Analysis of lithic artefact microdebitage for chronological determination of archaeological sites

George J. Susino
University of Wollongong

Recommended Citation

Unless otherwise indicated, the views expressed in this thesis are those of the author and do not necessarily represent the views of the University of Wollongong.
Analysis of Lithic Artefact Microdebitage for Chronological Determination of Archaeological Sites

This research is supported and partly funded by:
The University of Wollongong (School of Earth and Environmental Sciences, GeoQuEST Research Centre), The Flinders University of South Australia (Flinders Institute for Research in Science and Technology, Flinders Institute for Research in Society and Culture), The University of Sydney (Division of Geography, Australian Key Centre for Microscopy and Microanalysis, Electron Microscopy Unit), The Australian Museum (Division of Anthropology), The Australian Institute for Aboriginal and Torres Strait Islander Studies (AIATSIS), and The University of the Witwatersrand (Rock Art Research Institute).
Analysis of Lithic Artefact Microdebitage for Chronological Determination of Archaeological Sites

George J. Susino, BA (Hons), MSc

A thesis submitted to the University of Wollongong in fulfilment of the requirements for the award of the degree of Doctor of Philosophy in the School of Earth and Environmental Sciences.

2004
In memory of
Malcolm John Head
1943-2003
mentor and friend

© 2004
George J. Susino
School of Earth and Environmental Sciences
University of Wollongong, NSW 2522
Australia


Keywords: Optically stimulated luminescence; Artefacts age determination; Archaeological deposits; Sedimentation; Microdebitage analysis; Quartz surface textures.

Copyright in relation to this thesis*

Under the Copyright Act 1968 (several provisions of which are referred to below), this thesis must be used only under the normal conditions of scholarly fair dealing for the purpose of research, criticism or review. In particular no results or conclusions should be extracted from it, nor should it be copied or closely paraphrased in whole or in part without the written consent of the author. Proper written acknowledgement should be made for any assistance obtained from this thesis.

Under Section 35 (2) of the Copyright Act 1968, ‘the author of a literary, dramatic, musical or artistic work is the owner of any copyright subsisting in the work’. By virtue of Section 32 (1) copyright ‘subsists in an original literary, dramatic, musical or artistic work that is unpublished’ and of which the author was an Australian citizen, an Australian protected person or a person resident in Australia.

The Act, by Section 36 (1) provides: ‘Subject to this Act, the copyright in a literary, dramatic, musical or artistic work is infringed by a person who, not being the owner of the copyright, does in Australia, or authorises the doing in Australia of any act comprised in the copyright’.

Section 31 (1) (a) (l) provides that copyright includes the exclusive right to ‘reproduce the work in a material form’. Thus, copyright is infringed by a person who, not being the owner of the copyright and without the licence of the owner of the copyright, reproduces or authorises the reproduction of a work, or of more than a reasonable part of the work, in any material form, unless the reproduction is a ‘fair dealing’ with the work ‘for the purpose of research or study’ as further defined in Section 40 and 41 of the Act.

Section 51(2) provides that “Where a manuscript, or a copy, of a thesis or other similar literary work that has not been published is kept in a library of a university or other similar institution or in an archives, the copyright in the thesis or other work is not infringed by the making of a copy by or on behalf of the officer in charge of the library or archives if the copy is supplied to a person who satisfies an authorised officer of the library or archives that requires the copy for the purpose of research or study”

* ‘Thesis’ includes ‘treatise’, ‘dissertation’ and other similar productions
Abstract

This study explores the use of several different techniques to isolate and determine the age of lithic microdebitage in relation to archaeological deposits and associated sediments. Quartz microdebitage was identified on the basis of surface features and roundness index by applying scanning electron microscopy (SEM) and optical stereomicroscopy to archaeologically relevant sediments. Characteristics of the quartz microdebitage were compared with quartz grains from the same sedimentary layer. The observation of diagnostic features on quartz grains made it possible to discriminate between microdebitage and sedimentary background.

This investigation has established that microdebitage particles under 500 µm diameter are not easily resolved under optical stereomicroscopy, requiring the aid of SEM to discern between microdebitage and sedimentary quartz. It was also ascertained that no adverse effects on the optically stimulated luminescence (OSL) signal are measurable after exposure to SEM, provided that the electron beam is kept at, or under, 10 keV.

Sedimentary material previously excavated from the Jinmium rockshelter (Northern Territory) and Mushroom Rock West (Queensland) was used to determine the age of quartz microdebitage from the archaeological layers by applying the OSL dating technique. The microdebitage OSL signal behaves similarly to that of sedimentary quartz grains, and is subject to the same problems. The OSL single-aliquot regenerative-dose protocol (SAR) was successfully applied to the age determination of microdebitage. The modifications used for the dose rate (due to particle size and shape) and for the calibration of the beta source (due to particle size) did not produce any inconsistencies or anomalous results. In the investigation of two archaeologically relevant sediment layers from the Jinmium rockshelter deposit, the minimum OSL age at 68 cm depth for the microdebitage was estimated as 4100 ± 900 years (12,600 ± 4000 years using the central age model estimate, with 73% over-dispersion on the palaeodose), and, for the sedimentary material, a central age model of 5300 ± 800 years (with a minimum age model estimate of 1900 ± 400 years, and, 78% over-dispersion). At 115 cm in the deposit, the OSL central age model estimate for the microdebitage is 10,200 ± 1100 years, with a minimum age model of 4500 ± 600 years (and an over-
dispersion of 56%). In the case study of Mushroom Rock West rockshelter, the OSL central age model estimate for microdebitage at 268 cm depth into the archaeological deposit is 21,200 ± 3100 years (with a minimum age model estimate of 10,500 ± 5200 years, and 60% over-dispersion), compared to a central age model estimate for the sedimentary quartz grains of 31,500 ± 3100 years (with a minimum age model estimate of 11,100 ± 1500 years, and 67% over-dispersion). For the archaeological layer situated at 441 cm depth, the microdebitage yielded an OSL age of 27,400 ± 2200 years. This sample of microdebitage produced the lowest over-dispersion (0.1%) on the palaeodose of any of the samples analysed, lending confidence to the accuracy of the palaeodose determination. The sedimentary quartz from the same sample produced an OSL minimum age model estimate of 33,500 ± 5600 years (and a central age model estimate of 46,900 ±3400 years). Relationships between microdebitage and sediment OSL ages are discussed.

Direct OSL dating of the unheated quartz derived from the manufacture of lithic tools now provides an alternative to the reliance on sedimentary quartz as the primary source information regarding the age of archaeological deposits. This knowledge may be applied also to archaeological sediments previously excavated, for identifying episodes of lithic manufacture in temporal relation to other evidence of cultural activity. The ages of the two archaeological sites analysed differ widely, and this difference was also represented in the ages obtained from the microdebitage. None of the OSL age determinations of microdebitage was found to be unrealistically outside the boundaries of pre-existing age control. This is one indication of the validity of the novel experimental approach applied here.

Certification

I, George James Susino, declare that this thesis, submitted in fulfilment of the requirements for the award of Doctor of Philosophy, in the School of Earth and Environmental Sciences at the University of Wollongong, is wholly my own work unless otherwise referenced or acknowledged. The document has not been submitted for qualifications at any other academic institution.

George J. Susino
29th October 2004
Acknowledgements

This research thesis was made possible with the support of many individuals and organisations.

In particular, many thanks must go to my supervisors: Professor Lesley Head, Associate Professor Richard Roberts, and Associate Professor Deirdre Dragovich (School of Geosciences, University of Sydney) for their help, support and understanding. Special thanks must go to Associate Professor Mike Morwood (University of New England) for the use of material from the Mushroom Rock site, and to Dr Richard Fullagar (University of Sydney) for sharing data and the use of material from the Karlinga, Goorurarrmum and Jinmium sites. For their help and sharing their expertise: Dr Hiroyuki Yoshida and José Abrantes (Luminescence Dating Laboratory, University of Wollongong); Research Fellow Dr M. John Head, Mr David Carrie and Mr David Price (School of Geosciences, University of Wollongong); Mr Nelson Cano (School of Geosciences, University of Sydney); Dr Marion Stevens-Kalceff (University of New South Wales Electron Microscope Unit), and Ms Ghildaen Laue and Dr Benjamin Smith (The University of the Witwatersrand, Rock Art Research Institute).

I am also indebted to Dr Paul Taçon (Australian Museum); Dr Graeme Ward (AIATSIS); Dr Ian Kaplin and Mr Tony Romeo (Electron Microscope Unit, University of Sydney); Badger Bates (Mutawintji Local Aboriginal Land Council) and Dr Dan Witter (National Parks and Wildlife Service, Broken Hill, NSW) who helped with the original research. To these, and many others, go my gratitude for their encouragement and for their help in editing and revising the thesis. Special thanks must also go to Associate Professor Donald Pate and Dr Claire Smith, who supervised me, in the early stages of this thesis, in the Department of Archaeology at Flinders University, South Australia.

Many thanks must go to my wife Margot, for her help, support, and understanding during our time apart.

An Australian Postgraduate Award with stipend from the Department of Employment, Education, and Training financially supported this research.
# Table of Contents

Abstract iv  
Certification v  
Acknowledgements vi  
Table of Contents vii  
Tables x  
Figures xii  
Abbreviations and acronyms xvi  

Chapter one

*Introduction and research objectives*

1.1. Aims of this research 4  
1.2. Background to theory and methods 5  
1.2.1 Relationship between sediments and artefacts in archaeology 6  
1.2.2 Debates in the archaeology of human colonisation in Australia 10  
1.3 Thesis outline 12  

Chapter two

*Review of analytical methods and experimental techniques*

2.1 Developments in microdebitage identification 15  
2.2 Quartz grain surface textures and microdebitage 18  
2.3 Scanning electron microscopy and energy dispersive x-ray analysis 23  
2.4 Application of roundness index to sedimentary material 25  
2.5 Luminescence dating: general principles and techniques 26  
2.5.1 Optically stimulated luminescence and archaeology 28  
2.5.2 Single-aliquot regenerative-dose (SAR) protocol 32  
2.6 The SAR protocol and age determination of microdebitage 39  
2.7 Research into combining methods and techniques 43
Chapter three

Experimentation and validation of methods and techniques

3.1 Application of SEM/EDAX to microdebitage analysis
   3.1.1 Goorurarmum 2 rockshelter, microdebitage analysis
   3.1.2 Karlinga 1 rockshelter, microdebitage analysis
   3.1.3 Testing microdebitage recognition

3.2 Application of optical stereomicroscopy to microdebitage analysis
   3.2.1 Optical stereomicroscope (operator variance) tests
   3.2.2 Optical stereomicroscopy under red illumination
   3.2.3 Testing for luminescence signal in microdebitage

3.3 Application of OSL dating techniques to quartz microdebitage
   3.3.1 Test 1. Dose recovery from quartz after exposure to SEM
   3.3.2 Test 2. Dose recovery from sediment after exposure to SEM
   3.3.3 OSL chronological determination of microdebitage

3.4 Case studies and the reasons for choosing them

Chapter four

Case study 1, Jinmium, Keep River, Northern Territory

4.1 General description of the archaeological site
   4.1.1 Jinmium rockshelter age determination

4.2 Methods applied to this case study

4.3 Jinmium COOR 7/1(C1/III south) sample analysis
   4.3.1 Optical age of microdebitage particles
   4.3.2 Discussion of sample COOR 7/1

4.4 Jinmium COOR 1/3 (C1/III north) sample analysis
   4.4.1 Optical age of sedimentary quartz grains
   4.4.2 Optical age of microdebitage particles
   4.4.3 Discussion of sample COOR 1/3

4.5 Synthesis and discussion of the Jinmium case study
Chapter five

Case study 2, Mushroom Rock, Laura River, Queensland

5.1 General description of the archaeological site

5.1.1 Mushroom Rock West age determination

5.2 Methods applied to this case study

5.3 Laura 15 sample analysis

5.3.1 Optical age of microdebitage (250-500 µm)

5.3.2 Optical age of microdebitage (500-1000 µm)

5.3.3 Optical age of sedimentary quartz (250-500 µm)

5.3.4 Optical age of laboratory sediment sample WGO171B

5.3.5 Discussion of sample Laura 15

5.4 Laura 18 sample analysis

5.4.1 Optical age of sedimentary quartz grains (90-125 µm)

5.4.2 Optical age of microdebitage particles (250-500 µm)

5.4.3 Discussion of sample Laura 18

5.5 Synthesis and discussion of the Mushroom Rock West case study

Chapter six

Conclusions and further considerations

6.1 Discussion of results from the case studies

6.1.1 Microdebitage analysis

6.1.2 OSL age determination

6.2 Analysis of the methodology

6.3 Evaluation of the techniques used

6.3.1 Advances and advantages of using this model

6.4 Reliability and applicability of the methods

6.5 Application of the methods to archaeological sites

6.6 Further considerations

Bibliographic references
Appendix A  Experimental microdebitage analysis  208
Appendix B  Optical stereomicroscopy blind test score sheets  218
Appendix C  Operator variance test data  223
Appendix D  Beta source dose rate correction for large grains  225
Appendix E  Notes for the use of the raw data and images CD  226

OSL raw data and SEM micrographs (Appendix E, CD-ROM)   Inside back cover

Tables

2.1. Characteristics of quartz grain surface textures (Krinsley and Donahue, 1968: 744).   21
2.2. Range of quartz grain surface textures (Helland and Holmes, 1997).   22
2.3. Quartz grain textures for provenance analysis (Moral-Cardona et al., 1996: 161).   22
2.4. General single-aliquot regenerative-dose (SAR) protocol (Murray and Wintle, 2000).   33
2.5. Single-Aliquot Regenerative-dose (SAR) protocol sequence used in this research.   33
2.6. Evaluation of the annual alpha, beta and gamma doses from U, Th, and K.   40
2.7. Beta dose attenuation factors for $^{238}$U, $^{232}$Th, and $^{40}$K.   40
2.8. Visual comparison chart roundness classes, range, and mean index (Powers 1953).   45
2.9. Quartz grain surface features used to distinguish microdebitage from sediments.   45
3.1. Features recognised on experimental microdebitage (Susino, 1999: 102).   53
3.2. Quartz grain surface features to distinguish microdebitage (Figure 3.3).   53
3.3. Microdebitage counts and sample weights from the excavation of Goorurarmum 2 rockshelter.   56
3.4. Microdebitage counts and sample weights from the excavation of Karlinga 1 rockshelter.   60
3.5. Samples for preparation of the test vials.   66
3.6. Grain numbers and type used in the test.   66
3.7. Surface features and roundness index used by operators.   67
3.8. Chi squared test on five operators based on two paired categories.   69
3.9. Chi squared tests on the average count for operators 1-5, two paired categories.   70
3.10. SAR sequence used for testing the extended sample light exposure under an optical stereomicroscope.   73
3.11. Equivalent dose of the samples exposed for extended time to intense red illumination.   74
3.12. Single-aliquot regenerative-dose (SAR) protocol used in this test.   77
3.13. Testing the palaeodose on sediment and microdebitage from Laura 15 Disc 1.   78
3.15. Depth of electron penetration in quartz (Andersen and Wittry, 1968).
3.16. OSL dose recovery samples and SEM conditions of exposure.
3.17. Single-aliquot regenerative-dose (SAR) protocol used in this test.
3.18. SAR protocol sequence used for recording the natural signal.
3.20. Results of the OSL dose recovery test after exposure to SEM.
4.1. Previous age determinations of the Jinmium rockshelter (C1/III) sediments.
4.2. Radionuclide activities and dose rates (Roberts et al., 1998: 361).
4.3. Beta-dose attenuation factors (after Fain et al., 1999: 233).
4.4. Previously published OSL ages for the two samples from Jinmium rockshelter.
4.5. SAR protocol sequence used in this case study for recording the natural signal from microdebitage and sedimentary quartz.
4.6. Single-aliquot regenerative-dose (SAR) protocol used in this case study for all the sediment analysed and for the microdebitage from COOR 1/3.
4.7. Single-aliquot regenerative-dose (SAR) protocol used the analysis of microdebitage.
4.8. Palaeodose and recycling ratio for the 39 particles of microdebitage analysed.
4.9. Palaeodose, dose-rate and OSL age of Jinmium COOR 7/1 microdebitage.
4.10. Palaeodose and recycling ratio for the 33 grains of sediment analysed.
4.11. Palaeodose and OSL dating of the Jinmium COOR 1/3 sediment at 68cm.
4.13. Palaeodose and OSL age of the Jinmium COOR 1/3 microdebitage.
4.14. OSL ages obtained in this research compared with those published previously.
4.15. Previous age determinations of the Jinmium rockshelter (C1/III) archaeological deposit in comparison with the results of this research.
4.16. Comparison of results from this case study with TL, OSL and radiocarbon ages in other areas of the Jinmium archaeological site.
5.1. Age determination of Mushroom Rock West sediments derived from previous studies.
5.2. Mushroom Rock West radionuclide activities.
5.3. SAR protocol used for palaeodose determination of Laura 15 and 18 samples.
5.4. Palaeodoses and recycling ratios, microdebitage Laura 15, (250-500 µm).
5.5. Age determination of Laura 15 microdebitage (250-500 µm diameter fraction).
5.6. Palaeodoses and recycling ratios for the 8 particles of microdebitage analysed.
5.7. Age determination of Laura 15 microdebitage (500-1000 µm in diameter).
5.8. Palaeodoses and recycling ratios for the 39 grains of sediment retained after analysis.
5.9. Age determination of Laura 15 sediment sample (250-500 µm).
5.10. SAR protocol used for palaeodose determination of the WG0171B sample.
5.11. Palaeodoses and recycling ratios for the 22 aliquots of sediment analysed.
5.12. Age determination of Laura 15 sediment sample WG0171B (90-125 µm).
5.13. OSL age determinations of the Laura 15 sediment and microdebitage.
5.15. Age determination of Laura 18 sediment sample (90-125 µm).
5.16. Palaeodoses and recycling ratios for the 26 particles of microdebitage analysed.
5.17. Age determination of Laura 18 microdebitage sample (250-500 µm).
5.18. OSL age determination of the Laura 18 sediment and microdebitage.
5.19. Previous age determinations programme of the Mushroom Rock West archaeological deposit compared with the OSL ages from this research.

Figures

1.1. The methodology and techniques used in this research to meet the objectives. 5
2.1. Experimental microdebitage from the manufacture of rock engravings on Mootwingee sandstone, Broken Hill, NSW. 20
2.2. General differences between sedimentary materials. 23
2.3. Visual comparison chart for Powers’ roundness index (Briggs, 1977: 120). 26
2.4. Representation of the energy band model of a crystalline solid and OSL/TL production (modified from Aitken, 1999: 1348).
2.5. Graphic representation of the luminescence model (from Aitken, 1999: 1349). 29
2.6. Typical SAR sequence. 34
2.7. Stainless steel discs set on the turntable for the Risø TL-OSL-DA-15 reader. 35
2.8. The Risø TL/OSL System TL-DA-15, the OSL reader used in this research. 35
2.9. General schematic of an automated Risø TL/OSL reader (from Aitken, 1999). 36
2.10. Luminescent grain; typical quartz grain test dose OSL signal. 37
2.11. ‘Dead grain’: no OSL signal is induced by the test dose. 37
2.12. Beta dose absorption as a function of depth of material with a density of 2.7 g/cm³. 41
2.13. Average beta dose absorption factors for grains larger than 100-200 µm, plotted at the mid-points of the 100 µm-wide grain size intervals. 42
2.14. SEM micrograph composite image for Powers’ roundness index analysis. 44
2.15. Surface textures of microdebitage. 46
2.16. SEM micrograph of (a) quartz microdebitage and (b) sedimentary quartz derived from the sedimentary deposit of Malakunanja II, an archaeological site in the Alligator Rivers Region, Northern Territory, Australia. 46
2.17. Typical EDAX spectrum analysis for quartz grain cemented in a quartzite matrix. 47
3.1. Experimental application of the methods investigated in this research. 50
3.2. Location of the Goorurarmum and Karlinga archaeological sites. 52
3.3. Criteria for microdebitage identification. 54
3.4. Example of composite SEM image of sedimentary material from the archaeological deposit of Goorurarmum 2 rockshelter. 55
3.5. Goorurarmum 2, spit 1. Left, quartz microdebitage particle. Right, conchoidal...
fractures.


3.8. Diagram showing the distribution of raw material of complete flakes for each spit of the Goorurarmum 2 rockshelter (from Boer-Mah, 2002: 63).

3.9. Example of composite SEM image of sedimentary material from the archaeological deposit of Karlinga 1 rockshelter, used for roundness index analysis.

3.10. Sample of sandstone from the Karlinga 1 rockshelter.

3.11. Microdebitage from Karl-1 spit 4 at 9 cm; this material is consistent with surface parent sandstone material at the site.

3.12 Microdebitage from Karl-1 spit 6 at 15 cm; this material is consistent with the parent sandstone.

3.13. Karl-1 spit 1 at 2 cm; quartz microdebitage with features described in Table 3.2.

3.14. Karl-1 spit 11 at 33 cm; quartzite microdebitage with features described in Table 3.2.

3.15. Results of the test. Total grains counted by angularity and roundness.

3.16. Total counts by angular form (blue) and rounded form (red) for each operator.


3.18. Representation of the light test samples on the plane of the microscope under red illumination.

3.19. SAR protocol regeneration sequence; the double regeneration target dose is 25 Gy.

3.20. Decay curves of the regeneration sequence for all samples.

3.21. Radial plots: Equivalent doses (left) and recycling ratios (right).

3.22. The OSL 100 single-grain aluminium discs used in combination with the TL-OSL DA-15 Reader’s single grain facility.

3.23. Surface SEM micrograph of a single grain well.

3.24. Radial plots of all particles used in the palaeodose test.

3.25. Example of quartzite microdebitage from Jinmium rockshelter.

3.26. Uncoated grains exposed to the SEM electron beam.

3.27. Recovered dose, electron voltage, and time of exposure in three dimensions.

3.28. Dose recovery test 1, radial plots.

3.29. Graph showing the recovered dose and standard error of each set of aliquots (with inset histogram).

3.30. SEM micrographs of quartz grains exposed to a beta dose of 20 Gy for OSL dose recovery test.

3.31. Radial plots, dose recovery test 2.

4.1. Location of Jinmium Rockshelter (C1), Northern Territory, Australia.

4.2. Jinmium rockshelter (C1) during the 1993 archaeological excavation.

4.3. Jinmium archaeological site plan (image from Fullagar et al., 1996: 754).

4.4. Stratigraphic sections of the archaeological deposit at Jinmium, C1 rockshelter.

4.5. Methods used for the analysis and age determination of COOR 7/1 microdebitage.

4.6. Jinmium COOR 7/1 sediment. Composite SEM micrograph used for roundness index analysis.
4.7. Jinmium COOR 7/1 quartz microdebitage and surface conchoidal fractures.
109
4.8. Jinmium COOR 7/1, natural sedimentary particle. Surface features consistent with environmental diagenesis.
109
4.9. Dose-response (above) and decay curves (below) for 3 microdebitage particles analysed (Carousel 2) from sample COOR 7/1.
112
4.10. Radial plots showing the central age model palaeodose and recycling ratios for sample COOR 7/1 microdebitage.
112
4.11. Frequency distribution of the COOR 7/1 microdebitage palaeodoses (Gy).
113
114
4.13. Methods used for the analysis and age determination of COOR 1/3 microdebitage and sediment.
118
119
4.15. Dose-response and decay curves for 3 sedimentary quartz grains analysed
120
4.16. COOR 1/3 sediment; palaeodose (left) and recycling ratio (right).
121
4.17. Frequency distribution of the palaeodoses for the COOR 1/3 sediment (Gy).
121
4.18. Radial plots comparing COOR 1/3 palaeodoses with previously published data.
122
4.19. Multiple- aliquot additive-dose results for COOR1/3 reported by Roberts et al. (1999: 370).
123
4.20. COOR 1/3 quartzite microdebitage, SEM micrographs.
124
4.21. COOR 1/3 quartz microdebitage, SEM micrographs.
124
4.22. COOR 1/3, quartz microdebitage, SEM micrographs.
125
4.23. Dose-response and decay curves for the five microdebitage particles analysed.
126
4.24. COOR 1/3 microdebitage central age model palaeodose and recycling ratios.
127
4.25. Frequency distribution of the palaeodoses from COOR 1/3 microdebitage particles.
128
4.26. Radial plots of the palaeodoses for COOR 1/3
129
4.27. SEM micrograph of quartzite microdebitage from Jinmium COOR 1/3 sample.
133
4.28. Age-depth graph of the TL age determinations and the results of this case study.
135
4.29. Radial plots. Left, COOR 1/3 sediment palaeodose. Right, same without the largest and most precise palaeodose estimate.
136
4.30. Radial plots. Left, COOR 1/3 microdebitage. Right, same with the largest and most precise palaeodose point removed.
137
5.1. Laura region, S.E. Queensland, Australia.
142
143
143
5.4. Diagram of the Mushroom Rock West archaeological deposit, including the 1991 and 1994 excavations (diagram courtesy of Richard Roberts and Mike Morwood).
144
5.5. Methods used for the analysis and OSL age determination of Laura 15 sample.
148
5.6. SEM composite micrograph of Laura 15 sediment used for roundness index analysis.
149
5.7. Examples of HF dissolution on quartz microdebitage.
150
5.8. Examples of HF dissolution on quartzite microdebitage.
150
5.9. Dose-response (above) and decay curves (below) for 3 microdebitage particles analysed from sample Laura 15 microdebitage.
152
5.10. Laura15 microdebitage, the radial plot on the left shows the central age model palaeodose, the one on the right, the recycling ratio for the SAR double-regeneration dose.

5.11. Histogram showing the palaeodose distribution of all the microdebitage particles in the sample.

5.12. Dose-response (above) and decay curves (below) for the 8 microdebitage particles analysed.

5.13. Radial plots for Laura 15, 500-1000 µm diameter microdebitage particles.

5.14. Histogram showing the palaeodose distribution of the 8 microdebitage particles analysed.

5.15. Dose-response and decay curves for 3 sedimentary quartz grains analysed.

5.16. Radial plots for Laura 15 sediments, 250-500 µm diameter grains.

5.17. Histogram showing the palaeodose distribution for each grain. Laura15 sediment.

5.18. Dose-response and decay curves for 3 of the aliquots analysed.

5.19. Radial plots of Laura 15 sedimentary quartz grains (Sample WG0171B).

5.20. Histogram showing the palaeodose distribution of the 22 aliquots of Laura15 sedimentary grains (sample WG0171B).

5.21. Radial plots showing the comparison between the palaeodoses of microdebitage and sediment.

5.22. Laura 15, OSL age determination.

5.23. Methods used for the analysis and age determination of the Laura 18 sample.

5.24. Laura 18 sedimentary material used for roundness index analysis.

5.25. Dose-response and decay curves for 3 sedimentary quartz grains analysed.


5.27. Histogram showing the palaeodose distribution for 135 grains of Laura 18 sediment.

5.28. Dose-response and decay curves for 3 of the 26 microdebitage particles analysed.

5.29. Laura18 microdebitage particles. The radial plot on the left shows the palaeodose, the one on the right, the recycling ratio for the SAR double regeneration dose.

5.30. Laura18 microdebitage, 250-500 µm particles. Histogram showing the palaeodose distribution for each grain.

5.31. Radial plots of Laura 18 comparison of sediment and microdebitage palaeodoses.

5.32. Plot of all the OSL against the depth of the stratigraphy. Laura 18.

5.33. Mushroom Rock West: OSL ages of microdebitage and sediment compared with previous age determinations.
# Abbreviations and acronyms

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>$^{14}$C</td>
<td>Conventional radiocarbon dating technique</td>
</tr>
<tr>
<td>Al</td>
<td>Aluminium</td>
</tr>
<tr>
<td>AMS</td>
<td>Accelerator mass spectrometry (radiocarbon technique)</td>
</tr>
<tr>
<td>Au</td>
<td>Gold</td>
</tr>
<tr>
<td>BP</td>
<td>Before Present (A.D. 1950)</td>
</tr>
<tr>
<td>Bq</td>
<td>Becquerels (1 Bq = 1 disintegration/s$^{-1}$)</td>
</tr>
<tr>
<td>CRM</td>
<td>Cultural resources management</td>
</tr>
<tr>
<td>$D_0$</td>
<td>No dose given</td>
</tr>
<tr>
<td>$D_e$</td>
<td>Equivalent dose (Palaeodose)</td>
</tr>
<tr>
<td>$D_i$</td>
<td>Given dose</td>
</tr>
<tr>
<td>$D_n$</td>
<td>Natural dose (also ‘N’)</td>
</tr>
<tr>
<td>$D_R$</td>
<td>Dose rate</td>
</tr>
<tr>
<td>DRT</td>
<td>Dose recovery test</td>
</tr>
<tr>
<td>$D_t$</td>
<td>Test dose</td>
</tr>
<tr>
<td>EDAX</td>
<td>Energy dispersive x-ray analysis</td>
</tr>
<tr>
<td>ESEM</td>
<td>Environmental SEM</td>
</tr>
<tr>
<td>Gy</td>
<td>Grays (1 Gy = 1 J Kg$^{-1}$)</td>
</tr>
<tr>
<td>HCl</td>
<td>Hydrochloric acid</td>
</tr>
<tr>
<td>HF</td>
<td>Hydrofluoric acid</td>
</tr>
<tr>
<td>J</td>
<td>Joules</td>
</tr>
<tr>
<td>K</td>
<td>Potassium</td>
</tr>
<tr>
<td>ka</td>
<td>Thousand years</td>
</tr>
<tr>
<td>keV</td>
<td>Kilo-electron volts (SEM electron beam intensity measurement)</td>
</tr>
<tr>
<td>LED</td>
<td>Light emitting diodes</td>
</tr>
<tr>
<td>LGM</td>
<td>Last glacial maximum</td>
</tr>
<tr>
<td>$L_i$</td>
<td>OSL signal measured</td>
</tr>
<tr>
<td>Ma</td>
<td>Million years</td>
</tr>
<tr>
<td>mb</td>
<td>Millibar (1 mb = 100 Pa)</td>
</tr>
<tr>
<td>Multiple-aliquot</td>
<td>Many grains on a single disc</td>
</tr>
<tr>
<td>OSL</td>
<td>Optically stimulated luminescence</td>
</tr>
<tr>
<td>Pb</td>
<td>Lead</td>
</tr>
<tr>
<td>PM</td>
<td>Photomultiplier tube</td>
</tr>
<tr>
<td>Pt</td>
<td>Platinum</td>
</tr>
<tr>
<td>$R_1/R_X$</td>
<td>Double regeneration cycle ($R_1$ is the first, $R_X$ is cycle $x$)</td>
</tr>
<tr>
<td>Ra</td>
<td>Radium</td>
</tr>
<tr>
<td>Rd</td>
<td>Rubidium</td>
</tr>
<tr>
<td>Red illumination</td>
<td>Filtered red light (Lee 106 acetate filters)</td>
</tr>
<tr>
<td>$R_X$</td>
<td>Regeneration cycle ($x$ = regenerative dose no.)</td>
</tr>
<tr>
<td>SAR</td>
<td>Single-aliquot regenerative-dose protocol</td>
</tr>
<tr>
<td>SEM</td>
<td>Scanning electron microscopy</td>
</tr>
<tr>
<td>Si</td>
<td>Silica</td>
</tr>
<tr>
<td>Single-aliquot</td>
<td>100 single-grains individually analysed on one disc</td>
</tr>
<tr>
<td>Single-grain</td>
<td>One grain on a single disc.</td>
</tr>
<tr>
<td>SiO$_2$</td>
<td>Quartz</td>
</tr>
<tr>
<td>Th</td>
<td>Thorium</td>
</tr>
<tr>
<td>$T_i$</td>
<td>Test dose OSL signal</td>
</tr>
<tr>
<td>TL</td>
<td>Thermoluminescence</td>
</tr>
<tr>
<td>U</td>
<td>Uranium</td>
</tr>
<tr>
<td>Wt</td>
<td>Weight</td>
</tr>
</tbody>
</table>