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ONLY TIME WILL TELL: EPISTEMOLOGY OF DIRECT DATING OF ROCK ART

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Abstract. *Epistemology has not kept pace with the prodigious progress experienced in the direct dating of rock art. This paper reviews the experimental methods that have been developed in recent years. While many do provide important information about the possible ages of rock art, it is of concern that the precipitate archaeological interpretations these data are used for are often not warranted. Some are attributable to not understanding the severe qualifications that apply to most dating results, others perhaps to over-enthusiasm on the part of some researchers. The introduction of archaeological dynamics into direct dating of rock art threatens the reliability of this young methodology. Some of the pitfalls are considered in this paper, and a general rationale for the direct dating of rock art is developed.*

KEYWORDS: DATING, ROCK ART, REFUTABILITY, LOGIC, RADIOCARBON, ISOTOPES, CONTAMINATION, CATION-RATIO, EPISTEMOLOGY

INTRODUCTION

The history of archaeology has been determined by the flow and ebb of epistemological fads since its beginnings early last century, and initial rejection of new models was often followed by over-enthusiasm, misuse, disappointment and eventual rejection. It is not my intent to be critical of this cyclic pattern, but to prevent the young and promising methodology of direct dating of rock art from becoming discredited due to unrealistic expectations. Archaeology's lack of a unified theory of its own may well have contributed to this pattern: for well over a century it has had to make do with uniformitarianism, a theory of questionable pedigree (Cameron 1993; Bednarik 1995a).

Archaeological misuse of direct rock art dating began soon after this new methodology found the discipline's blessing around 1990. Essentially, direct dating is contingent on two prerequisites: first, the physical relationship of the rock art and the dating criterion must be direct and indisputable; and second, the propositions concerning the chronological relationship of the rock art and the dating criteria should be falsifiable and testable. Archaeologists experience difficulties with the second of these requirements, by applying traditional modelling dynamics of archaeological interpretation to direct dating information. Lorblanchet (1994a), for instance, lists five types of dating methods for rock paintings:

1. Internal (or direct) dating: the figures themselves supply dating criteria (a) from their pigment, or (b) by the subjects represented.
2. External (or indirect) dating: (a) by archaeological layers covering the paintings, (b) by topographical relation with archaeological layers, (c) by stylistic comparison.

The first four methods are proposed to produce accurate or highly probable results while the fifth involves a good deal of subjectivity. Under method 1b, the principal subjects considered in the case of Upper Palaeolithic art are pictures of animals.

I reject the idea that animal species apparently depicted in a rock art provide a basis for *direct dating*. In fact such an approach contravenes everything direct dating stands for. Not only is it essential in direct dating to secure scientific information from substances or features physically related to the rock art in question, the relationships between such data and the art must be falsifiable to qualify as direct dating. Identification of animal species (or any other objects purportedly depicted) in this context involves two assumptions: that the species (or other objects) can be correctly identified, and that their own chronological range in the region in question is securely established. The first assumption is unscientific: it is never falsifiable and relies on the naive proposition that a modern observer of markings on rock uses the same cognitive strategies of locating iconicity in them or of identifying Gestalts as the Palaeolithic artist used. We know that even contemporary peoples use very different such strategies, and culturally unconditioned individuals from our own society differ in their iconographic identification strategies considerably from culturally and academically conditioned individuals. Moreover, we know from the only experiment ever conducted of testing 'scientific' identifications of animal species apparently depicted in rock art that science failed the test completely (Macintosh 1977).

Secondly, there is even room for doubt when it is proposed that we know the past distribution of animal species. Such known distribution patterns are not of the species themselves, but of the distribution of palaeontological finds of them, which is quite a different proposition. The true past distribution of an animal species (or any other object class) is not known and will never be fully known. To appreciate this point one could consider, as an example, the known distribution of remains of *Ursus spelaeus*, the best-known Pleistocene species. It coincides almost precisely with the geographical distribution of limestone karsts in Europe (Bednarik 1993a). Bearing in mind that nearly all the thousands of tons of skeletal remains found of the cave bear are from limestone caves, it is obvious that the sample has been so taphonomically distorted that a distribution map of it, from any period, must be significantly incomplete. In short, we do not know either the full geographical distribution of this species, nor its temporal distribution. Taphonomic qualifications of some kind apply to the speculative distribution patterns of all other species or object classes in archaeology.

There are still other problems associated with animal depictions in rock art which I have discussed elsewhere (Bednarik 1993b): possible depiction of frozen carcasses, depiction of fantastic animals, or depiction of iconic hallucinations are just some possibilities. Suffice it to say that it is no more acceptable to claim that a certain species was depicted than it is to claim that one has access to the conceptual and cognitive world of the artist. These claims belong into the realm of mythology, as do all other claims concerning the iconographic meaning of prehistoric rock arts.

But even if that were not the case, the subject claimed to have been depicted in the imagery constitutes no criterion for *direct* dating, which is contingent on the two specific criteria noted above: directness of analytic data, and refutability. This brings us to the first type of method listed above, 1a: the dating of pigment. It is true that analytic data from paint components, including pigment (but preferably from binder or other additives), may provide falsifiable data about the age of the rock art. But to use it correctly one needs to take into account the limitations of the method used, the qualifications relating to such results, and their logical relationships to the question of antiquity. Some archaeologists have always misused such data, in archaeological dating generally. The introduction of slipshod epistemologies into rock art studies would soon discredit direct dating. The purpose of this paper is to prevent this from happening. It is helpful to first consider here the qualifications applicable to the method most often used by archaeologists, radiocarbon dating, because it is also used in direct dating of rock art.

FALLACIES IN INTERPRETING RADIOCARBON DATING RESULTS

The misuse and misinterpretation of data provided by radiocarbon laboratories has been discussed before, including by myself, so I will only briefly recapitulate on this topic. There are very few methods known of absolute dating, such as dendrochronology and counting of annual ice layers (another possibility might be the annual luminescence banding in carbonate speleothems; Baker et al. 1993). Radiocarbon analysis is one of a number of radiometric methods that offer no absolute or calendar dates, but provide sets of statistical information thought to relate to the age of samples. In this method, the remnant content of an unstable and thus radioactive isotope of carbon is determined to estimate the time when its decay to nitrogen commenced. For this to be accurate it is necessary to know the initial concentration of radiocarbon, the isotope's decay rate, and that the process had not been influenced by other factors. There are problems with all these conditions, some of them quite complex. The initial atmospheric concentrations of ^{14}C and ^{13}C are not known, and are the subject of various influences. For instance, there is an intricate relationship between atmospheric ^{13}C, climate and vegetation: different vegetation communities facilitate different carbon regimes. Shrub communities (C3 plants) provide values of between -12 and -10‰ ^{13}C in respiratory CO_2, graminae (C4 plants) -3 to +1‰ (Cole and Monger 1994). Hence the initial concentration of ^{14}C may not have been the same as today's. Other factors can also contribute to distortions in the initial atmospheric concentrations, among them the effects of vulcanism (tilting the regime in favour of ^{12}C, and so rendering atmospheric carbon appearing 'older'), large-scale fires, and variations in cosmic radiation (which have certainly occurred in the past). The atmospheric ratio of ^{14}C to ^{12}C has fluctuated through time, and in response to a number of variables. Calibration attempts with tree-rings (up to about 11,500 years BP) and uranium-thorium dating (to around 30,000 BP) have both shown the erratic behaviour of the radiocarbon content curve back through time. For instance, for 250 dendro-years between 11,150 and 11,400 BP, there was no appreciable change in radiocarbon age, while the dendro-years from 10,800 to 11,000 resulted in a decrease in ^{14}C equivalent to over 400 radiocarbon years.

In theory, radiocarbon ages are usually reported with an error of one standard deviation, but it is clear that the uneven nature of the calibration curves renders this assumption hopelessly unrealistic. A radiocarbon date of 10,000 ± 100 corresponds to dendro-dates of 11,000 to 11,700, and this is still at just one sigma. In other words, contrary to theoretical expectations, there is no 68.26% certainty that the true age of a sample would fall within the tolerances stated. Moreover, we have no certainty that calibration curves are valid universally.

None of these factors encourage a great deal of confidence in the accuracy of results of the radiocarbon method, and we know of course that they are all incorrect because we have chosen to maintain the use of Libby's inaccurate half-life of ^{14}C (of 5568 instead of 5730 years). But all of these (and still other) limitations are reasonably well known and can be allowed for in constructing scientific models of dating results, provided that the many qualifications that apply to them are borne in mind (consider here the deVries effect, isotopic fractionation, occasional laboratory error). However, the greatest problem with radiocarbon dating results is their archaeological misinterpretation, resulting from their use outside the complex scientific qualifications applying to them.

Archaeologists assume, for instance, that charcoal contained in a sediment layer must be the same age as the most recent deposition of this sediment. All components of a sediment are of different ages, most are older than the event of final deposition, some are more recent. Most charcoal is not found in the location where it became carbonized, hence there is little justification for assuming that it provides reliable dates. Like the soil particles it occurs with, it has been subjected to taphonomic processes. Similarly, the charcoal found in rock painting pigment is not the same age as the painting itself; it should be older, if we ignored the possibility of contamination (and can be significantly older; Bednarik 1994a). Two or more pieces of charcoal may have been used in its production, and there is no guarantee that they must all be of the same age. Hence it is certainly possible to obtain two discrepant radiocarbon dates from a single motif, even if it has not been repainted. Indeed, there are several possible generic explanations for obtaining two discordant radiocarbon dates from a single rock art motif:

a. Erroneous determination in one or both analyses.
b. Contamination of one or both samples.
c. True age lies outside stated tolerance, of one or both samples.
d. Charcoal fragments of different ages were used at the same time.
e. The painting was retouched subsequent to its production.

Not only can we not know which of these explanations is correct (although nanostratigraphy may help illuminating the issues), combinations of some of them may apply, rendering the truth even more obscure. It is therefore rash to claim, as Lorblanchet has done at Cougnac, that two different radiocarbon dates from charcoal pigment prove that rock art re-use has taken place (Lorblanchet 1994b). The Cougnac paintings are among the stylistically most homogeneous in French parietal art, and all commentators (including Lorblanchet 1984) have considered this relatively small assemblage to be of a single tradition. Unfortunately Lorblanchet has collected all datable pigment in Cougnac, without conducting nanostratigraphic studies, which seems to render it impossible to test his propositions (Lorblanchet 1994b).

There are still many other potential sources of error in the interpretation of radiocarbon concentrations, particularly when they are presented as direct rock art dates. In the limestone caves containing European Pleistocene rock art, bacteria, algae and fungi have been introduced by tourists and artificial lighting, and have been found to occur in rock paints. In many cases, these paint residues contain also reprecipitated calcite, whose isotopic carbon composition is determined by both the age of the limestone and the time of its reprecipitation. In rock art dating work it is attempted to excise these carbonates as well as organic contamination, either by purging them chemically or by oxidizing the carbon. Such treatment would not detect any distortion resulting from ionic exchange, nor does oxidation (be it by oxygen plasma or by combustion, see below) exclude organic contamination. Moreover, it is to be noted that the sample residues retained for such analyses are usually of exceedingly small size (in the order of milligrams of carbon). Hence even minor contaminants can have considerable effects, especially in the case of samples of Pleistocene age.

Pre-treatment of samples can differ between individual laboratories, and of course the actual contaminants themselves are likely to differ. This suggests once again that it is not appropriate to assume that radiocarbon dates from different sources can be reliably compared. So it is not only the statistical fact that, in comparing two radiocarbon results stated at one standard deviation, we reduce the probability of a valid comparison to 46.59%, but we may also be comparing results that are not fully compatible.

All of these reservations and others not considered here remind us to exercise greater scepticism, and to question archaeological constructs based on an inadequate understanding of the limitations of results from dating attempts. Before we consider this topic there is one more major issue to be reviewed here. It concerns the apparent assumption that rock surfaces are somehow sterile, free of organic substances.

ABOUT ORGANIC MATERIALS IN ROCK SUBSTRATA

One of the methods used to safeguard against the contamination of radiocarbon-dating samples from paint is the use of a low-temperature, low-pressure oxygen plasma to oxidize the organic matter (Russ et al. 1990). However, if organic contaminants are present, this technique will extract them as well as the targeted charcoal or other pigment or binder (Chaffee et al. 1994). The process cannot distinguish between different types of organic matter. Precisely the same applies to a very different method of extracting carbon from rock art-related samples, the 'focused laser extraction of carbon-bearing substances' (FLECS) followed by accelerator mass spectrometry (AMS) radiocarbon dating (Watchman 1993). Here, a small sample of rock varnish, paint residue or other rock art-related substance is combusted with the help of a laser, and the resulting carbon dioxide is then reduced to a graphite target for AMS dating. Again, the method is effective in excluding a variety of potential contamination factors, and it is very versatile: it can be applied to numerous datable inclusions and residues relating directly to rock art (e.g. plant remains, oxalates, organic binders or vehicles). But it is also this versatility that impairs the method's reliability. Without knowing precisely what the oxidized substances were, the radiocarbon date obtained may be difficult to relate to the actual age of the art concerned.

The problem is, very simply, that both methods cannot be targeted on a particular substance, but may in fact provide composite results to which any suitable matter present in the sample has contributed. This can include any organic pigment or binder, microscopic biota, lipids, proteins, carbohydrates, vegetable remains such as brush fibres, airborne debris and so forth − whatever happens to be present in the sample. It is therefore likely that two such dating results from different locations on the same motif, using precisely the same technique, will provide different results, depending on the proportions of the contaminating components (see McDonald et al. 1990 for greatly incompatible results from charcoal of a single motif). This renders it even impossible to make precise allowance for the contaminants by determining them and their magnitudes chemically or microscopically from a control sample: their relative proportions may differ locally.

The importance of organic materials present in rock substrata and on rock surfaces, quite independent of any human intervention, has been vividly demonstrated by a recent rock art dating controversy in Australia. Loy et al. (1990) had reported locating dark-red pigment at the Northern Territory site Laurie Creek, securing from it a proteinaceous substance they identified as human blood. The AMS radiocarbon date they obtained from this sample, 20,320 + 3100/ - 2300 years BP, was the earliest date secured from any rock art paint in the world at that time. However, the radiocarbon scientist of the team, E. Nelson, had second thoughts about this result and subsequently re-sampled the rock panel. He found that the 'pigment' layer was naturally precipitated iron oxide, and he detected organic matter at various surface locations that bore no 'paint'. When analyzing the deposit from which the original data had been secured he found only low concentrations of protein, and it was not a residue of human blood. Hence the radiocarbon date had no archaeological significance at all (Nelson 1993). Loy (1994) has responded to this correction, still maintaining that there was mammalian IgG present at the sampling site, and saying that Nelson's new data confirm the presence of organic carbon in the samples. Indeed they do, but the organic carbon is also present in the supposedly undecorated rock surface.

Nelson has noted an important point here: many archaeologists seem to think that rock surfaces are more or less 'inert' − of purely mineral composition. That this is not the case has long been pointed out in archaeological literature, even by rock art dating scientists (Bednarik 1979). Naturally deposited organic matter is not only present on all rock surfaces, it occurs also in profusion in substrata, including accretionary deposits such as rock varnish. Moreover, it is found in the subterranean weathering zones of regoliths and can be very common there. It even occurs in the interior of a visually unaltered and apparently unweathered rock mass. Finally, micro-organisms have been observed within the earth's crust, kilometres below the surface of the planet. The concentrations of lithospheric organic matter differ of course considerably in different locations, but here we are only concerned with the actual interface of lithosphere and atmosphere, or the immediate substrate.

Almost twenty years ago I analyzed numerous rock samples in the course of investigating the potential of direct dating of rock art. For instance, after studying weathering and ferromanganeous layers on basalt, I reported an increase of organic matter, from the interior of a boulder to the outermost layer, of 1824% (Bednarik 1979: Fig. 3), by individually analysing five successive weathering zones. This was derived from an increase in the loss on ignition component from 0.74% to 13.5%. One might secure AMS dates from such layers but what could their significance be? Certainly such dates would provide 'direct dating' information in the sense that the results are in some way relatable to the age of a specific feature on the rock, but the difficulty is to present that relationship in a credible and preferably refutable fashion.

Geomorphologically, residual rock paint is an anthropic accretionary deposit on a rock surface. It can resemble natural deposits so closely that these have occasionally been mistaken for paint by very experienced archaeologists (e.g. Loy et al. 1990; Loendorf 1986). If organic contents of 10% and more can be registered in natural iron oxide accretions, it would be extremely rash to assume that all the organic material in anthropic iron oxide accretions (or any other such applied substance) must all be of a radiocarbon age equivalent to the time of the paint's application. We then need to ask: what is the value of determining the combined radiocarbon content of such paint residues? Can it be expected to relate to the age of the painting?

No doubt it does relate to it in some fashion, but certainly not in the simplistic fashion some archaeologists have used such data. It is my contention here that such dates should be interpreted only within the context of all the analytical qualifications that apply to them, and within the rigorous epistemology of direct rock art dating as it was originally conceived (Bednarik 1981). They do not provide *true ages* as such, they provide *provisional dating information*.

VARIABILITY OF QUANTITATIVE INDICES ACCORDING TO SAMPLING SITE

So far I have reviewed only some of the methods using the determination of radiocarbon content to estimate the age of rock art, and none of those using alternative indices. The first direct dating method applied with some level of success was the determination of the radiocarbon content of a mineral deposit rather than an organic substance: re-precipitated carbonate in the form of calcite speleothem. The method has been developed and re-examined for some fifteen years now, and a recent review of the isotopic geochemistry it relates to (Bednarik in press) concludes it is unlikely 'that reliable dating of such travertine deposits can be obtained by simple radiocarbon determination alone'. This is not due to some inherent problem with the technique as such: about one half of the carbon in re-precipitated carbonate is derived from essentially atmospheric carbon (largely from pedogenetic, i.e. respiratory carbon dioxide; Hendy 1971). However, in the reaction leading to the solution of limestone, a surplus of carbon from the atmosphere is necessary and this is variable. Moreover, carbonate speleothems are often of 'porous' crystal lattices, and further deposition of solute in the pores inevitably leads to 'rejuvenation' of the radiocarbon age (Bednarik 1981, in press; Bednarik and Head 1995). When we add to these significant variabilities the uncertainties about past atmospheric carbon dioxide isotopic composition as well as carbon dioxide levels (which as we have noted were related to climate, vegetation patterns and cosmogenic radiation), the utility of such radiocarbon ages becomes questionable. For instance in the Mt Gambier region of South Australia, where this method was first used in the service of rock art dating, volcanic events occurred in the Holocene, and the percolation of volcanic gases in the region's porous Tertiary limestone could have had significant effects on the isotopic composition of the speleothems (Bednarik in press).

Qualifications equivalent to those encountered in this example may well apply to most other dating methods. Some of them, such as the last-named, certainly apply to all forms of radiocarbon dating: its basic assumption is that we know the isotopic carbon ratio in the atmosphere at the time of the event we are attempting to date. Even if we did know that it would not guarantee a valid date.

A technique that is similar to carbonate dating was developed by Watchman (1990) when he discovered the occurrence of oxalates at northern Australian rock art sites. As they are salts of oxalic acid, the isotopic carbon ratio of these minerals invites radiocarbon determination. But, just as the carbonates often contain interstitial spaces allowing rejuvenation, oxalate skins may also comprise spaces between crystal faces. Watchman (pers. comm. Sept. 1994) has observed such spaces measuring in the order of 1-5 µm in crystallized whewellite, and they can be penetrated by solution precipitating oxalate of a younger age. Consequently a radiocarbon date obtained from such a deposit with current methods would be distorted by this rejuvenation effect.

Once again, highly localized isotopic ratios may occur in the immediate sampling area. A sample taken alongside the first sampling site may produce a different result, reflecting a different combination of local ratios. We can generalize from this observation that there must be two generic classes of direct rock art dating methods: those providing results that are specific to the sampling site, and those providing results that should be fairly uniform over the entire area of a single motif.

A classical example of a method providing results of the first type, highly variable depending on sampling site, is cation-ratio dating (CR). This method seeks to calibrate the rate of leaching of the more soluble cations of rock varnish (potassium and calcium) relative to the supposedly more stable titanium content (Dorn 1983, 1986). After it was developed during the

1980s, its reliability and accuracy were seriously challenged (cf. Nobbs and Dorn 1988 and comments; see also Bednarik 1990; Bierman et al. 1991; Watchman 1992a, 1992b). Dorn has conceded that it is an inferior method (1990) and that it is susceptible to an excessively high number of variables (1994).

One of the numerous flaws of this technique is the great variability of the crucial indices, the cation ratios. For instance, sedimentary rocks have great variations in Ti on a millimetre scale, e.g. due to a single layer of heavy minerals, or spotting effects of low-grade metamorphism. Such differences of cation ratios in the host rock may be reflected in those of the varnish over the motif area. Anomalies can occur not only in Ti, but also in Ca and K. In addition, numerous other factors affect the CR of rock varnishes: the proximity of soil, oxalate, amorphous silica or organic matter; lichens, fungi, pH, water runoff; and of course relative exposure to leaching or weathering. Moreover, the ratio will differ laterally, depending on how the varnish spreads out from initial colonization sites. Structurally, rock varnishes are as a rule highly variable, again on a millimetre scale, which is precisely why I abandoned the idea of using them for dating in the 1970s (Bednarik 1979). The extent erosion episodes or of cation scavenging by micro-organisms, which certainly invalidate CR dates, is well demonstrated by SEM photographs of varnish stratigraphies. This applies also to episodes of microcolonial fungus attack or lichen activity. Even the fundamental proposition that cations are uniformly soluble is open to question. After all, they do not occur as pure elements and it would seem to be the solubility of the minerals they occur in that determines the relative leaching rates. The solubility of diverse Ti-minerals relative to different Ca-minerals varies considerable (some minerals in fact contain both cations, such as titanite). All of the factors determining the cation ratio of a weathered rock varnish are locally variable, besides distorting that ratio, and this probably explains the significantly discordant results of Watchman's re-sampling program (1992a, 1992b).

POTENTIAL ROCK ART DATING METHODS

The methods we have considered so far account for most of the recent attempts to date rock art directly. It should be of real concern to us that they all relate to age indices that are susceptible to local variation, i.e. the method is often not likely to produce consistent results through repeated sampling of the same motif. In some cases, such as in CR dating, the differences may be so dramatic (as demonstrated by Watchman 1992b) that any confidence in these results is misplaced. The utility of such a method to rock art dating must be seriously questioned: not only can it discredit the principle of direct dating, it tends to divert attention and resources away from more productive and more reliable approaches. There are many potential means of direct rock art dating which have attracted considerably less attention, if any at all. Oddly enough, they seem sometimes more promising than the popular methods, in that they seek to quantify indices from a motif that are essentially uniform over the motif area. The classical example of this is microerosion dating (Bednarik 1992, 1993c), but there exist also a number of potential alternative methods which have so far not been explored. In general these are of a geomorphological nature, mostly having to do with aspects of rock weathering or other alteration (e.g. through radiation).

Methods that might fall into this category could be those of luminescence dating (thermoluminescence, optically-stimulated luminescence or infrared-stimulated luminescence). Traditionally neglected in archaeology, luminescence dating is now receiving increased attention to overcome the radiocarbon dating 'barrier'. Some studies have suggested that these methods provide somewhat greater dates for Late Pleistocene events than radiocarbon dating (e.g. Nanson et al. 1987; Roberts et al. 1993), which would be consistent with the opinion that radiocarbon dates above 20,000 BP are generally too low, and with the same finding based on comparative uranium-thorium dating (about 4000 years by 30,000 BP). So far, luminescence dating has not been applied to rock art, but endeavours to do so are underway in Australia (Morwood et al. 1994: 84). Cosmogenic radiation products have not been used so far in rock art dating, because present sampling requirements would not be realistic for this application.

Even in the case of rock varnish, whose significance to direct rock art dating is beyond dispute, several dating methods appear to be more reliable than the CR technique. For instance, it is self-evident that this ferromanganeous accretion would be well suited to palaeomagnetic dating, and yet none of the projects favouring CR dating has included a comparative study using this method (Clayton et al. 1990). Uranium was known to precipitate with the Mn-oxides of rock varnish even before the CR method was conceived (Knauss and Ku 1980) and uranium series dating would provide more reliable information than the supposed leaching indices derived from the ratio of three cations. Rock varnishes contain clays that may be susceptible to potassium-argon dating where their ages are great enough, and if they conceal any quartz grains these may be datable by luminescence analysis. The latter would also offer far more reliable estimates of minimum age than the CR method is likely to provide, and yet again no comparative study has been attempted by the protagonists of CR dating.

Some of these considerations apply not only to rock varnish or other accretionary deposits, but also to rock paint residues. In the case of iron oxide pigments, palaeomagnetic dating – even if it is only correlative – may be valid where the pigment has been heated in order to alter its optical properties (as has been practised since the Acheulian). Luminescence dating may succeed where quartz grains can be located under paint residues, or in deposits occurring stratigraphically under or over the paint (e.g. in fossil nests of mud-daubing insects). All of these methods may well be more reliable than the indiscriminate AMS radiocarbon dating of unidentified substances in rock varnish, paint residue or any other deposit, simply because they would be repeatable: similar material from another sampling site relating to the same artistic event should produce identical results if subjected to the same techniques.

ARCHAEOLOGICAL USE OF ROCK ART DATING

The essence of the concept of direct dating as evident from the principles enunciated above was not just to secure dating information from substances physically related to the rock art in question, but also to define and express falsifiable relationships between such data and the art. Propositions of direct rock art dating are expected to be refutable, and are thus scientific propositions. Archaeologists, who have traditionally had difficulties in dealing with questions of refutability (Tangri 1989), can dilute this sound methodology by introducing the haphazard hypothesis building procedures of archaeology, with its application of confirmationist analogy, determinist deduction and systematic misinterpretation of hard data. This must inevitably lead to a devaluation of direct dating methodology, once it becomes evident that it does not deliver what it seems to promise – once its 'weaknesses' are exposed and its 'susceptibility to errors' is realized.

The problem is best explained by illustration. Lorblanchet has enthusiastically embraced direct rock art dating as the superior approach since 1990, but has consistently misinterpreted its results. The flaws in his arguments are attributable to a preference for archaeological modelling dynamics over scientific ones. For instance, there are numerous self-contradictions in his claims regarding rock art dating, too many to list here (see Bednarik 1994a and 1995b for examples). Having earlier regarded the rock art in Cougnac as stylistically homogeneous and belonging to a single tradition (Lorblanchet 1984: 487), he abandoned this view after securing just one AMS date from charcoal pigment (Lorblanchet et al. 1990), and rejected style as a chronological indicator (Lorblanchet and Bahn 1991). After a total of six radiocarbon determinations from four painted motifs in that site, he interpreted these as individual absolute dates, proposing that the figures must have been retouched (Lorblanchet 1994b) and must belong to at least three cultural phases representing most of the Upper Palaeolithic (Perigordian, Solutrean and Magdalenian). It has been shown that there is no scientific basis for these claims, and that the series of radiocarbon results he has procured could easily be explained in a number of alternative ways (Bednarik 1994a, 1995b).

In an application of a different form of logic he claims that the datable bones placed near hand stencils in Gargas (Clottes et al. 1992) are the same age as the stencils (Lorblanchet 1994b).

He thus contradicts his own logic at Cougnac, where he argues in favour of multiple uses of the art over long periods of time. Based on inadequate interpretation of carbon dates he is adamant at Cougnac that Palaeolithic rock art was re-used, yet when he observes traces of two different cultural activities in close proximity in Gargas, he pronounces them as contemporaneous without any evidence, deducing the age of one of them from the other. Obviously, such bones stuck into cracks could well indicate later responses to the art.

In yet another example, he was one of the first to pronounce the petroglyphs in the Côa valley in Portugal (Bednarik 1994b) as being Palaeolithic, on the basis of no evidence other than their style. And yet he is a foremost advocate of the rejection of style as a scientific dating criterion (Lorblanchet and Bahn 1991). Lorblanchet is not alone here: not one specialist of Palaeolithic art has proposed the application of scientific dating methods to any of the dozen or so supposedly Palaeolithic open air petroglyph sites presently known (Bednarik 1995c), in the fifteen years such sites have been discovered.

In a review of all the twenty direct AMS dates published by early 1994 from paints of Upper Palaeolithic rock art in France and Spain, Clottes (1994) found that there were difficulties with the interpretation of each one. Some had been obtained from obviously contaminated samples but were published because the results 'seemed to fit', while the publication of others had been suppressed because their values 'did not fit'. The latter include a radiocarbon date of c. 5000 BP for supposedly Palaeolithic paint. This illustrates how data are filtered by archaeological interpretations and how inappropriate it is to accept and repeat these uncritically.

Perhaps the most economical way of dealing with epistemological inconsistencies in the archaeological use of rock art dating results is to systematically respond to the various epistemological fallacies one finds in this area:

1) A radiocarbon date obtained from charcoal pigment does not indicate the age of the rock painting it is from, it should be greater. The taphonomy of the charcoal used in a painting is unknown, and charcoal thousands of years old may have been used. Such a radiocarbon date may be an approximate direct date for the pigment, but it is not so for the paint, because its chronological relationship with the paint is not testable. Many archaeologists believe the terms paint and pigment are synonymous, which may explain this fallacy. It is similar to assuming that the age of haematite pigment, which is many millions of years old, equals the age of the rock painting it forms.
2) Paint residues, accretionary deposits or surficial rock substrata contain organic matter whose chronological relationship with the event of art production is unknown. A radiocarbon date obtained from such features is a direct date for the combined carbon present in the prepared sample, but not for any rock art constituted by such residues, covered by such a deposit, or underlain by such a substratum.
3) Identifications of objects supposedly depicted in rock art may well be correct, but they are not refutable propositions and thus not relevant to scientific dating of the art. This does not impair their use in speculations, but it provides no scientifically valid or secure evidence.
4) Inductive dating (e.g. through supposed dating of a sediment covering rock art) may well be correct, at least as minimum dating, but it rests on non-refutable correlations, such as data obtained from components whose taphonomic relationship is usually not demonstrated (although there may be means of achieving valid correlations).
5) So-called stylistic dating of rock art may well be possible, but such correlation must be rendered falsifiable if it is to have scientific relevance. In particular, researchers have to express their stylistic pronouncements in refutable, quantifiable, repeatable or testable rather than intuitive terms.
6) When comparing two or more dating results, several considerations apply:
   a. What are the statistical constraints of each result and how does their correlation reduce statistical resolution of such sets of probabilities?
   b. Were all dating results obtained by the same method? To compare, say, results of radiocarbon

dating with those of TL dating from another site, is inappropriate, as their relationship with the common denominator time is not secure.

c. If the same method was used, were the methods limiting the effects of contaminants the same? If they were not, a comparison of results may be inappropriate.

d. Are the statistical methods used to interpret the relationships of the results valid?

A RATIONALE FOR DIRECT DATING OF ROCK ART

Some of the observations made above emphasize a dichotomy between two generic classes of direct rock art dating methods: those providing data of locally variable indices, and those providing data that can be expected to be uniform over the area of an entire motif. One of the basic requirements of science is the repeatability of experiments. A dating analysis is an experiment, and if it cannot be effectively repeated because there is a reasonable expectation that each sample taken from a motif may produce a different result, then the requirement of repeatability is not satisfactorily met. This applies even in cases where similar results are in fact secured by repeated sampling, because such consistency cannot be predicted or relied upon (unless the absence of distorting factors can be demonstrated). The possibility of such variations reminds us that these analyses are not of representative or random samples of a homogeneous substance; they can be, and often are, of randomly distorted samples. If repeatability is not assured, scientific credibility is impaired. It does not mean that the method is not scientific, or even that the result is not refutable, but these qualifying factors must be adequately considered in any interpretation of the results.

It follows from this that any method utilizing uniform criteria is preferable to one based on locally variable indices, even if the latter appears to offer chronometrically more precise results. This distinction may facilitate our understanding of direct dating, and perhaps the original definition of such dating methods should be expanded accordingly. Presumably *variable indices* for the direct dating of rock art include those obtained by all forms of radiocarbon dating, CR dating, and of course lichenometry. Determining their results' true relationship with the age of the art can be a great challenge indeed, and will always involve unknown variables. Securing similar results by repeated sampling may increase our confidence in them, but it is not expected to detect systematic distortion. Presumably *uniform indices* can be provided by any method that is likely to produce consistently similar results from the entity being analysed. This refers particularly to methods dealing with geological rather than organic phenomena, such as luminescence, microerosion and other geomorphological indices, palaeomagnetism, and the several methods of uranium series dating.

In a sound epistemology of direct rock art dating we need to distinguish between results that may seem very accurate, but whose actual relationship with the art is difficult or even impossible to establish; and results whose relationship with the art seem secure, irrespective of their apparent precision. The technological sparkle of the former has lulled researchers into a false sense of security. It would be more appropriate to favour the greater reliability of methods employing uniform indices, even where their precision leaves much to be desired.

Another important consideration in designing a rationale for direct dating of rock art concerns the susceptibility of results of different methods to statistical interpretation. This complex subject involves the following questions:

1. What does the dating result represent statistically? For instance, a CR date might be derived from the average of several cation-ratios determined from one sample, not an 'actual' date, as in the case of a coin's mint date (Lanteigne 1991).
2. What statistical errors are built into the result by way of calibration, e.g. through the qualifications inherent in radiocarbon dating in the case of CR dating? The uncertainties attached to the calibration method are compounded and magnified by those of the second method used.

3. Does the 'date' represent a statistically meaningful, large sample of individual measurements, or does it express a random choice from an available spectrum, the extent of which remains itself unknown?

There would appear to be two fundamental strategies in all of archaeological dating. One is to select a sample of the entity being dated and assume that chronological quantification derived from it is representative. The other is to accumulate a sufficiently large number of age-related characteristics to assure that their spectrum of chronological quantification is likely to encompass the true age of the entity being dated. In the first case we need to provide large enough statistical tolerances to make due allowance for all contingencies, and these are significantly larger than, for instance, the one-standard errors in the counting of radiocarbon. In the second case the number of indices the result is derived from is of adequate size to render it statistically meaningful. In rock art dating, only one method of the second type has been used so far, microerosion dating. In it the 'date', derived from a cluster of age-related measurements, is not expressed with any tolerance level, but is presented as a set of probabilities in the form of a histogram (Bednarik 1992: Fig. 6).

In summary, this paper shows the need for distinguishing between direct methods of dating rock art that relate to variable indices on the one hand, and those using uniform indices on the other. By resorting to the former we compromise refutability of our claims because with them the true relationships between 'date' and age of the art cannot be established. In preferring the use of uniform indices methods we should still be biased in favour of those that offer statistically meaningful numbers of measurements. Finally, we should favour methods that offer the facility of internal checking of results, i.e. without having to resort to a different method. It is certainly commendable to check dating results in any circumstances, but by checking them with those of a different method we must always remember that we are compounding two sets of qualifications and uncertainties. Microerosion dating does possess the facility of internal checking, by means of its multiple calibration curve: if one calibration curve is distorted by one of the variables controlling the erosion process, the corresponding values on the other curve(s) will be misaligned. It would be desirable to devise and introduce similar strategies of internal checking in other dating methods.

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