface production stages.



Fig 16 Points with marginal serrations

Cores

Eleven cores were identified in the Mandanari sample, which are morphologically distinct from the bifaces (Figure 17). The average platform angle of cores was 80.61 degrees, while the average edge angle of bifaces was 50.56 degrees; the difference in central tendency being significant ($t = 2.719$, $df = 6$, $p = 0.035$). The 5 cores at Wanalirri have an average platform angle of 90 degrees, while the two bifaces have an average edge angle of 46.25 degrees.

The qualitative difference between these blank producing cores and the biface may be obvious, however; it is informative to compare this difference in terms of mass per tool. The average mass of discarded cores at Mandanari was 148.72 grams, which is notably lower than the biface blanks discarded at the site, with an average of 158.77 grams. This mean difference in discarded mass suggests that the parent material of a single biface is initially greater in mass than the discarded cores used to produce multiple blanks for direct percussion points. While cores ($n = 11$) became increasingly smaller with increasing rotations ($r = 0.979$, $r = 0.959$, $df = 1$, $f = 2225.114$, $p = <0.001$), they are consistently discarded with less mass than the early stages of biface production.

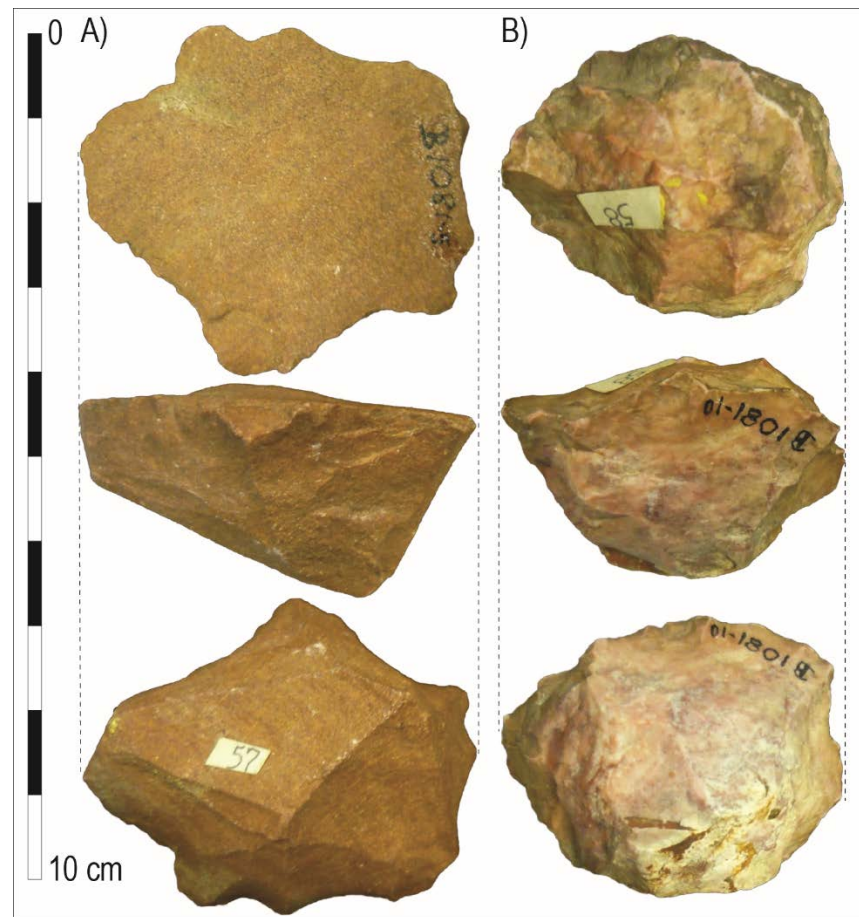


Fig 17 Examples of cores A) Quartzite single platform, unidirectional core B) Chert multiplatform, multidirectional core

Flakes

The unretouched flake morphologies in both assemblages further reveal that prepared cores were reduced using guiding dorsal ridges, formed by previous scars. The cross section morphologies of these flakes were plano-triangular, convex-triangular, or plano-trapezoidal. In the Mandanari assemblage, twenty (59%) of the discarded flakes had one or more parallel dorsal ridges with platform preparation and 23 (95%) of the Wanalirri flakes had one or more. This technique of standardised blank production requires cores to be prepared. This involved removing flakes to create the dorsal ridges, and control of external platform angle. Testimony to this level of core preparation is the presence of a single extremely large blade, or leilira blade (Akerman 2007:27), found at both sites (Figure 18). The percussion length of each is more than 2.5 times greater than any of the recovered cores' negative scars, and is twice the mean length of all other flakes and points.

In the Mandanari assemblage, thirteen flakes with bending initiations and longitudinal curvature could be associated with bifacial thinning. These identified flakes could very likely have been produced during biface production, indeed, these thirteen flakes do register a significant difference in terms of mass and platform area ($r = 0.495$, $r^2 = 0.245$, $df = 2$, $F = 5.672$, $p = 0.007$). In light of recent experimental data by Driscoll and García-Rojas (2014:140), this observation may not be an exclusive example of biface thinning. The Wanalirri assemblage included only a single example of a bending initiated flake.

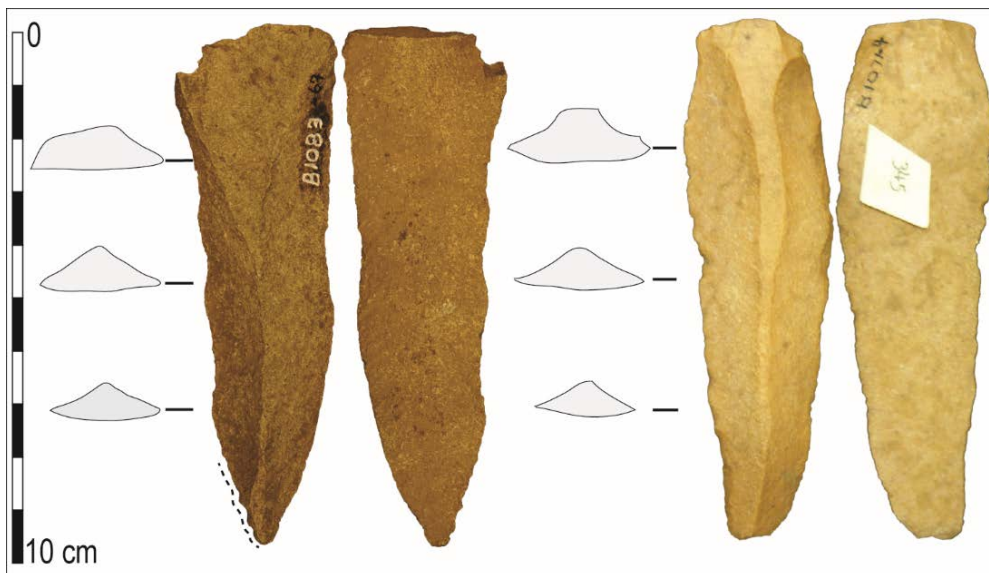


Fig 18 Large blades (aka Leilira) found at both Mandanari and Wanalirri

Percussors

The Wanalirri assemblage also contained percussion tools, including two small hammer stones with concentrations of pecked surfaces (Figure 19 A and B). A single bone tool is likely to be a pressure flaker, with edge ground surfaces at one end forming a rounded and slightly bevelled tip (Figure 19 C and D). This pressure flaker resembles those identified by other researchers, such as Love (2009:95 [1936]), and Akerman and Bindon (1995:95, fig. 95), as that used to further thin bifaces during production stage 4, rather than the thin spatula ended pressure flaking tool used to produce the marginal serrations.

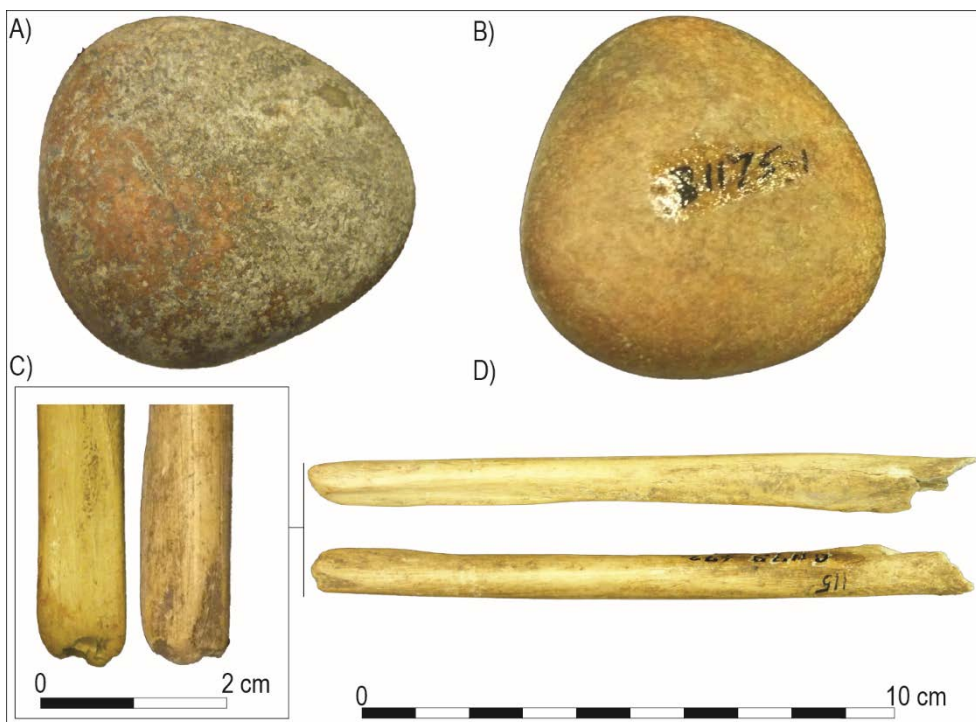


Fig 19 Percussion tools recovered at Wanalirri: A) and B) Hammer stones C) Edge ground tip of bone tool, showing rounded margins with intersecting striations D) Bone pressure flaker

Discussion

Raw material economy and standardisation

Now that the biface production stages and direct percussion point reduction continuum have been outlined, the raw material economy can be contrasted. In the Mandanari assemblage, bifaces are significantly greater in both size (total surface area) and mass, than the direct percussion points ($r = 0.704$, $r^2 = 0.497$, $df = 1$, $f = 7.905$, $p = 0.023$; $r = 0.769$, $r^2 = 0.591$, $df = 1$, $f = 28.870$, $p = <0.001$). Figure 20 illustrates the trend of bifaces toward greater total surface area values in the Mandanari assemblage. These tests were not possible for the Wanalirri assemblages, due to the small number of bifaces ($n = 2$).

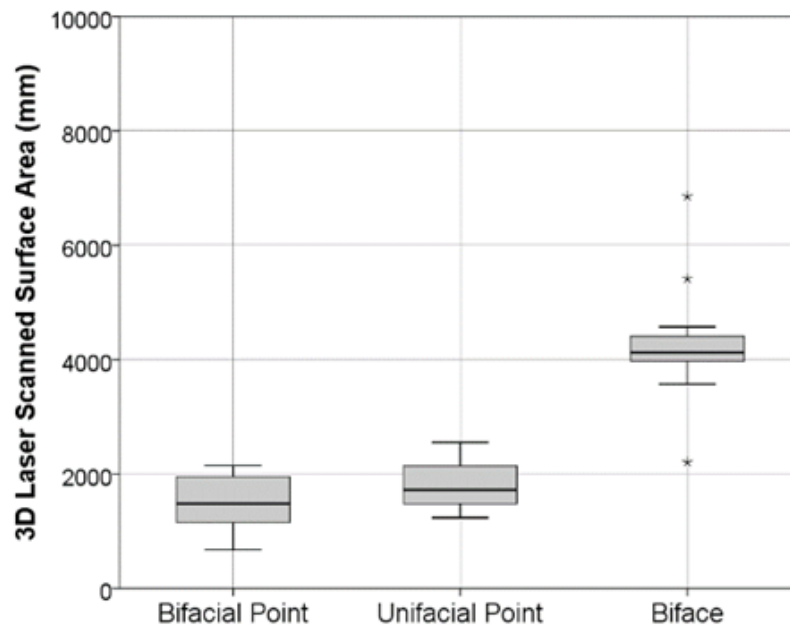


Fig 20 Total surface area of direct percussion points and bifaces

The standardization of the direct percussion point blanks results from careful preparation of cores. Points with varying degrees of retouch intensity, including backed points, were all made from the same standardized pool of flakes, which resemble what Australian archaeologists have called macro blades (Moore 2015), or lancet flakes (Clarkson 2007:89-90, 109). Davidson (2003) noted that despite frequent discussion of blade technology in terms of the efficient removal of core mass relative to potential working edge, experimental knapping suggests that the preparation of cores to produce multiple blades is actually expensive and time consuming (Bar-Yosef and Kuhn 1999). Clarkson (2007:136) suggested that point blank production was actually wasteful, since the most suitable flakes were produced early in the reduction sequence, which typically leads to the discard of cores with much of the original core mass underutilized. The discarded cores and bifaces at Mandanari and Wanalirri indicate that biface production was comparatively less efficient in terms of mass per tool. The cores reduced to produce multiple direct percussion point blanks were typically smaller than the bifaces, which potentially produced only a single pressure flaked biface. Standardization and probably the greatest skill level associated with direct percussion points, is most notable in the preparation of cores for blank production. Once these blanks were produced, points were highly flexible, a fact strongly supported by the diversity of morphologies and retouch

strategies documented in both these assemblages. The opposite is true for biface production, where standardization manifests at the end of the production stages; however, to produce these pressure flaked bifaces, a highly structured set of regularities has to be followed.

Modelling effective complexity

To discuss pedagogical contexts associated with these reduction sequences, the effective complexity is modelled using the descriptions of regularities. Discrete technological actions observed in these reduction sequences are used to represent these regularities, represented by a bracketed numerical count below.

In terms of effective complexity, direct percussion points consist of at least 4 regularities: (1) core preparation, (2) blank production, (3) gradual retouching of margins during use life, and finally, these points may have been incorporated into a composite tool (4). Reduction was accomplished only with direct percussion, and does not require the manufacture of percussion tools from bone and wood. Anvil resting is only occasionally practiced, with the bipolar retouching of backed points.

The effective complexity of pressure flaked biface production consists of at least 10 regularities, which include the observed production stages, the different percussion techniques, and the different percussion tools. Biface blanks could be either tabular pieces (1), or large flakes (2). These blanks were then thinned using direct percussion with a hammer stone (3). The buildup of step terminations and broken bifaces at this production stage indicates high error rates. This production stage must create a relatively thin morphology with a biconvex cross section; otherwise, continued production is impossible. The relatively thin morphology is accomplished with an invasive flaking technique, where flakes are initiated close to the margins of the biface, without terminating in steps or hinges (4). Variation in blank morphology likely determines the orientation of thinning flakes. Pending the production of biface stage 3 morphologies, which others have called a bifacial preform (Akerman et al. 2002:19; Akerman and Bindon 1995:94), a new technique of collateral pressure flaking is incorporated (6), using a manufactured bone or wood pressure flaking tool (5). This pressure flaking technique very likely involved anvil resting to immobilize the biface, and insulation such as paper bark, to prevent breakage (7). The final production stage involved pressure flaking the biface margins to produce serrations with a new pressure flaking technique (8), and the manufacture of a different, chisel ended pressure flaking tool (9). The pressure flaked biface could potentially have been incorporated into a composite tool, the technique of which could constitute another regularity (10).

The length of the description of regularities for biface production is notably longer than of direct percussion points. These lists are contrasted in Figure 21. Based on this measure of effective complexity, the direct percussion points require fewer regularities to be conveyed to a novice knapper and less time would have spent teaching and learning this technology. Biface production requires greater time spent in the learning of thinning techniques and different pressure flaking techniques. The production of pressure flaked bifaces progresses through regular design stages, each requiring different percussion techniques and tools, some of which are prone to failure and the discard of relatively large

units of stone. It is reasonable to conclude that greater frequencies of scaffolding would have been present in the difficult production stages of the pressure flaked bifaces.

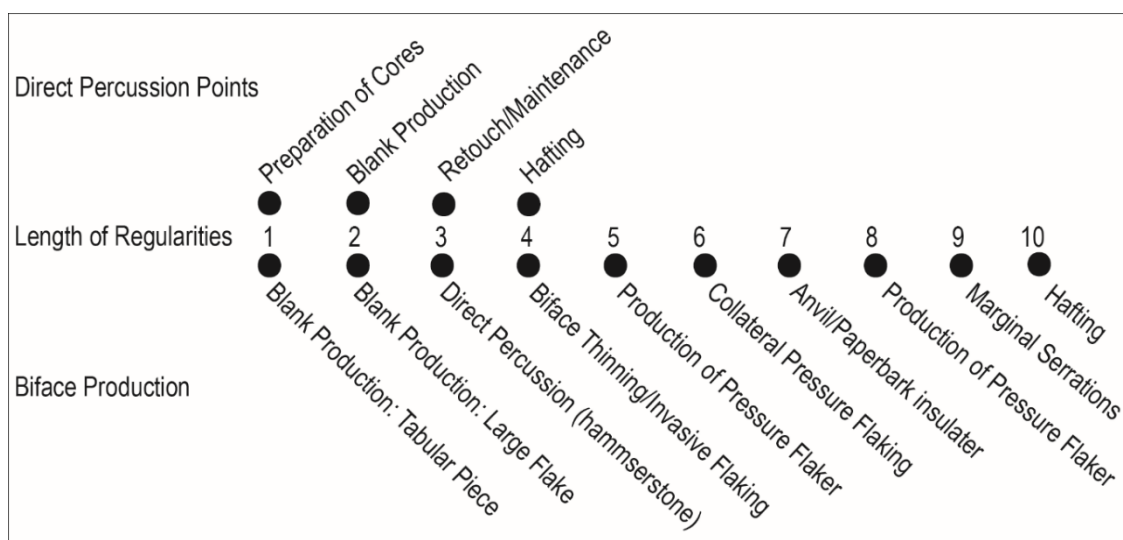


Fig 21 Comparing the length of the descriptions of regularities between direct percussion points and biface reduction

Time budgeting for pedagogy

The overall time allocated to manufacturing activities will undoubtedly affect the outcomes of any craft (Bettinger et al. 2006:544; Schillinger 2014a:2); however, time budgeting provides a useful framework to model the time allocation to pedagogy. Many archaeologists are familiar with time budgeting or time stress in technological organisation (Torrence 1983, 1989), yet there has been no explicit means of quantifying time invested into pedagogy. Adjusting time budgeting to promote the learning of more complex crafts is required for complex technologies such as pressure flaked bifaces to be learnt. The effective complexity of the technology presented in this study suggests that unlike the direct percussion points, the Kimberley Points could not be learnt through imitation alone. Time dedicated to teaching biface production was very likely bound to the requisite for a formal pedagogical context, which facilitated emulation.

Mackay and Marwick (2011:121) describe time costs entering technological organisation at three major intervals. First, in the magnitude of procurement episodes; second, in the frequency of these procurement episodes; and lastly, in the time spent during production and maintenance (2011:121). The magnitude of procuring units of stone for biface production is greater than that of direct percussion points, since greater units of stone are a requirement of the former. The same unit of material, or even less, could conceivably have been used to produce numerous direct percussion points, each with the ability of enhanced use life extension. The frequency of procurement for direct percussion points is therefore less than that of bifaces, allowing people to carry multiple point blanks, probably as multipurpose tools. Time spent maintaining margins of direct percussion points was both gradual and dynamic. This retouch is very unlikely to require formal teaching, due to the great variation in retouch intensity and morphological diversity. Conversely, production stages of bifaces result from structured planning, rather than

responses to situational constraints. The time spent on biface production is unlikely to be as flexible as that of direct percussion points, and so also provides an indication of the spatial restriction of manufacturing activities between these technologies. Biface production very likely involved dedicated or budgeted time at a limited number of sites, whereas direct percussion points were probably maintained over a wider range of sites, being employed in a multitude of tasks.

Time budgeting for pedagogy can also be applied to the wider social group. For example, Hiscock (2014:35) argues that given the patchy distribution of raw materials in the landscape, the cost of teaching and learning will include the cost of provisioning raw materials for apprentices, who will produce suboptimal results for some time. Theoretically, the cost for the social group to provide a given unit of stone for bifaces is much greater than the cost for the same unit to be reduced into numerous, highly adaptable, easily learnt, and less error prone direct percussion points. The difference in time budgeting for these two reduction sequences for the wider social group, involves what can be interpreted as a risk of material supply.

Pedagogy and foraging risk

Foraging risk refers to the degree and severity of failure to gain resources in subsistence practices (Bamforth and Bleed 1997:112-113; Torrence 1989:59). Foraging risk theory is a leading explanation of the underlying causes of point technologies in northern Australia during the Holocene (Clarkson 2006, 2007; Hiscock 1994a, 1994b; Maloney et al. In Review). This risk reduction model argues that direct percussion points developed in the mid Holocene out of an economic need for a multiple purpose, standardized, and maintainable technology. This need arose after environmental changes had roll on effects to ecological resources in many areas, which very likely increased foraging risk, and forced groups to expand their foraging range. In the Kimberley region, Maloney et al. (In Review) argue that pressure flaked bifaces developed when these multipurpose and highly maintainable technologies had diminished in economic importance after 1,000 cal BP (Maloney et al. 2014). This explanation implies that as populations became less mobile during the last millennium, the need for a maintainable technology diminished, and social groups invested more time and energy into complex bifaces with heightened social value. The model presented in this study implies that the pressure flaked bifaces which develop in the Kimberley within the last millennium, were also accompanied by changing investments of time into pedagogy, following this diminished forging risk.

Social exclusion of skill

One recent study from the north-west Kimberley argued that biface production stages were conducted in socially exclusive contexts and sites (Moore 2015). This argument also has many implicit implications for pedagogy associated with Kimberley Point technology; however, it cannot be ascertained whether either site in this study was socially exclusive. Biface production sequences at Mandanari and Wanalirri are mostly

composed of the first three production stages, prior to pressure flaking; although neither site was lacking in pressure flaking, or direct percussion points.

The sites themselves provide little indication that reduction techniques were socially exclusive. Wanalirri is a large site (approximately 55 x 15 meters) with a massive art panel, including numerous Windjana figures (see Akerman 2014) which were seasonally retouched (Blundell 1975:192, 195, fig. 42, 43; Blundell and Woolagoodja 2005). It was suggested by Blundell (1975:197) that on the basis of these seasonal visits in recent times, there was no restriction on women and children visiting the site. Wanalirri is also within 3 km of the Hann River (Blundell 1975:197, 305-305) and would have permanent fresh water. In contrast, Mandanari is a relatively small sandstone rock shelter (Blundell 1975:198-199, fig. 4) adjacent an ephemeral creek with seasonal fresh water supply. It was noted that this site is a major art site of Mandanari clan (Blundell 1975:198), and the shelter has a comparatively smaller art panel containing a single Windjana motif.

Part of Moore's (2015) argument, which relates Kimberley Point technology to socially exclusive production and by implication pedagogical process, is linked to population increase. Populations in Australia are modelled as increasing exponentially within the last 500 years, and generally increasing throughout the Holocene (Smith et al. 2008; Williams 2013). Elsewhere, population increase has been linked to major technological innovations and their widespread adoptions (Dennel 2009:433-437; Kuhn 2012:74-76; Lycett and Norton 2010; Powel et al. 2009; Shennan et al. 2013). Henrich (2004) demonstrated that complex technologies tend to be abandoned by decreasing populations, where simple technologies are more likely to be maintained, so if existing models of Australian demographics are correct, the temporal correlation of Kimberley Point technology with increasing populations appears very convincing. The earlier development of direct percussion points around 5,000 cal BP does not have the same correlation with demographic models (Maloney et al. In Review).

Pedagogical Theory

The processes by which innovations in stone technology occur and are subsequently passed on through different methods of pedagogy, appear to be affected by complexity and the cost of experimentation. For example, studies by Bettinger and Eerkens (1997, 1999) suggest that when raw material costs are high, greater complexity in technologies will be associated with a greater dependence on social learning. Conversely, when the cost of raw material is low and the complexity of technology is low, there is comparatively less dependence on social learning. Bamforth and Finlay (2008) argue that opportunities for novice knappers to learn increase when raw material availability is greater. Added to this, highly repetitive information where the cost of experimentation is low, is more likely to materialise with less error than information that is less common (Eerkens and Lipo 2007:248; Sperber and Hirschfield 2004; Sterenly 2012:136). From these arguments, four modes of innovation related to pedagogy can be envisaged, using two measures which can be quantified from archaeological data: Effective complexity and raw material cost (Figure 22). With reference to the data presented from Mandanari and Wanalirri, the

pressure flaked biface technology is certain to depend on social learning and a formal pedagogy. The raw material cost of this technology cannot be accurately reconstructed from available data, although it does appear that quartzite was relatively abundant at both sites, and that the cost of this production was high in terms of mass per tool. Perhaps the factors which encouraged the innovation of pressure flaked bifaces are a combination of reduced foraging risk, which freed more time for experimentation, but also the reduced cost of raw material experimentation. In contrast, the regularities of direct percussion points are highly repetitive in a technological sense, and do not require a formal pedagogy. Given the high foraging risks associated with the development of this technology in the mid to late Holocene (Maloney et al. In Review), raw material costs were high, which probably did not encourage similar rates of innovation. If the need to conserve raw material during the last millennium indeed diminished, it is plausible that this promoted innovations in existing techniques of bifacial reduction, as well as new percussion techniques and greater access for novice knappers to learn more complex technologies.

Effective Complexity	High	High dependence on social learning + greater rates of innovation?	High dependence on social learning/ formal pedagogy + low innovation rate
	Low	Low dependence on social learning/ minimal formal pedagogy + low error transfer	Less dependence on social learning + low innovation rate
		Low	High
		Raw Material Cost	

Fig 22 Theoretical contrast of effective complexity and raw material costs, with reference to levels of pedagogy and rates of innovation

Conclusions

Analysis of archaeological stone tool assemblages has the ability to inform on pedagogical contexts, as shown in this case study of Kimberley Point technology, and direct percussion points. Ethnographic records have recorded parts of learning stone technology in the Kimberley (Kaberry 1939:227-234; Love 2009[1936]:113-114). If archaeologists are to explore the nature of pedagogy in the remote past, without ethnographic analogy, methods of quantifying these social processes are of great analytical value. Recent studies from Australia (Moore 2015), have revealed that major

social changes can be strongly linked to pressure flaked biface production in the Kimberley. These technological changes are also accompanied by a new emphasis on pedagogy. The effective complexity of reduction sequence data presented here provides a viable method of modelling pedagogical contexts. The comparison of pressure flaked biface production with direct percussion points, indicates a more formal, emulation focused pedagogy can be associated with the former, and a more simple, imitation focused pedagogy can be associated with the latter. Diminished foraging risk and population increase within the last 1,000 years, both contributed to the innovation of pressure flaking bifaces. The teaching and learning of this technology likely spread when the cost of raw materials was reduced and the social value of Kimberley Points became widely established. This argument does not require ethnographic data, which strongly suggests similar tests can be made for other stone artefact assemblages in prehistory.

There are numerous assemblages that could similarly reflect on pedagogical contexts using this approach, and reveal more on the social contexts of major technological and evolutionary change. Shifts from lower to upper Paleolithic technologies for example, were very likely accompanied by different systems of pedagogy (Assaf et al. 2015:14). The effective complexity of new technologies that emerge during this time could be compared with other technologies throughout time and space. The presence of composite tool technology in MSA assemblages from South Africa (Mourre et al. 2011) would also likely involve teaching of new technological practices. Researchers can use reduction sequence data to model the description of regularities from stone tool assemblages and make valid comparison of effective complexity, leading to novel insights into the pedagogy of the archaeological past.

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Chapter 8

Australian lithic technology: evolution, dispersion and connectivity, In Tamar Hodos (Ed.), *Routledge Handbook of Archaeology and Globalisation*. Routledge

Authors: Peter Hiscock and Tim Maloney

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Peter Hiscock

Formulation of arguments and discussion in manuscript. Contributed to the overall question, background research, discussion, and conclusion of this paper and wrote parts of the paper.

Signed:



Tim Maloney

Australian lithic technology: evolution, dispersion and connectivity.

Peter Hiscock
Archaeology
School of Philosophical and Historical Inquiry
University of Sydney
Sydney
NSW 2006
AUSTRALIA

and

Tim Maloney
Archaeology and Natural History
School of Culture, History and Language
College of Asia and the Pacific
The Australian National University
Canberra
ACT 0200
AUSTRALIA

Introduction

In this paper we explore directionality and scale in social connectivity within the Antipodes. We do this through an examination of archaeological evidence for the growth of prehistoric globalization and the longevity of massive systems. Here we are concerned with social and economic connectedness and connectivity; an interest in globalisation as increased economic and social integration and inter-connectivity of communities across geographically large and varied areas (see Hodos 2010; Jennings 2011; Stek 2014; Tomlinson 1999; Versluys 2014). Our target in this chapter is to infer the scale of trends towards globalisation of technology within prehistoric Australia.

Technological change in Australia has varied in rate and mode. Some elements of these changes reflect responses to palaeoenvironmental change while others are articulated to shifts in the relationships between people. Mapping technological patterns onto proxies of either environment or social connections is a complex job but there is emerging evidence that both clarifies and challenges interpretations of lithic technologies across Sahul. In this chapter we synthesize evidence for some of the lithic production practices across Australia during the terminal Pleistocene and Holocene, and explore the social and economic dynamics that are associated with those practices.

Our analysis focusses on three kinds of artefacts, their production, distribution, history, and evolutionary context. Backed artefacts, bifacial points and edge-ground axes are distinctive, widely spread and display remarkably parallel patterns of chronological change. Examples are shown in Figure 1. We define each category as follows:

* *Backed artefacts* are flakes characterized by steep, usually bi-directional and bipolar retouch along one lateral margin, creating specimens with one blunted (or

partially-blunted) lateral edge and one low-angled unretouched lateral edge. Backed artefacts may be large or small, pointed or rounded, symmetrical or asymmetrical, and made on many kinds of stone; their only necessary character is backing.

* *Bifacial points* are flakes retouched along one or both lateral margins and on both faces, and on which the lateral margins converge. The extent of retouch is variable around the margins; point tips are usually shaped by retouch although butts are retouched on some specimens but not others. Invasiveness of retouch also varies between specimens and regions, with some being shaped extensively by invasive retouch and others by almost exclusively marginal retouch. Our concern in this paper is the class of bifacial points, irrespective of the refinement of production and the precise pattern of retouching.

* *Australian axes* typically have one bevel ground on both faces. Usually this is a slightly curved bevel positioned at the end of the long axis. Some axes are made on flakes, others on cores. Prior to grinding the edge, some specimens are shaped by flaking, others by dressing (ie. pounding), some by both flaking and dressing, and others are not shaped prior to grinding. The extent and orientation varies, and there are probably artefacts that function as axes without ground edges, but our discussion is limited to specimens with ground bevels irrespective of shape or manufacturing procedures.

Each of these forms is morphologically distinctive, often made on different materials and with different production and functional characteristics. And yet they all display similar evolutionary trajectories, with an increase in deposition and expansion of distribution following long after the initial adoption of the technological procedures. We know that many of the specimens were used as tools, and yet it is also clear that the objects carried social meaning. After discussing the nature of difference between these artefact categories and the technological strategies that created them, we will explore their operation and the environmental and social contexts in which they were situated. Our goal is to develop statements of the relationships between these technological changes and the scale of cultural networks across and beyond Australia.

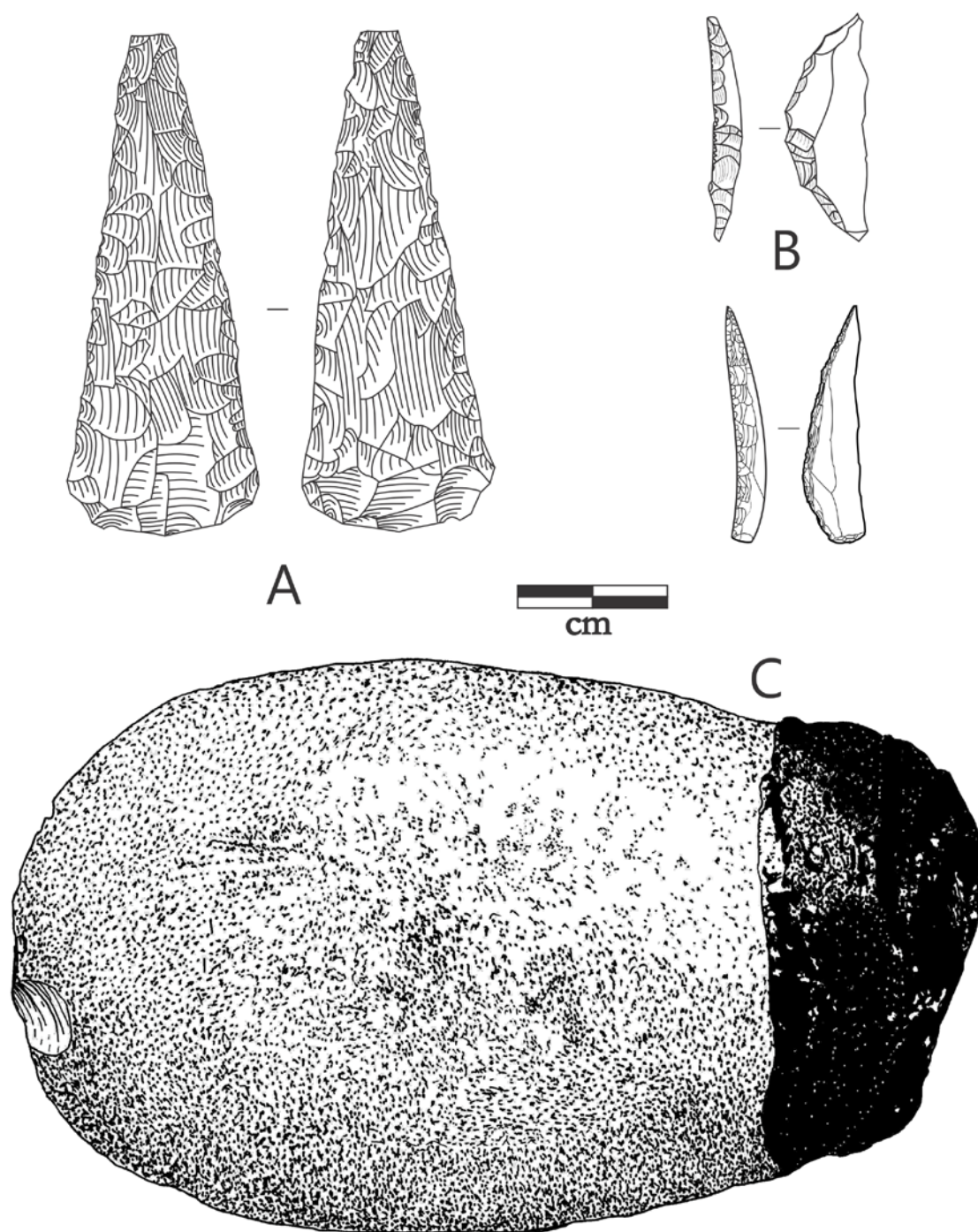


Figure 1. Three categories of artefact: A = Bifacial point from Arnhem Land, B = Backed artefacts from southern Australia, C = Axe from eastern Australia (Illustrations by Peter Hiscock and Chris Clarkson).

Class boundaries and behavioural meaning in Australian implement forms

The initial issue to be explored concerns the distinctiveness and nature of these three kinds of artefacts. Each group displays morphological variation across its geographical range, and through its manufacturing history and lifecycle. The long standing question is whether within this variation there are distinct and separable forms or whether we are observing continuums which cannot be non-arbitrarily

sub-divided. Our view is that the three categories we discuss here are in most regions and periods clearly distinguishable, both morphologically and in their operation within the human cultural system. Within each of the three classes there is variation that may be continuous and is more difficult to sub-divide.

Perceived ambiguities in establishing different high-level categories was reflected in twentieth century confusions, created by typological classifications, which employed shape alone rather than production process to understand relationships. The result was divisions of very similar things, made in the same way, into different categories based on subtle distinctions in shape. Hence small symmetrical backed artefacts were once classified as *microliths*, small asymmetrical backed artefacts as *Bondi Points*, and large asymmetrical backed artefacts as *Juan Knives* (McCarthy et al. 1946; Mulvaney 1969:123-126). More recently, these specimens are all considered part of a single variable class of backed artefacts (Hiscock 2014a). Of course the opposite practice also occurred, with different but superficially different forms being classified together. For example large backed specimens from northwestern Australia began being labelled as 'backed points' because they were asymmetrical and pointed and existed in assemblages that had unambiguous bifaces (Dortch 1977:117; O'Connor 1999:72). It has now been observed that while these specimens are made on the same blank forms as many points, they are manufactured in a distinctly different way, with bipolar anvil rested retouch (Maloney and O'Connor 2014). These confusions, and revisions, reflect the concerns of classifiers and do not indicate continuous variation in technology or artefact morphology.

Several strands of information indicate that these three classes are distinctive and discrete, while they contain variation that may be morphological continuous. Metrical studies of artefact morphology indicate that these forms are distinguishable and that they can be reproduced with statistical clustering methods. This is particularly true of the backed artefact class which has been subject to detailed morpho-metric analysis (Hiscock and Attenbrow 2005). Morphological differences between backed artefacts and other retouched flakes in eastern Australia reflect different blank production, different flake selection, and different retouch techniques and sequences (Hiscock 2003; Hiscock and Attenbrow 2005). These different treatments represent a different manufacturing history for specimens in each of the classes, creating the morphological differences that archaeologists find.

Compelling evidence for the separate morphology and technological history of each class comes from detailed studies of archaeological assemblages in regions where the forms coexist in large numbers. One of the most useful case studies comes from Lawn Hill in northwest Queensland, where Hiscock (1988, 1994b, 2005, 2007) presented production and distributional data on each form. The artefact classes were made of different materials: backed artefacts on chert, points on greywacke, and axes on exotic metabasalt. These materials had different physical properties and came in nodules of dissimilar sizes and shapes. Each artefact class was manufactured in a different way, using distinct flake blanks: backed artefacts from small, flat flakes with sub-parallel margins taken off small rotated cores and burinates, bifacial points from larger, thicker, broader and more convergent flakes taken from large single platform cores, and axes from very large, often hinge-terminated, flakes struck from massive rotated cores. The production and life

history of each class was distinct. Backed artefacts were retouched with a bipolar technique but once manufactured did not appear to undergo further modification. Points were invasively flaked by low-angled percussion blows, first on the dorsal face and then on the ventral, and were repeatedly modified as they were carried around the landscape for use. Axes were often unifacially flaked and then ground at the distal end, being reworked as they were extensively transported, damaged during use, repaired and re-hafted. Hence each artefact category is the product of different manufacturing treatments, reduction trajectories, and technological strategies.

The nature of strategies can be partly understood in terms of the extendibility continuum described by Hiscock (2006). This formulates relationships between stoneworking and conservation of stone material, by thinking of the ways a knapper might maximize the utility of their artefacts (Figure 2A). At one end of a continuum of options are *extension* strategies that seek to prolong the usefulness of the lithic artefact at hand, thereby reducing the rate at which new rock needed to be resupplied while at the same time keeping artefacts in a ready state. This involves extending the use-life of a tool by flaking, using and resharpening each item, and configuring the artefact so that repeated maintenance or recycling is expedited. Maintenance activities were often facilitated by creating larger items from which mass could be expended in flaking, and such artefacts are rarely highly standardized because of the ongoing alterations they receive. At the other end of this strategic continuum are *abundance* strategies in which a relatively large number of specimens are produced per unit stone, providing the capacity to use several specimens at once and/or to regularly and cost effectively replace specimens. In this approach benefit is obtained by increasing the number of artefacts available for use, an outcome facilitated by manufacturing smaller artefacts. Such artefacts have less capacity for extended maintenance but composite tool use could be prolonged through the replacement of exhausted specimens with fresh ones. This process is enhanced if specimens are similar dimensions, and so standardization of artefact sizes may accompany abundance strategies.

The extendibility continuum represents a series of non-exclusive strategic choices about how to supply stone tools at acceptable cost, each strategy containing subtly different economic advantages and costs. Technological strategies at both ends of the continuum may enhance the readiness of the toolkit although the nature of toolkit operation must be different at either end of the continuum.

Australian implements can be plotted along the continuum (Figure 2B). Measures of both production rate and reduction potential were provided by Hiscock (2006), drawn from independent technological studies of manufacturing processes (Dickson 1981; Hiscock 1993, Hiscock 1994b). Production rate is number of specimens per kilogram and weight is the simple proxy of reduction potential (see Hiscock 2006). Very few axes were produced per unit of stone, substantially more points, and a very high number of southern backed artefacts. Axes have very high mass and hence high capacity for reduction, points have a medium capacity, and backed artefacts a relatively low capacity.

While the positioning of the three artefact forms on this representation of the continuum is congruent with data, the situation is complex. These measures do not express the different ways each kind of object can be reworked, and it is likely that

the reduction potential of bifacial points in particular is somewhat underestimated. Additionally, there are variants of backed artefacts that overlap with points in production rate and size. This is the case with large asymmetrical backed artefacts found in the northeast of Australia (Lamb 2011) and the large backed 'points' in northwestern Australia (Maloney and O'Connor 2014). These were made on flakes the same size as large points while having the same shape and production process as the small backed artefacts. In some ways these variants represent morphological intermediates between small backed artefacts and bifacial points. On a continental scale, the characteristics and roles of these categories were more diverse than is found in any one region. Consequently patterns discussed here are indicative and typical without necessarily representing all aspects of patterns that changed across space and over time. We summarize the known histories and interpretations of these technological systems as follows.

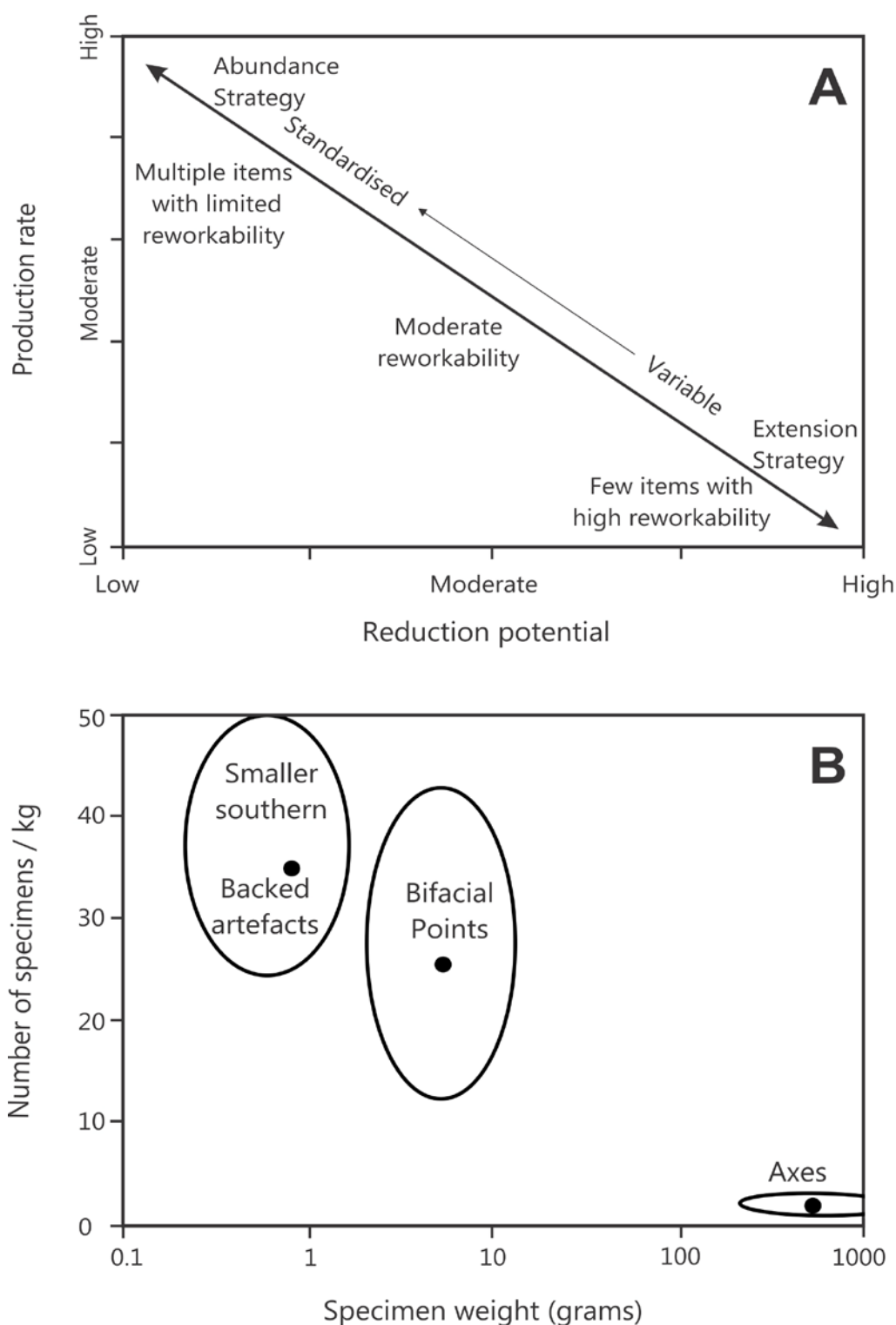


Figure 2. Model of the extension-Abundance continuum after Hiscock (2006). A = Continuum of possible artefact forms that play off reduction potential against production cost/rate. B = Plot of backed artefacts, bifacial points, and axes on the continuum using proxies for reduction potential (specimen weight) and production rate (number of specimens per kilogram). Dots indicate the central tendency (arithmetic mean) of each class, and an ellipse indicates variation exists (standard deviation).

Australian Backed Artefacts

In Australia, archaeologists adopt the term 'backed artefacts' to redefine the category elsewhere labeled 'microlith'. The distinguishing feature of backed artefacts is the near ninety-degree retouch, usually accomplished with bipolar techniques on anvils. The size of backed artefacts varies considerably between regions and in some places they are large, hence they are not always microliths in the Australian context. Redefining the phenomena in terms of backing that blunted an edge creates a useful image of this technological system in Australia (Hiscock in press).

Backed artefacts are absent from Tasmania and display clear geographical variation across the Australian mainland. They are not found in the northern portions of central and Western Australia. Across the rest of the mainland they are found in varying densities, with regionally different sizes, shapes and production systems. An index of symmetry records higher values for more symmetrical specimens and lower values for less symmetrical. Asymmetry is more typical on continental margins (Figure 3). This geographical variation in backed artefact morphology is hypothesized to reflect dispersal history for the artefact class, modification of morphology arising from transmission error, technological adjustments to different blank production strategies, and divergence in the backed forms to facilitate social signaling in learning/production contexts (see Hiscock 2014b).

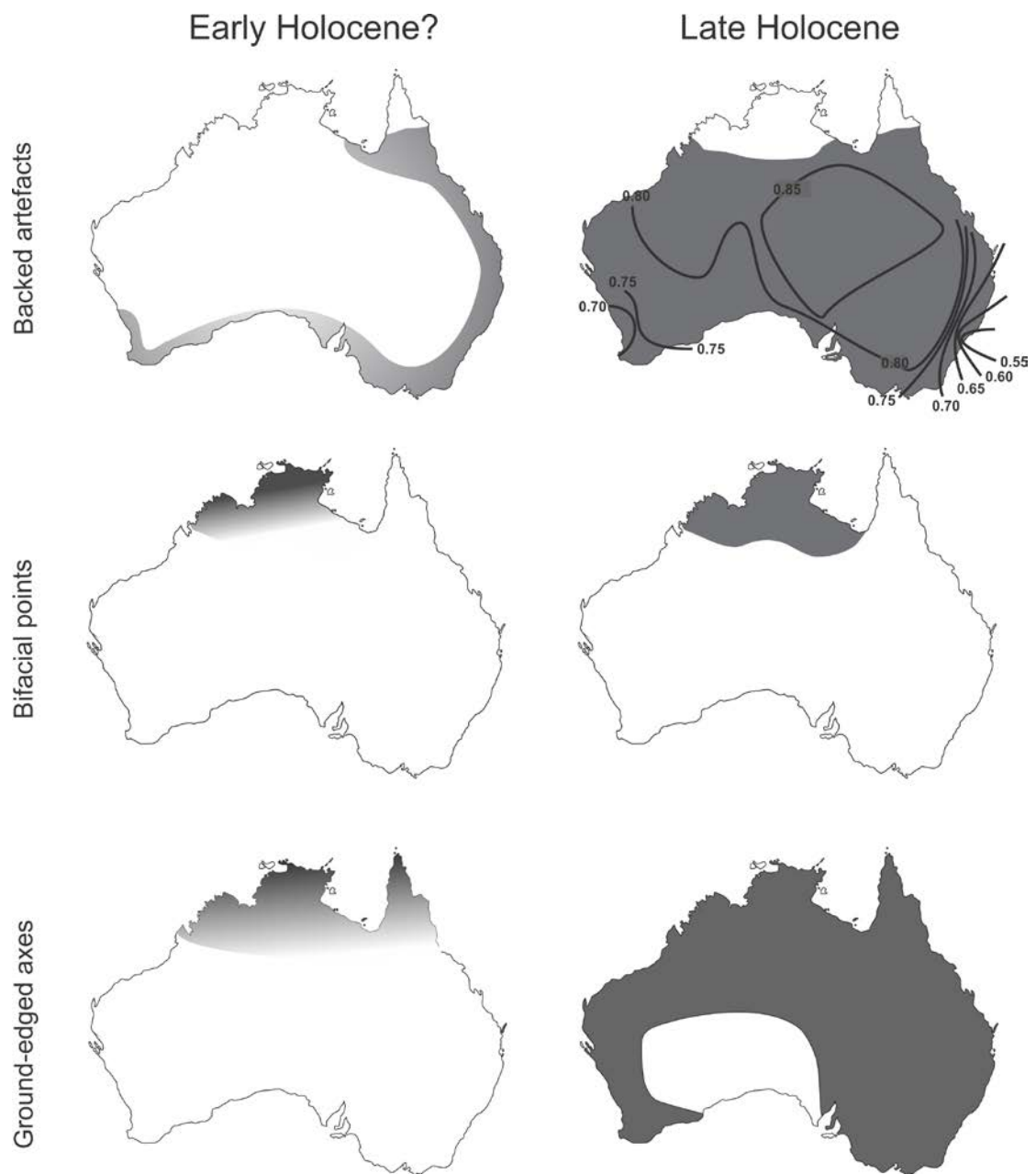


Figure 3. Distribution of backed artefacts, bifacial points and ground-edge axes across the current Australian mainland (from Hiscock 2008, 2014a; Morwood and Trezise 1989). Late Holocene distributions (c. 3-1,000 bp) are more accurately established than early Holocene distributions (c. 8-5,000 bp).

At any one location backed artefacts are often uniform in size and shape. The process of creating standardized forms was sometimes assisted by the production of flakes with regular shapes but it did not depend on standardized blanks. Specimens were made on any flake that had an appropriate cross-section and one straight or gently undulating margin of sufficient length (Hiscock and Attenbrow 1996; Hiscock 2006). This means that prehistoric manufacturing did not involve mechanically applying a fixed procedure to a uniform blank, but required the artisan to select a suitable

section of each flake to retouch. Standardisation was then achieved by careful retouching of flakes on an anvil.

Backed artefact production typically involved considerable investment. In some regions we know that high levels of backed artefact manufacture were associated with the procurement of 'higher quality' local lithic materials, reflecting a restructuring of economic activities. Knappers also improved material responsiveness by subjecting the rock to controlled thermal alteration. Heat treatment was often undertaken late in the production process, when the specimens were smaller, so that application of heat had a higher chance of successfully improving fracture quality of specimens. Heat treated pieces of rock were typically knapped with care, and in many instances flake production in preparation for backed artefact manufacture involved regular and precise knapping of small pieces of stone, involving careful platform preparation and structured core reduction. The combination of high investment in materials and regular skilful knapping conserved material by extracting a large number of specimens per unit of stone, and there may have been some degree of craft specialization involved in the organisation of production. If the geographically localised patterns of standardized backed artefacts reflect localised craft traditions and practices, then we can hypothesise that those manufacturing systems reflected social structures involved with learning, things like recognised craft specialists or craft contexts and connected apprenticeship learning. The way backed artefacts were used as tools suggests similar mechanisms.

Backed artefacts may well have been used as tools held individually in the hand, but there is abundant evidence that many were hafted as part of composite tools. Resin residues and stains from hafting adhesives have been widely found and suggest that specimens were most commonly positioned with backed edge towards a shaft, and with the sharp chord edge parallel or sub-parallel to the shaft. Residues and stains are concentrated along the backed edge, indicating that specimens were held in place by adhesive compounds packed around them and encircling or partly encircling the shaft. Figure 4 illustrates some of the possible hafting patterns. The length of the shaft remains unknown and it has often been presumed to be long, reflecting the widely held proposition that backed artefacts were armatures on spears, either hafted along the shaft as barbs and/or at the tip as projectile points. This use of backed artefacts cannot be entirely ruled out, and one recent review finds projectile armatures are still a plausible hypothesis (Fullagar 2014), but the weight of evidence indicates that at least in the southeast of the continent backed artefacts were commonly used on short-handled composite craft tools rather than on projectiles.

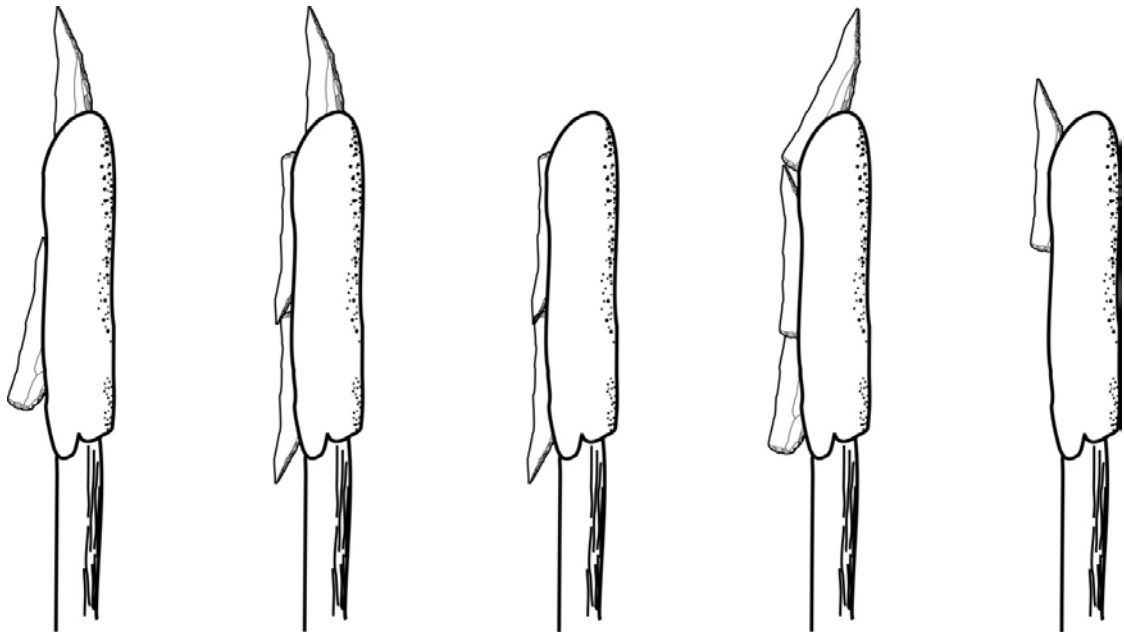


Figure 4. Idealized images of possible backed artefact hafting positions, inspired by McCarthy's (1976) illustration but excluding those options which are unlikely given existing usewear and residue evidence (after Hiscock in press).

In southeastern Australia, at places such as Mangrove Creek, use-residue studies reveal that backed artefacts were used for many tasks involving multipurpose cutting and slicing of both plant and animal materials, but rarely as thrown spears (Attenbrow et al. 2009; Robertson 2002; Robertson et al. 2009). Many specimens have residue or wear patterns documenting they were used for two or more purposes, indicating that the composite tool on which they were hafted was capable of being employed for diverse craft activities. This evidence compels us to abandon visions of Australian microliths as always being spear armatures, and eliminates explanations that rely on that proposition, such as suggestions that they had been used on spears for game hunting (McBryde 1974; Morwood 1986, 1987) for intense warfare/violence (Flood 1995; McDonald et al. 2007). The early version of Hiscock's (1994a) risk reduction model, which hypothesised that backed artefacts were made in regular shapes to provide easily maintainable spears that would reduce foraging risk in unpredictable environments, is also refuted by this evidence. The functional evidence we have instead reveals that backed artefacts were used to create intricate, sometimes delicate, crafts made from hide, bone, wood, feathers and other materials. These items were scraped, carved, incised and sliced. None have been preserved and so we cannot at this point infer the kinds of craft items being constructed. However Hiscock (in press) has argued that there are two possibilities to consider.

It may be that backed artefacts were being employed as craft tools to make diverse material culture of directly utilitarian kinds: clothing, bags, hunting gear such as nets/traps, shelters, bedding, boats, and so on. In that case Hiscock's (1994a) risk reduction model should be reformulated to state that regular-shaped backed artefacts were produced as the edges of critical multi-purpose craft tools, used in making a diverse range of utilitarian tools that provided acted as a buffer against foraging risk. In this model artisans maintain standardized backed artefact sizes and shapes because the regularity of artefact form assists in the maintenance of the composite tool which can be kept in a functional state.

Hiscock's (in press) alternative proposition is that some of the craft goods being produced were also employed as social signals, perhaps creating valued items for exchange and/or for use in cultic performances. The evidence that backed artefacts were embedded in composite tools adorned with red ochre and feathers reveals they were not only used for cutting, scraping and sawing; they simultaneously sent signals about social phenomena. Because most backed artefacts were very small a reliable signal could not have been sent simply by displaying the objects, as they would have been barely visible and at a distance it could be hard to distinguish a backed artefact from a simple and less costly flake (Hiscock et al 2011). Consequently the specimens must have been inspected in detail for the construction norms to be evaluated, and training would have been involved in maintaining the similar forms across space and time.

The proposition that backed artefacts delivered social signals is all the more intriguing because of the chronological changes that occurred in backed artefact production. In every region in which they are known archaeological sequences show a single significant 'proliferation event', in which the production rates of backed artefacts increased substantially for a short period and then decreased to very low levels before backed artefact manufacture ceased altogether in the last millennium. Low chronological resolution makes the length of the event difficult to measure but it is probably between a few hundred years and slightly more than a thousand years. The antiquity of the proliferation varies regionally, and is generally later in the arid zone than in better watered continental margins. In the Northeast, at locations such as the South Molle Quarry, the production of large backed artefacts appears to peak 9-6,000 bp (Lamb 2011). In the well-studied Sydney Basin of the southeast the proliferation occurred between 3,500 and 2,500 years ago, and this timing appears to apply broadly along the south-eastern seaboard (Hiscock 2008). These regional variations in the timing of these proliferations indicate that reference to a simple, single, explanatory mechanism may not be plausible.

The quest to understand backed artefact proliferations also benefits from a consideration of the nature of post-proliferation technological systems. After the proliferation ended, regions in southeastern Australia display diverse technological strategies and assemblages, variously emphasising forms such as 'scrapers', serrated saws, edge-polished flakes and cores, unifacial and bifacial cores made on pebbles, ground edge axes and bipolar cores. Although there are differences across the continent in the specific form of backed artefacts, they are all variants on a theme that reflect shared norms in production, shared technologies and shared perceptions about uses. The backed artefact proliferation can therefore be seen as a period in which foraging strategies and/or social signals were facilitated by a common set of materials across large tracts of the continent, whereas the following period was one in which patterns of flaked lithics became more regionally structured. We interpret the change as a shift from a phase of broad scale commonalities between regions in their shared use of the backed artefact forms, to a phase with more localised traditions. We may be observing a shift from greater emphasis of horizontal transmission of craft/social practices to a post-proliferation phase that emphasised vertical information transmission as regional trajectories developed. Intriguingly similar themes are visible in the transformations of technology making bifacial points in north-western Australia.

Australian Bifacial Points

Australian points come in a variety of sizes and shapes, although there is regional coherence to the variation. All share the definitional traits of retouch on convergent margins, but conventional typological divisions of points have not been powerful characterisations of either process or purpose in the formation of point variation. For example, it was traditional to distinguish unifacially flaked points from bifacially flaked ones, and many researchers argued that these were different kinds of tools with different histories. It is now clear that these often poorly defined typological categories do not track reduction processes in any simple way and therefore are not a basis for evaluating the relationship between the forms. Technical analyses of scar superimposition show that many bifacial points begin as unifacially flaked and eventually have a second face flaked to create bifaces, meaning that for bifaces the unifacial retouch was often an early production stage (Hiscock 1994b; Maloney et al. in press). However in the same sites, unifacially flaked points were discarded without ever being bifacially flaked, and hence for those specimens unifacial working was not an early stage, it was the only stage. The pattern reveals that knappers were not applying identical practices to every specimen; instead production procedures varied to reflect blank sizes, specimen shapes, material quality, functional context, and other factors. Responses of craftspeople to such factors, and the manufacturing processes themselves, are poorly revealed in the older typological classifications such as unifacial or bifacial, and our focus here is somewhat different. Tracing specific reduction processes (such as bifacial flaking or edge serration), techniques (such as percussion or pressure), and technological systems through time and space is a useful strategy with which to define change in point production.

Across north-eastern Australia there are a number of sites with evidence for bifacial point production in the mid-Holocene. In western Arnhem Land a single specimen at Nauwalabila I is dated to $6,675 \pm 110$ cal bp (Hiscock 1993) and in the Southern Kimberley region bifacial points are found at the coastal Widingarri 2 site associated with a sample dated to $5,742 \pm 94$ cal bp (O'Connor 1999:74), and at the inland Carpenter's Gap 3 site at around $5,529 \pm 46$ (O'Connor et al. 2014:17), and at Windjana Gorge Water Tank Shelter below a date of $5,416 \pm 66$ cal bp (O'Connor et al. 2008). These are statistically unlikely to be the earliest points made in the region and we conclude that bifacial point production was occurring over much of Arnhem Land and the Kimberley 6-7,000 years ago, although at low rates and as one component of a diversified tool kit. All of these early bifacial points were manufactured by direct hard hammer percussion, and this retouching technique was the only one employed in point manufacture until the last 1-2,000 years bp.

Discard of percussion flaked bifacial points becomes more common after 3,500-3,000 years ago, often increasing to double, triple or greater production rates. The onset of this point proliferation event, representing a greater investment in percussion point production in absolute terms and relative to other retouched forms, occurs at broadly the same time across much of the northwest. In a number of regions high production rates lasted only a few hundred years, perhaps as long as a millennium or so, and subsequently percussion bifacial point manufacture become either a minor element or eventually the practice ceased. In Arnhem Land the percussion point proliferation occurred between 3,000 and 2,000 years bp at well-dated sites: Ngarradj Warde Djobkeng and Nauwalabila I (Hiscock 1999). Dates for

the Scotch Creek 1 site are also consistent with this chronology (Smith and Brockwell 1994). Broadly similar chronologies are found in the Kimberley, with percussion-made point discard being greatest between about 3,000 cal bp and less than 2,000 cal bp at Mount Behn (Maloney et al. in press). Several other sites across the Kimberley have recovered early points associated with dates between 3,500 and 2,000 cal bp (eg. Dortch 1977; Veitch 1999). Maloney et al. (2014a) report several reliable early dates for percussion points in the southern Kimberley, although most have been reported from within this later proliferation period. Far from the Kimberley and from coastal Arnhem Land, Clarkson (2006:104) has argued that production rates of bifacial percussion points in the region south of Katherine were slightly later in time, with point discard peaking around 2,000 cal bp, perhaps reflecting a late adoption of the technological system. Distance from the region of innovation may in that way have created geographical variation in the antiquity of the biface proliferation.

The similarity in the timing of percussion point proliferation led researchers to propose common triggering mechanisms across northern and northwestern Australia. Explanations have often reflected the presumed functions of points. Many archaeologists presumed that pointed objects were spear armatures and hypothesised that the proliferation reflects increased projectile use, precisely the logic that had been employed for backed artefacts until detailed wear and residue evidence was obtained. For example, Smith and Brockwell (1994) proposed that the increased point production reflected greater use of duelling spears as intergroup conflict increased in response to local resource depression. An alternative proposition about bifacial point function is that these were forms that could serve many purposes and that we should expect to find different specimens put to different uses, and multiple uses on some specimens (Hiscock 1994a, 1994b, 2002, 2006, 2009, 2011; Clarkson 2006, 2007, 2008). There have been no extensive wear/residue studies to test this notion, but analysis of Widgingarri 1 and 2 points from the Kimberley showed the majority of points were used for processing plant materials (Wallis and O'Connor 1998), an observation more consistent with a multipurpose than a projectile function. Several researchers have evoked the relevance of generalist, multi-purpose tool forms for models in which technological was structured to buffer groups against increased foraging risk that developed as a result of environmental change (Clarkson 2007; Hiscock 2009; Maloney et al. in press).

Risk reduction models of Australian lithic technology predicted that risk-reducing techniques and strategies would occur in periods of resource depression and higher resource variability. For the northwest of the continent risk models, in which bifacial points are multifunctional extractive tools, have been built on the broad correspondence in time between environmental proxies indicating uncertain and diminished resources and the proliferation events. For instance, Maloney et al. (in press) argued that in the Kimberley region a bifacial percussion point proliferation occurs during a period of drying in which increasingly variable conditions including pulses of localised aridity. Similar contexts have been noted for the proliferation of bifacial points Arnhem Land (Hiscock 2006; 2009) and the inland Katherine region (Clarkson 2007). This environmental context is consistent with the proposition that these long-lived, multifunctional bifaces increased toolkit readiness and were selected in a period of heightened environmental uncertainty, and yet some archaeologists have emphasised that the covariation itself need not demonstrate

that technology was responding to the economic pressures created by climatic conditions.

The main voice decrying risk models is Moore (2011), who has in fact agreed that intensive biface production was probably a response to increased economic risks. However he views this as a 'proximate' cause and proposes that archaeologists should seek an 'ultimate' explanation which he asserts will be found in demographic factors. This argument follows from his use of a now common assertion by archaeologists: that there is a logical connection between population growth and the value of material signals of social interaction. In his model chronologically patchy occurrences of hierarchically complex and symbolically loaded technologies reflect demographic changes and were important in negotiating social relationships as they were employed "...as one form of information exchange to mediate the impact of a demographically stimulated rearrangement of Aboriginal land-use strategies" (Moore 2011:145). This proposition is plausible, and yet it is neither necessary nor evidentially supported. Since the environmentally-elicited economic stresses themselves were capable of stimulating reorganisations of land-use and since an emphasis on technically elaborate lithic artefacts could act both as social signals and as risk-buffering tools, as argued above for backed artefacts, there is no substantial explanatory benefit in demanding that there might be additional demographic processes in play. Indeed as solutions to economic risk would underpin demographic growth in a period of heightened environmental change, the causal direction of linkages between technology and population change remain to be established. Additionally, Moore does not present independent evidence for demographic fluctuations in the Kimberley region, and unless we posit new modes of production the expectation that population increases were occurring during a period of resource depression creates a further conundrum. A recent review has shown that in the Kimberley there is no clear correlation between purported proxies of population change and the timing of technological shifts (Maloney et al. in press).

Ongoing changes in technological strategies challenge claims for simple 'ultimate' explanations and suggest the long-term shifts in point technology are an outcome of multiple factors operating in historically contingent ways. After the hard hammer proliferation ended and point production declined or ceased in many regions, knappers invented or emphasised different production strategies. The pattern of change is one of radical technological transformations displayed in distinctive regional trajectories. In Arnhem Land bifacial point production diminished and by about 1,500 bp points were minor elements in assemblages dominated by large elongate quartzite flakes and tuff flakes steeply retouched on one margin, bipolar cores, and unretouched flakes (Allen 1996). Even these patterns were expressed differently in the landscapes within Arnhem Land (Hiscock 2009). To the south Clarkson (2007) showed that as bifacial point production diminished over time, points were made with less retouch until unifacial points were the norm, and in the last millennium large, unretouched flakes were a focus of manufacturing. In the proto-historic and early contact period production of "Kimberley points" was adopted in this region, diffused from the west (Davidson 1935). In the Kimberley region biface manufacture was re-emphasised in the last millennium with the production of elaborate pressure flaked specimens (Maloney et al. 2014a). Pressure flaking was associated at Mount Behn with a decline in the retouch intensity of percussion points (Maloney et al. in press) and is probably reflected in a regional trend where new forms of pressure flaking were adopted within the last millennium

(Maloney et al. 2014a). Kimberley Points were bifaces that are different to earlier percussion bifaces in several ways: i) they are finished with systematic pressure flaking across both surfaces, ii) in plan both lateral margins often have an s-shaped curve producing a thin tip, and iii) both margins are serrated (Akerman and Bindon 1995:89). In historical times they were observed to have functioned as spearheads and were also used as trade and prestige goods (Akerman 2008; Harrison 2002, 2006).

These regional trajectories contrast with the assemblage uniformities between regions during the percussion biface proliferation, a pattern that displays clear parallels with the backed artefact proliferation. Hiscock (1994a) observed these similarities in the timing and pattern of backed artefact proliferations in the southeast and the percussion point ones in the northwest, concluding that if different factors were responsible for each proliferation then there were probably mechanisms that articulated the processes of technological evolution in the diverse regions. He also made the observation that if there have been the same or similar factors triggering the proliferations, the technological responses in the two parts of Australia would have varied because of historical contingency represented in the different technological traditions. We therefore take the view that given available evidence there are few advances to be gained by claiming that we understand the factors that were responsible for the percussion point proliferation. Instead we propose to focus on our inference that these technological traditions and their evolutionary patterns reveal something of the scale of social connectivity that was operating at different time periods.

Australian Edge-ground Axes

Axes heads with a distinctive ground bevel at one end are found archaeologically across much of mainland Australia, although they are not reported from a broad region of the southern coast and southwestern stony and sandy deserts (Figure 3). They are also absent from Tasmania, because until recent millennia they were restricted to northern Australia, and axe production was only taken up in southern Australia after the flooding of Bass Strait had isolated that land. Across their distribution axe shapes and axe production varied. In most cases the rocks selected for edge grinding were tough metamorphic or volcanic varieties, although where such materials are scarce granular quartzites or similar rocks may occasionally be used. The investment of labour in axe manufacture could be little or great, reflecting not only the nature of raw materials but also whether the specimens were being created for personal use or for exchange (Hiscock 2005). Production processes normally reflected strategies for exploiting the material, with bedrock outcrops being quarried, surface boulders being directly reduced, and in some regions water-rounded cobbles being directly ground without preparatory working. Except in the latter case, specimens were shaped by hammer dressing (pounding) and/or by flaking. Grinding was achieved mainly through abrasion on sandstone, usually in creek beds where water could be used on the ground surface (Dickson 1981). The results of these procedures were axe heads that were often between 300g and 1,000g, although far larger specimens were occasionally made (Dickson 1981:19-20). In many instances there are visible signs of the maintenance of axes to extend their use life, with re-flaking of broken bevels and regrinding of edges. This is evidence of the functional value of many axes, and yet at the same time the

ethnography reveals that at the start of the colonial period axes and their hafts were distinctive of particular sources/makers and that as signals of identity they reflected and regulated social inter-actions (McBryde 1984). We also know that axes were incorporated into cosmology and myth, sometimes as the focus of social responses to changes in environment and culture (Hiscock 2013).

No study has demonstrated significant change in axe form or function over time, but the geographical distribution of axes expanded dramatically in recent millennia. In the Pleistocene and early Holocene axes were manufactured only in northern, tropical Australia (Morwood and Trezise 1989), whereas by the late Holocene they were also being made over much of southern Australia. While the rarity of axes in deposits means that there is a faint archaeological signal, axes appear in many southerly regions between 4-3,000 bp. This antiquity for the geographical expansion of axe production is broadly coincident with both the percussion biface and backed artefact proliferation events and the environmental shifts with which they are correlated. This pattern is consistent with our position that the proliferation events were phases of greater horizontal information transmission between social systems in Australia.

Conclusion

Our review of three Australian lithic technological systems indicates that they operated in distinctive ways, reflecting varied extendibility strategies, and that they satisfied a complex range of functional and communication needs. And yet they all share an evolutionary trend: massive geographic expansion in the production of specific implement forms during one period. Our analysis documents that neither tool function nor social roles alone are adequate explanations of these systems. These artefacts were useful and were used in multiple ways, especially in craft activities. The production systems, and the objects they created, were also understood socially, and sent public signals. We have shown that the geographic expansion of these signifying tools occurred during a period of climatic variability and resource depression, conditions in which standardized, multi-purpose tools would have been advantageous. We also argue that the dispersal and maintenance of similar artefact forms and similar production technology, across the breadth of areas over which the three categories of artefact were employed, indicate shared technical training, related craft norms and similar social contexts; all indications of social connections. The nature of those inter-group connections requires clarification. Shared lithic systems might have arisen through descent from an ancestral system, resulting from population movements/migrations, as well as from horizontal transmission of technologies and/or the foraging or craft practices that involved those technologies. Geographically extended networks may also reveal connections beyond Australia, indicated by some similar implement forms in island South-east Asia (Bellwood 2013), the arrival of dingo's in Australia (Hiscock *in press*) and the presence of Pacific axes in coastal, eastern Australia (White et al. 2014).

The broad covariation in the maximum distribution of backed artefacts and of the Pama-Nyungan family of languages, as well as the geographic covariation of bifacial points and Non-Pama-Nyungan languages, has been suggested to stem from common social processes of transmission (e.g. McConvell 1996) but this proposition remains untested. Hiscock (2002) has argued that those geographic similarities in

language and technological histories indicate long standing transmission networks and geographic boundaries to transmission. Our argument here is that the size of information transmission systems, for technology at least, changed over time and that their scale is indicated by the geographic extent of these technologies and products. From this viewpoint we observe periods with spatially constrained transmission systems, containing distinct regional patterns, and other periods with broad-scale transmission networks, containing specific technological elements that are found widely. We have shown that in these terms there was a significant upscaling in the magnitude of social transmissions across mainland Australia around 4-2,000 years ago, reflected in the three proliferation events. In southern and eastern Australia there was a massive expansion of backed artefact production across virtually all of the lands occupied by Pama–Nyungan speakers in the historic period. In northern Australia bifacial point production expanded to cover the lands from the base of the Gulf of Carpentaria to the Kimberley, a distribution that covered the mainland regions in which Non-Pama–Nyungan languages were distributed. Edge-ground axes became extremely widespread, and their distribution spans all major language groupings. After the proliferation phase was completed the emergence of more localised traditions may indicate reconfiguration of those broad-scale systems into more constrained transmission patterns. There have been interpretations, relying on other lines of data such as rock art, that the late Holocene was a period in which group boundaries became less permeable, or ‘closed’ (David and Lourandos 1998; Lourandos 1997), and this might articulate with the geographic scaling down of information transmission observable in the lithic technologies. In any case we emphasize that changes in the distribution of information, in social connectivity, would have been associated with transformations of the social and economic practices. Hence we anticipate that alterations in social learning, linked ideologies and iconographies, and group interactions would have accompanied the rescaling of transmission networks. In that way the patterns of lithic technologies in Australian record the serial reconfigurations of continental scale relationships between human groups.

We have argued that the emergence and subsequent disarticulation of spatially massive transmission networks in Australia during the Holocene is not explicable solely in terms of either environmental changes or as purely social dynamics. Instead, oscillations between geographically expansive and locally constrained social/signaling systems reveals compound cultural transformations related to the movement and interactions of societies across and beyond Australia. Trends in globalisation are not unidirectional and we see both expansion towards large systems and contractions as the scale of interaction became more regional in expression. Conceptualising these shifts is a step towards exploring them further. We have explored them with the idea that these systems are operating in specific social and economic contexts and we propose that their longevity will probably reflect the duration of those contexts. In that case it is not appropriate to think of the contractions of these systems as failures or as collapses, but rather we hypothesise they were shifts in social strategies and patterns of social connection. Similarly the emergence of contiguous and expansive signalling systems in the middle and late Holocene must reflect the contexts in each region before and during the technological proliferation of forms used for public signalling. In this paper we have synthesised some of the available information about the selective context in which Australian lithic technologies displayed trends towards and away from continental scale integration and inter-connectivities.

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Chapter 9: Conclusion

The following section compiles the arguments and discussions constructed in the previous papers, and summarises the answers to the research questions posed in the introduction. The thesis is concluded with a brief discussion of the implications of this research, leading to future directions for stone tool analyses, Kimberley prehistory, and Australian archaeology.

9.1 How old is point technology in the Kimberley?

The new archaeological data presented above, combined with a comprehensive literature review, provide a robust temporal model for point technology development in the Kimberley. While direct percussion points first appear in the archaeological record around 5,200 cal BP (Maloney et al. 2014), flake production was changing towards blade-like morphologies several thousand years before the first points appear in the sequences (O'Connor et al. 2014). These data support similar patterns of technological change observed in Wardaman Country, prior to the earliest points (Clarkson & David 1995). The recovery of multiple points associated with dates between 5,500 and 5,000 cal BP (Maloney et al. 2014), implies that points first became widespread between 6,000 and 5,000 years ago (Hiscock & Maloney In Review), and are contemporaneous with those reported from Western Arnhem Land (Jones & Johnson 1985). The comparatively lower frequency of points from between 6,000 and 5,000 years ago are simply less likely to be recovered in archaeological excavation. Points proliferate in the Kimberley archaeological record between 3,500 and 2,000 years ago, which increases the likelihood of recovering points from this period in excavations.

The varied claims for the antiquity of Kimberley Points, or pressure flaked bifaces, have largely been resolved by this research (Maloney et al. 2014). New excavations have recovered multiple pressure flaked bifaces dated to within the last millennium. While there is a high probability that pressure flaking was occasionally practiced in earlier times (Flenniken & White 1985:148), Kimberley people were the only Indigenous Australians to produce these elaborate pressure flaked bifaces. There is no convincing evidence for these distinctive bifaces in the Kimberley record before c. 1,000 cal BP.

9.2 Is the typological model for point variability valid?

Contrary to the arguments advanced by earlier researchers, direct percussion unifacial and bifacial points were produced within an underlying reduction continuum. There was no rigid bimodal design in point technologies (Maloney et al. In Review; Maloney In Review). The divergent or typological, model is not capable of capturing the morphological diversity of point life history in this region, and is a heuristic and oversimplified system for categorisation. Quantified measures of retouch intensity provide irrefutable evidence that direct percussion points were gradually maintained (Maloney et al. In Review; Maloney In Review), therefore, the extent of reduction is responsible for the diversity of point morphologies. Points from the Mt Behn excavation

and other surface collections were shown to exhibit a wide range of retouch strategies, often involving the transformation of unifacial to bifacial retouch via multiple pathways. Points were also recycled following breaks, either to rejuvenate the pointed morphology and margins, or to radically transform broken tools into burinates. A dominant pattern of retouch order and placement shows similarity with point reduction sequences found in Wardaman Country to the north (Clarkson 2007:104, 109) and Arnhem Land (Hiscock 1994a:77-80, 2009:84, 2011:78). This pattern, where most points begin with dorsal marginal retouch before retouch expands and diversifies, now appears to be a widespread trend in northern Australian points during the mid to late Holocene. Retouch intensity in point technologies across northern Australia, including the Kimberley, is indicative of an emphasis on tool use life extension.

While the typological interpretation of unifacial and bifacial points as discrete technological products is no longer tenable; the Kimberley Backed Point does represent technological divergence from this reduction continuum. Backed Points are consistently small components of point assemblages (Maloney & O'Connor 2014). These tools are an exception to the model advocated for continuous reduction as they appear to be an intentional end product. As opposed to direct percussion unifacial and bifacial points, no observations were made where these tools were recycled or transformed with continued reduction. The backed margin was produced from blanks and maintained. These backed margins could have offered a functional specialisation, and/or immobilisation or anvil resting may have offered a way to utilise even the smallest blanks. The function of these tools, and indeed all points, will only be resolved by the combination of residue and use wear analyses with vigorous experimentation, although exiting studies hint at multipurpose uses (Wallis & O'Connor 1998).

9.3 The underlying causes of point technology?

In recent years, Australian archaeologists have been focused on two models explaining the development of point technology: The ecological or risk reduction model (Hiscock 1994a, 1994b), and the demographic or social signalling model (Moore 2013). Both models were critically examined in this thesis using new data. The risk reduction model finds more support from the data within this study, although there are certainly crucial social aspects behind this technology (Hiscock & Maloney In Review).

The properties of the direct percussion points analysed in this study undermine the strength of the social signalling argument as an overall explanation for point technology. Points in this region of the Kimberley are typically very small, so distinguishing between points, unretouched flakes, and non-lithic technology, requires close examination for any social signal to be made. The hafted point from CG1 for example (Maloney et al. 2015), had only a tiny portion of stone projecting from the resin, making recognition of this tool as a point only possible by very close inspection. While tiny objects of material culture undoubtedly provided social signals, such as shell beads, patterns of point retouching are very unlikely to be a function of social signalling during the mid to late

Holocene. The reconstructed life history of points in this study demonstrates that people emphasised maintenance, extendibility, and transportability. If points were produced for their signalling properties, why would they be constantly reworked, reconfigured, and reduced during their life history?

The major problem with the demographic model is the lack of convincing temporal correlation between points in the archaeological record, and population density measures. From the radiocarbon dating data, population is predicted to be increasing from the early Holocene (Smith et al. 2008; Williams 2013), and peaking within the last 500 years (Williams 2013). It is therefore just as plausible to propose that any technological change during the Holocene occurred against the backdrop of both an increasing population and increasing interaction with new social groups. Data presented by Williams et al. (2015:6, Table 1) does not show a compelling correlation between the known development of point technology, and notable change in the modelled population density. Furthermore, the taphonomically corrected population peaks and declines given by Williams (2013:5), suggest that point technology developed during a period of population decline at approximately 5000 cal BP, and also proliferated during a population decline. This trend is the opposite of that expected if increasing populations encouraged social signalling via stone point technology. This explanation does not provide a convincing account for the development of points between 6,000 and 5,000 years ago and the changes that occurred in the mid to late Holocene point assemblages.

There is more convincing material culture evidence for transportable social signalling, such as marine shell beads, and extensive efforts at creating elaborate rock art galleries at all the analysed sites in this study. These items are found in Pleistocene, early Holocene, mid to late Holocene, and contemporary times, and so cannot provide supporting evidence of increasing emphasis on social signalling during the mid Holocene.

Changes in the point assemblage at Mt Behn are temporally correlated with changes in regional and local environmental proxy records. Points first appear when aridity is widely modelled as increasing, after 6,000 cal BP. The life history of points demonstrates dynamic transformations from thin sharp margins, to steep margins, bifacial acute margins, maintenance of the pointed tip, the production of many small sharp flakes, and the recycling of points into radically different tools. These properties were not emphasised in early Holocene lithic technologies, such as those from CG3 (O'Connor et al. 2014) and WG1 (Appendix C). In fact, it is not until after 6,000 years ago that these properties became an important feature of stone technology. At Mount Behn, points peak in discard frequency, reduction intensity, and recycling rates between 2602 and 1747 calBP. This proliferation period shows remarkable temporal correlation with local environmental proxy data predicting extreme aridity (McGowan et al. 2012:4) as well as regional records indicating greater periodicity in rainfall coupled with increased aridity (see Maloney et al. In Review). During this time such climactic changes undoubtedly altered ecologies. In the study area close to the desert margins, fresh water, edible

plants, and game animals most likely became less abundant, and access to them less predictable after 6,000 years ago, with an increase in foraging risk increasing as aridity intensified.

With the decrease in predictability of subsistence resources and freshwater, people greatly expanded their foraging range. This increased mobility required a technology that could equip people for longer foraging trips, and reduce the need to replenish raw materials. Point technology manifests several properties of risk reduction for a mobile population:

- Points are small and easily transportable, which allowed them to be carried over large areas.
- Point margins are easily and predictably maintained.
- Point technology provided a multipurpose and highly adaptable technology. This reduced the risk of being in foraging situations where technology was exhausted, or inappropriate, through lack of replacement materials, particularly in situations where access to replacement material was less predictable or unknown.
- The transport of multiple points allowed a range of specialised tools to be on hand, including backed points and the ability to recycle.
- Points are standardised and could likely be incorporated into hafting technology without major morphological change.
- Standardisation likely enhanced the market value of points as intra and inter group trade items, which plausibly provided social risk reduction methods, via tribute payments to different social groups for access to resources, or direct exchange.

Direct percussion points continued to be manufactured after the development of the pressure flaked bifaces around 1,000 cal BP. During this time, reduction intensity and recycling of these direct percussion points declines. Foraging risk very likely diminished during this time, seeing a return to predictable monsoon-driven regimes, and the likely establishment of ecological resources that resemble those found today. It is probable that permanent water in gorges, which support increased aquatic resources; rainforest thicket with more biodiversity; and highly predictable patterns of game animal movements, are one ecological consequence of this environmental change. The ecological need to forage in wider areas was reduced during this time, which is reflected in the diminished effort to extend the use life of points.

Novel, elaborate, technologies with greater social value develop around 1,000 years ago. These Kimberley Points lack the raw material conservation properties of the direct percussion points, indicating a reduced need for an extension strategy. The production of these pressure flaked bifaces was staged and required high levels of skill, a range of manufactured percussors, and most likely a formal pedagogy. These factors suggest that biface production was not as suitable to high foraging risk situations, unlike the direct percussion points, and were most likely part of changing social relationships with

regional groups and inter group social change (Hiscock & Maloney In Review; Maloney In Review).

Future study which continues to explore risk reduction arguments and changing social relationships during the mid Holocene may be able to link prominent changes in Kimberley rock art styles with point technologies. Contemporary Aboriginal people note that Wanjina have control over the monsoonal cycle, with its associated torrential rain, lightning, and thunder (Akerman 2014:36; Crawford 1973:108-117; Layton 1997). There is a strong cultural link between weather regimes and these art forms. If available dates of around 4,000 years are accepted for the earliest known Wanjina (Huntley et al. 2014:34; Morwood et al. 2010:5; see also Aubert 2012:575; O'Connor et al. 2013:539), which are notable later than the earliest points, it is plausible that environmental change, and technological change represented in point assemblages, could have some temporal correlation with this new art style.

9.4 What are the spatial distributions of point and backing technologies?

The spatial distribution of backing technology is far more variable than existing models depict. This study demonstrated that backing was a specialised retouch strategy found in several areas throughout the Kimberley (Maloney & O'Connor 2014; Maloney et al. In Review; Maloney In Review). There are many other reports of apparently isolated backing technology, in areas where many researchers have accepted an absence of backed artefacts (Akerman 1998; Brayshaw 1977:281; Flood 1970:47; Fullagar et al. 1996; Hiscock & Hughes 1980:93; Kamminga 1977:208–211; Lamb 1996; Morwood 1989:18 Table 7, 29 Table 11, 39 Table 15; Schrire 1982:40).

9.5 Were points in the mid Holocene hafted, if so, how?

Despite the common assumption that points were hafted projectiles, there is scant physical evidence for hafting of point technology from the mid to late Holocene. As cautioned by Binford (1968:86), observing technologies in recent, ethnographic or contemporary societies does not necessitate that this same observation can be reliably extended into the past; indeed, this assumption probably hinders our comprehension of past technologies. While the rich record of hafted stone technologies from recent times in the Kimberley provides an excellent record of hafting technology from this period, our understanding of hafting technology from the mid to late Holocene is limited by a paucity of remains from this period. The first recovery of a point with large portions of adhering mastic from the mid to late Holocene from the Australian record is presented in this thesis (Maloney et al. 2015). Impressions preserved in the resin indicate that hafting incorporated some form of binding, involving very fine strands of fibre (< 0.3mm) wound over the top of the mastic. This binding action is itself notably different to more recent modes of hafting from the Kimberley (Akerman 1978). This point, excavated from CG1, also implies that bifacial thinning and the symmetrical morphology of more recent pressure flaked bifacial points was not a requirement for hafting.

The CG1 point's mid-section break was most likely initiated through resistance created by the binding agent, which could have been produced by a projectile impact. It is equally plausible that the point was hafted for other functions; however, such as cutting, engraving and scraping.

The CG1 point is an isolated find amongst the assemblage, which suggests that there is a low probability of recovering similar artefacts in the future. However, excavation of sites with exceptional organic preservation could produce similar finds. Direct dating of the CG1 point provides encouragement for the reliability of directly dating other tools using small resin samples. With the recent changes in capability for dating very small samples resin could be potentially extracted and dated from other reported tools across Australia (e.g. Akerman et al. 2002:24, Fig 7 A & C, 38 Table 6; Brindley 2011:23, Fig. 3.1; Moore 2015 Fig. 12 C; Robertson 2011:96, Fig. 12-15; Robertson et al. 2009:302, Fig. 4 C).

9.6 Why did Kimberley people make Kimberley Points?

The timing of Kimberley Points in the archaeological record was revealed as concurrent with a declining effort to extend the use life of the earlier direct percussion points. The circumstances which led to the innovation of Kimberley Point technology are undoubtedly complex, and occurred during periods of reduced foraging risk, and probable population increase.

The timing of Kimberley Points appears to have some temporal parallels with neighboring regions technological change. For example, bifacial points decline in the record of Arnhem land around 1,500 years ago (Hiscock 1999), and Wardaman Country experiences similar declines while people increasingly produced large blades (Clarkson 2007:139, Fig. 7.7). The archaeological records from the central deserts suggest people increased the use of seed grinding technology after 1,400 years ago (Smith 1988:332-341). Allen (1996:149) noted that the relatively smaller points, from the mid to late Holocene, had a more restricted distribution than the large blades which spread far beyond the area where they were used as spear points. It is plausible that across northern Australia within the last 1,000 years, trade of new lithic materials such as leilira blades and Kimberley Points became far more prolific as trade items than any previous stone technology.

The case studies used in Maloney (In Review) contrast raw material economy and the effective complexity of two discrete reduction sequences: Direct percussion points, and pressure flaked biface production. Pressure flaked bifaces require staged production to successfully produce Kimberley Points, and I argue that only small numbers of individuals within social groups would have learnt to produce pressure flaked bifaces, within a formal teaching and learning environment. Incorporating these arguments into broader archaeological discussions of skill, cultural transmission, foraging risk, and population increase, the technological shift in the Kimberley region around 1,000 cal BP can be linked to the development of pedagogical relationships.

The value of using the description of regularities extrapolated from reduction sequences (Maloney In Review) has implications for future studies. Archaeologists can reveal more about the social nature of technologies from the past by quantifying the complexity of reduction sequences, and discussing the likely role of pedagogy in both technological organisation and stone artefact assemblage formation.

9.7 Summary

This thesis introduced the topic of stone technology and past human lifeways, with a brief review of current theory surrounding technological organization and the archaeological background to the study area. Theories such as the abundance strategy versus the extendibility strategy (see Hiscock & Maloney In Review), proved to make for a vibrant depiction of the meaning of stone artefact variability. The extendibility of points, demonstrated through the reconstructed reduction sequences, was used to discuss an overall technological strategy, which includes aspects of suitability, reliability, maintainability, standardization, and inherent design. This approach is well suited to the discussion of foraging risk, which remains a major theme in global hunter gather lifeways and probably the most engaging archaeological theory in Australia.

Typology was found to be defunct relic, in terms of value to archaeological analysis, which supports an ever widening trend of reduction intensity being the primary factor causing stone artefacts variability. Instead, varying degrees of reduction in points were found to be related to the extension of implement use life which implored an examination of competing theories for the underlying causes of point technology.

The mid Holocene development of points in the Kimberley was found to be best explained by the foraging risk model, where increased economic risk was brought on by environmental changes. Regional and local environmental proxy records were used to show a compelling correlation between technological change, and likely periods of increased foraging risk -- a trend now widely supported in the archaeological record of Holocene Australia. Future exploration of foraging risk during this period should continue to be examined against new data, particularly as local environmental proxy records increase in clarity, and as changes in rock art styles become chronologically clearer, which will offer a comparative record of cultural, technological change, and environmental change.

Other proxy records which were discussed in this thesis include demographic records. There is currently a new synthesis of population data for Australia archaeology (Williams 2013), which uses radiocarbon dating to model population changes. This proxy record has enabled comparison of technological change with modelled changes in population, which enables examination with theories of technological innovation, social signaling, and cultural transmission theory. The data in this thesis found that social signaling alone, does not provide an adequate explanation for the development of point technology in the mid to late Holocene, although does find support for significant social change within the last 1000 years (supporting Moore 2015). Pedagogy was advanced as a meaningful

aspect of this more recent social change in the Kimberley, which can be linked to stone artefact reduction sequences using a description of regularities.

Conclusion References

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Appendices

A) O'Connor S, Maloney T, Vannieuwenhuyse D, Balme B, Wood R 2014 Occupation at Carpenter's Gap 3, Windjana Gorge, Kimberley, Western Australia. <i>Australian Archaeology</i> , 78:10–23.....	250
B) O'Connor S, Hiscock P, Balme J, Maloney T In Review. World's earliest edge-ground axe production is coincident with human colonization of Australia and exemplifies the emergence of novelty during the global dispersion of humans. <i>Journal of Human Evolution</i>	284
C) Maloney T, Vannieuwenhuyse D, O'Connor D, Balme J, Fyfe J In Review. Re-examination of a Holocene rock shelter in the southern Kimberley, north Western Australia. <i>Australian Archaeology</i>	295
D) Australian National University thesis by compilation procedure.....	312
E) List of Recorded Variables.....	314
F) Maloney T 2013 I/TMC experimental examination. Unpublished Report.....	316
G) Maloney T, Marwick B Elliptical Fourier Analysis Unravels a Palimpsest of Point Technology. Poster given at the Society for American Archaeology annual conference in 2014.....	332
H) Analysed assemblages not included in published manuscripts.....	339

Occupation at Carpenters Gap 3,

Windjana Gorge, Kimberley, Western Australia

Sue O'Connor¹, Tim Maloney¹, Dorcas Vannieuwenhuyse², Jane Balme² and Rachel Wood³

¹ Archaeology and Natural History, College of Asia and the Pacific, The Australian National University, Canberra ACT 0200, Australia <sue.oconnor@anu.edu.au> <tim.maloney@anu.edu.au>

² Archaeology, School of Social Sciences, The University of Western Australia, 35 Stirling Highway, Crawley WA 6009, Australia <dorcas.vannieuwenhuyse@research.uwa.edu.au> <jane.balme@uwa.edu.au>

³ Radiocarbon Facility, Research School of Earth Sciences, College of Physical and Mathematical Science, The Australian National University, Canberra ACT 0200, Australia <rachel.wood@anu.edu.au>

Abstract

Carpenters Gap 3 (CG3), a limestone cave and shelter complex in the Napier Range, Western Australia, was occupied by Aboriginal people intermittently from over 30,000 years ago through to the historic period. Excavations at CG3 provide only slight evidence for occupation following first settlement in the late Pleistocene. Analysis of the radiocarbon dates indicates that following this there was a hiatus in occupation during the Last Glacial Maximum. In common with most Australian sites, the evidence for occupation increases sharply from the mid-Holocene. Faunal remains, interpreted predominantly as the remains of people's meals, all suggest foraging of the immediate surroundings throughout the entire period of occupation. Fragments of baler shell and scaphopod beads are present from the early Holocene, suggesting movement of high value goods from the coast (over 200 km distant). Flakes from edge-ground axes recovered from occupation units dated to approximately 33,000 cal. BP, when overall artefact numbers are low, suggest that these tools formed an important component of the lithic repertoire at this time.

Introduction

Carpenters Gap 3 (CG3) is a limestone cave and overhang complex in the Napier Range, southern Kimberley, Western Australia (WA) (Figure 1). It is located on the north side of the range, a few hundred metres east of the Lennard River, where it cuts through the range forming Windjana Gorge. CG3 includes an extensive overhang about 30 m above the plain containing a spectacular gallery of painted art, and a lower cave—which appears to have been formed by solution—that extends at least 30 m into the range. The floor of the overhang has extensive evidence of human occupation, such as in situ ground and incised surfaces, stone artefacts and freshwater mussel shell valves, but contains only small pockets of sediment with little excavation potential and in places the floor comprises bare rock. The main deposit at CG3 is found within the lower cave which, in places, shows extensive surface cracking, indicating that it is subject to seasonal or periodic wetting and drying. No cultural material was visible on this relatively level surface.

CG3 was first excavated by O'Connor in 1993 as part of a regional archaeological investigation programme, at which time a 1 m square (Pit A) was excavated about 17 m inside the drip-line within the lower cave (Figure 2). Pit A was excavated to a maximum depth of 168 cm without reaching bedrock (Figure 3), at which time excavation was discontinued and the pit was backfilled. Radiocarbon age estimates obtained on charcoal, seeds and freshwater shell demonstrated occupation spanning over 30,000 years and, although since incorporated into regional syntheses (e.g. O'Connor and Veth 2006:36), neither the CG3 dates nor

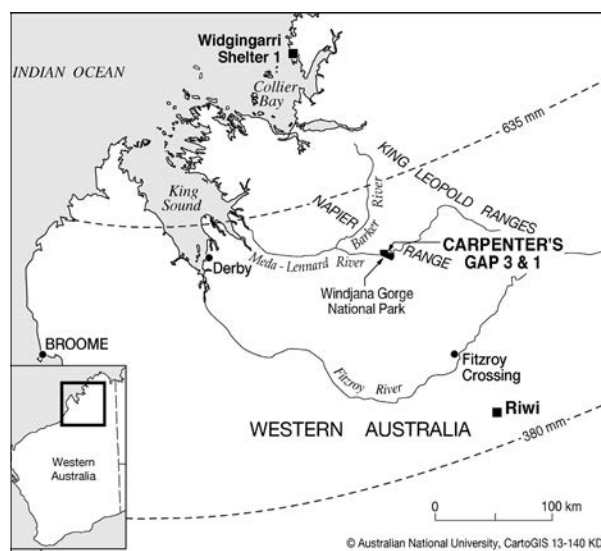


Figure 1 Location of CG3 in Windjana Gorge National Park and other sites mentioned in the text.

details of the excavation were ever fully reported. In August 2012 we returned to CG3 in order to extend Pit A, including for the purposes of reaching bedrock. The original pit was emptied and the excavation was continued to a maximum depth of 2.4 m, where bedrock was encountered (Figures 3 and 4). Here we present the full suite of radiocarbon dates and finds from CG3 Pit A from both the 1993 and 2012 field seasons.

Excavation and Recovery at CG3: The 1993 and 2012 Field Seasons

The 1993 excavation was carried out in 2–5 cm excavation units (spits). In the upper part of the deposit, excavation

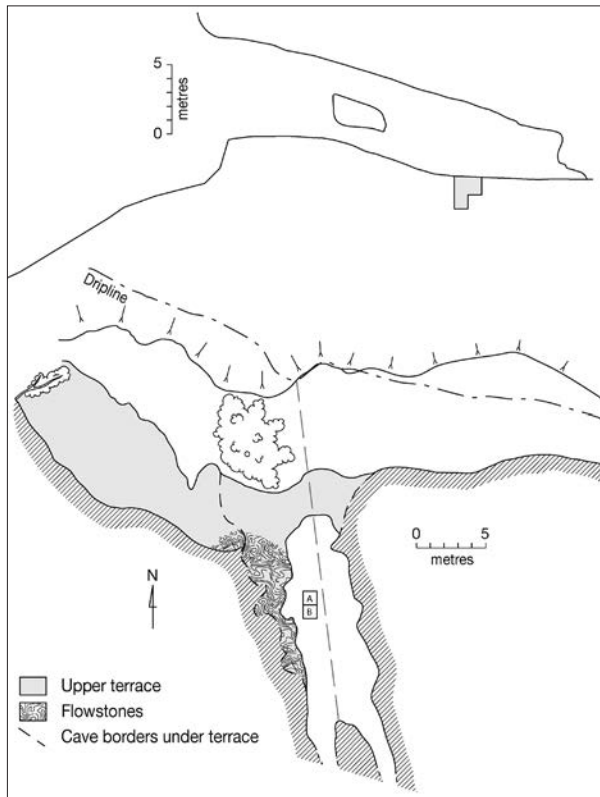


Figure 2 CG3 cross-section (top) and site plan (bottom) showing cave, overhang, and 1993 and 2012 excavations.

units (XUs) averaged 3 cm, whereas in the lower deposits excavated in 1993, as well as those during the 2012 field season, and in which little or no cultural material was encountered, XU thicknesses were greater. This is reflected clearly in the volumes of excavated sediment (Figure 3). The stratigraphic layers sloped towards the southeast corner of the excavation, with a slope gradient decreasing from bottom to top. Owing to the difficulty in identifying stratigraphic changes during excavation, XUs were horizontal, resulting in some cross-cutting stratigraphic layers (Figure 3). All excavated materials were dry sieved on-site through nested 6 and 3 mm sieves during the 1993 field season, and 5 and 1.5 mm sieves during the 2012 season. All dated organic material was recovered from the sieve residues.

CG3 Sediments and Depositional Processes

The CG3 sediments are relatively homogeneous, primarily brown (7.5YR4/4), though close inspection reveals some subtle colour differences (Figure 4). Texturally, the sediment is fine sandy silt in the upper part of the deposit (Stratigraphic Layers 1–11), becoming increasingly sandier below Layer 12. Loose gravels and rocks occur throughout. The sand fraction is primarily composed of quartz, though mica particles also occur through the profile in various proportions. All the sediment components seem to derive from the surrounding parent material of complex bedded limestone and sandstone, and have accumulated via run-off, aeolian or mechanical means. The cave's entrance is steeply sloped and this would have facilitated the movement of materials and sediments from the upper terrace into the lower cave. The enclosed character of the lower cave has worked as a natural trap for sediment, resulting in a greater accumulation of sediments than other excavated sites in the area (e.g. O'Connor 1995).

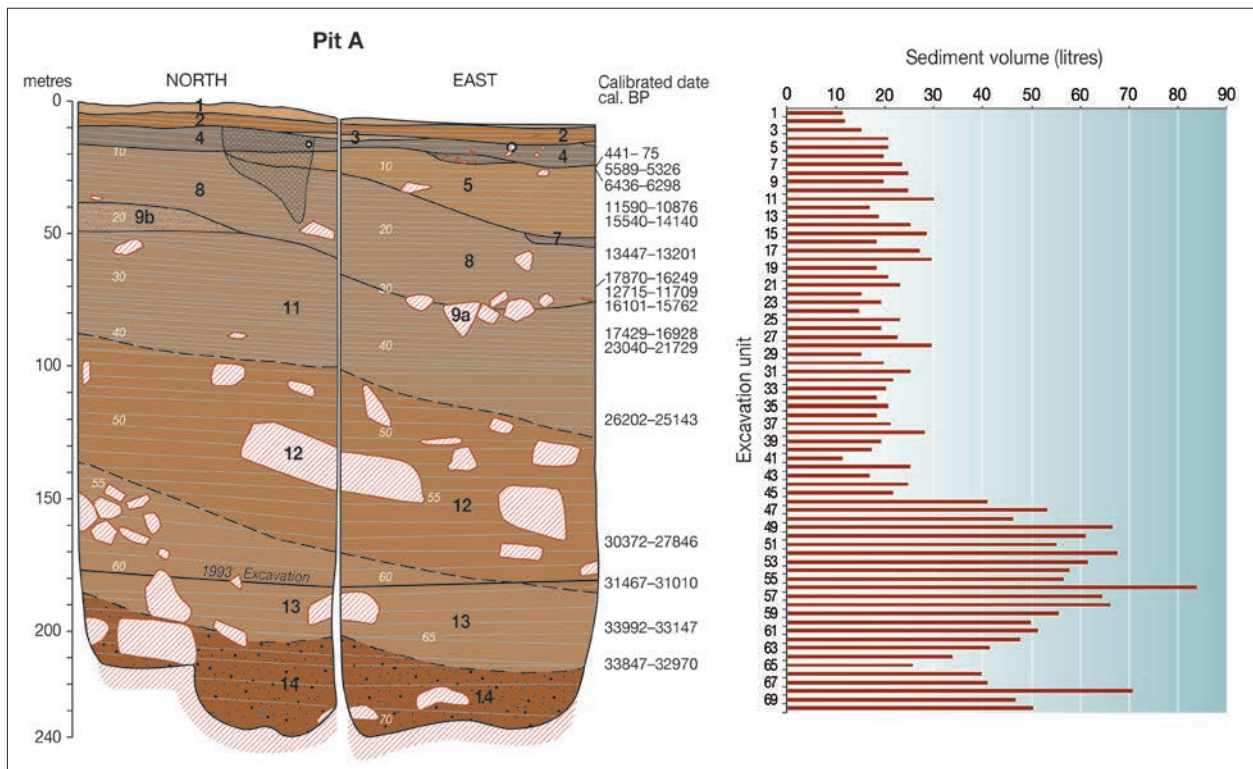


Figure 3 Profile of CG3 excavation Square A, showing XU depths as they relate to stratigraphic layers, depth of 1993 excavation and volume of sediment removed for each XU.

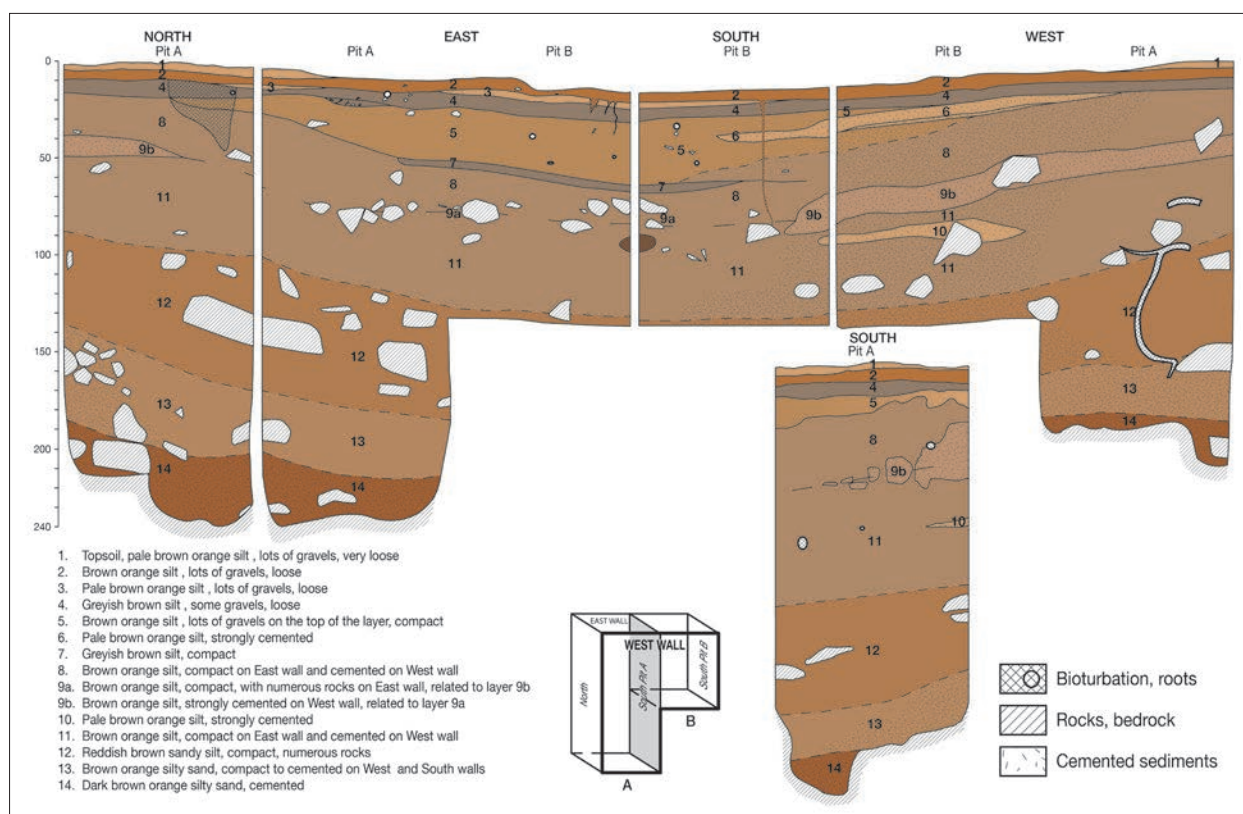


Figure 4 CG3 stratigraphic profiles of Pits A (1993) and B (2012).

Three major depositional strata can be distinguished in the deposit (Figure 4). The first includes Layers 14–12 (sediments of a sandy silt texture with large limestone cobbles), which corresponds to the initial accumulation episode in the cave. The second, comprising Layers 11–8, is a homogeneous, thick accumulation, except for Layer 9. The latter is represented on the east wall by rock fall (Layer 9a) and on the west wall as a carbonate cemented layer (Layer 9b). The latter may indicate a phase of wetter conditions where more water was entering or pooling in the cave. The last stratum (Layers 7–1) consists of several thin laminated layers, of which Layers 7 and 4 are greyer than the others, possibly due to larger amounts of organic matter and/or the presence of small charcoal particles. Future micromorphological and geochemical analyses may help determine whether these differences are related to increased anthropogenic activity or other causes.

Thick roots have penetrated through the sediment into the deeper layers, where moisture seems to be present all year long. Bioturbation, in the form of insect channels and small roots, is also visible in the upper layers. Processes resulting in the dissolution and precipitation of calcium carbonate have taken place throughout the history of the cave and have differentially affected the deposit. This is particularly evident in the western side of the deposit, which is heavily cemented below Layer 4. Speleothems and flowstones are present in both the cave and shelter, and are still actively forming during the wet season.

Owing to the high carbonate content in the sediments the pH is uniformly 8.5 (alkaline) throughout. Consequently, preservation is excellent, although organic cultural materials and stone artefacts were variously carbonate encrusted and had to be treated to remove the carbonate.

Radiocarbon Dating

Radiocarbon age estimates were obtained on a variety of cultural materials, including charcoal, freshwater mussel shell and *Celtis* sp. seeds (Table 1).

Small fragments or comminuted charcoal were recovered from most XUs (Figure 5b), though at depth the charcoal did not occur within the context of definite cultural features, such as hearths. In view of sediment cracking, bioturbation and root activity, these small fragments were regarded as unreliable for dating. *Celtis* sp. seeds and freshwater mussel shell also occurred in most XUs and, owing to their larger size, were considered less likely to have been displaced and, in the latter case, may be linked to human use of the cave (see below). However, the freshwater bivalves were once living within the limestone catchments and therefore have an unknown but potentially large freshwater reservoir effect (Keaveney and Reimer 2012; Lanting and van der Plicht 1998).

The endocarp of *Celtis* sp. seeds contains up to 70wt% carbonate (Wang et al. 1997). As seeds, they represent a single year of growth and derive their carbon from the atmosphere, and have been successfully used for dating elsewhere (Wang et al. 1997). Although they are regularly found in archaeological deposits in limestone caves, they are not likely to enter the cave as a result of human activity. Precisely how they enter the caves is unknown; they may be windblown, washed in by water or brought in by rodents, but if the latter they exhibit no gnawing damage.

Methods

Like shells and coral, *Celtis* sp. is subject to diagenesis, primarily through recrystallisation which can lead to the incorporation of carbon of a different age. As the stable polymorph of carbonate, calcite will be deposited

XU	Layers	Material	Laboratory Code	Radiocarbon Age (BP)	Calibrated Date cal. BP (95.4% Probability)	% Calcite
1	1	Charcoal and sand	ANU-10606	99.9±1.8 pMC	Modern	
10	5–8	Charcoal <i>Celtis</i> inorganic	OZF-033 OZF-325	260±40 4790±40	441–75 5589–5326	
12	5–8	<i>Celtis</i> inorganic	SANU-30229	5625±40	6436–6298	<1
16	5–8	<i>Celtis</i> inorganic	SANU-29413	9850±70	11,590–10,876	
18	5–8	Freshwater mussel	OZD-163	12,650±190	15,540–14,140	
24	8–9b	<i>Celtis</i> inorganic	OZF-327	11,520±50	13,447–13,201	
29	8–11	<i>Celtis</i> inorganic Charcoal	OZF-324 OZF-359	13,870±70 14,100±300	17,014–16,442 17,870–16,249	
30	8–11	Freshwater mussel	ANU-10784	10,486±179	12,715–11,709	
32	9a–11	<i>Celtis</i> inorganic	SANU-29414	13,300±30	16,101–15,762	1.1±0.2
37	11	<i>Celtis</i> inorganic	SANU-30227	14,020±60	17,208–16,658	<1
38	11	<i>Celtis</i> inorganic	SANU-29939	14,150 ±60	17,429–16,928	93.1±0.5
39	11	Freshwater mussel	OZD-166	18,550±280	23,040–21,729	
49	11–12	Freshwater mussel	OZD-167	21,450±270	26,202–25,143	
58	12–13	Charcoal Freshwater mussel	OZD-164 OZD-165	25,100±3590 24,900±570	46,660–23,955 30,372–27,846	
61	13	Charcoal Freshwater mussel (nacre)	D-AMS-001665 SANU-35003	25,875±103 27,400±160	30,484–29,624 31,467–31,010	<1
64	13–14	Freshwater mussel	SANU-35007	29,280±190	33,992–33,147	
67	13–14	Freshwater mussel	SANU-35006	29,450±200	33,847–32,970	

Table 1 Radiocarbon dates from CG3 calibrated against SHCal13 (Hogg et al. 2013) using OxCal v4.2 (Bronk Ramsey 2009a).

on recrystallisation. The carbonate of the endocarp is aragonite, meaning that recrystallisation, and therefore possible contamination, can be readily identified with x-ray diffraction (XRD). *Celtis* sp. seeds treated at The Australian National University (ANU) (i.e. laboratory codes prefixed SANU in Table 1) were subject to a 10% acid leach in 0.1M HCl at 80°C after removal of the surface with a scalpel. The cleaned carbonate was homogenised and divided into two aliquots. Approximately 8 mg was weighed into a blood collection vacutainer™, placed under vacuum and reacted with 0.5 mL 85% phosphoric acid. The CO₂ generated was cryogenically purified and graphitised over an iron catalyst with H₂ before measurement in a NEC SS-AMS (Fallon et al. 2010). The remaining material was used to screen for calcite. Approximately 10 mg of sample was crushed to a fine powder and suspended in an x-ray transparent glue on a plastic film. XRD analysis was performed in a STOE Stadi-P diffractometer operating at 30 mA and 40 kV. CoK radiation was used with a step size and time of 0.5° and 60 s between 24–60° 2 on the Bragg scale. Siroquant™ was used to quantify the calcite content, with a detection limit of ca 1% calcite. Of the five samples treated, three contained <1% calcite. One contained 5% calcite and was therefore not dated. A fifth sample (SANU-29939) contained more than 90% calcite, possibly suggesting the seed was burnt. Its date is not as reliable as the other dated seeds, though is similar in age to the sample from the XU above (SANU-30277). The pretreatment method used on the *Celtis* sp. seeds sent to ANSTO for dating is not known, though we do know that these seeds were not screened for calcite prior to analysis (i.e. laboratory codes prefixed OZF and OZD in Table 1).

Freshwater mussel shells dated at ANU (i.e. laboratory codes prefixed SANU) were treated using the same methods as the *Celtis* seeds. These shells naturally contain calcite and aragonite, but in one case (SANU-35003), nacre, made solely of aragonite, could be separated from the shell.

Charcoal and freshwater mussel shell samples were dated using conventional radiocarbon techniques at the ANU (i.e. laboratory codes prefixed ANU in Table 1). The charcoal/sand mixture of ANU-10606 was washed in 10% HCl prior to dating, whilst the surface of a freshwater mussel shell (ANU-10784), coated in a carbonate concretion, was ground with a dental drill and washed in water in an ultrasound bath.

Dates were calibrated in OxCal v4.2 (Bronk Ramsey 2009a) against SHCal13 (Hogg et al. 2013). A Bayesian chronological model was constructed to calculate dates for the transition between stratigraphic layers and to identify and down-weight outliers (Bronk Ramsey 2009a, 2009b; Bronk Ramsey et al. 2010). The latter is particularly important where radiocarbon dates on a variety of materials have been dated using different methods, and where quality indicators, such as XRD, are not available. Terms relating specifically to OxCal are given in *italics*.

Numerous examples and explanations of the OxCal programme are available (e.g. Bayliss et al. 2007; Bronk Ramsey 2009a, 2009b; Higham et al. 2011). Briefly, the programme allows information about the relative chronology provided by stratigraphy to be combined with radiocarbon dates. The radiocarbon dates are grouped within *phases* (stratigraphic layers), and these *phases* are arranged within a *sequence*. Between each *phase* is a *boundary* that provides an estimate for the date of transition between the two *phases*.

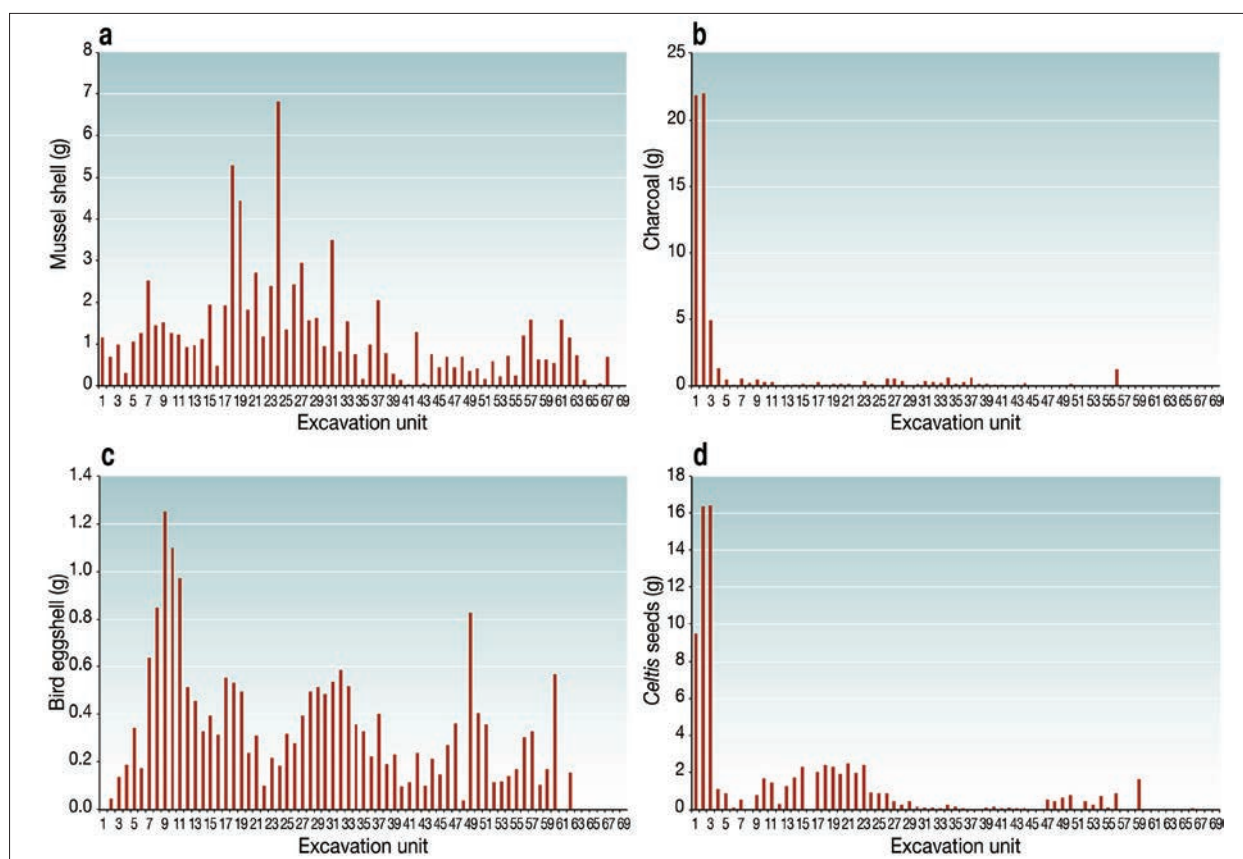


Figure 5 Weights of recovered remains from CG3 by XU: (a) mussel shell; (b) charcoal; (c) bird eggshell; and (d) *Celtis* sp. seed.

It is these *boundaries*, or ‘transition dates’, that are plotted in Figure 6b and listed in Table 2. As noted above, at CG3 most XUs cut through several stratigraphic layers, so a series of overlapping *sequences* were cross-linked to a primary *sequence* containing all *boundaries* (Figures 6a and 6b). With the exception of those on mussel shells, the radiocarbon dates were assigned a prior outlier probability of 5% within the *General t-Type Outlier Model*, a flexible model which allows outliers to be either too young or too old (Bronk Ramsey 2009b). The mussel shells may have been affected by a freshwater reservoir effect, and have been assigned a higher prior probability of 50%, while one young charcoal date (OZF-033) has been excluded from the model. The prior outlier probability is revised during modelling, and a date’s influence on the model is weighted according to the resulting outlier probability.

For a robust model, convergence should be above an arbitrary limit of ca 95% (Bronk Ramsey 2009a). Owing to the lack of stratigraphic constraints towards the top of the model, convergence of the final two *boundaries* (Transitions 7/5 and 5/4) is unacceptably low and these modelled date estimates should not be used (Table 2). Despite the variety of materials dated, the only samples found to have a much greater posterior probability of being an outlier than expected are OZD-166 and ANU-10784 (Figure 6c), both mussel shell. ANU-10784 is slightly young for its location, whilst OZD-166 is much older than expected. The significance of these dates has been down-weighted in the model, and they should not be used in discussions of the site chronology. Unfortunately, without XRD analysis, it is impossible to establish whether these outliers are the result of contamination, or whether the anomalously old sample may indicate that the shells are affected by a freshwater reservoir.

Whilst the imprecision of some *boundaries* in the Holocene limits their significance, others are more precise, particularly between Layers 8–12, where the highest number of dates have been obtained and XUs cross-cut fewer layers. The earliest occupation is found at the top of Layer 14 or, more likely, given the absence of any macroscopic or microscopic evidence of occupation in Layer 14, at the base of Layer 13. The earliest dates are on mussel shell in the spits cutting the top of Layer 14 and base of Layer 13. These place the first occupation after 34,440–31,340 cal. BP (at 68.2% probability, *boundary* ‘Base’), although this may be a slight overestimation because the base of the model is heavily dependent on shell dates.

At the end of Layer 12 there appears to be a hiatus from 27,640–23,360 to 15,550–15,060 cal. BP (at 68.2% probability, *boundaries* ‘End 12’ and ‘Start 11’), before deposition restarted. One sample, not identified as an outlier, OZD-167, falls within this gap. Unfortunately, this date is poorly constrained by the model, falling somewhere between the Transitions 13/12 and 11/9 *boundaries* (Sequence 4, Figure 6a). This means that the date could vary by 15,000 years and not be identified as an outlier by this model. The accuracy of the date is impossible to assess independently of the model as it is not accompanied by quality assurance data (e.g. XRD), and therefore this single date does not provide robust evidence for occupation during the otherwise apparent gap.

The Stone Artefact Assemblage

A total of 2119 flaked lithic artefacts was recovered at CG3 from the 6 mm sieve fraction. The 3 mm fraction has not yet been analysed. The lowest lithic artefact was recovered from

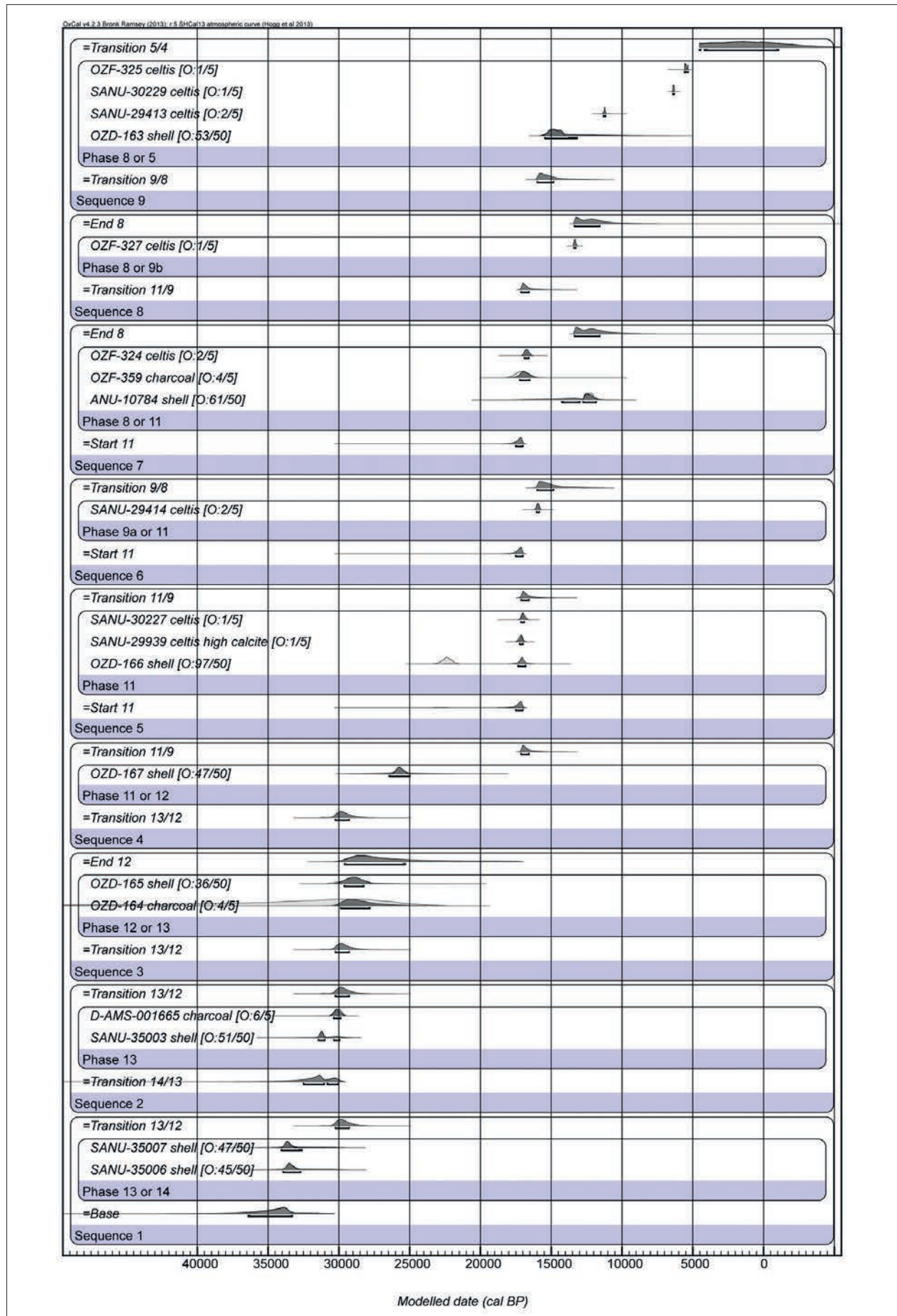


Figure 6a Bayesian model for the chronology of CG3. A series of single-phase sequences with radiocarbon dates, which have been cross-linked to the primary sequence in Figure 6b.

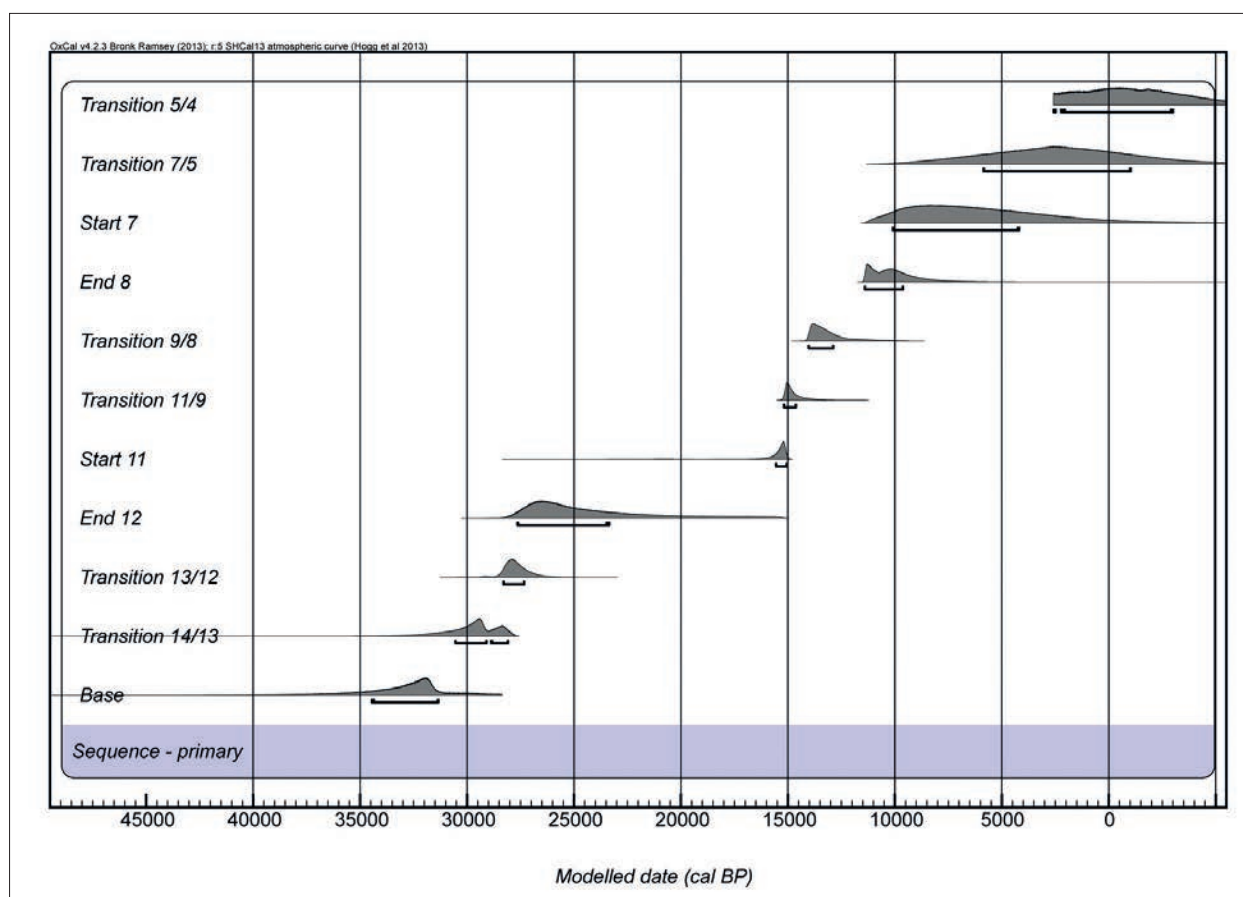


Figure 6b Summary of the 'transition dates' between layers. In Figures 6a and 6b the pale distribution represents the calibrated date, and the dark distribution the modelled date. The bar beneath each distribution denotes the 68.2% probability range.

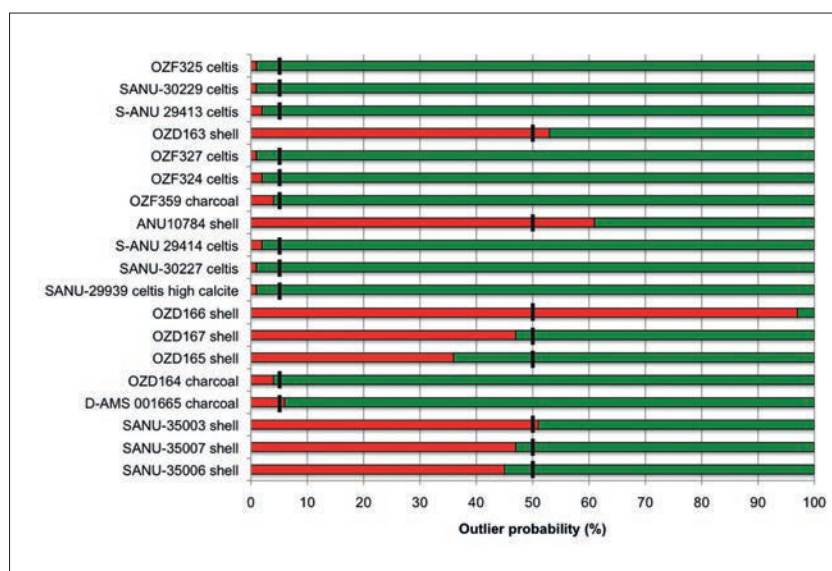


Figure 6c The probability the model found (the posterior probability) of each radiocarbon date being an outlier (red bar) compared to the prior likelihood of being an outlier (black line).

XU67 (Figure 7, Table 3). Figure 7 shows that the distribution of all stone artefacts and of the minimum number of flakes (MNF) correspond closely. The MNF is calculated by adding together the number of complete flakes, the higher number of proximal or distal fragments and a count of longitudinal fragments (after Hiscock 2002:254). This correlation demonstrates that lithic artefact accumulation is a real cultural trend and is not greatly affected by the tendency of

quartz assemblages to have a greater relative frequency of flaked pieces.

Although significantly more sediment was removed per XU in the lower Pleistocene units, lithic artefact frequency is low (Figure 3). The majority of lithic artefacts occurred in XUs 4–10 (Figure 7), from the mid- to late Holocene. The timing of this peak in artefact discard appears to correspond with distinct technological changes and innovations in flaking strategies, such as is seen in other excavated assemblages from northern Australia (e.g. Clarkson 2008). In contrast to the CG3 assemblage, in the Victoria River region Clarkson reported two distinct peaks in artefact discard from excavations, one in the early Holocene and another in the late Holocene. The CG3 deposit records only one peak in the mid- to late Holocene.

The dominant raw material throughout the CG3 assemblage, accounting for >85% of lithic artefacts, is high quality translucent crystal quartz in the form of crystals and waterworn pebbles (Figure 8). Crystal quartz is occasionally found in formed crystals in the limestone, but can be more readily acquired from gullies and creeks where it has eroded from the conglomerate deposits of the Napier Ranges. The

Boundary Between Layers	Modelled Date (cal. BP, 68.2% Probability)		Modelled Date (cal. BP, 95.4% Probability)		Convergence (%)
	From	To	From	To	
Transition 5/4	2578	-3002	...	-7869	35.5
Transition 7/5	5857	-1027	9187	-4636	79.6
Start 7	10,094	4189	11,163	-30	96.0
End 8	11,399	9622	11,482	7343	96.8
Transition 9/8	14,030	12,885	14,142	10,771	99.1
Transition 11/9	15,177	14,628	15,276	13,550	98.9
Start 11	15,552	15,058	21,631	14,886	98.4
End 12	27,641	23,359	28,068	17,232	97.2
Transition 13/12	28,293	27,326	29,199	26,180	99.6
Transition 14/13	30,537	28,088	32,536	27,796	90.8
Base	34,443	31,343	38,151	28,734	90.6

Table 2 Probability distributions of the *boundaries* between stratigraphic layers modelled in Figure 6.

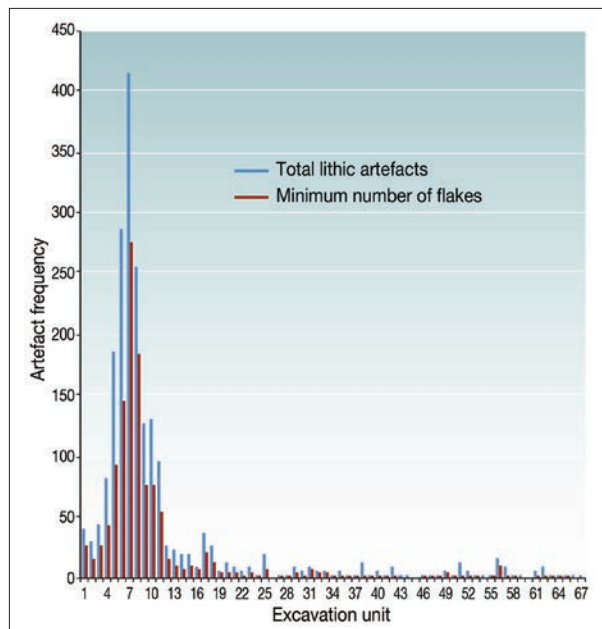


Figure 7 Lithic artefact frequency and minimum number of flakes by XU.

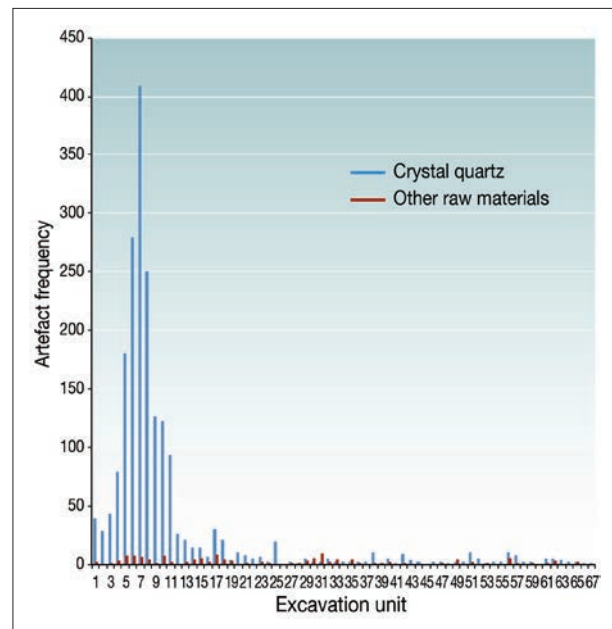


Figure 8 Crystal quartz and other raw materials by XU.

Lennard River gravels contain a consistent component of crystal quartz waterworn pebbles; however, only occasionally are they of the same high quality crystal quartz discarded at CG3 (2008:Figures 13.9 and 13.10). The cortex of cores and flakes indicate focused exploitation of formed crystals and waterworn cobbles and only occasional use of white vein quartz, which is locally abundant but substantially lower in quality. Vast sheets of rounded quartzite cobbles and pebbles are found within 5 km of the site and occur in conglomerate bands within the CG3 complex. Two volcanic outcrops also occur within 10 km southeast of the site, and the limestone conglomerate of the Napier Range has similar volcanic inclusions. The low frequency of chert and chalcedony artefacts, together with the dominance of crystal quartz, suggests that people generally avoided utilisation of locally abundant, poor quality material in favour of higher quality materials that were either exotic or far less abundant.

After the early to mid-Holocene, flakes at CG3 gradually became more elongate, with marginal angles (the expanding

or contracting of flake margins) approaching or exceeding 0 (ANOVA $df = 855$, $f = 1.829$, $p = 0.0001$). This trend is illustrated in Figure 9 and shows that, above XU16, there is a tendency for flakes to be more elongate, with either parallel or contracting margins. Flake mass relative to cutting edge (cf. Mackay 2008) also becomes gradually more standardised during this period (ANOVA $df = 831$, $f = 1.166$, $p = 0.007$). This is likely an indication of greater effort to control flake production, probably deriving from a combined need to maximise the economic utility of core and flake mass, as well as produce suitable blanks for point production.

The lowest bifacially flaked 'point' is made on hornfels and occurred in XU9, with three other bifacial points in XU8 (Figure 10). Five unifacially retouched points were also recovered above XU8. All nine points appear to be made on elongate flakes and none exhibit marginal pressure flaking (cf. Akerman and Bindon 1995:89).

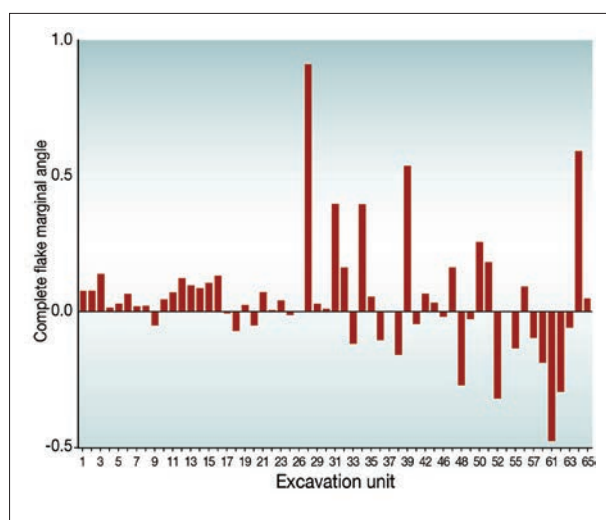


Figure 9 Mean complete flake marginal angle by XU.

Retouched artefacts ($n=74$) are found in low frequency throughout the deposit and do not show any significant changes in the amount of retouch through time, as gauged by the Index of Invasiveness (Clarkson 2002) (ANOVA $df = 25$, $f = 1.438$, $p = 0.158$) and the Geometric Index of Unifacial Reduction (Kuhn 1990; see Hiscock and Clarkson 2005) (ANOVA $df = 31$, $f = 1.438$, $p = 0.991$). With the exception of points, these retouched artefacts are made on a wide range of flakes and exhibit marginal retouch mostly on one face. There is no correlation between the platform area of retouched flakes and non-retouched flakes (ANOVA $df = 23$, $f = 0.582$, $p = 0.910$), which suggests that blank morphologies come from the entire range of flakes produced, as represented in the 6 mm sieve fraction.

Cores ($n=56$) occur throughout the deposit and also suggest that reduction levels were generally greater in the Holocene. The number of core rotations, as an indication of the degree of reduction (Clarkson and O'Connor 2006:174), shows a significant correlation with depth (ANOVA $df = 25$, $f = 1.908$, $p = 0.046$). Cores with more than two rotations are mostly found in the Holocene levels.

XUs 62 and 65 contained edge-ground flakes made on a fine grained volcanic material of a basaltic type (Figures 11 and 12). Both were recovered below XU61, which produced a calibrated age range of 30,484–29,624 cal. BP, while XUs 63 and 67 have overlapping age ranges of 33,992–33,147 cal. BP and 33,847–32,970 cal. BP (Table 1).

Table 4 lists metric values of size and shape for the two edge-ground flakes. Cemented carbonate is attached to the surface of both and, in order to preserve any possible surface residues, has not been removed. The platforms of both exhibit ground surfaces, with visible striations on the polished surfaces. The flakes were therefore most likely removed from the ground margin of an axe and were not modified after their detachment. The nearby site of Carpenters Gap 1 (O'Connor 1995), about 2 km to the west, contains grinding grooves in sandstone beds with widths that are equivalent to a complete axe found on the surface of the CG3 overhang. These sandstone outcrops are sparsely distributed in the Napier Range and are likely foci for edge-ground axe manufacture and maintenance. An additional edge-ground flake was recovered from XU10, seemingly made on the same fine grained volcanic material as the two Pleistocene flakes.

Organic Materials

The upper XUs of CG3 contain the greatest quantities of macrobotanics, including charcoal and *Celtis* sp. seeds (Figure 5 and Table 3).

The distribution of *Celtis* sp. seeds throughout the deposit is not correlated with that of the stone artefacts or other material of definite anthropogenic origin. As such, we suggest these seeds more likely reflect the changing vegetation conditions through time in the immediate environment outside the cave (Figure 5). *Celtis* sp. seeds occur in XUs 59–47, decline dramatically during the Last Glacial Maximum (LGM), then increase from the terminal Pleistocene after about 13,000 years BP. XUs 1–3 contain the most *Celtis* sp. seeds, as well as abundant charcoal, the better preservation in these spits no doubt due to their more recent deposition.

The freshwater mussel in CG3 is identified as *Lortietta froggatti* (Iredale 1934), which is the only species found in the Kimberley. They were most likely collected from the adjacent Lennard River. Mussel shell was found in almost all XUs to the base of the site, including within the LGM units (Figure 5). There is a marked decrease in mussel shell in XUs 41–39, suggesting that the freshwater pools in the Lennard shrank or dried completely at times.

Pit A also included some marine shells, including two fragments of baler (*Melo* sp.) in XUs 4 and 14, and two small segments of scaphopod in XUs 12 and 14. XU12 dates to 6436–6298 cal. BP. The scaphopod segment from XU14 is bracketed by this date and another from XU16 of 11,590–10,876 cal. BP, suggesting it is of early Holocene age. The scaphopod shells were probably worn strung as beads, or as hair adornments. The baler shell fragment in XU4 has possible evidence for abrasion along part of the margin. Based on their distance inland, the baler shell finds are presumed to be the remnants of high value goods reduced through use and breakage and eventually discarded.

Small quantities of bones from large to medium-sized macropods were recovered from the Holocene units. Below this the majority of the bones were from small fauna and were likely derived from bird roosts above Pit A (see below). Unfortunately, during a pretreatment to remove carbonate encrustations from the bone from the 1993 excavation the wrong acid treatment was used and the bone was dissolved or badly damaged. No identifications could be made, or reliable weights obtained, on the fragments remaining. Thus no comparison was possible with the fauna excavated during the 2012 field season and this category of find has not been quantified.

Small fragments of bird eggshell were also recovered but have not been further identified. As noted above, in the lower part of Pit A much of the bone is thought to derive from a bird roost overlying the test pit, and thus the eggshell may not have an anthropogenic origin.

Discussion and Conclusions

CG3 has evidence for intermittent occupation from 34,440–31,340 cal. BP through to the historic period. First habitation appears to coincide with the top of Layer 14, or more likely the base of Layer 13, with XUs 68–70 being culturally sterile. Scuffage and disturbance by people or animals in the upper shelter may have resulted in some cultural

XU	Number of Lithic Artefacts	Mussel Shell (g)	Charcoal (g)	Bird Eggshell (g)	<i>Celtis</i> sp. Seed (g)	Sediment Volume (L)
1	41	1.18	22.57	0	9.69	11.5
2	29	0.71	22.70	0.05	16.65	12.0
3	44	1.00	5.07	0.14	16.70	15.5
4	82	0.31	1.41	0.20	1.15	21.0
5	187	1.06	0.52	0.36	0.90	21.0
6	283	1.28	0.11	0.18	0.13	20.0
7	414	2.55	0.59	0.66	0.55	24.0
8	251	1.47	0.26	0.88	0	25.0
9	123	1.55	0.49	1.30	0.78	20.0
10	129	1.29	0.31	1.14	1.73	25.0
11	90	1.23	0.31	1.01	1.48	30.5
12	26	0.94	0	0.53	0.30	17.0
13	22	0.97	0.02	0.47	1.28	19.0
14	17	1.13	0.02	0.34	1.77	25.5
15	20	1.98	0.13	0.41	2.34	29.0
16	8	0.49	0.03	0.33	0	18.5
17	36	1.95	0.29	0.58	2.04	27.5
18	21	5.36	0.06	0.55	2.44	30.0
19	7	4.49	0.15	0.51	2.36	18.5
20	11	1.85	0.17	0.25	1.97	21.0
21	8	2.75	0.17	0.32	2.52	23.5
22	5	1.19	0	0.10	2.01	15.5
23	7	2.43	0.37	0.22	2.43	19.5
24	4	6.91	0.13	0.19	0.92	15.0
25	10	1.37	0	0.33	0.92	23.5
26	0	2.47	0.55	0.29	0.90	19.5
27	4	2.99	0.58	0.41	0.46	23.0
28	2	1.58	0.36	0.51	0.27	30.0
29	7	1.65	0	0.53	0.45	15.5
30	7	0.96	0.13	0.50	0.16	20.0
31	9	3.54	0.37	0.56	0.11	25.5
32	7	0.83	0.32	0.61	0.10	22.0
33	7	1.57	0.24	0.54	0.03	20.5
34	3	0.76	0.63	0.37	0.25	18.5
35	5	0.16	0.14	0.34	0.16	21.0
36	3	1.00	0.30	0.23	0.04	18.5
37	2	2.09	0.63	0.42	0	21.5
38	8	0.79	0.17	0.20	0	28.5
39	2	0.29	0.16	0.24	0.10	19.5
40	6	0.15	0.12	0.10	0.14	17.5
41	1	0.01	0.06	0.12	0.04	11.5
42	10	1.31	0	0.25	0.14	25.5
43	3	0.06	0.08	0.10	0.02	17.0
44	1	0.77	0.26	0.22	0.06	25.0
45	0	0.45	0	0.15	0	22.0
46	3	0.70	0	0.28	0	41.5
47	4	0.44	0	0.38	0.54	54.0

Table 3 Stone artefact numbers, weights of organic material and sediment volumes. Continued overleaf.

XU	Number of Lithic Artefacts	Mussel Shell (g)	Charcoal (g)	Bird Eggshell (g)	<i>Celtis</i> sp. Seed (g)	Sediment Volume (L)
48	1	0.70	0	0.04	0.46	47.0
49	7	0.35	0	0.86	0.63	67.5
50	2	0.41	0.16	0.42	0.78	62.0
51	2	0.16	0	0.37	0	56.0
52	4	0.59	0	0.12	0.48	68.5
53	2	0.23	0	0.12	0.28	62.5
54	1	0.72	0	0.14	0.77	58.5
55	3	0.25	0	0.18	0.13	57.5
56	12	1.22	1.30	0.32	0.90	85.0
57	7	1.60	0	0.34	0	65.5
58	2	0.63	0	0.11	0	67.0
59	2	0.63	0	0.18	1.69	56.5
60	0	0.55	0	0.59	0	50.5
61	6	1.61	0	0	0	52.0
62	8	1.17	0	0.16	0	48.5
63	4	0.75	0	0	0	42.1
64	3	0.13	0	0	0	34.3
65	4	0	0	0	0	26.0
66	1	0.05	0	0	0.07	40.5
67	1	0.69	0	0	0	41.5
68	0	0	0	0	0	71.7
69	0	0	0	0	0	47.5

Table 3 continued Stone artefact numbers, weights of organic material and sediment volumes.

material displaced into the lower cave; however, the small quartz flakes recovered in most XUs indicate that artefact maintenance and manufacture was taking place within the cave itself. In an earlier publication (O'Connor and Veth 2006:35), it was suggested that stone artefacts at CG3 might be more abundant during the LGM than at nearby CG1, owing to the fact that CG3 is located close to the Lennard River. However, detailed analysis resulted in the elimination as artefacts of many pieces of stone collected during the excavation. It is clear from Table 4 that artefact numbers are uniformly low from first occupation in XU67 through to the terminal Pleistocene.

There are no radiocarbon dates for the period 21,000–18,000 cal. BP at CG3. The Bayesian model indicates an even longer break in occupation, between 27,640–23,360 to 15,550–15,060 cal. BP. In view of the location of CG3 proximal to the Lennard River, evidence for habitation is surprisingly sparse during the terminal Pleistocene, and it is possible that the Lennard ceased to flow or dried completely at times during the LGM. There are also indications of extreme climate variability throughout this phase which, coupled with aridity, may have affected people's ability to occupy the region (Dennison et al. 2013). Nearby CG1 had extremely sparse evidence for occupation during this time period, while Riwi, ca 200 km to the southeast of CG3, contained no evidence for occupation between ca 34,000 cal. BP and 6000 cal. BP (Balme 2000; McConnell and O'Connor 1999:26, 32–33). It has been suggested that, due to aridity, the landscape may have presented limited opportunities for expansion into the margins of the arid zone during the terminal Pleistocene (Hiscock and Wallis 2004; O'Connor

and Veth 2006:36–37). Riwi was re-excavated in 2013, with a larger area excavated, much finer XUs, and dating samples collected in situ. The results of this work are pending and may alter what is currently known of the timing of occupation on the northern edge of the Great Sandy Desert.

Although low numbers of artefacts were discarded during the Pleistocene at CG3, the presence of flakes from edge-ground axes indicates that maintenance of tools was carried out within the cave during the earliest period of occupation about 34,000 years ago. These artefacts add to the known sample of Pleistocene edge-ground axe technology from northern Australia. The fact that flakes from axes are represented in assemblages with very low numbers of artefacts overall suggests that these tools formed an important component of the lithic repertoire following initial settlement across northern Australia (see Davidson and Noble 1992:49, Table 1; Geneste et al. 2010:4). We have suggested elsewhere that, like their Holocene counterparts, Pleistocene axes and hatchets were likely multipurpose tools used for a variety of extraction activities (Balme and O'Connor 2014). While they required hafting and the working edge required intense curation; the durability, long use-life and functional flexibility of these tools would have made them particularly useful in colonising situations where raw materials, resources and stone supply zones could not be anticipated.

In common with most Australian sites, evidence for occupation at CG3 increases sharply in the mid- to late Holocene. The timing of this change is poorly resolved at CG3 due to the small number of dates covering the upper

Artefact ID Number	Length (mm)	Width (mm)	Elongation (mm)	Thickness (mm)	External Platform Angle (°)	Mass (g)
XU-62 # 2105	36.3	52.8	0.69	10.4	90	23.6
XU-65 # 2093	24.4	34.3	0.71	6.7	50	10.2

Table 4 Measurements for Pleistocene edge-ground flakes from XUs 62 and 65.

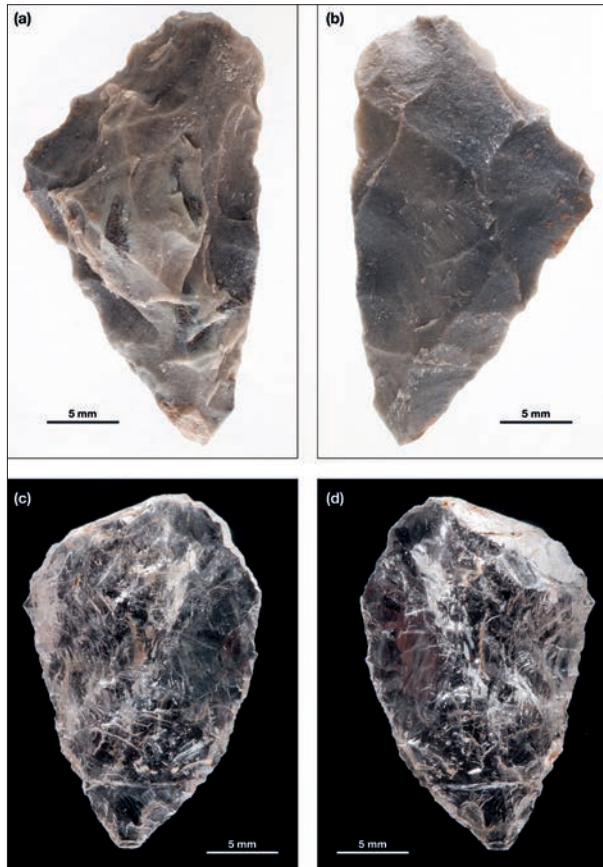


Figure 10 Bifacial points from CG3: (a) hornfels bifacial point recovered from XU9 showing likely dorsal face with invasive flaking scars; (b) likely ventral surface of the same hornfels bifacial point showing scars initiated from dorsal surface are truncated by preceding scars initiated from ventral surface; (c) crystal quartz bifacial point recovered from XU8 showing dorsal surface with invasive retouch scars; and (d) ventral surface of same crystal quartz bifacial point showing invasive retouch scars and a marginal break on the proximal end.

part of the sequence; however, in view of the sediment cracking and bioturbation in the upper XUs, additional dating is unlikely to clarify the situation. The evidence for increased site use is not a taphonomic effect, as it is most evident in the frequency of stone artefacts. It is also clearly unrelated to the volume of sediment excavated, as volumes removed were much greater in the lower XUs than in those dated to the mid- to late Holocene. Interestingly, the increase in occupation from the mid-Holocene at CG3 coincides with Holocene reoccupation at Riwi (Balme 2000), perhaps reflecting a demographic increase in the southern Kimberley followed by population expansion into the northern margins of the arid zone. Williams (2013:8) has recently argued that time-series modelling of all available radiocarbon dates from all Australian archaeological sites demonstrates population increase on a continent-wide basis in the mid- to late Holocene.

The presence of freshwater mussel shell in almost all XUs indicates that the people at CG3 exploited a nearby freshwater source, probably the Lennard River, as it is

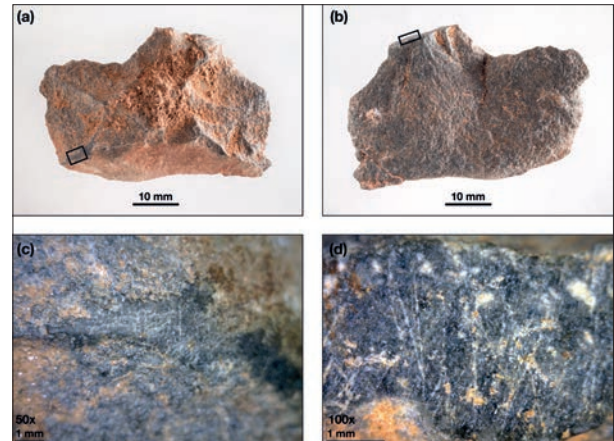


Figure 11 Pleistocene ground-edge flake recovered from XU62: (a) dorsal surface; (b) ventral surface; (c) 50x magnification of dorsal ridge on left distal portion of flake showing striations over polished surface; and (d) 100x magnification of platform surface showing multiple intersecting striations over polished surface.

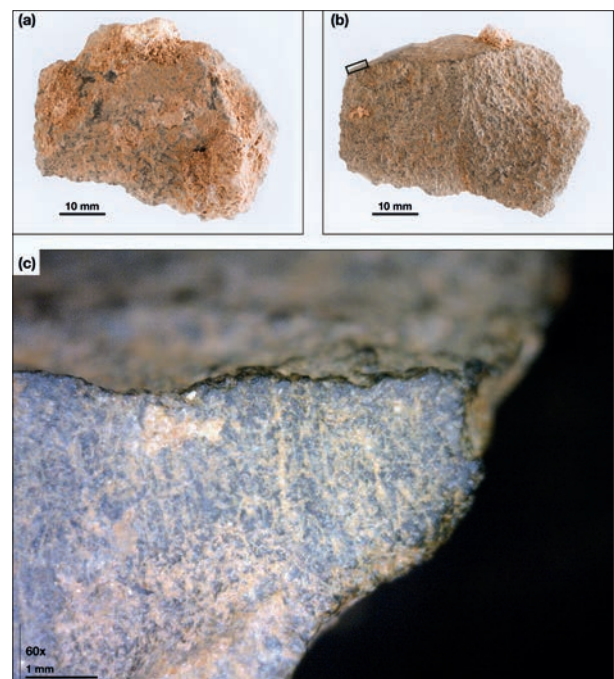


Figure 12 Pleistocene ground-edge flake recovered from XU65: (a) dorsal surface; (b) ventral surface, ground edge surface is located on platform; and (c) 60x magnification of edge-ground platform surface showing several striations over polished surface.

unlikely that these bivalves would have been transported any great distance. The marked decrease in freshwater mussel during the LGM no doubt reflects the effects of aridity and retraction of the freshwater pools where this resource was procured. In contrast, the scaphopod and baler shell must have derived from the coast over 200 km to the west and been transported inland along trade/exchange networks. All of the marine shell at CG3 occurs in Holocene units, with three of the four pieces in XUs 12 and 14 dated between

about 6000 cal. BP and the early Holocene. Scaphopod beads have been recovered from CGI and other sites in the southern inland Kimberley and as far east as Riwi, where they were in Pleistocene-aged deposits (Balme 2000; Balme and Morse 2006). The widespread archaeological distribution of such beads in the inland Kimberley suggests they were a reasonably common item of personal decoration, however, they are not documented in Museum collections as ethnographic items from this far inland. The presence of baler shell pieces in inland locations at approximately 32,000 cal. BP at Widgingarri Shelter 1 in the west Kimberley (O'Connor 1999:60, 121), and at ca 22,000 cal. BP at the Silver Dollar site, Shark Bay, in the Pilbara (Bowdler 1990), established an early archaeological context for use of baler shell in northwest Australia and its movement at least 70–100 km inland. In historic times, baler shells were traded many hundreds of kilometres from coastal regions into the desert where they were used in ceremony (Smith and Veth 2004). As they moved inland they gained value, changed meaning (Mulvaney 1976), and reduced in size.

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World's earliest edge-ground axe production is coincident with human colonization of Australia and exemplifies the emergence of novelty during the global dispersion of humans.

Sue O'Connor, Peter Hiscock, Jane Balme and Tim Maloney

Abstract

In most areas of the world axes finished by grinding are confined to Holocene Neolithic contexts, but here we report the earliest ground axes dating back to 44-48,000 years ago, an antiquity which is coincident with or immediately follows the arrival of humans in the Australian landmass. This is the most stunning evidence of a diversification of technological practices that was part of the adaptive process triggered by the colonization of the ice-age continent of Sahul (which comprised Australia, New Guinea, and a number of islands). These novel technologies reveal that previous characterisations of early Australian lithic industries as simple and unsophisticated are erroneous; a reflection of Eurocentric expectations but not of the archaeological evidence. Innovations, morphological elaboration and standardization in stoneworking found in the first Australian assemblages exemplify the role of technology in facilitating the global expansion of humans.

Introduction

Early Australian stone lithic industries have persistently been characterized as extremely simple; comprising unstandardized, expedient, tools. Often they have received unflattering comparisons with those from the Old World. Here we critique the evidential basis of such views and present evidence of the earliest known axes with ground edges. This evidence reveals that the first Australians were technological innovators who developed grinding and abrading as techniques with which to shape a range of new implements including hafted edge-ground axes, hatchets and adzes. We argue that this kind of innovation was common as dispersing humans created regional traditions as part of their adaptations to new landscapes.

Pleistocene Australian stone tool industries are by convention characterized as simple core and flake-based assemblages lacking specialized formal types of artefacts found in later Old World assemblages. This characterization has implied similarities to the technology employed by early African hominids, and has been used to build models of the timing and nature of out-of-Africa dispersions. For example Foley and Lahr (1) employed the Australian core and flake industries in constructing their 'Mode 3' dispersal hypothesis, in which humans left Africa with a lithic technology based on 'prepared' cores and flakes, and reached Australia with the same technology which they persisted in using throughout the Pleistocene.

Alternate scenarios have also referred to the image of simple Australian industries. Mellars (2), for example, described the arrival of anatomically modern humans on the edge of Sahul as the "greatest enigma in the current archaeological record". It was enigmatic to him because he perceived a dramatic contrast between the

sophistication and diversity of technology recorded for humans in Africa and implied by the watercraft that would have been used to cross water barriers to Sahul compared to the simple stone artefacts described for early Australian assemblages. He continued

These Australian technologies consist of very simple, flake-based industries, completely lacking in typical blade forms and apparently with little or no trace of typically Upper Palaeolithic tool forms such as end scrapers, backed blades, or burins - a pattern of technology that persisted in Australia from at least 45,000 yr B.P. down to the middle of the Holocene period, around 5000 to 7000 yr B.P.

Adding to the apparent paradox is the presence of diverse behaviors found in the 'modern' human societies that dispersed out-of-Africa, such as elaborate burials and the use of ochre for art. Mellars (3) mentions the presence of edge-grinding in Pleistocene Australia but does not explore the significance or age of those technologies, emphasizing instead the idea that Australia's earliest lithic assemblages were uniform and simple collections of cores and flakes. His emphasis on simple cores and unifacially retouched flakes mirrors published depictions of Australian Pleistocene assemblages and the sobriquet for those assemblages of "The Australian core tool and scraper tradition"(4), a name which fails to capture the persistent production of ground artefacts made from both stone and bone. That label and the story it embodies derives from a long history of approaches to Aboriginal culture and its evolutionary status.

Simplicity and uniformity in Aboriginal material culture was a conceptual theme established early and cemented by cultural evolutionary models of social change in the second half of the nineteenth century. Aboriginal societies were frequently depicted as examples, indeed as exemplars, of early foraging systems with basic tool kits and simple technology. Early archaeological studies of Australian assemblages reflected the nineteenth century themes of unilinear development and simplicity. They typically proposed images of technological change in terms of models of linear evolutionary progression (5,6,7,8). Using largely undated assemblages, they asserted that the earliest Australian tools were made on large heavy cores and large thick flakes sometimes retouched for use as scrapers(4). They suggested that over time there was a progressive reduction in the tool size and an increase in their cost-effectiveness, with smaller cores, fewer core tools and scrapers increasingly made on thinner flakes that had more 'cutting edge' per kilogram (5,6). Despite extended critiques of the evidence, showing that such trends are not demonstrated (9,10,11,12), these propositions have been reiterated even in recent scholarly articles. For example, O'Connell and Allen (13) accept the conventional story of a 'simple' and unvarying technology in Pleistocene Australia and seek to explain it in terms of unvarying narrow diet breadth by colonists.

The challenge of grinding technology

The depiction of early Australian lithic technology as simple and uniform persists only because researchers have paid little attention to the ground stone component of the archaeological record. For more than half a century archaeologists have known that grinding technologies were present in northern Australia during the Pleistocene (14). These technologies were entirely absent in the islands to the north of Australia at that time, evidence of their *in situ* invention in northern Australia. In Island Southeast Asia edge grinding on stone tools first occurs in Neolithic and Metal Age assemblages when small fully polished adzes appear. The context of Pleistocene axe production in Australia was entirely different and the chronology of axe production reveals a new aspect to both the dispersion of modern humans out-of-Africa and the nature of pre-historic occupation of Australia.

At all time periods it is rare to find whole edge-ground axes in excavated assemblages in Australia. As long-lived highly curated items, these specimens were kept and re-used for long periods and consequently they were infrequently discarded. The probability of finding complete axes is therefore partly a reflection of the size of the excavated assemblages. In the 1960s excavations were often extensive and consequently a number of Pleistocene axes were discovered. For instance, in three Arnhem Land sites Schrire recovered twenty whole axes of Pleistocene age, including five axes from Nawamoyne found in a recess in the back wall of the shelter where they may have been cached and lost (15) (Figure 1). However discoveries of this kind have been infrequent in more recent decades because, since the 1970s, excavations in Australia have become progressively smaller as the imperative to carry out precise recording has overridden the desire for larger collections (16). While this trend has reduced the discovery rate for axes themselves, a chronology for axe production has still been possible based on flakes removed from the ground bevels of axes during the reshaping and repair of damaged and worn edges. Repair of each bevel requires the removal of a number of flakes before the edge can be re-ground, and the repair cycle might be repeated several times, creating an order of magnitude more ground flakes than axes deposited into the archaeological record. This means that even with the smaller excavated samples of recent decades there have been many axe-resharpening flakes recovered from Pleistocene contexts, many of which have come from precision excavations.

Axe-resharpening flakes from caves and rock shelters across northern Australia recovered have produced a record of early axe-production (14, 15, 17, 18, 19, 20) (Figure 1). The previously published evidence for edge-ground axe manufacture has indicated an antiquity of at least 30-35,000 years bp across northern Australia. In Arnhem Land complete axes were recovered from Malangangerr in contexts dating back to about 29,000 cal BP (15), and highly weathered dolerite flakes in Nauwalabila I dated to 30,000 cal BP are inferred to be from ground-edged axes (21). In northeastern Australia a ground-edged axe was estimated to date to 32,000 cal

BP from Sandy Creek (Morwood & Trezise 1989 (19). In the northwest ground flakes have been recovered from Widinggarri 1 and Carpenter's Gap 3 dated to 33,000 cal BP (18, 20). Slightly older than all of these are the recent ground flakes reported from Nawarla Gabarnmang dated to $35,400 \pm 410$ cal BP (17). Many of these specimens come from small excavations and the small samples retrieved from them make it unlikely that all rare specimens such as axe flakes would have been discovered. It is therefore possible that older examples may exist in those sites but not have been discovered, in which case earlier examples of axe-grinding would eventually be discovered. However, there is now evidence of edge-ground axe production more than ten millennia earlier, demonstrating that ground-edge axes were made more than 44,000 years ago.

Carpenter's Gap Shelter 1

Carpenter's Gap 1 (CG1) is one of the oldest known habitation sites dated by the radiocarbon technique in Australia (Figure 1). It was first excavated over two field seasons in 1992 and 1993 when five 1 m square test pits were dug to bedrock (22, 23; Figures 2 and 3). The shelter contains an upper Holocene-aged deposit overlying Pleistocene-aged sediments dating from $\sim 48,000$ cal BP through to $\sim 18,000$ cal BP (Figure 4). Although work on deposit formation is ongoing, the sediments appear to have accumulated primarily as a result of *in situ* weathering of layers of softer sedimentary rocks embedded in the limestone reef from which the shelter is formed, with the addition of an aeolian component. Excavations units averaged 2 cm in depth but were dug within depositional units. For example, a hearth 10 cm in depth would be removed separately from other sediments, treated as one stratigraphic context, but would be subdivided into units of 2 cm depth to enhance assessments of provenience.

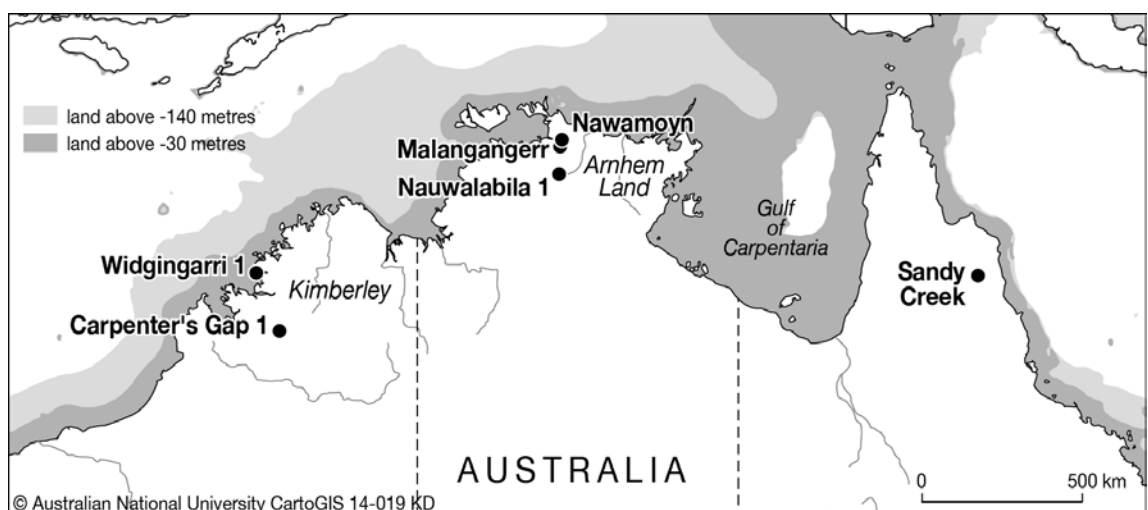


Figure 1. Carpenter's Gap 1 and other sites mentioned in text

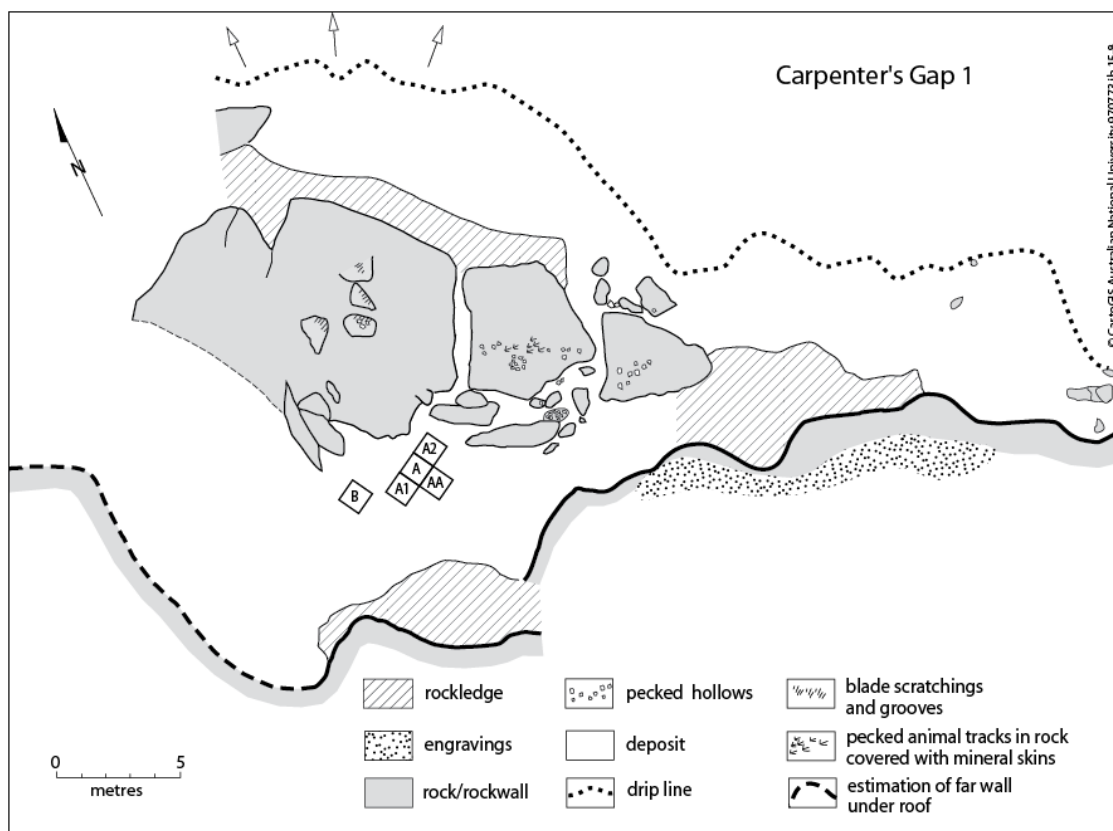


Figure 2. Site plan of CG1

Carpenter's Gap: Square A2

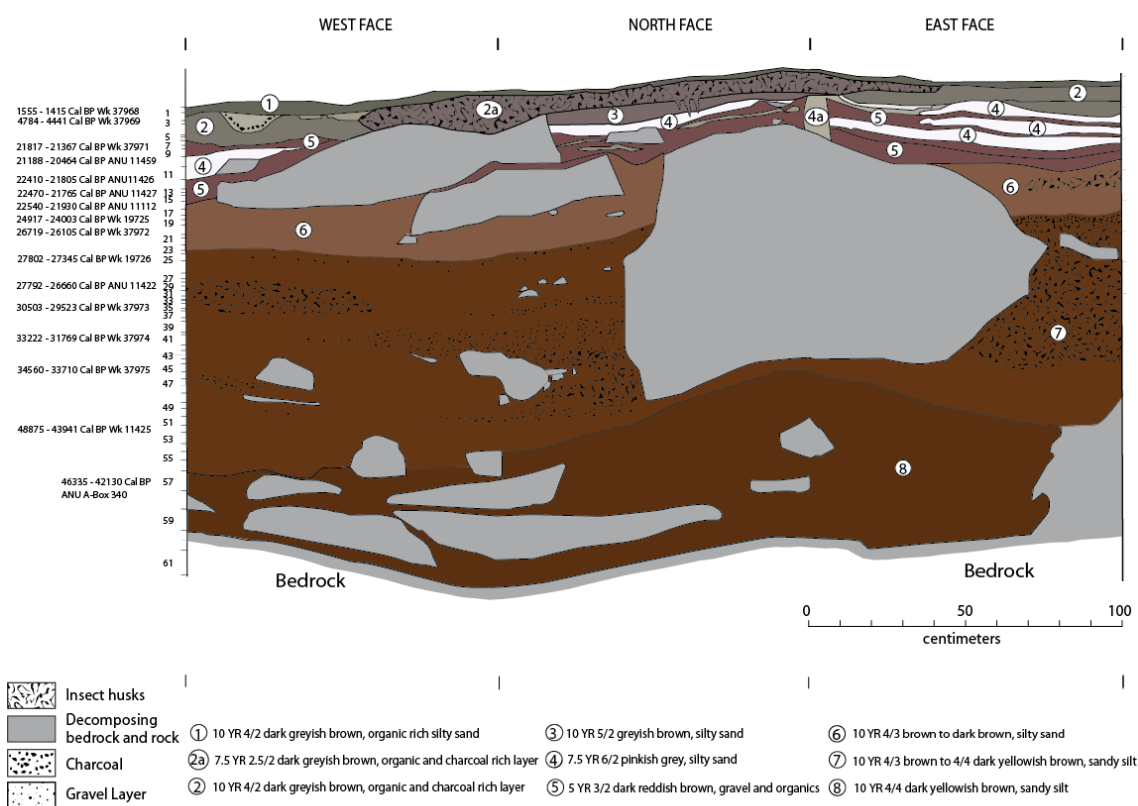


Figure 3. Stratigraphic drawing of square A2 (Tim Maloney)

The specimen central to this paper is a flake that has been removed from an edge ground axe (Figure 5). We argue that this piece of an axe is the earliest evidence for edge-ground axe production yet reported. The specimen can be technically described as a left longitudinal cone split flake fragment made on basalt with platform and feather distal termination preserved. The ventral surface shows morphological evidence of a hertzian fracture initiation, with clear evidence of a low but well expressed bulb formed underneath the impact point. There are pronounced fracture fissures radiating out towards the lateral margin and distal end from the point of fracture initiation. The flake is small: 0.16 g in weight, 10.9mm long, 1.4mm thick. However, despite its small size the technological history of this flake is unambiguous.

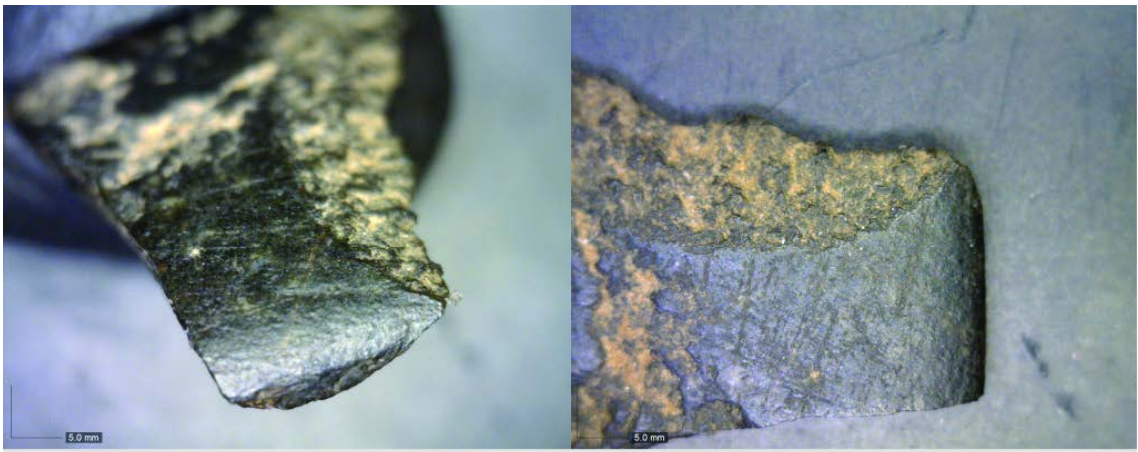


Figure 5. Edge ground flake

The entire flake platform and a portion of the dorsal face have been smoothed by grinding, and the junction of those surfaces preserves a part of the bevel made on the axe from which the flake was removed. Grinding covers the whole platform surface and on the axe it extended further from the bevel as the grinding surface was truncated by the fracture that created the flake. Obvious striatae are linear and are oriented at approximately right angles to the platform edge (Figure 5). On the dorsal face a grinding surface runs the length of the flake and was also truncated by the fracture, and by a dorsal scar, thereby showing that the grinding preceded flake creation. Here too there are distinct linear striations oriented approximately 75° to the bevel. These striations are most distinct in the distal portion of the flake and less pronounced close to the platform.

The junction of the platform and dorsal face represents the ground bevel of the axe before flaking. The angle of the bevel is $73^\circ \pm 2^\circ$ ($N=5$) but within the first 2mm of the edge there are a number of microscopic bevels with different angles, relics of slightly different contact positions when the axe was ground against a grinding stone. All of these features are typical of Australian axes in general.

This flake was probably the second or third flake struck from the edge of a ground axe, most likely during the repair of a damaged bevel or perhaps as a recycling of the axe as a core. It is typical of flakes struck from axes across Australia in the late

Holocene, and the axe from which it was struck would likely have been similar to many made in the historic period. There is too little of the axe preserved to be able to make any comment on its size prior to flaking or to assess the mode of hafting, but the identification of this specimen as having come from an axe is clear.

This flake was recovered from excavation unit 52 in Square A2. A charcoal sample from the same unit is dated to 48,875 – 43,941 cal BP (WK-37976). We argue that the axe fragment and the dated charcoal fragment are stratigraphically associated and that this represents evidence of grinding technology being employed to manufacture axes at or immediately after the arrival of people in Australia.

The chronological integrity of early assemblages in Australia has been questioned by Allen and O'Connell (24), who argue that post-depositional relocation of specimens has placed them in a false association with early radiometric age-estimates. Although their critique is overdrawn (25) the possibility of taphonomic modification should be examined for each deposit. To evaluate whether the Pleistocene assemblages at CG1 were affected by vertical displacement we looked for size-sorting of artefacts within the lower deposit. This is a well-established test of post-depositional movement of materials within archaeological deposits, with a variety of processes acting to lower small specimens and/or raise larger ones (26-32). We therefore predicted that, if there had been significant vertical movement that involved displacement of specimens into unit 52 from higher in the deposit, there would be smaller specimens in that and adjacent levels than in immediately higher ones. To this end we examined the relationship between depth and artefact size for specimens in excavation units 45-60, representing MIS3 – the period before the last glacial maximum. Using univariate GLM statistical and non-parametric regression tests we established that there is no significant relationship between depth and artefact mass ($F=0.403$, $d.f.=15$, $p=0.975$; $r_s=0.011$, $p=0.914$, $N=100$), maximum artefact dimension ($F=0.882$, $d.f.=15$, $p=0.586$; $r_s=0.079$, $p=0.433$, $N=100$) or flake percussion length ($F=0.998$, $d.f.=12$, $p=0.477$; $r_s=-0.141$, $p=0.384$, $N=40$). We view the failure to find size-sorting as a refutation of the hypothesis that there was persistent vertical movement of artefacts within the oldest levels of the deposit. We emphasize that this conclusion is consistent with other lines of evidence: basalt specimens common in excavation units 50-52 are rarely found in higher levels indicating that there is no 'reservoir' of similar specimens from which the axe flake could have derived, and the large, flat-lying ochre covered limestone plaque found at the base of the deposit (33) do not suggest displacement. Consequently we are confident that the axe flake is stratigraphically and temporally associated with the radiocarbon sample in that excavation unit, and that this represents evidence for ground-edge axe manufacture 44-49,000 years ago.

Technological novelty and the colonization of Australia

This age for ground axe production is close to, perhaps immediately after, the generally accepted age for colonization of Sahul, the Pleistocene continent combining Australia and New Guinea (12). We have already argued that the absence of ground axes in island Southeast Asia during the Pleistocene shows that this system for axe manufacture was invented once dispersing humans reached Australia, and the CG1 antiquity for ground axes indicates that invention came shortly after landfall. We therefore have evidence of substantial technological innovation in the context of the colonizing process.

Intriguingly there is a parallel example of ground tools being invented immediately after a new island landscape was colonized. *Homo sapiens* entered the Japanese archipelago about 38,000 years ago and edge-ground axes began being made immediately and continued to be manufactured over the next 6,000 years (34). This is likely to be an independent innovation, not only because there are no axes known from this time in the lands between Australia and Japan, but also because the axes in the two regions are extremely different. Early Japanese axes are small and elongated by steep flaking on their margins and with straight or slightly curved ground edges, while Australian axes are usually larger and more circular in plan with more curved ground edges. The implication of broadly parallel technical innovations, perhaps both building on pre-existing grinding applications on hematite for pigment or osseous tools, at the point of colonization suggests that dispersing humans were often innovating as they entered new lands, rather than maintaining technologies that had been employed previously. This would facilitate adjustments to both provisioning and production systems that would suit local materials and material availability/cost as well as enable functional integration of technology with new economic and social systems that would have suited new landscapes.

The preserved lithic materials are likely to have been part of a broader set of organic artefacts that have not been preserved but which might also have displayed innovation during the adaptations to new landscapes, reflecting new demographic, social and resource contexts (35). However, in the absence of well-preserved floral or faunal assemblages from the period 40-50,000 years ago, axes are a proxy for the process of innovation that was occurring at the point of colonization. We can illuminate the magnitude of technological experimentation and innovation in Australia by describing the growth of regional diversity in the production of edge-ground and waisted axes.

Technological diversity and regional traditions

Geographic variation and regional traditions of behaviour are evident in the technology of colonisers. This is best exemplified by the Pleistocene use of hafted edge-ground axes in northern Australia, and flaked and waisted axes in Papua New

Guinea, but not in the southern two thirds of Australia (eg. 17, 18, 35, 36). This north-south division in the use of axes originated around the time of colonisation and persisted until the late Holocene when axes began to be made in most southern parts of mainland Australia. This distinction between north and south in the manufacture of ground stone artefacts lasted 40,000 years or more, presumably bolstered by distinctions in language and social views. In historical times the major linguistic division within Aboriginal languages (between Pama-nugyen and other languages), mirrors this north-south divide and may indicate the long lasting cultural distinction established in initial adaptations by colonisers.

Conclusions

While the Pleistocene age of edge ground axes has been known for many years, we have not known when these technologies were developed. The results presented here show that the process of shaping artefacts by grinding stone to form axes was a technological innovation that occurred at colonization or shortly after. We have shown this by documenting ground edges on flakes in the earliest level of assemblages in the Kimberley region, where they date to 44-49,000 years ago. This finding demonstrates the flexible, adaptive nature of the modern humans who arrived in Australia and challenges views of the out-of-Africa diaspora that propose fixed cultural properties and invariant technological systems.

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Re-excavation of a Holocene rockshelter in the southern Kimberley, north Western Australia

Tim Maloney¹, Sue O'Connor¹, Dorcas Vannieuwenhuyse², Jane Balme² and Jane Fyfe²

¹Department of Archaeology and Natural History, College of Asia and the Pacific, The Australian National University, Fellows Road Acton, ACT 2601.

²Archaeology M257, School of Social Sciences, University of Western Australia, 35 Stirling Highway Crawley, WA 6009, Australia.

<tim.maloney@anu.edu.au>< <sue.oconnor@anu.edu.au>

<dorcas.vannieuwenhuyse@research.uwa.edu.au>

<jane.balme@uwa.edu.au><jane.fyfe@research.uwa.edu.au>

Corresponding Author: <tim.maloney@anu.edu.au> (+ 0261250309)

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Abstract

Here we report on the re-excavation of a shelter in Windjana Gorge National Park, southern Kimberley, which has extended the known occupation sequence to the terminal Pleistocene. The site was previously excavated in 1994 and the resulting sequence dating from ~7,000 cal. BP but did not reach bedrock. Significantly, the chronostratigraphic sequence represented in the earlier excavation is entirely 'missing' in the recent excavation demonstrating the stratigraphic variation within a relatively small rock shelter and the need for extensive inter and intra site sampling prior to modelling regional occupation patterning.

Introduction

In 1994 an exploratory 50 x 50 cm test pit was undertaken in a limestone rockshelter adjacent the Lennard River in the Windjana Gorge National Park (Figure 1). This produced an occupation sequence dating from ~7,000 to recent but, owing to the restricted size of the pit, bedrock was not encountered. In 2012 we returned to further test the deposit with a 1 m² excavation. Here we report on this excavation and the finds. The site is known by Bunuba as *Djuru*, meaning outlying or projecting rock (June Oscar and Dillon Andrews pers. comm. 2012). It had been earlier reported as Windjana Gorge Water Tank Shelter (DIA12588) (O'Connor et al. 2008) and Windjana Gorge 1 (Balme and O'Connor 2015; Maloney et al. 2014). The site was initially registered in 1988 by Vinnicombe and Bradshaw, who described it as a large monolithic column of limestone detached from the range, with mythological associations, surface artefacts, deposit and rock art (DIA12588). The monolith and surrounding boulders form two connecting shelters, each with deposit and art panels. The most westerly had a water tank placed within it obscuring the art (O'Connor et al. 2008:76, Fig. 3). This was removed in 1993 although associated disturbance, such as a plastic water pipe across the drip line, is still visible and extends at least 40 m to the east, where it follows the drip line of the second shelter, en route to a concrete ablution block. It is within this second shelter that the 1994 and 2012 pits were positioned (Figure 2).

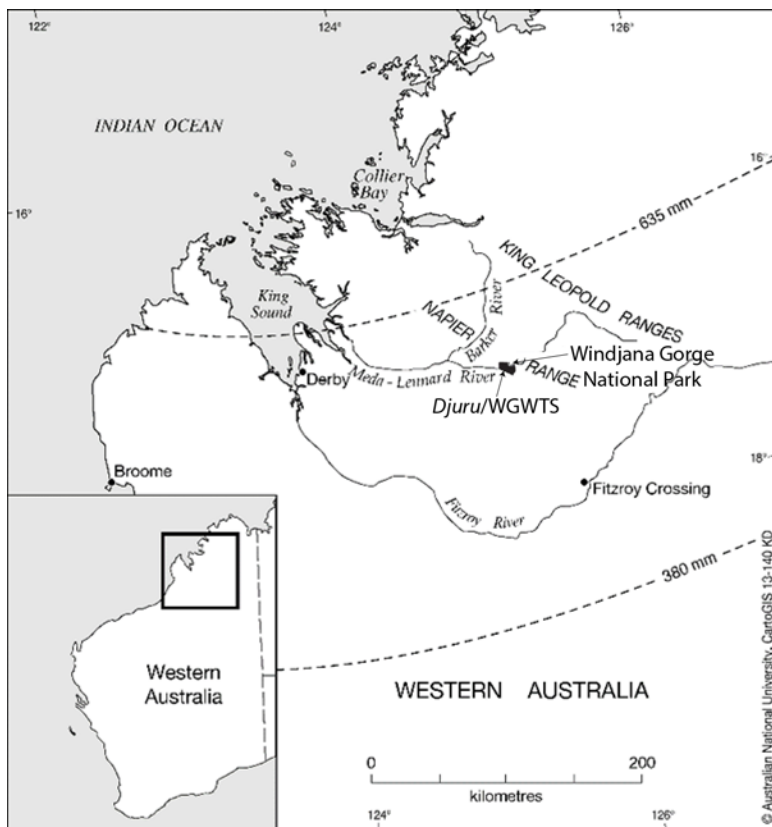


Figure 1. North Western Australia and Kimberley region showing Windjana Gorge National Park.

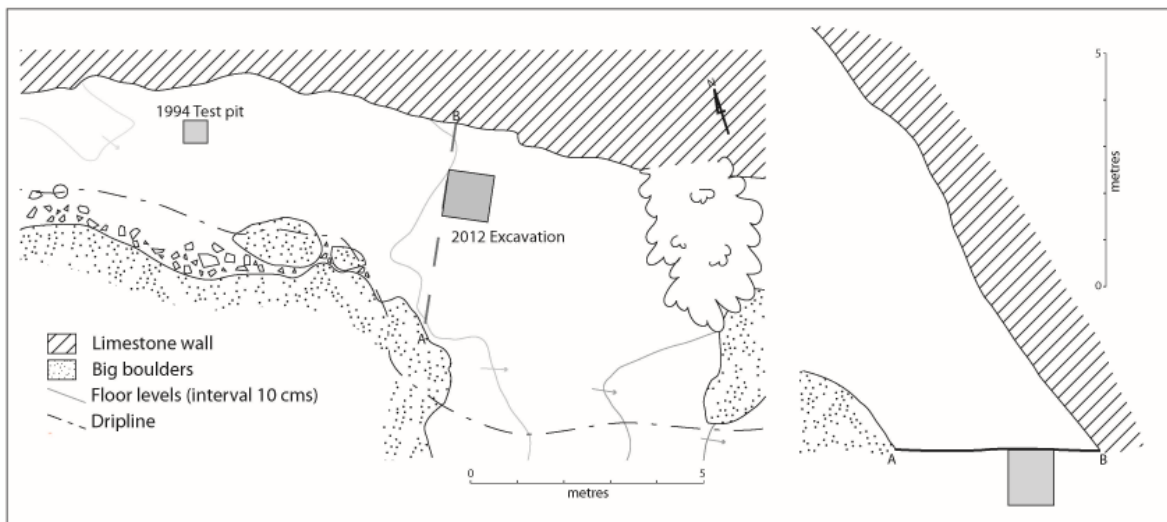


Figure 2. Site plan and profile (Dorcas Vannieuwenhuyse).

The 1994 pit (Square 1) produced a sequence with stone artefacts and well preserved faunal remains. The oldest radiocarbon age of 7,607 to 6,749 cal. BP (ANU-10786 AMS) was obtained from charcoal recovered from ~42 cm below surface where the excavation ceased without reaching bedrock (O'Connor et al. 2008). The four radiocarbon dates obtained from samples above this date are in sequence, with the most recent dating to historic times. Several direct percussion points were recovered associated with an age of ~5,200 cal. BP

(O'Connor et al. 2008:79). Faunal remains are predominantly from small rodents and reptiles, which may have derived from bird roosts (O'Connor et al. 2008:77).

2012 Excavation Results

Square 2 was excavated in 2 cm units [EU] (average = 1.45, range = 0.85 - 2.166) within 50 x 50 cm quadrants. Stratigraphic layers and features were recorded during excavation. All sediment was dry sieved through 3 and 1.5 mm screens. Sediment samples were taken from each EU and from individually recorded features. Charcoal, shell and seeds to be used for dating were plotted in 3-D, as were prominent or large stone artefacts.

The deposit is composed predominantly of a matrix of calcitic silt with fine quartz sand derived from the surrounding limestone erosion and the alluvial plain. Complex layering was identified with changes in colour (light grey, brown to dark grayish brown) indicating different proportion of ashes, organic matter and charcoals within the sediment (Figure 3). Bioturbation was visible in burrows and roots and have affected some areas of the deposit.

There is a major chronostratigraphic hiatus in square 2 which divides the sequence into two occupation phases. The lowest and earliest date of 13,051 to 12,759 cal. BP (D-AMS 001681) was obtained from a charcoal sample recovered from directly over the limestone bedrock (Figure 3). Multiple radiocarbon dates bracket the early Holocene between 13,000 and 8,700 cal. BP (EU 52 to 25 and stratigraphic layers 41 to 28). However, all of the charcoal samples from above stratigraphic layer 28, date within the last 1,300 years and decrease in age towards the surface (Table 1, Figure 3). Thus the mid-Holocene occupation found in the previous excavation is either not represented in this part of the deposit, or has only very ephemeral representation in layers 24, 25 or 27, which are so far undated. Here we refer to the earlier of the two occupation phases representing the period between about 13,000 and 8,700 cal. BP as the 'early Holocene phase' and the more recent occupation phase representing the last 1,300 years (EUs above 25, and stratigraphic layers above 28) (Figure 3) as the 'late Holocene phase'.

Table 1. Calibrated radiocarbon dates from Square 2.

Lab. Code	EU	Strat. Unit	Insitu Sample #	Material	Curve	d13C	PMC	Radiocarbon Age	C14 Age 2 σ	Occupation Phase
D-AMS 001666	1	1	[1]	Charcoal	SHcal13	-23.9	96.65	273 $\pm$ 23	323 - 151	Late Holocene
D-AMS 001667	5	3	(1)	Charcoal	SHcal13	-22.1	90.22	827 $\pm$ 25	736 - 671	Late Holocene
D-AMS 001668	10	6	(2)	Charcoal	SHcal13	-29.2	85.61	1228 $\pm$ 24	1,180 - 992	Late Holocene
D-AMS 001669	15	18	(3)	Charcoal	SHcal13	-26	87.56	1364 $\pm$ 29	1,296 - 1,185	Late Holocene
ANU - 33034	16	Burrow	a	Scaphopod	Marine2013			8105 $\pm$ 45	8,709 - 8,431	Early Holocene
D-AMS 001670	18	15	(4)	Charcoal	SHcal13	-31	87.32	1067 $\pm$ 25	966 - 820	Late Holocene
D-AMS 001671	18	15	[2]	Charcoal	SHcal13	-18.8	87.32	1089 $\pm$ 26	1,046 - 920	Late Holocene
ANU - 33035	18	23	b	Scaphopod	Marine2013			8100 $\pm$ 45	8,698 - 8,426	Early Holocene
D-AMS 001672	20	23	[3]	Charcoal	SHcal13	-35.8	83.39	1459 $\pm$ 25	1,359 - 1,285	Late Holocene
D-AMS 001673	25	Burrow	(5)	Charcoal	SHcal13	-32.4	88.2	1009 $\pm$ 31	930 - 797	Late Holocene
D-AMS 001674	25	28	(6)	Charcoal	SHcal13	-22.7	37.07	7972 $\pm$ 30	8,980 - 8,631	Early Holocene
D-AMS 001675	29	29	(7)	Charcoal	SHcal13	-29.8	33.95	8678 $\pm$ 38	9,690 - 9,531	Early Holocene
D-AMS 001676	29	28	(8)	Charcoal	SHcal13	-25	36.48	8101 $\pm$ 62	9,134 - 8,649	Early Holocene
D-AMS 001677	35	37	(9)	Charcoal	SHcal13	-27.5	33.41	8807 $\pm$ 50	10,120 - 9,553	Early Holocene
D-AMS 001678	35	37	[4]	Charcoal	SHcal13	-27.2	32.29	9081 $\pm$ 45	10,285 - 9,943	Early Holocene
D-AMS 001679	41	37	(10)	Charcoal	SHcal13	-21.1	31.86	9188 $\pm$ 50	10,489 - 10,219	Early Holocene
D-AMS 001680	45	40	(11)	Charcoal	SHcal13	-21.2	30.61	9510 $\pm$ 34	11,065 - 10,578	Early Holocene
D-AMS 001681	46	41	(12)	Charcoal	SHcal13	-17.5	25.16	11085 $\pm$ 51	13,051 - 12,759	Early Holocene
Charcoal samples were calibrated using OxCal v. 4.2 (Bronk Ramsey 2009a), with the Southern Hemisphere Atmospheric curve [SHcal2013] (Hogg et al. 2013). Marine samples were calibrated using the 2013 marine curve (Reimer et al. 2013)										

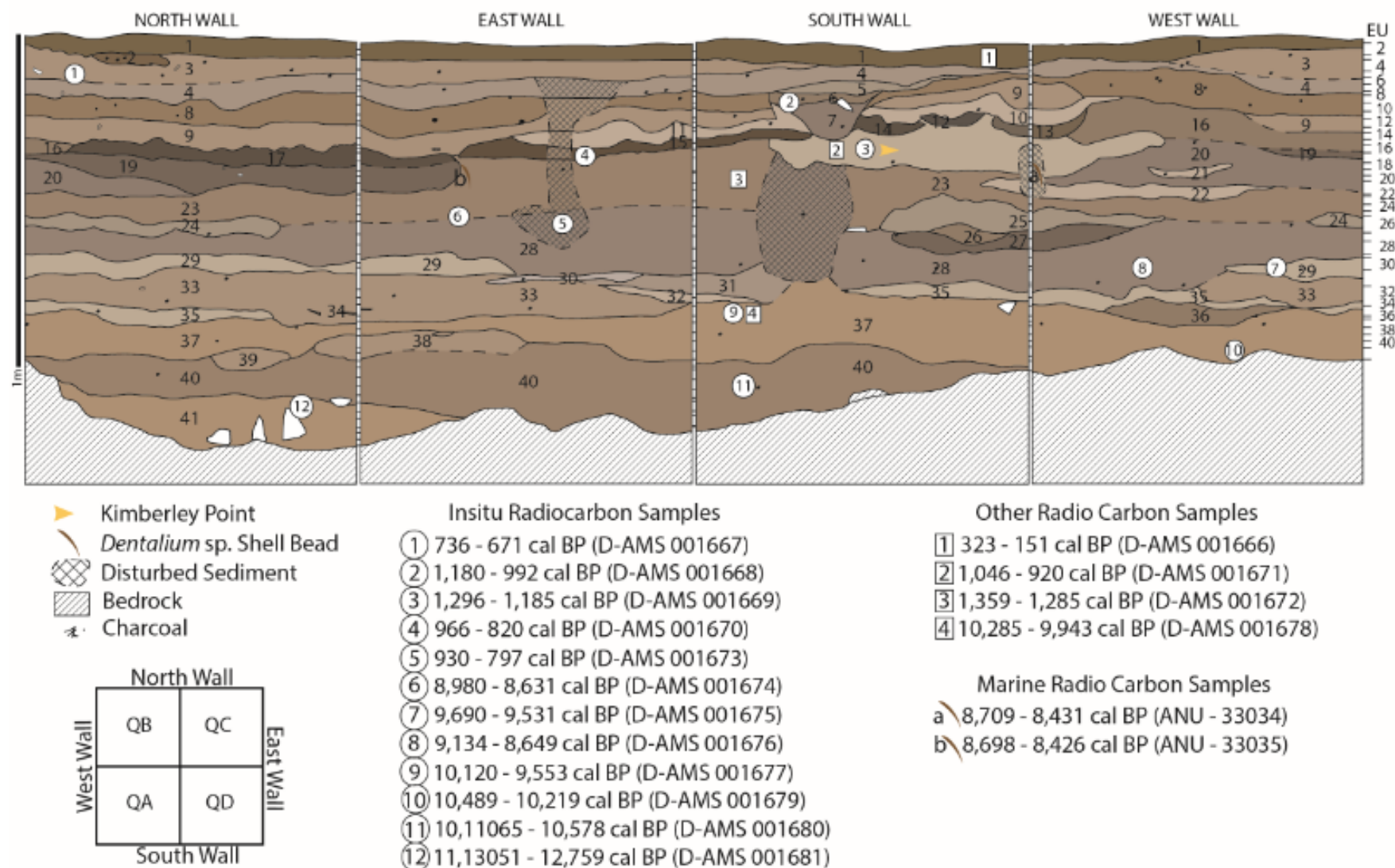


Figure 3. Stratigraphic drawing of square two (Dorcas Vannieuwenhuyse).

The 2012 excavation recovered bone, mussel shell, scaphopod beads and other marine shell fragments, charcoal, ochre, botanical remains, stone artefacts, and a single bone artefact. These finds are summarised in Table 2. As at other inland Kimberley sites (Balme and Morse 2006; Balme and O'Connor in press, O'Connor et al. 2014), marine shell is present throughout the Holocene both as ornaments and unmodified fragments. Two scaphopod shell beads (Figure 4) were directly dated to ~ 8,000 cal. BP (ANU-33034, ANU-33035). One was recovered within a burrow feature from the south west corner (ANU - 33034). The other is anomalously old for the late Holocene unit in which it was recovered (ANU – 33035), perhaps displaced by the large burrow feature in the eastern wall. Other recovered marine shells include eight fragments of *Melo* sp. (baler shell). Three of these are associated with charcoal radiocarbon dates within the last 1,200 years (EUs 16, 17 and 19). A single fragment of *Geloina* sp. was recovered from EU 21, also within the late Holocene occupational phase. The five remaining *Melo* sp. fragments were recovered from EUs 29, 30, 31, and 34, dated by association to the early Holocene. While these marine shell fragments may have been part of tools, perhaps similar to others reported from north Western Australia (O'Connor 1999:81, Fig. 5.19; Przywolnik 2003:19) they have no traces of use. Fresh water mussel shell (*Lortiella froggatti*) was found throughout square 2. The majority is burnt and highly fragmented. This species also occurs in the nearby sites of Carpenters Gap 1 and 3 (O'Connor 1995; O'Connor et al. 2014:18). It was probably collected from the Lennard River at the Gorge. Figure 5A illustrates the distribution of fresh water mussel shell, by weight, throughout the sequence. Fresh water mussel is most prevalent in the late Holocene occupation phase, particularly in the uppermost excavation units. This distribution may, in part, reflect the effect of poorer preservation with depth, however; a few peaks in the distribution of shell that appear to correlate with the distribution of charcoal (Figure 5 D), suggest that preservation is not the only factor at play. The recovered bone has not been identified to species, although long bones and teeth of rodents and small reptile vertebrae are abundant, and the species composition appears superficially similar to that reported in 2008. In contrast to the shellfish and charcoal, the greatest discard peak in bone occurs in the early Holocene occupational phase, with a marked decline in the late Holocene. This contrast may suggest a non- anthropogenic origin for the bone, especially as the discard rate for stone artefacts (Figure 6) appears to more closely follow that of charcoal and shellfish.

Table 2. Summary of recovered materials from Square 2.

EU	Total Vol. (L.)	Mean Depth Below Surface (cm)	TNA #	MNF #	Charcoal (g)	Bone (g)	Painted Limestone #	Pigment (g)	<i>Lortella froggatti</i> (g)	Avian Shell (g)	<i>Melo</i> sp. (g)	Scaphopod (g)	<i>Geloina</i> sp. (g)	Seeds (g)
1	32	0.005	33	23	.10	13.28			8.65					
2	30	0.103	47	24	7.02	8.43	1		9.64					2.20
3	27	0.132	53	31	14.88	4.41			12.52					1.29
4	30	0.153	43	22	1.29	2.21		3.87	20.68	.29				.33
5	22	0.176	35	16	8.93	5.60			12.52	.47				.10
6	25	0.196	33	18	3.04	3.86			7.40	.31				.13
7	20	0.217	16	7	2.24	2.78			21.83	.74				.14
8	23	0.354	16	9	.73	3.23			2.64					.17
9	20	0.253	6	4	2.06	1.97			1.13	.04				.51
10	27	0.270	15	11		3.43			.95					.16
11	29	0.292	37	22	.18	7.88			.35	.15				.25
12	26	0.318	20	9	.65	4.48			.32					
13	26	0.336	12	6	.02	11.50			1.22	.02				
14	26	0.358	22	13	3.06	17.53		10.53	6.29	.17				
15	29	0.373	17	11	.69	15.16			4.96		.60			
16	29	0.394	12	6	1.29	7.50		7.6	3.08	.06	.40	0.30		
17	32	0.414	21	14	4.53	7.10		1.5	4.76		.49			
18	31	0.440	19	9		5.25		0.8	6.36			0.18		.28
19	25	0.467	14	8	1.87	7.92	2	109.18	2.62		.12			
20	27	0.480	8	6	.00	12.75			.56					.05
21	31	0.507	15	12	3.77	37.34	2	3.29	3.28				2.41	
22	22	0.533	9	8	.79	4.37			.87	.26				
23	29	0.553	18	8	.24	8.42			3.21					
24	28	0.575	15	11	3.74	8.85			1.09					.11
25	30	0.599	16	10	1.12	12.80		5.26	1.28					
26	40	0.623	4	4	8.50	12.73			2.33					
27	37	0.666	21	11	2.10	21.23			3.80					
28	31	0.696	14	10	2.80	9.94			1.15					
29	31	0.730	3	2	2.37	7.22			.68		.52			
30	34	0.749	8	2		10.33			.23		1.91			
31	38	0.771	10	9	3.87	10.12			2.34		1.50			
32	27	0.812	15	9	2.26	7.45			2.48					
33	31	0.834	13	7		13.92		2.5	4.00					
34	27	0.856	13	9		11.73		0.7	3.45		.35			.27
35	25	0.875	8	6		28.45			.19					
36	34	0.904	13	6	.49	10.89			2.30					
37	32	0.922	13	8	1.07	38.05			.67					
38	22	0.947	39	18		29.44			.13					.13
39	24	0.969	67	35	.19	24.29			.70					1.38
40	27	0.994	41	24		39.28			.24					.08
41	24	1.014	40	20	2.50	15.10			.42	.05				.21
42	31	1.040	18	7	.50	19.77			.16	.08				1.29
43	27	1.059	9	7	5.80	15.19			.36					.18
44	17	1.170	3	1	.52	3.75			.53					
45	20	1.107	5	4	1.92	1.26			.09					
46	3	1.134	1	1		1.39								
47	21	1.164				.19								.18
48	17	1.186												
49	8	1.197			.10									
50	3	1.230			7.02									2.20
51	5	1.235			14.88									1.29
52	7	1.239			1.29									.33

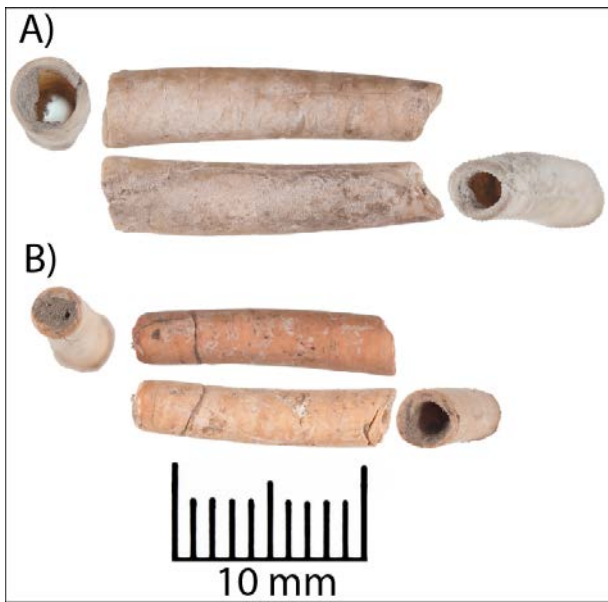


Figure 4. Scaphopod beads. A) Bead from EU 16; B) Bead from EU 18.

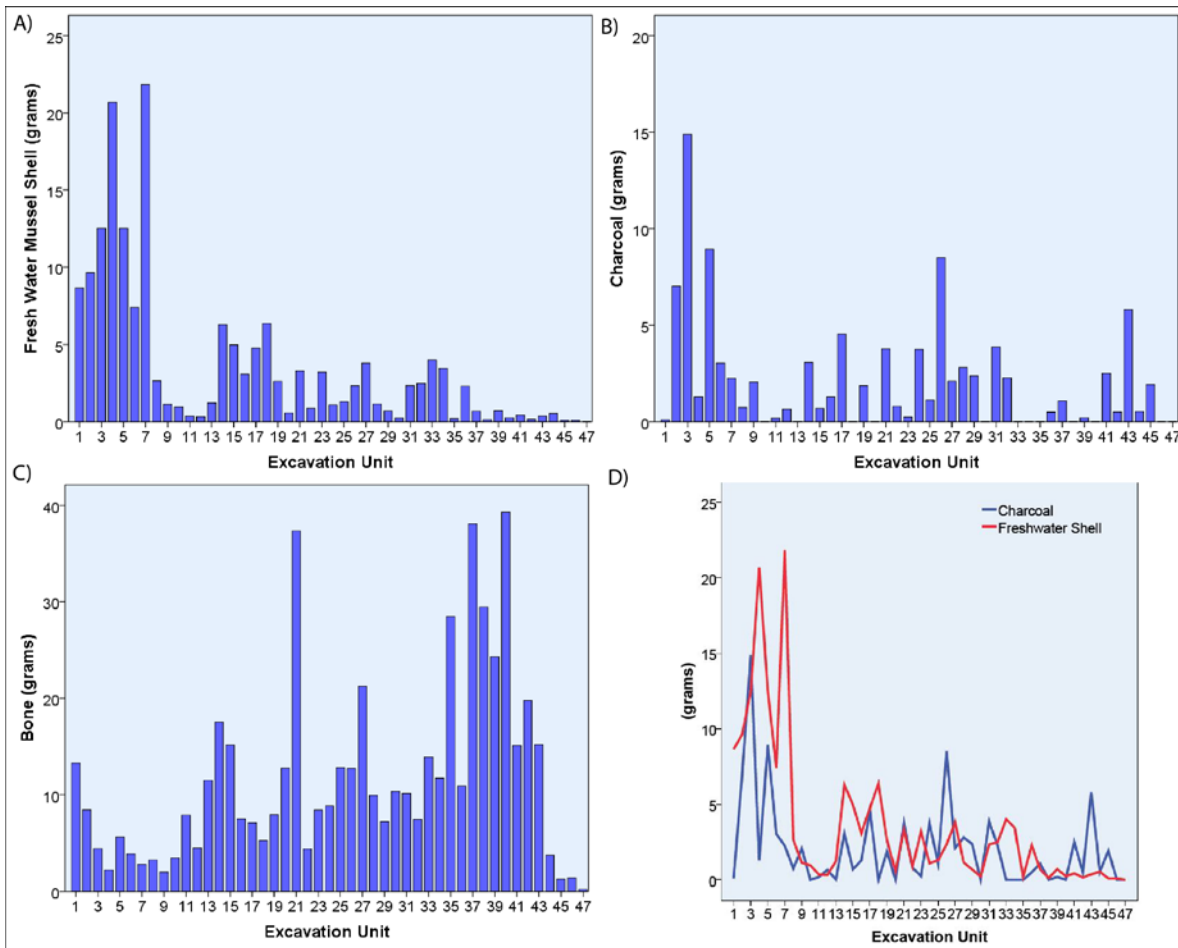


Figure 5. Discard trends relative to excavation units showing weight in grams combined for both 3 and 1.5mm sieve fractions. A) Freshwater mussel shell; B) Charcoal; C) Faunal remains; D) Correlation of fresh water shell and charcoal.

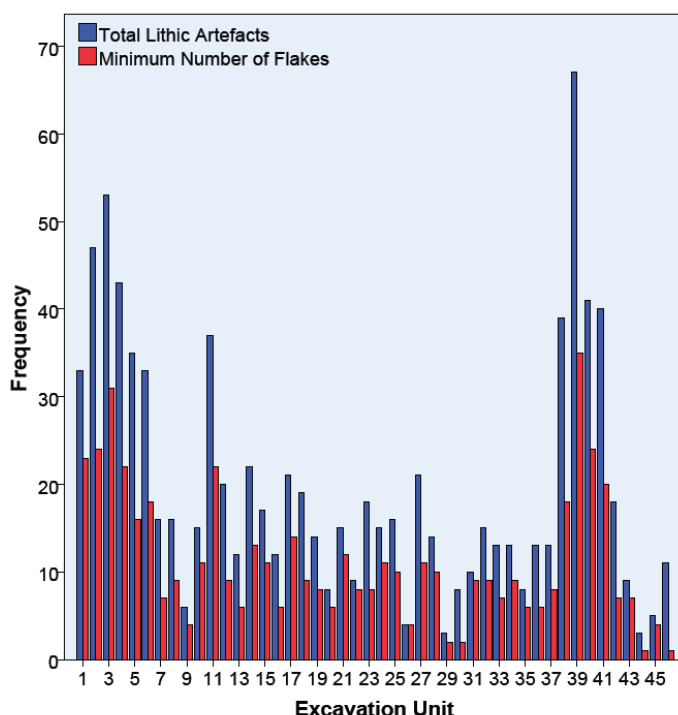


Figure 6. The total number of stone artefacts (936) and the minimum number of flakes (517) (after Hiscock 2002:254) for each excavation unit.

A bone point tip fragment was recovered from the late Holocene levels (EU5) (736 to 671 cal. BP D-AMS 001667). It has rounded margins and intersecting striations which form the tip, and is morphologically similar to those recovered at Widingarri (O'Connor 1999:78-79).

A total of 936 stone artefacts were recovered from square 2 of which the dominant raw material is crystal quartz (59%). Water rolled cobbles of crystal quartz can be found within the Lennard River gravel beds, and formed crystals occasionally occur in conglomerate bands in the limestone. White vein quartz is locally abundant, but was not as frequently exploited (4.2%) as crystal quartz. Fine-grained quartzite (12.5%) is present in similar proportions to chert (12.3%). The closest known major chert source occurs around 12 km to the west. Quartzite cobbles are found on the northern side of the range in vast sheets eroding from the Behn conglomerate (Playford 2009). Artefacts made of basalt, tuff, sandstone and chalcedony are also present (12%).

The lowest observed stone artefacts are from EU 46 (13,051 to 12,759 cal. BP D-AMS 001681) which marks the beginning of a stone artefact discard peak which ends in EU 35 (Figure 6) dated by two overlapping radiocarbon dates of 10,120 to 9,553 cal. BP (D-AMS 001677) and 10,285 to 9,943 cal. BP (D-AMS 001678). Following this, stone artefacts were less frequently deposited leading up to the hiatus in the deposit and the close of the early Holocene occupation phase. Size sorting of lithic artefacts is unlikely to be responsible for this early Holocene artefact accumulation, since the size and shape of flakes are not correlated with depth within units below EU 25 (Table 3). The late Holocene occupation (1,200 to modern), reveals a steady increase in artefact discard beginning after EU 25, which is associated with a date of 1,359 to 1,285 cal. BP (D-AMS 001672), and which contains an artefact discard peak around EU 5, dating to 736 to 671 cal. BP (D-AMS

001667). Changes in reduction between the early and late Holocene occupation phases within the deposit are evident.

Table 3. Univariate statistical analysis of flake size and shape below excavation unit 25.

Flake Variable	Shapiro-Wilk		Univariate		
	W	p	df	F	p
MLD	0.808	<0.001	21	1.308	0.165
Percussion Length	0.820	<0.001	21	0.895	0.598
Mid Width	0.790	<0.001	21	1.261	0.212
Mid Thickness	0.796	<0.001	21	1.133	0.329
Length: Thickness Ratio	0.895	<0.001	21	0.751	0.773
Width: Thickness Ratio	0.778	<0.001	21	0.643	0.880

A total of 17 cores were recovered - 11 from the early Holocene phase and 6 from the late Holocene phase. Morphological and reduction data presented in table 5, indicate that cores were reduced to greater levels in the early Holocene, were discarded as comparatively smaller nodules, probably having longer use lives than those from the late Holocene. The flake to core ratio also indicates that the proportion of cores to flakes was greater during the early Holocene phase, than the late Holocene phase (Table 4).

Table 4. Mean reduction and morphological data between early and late Holocene.

Period	Core Rotations	Core MLD (mm)	Core MLD x Mass (grams)	Flake to Core Ratio	Flake LPL x Mass (grams)
Early Holocene Occupation Phase	2.55	27.12	146.43	36	788.98
Late Holocene Occupation Phase	2	32.89	427.91	14	36.95

Changes in flake production are also evident between the two occupation phases. The frequency of retouched flakes increases dramatically. The flake lateral perimeter length multiplied by mass (Mackay 2008:615), suggests that flake production during the early Holocene, removed on average, less potential working edge or margin relative to mass (Table 4). The percussion length of complete flakes also decreases from the early to late Holocene ($W = 0.926$, $p = <0.001$; $U = 16289.5$, $p = <0.001$), although this may be affected by the frequency of flakes smaller than 10 mm in length from the more recent phase ($W = 0.922$, $p = <0.001$; $U = 18999$, $p = <0.001$). The increase in small flakes in the late Holocene could be related to greater rates of resharpening, or to the pressure flaking of Kimberley Points, known to first occur in the region around 1,000 cal. BP (Maloney et al. 2014). A single pressure flaked Kimberley Point made on crystal quartz recovered from EU 18 is consistent with this (Maloney et al. 2014:139, Fig. 2). While no other points were recovered from square 2, O'Connor et al. (2008) report several direct percussion points from square 1, within the mid-Holocene units. A further twenty five retouched flakes were found in square 2 deposit, none conforming to recognised formal tool types. Those from the early Holocene phase were rarely retouched to levels greater than AGIUR (Kuhn 1990) and Index of Invasiveness (Clarkson 2002) values of 0.2 and 0.3.

Basalt flakes likely removed from axes were only recovered from the late Holocene phase ($n = 9$), but have a much greater antiquity elsewhere in the region (O'Connor et al. 2014:18). Ground fragments of sandstone were also found in the late Holocene in EU 17, 2, and 1.

The shelter wall has an assemblage of painted art in red, orange and white pigments. The motifs are mostly snakes ($n = 18$) and eels ($n = 4$), differentiated by the presence of fins behind the head. Two limestone fragments had traces of red and white pigment (EU 19 and 21) and ochre pieces were found in both occupation phases (Table 2). A fine-grained quartzite cobble in EU3 had a smear of red pigment on one surface and was probably used for grinding ochre.

Discussion and Conclusion

The excavations in square 2 *Djuru* extended to bedrock, establishing that the site was used from at least the terminal Pleistocene 13,000 years ago and identified differences in the chronostratigraphic sequence across the site. The square 2 deposit contained two dated phases of occupation representing the terminal Pleistocene to early Holocene and the late Holocene. The period of 7,000 to 1,300 cal. BP identified in square 1 (O'Connor et al. 2008), is absent in the part of the site sampled by square 2. This small shelter, approximately 10 x 3 m, illustrates how stratigraphy and cultural materials within a site can vary dramatically over small spatial distances, emphasising the need for sampling across the floor of deposits and caution in using the chronological sequences in small pits to model regional occupation patterning.

The early Holocene occupants of the site produced a wide morphological range of flakes, which were seldom and minimally retouched. The late Holocene assemblage reveals a shift in reduction strategies, with cores less reduced, and flakes with greater margin relative to mass – a trend seen elsewhere in the region (O'Connor et al. 2014:17). Retouched flakes double in frequency during this period and new forms of pressure flaked point technology appear. The high rates of lithic discard in the early Holocene is unique within the local area, as sites such as CG3 indicate a marked rise in lithic discard only in the mid to late Holocene (O'Connor et al. 2014:16).

Occupants of the site used *Melo* sp. and *Geloina* shell imported from the coast over 200 km distant during the early and late Holocene although the fragments found in square 2 are too incomplete to determine their use. The two scaphopod shells have stringing wear and polish and were presumably threaded for use as a decoration. Scaphopods and *Melo* have been found in all the recent shelter excavations in the southern Kimberley suggesting that in this region they were used in secular realms of life (Balme and O'Connor in press).

The apparent absence of aquatic foods other than freshwater shellfish in the diet is puzzling given the site's proximity to Windjana Gorge (~200 m). O'Connor et al. (2008:78) noted the lack of fish bones in the 1994 excavation, suggesting the larger sieve may have been responsible, however; the 2012 excavation used a 1.5 mm sieve and still did not find fish remains. Aquatic resources such as freshwater crocodiles, barramundi, black bream, eels, freshwater crustacea and water birds are abundant in the gorge. The presence of mussel shell throughout indicates that the Gorge contained standing freshwater and was exploited for shellfish and thus the lack of other aquatic fauna seems curious.

Acknowledgements

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Thesis by Compilation

Purpose

There is an increasing expectation in many disciplines, that PhD students should publish journal articles during and shortly after their degrees. A thesis by compilation allows a student to focus their writing on publishable journal articles and book chapters.

Preamble

Because of disciplinary variability, the guidelines are not prescriptive in details such as number of papers required. Overall, the quantity and quality of the material presented for examination needs to equate to that which would otherwise be presented in the traditional thesis format. The guidelines assume a vital role for Colleges, Schools and supervisory panels thus aiming to embrace sensible disciplinary differences while ensuring an ANU PhD remains of the highest quality.

Procedure

1. Submission of a thesis by compilation requires approval by the Delegated Authority. The approval process ensures that the student has received important, discipline*specific guidance on the appropriate quantity and quality of papers for submission as a thesis. Only in exceptional circumstances will approval be given to a candidate for a Master of Philosophy or Professional Doctorate to submit a thesis by publishable papers.
2. The papers must have been researched and written during the course of the candidature, except in the case of students admitted to a program under the ANU staff provisions (Research Award Rules 2.3(3) and 2.3(4)). A thesis by compilation may include video recordings, film or other works of visual or sonic arts, computer software, digital material or other non*written material for which approval has been given for submission in alternative format.

Approval

3. The option to submit a thesis by compilation will require the support of the supervisory panel and the approval of the Delegated Authority well in advance of the submission. Typically, students should commit to this form of submission and seek approval at least 12 months from completion, no less than 6 months out, although in some disciplines a commitment to thesis by compilation would be appropriate much earlier. Supervisors should discuss the option early in the student's candidature and offer practical guidance about realistic peer*review and publication timeframes in their discipline.

Number and status of papers

4. The thesis will be based on a number of papers published in, accepted by, under review at, or in preparation for high*quality, peer*reviewed journals. In some disciplines (e.g. mathematics) a single long monograph may be acceptable; in others the discipline expectation might be 4–5 peer* reviewed papers. Normally it would be expected that the majority of papers were published, or accepted for publication. Those papers that have not been accepted for publication will be

examined in the same manner as traditional thesis chapters. Colleges, Schools and supervisory panels should provide sound disciplinary advice on appropriate number and publication status.

Authorship

5. Students who are undertaking a thesis by compilation should seek advice before signing publisher's agreements to ensure each agreement does not preclude the inclusion of the published work in their thesis.
6. Whether or not the candidate is sole author of all, some or any of the papers will vary by discipline and Colleges, Schools and supervisory panels should provide advice on what is most appropriate within particular disciplines. Where the candidate is not the sole author of a paper, they must demonstrate that they have made appropriately significant contributions to the paper.

Construction of the thesis

7. A number of distinct papers are expected, and while some overlap between related papers is acceptable, they should nevertheless be substantially different in focus or content. A thesis constructed of chapters/papers/manuscripts must be presented in a logical and coherent way and will require the addition of linking text to establish the relationship between one chapter and the next. This could, for example, be achieved by the inclusion of a foreword to each chapter.
8. An extended context statement demonstrating the relationship between all aspects of the research is also required as part of the thesis. This will include an introduction to the field of study and the hypothesis or research questions, how these are addressed through the ensuing chapters, and a general account of the theory and methodological components of the research where these components may be distributed across separate papers/chapters. The context statement should be in the order of 10,000 words in length. The outcomes of the project and the author's conclusions will either be summarised in the context statement, or covered in a concluding chapter.
9. The thesis may also include relevant appendices containing raw data, programs, questionnaires and other material that would normally appear in a standard PhD thesis.
10. A thesis by compilation must include a signed declaration that specifies:
 - Title, authorship and publication outlet of each paper.
 - The current status of each paper (In press, Accepted, Under Review, In preparation).
 - The extent of the contribution of the candidate to the research and the authorship of each paper.
 - For each paper where the candidate is not the sole author, the collaborating authors must also sign the declaration.
11. The entire thesis, including the published papers, must be formatted in an acceptable PhD thesis style, although journal formatting can be preserved. The papers and supplementary material should be on A4 paper (or similar), bound together in a single volume.

Examination

12. Following submission of the thesis the standard ANU examination procedures will apply.

Appendix F: List of recorded variables

Raw material variables

- Raw material type
- Raw material colour
- Grain size – Very fine (at invisible 20x), fine (<1mm), medium (~1mm), and coarse (>1mm)
- Cortex percentage overall
- Cortex quadrants q1 q2 q3 q4
- Cortex Index = $(q1 + q2 + q3 + q4) / 4$
- Heat affected – crazing, crenulations, and pot lidding

Typological data

- Technological class (core/flake/retouched flake/flaked piece)
- Typology – unifacial or bifacial point etc.
- Previously defined technological class (by original collector/analyst)

Qualitative Retouch variables

- Retouched over transverse, longitudinal, or marginal break (recycling)
- Retouch truncated by transverse, longitudinal, or marginal break
- Proximal/butt morphology – round, square, or unmodified
- Number of scars on dorsal butt surface
- Number of scars on ventral butt surface
- Number of burinate scar/spalls
- Number of burinate rotations
- Notches
- Dorsal retouch type – marginal, invasive, or backed
- Ventral retouched type – marginal, invasive, or backed
- Bifacial or unifacial retouch –retouch on one, or two superimposed surfaces
- Percussion method – direct, pressure, or bipolar
- Retouch order – dorsal only, ventral only, dorsal last, ventral last, rotated, or indeterminate

Edge damage/use wear variables

- Diagnostic impact fractures – unifacial/bifacial spin offs, burinate scars, step and hinge terminating scars
- Marginal edge damage (chattering)
- Marginal edge damage (location)
- Edge damage/rounding on dorsal ridges and platform
- Residues – silica, resin, or any visible matter

Flake and retouched flake qualitative observations

- Dorsal ridges frequency – parallel to margins
- Platform type – cortical, plain, flaked, focalised, crushed
- Platform preparation – overhang removal, faceting, and abrading

- Qualitative cross sectional shape
- Cross sectional symmetry
- Termination type – feather, step, hinge, and outtrapasse
- Dorsal scar orientation – unidirectional, bidirectional, and multidirectional
- Flake type – primary, secondary, and tertiary
- Initiation – bending, hertzian, and bipolar
- Weight (grams)

Flake breakage

- Breakage type – transverse, longitudinal, and marginal
- Remaining flake fragment – proximal, medial, distal, left or right longitudinal cone split
- Minimum number of flakes following Hiscock (2002)

Serration variables

- Serration types – serrate, dentate, and denticulate
- Serration location
- Total number of serrations
- Perimeter length with serrations (mm)
- Perimeter length with serrations (%)
- Number of serrations relative to perimeter length (%)
- Number of segments with serrations
- Number of serrations per 10 millimetres
- Maximum lateral extension of serrations
- Minimum lateral extension of serrations
- Mean lateral extension of serrations
- Maximum distance between serration terminations
- Minimum distance between serration terminations
- Mean distance between serration terminations
- Maximum distance between serration notches
- Minimum distance between serration notches
- Mean distance between serration notches

Metric variables for complete flakes and retouched flakes (mm)

- Maximum box length
- Percussion length
- Maximum linear dimension
- Maximum width
- Proximal width
- Mid width
- Distal width
- Width before proximal curve
- Proximal radius perpendicular to proximal width
- Thickness at distal quartile
- Thickness at mid width
- Thickness at proximal width

- Platform thickness at PFA
- Maximum platform thickness
- Platform width
- Lateral perimeter length

Shape Indices

- Elongation index
- Ventral area
- Marginal angle
- Distal width to thickness ratio
- Mid width to thickness ratio
- Proximal width to thickness ratio
- Base curvature index
- Length to thickness ratio
- Robustness index
- Tip cross-sectional area
- The sharpness index

Metric variables for angles (°)

- Average burinate scar/spall angle
- External platform angle
- Internal platform angle
- Average edge angle
- Average retouched edge angle
- Maximum retouch scar angle

Quantitative retouch variables (mm)

- Maximum retouch scar length
- Maximum retouch scar width
- Minimum retouched scar length
- Min retouch scar width
- Length of retouched perimeter

Reduction indices

- Percentage of retouched perimeter (Hiscock and Attenbrow 2003)
- Number of dorsal segments retouched
- Number of ventral segments retouched
- Total number of retouched segments
- Average geometric index of unifacial reduction (Hiscock and Attenbrow 2003; Kuhn 1990)
- Index of invasiveness (Clarkson 2002)
- Mean scar invasiveness (Clarkson 2007)

3D laser scanned variables

- Platform area (mm²) (Clarkson and Hiscock 2011)

- Total surface area (mm²)
- Edge ground surface area (mm²)
- Cross section shape

Edge ground axe/edge ground flake variables

- Edge ground surface location
- Edge ground percentage dorsal (%)
- Edge ground platform
- Edge ground platform percentage (%)
- Axe edge angle (°)
- Number of dorsal flake scars
- Number of ventral flake scars
- Negative scars truncate edge ground surface

Qualitative core variables

- Core type – single platform, multiplatform, levallois, and bipolar
- Scar orientation – parallel or centripetal
- Core platform types – plain, flaked, crushed, or faceted
- Platform preparation – overhang removal, faceting, and abrading

Quantitative core variables

- Number of discrete platforms
- Number of aberrant terminations – steps or hinges
- Number of faceting scars on platform
- Number of rotations
- Cortex percentage overall (%)
- Average platform angle (°)
- Maximum linear dimensions (mm)
- Platform length max (mm)
- Platform width max (mm)
- Platform area (mm²)
- Platform perimeter length (mm)
- Max scar length (mm)
- Max scar width (mm)
- Min scar length (mm)
- Min scar width (mm)
- Number of scars

Core shape indices

- Maximum linear dimension multiplied by mass (Andrefsky 2007)
- Maximum flake scar elongation
- Minimum flake scar elongation

An experimental examination of I/TMC with 3D laser scanning

Tim Ryan Maloney

Australian National University, College of Asia and the Pacific, School of Culture, History and Language, Coombs BLD 9, Fellows Road Acton, Canberra, Australian Capital Territory

tim.maloney@anu.edu.au

[+612 6261250309](tel:+6126261250309)

Abstract:

Accurate quantification of retouch intensity is paramount to discussion of lithic technology and technological organisation in the context of curation and technological investment. The mass removed from lithic tools through retouch is a powerful metric for inferences on technological systems of the past. This research showcases the legitimacy of one such method for calculating this metric: 3D laser scanning. Recent advances in 3D laser scanning technology have facilitated unprecedented accuracy in surface area measurements of lithic artefacts. With sub millimetre accuracy, this new methodology has been shown, by Clarkson and Hiscock (2011), to accurately estimate flake mass, based on regression of platform surface area. These authors theorised that where flake mass is estimable from the 3D laser scanning of platform surface area, the initial mass of retouched flakes with platform surfaces should also be predictable. This manuscript presents an analysis of ‘initial to terminal mass comparison’ [I/TMC] using an experimental sample. Results indicate that I/TMC was most reliable when EPA subsets were employed and further studies need to be conducted to improve I/TMC’s overall performance.

1. Introduction

The quantification of retouch observed on lithic artefacts has undoubtedly revolutionised Palaeolithic studies, leading to many insightful conclusions on technology from archaeological records around the world. Accurate quantification of retouch intensity is paramount to discussion of lithic technology and technological organisation in the context of curation and technological investment. The development, critique and verification of, reduction indices, each contributes to the discipline. The application of 3D laser scanning to this avenue of archaeology has created promising new indices of reduction (Clarkson and Hiscock, 2011; Morales et al., 2013; Muller and Clarkson, 2015); one of which, the I/TMC, will be examined in this study.

In many archaeological assemblages, discarded flakes are retouched along their margins, with the platform surface intact and unmodified. Archaeologists seek to quantify the mass removed from these tools, in an effort to model the role of lithic technology in human lifeway’s. The pertinent problem in archaeological contexts is that only terminal mass, or the mass of the discarded retouched flake, can be precisely known. Consequently, intact platforms offer an analytical vehicle with which the mass of a retouched flake, prior to its modification, might be estimated. Archaeologists have been occupied with this correlation for some time (Davis and Shea, 1998; Dibble, 1987, 1995, 1997; Dibble and Pelcin, 1995; Dibble and Rolland, 1992; Dibble and Whittaker, 1981; Pelcin, 1997; Shot *et al.*, 2000; Speth, 1972, 1974, 1981). Researchers have not been able to produce a

widely accepted method for predicting the mass lost from retouched flakes (for example Eren *et al.*, 2005; Hiscock and Clarkson, 2009; Hiscock and Tabrett, 2010:556-557). This shortfall is partially due to the inaccuracies of previous attempts at modelling mass based on platform area, and partly due to the obvious problem that the platform surfaces of retouched flakes will not always be left intact.

Building on the known correlation of platform size with flake mass, Clarkson and Hiscock (2011:1067) recently outlined a promising theoretical index that potentially estimates the mass lost from retouched flakes with intact platforms. Analysing a diverse experimental assemblage, Clarkson and Hiscock (2011) found a strong and significant relationship between 3D scanned platform surface area and flake mass. These results were achieved after logarithmic transformations of data and various technological subsets analysed as separate batches within the data were identified; such as platform surface type, flake termination and external platform angle [EPA]. The authors hypothesized that if the relationship between 3D laser scanned platform surface area and flake mass is robust, predictions of the initial mass of retouched flakes retaining platforms could be used to subtract from the known terminal mass and give an estimated value of mass lost (Clarkson and Hiscock, 2011:1067). The researchers termed this method the ‘initial/terminal-mass comparison or I/TMC’ (Clarkson and Hiscock, 2011:1067). Muller and Clarkson (2015) explore these trends further, by focusing on ITMC relationships with blade assemblages. This study demonstrated enhanced levels of prediction using the platform area, although like the original expose of I/TMC (Clarkson and Hiscock, 2011), there is still a critical absence of the actual comparison of terminal mass with initial mass. This study uses 3D laser scanning of an experimentally produced assemblage to empirically test the I/TMC method for the first time.

2. Methods

2.1 Laser scanning

Flakes were scanned with a Next Engine HD 3D scanner and 3D data were edited with HD Pro software (see Shott and Trail, 2012:12). Each scanned artefact is represented by a series of data points referred to as the data mesh. At the completion of each scan the data mesh was fused and all data points except the exact platform surface area were deleted, using the HD Pro Software’s trim function. The surface area of the remaining data mesh was then calculated. Because the HD pro software produces surface area values in inches squared, it was first necessary to convert each value from inches to millimetres. Secondly, the remaining data mesh of the platform surface actually includes the external surface removed from the core, as well as its internal surface, artificially revealed through editing the data mesh. Hence, all surface area values need to be subsequently divided by two to avoid falsely doubling the platform surface area. These steps are illustrated in Figure 1.

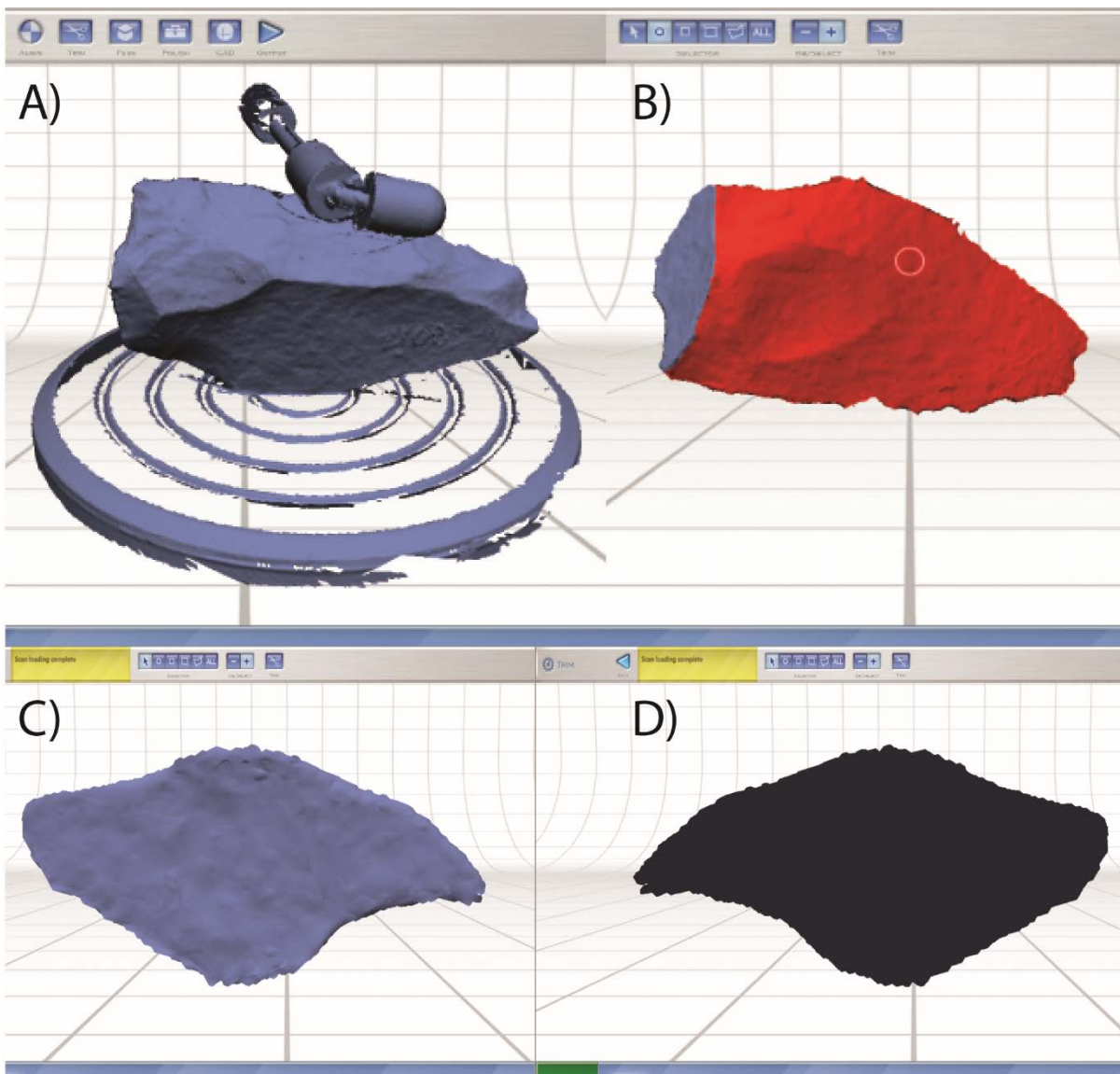


Figure 1. Editing data mesh in Next Engine HD pro software: A) Completed scan showing dorsal surface of retouched flake, including clamp mechanism B) Ventral surface of same artefact, where unwanted data mesh, including clamp mechanism and non-platform surfaces are deleted using the trim function C) Remaining platform surface removed from core D) Artificial internal platform surface revealed through editing.

2.2 I/TMC

The I/TMC has been explored in two experimental studies (Clarkson and Hiscock 2011; Muller and Clarkson 2015), yet the exclusion of retouched flakes continues to undermine the value of this index. The formula put forward by Clarkson and Hiscock (2011) implies that the mass lost [ML] from retouched flakes, can be estimated by comparing the retouched flakes' platform surface area, with the estimated initial mass [IM], which is derived from the non-retouched flakes' platform surface area regression line. The estimated IM of retouched flakes predicted by this regression is subtracted from the known terminal mass [TM] of retouched flakes. The given estimated ML value can then be quantified as a percentage of the initial mass (Hiscock and Tabrett, 2010:553). Figure 2 illustrates a theoretical example of this process. The experimental design allows for all

values involved in the I/TMC to be known, thus, the results will include and compare known and estimated values.

The strength and significance of regressions used to make these estimations is gauged by r , r^2 and p values, through the linear regression analysis functions of SPSS version 20. For the sake of clarity, logarithmic transformations of data have been avoided.

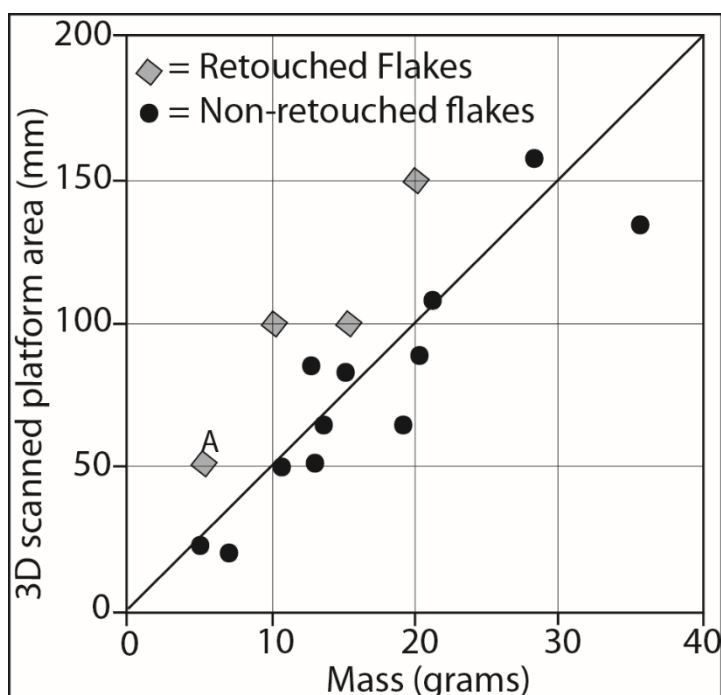


Figure 2. Theoretical comparison of the retouched flakes known TM is made with the IM predicted from the regression line of non-retouched flakes. Retouched flake A has a TM of 5 grams, an estimated IM of 10 grams, therefore, has an estimated ML of 5 grams and estimated percentage ML of 50 %.

2.3 Artefact attributes

To reconstruct subsets used in regression analyses by Clarkson and Hiscock (2011), a series of technological variables, measurements and indices were recorded. EPA was measured with a goniometer and taken where 'the sloping dorsal face is immediately adjacent and below the platform edge, ignoring overhang removal scars as well as more distal scar facets' (following Clarkson and Hiscock, 2011:1063). Flake termination types were recorded as feather, hinge, step or outpasse (or plunging). Platform types were recorded as flat (aka plain), flaked, focalised, or dihedral (following Clarkson and Hiscock, 2011:1063). Flake mass was recorded to two decimal places using a digital balance. The estimated percentage of ML was assessed by comparison with various reduction indices; such as the GIUR (Kuhn, 1990), the Index of Invasiveness (Clarkson, 2002), and the percentage of perimeter retouched (calculated by divided the linear length of retouched margins by the total flake margin).

3. Samples

An experimental assemblage of flakes and retouched flakes was produced using dacite, a very fine grained volcanic material that is brittle, easy to knap, and scans quickly due to the homogeneity of its structure. Two cores were reduced, each of which approximated a

tabular morphology and exhibited no prominent raw material flaws. The small amount of cortex on each core (<10%) made decortication flakes unnecessary. I attempted to produce blades on one core and less formalised flakes on the other. Core reduction continued with freehand direct percussion, until a practical threshold was reached and flake production could only continue with anvil resting ($n = 1$). Between flake removals, the platform of each core was abraded using a coarse lithic surface and occasionally further modified with overhang removal and faceting to assist flake production. The debitage produced from these actions was not counted in the total. Cores and retouched flakes were reduced with direct percussion using a hard hammer, 8 oz copper percussor.

Retouched flakes were selected from the pool of flakes based on their likely ability to be practically retouched along their margins. Blank selection resulted in the exclusion of small and relatively thin flakes that could not be practically retouched, although these flakes were still scanned and recorded. Consequently, the smallest retouched flake was 6.55 mm along its percussion axis and weighed 1.76 grams. The mean and minimum values of metric data for retouched flakes and all other non-retouched flakes are given in Table 2. Flakes selected for retouch generally appear larger than those not retouched.

Of the 104 flakes produced, 42 retouched flakes were subsequently reduced with varying levels of retouch intensity, whilst leaving the platform surface unmodified. This left 62 flakes unretouched. The morphologies consisted of retouched flakes with varied steep angled margins that typologically resembled informal expedient tools or scrapers ($n = 35$). Additionally, unifacial and bifacial points ($n = 7$) were produced from blade like flakes and more invasively retouched. Figure 3 illustrates three examples of these retouched flakes showing the length of the perimeter retouched and the platform surface area. Table 1 lists the technological class frequency.

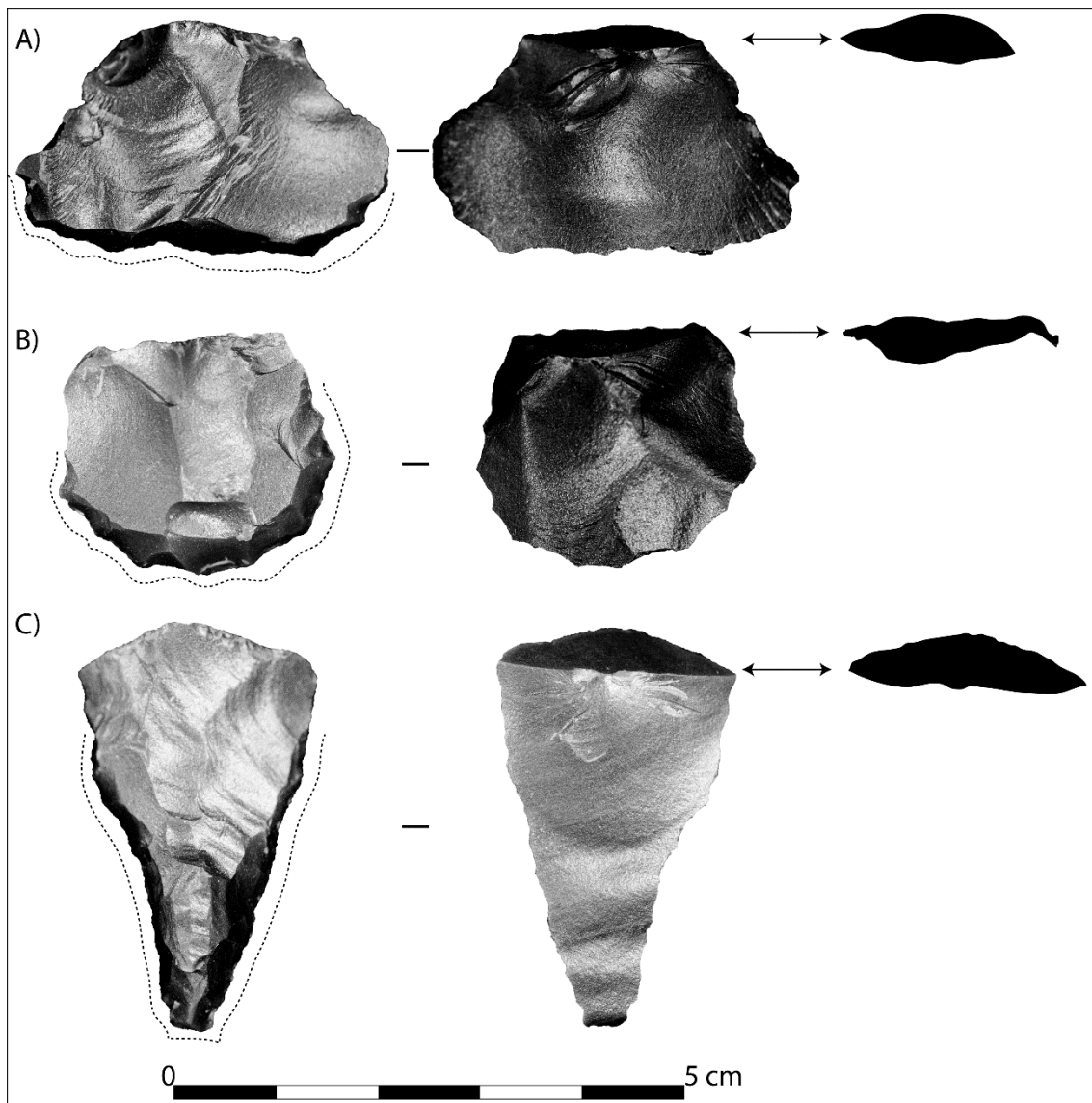


Figure 3. Examples of experimentally produced retouched flakes with intact platform surfaces: A) Retouched flake with distal marginal retouch on dorsal surface B) Retouched flake with medial and distal marginal retouch on dorsal surface C) Unifacial point with marginal and some invasive retouch on the dorsal surface.

Table 1. Technological class frequency in assemblage

Technological Class	Core	Flake	Bipolar Flake	Unifacial Point	Bifacial Point	Retouched Flake	Total
Frequency	2	62	1	3	4	35	107
Percentage	1.9	57.9	0.9	2.7	3.8	32.8	100

Table 2. Summary of morphometric values for retouched and non-retouched flakes

Variable	Retouched				Not retouched			
	Min	Max	Mean	SD	Min	Max	Mean	SD
Length (mm)	6.55	57.83	43.10	11.90	8.24	65	32.82	15.17
Elongation (length x width)	0.31	3.95	2.02	0.87	0.42	5.63	1.24	0.73
Width: Thickness Ratio	1.48	7.35	3.90	1.61	0.95	26.53	6.30	3.73
Mass (grams)	1.76	34.47	10.80	7.62	0.09	416.01	23.86	64.82

4. Results

4.1 3D scanned platform area and flake mass

The total sample of flakes demonstrated a moderately strong and highly significant correlation between platform area and mass ($r = 0.641$, $r^2 = 0.411$, $df = 1$, $f = 39.757$, $p = <0.001$). Linear regression analysis of the non-retouched flakes as a single batch produced lower r values ($r = 0.579$, $r^2 = 0.336$, $df = 1$, $f = 24.258$, $p = <0.001$), whilst r values of the retouched sample as a single batch, drastically improved r values ($r = 0.956$, $r^2 = 0.913$, $df = 1$, $f = 73.894$, $p = <0.001$).

Notably, the traditional method of estimating platform area (by multiplying platform width by thickness), is actually significantly different from the 3D laser scanned value, as revealed by a paired sample T-test ($t = -3.003$, $df = 29$, $p = 0.005$). These data support the findings by Braun *et al.* (2008:1057) and Clarkson and Hiscock (2011:1064) that platform area is over estimated using calliper measurements.

All subsets of EPA revealed significant correlations between platform surface area and mass and each subset improved in r values (Table 3). These data suggest that EPA subsets are important factors in the regression between platform area and mass across the assemblage and can be used as separate batches for creating the IM regression line.

Table 3. Linear regression results for subsets of EPA.

Variable	EPA below 70 (n = 31)	EPA above 70 (n = 38)	EPA < 80 (n = 45)	EPA > 80 (n = 20)
r	0.834	0.740	0.755	0.711
r ²	0.696	0.548	0.751	0.506
df	1	1	1	1
f	66.486	43.669	57.157	18.448
p	<0.001	<0.001	<0.001	<0.001

Flake termination subsets revealed a decline in r values in all but step and hinge terminating flakes, however, significant correlations are only present in feather and hinge subsets (Table 4). The sample size of step terminations and the abnormal removal of mass associated with outpasse terminations (Clarkson and Hiscock, 2011:1066), likely explain these poor results. These data suggest only feather and hinge subsets can be reliably used to create the IM regression line.

Table 4. Linear regression results for subsets of flake termination type.

Variable	Feather (n = 59)	Step (n = 13)	Hinge (n = 27)	Outpasse (n = 6)
r	0.362	0.704	0.909	0.210
r ²	0.131	0.495	0.826	0.044
df	1	1	1	1
f	4.520	2.946	76.048	0.920
p	0.042	0.185	<0.001	0.790

The platform type subsets revealed improved r values for each subset except for flat platforms and significant correlations were found in each subset except for dihedral platforms (Table 5). The improved r values are not reliable for the faceted subset, due to the small sample size (Table 5). These data suggest IM only flaked and flat platforms subsets can be used to create the IM regression line.

Table 5. Linear regression results for subsets of platform type.

Variable	Flaked (n = 34)	Flat (n = 56)	Dihedral (n = 5)	Faceted (n = 4)
r	0.781	0.331	0.718	0.981
r ²	0.611	0.109	0.515	0.963

df	1	1	1	1
f	25.100	3.566	2.125	51.632
P	<0.001	0.069	0.282	0.019

3.2 The I/TMC

Now that appropriate subsets of the mass and platform area relationship have been identified by high r , r^2 and appropriate p values; IM can be estimated. Using scatter plots (Figures 4 to 11), the IM of retouched flakes in each subset is estimated by the regression lined and is compared with the TM. Retouched flakes are represented by grey diamonds and all other data are non-retouched flakes within each subset. It is worth noting that numerous cases within these subset regressions produce negative values in estimated initial mass.

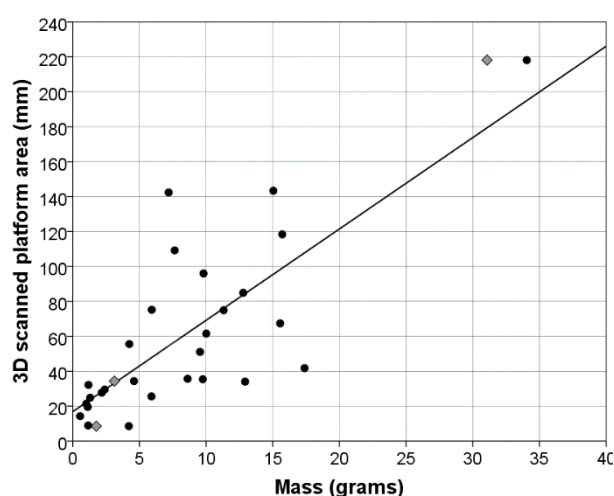


Figure 4. Subset regression of EPA below 70 degrees.

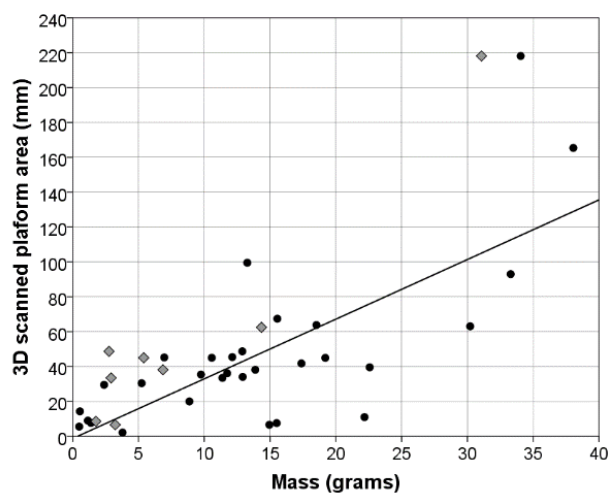


Figure 5. Subset regression of EPA above 70 degrees.

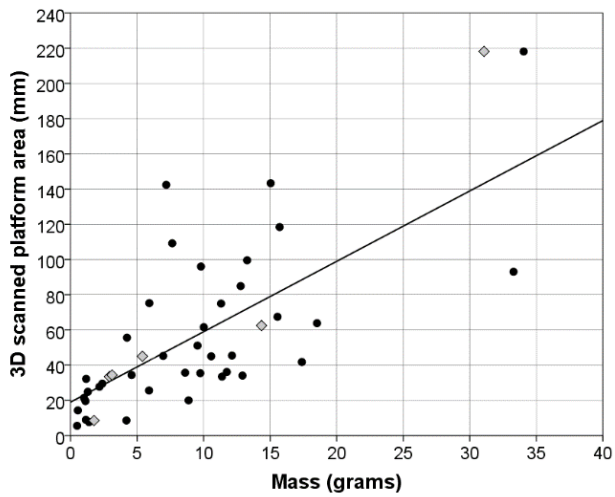


Figure 6. Subset regression of EPA below 80 degrees.

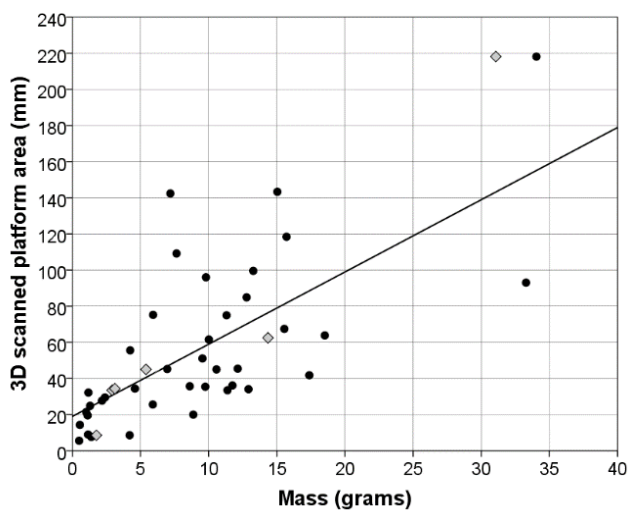


Figure 7. Subset regression of EPA above 80 degrees.

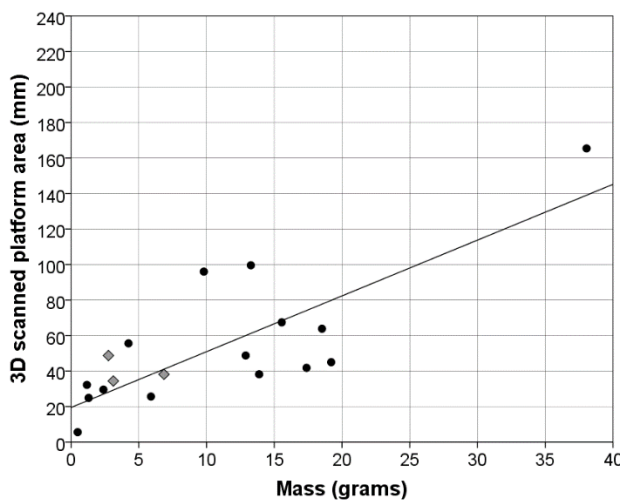


Figure 8. Subset regression of flaked platforms.

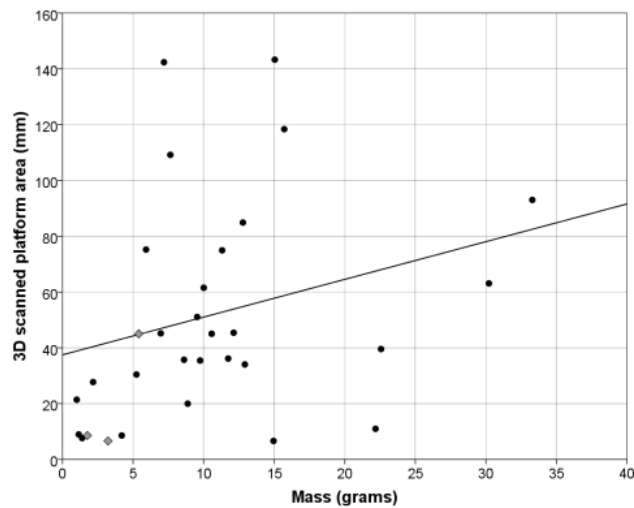


Figure 9. Subset regression of flat platforms.

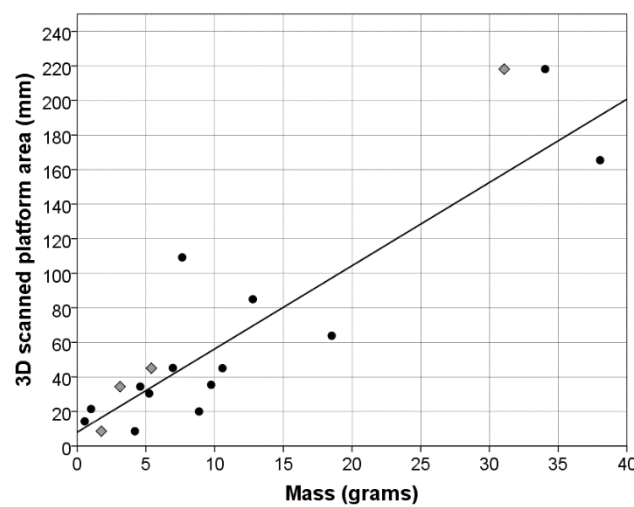


Figure 10. Subset regression of hinge terminations.

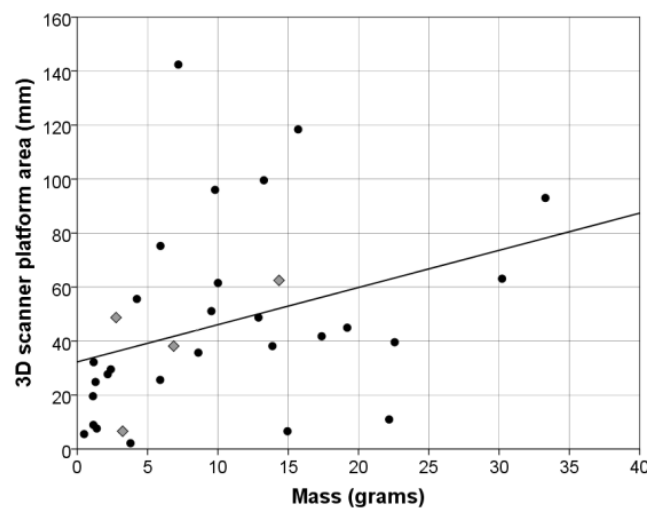


Figure 11. Subset regression of feather terminations.

4.2.1 External platform angle subset I/TMC

The various subsets of EPA all showed reasonable correlations between known IM and estimated IM (Table 6). The estimation of ML correlated with the known ML in EPA subsets below 70, above 70 and below 80 (Table 6). The correlations reflected in the

linear regression results include false estimations of ML. For example, using EPA subset above 70 degrees, six cases of estimated ML were negative values and most cases were simply out by ten grams or more (Figure 12).

Table 6. Linear regression results for EPA subsets, comparing known and estimated values of I/TMC.

EPA below 70 degrees	r	r ²	df	f	p
Known IM vs. estimated IM	0.472	0.233	1	4.022	0.065
Known ML vs. estimated ML	0.376	0.142	1	4.785	0.037
Known % ML vs. estimated % ML	0.19	0.000	1	0.005	0.947
EPA above 70 degrees	r	r ²	df	f	p
Known IM vs. estimated IM	0.608	0.369	1	8.778	0.010
Known ML vs. estimated ML	0.468	0.219	1	10.648	0.002
Known % ML vs. estimated % ML	0.283	0.080	1	3.210	0.081
EPA below 80 degrees	r	r ²	df	f	p
Known IM vs. estimated IM	0.576	0.331	1	12.393	0.002
Known ML vs. estimated ML	0.368	0.135	1	5.471	0.025
Known % ML vs. estimated % ML	0.302	0.091	1	2.506	0.126
EPA above 80 degrees	r	r ²	df	f	p
Known IM vs. estimated IM	0.788	0.621	1	9.847	0.020
Known ML vs. estimated ML	0.043	0.002	1	0.058	0.811
Known % ML vs. estimated % ML	0.467	0.218	1	1.671	0.244

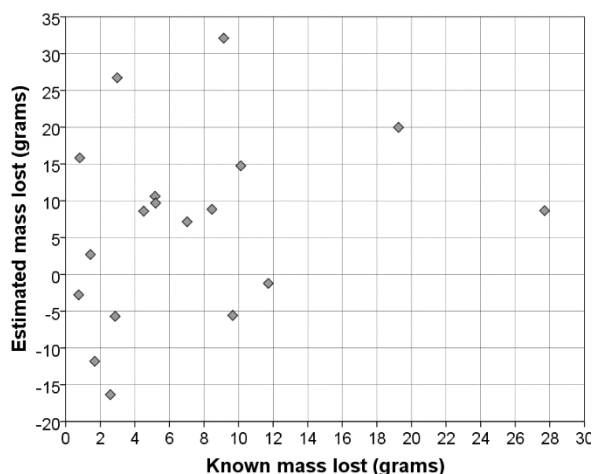


Figure 12. Poor correlation between known ML and estimated ML for the EPA sunset above 70 degrees. The positive relation reflected in the linear regression results are shown to include false estimations of ML.

4.2.2 Platform subset I/TMC

The flaked platform subset has a very strong correlation between estimated IM and the known IM (Table 7). The flat platform subset did not show any significant correlation with known values, which is in stark contrast to the findings of Muller and Clarkson (2015:36). The estimated ML did not show any significant correlations with the known ML in either platform subset (Table 7). Figure 13 illustrates this poor correlation between known ML and estimated ML for the flaked platform subset. Notably, if the three cases with the highest estimated ML values were excluded from this subset, the estimated ML

values would be in agreement. Unfortunately, there is no justification for exclusion, as EPA and flake terminations show no discernable patterning in these cases.

Table 7. Linear regression results for platform subsets, comparing known and estimated values of I/TMC.

Flaked platforms	r	r ²	df	f	P
Known IM vs. estimated IM	0.844	0.712	1	19.736	0.002
Known ML vs. estimated ML	0.247	0.061	1	0.518	0.492
Known % ML vs. estimated % ML	0.127	0.016	1	0.131	0.727
Flat platforms	r	r ²	df	f	p
Known IM vs. estimated IM	0.053	0.003	1	0.003	0.967
Known ML vs. estimated ML	0.446	0.199	1	0.248	0.706
Known % ML vs. estimated % ML	0.765	0.486	1	1.415	0.445

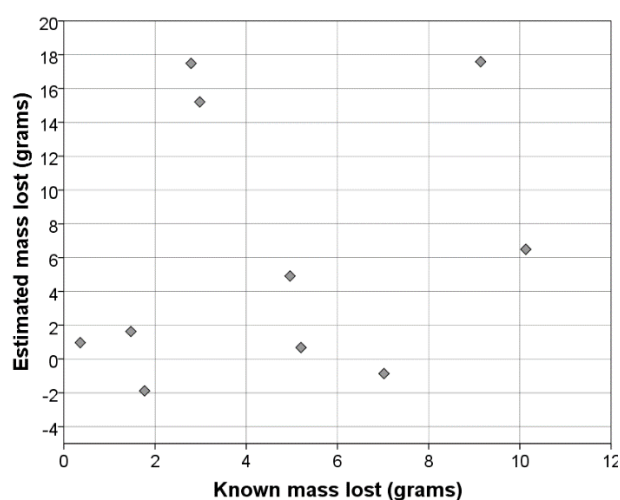


Figure 13. Correlation between known ML and estimated ML for flaked platform subset.

4.2.3 Flake termination subset I/TMC

The hinge termination subsets were the only flake termination subset to reveal significant correlations between estimated IM and known IM (Table 8). The estimated ML did not correlate with known ML in any flake termination subset (Table 8). For example, figure 14 illustrates the poor correlation between known ML and estimated ML in the feather termination subset, where three cases returned negative estimations of ML, the other cases from this subset were erroneous by at least 5 grams. Curiously, the hinge and feather termination subsets did produce a moderately strong and significant correlation between the estimated percentage of ML and the known percentage of ML.

Table 8. Linear regression results for flake termination subsets, comparing known and estimated values of I/TMC.

Feather terminating flakes (n = 59)	r	r ²	df	f	p
Known IM vs. estimated IM	0.594	0.352	1	1.088	0.406
Known ML vs. estimated ML	0.313	0.098	1	0.218	0.687
Known % ML vs. estimated % ML	0.975	0.951	1	38.874	0.025
Step terminating flakes (n = 13)	r	r ²	df	f	p
Known IM vs. estimated IM	0.694	0.482	1	2.788	0.194
Known ML vs. estimated ML	0.493	0.293	1	0.963	0.399
Known % ML vs. estimated % ML	0.806	0.650	1	5.561	0.100
Hinge terminating flakes (n = 27)	r	r ²	df	f	p
Known IM vs. estimated IM	0.877	0.769	1	26.664	0.001

Known ML vs. estimated ML	0.131	0.017	1	0.650	0.425
Known % ML vs. estimated % ML	0.651	0.425	1	4.895	0.041

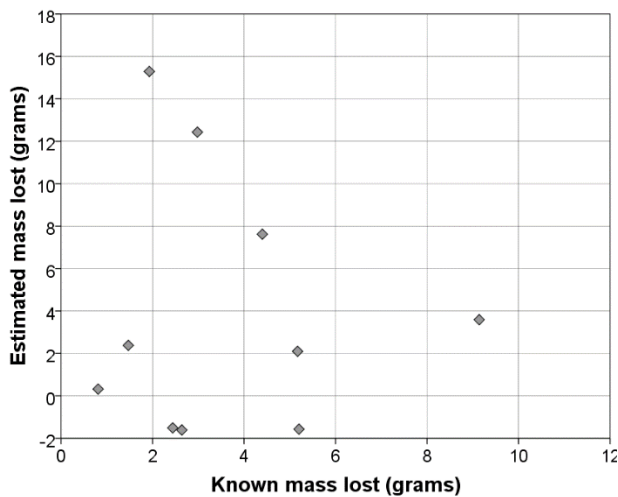


Figure 14. Correlation between known ML and estimated ML in the feather termination subset.

4.3 Examination of I/TMC

Examining those subsets that showed reasonable correlation with I/TMC, the estimated percentage of ML performed poorly against other reduction indices. No significant correlation between the estimated percentages of ML, using I/TMC method, was detected between retouch indices (Table 9). Notably, the EPA subset below 70 degrees was the closest to producing a significant correlation with the Index of Invasiveness.

Table 9. Linear regression results comparing estimated percentage of ML against other reduction indices. Blank cells indicate case values were too low to perform analysis.

Index of invasiveness vs. estimated % of mass lost I/TMC	r	r ²	df	f	p
EPA below 70 degrees	0.444	0.197	1	3.195	0.097
EPA above 70 degrees	0.147	0.022	1	0.322	0.573
Feather termination subset	0.088	0.008	1	0.16	0.912
Hinge termination subset	0.021	0.000	1	0.003	0.957
AGIUR vs. estimated % of mass lost I/TMC	r	r ²	df	f	P
EPA below 70 degrees	0.416	0.173	1	2.725	0.123
EPA above 70 degrees	0.235	0.055	1	0.526	0.487
Feather termination subset	-	-	-	-	-
Hinge termination subset	0.161	0.026	1	0.160	0.703
% of retouched perimeter vs. estimated % of mass lost I/TMC	r	r ²	df	f	p
EPA above 70 degrees	0.223	0.050	1	0.683	0.423
EPA above 70 degrees	0.046	0.002	1	0.031	0.862
Feather termination subset	0.650	0.422	1	1.462	0.350
Hinge termination subset	0.024	0.001	1	0.004	0.951

5. Discussion and Conclusion

This paper has demonstrated empirically that I/TMC (Clarkson and Hiscock, 2011) can reasonably estimate the IM of retouched flakes with intact platforms surfaces, however, is mostly unsuitable for the accurate estimation of ML from retouched flakes. The only I/TMC that showed reasonable correlation between estimated and known mass values

were EPA subsets above and below 70 degrees as well as below 80 degrees. Retouched flakes with EPA values above 70 degrees were the only subset where I/TMC showed close to a significant correlation between known and estimated values of percentage of mass lost ($r = 0.283$, $r^2 = 0.080$, $df = 1$, $f = 3.210$, $p = 0.081$). In this study, all other subsets, including the platform types which had the greatest sample sizes as subsets of the assemblage, did not reveal significant correlations with estimated and known ML values or the percentages calculated from these values. The EPA appears to be most promising pursuit of future I/TMC examinations.

The results do support the successful estimation of IM of retouched flakes with intact platform surface using 3D laser scanning, so why it is that ML could not be adequately determined? One possibility is that retouch was relatively diminutive. For example, more than half of the retouched artefacts examined here ($n = 24$) have AGIUR values less than 0.3 and Index of Invasiveness values less than 0.2. Therefore, perhaps variation in mass between modified and unmodified flakes may be so minute that the error in the estimation of initial mass may be greater than the difference (Braun *et al.*, 2008:1055). This may explain the estimation of negative values of estimated IM, which prevents logical estimation of ML. The findings of Muller and Clarkson (2015) suggest that I/TMC is very likely to be more suitable for blade assemblages as a specific sample, rather than a more diverse retouched flake assemblage such as that examined in this study. It is apparent from this study and other works (Clarkson and Hiscock, 2011; Muller and Clarkson, 2015) that I/TMC is promising in that the initial mass of unretouched flakes can be very accurately modelled using 3D laser scanning, however the leap towards comparing this value with that of discarded retouched flakes required further experimentation.

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**Elliptical Fourier Analyses Unravels a Palimpsest of Point Technology.
Poster given at the society for American Archaeology annual conference
in 2014.**

Tim Maloney and Ben Marwick

¹Department of Archaeology and Natural History, College of Asia and the Pacific, The Australian National University, ACT 0200, Australia.

²Department of Anthropology, University of Washington , Seattle WA, USA

Introduction

The Kimberley region of north Western Australia is famous for the Aboriginal peoples 'Kimberley Point' technology (see figure 1). These highly specialised bifacial points were first produced within the last 1,000 years (Maloney et al. 2014), and manufacture was spatially restricted to the Kimberley region. Direct percussion unifacial and bifacial points however, are known to occur at least as early as 5,200 cal BP, and continued to be manufactured throughout the later development of pressure flaked points. This technological history has created a palimpsest of point technologies throughout the Kimberley region that we seek to unravel using novel morphometric techniques. The application of Elliptical Fourier Analysis (EFA) to five surface assemblages demonstrates the value of this methodology for morphometric studies of Palaeolithic technology.

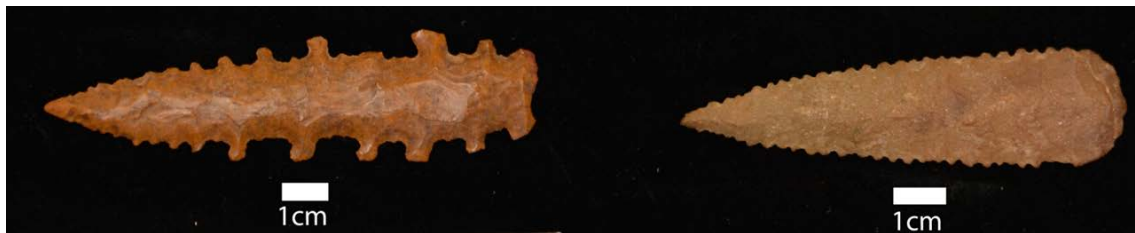


Figure 1. A) Dentate Kimberley Point made on chert, collected in 1923 in the southern Kimberley. B) Kimberley Point made on quartzite from the southern Kimberley.

The manufacture of pressure flaked points has been widely observed ethnographically throughout the Kimberley (see Akerman et al. 2002:18-19). These observations, augmented with experimental reproduction, reveal a staged production process, where the pressure flaked point is a specialised end product (Akerman and Bindon 1995; Akerman et al. 2002:30; Moore 2000). Blanks were selected from flakes, cores, and tabular pieces that lack any conchoidal surface (see Akerman et al. 2002:19; Moore 2000:7). Blanks were initially retouched with direct percussion to create an ovate shaped 'bifacial preform' (after Akerman and Bindon 1995:94) (Figure 2 A). Pressure flaking, with a range of indenters including hard wood, bone, and metal (post-contact), were then used to further thin (relative to thickness) the Biface (Akerman et al. 2002:19; Love 1936:93-95). Additional fine pressure flaking produced serrate, denticulate, and dentate projections along the margins (Akerman and Bindon 1995).



Figure 2. A) Bifacial preform or Biface made on quartzite from ME3 surface assemblage. B) Unifacial direct percussion point made on quartzite flake or blade.

Direct percussion points were made on a range of flakes, including those that resemble blades, and so are technically retouched flakes. Unlike pressure flaked points, these point technologies were discarded with varied levels of marginal, invasive, bifacial, and unifacial retouch. It is the latter retouch that was probably the modal discard stage of direct percussion points retouch intensity in these samples (Figure 2 B). These points lack both the bifacial preform stage and fine pressure flaking to the margins.

Samples

To assess the morphological differences between pressure flaked and direct percussion point technology, 169 lithic artefacts from five surface assemblages were analysed. Site locations are shown in figure 3, and technological classes are listed in table 1.

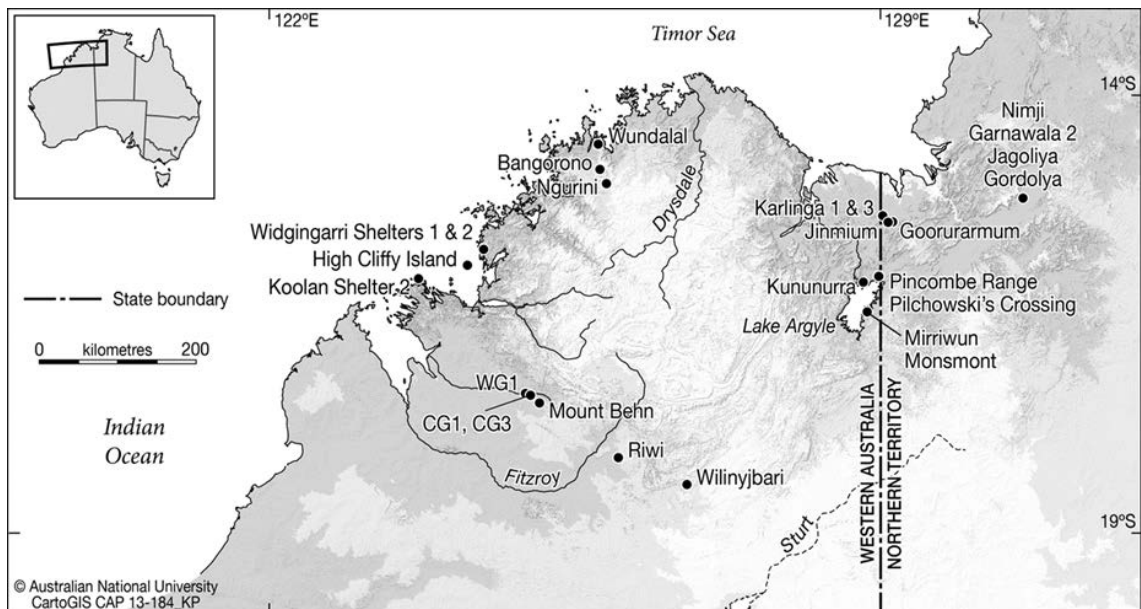


Figure 3. Map of the Kimberley region in north Western Australia, showing locality of sites.

Table 1. Technological class frequencies from each site.

Sample	Flakes	Retouched Flakes	Direct Percussion Points	Pressure Flakes Points	Bifaces	Tabular Piece	Total
ME3	16		13		5	2	36
LR9	47	4	21	1			73
LR12	20		8		1		29
MTB2	13	1	1		2		17
Ethnographic Collections			1	13			14
Total	96	5	44	14	8	2	169

Method

Artefact images were captured using a Next Engine 3D laser scanner. Data points were scanned in high resolution ($\pm 0.127\text{mm}$), and data edited using HD pro software. Each artefact is orientated with the same horizontal plane. The distal portion faces right, proximal portion faces left and ventral and dorsal surfaces orientated posterior to anterior. A screen shot of this image was exported to the program GIMP, to create a solid 2D black and white 'silhouette' image. These files are then exported as jpg files to be analysed in the program R. These stages of image manipulation are presented in figure 4.



Figure 4. Dorsal surface of unifacial direct percussion point, showing stages of image analysis, prior to importing files into R. A) Photograph of quartzite unifacial point. B) Screen shot of unifacial point, from the Next Engine HD pro software. C) Black and White silhouette image produced in GIMP.

Elliptical Fourier Analysis

EFA is a mathematical technique used to quantify the outline and variation of complex shapes such as stone artefacts (Gero and Mazzullo 1984; Sholts et al 2012; Iovita 2010). It is distinctive because unlike other shape analysis methods, no landmarks are required (Claude 2008). As many of the artefacts in the analysed sample have either lost the platform surface through retouch, or were made on blanks that never had such landmarks; EFA provides a powerful quantification of morphology not obtainable with traditional linear measurement, such as percussion length. For each artefact we used the Momocs package for R (Bonhomme et al. 2014) to compute four coefficients for 30 harmonics (determined by harmonic power analysis) to define an ellipse containing the artefact's shape information.

Principal Components Analysis

To analyse the harmonic coefficients we computed a Principle Components Analysis [PCA]. The results of the PCA allow us to assess the major modes of shape variation in the sample, and establish a low-dimensional space to investigate patterns of shape similarity and difference.

Results

The EFA analysis completed on the five surface assemblages revealed changes in artefact shape relative to retouch intensity. For example, the ME3 and LR9 assemblages indicated that all point technologies progressed from wide to thin morphologies, relative to length, and then further differentiated via the application of retouch, by either contracting or parallel margins. Variation in artefact size as gauged by length, marginal angle and mass (grams) did not have significant effects on shape variation.

This shape transformation is strongly correlated with reduction intensity in the ME3 assemblages, as indicated by the significant correlation of GIUR with PC1 ($r = 0.73$, $t = 2.84$, $df = 7$, $p\text{-value} = 0.025$). In particular retouch tends to make artefacts thinner rather than more triangular and more pointed. Points made on larger bifaces were more likely to have long thin shapes with parallel margins and the points made on flakes were more likely to have contracting margins. These trends are illustrated in figure 5, which shows how the plots produced by this methodology visualize reduction pathways. These data are from ME3.

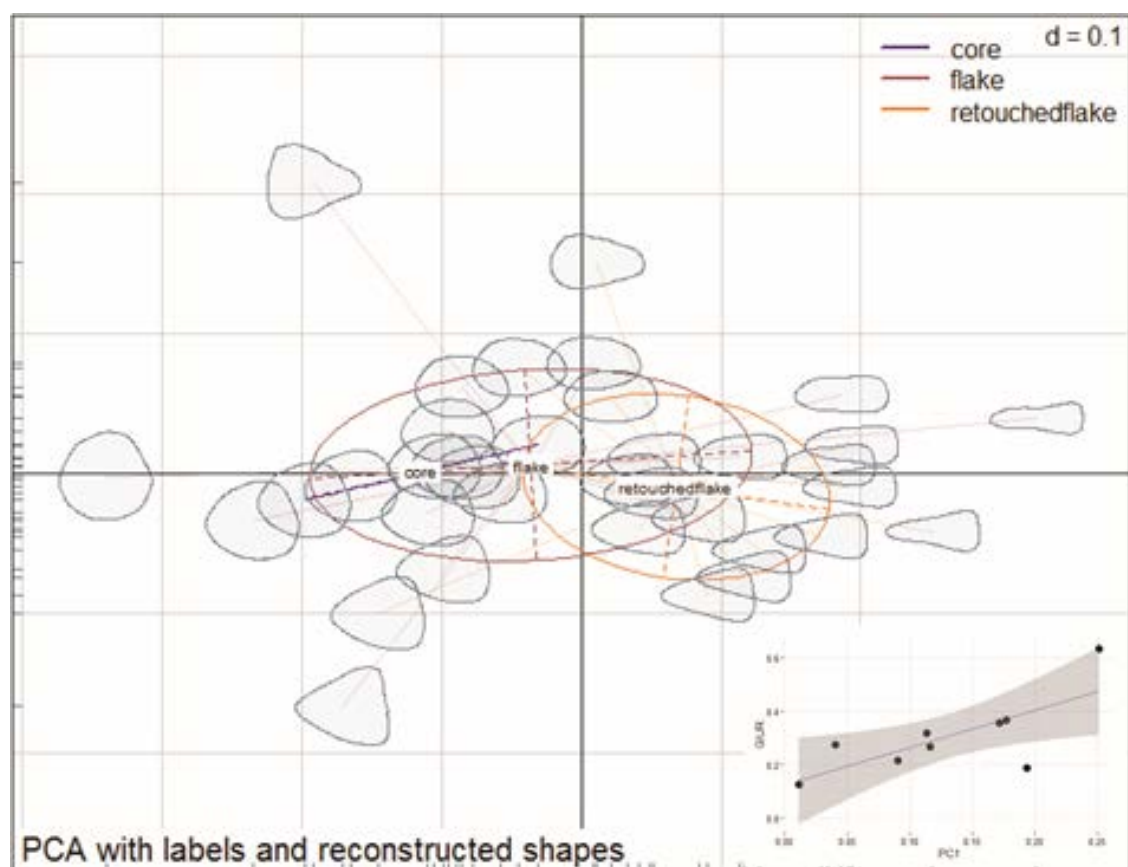


Figure 5. PCA biplot of artefacts from ME3. The first two components contain 81.5% of variation. There is a clear trend for unretouched flakes to be more rounded, and retouched flakes to be narrower with more parallel sides. Inset shows biplot of GIUR

of retouched pieces and the first principal component, which captures elongation and round to triangular shape changes.

The Kimberley points made on large bifaces or cores appear to have a distinctly more elongate shape with parallel margins. Direct percussion points or retouched flakes, were more likely to have contracting margins and were not made from larger Bifaces, but smaller flakes or 'blades'. This variation in shape is illustrated in figure 6 using the assemblage sample from LR9.

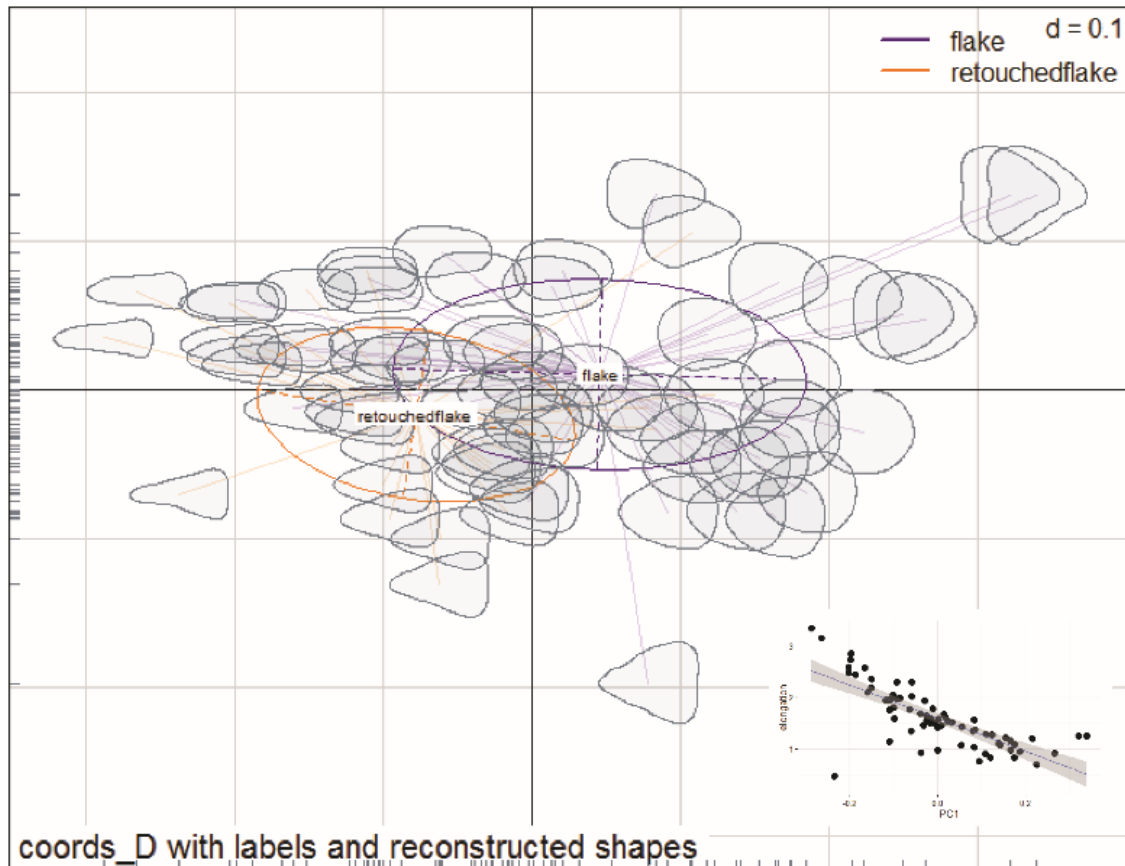


Figure 6. PCA biplot of artefacts from LR9 showing similar shape trajectory to ME3. The first two components contain 71.1% of variation. Inset shows biplot of elongation and PC1 ($r = -0.4$, $p = 0.001$).

The sample of complete Kimberley points from ethnographic collections, indicated shape variation mostly derives from elongation on the horizontal axis and the smoothness of the outline on the vertical axis (i.e. denticulate or serrate features). However, no significant correlations were detected. This trend is illustrated in figure 7.

Conclusion and Discussion

Code and data for this poster are online at:

Acknowledgements

Maloney 2015

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Analysed assemblages not included in morphometric and reduction sequence analyses of published manuscripts.

This appendix lists the sites and assemblages analysed from museum collections, as well as my own surface collections that were not included in the published manuscripts. These data include 3116 lithic artefacts, 239 direct percussion points, and 75 pressure flaked bifaces. All except the Pincombe Range assemblage were subject to morphometric analyses, and all complete flakes, retouched flakes, bifaces, axes, and cores were recorded with 3D laser scanning. The following lists the technological classes of these artefacts from each site, accompanying site plans where available, and provenance data previously unpublished.

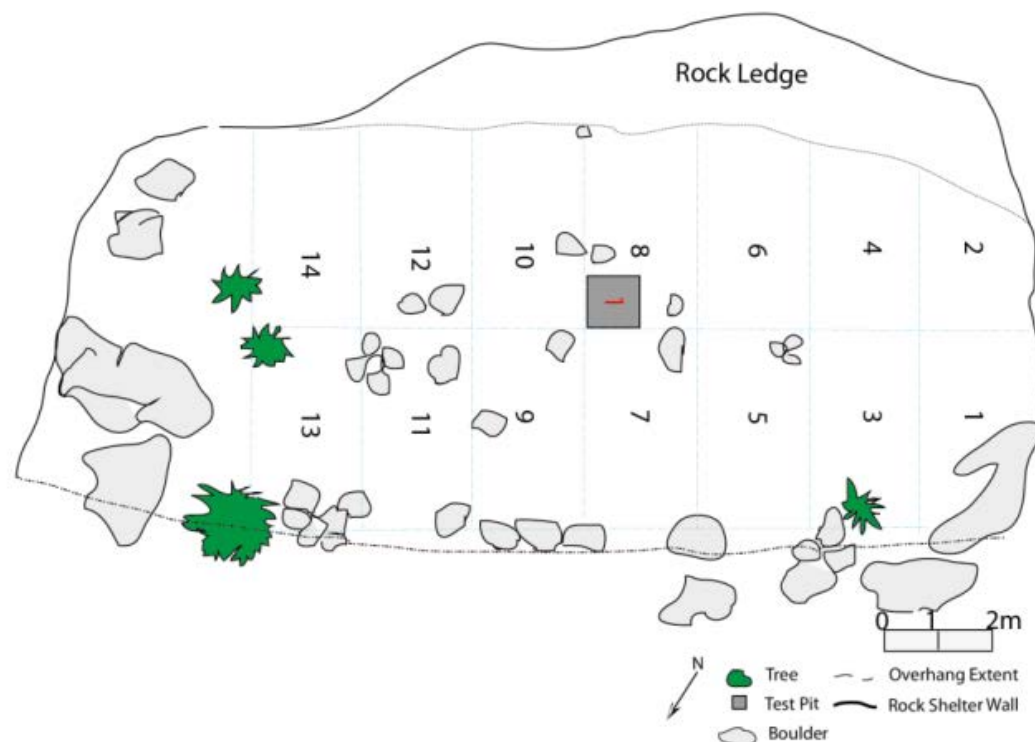
Lennard River 12

The Lennard River 12 [LR12] site was the furthest west along the Napier range of the sampled sites. The site is a large limestone rock shelter (Blundell 1975:232-236). The analysed sample included all recovered artefacts from a single 1 x 1 m excavation as well as all retouched flakes from the surface of the shelter; an area of approximately 110 square meters. The frequencies of analysed artefacts from the site and their collection context is listed in Table 1. Figure 1 illustrates the dimensions of the shelter and the location of the excavation and surface squares.

Table 1. Technological classes recorded from LR12 excavation

EU	Lithic Artefacts	Technological classes	Points Total	(Bifacial Points)	(Unifacial points)	(Kimberley Point)	(Dentate Kimberley Point)	(Backed points)	Blades	Retouched Flakes	Bipolar Flakes	Flakes	Cores	Pot lid	Hammer stones	Manuport	Burrenate	Biface	Flaked piece
General Surface	131																		
Surface Square 15	133		65	37	27			1	34	7		15	2		3		1	6	
1	224	10	11	5	3	1	1		14	21		121	2	1	1			3	50
2	185	8	6	3	2		1		5	15	4	115	1		3				36
3	99	8	6	2	4				5	9	2	60				2		1	14
4	18	2										14							4
5	44	5	1		1						1	30				1			11
Total	703	13	89	47	37	1	2	1	58	52	7	355	5	1	7	3	1	10	115

Figure 1. Site map of LR12 showing surface square and test pit locations modified from Blundell (1975)



Lennard River 9

The Lennard River 9 [LR9] site is a large limestone rock shelter in the Napier Range. Blundell's (1975:218–221) original collection included over 10,000 lithic artefacts from three excavations, as well as 14, 2 x 2 m surface squares. Figure 2 illustrates the dimensions of the shelter, relative to excavation and surface squares. The analysed sample included all of the material from test pit 1, a 1 x 1 m excavation which reached a depth of 80 to 100 cm below the surface (Blundell 1975:225, Fig. 50). This sample included 1,151 lithic artefacts. The upper two units of the second pit were also analysed and included a sample of 89 lithic artefacts. From the surface collection, the total sample of artefacts from one of the 14 2 x 2 m surface squares was analysed. All complete retouched artefacts from the remaining surface squares were analysed. Technological classes in the analysed samples from LR9 are listed in Tables 2, 3, and 4.

Figure 2. Site map of LR9 showing surface square and test pit locations modified from Blundell (1975)

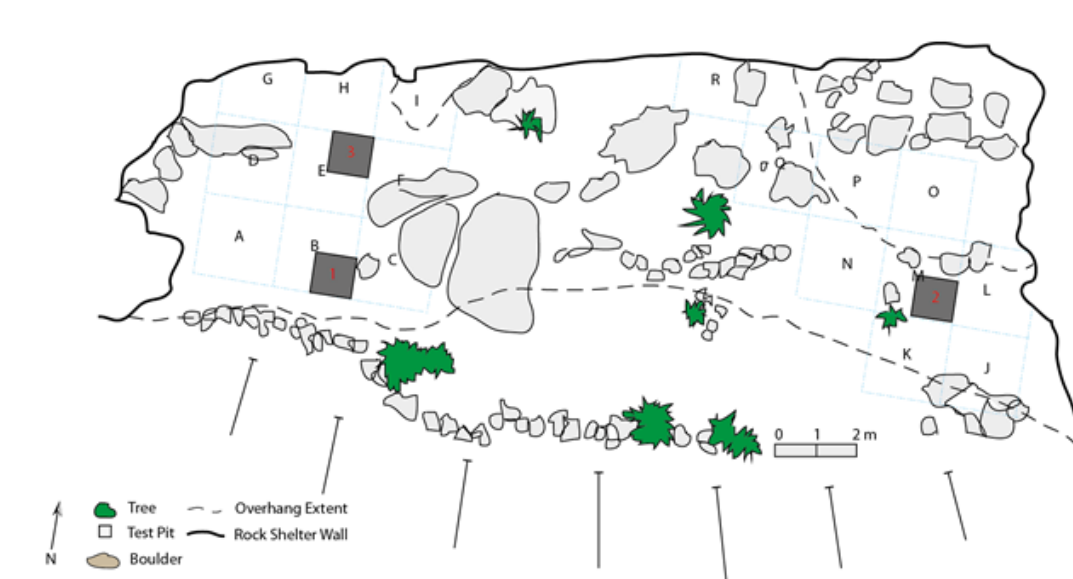


Table 2. Technological classes from Test pit 1 sample

EU	Lithic Artefacts	Points Total	(Bifacial Points)	(Unifacial points)	(Kimberley Point)	(Dentate Kimberley Point)	Backed points	Blades	Retouched Flakes	Flakes	Cores	Pot lid/Heat Shatter	Burinate	Edge ground Flake	Flaked piece
0	4	1				1				2				1	4
1	635	7	2	4	1			4	16	32	4			2	23
2	424	6		5			1	7	10	108		1		1	51
3	69	7		7				1	2	44			1		19
4	13	1		1					2	7					3
5	6	0								3					
Total	1151	22	2	17	1	1	1	13	30	194	4	1	1	3	96

Table 3. Technological classes from test pit 2 sample

EU	Lithic Artefacts	Points Total	(Bifacial Points)	(Unifacial points)	Blades	Retouched Flakes	Flakes	Pot lid/Heat Shatter	Flaked piece
1	60	1		1	1	6	35	2	15
2	33	7	2	5	2	1	18		5
Total	93	8	2	6	3	7	53	2	17

Table 4. Technological classes of surface collection samples

Surface Square	Frequency	Points Total	(Bifacial Points)	(Unifacial points)	(Backed points)	(Broken Points)	Retouched Flakes	Flakes	Bipolar Flakes	Cores	Burinate	Edge ground Flake	Flaked piece
A	122												
B	7												
C	3												
D	22												
E	8												
F	10												
H	1												
I	1												
J	1												
K	10												
L	2												
M	9												
N	13												
O	4												
P	17												
Q	3												
R	7												
S	1												
Total	276	44	19	25	3	30	12	96	2	10	1	8	32

Lennard River 4

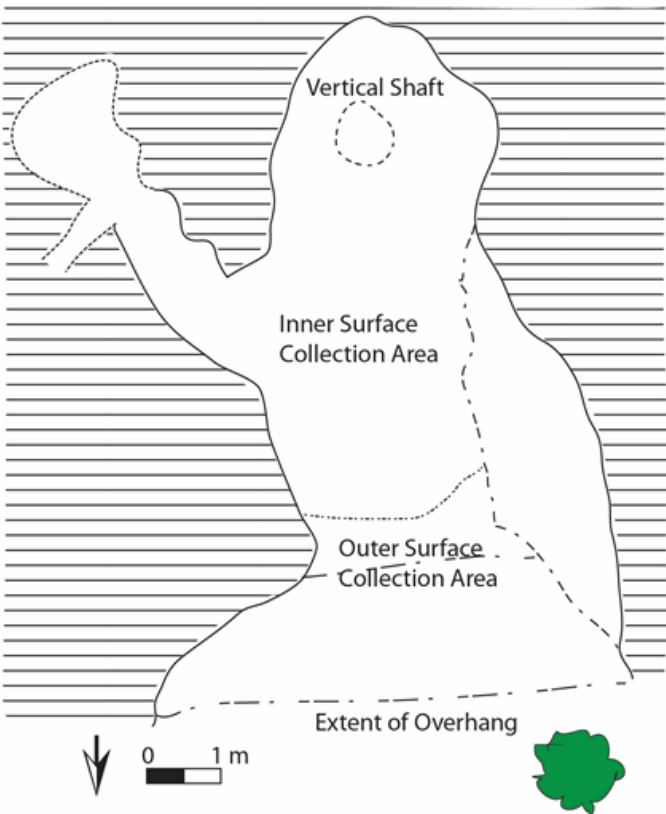
The Lennard River 4 [LR4] site is a limestone rock shelter with a deep cave at its rear. The site is immediately adjacent to Burralumna Spring (Blundell 1975:213). The site is

naturally divided into an inner and outer shelter by a limestone shelf (Figure 3), which Blundell used to demarcate the two surface collection areas. No excavation was conducted at this site. Blundell’s (1975:213) collection methodology attempted to recover all lithic artefacts on the surface, and screened a thin layer of sediment across the entire shelter (1975:213). The original collection recovered 146 lithic artefacts. The analysed sample recorded only point and biface morphologies, which amounted to 15 artefacts. Table 5 lists the frequency of technological classes from this site.

Table 5. Technological classes in the analysed sample from LR4

Points Total	(Bifacial Points)	(Kimberley Point)	(Broken Points)	Adze Tula	Biface
15	6	2	4	1	2

Figure 3. Lennard River 3 site map showing surface collection squares modified from Blundell 1975:211)



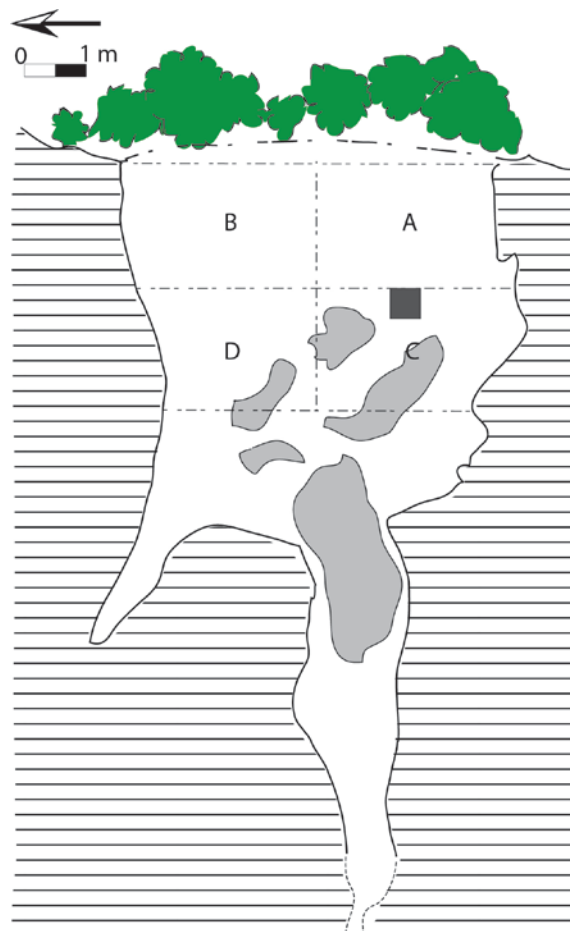
Lennard River 3

The Lennard River 3 site [LR3] is a small limestone shelter in the Napier Range. Figure 8 illustrates the dimensions of the shelter, and the surface collection areas. Blundell (1975:212) made a complete surface collection from the cave floor, which was arbitrarily divided into four squares. No excavation was conducted at this site. This original collection included 147 lithic artefacts from the surface. The analysed sample included all of the complete retouched flakes from surface squares A, B and C, which amounted to 29 artefacts. Technological classes are listed in Table 6.

Table 6. Technological classes from LR 3 analysed sample

Points Total	(Bifacial Points)	(Unifacial Point)	(Dentate Kimberley Point)	Adze Tula	Retouched Flake	Edge Ground Axe	Edge Ground Adze	Burinate	Biface
16	5	10	1	1	2	6	1	1	2

Figure 8. Lennard River 4 site map showing surface collection areas modified from Blundell 1975:214)



Mount Behn Surface Collections

A series of 1 meter square surface collections were taken from the dense scatters approaching the Mt Behn rock shelter. Figure 9 illustrates the location of these squares relative to the overall surface density and proximity to rock shelters. Three surface collections were taken over this area, labelled Mount Behn surface 1, 1b, and 4; each with several 1 meter square surface units. Tables 7, 8, and 9 list the technological classes observed in these collections.

Figure 9. Surface collections at Mt Behn

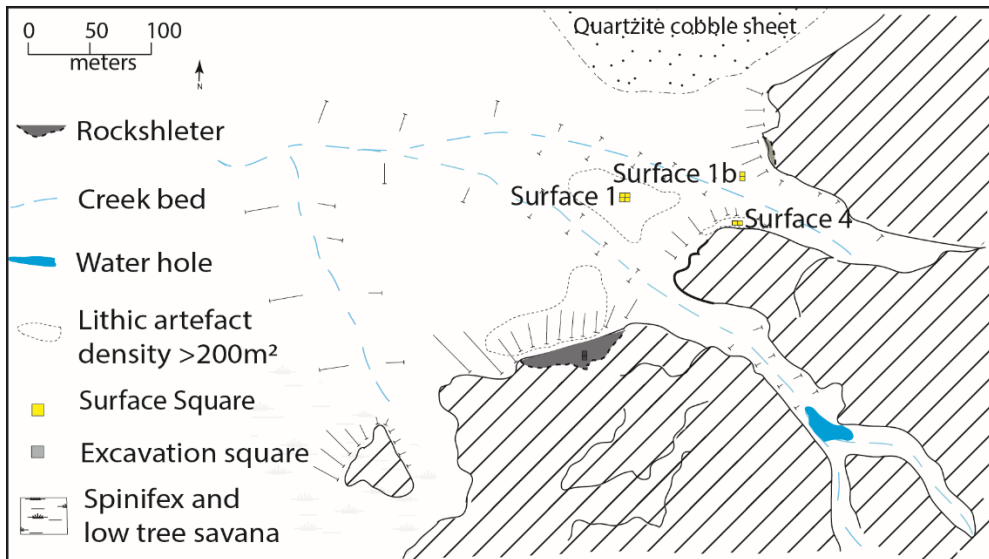


Table 7. Mt Behn surface area 1b

Square	Frequency	Points Total	(Bifacial Points)	(Unifacial points)	(Kimberley Point)	Retouched Flakes	Biface	Flakes	Broken Flakes	Cores	Edge Ground Adze	Flaked piece
1	50	3	1	1	1	4	1	18	4	4	1	15
2	21	1		1				6	4	1		9

Table 8. Mt Behn surface area 1

Square	Frequency	Retouched Flakes	Broken Retouched Flake	Biface	Flakes	Broken Flakes	Cores	Burinate	Edge ground Flake	Flaked piece
1	21				6	8	2	1	1	3
2	38	2	1	1	17	7	2		1	7
3	13				2	6				5
4	26	6	2		13	1	1		1	2

Table 9. Mt Behn surface area 4

Square	Frequency	Retouched Flakes	Broken Retouched Flake	Biface	Flakes	Broken Flakes	Cores	Edge ground Flake	Flaked piece
1	67	13	2	1	35	2	10	2	2

McSherry's Gap Surface Collections

Several surface scatters around the McSherry Gap area were also collected, each described Fairfield 2, and Fairfield Bluff 2 and 3. Tables 10, 11, and 12 list the technological classes observed in these collections.

Table 10. Frequency of artefacts in the Fairfield 2 surface collection

Square	Frequency	Retouched Flakes	Broken Retouched Flake	Biface	Flakes	Broken Flakes	Cores	Edge Ground Adze
1	31	6		1	18		6	
2	8	1			4	2	1	
3	3	2			1			
4		2			1		1	1
5	11	3	1		5		2	

Table 11. Frequency of artefacts in the Fairfield Bluff 3 surface collection

Square	Frequency	Points Total	(Unifacial points)	(Broken Points)	Retouched Flakes	Broken Retouched Flake	Flakes	Broken Flakes	Cores	Edge Ground Adze	Flaked piece
1	29	4	3	1	1	2	4	4	3	1	5

Table 12. Frequency of artefacts in the Fairfield Bluff 4 surface collection

Square	Frequency	Points Total	(Kimberley Point)	Broken Retouched Flake	Tabular Pieces	Flakes	Bipolar Flakes	Cores	Flaked piece
1	92	1	1	1	24	37	9	1	16

Prince Regent River 1

PR 1 is an open site collection conducted by Blundell (1975). The assemblage includes 42 complete and broken points, with a dominance of bifacial glass points ($n = 39$). Very few unifacial points and blades were present. Table 13 summarises the frequencies of technological classes, while Table 14 summarises raw materials.

Table 13. Technological classes from Prince Regent River 1

Bifacial Point	Unifacial Point	Broken Bifacial Point	Broken Kimberley Point	Broken Kimberley Dentate Point	Leilira Blade	Total
19	2	16	3	1	1	42

Table 14. Raw material frequency of Prince regent River 1 artefacts

Volcanic	Ceramic	Chert	Glass	Hornfels	Quartz	Quartzite
1	7	10	18	3	2	1

Ethnographic Collections of Kimberley Points and Edge Ground Axes

A sample of the ethnographic collection of Kimberley Points curated at the Western Australian Museum was also analysed. This sample includes 49 complete pressure flaked bifaces which were collected between 1887 and the early 1990's. Table 15 lists these points, their collector, and available providence data. This ethnographic collection also included 20 edge ground axes, from similar ethnographic contexts. None of these axes were hafted. Table 16 lists the edge ground axes, their collectors, and providence data.

Table 15. List of ethnographic collection of complete Kimberley Points analysed

Collector	Kimberley Point Frequency	Region	Date
A.H. Green	4	Fitzroy Valley/Fitzroy Area	1936/1941/1947
Kim Akerman	3	Turkey Creek/Old Cheribun Station	Post 1970
Kim Akerman	5	unknown	1970's
Butler	3	Tunnel Creek	1965
D. Odgers	1		1966
D. Merrilees	2	Windjana Gorge	October 1964
E. Mitchell	9	King Leopold Range	April 1932
H. Fuhrmann	1	Wolf Creek Junction	
G.H. Bostock	3	Napier Range	1887
Govt. Geologist	1	King Leopold Range	December 1922
G.W. Kendrick	1	Go Go station	1967
J. Lanagan	1	Fitzroy River Myroodah Station	November 1923
John Long	1	Laidlaw Range	1992
Miss H. Richardson	1	Mount Hart	1911
Mr E.C. Mitchel	1	King Leopold Ranges	1913/1930
Mrs Cavalli	4		
N. Hayes	3	Leopold Range	1902
P. Smith	2	Wyndham	1959
Randolph	1	Mount House Homestead	
T. Davis	3		
Unknown	1	Isdell Range	
Unknown	1		1896
Unknown	1		1911
Unknown	8		

Table 16. List of ethnographic collection of edge ground axes analysed

Collector	Edge Ground Axe/Adze Frequency	Region	Date
Kim Akerman	5	Pillara springs 18 21 125 47 - Akerman and Bindon BHP prospect	1981
B. Yarrick	1	Tunnel Creek	7 th December 1961
Butler	1	Tunnel Creek	June 1965

Ian Crawford	3	Fossil Downs 'painted rock peripheral collection' and Go Go Station 'Mt Pierre, burial Cave'	15 th - 16 th October 1961
Dougless and G.W. Kendrick	1	Tunnel Creek 'found among rocks NE end of the Tunnel near pigeons cave'	2 nd - 5th July 1966
E. Kolig	2	Fitzroy area	?
W. Dix	6	Napier Downs Lennard River	August 1970
A.E. West	1	King Leopold Ranges	14th May 1900

Pincombe Range

The excavation of the Pincombe Range site reported by Dortch (1977:109-110), was also examined to determine if radiocarbon dates could be reliably associated with points. These data are mentioned in Maloney et al. (2014). Morphometric data was not recorded on these points, instead, illustrations were taken to determine temporal trends represented in this excavation.

Experimental assemblage by Kim Akerman

An experimental assemblage produced by Kim Akerman was also analysed. A high quality block of silcrete was reduced to produce several blades, and a single Kimberley Point. Table 17 lists the technological classes analysed in this assemblage.

Table 17. Experimental assemblage knapped by Kim Akerman

Core	Flake	Broken flake	Blade	Flaked Piece	Kimberley Point
4	24	1	3	2	1