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The archaeology of western Arnhem Land's rock art

Bruno David, Paul S.C. Taçon, Robert Gunn, Jean-Jacques Delannoy and Jean-Michel Geneste

Introduction

Western Arnhem Land, in the Top End of Australia's Northern Territory, holds a special place in the history of Australian archaeology. Over 65 years of research since the late 1940s has led to numerous rockshelters being excavated and the documentation of an astonishing array of imagery on shelter walls and ceilings (Figure 1.1). Arnhem Land's spectacular rocky landscapes, home to rare flora and fauna, hold one of the richest and longest archaeological records in Australia. To the broader world remote and rugged in its physical state, Arnhem Land was transformed over tens of thousands of years of Aboriginal settlement into sequential networks of cultural landscapes, clan estates, sacred sites and places imbued with complex history. Its rock art is amongst the richest, most diverse and visually most impressive regional assemblage anywhere in the world. Themes in recent rock art research include detailed analysis of changing subject matter, radiocarbon dating of beeswax figures, Harris Matrix sequences and excavating in deposits under painted surfaces – all further developed in this monograph.

Interest in the rock art of western Arnhem Land began with overland explorer Ludwig Leichhardt, the first person of European descent to observe and comment on some of the paintings he saw while travelling over and around the massive Arnhem Land plateau in 1845: 'A turtle was depicted very accurately on a rock with red ochre, and a fish in caves, in which the natives were accustomed to paint themselves for corrobories' (Leichhardt 1846:6).

The first scientist formally to study the Aboriginal people of western Arnhem Land was W. Baldwin Spencer. In 1912, he spent over two months at Oenpelli (now called Gunbalanya), near the East Alligator River, as a guest of buffalo shooter Paddy Cahill. Spencer was particularly interested in the art and material culture of the region, collecting and photographing many objects, including paintings on sheets of bark. Remarking on the art he viewed, Spencer commented: 'the bark and rock drawings of Kakadu, Geimbio, and Umoriu tribes represent, I think, the highest artistic level amongst Australian aboriginals with the possible exception of the Melville and Bathurst Islanders' (1914:439). He was particularly struck by the widespread distribution of rock art across the greater Oenpelli landscape:

> Up on the hill sides, among the rocks, wherever there is an overhanging shelter where the native can screen himself from the sun and rain, these drawings are certain to be found in the country of the Kakadu.

> The colours used are red, white, black and yellow. They represent the animals with which the natives come in contact, and also their ideas in regard to the nature of certain mythical and mischievous spirits. So far as the animals are concerned, it is interesting to notice that the drawings are always more or less anatomical, that is they represent not only the external form, but, to a certain extent, the internal structure. The backbone is almost always represented, as are the heart and main features of the alimentary canal (Spencer 1914:432–433).

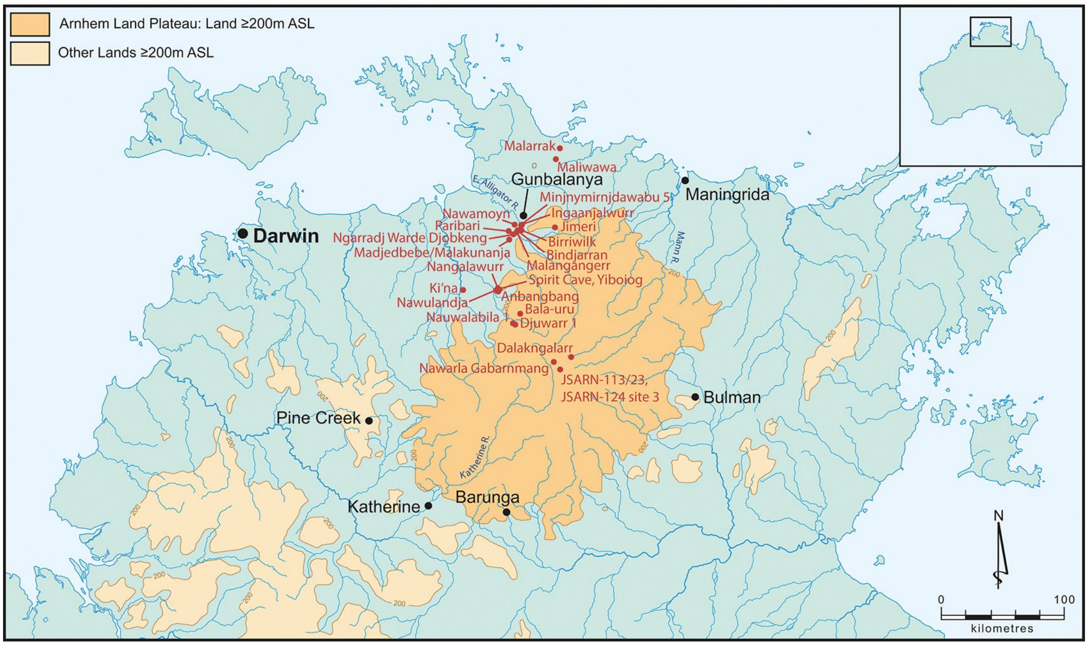

Figure 1.1 Location of excavated sites in western Arnhem Land, relative to land greater than 200 m above sea level (ASL).

Source: Map by Kara Rasmanis and Bruno David.

The 1948 National Geographic Society expedition to Arnhem Land put the art and archaeology of the region on the world map, particularly as a result of detailed rock art recording by Charles Mountford and numerous excavations by Frederick McCarthy (see May 2009). This was the first major scientific expedition with a strong archaeological focus by Australian and American scientists in Australia. Results not only led to decades of further archaeological research by others but also highlighted the potential of Arnhem Land to address major archaeological and art history questions of global concern.

Western Arnhem Land was the subject area of Carmel White's (now Schrire) doctoral research, resulting in the second PhD thesis ever produced on Australian Indigenous archaeology within Australia (White 1967), and preceded only by Isabel McBryde's 1966 study of the archaeology of the New England region of New South Wales. It was in western Arnhem Land that, dating to sometime between 18,000 ± 400 BP and 22,900 ± 1000 BP at Malangangerr, and to c. 21,450 ± 380 BP at Nawamoyn (Schrire [White] 1982:118, 143), White (1967, 1971) excavated what were then the earliest known ground-edge stone axes in the world; indeed, these artefacts represented the oldest evidence of stone grinding technology of any kind.

At the same time, Arnhem Land rock art began increasingly to capture the imagination of archaeologists both in Australia and abroad, as material evidence of intangible creativities in the Aboriginal past, eventually leading to the first PhD in Australia that focused exclusively on rock art and combined both archaeological and ethnographic investigations (see Taçon 1989). But this same body of rock art was not initially embraced as a field of study by most Australian archaeologists, in large part because at first it could not be dated, and therefore it could not be located within chronological models of the past. Eventually, tentative chronologies were developed through the presence of paintings of extinct fauna (Brandl 1972) and the attributions of faunal types in the art to particular environmental conditions of independently known, measured ages (Chaloupka 1984). These attempts achieved limited success, however, mainly because it still simply was not known how old the art was, nor quite how this could be determined.

The late 1980s saw major changes to this problem of age with the development of accelerator mass spectrometry (AMS) radiocarbon dating, which for the first time, gave archaeologists real hope of situating rock art into chronological frameworks and regional cultural histories. While these potentials were not fully carried through in western Arnhem Land – the one exception being the dating of beeswax art (e.g. see Nelson 2000) – the method gave hope, with Alan Watchman's (1987) experimental work extracting carbon trapped in micro-strata near rock surfaces showing one way by which maximum and/or minimum ages could be obtained for inorganic art. But, again, these methods have largely remained an untapped potential.

In this volume, we present the results of the most recent investigations into the archaeology of western Arnhem Land's rock art. While the recording and analysis of rock art flourished through the 1980s to the present (e.g. Chaloupka 1993; Chippindale and Taçon 1993, 1998; Lewis 1988; Taçon 1987, 1988, 1989), excavation slowed after Rhys Jones's (1985) research project in Kakadu National Park in the early 1980s (see below). After some 30 years of inactivity, a renewed phase of archaeological fieldwork involving co-ordinated survey, rock art recording and excavation programs began to flourish in different parts of Arnhem Land. As many as six independent or semi-independent projects suddenly dotted western Arnhem Land, projects that were co-ordinated from three different Australian universities and partner organisations. From 2008 onwards, projects were run by The Australian National University and Griffith University in the Wellington Range of northwest Arnhem Land, the Red Lily area near the East Alligator River and the Jabiluka Leasehold area surrounded by Kakadu National Park (see Chapters 2–8); and from 2009 onwards, by Monash University in Jawoyn Country in the southern half of the western Arnhem Land plateau (see Chapters 9–15), as well as another part of the Red Lily area (see Chapter 3).

By 2012, the multiplicity of research investigations had become more or less obvious to all of us working in the region, so we soon embarked on various attempts to collaborate, at first by making contact in the field or in the laboratory. In early 2014, these initially fruitful but limited attempts further ripened when we all decided to assemble a series of research papers into a joint publication that would showcase both Arnhem Land rock art and how we were investigating it. This was done in a spirit of enhanced collegiality, and because we realised that the research results were not only fascinating but of intellectual benefit to the Australian archaeological research community as a whole. Some of the research also has global implications.

This monograph is the outcome of this collaboration. It presents a series of results available at the time of publication by each of the research teams investigating the archaeology of rock art in various parts of western Arnhem Land.

Overdue collaborations

While these new academic collaborations may be both welcome and exciting, there lies at the heart of all these investigations an even more crucial conception of research. This is a recognition that all the places we are working in are Indigenous homelands and that for Aboriginal Traditional Owners and Custodians they are each 'Country', places of the ancestors and Spirit-Beings who imbue the art and the sites themselves with life, and areas where living Aboriginal descendants continue to care for rock art sites as at once material and numinous emplacements. All the research projects worked on here, and the results presented, were either requested by local Indigenous communities or clan members in the first place, or discussed and negotiated with the blessing and close involvement of local Aboriginal families or family members. All of us are grateful, and recognise the privilege, of having been entrusted to undertake what is in each case local family historical research into ancestral clan estates, where local Indigenous communities are the hosts and the university researchers are the guests (see McNiven and Russell 2005).

Environmental context

It has become normal, and even somewhat expected, to report on local climates, topography, geology, geomorphology and biogeography when writing about rock art sites. This is usually done to situate a site in its environmental context. Other than giving a context to the site, however, such environmental considerations are really of interest only if they enable us to better understand the art, the site or their surroundings. Examples include identifying the position and configuration of extant rock surfaces at the time the art was done; determining the antiquity of human presence; working out how regional landscapes changed with the arrival of people; exploring relationships between living fauna and faunal representations in the art, thereby allowing explorations of past symbolism; or understanding why rock paintings survived in some parts of a site but not in others. Such contextualisations of rock art, that variably take into account local Indigenous knowledge, results of archaeological excavations and geomorphological and other environmental contexts, are at the heart of this volume. Each studied site is positioned in its extant environment, and wherever possible in its past landscape setting relating to times of use and rock art creation.

The sites reported here are located in two very different environmental settings. The first corresponds with a part of Arnhem Land where the plateau meets the alluvial plains of the East Alligator River (Chapters 2–7). This plain has long acted as a sedimentary trap for flood-borne sediments, and in this it constitutes an excellent record of regional palaeoenvironments. Taking into account that the bedrock associated with local watersheds consists of very hard rocks (quartzites, hard sandstones, conglomerates rich in quartz) highly resistant to erosion, the plain's fluvial sediments tend to be more sensitive to eustatic, climatic and ecological influences than to the erosion of the rock. The floodplain's sediments are thus useful indicators of Holocene environmental dynamics associated with oscillations in climate and human land use. This has allowed researchers to determine in considerable detail what local environments were like when people occupied archaeological sites or made the art. On the other hand, here the shape of past landscapes is more difficult to determine, as landscape formations are highly variable. The contact zone between the plateau's lower slopes and the alluvial plain (see Chapters 2–5) could have had features unlike those visible today.

Against this variable and dynamic landscape in which are situated the sites discussed in the first part of this volume, are those of the second part where the morphology of the landscape has changed little over long geological time scales (Chapters 10–15). These sites are found in a very particular region at the height of the Arnhem Land plateau. This is an elevated watershed boundary zone where waters drain across all parts of the compass into a number of major hydrological basins (East Alligator River, Mann River, Katherine River). Here soft sediments are either absent or extremely shallow and initial erosional-depositional processes are very weak because there is a commensurately poor capacity to erode the headwaters' low gradient, highly resistant bedrock (quartzites, hard sandstones rich in quartz). The extreme shallowness of surface sediments and poor sediment load of waterways on the plateau has resulted in generally poor sediment build-up within waterholes, again signalling weak morphological dynamics in this particularly elevated region of the Arnhem Land plateau. Unlike the situation on the floodplains where landscape dynamics have had major impacts over much shorter time spans, here the exposed rock surfaces enable us to see how the landscape's relief has evolved over millions of years. On the one hand, this slow landscape evolution is a handicap for the study of rock art sites, as it does not allow us to say much about how the landscape has evolved, nor about details of the environment through the course of human presence. On the other hand, those limitations can be turned into an asset when looked at through a different geomorphological lens, as detailed here in the study of a number of sites from this part of the Arnhem Land plateau (Chapters 10, 11, 14 and 15). Slow natural morphogenic processes have allowed for a more detailed reading of how human engagements have impacted sites and their environments, such as the anthropic modification of rock surfaces over tens of thousands of years (Chapter 10) and the contemporaneity of earliest human occupation and commencement of aeolian mobilisation and redeposition of sands across the landscape shortly before 50,000 years ago (e.g. Jones 1985). Similarly, slow erosional and weathering processes enable researchers to distinguish relatively easily between natural and anthropic impacts on rockshelters, such as how different parts of a site have fragmented through gravitational overhang collapse, thermoclastic exfoliation, anthropic flaking and so forth. This preserved and analysable evidence enables researchers to study how the morphology of individual rockshelters has changed before, during and after human presence. It is from this potential that a chronology of geomorphological events was able to be determined for the so-called '*Genyornis*' site and its art (Chapter 15).

The diverse range of environments that sets the scene for the rock art sites discussed in this volume highlights the fact that each geomorphological context brings with it a particular set of opportunities and limitations for researching both site-specific and landscape histories. Consideration of such opportunities and limitations is a fundamental starting point for any research program relating to the long-term history of rock art sites, anywhere in the world; research undertaken needs to be commensurate with questions asked.

Western Arnhem Land's rock art: The dating dilemma

We are now well aware that Arnhem Land contains one of the world's richest and most diverse bodies of rock art, and is widely thought to span tens of thousands of years, with rock art produced since at the very least 27,000 years ago (David et al. 2013a) up until the late 20th century (e.g. May et al. 2010; Taçon 1992a). Despite decades of archaeological research within this region, the only rock art images to have been dated directly prior to this monograph are 151 mid to late Holocene beeswax images mainly dating to the past 600 years (Gunn and Whear 2008; Gunn et al. 2012; Nelson 2000; Nelson et al. 1995; Taçon et al. 2004, 2010) – with a total of 111 other pictograms superimposed over or subimposed under these (Gunn 2016: Chapter 4; Gunn et al. 2012:59–60; Taçon et al. 2010:2–4) – and a small excavated broken rock with part of a black linear painting or drawing from an original image of indeterminate form dated to c. 27,000 years ago from Nawarla Gabarnmang Square E (David et al. 2013a; see David et al. 2014 for the latest calibrations of the originally reported radiocarbon dates).

Watchman (1987) also obtained AMS radiocarbon dates on mineral salts in rock crusts to elucidate the ages of associated paintings from four sites in western Arnhem Land. During this early, experimental work, the micro-layers of carbon-bearing whewellite were not individually isolated from the multi-layered crusts, the radiocarbon determinations coming from the carbon trapped in the sum of micro-layers (see e.g. Watchman 1993, 2000 for subsequent studies from other parts of Australia where individual layers of cortex were scraped or laser-ablated and separately radiocarbon dated). In that work, Watchman obtained radiocarbon determinations of 12,250 ± 105 BP from Spirit Cave at Angbangbang, 8880 ± 590 BP and 8200 ± 460 BP from Ngarradj Warde Djobkeng, 7040 ± 200 BP from Baroalba Springs, and 4850 ± 300 BP from Nangalor, as well as younger, late Holocene ages, but it is not clear whether these radiocarbon dates relate to the age of rock crusts underlying (Watchman 1987:38), overlying (Watchman 1987:40), overlying and underlying (Watchman 1987:39) or near but away from the art (Watchman 1987:39). It is thus uncertain whether these results should be taken as maximum or minimum ages for the art, although Watchman (1987:40) concludes that 'this study has established a minimum age of 8880 ± 590 years BP for some rock art paintings' (see also David et al. 2013b:3).

To this day, the oldest stylistically visible image whose age has been confirmed from Arnhem Land is a naturalistic beeswax turtle figure (BW-4) from Gunbilngmurrung, from which radiocarbon determinations of 4040 ± 80 BP (Nelson et al. 1995) and 4460 ± 80 BP (Watchman and Jones 2002) have been obtained (calibrating within 4410–4800 cal BP and 4970–5290 cal BP respectively; we cite calibrated ages at 68.3 per cent probability using OxCal 4.2 with IntCal13 curve selection throughout this chapter), with older paintings lying underneath (see David et al. 2013b for a review). Yet this has not stopped a multitude of chronological models going back 40,000 years or more for rock art styles from being influentially posited for the region as a whole.

Modelling the chronology of western Arnhem Land's rock art

The vast quantity of rock art in Arnhem Land and the complexity of many of its heavily superimposed panels were apparent from W. Baldwin Spencer's photographs of the panels around Oenpelli taken over a century ago (Spencer 1914). Charles Mountford (1956) later subdivided the region's rock art into 'polychrome X-ray', 'monochrome Mimi' and 'hand stencils and prints'. He noted that X-ray paintings invariably overlie Mimi figures, indicating that the X-ray form was the more recent (Mountford 1956:262). The so-called Mimi class was expanded by Eric Brandl (1973) into 'Early Mimi' and 'Late Mimi (including types LM I and LM II)' on the basis of differences in composition and associated weaponry. Brandl divided the later X-ray art into four classes (Types 0–III) according to the degree of internal detail depicted. A similar subdivision was utilised by Jan Jelinek (1978, 1989), although he considered hand stencils as the earliest group (preceding the Mimi) and included a class of white dynamic paintings into the more recent group on the basis that they appeared to be contemporaneous with Type III X-ray paintings.

Perhaps the most influential chronological model for western Arnhem Land's rock art has been that of George Chaloupka. He (1984, 1993) proposed a far more exclusive classification than his predecessors, dividing the Mimi art into seven 'styles/techniques' (although these were not adequately defined) and the more recent art into four stylistic groups. The earliest style/technique included hand stencils and hand prints, while he subdivided the most conspicuous of the recent styles – X-ray art – into 'descriptive' and 'decorative' phases (Chaloupka 1993:162–165). He ordered his seven styles/techniques into a chronological sequence through perceived patterns of superimposition and then allocated each to a distinct chronological period on the basis of select faunal representations that he equated with particular environmental conditions. These broad periods were: Pre-Estuarine (from initial Aboriginal occupation some 50,000 years ago to 8000 years ago); Estuarine (8000 to 1500 years ago); Freshwater (1500 to 300 years ago); and Contact (300 years ago to the 'ethnographic present'). Chaloupka equated Brandl's Mimi period with the environmental Pre-Estuarine period (prior to 8000 years ago) identified by Quaternary researchers (e.g. Woodroffe et al. 1986), and the more recent art with the Estuarine period of the past 8000 years. While Chaloupka's stylistic groupings have to some degree (but not entirely) been accepted by his peers researching in western Arnhem Land, they remain largely subjective and dissenting views have also emerged (e.g. Chippindale and Taçon 1993, 1998; Haskovec 1992).

Identifying some of the shortcomings of Chaloupka's formal classification and chronology, Darrell Lewis (1983, 1988) divided the art of western Arnhem Land into four periods: Boomerang, Hooked Stick, Broad Spearthrower and Long Spearthrower. On the basis of changes in depicted items of material culture in the rock art, and linking these changes more systematically to the archaeological and environmental evidence, Lewis (1988:ix) proposed a somewhat different chronology to that of Chaloupka. Lewis also suggested that there were regional variations within the Hooked Stick period (pre-6000 BP).

Paul Taçon (1993) also identified regional variations in the most recent art (post-5000 BP), particularly manifest in a higher proportion of fish motifs (including those in the X-ray form) in the northern areas of the Arnhem Land plateau (see also Taçon 1988). Taçon undertook a re-classification of X-ray art (Taçon 1987, 1989, 1992b), subdividing it into Early and Recent. Taçon's Early versus Recent types of X-ray art are not simply a reiteration of Chaloupka's 'descriptive' versus 'decorative' types (Chaloupka 1984, 1993), which Taçon sees more as variations of types of X-ray infill often made at the same time and sometimes even by the same artists rather than as chronological phases (although Taçon also notes that there is more so-called 'decorative' X-ray art in the past 1000 years than previously). For instance, Early X-ray rock art is much less detailed than Recent X-ray art (Chaloupka's decorative and descriptive X-ray paintings), and was used primarily for faunal depictions (i.e. Early X-ray human-like figures are rare unlike Recent X-ray rock art). Early X-ray paintings usually just show a rectangular or circular body cavity but sometimes also have a thin line backbone, as in the beeswax turtle dated to more than 4000 years ago (see above). More recently, and with particular reference to western Arnhem Land, Taçon and others have highlighted the incorporation of outside influences (Contact art) – European but also including Macassan from Island Southeast Asia – into much recent Aboriginal rock art (e.g. May et al. 2010; Taçon et al. 2010).

In the most recent revision of the sequence and chronology of western Arnhem Land rock art, Christopher Chippindale and Taçon reduced the range of categories to three: New, Intermediate and Old (Chippindale and Taçon 1998; Taçon and Chippindale 1994). Each period had a number of particular styles or used particular techniques, although within each period different styles could coexist and overlap (Chippindale and Taçon 1998:105). The New period, including X-ray art and beeswax figures, is suggested to be the period from the present day to c. 6000 BP; the age of the Intermediary period remains unknown, but one of its stylistic groups (Dynamic figures) is proposed to have occurred around 10,000 BP; and the age of the Old period, with 'Panaramitee-like rock-engravings' and 'pigment in shelter deposits' (Chippindale and Taçon 1998:107), is also unknown although they suggest an age of ≥30,000–50,000 BP. The latter is based on the period of presumed earliest occupation of the region, as dated by Roberts et al. (e.g. 1994) to shortly before 50,000 years ago. Unlike Chaloupka (1993), who proposed that hand stencils occurred within his earliest styles/techniques, Chippindale and Taçon (1998) proposed that hand stencils (excluding the 3MF type, which has the three middle fingers pressed together and thumb and little finger splayed) and prints are not diagnostic and do not belong to a single style or period, as they are represented in both the Old and Recent categories. They also provide a cautionary note regarding the ages of extinction of some of the key animal species such as had been used by Chaloupka in developing his chronology (Chippindale and Taçon 1998:98–99).

Dating rock art

In such a context of variable modelling and uncertain antiquity for all of Arnhem Land's rock art styles (for a discussion on the use of the term 'style', see Chapter 6), and a total absence of dates on all forms of art except for a few dating to the mid-Holocene and more dating to the late Holocene, a major challenge for archaeologists in Arnhem Land – as elsewhere in the world of rock art – is to determine accurately the age of the art. Any evidence helping to elucidate the age of rock art styles, motifs or individual artistic traits, or even the antiquity of particular rock surfaces with implications for the maximum possible age of art on those surfaces, is of considerable service to both rock art research in Australia and archaeological modelling of symbolic behaviour, social practice as indicated by painted scenes and territoriality for the region.

The challenge is thus 'how do we date the art?'. Chippindale and Taçon (1998) outline 'many ways' by which Arnhem Land's rock art can be, and in some cases has been, dated. In exploring how we can refine our understanding of the antiquity of the region's rock art, here we restrict ourselves to some general principles along with the major absolute methods that can readily be applied – that is, those major methods that can accurately reveal actual or approximate ages.

'Direct' and indirect methods: Constructing scientifically rigorous and archaeologically meaningful chronological frameworks

Numerous methods are used to obtain absolute dates on materials directly implicated in the creation of rock art. Predominant among these is radiocarbon dating, where organic materials most commonly form part of the art's pigment.

Other dating methods can also reveal the age of events that through time have been associated with art on rock faces. One of these involves the dating of calcite accretions over or under rock art through Uranium-series dating ($U/^{230}Th$ series), enabling minimum or maximum ages to be determined for the creation of the art (see Chapter 7 for a comparable application of radiocarbon dating).

Thus, today most rock art dating projects in Australia and internationally try to employ as many 'direct' and indirect dating methods as possible, and on a range of materials. Following Wylie (1989), Chippindale and Taçon (1998:93) have termed such applications and cross-examinations of multifarious approaches towards the formulation of stronger and more reliable chronologies, 'cabling' (see David et al. 2013b for an example).

Notes on the construction of rock art chronologies

Numerous scientifically reliable methods enable the systematic construction of independently reproducible relative rock art chronologies. Essentially, all methods that reliably allow us to distinguish and sequence events or phases of activity over time frames of interest to archaeologists are usable in the construction of rock art chronologies. In this sense, those dating methods are not restricted to rock art dating.

It is necessary also to emphasise the importance of contextual evidence when interpreting relative or absolute age determinations. In the first instance, the relative chronological position of analysed samples should be worked out, and the relative position of a sample in a sequence should always be taken into account when interpreting the meaningfulness of absolute age determinations. Furthermore, it is imperative to 1) determine from the onset how the dated material(s) relate to the anthropic event(s) in question; and 2) take a diachronic approach so that various contextual events or phases can be sequenced relative to each other (e.g. a roof-fall event causing a new ceiling surface to be created, the first creation of a painting, the deposition of a rock surface crust, the partial flaking of the rock wall, a repainting event). It will often be necessary to date one or more of the archaeological phases at a site to better understand the age of artistic events, rather than to base one's conclusions solely on one isolated 'direct' date that somehow relates to an item of rock art. For example, we can try to understand the age of art by analysing the stratigraphic context of fallen and now buried painted rocks (e.g. David et al. 2013a); or of the sequence of unpainted to painted exfoliated cortex that now lies buried underground below painted walls (see David et al. 1990 for such an approach applied to Yiwarlarlay 1, the 'Lightning Brothers' site on Delamere Station in Wardaman Country, between Arnhem Land and the Kimberley). Or we can apply geomorphological arguments for the evolution of rock surfaces that today exhibit art (see Delannoy et al. 2013), as has been done to resolve definitively the broad time frame when the large bird painting suspected to be of a *Genyornis* was made at JSARN–124 site 3 in Jawoyn Country (see Chapter 15). Another example of the use of stratigraphic context to understand the age of rock art is the radiocarbon dating of small charcoal fragments found adjacent to dried paint drops now buried amidst the sands of ancient ground surfaces (see Chapter 11). Another example again is the revelation of the antiquity of art relative to the heating of rock wall surfaces at Chauvet Cave – that is, drawings were made on top of a rock surface that had been heated by nearby fires (Brodard et al. 2014; Ferrier et al. 2014).

Methodological considerations

Robust chronologies require reliable and multiple results, and absolute chronologies require large numbers of age determinations that cover the full diversity of targeted art and art types. It is always a good thing to seek to employ as many reliable analytical methods as possible, so that independent results can be cross-examined towards a stronger conclusion capable of withstanding critical examination. Let us not forget that each analytical technique brings with it its own particular strengths and limitations; the use of multiple techniques potentially enables cross-examination of results that do not share the same kinds of embedded technical limitations. Obtaining multiple dates through a range of dating techniques also allows for increasingly robust statistical results, including the application of Bayesian methods and the construction of chronological models that enable the researcher to better constrain archaeological interpretations (e.g. Quilès et al. 2014a, 2014b).

Major dating methods in rock art research

Indirect dating methods

Before absolute methods of dating rock art (outlined below) were invented, indirect dating was used to establish rock art chronologies. This approach is still useful today, especially in combination with absolute methods (Chippindale and Taçon 1998). Essentially, indirect dating involves examining the sequence of superimposed styles at rock art sites, determining subject matter as best as possible within styles, correlating subject matter with changing environmental records, bridging to the excavated archaeological record and its dates wherever possible and looking for indicative subject matter within styles to help better place them in sequences, such as depictions of extinct taxa (e.g. thylacines, Tasmanian devils), animals introduced thousands of years ago (e.g. the dingo) and contact period subject matter such as ships, horses and firearms. For instance, a painting of a kangaroo in a particular style under a painting of a thylacine would be at least c. 3500 years of age, and possibly much older, while a painting of a kangaroo in a different style on top of a European-introduced horse is necessarily less than about 200 years of age. Exciting results from indirect dating can be found in many of the chapters, along with results from more direct methods.

Accelerator mass spectrometry radiocarbon dating

Radiocarbon dating of rock art made of wood charcoal remains the most common 'direct' dating method in rock art research (e.g. Valladas et al. 2005), although it is critical never to lose track of the fact that such radiocarbon dates are proxies for when the wood died, rather than dating its burning to charcoal or the artistic events themselves. We must also remember that 'charcoal' can also be made of other materials, such as burnt bone. It is also possible to date meaningfully calcite layers that may have accumulated below or above art, thereby potentially revealing maximum or minimum ages for the associated art (e.g. Beck et al. 2001; Genty et al. 1999, 2001, 2004; Plagnes et al. 2003; see also Chapter 7). Those same calcite deposits can be dated by U/Th, allowing for the useful cross-examination of results. Major, regular inter-comparison programs that enabled the cross-interrogation of results are warranted (Cuzange et al. 2007; Quilès et al. 2014b).

Uranium-Thorium series dating

In rock art research, Uranium-Thorium (U/Th) dating is most rewarding when dating calcite that is directly associated with art, be they stencils, paintings or engravings. The dated calcite can lie underneath an artwork and thus predate it, or it can have accreted over it and thus post-date the art. It is most common to apply U/Th dating to layers of calcite that overlie items of rock art; its aim is thus to give a minimum age for that art.

Uranium-Thorium dating, long used for dating corals and speleothems (stalagmites, stalactites), is more difficult to apply to very thin and irregular layers of calcite that lie on rockshelter and cave wall surfaces. In effect, water runoff on rock walls could lead to the dissolution of Uranium and the distortion of age determinations, by making them older than would otherwise be the case (for a recent critical review, see Sauvet et al. 2015). One way to verify the validity of U/Th ages is to couple them with other methods such as radiocarbon dating that also allows the dating of calcite subject to minor corrections for 'dead' carbon (Beck et al. 2001; Fontugne et al. 2013; Genty et al. 1999, 2001; Plagnes et al. 2003; see also Chapter 7). At the limestone site of Chauvet Cave in France, speleothems 'growing' at ground level were covered with wood charcoal stains. The independent U/Th dating of the speleothems and radiocarbon dating of the charcoal revealed slightly older ages for the charcoal. This is consistent with their expected relative chronologies, as the speleothems could only have incorporated the charcoal in their growth if the charcoal already occurred on the ground prior to their development (taking into account that no new charcoal could enter the cave after the roof collapse that sealed off its entrance by 21,000 years ago). This cross-examination of two independent dating methods gave further confidence to the reliability of the results (Genty et al. 2004). Refinements in U/Th methods have taken place in recent years (e.g. TIMS $U/^{230}Th$), giving rise to MC-ICPMS (multicollector-inductively coupled plasma mass spectrometry) $U/^{230}Th$ dating (Aubert et al. 2014; Fontugne et al. 2013; Pike et al. 2012).

Thermoluminescence

Thermoluninescence (TL) can be used to date rock surfaces that have been heated, including limestone surfaces (Guibert et al. 2015; Roque et al. 2001). The dating of extant surfaces through TL is useful to rock art research in cases where decorated surfaces were created as a result of rock collapse or exfoliation caused by heating (i.e. giving maximum ages for the art), or where the pigments of the art contain minerals that were affected by the heating events, and where the heating events can be TL-dated through those mineral inclusions (giving minimum ages for the art) (Brodard et al. 2014; Ferrier et al. 2014; Watanabe et al. 2003).

Single grain optically stimulated luminescence

Single grain optically stimulated luminescence (OSL) dating of sand grains incorporated in pigments, or of mineral grains in biological structures such as wasp nests or bird nests found below or above layers of pigment, offer promising potential for better understanding the age of rock art (e.g. Roberts et al. 1997; Wallis 2002). Again, such investigations are best done by applying multiple dating techniques, such as OSL and radiocarbon dating of individual wasp nests overlying or underlying the art.

Cosmogenic dating of the rock support

The timing of changes in the configuration of rock walls as a result of rock collapse can in some cases be determined by cosmogenic dating. That is, it is possible in some situations to determine when a rock surface was created by dating when it became exposed to cosmogenic radiation, thereby offering maximum ages for art on those rock surfaces. Cosmogenic dating can be undertaken on a number of different isotopes, depending on the mineralogy of the rock in question. The dating of the closure of the entrance of Chauvet Cave is an example of how cosmogenic dating can help better understand the age and context of rock art. Cosmogenic dating (^{36}Cl) showed that the cliff above the entrance of Chauvet Cave collapsed a number of times between 29,000 and 21,000 years ago, sealing the cave during its later stages of collapse. Determining the age of the cave's closure enabled the Chauvet Cave researchers to narrow the timing of when people could have entered the cave to make the art within the site (Sadier et al. 2012). By comparing when the cave was open (as determined by ^{36}Cl dating of the entrance collapse) with radiocarbon and U/Th dates for periods of human activity including rock art inside the cave, a coherent and more robust chronological model could be constructed for human activity within the site (see Quilès et al. 2014a, 2014b; Sadier et al. 2012).

Conclusion

The case studies presented in this monograph are in many ways a work in progress, in the sense that none of these projects have yet finished. Thus, this monograph is not a single story with a beginning and an end, but rather something that brings together the results of many recent research projects on the archaeology of western Arnhem Land rock art. Clearly, significant results have already been achieved, both in terms of particular findings (e.g. Chapters 3, 4, 7, 11, 12, 14, 15) and in terms of the development of novel investigative methods (e.g. Chapters 10, 15). These results have allowed innovative chronological models to be developed for the art (e.g. Chapters 4, 6, 11, 12), setting the scene for further challenges as well as reflections and reassessments. We see this volume as the start of something new, not as the presentation of the results of past projects from which we can comfortably brush aside the cobwebs and exit the scene.

In presenting this volume, there has been little need to standardise terms across chapters, as the language used by each author has generally been comparable from the onset. The one exception is in the use of the term 'motif', which different authors initially used in very different ways. Throughout this volume, 'motif' is used to refer to an image type, while individual paintings and other art are referred to as 'images'. For example, three paintings of circles and one painting of a square would equate to two *motifs* (circles and squares) but four *images*.

Finally, as local families have told us, we hope that the research presented in this volume will both instil new pride about heritage and culture in Arnhem Land Aboriginal communities, and inspire a new generation of rock art researchers so that collaborative research on Arnhem Land rock art will continue to grow. We also would like this volume to influence federal, territory and local governments to initiate new programs that will assist with the conservation and management of Arnhem Land rock art so that it may continue to inform and inspire the world long into the future.

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