# AN EXPLORATION OF USE-WEAR ANALYSIS ON ACHEULEAN LARGE CUTTING TOOLS: THE CAVE OF HEARTHS' BED 3 ASSEMBLAGE

Timothy Stephen Lambert-Law de Lauriston

A dissertation submitted to the Faculty of Science, University of the Witwatersrand, in fulfilment of the requirements for the degree of Masters of Science in Archaeology.

Johannesburg, 2015

## Declaration

I declare that this Dissertation is my own, unaided work. It is being submitted for the Degree of Masters of Science in Archaeology at the University of the Witwatersrand, Johannesburg. It has not been submitted before for any degree or examination at any other University.

*T. S. Lambert-Law de Lauriston*

Timothy Stephen Lambert-Law de Lauriston

This 25th Day of May, 2015 Johannesburg

# Abstract

Large cutting tools (LCTs) are a stone tool techno-group that appeared *ca.* 1.76 Ma in Africa and marked the beginning of the Acheulean. The group is conventionally comprised of three tool types called handaxes, cleavers, and picks. The function of LCTs has only been determined through assumptions (e.g., names based on historical antecedents or assigning functional names to morpho-types) or through experimental tasks designed to determine if a particular tool type was efficient for a given task, (e.g., are handaxes conducive to butchery tasks?). To date, no extensive use-wear analysis has been carried out on African Acheulean LCTs. This is the pioneering study. Utilising a multi-stranded approach comprised of experimental archaeology, blind testing and low- power use-wear analysis the functions of a sample of LCTs from The Cave of Hearths were derived.

The Cave of Hearths (CoH) lies in the Makapan Valley in the Limpopo Province of South Africa. Excavations were carried out from 1947 to 1954, and it is these excavations from which this study draws its sample. Thirty-eight handaxes and cleavers from the CoH Bed 3 Acheulean (*ca.* 0.5 Ma) were submitted to a low-power use-wear analysis. The results showed that a full range of tasks was performed on site including: wood- working, animal and vegetal matter processing, accompanied by digging and a number of other tasks. Corroborated by faunal analysis and an environmental reconstruction, the results suggest that the cave acted as a home camp/ residential base to the hominins that inhabited the area during the Acheulean. Additionally, evidence was found which may indicate that two of the tools were possibly hafted. If this finding is corroborated by future studies it would push back by approximately 150 Ka the earliest date previously published for hafting with Mode 3 tools.

## Dedication

For my parents...who always encouraged and taught me to follow my bliss and pursue my passion.

For my Pa-Paw and the late Mr. Richard Daye…for helping me realise that my bliss *is* my passion for archaeology.

# Acknowledgements

As with any work of this magnitude, much of it would not been possible without the guidance and support of a great number of people. Firstly, I owe special thanks to my supervisor Prof. Kathleen Kuman for encouraging me to stay the course no matter the circumstances.

I thank the students and staff in the Archaeology division, the School of Geography, Archaeology and Environmental Studies, and the Faculty of Science. Of note: Nicci Sherwood for all the time and effort she put into designing, arranginging and administering blind tests; Drs. Alex Schoeman, Christine Sievers and Profs. Karim Sadr and Tom Huffman for their always open doors and willingness to answer my questions. Prof. Stefan Grab, Prof. Fehti Ahmed, Donna Koch, Andre Frank, Thandiswe Nsimbi, Barbie Pickering, Ena Mafora, Gita Patel, and Simphiwe Goba each should be thanked for their individual contributions, albeit in vastly different ways, to my success.

Special thanks goes to Prof. Amanda Esterhuysen, Dr. Patrick Randolph-Quinney, and Dr. Anthony “Steam” Sinclair for their many meetings and discussions they had with me. I would have been lost on many occasions had it not been for their specialist knowledge on all things regarding the Makapan Vally and particularly Cave of Hearths.

To Bronwyn Quinn and Tandi Scott-Turner for the many cigarette breaks, which in most cases led to a deep sense of relief about whatever it was I was working on at the time, after a good conversation of course.

A debt of graditude is owed to the National Research Foundation of South Africa (NRF) for providing financial assistance without which this research would not have been possible.

I also wish to express my deepest appreciation to Profs. †George Odell, Garrick Bailey, and Jane Ackerman, who I consider mentors in life and in academia. They continually encourage me to pursue my studies. Without their inspiring words I may have given up a long time ago. You all still inspire me and your words will always be with me.

Lastly, and most importantly, to Mac. You have, through the years, endured more than any individual should ever have to put up with in a single lifetime (or several for that matter). You have always had my back, even if to your detriment, and encouraged me to be a better person and inspired me to do great things. You are and always will be my best friend, soul mate and twin flame. You are truly the kindest, noblest, and most selfless person I have ever had the honour and privilege of knowing. If I can be but half the man you are, then I will have accomplished something truly great in my life.

# Table of Contents


| | | Page |
|---|---|---|
| **DECLARATION** | | ii |
| **ABSTRACT** | | iii |
| **DEDICATION** | | iv |
| **ACKNOWLEDGEMENTS** | | v |
| **TABLE OF CONTENTS** | | vi |
| **LIST OF FIGURES** | | ix |
| **LIST OF TABLES** | | xii |
| **LIST OF ACRONYMS** | | xiii |
| **Chapter 1: Introduction and Thesis Structure** | | |
| 1.1 | Introduction and Thesis Structure | 1 |
| 1.2 | Rationale | 2 |
| 1.3 | Method, Techniques and Approach | 2 |
| 1.4 | Thesis Structure | 3 |
| **Chapter 2: Introduction to the Acheulean** | | |
| 2.1 | Introduction to the Acheulean Industrial Complex | 5 |
| 2.2 | The Acheulean in Africa and South Africa | 7 |
| 2.2.1 | The Acheulean in Africa | 7 |
| 2.2.2 | The Acheulean in South Africa | 10 |
| 2.3 | Chapter Conclusion | 12 |
| **Chapter 3: The Cave of Hearths (CoH)** | | |
| 3.1 | Introduction | 13 |
| 3.2 | Geology and Geophysical Setting of CoH | 13 |
| 3.3 | Speleogenesis and Infilling of the CoH-HC Complex | 17 |
| 3.3.1 | Speleogenesis | 17 |
| 3.3.2 | Sedimentary Infilling of the CoH-HC Complex | 18 |
| 3.4 | History of Discovery and Early Excavations | 21 |
| 3.4.1 | Post-war Excavations “Phase One” | 23 |
| 3.4.2 | Post-war Excavations “Phase Two” | 25 |
| 3.5 | Makapan Middle Pleistocene Research Project (MMPRP) | 30 |
| 3.5.1 | Hearths and Fire-use | 30 |
| 3.5.2 | Chronology and Dating | 33 |
| 3.5.3 | The CoH Acheulean in a Broader ESA Context | 34 |
| 3.5.4 | Additional MMPRP Analysis | 36 |
| 3.6 | Conclusion | 36 |

**Chapter 4: Techniques Utilised and Previous Studies**


4.1 Introduction 37
4.2 Experimental Archaeology 37
4.2.1 Case Study 1: An Axe To Grind 38
4.2.2 Case Study 2: Smoke 'Em if You Got 'Em 42
4.3 Experimental Archaeology Conclusion 49
4.4 History of Micro-wear 50
4.4.1 The Early Era 50
4.4.2 The Early Modern Era 51
4.4.3 The Modern Era 53
4.5 Types of Micro-wear Analysis 56
4.5.1 Macroscopic Use-wear Analysis 56
4.5.2 High-power Use-wear Analysis 58
4.5.3 Residue Analysis 60
4.5.4 Low-power Use-wear Analysis 63
4.6 Suitability of CoH Bed 3 Acheulean for Analysis 65
4.7 Previous Functional Studies in the African ESA 67
4.7.1 Non-microwear Studies 67
4.7.1a Handaxe Hurling 68
4.7.1b Sexy Handaxes 72
4.7.1c Experimental Work 74
4.7.2 Micro-wear Analyses of African ESA Materials 77
4.7.2a High-power Use-wear 78
4.7.2b Residue Analyses 86
4.7.2c Macroscopic Analyses 89
4.7.2d Multi-stranded Analyses 92
4.8 Chapter Conclusion 93


**Chapter 5: Experimental Programme and Blind Test**


5.1 Introduction 94
5.2 Experimental Programme 94
5.2.1 Methods and Equipment 95
5.2.2 Experimental Results 100
5.3 Blind Test 114
5.3.1 Results and Lessons Learned from Blind Testing 118
5.3.2 Blind Test Summary 120
5.4 Chapter Conclusion 120

**Chapter 6: The CoH Bed 3 Sample: Use-wear Analysis and Results**
6.1 Introduction 121
6.2 The CoH Bed 3 LCT Assemblage 121
6.3 Results of Use-wear Analysis 125
6.3.1 Hafting Results 144
6.3.1a CoH # 231 147
6.3.1b CoH # 265 150
6.3.2 Quantitative Results 153
6.3.2a Statistical Results for Handaxe, Cleaver, and Other 154
6.3.2b Statistical Results for McNabb *et al.'s* (2004) Tip Shapes 163
6.3.3 Non-statistical Quantitative Results 169
6.4 Discussion of Quantitative Results 173
6.5 Chapter Conclusion 174

**Chapter 7: Discussion and Conclusions**
7.1 Introduction 176
7.2 The Larger Picture 177
7.3 Limitations of This Study 178
7.4 Suggestions for Future Research 181
7.5 Dissertation Summary 181

**Appendices**
Appendix A (Pertains to Chapter 6) 184
Appendix B (Pertains to Chapter 6) 188
Appendix C (Pertains to Chapters 5 and 6) 196
Appendix D (Pertains to Chapters 5 and 6) 204

**References** 208

## List of Figures


| | | |
|---|---|---|
| Fig. 1.1 | Tip Shapes | 2 |
| Fig. 2.1 | Acheulean Sites Near the Type Site of Saint-Acheul | 6 |
| Fig. 2.2 | African Sites Mentioned in Text | 8 |
| Fig. 2.3 | South African Sites Mentioned in Text | 11 |
| Fig. 3.1 | Makapansgat Valley Caves | 13 |
| Fig. 3.2 | Vegetation Zones Surrounding CoH | 14 |
| Fig. 3.3 | The Red Cliffs | 15 |
| Fig. 3.4 | The Red Cliffs | 16 |
| Fig. 3.5 | Cross Section of the Makapansgat Valley Geology | 16 |
| Fig. 3.6 | Contour Map of Makapansgat Valley | 19 |
| Fig. 3.7 | Section of CoH and Hyena Cave | 20 |
| Fig. 3.8 | Van Riet Lowe's Photo at Moment of Discovery January 1937 | 22 |
| Fig. 3.9 | Van Riet Lowe's Photo From June 1937 | 23 |
| Fig. 3.10 | Start of Phase One excavations 1947 | 24 |
| Fig. 3.11 | The Cave of Hearths Mandible | 25 |
| Fig. 3.12 | Start of 1953 Excavations | 27 |
| Fig. 3.13 | End of 1954 Excavations with Cave Legend Sequence Painted on Back Wall | 28 |
| Fig. 3.14 | End of 1954 Excavations | 29 |
| Fig. 3.15 | Plan View of CoH | 29 |
| Fig. 3.16 | Mason's Stratigraphic Sequence | 30 |
| Fig. 3.17 | 'Hearth Feature' from Bed 3 | 32 |
| Fig. 3.18 | Palaeomagnetic Data | 34 |
| Fig. 4.1 | Hafted Bronze Axes Used | 40 |
| Fig. 4.2 | Hafted Stone Axes Used | 40 |
| Fig. 4.3 | Replicated Tools used by Chandlee *et al.* (2014) | 44 |
| Fig. 4.4 | Archaeological Examples from Robb Collection | 44 |
| Fig. 4.5 | Block of Minnesota Pipestone used by Chandlee *et al.* (2014) | 46 |
| Fig. 4.6 | Roughout of Pipe | 46 |
| Fig. 4.7 | Sanding the Pipe | 48 |
| Fig. 4.8 | The Finished Pipe (After Polishing) | 48 |
| Fig. 4.9 | Macroscopic Scars on Projectile Points | 57 |
| Fig. 4.10 | The Hand Bolt | 69 |
| Fig. 4.11 | Comparisons of Wilkins et al's Photos and Rots and Van Plisson's Photos | 91 |

Fig. 5.1 The 8 Polar-coordinate System 96
Fig. 5.2 Focus Stacking Example 99
Fig. 5.3 Edge of TS.2013.11 101
Fig. 5.4 Macroscopic View of TS.2013.11 101
Fig. 5.5 Tip of TS.2013.2 102
Fig. 5.6 Macroscopic View of TS.2013.2 102
Fig. 5.7 Edge of TS.2013.5 103
Fig. 5.8 Macroscopic Views of TS.2013.5 104
Fig. 5.9 Macroscopic View of TS.2013.8 104
Fig. 5.10 Edges of TS.2013.8 105
Fig. 5.11 Butt of TS.2013.16 106
Fig. 5.12 Tip of TS.2013.16 107
Fig. 5.13 Macroscopic View of TS.2013.16 108
Fig. 5.14 Hafting Arrangement of TS.2013.16 108
Fig. 5.15 Tip of TS.2013.19 109
Fig. 5.16 Macroscopic View of TS.2013.19 109
Fig. 5.17 Sawing Edge of TS.2013.1 110
Fig. 5.18 Scraping Edge of TS.2013.1 111
Fig. 5.19 Macroscopic View of TS.2013.1 112
Fig. 5.20 Edge of Blue Flake 19 113
Fig. 5.21 Macroscopic View of Blue Flake 19 113
Fig. 5.22 Selected Blind Test Tools 118
Fig. 6.1 McNabb *et al.'s* (2004) Tip Shapes and Definitions 123
Fig. 6.2 Edge of CoH # 151 128
Fig. 6.3 Macroscopic View of CoH # 151 128
Fig. 6.4 PESM 129
Fig. 6.5 PDSM and PESM 130
Fig. 6.6 Butt End of CoH # 243 131
Fig. 6.7 Tip of CoH # 243 132
Fig. 6.8 Macroscopic View of CoH # 243 133
Fig. 6.9 Edge of CoH # 177 133
Fig. 6.10 Macroscopic View of CoH # 177 134
Fig. 6.11 Macroscopic View of CoH # 231 134
Fig. 6.12 Edge of CoH # 231 135
Fig. 6.13 Edge of CoH # 234 136
Fig. 6.14 Macroscopic View of CoH # 234 136
Fig. 6.15 Edges of CoH # 178 137
Fig. 6.16 Macroscopic View of CoH # 178 138
Fig. 6.17 Macroscopic View of CoH # 263 138
Fig. 6.18 Edge of CoH # 263 139
Fig. 6.19 Un-used Flake Edge 139

Fig. 6.20 Edge of CoH # 218 140
Fig. 6.21 Macroscopic View of CoH # 218 141
Fig. 6.22 Macroscopic View of CoH # 221 141
Fig. 6.23 Edge of CoH # 221 142
Fig. 6.24 Edges of CoH # 255 143
Fig. 6.25 Macroscopic View of CoH # 255 144
Fig. 6.26 “Sliced-into-Scalar” Scars 145
Fig. 6.27 “Sliced” Scars 146
Fig. 6.28 Hafting Bright Spots 146
Fig. 6.29 Hafting Striae 147
Fig. 6.30 Sliced-into-Scalar scars on CoH # 231 148
Fig. 6.31 Rounding on CoH # 231 148
Fig. 6.32 Hafting Scarring on CoH # 231 149
Fig. 6.33 Scars Resulting From Hafting 149
Fig. 6.34 Location of Hafting Traces on CoH # 231 150
Fig. 6.35 Hafting Scars on CoH # 265 151
Fig. 6.36 More Hafting Scars on CoH # 265 151
Fig. 6.37 Rounding on CoH # 265 152
Fig. 6.38 Hafting Polish on CoH # 265 152
Fig. 6.39 Location of Hafting Wear on CoH # 265 153

Fig. B.1 Use-wear Code Sheet 184
Fig. C.1 Tip Shape 1 Sample Analysed 188
Fig. C.2 Tip Shape 2 Sample Analysed 188
Fig. C.3 Tip Shape 4 Sample Analysed 197
Fig. C.4 Tip Shape 5 Sample Analysed 197
Fig. C.5 Tip Shape 6 Sample Analysed 198
Fig. C.6 Tip Shape 7 Sample Analysed 198
Fig. C.7 TS.2013.1-5 199
Fig. C.8 TS.2013.6-10 199
Fig. C.9 TS.2013.11-15 200
Fig. C.10 TS.2013.16-20 200
Fig. C.11 Hafted Experimental Pieces 201
Fig. C.12 Blue Flakes 201
Fig. C.13 Blue Flakes in Wooden Box 202
Fig. C.14 Blind Test Tools 1-10 202
Fig. C.15 Blind Test Tools 11-20 203
Fig. C.16 Blind Test Tools 21-30 203
Fig. D.1 Scar Termination Types 205

## List of Tables


| | | |
|---|---|---|
| Table 4.1 | Lemorini *et al.'s* (2014) Table 5 | 83 |
| Table 4.2 | Corrected Scoring of Lemorini *et al.'s* (2014) Blind Test | 83 |
| Table 5.1 | Experimental Tools | 97 |
| Table 5.2 | Blind Test Results | 116 |
| Table 6.1 | Bed 3 LCTs | 124 |
| Table 6.2 | Final Sample Submitted to Use-wear Analysis | 124 |
| Table 6.3 | Summary of Use-wear Results of Used Tools | 126 |
| Table 6.4 | Single-Use and Multiple-Use Tools (Action) | 155 |
| Table 6.5 | Single-Use and Multiple-Use Tools (Resistivity) | 156 |
| Table 6.6 | Single-Use and Multiple-Use Tools (Worked Material) | 156 |
| Table 6.7 | Single-Use and Multiple Use Tools (Full Task) | 157 |
| Table 6.8 | Use by Action | 159 |
| Table 6.9 | Use by Resistivity | 160 |
| Table 6.10 | Use by Worked Material | 161 |
| Table 6.11 | Single-Use and Multiple-Use Tools (Action) | 163 |
| Table 6.12 | Single-Use and Multiple-Use Tools (Resistivity) | 164 |
| Table 6.13 | Single-Use and Multiple-Use Tools (Worked Material) | 164 |
| Table 6.14 | Single-Use and Multiple Use Tools (Full Task) | 165 |
| Table 6.15 | Use by Action | 166 |
| Table 6.16 | Use by Resistivity | 167 |
| Table 6.17 | Use by Worked Material | 168 |
| Table 6.18 | Resistivities, Their Frequencies, and Percentages | 170 |
| Table 6.19 | Worked Materials, Their Frequencies, and Percentages | 170 |
| Table 6.20 | Actions, Their Frequencies, and Percentages | 170 |
| Table A.1 | Cave of Hearths Bed 3 Population | 184 |
| Table B.1 | Use-wear Results of Complete Sample | 189 |

# List of Acronyms

| | |
|---|---|
| **CIEP** | Cross-over Immune-ElectroPhoresis |
| **CLSM** | Confocal Laser Scanning Microscopy |
| **cm** | Centimetre (One one-hundredth of a metre) |
| **CoH** | Cave of Hearths |
| **CoH-HC** | Cave of Hearths-Historic Cave |
| **DIFs** | Diagnostic Impact Fracture |
| **DOF** | Depth of Field |
| **EA** | Experimental Archaeology |
| **ELISA** | Enzyme-Linked Immune-absorbant Assay |
| **ESA** | Earlier Stone Age |
| **EU** | Employed Unit |
| **FIB** | Focused Ion Beam |
| **FTIR** | Fourier Transform Infrared spectrocscopy |
| **GIS** | Geographic Information System |
| **HDTs** | Heavy Duty Tools |
| **HV** | Vickers Pyramid Number |
| **IEF** | Isoelectric Focusing |
| **IHRB** | Imjin/Hantan River Basins |
| **Ka** | Kilo annum (Thousand years) |
| **km** | Kilo metre (Thousand metres) |
| **K/ Ar** | Potassium/ Argon |
| **LCTs** | Large Cutting Tools |
| **LFB** | Large Flake Blank |
| **LSA** | Later Stone Age |
| **m** | metre(s) |
| **Ma** | Mega annum (Million years) |
| **mm** | Millimetre (One one-thousandth of a metre) |
| **MMPRP** | Makapan Middle Pleistocene Research Project |
| **mFTIR** | micro-morphological and Fourier Transformed InfraRed micro-spectroscopy |
| **MSA** | Middle Stone Age |
| **OGAP** | Olduvai Geochronology and Archaeology Project |
| **PC** | Polar-Coordinate |
| **PCT** | Prepared Core Technology |
| **PDSM** | Post-Depositional Surface Modification |
| **PESM** | Post-Excavation Surface Modification |
| **RIA** | Radio-Ammunoassay |
| **S/ M** | Strokes per Minute |
| **SEM** | Scanning Electron Microscopcy |

| | |
|---|---|
| **UNESCO** | United Nations Educational, Scientific, and Cultural Organization |
| **USO** | Underground Storage Organ |
| **XRF** | X-Ray Florescence |

# Chapter 1
# Introduction and Thesis Structure

"And first, before we begin the history of life, let us tell something of the stage upon which our drama is put and of the background against which it is played" (Wells 1951:1)

## 1.1 Introduction and Goals

The main goals of this research are: 1) determining the functions of a sample of Acheulean Industrial Complex (hereafter 'the Acheulean') Large Cutting Tools (LCTs) from the Cave of Hearths (CoH) Bed 3 Later Acheulean assemblage, and 2) statistically testing a null hypothesis that morphology (form) = function, where form is defined using McNabb *et al.'s* (2004: 657) "tip shapes" (see Fig. 1.1) and the broader typological categories of handaxe and cleaver.[1]

Handaxes, cleavers, picks, pick-like handaxes, roughouts, and generally all bifaces have been conventionally labelled LCTs (Kuman 2014). Leakey (1971) preferred the term 'biface' when describing LCTs to avoid functional terms like pick, handaxe, and cleaver; but not all LCTs are bifacially flaked, making her terminology problematic. Since then, handaxes, cleavers, etc. have been subsumed under the all- encompassing term LCTs, which is just as problematic as Leakey's earlier terminology, because LCTs imparts functions to tools that most often have not been corroborated by evidence from functional analyses (see rationale below). That is, since they are referred to as Large Cutting Tools, they are associated with the activity of cutting. However, unless otherwise specified, the term 'LCTs' herein refers to the *morphological* types of handaxes and cleavers, which are the focus of this research. The only exception is when 'LCTs' appears in a direct quotation. The term Heavy- Duty Tools (HDTs) will be utilised if needed, in the way that LCTs has conventionally been used. (i.e., a broad category that includes handaxes, cleaves, picks, pick-like handaxes, roughouts and generally all Acheulean bifaces).

[1] The LCTs were morphologically typed as handaxes or cleavers with the assistance of Prof. Kathleen Kuman at the University of the Witwatersrand.

## 1.2 Rationale

The overriding rationale for this study is that there have been few true functional studies carried out on Acheulean LCTs. The majority of functional research projects to date have been actualistic experimental studies. That is, the researchers focused on whether or not a particular tool type (e.g., handaxe or cleaver) was efficient for a given task (e.g., butchery or wood-working) (Jones 1980, 1994; Mitchell 1995; Machin *et al*. 2006; however, see section 4.7.2 and subsections therein for an overview of studies that have employed reliable methods of functional analyses). While these actualistic studies may be valuable in their own right—providing possible answers to the question of how HDTs' were used—they offer only a partial interpretation for the function of HDTs and are not corroborated by any other lines of evidence, making their conclusions less reliable than those gained from a multi-stranded approach.

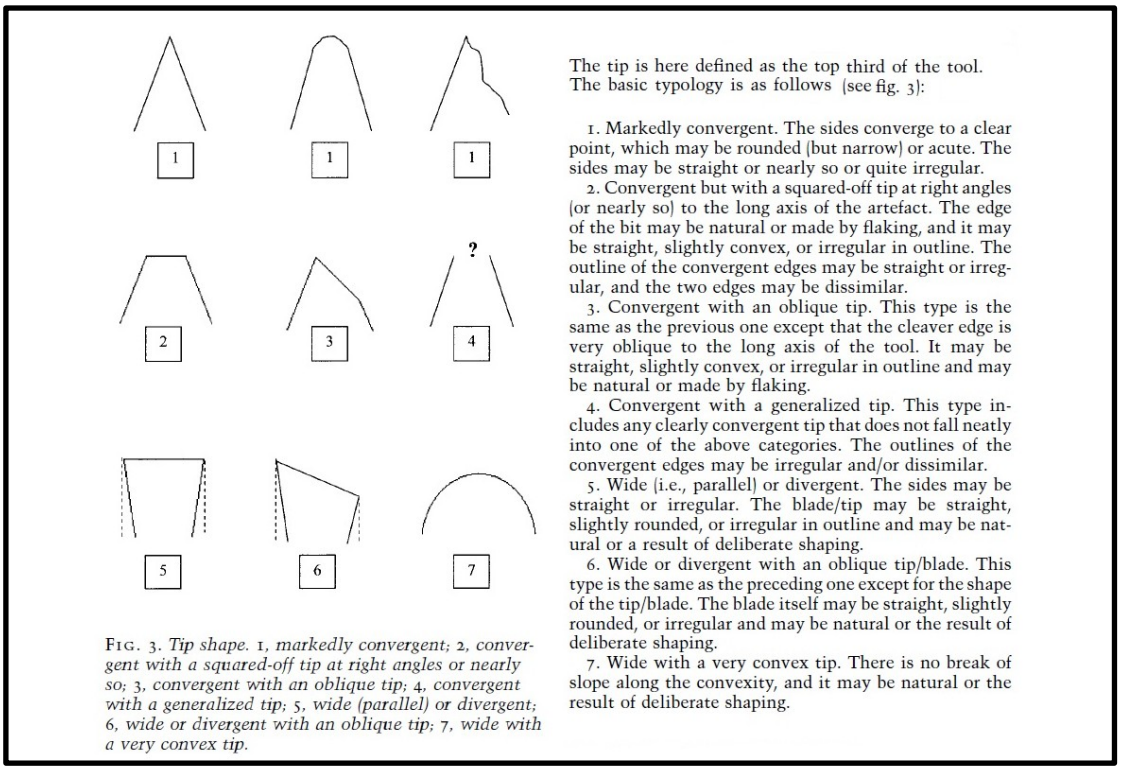


**Figure 1.1 Tip Shapes for LCTs** (Image from McNabb *et al.* 2004).

## 1.3 Method, Techniques, and Approach

To meet the main research goals, the method utilised in this study employed a multi-stranded approach that is both quantitative and qualitative. This multi-stranded approach includes the techniques of experimental archaeology, blind testing, and low-power use-wear analysis

(one type of microscopic functional analysis). Statistical analyses were then performed on the results of the use-wear analysis to determine if there were significant differences in functions and morphology (i.e., handaxe and cleaver), functions and tip shapes and to decide how tool function corresponded to morphological typing, if it did at all. However, before the method was applied, it was necessary to establish whether or not experimental archaeology (Section 4.2), blind testing (Section 4.4.3), low-power use-wear analysis (Section 4.5.4), and statistical analysis were reliable analytic tools (Section 4.6) for a multi-stranded approach aimed at identifying the functions of Acheulean LCTs, as this particular combination of techniques has not been previously used in studying LCTs.

## 1.4 Thesis Structure

A discussion of select Acheulean sites from the African continent is presented in Chapter 2, providing the background to the Acheulean and illustrating the geographic and temporal range of this industry. It also introduces a few of the debates surrounding the Acheulean (e.g., the hominins responsible for the Acheulean).

An in depth discussion of CoH is presented in Chapter 3 including, its discovery and subsequent excavations, the geology of the area, the palaeo-climatalogical data, the importance of the CoH stratigraphic sequence, and the Acheulean assemblage, as well as earlier scholars' interpretations made about this assemblage. Additionally, the most recent work performed by the Makapan Middle Pleistocene Research Project (MMPRP) is reviewed.

Chapter 4 provides a discussion of the techniques used in the multi-stranded approach applied to this study of CoH LCTs. A review of the history of these techniques, a critique of their previous uses, or lack thereof, and a discussion of the advantages and disadvantages of each are presented. Previous studies focusing on the functions of HDTs are also presented.

Chapter 5 outlines the experimental archaeological scheme used in this study and the blind test that was conducted. An explanation of how the data obtained from these techniques was used to aid in analysis of the CoH Bed 3 assemblage concludes the chapter.

Chapter 6 introduces the CoH Bed 3 assemblage. Information is presented on: 1) the total population of LCTs from Bed 3; 2) the statistical random sampling strategy used in selecting the sample analysed; 3) the results of the use-wear analysis; and 4) the statistical analyses of these results. This is followed by a discussion of the findings.

The conclusions and interpretations drawn from the results of this study are presented in Chapter 7. A discussion of the potential impact of this study's findings in the framework of a larger Acheulean picture, lessons learned from my work, and suggestions for future research conclude the study.

# Chapter 2
# Introduction to the Acheulean

## 2.1 Introduction to the Acheulean Industrial Complex

The Acheulean is a stone tool techno-complex that is found throughout most of the Old World including Africa, Asia, Europe and the Indian sub-continent (Clark 1970, 1994; Kuman 2014). The first discovery of HDTs was in the late 19th century in the Somme terrace gravels near Amiens, France, though the name of Acheulean had not yet been applied to the finds. The Acheulean was initially characterised only by the large bifacially flaked handaxes found in the Somme River Valley (Bordes 1984). Around the turn of the 20th century, however, "relatively undisturbed activity areas at localities around Saint-Acheul [from which the Acheulean takes its name] were discovered and excavated" (Clark 1994: 451; This study's Fig. 2.1 Letter A). Further discoveries from sites such as Comment's Workshop (Commont 1908, 1909; Howell 1966: 167-169) led to the realisation that the Acheulean was a full techno-complex comprised of flakes, cores, HDTs, and debris/debitage, rather than HDTs only. This, followed by the discovery of Acheulean localities across the Old World, sparked debates over what a 'true' Acheulean assemblage should contain. Some Acheulean sites that were discovered were dominated by assemblages of cores and flakes with few or no HDTs, while others were composed mainly of HDTs with low percentages of flakes, cores, etc. However, it is now accepted that an Acheulean assemblage is generally "defined as having varying proportions of large bifacial tools...[HDTs]... associated with cores of different kinds from which flakes were removed by hard hammer technique and sometimes reworked" (Clark 1994: 453).

This techno-complex has long intrigued archaeologists for several reasons. The most interesting, in my opinion, is the seemingly abrupt change from the relatively simple Mode 1 (core-and-flake) tradition called the Oldowan, with assemblages comprised of smaller flakes struck from cores with no secondary modification (retouch), to the more complicated Mode 2 (biface) Acheulean containing assemblages with large flakes and flake blanks (>10 cm long), to which retouch is applied. Many hypotheses have been put forward to explain why this occurred.

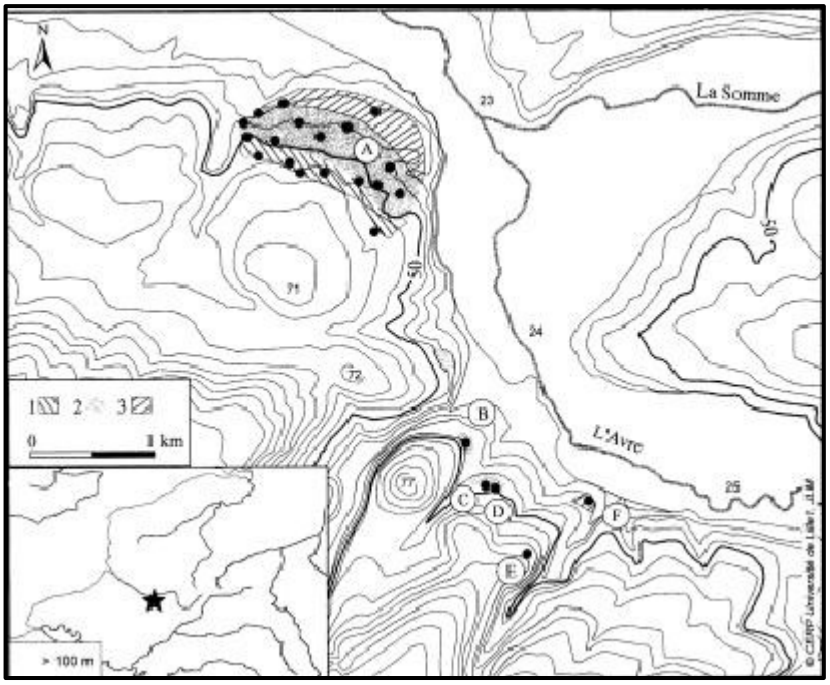


**Figure 2.1 Acheulean Sites Near the Type Site of Saint-Acheul** (Image modified from Tuffreau *et al.* 1997). Contour lines are 5 m. A: Saint-Acheul; B: Cagny-Cimetière; C: Cagny-la Garenne 1; D: Cagny-la Garenne 2; E: Cagny-Ferme de l'Epinette; F: Cagny-l'Epinette

The most widely accepted hypothesis attributes the change in technology to the apearance of a new species of hominin (i.e., *Homo ergaster*[2]) in the archaeological record *ca.* 50 Ka before the advent of the Acheulean. This suggestion, however, is now being challenged as it is not firmly "grounded in the current available evidence, but rooted in cultural-history paradigms that should now be superseded" (de la Torre *et al.* 2012).

According to current knowledge, the Acheulean is the longest lasting stone tool tradition, spanning more than 1.5 million years. The earliest known, securely dated finds of this techno-complex are from Konso-Gardula, Ethiopia radio-isotopically dated to 1.74 ± 0.03 Ma (Asfaw *et al.* 1992; Beyene *et al.* 2013) and from Kokiselei, Kenya, palaeomagnetically and stratigraphically dated to 1.76 Ma (Lepre *et al.* 2011 Fig. 3). The most recent occurrences of the Acheulean however, are not as securely dated as the earliest. Klein (2000: 108) suggests that a date for the end of the Acheulean might be the date range currently available for beginning of the Middle Stone Age (MSA), which follows the Acheulean, *ca.* 0.25-0.3 Ma.

[2] Herein *Homo ergaster* is used only to refer to the species which appeared on the African landscape *ca.* 1.8 Ma, discovered by Dr. Robert Broom in 1949 in the form of the mandibular specimen SK 15. The term *H. erectus* is used to denote the Asian form of the species, though the topic of how the two species relate to each other is debated (Kuykendall 2007: 64). Some researchers (e.g Barham and Mitchell 2008: 73) prefer to use *H. erectus* to refer to both Asian and African varieties while others (e.g. Prothero 2007: 336-343) employ the terminology as I do.

Additionally, regional variations (e.g., prepared core technology (PCT), such as the Victoria West Industry in South Africa (Kuman 2001) and blade production as seen in the Amudian in Israel (Lemorini *et al.* 2006) or in the Kapthurin Formation in Kenya (Johnson and McBrearty 2010) and at Kathu Pan 1 in South Africa (Wilkins and Chazan 2012)) begin to manifest in Acheulean assemblages *ca.* 0.6 Ma, and there are debates over whether or not an assemblage should be called Acheulean based on the presence of HDTs alone (Clark 2001; Adler *at el.* 2014).

These regional variants are seen in assemblages in different areas of the world until *ca.* 0.3-0.2 Ma and are problematic because they generally contain a mix of typical Acheulean HDTs with the aforementioned technologies (i.e., blade production and PCT), which are viewed as Middle Stone Age (MSA) in nature. Thus, the end of the ESA and the beginning of the MSA "is ambiguous, and handaxes and other large cutting tools co-occur with typical MSA flakes, blades, and points for an extended period, from 500,000 to 125,000 years ago…" (Wurz 2014: S306). A prime example of this situation are the results from Kalambo Falls, Zambia, where there are small Acheulean handaxes present within the industry known as the Sangoan, accepted by some researchers as an ESA/ MSA transitional industry (e.g., Clark 2001; Wurz 2014) and by some (e.g., McBrearty 1988; Clark 2001; Rots and Van Peer 2006; Basell 2010) as a MSA industry. Other researchers "see the Sangoan industry as a variant of the Later Acheulean with the addition of some new types related to the prominence of woodland resources" (Kuman 2014: 16). While analysis of these variants *is not* the focus of this research, it is important to mention them in order to gain a fuller understanding of the complexity of the Acheulean.

## 2.2 The Acheulean in Africa and South Africa

Though there are numerous sites that could be mentioned, the purpose of this review is not to provide an exhaustive listing of all known Acheulean sites. Rather, it is important to briefly review a few select Acheulean sites, from the African continent to demonstrate the wide ranging nature of this techno-complex.

### 2.2.1 The Acheulean in Africa

The Acheulean sites at Olduvai Gorge, Tanzania (Fig. 2.2) are the first recorded discovery of the Acheulean in Africa. Mary Leakey's (1971) pioneering descriptive and typological work provided a wealth of

information and laid the foundation for the study of the Acheulean in Africa. Analysis of Olduvai Gorge materials has been ongoing for almost a century and has “produce[ed] an unparalleled wealth of archaeological and palaeontological data for the study of some key phases of early human evolution” (de la Torre *et al.* 2012: 90). Studies conducted on the Olduvai assemblages have included experimental replication of the stone industries (Jones 1994) and the general and specific geology of the area (Hay 1976).

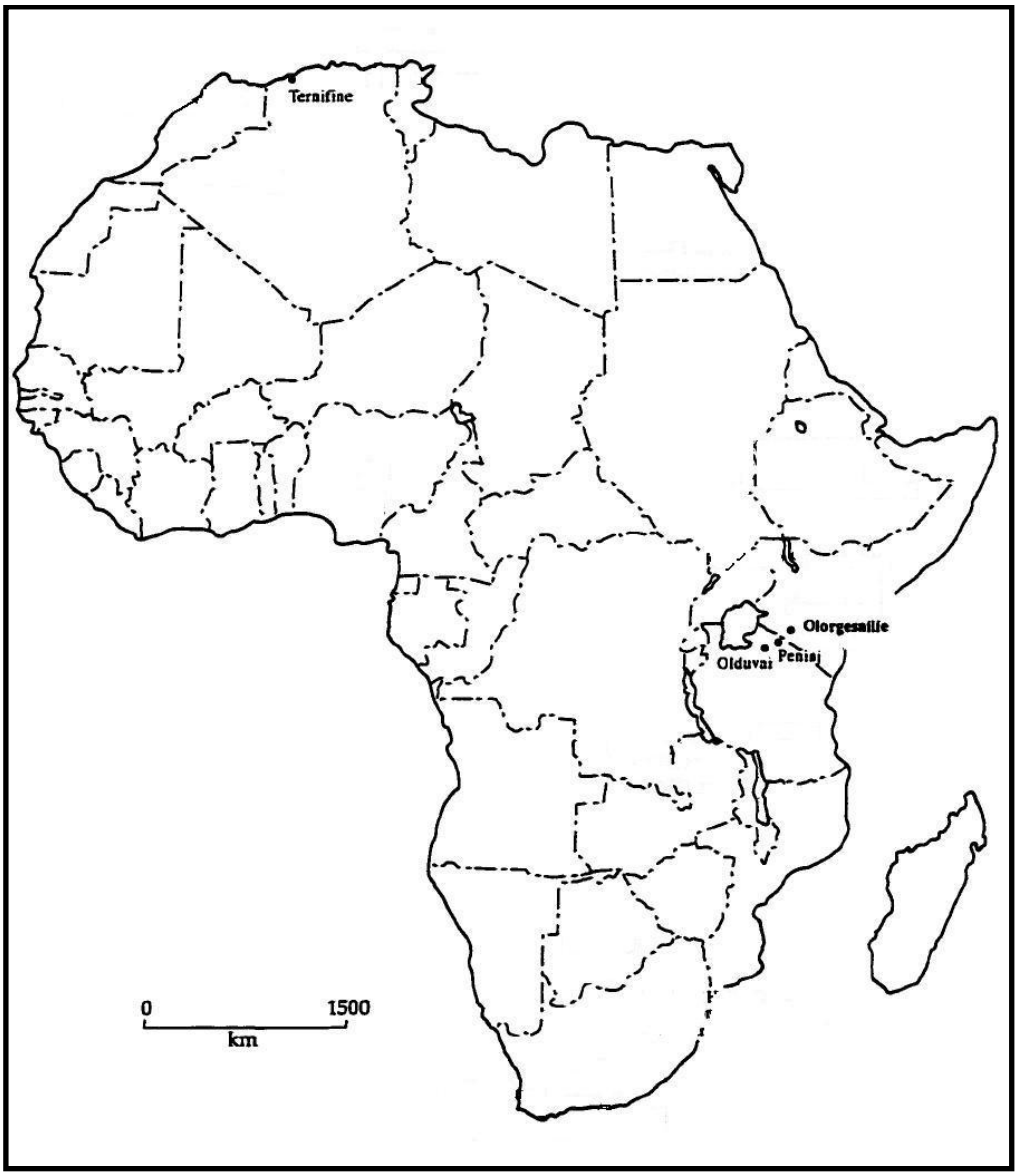


**Figure 2.2 African Sites Mentioned in Text** (Image modified from Noll 2000).

In 2008 a new study programme was launched by the Olduvai Geochronology and Archaeology Project (OGAP) to investigate the origins of the Acheulean at Olduvai Gorge. OGAP intends to investigate when *Homo ergaster* appeared at Olduvai and whether or not its appearance is linked with the emergence of the Acheulean (de la Torre *et al.* 2012). They also aim to discover when exactly the Acheulean first appeared at Olduvai Gorge. Current dates from the Acheulean strata range from 1.66 ± 0.1 Ma to 1.803 ± 0.002 (Deino 2012) and OGAP would like to refine this range (de la Torre *et al.* 2012). Results from OGAP are still forthcoming, but their findings may greatly enhance our understanding of the Acheulean in Africa.

Several other sites in East Africa (Fig. 2.2) have provided a rich prehistoric record. Glenn Isaac (1967a, 1968, 1969) has extensively studied the site of Olorgesaile in Kenya and it has been dated by Uranium series and K/ Ar methods to *ca.* 0.4 Ma (Potts 1989) placing it in the Later Acheulean. Analyses of materials at the sites around Peninj, Tanzania (de la Torre *et al.* 2008), dated through K/ Ar methods to *ca.* 1.5 Ma (Isaac and Curtis 1974; Thouveny and Taieb 1987), produced results including the possibility of wood-working residues (i.e., phytoliths) on HDTs (Dominguez-Rodrigo *et al.* 2001); though the reliability of results from residue analysis are still debated (see section 4.5.3). Other studies have focused on reconstructing palaeoenvironmental records (Dominguez-Rodrigo *et al.* 2000) and on stratigraphic records of the region (Isaac 1967b). Kleindienst (1961, 1962) and Kleindienst and Keller (1976) laid pioneering groundwork for the typology of Acheulean artefacts and standardised much of the terminology still used today.

Acheulean sites are not restricted to East Africa and have been found in various regions of the continent. One such non-East African site isTernifine, which lies on the Algerian Plateau 20 km east of Mascara (Fig. 2.2). This site has a long excavation and collection history, with the documentation and excavation of prehistoric levels starting in 1882 (Tommasini 1886; Geraads *et al.* 1986). While the initial study (Geraads *et al.* 1986) mainly described the faunal remains with little mention given to the tools, the researchers did establish an age, through means of a palaeomagnetic sample and paleontological studies, of *ca.* 0.7 Ma. In addition, two hominin mandibles were found in the lower part of the site. At the time they were attributed to *Homo erectus* (though some might now classify them as *H. ergaster,* see footnote 3). Regardless of the species identification, according to Sharon (2011: 127), “they are [currently] still considered the oldest human remains from North Africa”.

More recently, the site's assemblage has become the study of a unique reduction strategy, dubbed the '*entame'* method, used in opening cobbles to obtain flake blanks suitable for further modification (Sharon 2011). Sharon (2011) looked at 47 cleavers, 57 handaxes, and 41 "large flakes" and tried to experimentally reproduce the knapping methods that were employed at Ternifine. He ultimately concluded that the *entame* method, while represented at other Acheulean sites, was the primary core reduction technology used at Ternfine, unlike most other Acheulean sites (Sharon 2011: 137-138). The author found that between 35 % and 44 % of different tool classes' blanks were made using the *entame* method compared with much lower percentages from other sites (Sharon 2011: 131 Table 1).

### 2.2.2 The Acheulean in South Africa

South Africa is home to the oldest known Acheulean assemblages outside of East Africa. Knowledge of Acheulian localities in South Africa has a long history (e.g., Söhnge *et al.* 1937; Mason 1961; for an overview of the history of ESA research in South Africa see Underhill 2011) and the earliest Acheulean in South Africa comes from the Cradle of Humankind, which was declared a United Nations Educational, Scientific, and Cultural Organization (UNESCO) world heritage site in 1999 (UNESCO 1999: 17). Two sites of particular interest are Swartkrans and Sterkfontein (Fig. 2.3) which have Early Acheulean age estimates of *ca.* 1.5-1.0 Ma and *ca.* 1.6 Ma respectively (Kuman 2007). According to Kuman (2014: 8-9) there are claims for earlier dates from Sterkfontein, but "the absolute methods employed [in dating Sterkfontein] have their own problems at these karst sites", meaning if the problems can be worked out then an earlier origin at Sterkfontein may be plausible. It is possible, however, that earlier assemblages do exist in South Africa.

Gibbon *et al.* (2009) report dates ranging from 1.9 to 1.3 Ma for localities in the Rietputs Formation (Fig. 2.3), though this date range has been refined to *ca.* 1.7 to 1.3 Ma due to newer models employed by the dating specialists (Kuman pers. comm. 2014). However, the dates were obtained using cosmogenic nuclide burial dating, which may be problematic in some cases (see Granger and Muzikar 2001 for an overview of this method and its possible problems). Whatever the final outcome for the dating of Rietputs, it, together with Sterkfontein and Swartkrans, points to the fact that by *ca.* 1.6 Ma the Acheulean is seen in South Africa and in fact, at Sterkfontein, it is in direct association with *Homo ergaster*, shedding some

light on the possible makers and users of the HDTs (Kuman and Clarke 2000).

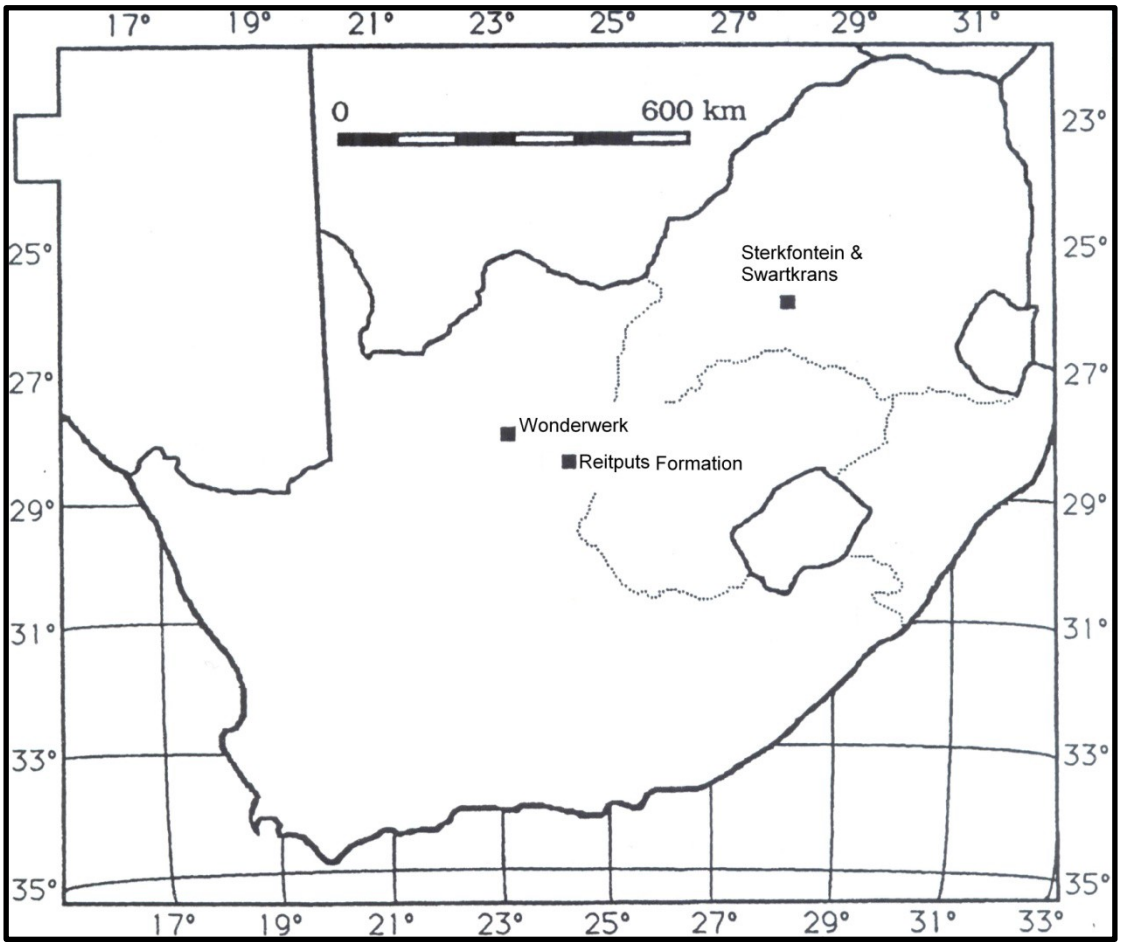


**Figure 2.3 South African Sites Mentioned in Text** (Image modified from Klein 1988).

Wonderwerk Cave (Fig. 2.3) in the Northern Cape Province, provides another case study as archaeological material, particularly fossilised bones, were unearthed during excavations for bat guano in the 1930s (Klein 1988: 10). These finds attracted archaeologist B.D. Malan who visited the site in 1940 and conducted excavations from 1943-1944 (Malan and Cooke 1941; Malan and Wells 1943). Among other things, the excavations uncovered Acheulean (at the time “Fauresmith”) artefacts. Excavations were renewed by P.B. Beaumont in 1978, and continued until the 1990s, with co-operation from A.I. and J.F. Thackeray. The results of Beaumont’s excavations confirmed the presence of Acheulean artefacts in the stratigraphic sequence (Beaumont 1982; Beaumont and Vogel 2006).

Work has recently been renewed by a team of archaeologists who have re-opened excavations, performed chronometric dating (Chazan *et al.* 2008; Matmon *et al.* 2012) and reanalysed the previously excavated material (Berna *et al.* 2012). The team securely dated the onset of the Acheulean at Wonderwerk to *ca.* 1.6 Ma (Chazan *et al.* 2008: 1), providing another Early Acheulean site for the South African archaeological record. In particular, the team was also interested in the first evidence of fire use. Combining micro-morphological and Fourier transformed infrared micro-spectroscopy (mFTIR) analyses, Berna *et al.* (2012: 1215) believe that they have "provide[d] unambiguous evidence—in the form of burned bone and ashed plant remains—that burning took place in the cave...~1.0 Ma". If this interpretation can be confirmed by future research, then Wonderwerk Cave will have the earliest known evidence for burning and fire use in the archaeological record.

### 2.3 Chapter Conclusion

This chapter provided a short discussion of select Acheulean sites from around the world and introduced some aspects of the Acheulean, such as the history of the discovery (section 2.1), and some of the debates surrounding the Acheulean (e.g., the species identification of hominins possibly associated with the Acheulean). The following chapter provides an in-depth review of the Later Acheulean site Cave of Hearths, located in the Limpopo Province of South Africa, as it is this site's assemblage from which the current study draws its sample.

Chapter 3
# The Cave of Hearths (CoH)

## 3.1 Introduction

The Cave of Hearths (24º08'25.8" S, 29º11'58.6" E) archaeological site is situated in the Makapansgat Valley 17 km east of Mokopane (formerly Potgietersrus) in the Limpopo Province of South Africa (Fig. 3.1). It is one of only a few currently known sites in South Africa that contains ESA, MSA, LSA, Iron Age and Historic Era artefacts, faunal remains, and hominin remains in one stratigraphic sequence (Mason 1988; Ogola 2003, 2009; McNabb and Sinclair 2009b). CoH forms part of a larger complex of caves, including Historic Cave, Buffalo Cave, Rainbow Cave, and Limeworks Site further down the valley, which lie along the west-facing flank of a north-south trending spur of the Strydpoort Mountains called The Highland Mountains (Latham and Herries 2004: 323; Maguire 2009: 30).

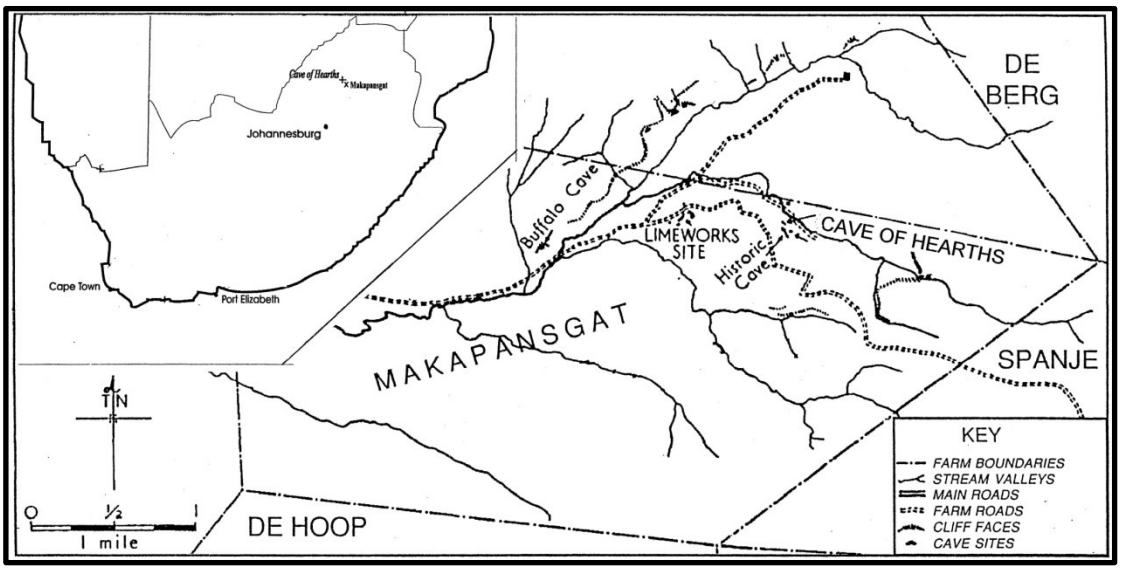


**Figure 3.1 Makapansgat Valley Caves** (Image modified from Latham and Herries 2004).

## 3.2 Geology and Geophysical Setting of CoH

The Makanpansgat Valley is home to both the savannah and grassland biomes (Fig. 3.2). This, coupled with "...the presence of nearby migration corridors whereby plant and animal species enrichment could occur...," has allowed for "...an exceptional focus of plant biodiversity and species richness, which includes a high proportion of endemic species" (Maguire

2009: 30-31). Maguire (2009) believes this is likely the reason that there is evidence for hominin activity going back to *Australopithecus*.

The Makapan stream, locally called the Mwaridzi, emanating from the Red Cliffs (Figs. 3.3 and 3.4) provides year round access to water. Though ephemeral, the stream in dry seasons leaves behind deep pools creating a year-round supply of water when the stream is not flowing.

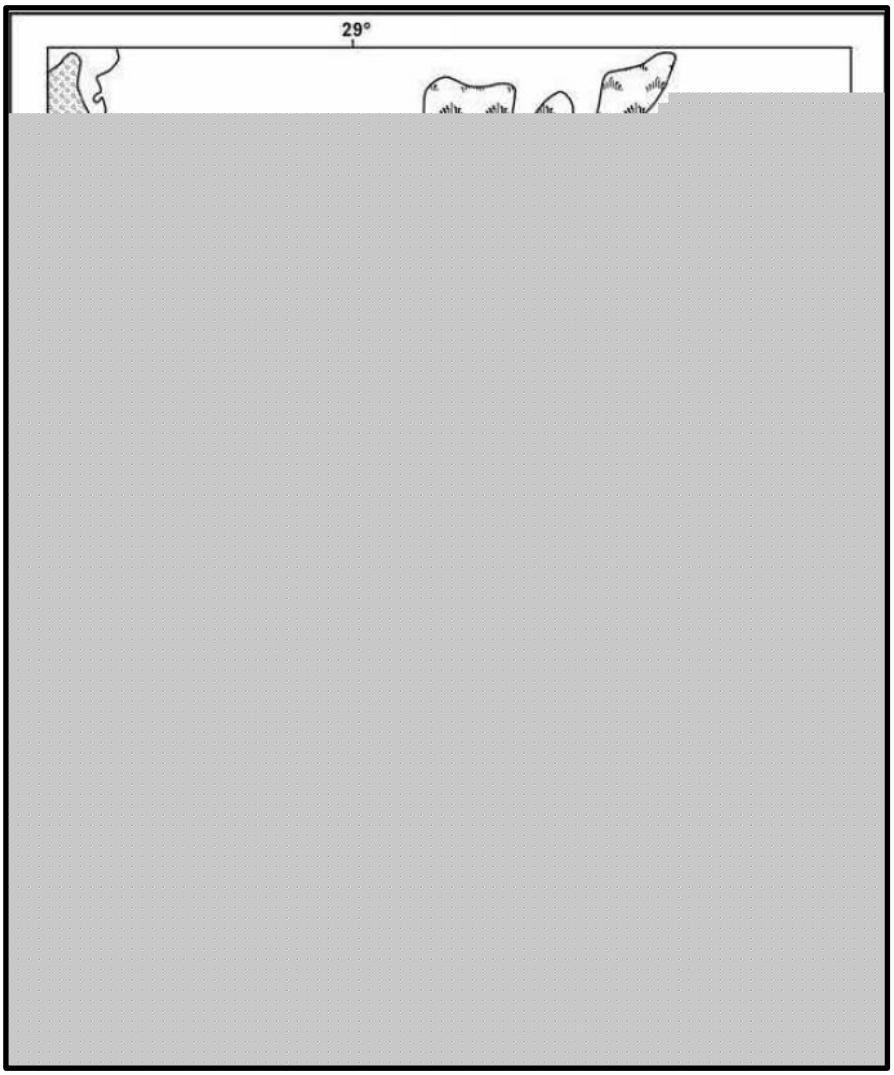


**Figure 3.2 Vegetation Zones Surrounding CoH** Makapan on the map is approximately the location of CoH (Image from Maguire 2009).

The Black Reef Quartzite is weather resistant, relative to the dolomitic limestone surrounding it. Outcrops frequently appeared in the CoH area as the limestone eroded away exposing the quartzite. It is characterized as a fine grained quartzite varying in colour from light grey-blue to dark grey-blue grading into black (Maguire 2009). As evidenced in the data for Bed 3 lithic items provided in McNabb and Sinclair (2009a Table 2.3), this quartzite appears to have been preferred for tool manufacture during the Acheulean. Of the 268 HDTs listed in the aforementioned table, approximately 81% (n=218) are made from quartzite, with this holding true for all lithic artefacts (N=2673) from Bed 3 of which approximately 80% (n=2148) were manufactured from Black Reef Quartzite. This is probably due to the quartzite's fine grained nature making it easily knappable (McNabb *et al.* 1999:153; pers. obs. 2013) and the conveniently located outcrops near CoH. Therefore, in order to maintain accurate raw material representation, a large majority of experimental tools (see section 5.2) made and utilised for the comparative collection were produced from Black Reef Quartzite collected from the outcrop directly above CoH.

## 3.3 Speleogenesis and Infilling of the CoH-HC Complex

The speleogensis and infilling of CoH cannot be discussed on its own, as it forms part of a much larger cave system (see Section 3.1). In proper terms, CoH is part of an integrated cave system—the speleological counterpart to a fluvial geomorphological river network (Ford and Williams 2007: 209-212)—including CoH, Historic Cave, Rainbow Cave, and Hyena Cave (sometimes referred to as Hyena Mandible Cave seen in Fig. 3.7 (Brain 1988; Latham and Herries 2004; Latham and Herries 2009). In the following Section, I use the term 'CoH-HC complex' to refer to this cave network. While this section deals with the basics of speleogensis within a karstic landscape, particularly the Makapansgat Valley, an in depth discussion on this topic is provided by Klimchouk *et al.* (2000) and Ford and Williams (2007).

### 3.3.1 Speleogenesis

There are two basic ways in which a cave, or cave system, can be formed out of soluble rocks such as limestone or dolostone. One is in a 'low relief system' in which the cave is "...formed by solution below a water table as, for example Sterkfontein and Swarkrans" (Latham and Herries 2004: 330; see also Brain 1993). The other, and most probable way in which the CoH-HC complex formed, is in a 'high relief system' in which a stream or river, either above or below ground, flows to lower altitudes carving

cave(s) out of the soluble rock. In either case, the cave being formed generally goes through a series of stages, beginning with a subaqueous (phreatic) phase, then a partially air-filled phase (vadose), then a phase of sedimentary infilling, and sometimes the final stages of unroofing (i.e., the opening of the cave to the surface) and/ or erosion (Bögli 1980; Latham and Herries 2004; 2009; Ford and Williams 2007).

In the CoH-HC complex there is evidence for the phreatic, vadose, and infilling phases. A theory called the Makapan River Cave Hypothesis has been suggested by Latham and Herries (2004: 334; 2009: 54-55) to explain the speleogensis of the CoH-HC complex, although "...it has not been possible to identify any water-lain deposits that might relate to when a river ran through the cave passages". According to this theory, the Makapan River would have followed a different course than it does today (see Fig. 3.6 blue line), carving out the caves from the dolomitic limestone as it flowed. Despite a paucity of evidence, Latham and Herries (2004; 2009) believe that this process likely began *ca.* 5.1 Ma, a time when the dolomite was likely first exposed to the Makapan River flow. The river would have possibly later changed directions (Fig. 3.6. yellow line), to flow along a path of least resistance, beginning to follow the course it does today. If this is the case, then the CoH-HC complex is probably the equivalent of an abandoned oxbow (Latham and Herries 2004: 336, 2009: 55). The oxbow phenomenon is common and provides a plausible, logical explanation if the Latham and Herries model is correct. (See Constantine and Dune 2008 for an overview of oxbow formation.)

### 3.3.2 Sedimentary Infilling of the CoH-HC Complex

The deposition of a basal flowstone (i.e., travertine) was the first event to take place at the CoH-HC complex. It likely originated in Hyena Cave and then slowly filled Cave of Hearths. This is evidenced by "...the two witness sections [see This study's Fig. 3.15] clearly show[ing] the deposition of this last flowstone layer as being higher at the Hyena Cave than at Cave of Hearths" (Latham and Herries 2009: 56). The basal travertine, however, was deposited on top of the dolomitic cave floor, pieces of cave roof fall, and "especially towards the rear and the east of the cave onto soft sediment" (Latham and Herries 2004: 340). Evidence for this came in 1999, when Dr. P. Randolph-Quinney dug a shallow test pit next to the Hut Witness Section and found the underside of the flowstone deposited on top of chunks of rubble and pieces of, likely original, cave breccia.

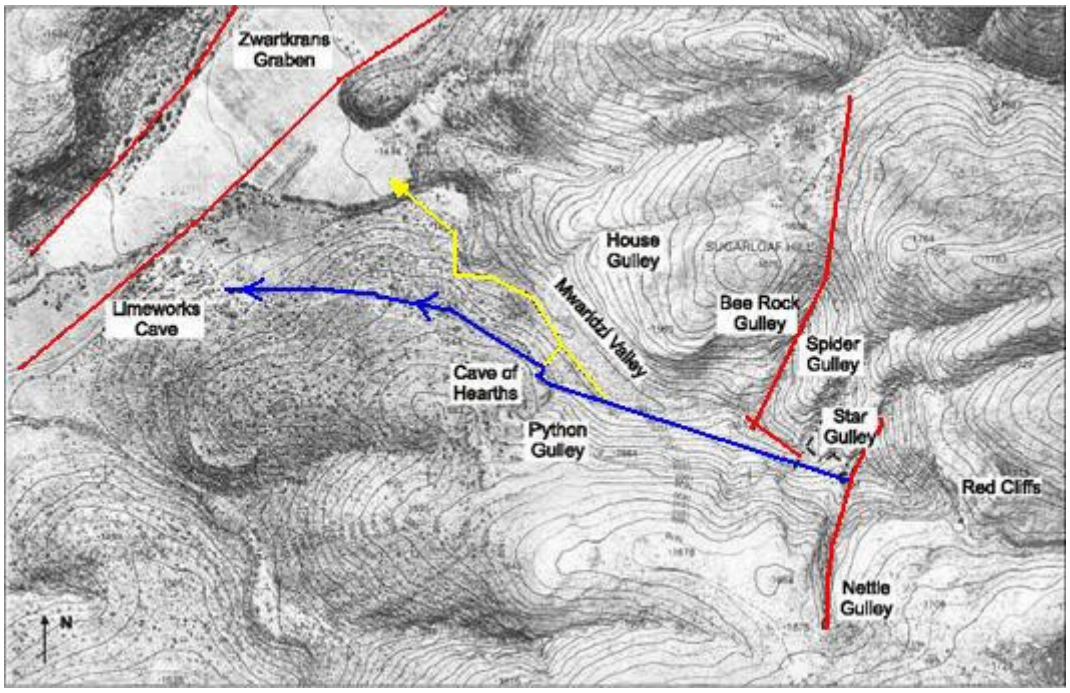


**Figure 3.6 Contour Map of Makapansgat Valley** Red lines represent major faults in the area; the blue line represents the putative original route of the Makapan River showing how it could have carved the CoH-HC complex from the dolomite; the yellow line represents the later change of direction of the Makapan River to its modern day course (Image modified from Latham and Herries 2004).

At one time, Hyena Cave and CoH were one chamber partially separated by a 'septum' that was probably the bottommost projection of hardened sediments which accumulated in a depression of the flowstone (Latham and Herries 2009: 57). This gap eventually closed as the basal travertine filled the passage between the two caves and separated them from one another (Figs. 3.7 and 3.13). After separation, the two caves experienced different depositional histories. Hyena Cave continued to experience sedimentary infilling through its opening to the surface, while CoH was likely closed off to the surface for some time after. It probably remained this way until the edge of the Makapan Valley retreated, possibly due to the change in course of the Makapan River, providing CoH with an opening to the surface which was likely similar to the modern day Historic Cave openings (Brain 1988: 560).

After CoH opened to the surface, true sedimentary infilling began (Mason 1988: 46-48). The first part of this sequence probably occurred before hominins inhabited the cave and consisted of droppings and pellets from bats and owls, likely the first 'inhabitants' of the cave, forming the guano layer underlying Mason's Bed 1. The second step in the infilling process of CoH is one that happens in most cave formed in a karstic landscape (Ford

and Williams 2007). That is, parts of the original cave roof and walls slowly eroded away and fell to the floor. Fine grained sediments were also deposited around the same time, (i.e., Bed 1 times) as evidenced in the stratigraphy left in the Wall Witness Section (Fig. 3.15 number 7; see also Latham and Herries 2009: 57). It is currently unknown whether they were placed there through creep processes—the gradual downhill movement of soil, sediment, and debris causing larger pieces to break down into smaller pieces (Marshak 2001: 482-483)—or through the winnowing away of sediments from in-between breccia clasts, already fallen from the roof and walls.

However these sediments were deposited, the winnowing of sediments and creep processes continued and may have been underway when the cave was discovered. A significant portion of the cave wall collapsed (see Section 3.4) sometime between the first discovery of CoH (January 1937) and the second visit (June 1937) suggesting that winnowing and the creep process were still occurring. These two processes, along with the accumulation of surface soil, rubble, and general debris able to enter the cave, formed the main bulk of the sedimentary infill. The only exception to this would have been residues left behind by hominins, though we do not know to what extent human agency modified the infilling process, if at all.

Evidenced in the Wall Witness Section, carbonate rich runoff water cemented the higher Acheulean sediments into breccia leaving the underlying sediments uncemented (Latham and Herries 2009: 57). The last development that occurred was the induration of the remaining deposits probably caused by “the dissolution of dolomite clasts within the breccia followed by the reprecipitation of the carbonate as cement” (Latham and Herries 2009: 57).

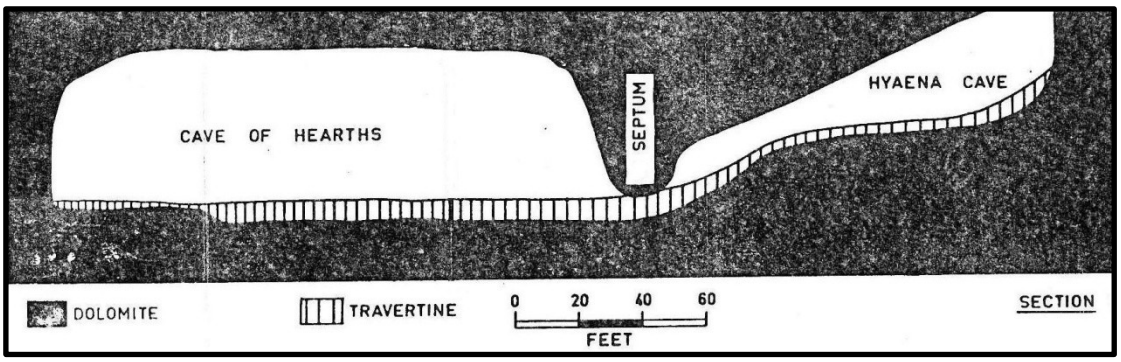


**Figure 3.7 Section of CoH and Hyena Cave** Showing the septum separating the caves and the travertine that eventually closed the gap (Image modified from Brain 1988).

### 3.4 History of Discovery and Early Excavations

A brief background of the Makapansgat Valley is important for understanding the discovery of CoH. As the name Limeworks suggests, the valley was the location of an industrial work site, primarily during the late 19th and early 20th centuries, from which travertine (i.e., flowstone or speleothem; $CaCO_3$) was mined, then calcined into pure lime (CaO) for use in the gold extraction process (McNabb and Sinclair 2009b). Sometime between 1917 and 1935 travertine miners cut a trench approximately 19 m long and 4.5 m wide through an area that was likely the collapsed original outer wall of the cave. The left hand side of this trench is now preserved as the 'barrier' (Figs. 3.8 & 3.9 left hand side and Fig. 3.15 'barrier'). In or before 1935, the lime workers abandoned the CoH site, presumably because they found higher quality or a greater quantity of travertine elsewhere.

In 1937 Clarence van Riet Lowe discovered CoH while visiting the neighbouring Historic Cave (van Riet Lowe 1938; this study's Fig. 3.8). He immediately recognised the archaeological significance of the site upon seeing bones eroding out of the cave breccia and an ashy layer he believed to be a hearth. In June of the same year (Fig. 3.9) he returned to the site with a few colleagues. Though recorded accounts are unclear as to who visited the site with van Riet Lowe in June and October (see below) of 1937, it is likely that Raymond Dart, H.B.S. Cooke, and Robert Broom were among the visitors (van Riet Lowe 1948; Malan 1988; McNabb and Sinclair 2009b). Between the discovery and his visit in June, part of a wall had collapsed revealing more bones as well as stone tools, including a cleaver and a handaxe. Initially, van Riet Lowe was cautious about assigning an age to the finds. He stated:

"It was the first time that handaxes and cleavers which characterize the Earlier Stone Age had been found in association with faunal remains in an artificially accumulated deposit in a sealed and well cemented breccia-filled limestone cave ... " (van Riet Lowe 1948: 128).

After a further visit to the site in October 1937, during which he saw that more of the cave wall had collapsed, van Riet Lowe undertook a rescue excavation in 1938, during which B.D. Malan, van Riet Lowe's assistant, and A.G. White, of the Transvaal Museum, recovered hundreds of artefacts and processed approximately 13 tons of collapsed breccia from the original collapsed material, estimated to be 600 tons (Mason 1962: 159-169). With the exception of one visit with B.D. Malan and Abbé

Breuil, van Riet Lowe was unable to continue work at CoH as the outbreak of World War II impeded excavations and recovery efforts.

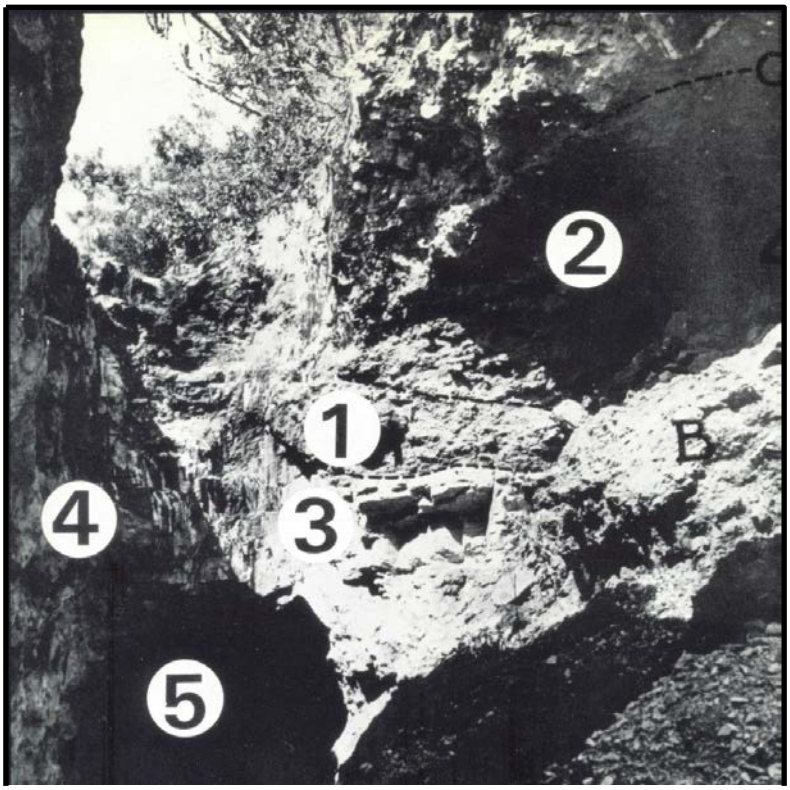


**Figure 3.8 Van Riet Lowe's Photo at Moment of Discovery January 1937** 1) Basal Guano Layer; 2) Acheulean Beds; 3-4) Position of wooden deck built in 1947 excavations; 5) Miner's Cutting; B and O) ('O' in upper right hand corner of figure) Correspond to the location of letters B and O in Fig. 3.9 (Image from Mason 1988).

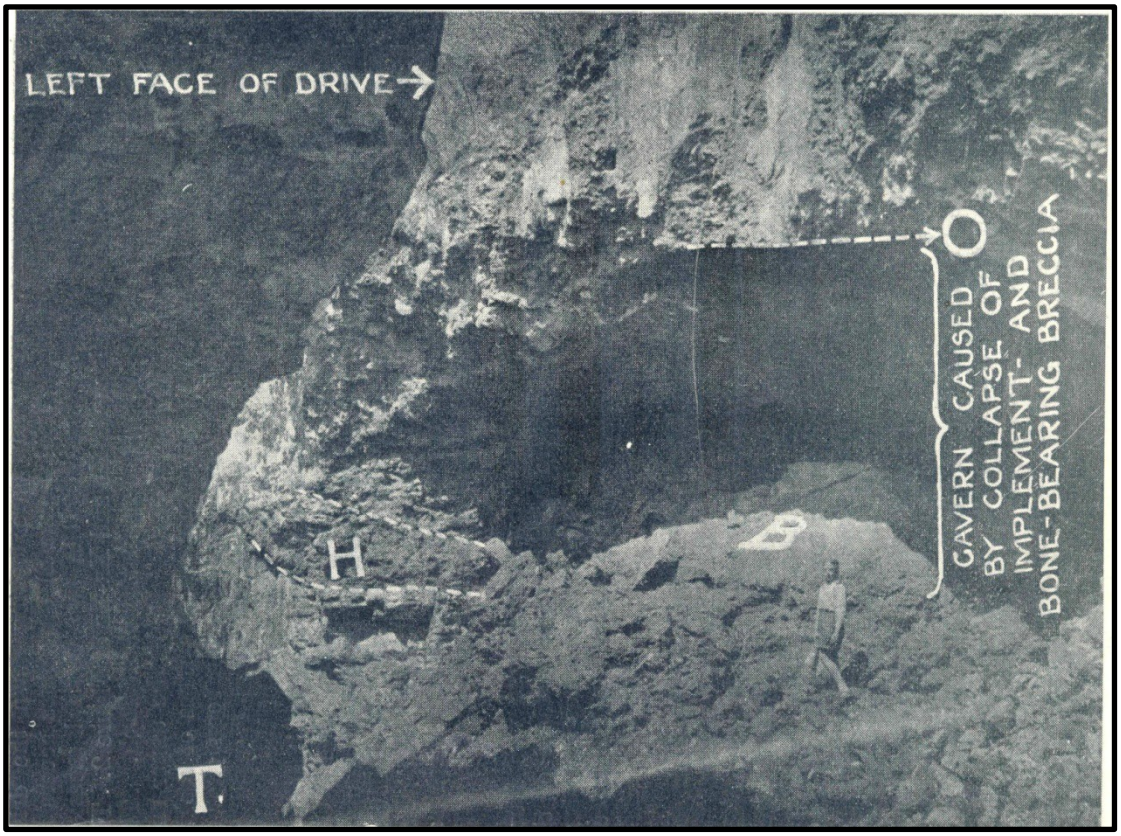


**Figure 3.9 Van Riet Lowe's Photo From June 1937** B) Largest block of breccia that collapsed between the January visit and the June visit; H) Basal Guano Layer; O) Acheulean Layers and cavern caused by collapse; T) Miner's Tunnel (Image from Riet Lowe 1938).

### 3.4.1 Post-war Excavations 'Phase One'

Two phases of excavations at CoH were undertaken after World War II ended. Dr. Bernard Price of the University of the Witwatersrand funded the first phase (Fig. 3.10) from 1947-1949 which was supervised alternately by G. Gardener and James Kitching. Though no official reports were published on these excavations, some of the recovered materials are mentioned in Mason's 1988 monograph and Maguire's 1998 Excursion Guide for the Dual Congress of the International Association for the Study of Human Palaeontology and the International Association of Human Biologists (McNabb and Sinclair 2009a: 17). What is known about their work is that it focused on clearing the site of rubble and stabilising unsafe portions of the site, while restricting excavations to the surface of the exposed breccia and the front of the cave. Most importantly, in 1947 the site's recording grid was laid, allowing for excavations to be as accurate as possible. Without the aid of dynamite or compressor driven drills, approximately 100 tons of breccia were removed and processed.

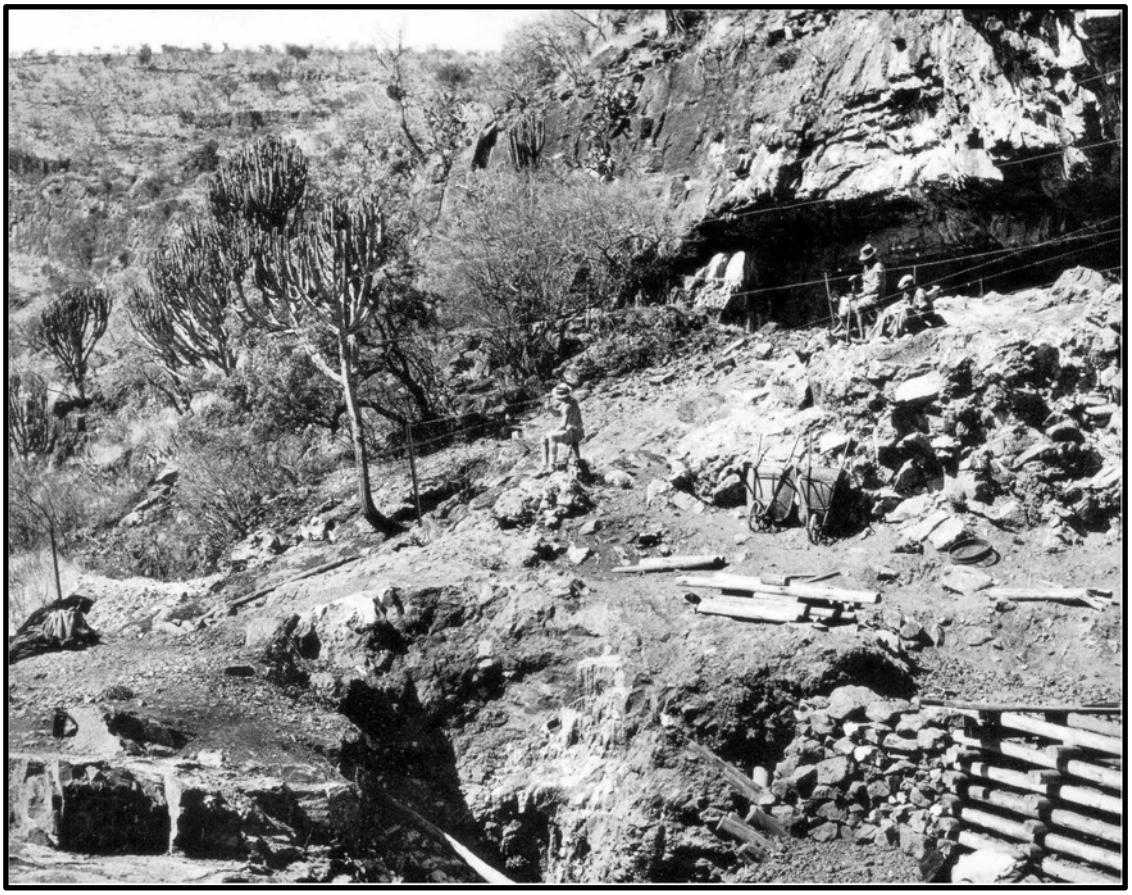

**Figure 3.10 Start of Phase One excavations 1947** (Image from Mason 1988); Mason's original caption reads "*Start of Cave of Hearths excavation, 1947. Ben Kitching, who discovered the Cave of Hearths Acheulean mandible, is at work in the foreground*".

The most significant find of the phase one excavations was Ben Kitching's (Fig. 3.10 foreground) recovery of a *Homo* sp. mandible (Fig. 3.11). Several interpretations have been published about this particular specimen (e.g., Dart 1948; Wells 1952; Tobias 1971), each arguing for or against a particular species identification. The mandible was re-examined by Darren Curnoe (2009) who re-classified it as *H. sapiens sapiens.*
However, most scholar's still accept Tobias' (1971) interpretation and generally term it an 'archaic *H. sapiens'*, rather than a truly modern *H. sapiens sapiens.* If this interpretation is confirmed then, "...the Cave of Hearths mandible is presently the oldest known modern human specimen..." based on its correlation with the Acheulean layers dated to *ca.* 0.6 Ma (see Section 3.5.2). Phase one excavations ended a year after the 1948 death of Dr. Bernard Price.

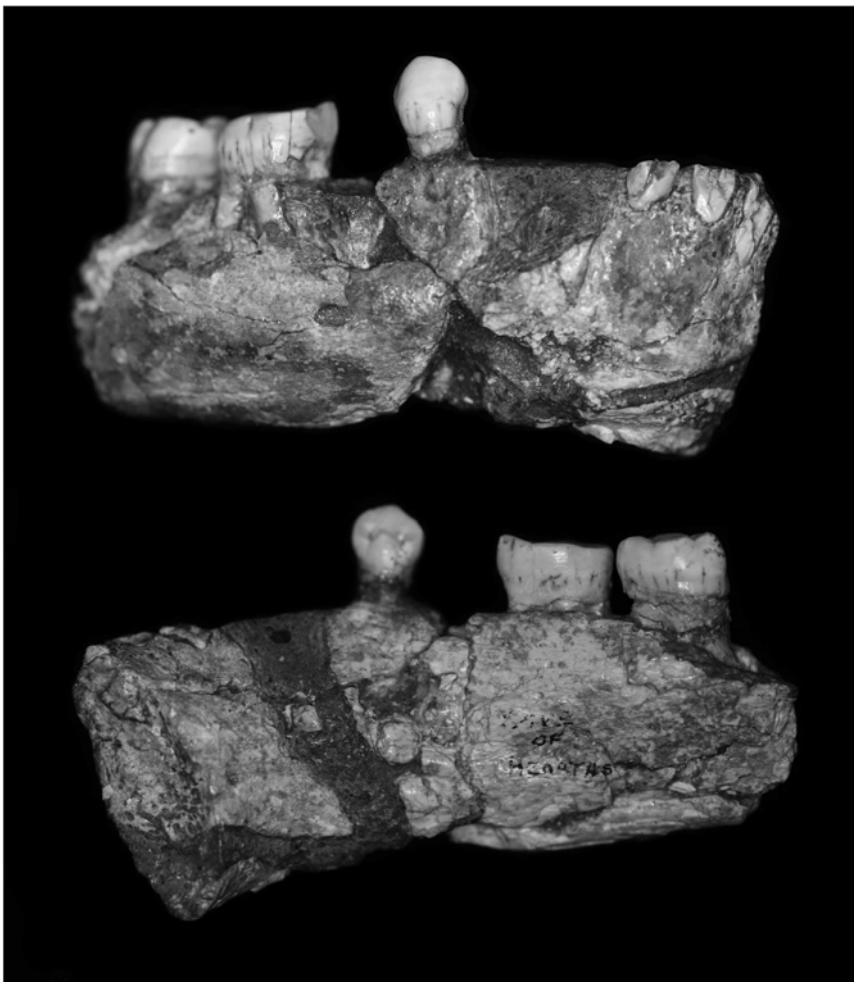

**Figure 3.11 The Cave of Hearths Mandible** (Image from Curnoe 2009).

### 3.4.2 Post War Excavations 'Phase Two'

Phase two excavations began in April of 1953 (Fig. 3.12) and consisted of two field seasons, in 1953 and 1954 respectively. Primary funding for these excavations was obtained by van Riet Lowe from the Wenner-Gren Foundation ($10 000) with smaller amounts received from personal contributions from American geologist Professor G. Barbour and French Jesuit Pierre Teilhard de Chardin after they had both visited the site (Mason 1988; McNabb and Sinclair 2009b). Additionally, another Wenner-Gren grant in the amount of $4000 allowed for the use of controlled dynamite blasting, a pneumatic drill, and a set of 'cocopan rails' to be built, which permitted faster excavation and processing of materials (R. Mason pers. comm. to T.C. Partridge 1976).

Dr. Revil Mason, newly appointed to the staff of the Archaeological Survey, of which van Riet Lowe was the Head, supervised the excavations. During

the 1953 excavations Mason (1988: 25) reports that he removed “4878 cocopan loads of rubble (approx. 1827 tons)”. While impressive amounts of deposits were excavated, the 1953 season’s primary contribution was a partial understanding of the complexity of the stratigraphy, which would only be fully comprehended after the 1954 field season. Under the direction of Mason, the rear and central portions of the cave were excavated during the 1953 season. That the stratigraphy was more complex than originally thought was realised while excavating the central section (Mason’s ‘Central Subsided Block’). The excavators encountered the central section top of Bed 4 three metres below top of Bed 4’s location at the rear of the cave, indicating that either the infilling of the cave was sloped, or that some portions of the cave had subsided.
During the 1954 field season it would be discovered that subsidence was the answer.

In October 1953, the field season concluded with the construction of a small hut, now called the Hut Witness Section, to preserve the basal guano layer in contact with Bed 1 (see Mason 1988 Figure 11 for the hut while under construction by James Kitching). The full results, details, and initial interpretations of this field season are recorded in a series of weekly reports addressed to Prof. van Riet Lowe from Mason’s field journal, reprinted in his 1988 monograph on pages 89-180, as well as in a short report by van Riet Lowe (1954). Also contained in these reports is Mason’s outline for the 1954 field season, the sole purpose of which was “the discovery of human remains” and finalising the stratigraphy by “explor[ing] the sub- 30’ levels in section OR.13-15. [as] Post-Early Stone Age [Bed] III horizons might exist in these levels” (Mason 1988: 179).

**Figure 3.12 Start of 1953 Excavations** The two men are standing on top of the Iron Age Bed 12. The overhang they are leaning against is now preserved as the roof above the cave legend sequence painted on the wall in Fig. 3.13 red number 1 (Image from Mason 1988).

The 1954 field season began in April and ended in October, completing all major excavations carried out to date at CoH (Fig. 3.13 and Fig. 3.14). The majority of the rest of the cave was excavated leaving a 'wall witness section' (Fig. 3.15 number 7). Mason (1988: 25) reports that the remaining breccia and rubble removed was "1334 cocopan loads (approx. 500 tons)". It was during this field season "that many of the missing clues were fitted into place and Mason was able to reconstruct the real extent of subsidence in the deposits" (McNabb and Sinclair 2009a: 20). Additionally, the results of the 1954 field season allowed Mason to make his final interpretations about the stratigraphic (Fig. 3.16), cultural, and depositional sequences.

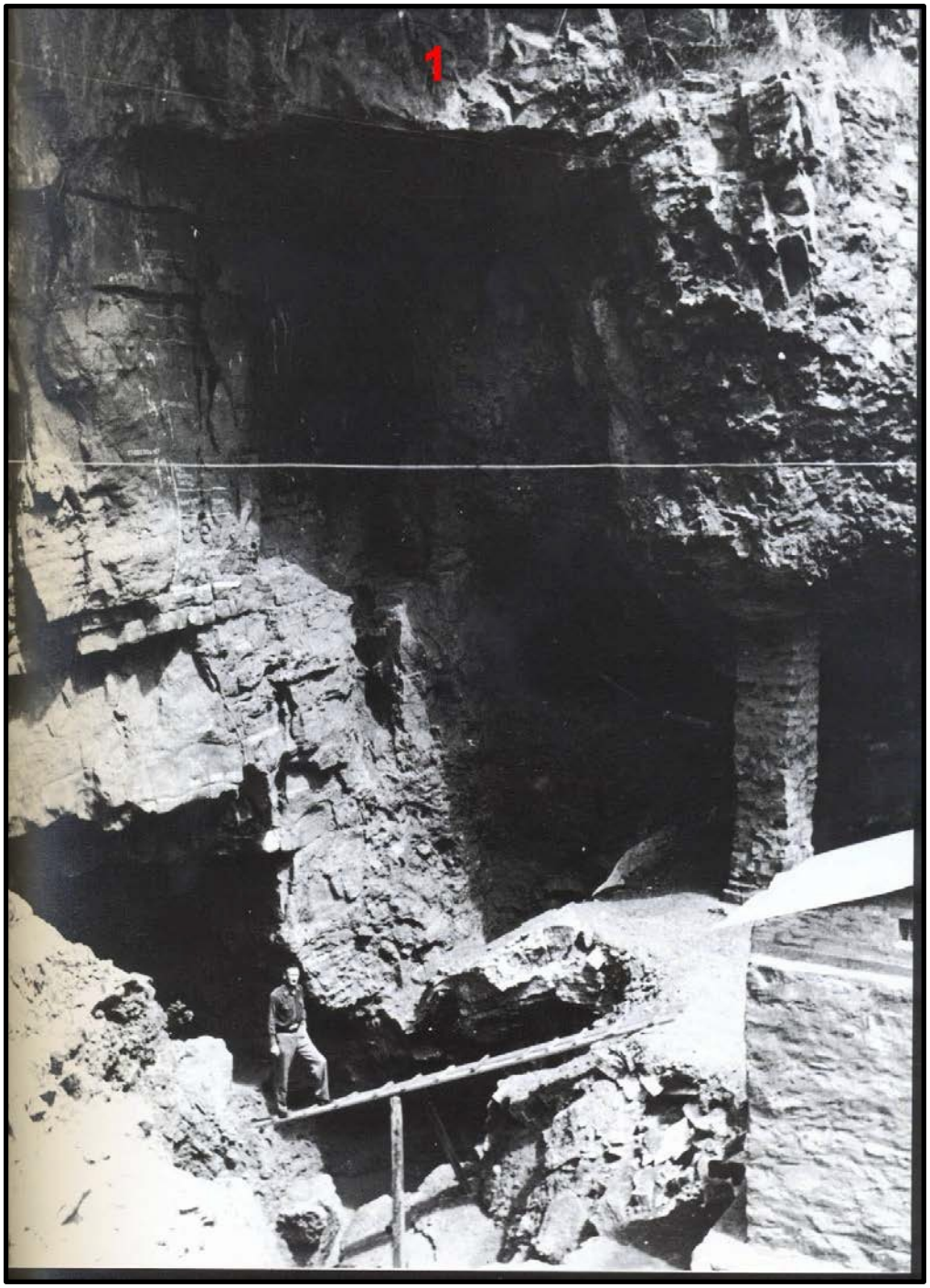


**Figure 3.13 End of 1954 Excavations with Cave Legend Sequence Painted on Back Wall** Red number 1 corresponds to the overhang the two men are leaning against in Fig. 3.12 (Image modified from Mason 1988).

**Figure 3.14 End of 1954 Excavations** Hut Witness Section roof can be seen as well as cocopan rails leading to rubble heaps (Image from Mason 1988).

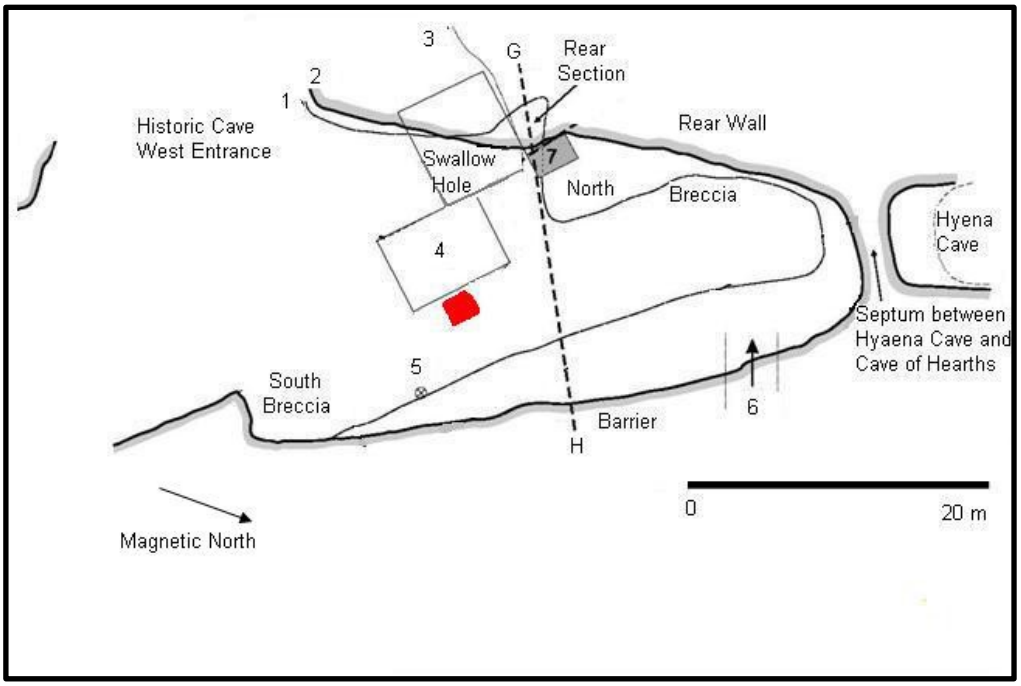


**Figure 3.15 Plan View of CoH** 1) Wall at datum, Top of Bed 11; 2) Wall at *ca.* 9 m below datum; 3) Swallow Hole at just over 13 m below datum; 4) Subsided Block; 5) Position of *H.* sp. mandible shown in Fig. 3.11; 6) Modern entrance to cave blasted through barrier; 7) Wall Witness section; Red Square) Hut Witness Section (Image modified from McNabb and Sinclair 2009b).

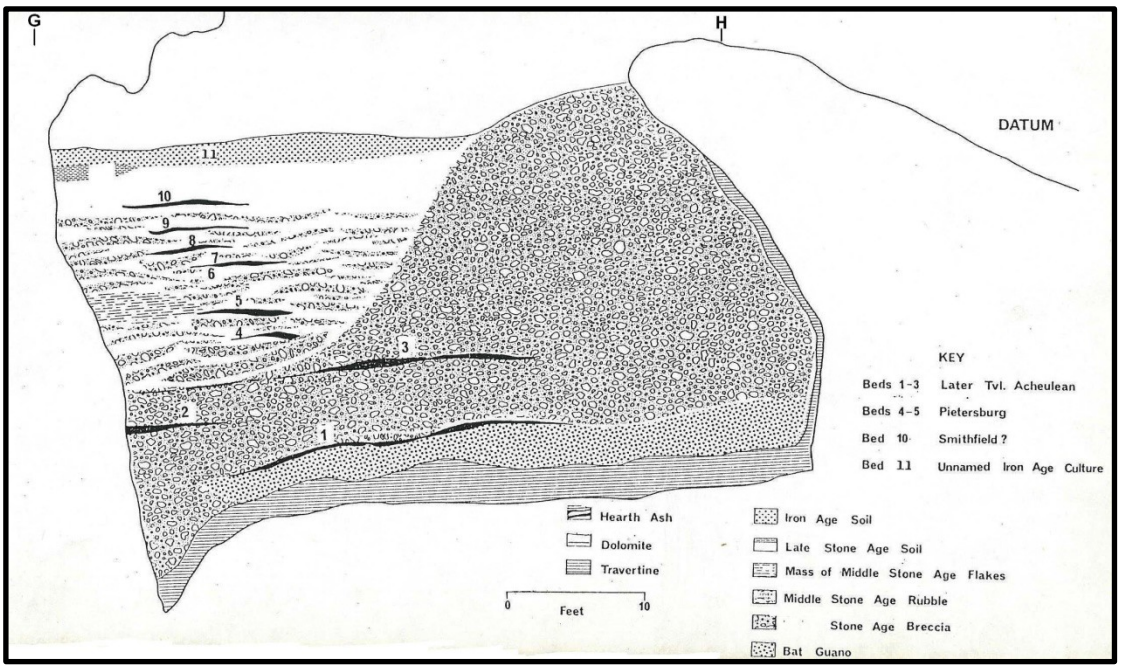


**Figure 3.16 Mason's Stratigraphic Sequence** Profile view along line G-H in Fig. 3.15 (Image from Mason 1988).

### 3.5 Makapan Middle Pleistocene Research Project (MMPRP)

While Mason's 1988 monograph is still accepted as the authoritative text on CoH, Dr. Anthony Sinclair, of the University of Liverpool, and Dr. Patrick Randolph-Quinney, of the University of the Witwatersrand recently initiated a re-examination and reanalysis of the artefacts recovered from Mason's excavations. Additionally, their results included new findings based on fieldwork carried out during 1996-2001.

#### 3.5.1 Hearths and Fire-use

Upon discovering CoH, van Riet Lowe interpreted the basal Pre-Bed 1 "white ashy layers" to be hearths (van Riet Lowe 1938, 1954; this layer is still preserved in the Hut Witness Section). That is, they were interpreted as evidence of intentional fire use, implying that the hominins at CoH knew how to, and did, control fire (Mason 1962). A preliminary analysis of the soil by the Director of the Geological Survey revealed 'free-carbon' (van Riet Lowe 1938: 372), which at the time was a sure sign of hearth accumulation (McNabb and Sinclair 2009a: 13) and strengthened the argument for ESA hearths at CoH. However, the Director cautioned that the soil could have been set alight by a natural fire (van Riet Lowe 1938: 372). To this, van Riet Lowe replied, "The possibility that the stratum with the free carbon...is due to natural agencies in the particular situation in which it occurs is I feel, very slight, though it naturally cannot be ruled out

at this stage" (van Riet Lowe 1937, 1938: 372). In 1954 results of a re-analysis of the soils, conducted by Miss P. Hammond and Mr. A.E. Rixon of the Palaeontological Laboratory of the British Museum of Natural History (Oakley 1954), revealed a total lack of free-carbon. This finding was so surprising that two additional samples were tested, yielding similar findings (Oakley 1954: 262). To further verify the results, Oakle visited the site in March of 1953 with Prof. van Riet Lowe and Prof. and Mrs. Raymond Dart, before Mason's excavations began. He collected another sample of the basal hearth deposit during this visit and upon testing it again found the same result. This cast doubt on the notion that the white ashy layers were hearths. Oakley's interpretation was that the basal-hearth was likely calcined bat guano and he asked Mr. Rixon to perform phosphate analysis of the soil to confirm this suggestion. The results showed that the samples:

> "were in fact largely phosphatic (averaging more than 20 per cent $P_20_5$, compared with 15 percent in a sample of experimentally calcined bat-guano and 2 per cent in an overlying [MSA] undoubted hearth). A further test showed that the material contained sufficient oxides of iron to account for its colour (dark grey with yellowish streaks)" (Oakley 1954: 262).

Oakley believed the basal layer had, in some way, been naturally combusted, possibly through a lightning strike or a grass fire. He seems to have favoured the latter explanation as Dr. Desmond Clark had reported an incident while working at Mumbwa Caves in Zambia in which a grass fire burned up to the mouth of a cave and roared into the cave, because of a through draft, as if it were a furnace. Oakley supports his natural combustion theory by saying that "...in such circumstances the ignition of bat-guano and local fusion of intermixed sand would be by no means inconceivable" (Oakley 1954: 262). Despite this evidence, Mason still believed that there were hearths in the Acheulean layers at the cave, and presented this interpretation in his 1962 and 1988 publications. An alternate suggestion for the white ashy layer is that the guano layer spontaneously combusted during a particularly dry and hot period (P. Randolph-Quinney pers. comm. 2013). Further evidence for the lack of hearths at CoH is Herries and Latham's (2009: 59) observation that the layer initially interpreted to be a hearth contained "...intact, un-burnt rodent bones incorporated in the sediment at the base of the Hut Witness Section..." suggesting that, at least in this section of the stratigraphy, there had been no fire at all.

To settle this debate, as well as to provide chronological data, Herries and Latham (2009) carried out a series of studies on soil samples from CoH. They focused on two lines of inquiry: 1) studying the presence and intensity of the Earth's magnetic field, in particular looking for the Brunhes-Matuyama boundary in the basal layer, which if found would give an oldest age estimate of *ca.* 0.78 Ma (see Section 3.5.2); and 2) mineral magnetic studies observing the magnetic minerals present in the soil, and their grain size and concentration, as this line of inquiry can provide evidence for the presence or absence of fire in the sediments at CoH. The best preserved evidence for possible fire-use at CoH is at the bottom of Bed 3, now preserved in an *in situ* breccia block. If one stands near the stone pillars (see Fig. 3.13 right hand side) and looks directly up, the observer will see a circle of bones with a small black patch, effectively viewing the underside of a hearth (Fig. 3.17) as Mason interpreted it. Though laboratory samples could not be taken from this particular feature, Herries and Latham (2009) conducted *in situ* studies using a portable susceptibility meter.

**Figure 3.17 'Hearth Feature' from Bed 3** (Image from Herries and Latham 2009).

Herries and Latham (2009) also took samples from the presumed hearth layers still preserved in the Hut Witness Section, from layers preserved in the Wall Witness Section, and control samples of un-burnt breccia and soil

from various locations in and around the CoH area, including the dolomite barrier, Hyena Cave, and Historic Cave- West Entrance. They report that standard mineral magnetic methods, established by Walden *et al.* 1999, were used in their analyses. By comparing the 'hearth' samples with un-burnt specimens, Herries and Latham (2009: 62) determined that none of the samples taken from CoH had been burnt. They report that the minerals and grain sizes observed in the samples are the "opposite of what would be expected in burnt sediments from experiments and work at other South African MSA cave sites" (Herries and Latham 2009: 63).

Essentially, the pre-Acheulean guano layers interpreted as hearths by Mason are not hearths at all. The *in situ* results from the magnetic susceptibility test of the 'hearth feature' (Fig. 3.17) also showed no indication that this area had been exposed to fire. It is likely that the black colouration around the feature is the result of manganese dioxide staining from running water, similar to the process that blackened the bones at the Makapan Limeworks (Herries and Latham 2009: 63). Furthermore, results from Fourier Transform Infrared Spectrocscopy (FTIR) point to the same conclusion, (i.e., based on the analysis of the materials available to us at the present time, it is highly likely that there were never any hearths at CoH during the Acheulean). The authors conclude their section on fire-use at CoH by saying:

> "We have so far not found convincing evidence of hearths…at the Cave of Hearths…Unfortunately there is no extant evidence from the excavations of areas described as hearths other than those studied. We do not rule out the possibility, indeed probability, of hearths being present, but so far our studies have not demonstrated any evidence for them" (Herries and Latham 2009: 64).

### 3.5.2 Chronology and Dating

In addition to the mineral magnetic studies carried out, Herries and Latham (2009) analysed the samples taken for palaeomagnetic shifts to establish a date for the deposition of the CoH deposits. Their analysis was based on standard palaeomagnetic techniques established by Butler (1992) and they reached several conclusions regarding the age of the deposits: 1) The Brunhes-Matuyama Boundary was not found in the basal levels below Bed 1; 2) One palaeomagnetic reversal was recorded in the soil samples (Fig. 3.18 'magnetic excursion'), but it was neither old enough

nor long enough to be the Brunhes-Matuyama boundary, and the authors state that the likely candidates for this magnetic reversal are “the Biwa III at 390 kya, Emperor at 460 kya, or Big Lost at 560 kya” (Herries and Latham 2009: 62); and 3) these data suggest that the basal layers at CoH were deposited after 0.78 Ma, as the Brunhes-Matuyama boundary is not evidenced in the sediments. The sediments are probably *ca.* 0.5 Ma old based on the aforementioned candidates for the magnetic polarity shift. This new data gives the Acheulean archaeology at CoH a relatively secure age range of *ca.* 0.5 to 0.77 Ma.

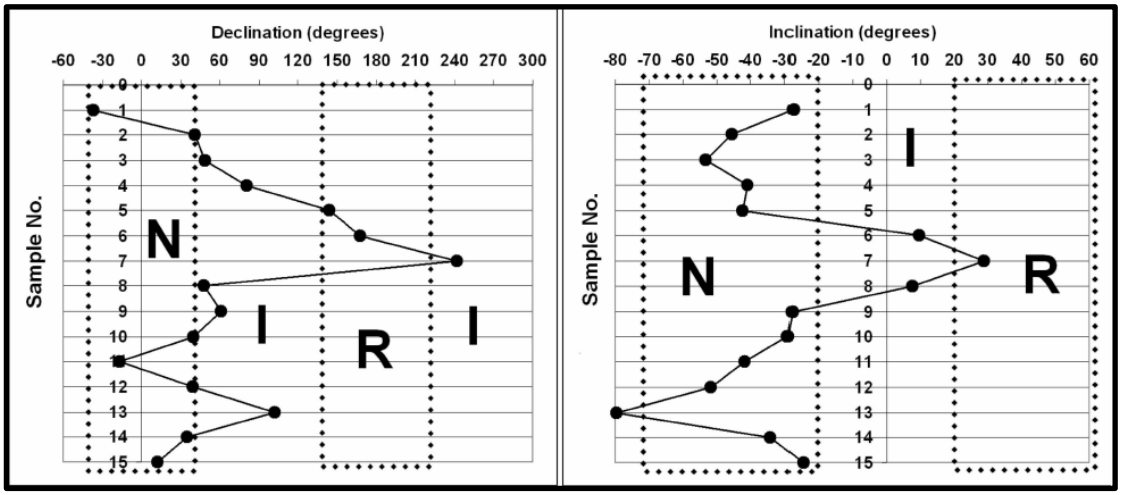


**Figure 3.18 Palaeomagnetic Data** (Image from Herries and Latham 2009) original caption reads “*Palaeomagnetic data; Declination (horizontal component) and inclination (vertical component) for the Cave of Hearths versus sample number (with depth in strata). N = normal polarity region, I= intermediate polarity region and R = reversed polarity region. The magnetic excursion can be seen from samples 3 to I 0. The excursion in sample 13 is thought to be due to depositional issues”.*

### 3.5.3 The CoH Acheulean in a Broader ESA Context

One of the MMPRP’s goals was to place the CoH Acheulean in a broader ESA context, with particular regards to its chronology (see Section 3.5.2) as well as its ‘tradition’ (i.e., Early, Middle, or Later Acheulean). These two are seen as mutually inclusive with the technological tradition changing with the times—a product of *zeitgeist*. On this point, Wadley and McNabb (2009: 4) state: “The search for an effective cultural succession within the Acheulean…still remains a high priority of South African ESA research.

But it is one that must be linked to a robust chronological framework”. The succession generally starts with the Early, or Earliest, Acheulean *ca.* 1.76 Ma and is composed of ‘crude’ HDTs with little refinement (read retouch or

secondary modification) occurring on the tools, and largely made from pebbles or boulders rather than from flake blanks. Moving forward in time, and into a possible 'Middle Acheulean', refinement improves and a higher percentage of HDTs are made from flake blanks and large flake blanks (LFB) rather than from pebbles or boulders. This change to using LFBs is perceived "as a technological threshold, enabling the Acheulian biface makers to evolve beyond the developed Oldowan" (Sharon 2010: 230). Following this is the Later/ Latest/ Final Acheulean, which begins to incorporate regional variants (see Section 2.1) possibly leading into the MSA Levallois.

After the re-analysis of the CoH Beds I-III lithic items, as well as the dating analysis carried out, McNabb *et al.* (2009) believe that they have sufficient evidence to place the CoH within the LFB Acheulean (initially defined by Sharon 2007, 2008, 2010). One of the characteristics of the LFB Acheulean—a high percentage of cleavers in an assemblage—is clearly represented in the CoH Acheulean. McNabb and Sinclair's (2009a) Table 2.3 shows that, of the 268 HDTs recovered from Bed 3, approximately 78% (n=210) are cleavers. For the total Acheulean assemblage from undisturbed and properly provenanced locations, McNabb's (2009) Table 7.1 shows the same trend. Of the total 226 HDTs, approximately 63% (n=142) are cleavers. These two tables also present data that supports Sharon's second character trait of the LFB Acheulean -- a preference for coarse grained material in manufacture of HDTs. Of the 268 HDTs from Bed 3 presented in Table 2.3, approximately 81% (n=218) are made from quartzite. Table 7.1 presents a total of 226 HDTs, of which approximately 66% (n=150) are made from quartzite. Sharon (2008: 1342) has shown that Acheulean LFB tool makers preferred coarse-grained material, even when finer grained materials, such as flint, chert, or obsidian, were available. However, as I noted (Section 3.2), and as mentioned by McNabb *et al.* (2009: 153), the Black Reef Quartzite is fine grained and easily knappable, possibly making the "coarse-grained" character trait of Sharon's LFB not applicable at CoH. In the end, McNabb *et al.* (2009: 154) interpret the CoH Acheulean as "an LFB Acheulean assemblage, albeit one with a local character imprinted on to an LFB Acheulean base-plan".

### 3.5.4 Additional MMPRP Re-analysis

In addition to the results presented in the previous sections, a number of other studies was carried out as part of the MMPRP, including: 1) analysis of the taphonomy of the Acheulean faunal assemblage (Ogola 2003, 2009); 2) re-analysis and re-interpretation of the MSA assemblage(Sinclair 2009); 3) the aforementioned (Section 3.4.1) re-classification of the CoH Bed 3 mandible (Curnoe 2009); and 4) most importantly for this study, re-analysis of the entire ESA stone assemblage from Beds I-III (McNabb 2009).

## 3.6 Conclusion

This chapter presented a background for CoH, including sections on the geology, history of discovery, excavations, and geophysical settings. New data generated by the MMPRP was presented, providing the most recent interpretations of the Acheulean at CoH. Finally, the analyses done by the MMPRP indicate that the CoH Acheulean is part of Sharon's (2007, 2008, 2010) LFB Acheulean, but with a local character, possibly due to the fine grained nature of the quartzite from which the LFBs were manufactured.

# Chapter 4
# Techniques Utilised and Previous Studies

## 4.1 Introduction

This chapter presents the techniques that constitute the multi-stranded approach. Each has its own section discussing their advantages and disadvantages, their history, and case studies that highlight the benefits of these techniques when employed properly. Additionally, previous studies focusing on the usage of HDTs are presented.

## 4.2 Experimental Archaeology

Experimental archaeology (EA) has been defined in various ways. Rouse's (1939) study of the prehistory of Haiti was considered experimental because he tested a proposed analytic method. Other studies (e.g., Meighan 1950) termed EA evaluated different field techniques and tested their relative efficiency against one another. Wiley's (1953) study of settlement patterns in the Viru Valley, Peru was called EA because it combined the testing of both a particular field and an analytic method. Using one's imagination to create a model on which conclusions are based has also been considered EA, such as Thompson's (1954) study of a Roman aqueduct in which his excavations "were guided by entertaining and manipulating mental images of the course the aqueduct reasonably could have taken" (Ascher 1961: 793). However, EA has advanced considerably since these early publications and is now seen as a viable technique for solving archaeological problems.

In this study I utilise Ascher's (1961) definition of EA, which clearly explains its goals. Ascher (1961: 793) states that EA is a "category of experiments [that] entails operations in which matter is shaped, or matter is shaped and used, in a manner simulative of the past". This definition should not be confused with the re-creation of prehistoric/ historic items as a hobby or profession in which the task is done for the sake of art, enjoyment, or to provide an income. Rather, this process is based in science and logic (Coles 1973, 1979a; Outram 2008) and can be placed within a sound methodological framework, if using materials and processes which were likely available to the prehistoric culture(s) under study (Ascher 1961: 809).

This technique is valuable in several ways: 1) it provides insights that are

not obtainable through other avenues of study (e.g., Chandlee *et al.* 2014); 2) it allows for inferences and provides data about the past without the destruction of the archaeological materials (e.g., Ferguson 2010); 3) it often raises new questions that would not have been investigated had EA not been undertaken (e.g., Lipo *et al.* 2013); and 4) it can be applied to a wide range of archaeological disciplines and questions. In short, few other techniques can provide the same quantity and quality of data that EA can. However, EA should not be used solely by itself in addressing an archaeological problem. Experimental archaeology is best utilised in tandem with other lines of archaeological inquiry as this is when it provides the most fruitful results (seen in the following case studies).

### 4.2.1 Case Study 1: An Axe to Grind

The study of axes and their functions has long been a research interest of archaeologists. For over 100 years different forms of experimental archaeology have been used to investigate possible factors revolving around the chopping, cutting, shaping, and felling of trees (e.g., Sehested 1884; Smith 1891; Montelius 1906; Pond 1930; Coles 1979b). The earliest studies focused solely on whether or not stone axes were capable of felling trees (Sehested 1884; Smith 1891; Montelius 1906). Later researchers were concerned with the efficiency—defined in various ways (e.g., kilocalories expended per minute, time taken to fell a tree, oxygen used per minute)—of stone axes compared to metal axes (Carneiro 1979; Saraydar and Shimada 1971, 1973).

Mathieu and Meyer (1997), however, recently conducted a study into the efficiency—defined as minutes taken to fell a tree—of bronze, steel, and stone axes. The authors' goals in this study were not only to test and compare the efficiency of the tools, but also to: 1) test the efficiency of bronze axes and compare them with steel and stone because "surprisingly there has been little published experimentation with bronze" and of the experimentation that has been done "practically all of the specific experimental information can only be found in archived documents" (Mathieu and Meyer 1997: 335); 2) investigate some of the key variables that may influence efficiency in felling trees (e.g., type [hardness]), haft length, blade width, axe weight, axe shape, and tree size). They note that previous researchers have attempted to quantify these variables, but with small sample sizes and insufficient control over the variables (Mathieu and Meyers 1997: 336); and 3) they intended to "identify and discuss variables that have not received sufficient treatment in the literature" (Mathieu and Meyers 1997: 336).

To meet these goals, the authors chose four pre-manufactured steel axes, which would have been commercially available in the mid- to late-twentieth century. For the bronze axes, replicas were manufactured for the study, which included two axes modelled after “palstave” type axes, typical of the Middle Bronze Age (Davey 1973: 52-53: Tylecote 1986: 32-33), found in the University Museum of Archaeology and Anthropology, University of Pennsylvania (Mathieu and Meyers 1997: 336). For the stone axes, four Neolithic axes were chosen from the collection held at the aforementioned museum, two of which were polished flint and the remaining two were axes “made by pecking and grinding an aphanitic or granular, greenish, simatic stone” (Mathieu and Meyers 1997: 336). While this is atypical in experimental archaeology, (i.e., using authentic artefacts in the experiments), the authors report that “The Artifact Destructive Testing Committee approved their use with the consent of the curator of the European Section” (Mathieu and Meyers 1997: 336).

Next, the authors chose different handles and hafting arrangements (Figs. 4.1 & 4.2) but used the same species of wood, throughout, *Acer negundo*, or ash-leaved maple, to keep this variable consistent. They did, however, vary the lengths of the handles and the weights of the axe and handle combination to determine if these variables played any part in the efficiency of the axes. After the axes were successfully hafted, the authors decided which trees to fell and what variables they wished to control. Ultimately, they decided to chop five hardwood trees and five softwood trees with each axe. They used each bronze and steel axe to chop five Poplars (*Populus deltoids)* and five Ash-leaved Maples (*Acer negundo)*. However, there were not enough trees available to use each stone axe to cut the same species used for the metal axes. The authors consequently decided to employ the two polished flint axes to cut five White Pine (*Pinus strobes*) and five Sugar Maples (*Acer saccharum*), while they utilised the ground-stone axes in chopping five Poplars (*Populus deltoids*) and five American Elms (*Ulmus Americana*).

Before the tree cutting began, the authors chose to control multiple variables (e.g., swing type, tree type, handle length, tree diameter, etc.). Once the experiments were completed, the authors recorded all the data and found some interesting results. One of the most interesting is that for trees with diameters less than or equal to about 10 cm, no one axe type was more efficient than another and no variables affected efficiency (Mathieu and Meyer 1997: 347). After this “10 cm threshold”, however, the situation changed with bronze and steel becoming more efficient than stone as tree diameter increased (proven in multiple previous studies).

**Figure 4.1 Hafted Bronze Axes Used** For scale: the blade widths (lengths of the cutting edge) are 5.5 cm and 6.0 cm (Image from Mathieu and Meyer 1997).

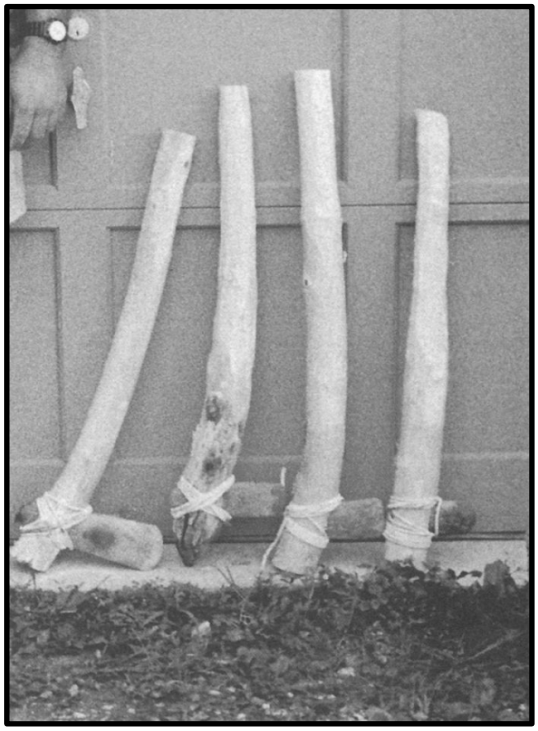

**Figure 4.2 Hafted Stone Axes Used** For scale: The length of the handle to the far left is 73 cm (Image from Mathieu and Meyer 1997).

One finding that surprised the authors is that the bronze axes performed no less efficiently than steel axes. It had been previously proven that bronze was a softer metal than steel, suggesting that "one would suppose that the bronze axes would be inferior to the steel axes" (Mathieu and Meyers 1997: 340). To strengthen their case, the authors performed the standard Vickers Hardness Test, which gives readings of hardness in Vickers Pyramid Numbers (HV). The premise of the test is that a machine with a pyramid shaped diamond tip is pushed into a given metal to test the resistivity to plastic deformation. The bronze axes received values of 108 HV and 144 HV, while the steel values centred around 580 HV, or four to five times harder than the bronze.

Ultimately, the authors concluded that one of the previously held notions for switching from bronze to steel (i.e., it was a harder and therefore more efficient metal) was not proven by their tests—at least when it came to woodworking. They also found that hardwood trees (e.g., maple) took longer to fell than softwood trees (e.g., pine), irrespective of the type of axe used. With regard to stone axes, they found that each type, polished flint and ground stone, had their advantages and disadvantages, and that one was no more efficient than the other (Mathieu and Meyer 1997: 343). They observed that the polished flint axes had sharper and thinner cutting edges making it easier to penetrate the tree, but that this often led to the possibility of the axe head breaking, which happened to one of their artefact experimental axes. On the other hand, the ground stone axes had slightly thicker and duller cutting edges, making initial penetration more difficult; but they resisted breaking because of their thickness. This observation led the authors to suggest that:

> "The choice of material for axe manufacture may not only be linked to the availability of certain stone types, but also to the local flora. If the local flora is of a softwood nature, we may expect to find more polished flint axes, and conversely if the flora is normally hardwood, we may expect to find a higher proportion of ground stone axes" (Mathieu and Meyer 1997: 343-344).

Other variables that were reported to affect efficiency were: 1) length of handle, but only when the tree's diameter exceeded 25 cm; and 2) angle of cut, with an average angle of penetration of 70º for metal axes and 85º for the stone axes. The authors ran a one tailed t-test and the data "produced a probability of less than 0.0005, demonstrating a significant difference in the angle of cut for the two axe types". They continue by explaining that "the metal axes were more efficient at penetrating the heartwood

[duramen] because they required a smaller entry into the tree, with the result that less wood needed to be removed from the tree in order to fell it" (Mathieu and Meyer 1997: 346).

Finally, the authors conclude with several observations that could have only been made by analysing data generated through EA. The first was that bronze was no less efficient at tree felling than steel, contrary to what had long been presumed because of bronze's softness compared to steel. The second was that handle length did affect efficiency, but only once the tree being felled reached 25 cm in diameter. Third, they discovered, as had been expected, that hardwood trees took longer to cut down than softwood trees, whether the operator was using a stone or metal axe. Lastly, they noted that trees at or below 10 cm in diameter could just as efficiently be cut down with either metal or stone. One of the most important outcomes of the study is their data and conclusions could only have been obtained by using EA, and they advocate further studies that include and evaluate more variables than used in their own experiments (Mathieu and Meyer 1997: 350).

The results of this study can be applied to and inform my study in a few ways. The first is that the authors have proven that stone axes are perfectly capable of cutting down trees (whether hardwood or softwood). This means that it is possible that Acheulean handaxes could have been used to work wood, especially if hafted in ways similar to those that Mathieu and Meyer used (Fig. 4.2). Thus, I should be particularly cautious when analysing the LCTs from CoH and look for hafting traces as well as a combination of woodworking and hafting traces on the same tool. If this combination is found then it could suggest that the tool was used in cutting wood in an axe like motion. Additionally, the study highlights the importance of controlling as many variables as possible so that the conclusions reached are as robust as possible. Lastly, it highlights how well experimental archaeology works when compared with other lines of inquiry (e.g., statistics and material sciences).

### 4.2.2 Case Study 2: Smoke 'Em If You Got 'Em

The smoking of various plants, usually through a pipe made of wood, clay, stone, or bone, has been recorded for most cultures around the world. Finds and results from Australia (Gojak and Stuart 1999), Africa (Phillips 1983), England (Davey 1981), and the United States (Rafferty 2002) are but a few examples of the extensive literature that all attest to the fact that for hundreds, and possibly thousands of years, *Homo sapiens sapiens* have smoked pipes (for a global perspective of pipe smoking see Shaw 1960).

Despite this knowledge, there has been relatively little research into the manufacture of pipes, particularly those of stone. Recently, Chandlee *et al.* (2014) of which I was a co-author, undertook the task of recreating a form of pipe, called the Florence/ Windom pipe (Blakeslee 2012), common to the central plains of the United States (Wedel 1959; Blakeslee and Hawley 2006; Blakeslee 2012). Based on archaeological evidence it appears that the Florence/ Windom pipe preceded the better known Calumet pipe (Blakeslee 1975, 1981, 2012; Brown 1989; Turnbaugh 1979) and was used solely for mediation within and between Great Bend Aspect peoples, whereas the Calumet ceremony is known to have been used inter-tribally as well as between tribal and European nation representatives (Blakeslee 2012).

Chandlee *et al.'s* (2014) work was part of a larger project (Law de Lauriston *et al.* 2015, of which I was also a co-author ), the goal of which was to determine if stone artefacts from the Robb Collection (Blakeslee 2012) were utilised in the process of pipe manufacture. Chandlee *et al.'s* (2014) work provided the experimental archaeology portion of the project while Law de Lauriston *et al.'s* (2015) work provided a use-wear analysis of a sample of the Robb Collection tools. Both projects were also undertaken to aid in confirming a preliminary chaîne opératoire of pipe manufacture proposed by Blakeslee (2012).

First, Chandlee *et al.* (2014) replicated tools (Fig. 4.3) that were of a similar morphology to those found in the Robb Collection of artefacts (Fig. 4.4).

**Figure 4.3 Replicated Tools used by Chandlee *et al.* (2014)** Left to right: unhafted drill, endscraper, and reamer (Image from Chandlee *et al.* 2014).

**Figure 4.4 Archaeological Examples from Robb Collection.** Left to right: buttonhole maker, endscraper, and reamer (for morphological definitions of these types see Blakeslee 2012).

The next step in our process was the procurement of a piece of raw material from which to make the experimental pipe. We used a piece of Minnesota Pipestone (Fig. 4.5), though the Windom pipes are made of Kansas Pipestone, as the two are both geologically similar and a piece of Kansas Pipestone large enough from which to create a pipe was not available. We followed the steps suggested by Blakeslee (2012) in making our pipe to accurately test whether or not Blakeslee's proposal was plausible.

We began by sawing into the block of pipestone to create the rough shape of the pipe. We report that sawing "was a much more difficult process than anticipated; therefore the pipe was re-oriented within the block to reduce the number of cuts necessary to complete the primary stages" (Chandlee *et al.* 2014: 123). We believe that this is likely to have happened in proto-historic times as well, as it seems like a logical way to reduce the overall time spent on making the pipe. Initially, we used the sides of an endscraper to saw into the block, but noted that after approximately 1.5 cm, the high edge angle of the scraper widened the cut rather than deepening it (Chandlee *et al.* 2014: 123).

From this point forward, we switched to using thinner flake tools, one cortical flake with retouch and one without to determine if retouch provided any advantage when sawing through pipestone. We found that retouch hindered the sawing process and the un-retouched flake worked more efficiently as the edge of the flake fractured during use, effectively re-sharpening the flake as sawing proceeded and adding bits of raw material that acted as abrasive matter which reduced the sawing time. In total, to make the roughout of the pipe (Fig. 4.6) it took "approximately 122 hours and the cuts covered a combined length of 64.5 cm...at approximately 123.5 strokes per minute" (Chandlee *et al.* 2014: 124-125).

For sawing, and for all activities, we recorded the time spent and the number of strokes (based on counting the number of strokes in a 2-3 minute period, averaging that number for one minute, then multiplying that number by the total amount of minutes spent on that activity). Each of the three authors took part in all activities and each authors' time and strokes per minute (S/M) were recorded using the aforementioned method. The reported S/M for each activity were recorded for each author then "averaged to obtain a more standardized [sic] number". The times were added to obtain the total amount of man-hours needed to produce a finished pipe (Chandlee *et al.* 2014: 125).

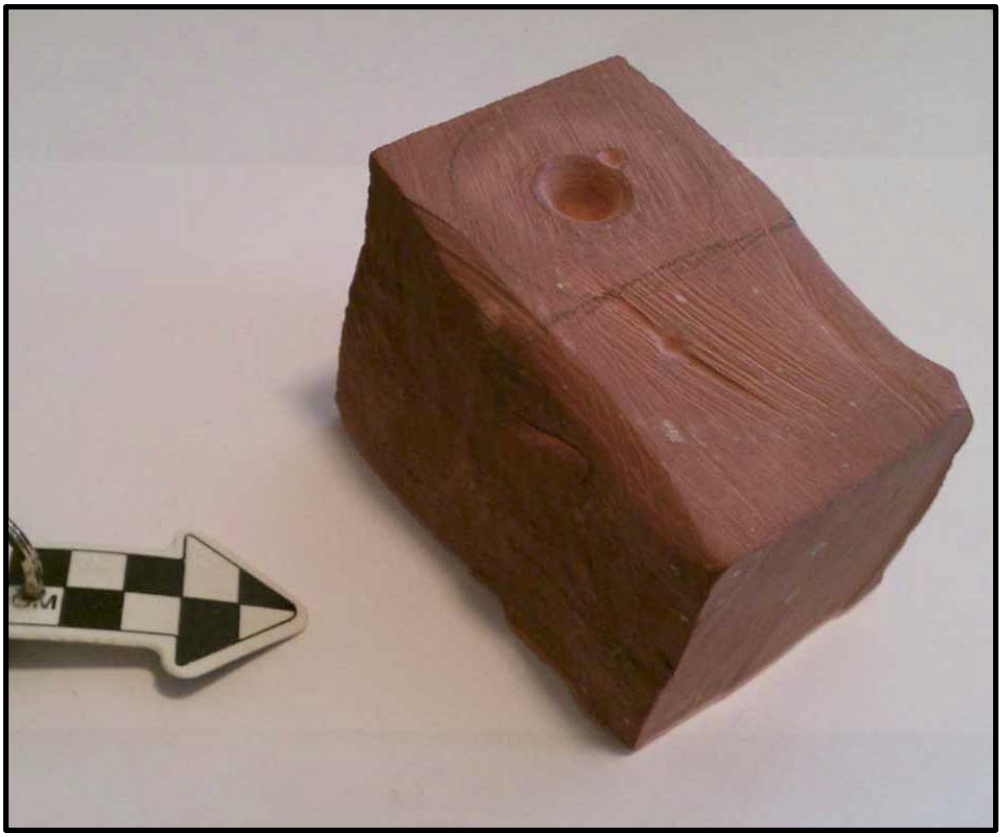

**Figure 4.5 Block of Minnesota Pipestone used by Chandlee *et al.* (2014)** Note that a drilling experiment had already taken place as evidenced by the shallow hole (Image modified from Chandlee *et al.* (2014).

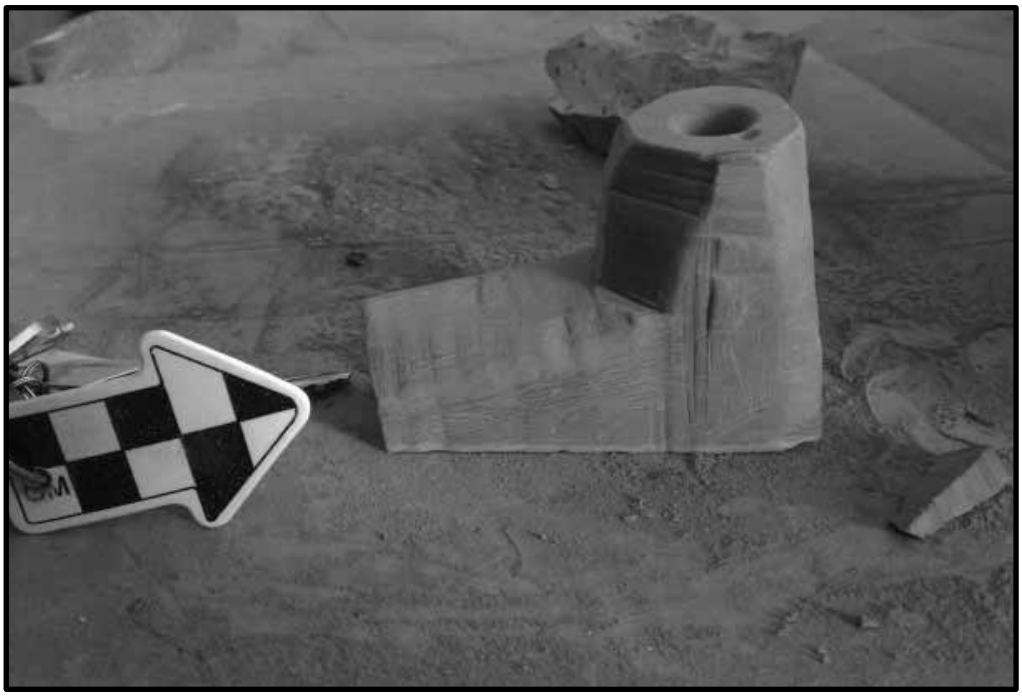

**Figure 4.6 Roughout of Pipe** (Image modified from Chandlee *et al.* 2014).

Once the roughout was formed, we began to scrape away the rough edges to make the pipe more refined. At first, we tried using endscrapers, believing the thick edges would prove useful in this task. What we found however, was that the endscrapers were not at all efficient. We then tried using various other stone tools (e.g., retouched flakes, reamers, or un-retouched flakes) none of which removed as much material as expected. With the scraping progressing rather slowly, we decided to switch to using various grits of sandstone to 'scrape' the pipe. We found "that sandstone was the most productive, both in ease of use and quantity of material removed"[3], and sanding and scraping together continued for approximately four hours at an average rate of 114 S/M (Chandlee *et al.* 2014: 125).

With the pipe now fairly smooth (Fig. 4.7) we began the drilling process, cautious about possibly breaking the pipe if the walls were thinned to their final proportions before drilling started. A variety of different drilling tools were used (e.g., an unhafted, hand-held drill (see Fig. 4.3), a hafted drill, and reamer). We believe that a bow drill would have been advantageous, but the materials needed for the construction of a proper bow drill were not readily available. We found the unhafted drill and the reamer tools to be the most efficient "because [they] combined the motions of drilling and reaming, limited only by the endurance of the individual and length of the drill" (Chandlee *et al.* 2014: 126). To complete the drilling of the two holes, so that they met in the elbow of the pipe, a hafted drill was used, which was constructed of a reed, resin, and a small flint drill bit. The total amount spent drilling was recorded as "11 hours...drilling through 13.5 cm of pipestone at 84 strokes per minute" (Chandlee *et al.* 2014: 126). Once the pipe was complete, a final bit of sanding was done and the pipe was polished with rendered animal fat. The completed pipe (Fig. 4.8) took a total of "approximately 136.8 hours, or 5.7 days" and gave us an appreciation for the time commitment needed to produce even the most basic of stone pipes using non-modern methods (Chandlee *et al.* 2014: 127).

[3] After the pipe was finished and while presenting the results at a conference in Kansas, USA, we had the opportunity to observe a private collection of artefacts. Among the various bits of pipes, pipestone, flint tools, etc. we saw several large pieces of sandstone that had troughs running through them stained red, with what we expected was pipestone dust. This served to confirm our hypothesis that sandstone was likely used in the pipe manufacture process.

**Figure 4.7 Sanding the Pipe** (Image from Chandlee *et al.* 2014).

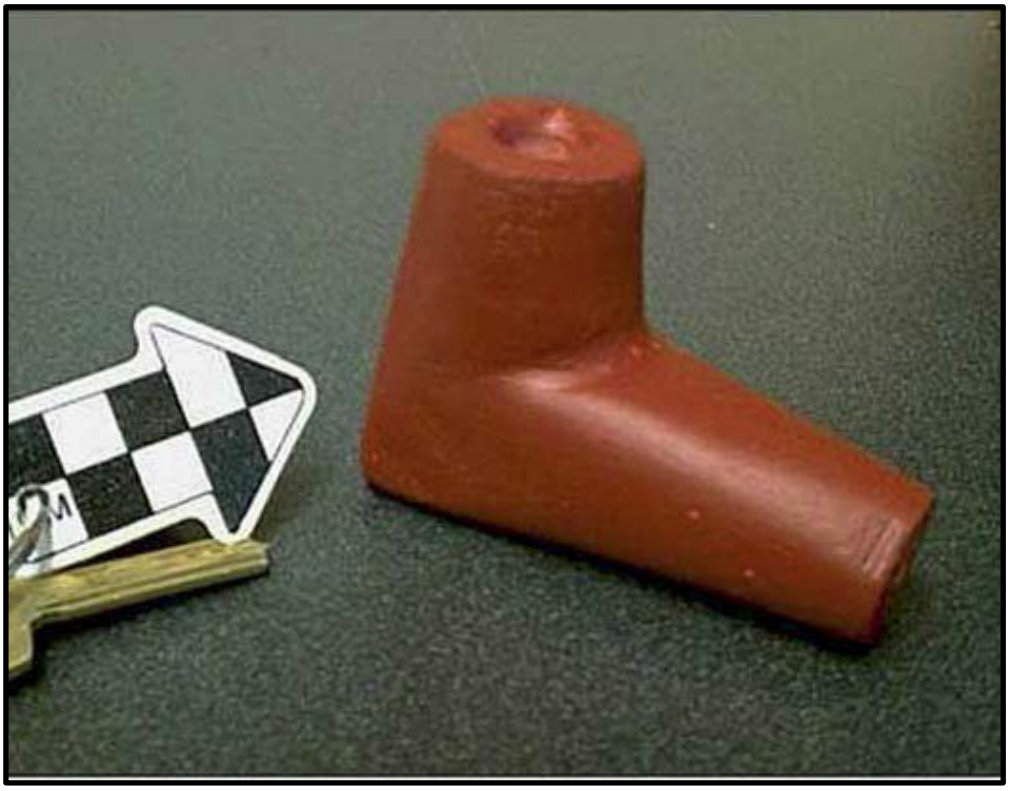

**Figure 4.8 The Finished Pipe (After Polishing)** (Image modified from Chandlee *et al.* 2014).

Though the pipe was completed, our work was not entirely finished. We noticed that while manufacturing the pipe a large amount of pink coloured dust was produced. We decided to try to use the dust as a dye and applied the dye to two white cotton washcloths, one using a mixture of the dust and water, and the other using the dust and rendered animal fat. To our surprise, both washcloths did not fade, even after multiple washing and drying cycles in modern day machines. We contacted Dr. Donald Blakeslee to let him know about the dye as, “pipestone pink”, as we dubbed it, is a colour often seen in rock paintings in the area. Dr.

Blakeslee replied that one of his students had in fact done a similar project in which she successfully made paint colours using the dust (Felicia Hammons pers. comm. 2011; Chandlee *et al.* 2014). We also made efforts to contact professional and hobbyist pipe makers, as a form of ethnographic study, and received replies from two individuals who confirmed that they use the same methods that we had used (Chandlee *et al.* 2014: 127).

This study highlights several of the primary goals that EA aims to achieve: 1) we gained insights into the pipe making process that may never have been known had EA not been undertaken (e.g., the more efficient use of sandstone in 'scraping' the pipe and the amount of time needed to make a working pipe); 2) avenues of inquiry were explored may otherwise have been overlooked or ignored had EA not been utilised (e.g., the use of the pipestone dust as a dye and as a base for paint colours); 3) we gained valuable knowledge without destroying any authentic archaeological materials; and 4) we combined our study with ethnographic research, low-power use-wear analysis (Law de Lauriston *et al.* 2015) and a chaîne opératoire analysis (Blakeslee 2012) to confirm the pipe making process, the tools involved, and some of the by-products of the pipe manufacture process, making this a prime example of a truly multi-stranded approach to addressing an archaeological problem.

### 4.3 Experimental Archaeology Conclusion

Experimental archaeology can provide information which cannot be gained using other lines of inquiry. The aforementioned case studies highlight the benefits of using EA in tandem with other methodological approaches (e.g., ethnography, use-wear analysis, chaîne opératoire) and display how a fuller understanding of an archaeological question can be reached when EA is utilised within a multi-stranded methodological framework. The first case study proved that axes hafted in a particular way can be used for wood working and has given me a particular combination of wear traits to be on the lookout for. Additionally, it made me think about the variables I wished to control in my own experimental work. The second study provided me with a good understanding of the processes one has to go through to create an adequate experimental archaeology collection and, as co-author on all papers involved, gave me a good base for interpreting use-wear patterns, albeit on a different raw material than the CoH tools are made from.

## 4.4 History of Micro-wear

Micro-wear is an all-encompassing term that includes several techniques (e.g., low-power use-wear analysis, high-power use-wear analysis, macroscopic use-wear analysis, and residue analysis), the goal of which is to find traces of activities left on archaeological tools whether they are manufactured of bone or stone. Generally speaking, the traces are not only related to the use of the tool, but can also be consequences of non-anthropogenic forces (e.g., weathering, PDSM, PESM, sub-surface soil movements, trampling, etc.). That stated, most micro-wear studies focuson "reconstruct[ing], as completely as possible, the economic activities of prehistoric groups" (Keeley 1974: 323), and by doing so it allows archaeologists to "examine questions of culture process and change by way of prehistoric activities" (Odell 1975: 237).

### 4.4.1 The Early Era

Though most archaeologists think micro-wear is a relatively recent specialisation within the field of archaeology, its history goes back over 170 years, beginning with the work of Sven Nilsson, a Swedish-born zoologist and archaeologist. Though most of his work focused on zoology, one of his studies, entitled *The Primitive Inhabitants of the Scandinavian North* (from the original Swedish *Skandinaviska nordens ur-invånare*), "made considerable use of ethnographic analogy to determine the probable uses of tools from the past" (Olausson 1989: 48). Nilsson (1838-1843: 49) stated that "through carefully examining how tools were worn, one can often with certainty conclude how they were used (Olasusson's 1989 translation). In short, he made a comparative sample of ethnographically collected tools used for specific tasks and compared their wear traces to traces on archaeological pieces to suggest possible functions.

Several years later in 1872, John Evans, an English-born archaeologist and geologist published his book, *The Ancient Stone Implements: Weapons and Ornaments of Great Britain,* in which he took a similar approach to Nilsson's. The difference between the two publications is that Nilsson compared the ethnographic samples with archaeological samples and Evans did not (Olausson 1989: 48). However, Evans' work is regarded as a seminal piece by some authors (e.g., Tringham *et al.* 1974: 172) as he described and sketched in detail flaking techniques and wear patterns that he believed were related to use (e.g., edge damage, polish, and striae). One crucial piece of modern micro-wear studies that the aforementioned 19th Century authors did not include was experimental

and/ or replicative studies to attempt to reproduce the wear seen on the tools. However, this would change within a few years of Evans' 1872 work.

Experimental archaeology, in tandem with micro-wear, finds its earliest use in the 1884 publication of N.F.B Sehested's *Practical Experiments: Archaeological Studies* (from the original Danish *Forsøg. Arkaeologiske Undersøgelser*) in which he tried to experimentally reproduce striations he observed on archaeological axes he found around Manor Broholm, an estate located on the Danish island on Funen. He did so by using different methods of polishing and grinding with different abrasives on non-archaeological specimens. Additionally, Sehested utilised some of the archaeological finds and "by means of these original artefacts he constructed a log cabin in 1879, proving that flint axes were in fact useful tools" (Paardekooper 2013: 45). In the same year, Spurrell (1884) published an article on his knapped tools, attempting to distinguish between flakes that occurred from knapping and those that detached during use. A few years later, Spurrell (1892) experimentally tried to reproduce the "sickle polish" that he observed on sickle-like blades, by sawing different materials (e.g., ripe straw, bone, horn, vegetable matter, and wood) and found that only when sawing ripe straw was he able to reproduce the sickle polish seen on the archaeological specimens (Spurrell 1892: 58).

### 4.4.2 The Early Modern Era

This era of micro-wear studies began around the turn of the 20th century with the 1912 publication of Pfeiffer's monograph, *Stone Age Technology and Its Relationship to The Present*: A *History of Contributions to The Work* (from the original German *Die steinzeitliche Technik und ihre Beziehungen zur Gegenwart: ein Beitrag zur Gaschichte der Arbeit*). Pfeiffer focused primarily on replicative experiments, but took his analyses several steps further by performing macroscopic use-wear on the archaeological specimens and comparing them to ethnographically collected pieces, providing the first published multi-stranded approach. In essence, Pfeiffer's work laid the foundation for the studies that would be undertaken between 1912 and Sergei Semenov's 1957 publication of *Prehistoric Technology* (in Russian).

Following Pfeiffer's work, two archaeologists published studies that investigated possible natural causes of edge damage (Moir 1914; Warren

1914), and one published results on the hafting and use of axes and celts in Germany (Quente 1914). Moir and Warren were concerned with natural causes of edge damage, as during that time period they were “[i]n the midst of the controversy over whether eoliths [in England] were natural or man-made” (Olausson 1989: 49). They both advocated experimental archaeology as a way to replicate the possible natural ways that the traces found on eoliths could have been made. In fact, Warren (1914: 413) felt so strongly about experimental replication of micro-wear features that he stated, "experiment should hold a similar position in these [archaeological] problems to that which it holds in physics or in chemistry”. Even though Warren had demonstrated that the wear features, particularly striations, that he saw on the eoliths could have been caused by natural forces, he remained open to the possibility that there were factors at work that he could not identify or quantify. Moir came to the same conclusions, although “his experiments... [were]...not as thorough as Warren's” (Olausson 1989: 49). However, both provided photomicrographs of the experimental and archaeological traces they observed, presenting the first examples of photomicrographs in the field of micro-wear. Similarly, Quente (1914) used magnification to study the wear traces left on experimental tools that he utilised for hoeing and ploughing and compared them to his archaeological pieces. According to Olausson (1989: 49), Quente’s work is one of the earliest recorded uses of magnification in micro-wear studies, which “enabled him to state with some assurance the probable mode of use and material worked by many celts and axes”.

The next published work was by Vayson de Pradenne (1922), who was largely concerned with the use of ethnographic analogy in micro-wear when it was not accompanied by an analysis of edge damage, as he believed ethnographic analogy, when used alone, could lead to incorrect interpretations. He was one of the first to suggest that form does not equal function when he stated that “identity of form need not mean identity of use” (Vayson de Pradenne 1922: 34). To illustrate his point he stated that, based on morphology, a “hache néolithique” and an Eskimo scraper would have been put to the same use (Vayson de Pradenne 1922: 36).

The last works of this era were Curwen’s (1930, 1935) study of sickle polish. Curwen (1930: 184) sought to distinguish between the polishes that were produced from cutting different materials (e.g., wood, dry bones and corn stalks), which addressed an ongoing argument as to whether or not the different polishes could be distinguished. He ultimately concluded that it may be possible to distinguish the types of polish, but that his observations were made not to settle opinions, but rather were made

hoping more detailed information could be obtained (Curwen 1930: 186).

After the publication of his 1930 work, Curwen was criticised for some of his conclusions, and in response, published a new set of experimental data in 1935. With flint tools, he again worked wood, bone, and straw. However, in reply to some of the criticisms his first paper received, Curwen decided to test the effects of prolonged friction between the worked material and the tool. To this end, the three different materials were "spun on an electric lathe and the flint blades were applied with sufficient pressure to cut into each kind of substance" (Curwen 1935: 64). The polish, or 'lustre' in Curwen's terms, for the straw was very bright and could not be removed by scrubbing with a brush or with a solvent, a criticism that had been levied against his earlier work (i.e., the polishes produced from his 1930 study were not true polishes because they could be removed by cleaning). In the case of bone working he reports that no polish could be identified, but that splintering and/ or chipping of the serrations on the stone tools took place (Curwen 1935: 65). For wood, Curwen reports that a very dull lustre (i.e., not shiny like the straw polish) occurred, but only intruded onto the tool less than one-eighth of one inch, while the straw polish intruded much further into the body of the tool. Curwen also made an observation that would set the stage for the next era of micro-wear research. He stated "These experiments, though far from being exhaustive, do surely support the view that the polish on the flint blades is not merely the result of hard usage, but is conditioned by the nature of the material cut" (Curwen 1935: 65). In this phrase, Curwen was much ahead of his time, as it would be another forty to fifty years before high-power use-wear analysis would achieve the distinction between polishes left by different worked materials.

### 4.4.3 The Modern Era

The modern era of micro-wear research laid the foundations for research for many decades to come. It began with Sergei Semenov's work published in the U.S.S.R. in 1957 and translated into English in 1964. In this seminal piece of work, Semenov describes how tool morphology in conjunction with microscopic observations of edge damage, striae, fractures and polish could be used to explain the function (e.g., cut, saw, or scrape) of tools, as well as the materials they had been used to work (e.g., hide, bone, or wood). Semenov's work sparked an ever-increasing interest in micro-wear studies that continues today. As Hayden and Kamminga (1979) point out, this fact alone showcases the importance of Semenov's contributions to the field.

Semenov was the first archaeologist who carried out his experiments according to a strict methodological framework, recording as many variables as possible, which today is common practice in any experimental programme studying tool utilisation (e.g., time used, worked material, and strokes per minute). Semenov's work was not without its flaws however; the most striking is that the majority of his experimental tools were machine manufactured metal instruments made to his specifications. Odell (1975) pointed out flaws in Semenov's work, such as wear traces being linked to hypothesised functions of particular tools, and lack of consideration of other possible factors that may have caused the wear traces (e.g., PDSM, weathering, trampling). Awareness of these problems, as well as Keeley's (1974) call for a new approach to micro-wear that would ensure the wear traces observed were related to use and not other activities or forces (e.g., knapping, trampling, or PDSM) ushered in a new wave of micro-wear studies.

Though Semenov's studies were problematic, Tringham *et al.* (1974) credit him for using a truly analytical framework in the study of prehistoric tools, superseding typological systems that had been utilised up to that point. The late 1970's and early 1980's saw a host of pioneering archaeologists take Semenov's work and improve upon it. These scholars (e.g., Keeley 1974a; Odell 1975; Newcomer 1977; Diamond 1979; Del Bene 1979; Kamminga 1979) explored new methodological approaches for identifying wear while others researched methodological frameworks for experimental design and analysis (e.g., Binneman 1982, 1984). During this period there was also a call for a uniform terminology in the description of wear patterns. Therefore, the Ho Ho Classification and Nomenclature Committee (Cotterell *et al.* 1979) was created. The committee's report standardised terminology that is still in use today (e.g., feather, step, and hinge terminations). The first Conference on Lithic Use- Wear Analysis (at which the Ho Ho Committee met), hosted by Brian Hayden in Vancouver, British Columbia brought together a host of scholars that specialised in varying fields and methods to discuss the new field of micro-wear analysis (Odell 2004: 137). Out of this conference came what Odell (2004: 137) calls "the most all-inclusive series of articles ever to be compiled for this subdiscipline", (i.e., Hayden 1979). This period was a time of great optimism (Schiffer 1979) in which it was believed that micro-wear analysis "would provide unquestionable evidence to explain changes in culture, economies, and behaviour" (Law de Lauriston 2014: 140).

However, these sentiments were not to last, as the following 20 years brought about a series of intense debates regarding the legitimacy of different approaches to micro-wear, particularly low-power use-wear vs. high-power use-wear. These arguments centred on the interpretations made and how accurate each approach was. Thus began a series of blind tests to prove, or disprove, the accuracy of each approach. The basic tenant of a blind test is that tools are made and used without the use-wear analyst knowing how the tools were made, what materials they were used on, and how (e.g., motion, action) they were used. The analyst is then given the tools and asked to make his/ her interpretation as to their use. Answers are then compared with the known uses and an accuracy score is given.

In early blind testing, strict rules were set in place (e.g., Keeley and Newcomer 1977; Odell and Odell-Vereecken 1980; Newcomer *et al.* 1986) to aid in standardising the results for comparing the accuracy of the low-power and high-power approaches. The rules were: 1) No trick specimens were to be introduced, meaning that no pieces could be utilised on a material like plastic (Evans 2014) or on a material that would not have been available in a prehistoric setting; 2) generally one use per tool was the rule, though in some blind tests (e.g., Odell and Odell-Vereecken 1980) multiple uses were allowed on a small number of the tools; 3) the analyst was allowed no knowledge of how or on which materials the tools were used; 4) un-used specimens were allowed to test the analysts' ability to identify those pieces that had not been utilised; 5) retouched and un-retouched pieces were allowed; 6) in these early blind tests, hafting was not allowed, but the experimenter was allowed backing (e.g., a leather pad or a glove), although in later blind tests hafting would be permitted; and 7) the analyst was asked to make interpretations as to use motion, area of the tool that was used, relative resistivity of the worked material (e.g., soft, medium, or hard), and the worked material (e.g., bone, hide, wood).

The results from these early tests were wide ranging with scores from 14% to 86% for overall accuracy. This cast doubt on interpretations of tool functions by use-wear analysts of both high- and low-power approaches. What did come from the tests, however, was the establishment of protocols for conducting and grading blind tests. Areas of research that needed further refinement (e.g., hafting traces, recognition of traces left from expedient use, traces left by soft materials) were pointed out in hopes of enabling analysts to make more secure interpretations. Over the years more blind tests were conducted and techniques were refined (see Evans 2014 for a comprehensive listing of blind tests from 1988 to present and

Bamforth 1988 for blind tests prior to 1988). What resulted from this early work, and the often fiery debates, was an understanding that both the high- and low-power approaches to use-wear had its advantages and disadvantages and that, if possible, both should be used alongside additional evidence (e.g., residue analysis, ethnography, experimental archaeology, archaeobotany) to create an integrated and multi-stranded approach (e.g., Donahue and Burroni 2004; Rots and Williamson 2004; Wadley *et al.* 2004; Lombard 2006; Rots and Van Peer 2006; Lombard and Pargeter 2008). Furthermore, results from this early work led to the refinement of blind testing regulations, which in turn led to higher accuracy rates. For example, Rots *et al.* (2006) report accuracy rates of between 60% and 100% depending on the approach. Most recently, Law de Lauriston (2014) in a series of three blind tests and one double-blind test, scored accuracy rates of 81% to 91%. The field of micro-wear analysis and use-wear analysis has come far in the past 40 years, yielding fruitful information whenever and wherever it has been applied.

## 4.5 Types of Micro-wear Analyses

As noted in the previously noted (Section 4.4), there are multiple techniques that fall under the term micro-wear analysis. Before discussing low-power use-wear analysis, other techniques (e.g., macroscopic use-wear, high-power use-wear, and residue analysis) will be reviewed as it is important to understand why they were not employed in this study.

### 4.5.1 Macroscopic Use-wear Analysis

Macroscopic analysis (e.g., Young and Bamforth 1990; Andrefsky 1998) is performed by unaided visual inspection or with a 10x magnifying glass or hand lens—no microscopes are employed when performing this kind of analysis. It is therefore generally excluded from micro-wear discussions. Odell (2004) states that microscopic magnification of some kind is needed to reliably reconstruct the function of tools. However, some very coarse-grained interpretations may be made about tool function using macroscopic analysis. Therefore, it is briefly discussed below.

One of the most notable drawbacks of macroscopic observation is that wear features (e.g., striae, edge scarring, or abrasion) that form are rarely observable without magnification. In some cases, such as the sickle polish (see Section 4.4.2), traces do form that are viewable at the macroscopic level, but this is the exception, not the rule. A few studies have attempted to use macroscopic observations to interpret use, but all of these studies

were focused on impact damage (e.g., Ahler 1971; Bergman and Newcomer 1983; Odell and Cowan 1986; Shea *et al.* 2001; Wilkins *et al.* 2012). The aforementioned researchers experimentally reproduced arrows and spears then shot or thrust them into animal targets to produce macro-scarring (Fig. 4.9) on the tips and possibly bases of the projectile points.

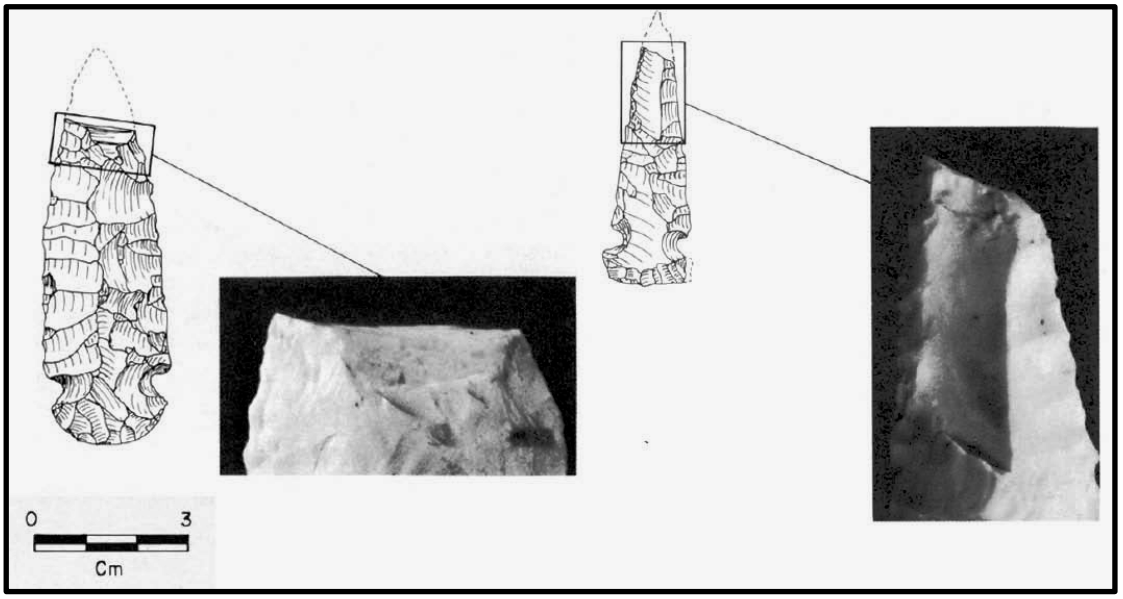


**Figure 4.9 Macroscopic Scars on Projectile Points** (Image from Odell and Cowan 1986).

Although macroscopic damage can form (Fig. 4.9) it should not be used solely as an indicator of function, as non-use related patterns can form from activities such as knapping (Newcomer 1976), PDSM (Levi-Sala 1986), or PESM (Young and Bamforth 1990). Moss (1983a) found that simply dropping a flake from no greater a height than the legs of a seated knapper can form wear patterns that can be confused with retouch or use-wear.

To date, the only other known circumstances in which macroscopic damage will form is when a thin-edged tool comes into contact with a hard or very hard substance (e.g., bone, stone, or earth). It may rarely form on thicker-edged tools that have extremely prolonged use times (i.e., greater than several hours). Taylor (2009) used macroscopic analysis to observe possible digging or cutting functions of Lupemban core axes from Kalambo Falls, but only because he determined all other techniques to be unsuitable for the Kalambo Falls collection. Recently Rots and Plisson

(2014) have criticised many publications for utilising, and in their words "abusing", macroscopic observations and macro-fractures as solid evidence for the earliest use of hafted armatures.

In short, there is little evidence that macroscopic use-wear can reliably be used to make secure interpretations of tool use. In fact, Young and Bamforth's (1990) macroscopic blind test found that when aided by only a hand lens, they were able to achieve an accuracy score of less than 25% when describing tool use and suggested that microscopic analyses be employed whenever possible.

### 4.5.2 High-power Use-wear Analysis

Microscopes involved in this approach utilise higher magnifications (greater than approximately 200x) to observe wear patterns than low-power use-wear analysis. Odell (2004: 142), commenting on distinguishing the two approaches based on magnifications used, states that "this is an unfortunate use of terminology, because the most important distinction between the two...is their use of different kinds of illumination". The high-power technique generally employs binocular metallurgical microscopes in which incident lighting built into the microscope is directed from above and strikes the piece being viewed at a 90º angle (referred to as light-field illumination), or at a 45º angle (called dark-field illumination). Though generally not useful for use-wear analysis, the light can come from below, as in those microscopes that are built for viewing glass slides with prepared samples of bacteria, blood, or phytoliths.

High-power microscopes have movable stages on which the specimen is stabilised, and the stage is moved left to right and front to back using knobs. Additionally, they generally have set objective eyepieces that rotate from one magnification (e.g., 200x) to another magnification (e.g., 300x), without allowing for any stops in-between the pre-set eyepieces. Details of the eye-pieces and magnifications vary extensively from model to model. For example, Mansur-Franchomme (1983: 83-84) employed a Wild M-20 microscope that allowed for magnifications up to 500x, but she reports that later in her analysis she switched to a Olympus PME allowing for magnifications up to only 400x. Additional studies may employ Scanning Electron Microscopy (SEM) and other extremely high powered microscopes (achieving magnifications of 1000 x and upwards) (e.g., Focused Ion Beam (FIB) microscopes, Confocal Laser Scanning Microscopy (CLSM), Fourier Transform InfraRed spectroscopy (FTIR), focus variation microscopy).

Most metallurgical scopes lack stereoscopic capabilities and only provide a 2D image. Their strong point lies in the ability to reach magnifications that may allow analysts to distinguish between polishes left from specific contact materials (e.g., differentiating between wood polish and hide polish). This provides an analyst the ability to make very fine-grained interpretations about use-tasks. Although Keeley and Newcomer (1977) state that all wear patterns (e.g., striae, edge damage, or fractures) must be utilised when reconstructing tool function, they also state that polish is the most diagnostic use-trace when using the high-power method. Despite Keeley's advocating the necessary observation of *all* wear-traces, the high-power examination of *only* polish has been the focus of many analysts' studies (e.g., Diamond 1979; Anderson-Gerfaud 1980; Moss 1983b; Unger-Hamilton 1984; Levi-Sala 1996; Ollé and Vergès 2003), meaning that their interpretation of tool functions were derived from limited information and crucial data may have been overlooked.

While the validity of high-power analysis has been proven through the aforementioned blind-tests, problems do exist. For instance, Vaughn (1981) studied polish formation and found that polish goes through several stages of development, with differentiation of polishes only possible after a tool had been utilised for an extensive period of time. Newcomer *et al.* (1986) and Moss (1987) state that well-developed polishes can overlap and be confused if a tool was used for multiple tasks. Additionally, high-power use-wear analysis has been criticised for problems associated with accurately recognizing non-use related wear, such as transportation (Rots 2003a) or PDSM (Basemann 1986). Levi-Sala's (1986) experiments that imitated prolonged burial and solifluxion showed that contact with sediments and rocks produced concentrated areas of reflective polish that were easily confused with, and in some cases completely obscured, actual use-wear polishes. Keeley (1980) and Anderson-Gerfaud (1980) both report that several high-power analysts have excluded 25% to 40% of their assemblages from analysis as a result of this problem. This issue, coupled with the much longer period of time needed to analyse one artefact using high-power microscopy, compared to low-power microscopy, means that most published studies using high-power have consisted of small sample sizes (e.g., Binnemann and Beaumont 1992 analysed two pieces).

However, this field has its advantages. Moss (1983a, b) states that the clearest advantage is that high-power microscopy has the potential to

identify the exact worked materials which would lead to more precise technological and functional interpretations. According to Rots (2003a, b), wear from non-use related tasks (e.g., striae and polish from manufacture or secondary modification) can generally only be viewed using high-power microscopy, which can aid in understanding the taphonomy of the tool versus the use of the tool. Burroni *et al.* (2002) make a similar claim stating that high power can afford a more secure interpretation of the post-depositional processes to which a tool has been exposed.

Overall, high-power can make interpretations about stone tool functions with a high degree of accuracy, particularly when it comes to specific worked material. However, in general, due to time constraints, the interpretations are made on quite limited sample sizes. Additionally, most published studies have focused solely on polish, ignoring other lines of evidence that may have provided additional information about the function of the tool.

### 4.5.3 Residue Analysis

Residue analysis is at least as old as the early era of micro-wear research. Schleiden (1849) reported that the optical properties of starch grains could be utilized to identify the grains to the species level. It was much later, however, before this kind of knowledge was used in the archaeological community (e.g., Von Stokar 1938; Briuer 1976). Much like micro-wear analysis, residue analysis encompasses a multitude of techniques, particularly because there are a host of different organic and inorganic remains that may be termed residues (e.g., phytoliths, blood, starch grains, wood, hair, pollen, and even soil). Generally, however, residue analysis uses much the same equipment as does high-power use-wear analysis (e.g., high-powered incident light microscopes, SEM/ FIB machines, and FTIR).

Before residue analysis takes place, however, a site should be assessed for preservation conditions (Langejans and Lombard 2015). The suitability of a given site generally depends on what type of residue is being investigated, as different kinds of micro-materials decay at different rates and under different circumstances. For example, bone preserves well in a *non-acidic*, waterlogged site (e.g., Painter 1991; Borsheim *et al.* 2001), whereas the muscle tissue attached to the bone preserves well in *acidic*, waterlogged deposits (e.g., Child 1995; Gernaey *et al.* 2001). Generally speaking, muscle tissues and starch grains are prone to decay faster than bone and plant tissues (Langejans 2010). However, decay can be caused

by biological (fungi and bacteria), mechanical (erosion), and chemical (leaching and crystal growth) forces making site assement all the more important before analysis begins (Kars 2003; Langejans 2010).

Usually a site will preserve residues well if it has any combination of the following: 1) stable *in situ* deposits; 2) dessicated, oxygen deprived, or waterlogged layers; 3) alkaline (pH >7.5) or acidic (pH <6.5) soils; 4) a consistently hot (*ca.* >25°C) or cold (<0°C) environment; and most importantly 5) whichever of the aforementioned factors the site exhibits, they should be fairly constant over long periods of time and not fluctuate greatly (e.g., going from hot to cold or wet to dry).

Because of the large amount of variation in site preservation conditions, the different kinds of decay, and the variability of the residues themselves, this approach has been characterised by both positive and negative results, depending on the methods used and the residue(s) being investigated. Items like phytoliths, starch grains, and pollen have, through the years, come to be accepted as viable subjects of inquiry (e.g., Shafer and Holloway 1979; Piperno 1984; Piperno *et al.* 1985; Piperno 1988; Fullagar *et al.* 1992; Hall *et al.* 1999; Sobolik 1996; Hardy and Garufi 1998; Barton *et al.* 1998; Pearsall 2000; Dominguez-Rodrigo *et al.* 2001; Balme and Beck 2002; Xhauflair and Pawlik 2010), provided the analysts can in some way prove that the residues they observe are from use and not from other sources (e.g., soil or modern contaminants). This is generally done by taking soil samples from around and off of the tool and various other locations of the site and subjecting them to the same kinds of tests used on the archaeological pieces to determine if the same residues occur in the soil.

Painstaking care is taken to properly excavate and handle the specimens intended for analysis and immediately put them into airtight containers as "cleaning, handling, transportation and storage conditions may all negatively affect the integrity of micro-residue results" (Langejeans and Lomabrd 2015: 203). These protocols also ensure that contamination of the samples does not occur as modern contaminants can confuse analysts and complicate a study (e.g., Wadley *et al.* 2004). With this and other strict procedures (e.g., cleaning and preparation of analysed samples), the aforementioned studies have proven that these kinds of residues can be used as reliable indicators of tool function, especially when combined with other techniques of inquiry (Lombard 2011; Langejans and Lombard 2015).

However, several other approaches to and subjects of residue analysis

(e.g., blood residues, hairs, fleshy tissue, and proteinous residues in general) have not met with as much success. This is largely due to arguments over how long these kinds of residues can survive before the proteins are degraded to the point that they cannot be positively identified. The medical community has reported that the taphonomic processes which break down proteins on sub-surface samples are too great to warrant successful identification of blood residues. For example, Fletcher *et al.* (1984) stated that blood lost all immunological activity (essential for identification) within 16 months. Similarly, Sensebaugh *et al.* (1971a, b) found that protein-based specimens lost all "physiological viability" in less than ten years—in a dry, clean laboratory setting. Additionally, Child *et al.* (1993) found and identified over 200 micro-organisms that destroy proteins in materials as strong as teeth and bones. The results for surface finds are even worse and have been considered far too great to allow for the successful identification of blood residues (e.g., Davis 1975; Barton 2009; Cooper and Nugent 2009). Barton and Matthews (2006) state that chemical and physical processes (e.g., moisture, pH levels, temperature, or oxygen content) significantly affect the biological activities that occur in sediments.

Despite these tightly controlled laboratory experiments and conditions and the medical community's evidence to the contrary, some archaeologists still argue that protein based residues can last for hundreds-of-years to tens-of-thousands of years (e.g., Loy 1983; Loy and Wood 1989; Kooyman *et al.* 1992; Loy and Hardy 1992; Eisele *et al.* 1995; Loy 1998; Loy and Dixon 1998; Gibson *et al.* 2004; Langejans 2007; Sterner 2012; Sterner-Miller *et al.* 2013; Lombard 2014; Wadley and Langejans 2014).
Using various techniques (e.g., hema-stix tests, cross-over immune-electrophoresis (CIEP), enzyme-linked immune-absorbantassay (ELISA), radio-ammunoassay (RIA), isoelectric focusing (IEF), Hemastix® and most recently Blue-star® Forensic), they argue that they are able to accurately identify these protein-based substances.

Residue blind tests (e.g., Wadley *et al.* 2004; Lombard and Wadley 2007; Wadley and Lombard 2007) have been undertaken to help confirm the validity of this approach. Lombard and Wadley (2007) report between 80% and 100% accuracy, though this was only after their initial blind tests (Wadley *et al.* 2004) had been heavily criticised by Crowther and Haslam (2007) for their protocols, or rather lack thereof, as well as their inefficiency in controlling for several variables (e.g., contamination of pieces from powdered latex gloves or losing experimental control over pieces deposited in compost). Additional problems with blind testing protocols

included: 1) the use of a comparative collection during the blind test, which is not accepted practice for blind testing; 2) the interpretation of processing plants based on the identification of starch contaminants from powdered latex gloves was scored as correct, though the tools had not been used; 3) tools that were buried to test possible effects of PDSM were not examined *before* and *after* they were buried, which should have been done to ascertain which residues came solely from use and which ones were caused by the burial process; and 4) the definition of what was a correct answer and what was incorrect and the reasoning behind these definitions were not included.

While Lombard and Wadley (2007) overcame some of these flaws in their later publication, the application of their results to archaeological assemblages on the order of 60 000 to 80 000 years old (e.g., Gibson *et al.* 2004; Lombard 2004, 2005, 2008, 2014; Langejans 2007; Lombard and Phillipson 2010; Wadley and Langejans 2014) should be taken with caution, particularly in light of the aforementioned medical community's studies.

On the whole, certain aspects of residue analysis are undoubtedly going through the challenges that use-wear analysis has experienced in the past 50 years (i.e., debates and arguments over techniques, approaches, blind tests, accuracy). Hopefully, some good will come from the often turbulent situation for residue analysis, and efforts from current researchers (e.g., Wadley, Langejans, Sterner, and Lombard) may result in innovations and refinement of techniques, making the field a more viable approach to micro-wear analysis.

### 4.5.4 Low-power Use-wear Analysis

Until his unfortunate passing in 2011, George Odell was one of the world's leading experts on low-power use-wear analysis, and most practitioners of this approach use his methods and research as foundational and seminal studies in the field. His continued research and efforts in refining the approach have made it what it is today. Without his work, it is possible that the approach of low-power use-wear analysis would still be where it was in the late 1960s. I had the fortunate opportunity to be one of his protégés while he held a post at the University of Tulsa, and I rely heavily on his works when discussing and defining the low-power approach.

This approach uses what is today called a stereoscopic microscope, but in the past was known as a dissecting microscope, because of its frequent

use in biology classrooms for the dissection of small animals. These types of microscopes achieve magnifications of approximately 6x up to approximately 200x, depending on the model, and do not have a movable stage. Instead the microscope is attached to a platform upon which the object being viewed is placed. Utilising stereoscopic microscopes and reflective lighting (external to the microscope) allows the analyst the freedom to stabilise the specimen and adjust the angle at which the light strikes it, or to hold the piece in his/ her hands and move it around while the light is stationary. This is particularly helpful as it "enhance[s] shadow effects and depth of field necessary for interpreting topographic features stereoscopically" (Odell 2004: 143). Additionally, a 3D view of the artefact under observation is provided, aiding in the interpretation of micro-topographic features.

It is important to note here that there is a common misconception in use-wear literature regarding this approach. Odell (1990) explains that when utilising low-power use-wear, *all* observable wear traces (e.g., rounding, striations, crushing, polish, scarring) are used to reconstruct tool function. However, many critics of this approach think low-power analysts only use edge scarring to make functional interpretations (e.g., Moss 1983a, b; Vaughn 1985; Gamble 1986: 129; Anderson-Gerfaud *et al.* 1987: 229; Toth and Schick 1988). Odell (1990: footnote 15) states that in no treatise on low-power use-wear can one "...locate [an] instance in which low-magnification researchers have maintained that they employ only fractures in their functional assessments...". In fact, Odell (2004) states that it "dangerous" to interpret function based on any one variable alone and criticises himself for having not stated this more forcefully in his earlier publications (e.g., Tringham *et al.* 1974; Odell 1980a, b, 1981; Odell and Odell-Vereecken 1980). Nevertheless, he does mention that, in one of the single most important exegeses on low-power use-wear analysis (Kamminga 1982), this was stated repeatedly, but many people have either ignored this admonition, or overlooked or an unaware of this work.

It is possible that, unless employing the higher end of the low-power spectrum approximately 150-200x, one may not be possible to observe some of the finer use-wear traces (e.g., striations or polish), which may be the cause for the misconception. While this may be true, edge damage (e.g., scarring, rounding, abrasion, crushing) is considered by most low-power practitioners as one of the most reliable indicators of function, especially if it can be confirmed through observations of striations and polish at higher magnifications (Keeley and Newcomer 1977; Odell and Odell-Vereecken 1980; Odell 1981; Moss 1983a, Rots 2002).

With low-power analysis, it is possible to analyse larger areas and a larger number of pieces, in a shorter amount of time than with the high-power or residue approaches; but the results will be coarse-grained, providing details such as relative resistivity (e.g., hard, medium, soft) of the material worked and the use action (e.g., saw, cut, scrape). Through blind tests (e.g., Odell and Odell Vereecken 1980; Rots *et al.* 2006; Hanten and Stevens 2010), this has been proven to be the case, i.e., the analyst can accurately identify the resistivity of the worked material, but inferring the worked material is more difficult, with accuracy scores ranging from 40% to 60%. However, it must be stated that some analysts using the low power approach have reported much higher blind test scores for worked material (e.g., Gendel and Pirnay 1982 scored 73 % for worked material; Vaughn 1985 scored 83%; Shea and Odell 1987 scored 80%; Law de Lauriston 2014 scored 89%), proving that it is possible to achieve acceptable accuracy results (even comparable to the higher-end scores for high-power blind tests) for worked material using the low-power method.

This approach is best used to make assemblage-wide interpretations, with coarse-grained information, but from a large sample (e.g., Odell 1977, 1996; Kamminga 1982; Law de Lauriston 2014). Researchers conducting such studies have analysed whole assemblages, or statistically significant portions of the assemblages, which, given time constraints, would not have been possible utilising the high-power and residue-analysis approaches. With these results, it has been possible to determine and interpret differences in tool use and behaviour across vast distances of space and time (Odell 1977, 1990, 2004). The low power approach also does not suffer from the drawback of having problems identifying wear-patterns on more coarse grained raw materials (e.g., quartzite) when compared with the high-power approach (Rots and Williamson 2004). Furthermore, high-power has difficulties with transparent materials (e.g., quartz or obsidian). Wadley and Binneman (1995) excluded all quartz materials from their study as “the high power observation and interpretation of micro-polish on quartz is difficult and inconclusive” (Law de Lauriston 2014: 167).

### 4.6 Suitability of CoH Bed 3 Acheulean for Analysis

With the above reviews of the different techniques presented, it is possible to now discuss the suitability of the CoH Bed 3 Acheulean LCTs for analysis, using the multi-stranded approach that I have formulated.

The first technique of experimental archaeology can definitely be utilised in an analysis of the CoH Bed 3 assemblage. However, as noted in Section 4.2, it cannot and should not be used alone. The most fruitful data that comes from experimental archaeology is derived from those projects that use it as one technique in a multi-stranded approach. Thus, experimental archaeology can only be used at CoH if the other proposed techniques are found to be suitable for analysing CoH artefacts.

The second technique of blind testing is most applicable when studying CoH LCTs. In order to place confidence in my interpretations of the archaeological tools, I must prove that I am adept at utilising the chosen micro-wear approach. The blind test results, presented in Section 5.3, indicate how much confidence can and should be placed in my interpretations and are critical to any micro-wear study.

The last technique of low-power use-wear analysis has, for several reasons, been determined to be the best approach to use in microscopically examining the LCTs from Bed 3. The other techniques were ruled out for the following reasons: 1) some of the tools have experienced a very turbulent depositional history and all of the LCTs have been poorly curated (Section 3.3). This may have removed the finer use-traces that high-power analysts look for (e.g., polish, striae) and rely on to make their interpretations; 2) the LCTs from CoH that I am analysing are made solely of quartzite, a coarse-grained material. This generally excludes high-power analysis. As mentioned in Section 4.5.4, this technique has problems with coarse-grained materials; 3) the site was excavated in the late 1940s and early-mid 1950s. It was not routine during that time to specially excavate and handle artefacts for residue analysis to be undertaken. The tools have also been exposed to a vast array of modern day contaminants (e.g., residues from handling, residues from storage in wooden boxes and paper bags) that would negate any results that residue analysis might provide; and 4) it is likely that all LCTs were not utilised in such a way that would leave macroscopic traces on the tools. Granted, some LCTs may have been used in heavy duty tasks or may have edges that are thin enough to evince macro-damage, but if macroscopic analysis was used there is a high likelihood that a large amount of functional information would be missed.

Given the potential problems with other techniques (see Sections 4.5.1—4.5.3) the low-power approach is the best suited microscopic technique for analysing the CoH Bed 3 LCTs. This technique, coupled with and verified by the results of my experimental programme (Section 5.2) can overcome

the aforementioned difficulties in several ways. First, unlike high-power, the use of low-power enables analysts to overcome problems with observing and interpreting wear on coarse-grained materials. This alone makes low-power suitable; however there are other reasons. Secondly, low-power analysts do not rely on polish and striae as heavily as high-power analysts do. They rely more on edge damage (e.g., rounding, crushing, micro-scarring) and incorporate striae and polish if observable on the sample being analysed. The edge damage resulting from PDSM and PESM has been extensively studied and has proven to have entirely different characteristics than the scarring produced by use (e.g., Asryan *et al.* 2014; Law de Lauriston 2014; McBrearty *et al.* 1998; Levi-Sala 1986; Tringham *et al.* 1974). Lastly, any wear traces from softer materials (e.g., animal or vegetal products) can be observed using low-power, whereas macroscopic analysis cannot identify these tasks.

## 4.7 Previous Functional Studies in the African ESA

As mentioned in Section 1.1, there is a paucity of functional analyses on Acheulean HDTs in Africa, especially if we define the term 'functional analyses' to mean something more than an actualistic, experimental, or theoretical study of what the HDTs, function might have been. For this dissertation, a 'functional study' is defined as a study that has employed one of the micro-wear approaches along with other lines of corroborating evidence. There have been functional studies carried out on Acheulean aged assemblages elsewhere around the world (e.g., Keeley 1980 in Great Britain; Márquez *et al.* 2001 in Spain; Pawlik 2002 in the Philippines; Lemorini *et al.* 2006 in Israel). However, in Africa most notions about how HDTs were used derive from non-microwear studies. Therefore, this section presents studies of HDTs' functions whether or not they employed micro-wear analysis.

### 4.7.1 Non-microwear Studies

There have been numerous non-microwear studies carried out with the goal of identifying the possible function(s) of HDTs. These investigations include experimental work, theoretical ideas, and actualistic studies. This section focuses on a few of these works and is not intended to be an exhaustive listing of all studies undertaken. Instead, a few analyses are presented that highlight some of the suggested uses of HDTs.

#### 4.7.1a Handaxe Hurling

Jeffreys' (1965) study was the first to suggest that handaxes may have been thrown or used as a projectile in theoretical hunting situations. Jeffreys called this idea the 'hand bolt theory' and postulated that a traditional handaxe would have been held by its point or tip (Fig. 4.10) and then thrown, turning end over end towards an animal. He reports that in South Africa, the most common localities he had discovered handaxes were near water courses (e.g., lakes, pools, or rivers) and that the animals would have likely been waterfowl (Jeffreys 1965: 154). Jeffreys provides no experimental data to support his claim, which is likely the reason it took several decades for the 'hand bolt theory' to be considered plausible.

However, in 1981 Eileen O'Brien took this idea and applied an experimental approach by making a weighted fibreglass cast of a handaxe specimen from Olorgesaile and conducting a number of throwing experiments with it. O'Brien states that the goals of the experiments were to determine: 1) the stability and pattern of flight of the handaxe; 2) the horizontal range; 3) the accuracy; and 4) the surface of contact at impact (i.e., lying flat or edge on) (O'Brien 1981: 76). Before the actual experiments began she reports that the handaxe was thrown in several different fashions to determine the best throwing style to test (i.e., overhand, underhand, discus). She determined that the discus, or side-arm, style was the most suitable way of throwing the handaxe, and the experiments proceeded utilising two athletes as throwers, one trained solely in discus throwing (A), and the other primarily trained in javelin throwing but "with some knowledge of discus" (B) (O'Brien 1981: 77).

The handaxe replica was thrown 25 times by thrower A and 20 times by thrower B in the side-arm style. Additionally, thrower B threw the handaxe 6 times in an overhand fashion for comparison. The results showed that when thrown side-arm style, the handaxe performed similarly to a discus during the ascent (i.e., horizontal rotation around the centre of gravity), but at the apex of the trajectory the handaxe slowly pivoted around and rotated end over end in a perpendicular fashion.

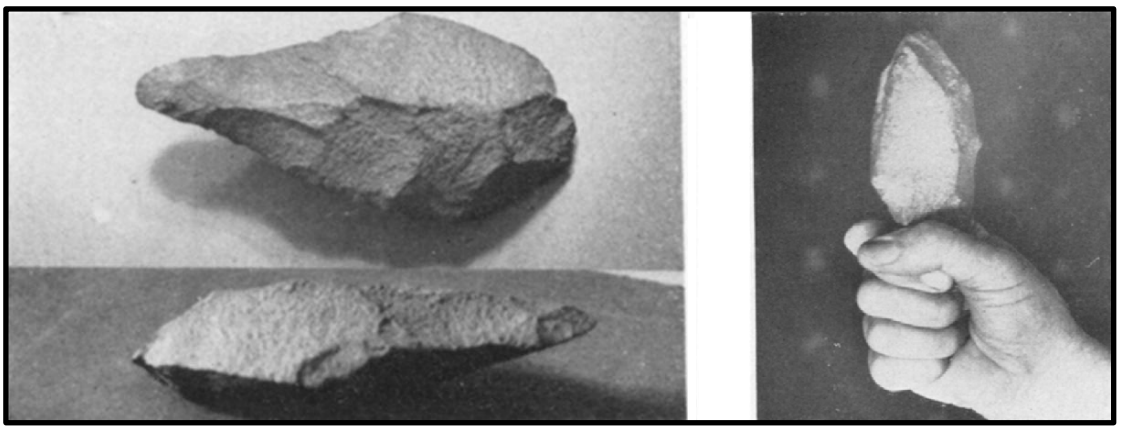

**Figure 4.10 The Hand Bolt.** On the left is a typical Acheulean handaxe and on the right is how Jeffreys imagined it would have been held for throwing purposes (Image from Jeffreys 1965).

This rotation caused the handaxe to land edge-on (defined as any landing other than flat on the ground) 93.3% of the time, with 68.9% of the throws landing tip first. O'Brien reports that the discus style maintained a mean distance (calculated using both throwers statistics) of 31.9 m with a range of 22.6-37.5 m and a mean accuracy of 1.77 m, with a range of 0-5.72 m. The additional 6 throws done overhand style produced similar results, with the exception that, during the ascent and descent, the handaxe maintained a perpendicular rotation and resulted in 100% of the throws landing edge on with 33.3% of the throws landing tip first.

Additionally, O'Brien calculated the average velocity at 63 km per hour (see O'Brien 1981: 77 footnote three for the formula used). Using this velocity combined with the weight of the replica handaxe (1914.6 g), she was able to calculate the force at point of impact to 36.7 kgF (kilogramme-force, a metric unit of force). She reports that this would be able to provide a good idea as to what kind of game animals would be susceptible to predation using the hand bolt, although she does not elaborate on what animals these might be. However, she does state that hunting near "watercourses" would provide an explanation for the accumulation of handaxes found near palaeo-watercourses, much like Jeffreys suggested 16 years earlier. Ultimately O'Brien (1981: 78) concludes that "as a projectile, the classic handaxe is functionally and efficiently designed", though she states that further experimentation is needed to confirm her results.

This theory lay dormant for 20 years. Then in 2001, Whittaker and McCall presented a critique of this study and conducted a new set of experiments. Two handaxes were used, one made of basalt with the intention of

replicating the shape and weight of O'Brien's handaxe, and the other a smaller, more triangular shaped handaxe made of chert. Four throwers were used in this study and both overhand and side-arm style throws were employed for a total of 118 discus throws and 21 overhand throws.

One of the primary problems that Whittaker and McCall (2001: 570) faced was that when employing raw materials, and not fibreglass, the sharp edges of the larger basalt handaxe cut the hands of the throwers and even cut through leather padding. Thus, they purposefully blunted the butt of this handaxes in order to complete their set of experiments without medical assistance being required. The experiments then continued, and the following results were recorded: the discus throws produced an average distance, for all throwers, of 29.54 m with a range of 18-41.7 m, though Whittaker and McCall (2001: 570) did not attempt to measure accuracy in any way. The main difference between the Obrien's study and this one was that of the in-flight trajectory. None of the four throwers could achieve rotation of the handaxe at the apex of its flight, as did O'Brien's throwers. Admittedly, O'Brien (1984: 24) states that the rotating was likely caused by the exact way of releasing the handaxe and was thus under the control of the thrower. However, even when they tried, Whittaker and McCalls' four throwers could not produce apex rotation. This resulted in the average rate of flat surface landings to be 72.4% with a range of 6.7-100% (averaged for all four throwers). However, a different picture came out of the 21 overhand throws. Of these throws, the mean distance was 29.75 m, with a range of 29.3-30.2 m. Unlike the side-arm throws, 100% of overhand throws landed edge on, with 30% of them landing point first on average, almost exactly the same percentages as O'Brien's' overhand throws, but the authors report that the smaller handaxe was unstable during flight.

They ultimately conclude that O'Brien's' experiments were flawed in her use of fibreglass rather than actual stone materials and her results were "based on exaggeration and stereotyping of the archaeological record: [as] most handaxes are not the 'classic' form envisioned" (Whittaker and McCall 2001: 571). They add that there has been no micro-wear results that suggest impact damage on handaxes, and that handaxes are not solely found around palaeo-watercourses, effectively nullifying the hand bolt theory and O'Briens' results.

Because of the disparity between the results of the two studies, Samson (2006) conducted another series of experiments. In this series of experiments two throwers were utilised, one having no experience with

any kind of athletic throwing events (B) and the other having several years of discus throwing experience (A). Three morphologically different handaxes were used, all made of chert, and one “1.245 kg rock that had been sparingly knapped was also thrown” (Samson 2006: 129). All throws were conducted discus style and the data set comprised 150 throws (75 for each participant, with 25 throws of each handaxe). Thrower A obtained a mean distance of 41.1 m, with a standard deviation (S) of 3.8, while Thrower B only reached 28.6, S=2.7. The average distance for the rock was 24.9 m, but no further data could be obtained from this experiment because the author could not asses the landing orientation. The average accuracy rates, measured as distance left or right of a centre line of trajectory, for Thrower A was 6.0 m, S=5.3, and for Thrower B was 6.6 m, S=4.5.

Samson (2006: 130) reports that of the 150 throws, 120 of them produced edge/point landings, a rate of 80%, with 70% (n=105) landing edge first, 10 % (n=15) point first, and 20 % (n=30) flat-faced. Samson (2006: 131) also calculated that given a handaxes’ 6 basic surfaces (i.e., 2 flat surfaces, 2 edges, a butt, and a tip) the probability a landing will be edge or point first is 67%. Using this number and a two-tailed exact binomial test revealed a statistically significant difference between the experimental results and the probability percentage, meaning that the experimental landings were significantly greater than the random chance of an edge or point landing first. With this, the author ultimately concludes that: 1) the discus throwing method is the best, confirming previous research; 2) his results indicate that O’Brien’s’ (1981) experiments are more representative of reality than Whittaker and McCalls’ (2001); and 3) the agreement between his study and O’Brien’s highlights that it could have been possible for the handaxe to have been thrown accurately as a projectile weapon (Samson 2006: 134).

The following year McCall and Whittaker (2007) published a rebuttal and critique of Samson’s work. The study did not include any new experimental data, but rather presented arguments based on theoretical perspectives, flaws in previous research, and archaeological data that, from their perspective, do not support the handaxe hurling theory. Admittedly, they do say that there are some aspects of this theory that experiments, archaeological data, and theory cannot answer. Ultimately, they call for a “handaxe hurl-off challenge”, which would bring together all anthropologists and archaeologists investigating this theory in a conference type setting to experiment, exchange ideas, and to discuss possible flaws in the previous research and how those flaws could be

overcome (McCall and Whittaker 2007: 201). To my knowledge, no such event has taken place, and thus the hypothesis still remains debated.

While this theory may seem odd to some archaeologists, Odell (2004: 135 emphasis original) states that most notions of how prehistoric tools were used are based on "limited ethnographic examples and nineteenth or twentieth century views on what these tools *should* have been used for". I think that given the experimental data available it is likely that handaxes could have been used in this manner. However, I also think that it is premature to accept or reject this theory until more experimentation, along with the observation of microwear from experimental and archaeological pieces, is conducted.

#### 4.7.1b Sexy Handaxes

As an archaeologist, and particularly as a micro-wear analyst, most of the time I associate the word 'function' with a hands-on use (e.g., butchering an animal). However, the word function is not restricted to the physical realm. Gamble (1997: 108) states that handaxes were part of a 'social technology', with White (1998: 32) adding that the 'apparent over-sophistication' of many handaxes for mundane tasks such as butchery maybe a sign of some 'historically accrued social significance'.

One explanation put forward by Kohn and Mithen (1999) for this social significance is that handaxes were products of sexual selection among early hominins. They explain that despite the extensive literature dealing with handaxes, there are five "fundamental questions" that have never been answered. These are: 1) why are handaxes so pervasive in the archaeological record? 2) why are they often found in such prolific numbers at individual sites? 3) why was time invested in manufacturing handaxes when much simpler tools (e.g., flake tools) are just as effective for tasks such as butchery and woodworking? 4) why do so many handaxes have such high degrees of symmetry? and 5) how does the archaeological community explain the "handaxe oddities" (e.g., giant handaxes, some *ca.* 28 cm long, that were too unwieldy to actually have been used)? (Kohn and Mithen 1999: 518). The authors believe that using the 'handicap principle' (Zahavi 1975; Zahavi and Zahavi 1997) and the notion of aesthetic display they can answer the aforementioned questions. Zahavi's handicap principle states that traits indicative of good genes may be selected for specifically because possession of those traits imposes a cost to their owner (e.g., a peacock's attractive tail fan imposes a cost of being more easily seen by predators, yet the tail fans play an important

role in mate selection [Miller 1997]). The most important point of the handicap principle is that the indicator of the trait, usually a kind of aesthetic display (e.g., the peacock tail fan) is costly, in some way, to possess or it can be easily faked. Kohn and Mithen (1999: 519) state that these two ideas are “both well established and complementary evolutionary processes, essential for an understanding of the...behaviour of many animal species”.

According to Kohn and Mithen (1999: 520), for handaxes, the costs include raw material procurement, and the time spent on the manufacture of a highly symmetrical handaxe. The authors believe that handaxes acted as Zahavian handicaps and aesthetic displays, indicating “good genes” and that hominins who could make symmetrical handaxes were seen as preferential mating partners. In tandem with this, the manufacture of a fine symmetrical handaxe would act as an indicator of the hominin’s ability to live successfully in their environment while still investing in the costs of making a handaxe. Kohn and Mithen (1999: 521) write that a critical point to their argument is the wide range of variability that is seen in handaxe symmetry and refinement. If viewed through the lens of Kohn and Mithen’s theory, this range equates with the cost that any given hominin was willing to invest in the handaxe. Additionally, they suggest that if early hominins are like most species, then males would have been the ones who put on a display for mating purposes. Thus the highly symmetrical handaxes may be linked to a male sexual display, while the less refined handaxes would be attributed to females who were not concerned with a sexual display.

They argue that a symmetrical handaxe would have been attractive to a potential mate due to a preconceived bias towards symmetry as hominin’s “visual systems, like...many...animals...are exquisitely sensitive to patterns with a vertical axis of symmetry” (Dennett 1991:179) and whether consciously or sub-consciously, early hominins knew this and made symmetrical handaxes that would have been pleasing to the eye. They continue by explaining that one problem area when imposing Zahavian’s handicap principle to symmetrical handaxes is that it would be possible for fakes to be introduced into the system (i.e., a hominin could end up with a symmetrical handaxe that he did not make), which breaks the prime rule of the handicap principle (i.e., the indicator must be so costly to possess that it cannot easily be faked). Kohn and Mithen (1999: 522-523) believe that this potential for ‘faking it’ was mitigated by a potential mate’s direct observation of the handaxe manufacturing process from beginning to end, thus ensuring that the indicator was not faked.

With this, Kohn and Mithen (1999: 524) believe they have been able to answer the five questions posed at the beginning of their study. Their answers are as follows 1): Handaxes are so pervasive because hominins likely would have lived in large, socially complex societies in which social pressures, and particularly inter-male competition for mates, were intense; 2) handaxes are abundant at many sites because members of the opposite sex had to observe the maker of the handaxe during manufacture; 3) greater time and effort were invested in making highly symmetrical handaxes, even when other less refined tools were just as adequate for similar tasks, because they functioned in the social realm as a product of sexual selection and as indicators of good genes; 4) handaxes were symmetrical because hominins were exploiting preconceived biases towards symmetry due to the evolution of the hominin visual system; and 5) handaxe oddities (e.g., the exceptionally large specimens) were particularly elaborate indicators made by a hominin wishing to display their exceptional knapping skills.

Kohn and Mithen's original work was followed by several other archaeologists debating the validity of this theory through various other lines of inquiry (e.g., Machin *et al.* 2006; Machin 2008; Mithen 2008; Hayden and Villeneuve 2009; Hodgson 2009; Nowell and Chang 2009). The main flaw with this functional study is that it is completely theoretical. There is no experimental archaeology, experimental psychology, micro-wear analysis, or other field of inquiry that can definitively prove or disprove this theory. Kohn and Mithen, however, have been praised for their attempt to discuss handaxes in a social role. Machin (2008: 766), even though she ultimately disagrees with their theory, states that their efforts "should be saluted as one of the first attempts to suggest a role for the handaxe within the social domain".

#### 4.7.1 c Experimental Work

The most prolific work that has been published on experimental use of HDTs in Africa is probably that of Jones (1980, 1981, 1994). While working with Mary Leakey at Olduvai Gorge, Jones began an experimental programme which initially was a series of unrelated experiments that were meant to solve particular research problems as they arose (1994: 254). Jones was particularly interested in the raw materials and morphological characteristics of the Acheulean from Beds III and IV. Thus, his work focused mainly on the replication of Acheulean tools and their possible uses.

Jones' earlier work was solely a study of butchery and the tools that were best suited to this task. He butchered goats, a cow, and one zebra most of which he reports were obtained through the local Maasai peoples, while the zebra was found dead on the landscape, untouched by carnivores (Jones 1980: 154). For butchering the goats he used a traditional method taught to him by some of his Wakamba co-workers who all came from Machakos, east of Nairobi in Kenya. He documents this technique first, noting that butchery techniques generally receive little mention in the published literature. He found in this study that the overall butchery process was best carried out with a biface, or handaxe, as it had noticeable advantages -- it was heavier, had a long continuous cutting edge, and was easily manipulated in the hand. He does, however, report that for skinning goats, flakes worked better than a handaxe as the goat skin was very thin and required precise cuts so as to not leave meat on the hide (Jones 1980: 158), while the zebra and cow hides were more easily removed with a handaxes as they were noticeably thicker than the goat skin. Disjointing and meat removal was found to be much more easily accomplished using any kind of biface (e.g., a HDT) than with flakes, whether retouched or not. He found that in this particular case, the bifaces' secondarily modified edge made them much better for use as the sawing and hacking motions necessary to complete this stage broke primary edges more easily than a retouched one.

Ultimately, he concludes that for smaller animals (e.g., goats weighing between 70 and 100 pounds), skinning was more easily carried out with the use of flakes; while for larger animals (e.g., cow and zebra), skinning was more efficiently done with a biface. He found that over longer periods of time (i.e., 1-2 hours), the biface was less tiring to use. He makes the accurate analogy of using a razor blade held between the thumb and forefinger versus a kitchen knife grasped firmly in the palm for heavy-duty butchering. While the razor blade may be sharper, it has less weight and in many cases this causes the butcher to use more of his/ her own strength rather than relying on the weight of the instrument being used. He also found that he rarely cut himself when using a biface for butchering. Even though the edges were sharp, the length of the cutting edge was long and the force of his palm was spread out over a larger area than if using a flake. Additionally, he notes that he frequently received small cuts on his fingers when using flakes in tasks for which bifaces were better suited (Jones 1980: 160).

Jones' later work (1994) was a much more detailed analysis of the same materials he reported on in his early work, but with more information, data,

and conclusions drawn as by then he had been working at Olduvai for a much longer period of time. This work provides more detail about the knapping methods he utilised in creating the different morphologies and the raw materials best suited for each knapping method.

For HDTs he reports several stages of experimentation with knapping technologies to produce sufficiently sized blanks for secondary modification into a finished HDT. He notes that most of the Acheulean HDTs from Olduvai were manufactured from large flake blanks rather than smaller river cobbles. Thus he focused more of his attention on what was needed to produce these flake blanks (Jones 1994: 262). He reports that, with approximately a month of practice, he was soon able to remove large flakes (i.e., greater than 10 cm) from basalt boulders using a hammerstone that only weighed 2 kg. On average he could produce five to ten usable flake blanks (each weighing about 0.5 kg) from a boulder of 13 kg in weight. He found that the "cushioning" of the boulder was very important and when wedged in-between other large boulders and river cobbles, rather than in just sandy soil, he was able to make more efficient use of the core as the boulders helped to stabilise the main core when struck with a hammerstone (Jones 1994: 263). Additionally, he states that on just about any of the raw materials evidenced in the archaeological record, he could produce a HDT rather quickly—between 55 seconds and three minutes—and very few secondary flakes needed to be removed to obtain a functional Acheulean HDT (Jones 1994: 263-266).

Jones also reports on the different blank types used (e.g., flake versus core/slab) and the technological considerations of each type. For instance, he states that on average a HDT can be made from a flake blank in one-half to two-thirds the amount of time it would take to make the same HDT from a core/slab blank. He thinks this is largely due to the thin tapering edge of the flake blank that readily lends itself to retouch, whereas a core/slab blank, to start with, has a thicker edge, with a greater edge angle, and much more effort is needed to make a finely retouched edge than with a flake blank (Jones 1994: 269). Additionally, he notes that when using flake blanks one can more efficiently transform greater amounts of raw material into HDTs than one can with core/slab blanks. He further reports on other characteristics (e.g., shape, weight, usable edge length) and how all of these can be inter-related and in fact appear to be so in the archaeological record at Olduvai (Jones 1994: 269-275).

Finally, he presents further experimental work on the actual use of the tools he had manufactured. He states that some experiments were very

carefully controlled and recorded, whereas others were very opportunistic in nature. He focuses on a series of butchery tasks that were undertaken on elephants, because his earlier work deal only with the butchery of smaller animals. Similar to his earlier experiments, he found that a flake was as useful as a HDT for the first step of cutting through the skin. However, he notes that there are multiple variables (e.g., skin tension, raw material, sharpness, edge strength) that will dictate whether or not a flake will be more efficient. He found that for the cutting and removal of meat, a HDT was much more efficient, although, he states that there is a large difference in the processes involved in the actual removal of meat versus simply cutting into it.

With regard to both processes he reports that "serrated quartzite cutting edges" were the sharpest and the longest lasting (Jones 1994: 293). Additionally, he reports on cutting and peeling tubers, noting that flakes are much better suited to this task, while experiments in woodworking (e.g., making a pointed stick for use as a digging implement or as a spear) were best carried out using a large stone tool and a chopping motion to render the tip of the stick fairly sharp. He asserts that once the initial shaping is done, smoothing out the rough edges with a smaller tool produces a sharp implement. He states that the most important aspect to consider for woodworking is the edge angle and weight of the tool. A heavier-weighted tool with an edge angle approaching 90º will work more efficiently than tools without these characteristics (Jones 1994: 294). He posits that the common HDT design is not very efficient at this task as holding the tool and applying sufficient amount of force to cut the wood left little edge of the tool available for use.

In essence, Jones has proven through multiple studies that it is possible to utilise HDTs in various forms of butchery and woodworking tasks. His experimental data set has certainly shed much light on the *possible* uses of HDTs but his results have not yet been confirmed by any micro-wear approaches. However, he has made pioneering efforts into the field of experimental archaeology with regards to Acheulean technology on the African continent.

### 4.7.2 Micro-wear Analyses of African ESA Materials

To date, there are only a few micro-wear analyses of African ESA stone tools published. Of these, there are examples for high-power use-wear, residue analysis, macroscopic use-wear, and multi-stranded analyses; yet, no low-power use-wear analysis has been undertaken on any materials

that can be reliably dated to the ESA. The following presents the studies that have examined ESA stone tools, sub-divided by the micro-wear approach utilised.

#### 4.7.2a High Power Use-wear

The earliest example of high-power use-wear analysis of ESA materials is Keeley and Toth's (1981) examination of 54 artefacts from five different sites in the Koobi Fora region of Kenya, from the Karari Industry dated to *ca.* 1.5 Ma (now regarded as a form of Developed Oldowan). All of the artefacts examined were flakes or flake fragments, except for one "minimally retouched pebble core" (Keeley and Toth 1981: 464). Additionally, all the artefacts were non-basalt, even though more than 90% of the artefacts from the sites were made on basalt. The authors excluded more than 90% of the assemblage due to a slight chemical dissolution (weathering) that made them unsuitable for high-power micro-wear analysis.

In this study, the primary problem was that the analysts utilised only high-power use-wear, which as previously mentioned (Section 4.5.2), can cause problems in distinguishing between PDSM polish and that created through use. The problem of recognizing PDSM (weathering) polish is evident as well, when the authors reported that of the 54 non-basalt (e.g., cryptocrystalline silicates and ignimbrite) pieces examined for their study none showed any signs of weathering (e.g., natural abrasion by wind, water, or sand) and only five showed signs of slight chemical weathering. This claim is problematic as: 1) the site contexts from which the artefacts come (i.e., floodplain deposits next to ancient stream courses and one site in river gravels) are areas where it is likely that weathering has taken place due to the hydrological activities that were going on in the area; and 2) the basalt pieces from the sites, more than 90% of each site's assemblage, showed weathering patterns (Keeley and Toth 1981: 464). The authors' failure to identify any weathering on the pieces that they examined is likely due to the fact that at the time of their study (1981), PDSM and its resultant wear traces were poorly understood. However, Keeley (1980) noted that natural traces should not be ignored and even minor soil movements could constitute a problem for high-power analysts.

Despite this, the analysts continued their study, reporting that at 400x magnification the ridges and edges of all but the five weathered flakes

were indistinguishable from freshly knapped modern specimens of the same raw materials. The authors state that this finding implies that any use-wear traces would have likely survived. However, there is no quantification of any edge rounding, making this claim hard to corroborate, even though six years prior to this study, Shackley (1974) proposed a method for quantifying edge rounding, especially for use in micro-wear studies. Additionally, the authors state that their inferences were made on "the reflectivity and texture of the microwear polish, the size and directions of scratches ('striae') [and] the size and character of the edge damage" (Keeley and Toth 1981: 464). While this statement may have been true, the authors present only descriptions of polish and striae, neglecting edge damage, apart from mentioning "step scars" on one tool and "crescent-shaped scars" on another tool.

Keeley and Toth ultimately concluded that nine of the fifty-four implements examined showed clear evidence of use. They state that four show a polish similar to that produced when experimentally cutting meat and other soft fleshy tissues. However, they stated earlier that some of the Koobi Fora tools, both experimental and archaeological, showed a natural polish that resembled low-intensity meat cutting polish. Even though they stated this earlier, they do not discuss the natural polish as a possible source of confusion with the meat polish observed on the analysed sample (Keeley and Toth 1981: 464). Two pieces showed a smooth-textured polish generally associated with use on silica rich plants, such as grasses or reeds. The remaining three implements bore wear traces similar to those created by experimentally working wood, two for scraping and one as a saw (Keeley and Toth 1981: 465).

Though it was considered pioneering for the time, as no one else had attempted micro-wear analyses of any lithic materials of a similar age to those examined in the aforementioned study, by today's standards the study was flawed and the findings should be taken with caution.

In 1992 Binneman and Beaumont published a high-power analysis of two Acheulean handaxes from Wonderwerk Cave, South Africa (Section 2.2.2). The authors report that of the four handaxes received for analysis, only two from levels dated to *ca.* 0.35 Ma were selected for analysis. The authors provided no explanation for the exclusion of the other two handaxes or why their sample size was so small (Binneman and Beaumont 1992: 93). As with the other high power studies, only polish and striae were reported on, and other wear traces were not mentioned.

The authors report that both of the handaxes have polish that resembles that created by the working of plant material, but they are noticeably different from those polishes resulting from plant usage under 'clean' conditions. In other words, the polish resembled plant working experiments under 'dirty' conditions in which abrasives (e.g., sand or dirt) were added by the experimenters in contrast to the working of plant materials without the artificially introduced abrasives (Binneman and Beaumont 1992: 94-95).

They report the identification of three polish types as follows: 1) sedge worked under 'dirty conditions'; 2) 'clean' plant polish, particularly sedge, though they mention it could be reed or wood; and 3) wood worked under 'dirty' conditions. As a use-wear analyst, I find problematic the purposeful addition of abrasives that may or may not have been present during prehistoric activities as this *will* affect wear-traces and may compromise the reliability of said wear traces. The abrasives could have possibly come from the environment or the dirty conditions in which hominins would have been working. I am, however, hesitant to accept that they purposefully added abrasives when working comestibles. Nevertheless, they report the aforementioned polishes and suggest that there may be some linkage between these *two* Acheulean handaxes and LSA Wilton adzes from Boomplaas Cave (Binneman and Deacon 1986), as both were observed to have been used to work wood, even though there are hundreds of thousands of years separating the two traditions and more than 500 km separating the two sites.

Although there is a decade of research separating this study and this first example (i.e., Keeley and Toth 1981), many of the pitfalls of the earlier work are found in this case study as well. The authors do not mention any PDSM or the possibility that it could be affecting their sample. Their sample size is small, and they discuss only polish and striae without mentioning edge damage. Additionally, using results from *two* pieces, Binneman and Beaumont make generalisations about handaxe use, and many studies have cited this work, although it has not been confirmed by any further research.

More recently, Lemorini *et al.* (2014) conducted a study of Oldowan artefacts from Kanjera South, Kenya with an age estimate of 1.95 Ma. They state that the reason this particular assemblage is well suited for use-wear analysis is that "stone artifact surfaces have not undergone extensive post-depositional modification, and *multiple* raw materials preserve use-wear traces" (Lemorini *et al.* 2014: 11, my emphasis).

However, even though “multiple” raw materials preserve use-wear traces (one of the criteria for this assemblage being “well suited” for use-wear analysis), the authors chose to analyse only quartz and quartzite tools. These two raw materials were chosen for a couple reasons. One was that there was not yet a big enough comparative collection of experimental tools for other raw material types (e.g., chert, rhyolite). An understandable reason that many analysts face due to time and budget restrictions. The other was that quartz and quartzite were, according to the authors, overall more resistant to weathering and PDSM than most of the other raw materials evidenced at Kanjera South (e.g., basalt, felsite, carbonatite) (Lemorini *et al.* 2014: 13). This is a similar problem to the one in the aforementioned study by Keeley and Toth (1981) in that the authors excluded over 90% of the entire lithic assemblage and took their sample from two raw materials that together equal only 7.8% (339 out of 4474) of the total stone tool assemblage. Furthermore, out the 339 artefacts (n=91for quartz and n=248 for quartzite) a total of 62 artefacts (n=35 for quartzite and n=27 for quartz) or 18.3% (62 of 339) were chosen for analysis. This is a sample size of 1.39% of the total assemblage, which is quite a small number.

The artefacts were chosen after a quick macroscopic and/ or low-power scan for possible use-areas and to exclude tools that the authors believed showed signs of moderate to heavy PDSM and weathering.

To aid in their analysis, the authors conducted a set of 94 experiments on 14 quartz and 70 quartzite tools made from both local and non-local raw materials. The experiments included a wide range of tasks including butchering, working wood, working vegetal materials, etc. (Lemorini *et al.* 2014 Table 3). An additional 10 tools were made to be utilised as blind test specimens for Lemorini, to test the reliability of her interpretive results of the archaeological specimens.

While both of these steps are now generally expected for use-wear analyses, there are a few issues with these two areas. First of all, the blind test was given accuracy scores of between 71% and 100%. According to blind test scoring conventions (e.g., Keeley and Newcomer 1977; Odell and Odell-Vereecken 1980; Newcomer *et al.* 1986; Shea and Odell 1987), the authors incorrectly scored the blind test in two ways. The first is that the authors focused only on the tools *identified* by the analyst to have use-wear on them (i.e., even though all 10 tools were utilised in a total of 14 distinct tasks, the author only observed use on eight of them). Rather than taking a mark away for these tools, the authors exclude them from their

discussions and state that “the hardness [resistivity] of the material being worked was correctly recognized in all eight cases where use-wear was identified (100% success rate)” (Lemorini *et al.* 2014: 17). In reality, the analyst scored 21.43% (3/14) as two points should have been taken away for assigning “not-used” to a tool that had been utilised for two separate tasks, another point taken away for assigning the same non-use to a tool used for one task, and an additional 8 points for not assigning hardness to the other used tools. Additionally, the worked material accuracy score was marked as 71% (or 5 correct of 7 attempts). Again, points should have been taken away for the no-use answers on used tools (a total of 3 points), an additional two points should have been subtracted for interpreting fresh grass as animal flesh, half a point should have been subtracted as the analyst only listed animal flesh for a tool that was used on flesh and bone, and an additional three points taken away for not listing materials on tools that were used. This would give an actual accuracy rate of 39.28% (5.5/14). Lastly, for the category of tool motion, the authors report that it was “correctly inferred in seven of eight cases (success rate of 88%)” (Lemorini *et al.* 2014: 17-18). As with the other two categories, three points should have been taken away for the no-use tools, an additional two should have been subtracted for a tool used for scraping and cutting while the analyst’s answer was piercing, and a further one point taken away for an answer of piercing and scraping for a tool that was used for piercing and cutting. This would result in an accuracy rate of 57.14% (8/14).

The second way the test was incorrectly scored was that points were not subtracted for answers given (e.g., cutting soft material) when that area of the tool was completely un-used (usually listed in the “inferred….2” categories). According to Shea and Odell (1987: 29), “attributing contact wear to a portion of a tool where none exists is just as much a mistake as missing an area that has sustained contact with a worked material”. Had the authors subtracted points for these incorrect answers as well, the accuracy results would have actually been 14.28% for hardness (2/14), 25% for worked material (3.5/14), and the results for activity/ motion would have been 35.71% (5/14). For a visual comparison of the two sets of results compare Table 4.1 (from Lemorini *et al.* 2014) and Table 4.2 (the correct marking of the results according to convention).

## Table 4.1 Lemorini *et al.'s* (2014) Table 5

| Flake number | Experimental protocol | | Use-wear analysis | | | |
|---|---|---|---|---|---|---|
| | Material worked | Activity carried out | Inferred material worked 1 | Inferred activity carried out 1 | Inferred material worked 2 | Inferred activity carried out 2 |
| B1 | Soft wood (ornamental cherry, *Prunus* sp.) | Cutting (500 strokes) | Wood | Cutting | Soft material (animal tissue?) (gripping wear) | Cutting |
| B2 | Sweet potato (*Ipomoea batatas*) covered with fine sand | Scraping off dirt (322 strokes) + Cutting (333 strokes) | No use-wear detected | n/a | | |
| B3 | Sweet potato covered with fine sand | Scraping off dirt (350 strokes) + Cutting (459 strokes) | Grit covered plant tissue/USO | Cutting and scraping | | |
| B4 | Hard wood (black maple, *Acer nigrum*) | Scraping (470 strokes) | Wood | Scraping | Medium-hard material (hide?) (gripping wear) | Scraping |
| B5 | Clean sweet potato | Scraping (486 strokes) + Cutting (120 strokes) | Soft material | Piercing | | |
| B6 | Goat (*Capra hircus*) limb | Cutting off meat + hitting bone a few times (500 strokes) | Animal flesh | Cutting | Medium-hard material (hide?) | Transverse motion |
| B7 | Goat limb | Cutting meat and piercing fascia sheets (350 strokes) | Animal flesh | Piercing | Soft material (plants?) | Scraping |
| B8 | Goat bone (femur) | Bone scraping (400 strokes) | No use-wear detected | n/a | | |
| B9 | Fresh grass, field in southern New York | Cutting (300strokes) | Animal flesh | Cutting | | |
| B10 | Fresh grass, field in southern New York | Cutting (500 strokes) | Animal flesh | Cutting | | |

## Table 4.2 Corrected Scoring of Lemorini *et al.'s* (2014) Blind Test

Answers highlighted in green equal one full point; those highlighted in yellow equal 0.5 points; and those highlighted in red equal 0 points.

| Experimental Protocol | | | | Analyst's Answers | | |
|---|---|---|---|---|---|---|
| **Flake #** | **Resistivity** | **Worked Material** | **Action** | **Resistivity** | **Worked Material** | **Action** |
| B1 | Medium- Soft | Soft Wood | Cut | None<br>Soft | Wood<br>? | Cut<br>Cut |
| B2 | Soft and Hard-3 | Sweet potato covered with fine sand | Scrape off Dirt<br>Cut potato | None<br>None | None<br>None | None<br>None |
| B3 | Soft and Hard-3 | Sweet potato covered with fine sand | Scrape off Dirt<br>Cut potato | None<br>None | Grit Covered Plant Tissue For Both Tasks | Scrape<br>Cut |
| B4 | Medium- Hard | Hard Wood | Scrape | None<br>Medium- Hard | Wood<br>? | Scrape<br>Scrape |
| B5 | Vegetal- Soft | Sweet potato | Cut<br>Scrape | Soft<br>None | None<br>None | Pierce<br>None |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| B6 | Animal Soft and Hard-1 | Meat and Bone | Cut | | None<br><br>Medium-Hard/ Soft | Flesh<br><br>None | Cut<br><br>Scrape |
| B7 | Animal Soft | Meat and fascia | Cut<br><br>Pierce | | None<br><br>Soft | Flesh<br><br>None | Pierce<br><br>Scrape |
| B8 | Hard-1 | Bone | Scrape | | None | None | None |
| B9 | Vegetal Soft | Fresh Grass | Cut | | None | Flesh | Cut |
| B10 | Vegetal Soft | Fresh Grass | Cut | | None | Flesh | Cut |
| | | | | | | | |
| Total using 1st method | | | | | 3/14<br>21.43% | 5.5/14<br>39.28% | 8/14<br>57.14% |
| Total using 2nd method | | | | | 2/14<br>14.28% | 3.5/14<br>25% | 5/14<br>35.71% |

As evidenced by the data in Table 4.2, the actual range of accuracy percentages should be approximately 21% to approximately 57% if using the first method or approximately 14% to approximately 35% using the second method. This casts doubt on Lemorini *et al.'s* (2014: 17-18) statements that "the results of the blind test broadly confirmed the utility of use-wear analysis for the interpretation of the function of quartzite artefacts" and that their results "fall at the high end of other published blind test results". If anything, these results fall in the lower to lower-middle end of the published results. Additionally, this should serve as a prime example of a blind test in which the protocols and procedures were carried our poorly, which lead to using incorrect information when applying the results to archaeological assemblages (for another example see Section 4.7.2b).

Another problem area with this study is that, for both the experimental and the archaeological pieces, all observations were made from silicone moulds (negative replicas). The authors state that many of the experiments took place in Kenya, but the microscopy was done at the University of Rome in Italy, meaning that the moulds of the experimental and archaeological pieces had to be transported over 5000 km (as the

crow flies, or over 9000 km if travelling by land) before they were observed under a microscope (Lemorini *et al.* 2014: 16). They state the main reason for using moulds instead of the authentic pieces was that it helped to reduce the intense glare that is not uncommon when looking at quartz rich lithics. This glare is a problem in general for high-power use-wear analysis (as noted in Section 4.5.4). Additionally, the problems with utilising moulds (e.g., air bubbles, polymerization shrinkage, or the mould not being a perfect negative of the actual piece) coupled with the problems of transporting the moulds such a great distance (e.g., extreme temperature changes or packaging wear not related to use) have been noted in various publications on differing materials (e.g., teeth, bones, lithics, metal) (e.g., Schoen *et al.* 1978; Scott 1982; Plisson 1983; Gordon 1984; Knutsson and Hope 1984; D'Errico 1988; Palin-Luc *et al.* 2002; Banks and Kay 2003). Specifically regarding high-power use-wear analysis, Plisson (1983: 19) states that "on the casts made with silicon rubber…the outline of the micro-polish is recognizable but the details of its structure…are lost". This, too, casts doubt on the results of this study's analysis.

Despite these pitfalls the authors continued the study and reached the following conclusions. Of their quartzite sample, 71.43% (25 of the 35 tool moulds) showed use-wear traces. Cutting represented 42.3% (11 of 26 used edges) of the observed use, over a range of materials (e.g., animal tissue, wood, vegetal matter). Scraping constituted 34.6% (9 of 26) of the interpreted use with a similar spread of worked materials. Finally, the additional six used edges (23.1%) were mixed action tools consisting of both cutting and scraping wear (Lemorini *et al.* 2014: 19).

For the quartz tools, 51.58% (14 of 27) showed use traces spread across a variety of tasks, with no single task dominating. Altogether the authors state that 70% (16 of 23 used edges) were utilised to process plant (including grass, sedge, wood, and vegetal material) while 30% (7 of 23) were used on animal products. However, even these numbers are not quite correct, as the authors state that these are figures for 23 artefact edges when their own Table 6 shows 41 used edges (Lemorini *et al.* 2014: 21). Again, the authors chose to ignore the overall picture and calculate percentages only on the tools with secure wear-patterns, rather than use the total assemblage of analysed edges and calculate percentages with those numbers. Had they done so, the actual percentages would have been 39.02% (16 of 41 edges) used on plant materials, 17.07% (7 of 41) utilised on animal products, and the majority (43.9% or 18 of 41) used but not classified any further than resistivity or is some cases indeterminate.

The authors go on to make several conclusions about the life, dietary patterns and subsistence patterns of the Kanjera South Oldowan hominins (Lemorini *at al.* 2014: 19-23). However, given the above discussion and the aforementioned flaws with their work, the results should not be relied upon and the conclusions they draw should be seen as dubious at best.

Overall, high-power use-wear analysis has contributed little to the African ESA record thus far. Reports that have been published are flawed in multiple areas (e.g., selection criteria, blind testing, sample size), making the results unreliable.

**4.7.2b Residue Analyses**

There have only been two studies using residue analysis to reconstruct tool functions from Acheulean tools. Dominguez-Rodrigo *et al.* (2001) investigated residues found on three handaxes and two flakes from site PEES 2 of the Peninj suite of sites, the Acheulean layers of which have been dated to *ca.* 1.7-1.4 Ma. The site is located in an ancient deltaic environment, which the authors suggest would have been the modern day equivalent of a swamp. The lack of artefact orientation, size sorting and abrasion, plus the sediment type, all indicate a very low energy depositional environment in which the tools may have been slightly rearranged but not highly disturbed by hydrological activity (Dominguez-Rodrigo *et al.* 2001: 292).

The authors began by taking samples of the soil around the tools they were going to observe as a control sample, which is now common practice in residue analysis, so that they could compare any residues found in the soil with those found on the tools. They were looking specifically for phytoliths, rather than residues in general, which may have biased their results, but the first methodological steps taken are sound even by current standards. Additionally, they removed samples of sediments still adhering to tools, with a mean thickness of greater than 5 mm, from three different areas of each piece and ensured that they were not contaminated by the encasing soil deposits. After extraction of the adhering sediments, samples were taken directly from the stone tool surfaces. They followed Serrallonga *et al.'s* (1999) protocols for preparing, sorting, and mounting slides. Samples were observed using an Olympus BH-2 at 400x. Other samples to be observed with a Cambridge Stereoscan S-120 SEM with a resolution of 6 nm and magnifications of 6x to 20 000x, were coated with carbon (for X-ray microanalysis) and gold for photography utilising a

Hitachi S-2300 SEM (Dominguez-Rodrigo *et al.* 2001: 293).

Dominguez-Rodrigo and colleagues report that the phytolith morphotypes recovered from the artefact bearing paleosol were dominated by saddle-shaped phytoliths typical of the sub-family *Chloridoideae*. This discovery, with a few other observations, allowed the researchers to posit that the environment during the Acheulean times around Peninj consisted mostly of short-grasses with a minor presence of dicotyledons and some forbs/ shrubs (Dominguez-Rodrigo *et al.* 2001: 295). They compared these samples with those found on the tools and reported that they were significantly different, allowing them to argue that the archaeological specimens examined had not been contaminated by the surrounding matrix.

They state that phytoliths were found on three stone tools and were polyhedral in shape, rather than saddle-shaped, suggesting a different origin to those found in the soil samples. Also, the authors report finding calcium oxylate phytoliths in combination with parenchyma tissues, silicified tracheids and fibres (Dominguez-Rodrigo *et al.* 2001: 295) which are documented to come from some *Leguminosae* (e.g., *Acacia* sp.) and some leaf tissue from dicotyledons. Furthermore, they state that from an earlier pollen analysis, *Acacia* sp. is the only legume found at Peninj and that the preservation of parenchyma tissues indicates a good preservation environment, making their results more secure (Dominguez-Rodrigo *et al.* 2000). Cortical cells were found on one of the flakes indicating that it may have been used to remove cortical fibres (i.e., the outer layers) of branches. The two handaxes were more likely used for chopping wood due to the lack of these cortical fibres. They argue that based on previous researchers work (e.g., Prior and Cutler 1992; Gourlay 1995; Runge 1996) the phytoliths they found on the archaeological tools are indistinguishable from those reported to belong to *Acacia* sp. (Dominguez-Rodrigo *et al.* 2001: 296). They also state that the only other plant remains from which the phytoliths could have come (i.e., *Salvadora persica*) can easily be worked by non HDTs, such as the flake examined, and that the edge-damage they observed on the handaxes was not consistent with working this soft tissue shrub. Finally, they also report that some plant fibres were found on the inner surface of the handaxes, although their identification could not be refined. They posit that it is possible that the plant fibres are from hafting or padding placed in the hand during use so as to not cut the user's skin (Dominguez-Rodrigo *et al.* 2001: 297). They conclude that their results point to hominins making, working, and using wooden tools (e.g., digging sticks) as early as the early Acheulean and moreover suggest that

hominins could have been making crude spears for hunting purposes.

This study has a few points of contention, but overall it is methodologically sound. Two pitfalls are that the authors analysed a small sample and failed to mention that wood tissues are some of the hardiest and longest lasting organic remains (as reported by Hardy and Garufi 1998) being preserved in a wide range of depositional contexts. However, they seem to have compensated for this by taking control samples from the surrounding palaeosol and from soils clinging to the surface of the tool and subjecting them to the same kinds of analyses to which the samples taken from the stone tools were subjected. When they found that the phytoliths preserved on the surfaces of the tools were dramatically different from those preserved in the soil samples, this allowed them to say, with some authority, that the samples taken from the tools had not been contaminated by the depositional context.

The second study was undertaken by Herrygers (2002) and focuses on the same kind of analysis but on samples from the Okote Member, (*ca.* 1.5 Ma) Koobi Fora, Kenya. The major exception is that Herrygers (2002: 66) performed wood working on various indigenous species in the area with local raw materials to create her own comparative collection. This makes Herrygers' study more reliable than Domiguez-Rodrigo *et al.'s* (2001) as she combined experimental archaeology with residue analysis to determine if residues were present. Though her study is sparse in details in some places (e.g., she does not mention how many tools were analysed, but rather just reports on the archaeological tools that were found to have residues on them, or she does not mention to which industry the tools belong), her conclusions were the same as the aforementioned study. She found that on at least three basalt flakes there was evidence for intensive wood working as seen through wood residues left on the flakes (Herrygers 2002: 67).

Overall, residue analysis has proven that woodworking residues have survived on HDTs and flakes, suggesting that early hominins may have been making and using wooden tools (e.g., spears, digging sticks) or possibly that the tools may have been hafted (Dominguez-Rodrigo *et al.* 2001). Hopefully, future research will confirm these findings as currently the earliest known archaeological evidence for the presence of wooden spears comes from Schöningen, Germany (Dennel 1997; Thieme 1997) dated to *ca.* 0.4 Ma.

#### 4.7.2c Macroscopic Analyses

To date there has only been one macroscopic study focusing on ESA materials. Wilkins *et al.* (2012) conducted an analysis of supposed points from the Fauresmith Industry, which is generally considered to be a later to final ESA tradition. The authors were specifically looking for diagnostic impact fractures (DIFs), which may form when pieces are used as projectile points (e.g., as a spear, an arrow, a dart, etc.). They analysed 210 points and point fragments from stratum 4a at Kathu Pan 1 in South Africa, with an age of *ca.* 0.5 Ma. To inform their analysis they re-created thirty-two points of the same raw materials and morphologies as the archaeological specimens and hafted them to wooden spears, then shot them into culled springbok carcasses with a calibrated crossbow to simulate a thrusting spear and to keep the variable of force consistent (Wilkins *et al.* 2012: 943). They note that the experimental points performed well and that most of the points had to be fired multiple times before any macroscopic damage appeared. Additionally, they report that only two experiments resulted in "catastrophic damage that prevented the reuse of the points" (Wilkins *et al* 2012: 493).

The authors ultimately concluded that, based on a battery of statistical analyses, the archaeological specimens showed edge damage, and in particular, distribution of edge damage that was consistent with their replicated spear points. Thus, they state that 29 of the 210 pieces analysed (13.8%) had DIFs.

However, this study has some drawbacks. The first is the approach used. As mentioned in Section 4.5.1, there are serious complications with identifying use based solely on macroscopic traces, and some kind of microscopic approach should be utilised if possible. Additionally, this article, along with some other macroscopic use-wear studies, has recently been critiqued for several failures by Rots and Plisson (2014). Rots and Plisson (2014: 157) point out that the depicted examples of DIFs, supposedly step-terminating bending fractures according to Wilkins *et al.* (2012: Figs. 2A and 2B), are not the step-terminating bending fractures defined by previous researchers (e.g., Odell and Cowan 1986). In fact both of the pictures do not show bending initiation at all, making one of the criteria for DIFs unfulfilled. Figure 2A instead shows a "clear ridge" on the fracture negative, indicating that two fractures are evidenced and Figure 2B shows a snap fracture that cuts through the initiation point of a step-terminating scar (Rots and Plisson 2014: 157). The other two figures (2C and 2D) reportedly show distal impact burination spalls. Figure 2C actually shows a crushed tip that has destroyed the initiation of the spall, but it appears to have started from the ventral surface and "thus qualifies as a

break" facture (Rots and Plisson 2014: 157). Additionally, Figure 2D shows a blow that is not axial but rather is initiated from the dorsal surface. According to published definitions of DIFs (e.g., Fischer *et al.* 1984; Odell and Cowan 1986), none of the pictures in Wilkins *et al.'s* study are DIFs.

Rots and Plisson (2014: Figs. 7A , 7B, 7C and 7D) show wear patterns that are similar to the ones seen in Wilkins and colleagues photos but resulting from uses such as drilling fresh bone, butchering, and the knapping process. These two sets of figures are compared in Fig. 4.11 below. As can be seen, Rots and Plisson (2014) present a convincing argument against the DIFs in Wilkins *et al.'s* (2012) and conclude that they have misidentified wear patterns. Additionally, Rots and Plisson (2014: 157) state that Wilkins *et al.* no doubt "chose to illustrate the most explicit examples in their dataset", thus calling into question whether there are any DIFs on the pieces examined.

Wilkins and her colleagues published a response to Rots and Plisson (2014) in which they state that the argument over whether there are truly DIFs on the tools "stems from a differing perspective on how lithic functional studies should deal with equifinality and the challenge of confidently assessing stone tool function" (Wilkins *et al.* 2015: 294). As of now, Rots and Plisson have not responded to this new argument and it will likely be interesting if they do.

Thus far, the results of macroscopic analyses of ESA lithics may be questionable and have not significantly contributed to the African ESA record.

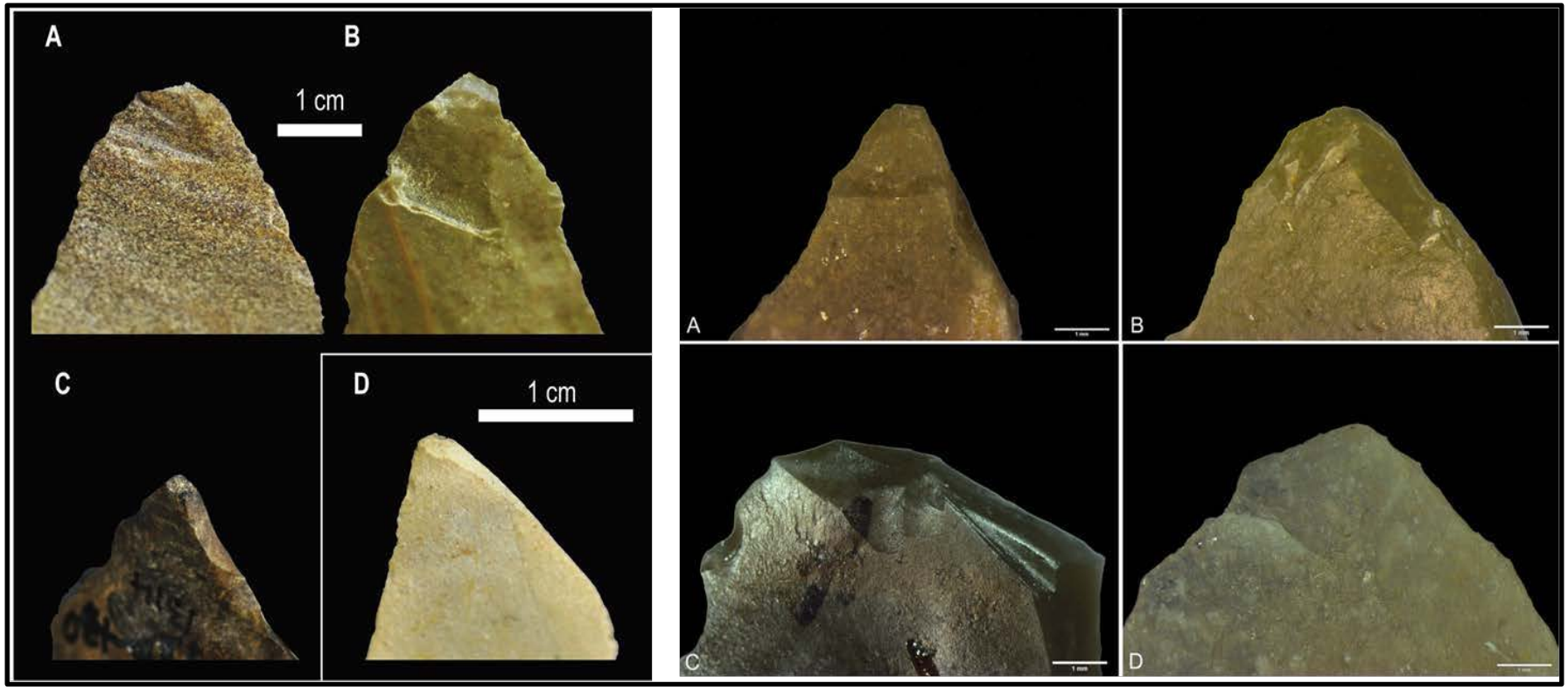


**Figure 4.11 Comparisons of Wilkins et al's Photos and Rots and Van Plisson's Photos** On the left are the images from Wilkins *et al.* (2012) showing supposed DIFs from archaeological specimens. On the right are Rots and Plisson's images showing similar wear from experimentally utilised pieces, but from tasks other than impact. Compare: Left side A and B (supposed DIFs) with right side A (used to drill fresh bone); Left side C and D (again supposed DIFs) with right hand B (used to drill fresh bone). Additionally, compare left side A with right side D (used for butchering) and left side D with right side C (scarring caused by knapping) (Left hand photo modified from Wilkins *et al.* 2012 and right hand photo from Rots and Plisson 2014.

#### 4.7.2d Multi-stranded Analyses

As with macroscopic analysis, I am only aware of one study that utilised a multi-stranded micro-wear approach to analysing African ESA materials. Results from previous analyses (Sahnouni & de Heinzelin 1998 analysed 11 flint artefacts; Vergés 2003 analysed 47 flint artefacts) indicated that a majority of the stone tools from the Oldowan levels at El-Kherba (Ain Hanech) in Algeria, dated to 1.78 Ma, were utilized in butchery related tasks. Sahnouni *et al.* (2013) sought to confirm these findings by using a multi-stranded approach which included an experimental programme, a taphonomic analysis of the mammalian faunal remains and a use-wear analysis of 50 flint artefacts.

The analysis of the bones and the flint artefacts were undertaken with a SEM and the authors hoped that the results would largely confirm each other (i.e., they would find cut marks on the bones, and bone working traces on the stone tools). However, the bones were first subjected to a quick analysis by hand lens and by a low-power stereoscopic microscope before they were analysed with the SEM. That stated, the authors say that bones with presumed cut marks were "analysed from polyurethane casts [of the bones]" instead of the bones themselves. The problems with casting have been discussed elsewhere (Section 4.7.2a) and will not be restated here, save the reiteration that casts may result in incorrect interpretations of wear signs (Sahnouni *et al.* 2013: 141). The authors report that thirteen bones with cut marks were found, though they do not state what the sample size of analysed bones was (Sahnouni *et al.* 2013: 142). Additionally, they found other signs of bone usage such as bone flakes, percussion notches, and crenulated edges from bashing or smashing bones apart for marrow extraction (Sahnouni *et al.* 2013: 143). These two sets of use-wear signs indicated to the authors that butchery events had likely taken place and further use (i.e., marrow consumption) of the bones had occurred.

The use-wear analysis confirmed these findings and dovetailed nicely with previous studies. Of the 50 pieces analysed, seven were observed to have use-wear traces. The authors stated that "the use deformations represent clear butchery traces" on all seven tools. This, too, confirmed their hypothesis that butchery had taken place.

While this study is sound, especially in its multi-stranded approach (i.e., using experimental archaeology, faunal analysis, and lithic use-wear) there are a couple of problem areas. The first is that the authors selected the

stone tools to be analysed based on “the morphology of the artefacts…and their spatial association with faunal concentrations” (Sahnouni *et al.* 2013: 141). Selecting artefacts that are directly associated with concentrations of faunal remains makes it likely that any wear observed will be linked to butchery tasks in some manner, and as the authors report, this was the case. An apt analogy would be selecting only stone axes that were found embedded in logs to subject to a use-wear analysis and finding that the use-wear indicated contact with a medium material such as trees. This arbitrary selection should cast some doubt on study’s validity, but I believe this is overcome by the study of the bones as well, which had cut marks on them.

The second problem is that using these results the authors state that “only soft animal biomass polishes are present on the flint artifacts, suggesting that early hominins made sharp-edged cutting artifacts for processing meat, which likely formed a major component of their diet” (Sahnouni *et al.* 2013: 148). As the authors did not sample artefacts from around the whole site and particularly sampled those directly associated with mammalian faunal remains, it is unlikely that the full range of use-tasks at Ain Hanech were represented in their analysis. Thus, suggesting that early hominins manufactured sharp-edged cutting artefacts specifically for processing meat is speculative. Furthermore, had the authors selected artefacts from other areas of the site, they might have found that just as many, possibly more, artefacts bore wear traces associated with plant use than with animal use (as did Lemorini *et al.* 2014 problematic though their study was). In short, the sample procedure and sample size can allow for some observations, but without further research the generalised statements the authors make are unfounded.

### 4.8 Chapter Conclusion

This chapter presented a wide range of topics but provided the needed background for the method, technique, and approach utilised in this study. Additionally, it presented previous functional studies that have been carried out on African ESA lithic materials, and as can be seen, the paucity of literature that utilises a reliable functional method is overwhelming. Given the state of the CoH Bed 3 assemblage (Chapter 6), it was decided that the low-power use-wear analysis approach (Section 4.5.4) coupled with an extensive experimental archaeology (Section 4.2) programme was the most fitting way to examine any extant wear traces on CoH LCTs. The following chapter discusses the experimental programme and blind test developed and implemented to aid in the interpretation of the use-wear traces from the CoH Bed 3 LCTs reported on in Chapter 6.

# Chapter 5
# Experimental Programme and Blind Test

## 5.1 Introduction

Crucial to any use-wear analysis study (irrespective of the approach used) is an experimental programme for the purpose of providing a comparative collection. The programme should be designed to control as many variables as possible (e.g., raw material type, morphological characteristics, worked materials, motions); however, the exact design of the experiments will depend upon the archaeological question being investigated. Additionally, a blind test (or series of blind tests) should be administered to determine the analyst's accuracy level, and thus the amount of confidence that can be placed in the observations and interpretations the analyst makes can be gauged (for the basics of how a blind test is performed see Section 4.4.3). Presented below are the experimental programme and its design and execution (Section 5.2). The 71 experimental tools are separate from and should not be confused with the additional 30 tools used for the purpose of the blind test (discussed in Section 5.3)

## 5.2 Experimental Programme

Experimental work is the foundation upon which use-wear analysis rests. It provides a collection of tools with known uses, and thus known use-wear patterns associated with those uses, with which the analyst can compare the archaeological assemblage (Keeley 1980; Law de Lauriston 2014). Another advantage that experimental work provides is that it can help the analyst achieve a greater understanding of the patterning and variability of use traces left by: 1) independent variables (e.g., raw material, edge morphology, use-duration, etc.) (Tringham *et al.* 1974); 2) different contact materials (e.g., animal flesh, bone, wood) and use-motions (e.g., cut, scrape, drill) (Odell 1980b; Odell and Odell-Vereecken 1981); and 3) human versus natural agency (e.g., trampling, PDSM, retouch) (Levi-Sala 1986; McBrearty *et al.* 1998; Pargeter 2011). The experimental programme carried out for this study consisted of several sets of experiments that all conform to the following rules:

1). The tools were manufactured from the quartzites likely available to the hominins within the vicinity of CoH during the Later Aheulean or out of raw materials that were as

similar as possible to those at CoH.

2). The tools that were to be utilised could only be used on materials that would have been available to hominins *ca.* 0.5 Ma (e.g., wood, animal remains, vegetal materials) and no tools were allowed to be used on materials that would not have been available at that time (e.g., plastic, metal, brick). Additionally, a wide array of materials was to be worked to help capture the variability of use-wear patterns that exist from working different materials in different motions.

Following these rules, 20 stone tools were made and utilised in various tasks (e.g., cutting meat, scraping wood, sawing bone), and an additional 20 tools were manufactured, not used, and stored in individual plastic bags to provide a collection of un-used tool edges. Finally, 31 tools were made, not utilised, then spray painted blue and stored in a wooden box without individual artefact protection to supply examples of tools damaged by PESM. The last set of experiments was inspired by the "Blue Flake Experiment" conducted by Odell and Cowan (1987) in which similar procedures were followed, but tested for PDSM and tillage effects rather than PESM. All together a total of 71 tools was made by the author for the experimental programme and are presented in Table 5.1.

### 5.2.1 Methods and Equipment

All tools (experimental, archaeological, and blind test) were analysed with an Olympus SZ61 with 10x and 20x interchangeable eyepieces allowing for magnifications of 6.7x to 90x and a Nikon SMZ-745T with 10x and 20x interchangeable eyepieces, as well as a 2x viewing tube attachment which permitted a range of magnifications from 6.7x to 200x. Macroscopic photographs were taken with a Nikon D 300s digital camera. All microscopic photos were taken a Nikon DS-Fi1 microscope attachable digital camera with a resolution of 2742 x 1942 (5MP). The camera was connected to a desktop computer with real-time feed to make image processing easier. Additionally, all microscopic photos were taken using the software interface of TSView7. A calibrated scale was inserted into all pictures using ImageJ 1.47v after the microphotograph was taken.

Before the experiments took place, the stone tools were examined and any manufacture wear was noted so that it would not be confused with wear related to use. Once the experiments were completed, the tools were

analysed with the same equipment later used to analyse the archaeological specimens. This was done so that I could train my eye for wear patterns that occur on the quartzites from the CoH area and to assist me in preparing for my blind test.  Locations of observed wear traces were recorded according to an 8 polar co-ordinate system in which the tool is placed inside of a circle that is split into eight equal sections (Odell 1979). The piece is oriented so that the bulb of percussion is placed in PCs 4-5 with the dorsal side facing out (Fig. 5.1). The code sheet utilised for recording the wear (see Appendix B, Fig. B.1) has a section that is filled out to describe on which face the wear occurs so that two records do not have to be made of the same piece. For terms and definitions used in recording and discussing wear patterns see Appendix D and Fig. D.1.

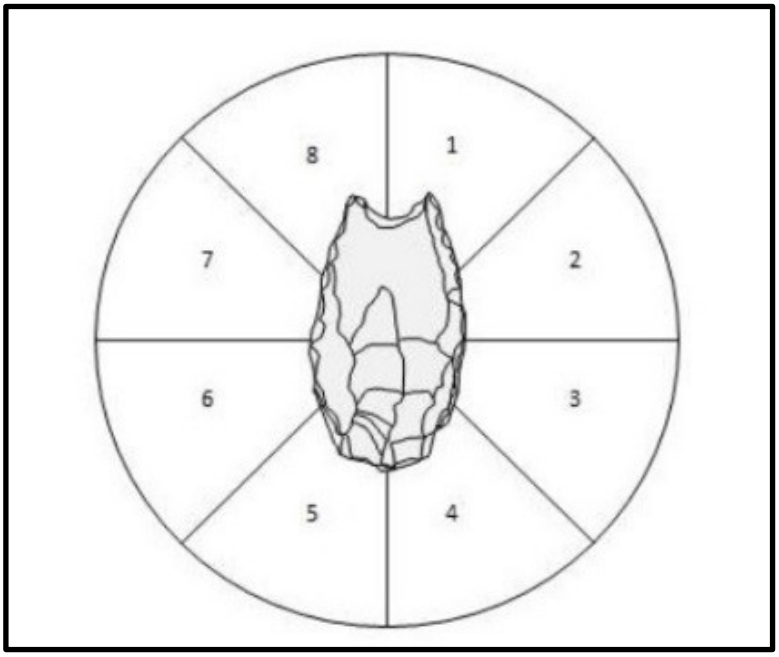


**Figure 5.1 The 8 Polar-coordinate System** (Image from Maika 2012, after Odell 1979).

**Table 5.1 Experimental Tools.** All hafted tools were hafted to a piece of de-barked *Ficus sur* branch, using the inner bark of *F. sur* as a binding and rendered *Sus domesticus* fat for mastic. A.S.= animal soft, 1M = medium-soft (e.g., a green or soft wood), 2M = medium-hard (e.g., a dry or hard wood), 1H = hard-1 (e.g., bone or antler), and 3H = hard-3 (e.g., dirt, soil, rock). B.R. Quartzite= Black Reef Quartzite collected from the outcrop above CoH (see Figs. 3.4 and 3.5).

| Experiment # | Type | Action | Resistivity | Worked Material | Raw Material | Time Used (in minutes) | Strokes |
|---|---|---|---|---|---|---|---|
| TS. 2013. 1 | Flake-retouched on edge used to scrape | Scrape<br>Saw | 2M<br>2M | *Ficus sur* (Broom Cluster Fig) branch. Seasoned 3 months | Gabbro | 18<br>18 | 2250<br>2250 |
| TS. 2013.2 | Handaxe (Hafted) | Dig | 3H | Soil/ Earth | Quartzite | 11 | 1320 |
| TS. 2013.3 | Retouched Flake | Dig | 3H | Soil/ Earth | Gabbro | 20 | 2000 |
| TS. 2013.4 | Retouched Flake | Drill<br>Scrape | 1M<br>1M | *Podocarpus falcatus* (Outeniqua Yellowod) branch. Fresh | Quartzite | 26<br>10 | 2340<br>1250 |
| TS. 2013.5 | Retouched Flake | Saw | 1H | *Bos taurus* (Domestic Cow) bone. Fresh | Quartzite | 30 | 3750 |
| TS. 2013.6 | Un-retouched Flake | Scrape<br>Scrape | 2M<br>1H & AS | *P. falcatus* branch. Seasoned 2 weeks<br>*B. taurus* bone and meat. Fresh | Gabbro | 25<br>20 | 3250<br>2800 |
| TS. 2013.7 | Un-retouched Flake | Slice | 1H & AS | *B. taurus* bone and meat. Fresh | Gabbro | 15 | 1500 |
| TS. 2013.8 | Retouched Flake | Scrape<br>Drill | 1H & AS<br>2M | *B. taurus* bone and meat. Fresh<br>Seasoned wood (species unknown) | Quartzite | 20<br>17 | 2600<br>1870 |
| TS. 2013.9 | Retouched Flake | Incise | 1H | *B. taurus* bone. Fresh | Quartzite | 25 | 3250 |
| TS. 2013.10 | Un-retouched Flake | Scrape | AS | *Sus domesticus* (Domestic Pig) belly. Fresh | B. R. Quartzite | 20 | 2200 |
| TS. 2013.11 | Un-retouched Flake | Scrape | AS | *S. domesticus* (Domestic Pig) belly. Fresh | B. R. Quartzite | 25 | 2750 |
| TS. 2013.12 | Un-retouched Flake | Slice | AS | *S. domesticus* (Domestic Pig) belly. Fresh | B. R. Quartzite | 23 | 2645 |
| TS. 2013.13 | Handaxe | Slice | AS | *S. domesticus* (Domestic Pig) belly. Fresh | B. R. Quartzite | 23 | 2875 |
| TS. 2013.14 | Handaxe (Hafted) | Dig | 3H | Soil/ Rock | B. R. Quartzite | 10 | 1100 |

**Table 5.1 Experimental Tools contd.**

| Experiment # | Type | Action | Resistivity | Worked Material | Raw Material | Time Used (in minutes) | Strokes |
|---|---|---|---|---|---|---|---|
| TS. 2013.15 | Handaxe (Hafted) | Thrown Projectile | 1H & AS 3H | Several *B. taurus* bones and meat. Fresh. Lying on the ground. | B. R. Quartzite | N/A | 20 throws |
| TS. 2013.16 | Handaxe (hafted) | Split/ Wedge | 2M | Seasoned wood (species unknown) | B. R. Quartzite | N/A | 110 |
| TS. 2013.17 | Un-retouched Flake | Saw<br>Drill<br>Scrape | 1M<br>1M<br>1M | *F. sur* branch. Fresh | B. R. Quartzite | 23<br>20<br>13 | 2530<br>2000<br>1560 |
| TS. 2013.18 | Un-retouched Flake | Saw | 2M | Seasoned wood (species unknown) | B. R. Quartzite | 30 | 3150 |
| TS. 2013.19 | Un-retouched Flake | Drill<br>Saw | 1H<br>1H | *B. taurus* bone. Seasoned 4 weeks | B. R. Quartzite | 16<br>45 | 1760<br>5625 |
| TS. 2013.20 | Un-retouched Flake | Drill<br>Saw<br>Scrape | 2M<br>1H<br>2M | Seasoned wood (species unknown)<br>*B. taurus* bone. Seasoned 4 weeks<br>*F. sur* branch. Seasoned 2 weeks | B. R. Quartzite | 24<br>10<br>20 | 3000<br>1150<br>2200 |
| | | | | | | | |
| Un-used 1-20 | Retouched & un-retouched flakes | Un-used | Un-used | Un-used. Individually stored in plastic bags then put in a cardboard box. | Quartzite | Un-used | Un-used |
| | | | | | | | |
| Blue Flake 1-31 | Retouched & un-retouched flakes, cores, and chunks | Un-used, painted blue | Un-used, painted blue | Un-used, painted blue. All stored in a wooden box with no individual protection. Box transported, shaken, and moved around to test for PESM. | B.R. Quartzite, painted blue | Un-used, painted blue | Un-used, painted blue |

Many of the wear patterns I was attempting to capture with the microphotographs were either on relatively large tools or relatively large areas of a single tool. This made for a generally "rough" micro-topography, meaning that only parts of a single wear trace (e.g., a flake scar or a striation) could be captured in focus in one photograph. Thus, I employed a method called "focus stacking", "focal plane merging", or "z stacking" in which multiple photographs were taken of the same wear feature, but with different parts of the feature in focus. All of the photos were loaded into a "stack" in Adobe PhotoShop CC. This programme allowed me to create layer masks on each of the photos so that only those areas that were in focus would be shown. Once the out-of-focus areas were masked out, all of the photographs were merged together to produce a final version that creates a highly extended depth of field (DOF) allowing for one picture to show wear traces that normally would not be seen in a single exposure (Fig. 5.1). This method has been used for some time, though employing different software than I did, and it has been advocated as a more time and cost effective solution than using a SEM or other optical imaging systems while delivering the same quality of final image (Sheppard *et al.* 1983; Weiss 2003; Bercovici *et al*. 2009). To my knowledge, however, this method has not yet been applied to micro-wear analysis, or at least has not been reported.

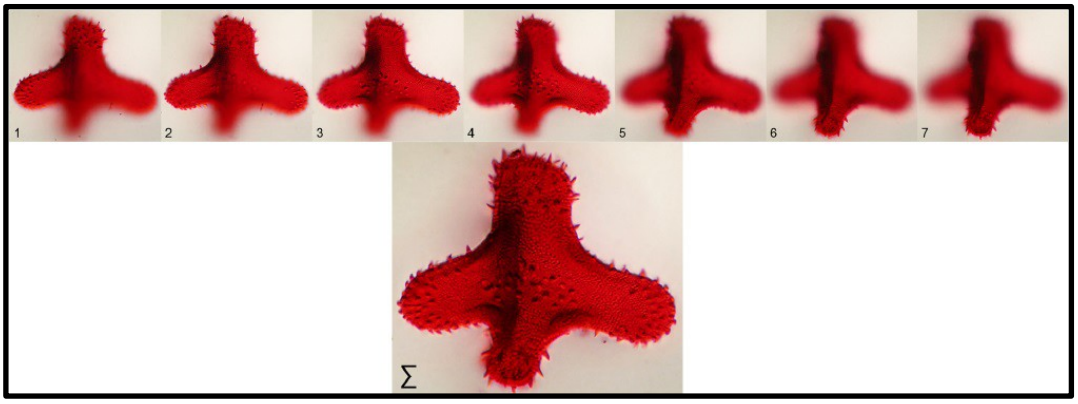


**Figure 5.2 Focus Stacking Example** Reconstruction of *Aquilapollenites attenuates.* The original seven photos are seen at the top, with different areas of focus. The bottom image is the final picture after layer masks have been applied to allow only those areas that are in focus to show through (Image from Bercovici *et al.* 2009).

### 5.2.2 Experimental Results

Each experiment was rigorously controlled and as many variables were recorded as possible, so that changes in different variables (e.g., use-time, action, retouch, raw material) could be correlated with subtle changes in wear-features. The over-arching results of the experimental work was that, in general, a primary edge of either Black Reef Quartzite, gabbro, or other quartzites stayed sharp for a long period of use-time and continued to be efficient for any given task. Retouch was not necessary to re-sharpen any of the tools during the course of utilisation, though some tools did become dull after prolonged use-times, particularly on medium-hard (e.g., seasoned or dry wood) and hard materials (e.g., bone, rock, soil). However, this was easily overcome by using a tool with secondary modifications (i.e., a handaxe), which made the edge stronger and consequently the tool was more efficient for those experiments that were performed on harder materials. For materials of a softer nature (e.g., meat, hide, etc.) the edges held up well under any circumstances (i.e., retouched or not). The tools generally never became dull and the experiments could have lasted several hours, were it not for the limited amount of material I had to work with and the limited amount of time, due to fatigue, that I was able to grasp each particular piece while experimenting. Figs. 5.3—5.21 show exemplary images of use-wear traces observed on the experimental tools and macroscopic images of the tools that exhibit the traces. (See Appendix C, Figs. C.7—C.13 for photos of all experimental tools.) “Plain English” descriptions and discussions of the wear patterns are provided in the captions for ease of reading the explanations while still seeing the figures. All experimental tool numbers in image captions correlate to numbers listed in Table 5.1.

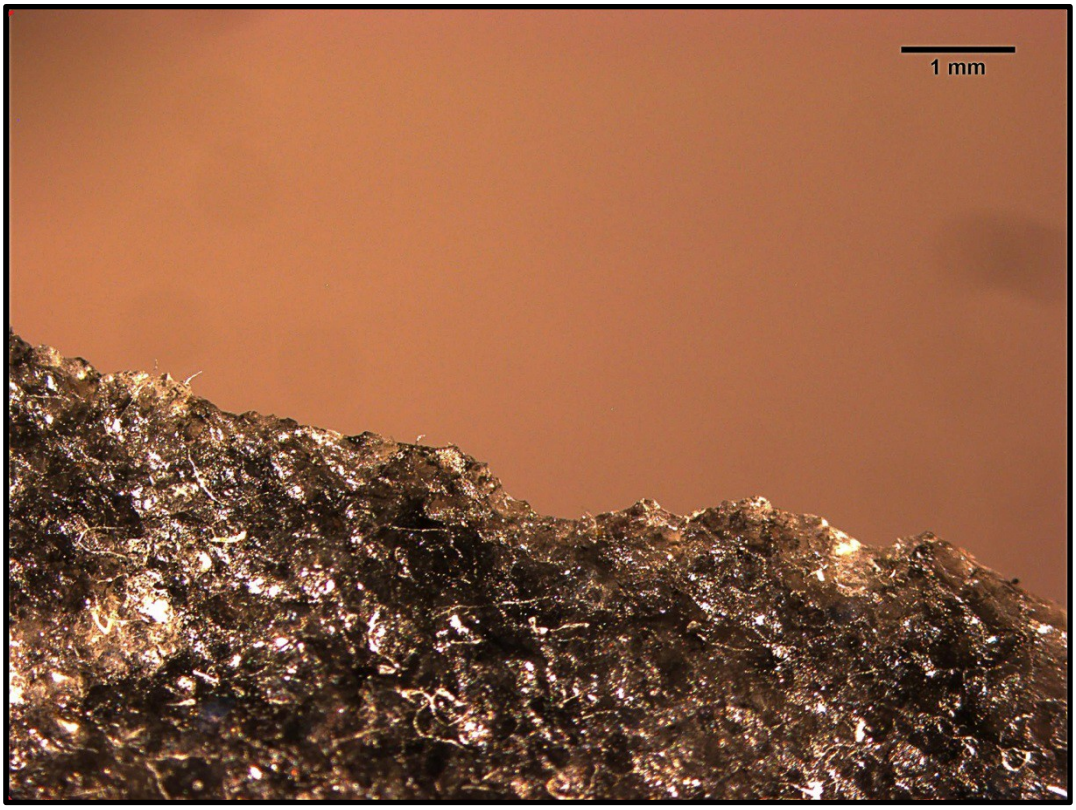


**Figure 5.3 Edge of TS.2013.11** Unretouched quartzite flake edge used for scraping fat from pork belly (to simulate working hide). Note that the edge is still sharp, there is little to no rounding or crushing of the edge, and there are no use-wear related fractures. The slight denticulation of the edge is a result of the edge being ground as a ridge on the core during the knapping process and was noted before the experiment began.

**Figure 5.4 Macroscopic View of TS.2013.11** The area circled in black is that shown in Fig. 5.3.

**Figure 5.5 Tip of TS.2013.2** Tip of hafted quartzite handaxe used in a digging motion in soil. The tip area (in/ around the black circle) shows smoothing of surface features. This "abrasion polish" is unique to a tool having made contact with soil (generally sandy, with no large inclusions). This kind of "polish" was specifically linked to digging by Taylor (2009: 257-259). Also note the other areas of the tool that do not show abrasion polish for a good comparison.

**Figure 5.6. Macroscopic View of TS.2013.2** The area circled in red is shown in Fig. 5.5.

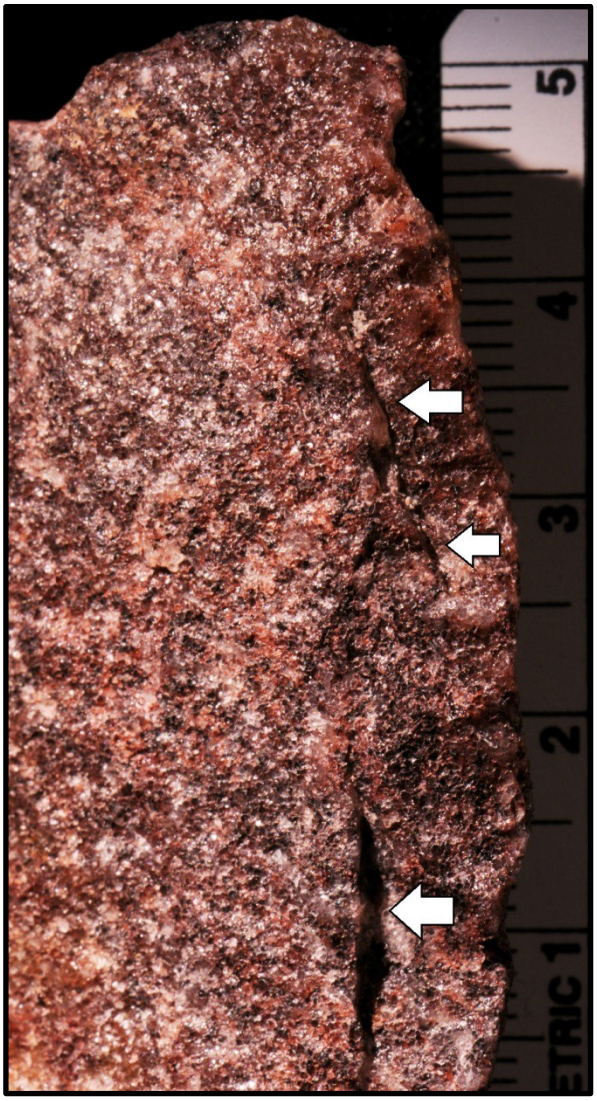


**Figure 5.7 Edge of TS.2013.5** Edge of retouched quartzite flake used for sawing cow bone. The large step fractures (white arrows) are the result of use and intrude several mm into the body of the piece. The edge is generally rounded and crushed due to the hard nature of the bone.

**Figure 5.8 Macroscopic Views of TS.2013.5** The area in the red circle is pictured in Fig. 5.7. The retouch on the piece consists of the large flake scars that have removed the cortex from the dorsal surface (left photo). There is no retouch on the ventral face (right photo and Fig. 5.7).

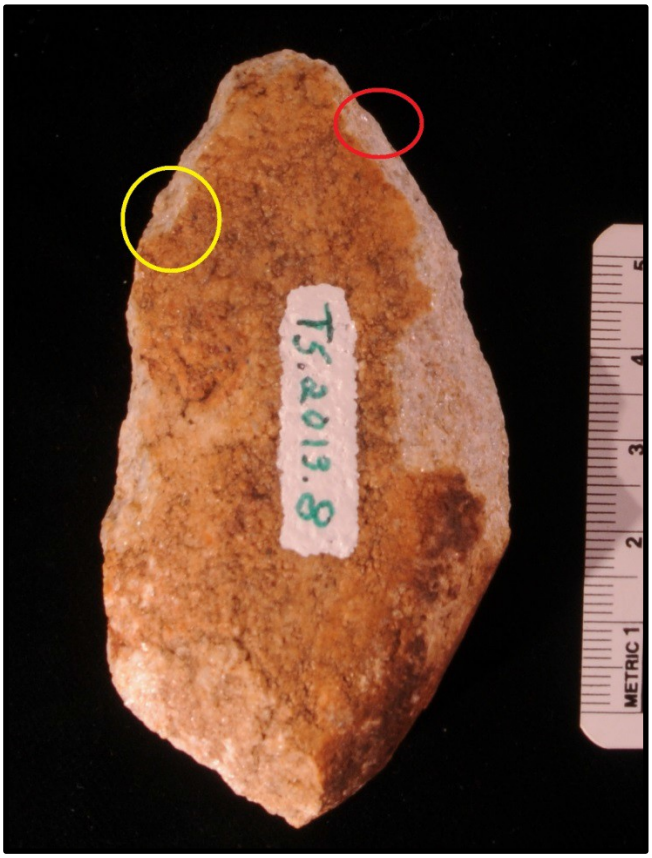


**Figure 5.9 Macroscopic View of TS.2013.8** The area circled in yellow is the used edge shown in the right hand photo in Fig. 5.10. The area is red is the un-used edge shown in the left hand photo in Fig. 5.10.

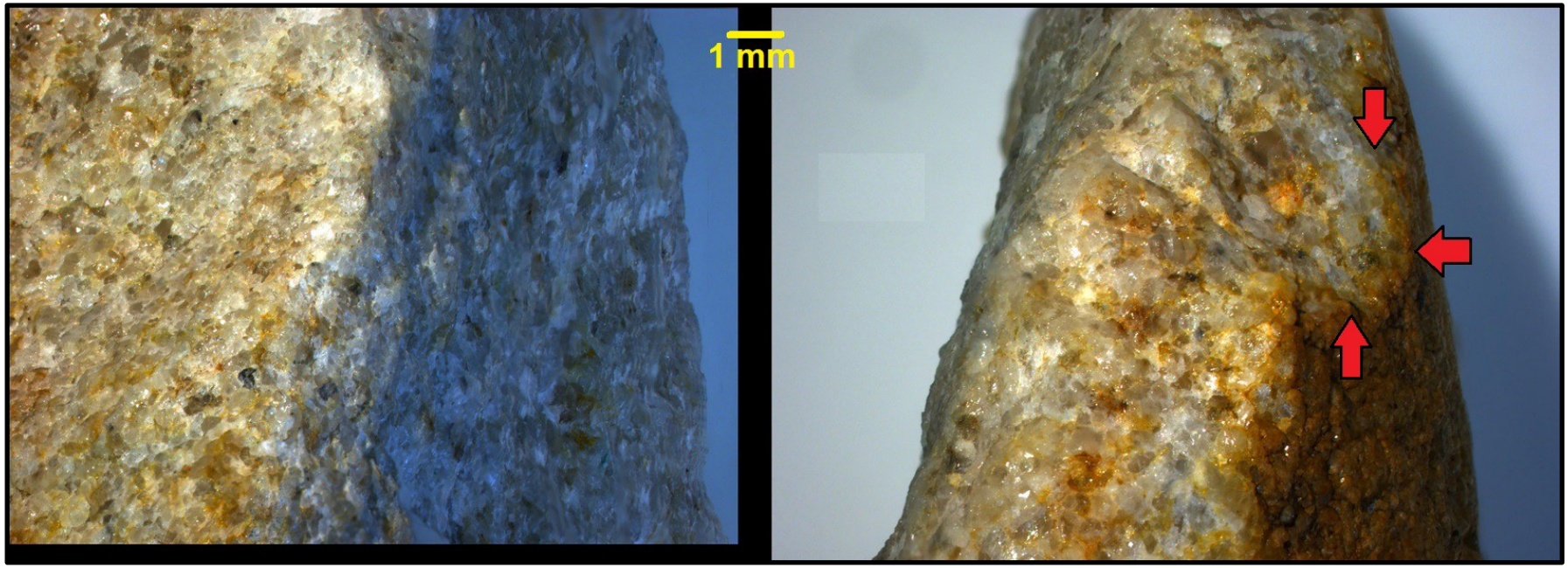


**Figure 5.10 Edges of TS.2013.8** The left photo is showing the un-used edge for comparison. The right picture is showing the edge of a retouched quartzite flake used for scraping meat from bone. Note the extreme rounding and crushing of the edge in the right hand photo when compared to the left hand picture. Also note the rounding on the arêtes of the retouch scar (red arrows) seen in the right photo. It was likely that the used edge was first flattened through snap and break fractures; as the experiment continued, the hard bone and the use-time combined to "grind" all of the technological features of the flake scars into non-existence, until the edge stabilised and no more scars were removed due to use.

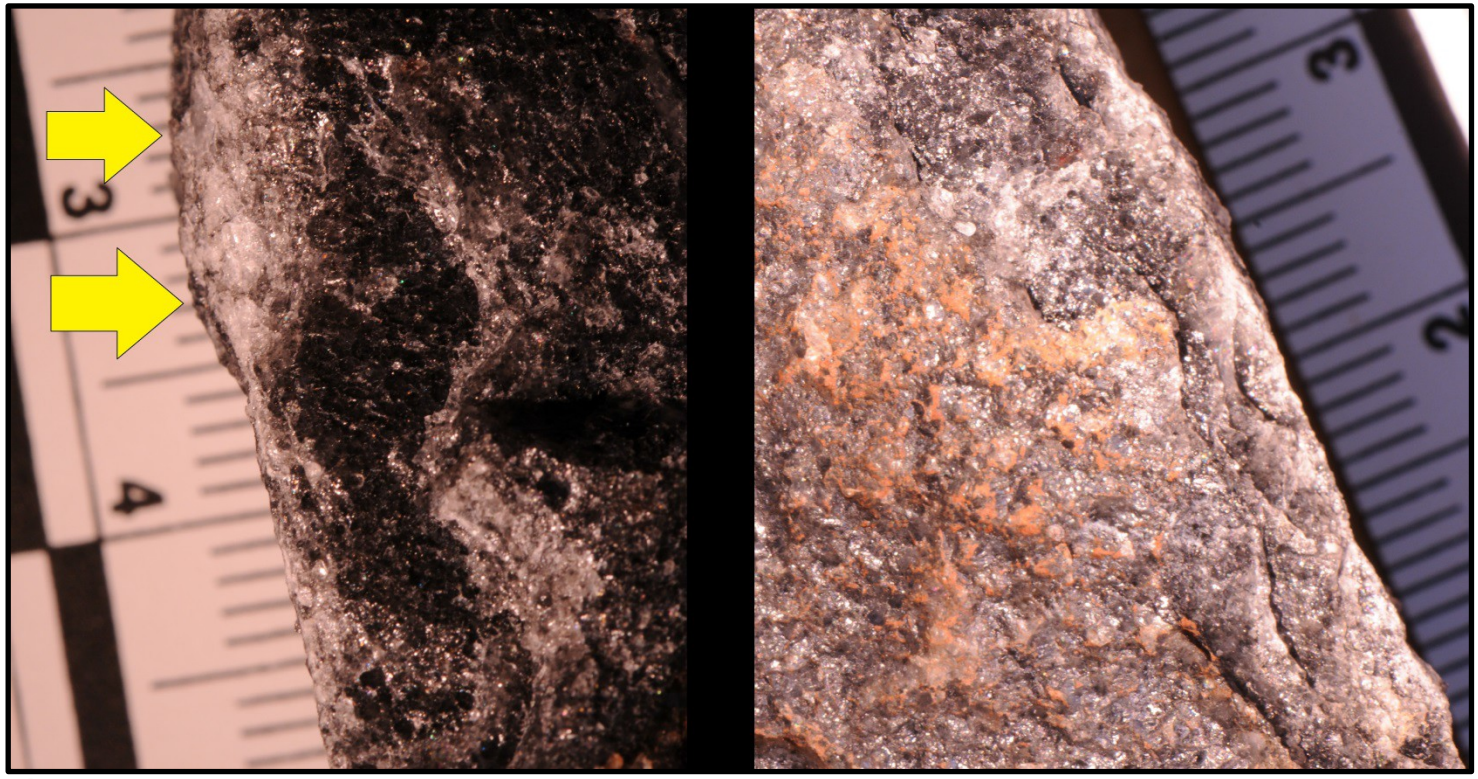

**Figure 5.11 Butt of TS.2013.16** Edge of hafted quartzite handaxe that made contact with a hammerstone, the other end of which (Fig. 5.12) was used to split a piece of seasoned wood. Note the numerous, compounded step scars that occur on both faces of the piece. Also note the extreme crushing of quartz grains (yellow arrows) due to impact from the hammering motion.

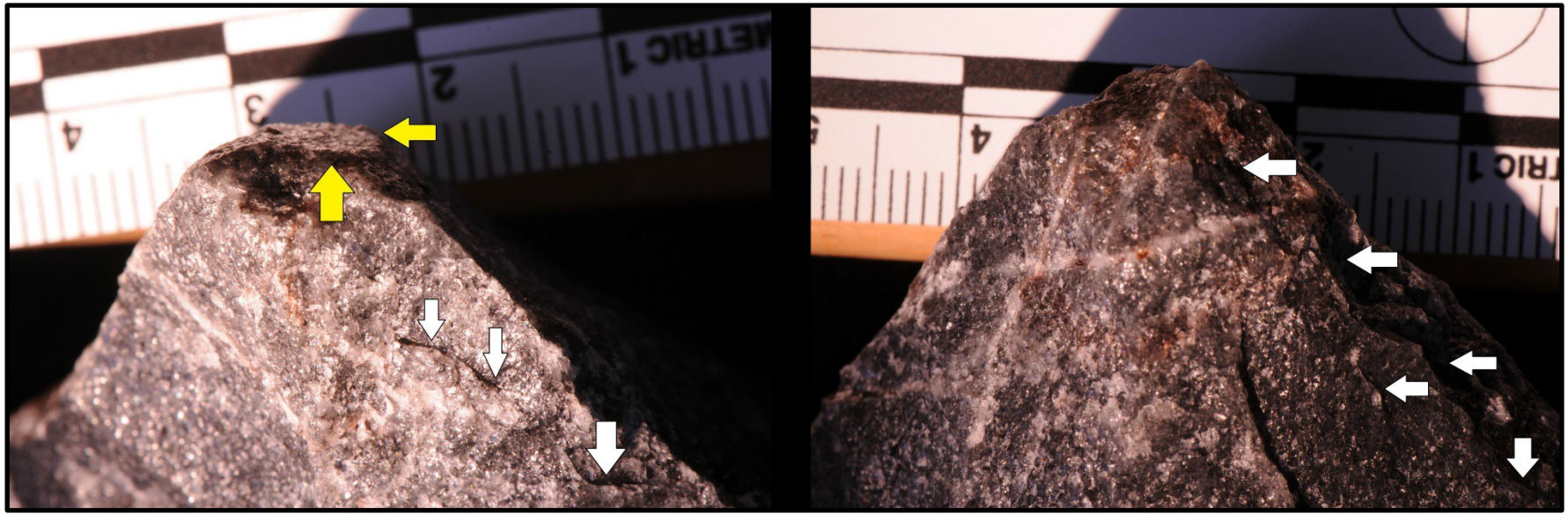

**Figure 5.12 Tip of TS.2013.16** Note the extreme rounding of the tip (yellow arrows) and the large step scars (white arrows) that intrude into both faces of the handaxe. These are indicative of both faces coming into contact with something fairly hard. In this case, a piece of very seasoned and hard wood, into which the tip was placed and the back end (Fig. 5.11) was hammered to split the wood apart.

**Figure 5.13 Macroscopic View of TS.2013.16** The area circled in yellow is shown in the left hand photo of Fig. 5.11. The area in white is the left hand photo in Fig. 5.11. The tip area circled in black is shown in Fig. 5.12.

**Figure 5.14 Hafting Arrangement of TS.2013.16** The haft is a piece of debarked *Ficus sur* (Broom Cluster Fig) the lashings are made from the bark and inner bark of the *F. sur,* and the main mastic is rendered lard from *Sus domesticus* (Domestic pig).

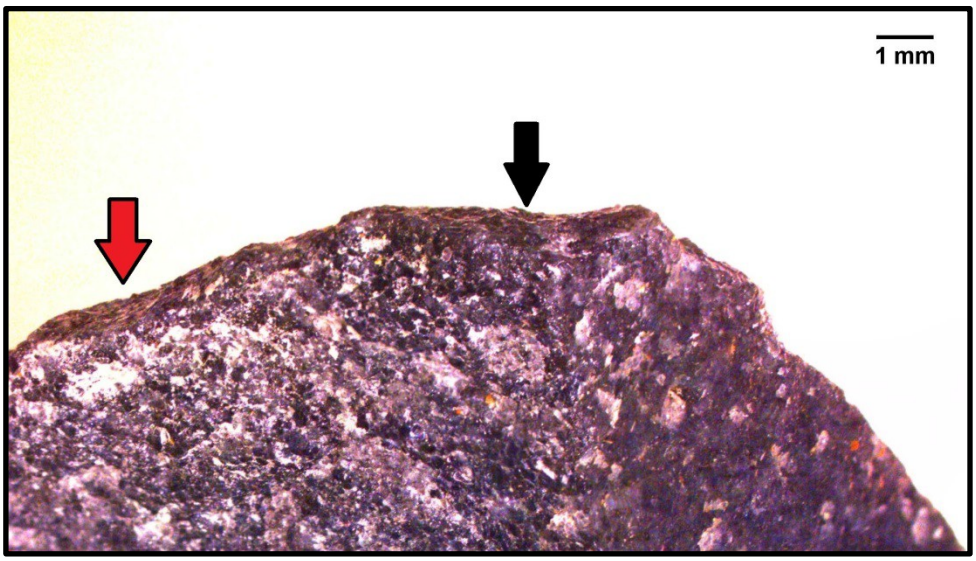


**Figure 5.15 Tip TS.2013.19** Projection of unretouched quartzite flake used to drill seasoned bone. A large snap fracture has removed most of the tip, yet the tip is still extremely rounded (Black arrow). This is likely because the tip fractured early in use, but drilling continued and stabilised the edge. Also note the same type of fracture and extent of rounding on the left hand side of the tool (red arrow); however, the right margin is not as fractured or rounded. This indicates that the left side made contact for a longer period of time or with a portion that was slightly harder than other areas of the bone.

**Figure 5.16 Macroscopic View of TS.2013** The projection circled in black is the tip pictured in Fig. 5.15

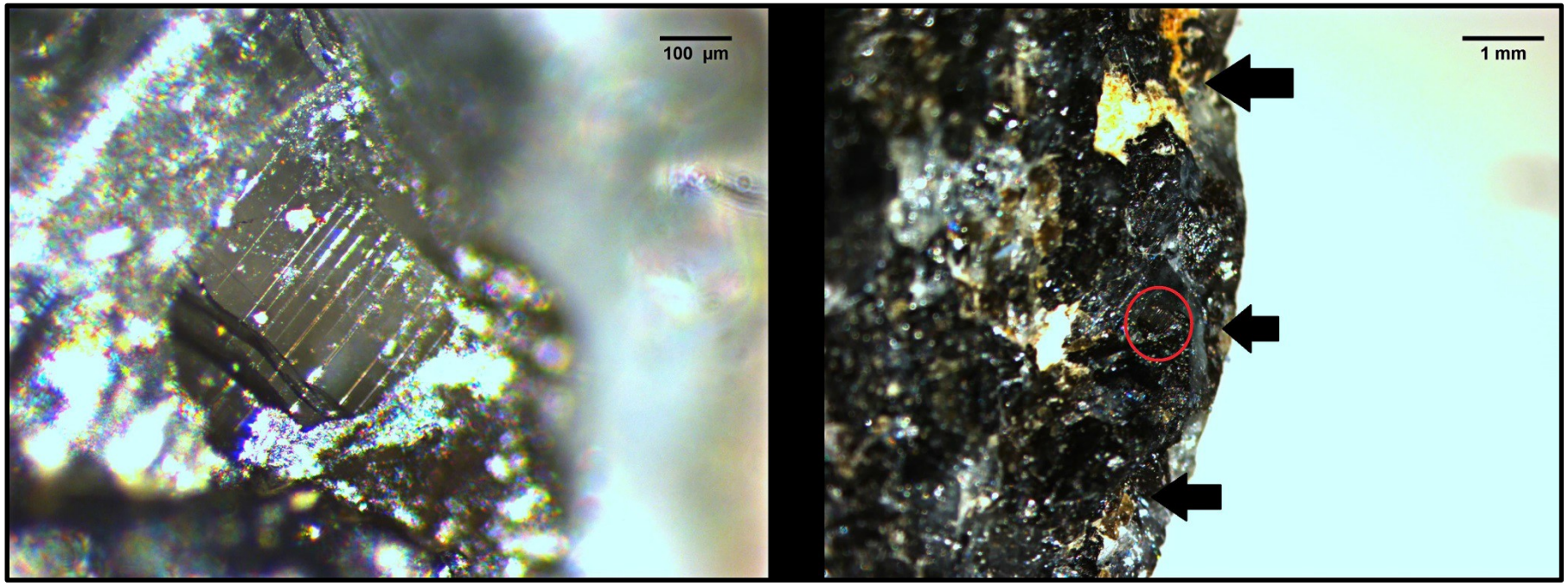


**Figure 5.17 Sawing Edge of TS.2013.1** An area of striae (left picture) and a zoomed out photo (right picture) showing the location of the striae in relation to the unretouched used edge of a gabbro flake . The edge has been used to saw a 2M material (a seasoned wood) and the striae are running almost parallel to the used edge. Also notice the rounding of the edge and the step scars (black arrows) along the whole edge. In this case, the "bright spot" near the top is a piece of wood dust (i.e., residue) left behind after cleaning.

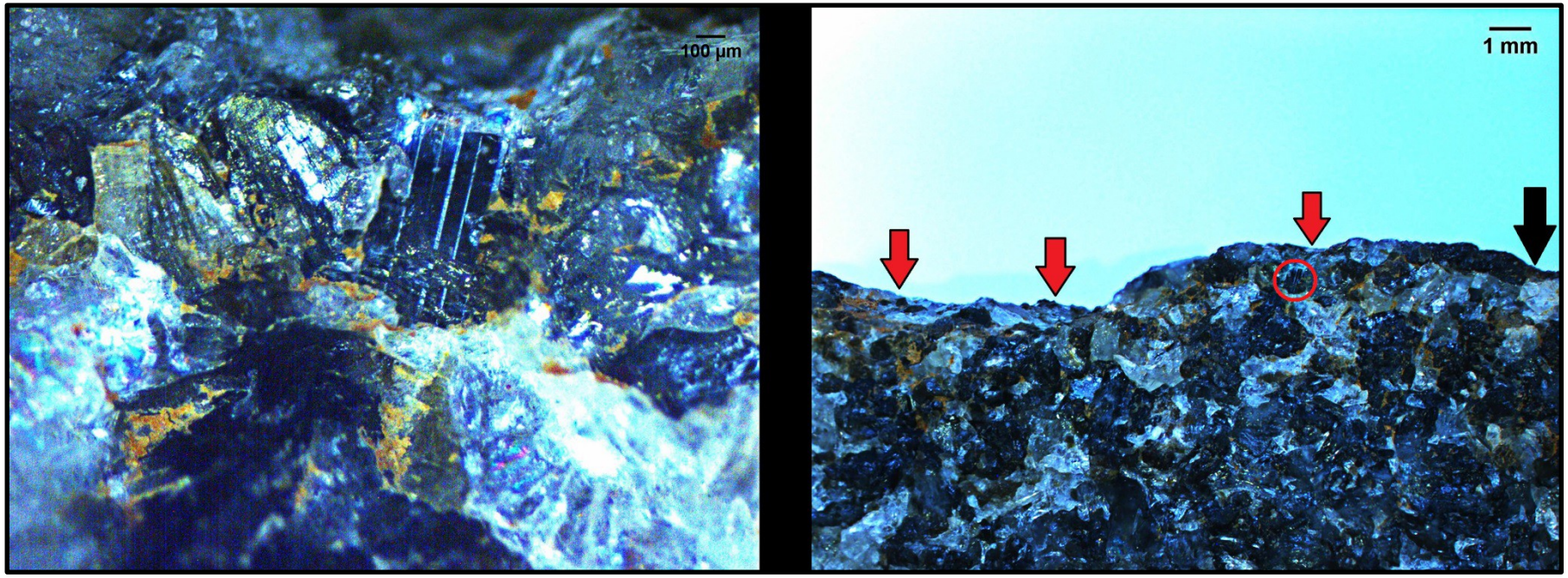


**Figure 5.18 Scraping Edge of TS.2013.1** A different edge of TS.2013.1 than Fig. 5.17, which has been retouched and used to scrape the same seasoned wood. Striae are seen in the left photo with the location along the edge shown with a red circle in the right photo. However, the striae are running perpendicular to the edge, as would be expected from a scraping motion. The rounding is to the same extent as that seen in Fig. 5.17. The scars in this photo (red arrows) mainly intrude into one surface, the one pictured on the right, and consist mostly of hinge and step, though one larger snap fracture can be seen at the top right of the edge (black arrow).

**Figure 5.19 Macroscopic View of TS.2013.1** The area within the red circle is that shown in Fig. 5.17, while the yellow circle indicates the area shown in Fig. 5.18.

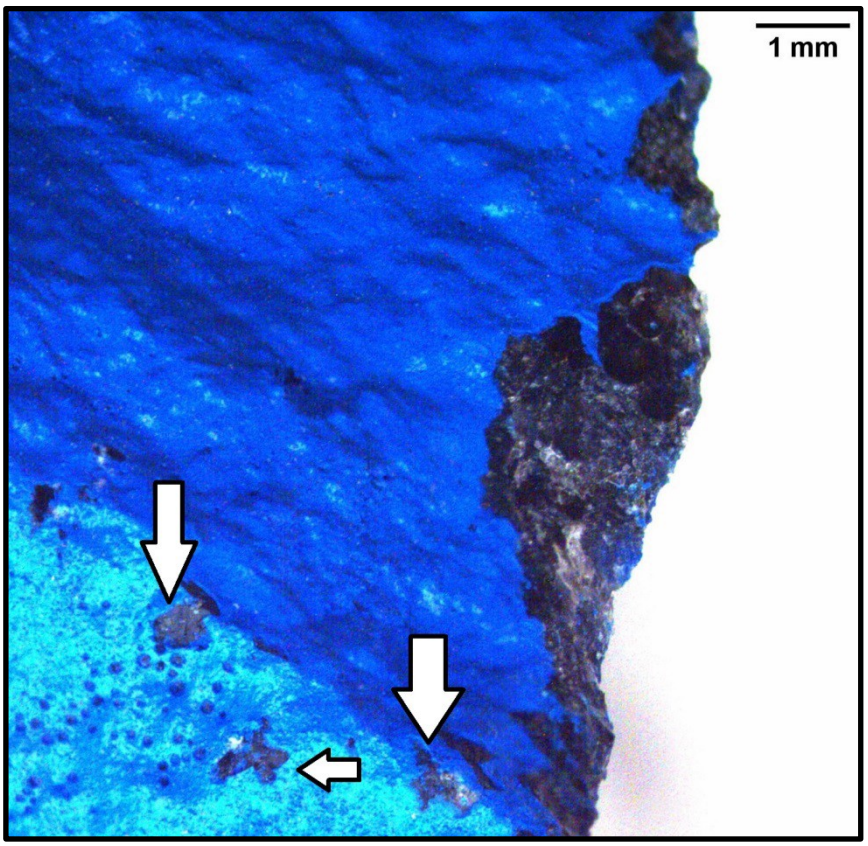


**Figure 5.20 Edge of Blue Flake 19** Cleaver with typical PESM wear. The scars intrude into the surface of the stone tool very little, are generally feather terminated, and remove very little material. Some abrasion (white arrows) can be seen in the lower left hand portion of the photo along an arête.

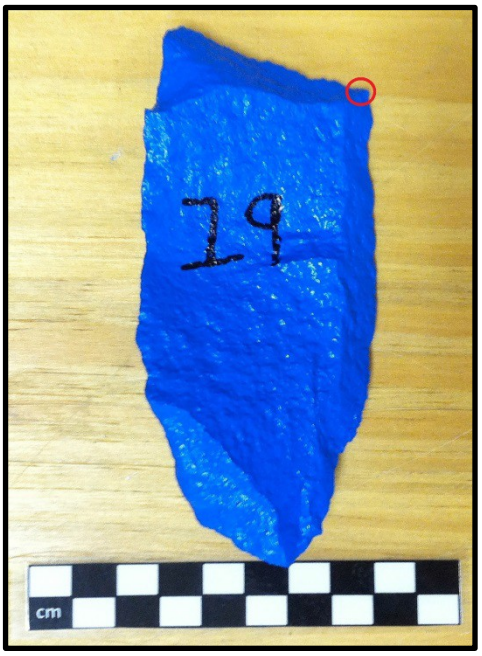


**Figure 5.21 Macroscopic View of Blue Flake 19** The red circle indicates the area shown in Fig. 5.20.

## 5.3 Blind Test

For this study, I undertook a single blind test consisting of 30 quartzite tools. In some cases, analysts have decided to break the same number of tools into smaller tests (e.g., three tests of 10 tools each); however, through my own experience and communication with other use-wear analysts, some have come to the conclusion that "the task of correctly identifying the information in attribute testing categories… became easier when analysing a larger number of pieces (e.g., 30) than when facing a small collection of items for analysis" (Law de Lauriston 2014: 215). Simply put, as one analyses more artefacts, an intra-test comparative collection is built, allowing the analyst the ability to go back and re-think, perhaps correct earlier mistakes, based on later observations from other tools. This also allows the analyst to detect the effects of slight changes in any given attribute (e.g., time used or angle of contact) that may not be noticeable in a smaller sample.

The tools were made and utilised by University of the Witwatersrand PhD archaeology student Nicci Sherwood, as she has had several years' experience in knapping and using stone tools. Consequently, the grading of the test was also carried out by Miss Sherwood. The raw material for the tools was collected from the Jukskei River, in the Jukskei Park, South Africa. The quartzite collected was similar to the quartzite locally available to the hominins at CoH *ca.* 0.5 Ma and was of a medium grain, while the quartzite at CoH exhibits a range of medium to fine grains.

The protocols used to carry out the blind test and blind test experiments were modelled after those found in Odell and Odell-Vereecken (1980). These researchers were attempting a blind test for the low-power approach that could be compared to that of Keeley and Newcomer's (1977) test using the high-power approach. However, a couple of rules were altered for this blind test solely to increase the level of potential difficulty: 1) tools could be either hafted or prehended (hand-held) by the experimenter; 2) only materials that were available prehistorically could be worked; and 3) tools could be used for multiple tasks. The original rules were that only non-agricultural experiments could take place with hand-held tools and only a small number of tools could be utilised for multiple tasks. However, all other rules (see Keeley and Newcomer 1977 and Odell and Odell-Vereecken 1980) regarding grading, wear descriptions, and cleaning procedures were adhered to. Any items that may have been hafted were removed from the haft and cleaned with a soft bristle tooth brush, warm water, and a non-abrasive liquid dish soap, as were all other tools before the test began. This was done so that no residues would

adhere to the tools, which could possibly provide clues as to use Additionally, no photos of wear, tools, or experimental collections were allowed for reference during the course of the blind test. I was permitted to study my experimental collection in the days leading up to the blind test, but once it began I was no longer allowed access to any tools, experimental or archaeological, other than those made and used for the blind test. Lastly, I was not allowed microscopically examine the test series tools before the actual test took place.

The attributes and categories recorded for accuracy grading purposes followed (*sensu*) Shea and Odell (1987) and Law de Lauriston (2014) and are: 1) location of wear (according to PCs); 2) motion (e.g., cut, scrape, drill); 3) material resistivity (e.g., soft, medium-hard, hard); 4) worked material (e.g., hide, meat, wood); and 5) prehension (e.g., hand or haft). A correct identification, in any category, counted as one point. An incorrect identification took one point away, and a partially correct answer was awarded one-half of a point (e.g., answering medium for a resistivity that is considered medium-hard). Additionally, a point was subtracted for assigning wear to a portion of a tool that was unused. Though some analysts do not follow the last convention listed (e.g., Lemorini *et al.* 2014), it should be conformed to, as Shea and Odell (1987: 29) state that "attributing contact wear to a portion of a tool where none exists is just as much a mistake as missing an area that has sustained contact with a worked material". The results of the blind test are listed in Table 5.2. (See Appendix C, Figs. C.14—C.16 for all Blind Test Tools.)

**Table 5.2 Blind Test Results.** PC = Polar co-ordinate, and EU = employed unit. () = a portion of the tool that was used, but that I did not record as being used. Answers highlighted in green = 1 full point, those in yellow = 0.5 points, while those answers in red were awarded no points. Note that for Tool 7 drilling in EU 2 was given a partial answer rather than a completely wrong answer as in my handwritten notes I mention that I believed the drill had penetrated the worked material deeply causing "drilling wear" to move into a separate area of the tool. In actuality, the piece was used to drill and scrape the same material on adjacent PCs.

| Tool # | Location | Action | Resistivity | Worked Material | Prehension | Error |
|---|---|---|---|---|---|---|
| 1 | PCs 7-2 | Sawing | Medium-Hard | A seasoned or dry wood | Hand | |
| 2 | PCs 1-3 | (Scraping) | Soft | Vegetal Matter | Hand | (Slice) |
| 3 | EU 1 (PCs 5-6)<br>EU 2 (PCs 2-3) | Scraping<br>Scraping | Medium-Soft<br>Medium-Hard | A soft or green wood<br>A seasoned or dry wood | Hand | |
| 4 | PCs 7-8 | Scraping | Hard-1 | Bone | Hand | |
| 5 | PCs 2-4 | Sawing | Medium-Soft | A soft or green wood | Hand | |
| 6 | (Not Used) | (Not Used) | (Not Used) | (Not Used) | (Not Used) | (Scrape Potato) |
| 7 | EU 1 (PCs 8/1Tip)<br>EU 2 (PC 2) | Drilling<br>(Drilling) | Medium-Soft<br>Medium- Soft | A soft or green wood<br>A soft or green wood | Hand | (Scrape) |
| 8 | PCs 7-8 | Slicing | Soft | Grass/ Reed/ Sedge | Hand | |
| 9 | PCs 7 & Part of 6 | Scraping | Medium-Hard | A seasoned or hard wood | Hand | |
| | () | () | () | () | | (Scrape Wood) |
| 10 | PCs 2-3 | (Scraping) | Animal Soft and Hard-1 | Butchery Task | Hand | (Slice) |
| 11 | PCs 5-8 | (Scraping) | Animal Soft and Hard-1 | Butchery Task | Hand | |
| 12 | PCs 8/1-The Tip | Drilling | Hard-1 | Bone | Hand | |
| 13 | PCs7-2 | (Scraping) | Animal Soft and Hard-1 | Butchery Task | Hand | (Remove) |
| 14 | PCs 3-4 | Scraping | Animal Soft | Hide | Hand | |
| 15 | (Not Used) | (Not Used) | (Not Used) | (Not Used) | (Not Used) | (Scrape vegetal matter) |
| 16 | (PCs 6-7) | (Saw) | (Medium-Soft) | (A soft or green wood) | (Hafted) | (Cleave Grass) |
| 17 | PCs 8-1 & Tip | Digging | Hard-3 | Soil/ Earth/ Ground | Hand | |
| 18 | PCS 5-8 | Slicing | Animal soft and Hard-1 | Butchery Task | Hand | |
| 19 | PCs 1-2<br>() | Slicing<br>() | Soft<br>() | Grass/ Reed/ Sedge<br>() | Hand | (Slice Grass) |
| 20 | PCs 8-1 | Chopping | Hard | Bone | Hand | |

**Table 5.2 Blind Test Results contd.**

| Tool # | Location | Action | Resistivity | Worked Material | Prehension | Error |
|---|---|---|---|---|---|---|
| 21 | PCs 1-3 | Scraping | (Medium) | Wood | (Hafted) | (Medium-Hard) (Hand) |
| 22 | PCs 8-1 | Sawing | (Medium-Soft) | (A green or soft wood) | Hand | (Soft) (Vegetal Matter) |
| 23 | PCs 2-3 | Slicing | Soft | Vegetal Matter | Hand | |
| 24 | PCs 8-1 | Chopping | Medium-Hard | A seasoned or hard wood | Hand | |
| 25 | PCs 6-7 | Slicing | Animal Soft | Hide | Hand | |
| 26 | PCs 8-2/ Cleaver Bit | Chopping | Animal Soft and Hard-1 | Butchery Task | Hand | |
| 27 | PCs 4-5 | Digging | Hard-3 | Soil/ Earth/ Ground | Hand | |
| 28 | EU 1 (PCs 8/1)<br>EU 2 (PCs 4/5) | Drilling<br>Digging | Hard-1<br>Hard-3 | Bone<br>Soil/ Earth/ Ground | Hand | |
| 29 | PCs 5-8 | Chopping | Soft | Vegetal Matter | Hand | |
| 30 | PCs 2-3 | Scraping | Animal Soft and Hard-1 | Butchery Task | Hand | |

| **Overall Accuracy: Total number correct followed by percentage** | | | | | |
|---|---|---|---|---|---|
| Location | Action | Resistivity | Worked Material | Hafted | Overall |
| 30 out of 35<br>85.7 % | 27 out of 35<br>77.1% | 28.5 out of 35<br>81.4% | 29 out of 35<br>82.8% | 26 out of 30<br>86.7% | 139.5 out of 170<br>82 % |

Images of select tools from the blind test are pictured in Figure 5.22.

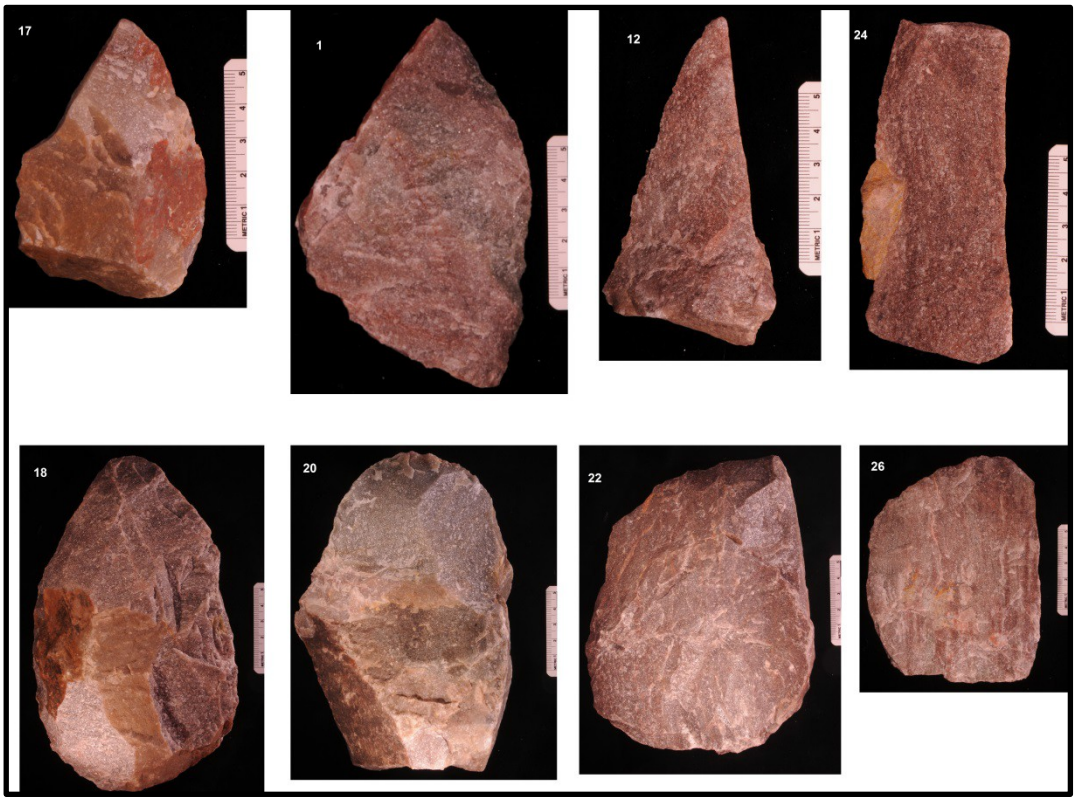


**Figure 5.22 Selected Blind Test Tools** Tool numbers correspond to those listed in Table 5.2.

### 5.3.1 Results and Lessons Learned from Blind Testing

The results of this blind test have shown that a fair amount of confidence should be placed in the observations and interpretations that I make about the archaeological tools. With an overall accuracy score of 82%, and a range of 77% to 86% for the individual categories, these results are at the high end of the spectrum of published results (e.g., Keeley and Newcomer 1977; Odell and Odell-Vereecken 1980; Newcomer *et al.* 1986; Bamforth 1988; Rots *et al.* 2006; Hanten and Stevens 2010; Evans 2014; Law de Lauriston 2014) . The main area that might be of concern is for tools that may have been used to work vegetal soft material (e.g., vegetables, fruit, grass). Tools 6 and 15 provide a perfect case in point. In both cases, I answered not used, when both tools had been used to work vegetal matter. Additionally, piece 19 had an EU that was used to work vegetal matter that I missed during the blind test, and I misidentified the resistivity and worked material on piece 22 which was used to work vegetal matter. This is likely due to the fact that, in general, analysts have the hardest time distinguishing use from non-use when a soft material (either animal or vegetal) is worked for a short period of time, as these softer materials tend not to leave recognizable wear traces on the edge of a tool that can be

observed at low power magnifications. In this case, according to the notes taken during the experimental work for the blind test, Tool 6 was utilised for two minutes, Tool 15 for one minute, and Tool 19 for two minutes for the portion that I did not recognize.

This failure to recognize wear on tools that were used for very short durations has been noted throughout the literature (Moss 1987; Shea and Odell 1987; Bamforth 1988; Hurcombe 1988; Law de Lauriston 2014) and is not an uncommon problem. In fact, Driver (2006) performed a series of blind tests with three individuals being given 20 chert tools each that had been used for short periods of time (between 1 and 15 minutes). Driver (2006) found that the analysts had an accuracy rate of less than 50% overall and that as the material became softer the analysts had a more difficult time correctly identifying use-wear patterns. While my results, and those of other use-wear analysts, confirm Driver's (2006) finding, it should not be taken as the failure of an analyst to accurately recognize soft materials when they are worked. For instance, Tools 2, 8, an EU of 19, 23, and 29 were all used to work vegetal matter and I correctly identified the resistivity and worked material in those cases, showing that it is possible to recognise wear traces left by soft materials. However, it should be noted that in the use-wear results discussed in Chapter 6, it may be possible that soft materials are underrepresented because of the difficulty of accurately identifying wear traces left by those materials.

The weakest area overall for my blind test was that of action, in which I scored 77%, although this score is still on the high end of the published scores. Additionally, I think the assumption that analysing a larger number of tools in one test, rather than several tests of a smaller number of tools, did indeed make the identification of wear patterns easier as an intra-test comparative collection was accumulated during the test. Results from previous blind tests I have taken, though they were on different raw materials (i.e., obsidian and chert), support this idea, with overall accuracy rates ranging from 60% to 70% for (respectively) three sets of ten tools each and two sets of 15 tools. I would, therefore, encourage use-wear analysts of any approach to structure their blind tests as I did for this study as it may increase their accuracy rates and the analysts may gain a greater appreciation for small changes in variables that are likely not recognisable in a smaller number of blind test tools.

### 5.3.2 Blind Test Summary

This blind test confirmed several things about low-power use-wear analysis that fall in line with previously published results regarding the approach. They are: 1) The motion of the tool (e.g., cut or saw) and the resistivity of the worked materials (e.g., soft, medium, and hard) can be easily identified and often with a high percentage of accuracy; 2) the exact worked material (e.g., cow flesh versus springbok flesh) is more difficult to identify than resistivity and motion but can successfully be classified into general categories (e.g., meat, hide, vegetal matter); 3) wear resulting from prehension can be identified separately from wear related to use with a high degree of accuracy; and 4) it is possible to identify wear traces left from a variety of motions and worked materials even on coarse-grained materials such as gabbro and quartzite. These same four points were equally noticed, recorded, and confirmed by the experimental programme reported on in Section 5.2

## 5.4 Chapter Conclusion

Seventy-one experimental tools were made from Black Reef Quartzite from the CoH locality (supplemented by quartzite and gabbro that were similar to the Black Reef Quartzite). Twenty of these tools were utilised in ways that likely took place at CoH *ca.* 0.5 Ma and served to confirm the use-wear patterns, and the interpretations of those patterns, seen in the archaeological assemblage. Additionally, twenty of the tools were un-used and placed in plastic bags to provide a comparative collection of un-used edges. The remaining 31 tools were painted blue and put in a box without individual artefact protection to have a comparative collection of tools that had suffered from PESM. Lastly, a blind test consisting of 30 quartzite tools confirmed my ability as an analyst and my capability of identifying wear traces left from using similar tools in similar ways on similar materials. Moreover, the blind test tools can now be added to an ever-growing comparative collection to be used for future studies.

# Chapter 6
# The CoH Bed 3 Sample: Use-wear Analysis and Results

"Our attempt to determine Hearths stone-artefact use from a microscope study of artefacts edges did not produce positive results…the functional interpretation of the Hearths Stone Age artefacts as a whole remains a mystery" (Mason 1988: 185)

## 6.1 Introduction

Almost 30 years later, the functional interpretation of "Hearths Stone Age Artefacts" is no longer a mystery. With the advancements in the field of micro-wear (Section 4.4) and the particular approach of low-power use-wear analysis (Section 4.5.4) within the last 25 years, questions that remained unanswered at the time of Mason's monograph can now be answered. Although it is on a limited sample size restricted to LCTs, this study begins to answer the question of what the hominins at CoH were doing with their stone tools.

I now turn to the CoH Bed 3 tools themselves, the sampling procedures used to obtain the analysed specimens, and the results of the use-wear analysis.

## 6.2 The CoH Bed 3 LCT Assemblage

Before a random sample could be obtained from the CoH Bed 3 assemblage, I had to recover all the LCTs that could be securely provenanced to Bed 3. This was not an easy task as no catalogue was in existence when the project started. Though McNabb and Sinclair (2009b) did relocate and reanalyse the lithic materials from the entire ESA sequence from CoH, no catalogue of these materials was found in the archived material. Thus, I created a catalogue from scratch including all relevant information (e.g., tool type, provenance, artefact numbers) for all LCTs from Beds 1-3 and for those LCTs that had limited or no provenance information. This catalogue is now on file with Dr. Thembi Russell, the collections manager, at the University of the Witwatersrand.

When the catalogue was completed there was a total of 302 LCTs from the ESA sequence with 83 belonging to Bed 1, 54 to Bed 2, 130 to Bed 3, and the remaining 35 having limited or no provenance information. The

total number of LCTs from the ESA sequence differs from those published by both Mason (1988; N = 373), and by McNabb (2009 N= 320). However, these earlier counts included both HDTs and the by-products of HDT production (e.g., thinning and shaping flakes), whereas my number only included LCTs.

Before the catalogue was finalised all the tools were typed as handaxe, cleaver, or other with the assistance of Prof. Kathleen Kuman. When this was done, of the 130 LCTs from Bed 3, 96 were typed as cleavers, 29 as handaxes, and the remaining 5 were classed as indeterminate or other (e.g., roughouts or broken pieces that could not be securely identified as handaxe or cleaver). For the Bed 3 portion of the final catalogue see Appendix A.

With all the tools morpho-typed, the sampling began. As mentioned in Chapter 1, one of the questions I was interested in investigating was if there was any relationship between form (morphology) and function. I decided that the most appropriate way to study this question was to utilise a more refined typological scheme than the simple split between handaxe and cleaver. Fortunately, McNabb *et al.* (2004) had already established such a scheme for LCTs from South African sites, including CoH. McNabb *et al.'s* (2004) typological scheme is based on the shape of the tip, defined as the upper-third of the tool. McNabb *et al.* (2004: 657) state that this approach was taken rather than the traditional typological scheme of a Roe diagram because the outline shape (which is what Roe diagrams measure) of CoH LCTs "was infinitely variable…and because a small number of tip shapes persistently recurred irrespective of the outline shape". Figure 6.1 show the tip shapes and their definitions as described by McNabb *et al.*

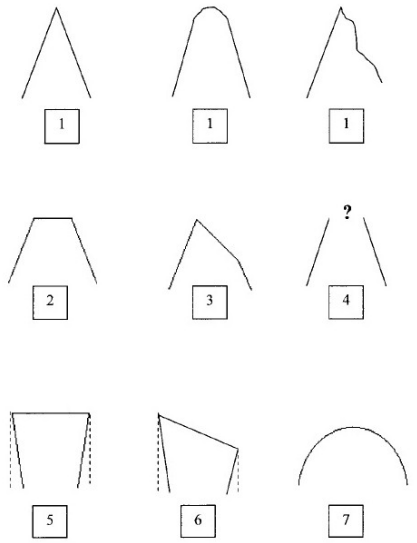


FIG. 3. *Tip shape. 1, markedly convergent; 2, convergent with a squared-off tip at right angles or nearly so; 3, convergent with an oblique tip; 4, convergent with a generalized tip; 5, wide (parallel) or divergent; 6, wide or divergent with an oblique tip; 7, wide with a very convex tip.*

The tip is here defined as the top third of the tool. The basic typology is as follows (see fig. 3):

1. Markedly convergent. The sides converge to a clear point, which may be rounded (but narrow) or acute. The sides may be straight or nearly so or quite irregular.
2. Convergent but with a squared-off tip at right angles (or nearly so) to the long axis of the artefact. The edge of the bit may be natural or made by flaking, and it may be straight, slightly convex, or irregular in outline. The outline of the convergent edges may be straight or irregular, and the two edges may be dissimilar.
3. Convergent with an oblique tip. This type is the same as the previous one except that the cleaver edge is very oblique to the long axis of the tool. It may be straight, slightly convex, or irregular in outline and may be natural or made by flaking.
4. Convergent with a generalized tip. This type includes any clearly convergent tip that does not fall neatly into one of the above categories. The outlines of the convergent edges may be irregular and/or dissimilar.
5. Wide (i.e., parallel) or divergent. The sides may be straight or irregular. The blade/tip may be straight, slightly rounded, or irregular in outline and may be natural or a result of deliberate shaping.
6. Wide or divergent with an oblique tip/blade. This type is the same as the preceding one except for the shape of the tip/blade. The blade itself may be straight, slightly rounded, or irregular and may be natural or the result of deliberate shaping.
7. Wide with a very convex tip. There is no break of slope along the convexity, and it may be natural or the result of deliberate shaping.

**Figure 6.1 McNabb *et al.'s* (2004) Tip Shapes and Definitions** (Image from McNabb *et al.* 2004).

Using McNabb *et al.'s* diagram of tip shapes, I employed an optimal random stratified sampling strategy so that exactly six tools from each tip shape would be sampled. It should be noted, however, that tip shape 3 was excluded because there were no pieces in the Bed 3 population that corresponded to this tip shape. When this initial sample of 36 pieces was selected, it was discovered that the relative proportions of handaxes, cleavers, and other in the sample was very close to the percentages of handaxes, cleavers, and other for the Bed 3 population. In order to get the percentages of the sample as close as possible to the proportions of the total Bed 3 population two additional handaxes were statistically randomly selected resulting in a total of 38 pieces selected for analysis, or 29.23% of the Bed 3 tools. Additionally, pieces that came from the Swallow Hole or Central Subsided Block (see Fig. 3.15) were specially recorded, so that extra care would be taken to look for signs of PDSM on these nine pieces that likely had an extraordinarily turbulent depositional history. It was not known how many, if any at all, would be affected by PDSM/ PESM before the analysis began. This was only discovered after the analysis was complete. For each piece, all surfaces of both faces were scanned during analysis for signs of PDSM and PESM to rule out any pieces that may have been badly affected by either of these processes. Table 6.1 presents the Bed 3 population, the sample, and their percentages broken into the three main categories of handaxe, cleaver, and other. The final sample, with their tip shapes and tool types, are listed in Table 6.2.

**Table 6.1 Bed 3 LCTs**

| | | Cleavers | Other | Total |
|---|---|---|---|---|
| **In Population (% of population)** | 29 (22.30%) | 96 (73.85%) | 5 (3.85%) | 130 (100%) |
| **Sample (% of Sample) (% of Population)** | 8 (21%) (6.15%) | 28 (74%) (21.54%) | 2 (5%) (1.54%) | 38 (100%) (29.23%) |

**Table 6.2 Final Sample Submitted to Use-wear Analysis** Those numbers highlighted in yellow indicate tools from the Central Subsided Block or Swallow Hole. Fonts in red are tools that were interpreted as un-used and those fonts in blue indicate either extensive PESM or PDSM (only discovered after the analysis).

| CoH # | Tip Shape | Morphological Type |
|---|---|---|
| 140 | 6 | Cleaver |
| 144 | 1 | Handaxe |
| 147 | 7 | Cleaver |
| 151 | 7 | Cleaver |
| 155 | 1 | Handaxe |
| 165 | 5 | Cleaver |
| 171 | 2 | Cleaver |
| 173 | 7 | Cleaver |
| 174 | 5 | Cleaver |
| 177 | 6 | Cleaver |
| 178 | 1 | Handaxe |
| 179 | 6 | Cleaver |
| 181 | 4 | Cleaver |
| 187 | 5 | Broken/Cleaver |
| 192 | 1 | Handaxe |
| 196 | 2 | Cleaver |
| 199 | 2 | Cleaver |
| 208 | 2 | Other |
| 212 | 7 | Cleaver |
| 213 | 1 | Handaxe |
| 214 | 1 | Handaxe |
| 218 | 7 | Cleaver |
| 220 | 6 | Cleaver |
| 221 | 2 | Cleaver |
| 225 | 5 | Cleaver |
| 226 | 5 | Cleaver |
| 229 | 1 | Cleaver |

**Table 6.2 Final Sample Submitted to Use-wear Analysis contd**. Those numbers highlighted in yellow indicate tools from the Central Subsided Block or Swallow Hole. Fonts in red are tools that were interpreted as un-used and those fonts in blue indicate either extensive PESM or PDSM (only discovered after the analysis).

| CoH # | Tip Shape | Morphological Type |
|---|---|---|
| 231 | 1 | Handaxe |
| 234 | 2 | Cleaver |
| 238 | 4 | Cleaver |
| 240 | 4 | Cleaver |
| 243 | 4 | Handaxe |
| 255 | 4 | Cleaver |
| 258 | 6 | Cleaver |
| 263 | 7 | Cleaver |
| 265 | 6 | Other |
| 266 | 4 | Cleaver |
| 267 | 5 | Cleaver |

## 6.3 Results of Use-wear Analysis

The results of the use-wear analysis of the tools found to be utilised are reported in Table 6.3. Images of exemplary wear patterns and the macroscopic tools that exhibit those traces are shown in Figs. 6.2—6.25. As with the experimental tools, “Plain English” descriptions and discussions of the wear patterns are given in the captions of the figures. Again, this is for ease of seeing the explanations while still seeing the photos. The CoH #s in the following figures correspond to the numbers listed in Table 6.3. For the descriptions of wear for the entire sample see Appendix B (Table B.1). For images of all analysed pieces see Appendix C (Figs. C.1-C.6).

**Table 6.3 Summary of Use-wear Results for Used Tools.** PC = Polar Co-ordinate

| CoH # | Type | Tip Shape | Utilised PCs | Motion | Resistivity | Worked Material |
|---|---|---|---|---|---|---|
| 144 | Handaxe | 1 | 7-1<br>5-7 | Dig<br>Scrape | Hard-3<br>Medium-Hard | Soil/ Earth<br>Uncertain |
| 151 | Cleaver | 7 | 8-1<br>8-1 | Scrape<br>Impact[4] | Soft<br>Hard-1 | Animal Soft (e.g., hide)<br>Bone |
| 155 | Handaxe | 1 | 7-8<br>1-2 | Saw<br>Saw | Hard-1<br>Hard-1 | Bone<br>Bone |
| 165 | Cleaver | 5 | 1<br>8 | Cut/ Slice<br>Scrape | Soft<br>Hard-1 | Vegetal Soft (e.g., grass)<br>Bone |
| 174 | Cleaver | 5 | 8-1<br>8 | Plane<br>Drill | Medium-Soft<br>Medium-Soft | Wood (e.g., soft or green)<br>Wood (e.g., soft or green) |
| 177 | Cleaver | 6 | 6-8<br>3-4 | Scrape<br>Scrape | Hard-1 Hard-1 & Soft | Bone<br>Bone and Animal Soft (e.g., meat) |
| 178 | Handaxe | 1 | 6<br>8-1 | Dig<br>Dig | Hard-3<br>Hard-3 | Soil/ Earth<br>Soil/ Earth |
| 181 | Cleaver | 4 | 8-1<br>2-3 | Chop/ Adze<br>Scrape | Medium-Hard<br>Medium-Hard | Wood (e.g., seasoned or hard)<br>Wood (e.g., seasoned or hard) |
| 187 | Cleaver | 5 | 8-1 | Saw | Medium-Soft | Wood (e.g., soft or green) |
| 192 | Handaxe | 1 | 7-8 | Cut/ Slice | Hard-1 & Soft | Bone and Animal Soft (e.g., meat) |
| 196 | Cleaver | 2 | 7-8<br>8-1 | Saw<br>Uncertain | Medium-Hard<br>Medium-Hard | Uncertain<br>Uncertain |
| 199 | Cleaver | 2 | 7<br>1 | Plane<br>Scrape | Hard-1 & Soft<br>Hard-1 & Soft | Bone and Animal Soft (e.g., meat)<br>Bone and Animal Soft (e.g., meat) |
| 212 | Cleaver | 7 | 1-2<br>3<br>6-7 | Cut/ Slice<br>Saw<br>Scrape | Soft<br>Hard-1<br>Medium-Soft | Animal Soft (e.g., meat)<br>Bone<br>Uncertain |
| 218 | Cleaver | 7 | 2-3<br>8-1 | Scrape<br>Possibly Cut/ Slice | Medium-Hard<br>Possibly Soft | Wood (e.g., seasoned or hard)<br>Uncertain |

[4] I do not use this term to suggest that the piece was used as a projectile. I use it to indicate that force was introduced directly into the tip of the piece causing an “Impact Fracture” to occur. However, this could serve as evidence for the hand bolt theory (see Section 4.7.1a).

**Table 6.3 Summary of Use-wear Results for Used Tools contd.** PC = Polar Co-ordinate

| CoH # | Type | Tip Shape | Utilised PCs | Motion | Resistivity | Worked Material |
|---|---|---|---|---|---|---|
| 220 | Cleaver | 6 | 8 | Scrape | Medium-Soft | Uncertain |
| 221 | Cleaver | 2 | 8-1<br><br>6-7 | Possibly Cut/ Slice<br>Scrape | Possibly Hard-1<br><br>Medium-Soft | Possibly Bone<br><br>Wood (e.g., soft or green) |
| 229 | Cleaver | 1 | 6-7 | Possibly Scrape | Possibly Medium | Uncertain |
| 231 | Handaxe (Hafted) | 1 | 8<br>1 | Cut/ Slice<br>Saw | Hard-1 & Soft<br>Medium-Hard | Bone and Animal Soft (e.g., meat)<br>Uncertain |
| 234 | Cleaver | 2 | 5-8 | Scrape | Medium-Hard | Possibly Wood |
| 238 | Cleaver | 4 | 8 | Cut/ Slice | Soft | Possibly Vegetal Soft |
| 243 | Handaxe | 4 | 8<br>1<br>4-5 | Wedge/ Split<br>Wedge/ | Medium-Soft<br>Medium-Soft<br>Hard-3 | Wood (e.g., soft or green) Wood (e.g., soft or green) Stone |
| 255 | Cleaver | 4 | 2<br>6-8<br>1 | Drill<br>Saw<br>Scrape[5] | Medium-Soft<br>Hard-1<br>Medium-Soft | Wood (e.g., soft or green) Bone<br>Wood (e.g., soft or green) |
| 258 | Cleaver | 6 | 7 | Scrape | Medium-Hard | Wood (e.g., seasoned or hard) |
| 265 | Cleaver (Hafted) | 6 | 8-1 | Saw | Medium-Soft | Wood (e.g., soft or green) |
| 266 | Cleaver | 4 | 7-1<br>8-1 | Saw<br>Impact[4] | Hard-1<br>Uncertain | Uncertain Uncertain |
| 267 | Cleaver | 5 | 8-1<br>8 | Cut/ Slice<br>Scrape | Hard-1 & Soft<br>Hard 1+ | Bone and Animal Soft (e.g., meat)<br>Bone, possibly very dry |

[5] Although this is listed as scraping wear, I believe that it is related to the drilling wear in P.C. 2. (i.e., the projection in P.C. 2 penetrated the worked material deeply enough to cause P.C. 1 to have contact with the worked material, scraping across the surface of the worked material while the projection continued in the drilling motion)

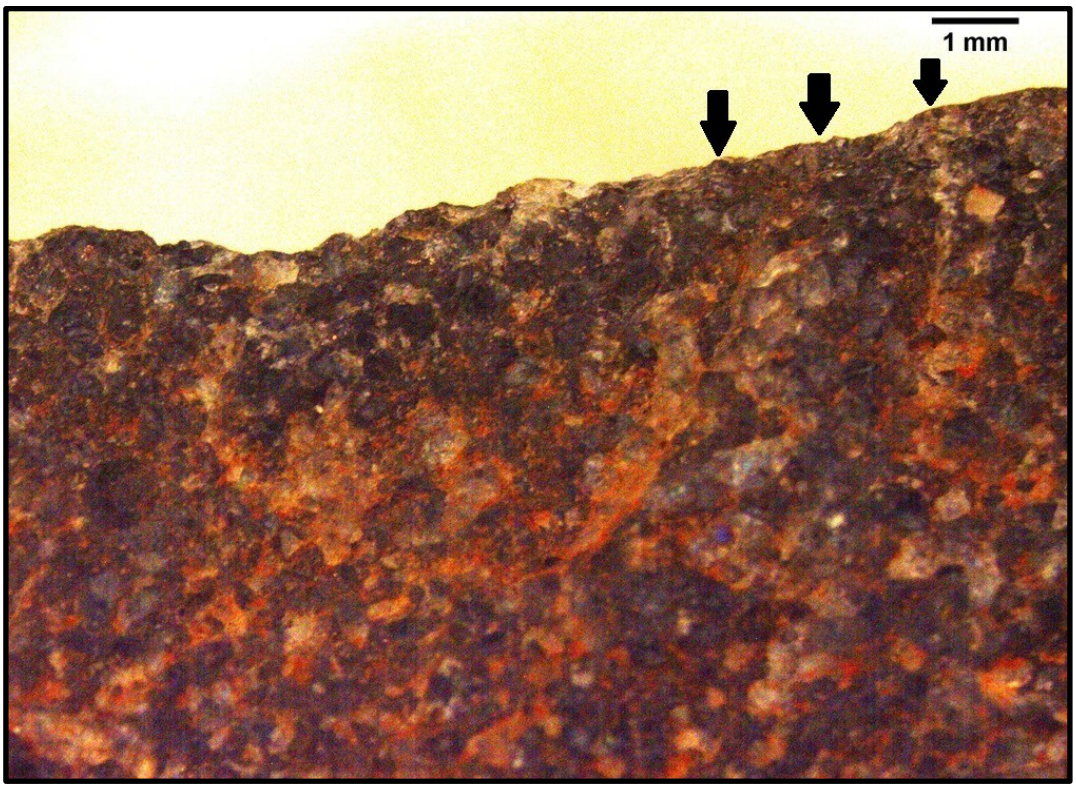


**Figure 6.2 Edge of CoH # 151** Cleaver, tip shape 7. Used for scraping hide. Note that the edge is slightly rounded and slightly denticulated as well. There are no large sized scars and at this magnification the very small feather scars that are present cannot be seen. However, the very small denticulations (black arrows) are the result of the feather and hinge scars. To be compared with Fig. 5.3, an experimental piece used to scrape fat from pork belly to simulate scraping hide.

**Figure 6.3 Macroscopic View of CoH # 151** The area in the red circle is that shown in Fig. 6.2.

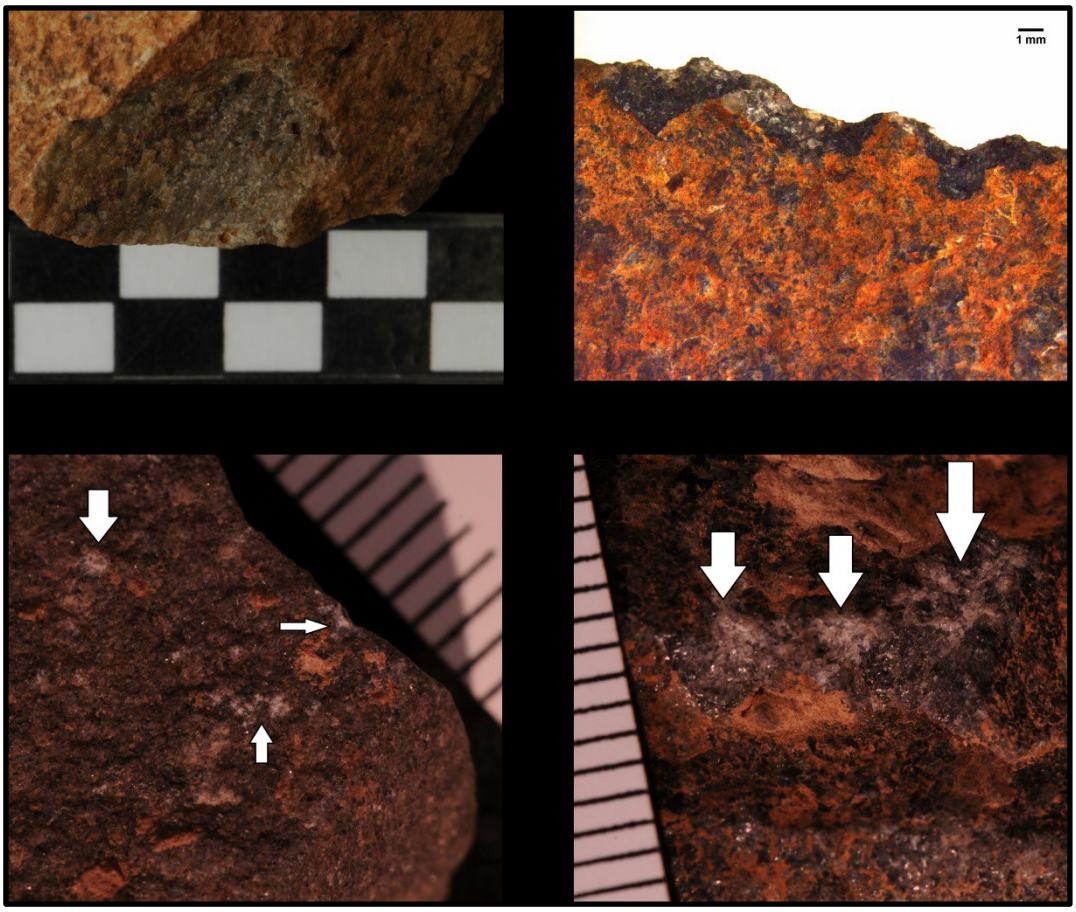


**Figure 6.4 PESM** Top left, clockwise CoH #s 213, 258, 225 and 265. All showing PESM. In the top two images it presents itself as small “fresh” scars that have removed the natural patina, or weathering, and revealed the quartzite underneath. In the bottom two images it is seen as localised abrasion and crushing (white arrows) that look “whiter and shinier” than the PDSM abrasion seen in Fig. 6.5. Compare these photos of PESM with Fig. 5.20 of experimentally produced PESM.

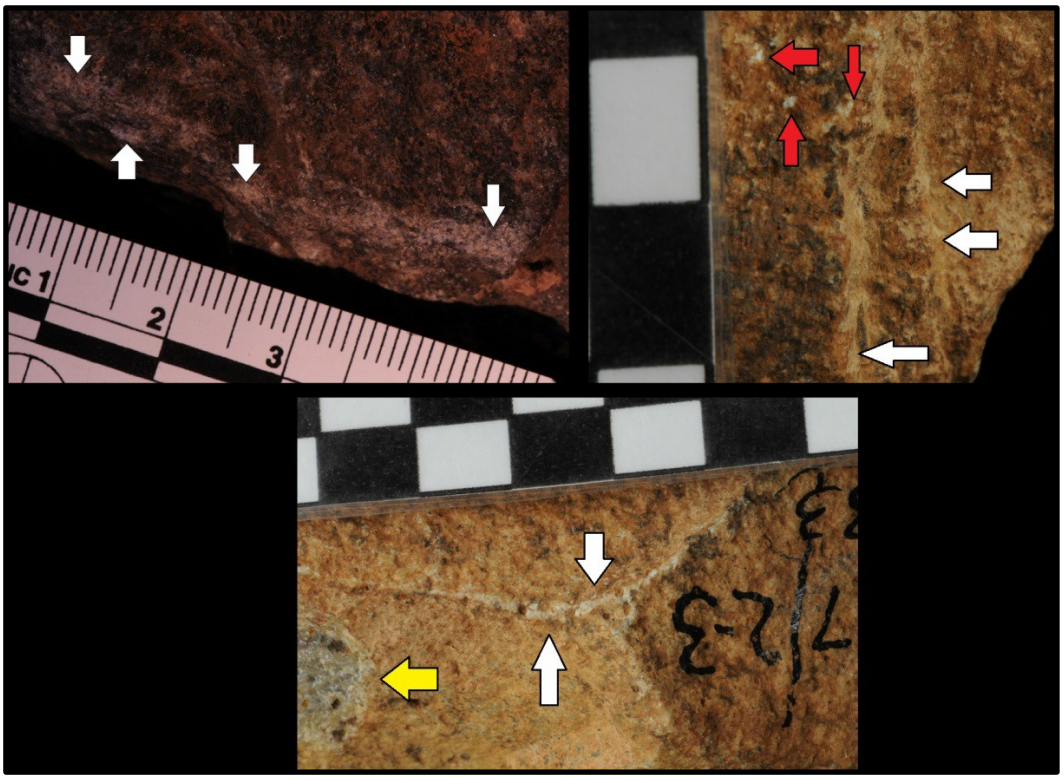

**Figure 6.5 PDSM and PESM** Clockwise from top-left CoH #s 226, 213, and 213. Note that the same kind of crushing and abrasion (white arrows) are seen in this image as are seen in the bottom two images of Fig. 6.4. However, the abrasion is much “duller” than that seen in Fig. 6.4, indicating that it happened after discard, but before excavations began. The yellow arrow indicates the edge of a PESM flake scar, while the red arrows show the same kind of localised abrasion from PESM that looks fresher, like that seen in Fig. 6.4.

**Figure 6.6 Butt End of CoH # 243** Handaxe, tip shape 4. Showing multiple compounded step fractures (black arrows). This has made contact with stone, I believe a hammer stone, so that the tip (Fig. 6.7) could split wood. Compare this image with Fig. 5.11 of the butt end of experimental piece TS.2013.16 that was hammered so that the tip (Fig. 5.12) could split seasoned wood.

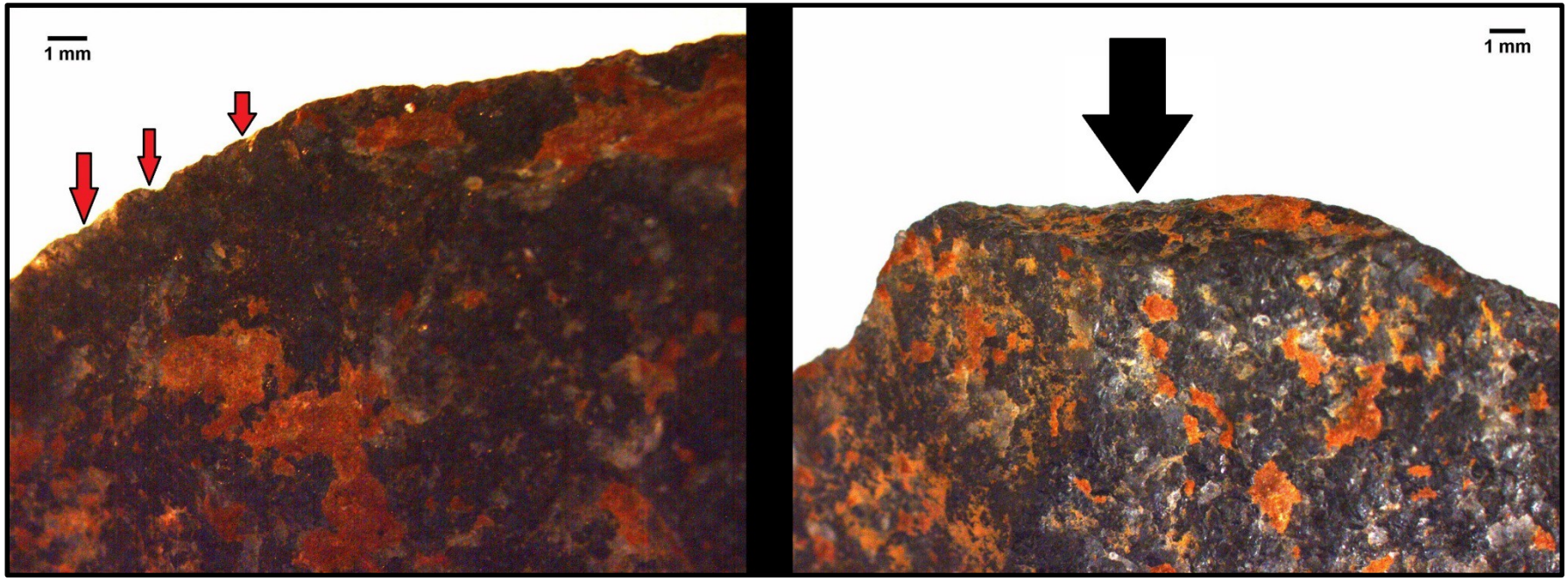


**Figure 6.7 Tip of CoH # 243** Handaxe, tip shape 4. Showing the tip that was used to split wood. To be compared with the tip of TS.2013.16 in Fig. 5.12. Note the same type of fracture (snap, black arrow) in the right picture that removed the tip due to the excessive pressure being exerted upon it. The left picture shows the edge leading up to the tip. It is slightly denticulated by smaller snap and hinge scars (red arrows).

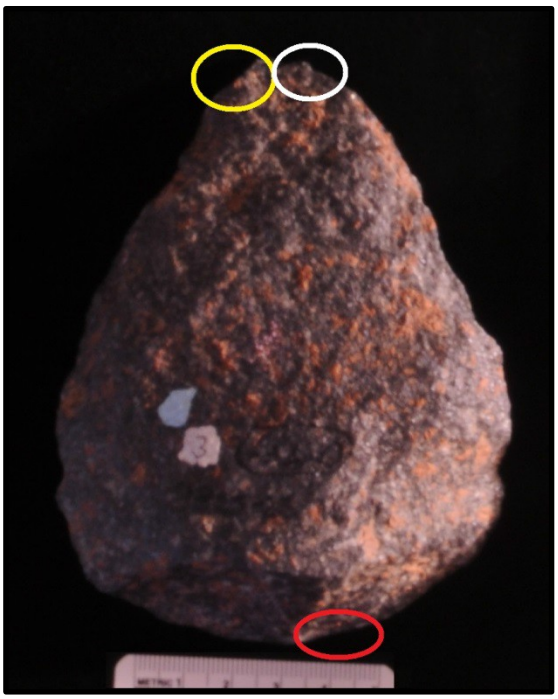

**Figure 6.8 Macroscopic View of CoH # 243** Area circled in red is the portion shown in Fig. 6.6. The area in yellow is the right hand photo in Fig. 6.7, while the white circle indicates the left hand area seen in Fig. 6.7.

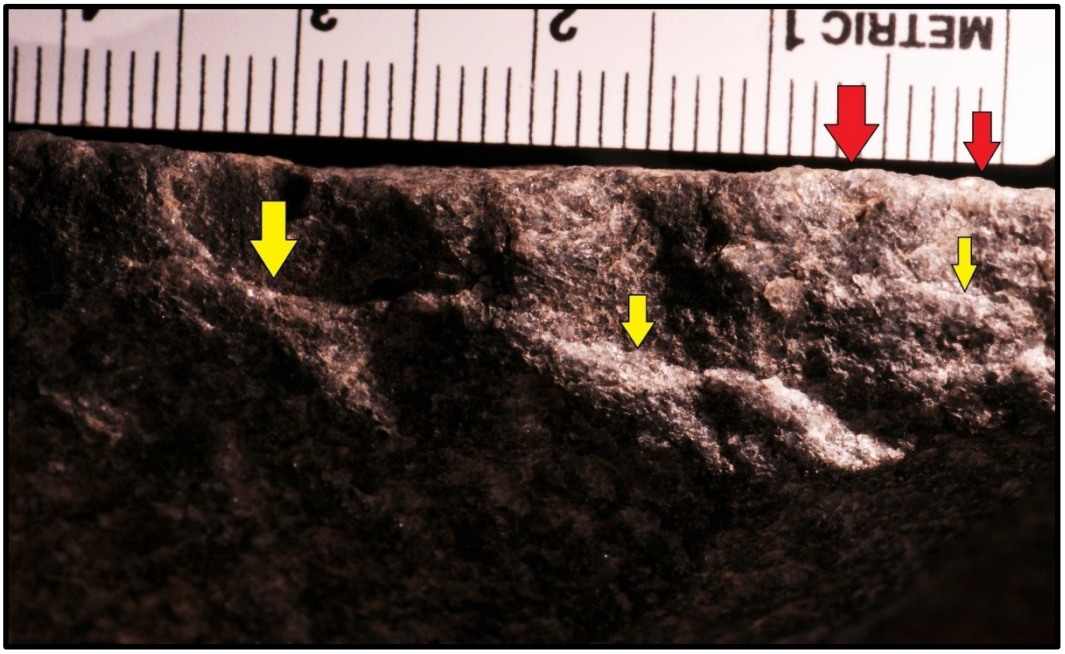


**Figure 6.9 Edge of CoH # 177** Cleaver, tip shape 6. Showing a portion of the edge that was used to scrape bone. Note the heavy rounding and crushing (red arrows) and the multiple step fractures (yellow arrows) that are spread along the whole edge. The fractures only propagate onto the surface shown, suggesting that the motion was a unilateral scraping motion in which the tool was only pulled or pushed and not both. Should be compared with Fig. 5.7 (though used to saw bone the shape, size and termination of the scars are similar) and with Fig. 5.10 for comparison of the rounding and crushing.

**Figure 6.10 Macroscopic View of CoH # 177** Area circled in red is that shown in Fig. 6.9.

**Figure 6.11 Macroscopic View of CoH # 231** The area circled in yellow is the same area shown in the two photos in Fig. 6.12.

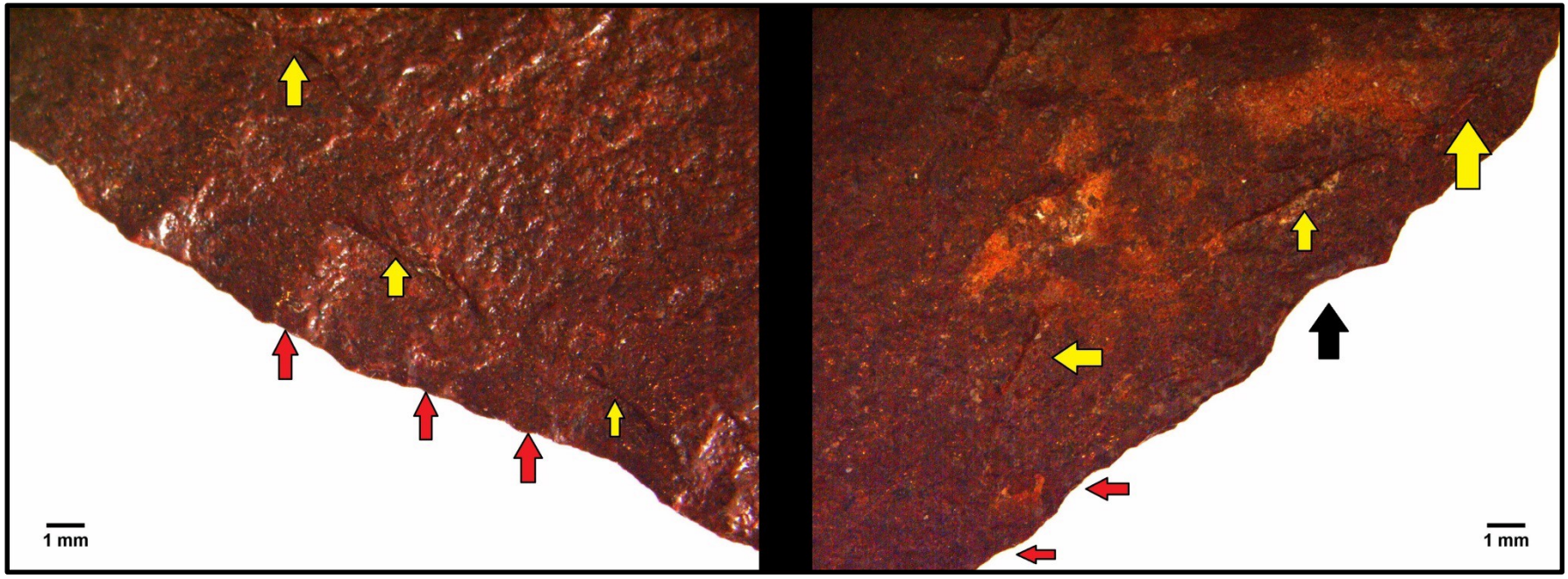


**Figure 6.12 Edge of CoH # 231** Handaxe, tip shape 1. The images show part of the edge used to cut soft & hard material (i.e., a butchery task). They are of the same area, just of opposite faces. Notice that in each of the pictures there are larger step scars (yellow arrows) and one large snap scar (black arrow) that are accompanied by much smaller feather and hinge terminated scars (red arrows) that have given the edge its denticulation. These are classic signs that the edge came into contact with both a hard material and a soft material.

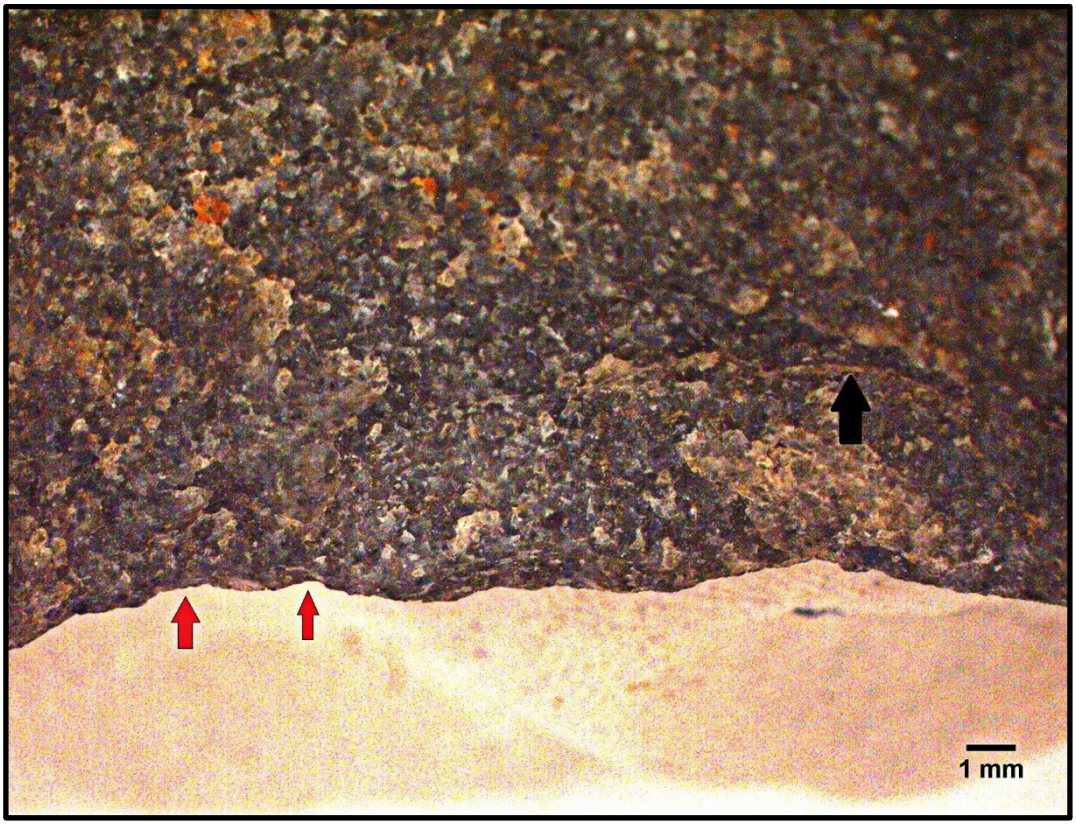


**Figure 6.13 Edge of CoH # 234** Cleaver, tip shape 2. Showing a portion of the edge that was used to scrape a medium-hard substance, possibly wood. Note the medium rounding of the edge, as well as the one large hinge fracture (black arrow) and the smaller snap fractures (red arrows). Like the other scraping tools, the fractures only propagate into this face and suggest that the tool was used in a unilateral motion. To be compared with Fig. 5.18 used to scrape seasoned wood.

**Figure 6.14 Macroscopic View of CoH # 234** The area circled in red is the edge shown in Fig. 6.13.

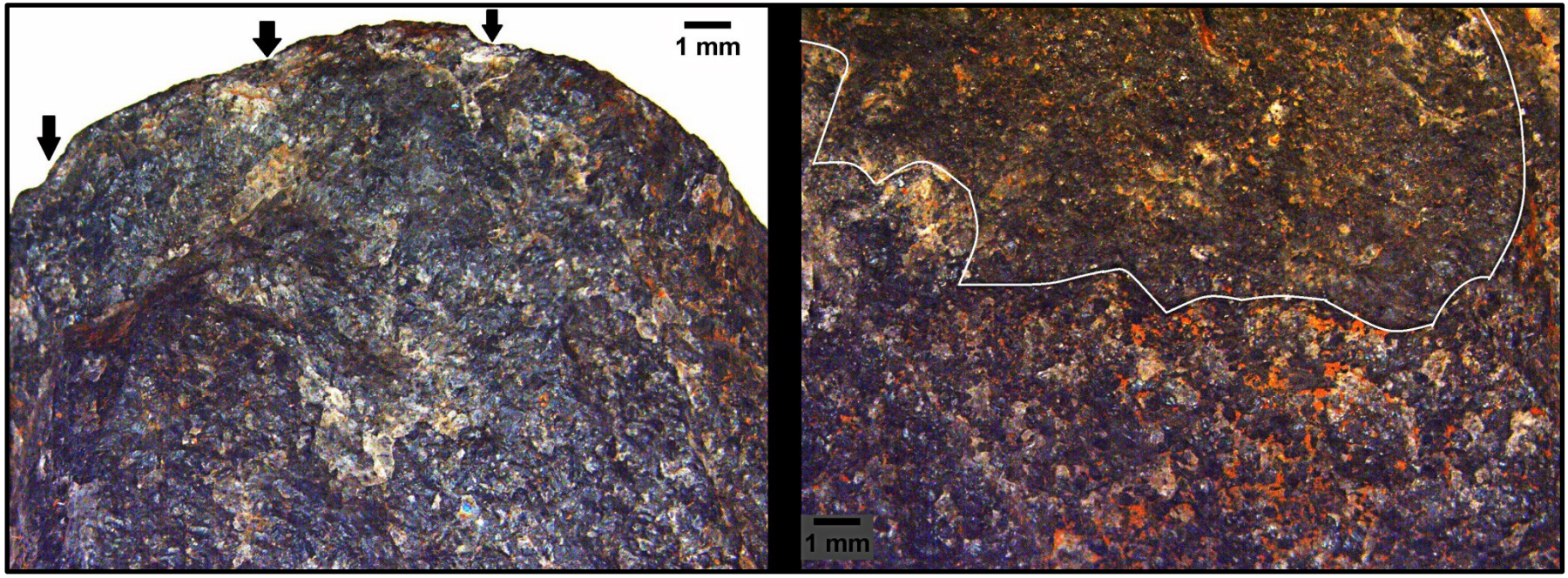


**Figure 6.15 Edges of CoH # 178** Handaxe, tip shape 1. Showing the tip (left photo) and a portion of the edge (right photo) leading up to the tip that have both been used for digging. Both photos show the abrasion polish that is similar to that seen on experimental piece TS.2013.2 (Fig. 5.5). The right hand photo only exhibits the polish inside the white line, while the left hand photo shows it everywhere. The general characteristics are that is has "ground" down all technological features of any flakes scars, grains, arêtes, etc. leaving a smooth surface. The area below the line in the right hand photo is a good comparison as the surface is still rough in texture and individual grains and ridges can be made out. The few scars seen in the left photo (black arrows) are likely from the tip hitting rocks, or consolidated areas of soil.

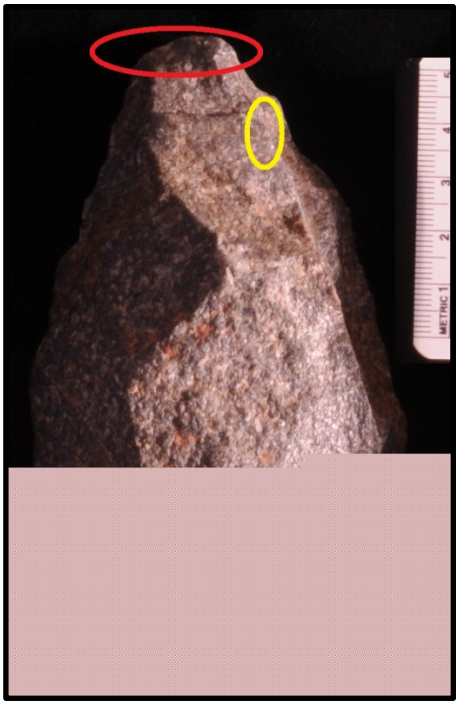

**Figure 6.16 Macroscopic View of CoH # 178** The area in the red circle is the same area seen in the left photo of Fig. 6.15, while the yellow circle indicates the area seen in the right hand picture of Fig. 6.15.

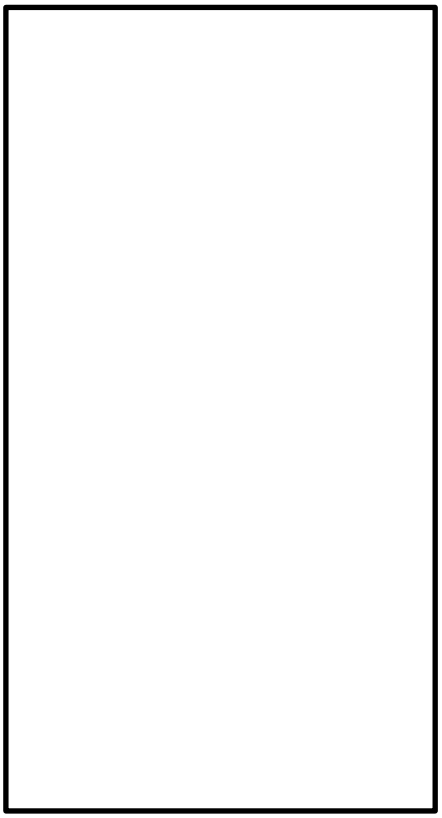

**Figure 6.17 Macroscopic View of CoH # 263** The area inside the red circle is the edge shown in Fig. 6.18.

**Figure 6.20 Edge of CoH # 218** Cleaver, tip shape 7. Showing a portion of the edge that was used to scrape wood. Note that the scars (black arrows) all intrude into only one face, indicating that the motion was unilateral. Additionally, most of the scars are hinge and step scars of a medium size. Had this piece been used on anything harder (e.g., bone), the edge would be crushed, abraded, and rounded more than it is. Also note that the edge has been mildly affected by PESM in the form of abrasion (red arrows). To be compared with Fig. 5.18 used to scrape seasoned wood.

**Figure 6.21 Macroscopic View of CoH # 218** The area in red is the edge pictured in Fig. 6.20.

**Figure 6.22 Macroscopic View of CoH # 221** The area inside the red circle is the edge shown in Fig. 6.23.

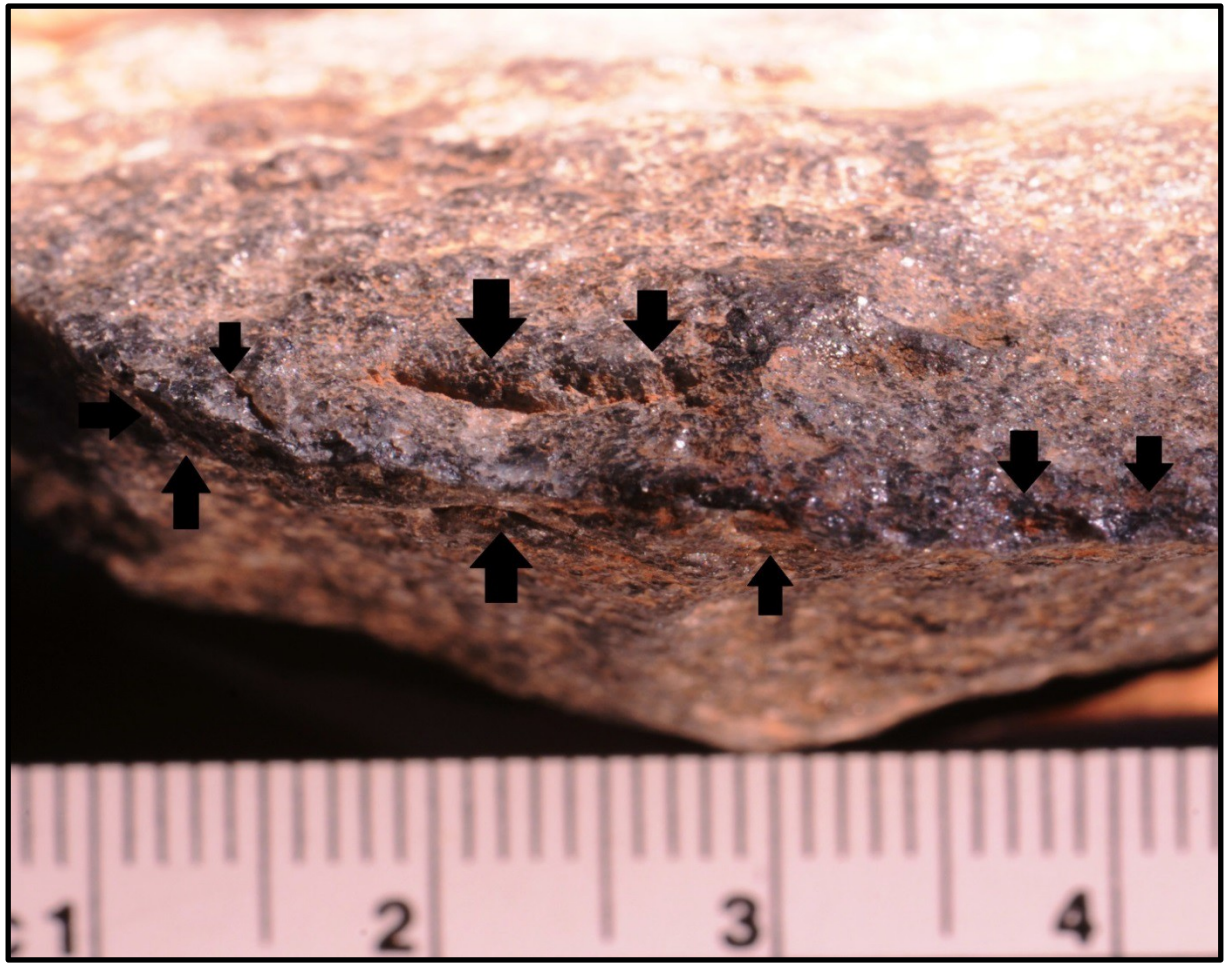


**Figure 6.23 Edge of CoH # 221** Cleaver, tip shape 2. Showing an area of the bit that was likely used to saw a hard material. This is seen by the large step and hinge fractures (black arrows) that intrude onto both faces of the tool. The edge is generally heavily rounded, as are the surrounding ridges and arêtes further away from the edge, indicating that the tool may have penetrated the worked material fairly deep. Should be compared with Fig. 5.7 an experimental piece which was used to saw cow bone.

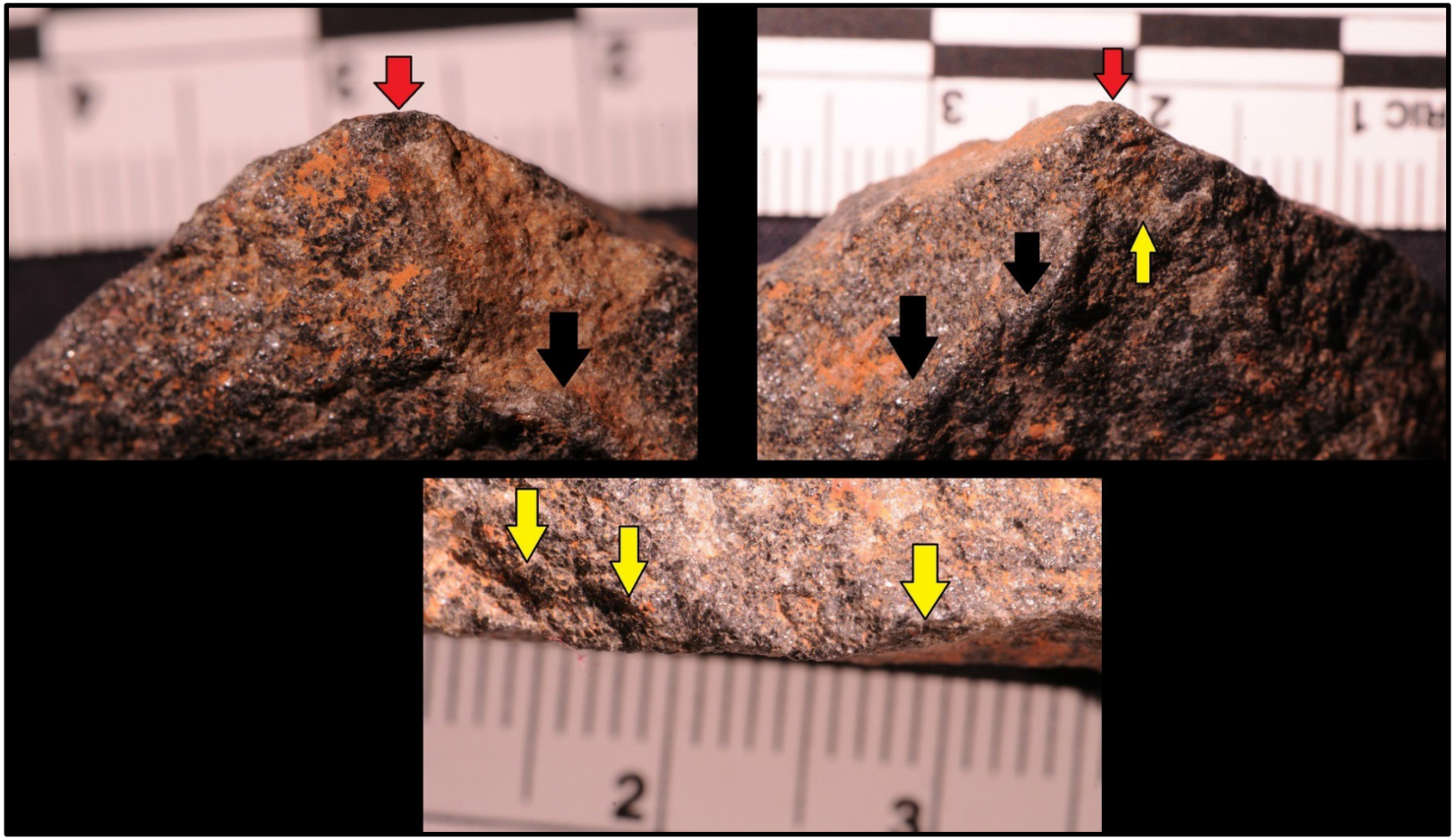

**Figure 6.24 Edges of CoH # 255** Cleaver, tip shape 4. The top two images show both faces of the tip that was used for drilling wood. Note the rounding of the ridges and arêtes away from the tip (black arrows) and the tip rounding and crushing (red arrows). The bottom image shows part of the edge that was scraped across the surface of the wood as the drilling motion happened. Note the medium sized scars (yellow arrows) and that the edge is only moderately rounded suggesting use on a medium material. Should be compared to Fig. 5.12 (though note that Fig. 5.12 was used to split wood. However, the scarring is of the same type as one would expect from working the same material, just in a different motion).

**Figure 6.25 Macroscopic View of CoH # 255** The tip circled in red are the top two photos in Fig. 6.24, while the area within the yellow brackets is seen in the bottom photo of Fig. 6.24.

### 6.3.1 Hafting Results

This discussion is not included in the Quantitative Results section (Section 6.3.2) because there were only two pieces (CoH #s 231 and 265) that were found to possibly exhibit hafting wear. Additionally, I did not expect to find any traces of hafting on LCTs when the project began as there has been no evidence, to date, to indicate that Acheulean tools were hafted. Some researchers have suggested this might be a possibility (e.g., Dominguez- Rodrigo *et al.* 2001), but as of yet no proof has been provided for these assumptions.

Hafting leaves particular traces that are generally easily distinguishable from use related wear. This has been proven through Veerle Rots extensive publications on the subject supported by an experimental comparative collection of over 400 pieces (Rots 2002, 2003a, b, 2004, 2005, 2008, 2009, 2010, 2013; Rots *et al.* 2001; Rots *et al.* 2006; Rots *et al.* 2011). These hafting traces consist of very typical patterns such as “sliced-into-scalar” scars (Fig. 6.26), and “sliced” scars (Fig. 6.27). This coupled with things such as bright spots (Fig. 6.28) and striae (Fig. 6.29) associated with the scarring make the interpretations more confident.

Additionally, Rots *et al.* (2006: 950) performed a series of three hafting blind tests and came to the conclusion that the tests "demonstrated that it is possible to distinguish between hand-held and hafted stone tools and that even the hafting arrangement could be inferred correctly in most cases".

Currently, the earliest evidence the archaeological community has for hafting comes from the Sangoan component of site 8-B-11, Sai Island in the Sudan (Rots and Van Peer 2006; Rots *et al.* 2001). Using experimental archaeology and low-power use-wear analysis, Rots and Van Peer (2006: 360) and Rots *et al.* (2011) identified hafting traces on quartz core-axes from levels with a date range of 220-180 Ka. Herein, I present evidence for possible hafting traces on a handaxe (CoH # 231) and one "other[6]" tool (CoH # 265) with the overall shape of a cleaver, which if vindicated by future research, will put the earliest date for hafted tools at *ca.* 0.5 Ma, roughly 150 000 years earlier than the current earliest evidence from Northeast Africa. However, it should be noted that these are but preliminary results on only two pieces and until further work is done it should not be taken as authoritative.

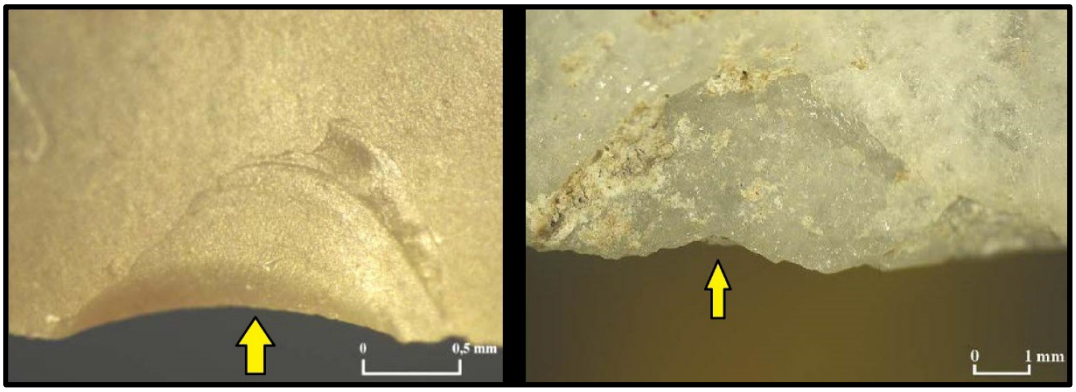


**Figure 6.26 "Sliced-into-Scalar" Scars** Left image shows this type of scar (yellow arrow) from haft bindings of a retouched experimental flake tool to a handle (Image from Rots 2008). The right image shows the same type of scar (yellow arrow) on a quartz core-axe from site 8-B-11, Sai Island, Sudan (Image modified from Rots and Van Peer 2006).

[6] Prof. Kuman has relayed to me the information that this piece may be typed as a notched scraper or a large denticulate. It is listed as other as it is neither a handaxe nor a cleaver.

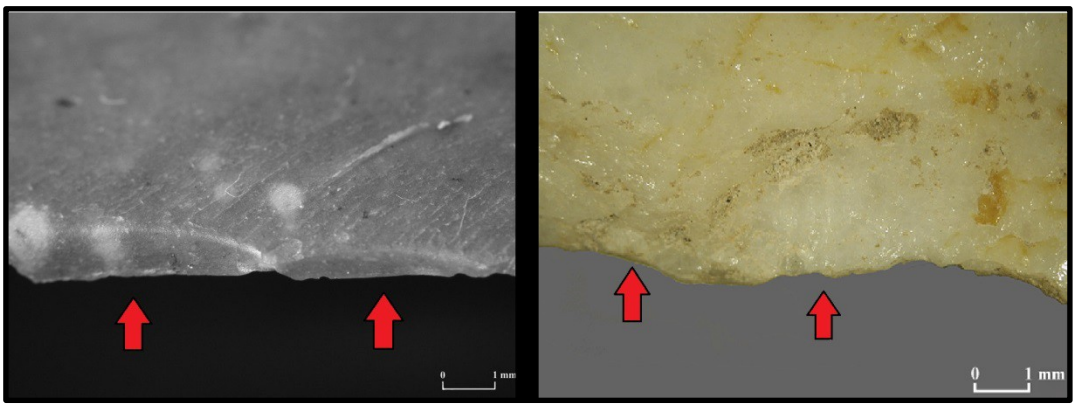


**Figure 6.27 "Sliced" Scars** Examples of "sliced" scars (red arrows) resulting from hafting. The left image is from an experimental tool (Image modified from Rots 2008) and the right image is from an archaeological core-axe from Sai Island, Sudan (Image modified from Rots and Van Peer 2006).

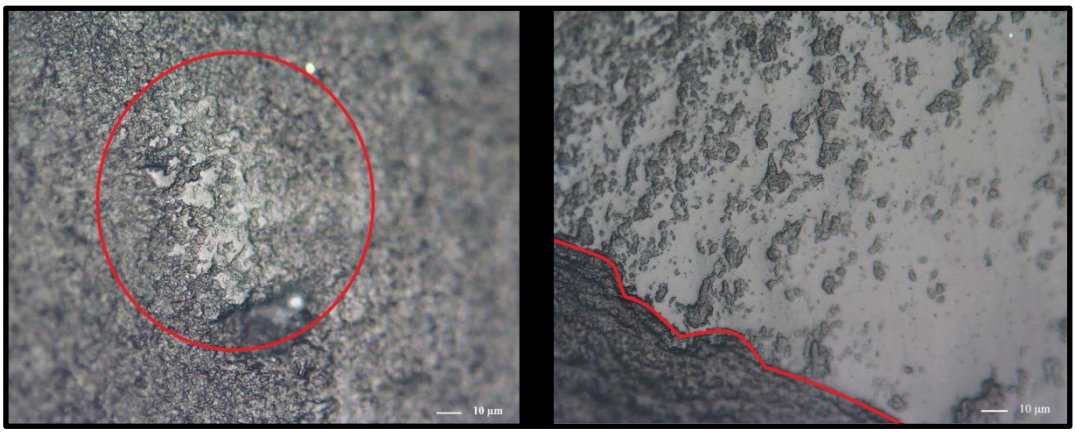


**Figure 6.28 Hafting Bright Spots** The left image shows the bright spot circled in red, whereas in the right image the bright spot is seen above the red line (Image modified from Rots *et al.* 2001).

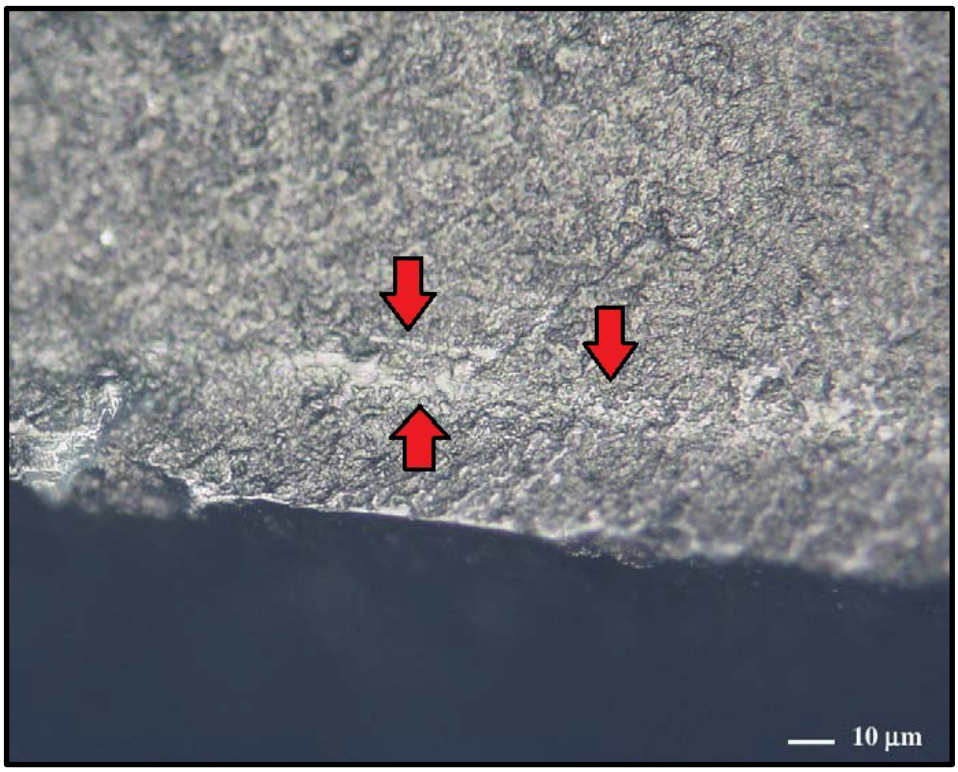


**Figure 6.29 Hafting Striae** Striae (red arrows) on an experimental tool that have occurred as a result of contact with a wooden haft (Image modified from Rots *et al.* 2006).

### 6.3.1a CoH # 231

On CoH # 231 the wear interpreted as hafting traces consist of the typical "sliced-into-scalar" scars (Fig. 6.30), rounding of the arêtes and ridges just above and around the scars (Fig. 6.31), as well as a series of compounded step fractures (Fig. 6.32).Figure 6.32 should be compared to Figure 6.33 from Rots (2013). It should be noted that all of the figures show a heavy rounding of the edges in association with all of the aforementioned features which is also indicative of hafting. Unfortunately, this piece had been moulded so a replica could be made. The chemicals used in this process have made the entire surface of the tool glossy, thus polish and bright spots that might have been seen were completely covered over. The same is true for any striae that might have been present. Thus, the interpretation is less secure than if the dull suite of use-traces were present. However, I think that based on the evidence presented that this piece was possibly hafted, especially since the wear presents itself on opposite sides of the tool (Fig. 6.34) making it likely that a split-male hafting arrangement was used, much like the hafting arrangements used for my experimental work (see Fig. 5.14).

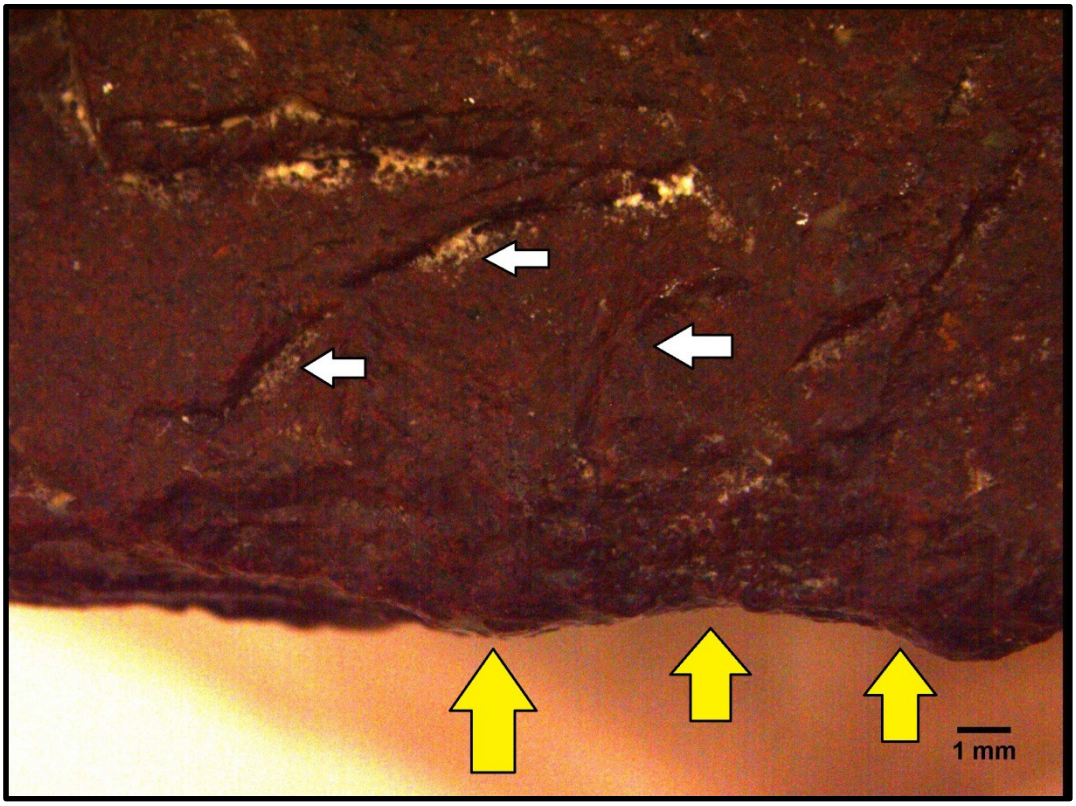


**Figure 6.30 Sliced-into-Scalar scars on CoH # 231** This edge exhibits the typical sliced-into-scalar scar (white arrows), accompanied by heavy edge rounding (yellow arrows), which are both indicative of hafting.

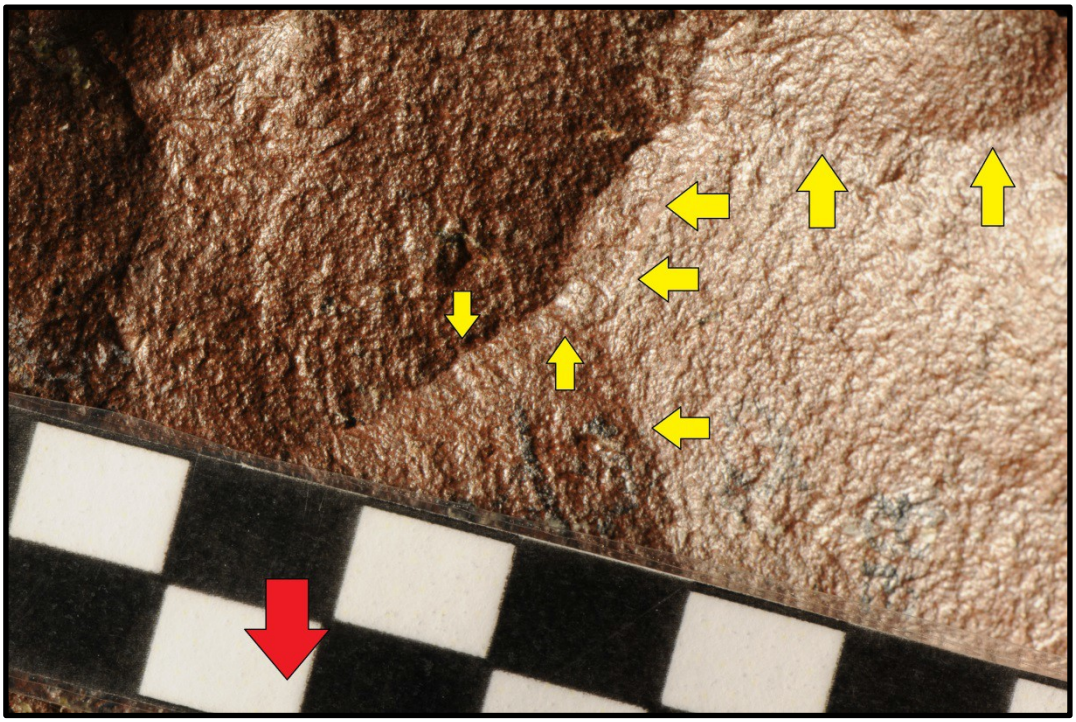

**Figure 6.31 Rounding on CoH # 231** The yellow arrows indicate the intense rounding of the ridges and arêtes that are immediately above the scars pictured in Fig. 6.30. The red arrow indicates in which direction the scars in Fig. 6.30 are located.

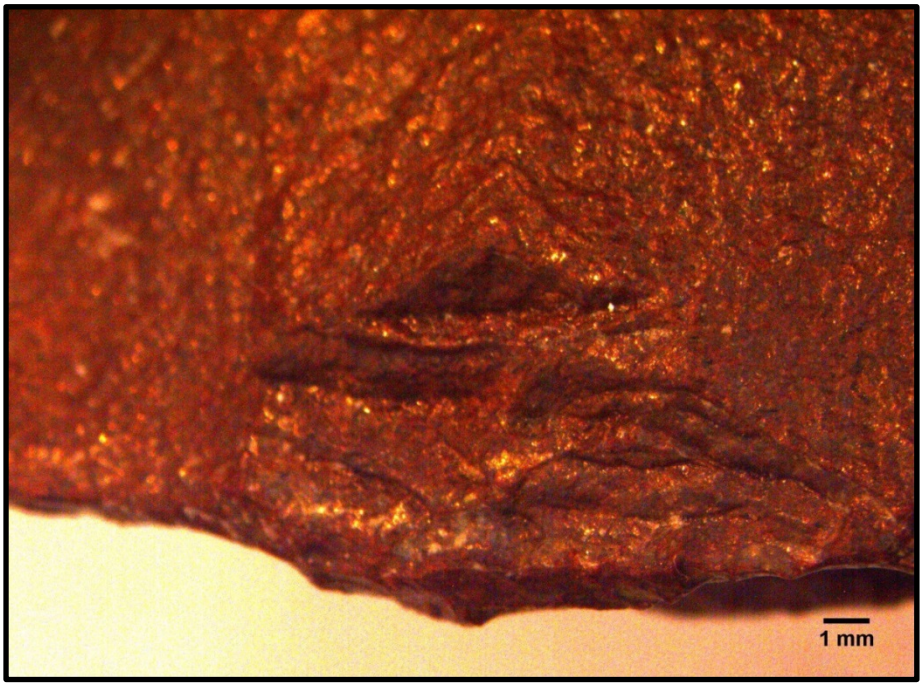


**Figure 6.32 Possible Hafting Scarring on CoH # 231** Note the layered, superimposed step scars and the heavy rounding of the edges, especially just above the scale bar.

**Figure 6.33 Scars Resulting from Hafting** Note the similarity to Figure 6.32 in that they exhibit multiple, compounded, superimposed and layered step-fracturing. Heavy rounding is also present. Image from Rots 2013. (Her caption reads "...dorsal hafting scarring at haft boundary".)

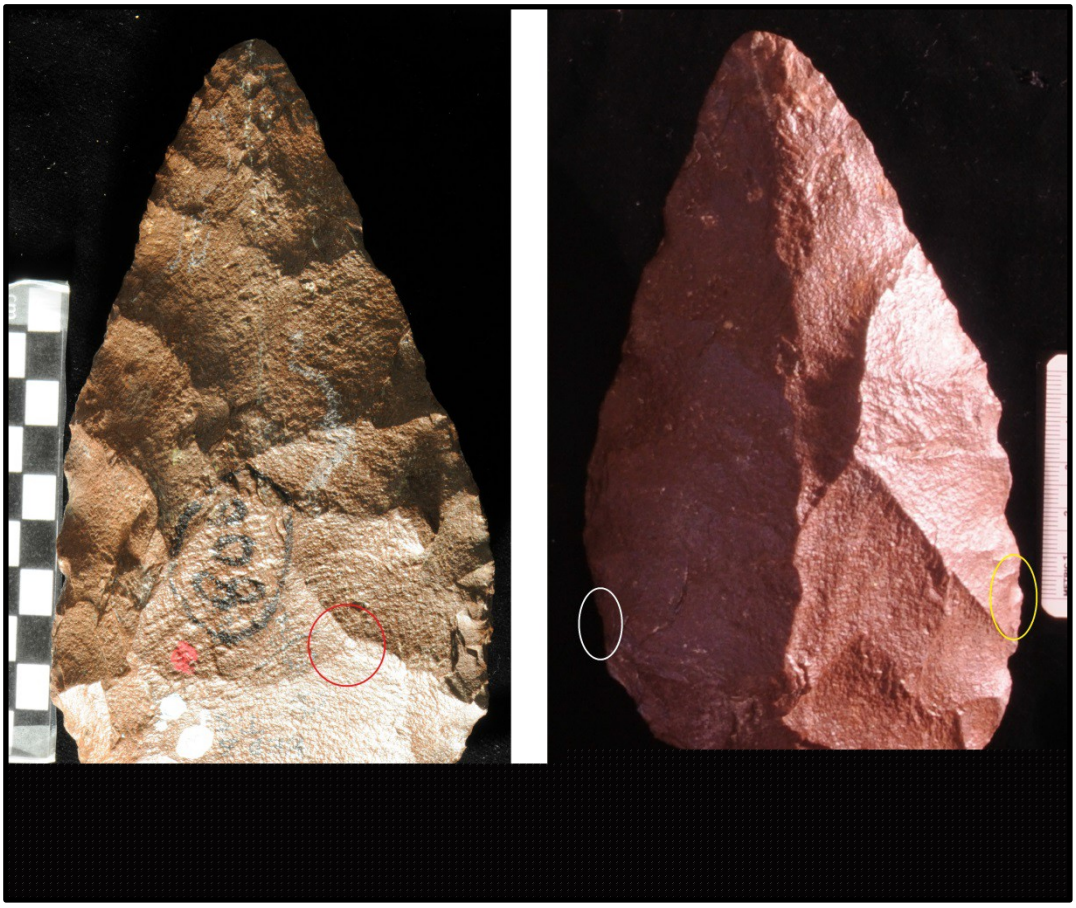

**Figure 6.34 Location of Possible Hafting Traces on CoH # 231** The area circled in white in the right photo the location of Fig. 6.30, the area circled in red on the left image is the location of Fig. 6.31, and the area encircled in yellow is the location of Fig. 6.32.

### 6.3.1 b CoH # 265

The possible hafting wear seen on CoH # 265 is similar to that evidenced on CoH # 231. There are the typical sliced-into-scalar scars but on this piece they are accompanied by sliced scars (Figs. 6.35 and 6.36). There is the same type of arête and ridge rounding on areas near the scars (Fig. 6.37). Fortunately, this piece was not cast so possible hafting polish could be observed and in fact was found along a ridge associated with the sliced scars (Fig. 6.38). When compared with the published results of experimental and archaeological hafting wear I believe that the evidence presented for both pieces makes it likely that they were hafted. However, I must reiterate that these are preliminary results that need further evidence to be for sure.

**Figure 6.35 Possible Hafting Scars on CoH # 265** The yellow arrow shows the classic sliced-into-scalar scar. The red arrow is pointing towards a classic sliced scar and the black arrow is indicating the heavy rounding that is to be expected from haft contact.

**Figure 6.36 More Possible Hafting Scars on CoH # 265** As with the previous figure, the yellow arrows indicate the sliced-into-scalar scars, while the red arrows show the sliced scars.

**Figure 6.37 Rounding on CoH # 265** The black arrows indicate the rounding of the arêtes and ridges near the scarring seen in Fig. 6.35. The red arrow indicates the direction in which the scarring seen in Fig. 6.35 is located.

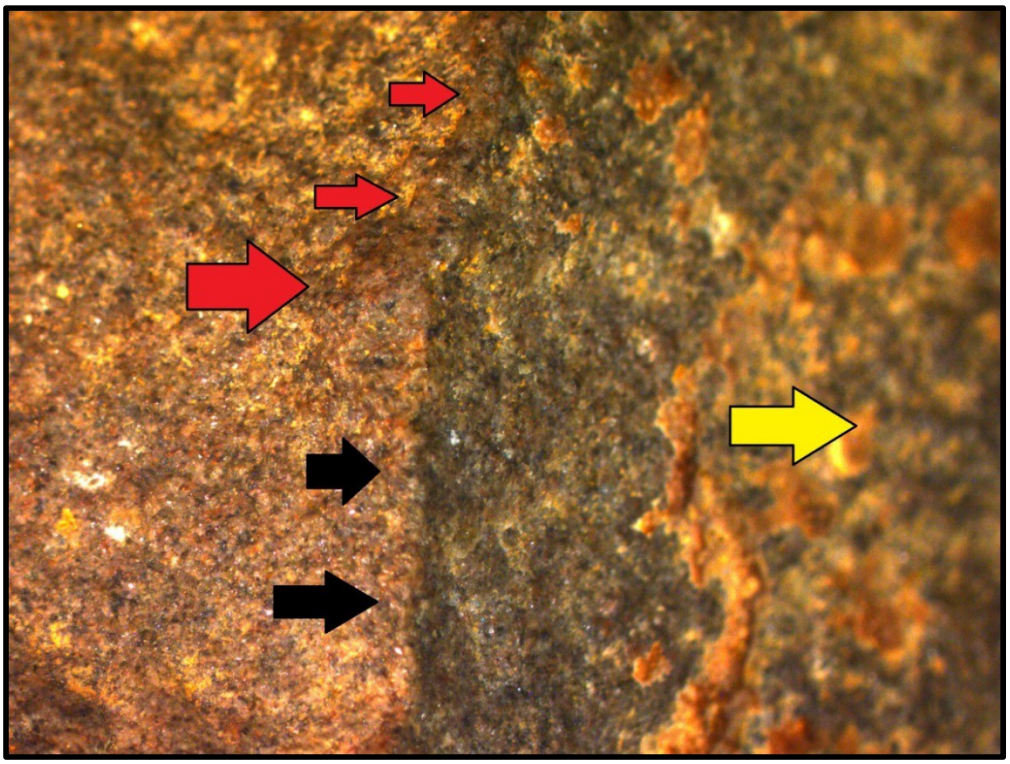

**Figure 6.38 Possible Hafting Polish on CoH # 265** The red arrows indicate a line of polish that runs along a ridge on the body of the piece (seen as the glossy line that is more red in colour than the rest of the piece) .The black arrows show the rounding of the ridge without the polish present for comparison. The yellow arrow indicates the direction of the wear seen if Fig. 6.34.

**Figure 6.39 Location of Possible Hafting Wear on CoH # 265** The yellow circle indicates the position of the wear seen in Fig. 6.35. The white area shows the location of the wear pictured in Fig. 6.36. The area encircled in red shows the location of the rounding seen in Fig. 6.37, while the black circle indicates the location of the polish seen in Fig. 6.38.

### 6.3.2 Quantitative Results

Before any discussion of the quantitative results can take begin it should be noted that the sample analysed only constitutes 29.23% of the Bed 3 population and an even smaller 12.6% of the entire CoH Acheulean LCT population. These percentages mean that the results, discussed below, may not represent that entire picture at CoH, but rather they should be taken as a starting point from which further analyses can be done. In line with this notion, any conclusions drawn from this data should be taken with caution until more research can be done on the functions of Acheulean HDTs and in particular at CoH.

As can be seen from the data presented in Table 6.3, of the total 38 tools that were sampled, 26 (68.4%) exhibited traces that could reliably be linked to use. These 26 tools represent a sum of 47 distinct use-episodes (tasks), with the majority of the tools (16) exhibiting traces of more than one use. While the percentages of utilised tools may seem lower than expected, especially when dealing with LCTs (or formal tools in general), which have been assumed to have been utilised until they were no longer

usable, this is likely due to a couple reasons. First is that the depositional history of CoH (see Section 3.3) was likely a high energy system in which a large portion of the LCTs were subjected to PDSM in some fashion or another, possibly erasing use-wear traces that might have otherwise been seen. Another possible reason is that the tools that have been recorded as un-used (n=5, blue font in Table 6.2) may have been used on soft materials (e.g., vegetal or animal matter), and burial processes, weathering, PDSM, PESM, etc. have obliterated the fine wear traces that come from working those kinds of materials. Additionally, those that were recorded as too badly damaged by PDSM or PESM (n=7, red font in Table 6.2) for any functional information to be obtained, could have possibly been used, even for heavy-duty tasks, but the effects of poor curation and an un-desirable depositional history may have removed all wear traces. This may also have a potential impact on the statistical analyses run, making the numbers even smaller (n=26 used pieces). Again, I restate that this is solely preliminary data that should be tested with larger sample sizes in future studies.

### 6.3.2a Statistical Results for Handaxe, Cleaver, and Other

One of the main questions this study intended to investigate was if there was a statistically significant relationship between function and morphology, or more simply put, does form equal function?

This study utilised the formula $\chi^2 = \sum_{i=1}^{n} \frac{(O_i - E_i)^2}{E_i}$ also known as Pearson's Chi-square test, to determine whether or not there was a statistically significant relationship between the categories of morphology and function. The standard Alpha of p=0.05 was utilised as the threshold for significance or non-significance in all tests. The conventional rule of thumb when utilising the Chi-square test is that the *expected* value (represented by E in the equation) is greater than five for all cells. However, according to McDonald (2014: 86) this rule comes from a time when "the calculations necessary for an exact test were exceedingly tedious and error-prone. Now that we have…computers it's time to retire the 'no expected values less than 5' rule". McDonald (2014) does, however, advocate the pooling of data (e.g., placing the medium-soft and medium-hard categories into one category called medium) as much as possible before running the Chi-square test, which has been done throughout this study. As mentioned above, these tests were run using small numbers and thus the results should be considered preliminary, until more research can be done.

For each of the morphologies (i.e., handaxe, cleaver, and other), and for the tip shapes reported on in Section 6.3.1b, the statistical testing was broken into four main categories which correspond to action, resistivity, worked material, and “full-task reconstructed”. It was decided that this was the best way to the data as some tools have one category (e.g., action) that was securely identified, but another category (e.g., worked material) that was uncertain. For this reason, not all categories will retain the same frequency across all tests. Setting the tests up this way allowed the data to be as fine-grained as possible, thus producing results which could be more readily relied upon.

The first series of Chi-square tests was run was to determine if there was a significant relationship between single-use tools, multiple use tools and morphology. Tables 6.4—6.7 present the data used in these tests with a discussion following (*N.B.* all “CoH #s” in all following tables correspond to the numbers listed in Tables 6.2, 6.3, and B.1).

**Table 6.4 Single-Use and Multiple Use Tools (Action)**

| | **Single Use** | **CoH #** | **Multi-Use** | **CoH #** |
|---|---|---|---|---|
| **Handaxe** | 3 | 178, 192, 231 | 3 | 144, 155, 243 |
| **Cleaver** | 9 | 151, 177, 187<br>199, 220, 229<br>234, 238, 258 | 10 | 165, 174, 181<br>196, 212, 218<br>221, 255, 266,<br>267 |
| **Other** | 1 | 265 | 0 | |

$X^2$ test

| Count | Rows | Columns | Degrees of Freedom |
|---|---|---|---|
| 26 | 3 | 2 | 2 |

| | *Alpha* | *0.05* |
|---|---|---|
| Chi-sq | p-value | significant |
| 1.0526 | 0.5907 | NO |

**Table 6.5 Single-Use and Multiple Use Tools (Resistivity)**

| | Single Use | CoH # | Multi-Use | CoH # |
|---|---|---|---|---|
| **Handaxe** | 3 | 155, 178, 192 | 3 | 144, 231, 243 |
| **Cleaver** | 11 | 151, 174, 181, 187, 196, 199, 220, 229, 234, 238, 258 | 8 | 165, 177, 212, 218, 221, 255, 266, 267 |
| **Other** | 1 | 265 | 0 | |

$X^2$ test

| Count | Rows | Columns | Degrees of Freedom |
|---|---|---|---|
| 26 | 3 | 2 | 2 |

| | *Alpha* | *0.05* |
|---|---|---|
| Chi-sq | p-value | significant |
| 0.8791 | 0.6443 | NO |

**Table 6.6 Single-Use and Multiple Use Tools (Worked Material)**

| | Single Use | CoH # | Multi-Use | CoH # |
|---|---|---|---|---|
| **Handaxe** | 3 | 155, 178, 192 | 3 | 144, 231, 243 |
| **Cleaver** | 6 | 151, 174, 181, 187, 199, 258 | 7 | 165, 177, 212, 218, 221, 255, 267 |
| **Other** | 1 | 265 | 0 | |

$X^2$ test

| Count | Rows | Columns | Degrees of Freedom |
|---|---|---|---|
| 20 | 3 | 2 | 2 |

| | *Alpha* | *0.05* |
|---|---|---|
| Chi-sq | p-value | significant |
| 1.0769 | 0.5836 | NO |

**Table 6.7 Single-Use and Multiple Use Tools (Full Task)**

| | Single Use | CoH # | Multi-Use | CoH # |
|---|---|---|---|---|
| **Handaxe** | 2 | 178, 192 | 4 | 144, 155, 231, 243 |
| **Cleaver** | 4 | 151, 187, 199, 258 | 9 | 165, 174, 177, 181, 212, 218, 221, 255, 267 |
| **Other** | 1 | 265 | 0 | |

$X^2$ test

| Count | Rows | Columns | Degrees of Freedom |
|---|---|---|---|
| 20 | 3 | 2 | 2 |

| | *Alpha* | *0.05* |
|---|---|---|
| Chi-sq | p-value | significant |
| 1.9668 | 0.3740 | NO |

For the category of action, though the frequencies of the single and multiple use cleavers are around triple that of handaxes, the Chi-square test result was p=0.5908 showing that there is no significant relationship between single-use tools, multiple use tools and morphology. The results for the other three tests all returned a result of no significance confirming the fact that there is no statistically significant relationship between single-use tools, multiple use tools and form. In other words, the hominins at CoH were just as likely to use a handaxe for multiple uses as they were to use a cleaver. The results are as follows: resistivity (p=0.6443) worked material (p=0.5836), and full task (p=0.3740).

This runs counter-trend to the general conception of LCTs and how they were used. It has been held that handaxes were made in the classic teardrop shape because doing so offered longer expanses of cutting edge than did the classic cleaver shape, making them more useful for a larger number of tasks, and therefore likely to have been used for more than one task (regardless of whether those tasks took place over a long period of time or were performed in a few hours) (Jones 1980, 1981, 1994; White 1998). However, the results from my study contradict this idea and instead point to the opposite fact—that a cleaver may have been just as useful as a multi-purpose tool as a handaxe was, despite what we modern archaeologists think.

The interesting thing to note, however, is that even though there is no

significant relationship between these two categories, cleavers were consistently used at least twice as often as handaxes were for multiple purposes. This trend that seems to contradict the numbers from the Chi-square tests is likely due to two main reasons: 1) the fact that, in my sample, cleavers outnumber handaxes at a ratio of 7:2, meaning it may be possible that handaxes are simply underrepresented and had there been more handaxes in the sample they would have just as frequently been used as multi-purpose tools as cleavers were; and 2) my sample size consists of only 26 used pieces; it is possible that if I had a larger sample size (e.g., had I analysed all of Bed 3 (130 LCTs)) this trend might not have shown up. A third explanation, though it is far less likely, is that during the random sampling procedure, through sheer coincidence or some kind of infinitesimally small chance, I happened to sample most of the cleavers that had been used for more than one task. In any case, there is no statistically significant relationship between those LCTs that were used for single tasks and those that were used for multiple tasks.

The second series of Chi-square tests was run with the original categories of action, resistivity, and worked material being further sub-divided (e.g., resistivity being split into soft, medium, hard, and soft & hard). This was done to determine if refining the categories would reveal any relationship with any morphological category. A test for Full Task Reconstructed was not run because of the tools on which the full suite of use-wear data was recovered (i.e., action, resistivity, and worked material) there were only two tools that had the same fully reconstructed tasks (CoH # 218 & 221). It should be noted that in the following tables (Tables 6.8—6.10) multi-purpose tools were counted for each of their tasks. For example CoH # 144 was counted for both the hard and the medium categories as the tool was utilised on both these resistivities on separate areas of the tool. Likewise it was counted for both the transverse and percussive activity categories as it was used to scrape and to dig.

**Table 6.8 Use by Action.** Transverse= scrape & plane; Longitudinal= cut/ slice, & saw; Percussive= dig, hammer, chop/ adze, wedge/ split & impact; Rotary= drill. No. 243 is listed twice because it was utilised in two distinct motions (both percussive) on two different areas of the tool.

| | **Transverse** | **CoH #** | **Longitudinal** | **CoH #** | **Percussive** | **CoH #** | **Rotary** | **CoH #** |
|---|---|---|---|---|---|---|---|---|
| **Handaxe** | 1 | 144 | 3 | 155, 192, 231 | 5 | 144, 155, 178, 243, 243 | 0 | |
| **Cleaver** | 14 | 151, 165, 174, 177, 181, 199, 212, 218, 220, 221, 229, 234, 258, 267 | 8 | 165, 187, 196, 212, 238, 255, 266, 267 | 2 | 181, 266 | 2 | 174, 255 |
| **Other** | 0 | | 1 | 265 | 0 | | 0 | |

$X^2$ test

| Count | Rows | Columns | Degrees of Freedom |
|---|---|---|---|
| 36 | 3 | 4 | 6 |

| | *Alpha* | *0.05* |
|---|---|---|
| Chi-sq | p-value | significant |
| 13.5897 | 0.0345 | YES |

**Table 6.9 Use by Resistivity.** The last category of Soft & Hard represents tools that were interpreted as having been used in butchery tasks, or those tasks in which the tool came into contact with animal products and a hard material in the same task.

| | Soft | CoH # | Medium | CoH # | Hard | CoH # | Soft & Hard | CoH # |
|---|---|---|---|---|---|---|---|---|
| **Handaxe** | 0 | | 3 | 144, 231, 243 | 4 | 144, 155, 178, 243 | 2 | 192, 231 |
| **Cleaver** | 4 | 151,165, 212, 238, | 12 | 174, 181, 187, 196, 212, 218, 220, 221, 229, 234, 255, 258 | 6 | 165, 177, 212, 255, 267, 266 | 3 | 177, 199, 267 |
| **Other** | 0 | | 1 | 265 | 0 | | 0 | |

$X^2$ test

| Count | Rows | Columns | Degrees of Freedom |
|---|---|---|---|
| 35 | 3 | 4 | 6 |

| | *Alpha* | *0.05* |
|---|---|---|
| Chi-sq | p-value | significant |
| 4.4683 | 0.6136 | NO |

**Table 6.10 Use by Worked Material**

| | Animal | CoH # | Vegetal | CoH # | Wood | CoH # | Bone | CoH # | Stone/ Soil | CoH # | Animal & Bone | CoH # |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Handaxe** | 0 | | 0 | | 1 | 243 | 1 | 155 | 3 | 144, 178 243 | 2 | 192, 231 |
| **Cleaver** | 2 | 151, 212 | 1 | 165 | 7 | 174,181 187, 218 221, 255 258 | 5 | 177, 165 212, 255 267 | 0 | | 3 | 177, 199, 267 |
| **Other** | 0 | | 0 | | 1 | 265 | 0 | | 0 | | 0 | |

$X^2$ test

| Count | Rows | Columns | Degrees of Freedom |
|---|---|---|---|
| 26 | 3 | 6 | 10 |

| | *Alpha* | *0.05* |
|---|---|---|
| Chi-sq | p-value | significant |
| 12.8509 | 0.2321 | NO |

As can be seen from the data presented in Table 6.8 there does appear to be a statistically significant relationship between use action and morphology, with the result of the Chi-square test being p=0.0345 I believe however, that this may be a “false positive”. The main reason I think this is that, if one subdivides the categories into their “non-pooled” parts (e.g., split the percussive category into dig, hammer, chop/ adze, wedge/ split & impact) and runs the test again, one gets a result of p=0.1812, or an outcome of no-significance. This later test is likely more representative of the situation at CoH since each individual activity is represented. What the pooled data may suggest, however, is that the CoH hominins did not select tools based on the *specific* action they wished to perform, but rather on the *general* motion of the task. For example, based on the frequencies, cleavers were preferred more often for use-actions that were transverse to the edge being used, whereas handaxes were preferred for those motions that involved a percussive force being exerted on the used edge. This, from my own (and other published) experimental work makes logical sense as cleaver bits are usually unretouched and generally have thin edge angles, making them a poor choice for a task that would apply a large amount of force on the use-edge (i.e., hammering or chopping), while handaxes are generally retouched and have larger edge angles allowing for more robust activities to take place.

The results from the other two tests both returned a result of no significance, indicating that when it came to general resistivity (p=0.6136) and worked material (p=0.2321) either type of tool was just as likely to be selected for the task. Additionally for resistivity, a test was performed on the non-pooled data (e.g., subdividing hard and medium into their constituent parts of Hard-1 and Hard-3 and Medium-Soft and Medium-Hard respectively) and the same result of no significance (p=0.1327) was returned.

The results, thus far, of the two series of Chi-square tests that have been run seem to indicate that on the whole no particular morphology was selected for any given action, resistivity, or worked material. With the exception of the data in Table 6.8, no test resulted in a significant relationship being seen. That particular aberration has been discussed and it was suggested that it may represent a preference of a particular morphology when it came to *general* tool motion rather than *specific* tool action. However, a further set of statistical tests were run on McNabb *et al.’s* (2004) tip shapes (Fig. 6.1) and are reported below.

### 6.3.2b Statistical Results for McNabb *et al.'s* (2004) Tip Shapes

The same procedures were utilised for the third and fourth sets of Chi-square tests as were used for the first and second. The only variable that has changed is that of morphology, in which McNabb *et al.'s* (2004) tip shapes have replaced handaxe, cleaver and other. Again, it was hoped that by further refining the category of morphology a relationship might be discovered that did not exist at the gross levels of morphology that are normally employed for LCTs. Tables 6.11—6.14 present the data of tip shape over function and the result of the Chi-square test.

**Table 6.11 Single Use and Multiple Use Tools (Action)**

| Tip Shape | Single Use | CoH # | Multi-Use | CoH # |
|---|---|---|---|---|
| **1** | 4 | 178, 192, 229, 231 | 2 | 144, 155 |
| **2** | 2 | 199, 234 | 2 | 196, 221 |
| **4** | 1 | 238 | 4 | 181, 243, 255, 266 |
| **5** | 1 | 187 | 3 | 165, 174, 267 |
| **6** | 4 | 177, 220, 258, 265 | 0 | |
| **7** | 1 | 151 | 2 | 212, 218 |

$X^2$ test

| Count | Rows | Columns | Degrees of Freedom |
|---|---|---|---|
| 13 | 6 | 2 | 5 |

| | *Alpha* | *0.05* |
|---|---|---|
| Chi-sq | p-value | significant |
| 7.80 | 0.1676 | NO |

**Table 6.12 Single Use and Multiple Use Tools (Resistivity)**

| Tip Shape | Single Use | CoH # | Multi-Use | CoH # |
|---|---|---|---|---|
| **1** | 4 | 155, 178, 192, 229 | 2 | 144, 231 |
| **2** | 3 | 196, 199, 234 | 1 | 221 |
| **4** | 2 | 181, 238 | 3 | 243, 255, 266 |
| **5** | 2 | 174, 187 | 2 | 165, 267 |
| **6** | 3 | 220, 258, 265 | 1 | 177 |
| **7** | 1 | 151 | 2 | 212, 218 |

| $X^2$ test | Count | Rows | Columns | Degrees of Freedom |
|---|---|---|---|---|
| | 15 | 6 | 2 | 5 |

| | | *Alpha* | *0.05* |
|---|---|---|---|
| | Chi-sq | p-value | significant |
| | 2.6472 | 0.7542 | NO |

**Table 6.13 Single Use and Multiple Use Tools (Worked Material)**

| Tip Shape | Single Use | CoH # | Multi-Use | CoH # |
|---|---|---|---|---|
| **1** | 3 | 155, 178, 192 | 2 | 144, 231 |
| **2** | 1 | 199 | 1 | 221 |
| **4** | 1 | 181 | 2 | 243, 255 |
| **5** | 2 | 174, 187 | 2 | 165, 267 |
| **6** | 2 | 258, 265 | 1 | 177 |
| **7** | 1 | 151 | 2 | 212, 218 |

| $X^2$ test | Count | Rows | Columns | Degrees of Freedom |
|---|---|---|---|---|
| | 20 | 6 | 2 | 5 |

| | | *Alpha* | *0.05* |
|---|---|---|---|
| | Chi- sq | p-value | significant |
| | 1.20 | 0.9449 | NO |

**Table 6.14 Single Use and Multiple Use Tools (Full Task)**

| Tip Shape | Single Use | CoH # | Multi-Use | CoH # |
|---|---|---|---|---|
| **1** | 2 | 178, 192 | 3 | 144, 155, 231 |
| **2** | 1 | 199 | 1 | 221 |
| **4** | 0 | | 3 | 181, 243, 255 |
| **5** | 1 | 187 | 3 | 165, 174, 267 |
| **6** | 2 | 258, 265 | 1 | 177 |
| **7** | 1 | 151 | 2 | 212, 218 |

| $X^2$ test | Count | Rows | Columns | Degrees of Freedom |
|---|---|---|---|---|
| | 20 | 6 | 2 | 5 |

| | | *Alpha* | *0.05* |
|---|---|---|---|
| | Chi-sq | p-value | significant |
| | 3.3699 | 0.6431 | NO |

From the data presented in the above tables it can be seen that there is no statistically significant relationship between tip shape and single use or multiple use tools in any of the categories. The results are as follows: action (p=0.1676), resistivity (p=0.7542), worked material (p=0.9449), and full task (p=0.6431). However, the same cautions must be observed for these results as were mentioned for the first series of tests, namely that the sample size is small and these results are preliminary. There needs to be more work done on a larger number of pieces to confirm the findings of this study.

The fourth and last series of tests that were run correspond to the second series of tests in that the original categories of Action, Resistivity, and Worked Material were further subdivided into their smaller components to determine if there was any relationship in the nuanced data. Tables 6.15—6.17 present the results of these tests.

**Table 6.15 Use by Action.** Transverse= scrape & plane; Longitudinal= cut/ slice, & saw; Percussive= dig, hammer, chop/ adze, wedge/ split & impact; Rotary= drill

| Tip Shape | Transverse | CoH # | Longitudinal | CoH # | Percussive | CoH # | Rotary | CoH # |
|---|---|---|---|---|---|---|---|---|
| **1** | 2 | 144, 229 | 3 | 155, 192, 231 | 3 | 144, 155, 178 | 0 | |
| **2** | 3 | 199, 221, 234 | 1 | 196 | 0 | | 0 | |
| **4** | 1 | 181 | 3 | 238, 255, 266 | 4 | 181, 243, 243, 266 | 1 | 255 |
| **5** | 3 | 165, 174, 267 | 3 | 165, 187, 267 | 0 | | 1 | 174 |
| **6** | 3 | 177, 220, 258 | 1 | 265 | 0 | | 0 | |
| **7** | 3 | 151, 212, 218 | 1 | 212 | 0 | | 0 | |

$X^2$ test

| Count | Rows | Columns | Degrees of Freedom |
|---|---|---|---|
| 36 | 6 | 4 | 15 |

| | *Alpha* | *0.05* |
|---|---|---|
| Chi-sq | p-value | significant |
| 16.7345 | 0.3349 | NO |

**Table 6.16 Use by Resistivity** The last category of Soft & Hard represents tools that were interpreted as having been used in butchery tasks, or those tasks in which the tool came into contact with animal products and a hard material in the same task.

| Tip Shape | Soft | CoH # | Medium | CoH # | Hard | CoH # | Soft & Hard | CoH # |
|---|---|---|---|---|---|---|---|---|
| **1** | 0 | | 3 | 144, 229, 231 | 3 | 144, 155, 178 | 2 | 192, 231 |
| **2** | 0 | | 3 | 196, 221, 234 | 0 | | 1 | 199 |
| **4** | 1 | 238 | 3 | 181, 243, 255 | 3 | 243, 255, 266 | 0 | |
| **5** | 1 | 165 | 2 | 174, 187 | 2 | 165, 267 | 1 | 267 |
| **6** | 0 | | 3 | 220, 258, 265 | 1 | 177 | 1 | 177 |
| **7** | 2 | 151, 212 | 2 | 212, 218 | 1 | 212 | 0 | |

$X^2$ test

| Count | Rows | Columns | Degrees of Freedom |
|---|---|---|---|
| 35 | 4 | 6 | 15 |

| | *Alpha* | *0.05* |
|---|---|---|
| Chi-sq | p-value | significant |
| 12.0369 | 0.6762 | NO |

**Table 6.17 Use by Worked Material**

| Tip Shape | Animal | CoH # | Vegetal | CoH # | Wood | CoH # | Bone | CoH # | Stone/ Soil | CoH # | Animal & Bone | CoH# |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **1** | 0 | | 0 | | 0 | | 1 | 155 | 2 | 144, 178 | 2 | 192, 231 |
| **2** | 0 | | 0 | | 1 | 221 | 0 | | 0 | | 1 | 199 |
| **4** | 0 | | 0 | | 3 | 181, 243, 255 | 1 | 255 | 1 | 243 | 0 | |
| **5** | 0 | | 1 | 165 | 2 | 174, 187 | 2 | 165, 267 | 0 | | 1 | 267 |
| **6** | 0 | | 0 | | 2 | 258, 265 | 1 | 177 | 0 | | 1 | 177 |
| **7** | 2 | 151, 212 | 0 | | 1 | 218 | 1 | 212 | 0 | | 0 | |

$X^2$ test

| Count | Rows | Columns | Degrees of Freedom |
|---|---|---|---|
| 26 | 6 | 6 | 25 |

| | *Alpha* | *0.05* |
|---|---|---|
| Chi-sq | p-value | significant |
| 29.8970 | 0.3126 | NO |

As shown by the data presented above, the results for the fourth series of test are the same as the third, that is, none of the tests returned a result of any significance. The category of action had a result of p=0.3349, resistivity (p=0.6762), and worked material (p=0.3126). To keep absolute consistency with the second series of Chi-squares, tests were run on the non-pooled data for action and for resistivity. Both of these tests also returned results of no significance with the non-pooled data for action being p=0.7862 and for the non-pooled resistivity data equalling p=0.8881. These results point to the same conclusion that all the others have; there is no statistically significant relationship between morphology and any category of function (i.e., action, resistivity, worked material, and full task). However, it must be re-stressed that these results are preliminary and more investigation should be done in the future on larger sample sizes.

### 6.3.3 Non-statistical Quantitative Results

While all the statistical tests, with the exception of one (Table 6.8), resulted in an answer of no significance, statistics are but one way to arrange data. Some understanding of the situation at the CoH may come of discussing the frequencies that occur in each category and what kind of implications this might have for our understanding of what was happening at the CoH *ca.* 0.5 Ma and possibly what type of site it was (i.e., home base or specialised camp).

The main categories of interest are resistivity and worked material as these reveal what kind of materials were being worked with the stone tools and thus give us a window into what the subsistence economy of the inhabitants of CoH may have been. Though not as important to the discussion about economy and subsistence as the aforementioned categories are, it will also be interesting to look at the category of action as well. The results of the resistivity category with frequency and percentages are listed in Table 6.18, while the worked materials category is listed in Table 6.19, and actions are listed in Table 6.20.

**Table 6.18 Resistivities, Their Frequencies, and Percentages**

| Resistivity | Frequency | Percentage |
|---|---|---|
| Medium | 16 | 45.71 |
| Hard<br>(Hard-1)<br>(Hard-3) | 10<br>(7)<br>(3) | 28.57<br>(20)<br>(8.57) |
| Soft & Hard | 5 | 14.30 |
| Soft<br>(Animal)<br>(Vegetal)<br>(No refinement) | 4<br>(2)<br>(1)<br>(1) | 11.42<br>(5.70)<br>(2.86)<br>(2.86) |
| | | |
| Total | 35 | 100 |

**Table 6.19 Worked Materials, Their Frequencies, and Percentages**

| Worked Material | Frequency | Percentage |
|---|---|---|
| Wood | 9 | 34.62 |
| Bone | 6 | 23.07 |
| Meat & Bone | 5 | 19.23 |
| Stone/ Soil | 3 | 11.54 |
| Animal Materials | 2 | 7.69 |
| Vegetal Materials | 1 | 3.85 |
| | | |
| Total | 26 | 100 |

**Table 6.20 Actions, Their Frequencies, and Percentages**

| Action | Frequency | Percentage |
|---|---|---|
| Scrape | 15 | 41.67 |
| Cut | 12 | 33.33 |
| Dig | 2 | 5.56 |
| Impact | 2 | 5.56 |
| Drill | 2 | 5.56 |
| Hammer | 1 | 2.77 |
| Chop | 1 | 2.77 |
| Split | 1 | 2.77 |
| | | |
| Total | 36 | 100 |

As seen in the data in Table 6.20, the most often performed action was scraping with 15 out of 36 (41.67%), followed closely by cutting (33.33%). While this may be the case, it does not tell us much about the subsistence patterns at CoH, as the scraping and cutting evidenced was carried out across all categories of worked materials and was not limited to any single category. Though not very informative, I believe it is significant to note this as it may become important or more informative in future studies as the field progresses.

For the category of resistivity, the sub-division of medium was the most often worked with 16 of 35 or 45.71 % (Table 6.18) of use-tasks occurring in this category. This category generally is represented by the worked material wood, but other materials do occur as well (e.g., a variety of nuts, sedges, canes, and reeds). Additionally, the data listed in Table 6.16, shows that no particular tip shape seemed to have been preferred over any other for the working of this resistivity. Coupled with the data from Table 6.19 in which 9 of 26 (34.62%) of use-tasks were carried out on wood, it is likely that wood working was an activity that happened often at CoH. It is possible, based on previous residue and phytolith studies from other Acheulean sites (see Section 4.7.2b), that wood was likely being worked at CoH, and if my sample is representative of the entire situation, then it was being worked a lot. Whether the wood that was being worked was being used as hunting implements (e.g., spears or hafts), as digging sticks, or for some other unknown reason is not clear. Since no evidence of wooden artefacts from the Acheulean levels at CoH is known, then what exactly was being made from wood may always remain a mystery.

After medium materials, the next most frequent resistivity that was being worked was the hard category with 10 of 35 (28.57%) tasks carried out being done so on this material. However, this category encompasses both the Hard-1 and Hard-3 worked materials category and thus should be discussed in relationship to the constituent parts rather than the whole. Hard-1 (usually interpreted as bone) represents 7 out of 35 (20%) of the resistivity category, indicating that bone was often worked at CoH as well. Since there is very little evidence for the working of bone in the Later Acheulean outside of tasks relating to food procurement (though see Joordens *et al.* 2015 and Zutovski and Barkai 2015), it is safe to assume that any signs of bone being worked at CoH was related to butchery or food procurement is some way. Thus, I think that adding the category of soft & hard (interpreted as contact with meat and

bone) (n=5) to that of Hard-1 (n=7) represents a better picture. Doing so gives us 12 out of 35 (34.28%) use-tasks that were carried out on materials that were likely associated with obtaining animal products, probably for use as comestibles, indicating that some amount of butchery tasks were occurring at CoH. Additionally, Ogola (2009: 69, Table 6.3) found that 3.85% of the faunal assemblage she analysed bore evidence of stone tools marks, further strengthening the idea that butchery tasks were taking place at CoH, and possibly that the hominids had early access to carcasses processed based on the location and type of some of the stone tool marks (Maguire 2009: 74).

The other part of the Hard category is Hard-3, most often reserved for those tasks that have come into contact with inorganic hard materials (i.e., soil or rock). Out of the 35 securely identified resistivity tasks, 3 (8.57%) were interpreted as having made contact with Hard-3. It should be noted that one of these represents a portion of CoH # 243 that was hammered on the butt so the tip would penetrate wood in a splitting or wedging motion. That leaves 2 of 35 (5.70%) tasks that likely had contact with soil. Indeed 2 tools (CoH #s 144 and 178) were interpreted as digging instruments, due to the quite specific suite of wear traces that are left on a stone tool when used in a digging motion (see Taylor 2009), including abrasion polish, striae parallel or diagonal to the used edge, and extreme rounding of arêtes and edges surrounding the edge used. Therefore, it is probable that some amount of digging occurred at CoH, though whether the digging was for underground storage organs (USOs) such as tubers, corms, or bulbs or for another reason is not currently known, and may not ever be known unless phytolith (or other form of reliable residue) analysis takes place.

The final and last category of resistivity is that of Soft, represented by both animal soft (e.g., hide or meat) and vegetal soft (e.g., USOs or grass). Out of the 35 resistivity tasks 4 (11.42%) were assigned to this category, with only 1 (2.86%) being assigned to vegetal soft, leaving the other 2 (5.70%) assigned to animal soft and one (2.86%) that could not be identified further than the gross category of soft. Though low in frequency and percentage, these numbers further indicate that animal products were being worked at CoH, whether for food, clothing, or other items (e.g., leather straps). Additionally, it is possible that vegetal materials were being worked as well, though this should be taken with caution as only one tool bore evidence of this worked material.

### 6.4 Discussion of Quantitative Results

With the above discussion and using the data presented in Table 6.18 and 6.19, I now believe that I can state something about the type of site CoH may have been as well as what the subsistence economy of the CoH hominins may have been like. It can clearly be seen that even though wood was being worked most frequently, a range of other activities took place at CoH as well. Indeed, the full range of what might be expected from a typical hominin *ca.* 0.5 Ma is represented at CoH. In my view, this makes CoH a "residential/ mapped-on" (Binford 1980) or "well-established home base" (Wadley 1987: 76) site. This is based on the fact that an array of activities occurred at CoH, rather than just a couple tasks (e.g., butchering or wood-working) which indicates that it is probably not a logistical site or a specialised camp area. Additional evidence for this interpretation comes from the environmental and faunal data we have available from CoH. Binford (1980: 15) states that having a "mapped-on" or home base kind of site "would work only if all the critical resources were within foraging range of a residential base". From the environmental reconstruction done by Maguire (2009: 39) she concludes that in the CoH area:

> "an infinite variety of microhabitats and hence a remarkable range of growing conditions, all [occur] within a radius of 16 kilometres of the Makapan Limeworks. This in turn has been responsible for the growth and preservation of a wealth and diversity of plant species…over 800 species [occur] within the Makapan Cave Valley alone."

Of these 800 species there is evidence for 117 edible species within 8 Km of the Limeworks, and that number increases to 150 if the radius is increased to 16 Km (Maguire 1980, 2009).

The faunal analysis done by Ogola (2003, 2009) has shown that at least 59 individuals from 12 distinct taxa are represented at CoH, with over 70% of the Minimum Number of Individuals (MNI) being solely herbivores (Ogola 2009: 67 Table 6.1), and thus much of this fauna was likely hunted or scavenged as a food source. With the range of flora and fauna available, as well as a year round water source (see Section 3.2), the hominins at CoH likely had access to "all the critical resources" that would be necessary to survive on the landscape *ca.* 0.5 Ma and thus CoH likely represents a home-base, rather than anything else.

These same aforementioned studies, and my use-wear data, indicate that the subsistence economy of the CoH hominins included a full range of foods. This definitely included animal products, very probably meat, but also likely marrow since Ogola (2009: 71) mentions that the largest amount of stone tool marks on the faunal assemblage were “percussion induced flake scars” likely indicating crushing or hammering of bones to access the fat-rich marrow. Additionally, plant remains were very likely consumed. Given the number of edible species identified by Maguire (2009) in the immediate area, it would be hard to imagine that the inhabitants of the CoH did not take advantage of these resources as well. The use-wear traces indicative of digging (possibly for USOs) and of working vegetal materials are small in number (a total of three, two for digging and one with vegetal matter wear), but this could be due to the taphonomic processes which may have erased the fine scale use- traces that come from working vegetal materials. Those tools that have been interpreted as not utilised (n=5, red font in Table 6.2) may very well have been used on soft materials including vegetal matter. However, if one assumes that the wood-working being done on site was to create digging sticks to uproot USOs, then a large amount of time and energy was being spent on the procurement of vegetal matter. Informative though these results may be, it must be stressed that they should be taken with caution since they are derived from a small sample size. Only time and future research will tell if these results are in fact indicative of the subsistence patterns at CoH or not.

### 6.5 Chapter Conclusion

This chapter has presented the detailed results of the use-wear analysis. It was found, with one exception, that no statistical relationship was to be found between morphology and use-tasks, whether using a gross morphology of handaxe, cleaver, and other, or McNabb *et al.’s* (2004) refined tip shape morphology. The one exception (Table 6.8) may be pointing to the fact that the CoH hominins selected tools based on the *general* motion of the activity they wished to perform and not the *specific* action. However, the statistical test was peformed on a small sample size and should be taken with caution until more work can be done in this area.

Additionally, it was found that wood was worked most often (34.62%), followed closely by bone (23.07%) and meat and bone (19.23%), of which the two latter are likely linked to procuring animal products for use as food,

clothing, or shelter. With the use-wear analysis supported by environmental data (Maguire 1980, 2009) and faunal analysis (Ogola 2003, 2009), it was possible to state that CoH was likely a “residential/ mapped-on” site (Binford 1980), or more simply put, it was probably not a specialised or temporary camp. Moreover, with the same data, it was possible to suggest that the subsistence economy of the CoH hominins was likely a varied one that included animal and vegetal products used in a variety of ways, which included but was probably not limited to ingestion as food stuffs.

# Chapter 7
# Discussion and Conclusions

"Without experiment nothing can be adequately known…
The strongest arguments prove nothing so long as the
conclusions are not verified by experience.
Experimental science is the queen of sciences
and the goal of all speculation" (Bacon 1267).

## 7.1 Introduction

As Roger Bacon so eloquently stated over 700 years ago in his *Opus Majus* (1267), "Without experiment nothing can be adequately known". This holds true today and my study has surely been based on experimental evidence which serves to verify the conclusions reached in this study.

The results of the lithic use-wear analysis of the Cave of Hearths Bed 3 Later Acheulean component (Chapter 6) have revealed several things. First and foremost, the results have shown that, for the sample of LCTs analysed, form and function have no statistically significant relationship. However, one may exist between form and the *general* motion of the task to be performed rather than the *specific* action of the task (Table 6.8). Two examples of this are: 1) cleavers were preferred more often than handaxes for transverse tasks (e.g., scraping planing), as well as, longitudinal actions (e.g., cutting or slicing); and 2) handaxes were utilised more often than cleavers for tasks that were percussive (e.g., chopping or splitting). Caution must be urged for these findings though due to the small sample size analysed and should not be taken as fact until more research can be done. Secondly, the results indicate that a wide variety of tasks was performed at CoH, including the full range of "every day, mundane" actions from working wood, to butchery, to digging. Additionally, evidence was presented which may indicate that two specimens, a cleaver and a handaxe, were hafted. This data is, however, tentative and only on two pieces. As such, it should be taken with caution until more work can be done to confirm this finding. If this evidence is vindicated, however, then it may provide the earliest evidence for the hafting of stone, and it is certainly the first evidence for the possibility of hafting in the Acheulean. Lastly, it was shown that cleavers and handaxes were both multi-purpose tools used for a variety of activities across all tool types and tip shapes.

## 7.2 The Larger Picture

Though this is one study performed on LCTs from one site, it is a starting point which allows me to say something about the Acheulean in general, and at CoH in particular. Only time and additional research will tell if the results and conclusions reached in this study will be supported.

Wadley (1976: 76) states that "the more varied the artefacts and their raw materials, the more likely it is that an assemblage will belong to a well-established home base where a wide variety of processing and manufacturing tasks take place". Although this study was conducted solely on quartzite LCTs, there are other raw materials at CoH, and according to McNabb *et al.* (2004: 657), the outline shapes of the CoH LCTs "were infinitely variable". This alone would be sufficient to make CoH a well- established home base or a "mapped on/ residential" site according to Binford (1980). However, the use-wear analysis provides the proof for the latter part of Wadley's statement. From the results of the analysis it can be seen that a wide array of processing activities did take place at CoH. In general, there was no predominace of any given task, likely pointing to the fact that this site was not a specialised one, which may have only been briefly occupied. This, in tandem with the faunal analysis (Ogola 2003, 2009) and the environmental reconstruction (Maguire 2009), suggests that the CoH was a well-established home base, and not a specialised camp. Almost every task that would be expected at a home base is represented at CoH (see Chapter 6). Thus, the results of this study confirm some of Mason's (1988: 187) original statements, such as: "Acheulean people found a convenient home in the Cave of Hearths, only a fortnight's walking north of their southern focus, the valley of the Vaal River", or that "The home base [of the hominins] was presumably the Cave of Hearths….[in which] Stone Age hunters found an exceptionally varied biome, ranging from the swamps of the Nyl River….to the windswept summits of the escarpment edge" (Mason 1988: 587). Without the evidence that we have today, Mason correctly asserted that CoH likely served as a home base for the hominins in the area.

In the larger ESA picture this study has implications for Acheulean sites in general and cave sites in particular. First of all, this study has confirmed that low-power use-wear analysis is a reliable form of functional analysis for artefacts from the ESA and should be attempted on other assemblages if possible. The study has presented evidence for the possible hafting of LCTs, an idea that, until now, has had no evidence to support it. Hopefully, this will

encourage other use-wear analysts to look specifically for hafting traces on ESA tools during the course of routine analyses, and provide more secure evidence from larger sample sizes for the possibility of hafting traces. Most importantly the results can be compared with future use-wear analyses on assemblages of a similar age. Additionally, though it is but one cave site, the evidence from CoH suggests that cave sites, and their immediate vicinity, may have been home camps for Acheulean peoples, at least in the later Acheulean. This should encourage researchers to look for evidence at other Acheulean cave sites that might suggest the same situation. This would include a proliferation of activities seen through a use-wear analysis, confirmed by faunal analyses and environmental data, which when all tied together may indicate that the area was rich in resources of all kinds and a perfect place for a home camp. Hopefully future research will bear out some of these ideas presented here and build upon them to give us a more complete view of the Acheulean lifeway.

### 7.3 Limitations of This Study

As with any archaeological study, this undertaking has its limitations which should be commented upon if future studies are to be better and more comprehensive. First and foremost, it must be understood that this analysis was carried out on a modest sample size (n=38) and one in which the majority of tools were cleavers (n=28). It was hoped, at the beginning of this endeavour, that use-wear analysis would reveal why the CoH Bed 3 LCT population was dominated by cleavers (96 of 130 or 73.85%), but this did not happen. However, with this sample size, some patterns may have been missed and the whole picture may not be represented. Analysis of a larger portion of the assemblage might have provide answers to more questions, but the constraints of time and money prevented me from doing so.

Secondly, the artefacts that were examined have a less than desirable curation history, and others (those from the Central Subsided Block and the Swallow Hole) experienced a very turbulent depositional environment. These two factors combined mean that some of the finer wear traces (e.g., polish or striae) may have been destroyed or obscured on some tools, which could have affected the accuracy of their intepretation. For example, some wear traces (e.g., flake scars or striae) may have been misinterpreted as the results of use, rather than wear from potential post-depositional forces. Luckily, PESM is easily distinguished on tools this old as any wear from improper curation tends

to leave scars that are differently patinated than the rest of the tool. Likewise, abrasion and crushing appear “fresh” and generally stand out from the surrounding area. Fortunately, on many of the pieces, the PDSM could be distinguished from the use-wear, but we still do not have the ability to experimentally recreate what Mother Nature can do to a stone tool over a period of half-a-million years. This means that some traces interpreted as use could be a very complex series of PDSM events that have accumulated and look like use-related wear. Conversely, this also means that tools which were interpreted to have not been used may have, in fact, been used, but post-depositional forces might have removed the relevant wear traces needed to discern use. More research into the effects of post-depositional environments will certainly alleviate some confusion, but the “problem” of PDSM may never be solved.

These issues all come together and point to the fact that doing use-wear analysis on such an old assemblage is, and likely will continue to be, more difficult that those assemblages that are younger. As seen in Section 4.7.2 many analysts have in the past tried to conduct micro-wear analyses on ESA aged materials and ran into multiple problems, including but not limited to: 1) PDSM that has occurred over the many hundreds of thousands of years that likely removed some use-wear traces; 2) poor curation on those assemblages (like CoH) that were excavated many decades ago before micro-wear studies were a common practice: 3) in the case of residue studies, improper excavation, handling, and preparation techniques, as they were not general practice on assemblages excavated even just a couple decades ago; 4) the types of raw materials that hominins were using during the ESA are not generally the easiest materials to carry out a micro-wear study on given the coarse grained nature which does not preserve use-wear traces as easily as does CCS (e.g., flint, chert, opalines, etc.); 5) wear traces left by working softer materials (e.g., animal flesh or plant matter) are generally not robust and thus have likely been destroyed due to weathering, solifluction, soil compaction, etc.; and 6) the possibility that traces have been created on stone tools over the millennia that appear to be from use, but in fact are from other agents such as trampling, PDSM, geologic activities, etc.

One possible way to mitigate for some of these factors is to start the analysis with a low-power use wear scan that can rule out pieces that have been badly damaged through PDSM and/ or PESM. As sesen in this study, low-power generally excels in recognising the signs that these processes leave behind. It

also is easier to observe wear patterns on the coarse grained materials that are generally associated with ESA stone tools using low-power magnifications. This is, however, just a starting point. As many techniques as possible should come together and be used to confirm the findings of one another. Studies should include the full range of micro-wear analyses, time and budget permitting, of low and high-power microscopy, residue analysis, as well as being confirmed by an extensive experimental programme. If this can be done then other studies will have much more secure and reliable results than any analysis that has been carried out to date.

Though this task may seem daunting, there is hope for future analysts. As technology continues to develop more rapidly than it ever has before, hopefully new techniques will develop in the coming years that will help mitigate some of these problems. Additionally, technologies already exist that can help in controlling for these variables (e.g., 3D scanning, GIS modelling, CT Scanning, etc.) but generally due to time and budget constraints not all of these technologies are accesbile to every project. As technology continues to advance, the costs (i.e., time and money) involved with using these technologies should decrease, meaning that many future archaeology studies will feasibly be able to conduct truly multi-stranded studies to add creedance to their findings. If, or rather when, this happens, then any results obtained through any kind of micro-wear method on ESA assemblages will be more secure.

Lastly, the sample analysed came from one cave site in a very particular environmental setting. While the conclusions in this study can be used to inform future analyses, it must be done with caution. The Makapan Valley and the surrounding area is a very specialised environment in which a large variety of micro-climates exist within approximately 20 km from the cave. This means that the archaeological situation at the CoH may also be a very specialised one, due to the environmental factors at work, some of which are visible in the archaeological record while others are not. If this is the case, then applying the results from and analysis used in this study to a site that is within a different environmental setting may lead to different results. As with all cases, caution must be exercised so that most answers are investigated before conclusions are drawn.

## 7.4 Suggestions for Future Research

This study has been as much about proving that low-power use-wear analysis can be accomplished on ESA tools as it has been about investigating what the hominins at CoH were doing with their tools. Now that there is a foundation for low-power research on Acheulean HDTs, there must be more research into this time period using any approach of micro-wear analysis that is possible. Future research should include analyses from a variety of site types (e.g., cave, open-air, quarry) so that we may more fully understand land-use patterns and what was happening at each of these site types. Future analyses should also incorporate as much evidence as possible to reach their conclusions. Time and resources permitting, everything from high-power use- wear, low-power use-wear, and residue analyses to faunal, environmental, and archaeo-botanical analyses should all come together to paint a larger and fuller picture of what the hominins at any site may have been doing. If these kinds of multi-stranded analyses take place, then much more information can be gained about the Acheulean time period than has ever been known, possibly including: land-use strategies, dietary trends, cognitive abilities, and evidence of complexity, just to name a few. However, only time will tell if these types of studies will be carried out, and as always, time and money will dictate the extent to which these studies can be accomplished.

## 7.5 Dissertation Summary

Chapter 2 provided a background to the Acheulean Industrial Complex around the world. Basic issues and debates were briefly discussed, such as the history of the discovery of this complex, the earliest dates for the Acheulean, and which hominins may have been involved in the making of HDTs. A few select sites from each continent, and from South Africa, were selected and briefly presented to highlight the nature of the Acheulean and how far ranging it truly is.

Chapter 3 presented the necessary background to the Cave of Hearths archaeological site. This included its discovery, history of excavations, and renewed work undertaken within the last seven years. Additionally, the environment in which the cave sits was reviewed as well as the formation and sedimentary infilling of the cave itself and the geophysical setting and surrounding geology. It was seen that CoH is part of a much longer cave complex that may span many miles underground. The dating of the cave was discussed in addition to the work done on the “hearths”, which indicated that

there are actually no hearths present in the ESA layers at all.

Chapter 4 provided the literature review for the method, technique, and approach utilised in this study, and a review of previous studies on HDT usage. A background for the evolution of experimental archaeology and its importance to the field in general, and to micro-wear analyses in particular, was presented with case studies that highlighted experimental archaeology's significance. Additionally, the history of micro-wear was presented and some of the key debates were discussed such as: approach used, applicability of each of the approaches to the CoH Bed 3 assemblage, and how the field has evolved over the past century. Lastly, a review of previous work into the function of HDTs was presented and it was found that there is a paucity of literature that uses a reliable method of functional interpretation and most of the hypotheses have been based on solely experimental or theoretical work.

Chapter 5 presented the experimental scheme used for this study and the results of the blind test. The scheme was discussed in detail with regards to how each tool was used, for how long, and on what materials. Other experiments were presented that helped provide a comparative collection of un-used tools, and tools that have been un-used but affected by poor curation practices. In total, 71 experimental tools were created for the comparative collection. Additionally the results of a blind test confirmed my abilities as a use-wear analyst and with an overall accuracy score of 82% showed that confidence could be placed in my interpretations of the archaeological tools. This blind test is also important as it is, to my knowledge, the only one ever conducted solely on quartzite, confirming that low-power analysts can reliably interpret wear patterns on those rocks that have been termed coarse grained. These 30 blind test tools can now be added to an ever growing comparative collection for future research into the function of tools.

Chapter 6 presented the results of the study. The results showed that there was no statistically significant relationship between form and function, except that tools may have been selected for the *general* motion of the task to be performed, rather than the *specific* action. The results, coupled with the published faunal analysis and environmental reconstruction, indicated that the cave was likely a home base with plentiful resources available within a 15 Km radius. The results also showed that cleavers and handaxes of any tip shape were just as likely to be used for multiple purposes, overturning some of the previously held ideas about the uses of LCTs. Additionally, evidence was found

which may indicate that two pieces were possibly hafted.

Chapter 7discussed the importance of the findings of Chapter 6 for the larger ESA picture, made suggestions for future research, and reflected on the limitations of this study. Lastly a brief review of the study was given chapter by chapter and served to conclude the study.

# Appendix A

## Pertains to Chapter 6

**Table A.1 Cave of Hearths Bed 3 Population**

| Catalogue Number | Pit Letter | Pit Number | Depth in Feet | Artefact Number | Artefact Type |
|---|---|---|---|---|---|
| CoH 138 | CH | 15-16 (A) | ? | 253 | Cleaver |
| CoH 139 | CH | ? | 20 (A) | 325 | Cleaver |
| CoH 140 | CH | ? | 14-15 (A) | 2790 | Cleaver |
| CoH 141 | DQ | 23-24 | 14-16 | 354 | Cleaver |
| CoH 142 | E | 7 | 14-16 | 473 | Handaxe |
| CoH 143 | EH | 1-3 | 13-15 | 443 | Handaxe |
| CoH 144 | EH | 1-3 | 13-15 | 448 | Handaxe |
| CoH 145 | EH | 3 | 13-15 | 430 | Other |
| CoH 146 | EH | 4-5 | 13-18 | 1 | Handaxe |
| CoH 147 | EH | 4-5 | 13-18 | 319 | Cleaver |
| CoH 148 | EH | 5 | 13-18 | 36 | Cleaver |
| CoH 149 | F | 4 | 12 | 244 | Other |
| CoH 150 | F | 6 | 11-13 | 462 | Handaxe |
| CoH 151 | G | 5 | 11-13 | 278 | Cleaver |
| CoH 152 | G | 10 | 11-13 | 288 | Cleaver |
| CoH 153 | G | 10 | 18-21 | 255 | Cleaver |
| CoH 154 | H | 5 | 11-13 | 377 | Handaxe |
| CoH 155 | H | 6 | 16-18 | 480 | Handaxe |
| CoH 156 | H | 7 | 13-16 | 820 | Other |
| CoH 157 | H | 10 | 13-16 | ?74 | Cleaver |
| CoH 158 | H | 12 | 8-10 | 283 | Cleaver |
| CoH 159 | H | 12 | ? | ? | Cleaver |
| CoH 160 | H | 12 | 11-13 | 299 | Cleaver |
| CoH 161 | H | 12 | 11-13 | 412 | Cleaver |
| CoH 162 | H | 13 | 11-13 | 250 | Cleaver |
| CoH 163 | H | 13 | 11-13 | 258 | Cleaver |
| CoH 164 | H | 13 | 11-13 | 259 | Cleaver |
| CoH 165 | H | 16 | 13-16 | 269 | Cleaver |
| CoH 166 | H | 17 | 7-9 | 284 | Cleaver |
| CoH 167 | H | 17 | 9-11 | 945 | Cleaver |
| CoH 168 | H | 17 | 11-14 | 305 | Cleaver |
| CoH 169 | H | 17 | 11-14 | 458 | Handaxe |
| CoH 170 | H | 18 | 11-13 | 312 | Cleaver |
| CoH 171 | H | 19 | 9-11 | 280 | Cleaver |

| | | | | | |
|---|---|---|---|---|---|
| CoH 172 | H | 19 | 9-11 | 287 | Cleaver |
| CoH 173 | H | 19 | 10-12 | 304 | Cleaver |
| CoH 174 | H | 19 | 10-12 | 306 | Cleaver |
| CoH175 | H | 19 | 11-13 | 249 | Cleaver |
| CoH 176 | H | 19 | 11-13 | 402 | Cleaver |
| CoH 177 | H | 20 | 5-8 | 323 | Cleaver |
| CoH 178 | H | 20 | 5-8 | 447 | Handaxe |
| CoH 179 | H | 20 | 10-12 | 247 | Cleaver |
| CoH 180 | H | ? | 13-16 | 257 | Cleaver |
| CoH 181 | HL | 0-3 | 11-14 | 8089 | Cleaver |
| CoH 182 | HL | 0-3 | 11-4 | 8090 | Cleaver |
| CoH 183 | I | 7 | 9-13 | 330 | Cleaver |
| CoH 184 | I | 7 | 9-13 | 364 | Cleaver |
| CoH 185 | I | 7 | 9-13 | 410 | Cleaver |
| CoH 186 | I | 7 | 9-13 | 418 | Cleaver |
| CoH 187 | I | 7 | 10-13 | 342 | Cleaver |
| CoH 188 | I | 7 | 13-16 | 349 | Cleaver |
| CoH 189 | I | 7 | 13-16 | 427 | Handaxe |
| CoH 190 | I | 10 | 13-16 | 417 | Cleaver |
| CoH 191 | I | 11 | 11-13 | ?22 | Cleaver |
| CoH 192 | I | 11 | 13-16 | 453 | Handaxe |
| CoH 193 | I | 12 | 11-13 | 282 | Cleaver |
| CoH 194 | I | 12 | 11-13 | 460 | Handaxe |
| CoH 195 | I | 13 | 11-14 | 252 | Cleaver |
| CoH 196 | I | 13 | 13-16 | 279 | Cleaver |
| CoH 197 | J | 6 | 13-16 | 441 | Handaxe |
| CoH 198 | J | 7 | 13-16 | 428 | Handaxe |
| CoH 199 | J | 12 | 13-16 | 290 | Cleaver |
| CoH 200 | J | 13 | 8-11 | 376 | Cleaver |
| CoH 201 | J | 13 | 13-16 | 275 | Cleaver |
| CoH 202 | J | 13 | 16 | 483 | Handaxe |
| CoH 203 | J | 14 | 13-16 | 316 | Handaxe |
| CoH 204 | JL | 0-(-3) | 14 | 8086 | Cleaver |
| CoH 205 | JL | 0-3 | 11-14 | 8163 | Cleaver |
| CoH 206 | K | 15 | 8-10 | 317 | Cleaver |
| CoH 207 | K | 19 | 12-14 | 264 | Cleaver |
| CoH 208 | KL | 15-19 | 28 | 19 | Other |
| CoH 209 | L | -2 | 16 | ? | Handaxe |
| CoH 210 | L | 16 | 22 | 2017 | Cleaver |
| CoH 211 | L | 16 | 23 | 2052 | Cleaver |

| | | | | | |
|---|---|---|---|---|---|
| CoH 212 | L | 16 | 26 | 33 | Cleaver |
| CoH 213 | L | 17 | 2-3 | 433 | Handaxe |
| CoH 214 | L | 17 | 23 | 2053 | Handaxe |
| CoH 215 | L | 18 | 12-14 | 362 | Cleaver |
| CoH 216 | M | 18 | 8-9 | 273 | Cleaver |
| CoH 217 | M | 20 | 12-14 | 248 | Cleaver |
| CoH 218 | M | 20 | 12-14 | 267 | Cleaver |
| CoH 219 | M | 20 | 12-14 | 454 | Handaxe |
| CoH 220 | MN | 13-15 | 30 | 8018 | Cleaver |
| CoH 221 | MO | 10-12 | 26-28 | 2001 | Cleaver |
| CoH 222 | MO | 10-12 | 26-28 | 2015 | Cleaver |
| CoH 223 | MO | 10-12 | 26-28 | 2034 | Cleaver |
| CoH 224 | MO | 12-13 | 23-25 | 2013 | Cleaver |
| CoH 225 | MO | 12-13 | 23-25 | 2014 | Cleaver |
| CoH 226 | MO | 23-24 | 16-18 | 352 | Cleaver |
| CoH 227 | N | 17 | 28 | 3 | Handaxe |
| CoH 228 | O | 12-13 | 28-30 | 8079 | Cleaver |
| CoH 229 | O | 13 | 30 | 8080 | Cleaver |
| CoH 230 | O | 17 | 24-27 | 85 | Other |
| CoH 231 | O | ? | 32 | 806 | Handaxe |
| CoH 232 | OQ | 23-24 | 13-16 | 338 | Cleaver |
| CoH 233 | OQ | 23-24 | 13-16 | 351 | Cleaver |
| CoH 234 | OQ | 23-24 | 13-16 | 365 | Cleaver |
| CoH 235 | OQ | 23-24 | 13-16 | 374 | Cleaver |
| CoH 236 | OQ | 23-24 | 13-16 | 385 | Cleaver |
| CoH 237 | OQ | 23-24 | 13-16 | 438 | Handaxe |
| CoH 238 | OQ | 23-24 | 16-18 | 360 | Cleaver |
| CoH 239 | OQ | 24 | 16-18 | 1005 | Cleaver |
| CoH 240 | OQ | 24-25 | 16-18 | 423 | Cleaver |
| CoH 241 | OQ | 25-26 | 12-14 | 346 | Cleaver |
| CoH 242 | OQ | 25-26 | 14-16 | 366 | Cleaver |
| CoH 243 | OQ | 25-26 | 14-16 | 440 | Handaxe |
| CoH 244 | OQ | 25-26 | 16-18 | 888 | Cleaver |
| CoH 245 | OQ | 25-27 | 14-18 | 246 | Cleaver |
| CoH 246 | OQ | 25-27 | 14-18 | 328 | Cleaver |
| CoH 247 | OQ | 25-27 | 14-18 | 444 | Handaxe |
| CoH 248 | OQ | 26 | 16-18 | 463 | Handaxe |
| CoH 249 | OR | 13-15 | 28 | 8069 | Handaxe |
| CoH 250 | OR | 13-15 | 29-30 | ? | Cleaver |
| CoH 251 | P | 12 | 28 | 8083 | Cleaver |

| | | | | | |
|---|---|---|---|---|---|
| CoH 252 | P | 22 | 14-15 | 370 | Cleaver |
| CoH 253 | PR | 19-22 | 22-23 | 213 | Cleaver |
| CoH 254 | PR | 19-22 | ? | 215 | Cleaver |
| CoH 255 | PR | 22-23 | 11-14 | 262 | Cleaver |
| CoH 256 | PR | 22-23 | 12-15 | 409 | Cleaver |
| CoH 257 | PR | 22-23 | 14-16 | 372 | Cleaver |
| CoH 258 | PR | 22-23 | 14-16 | 375 | Cleaver |
| CoH 259 | PR | 22-23 | 14-16 | 379 | Cleaver |
| CoH 260 | PR | 22-23 | 14-16 | 390 | Cleaver |
| CoH 261 | PR | 22-23 | 14-16 | 455 | Handaxe |
| CoH 262 | PR | 22-23 | 14-16 | ?79 | Handaxe |
| CoH 263 | PR | 22-23 | 16-18 | 329 | Cleaver |
| CoH 264 | PR | 22-23 | 16-18 | 405 | Cleaver |
| CoH 265 | PR | 22-23 | 18 | 214 | Cleaver |
| CoH 266 | PR | 22-13 | ?-16 | 327 | Cleaver |
| CoH 267 | R | 15-17 | 30 | 807? | Cleaver |

# Appendix B

## Pertains to Chapter 6

USE-WEAR INVENTORY FORM

Page: _____

Organization: _____ Site: _____ Analyzer: _____

Project: _____ Sampling: _____ Date: _____

| A | B | C | D | E | | | | F | | | | G | H | I | J | K | L |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Abrasion | | | | Scarring | | | | | | | | | |
| E.U. | P.C. | ACT. | W.M. | Rdg. | Pol. | Str. | Loc. | L | D | T | S | R.M | Ret. | Burn | Comp. | Type | Artifact # |
| | | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | |

**Figure B.1 Use-wear Code Sheet** An example of the coding sheet that is the basis for Table B.1.

**Table B.1 Use-wear Results of Complete Sample** PC = polar co-ordinates of wear; PESM = Post-excavational Surface Modification; PDSM = Post-depositional Surface Modification; AS = animal soft, VS = vegetal soft; 1M = Medium-softer; 2M = Medium-harder; 1H = Hard 1 (e.g., bone); 3H = Hard 3 (e.g., soil, rock); v = ventral; d = dorsal. Text highlighted in yellow indicate pieces that came from the Central Subsided Block or the Swallow Hole. Hyphens in PCs indicate "through" (e.g., 1-8= one through eight or 8-1= eight through 1).

| CoH # | PC | Motion | Resistivity | Worked Material | Abrasion (type, location) | Scarring (location, size, termination, distribution,) | Morpho-Type | Tip Shape |
|---|---|---|---|---|---|---|---|---|
| 140 | 1-8 | Too badly damaged by PESM for ay functional information to be obtained | | | | | Cleaver | 6 |
| 144 | 7-1 (tip) | Dig | 3H | Earth/ Soil | Very heavy rounding, weak abrasion polish, 7-1 | v/ d, large, feather, step & hinge, clumped & alternating | Handaxe | 1 |
| | 5-7 | Scrape | 2M | Uncertain | Medium rounding, 5-7 | d, large, step, clumped | | |
| 147 | 1-8 | Too badly damaged by PESM & PDSM for ay functional information to be obtained | | | | | Cleaver | 7 |
| 151 | 8-1 | Scrape | AS | Animal Matter (e.g., hide) | Very light rounding, 8-1 | v/ d, small feather & medium hinge, alternating | Cleaver | 7 |
| 155 | 8-1 (tip) | Impact[7] | 1H | Bone | Heavy rounding | v/ d, large, step, alternating & compounded | Handaxe | 1 |
| | 7-8 | Saw | 1H | Bone | Heavy rounding, medium crushing, 7-8 | v/ d, large, step, clumped & alternating | | |
| | 1-2 | Saw | 1H | Bone | Heavy rounding, heavy crushing, 1-2 | v/ d, large & very large, step, alternating | | |

[7] I do not use this term to suggest that the piece was used as a projectile. I use it for lack of a better term to indicate that force was introduced directly into the tip of the piece causing an “Impact Fracture” to occur. However, this could serve as evidence for the hand bolt theory (see Section 4.7.1a).

| CoH # | PC | Motion | Resistivity | Worked Material | Abrasion (type, location) | Scarring (location, size, termination, distribution,) | Morpho-Type | Tip Shape |
|---|---|---|---|---|---|---|---|---|
| 165 | 1<br><br>8 | Cut/ Slice<br><br>Scrape | VS<br><br>1H | Vegetal Matter<br><br>Bone | Medium rounding<br><br>Heavy rounding, heavy crushing, polish | v/ d, very small, feather, uneven & alternating<br><br>v/ d, medium to large, step, uneven | Cleaver | 5 |
| 171 | 1-8 | Not Utilised | | | | | Cleaver | 2 |
| 173 | 1-8 | Too badly damaged by PESM for ay functional information to be obtained | | | | | Cleaver | 7 |
| 174 | 8-1<br><br>8[8] | Scrape<br><br>Drill | 1M<br><br>1M | Wood<br><br>Wood | Very light rounding, 8-1<br><br>Heavy rounding, tip crushing | Mainly v, a couple on d, small, feather & hinge, uneven & alternating<br><br>v/ d, small & medium, feather & hinge, clumped & alternating | Cleaver | 5 |
| 177 | 6-8<br><br>3-4 | Scrape<br><br>Scrape | 1H<br><br>AS & 1H | Bone<br><br>Meat & Bone | Heavy rounding, polish, localised heavy crushing, 6-8<br><br>Light rounding, 3-4 | d, very large, hinge & step, run-together<br><br>d, large step & small feather, close | Cleaver | 6 |
| 178 | 6<br><br>8-1 | Dig<br><br>Dig | 3H<br><br>3H | Earth/ Soil<br><br>Earth/ Soil | Light rounding, abrasion polish<br><br>Heavy rounding, abrasion polish, 8-1 | d & surfaces away from edge, large, step, uneven<br><br>d & surfaces away from edge, large, step & hinge, uneven | Handaxe | 2 |
| 179 | 1-8 | Not Utilised | | | | | Cleaver | 6 |

[8] An angle forms where the edge of the cleaver bit meets a lateral edge. Two different functions were performed on either edge of this angle.

| CoH # | PC | Motion | Resistivity | Worked Material | Abrasion (type, location) | Scarring (location, size, termination, distribution,) | Morpho-Type | Tip Shape |
|---|---|---|---|---|---|---|---|---|
| 181 | 8-1<br><br>2-3 | Chop/ Adze<br><br>Scrape | 2M<br><br>2M | Wood<br><br>Wood | Medium rounding, heavy crushing<br><br>Medium to heavy rounding | v/ d, large & very large, step, close<br><br>v, medium & large, step & hinge, close | Cleaver | 4 |
| 187 | 8-1 | Saw | 2M | Wood | Light rounding, 8-1 | v/ d, medium to large, step & hinge, close & alternating | Cleaver | 5 |
| 192 | 7-8 | Cut/ Slice | AS & 1H | Meat & Bone | Very light rounding, 8, & heavy rounding & crushing, 7 | v/ d, small feather & large step, alternating | Handaxe | 1 |
| 196 | 7-8<br><br>8-1 | Saw<br><br>Uncertain | 2M<br><br>2M | Uncertain<br><br>Uncertain | Medium rounding, localised light crushing, 7-8<br><br>Medium rounding | v/ d, large step & hinge, small feather, clumped & alternating<br><br>v/ d, medium, step & hinge, uneven & alternating | Cleaver | 2 |
| 199 | 8<br><br>7 | Scrape<br><br>Scrape | AS & 1H<br><br>AS & 1H | Meat & Bone<br><br>Meat & Bone | Medium to heavy rounding, medium crushing, striae perpendicular to edge<br><br>Medium rounding, striae perpendicular to edge | v/ d, small feather & hinge, large comminutions & step,<br><br>uneven<br>v/ d, small feather & large step, uneven | Cleaver | 2 |
| 208 | 1-8 | Too badly damaged by PESM & PDSM for ay functional information to be obtained | | | | | Other | 2 |

| CoH # | PC | Motion | Resistivity | Worked Material | Abrasion (type, location) | Scarring (location, size, termination, distribution) | Morpho-Type | Tip Shape |
|---|---|---|---|---|---|---|---|---|
| 212 | 1-2<br><br>3[9]<br><br>6-7 | Cut/ Slice<br><br>Saw<br><br>Scrape | AS<br><br>1H<br><br>2M | Animal Matter (e.g., meat)<br><br>Bone<br><br>Uncertain | Very light rounding, 1-2<br><br>Medium to heavy rounding, light crushing<br><br>Light rounding, 6-7 | v/ d, small & very small, feather & hinge, alternating<br><br>d, medium & large, step & hinge, close<br><br>d, medium & large, feather & hinge, close | Cleaver | 7 |
| 213 | 1-8 | Too badly damaged by PESM & PDSM for ay functional information to be obtained | | | | | Handaxe | 1 |
| 214 | 1-8 | Too badly damaged by PESM & PDSM for ay functional information to be obtained | | | | | Handaxe | 1 |
| 218 | 2-3<br><br>8-1 | Scrape<br><br>Possibly cut/ slice | 2M<br><br>Possibly AS | Wood<br><br>Uncertain | Heavy rounding, 2-3<br><br>Light rounding, 8-1 | d, large step & medium hinge, run-together<br><br>n/a | Cleaver | 7 |
| 220 | 8 | Scrape | 2M | Uncertain | Light rounding & slight denticulation | d, medium, feather & hinge, uneven | Cleaver | 6 |
| 221 | 8-1<br><br>6-7 | Saw<br><br>Scrape | Possibly 1H<br><br>1M | Possibly Bone<br><br>Wood | Medium to heavy rounding, medium crushing, 8-1<br><br>Light rounding, 6-7 | v/ d, medium step, large snap, & comminutions, alternating<br><br>d, medium, step, close | Cleaver | 2 |
| 225 | 1-8 | Not utilised | | | | | Cleaver | 5 |
| 226 | 1-8 | Too badly damaged by PESM for ay functional information to be obtained | | | | | Cleaver | 5 |

[9] I believe that this contact with a hard material, likely bone, is an extension of the wear seen in PCs 1-2. I think that what happened is the tool was being used in a butchery task and PCs 1-2 were used mainly for removing meat from bone and during this task PC 3 came into contact with the bone that the meat was being removed from.

| CoH # | PC | Motion | Resistivity | Worked Material | Abrasion (type, location) | Scarring (location, size, termination, distribution,) | Morpho-Type | Tip Shape |
|---|---|---|---|---|---|---|---|---|
| 229 | 6-7 | Possibly Scrape | Possibly 2M | Uncertain | Light rounding, 6-7 | d, medium, hinge & step, close | Cleaver | 1 |
| 231 (Hafted) | 8<br><br>1<br><br>3 & 6 (Hafted) | Cut/ Saw<br><br>Cut/ Saw<br><br>Haft | AS & 1H<br><br>2M<br><br>2M | Meat & Bone<br><br>Uncertain<br><br>Wood | Light rounding & heavy rounding, 8<br><br>Medium rounding, 1<br><br>Light rounding, 3, medium rounding, 6 | v/ d small hinge & feather, large step, alternating<br><br>v/ d, large step & medium hinge, alternating<br><br>v/ d, medium & large, step, clumped | Handaxe | 1 |
| 234 | 5-8 | Scrape | 2M | Possibly Wood | Light rounding, polish, 5-8 | d, medium & large, step & hinge, close | Cleaver | 2 |
| 238 | 8 | Cut/ Slice | Possibly VS | Possibly Vegetal Matter | Light rounding | v/ d, very small & small, feather & hinge, uneven & alternating | Cleaver | 4 |
| 240 | 1-8 | Not Utilised | | | | | Cleaver | 4 |
| 243 | 4-5<br><br>8-1 (tip) | Hammered<br><br>Wedge | 3H<br><br>1M | Stone<br><br>Wood | Heavy crushing & heavy rounding 4-5<br><br>Light rounding 8-1 | v/ d, large & very large, step, clumped & superimposed<br><br>v/ d, small & medium, ill-defined feather & hinge, close. tip, snap fracture | Handaxe | 4 |

| CoH # | PC | Motion | Resistivity | Worked Material | Abrasion (type, location) | Scarring (location, size, termination, distribution,) | Morpho-Type | Tip Shape |
|---|---|---|---|---|---|---|---|---|
| 255 | 2 | Drill | 1M | Wood | Medium rounding, tip crushing, polish | v/ d, medium, step & ill-defined feather, run-together | Cleaver | 4 |
| | 6-8 | Saw | 1H | Bone | Heavy rounding, medium crushing, polish 6-8 | v/ d, medium & large, step, alternating | | |
| | 1[10] | Scrape | 1M | Wood | Medium rounding, polish | v/ d, small & medium, feather & step, uneven | | |
| 258 | 8-1 | Too badly damaged by PESM for ay functional information to be obtained | | | | | Cleaver | 6 |
| | 1-6 | Too badly damaged by PESM for ay functional information to be obtained | | | | | | |
| | 7 | Scrape | 2M | Wood | Light rounding, 7 | d, medium & large, step & hinge, close | | |
| 263 | 1-8 | Not Utilised | | | | | Cleaver | 7 |

[10] Though this is listed as scraping wear, I believe that it is related to the drilling wear in PC 2. (i.e., the projection in PC 2 penetrated the worked material deeply enough to cause PC 1 to have contact with the worked material, scraping across the surface of the worked material while the projection continued in the drilling motion).

| CoH # | PC | Motion | Resistivity | Worked Material | Abrasion (type, location) | Scarring (location, size, termination, distribution,) | Morpho-Type | Tip Shape |
|---|---|---|---|---|---|---|---|---|
| 265 (Hafted) | 8-1<br><br>3, 5-6 (Hafted) | Saw<br><br>Haft | 1M<br><br>VS & 1M | Wood<br><br>Wood & Plant Matter | Light to medium rounding, 8-1<br><br>Light rounding in 3 & 5-6, & of arêtes away from edge | v/ d, medium feather, small step & hinge, alternating<br><br>v/ d & surfaces away from edge, small, feather & hinge, clumped & uneven | Other | 6 |
| 266 | 7-8<br><br>8-1 (tip) | Cut/ Saw<br><br>Impact[7] | 1H<br><br>Uncertain | Uncertain<br><br>Uncertain | Heavy rounding & crushing, 7-8<br><br>Slight crushing & rounding, tip | v/ d, small to medium, step, comminutions, alternating & uneven<br><br>v/ d, medium feather & step, alternating | Cleaver | 4 |
| 267 | 8-1<br><br>8[11] | Cut/ Slice<br><br>Scrape | AS & 1H<br><br>1H + | Meat & Bone<br><br>Bone, possibly very dry | Medium to heavy rounding, 8-1<br><br>Very heavy rounding, heavy crushing, polish, 8-1 | v/ d, large snap & small step, uneven<br><br>d, medium & large, step, uneven | Cleaver | 5 |

[11] An angle forms where the edge of the cleaver bit meets a lateral edge. Two different functions were performed on either edge of this angle.

# Appendix C
## Pertains to Chapters 5 and 6

**Figure C.1 Tip Shape 1 Sample Analysed** Left to right; Top row: CoH #s 144, 155, 178, 192. Bottom row: CoH #s 213, 214, 229, 231.

**Figure C.2 Tip Shape 2 Sample Analysed** Left to Right; Top Row CoH #s 199, 171, 196. Bottom Row CoH #s 208, 221, 234.

**Figure C.3 Tip Shape 4 Sample Analysed** Left to Right; Top Row: CoH #s 181, 238, 240. Bottom Row: CoH #s 243, 255, 266.

**Figure C.4 Tip Shape 5 Sample Analysed** Left to Right; Top Row: CoH #s 165, 174, 187. Bottom Row: CoH #s 225, 226, 267.

**Figure C.5 Tip Shape 6 Sample Analysed** Left to Right; Top Row: CoH #s140, 177, 179. Bottom Row: CoH #s 220, 258, 265.

**Figure C.6 Tip Shape 7 Sample Analysed** Left to Right; Top Row: CoH #s 147, 151, 173. Bottom Row: 212, 218, 263.

**Figure C.7 TS.2013.1-5** Left to right; Top Row: TS.2013.1, TS.2013.2, TS.2013.3. Bottom Row: TS.2014.4 and TS.2014.5

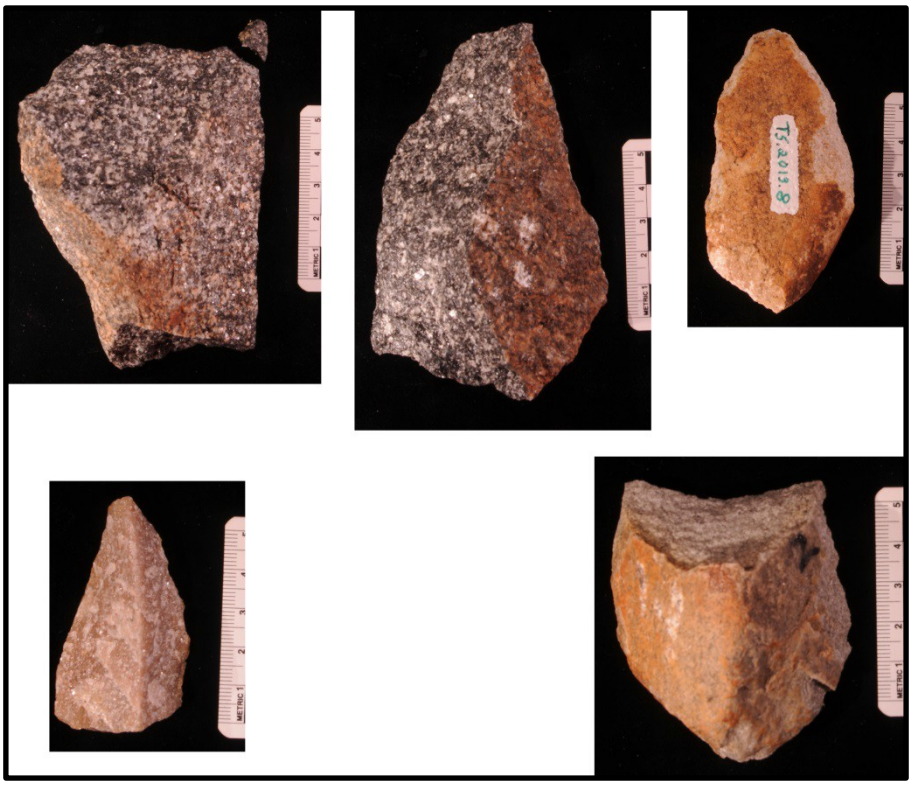


**Figure C.8 TS.2013.6-10** Left to right; Top Row: TS.2013.6, TS.2013.7, TS.2013.8. Bottom Row: TS.2014.9 and TS.2014.10

**Figure C.9 TS.2013.11-15** Left to right; Top Row: TS.2013.11, TS.2013.12, TS.2013.13. Bottom Row: TS.2014.14 and TS.2014.15

**Figure C.10 TS.2013.16-20** Left to right; Top Row: TS.2013.16, TS.2013.17, TS.2013.18. Bottom Row: TS.2014.19 and TS.2014.20

**Figure C.11 Hafted Experimental Pieces** Showing the pieces in their hafting arrangements. Left to right; Top Row; TS.2013.2 and TS.2013.14. Bottom Row: TS.2013.15 and TS.2013.16

**Figure C.12 Blue Flakes** Showing the tools after painting but before placement in wooden box (Fig. C.12).

**Figure C.13 Blue Flakes in Wooden Box**

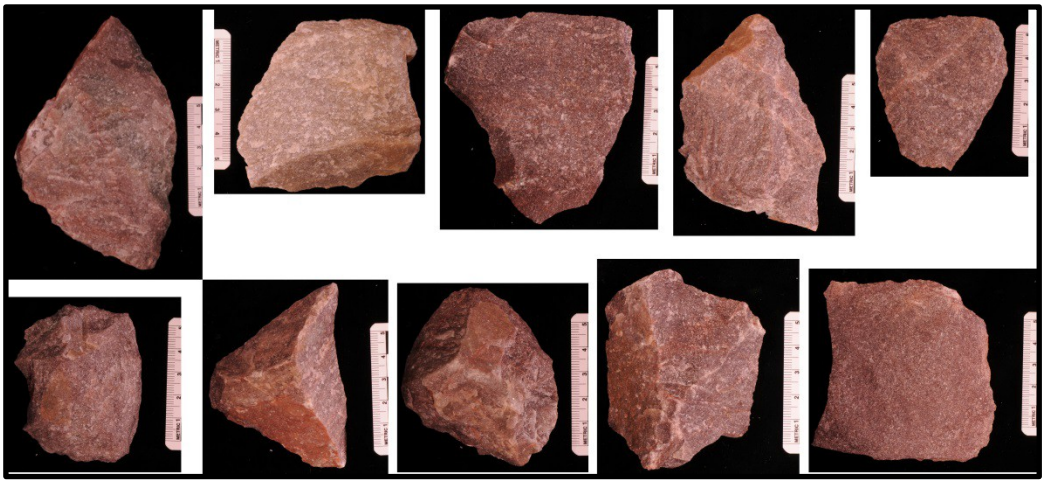

**Figure C.14 Blind Test Tools 1-10** Left to right; Top Row: Numbers 1-5. Bottom Row: Numbers 6-10

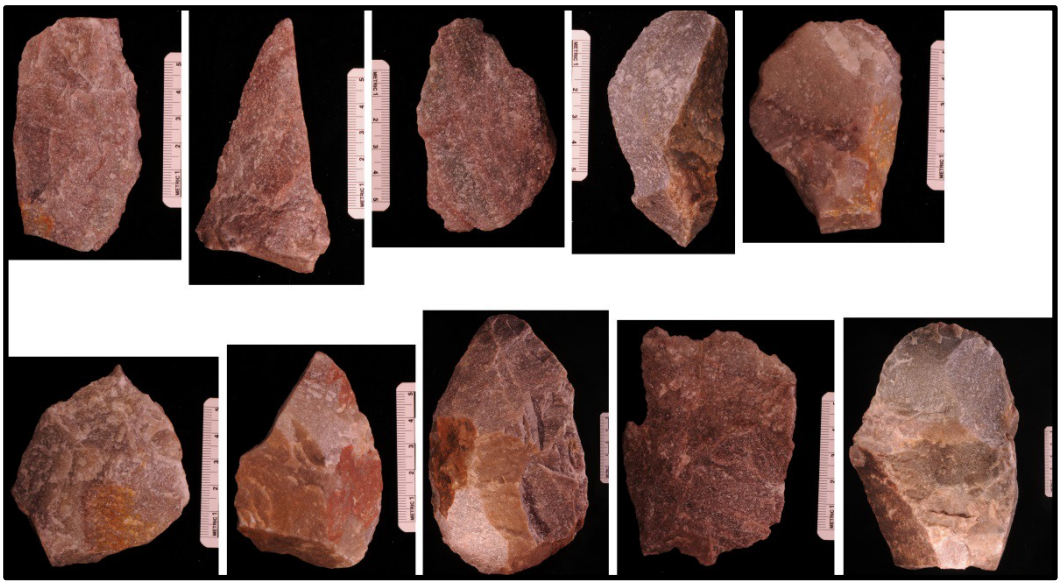

**Figure C.15 Blind Test Tools 11-20** Left to right; Top Row: Numbers 11-15. Bottom Row: Numbers 16-20

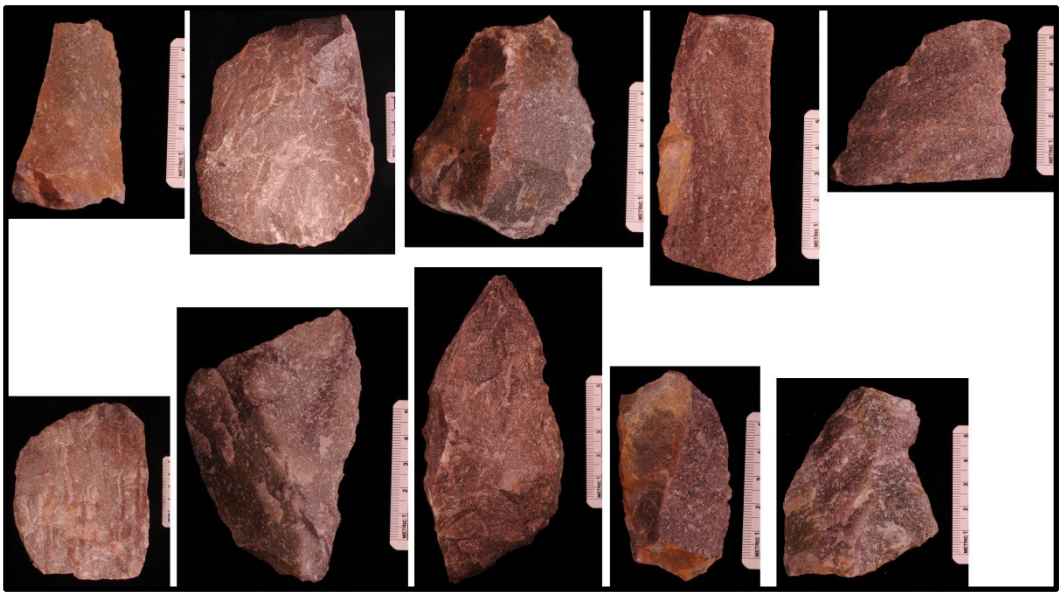

**Figure C.16 Blind Test Tools 21-30** Left to right; Top Row: Numbers 21-25. Bottom Row: Numbers 26-30

# Appendix D
## Pertains to Chapters 5 and 6

### D.1 Definitions of Scar Terminations

The following definitions adhere to those prescribed in The Ho Ho Classification and Nomenclature Committee Report (Cotterell *et al.* 1979) and are still used today by both use-wear analysts and lithicists in general. Figure D.1 visually represents the fracture types.

**Feather Termination-** A feather termination is one that ends in a gradual slope resulting "in an edge with a minimal margin" (Crabtree 1972:64). It is normally the result of a fracture running more or less parallel to the outside edge and produces a thin tapering edge around the whole margin (Law de Lauriston 2014: 273).

**Step Termination-** A step termination is a scar that usually ends in an abrupt way resulting in a "right angle break" (Crabtree 1972: 93). It is the result of the dissipation of the introduced force or the result of the force "running into" an impurity or inclusion that causes the force to abruptly exit the piece.

**Snap Termination-** Snap fractures "only occur with bending initiations and continue in a relatively straight line to terminate nearly perpendicular to the opposite face" (Cotterell *et al.* 1979: 134). They are generally the result of a misplaced blow when knapping or working a harder material in use-wear analysis.

**Hinge Termination-** "a hinge fracture meets the surface at a steep angle or approximately right angles to the longitudinal axis" (Cotterell *et al.* 1979: 134). It is the result of the introduced force gradually exiting the piece in a curvilinear style. The force is deflected back to the outside surface due to any number of reasons including excessive or misdirected force, too little force, or the force encountering an impurity of inclusion as with a step termination.

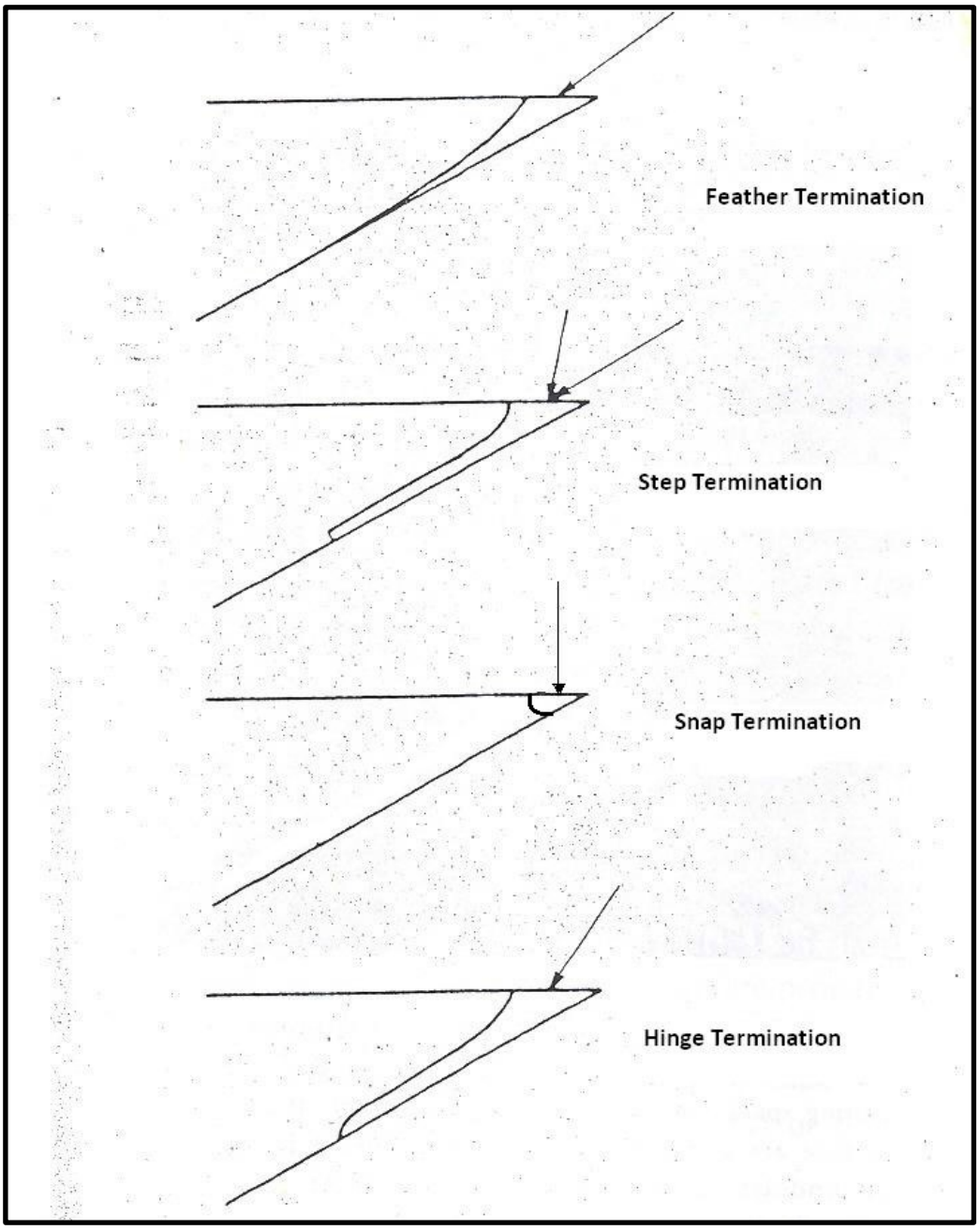


**Figure D.1 Scar Termination Types** (Image modified from Cotterell *et al.* 1979)

### D.2 Use-wear Motion Definitions

The following definitions are a compilation of several sources including Tringham *et al.* 1974; Odell 1970, 1980; Odell and Odell-Vereecken 1981; Lemorini *et al.* 2006; and Law de Lauriston 2014 as any given source may not discuss the full range of motions, or the motions that the CoH LCTs were used for.

**Cut/ Slice**- a motion that is generally considered to be uni-linear and is always parallel to the worked edge. It is usually 'strongly associated with fleshy tissues and, more generally, with soft materials... and herbaceous

plants...' (Lemorini *et al.* 2006: 925). Additionally, the lithic tool is most often pulled towards the user rather than being pushed away from them.

**Chop/ Adze**- a motion in which the tool is used to deliver repeated blows into the worked material (e.g., think of splitting pieces of firewood with an axe). The motion is technically bi-lateral as it involves an up and down motion. However, during the up motion, the used edge is generally not in contact with the worked material and therefore should be considered a uni-lateral motion. This can be either transverse or parallel to the edge, depending on the angle at which the edge penetrates the worked material.

**Dig-** a motion similar to Chop/ adze, but usually reserved for when the tool has made contact with soil. It is a bi-lateral motion and is both parallel and transverse to the used edge. The used edge generally penetrates the soil at a more or less right angle, then the used edge is dragged towards the utilizer in a scraping type motion.

**Drill-** a motion which is generally rotary in nature. The used edge is twisted either clockwise or counter-clockwise while inserted in the worked material. Usually, the objective is to create a hole. The motion is transverse to the worked edge and can be uni-lateral but is generally bi-lateral. Additionally, a scraping motion may accompany the rotary motion as the tool is held at varying angles to both deepen and widen the hole.

**Hammered**- the used edge is the inactive piece in this motion. The piece is being hammered upon rather than being used as a hammer. The goal of this is generally to aid in accomplishing another motion, such as wedge/ split in which additional force is needed. The motion involved in an object being hammered is neither transverse nor parallel to the used edge but rather is percussive in which the edge is being struck at approximately 90 degrees causing crushing and rounding of the edge.

**Impact-** this motion is generally reserved for those pieces that have been used as a projectile in some way (e.g., a spear, an arrow) and thus have had force introduced into a tip or projection of the tool directed towards and into the body of the piece. However, the way in which I utilise the term is not to indicate that a tool has been used as a projectile, especially as they are LCTs, though I do not rule out the possibility that they were projected. I use it simply to mean that force has been directed into the body of the piece, usually at the tip, resulting in what has been termed "Impact Fractures" occurring. The motion is usually uni-lateral and depending on how deeply the piece penetrates the worked material it can be either/ or/ both transverse and parallel to the used edge.

**Incise-** a bi-lateral motion in which a tip or projection of the piece is placed into the worked material with the specific intent of creating a groove or decoration of the material (e.g., incising shell or pottery for decoration). The motion is similar to sawing as the used projection is moved back and forth across and into the worked material. Thus, the motion can be either/ or/ both parallel and transvers to the used edge.

**Plane**- a uni-lateral motion that is similar to scraping. The motion is transverse to the used edge in most cases, but can be a combination of parallel and transvers, depending on the angle at which the tool is held and the direction in which the tool is pushed. Usually used to remove bark from trees, to sharpen a stick, etc. The tool is pushed down and away from the user with the intent to remove thin pieces of the worked material.

**Saw**- a bi-lateral motion, which is generally associated with medium and hard materials (e.g., wood or bone). The piece in use is pushed away from then pulled towards the user. The motion is both parallel and transverse to the edge as in the course of the parallel motions of pushing and pulling, a force is exerted in a downward direction as well to make the used edge penetrate the worked material more deeply.

**Scrape**- a motion similar to plane, except that it is bi-lateral. The motion is generally transverse to the used edge. The tool is pushed and pulled back and forth across the worked material with the intent to remove small amount of material with any given stroke.

**Wedge/ Split**- usually a complementary motion that accompanies hammer. Again, the used edge is generally inactive. That is, the edge is placed onto the worked material and held steady, then force is introduced through the hammering motion of another tool. The motion is generally transverse to the used edge and the goal of the motion is to separate a larger piece of worked material into smaller pieces (e.g., splitting a piece of wood).

## References


Adler, D.S., Wilkinson, K.N., Blockley, S., Mark, D.F., Pinhasi, R., Schmidt-Magee, B.A., Nahapetyan, S., Mallol, C., Berna, F., Glauberman, P.J., Raczynski-Henk, Y., Wales, N., Frahm, E., Jöris, O., MacLeod, A., Smith, V.C., Cullen, V.L. & Gasparian, B. 2014.Early Levallois technology and the Lower to Middle Paleolithic transition in the Southern Caucasus. *Science* 345(6204): 1609-1613

Ahler, S. 1971. Projectile point form and function at Rodger Shelter, Missouri. *Missouri Archaeological Society, Research Series 8.* Columbia: Missouri Archaeological Society

Anderson-Gerfaud, P. 1980. A testimony of prehistoric tasks: diagnostic residues on stone tool working edges. *World Archaeology* 12:181-194

Anderson-Gerfaud, P., Moss, E. & Plisson, H. 1987. A quoi ont-ils servi? L'apport de l'analyse fonctionelle. *Bulletin de la Societe Prehistorique Francais* 84(8): 226-237

Andrefsky, W. 1998. *Lithics: Macroscopic Approaches to Analysis, Cambridge Manuals in Archaeology.* Cambridge: Cambridge University Press

Asfaw, B., Beyene, Y., Suwa, G., Walter, R., White, T., WoldeGabriel, G. & Yemane, T. 1992. The earliest Acheulean from Konso-Gardula. *Nature* 360(6406): 732-735

Ascher, R. 1961. Experimental Archaeology. *American Anthropologist, New Series* 63(4): 793-816

Asryan, L., Ollé A. & Moloney, N. 2014. Reality and confusion in the recognition of post-depositional alterations and use-wear: an experimental approach on basalt tools. *Journal of Lithic Studies* 1(1): 9-32

Balme, J. & Beck, W.E. 2002. Starch and charcoal: useful measures of activity areas in archaeological rockshelters. *Journal of Archaeological Science* 29(2): 157-166

Bamforth, D.B. 1988. Investigating micro-wear polishes with blind tests: the institute results in context. *Journal of Archaeological Science* 15: 11-23

Banks, W.E. & Kay, M. 2003. High resolution casts for lithic use-wear analysis. *Lithic Technology* 28(1): 27-34

Barham, L., and Mitchell, P.J. 2008. *The First African: African Archaeology From the Earliest Toolmakers to Most Recent Foragers.* New York: Cambridge University Press.

Barton, H. 2009. Starch granule taphonomy: the results of a two year field experiment. In: Haslam, M., Robertson, G., Crowther, A., Kirkwood, L. & Nugent, S. (eds) *Archaeological Science Under a Microscope: Studies in Residue and Ancient DNA Analysis in Honour of Tom Loy*: 129-140. Brisbane: University of Queensland

Barton, H. & Matthews, P. 2006. Taphonomy. In: Torrence, R. & Barton, H. (eds) *Ancient Starch Research*: 75–94. Walnut Creek: Left Coast Press, Inc

Barton, H., Torrence, R. & Fullagar, R. 1998. Clues to stone tool function re-examined: comparing starch grain frequencies on used and unused obsidian artefacts. *Journal of Archaeological Science* 25(12): 1231-1238

Basell, L.S. 2010. Middle Stone Age Sangoan-Lupemban lithic assemblages in Africa. In: Allsworth, J. (ed.) *West African Archaeology New Developments, New Perspectives: 15-28. BAR International Series S2164. Oxford: British Archaeological Reports*

Basemann, R. 1986. Natural alterations on stone artefact materials. In: Owen, L. and Unrath, G. (eds) *Technical Aspects of Microwear Studies on Stone Tools*. 1st ed. Early Man News 9/10/11: 97-102.

Beaumont, P.B. 1982. Aspects of the northern Cape Pleistocene Project. *Palaeoecology of Africa* 15: 41-44

Beaumont, P.B. & Vogel, J.C. 2006. On a timescale for the past million years of human history in central South Africa. *South African Journal of Science* 102(5-6): 217-228

Bercovici, A., Hadley, A. & Villanueva-Amadoz, U. 2009. Improving depth of field resolution for palynological photomicrograohy. *Palaeotologia Electronica* 12(2): 5T; 12 p.

Berman, C.A. & Newcomer, M.H. 1983. Flint arrowhead breakage: examples from Ksar Akil, Lebanon. *Journal of Field Archaeology* 10: 238-243

Berna, F., Goldberg, P., Horwitz, L.K., Brink, J., Holdt, S., Bamford, M. & Chazan, M. 2012. Microstratigraphic evidence of in situ fire in the Acheulean strata of Wonderwerk Cave, Northern Cape Province, South Africa. *Proceedings of the National Academy of Sciences* 109(20): E1215-E1220

Beyene, Y., Katoh, S., WoldeGabriel, G., Hart, W., Uto, K., Sudo, M., Kondo, M., Hyodo, M., Renne, P., Suwa, G., & Asfaw, B. 2013. The characteristics and chronology of the earliest Acheulean at Konso, Ethiopia. *Proceedings of the National Academy of Sciences* 110(5): 1-8

Binford, L.R. 1980. Willow smoke and dog's tails: hunter-gatherer settlement systems and archaeological site formation, in *American Antiquity*:45:1:4-18. Society for American Archaeology.

Binneman, J.N.F. 1982. Mikrogebruikstekene op steenwerktuie: eksperimentele waarnemings en 'n studie van werktuie afkomstig van Boomplaasgrot. Ongepubliseerde MA tesis. Stellenbosch: Universiteit Stellenbosch.

Binneman, J.N.F. 1984. Mapping and interpreting wear traces on stone implements: a case study from Boomplaas Cave. In: Hall, M., Avery, G., Avery, D.M., Wilson, M.L. & Humphreys, A.J.B. *Frontiers: Southern African Archaeology Today*: 143-151. Oxford: BAR International Series 207.

Binneman, J.N.F. & Beaumont, P.B. 1992. Use-wear analysis of two Acheulean handaxes from Wonderwerk Cave, Northern Cape. *Southern African Field Archaeology* 1: 92-7

Binneman, J.N.F. & Deacon, J. 1986. Experimental determination of usewear on stone adzes from Boomplaas Cave, South Africa. *Journal of Archaeological Science* 13(3): 219-28.

Blakeslee, D.J. 1975. The plains interband trade system: an ethnohistoric and archaeological investigation. Unpublished PhD thesis. University of Wisconsin-Milwaukee.

Blakeslee, J.D. 1981. The origin and spread of the Calumet ceremony. *American Antiquity* 46(4): 759-768

Blakeslee, D.J. 2012. The Windom pipe: a chaîne opératoire analysis. *Plains Anthropologist* 57(224): 299-323

Blakeslee, D.J. & Hawley, M.F. 2006. The Great Bend Aspect. In: Hoard, R.J. & Banks, W.E (eds) *Kansas Archaeology*: 165-179. Lawrence: University of Kansas Press

Bögli, A. 1980. *Karst Hydrology and Physical Speleology*. Berlin: Springer-Verlag

Bordes, F. 1984. Leçons sur le Paléolithique, Vol. 2: Le Paléolithique en Europe. *Cahiers du Quaternaire* 7. Paris: CNRS

Borsheim, K.Y., Christensen, B.E. & Painter, T.J., 2001. Preservation of fish by embedment in *Sphagnum* moss, peat or holocellulose: Experimental proof of the oxopolysaccharidic nature of the preservative substance and of its antimicrobial and tanning action. *Innovative Food Science & Emerging Technologies* 2(1): 63-74

Brain, C.K. 1988. Geological aspects of the Cave of Hearths. In: Mason, R.J. (ed.) *Cave of Hearths: Makapansgat Transvaal.* Occasional Paper 21: 556-579. Johannesburg: Archaeological Research Unit

Brain, C.K. (ed.) 1993. *Swartkrans: A Cave's Chronicle of Early Man*. Monograph 8. Pretoria: Transvaal Museuem

Briuer, F.L. 1976. New clues to stone tool functions: plant and animal residues. *American Antiquity* 40(4): 150-160

Brown, I.W. 1989. The Calumet ceremony in the southeast and its archaeological manifestations. *American Antiquity* 54(2): 311-331

Butler, R. F. 1992. *Palaeomagnetism; Magnetic Domains to Geologic Terranes.* Oxford: Blackwell Scientific Publications.

Burroni, D., Donahue, R. E., Pollard, A. M. & Mussi, M. 2002. The surface alteration features of flint artefacts as a record of environmental processes. *Journal of Archaeological Science* 29(11): 1277-1287

Carneiro, R.L. 1979. Tree felling with the stone axe. In Kramer, C. (ed.) 1979. *Ethnoarchaeology*: 21-58 New York: Columbia University Press

Chandlee, S.N., Bell, C.A. & Lambert-Law de Lauriston, T. 2014. Pipe manufacture on the plains and experimental archaeology: not just blowing smoke. *Lithic Technology* 39(2): 122-128

Chazan, M., Ron, H., Matmom, A., Porat, N., Goldberg, P., Yates, R., Avery, M., Sumner, A. & Horwitz L.K. 2008. Radiometric dating of the Earlier Stone Age sequence in Excavation I at Wonderwerk Cave, South Africa: preliminary results. *Journal of Human Evolution* 55(1): 1-11

Child, A.M., 1995. Towards an understanding of the microbial decomposition of archaeological bone in the burial environment. *Journal of Archaeological Science* 22, p. 165-174.

Child, A. M., Gillard, R. D. & Pollard, A. M. 1993. Microbially induced promotion of amino acid racemization in bone: isolation of the organisms and detection of their enzymes. *Journal of Archaeological Science* 20(2): 159-168

Clark, J.D. 1970. *The Prehistory of Africa*. New York: Praeger Publishers Inc.

Clark, J.D. 1994. The Acheulian Industrial Complex in Africa and elsewhere. In: Corruccini, R. & Ciohon, R. (eds) *Integrative Paths to the Past: Paleoanthropological Advances in Honor of F. Clark Howell*: 451-469. New Jersey: Prentice Hall

Clark, J.D. 2001. *Kalambo Falls Prehistoric Site, Vol. III*. London: Cambridge University Press.

Coles, J. 1973. *Archaeology by Experiment*. London: Hutchinson University Library

Coles, J. 1979a. *Experimental Archaeology*. London: Academic Press

Coles, J. 1979b. An experiment with stone axes. In Clough, T. & Cummins W. (eds) *Stone Axe Studies. Council for British Archaeology Research Report 23*: 106-107.

Commont, V. 1908. Les industries de l'ancien Saint-Acheul. L'Anthropologie, 19: 527-572.

Commont, V. 1909. Saint-Acheul et Montières, notes de géologie, de paléontologie et de préhistoire. *Mémoires de la Société Géologique du Nord de la France* 6(3).

Constantine, J.A. & Dunne, T. 2008. Meander cutoff and the controls on the production of oxbow lakes. *Geology* 36(1): 23-36

Cooper, J. & Nugent, S. 2009. Tools on the surface: residue and use-wear analyses of stone artefacts from Camooweal, northwest Queensland. In: Haslam, M., Robertson, G., Crowther-Smith, A., Nugent, S. & Kirkwood, L. (eds) *Archaeological Science Under a Microscope*: *Studies in Residue and Ancient DNA Analysis in Honour of Thomas H. Loy:* 202-227. Canberra: Australian National University

Cotterell, B., Hayden, B., Kamminga, J., Kleindienst, M., Knudson, R., & Lawrence, R. 1979. The Ho Ho classification and nomenclature committee report. In: Hayden, B. (ed.) *Lithic Use-Wear Analysis*: 133-135. New York: Academic Press.

Crabtree, D. 1972. An introduction to flintworking*. Occasional Papers of the Idaho State University Museum, no. 28.* Pocatello

Crowther, A. & Haslam, M. 2007. Blind tests in microscopic residue analysis: comments on Wadley et al. (2004). *Journal of Archaeological Science* 34(6): 997-1000

Curnoe, D. 2009. The mandible from Bed 3, Cave of Hearths. In: McNabb, J. & Sinclair, A. (eds) *The Cave of Hearths: Makapan Middle Pleistocene Research Project: Field Research by Anthony Sinclair and Patrick Quinney, 1996-2001*: 138-149. University of Southampton Series in Archaeology 1. Oxford: Archaeopress

Curwen, E.C. 1930. Prehistoric flint sickles. *Antiquity* 4(14): 179-186

Curwen, E.C. 1935. Agriculture and the flint sickle in Palestine. *Antiquity* 9(33): 62-66

Dart, R.A. 1948. The first human mandible from the Cave of Hearths, Makapansgat. *South African Archaeological Bulletin* 3(12): 96-98

Davis, O. K. 1975. Pollen analysis of Wildcat Lake, Whitman County, Washington: the introduction of grazing. Unpublished MA thesis. Pullam, WA: Washington State University

Davey, P.J. 1973. Bronze age metalwork from Lincolnshire. *Archaeologia (Second Series)* 104: 51-127

Davey, P.J. (ed.) 1981. *The Archaeology of the Clay Tobacco Pipe VI: Pipes and Kilns in the London Region*. BAR British Series 97. BAR: Oxford

Deino, A.L. 2012. 40Ar/39Ar dating of Bed I, Olduvai Gorge, Tanzania and the chronology of early Pleistocene climate change. *Journal of Human Evolution* 63(2): 251-273

D'Errico, F. 1988. The use of resin replicas for the study of lithic use-wear. In: Olsen, S. (ed.) *Scanning Electron Microscopy in Archaeology*: 155-167. Oxford: BAR International Series 452.

de la Torre, I., Mora, R. & Martínez-Morego, J. 2008. The early Acheulean in Peninj (Lake Natron, Tanzania). *Journal of Anthropological Archaeology* 27(2): 244-264

de la Torre, I., McHenry, L., Njau, J. & Pante M. 2011-2012. The origins of the Acheulean at Olduvai Gorge (Tanzania): a new paleoanthropological project in east Africa. *Archaeology International 15*: 89-98

Dennel, R. 1997. The world's oldest spears. *Nature* 385(6619): 767-768

Dennett, D. 1991. *Consciousness Explained*. London: Penguin

Diamond, G. 1979. The nature of so-called polish surfaces on stone artifacts. In: Hayden, B. (ed.) *Lithic Use- Wear Analysis*: 159-166. New York: Academic Press

Del Bene, T. 1979. Once upon a striation: current models of striation and polish formation. In: Hayden, B. (ed.) *Lithic Use-Wear Analysis*: 167-178. New York: Academic Press.

Dominguez-Rodrigo, M., Lopez-Saez, J.A., Vincens, A., Alcala, L., Luque, L. & Serrallonga, J. 2000. Fossil pollen from the upper Humbu Formation of Peninj (Tanzania): hominid adaptation to a dry open Plio-Pleistocene savanna environment. *Journal of Human Evolution* 40(2): 151-157

Domiguez-Rodrigo, M., Serallonga, J., Juan-Tresserras, J., Alcala, L. & Luque, L. 2001. Woodworking activities by early humans: a plant residue analysis on Acheulian stone tools from Peninj (Tanzania). *Journal of Human Evolution* 40(4): 289-299

Donahue, R.E. & Burroni, D.B. 2004. Lithic microwear analysis and the formation of archaeological assemblages. In: Walker, E.A., Wenban-Smith, F. & Healy, F. (eds) *Lithics in Action: Papers for the Conference Lithic Studies in the Year 2000*: 140-148. Oxford: Oxbow Books

Driver, C. A. (2006). "Wear It's At"(or Isn't): an experimental program and functional re-analysis of an Oneota lithic assemblage towards evaluating error rates of expedient tool identification. Unpublished PhD thesis. University of Wisconsin—La Crosse.

Eisele, J.A., Fowler, D.D., Haynes, G. & Lewis, R.A. 1995. Survival and detection of blood residues on stone tools. *Antiquity* 69(262): 36-46

Evans, A.A. 2014. On the importance of blind testing in archaeological science: the example from lithic functional studies. *Journal of Archaeological Science* 48: 5-14

Evans, J. 1872. *The Ancient Stone Implements: Weapons and Ornaments of Great Britain*. London: Longmans, Green & Co.

Ferguson, J. R. (ed.) 2010 *Designing Experimental Research in Archaeology: Examining Technology Through Production and Use*. Boulder: Colorado University Press

Fletcher, S.M., Dolton, P. & Harris-Smith, P.W. 1984. Species identification of blood and saliva stains by enzyme-linked immunoassay (ELISA) using monoclonal antibody. *Journal of Forensic Sciences* 29(1): 67-74.

Fischer, A., Vemming Hansen, P. & Rasmussen, P. 1984. Macro and micro wear traces on lithic projectile points: experimental results and prehistoric examples. *Journal of Danish Archaeology* 3: 19-46

Ford, D. & Williams, P. 2007. *Karst Hydrogeology and Geomorphology*. Chichester: John Wiley & Sons Ltd.

Fullagar, R. Meehan, B. & Jones, R. 1992. Residue analysis of ethnographic plant-working and other tools from northern Australia. In: Anderson P. (ed.) *Préhistorie de l'agriculture: nouvelles approaches expérmentales et ethnographiques*: 39-53. Paris: CNRS

Gamble, C. 1986. *The Palaeolithic Settlements of Europe*. Cambridge: Cambridge University Press

Gamble, C. 1997. Handaxes and palaeolithic individuals. In: Ashton, A., Healey, F. & Pettitt, P. (eds) *Stone Age Archaeology*: 105-109. Oxford: Oxbow Books. Monograph 102

Gendel, P. A. & Pirnay, L. 1982. Microwear analysis of experimental stone tools: further test results. *Studia Praehistorica Belgica Leuven* 2: 251-265

Geraads, D., Hublin, J-J., Jaeger, J-J., Tong, H., Sen, S. & Toubeau, P. 1986. The Pleistocene hominid site of Ternifine, Algeria: new results on the environment, age, and human industries. *Quaternary Research* 25(3): 380-386

Gernaey, A.M., Waite, E.R., Collins, M.J., Craig, O.E. & Sokol, R.J. 2001. Survival and interpretation of archaeological proteins. In: Brothwell, D.R. & Pollard, A.M. (eds). *Handbook of Archaeological Sciences*: 323-329. Chichester: John Wiley & Sons,

Gibbon, R.J., Granger, D.E., Kuman, K. & Partridge, T.C. 2009. Early Acheulean technology in the Vaal River gravels, South Africa, dated with cosmogenic nuclides. *Journal of Human Evolution* 56(2): 152-160

Gibson, N.E., Wadley, L. & Williamson, B.S. 2004. Microscopic residues as evidence of hafting on backed tools from the 60 000 to 80 000 year-old HowiesonsPoort layers of Rose Cottage Cave, South Africa. *Southern African Humanities* 16(1): 1-11

Gojak, D. & Stuart, I. 1999. The potential for the archaeological study of clay tobacco pipes from Australian sites. *Australasian Historical Archaeology* 17: 38-49

Gordon, K.D. 1984. Pitting and bubbling artefacts in surface replicas made with silicone elastomers. *Journal of Microscopy* 134(2): 183-188

Gourlay, I.D. 1995. The definition of seasonal growth zones in some African Acacia species—A review. *International Association of Wood Anatomists Journal* 16(4): 353-359

Granger, D.E. & Muzikar, P.F. 2001. Dating sediment burial with in situ-produced cosmogenic nuclides: theory, techniques, and limitations. *Earth and Planetary Science Letters* 188(1-2): 269-281

Hall, J., Higgins, S. & Fullagar, R. 1999. Plant residues on stone tools. In: Beck, W., Clarke, A. & Head, L. (eds) *Plants in Australian Archaeology Tempus 1*: 136-160

Hanten, N.J. & Stevens, N.E. 2010. The reliability of microscopic use-wear analysis on Monterey Chert Tools. In: Laylander, D., Waechter, S.A., Rosen, M.D., Andrews, S., & Davis-King, S. (eds) *Proceedings of the Society for California Archaeology Volume 24: Papers Presented at the 44th Annual Meeting of the Society for California Archaeology*. Riverside, California 17 March—20 March 2010.

Hardy, B.L. & Garufi, G.T. 1998. Identification of woodworking on stone tools through residue and use-wear analyses: experimental results. *Journal of Archaeological Science* 25(2): 177-184

Hay, R.L. 1976. *Geology of the Olduvai Gorge.* Berkley: University of California Press.

Hayden, B. (ed.) 1979. *Lithic Use-Wear Analysis*. New York: Academic Press

Hayden, B. & Kamminga, J. 1979. An introduction to use-wear: the first CLUW. In: Hayden, B. (ed.) *Lithic Use-Wear Analysis*: 1-13. New York: Academic Press.

Hayden, B. & Villeneuve, S. 2009. Sex, symmetry and silliness in the bifacial world. *Antiquity* 83(322): 1163-1175

Herries, A.I.R. & Latham, A.G. 2009. Archaeomagnetic studies at the Cave of Hearths. In: McNabb, J. & Sinclair, A. (eds) *The Cave of Hearths: Makapan Middle Pleistocene Research Project: Field Research by Anthony Sinclair and Patrick Quinney, 1996-2001*: 59-64. University of Southampton Series in Archaeology 1. Oxford: Archaeopres

Herrygers, C. 2002. A comparative analysis of wood residues on experimental stone tools and early stone age artifacts: a Koobi Fora case study. *McNair Scholars Journal* 6(1): 65-75

Hodgson, D. 2009. Symmetry and humans: reply to Mithen's 'sexy handaxes theory'. *Antiquity* 83(322): 195-198

Howell, F.C. 1966. Observations on the earlier phases of the European Lower Paleolithic. *American Anthropologist* 68(2) Part II: 88-201

Hurcombe, L. M. 1988. Some criticisms and suggestions in response to Newcomer et al. *Journal of Archaeological Science* 15(1): 1-10.

Isaac, G.L. 1967a. Some experiments in quantitative methods for characterizing assemblages of Acheulian artefacts. In: Mortelmans., G. & Nenquin J. (eds) *Actes du VI Congrès Panafricain de Préhistoire et de l'Etude du Quaternaire, Dakar 1967,* Chambéry: 547-555. Tervuren: Musée Royale de l'Afrique Centrale

Isaac, G.L. 1967b. The stratigraphy of the Peninj Group. Early and middle Pleistocene formations west of Lake Natron, Tanzania. In: Bishop, W.W. & Clark, J.D. (eds) *Background to Evolution in Africa:* 229-257. Chicago: University of Chicago Press.

Isaac, G.L. 1968. The Acheulian site complex at Olorgesaile, Kenya: a contribution to the interpretation of Middle Pleistocene culture in East Africa. Unpublished PhD thesis. Cambridge: Cambridge University

Isaac, G.L. 1969. Studies of Early Cultures in East Africa. *World Archaeology* 1(1): 1-28

Isaac, G.L. & Curtis, G.H. 1974. Age of the early Acheulian industries from the Peninj Group, Tanzania. *Nature* 249(5458): 624-626

Jeffreys, M.D.W.. 1965. The hand bolt. *Man* 65(5): 153-154

Johnson, C.R. & McBrearty, S. 2010. 500,000 year old blades from the Kapthurin Formation, Kenya. *Journal of Human Evolution* 58(2): 193-200

Jones, P.R. 1980. Experimental butchery with modern stone tools and its relevance for Paleolithic archaeology. *World Archaeology* 12(2): 153-175

Jones, P.R. 1981. Experimental implement manufacture and use; a case study from Olduvai Gorge, Tanzania. *Philosophical Transactions of the Royal Society B: Biological Sciences* 292(1057): 189-195

Jones, P.R. 1994. Results of experimental work in relation to the stone industries of Olduvai Gorge. In: Leakey, M.D. & Roe, D.A. (eds) *Olduvai Gorge, Vol. V. Excavations in Beds III, IV and the Masek Beds, 1968-1971:* 254-298. Cambridge: Cambridge University Press

Joordens, Josephine C.A., d'Errico, F., Wesselingh, F.P., Munro, S., de Vos, J., Wallinga, J., Ankj*ærgaard, C., Reimann, T., Wijbrans, J.R., Kuiper, K.F., Mücher, H.J., Coqueugniot, H., Prié, V., Joosten, I., van Os, B., Schulp, A.S., Panuel, M., van der Haas, V., Lustenhouwer, W., Reijmer, J.J.G. & Roebroeks, W. 2015. Homo erectus at Trinil on Java used shells for tool production and engraving. Nature 518(7538): 228-231*

Kamminga, J. 1979. The nature of use-polish and abrasive smoothing on stone tools. In: Hayden, B. (ed.) *Lithic Use-Wear Analysis*: 143-58. New York: Academic Press.

Kamminga, J. 1982. *Over the Edge: Functional Analysis of Australian Stone Tools.* Occasional Papers in Anthropology No. 12. Anthropology Museum: University of Queensland

Kars, H., 2003. Het bodemarchief is kwetsbaar. In: Kars, H. & Smit, A. (eds). *Handleiding Fysiek Behoud Archeologisch Erfgoed*: 1-6. Amsterdam: Vrije Universiteit

Keeley, L.H. 1974. Technique and methodology in microwear studies: a critical review. *World Archaeology* 5(3): 323-336

Keeley, L. H. 1980. *Experimental Determination of Stone Tool Uses: A Microwear Analysis*. Chicago: University of Chicago Press

Keeley, L. H. & Newcomer, M. H. 1977. Microwear analysis of experimental flint tools: a test case. *Journal of Archaeological Science* 4(1): 29-62

Keeley, L. & Toth, N. 1981. Microwear polishes on early stone tools from Koobi Fora, Kenya. *Nature* 293: 464-465

Klein, R.G. 1988. The significance of animal bones from Acheulean sites in southern Africa. *The African Archaeological Review* 6: 3-25

Klein, R.G. 2000. The Earlier Stone Age of southern Africa. *South African Archaeological Bulletin* 55(172): 107-122

Kleindienst, M.R. 1961. Variability in the Late Acheulian assemblage in Eastern Africa. *The South African Archaeological Bulletin* 16(62): 35-52

Kleindienst, M.R. 1962. Component of the East African Acheulian Assemblage: an analytic approach. In: Mortlemans, G. & Nenquin, J. (eds) *Actes de IV Congrès Panafricain de Préhistoire et de l'Etude du Quaternaire, Leopoldville, 1959, Belgie* Annalen: 81-108. Tervuren: Musee Royal de l'Afrique Centrale

Kleindienst, M.R. & Keller, C.M. 1976. Towards a functional analysis of handaxes and cleavers: the evidence from Eastern Africa. *Man: New Series* 11(2): 176-187

Klimchouk, A.B., Ford, D.C., Palmer, A.N. & Dreybrodt, W. (eds) 2000. *Speleogenesis: Evolution of Karst Aquifers*. Huntsville: National Speleological Society Press

Knutsson, K. & Hope, R. 1984. The applicationof acetate peel in lithic usewear analysis. *Archaeometry* 26(1): 49-61

Kohn, M. & Mithen, S. 1999. Handaxes: products of sexual selection?. *Antiquity* 73(281): 518-526

Kooyman, B., M.E. Newman & Ceri, H. 1992. Verifying the reliability of blood residue analysis on archaeological tools. *Journal of Archaeological Science* 19(3): 265-9

Kuman, K. 2001. An Acheulean site with prepared core technology near Taung, South Africa. *The South African Archaeological Bulletin* 56(173/174): 8-22

Kuman, K. 2007. The Earlier Stone Age in South Africa: site context and the influence of cave studies. In: Pickering, T.R., Schick, K. & Toth, N. (eds) *Breathing Life Into Fossils: Taphonomic Studies in Honor of C.K. (Bob) Brain:* 181-198. Bloomington: Stone Age Institute Press

Kuman, K. 2014. The Acheulean Industrial Complex. In: Smith, C (ed.) *Encyclopedia of Global Archaeology*: 7-18. New York: Springer

Kuman, K. & Clarke, R.J. 2000. Stratigraphy, artefact industries and hominid associations for Sterkfontein, Member 5. *Journal of Human Evolution* 38(6): 827-847

Kuykendall, K. 2007. Fossil hominids of the 'Cradle of Humankind'. In: Bonner, P., Esterhuysen, A. & Jenkins T. (eds) *A Search for Origins: Science, History and South Africa's 'Cradle of Humankind':* 50-77. Johannesburg: Wits University Press

Langejans, G.H. 2007. PIXE and residues: examples from Sterkfontein and Sibudu, South Africa. *South African Archaeological Bulletin* 62(185): 71-73

Langejans, G.H.J., 2010. Remains of the day-preservation of organic micro-residues on stone tools*. Journal of Archaeological Science* 37(5): 971-985.

Langejans, G.H. & Lombard, M. 2015. About small things and bigger pictures: An introduction to the morphological identification of micro-residues on stone tools. In: Marreiros, J., Gibaja Bao, M., Ferreira, J.F. & Bicho, N. (eds) *Use-Wear and Residue Analysis in Archaeology*: 199-219. Heidelberg: Springer

Latham, A.G. & Herries, A.I.R. 2004. The formation and sedimentary infilling of the Cave of Hearths and Historic Cave Complex, Makapansgat, South Africa. *Geoarchaeology: An International Journal* 19(4): 323-342

Latham, A.G. & Herries, A.I.R. 2009. The formation and sedimentary infilling of the Cave of Hearths and Gwaša/Historic Cave Complex, Makapan, South Africa. In: McNabb, J. & Sinclair, A. (eds) *The Cave of Hearths: Makapan Middle Pleistocene Research Project: Field Research by Anthony Sinclair and Patrick Quinney, 1996-2001*: 79-58. University of Southampton Series in Archaeology 1. Oxford: Archaeopress

Law de Lauriston, P.B. MacLaren. 2014. The effects of contact with farmers on hunter-gatherers' lithic assemblages: use-wear analysis of stone tools from Holkrans, North West Province, South Africa. Unpublished PhD thesis. University of the Witwatersrand.

Law de Lauriston, P.B. MacLaren, Odell, G.H. & Lambert-Law de Lauriston, T.S. 2015. Stone pipe making tools in ancient North America. *Journal of Archaeological Science* 57: 32-41

Leakey, M.D. 1971. *Olduvai Gorge, Vol. III*. Cambridge: Cambridge University Press

Lemorini, C., Stiner, M., Gopher, A., Shimelmitz, R. & Barkai, R. 2006. Use-wear analysis of an Amudian laminar assemblage from the Acheuleo-Yabrudian of Qesem Cave, Israel. *Journal of Archaeological Science* 33(7): 921-934

Lemorini, C., Plummer, T.W., Braun, D.R., Crittenden, A.N., Ditchfield, P.W., Bishop, L.C., Hertel, F., Oliver, J.S., Marlowe. F.W., Schoeninger, M.J. & Potts, R. 2014. Old stones' song: use-wear experiments and analysis of the Oldowan quartz and quartzite assemblage from Kanjera South (Kenya). *Journal of Human Evoultion* 72: 10-25

Lepre, C.J., Roche, H., Kent, D., Harmand, S., Quinn, R., Brugal, J-P., Texier, P-J., Lenoble & Feibel, C. 2011. An earlier origins for the Acheulean. *Nature* 477(7362): 82-85

Levi-Sala I. 1986. Use wear and post-depositional surface modification: a word of caution. *Journal of Archaeological Science* 13(1): 229-244.

Levi-Sala, I. 1996. *A Study of Microscopic Polish on Flint Implements*. Oxford: BAR International Series 629

Lipo, C.P., Hunt, T.L. & Haoa, S.R. 2013. The 'walking' megalithic statues (*moai*) of Easter Island. *Journal of Archaeological Science* 40(6): 2859-2866

Lombard, M. 2004. Distribution patterns of organic residues on Middle Stone Age points from Sibudu Cave, Kwazulu-Natal, South Africa. South African Archaeological Bulletin 59(1): 37-44

Lombard, M. 2005. Evidence of hunting and hafting during the Middle Stone Age at Sibudu Cave, Kwazulu-Natal, South Africa: a multi-analytical approach. *Journal of Human Evolution* 48(3): 279-300

Lombard, M. 2006. Direct evidence for the use of ochre in the hafting technology of Middle Stone Age tools from Sibudu Cave. *Southern African Humanities* 18(1): 57-67.

Lombard, M. 2008. Finding resolution for the Howiesons Poort through the microscope: micro-residue analysis of segments from Sibudu Cave, South Africa. *Journal of Archaeological Science* 35(1): 26-41

Lombard, M. 2011. Quartz-tipped arrows older than 60 ka: Further use-trace evidence from Sibudu, KwaZulu-Natal, South Africa. *Journal of Archaeological Science* 38(8): 1918-1930.

Lombard, M. 2014. *In situ* presumptive test for blood residues applied to 62 000-year-old stone tools. *South African Archaeological Bulletin* 69(199): 80-86

Lombard, M. & Pargeter, J. 2008. Hunting with Howiesons Poort segments: pilot experimental study and the functional interpretation of archaeological tools. *Journal of Archaeological Science* 35(9): 2523-2531

Lombard, M. & Phillipson, L. 2010. Indications of bow and stone-tipped arrow use 64 000 years ago in KwaZulu-Natal, South Africa. *Antiquity* 83(325): 635-648

Lombard, M. & Wadley, L. 2007. The morphological identification of micro-residues on stone tools using light microscopy: progress and difficulties based on blind tests. *Journal of Archaeological Science* 34(1): 155-165

Loy, T.H. 1983. Prehistoric blood residues: detection on tool surfaces and identification of species of origin. *Science* 220(4603): 1269-1271

Loy, T. H. 1998. Blood on the axe. *New Scientist* 159(2151): 40-43

Loy, T.H. & Dixon, E.J. 1998. Blood residues on fluted points from Eastern Beringia. *American Antiquity* 63(1): 21-46

Loy, T.H. & Hardy, B.L. 1992, Blood residue analysis of 90, 000-year-old stone tools from Tabun Cave, Israel. *Antiquity* 66(250): 24-35

Loy, T.H. & Wood, A.R. 1989. Blood residue analysis at Çayounu Tepesi, Turkey. *Journal of Field Archaeology* 16(4): 451-460

Machin, A. 2008. Why handaxes just aren't that sexy: a response to Kohn and Mithen. *Antiquity* 82(317): 761-766

Machin A., Hosfield R. & Mithen, S. 2006. Why are some handaxes symmetrical? Testing the influence of handaxe morphology in butchery effectiveness. *Journal of Archaeological Science* 34(6): 883-893

Maguire, B. 1980. The potential vegetable dietary of Plio-Pleistocene hominids at Makapansgat. *Palaeontologia Africana* 23: 69

Maguire, J. M. 1998. *Makapansgat. A Guide to the Palaeontological and Archaeological Sites of the Makapansgat Valley.* Excursion Guide for the 1998 Dual Congress of the International Association for the Study of *Human Palaeontology and the International Association of Human Biologists. Sun City. Northern Province.*

Maguire, J.M. 2009. An overview of the physical setting of Makapan. In: McNabb, J. & Sinclair, A. (eds) *The Cave of Hearths: Makapan Middle Pleistocene Research Project: Field Research by Anthony Sinclair and Patrick Quinney, 1996-2001*: 30-48. University of Southampton Series in Archaeology 1. Oxford: Archaeopress

Maika, M.S. 2012. A Use-Wear analysis of gravers from Paleo-Indian archaeological sites in southern Ontario. Unpublished PhD thesis. University of Western Ontario

Malan, B. D. 1988. The Cave of Hearths an Historical Foreword. In Mason, R. (ed.) *Cave of Hearths, Makapansgat, Transvaal.* Occasional Paper 21: 9-16. Johannesburg: Archaeological Research Unit.

Malan, B.D. & Cooke, H.B.S. 1941. A preliminary account of the Wonderwerk Cave, Kuruman District. *South African Journal of Science* 37: 300-312

Malan, B.D. & Wells, L.H. 1943. A further report on the Wonderwerk Cave, Kuruman. *South African Journal of Science* 40: 258-270

Mansur-Franchomme, M.E. 1983. Traces d'utilisation et technologie lithique: exemples de la Patagonie. Unpublished PhD thesis. Université de Bordeaux I

Márquez, B., Ollé, A., Sala i Ramos, R. & Vergès, J.M. 2001. Perspectives méthodologiques de l'analyse functionelle des ensembles lithiques du Plèistocéne Inférieur et Moyen d'Atapuerca (Burgos, Espagne). *L'Anthropologie* 105(1): 281-299

Marshak, S. 2001. *Earth: Portrait of a Planet*. New York: W.W. Norton & Company, Inc.

Mason, R.J. 1961. The Acheulian Culture in South Africa. *South African Archaeological Bulletin* 16(63): 107-110

Mason, R. J. 1962. *Prehistory of the Transvaal: A Record of Human Activity.* Johannesburg: Witwatersrand University Press.

Mason, R.J. 1976. Copy of personal letter to Dr. T.C. Partridge dated 25 November 1976 entitled *Cave of Hearths Working Committee*. Housed in the University of the Witwatersrand, Division of Archaeology Archives

Mason, R.J. 1988. *Cave of Hearths: Makapansgat Transvaal.* Occasional Paper 21. Johannesburg: Archaeological Research Unit

Mathieu, J.R. & Meyer, D.A. 1997. Comparing axe heads of stone, bronze, and steel: studies in experimental archaeology. *Journal of Field Archaeology* 24(3): 333-351

Matmon, A., Ron, H., Chazan, M., Porat, N., & Horwitz, L.K. 2012. Reconstructing the history of sediment deposition in caves: a case study from Wonderwerk Cave, South Africa. *Geological Society of America Bulletin* 124(3-4): 611-625

McBrearty, S. 1988. The Sangoan-Lupemban and Middle Stone Age sequence at the Muguruk site, western Kenya. *World Archaeology* 19(3): 388-420

McBrearty, S., Bishop, L., Plummer, T., Dewar, R., & Conard, N. 1998. Tools underfoot: human trampling as an agent of lithic artifact edge modification. *American Antiquity* 63(1): 108-129

McCall, G.S. & Whittaker, J. 2007. Handaxes still don't fly. *Lithic Technology* 32(2): 195-202

McDonald, J.H. 2014. *Handbook of Biological Statistics*. (3rd ed.) University of Delaware, Baltimore, Maryland: Sparky House Publishing.

McNabb, J. 2009. The ESA stone tool assemblage from the Cave of Hearths, beds 1-3. In: McNabb, J. & Sinclair, A. (eds) *The Cave of Hearths: Makapan Middle Pleistocene Research Project: Field Research by Anthony Sinclair and Patrick Quinney, 1996-2001*: 76-104. University of Southampton Series in Archaeology 1. Oxford: Archaeopress

McNabb, J. & Sinclair, A. 2009a. An overview of the archaeological history of the Cave of Hearths and its lithic assemblages. In: McNabb, J. & Sinclair, A. (eds) *The Cave of Hearths: Makapan Middle Pleistocene Research Project: Field Research by Anthony Sinclair and Patrick Quinney, 1996-2001*: 12-28. University of Southampton Series in Archaeology 1. Oxford: Archaeopress

McNabb, J. & Sinclair, A. (eds) 2009b. *The Cave of Hearths: Makapan Middle Pleistocene Research Project: Field Research by Anthony Sinclair and Patrick Quinney, 1996-2001*. University of Southampton Series in Archaeology 1. Oxford: Archaeopress

McNabb, J., Binyon, F. & Hazelwood L. 2004. The large cutting tools from the South African Acheulean and the question of social tradition. *Current Anthropology* 45(5): 653-677

McNabb, J., Sinclair, A. & Underhill, D. 2009. Overview and broader significance of the ESA and MSA at the Cave of Hearths. In:

Meighan, C.W. 1950. Observations on the efficiency of shovel archaeology. *University of California Archaeological Survey, Reports* 7: 15-21.

Miller, G.F. 1997. How mate choice shaped human nature: a review of sexual selection and human evolution. In: Crawford, C. & Krebs, D.L. (eds) *Handbook of Evolutionary Psychology: Ideas, Issues and Applications*: 87-129. Mahwah: Lawrence Erlbaum Associates

Mithen, S. 2008. 'Whatever turns you on': a response to Anna Machin, 'Why handaxes just aren't that sexy'. *Antiquity* 82(317): 766-769

Moir, J. R. 1914. The striation of flint surfaces. *Man* 90: 177-182 Montelius, O. 1906. Kulturgeschichte Schwedens. Leipzig: E.A. Seemann

Moss, E. H. 1983a. Some comments on edge damage as a factor in functional analysis of stone artifacts. *Journal of Archaeological Science* 10(3): 231-242

Moss, E. H. 1983b. *The Functional Analysis of Flint Implements: Pincevent and Pont d'Ambon: Two Case Studies from the French Final Palaeolithic*. Oxford: BAR International Series 177

Moss, E.H. 1987. A review of “Investigating microwear polishes with blind tests”. *Journal of Archaeological Science* 14(5): 473-481

Newcomer, M. H. 1976. Spontaneous retouch. In: Baijot-Stroobants, J. & Bodart, F. (eds) *Second International Symposium on Flint, Staringia* 3: 62-64. Cambridge: Cambridge University Press

Newcomer, M.H. 1977. Experiments in upper Palaeolithic bone work. *Méthodologie appliquée à l'industrie de l'os préhistorique* 586: 293-301. Paris: CNRS.

Newcomer, M., Grace, R. & Unger-Hamilton, R. 1986. Investigating microwear polishes with blind tests. *Journal of Archaeological Science* 13(3): 203-217

Nilsson, S. 1838-1843. *Skandinaviska nordens ur-invånare.* Lund: Berlingska Boktryckeriet

Noll, P.M. 2000. Components of Acheulean lithic assemblage variability at Olorgesailie, Kenya. Unpublished PhD thesis. University of Illinois at Urbana-Champaign

Nowell, A. & Chang, M.L. 2009. The case against sexual selection as an explanation of handaxe morphology. *PalaeoAnthropology* 2009(1): 77-88

Oakley, K. 1954. Evidence of fire in South African cave deposits. *Nature* 254(4423): 261-262

O’Brien, E.M. 1981. The projectile capabilities of an Achuelian handaxe from Olorgesailie. *Current Anthropology* 22(1): 76-79

Odell, G.H. 1975. Micro-wear in perspective: a sympathetic response to Lawrence H. Keeley. *World Archaeology* 7(2): 226-240

Odell, G. H. 1977. The application of micro-wear analysis to the lithic component of an entire prehistoric settlement: methods, problems and functional reconstructions. Unpublished PhD thesis. Cambridge, MA: Harvard University.

Odell, G.H. 1979 A New improved system for the retrieval of functional information from microscopic observations of chipped stone tools. In: Hayden, B. (ed.). *Lithic Use-Wear Analysis:* 329-344. New York: Academic Press.

Odell, G. H. 1980a. Toward a more behavioral approach to archaeological lithic concentrations. *American Antiquity* 45(1): 404-431.

Odell, G. H. 1980b. Butchering with stone tools: some experimental results. *Lithic Technology* 9(2): 39-48.

Odell, G.H. 1981. The morphological express at Function Junction: searching for meaning in lithic tool types. *Journal of Anthropological Research* 37(4): 319-342

Odell, G. H. 1990. Brer Rabbit seeks true knowledge. In: Graslund, B. (ed.). *The Interpretive Possibilities of Microwear Studies*: 125-134. Uppsala: Societas Archaeologica Upsaliensis

Odell, G.H. 1996. *Stone Tools and Mobility in the Illinois Valley: From Hunter-Gatherer Camps to Agricultural Villages*. Ann Arbor: International Monographs in Prehistory

Odell, G.H. 2004. *Lithic Analysis*. New York: Klewer Academic / Plenum Publishers.

Odell, G.H. & Cowan, F. 1986. Experiments with spears and arrows on animal targets. *Journal of Field Archaeology* 13(2): 195-212

Odell, G. H., & Cowan, F. 1987. Estimating tillage effects on artifact distributions. *American Antiquity* 52(3): 456-484

Odell, G.H. & Odell-Vereecken, F. 1980. Verifying the reliability of lithic use-wear assessments by “blind tests”: the low-power approach. *Journal of Field Archaeology* 7(1): 87-120

Ogola, C. 2003. Taphonomy of the cave of hearths Acheulean bone assemblage. MSc Dissertation. The University of the Witwatersrand.

Ogola, C. 2009. The taphonomy of the Cave of Hearths Acheulean faunal assemblage. In: McNabb, J. & Sinclair, A. (eds) *The Cave of Hearths: Makapan Middle Pleistocene Research Project: Field Research by Anthony Sinclair and Patrick Quinney, 1996-2001*: 65-74. University of Southampton Series in Archaeology 1. Oxford: Archaeopress

Olausson, D.S. 1989. Starting from scratch: the history of edge-wear research from 1838 to 1978. *Lithic Technology* 9(2): 48-60

Ollé, A. & Vergès, J. M. 2003. SEM functional analysis and the mechanism of microwear formation. In: Longo, L. & Skakun, N. (eds) *Prehistoric Technology 40 Years*: *Functional Studies and the Russian Legacy:* 39-49. Oxford: BAR International Series 1783

Outram, A.K. 2008. An introduction to experimental archaeology. *World Archaeology* 40(1):1-6

Paardekooper, R. 2013. *The Value of an Archaeological Open-Air Museum is in its Use: Understanding Archaeological Open-Air Museums and their Visitors.* Leiden: Sidestone Press

Painter, T.J., 1991. Lindow man, Tollund man and other peat-bog bodies: The preservative and antimicrobial action of *Sphagnan*, a reactive glycuronoglycan with tanning and sequestering properties. *Carbohydrate Polymers* 15(2): 123-142.

Palin-Luc, T., Sellier, E., D'Errico, F. & Vanhaeran, M. 2002. Elastomer and resin replicas for SEM observation of metallic materials. *Experimental Technique* 26(3): 33-37

Pargeter, J. 2011. Assessing the macrofracture method for identifying Stone Age hunting weaponry. *Journal of Archaeological Science* 38(11): 2882-2888

Pawlik, A.F. 2002. Achuelan in Nueva Ecija? A Report from the 2001 ASP Fieldschool in Arubo, General Tinio, Nueva Ecija, Central Luzon. *Bulletin of the University of the Phirippines Archaeological Studies Program* 4(1): 1-22

Pearsall, D.M. 2000. *Paleoethnobotany: a Handbook of Procedures*. 2nd edn. San Diego: Academic Press.

Pfeiffer, L. 1912. *Die steinzeitliche Technik und ihre Beziehungen zur Gegenwart: ein Beitrag zur Gaschichte der Arbeit.* Festschrift zur XLIII algemeinen Versammlung der deutschen anthropologischen Gesellshaft Vol. 1. Jena: Gustav Fischer

Phillips, J.E. 1983. African smoking and pipes. *The Journal of African History* 24(3): 303-319

Piperno, D.R. 1984. A comparison and differentiation of phytoliths from maize and wild grasses: use of morphological criteria. *American Antiquity* 49(2): 131-144

Piperno, D.R. 1988. *Phytolith Analysis: an Archaeological and Geological Perspective.* San Diego: Academic Press

Piperno, D.R., Clary, K.H., Cooke, R.G., Ranere, A.J. & Weiland, D. 1985. Precermaic maize in central Panama: phytolith and pollen evidence. *American Anthropologist* 87(4): 871-878

Plisson, H. 1983. An application of casting techniques for observing and recording of microwear. *Lithic Technology* 12(1): 17-21

Pond, A.W. 1930. *Primitive Methods of Working Stone Based on the Experiments of Havlor F. Skavlem. The Logan Museum, Beloit College Bulletin* 2(1). Beloit: The Logan Museum.

Potts, R.B. 1989. Olorgesailie: new excavations and findings in Early and Middle Pleistocene contexts, Southern Kenya Rift Valley. *Journal of Human Evolution* 18(5): 477-484

Prior, J. & Culter, D. 1992. Trees to fuel Africa's fire: Trees are a vital source of firewood in rural Africa, but the wrong ones turn savannas into desert. *New Scientist* 1836: 35-39

Prothero, D.R. 2007. *Evolution: What the Fossils Say and Why It Matters.* New York: Columbia University Press

Quente, P. 1914. Steinzeitliche Ackerbaugeräte aus der Ostprignitz, Erdhacken und Pflüge, und ihre Schaftungsmöglichkeit. *Praehistorische Zeitschrift* 8: 180-187

Rafferty, S.M. 2002. Identification of nicotine by gas chromatography/mass spectroscopy analysis of smoking pipe residue. *Journal of Archaeological Science* 29(8): 897-907

Rots, V. 2002. Hafting traces on flint tools: possibilities and limitations of macro- and microscopic approaches. Unpublished PhD thesis. Leuven: Katholieke Universiteit

Rots, V. 2003a. Towards an understanding of hafting: the macro- and microscopic evidence. *Antiquity* 77(298): 805–815

Rots, V. 2003b. The identification of experimental microscopic hafting traces on lithic tools. In: Le Sécretariat du Congrès (ed.) *Acts of the XIVth UISPP Congress*: 47-55. Oxford: BAR International Series 1145.

Rots, V. 2004. Prehensile wear on flint tools. *Lithic Technology* 29(1): 7-32

Rots, V. 2005. Wear traces and the interpretation of stone tools. *Journal of Field Archaeology* 30 (1): 61-73

Rots, V. 2008. Hafting and raw materials from animals. Guide to the identification of hafting traces on stone tools. *Anthropozoologica* 43(1): 43-66.

Rots, V. 2009. The functional analysis of the Mousterian and Micoquian assemblages of Sesselfelsgrotte, Germany. Tool use and hafting in the European Late Middle Paleolithic. *Quartär* 56(1): 37-66

Rots, V. 2010. *Prehension and Hafting Traces on Flint Tools. A Methodology.* Leuven: Leuven University Press

Rots, V. 2013. Insights into early Middle Palaeolithic tool use and hafting in Western Europe. The functional analysis of level IIa of the early Middle Palaeolithic site of *Biache-Saint-Vaast* (France). *Journal of Archaeological Science* 40(1): 497-506.

Rots, V. & Plisson, H. 2014. Projectiles and the abuse of the use-wear method in a search for impact. *Journal of Archaeological Science* 48: 154-165

Rots, V. & van Peer, P. 2006. Early evidence of complexity in lithic economy: core-axe production, hafting and use at Late Middle Pleistocene site 8-B-11, Sai Island (Sudan). *Journal of Archaeological Science* 33(3): 360-371

Rots, V. & Williamson, B. S. 2004. Microwear and residue analyses in perspective: the contribution of ethno-archaeological evidence. *Journal of Archaeological Science* 31(9): 1287-1299

Rots, V., Pirnay, L., Baudoux, O. and Vermeersch, P.M. 2001. Experimental hafting traces: identification and characteristics. *Notae Praehistoricae* 21: 129-137

Rots, V., Pirnay, L., Pirson, P. & Baudoux, O. 2006. Blind tests shed light on possibilities and limitations for identifying stone tool prehension and hafting. *Journal of Archaeological Science* 33(7): 935-952

Rots, V., Van Peer, P. and Vermeersch, P.M. 2011. Aspects of tool production, use, and hafting in Palaeolithic assemblages from Northeast Africa. *Journal of Human Evolution* 60(5): 637-664.

Rouse, I. 1939. *Prehistory in Haiti. Yale University Publications in Anthropology 21*. New Haven: Yale University Press

Runge, F. 1996. Opal phyolithe in Pflamzen aus dem humiden und semi-airden Ostens Afrikas und ihre Bedeutung fur die Klima und Vegetationgeschichte*. Botanische Jahrbücher fur Systematik, Pflanzengeschichte und Pflanzengeographie* 118: 303-363

Sahnouni, M. & de Heinzelin, J. 1998. The site of Ain Hanech revisited: new investigations at this lower Pleistocene site in Northern Algeria. *Journal of Archaeological Science* 25(11): 1083-1101

Sahnouni, M., Rosell, J., van der Made, J., Vergès, J.P., Ollé, A., Kandi, N., Harichane, Z., Derradji, A. & Medig, M. 2013. The first evidence of cut marks and usewear traces from the Plio-Pleistocene locality of El-Kherba (Ain Hanech) Algeria: implications for early hominin subsistence activities circa 1.8 Ma. *Journal of Human Evoultion* 64(2): 137-150

Saraydar, S.C. & Shimada, I. 1971. A quantitative comparison of efficiency between a stone axe and a steel axe. *American Antiquity* 36(2): 216-217.

Saraydar, S.C. & Shimada, I. 1973. Experimental archaeology: a new outlook. *American Antiquity* 38(3): 344-350

Samson, D.R. 2006. Stones of contention: the Acheulean handaxe lethal projectile controversy. *Lithic Technology* 31(2): 127-135

Schiffer, M. B. 1979. A preliminary consideration of behavioral change. In: Renfrew, C. & Cook, K. (eds) *Transformations: Mathematical Approaches to Culture Change*: 353-368. New York: Academic Press.

Schleiden, M.J., 1849. *Principles of Scientific Botany*. London: Longman, Brown, Green and Longmans.

Schoen, F.J., Mohammed, H., Fischlschweiger, W., & Going, R.E. 1978. Objective evaluation of surface microreplication by dental impression materials. *Journal of Dental Research* 57(2): 283-290

Scott, E.C. 1982. Replica production for scanning electron microscopy: a test of materials suitable for use infield settings. *Journal of Microscopy* 125(3): 337-341

Sehested, N.F.B. 1884. *Praktiske Forsøg. Arkaeologiske Undersøgelser 1878-1881*. Copenhagen.

Semenov, S.A. 1964. *Prehistoric Technology*. London: Coray, Adams & Mackay

Sensebaugh, G. F., Wilson, A.C. & Kirk, P.L. 1971a. Protein stability in preserved biological remains I. Survival of biologically active proteins in an 8-year-old sample of dried blood. *International Journal of Biochemistry* 2(11): 545–557.

Sensebaugh, G.F., Wilson, A.C. & Kirk, P.L. 1971b. Protein stability in preserved biological remains II. Modification and aggregation of proteins in an 8-year-old sample of dried blood. *International Journal of Biochemistry* 2(11): 558–568

Serrallonga, J., Medina, V., Juan, J. & Fullola, J.M. 1999. La importancia de los frutos secos en la nutricion de los cazadores-recolectores prehistoricos. Una aproximacion interdiscplinar: dietica, etnologica, etoprimatological, arquecologica y analisis bioquimico microscopio. In: Guerci, A. (ed.) *Food and Body. From Food to Culture. From Culture to Food:* 64-75. Genoa: Erga Edizioni

Shackley, M.L. 1974. Stream abrasion of flint implements. *Nature* 248: 501-502.

Shafer, H.J. & Holloway, R.G. 1979. Organic residue analysis in determining stone tool function. In: Hayden, B. (ed.) *Lithic Use-Wear Analysis*: 385-399. New York: Academic Press.

Sharon, G. 2007. *Acheulean Large Flake Industries. Technology, Chronology, Significance.* BAR International Series 1701. Oxford: Archaeopress

Sharon, G. 2008. The impact of raw material on Acheulian large flake production. *Journal of Archaeological Science* 35(5): 1329-1344

Sharon, G. 2010. Large flake Acheulian. *Quaternary International* 223-234: 226-233

Sharon, G. 2011. Flakes crossing the straits? Entame flakes and Northern Africa–Iberia contact during the Acheulean. *African Archaeological Review* 28(2): 125-140

Shaw, T. 1960. Early smoking pipes: In Africa, Europe, and America. *The Journal of the Royal Anthropological Institute of Great Britain and Ireland* 90(2): 272-305

Shea, J. J. & Odell, G. H. 1987. Recent Developments in Lithic Use- Wear Research. Unpublished manuscript in possession of this author.

Shea, J.J., Davis, C. and Brown, K. 2001. Experimental tests of Middle Palaeolithic spear points using a calibrated crossbow. *Journal of Archaeological Science* 28(8): 807-816

Sheppard, C.J.R., Hamilton, D.K. & Cox, I.J. 1983. Optical microscopy with extended depth of field. *Proceedings of the Royal Society of London. Series A, Mathematical and Physical Sciences* 387(1792): 171-186

Sinclair, A. 2009. The MSA stone tool assemblages from the Cave of Hearths, beds 4-9. In: McNabb, J. & Sinclair, A. (eds) *The Cave of Hearths: Makapan Middle Pleistocene Research Project: Field Research by Anthony Sinclair and Patrick Quinney, 1996-2001*: 105-137. University of Southampton Series in Archaeology 1. Oxford: Archaeopress

Smith, G.V. 1891. The use of flint blades to work pine wood. *Annual Report of the Smithsonian Institution* Part 1: 601- 605.

Sobolik, K.D. 1996. Lithic organic residue analysis: an example from the Southwestern Archaic. *Journal of Field Archaeology* 23(4): 461-469

Söhnge, P.G., Visser, J.L. & van Riet Lowe, C. 1937. Geology and archaeology of the Vaal River basin. *Memoirs of the Geological Survey of South Africa No. 35.* Pretoria: Government Printer

Spurrell, F.C.J. 1884. On some Palaeolithic knapping tools and modes of using them. *Journal of the Royal Anthropological Institute* 13: 109-118

Spurrell, F.C.J. 1892. Notes on early sickles. *Archaeological Journal* 49: 53-69

Sterner, K.M. 2012. Oneota lithics: a use-wear analysis of the Crescent Bay Hunt Club assemblage from the 2004 excavations. Unpublished MSc dissertation. The University of Wisconsin-Milwaukee

Sterner-Miller, K.M., Jeske, R.J., & Shuler, S.A. 2013. Results of blood residue analysis and microwear of suspected arrow points and scraping tools from the Crescent Bay Hunt Club site (47JE904). Paper presented at the 2013 Mid-west Archaeological Conference, Columbus, Ohio

Taylor, N.J. 2009. The role of Lupemban core-axes in the hominin dispersal into the Congo basin, central Africa: a functional assessment by use-wear analysis. Unpublished PhD thesis. University of Liverpool

Thieme, H. 1997. Lower Paleolithic hunting spears from Germany. *Nature* 385(6619): 807-810

Thompson, F.H. 1954. The Roman aqueduct at Lincoln. *The Archaeological Journal* 111: 106-28

Thouveny, N. & Taieb, M. 1987. Etude plaeomagnetique des formations du Plio-Pleistocene de la region Peninj (Ouest du lac Natron Tanzanie). *Sciences Geologiques* 40(1-2): 50-62

Tobias, P.V. 1971. Human skeletal remains from the Cave of Hearths Makapansgat, Northern Transvaal. *American Journal of Physical Anthropology* 34(3): 335-367

Tommasini, M. 1886. La sablière de Ternifine. *Bulletin de la Société de Géographie et d'Archéologie de la Province d'Oran* 6: 51-52

Toth, N. & Schick, K. 1988. Lithic Use-wear. In: Tattersall, E., Delson, E., & van Couvering, J. (eds) *The Encyclopedia of Human Evolution and Prehistory*: 319-321. New York: Garland Press

Tringham, R., Cooper, G., Odell, G., Voytek, B., & Whitman, A. 1974. Experimentation in the formation of edge damage: a new approach to lithic analysis. *Journal of Field Archaeology* 1(1-2): 171-196.

Tuffreau, A., Lamotte, A. & Marcy, J-L. 1997. Land-use and site function in Acheulean site complexes of the Somme Valley. *World Archaeology* 29(2): 222-241. High Definition Archaeology: Threads Through the Past.

Turnbaugh, W.A. 1979. Calumet ceremonialism as a nativistic response. *American Antiquity* 44(4): 685-691

Tylecote, R.F. 1986. *The Prehistory of Metallurgy in the British Isles*. London: The Institute of Metals

Unger-Hamilton, R. 1984. The formation of use-wear polish on flint: Beyond the “deposit versus abrasion” controversy. *Journal of Archaeological Science* 11(1): 91-98

Underhill, D. 2011. A history of Stone Age archaeological study in South Africa. *South African Archaeological Bulletin* 66(193): 3-14

United Nations Educational, Scientific, and Cultural Organization. 1999. Report submitted to the Convention Concerning the Protection of the World Cultural and National Heritage. World Heritage Committee. Twenty-third Session in Marrakesh, Morocco, 29 November—4 December. Section VIII: 17

van Riet Lowe, C. 1937. *Annual Report No. 2.* Bureau of Archaeology. Pretoria: Government Printer

van Riet Lowe, C. 1938. The Makapan Caves. An Archaeological Note. *South African Journal of Science* 35: 371-381.

van Riet Lowe, C. 1948. Cave breccias in the Makapan Valley. In: du Toit, A.L. (ed.) *Robert Broom Commemorative Volume.* Special Publication of the Royal Society of South Africa: 127-131. Cape Town: Royal Society of South Africa

van Riet Lowe, C. 1954. The Cave of Hearths. *South African Archaeological Bulletin* 9(33): 25-29

Vaughn, P.C. 1981. Lithic microwear experimentation and the functional analyses of a Lower Magdalenian stone tool assemblage. Unpublished PhD thesis. University of Philadelphia

Vaughn, P.C. 1985. *Use-Wear Analysis of Flaked Stone Tools.* Tucson: University of Arizona Press

Vayson de Pradenne, A. 1922. L'etude des outillages en pierre. *L'Anthropologie* 32: 1-38

Vergés, J.M. 2003. Caracterització dels models d’instrumental líthic del mode 1 a partir de les dades de l’anàlisi funcional dels conjunts litotècnics d’Aïn Hanech i El-Kherba (Algèria). Monte Poggiolo i Isernia la Pineta (Itàlia). Unpubslihed PhD dissertation. Rovira i Virgili University, Spain

Von Stokar, W., 1938. Prehistoric organic remains. *Antiquity* 12: 82-86

Wadley, L. 1987. Later Stone Age Hunters and Gatherers of the Southern Transvaal: Social and Ecological Interpretations. Oxford: British Archaeological Reports

Wadley, L. & Binneman, J. 1995. Arrowheads or penknives? A microwear analysis of mid-Holocene stone segments from Jubilee Shelter, Transvaal. *South African Journal of Science* 91(3): 153-155

Wadley, L. & Langejans, G.H. 2014. Preliminary study of scrapers around combustion features in layer SS, Sibudu, 58 000 years ago. *South African Archaeological Bulletin* 69(199): 19-33

Wadley, L. & Lombard, M. 2007. Small things in perspective: the contribution of our blind tests to micro-residue studies on archaeological stone tools. *Journal of Archaeological Science* 34(6): 1001-1010.

Wadley, L. & McNabb, J. 2009. Introduction. In: McNabb, J. & Sinclair, A. (eds) *The Cave of Hearths: Makapan Middle Pleistocene Research Project: Field Research by Anthony Sinclair and Patrick Quinney, 1996-2001*: 1-11. University of Southampton Series in Archaeology 1. Oxford: Archaeopress

Wadley, L., Lombard, M. & Williamson, B. 2004. The first residue analysis blind tests: results and lessons learnt. J*ournal of Archaeological Science* 31(11): 1491-1501

Walden, J., Oldfield, F. & Smith, J. 1999. *Environmental Magnetism: a Practical Guide. Technical Guide No. 6.* London: Quaternary Research Association

Warren, S.H. 1914. The experimental investigation of flint fracture and its application to problems of human implements. *Journal of the Royal Anthropological Institute* 44: 412-450

Wedel, W. 1959. *An Introduction to Kansas Archaeology. Bureau of American Ethnology Bulletin Number 174*. Washington D.C.: Smithsonian Institution

Weiss, P. 2003. Pictures only a computer could love. *Science News* 163(13): 200-202

Wells, H.G. 1951. *The Outline of History: Being a Plain History of Life and Mankind.* Book 1 Revised Edition. Revised by Postgate, R. Watford: Taylor Garnett Evans & Co. Ltd.

Wells, L.H. 1952. Fossil Man in Southern Africa. *Man* 52(3): 36-37.

White, M.J. 1998. On the significance of Acheulian biface variability in southern Britain. *Proceedings of the Prehistoric Society* 64(1): 15-44

Whittaker, J.C. & McCall, G. 2001. Handaxe-hurling hominids: an unlikely story. *Current Anthropology* 42(4): 566-572

Wilkins, J. & Chazan, M. 2012. Blade production ~500 thousand years ago at Kathu Pan 1, South Africa: support for a multiple origins hypothesis for Early Middle Pleistocene blade technologies. *Journal of Archaeological Science* 39(6): 1883-1900

Wilkins, J., Schoville, B.J., Brown, K.S. & Chazan, M. 2012. Evidence for early hafted hunting technology. *Nature* 338(6109): 942-946

Wilkins, J., Schoville, B.J., Brown, K.S. & Chazan, M. 2015. Kathu Pan 1 points and the assemblage-scale, probabilistic approach: a response to Rots and Plisson, “Projectiles and the abuse of the use-wear method in a search for impact”. *Journal of Archaeological Science* 54: 294-299

Willey, G.R. 1953. *Prehistoric Settlement Patterns in the Viru Valley, Peru*. *Bulletin of the Bureau of American Ethnology 155.* Washington D.C.: Smithsonian Institution

Wurz, S. 2014. Technological trends in the Middle Stone Age of South Africa between MIS 7 and MIS 3. *Current Anthropology* 54(S8): S305-S319.

Xhuauflair, H & Pawlik, A. 2010. Usewear and residue analysis: contribution to the study of the lithic industry from Tabon Cave, Palawan, Philippines. *Museologia Scientifica e Naturalistica* 6: 147-154

Young, D. & Bamforth, D.B. 1990. On the macroscopic Identification of used flakes. *American Antiquity* 55(2): 403-440

Zahavi, A. 1975. Mate selection: a selection of handicap. *Journal of Theoretical Biology* 53(1): 205-214

Zahavi, A. & Zahavi, A. 1997. *The Handicap Principle.* New York: Oxford University Press

Zutovski, K & Barkai, R. 2015. The use of elephant bones for making Acheulian handaxes: a fresh look at old bones. *Quaternary International* doi:10.1016/j.quaint.2015.01.033

# “So long and thanks for all the fish!”