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MUD-WASP NESTS AND ROCK ART

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Abstract. The optically stimulated luminescence analysis of fossil and mineralised nests of mud-dauber wasps is examined and difficulties in the interpretation of results are considered. The utility of carbon isotope analysis of such features is advocated, and an example of its application to a Late Pleistocene specimen is reported. Also considered, through the example of a major Australian contact rock art site, are some difficulties in interpreting direct dating information pertaining to rock art. It is shown that organics in paint residues may be taphonomic features acquired over time, and that the time intervals between datable elements and physically relatable rock art may be of such great duration that such results are of limited practical value.

Introduction

The pioneering study of Roberts et al. (1997) offered a valuable tool for archaeological and palaeoclimatic research by demonstrating the potential of nests of mud-dauber wasps for providing environmental and dating information. These authors hoped that the 'worldwide distribution of mud-wasps' would facilitate wide applicability of their technique, but in the sixteen years since this potential has not been realised. The only factor of their report that has had wide repercussions is the proposition that one of their optically stimulated luminescence (OSL) determinations provides a minimum age of 17.5 ± 1.8 ka for an anthropomorphous rock painting, which has given rise to many derivative claims. Significantly, this result is not only at odds with alternative Holocene age estimates of the Gwion rock art traditions in question (Watchman et al. 1997), it is also the only 'direct date' (Bednarik 2002, 2010) from any Australian rock art suggesting the use of iconic depiction in the Pleistocene. All other cases of such age claims are based on the purported depiction of extinct animal species or their tracks, which are untestable propositions guided by the belief to be able to discern those aspects of a motif that are naturalistically depicted (Bednarik 2013). Therefore the OSL determinations of Roberts et al. are of particular importance.

Roberts et al. (1997) provide data from two fossil wasp nests, one of which (KERC5) has yielded the above date, but is in fact not associated with any rock art. Another, nearby nest (KERC4) 'may be related to the Bradshaw style' (Roberts et al. 1997: 697), represented only by an untypical pictogram, not a typical Gwion figure. It yielded a wide range of palaeodoses, from 0.5 Gy (Gray) to about 75 Gy. After discarding those grains that were thought to have been exposed to 'modern sunlight', of the remaining 36 grains a mean age of 23.8 ± 2.4 ka BP was proposed for 21 of them, and 16.4 ± 1.8 ka BP for the remaining 15 grains. However, only a few millimetres of the rim of this nest overlies the painting (Aubert 2012: Fig. 1), where it is less than 1 mm thick, therefore only the 'most recent' of the grains (those discarded) are likely to relate to this paint residue. No data were reported from grains overlying the pictogram, therefore no dating was achieved. It is well known that mud-dauber wasps prefer to construct nests on the remains or stumps of pre-existing nests, which may account for the wide range of palaeodoses from KERC4. Moreover, the grains most likely postdating the painting are those discarded by Roberts et al. as being 'contaminated' (Fig. 1). In this determination they

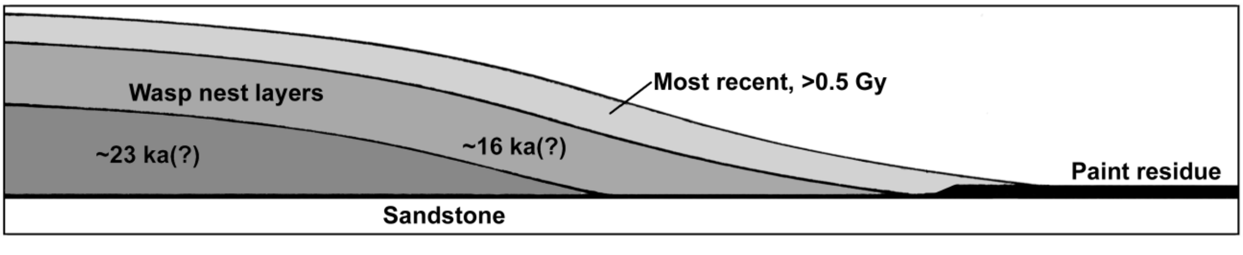

Figure 1. *Schematic section of the lower edge of wasp nest KERC4 (after Roberts et al. 1997; Aubert 2012), showing that only the surface-nearest but discarded deposit postdates the paint residue. There is no stratigraphical or temporal relationship between the pictogram and the presumed two older cohorts of grains.*

*Figure 2. (a) Black and yellow mud dauber (*Sceliphron caementarium*); (b) collecting mud and (c) constructing nest.*

ignore that all other grains in a wasp nest must also have been near the surface at some stage, and would then have been similarly affected by sunlight. Therefore their dates, if they are relevant, would have to be conservative minimum dates. Clearly, the taphonomic history of each nest, which is essentially unknown, needs to be taken into account in considering the OSL data secured from it, as is the case in concealment by other accretionary deposits (Liritzis et al. 2012).

Mud-dauber or potter wasps, of the families Sphecidae and Eumenidae, can be divided into primary and secondary nest builders: those that construct new nests, and those that occupy abandoned nests of other species and modify them by creating their own cells. Several species have been reported to impact upon rock art by establishing nests in rockshelters, including *Sceliphron laetum*, *Sceliphron formosum*, ?*Pison* sp., ?*Abispa splendida*, *Paralastor alexandriae* and ?*Odynerus* sp. (Naumann 1983; Naumann and Watson 1987) and *Sceliphron caementarium*. Each of them builds distinctive structures from mud (Fig. 2), which under favourable conditions can survive for many millennia because they tend to occur in sheltered locations and they can become mineralised. Although mud-dauber wasps are of wide distribution, their nests are particularly common in tropical or subtropical sandstone shelters. They share this trend with termites (Isoptera), whose covered runways or galleries provide the same potential to assist in both dating and palaeoenvironmental studies (Watson and Flood 1987), although this has remained unexplored so far.

The mud from which the nests of the mud daubers are made is gathered by the females along the margins of ponds and streams, carried in their mandibles and brought to protected sites. As each cell is completed it is provisioned by *Sceliphron caementarium* with spiders, such as crab spiders, orb-weaver spiders and jumping spiders, still live but immobilised (Fig. 3). Each cell is sealed once an egg has been deposited, and the spiders serve as food for the developing larvae. Each wasp species prefers particular kinds and sizes of spiders in stocking these larders, and there may be more than twenty spiders stored in one cell. The mud typically contains grains of clay, silt and small sand fraction, organic ketones (probably of salival origin), as well as numerous incidental inclusions. Among these have been reported pollen grains, spores, sponge spicules, phytoliths, carbon particles (charcoal), starch grains, and parts of graminae and dicotyledons. Much of the organic component can be assumed to be of an age similar to that of the nest, yet its obvious potential to provide relevant carbon isotope age estimations has not been exploited for the presumed Pleistocene nests, except that Yoshida et al. (2003) reported a conventional (uncalibrated) radiocarbon age of 26.3 ± 0.2 ka BP (OZE069) for pollen grains of 5–10 μm diameter extracted from a mud-wasp nest unrelated to rock art. The same applies to the termite runways, which are even more common at rock art sites than mud nests (e.g. Brady et al. 2010), and which consist essentially of soil, tiny rock fragments or grains and digested wood.

Figure 3. Provisioning mud dauber nest with immobilised spider.

OSL analysis of mud-wasp nests

'Thermoluminescence' (TL) refers to the release of energy by crystalline solids when heated or exposed to light (Kennedy and Knopf 1960; Aitken et al. 1968; Fleming 1968; Fagg and Fleming 1970; Aitken 1990; Elias 2007). Ionising environmental alpha, beta and gamma radiation results in the release of electrons and other charge carriers ('holes') in these materials. Electrons become trapped in defects of their crystal lattice, such as impurities or chemical substitutions. These metastable charge carriers accumulate over time at a largely constant rate determined by the dose of the radiation. They can be ejected from their 'traps' by an input of additional energy, which releases their excess energy as light, measurable in photons. This energy, the TL, is therefore, with some qualifications, a function of the time since the material was last heated (e.g. ceramics or heating stones) or exposed to light (e.g. crystalline mineral grains). In using OSL analysis (Huntley et al. 1985; Wintle 1993; Aitken 1994; Duller 1996; Murray et al. 1997) to estimate the antiquity of an ancient mud-wasp nest, an aliquot of quartz grains of the former mud is extracted and the environmental radiation of the rock is measured with a gamma spectrometer. The 'trapped' energy is released by green/blue light (~500 nm) and is thought to represent the time since the grains were last exposed to bright light.

However, there are numerous sources of imprecision or uncertainty, such as the variability of the environmental dose rate (Dunnell and Feathers 1994) or the moisture content. In order to eliminate the need to account for dose rate alpha and beta radiation (which is far more ionising than gamma radiation but has very limited power of penetration), the outermost 2 mm of samples is usually removed in the case of TL analysis of pottery. But this may not be readily possible with the small deposits of mud-nest residues and has not been attempted. Instead, individual grains of the fine sand fraction (~100 μm) were etched with hydrofluoric acid to remove their outermost layers of 10–20 μm, the presumed penetrating range of alpha particles (Roberts et al. 2000). Disequilibrium in the U and Th decay might occur in such accretions on rock surfaces (Aitken 1985; Roberts et al. 1997; Yoshida et al. 2003), and radon is likely to be present in sandstones, effecting further distortion. Another problem with applying OSL to a rock accretion is that the gamma dose rate is not acquired from a surrounding matrix, as in a soil sample, but from a rock mass adjacent to the sample. It was attempted to counter this factor by placing a calcium fluoride TL dosimetry capsule at the sample site for a period of one year (Roberts et al. 2000). Similarly, cosmogenic radiation dose, which also contributes to the system, has to be estimated (Prescott and Hutton 1994), yet it is difficult to account for because it relates significantly to rock geometry. It tends to penetrate well into a rock mass but the location within a deep rockshelter introduces yet another variable that is difficult to quantify.

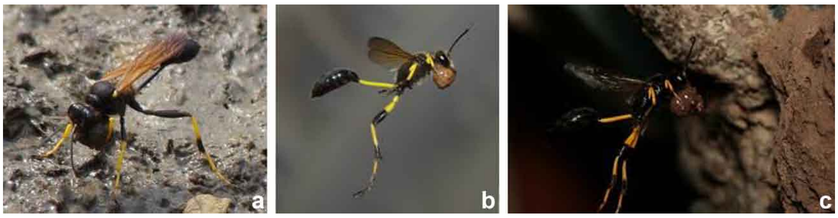

Figure 4. *(a) Mud dauber wasp collecting mud and carrying it to the nest (b, c). Note size of the mud droplets, suggesting that the quartz grains in its interior were not exposed to sunlight.*

As an internal test analysts have provided results from two parts of a mud nest (DR6 and N6), each excavated in seven layers, securing optical dates from each of these (Roberts et al. 1997, 2000). The results have been interpreted as evidence that the nest was constructed in two phases, with the two innermost samples being markedly older than the next four. Mud-dauber wasps prefer to build nests on the stumps of abandoned ones (Naumann 1983). The outermost layers of both samples yielded much lower ages, 110 ± 20 years for DR6 and 165 ± 25 years for N6. This was explained by bleaching of some of the quartz grains nearest to the surface (Roberts et al. 2000). However, other explanations are possible. For instance, exposure to the dim light of a shelter might result in a specific pattern in the release of trapped electrons, especially after the fabric has become indurated by silica mineralisation. This might reflect such factors of the refractory characteristics of the quartz grains, or some other systematic process not accounted for.

Similarly, there are possible scenarios that could greatly increase the apparent age of such a sample. As Roberts et al. (2000) observe, the recorded age of the outermost layer indicates 'that even this thin layer includes quartz grains which are buried too deep to be bleached by modern sunlight and/or that the quartz grains retain a "residual" dose of about 0.2 Gy at the time of nest construction'. It is possible that the grains in the mud used by the wasps were not adequately exposed to direct sunlight to be fully 'bleached', especially those innermost in each droplet collected, and the 'OSL clock' may not have been fully reset. The author has observed specimens of *Sceliphron laetum* collecting mud at early dawn, at a heavily shaded mud bank that had been churned up by animals in the previous night. Therefore the individual quartz grains in the mud droplets transported in the mandibles of the insects may not have received adequate sunlight to release all trapped electrons (Fig. 4). Moreover, they were certainly coated by a film of water at that stage (which does affect the process; Dunnell and Feathers 1994), and the relevant effects of the salival ketones are unknown.

This is not to suggest that OSL results from mud-wasp nests should be expected to be false; but it is a reminder that such 'ages should be considered as provisional', as Roberts et al. (2000) are careful to emphasise. Indeed, there is almost no method of rock art dating available that can provide reliable results (Bednarik 1996, 2002), but many methods, including OSL, provide scientific evidence for age estimation — as long as the many qualifications applying to their results are heeded (Aubert 2012). Unfortunately this has frequently not been the case in their interpretation, and the tentative Pleistocene OSL estimate from one Kimberley wasp nest has been cited in support of various otherwise unjustified hypotheses. Among them is the notion that Gwion rock art is not the work of Aboriginal people (which is an absurdity, in view of its iconography, as Welch 1996 has convincingly shown), and the idea that it proves the use of iconic representation in the Pleistocene of Australia. Perhaps that idea is right, but its acceptance would require more than one anomalous OSL result and the numerous frivolous claims concerning the depiction of megafauna and megafaunal tracks of species thought to be extinct for 45000 years (Bednarik 2010, 2013; Aubert 2012).

The rich organic contents of mud-wasp nests render them suitable for ^{14}C analysis, but this potential has remained almost untapped. An exception is a series of results secured by Wilson et al. (2001) from relatively recent wasp nests in the limestone cave Hopnarop, Vanuatu. Roberts et al. (1997) applied the method to a few very recent samples, none of which were apparently >112 years old, and to one older sample unrelated to rock art. As in the case of testing $^{230}Th/^{234}U$ results by ^{14}C analysis (Bednarik 1984, 2012), the provisional OSL dating of wasp nests could be tested in the same way. They note that their samples did not contain a sufficient mass of phytolith for AMS ^{14}C dating, but there are numerous alternative sources of carbon available from these structures. Isolating carbon at the object or molecular level is an admirable aim in rock art dating (Bednarik 2002), but in this case, for the purpose of testing tenuous OSL results, only orders of magnitude of age are required.

Figure 5. *Anthropomorph at contact rock art site; the arrow indicates the wasp nest sampling site (see Fig. 8). Note numerous recent wasp nests in upper part of image.*

Here, Pleistocene results from a wasp nest related to rock art are reported, and this example also provides a salutary lesson about direct dating of rock art in general.

'Maximum dating' for Australian contact rock art

'Contact art' in Australia refers to rock art created by Aborigines during the initial period of external contact (Macassan, Dutch, but especially British), and is identified by the frequent depiction of objects of exotic origin. One of the country's most impressive contact rock art sites is situated in Princess Charlotte Bay, northern Queensland; for its protection the location is not provided here. There are further painting sites in its vicinity, some featuring more contact rock art, forming a site complex of which the subject site contains the main concentration of motifs. It comprises two angular sandstone shelters formed by the loss of rock mass along distinctive horizontal bedding planes in the coarse-grained sandstone. The eastern shelter is about 4 m deep and 2 m wide, its flat horizontal ceiling decorated with white hand stencils. The walls of this small chamber bear almost 50 painted motifs, dominated by an anthropomorph with a decorated 'torso', almost the height of the chamber, of about 1.2 m (Fig. 5). There are also images of sailing ships and numerous other exotic artefacts, such as knives, scissors, clay pipes and axes (Fig. 6). Some 6 m to the west of this chamber begins a walk-through cave, 8 m long, 3–4 m wide, and 1.2–1.6 m high. It is also distinctly rectangular in section and bears paintings along most of its southern wall, as well as on the flat ceiling — in total over 70 figures. These include again numerous images of non-indigenous items, such as several boats, a rifle and a domestic quadruped, as well as some traditional motifs, such as marine species (Fig. 7).

The paintings are dominated by imagery relating to the pearling activities that occurred in the area towards the end of the 19th century, such as a large number of pearling luggers and the depiction of two rows of pearl shell bags, some marked with a known company logo. Most

Figure 6. *Contact art in eastern shelter; note delicate depiction of scissors in centre, and of rows of pearl shell bags on right.*

of the local pearling fleet of eight schooners and about 80 luggers was destroyed in the category 5 tropical cyclone of 4 and 5 March 1899 (seven schooners and 66 luggers were lost or wrecked, with a loss of about 400 lives). Many local Aboriginal people worked in this pearling industry, and it is most probable that the rock art predates the disaster, therefore being in the order of 120 years old. It was clearly preceded by earlier traditions, of which only indistinguishable traces of darker red paint remain, and what survives well of the corpus is therefore likely to be the product of a relatively short interval of activity. Although much of the paintwork remains well preserved, the site is not well suited for long preservation and the extent of green algae has greatly increased in recent years. The recent origin of the rock art is confirmed by the almost complete absence of granular exfoliation along cracks crossing paintwork. Similarly, the excellent preservation of white pigment, generally regarded as the most fugitive, confirms a recent origin. Locally a very thin veil of whitish silica accretion covers rock art, indicating that the shelter walls are subjected to occasional water run-off.

Figure 7. *Contact art in western shelter.*

The eastern shelter features numerous recent nests of mud-wasps, especially on its ceiling, but none are superimposed over rock art and they appear to be relatively short-lived. However, in one of the four red and white lines indicating the 'legs' of the large anthropomorph, the white line runs over the stumps of a thoroughly silicified nest of *Sceliphron laetum* [Smith, 1856] (Fig. 8). This mineralised feature is at least as hard as the rock's substrate, and the kaolinite ($Al_2Si_2O_5(OH)_4$) paint residue applied over it is particularly thick on account of the recesses in it having been filled with pigment paste. Therefore this location was considered suitable to provide direct minimum and maximum ages for the motif in question. Following a request from the appropriate Traditional Custodians, samples were secured from the kaolinite applied over the remains of the fossil mud-wasp nest, and from the nest itself, to be subjected to AMS ^{14}C analysis. It was not envisaged that the paint would yield a valid date for the motif, because the carbon system of such anthropic deposits is open and likely to be rejuvenated — although there are also possibilities of contamination by 'older' carbon (Bednarik 2002).

The results of this experiment reinforce the need of

Figure 8. *Fossil stump of mud-wasp nest, with superimposed white paint, both of which were sampled.*

appreciating the significant limitations of all rock art dating endeavours. The 2.84 g sample from the wasp nest was free of $CaCO_3$ but contained ample carbon for an accurate measurement. This provided a measured date of 15 720 ± 90 years BP ($^{13}C/^{12}C$ ratio -21.2‰), which corresponds to a conventional radiocarbon age of 15 780 ± 90 years (Beta-278167). At 2 sigma, this converts to a calibrated age of 19 100 to 18 870 years BP. It represents a 'direct rock art date' for the anthropomorph, in that it suggests that it must be <19 ka old, but if an age in the order of 120 years is accepted, such a maximum age is of no practical relevance. Moreover, as abandoned mud-wasp nests attract fresh nests, the various construction phases may not be separable. On the other hand, the kaolinite paint residue, which also contained no calcium carbonate, was practically devoid of any carbon, and thus unsuitable for carbon isotope analysis.

Discussion

It has thus been demonstrated that silicified mud-wasp nests, even specimens of the Late Pleistocene, contain ample carbon, and therefore any future OSL dating of these and other insect structures physically related to rock art needs to be checked against bulk radiocarbon results. Such features, commonly associated with rock art, can only survive long-term in thoroughly mineralised condition, which is likely to be effected within a few centuries of their establishment (Bednarik 2000). Where the induration is by silica, the organics tend to become well sealed in and are likely of an age matching that of the nest, or are only marginally younger. If it is by oxalate, the bulk carbon analysis will probably yield a slightly lower radiocarbon age than the true age of the nest. In the absence of carbonate there is very limited potential for the inclusion of 'older' carbon: various materials of plant origins, ketones and spider bodies would match the nest's age, although charcoal fragments may differ. Paint residues, unless sealed in mineral accretions, remain open to numerous potential candidates of carbon contamination, and contrary to popular belief provide no 'secure' radiocarbon dates.

Mud-wasp nests as well as termite runways and nests co-occur widely with rock art, in many parts of the world, and not only with rock paintings. For instance the author has reported numerous fossil and fully mineralised mud-wasp nests from Toro Muerto, a sandstone shelter in central Bolivia densely decorated with petroglyphs (Bednarik 2000). Their potential for dating will be examined.

This study has also graphically shown that, although direct dating is in most circumstances derived from features older or younger than the rock art relating to them, the data they provide may differ greatly from the target event (Dunnell and Redhead 1988), which is the production time of the rock art. In the extreme case reported here, the target event is thought to have occurred about 120 years ago, but the spatially immediately preceding mud-wasp nest appears to be in the order of 19 000 years old. This should caution against an inclination to hope that the target event is neatly bracketed by minimum or maximum ages derived from direct dating endeavours. Certainly it is bracketed by them, but the separating intervals may be so great that the result is of limited practical utility.

Finally, the absence of organics in a relatively recent mineral pigment serves to reiterate the possibility that the radiocarbon analysis of unidentified matter contained in paint residues is likely to refer to materials acquired subsequent to the time of rock art production: the carbon system of all rock subsurfaces is open (Bednarik 1979). This applies to all surface deposits, be they natural ferromanganese accretions, speleothems or pigment remains.

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