2012

Archaeological science in Australia: integrating across disciplines and scales of analysis

Zenobia Jacobs
University of Wollongong, zenobia@uow.edu.au

Publication Details

Jacobs, Z. (2012). Archaeological science in Australia: integrating across disciplines and scales of analysis. In I. J. Donaldson & M. Finnane (Eds.), Taking Stock: The Humanities in Australian Life Since 1968 (pp. 230-242). Crawley, Western Australia: UWA Publishing.

Archaeological science in Australia: integrating across disciplines and scales of analysis

Abstract
The basic questions in prehistoric archaeology have not changed much over the last forty years. In Australia, we continue to debate when and where Australia and its arid interior were first colonised, and whether or not these early colonisers were responsible for the extinction of the Australian megafauna. These questions are broad and any answers involve interdisciplinary teamwork that crosses conventional academic boundaries - the humanities and sciences.

Keywords
science, archaeological, integrating, across, disciplines, scales, analysis, australia, CAS

Disciplines
Medicine and Health Sciences | Social and Behavioral Sciences

Publication Details
Jacobs, Z. (2012). Archaeological science in Australia: integrating across disciplines and scales of analysis. In I. J. Donaldson & M. Finnane (Eds.), Taking Stock: The Humanities in Australian Life Since 1968 (pp. 230-242). Crawley, Western Australia: UWA Publishing.

Archaeological science in Australia: integrating across disciplines and scales of analysis

Zenobia Jacobs

Introduction

The basic questions in prehistoric archaeology have not changed much over the last forty years. In Australia, we continue to debate when and where Australia and its arid interior were first colonised, and whether or not these early colonisers were responsible for the extinction of the Australian megafauna. These questions are broad and any answers involve interdisciplinary teamwork that crosses conventional academic boundaries – the humanities and sciences. Merrilees' 'Man the Destroyer' and Jones' 'Geographical Background to the Arrival of Man in Australia and Tasmania' already set the interdisciplinary tone forty years ago by sparking our interest in understanding how the arrival of man may have interrupted the ecology and evolutionary trajectory of the indigenous fauna and flora.[1] These sentiments were also more recently highlighted by Tim Flannery in his book *The Future Eaters*.[2] In 1971, John Mulvaney delivered a seminal paper 'Discovering Man's Place in Nature'

to the Australian Academy of the Humanities in which he also indicated the reality of the interplay between different disciplines. He said: '…archaeologists working systematically and in close interdisciplinary co-operation with both social and natural scientists have extended prehistoric frontiers into hitherto unexplored regions'.[3] Thus, almost since the beginnings of archaeology as a professional discipline in Australia, questions have been asked and answers been constructed with the help of scientific technologies and procedures, and archaeological science as a sub-discipline has been debated. Archaeology and science were, in many ways, an unhappy marriage of terms and the vigorous debating in the 1970s about defining archaeological science was to a large extent symptomatic of the genuine inner feeling of the time that archaeology was diminished or subjugated by science.[4] Nevertheless, archaeologists at the time realised the potential, and in many ways Australia, forty years ago, was at the forefront of archaeological science developments and the use of technologies to answer questions.

So, perhaps the key differences forty years later lie in how advances in technologies and procedures have given us the opportunity to answer these same questions with greater accuracy and precision, and to frame these questions in a different way, expecting to find the answer. Furthermore, it also opened up new areas of enquiry that could not have been foreseen four decades ago.

Thinking small to answer big questions

When excavating an archaeological site, its setting and contents can be likened to noise from which the archaeologist endeavours to extract a meaningful signal. Typically, the archaeologist will focus on aspects that are visible on the macroscopic scale – stone tools, food debris, art, skeletons, stratigraphy. But, a major obstacle in resolving the signal from the noise is preservation.

Only some parts of the cultural activities are preserved, obstructing the archaeologist to fully determine the meaning of ancient materials, and importantly, the order in which events have taken place.

Almost all aspects of enquiry in archaeological science over the past decade have witnessed increased miniaturisation with the focus of attention shifting from the macroscopic to the microscopic. This miniaturisation is not just a novelty, it actually helps to increase the signal to noise ratio, overcoming to some extent the perceived lack of preservation. Therefore, by combining the macro with the micro, greater accuracy in the reconstruction of the sequence of events can be achieved, which, in itself, liberates new areas of investigation. The miniaturisation trend also brought about data overload; digital technologies, therefore, play an important role through which the data overload can be analysed, and prevent it from being a significant bottleneck. Furthermore, doing smaller samples also provides a purifying element that ultimately results in more accurate and precise outcomes and greater resolution.

In the next section I will discuss four different areas of investigation in which advanced technologies and microscopic investigations are increasingly used to answer big questions. These are not exhaustive, but merely used to give a general impression of the impact and scope that the practice of archaeological science has on framing and addressing questions that will help to understand the behaviour of humans and their place in nature. A wealth of scientific methods with a plethora of possible applications in archaeological science is widely available today. Collaboration between the archaeologist and the scientist, however, is fundamental so that the research question can be framed correctly with the common archaeological goal in mind. This will ultimately ensure that the best and most appropriate analytical and measurement techniques are used. This important partnership is often overlooked when samples are collected and simply sent off for commercial analyses.

Chronology

Chronology underpins much of archaeology. Mulvaney remarked that 'Man's concept of time and his means of measuring it are crucial determinants both of his understanding of his origins and of his status in nature'.[5] When Mulvaney first made these remarks about forty years ago, the mere ability to determine the age of archaeological deposits and objects was overwhelming. Forty years later, very few archaeological excavations will proceed without independent proof of the age of the site; it is a perceived necessity.

Advances in both technologies and procedures over the last four decades have had a common goal in mind – to improve the accuracy and precision with which ages can be measured in order to determine the sequence in which events have taken place in prehistory. If ages are not comparable between different sites and locations, and not on a common timescale, then much of the resolution required to determine the order of events will be lost. Without a stringent chronology, one might be able to look at the relative timing of events at a specific site or in a local area, but correlation between sites to answer the 'big questions' requires a common time-scale.

Improved technologies allow the measurement of smaller sample sizes and ultimately the calculation of an age from the smallest measurable unit. This is a shared feature of almost all numerical dating methods used in archaeology. Forty years ago, this was not possible and in radiocarbon (14C) dating, for example, many separate fragments of charcoal had to be combined to have enough material to obtain a measurable count rate. This approach of combining fragments may have produced ages that are significantly in error, especially if younger charcoal has intruded into older deposits. A similar caveat applies to optically stimulated luminescence (OSL) dating where the conventional approach involved the simultaneous measurement of a large number of grains. If these grains have different ages,

because of mixing of older and younger sediments, an average age that may not be accurate can be obtained. Today, with accelerator mass spectrometers and improved pre-treatment procedures, individual charcoal fragments can be measured, and in OSL dating, individual grains of sand can be measured using a focused laser beam. Contamination issues can, therefore, be addressed, purer samples are measured and more accurate ages are obtained. Also, with existing instrumentation, measurements are done more efficiently and many more measurements can be made routinely to obtain a statistically significant number of measurements, which, when combined in an appropriate statistical manner, result in improved precision.

Archaeologists, of course, have been aware of the limitations of these techniques since the beginning and have come up with schemes that partly overcame the problems. One example is the 'chronometric hygiene' scheme developed by Spriggs.[6] Miniaturisation and technological advances, however, now allow for improvements in chronologies that overcome these 'after the event' assessments by doing it 'before the event' – that is, before ages are determined. This also deals with potential biases that may be introduced by such schemes.

Biomolecules and genetics

Organic residues can survive in a range of archaeological contexts including pottery, human, animal and plant remains, dyes and pigments, soils and sediments, resins and bitumen, in glass and metal containers and on stone tools. Many of these residues are invisible or amorphous, but can be exploited in biomolecular archaeology that utilises analytical chemistry techniques.

Forty years ago, the development of spectroscopic methods such as infrared, Raman and nuclear magnetic resonance spectroscopy, provided insights into *bulk* organic compositions that proved useful in 'fingerprinting' the sources of certain classes

of organic residues such as ambers and resins and their by-products, but its application can be problematic in archaeological sites. Human activities can cause mixing of biological materials (i.e. mixing food during food preparation), and the composition of the remains are often altered (i.e. heat treatment through cooking or decay during burial). To overcome these complexities, molecular-level resolution, rather than bulk measurements, is imperative. Today, this is possible as a result of developments in chromatographic and mass spectrometric technologies, a well-developed understanding of where biomarkers survive at archaeological sites and an appreciation of the major classes of biomarkers likely to be encountered.

Biomolecular archaeology thus has the ability to help answer questions that have been around for a long time. In pottery, for example, it can inform about vessel use, site and regional economies and technologies, whereas organic residues in resins and bitumen may answer questions about their botanical origins, how they were acquired and prepared and their geographical provenance. Biomolecular analyses of plant remains may also play a role in providing insights into the preservation biases that exist in the palaeobotanical record. Determining the origins of animal husbandry and crop cultivation are two areas that have hugely benefited from the use of biomarkers.[7] Evershed et al.'s study on the timing and region of the emergence of milk use and its large-scale processing in pottery vessels is one such landmark study. Although associated artefacts such as horse bridles in the archaeological record can be used to infer animal husbandry, such artefacts are rare and the association is inferential. The study of biomarkers, for the first time, provides the archaeologist with direct ways to prove certain developments. The advances are thus in being able to extend the reach of preservation and to improve the accuracy in our interpretations by overcoming issues associated with inferential versus direct evidence.

A related but different area of enquiry is archaeogenetics, a relatively new field which studies genetic ancestry using

molecular population genetics, coupled with ancient DNA analysis of archaeological specimens to blueprint the human past and the genetic legacy of human interaction with the biosphere. Classic genetic markers have been studied since the 1960s, but the breakthrough publication came when Cann, Stoneking and Wilson published their well-known 'Mitochondrial DNA and Human Evolution' paper in *Nature* in 1987.[8] Since then, through genetic studies using mitochondrial, Y-chromosome and autosome (non-sex chromosomes) DNA variations of many existing human populations, almost all our major domestic plants (e.g. wheat, rice, maize) and animals (e.g. cattle, goats, pigs, horses) have been analysed. Major leaps forward have been made in questions central to archaeology, such as the dispersal of people, the domestication and husbandry of plants and animals and the spread of agriculture.

Isotopes in humans and environments

Humans are what they eat and the evidence is captured in our bones and in our teeth. Stable light isotope analysis is one of the few methods capable of identifying events within the lives of individuals on many different scales. It can ascertain the dietary and life-history differences between individuals, between groups, and also between species. Forty years ago, the uses of light stable isotopes were not yet realised in archaeology. It came about a decade later when the first pioneering publication reported that carbon isotopes, extracted from human bone collagen, could be used to determine when maize, a domesticated crop, was first included in the diet of North Americans about AD 1000.[9] This was possible because maize is a C_4 crop and the natural environment of the area was predominantly C_3. Carbon isotopes on bones and tooth enamel has since become a standard method in the toolkit of an archaeologist, and the introduction of other domesticates, the use of marine food sources, and the amount of

protein in diets, as a proxy for meat eating and, thus, hunting, has since been explored. Stable isotope analysis is, however, still developing as a field. New isotopes are explored to target specific questions. For example, the use of δ15N is now used in studies on Neanderthal diets, to look specifically at the question of trophic level and meat consumption. Alternatives are required since conventional carbon isotope studies reveal little about their diets because the environment in which they lived was mostly a mono-isotopic C_3 environment.

Constant developments in mass spectrometry allow for continuous advances in this field. Smaller sample sizes, automated sample delivery and less destructive techniques are all currently at the forefront. For example, with laser-ablation sampling systems, high resolution transects or profiling of tooth crowns, or the dentine of roots, hold enormous potential for addressing questions about the life histories of individuals in the past. Studies have already shown that the age at which important culturally influenced biological events occur, particularly the duration of breastfeeding and the age of weaning, can be deciphered. Stable light isotopes are also used to reconstruct the environments and climates in which prehistoric people lived, thus allowing for closer inspection of the human–environment interaction. Like other methods of scientific enquiry, stable isotopes get down to the forensic level of investigation to overcome the issue of perceived lack of preservation and expand the scope of investigation that can be achieved using macroscopic approaches alone.

Excavations, data logging and archives

The moment an archaeologist starts to excavate, the method of excavation and the logging of information will dictate the resolution at which the story we want to tell will be based. No matter how advanced the scientific methods employed are, or the precision with which the ages can be determined, the resolution

of the archaeological context remains important. As a result, excavation methods have also advanced over the last forty years and have changed the way we set up an excavation, record the information and utilise the outputs in an integrated framework. These form the basis for most of the answers to the questions we try to resolve. The use of total stations in archaeological excavations to record and measure field observations are now commonplace. Typically all stone artefacts, fauna, and any other artefact or ecofact, are plotted piece-by-piece, where their 3-D coordinates are recorded with millimetre precision using a total station. Often, small paper targets will also be recorded with the total station on all plan and stratigraphic photos to allow it to be rectified and used in a GIS database. All this information is then later used to draw features and stratigraphic profiles. Obtaining all the measurements and the 3-D dimensions is relatively easy and technologies are advanced, cost-effective, and easy to come by. The challenge, however, is to connect all the recorded coordinates to the actual objects and to maintain the links throughout subsequent processing and analysis. Such connections are usually made through the use of unique identification numbers that are assigned to an object as it is excavated. In large projects, the number of objects excavated can easily amount to several thousand or hundreds of thousands of objects, resulting in long numbers that can take time to type into a computer and for which there is ample space for human error. Digital technologies in the form of barcode technology, linked to a relational database, has greatly increased both the speed and the accuracy of maintaining these vital connections, overcoming human transcription errors, and assisting in the day-to-day handling of these objects. Once the database is transferred into a GIS database, all plotted finds and any 'after the event' analytical information can be directly and visually compared at different scales. Spatial analyses of plotted finds can also be made and disturbances can be deduced from, for example, the dip and strike patterns of artefacts. All aspects

of scientific enquiry can therefore be related to each other and the excavation with relative ease. The great advantage of these approaches and the use of digital technologies in archaeological excavations is that it can collect data quickly, and these data can then be analysed simultaneously. It can result in many different forms of output that can be tailored to address specific questions. It can also be a very useful and accurate archival source.

Conclusions

All archaeological science research is interdisciplinary by nature, drawing on specialist experts from a wide range of disciplines that include, amongst others, engineering, natural sciences, physics, chemistry and spatial sciences. The involvement of these specialists is essential, as many of the investigations require a full understanding of the scientific nitty gritty associated with each method. This requires fully integrative projects with specific archaeological questions in mind. This perception was already voiced in the early 1980s when Jones, in his landmark 'Ions and Eons' paper said that 'if archaeometry is not archaeology, it is nothing'.[10] He, however, qualified this statement by adding that studies where scientific methods are used must be done correctly and must be well integrated into the field from which they came. In other words, both the archaeologist and the scientist should engage in the problem solving of the big questions being asked. This intellectual collaboration to answer the question is important, because in almost all areas where scientific methods are involved, the design of the analytical protocol is predicated on the question to be answered. The basic philosophy of the analytical program may not differ much from its application in other fields, but archaeological applications almost always come with considerable challenges because of the fragmentary nature of the material record, the anthropogenic impacts on the formation of sites and the unpredictable way in which

finds present themselves. There are many international projects, small and large, with small and big budgets, achieving this collaboration. It is often these projects that also achieve the big breakthroughs and outcomes.

But in Australia it seems that, although initially, we were at the forefront of many of the scientific developments and had the initiative, we have now lost it. This may, in part, be due to the consultancy-based approach commonly used in archaeology in this country. In many quarters, scientists are not treated as if they can address an archaeological problem. Instead, they are regarded as technicians and generally thought of as 'scientific guns for hire', as if the scientist has no interest in the problem. This has been very problematic in Australia, as is evident from 'The Bone Readers', which provides a vivid account of this 'them' and 'us' scenario.[11] On the flip side, it can also be said that scientists often develop and use techniques in search of the problem, without keeping the archaeological context and problems in mind, a danger foreseen nearly thirty years ago.[12] This dichotomy may be conquered if archaeologists do a bit more scientific training so that they can better understand the scientific perspective on the question. The opposite is, of course, also true, where it will help the scientist to obtain some archaeological training to better engage in the archaeological angle on the same question. The optimal combination would, therefore, be a team consisting of scientists that are archaeologically literate and archaeologists who are scientifically empathetic. Such conjunction of minds will result in meaningful archaeological questions being proposed, with sensible odds on achieving success, because optimal analytical protocols will be formulated.

So, how can we improve the Australian scene to increase the momentum and gain ground on becoming leaders in the field again? We have, no doubt, the archaeological and scientific expertise in this country to do it. The Premier of New South Wales in 1982 already realised the highly skilled and technological nature of archaeological science and suggested the need for a

single, centralised 'Centre of Excellence' – a so-called 'one-stop shop'.[13] Perhaps it is time to revisit this proposition, where different institutions can pool resources, strategically grow areas to create critical mass in areas currently under-represented, agree on acceptable standards and practices, and work towards cross-disciplinary training of students to overcome the disciplinary dichotomy. The offering of intensive short-courses to students, consultants and academics alike may contribute towards gaining momentum. Unless practitioners of archaeological science unify, the way we answer the same questions will change negligibly over the next forty years, despite rapid advances in technology and procedures in almost all areas of enquiry.

Notes

1 D. Merrilees, 'Man the Destroyer: Late Quaternary Changes in the Australian Marsupial Fauna', *Journal of the Royal Society of Western Australia*, vol. 51, no. 1, 1968, pp. 1–24; R. Jones, 'The Geographical Background to the Arrival of Man in Australia and Tasmania', *Archaeology and Physical Anthropology in Oceania*, vol. 3, 1968, pp. 186–215.

2 T. F. Flannery, *The Future Eaters: An Ecological History of the Australasian Lands and People*, Reed, Chatswood, NSW, 1994.

3 D. J. Mulvaney, 'Discovering Man's Place in Nature', in The Australian Academy of the Humanities, *Proceedings 1971*, Sydney University Press, Sydney, 1971, p. 52.

4 See, for example, S. Fleming, 'Scientific Measurement in Archaeology – Historical Review', in W. Ambrose and P. Duerden (eds), *Archaeometry: An Australian Perspective*, Occasional Papers in Prehistory 12, Department of Prehistory, Research School of Pacific Studies, Australian National University, Canberra, 1982, pp. 7–21; R. Jones, 'Ions and Eons: Some Thoughts on Archaeological Science and Scientific Archaeology', in W. Ambrose and P. Duerden (eds), *Archaeometry: An Australian Perspective*, pp. 22–35; and A. Anderson, 'Supertramp Science: Some Thoughts on Archaeometry and Archaeology in Oceania', in W. R. Ambrose and J. M. J. Mummery (eds), *Archaeometry: Further Australasian Studies*, Occasional Papers in Prehistory 14, Department of Prehistory, Research School of Pacific Studies, Australian National University, Canberra, 1987, pp. 3–18.

5 Mulvaney, 'Discovering Man's Place in Nature', p. 52.

6 M. Spriggs, 'The Dating of the Island Southeast Asian Neolithic: An Attempt at Chronometric Hygiene and Linguistic Correlation', *Antiquity*, vol. 63, 1989, pp. 587–613.

7 P. P. Evershed, S. Payne, A. G. Sherratt, M. S. Copley, J. Coolidge, D. Urem-Kotsu, K. Kotsakis, M. Özdoğan, A. Özdoğan, O. Nieuwenhuyse, P. M. M. G. Akkermans, D. Bailey, R. R. Andeescu, S. Cambellm, S. Farid, I. Hodder, N. Yalman, M. Özbaraşan, E. Bicakci, Y. Garfinkel, T. Levy and M. M. Burton, 'Earliest Date for Milk use in the Near East and Southeastern Europe Linked to Cattle Herding,' *Nature*, vol. 445, 2008, pp. 528–31; H. Lu, J. Zhang, K. Liu, N. Wu, Y. Li, K. Zhou, M. Ye, T. Zhang, H. Zhang, X. Yang, L. Shen, D. Xu and Q. Li, 'Earliest Domestication of Common Millet (*Panicum miliaceum*) in East Asia Extended to 10,000 Years Ago', *Proceedings of the National Academy of Sciences of the USA*, vol. 106, no. 18, 2009, pp. 7367–72.

8 R. L. Cann, M. Stoneking and A. C. Wilson, 'Mitochondrial DNA and Human Evolution', *Nature*, vol. 325, no. 6099, 1987, pp. 1–7.

9 N. J. Van der Merwe and J. C. Vogel, '13C Content of Human Collagen as a Measure of Prehistoric Diet in Woodland North America', *Nature,* vol. 276, 21 December 1978, pp. 815–16.

10 R. Jones, 'Ions and Eons: Some Thoughts on Archaeological Science and Scientific Archaeology', p. 33.

11 C. Tuniz, R. Gillespie and Cheryl Jones, *The Bone Readers: Science and Politics in Human Origins Research*, Left Coast Press, Walnut Creek, CA, 2009.

12 Fleming, 'Scientific Measurement in Archaeology'.

13 N. K. Wran, 'Foreword', in W. Ambrose and P. Duerden (eds), *Archaeometry: An Australian Perspective*, pp. 3–5.