Methods of direct dating of rock art. *Sahara* 8: 43-52, 1996

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Riassunto

L'autore prende in esame la metodologia per la datazione diretta dell'arte rupestre, critica la tendenza a favorire soluzioni tecnologicamente complesse ed elenca diversi casi di errata interpretazione dei risultati ottenuti in vari paesi. L'articolo comprende un elenco e una discussione dei metodi per la datazione diretta dell'arte rupestre utilizzati finora, o che potrebbero essere utilizzati in futuro. L'autore si augura un approccio più allargato agli studi scientifici della paleoarte, che dovrebbe prevedere la raccolta completa dei dati geomorfologici relativi alle pareti decorate.

Summary

In reviewing the methodology of direct rock art dating, the author is critical of the bias favouring technologically complex solutions, and lists several cases of misinterpretation of dating results from various countries. The paper includes a comprehensive listing and discussion of the methods which have been used in direct rock art dating, or which conceivably could be used in the future. The author advocates a broadly based approach to scientific palaeoart studies, which should include a practice of comprehensive recording of geomorphic details of art panels.

Résumé

En révisant la méthodologie de la datation directe de l'art rupestre, l'auteur critique la tendance à favoriser des solutions technologiquement complexes et dresse une liste de plusieurs cas de mauvaise interprétation des résultats obtenus dans divers pays. L'article inclut une liste complète et une discussion des méthodes qui ont été employées dans la datation directe de l'art rupestre ou qui pourraient être utilisées dans le futur. L'auteur souhaite une approche plus élargie et basée sur des études scientifiques du paléoart, qui devrait inclure la documentation complète des détails géomorphologiques des parois décorées.

Some initial considerations

This is the second of two papers addressing the topic of current methodology of rock art dating. In the previous issue of *Sahara*, we considered the logical and epistemic basis of direct dating results. In particular, we examined the archaeological dating approaches, and how «direct dating» of rock art differs from them. We found that the results of direct dating can easily be misinterpreted if we use them in traditional archaeological model building dynamics.

Since archaeologists have not had much access to direct dating methods other than those based on radiocarbon analysis so far, the above concerns are largely restricted currently to charcoal samples obtained from black rock paintings. However, it is only appropriate to outline other qualifications to radiocarbon dating, and to consider potential problems before we move on to the consideration of the potential of specific techniques for application in the Sahara.

Radiocarbon dating, as we have seen, depends on a great many variables, and its application should not be an uncritical acceptance, but should be qualified by any relevant limitations. Some aspects of isotopic fractionation, for instance, have received inadequate consideration. We do not know the true isotopic chemistry of the atmosphere that provided the carbon we are sampling today, but it may have been influenced by quite a number of factors - for instance, former plant communities[1]. This raises questions about the causes and effects of climatic oscillations, their relationships with atmospheric carbon dioxide levels, vegetation regimes (which may have the ability to influence temperature for their own ends) and the isotopic ratios of atmospheric carbon. It is therefore relevant to remember that radiocarbon dating results are not without

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[1] The calculation of a radiocarbon date is contingent on the measured $\delta^{13}C$, which is always reported together with the ^{14}C, but usually not cited in archaeological literature. Plant communities have a significant effect on the $\delta^{13}C$ value of reprecipitated carbonate, for instance: values of between -12 and -10‰ apply to respiratory carbon dioxide derived from C3 plants, while the $\delta^{13}C$ compositions of carbonate in equilibrium with carbon dioxide respired from C4 plants range from -3 to +1‰ (Cole and Monger, 1994). C4 plants, so called because of the four-

their significant qualifications. Moreover, it must be remembered that the attempted calibration of radiocarbon dates through dendrochronology may provide a false sense of security in the interpretation of results.[2]

Seen in this light, many alternative dating approaches may look rather more attractive than some radiocarbon-addicted archaeologists perceive them. A case in point are the luminescence dating methods, which have remained rather neglected until quite recently. Applications of thermoluminescence (TL) or optically stimulated luminescence (OSL) dating to rock art may not be immediately obvious, but they certainly do exist[3]. There are various potential applications, innovative if experimental, of this methodology, and most certainly these are relevant in the Sahara. Indeed, the key factor in future direct rock art dating will be innovativeness: researchers will need to use a variety of methods in tandem, and they will have a good understanding of their respective potentials and limitations. Rock art scientists will continue to be as opportunistic and adventurous in the design of their dating projects as they have been in the past, but instead of relying on simplistic deductions and on the advice of dating scientists they need to be prepared to take the initiative. They need to inform themselves about the range of options available to them and design their approaches around their own knowledge, rather than continue the past laboratory-client relationship in which they are to some degree the dilettante consumers. Not all dating methods involve a dependence on laboratories, and the differences in what various methods can or cannot deliver, in specific circumstances, are enormous. Most methods, clearly, apply only under a complex set of preconditions, have severe limitations, sources of contamination and so forth, and it seems to me that in order to design effective scientific dating programs, the rock art researcher will have to break out of the archaeologist's dependency on «others» and become more self-sufficient, more self-reliant. To do this, he or she first has to become thoroughly familiar with the options, their possible applications and limitations, and must acquire the acumen to make informed decisions in the field about alternative courses of analysis, and to extract the maximal sound information from any set of on-site circumstances. No two rock art sites are identical; in fact I prefer to think that no two sites are even similar. Each presents numerous possibilities of deriving some information that might help in dating the art, but always in unique combinations and conditions. Textbook solutions are usually of little help, and good advice from a laboratory is no doubt valid, but when confronted by real site situations in the field it may seem quite irrelevant.

To acquire the necessary knowledge is not as difficult as one may be prone to think. We need to be aware of the possibilities that exist, eliminate those that are beyond our means or are inappropriate, and see how we can best apply the rest to the set of circumstances a site or a series of sites present us with. It is necessary to compare all the available methods frankly and practically, and to consider such questions as:

1. Will the proposed method involve sample removal, and if so, how much damage will I cause? Can I justify this, in terms of the amount of knowledge I can reasonably expect to gain? Do I possess the necessary expertise to conduct such sample collection properly?
2. What are the economical considerations? The costs of some rock art dating methods are very high, and to spend $10,000 for one single calibration curve of cation-ratio (CR) dating was justified when the method was originally developed and tested, but is no longer justified now that it is discredited.
3. Reliability and precision are often inversely related in dating work: a reliable method may be very imprecise, while precision may be acquired at the cost of reliability. I believe that a judicious researcher prefers reliability over perceived precision.
4. In a choice between a method that offers a date for the art itself, and one that offers a date for a feature related to the art (either older or younger than the art), the former should have precedence in most research designs, but not necessarily so (e.g. where a compromise involves a considerable loss of resolution).
5. In any dating project, any procedure that promises some form of checking a result by some means or method is to be preferred to a possibly

carbon acids as which carbon dioxide is initially captured in their outer mesophyll cells, include about half of the world's grasses, which have a physiological advantage over C3 plants in low atmospheric carbon dioxide concentrations (Robinson, 1994). The latter are directly related to world climate, and were significantly lower during the Pleistocene glacials, as shown by ice cores from Antarctica and Greenland (Morgan, 1993). This introduces yet another variable to challenge the utility of uncalibrated Pleistocene radiocarbon dates.

[2] Calibrated radiocarbon datings tend to foster a false sense of security in some archaeologists who regard them as calendar years. It should be noted that a calibration curve from Sierra Nevada bristlecone pine or Tasmanian huon pine has no direct bearing on the precision of a radiocarbon date from some other location in the world. Radiocarbon concentrations in atmospheric carbon fluctuate in accordance with many factors, including volcanic eruptions, large forest fires, cosmogenic radiation, types of plant communities, ozone holes, temperature and so forth. It is a fundamental limitation that in most cases we do not know the precise atmospheric isotope composition at the time the radiocarbon was assimilated by vegetation, and would need local calibration curves to overcome this restriction.

[3] For instance, in the Kimberley of Australia, mud nests created by wasps are commonly found together with rock art in sandstone shelters (Morwood *et al.*, 1994). Sometimes they obscure rock art, or paintings were executed over them. As I write this, researchers are engaged in determining whether quartz grains from such wasp nests can be effectively dated by OSL, and are conducting background radioactivity measurements in the sites.

self-validating procedure (e.g. a series of dates, all derived by the same method).

6. Some methods provide results only months after the field work, others provide immediate results, or at least an indication of what result might be expected. Clearly it is of benefit to have an early indication, it may save us having to return to the site to collect more samples. In a region such as the Sahara this is of particular importance, due to extreme remoteness of most sites and the considerable efforts involved in the collection of data.

7. Any dating method that can be used without the involvement necessarily of dating specialists has considerable attractions. Excessive sophistication in rock art dating techniques is absolutely no guarantee for precision or reliability, but involves significant drawbacks: it soaks up research funds and it widens the gap between researchers in developed and developing countries, by encouraging restrictive methodologies and practices.

8. In choosing between a method that produces spatially variable results, and one offering uniform results, the latter is clearly the preferred option. As in point 4 above, this choice also involves a trade-off of precision, as the methods offering uniform results are usually the less precise[4].

9. A rigorous rock art dating project would involve a «blind test» by several different methods and specialists, a procedure fundamentally different from archaeological or stylistic dating. Only one such project has so far been conducted (in Portugal; Bednarik, 1995a; Watchman, 1995). Stylistic dating, by contrast, is based on a consensus of similarly conditioned practitioners. In a blind test, participants cannot influence each other and must rely entirely on the merits of their respective methods. Such practices are fundamental in the sciences, but virtually unknown in archaeological procedures.

Some archaeological dating methods are capable of providing absolute ages with precision, but most are not. There are very few of the former, and they seem not applicable to rock art[5]. However, the results of all other dating methods used in archaeology generally are only expressions of age estimation. Most of those that offer some realistic level of precision are sets of statistical data that serve to express their limitations. It is therefore fundamental to appreciate their statistical constraints. Almost none of these methods are likely to produce adequate numerical sample sizes for meaningful statistical treatment, i.e. within meaningful confidence intervals. A notable exception is microerosion dating (Bednarik, 1992a, 1995a), which is not designed to provide one single «date», but offers in each case a large cluster of age-related numerical values from which one can generate variance analyses and other statistical solutions (Fig. 1). The statistical impotence of the results of most dating techniques is well explained by Lanteigne (1991), and although he addresses only one method, CR-dating, what he says also applies to most others.

A comparison of some direct dating techniques

Microerosion dating has several other characteristics making it a prime candidate for rock art dating in the Sahara (Bednarik, 1993). It is the only method of direct rock art dating that involves no damage of the rock art or an associated feature, because no sample is removed in it; and it is the only petroglyph dating method that seeks to establish the time of art production, rather than the age of some related feature. Moreover, its practical application is simple, it can be learnt easily by any researcher, it is one of the cheapest methods available, and it can potentially be used by most researchers in developing countries (Bednarik, 1993). It also provides results in the field, and because it involves detailed microscopic scanning of petroglyph surfaces, it is likely to result in other important information about the art. Unfortunately it is a new method which can be used only with appropriate calibration, and that still has to be established for most climates. At this early stage, its use involves the creation of calibration curves, for which a number of rock surfaces of at least approximately known ages (a minimum of two or three, but preferably more) must be available which have been subjected to similar conditions. They need not necessarily be of the same rock type, it would suffice if they contained the same component minerals as those used in the rock bearing the petroglyph (e.g. the quartz in a rhyolite could be

[4] I distinguish between two generic classes of direct rock art dating: methods providing data of locally variable indices, and those providing data that can be expected to be uniform over the entire area of a specific motif. I have argued (Bednarik, 1996) that in science, replicability of experiments is a basic requirement, but when there is a reasonable expectation that each sample taken from a motif may produce a different result such a demand for replicability cannot be met. This applies, for instance, to radiocarbon dates from rock art paints as well as from mineral deposits over petroglyphs, both of which are likely to be contaminated by organic matter and other carbon-bearing substances. There are ways to address this problem: for instance, one could date the organic matter at the molecular level, dating different compounds and discounting those that produce variable results (Bednarik, 1996). This promising procedure has not been attempted so far, however. Alternatively, the substance being dated could be identified (e.g. visually) before being prepared as a dating target. Local variability certainly applies also to CR dating and to lichenometry, both of which are thought to yield highly variable results according to location. This means that different dating estimates may be derived from different parts of the same motif. Presumably uniform indices can be secured by methods that are likely to yield consistently similar results from the entity being analysed. Typical candidates would be methods involving luminescence, microerosion and other essentially geomorphic indices, and palaeomagnetism or uranium series dating if they could be used.

[5] Dendrochronology can, in certain conditions, provide ages in calendar years from annual growth rings found in wood, and this is used for calibrating other methods. It is hoped that current work with the huon pine of Tasmania may one day furnish such data of up to 20,000 years or so. Similarly, the annual growth layers of polar ice deposits have been shown to provide reliable calendar dates, besides revealing information about past temperatures, carbon dioxide regimes and volcanic events (Morgan, 1993). Another phenomenon of this type is the annual luminescence banding in carbonate speleothems (Baker *et al.*, 1993), but it has not yet produced absolute calendar dates.

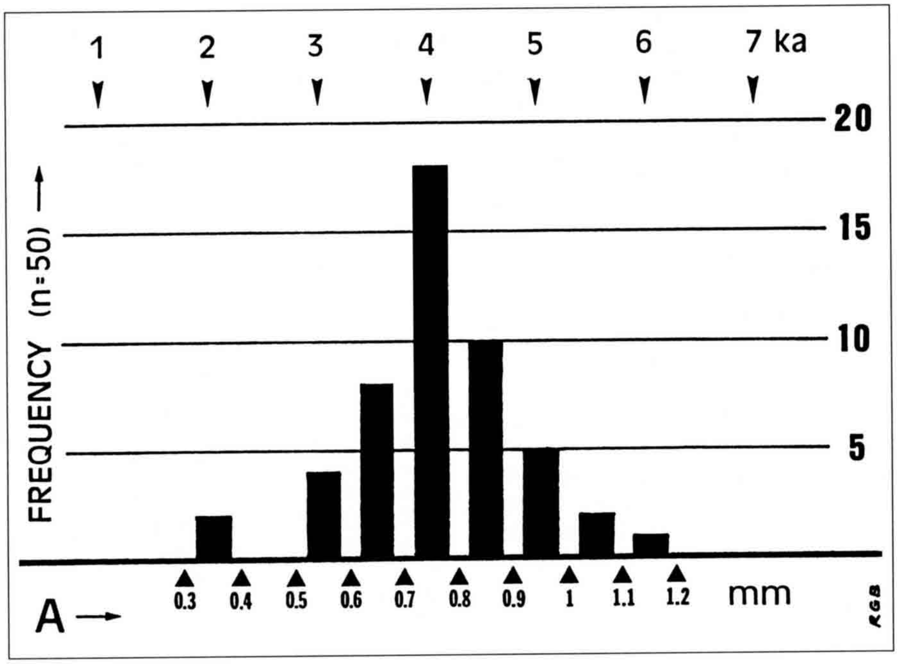

Fig. 1. Depiction of a result of a typical microerosion analysis: it consists of a histogram of (in this case 50) age-related numerical values, not of a single value with stated «tolerances».

used to calibrate that in a granite). As more calibration curves become available for different environments, this dependence will progressively diminish and applications of the method will become much easier. Another restriction, however, will remain: microerosion dating is entirely contingent on the presence of some remnants of the original surface of a petroglyph, and on the certainty that the petroglyph was not covered by water, soil or accretionary deposits in the past. The second qualification is not a serious impediment in the Sahara, it can often be credibly excluded. However, the first qualification means that only erosion-resistant rocks can be suitable in the case of older petroglyphs. Most sedimentary rocks are probably unsuitable, except perhaps dense quartzite, while composite rocks such as granite or well recrystallized metamorphic rocks are the most suitable. Any Saharan petroglyphs carved on fairly hard rock containing several discrete minerals, one preferably being quartz, are prime candidates for microerosion dating - if they are not concealed by varnish and if some similarly exposed stone surfaces of known age occur nearby (e.g. grave stones, dated inscriptions, monuments, quarries, even stone tools perhaps).

The requirement of having several component minerals present in the rock relates to another feature of microerosion dating which it shares with no other dating method: it comes with a built-in checking mechanism. While one mineral might suffice to provide dating information, it is preferred to use two or more, because this helps to detect results which reflect past environmental distortions. Most such influences, if they were severe enough, would be detectable by deviations between the various calibration curves (Fig. 2). Each mineral is likely to respond to a major change differently, be it in moisture, pH or temperature, and the analyst would then know that the results are unreliable (as they would not be aligned on the same ordinate). None of the other dating methods offers such a feature, they can be checked only by recourse to the results of a second method.

Petroglyphs in the Sahara are frequently coated by rock varnish, and while the use of CR dating of the varnish may not be a viable option for their minimum dating, Dorn and his colleagues have introduced a more promising method. They have detected microscopic inclusions of organic matter, concealed under the varnish from petroglyph grooves. Despite the minute size of these residues, they can be susceptible to accelerator mass spectrometry (AMS) radiocarbon dating (Dorn *et al.*, 1992). This new method meets the criteria of a valid direct method if it can be ascertained that the organic matter was present as the varnish formed, and not introduced in some post-genetic form (e.g. as algae). Rock varnish may be reworked by micro-organisms, in which case the age derived would be younger than that of the varnish. It is therefore

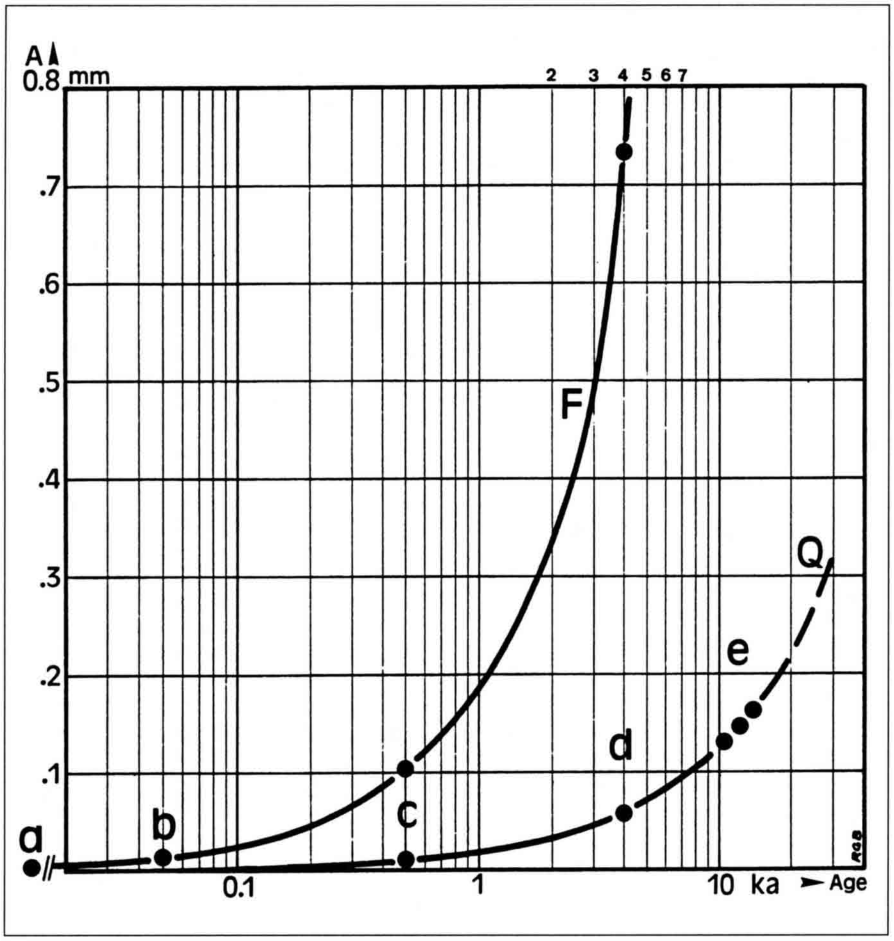

Fig. 2. Example of two calibration curves for microerosion dating, one for quartz (*Q*), the other for feldspar (*F*), for plagioclase granite at Lake Onega, Russia.

essential that the material being dated be identified, or at least, that its original presence be ascertained by some other means. The method provides only a minimum date for the art, but if used judiciously it can yield useful results.

This applies equally to organic inclusions in other mineral accretions (e.g. silicas, oxalates, carbonates). Watchman has recently dated carbonaceous matter in silica skins he located over petroglyphs at some of the controversial Côa valley sites in Portugal (Watchman, 1995). He found two such deposits, one older and one younger than the rock art, and by securing a series of AMS radiocarbon dates from both silica deposits he attempted to provide maximum and minimum ages for some of the Côa petroglyphs.

A problem does arise with this method when the laser-induced combustion technique of Watchman (1993) is used, unless the sampled matter could be identified before it is converted. In this method, the graphite target for ionization is produced by burning the entire accretion, or a selected lamina of it, with the use of a finely focused laser beam. The area of varnish destroyed in one application of this technique is in the order of 1 cm^2 (more where the organic content is low), and the entire carbon in the layer sacrificed is converted into carbon dioxide. After reduction to graphite, the sample's isotopic composition is determined.

The application of this method is not restricted to mineral accretions, it extends to organic matter occurring in rock paints. Some of the theoretical limitations applying to charcoal pigment, which we discussed above, do not apply to such substances as binders, solvents, brush fibres and incidental organic inclusions (airborne matter). Binders, in particular, may have to be the same age as the paint itself, because they remain usable for only a very short time. Blood, for instance, coagulates rapidly, and has been reported from Australian rock paints (Loy *et al.*, 1990)[6]. Other ethnographically known or analytically demonstrated binders (Cole and Watchman, 1992) are equally likely to provide valid AMS dates. Even other proteins, lipids, plant fibres, milk, egg white, honey, urine and saliva can provide radiocarbon dates that are more reliable than those derived

[6] Loy claims to have identified blood residues at two Australian rock art sites. However, there are serious problems at the site Laurie Creek (Northern Territory). Underlying sub-modern paintings, «fragmentary panels of weathered dark red pigment» were reported from which Loy secured a proteinaceous substance he identified as human blood. An AMS radio-

from charcoal, because their age can be assumed to closely resemble that of the painting. Although the majority of rock paints are thought to contain neither organic binders, solvents or pigments, charcoal is not the only pigment that is itself purely organic. I have described other organic pigments from various continents (Bednarik, 1992b) and they are just as susceptible to radiocarbon dating. Moreover, a number of datable substances can occur above or below a paint stratum. These include insect nests, bacterial and other fatty acids encapsulated in silica skins (Watchman, 1993), carbonates and oxalates. In northern Australia, rock art made from native bees wax occurs frequently, and such art has been dated to up to 4000 years BP, using AMS radiocarbon dating (Nelson *et al.*, 1993). Watchman and others have shown that many Australian rock paintings have frequently been repainted, and up to about forty such paint layers have been counted in some cases. These are often separated by layers of other matter, such as mineral encrustations, which are either themselves datable, or may contain organic inclusions. A comprehensive methodology is being developed at the present time, much of which would be widely applicable to the rock paintings of the Sahara.

The method involving reprecipitated carbonates (e.g. speleothems), with which direct dating of rock art began, has been subjected to more testing recently. Based on a simple but valid proposition, that one half of the carbon in such a substance should have been derived from the atmosphere and thus contain ^{14}C, it was found to be rather more complex in practice (Bednarik, 1994). This study adds considerable weight to the need for restraint in interpreting direct dating results. Rejuvenation of porous travertine samples has long been shown to occur (Bednarik, 1981), and more recent data suggest the influence of non-biological carbon dioxide in regions of recent volcanic activity and highly porous limestones of the late Tertiary (Bednarik, 1995c). Moreover, the many reservations I have already expressed in relation to the radiocarbon dating method (Bednarik, 1995b, and above) apply here too, or may even be amplified. The biological carbon dioxide usually responsible for carbonate speleothem formation derives largely from the respiration of mycorrhizal micro-organisms living on plant roots, from other soil organisms and from the oxidation of plant matter. Plant communities, however, are known to be sensitive to atmospheric carbon dioxide levels, and the $\delta^{13}C$ levels they regulate are linked to their carbon dioxide sensitivity. An intricate relationship between isotopic carbon fractionation, plant types and climate seems to exist in nature. These uncertainties about past, environmentally determined isotopic regimes have an obvious effect on the reliability of carbonate dating, which further compounds the previously mentioned difficulties. This does not negate the method itself, but it renders its practical application so difficult that it can at best be considered as an experimental technique. Much the same applies to oxalate dating.

Diversifying and improving direct rock art dating methodology

In comparing different dating methods we should not restrict ourselves to those that have been used with some measure of success, but should also consider the many alternative options that remain unexplored. Some of these actually seem more attractive than some methods being used, at least from the point of view of availability and simplicity. Others may appear more unconventional or even precarious, but it seems to me that we cannot neglect being venturesome in this field. When reviewing the options seventeen years ago, I favoured creative approaches using multiple techniques and tailoring methodology to site conditions (Bednarik, 1979). Some of the options then considered have not been taken up in the years since. For instance, we know that freshly broken rock edges become progressively rounded with age, and that the wanes so formed are clearly a function of antiquity. Since Cernohouz and Solc (1966) last examined the possibility of using rock wanes to date fracturing events (and claimed excellent precision in their experimental results), no-one has developed this simple method further. We now understand the geometry of wane formation fully (Fig. 3), but instead of

carbon date of 20,320 + 3100/-2300 years BP was obtained from this substance. The radiocarbon scientist of the group, Erle Nelson, had «second thoughts» about the results and later returned to the site to re-sample the surface deposit. According to his findings (Nelson, 1993: 893-5), the earlier reported analytical details are essentially worthless, and the date obtained is archaeologically irrelevant. He found that the «pigment» layer was nothing more than naturally reprecipitated iron oxides of a type common on sandstone surfaces. He detected organic matter at various surface locations that bore no paint (refer Bednarik, 1995b: Note 7). When he re-analysed the deposit from which the original data had been obtained, he found only very low concentrations of protein. He reports that «the material dated was not proteinaceous, and therefore not a remnant of human blood. ...It is not a date with any archaeological meaning.» This is not the first time that archaeologists have tried to date what they thought to be a rock painting, but was subsequently shown to be a natural deposit of iron compounds. In 1986, a charcoal date was secured at the well-known petroglyph site of Rochester Creek in Utah, USA, and related stratigraphically to a triangular colour patch on the petroglyph panel. This red patch had been found below ground and had been considered to be a painting of the «Barrier Canyon style». I found it to be a discolouration of the rock varnish, probably involving dehydration of the varnish's goethite to haematite through a fire (Bednarik, 1987).

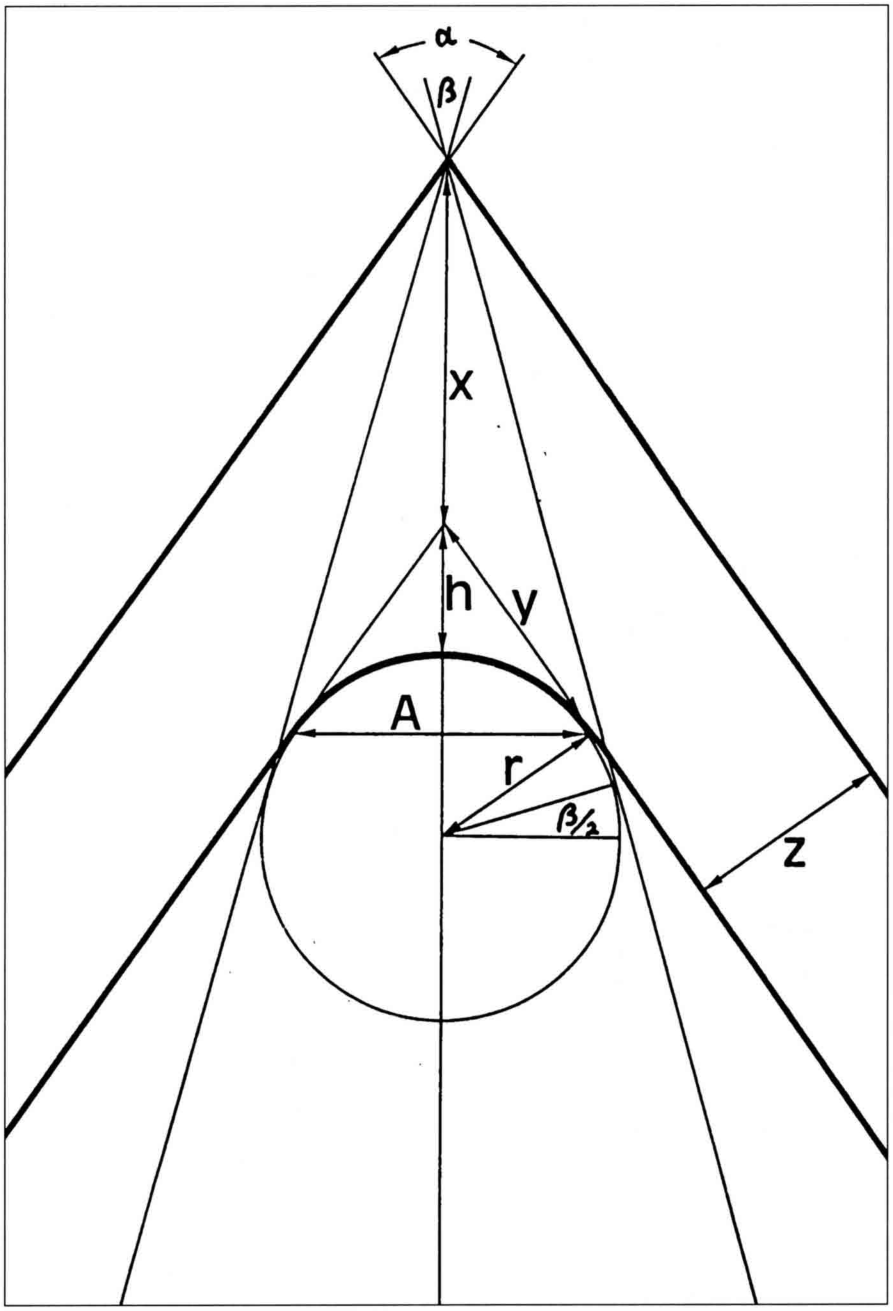

Fig. 3. Geometric depiction of the universal principles of wane formation (After Bednarik, 1992a).

pursuing this worthwhile direction we choose to use ever more sophisticated and expensive «technological solutions». A simple method such as measuring wane radii attracts no attention from technology's addicts, but that should not be taken as an indication that it has no merits. I categorically reject the naive notion that dating technology must be complex and expensive to be useful; as so often in science, the best and most elegant solutions may be the simplest. We can see this with CR dating, one of the most expensive rock art dating methods ever developed, which we now consider obsolete. Why, for instance, has CR dating never been cross-checked with palaeomagnetic data from the same samples? We know that organically accreted iron salts are particularly susceptible to palaeomagnetic analysis. It would have seemed obvious to test CR dating by this under-utilized method that has so far been applied only once to rock art. The potential of pure-black varnishes, which Derbyshire *et al.* (1984) described from Pakistan and I observed on the shores of the White Sea (where they cover petroglyphs), remains unexplored. Uranium usually precipitates with the manganeous salts in rock varnish, which can thus be dated by the uranium-thorium method, but this has also never been correlated with CR dating (although used many years ago on rock varnish; Knauss and Ku, 1980), or used for rock art minimum dating.

The same applies to varnish stratigraphy, which may be assisted by geochemical tephra identification in some cases (Harrington, 1988).

There are many accretionary deposits other than rock varnish found at rock art sites (Bednarik, 1979), but their potential in rock art dating has remained largely ignored. A range of possibilities exists in this area alone. It is even clear from some publications that their authors use the term rock varnish as a definition of any ferro-manganeous coating, or indeed any brown rock patina (e.g. in Africa, Pineda *et al.*, 1989). I have considerable reservations about the view that the types of phenomena collectively defined as rock varnish are indeed diagenetically uniform. I have long held this view (Bednarik, 1979), and Dorn (1992) has recently also noted that there appear to be several quite distinctive variations of this phenomenon.

Amino acid racemization may have valid applications in rock art dating, despite the severe limitations imposed on this method by the extreme susceptibility of the reaction to temperature (Murray-Wallace, 1993), and despite Denninger's (1971) refuted attempt. Amino acid residues can be preserved in rock paints. Another possibility that remains unexplored in rock art dating is the use of TL dating of paint impurities. It should be remembered that ochrous substances (combinations of various iron salts and other minerals) have sometimes been heated by the rock artists in order to alter the colour (through dehydration, reduction or oxidation)[7]. Any quartz grains present are likely to have had their «TL clocks» re-set by this treatment and ought to be datable by their luminescence characteristics. Similarly, the inevitable iron component of ochre or haematite pigment may be susceptible to palaeomagnetic dating, another neglected method, for precisely the same reason. A more recent suggestion has been to attempt dating of rock surfaces by extracting radiogenic nuclides which are the result of cosmic radiation. This technique of determining accumulated cosmogenic isotopes held little promise for rock art in the past, requiring in the order of 1 m^2 of rock surface until very recently. But Fred Phillips developed a method of using ^{36}Cl for which he requires only a few square centimetres of surface. While this sampling requirement is still too great for petroglyphs themselves, the method can now be used for dating rock exposure ages, which provide maximum ages for the rock art located on decorated exposures. It was one of the dating methods recently used on the Côa valley petroglyphs (Bednarik, 1995d).

An innovation that may be much more useful in the near future, and that was initially introduced in the context of Saharan rock art, provides no immediate dating information, but may cumulatively do more for rock art dating than over-sophisticated technological solutions. I refer to François Soleilhavoup's proposal of including, on all rock art recordings, details of the rock surface as well: patination, exfoliation, erosion, accretion, fissures, striae, lichen and so forth. Besides the obvious benefits of preserving in the recording some environmental and micro-topographical detail, this practice may have considerable benefits for rock art dating. It has certainly not been adequately appreciated, nor is there evidence of its wider application. Soleilhavoup (e.g. 1985, 1988, 1990, 1992-93) records art panels in the manner of a topographic map, on which he shows the various features using standard symbols. A wide adoption of his technique would be of very considerable benefit to rock art dating, most especially if we added to the information shown metric determinations of the radii of any rock wanes that may either relate to the art, or to any feature related to the art. The information from such a comprehensive recording method, showing all features that may seem relevant, might do much more for the scientific study of rock art than the recording of vast numbers of motifs, taken from their petrographic and geomorphological contexts, and presented as sterile abstractions of form. This traditional practice of recording purely the art itself is a form of deconstruction: it would be nonsensical to later impose the recorded figure on some other rock panel and suggest that one has recreated the art, recaptured its essence. Quite obviously that would not be the case, because the rock panel, the context of the art, even its entire setting, were all part of it. Thus it is practically impossible to record the art without any degree of abstraction; pre-Historic art exists for us *only* as an abstraction.

Our recordings are only *interpretations* of what we see on the rock surface, not some objective record, therefore we need to give a great deal

[7] Such treatment can be found as far back as in the Acheulian of southern France, several hundred thousand years ago.

more consideration to what we should actually include in such a subjective record. The simple recording of a two-dimensional art motif, as we choose to perceive it (or are perhaps compelled to do so by our cognitive, perceptual and cultural conditioning), is an essentially archaeological practice, bound up with archaeology's implicit penchant for interpreting the art after removing it from its geomorphological context, and creating a subjective taxonomy. Students of rock art need to reflect on how this propensity has affected the discipline. If it is their aim to create a science about rock art, they need to review the arbitrary cut-off point of abstraction introduced by one discipline. Chippindale and Taçon (1993) have recently sought to overcome some aspects of the limitation after pointing out the subtle distortions inherent in graphic depiction of rock art, but their answer to the problem does not address the part of it that does not relate to the art itself. Recordings need to contain more information than the iconographic perception of an alien (usually Eurocentric) observer may readily detect, and in particular, there needs to be a reasonable recording level of information about the rock panel and its history. Glacial striae, aeolian erosion, thermal damage, and the various types of weathering traces need to be recorded also, which presupposes that they must be effectively identified. All of these marks left during the history of the rock panel refer to specific events or processes, and they are all spatially related to the art, some even culturally (e.g. where a natural rock marking or topographical feature was incorporated in the rock art, as is often the case). Most importantly in the present context, however, is that they are chronologically related to the rock art - as well as to each other. These spatial, cultural and chronological relationships are often very clear, and all these traces have the potential of being somehow datable, or becoming datable in the future. By adding this considerable geomorphological potential, which until now has remained largely untapped because of the often archaeological orientation of the discipline, we can greatly enlarge the potential data source for direct dating of the art; we are virtually adding a new dimension to the subject. Cracks dissecting an art motif may be dated, the surfaces that have formed in them may also be dated, as may the wanes developed on the new edges. The accretions formed on the new surfaces may be dated as well as those on the older, and all of these traces and others form a chronological framework within which, somewhere, the event of the art production is inevitably located in time.

Ultimately, this is how petroglyphs will be dated securely. In contrast to rock paintings, they offer us no datable substance that marks the time of their creation and that may be analytically dated. In determining their antiquity, we will need to be extraordinarily resourceful, and we will need a more broadly based approach to recording and examining motifs. An initial step is to introduce a much more comprehensive recording system, modelled on that proposed by Soleilhavoup on the basis of his work in the Sahara. Microscopic examination, or at least the use of a magnifying glass, is often an essential precondition for such work. This research philosophy differs significantly from the «technological» approaches, which are often based on hasty forays into the field - expeditions to collect samples[8]. Laboratories can be of much help to us, but the ultimate answers are out there, in the field. It is my contention that, once rock art students take a much greater interest in the many phenomena found near petroglyphs, by having to record and examine their various manifestations, new ways of studying the art will be found, new methods will be developed, and new levels of understanding will become attainable for scientific rock art research. The role of a comprehensive methodology of direct rock art dating is therefore central to the development of a mature discipline of palaeoart studies.

[8] I use the term «samples» in an extended sense here; it includes traditional recordings, which are merely samples of iconographic information, subjectively selected as determined by the subjective perception of the recorder. It also includes, of course, samples of substances, such as those one might use for dating attempts.

Bibliography

BAKER A., P.L. SMART, R.L. EDWARDS AND D.A. RICHARDS, 1993. Annual growth banding in a cave stalagmite. *Nature*, 364: 518-520.

BEDNARIK R.G., 1979. The potential of rock patination analysis in Australian archaeology - part 1. *The Artefact*, 4: 14-38.

BEDNARIK R.G., 1981 (*unpubl. MS*). Finger lines, their medium, and their dating. Melbourne: Archive of the Australian Rock Art Research Association. 34 pp.

BEDNARIK R.G., 1987. No pictographs at Rochester Creek rainbow. *La Pintura*, 15 (2+3): 14-18.

BEDNARIK R.G., 1992a. A new method to date petroglyphs. *Archaeometry*, 34: 279-291.

BEDNARIK R.G., 1992b. Developments in rock art dating. *Acta Archaeo-*

logica, 63: 141-155.

BEDNARIK R.G., 1993. A strategy for the practical application of microerosion dating. *In*: J. Steinbring and A. Watchman (eds), *Time and space: dating and spatial considerations in rock art research*. Melbourne: Occasional AURA Publication, 8: 64-66.

BEDNARIK R.G., 1994. Conceptual pitfalls in dating of Palaeolithic rock art. *Préhistoire Anthropologie Méditerranéennes*, 3: 95-102.

BEDNARIK R.G., 1995a. The age of the Côa valley petroglyphs in Portugal. *Rock Art Research*, 12: 86-103.

BEDNARIK R.G., 1995b. Logic in direct dating of rock art. *Sahara*, 7: 69-78.

BEDNARIK R.G., 1995c. The speleothem medium of finger flutings and its isotopic geochemistry. *International Journal of Speleology*.

BEDNARIK R.G., 1995d. Refutation of stylistic constructs in Palaeolithic rock art. *Comptes Rendus de l'Académie des Sciences Paris*, 321 (sér. IIa): 817-21.

BEDNARIK R.G., 1996. Only time will tell: a review of the methodology of direct rock art dating. *Archaeometry* 38 (1).

CERNOHOUZ J. AND I. SOLC, 1996. Use of sandstone wanes and weathered basaltic crust in absolute chronology. *Nature*, 212: 806-807.

CHIPPINDALE C. AND P. TAÇON, 1993. Two old painted panels from Kakadu: variation and sequence in Arnhem Land rock art. *In*: J. Steinbring and A. Watchman (eds), *Time and space: dating and spatial considerations in rock art research*. Melbourne: Occasional AURA Publication, 8: 32-56.

COLE D.R. AND H.C. MONGER, 1994. Influence of atmospheric CO_2 on the decline of C4 plants during the last deglaciation. *Nature*, 368: 533-536.

COLE N. AND A. WATCHMAN, 1992. Painting with plants: investigating fibres in Aboriginal rock paintings at Laura, north Queensland. *Rock Art Research*, 9: 27-36.

DENNINGER E., 1971. The use of paper chromatography to determine the age of albuminous binders and its application to rock paintings. *Rock paintings in southern Africa*, supplement to the *South African Journal of Science*, Special Issue, 2: 80-84.

DERBYSHIRE E., L. JIJUN, F.A. PERROTT, X. SHUYING AND R.S. WATERS, 1984. Quaternary glacial history of the Hunza Valley, Karakorum mountains, Pakistan. *In*: K.J. Miller (ed.), *The International Karakorum Project*, Vol 2. Cambridge: Cambridge University Press, p. 456-495.

DORN R.I., 1992. A review of rock varnish dating of rock engravings. *International Newsletter on Rock Art*, 2: 10-14.

DORN R.I., P.B. CLARKSON, M.F. NOBBS, L.L. LOENDORF AND D.S. WHITLEY, 1992. New approach to the radiocarbon dating of rock varnish, with examples from drylands. *Annals of the Association of American Geographers*, 82: 136-151.

HARRINGTON C.D., 1988. Recognition of components of volcanic ash in rock varnish and the dating of volcanic ejecta plumes. *Geological Society of America Abstracts with Programs*, 20: 167.

KNAUSS K.G. AND T.L. KU, 1980. Desert varnish: potential for age dating via uranium-series isotopes. *Journal of Geology*, 88: 95-100.

LANTEIGNE M.P., 1991. Style, statistics and the Karolta petroglyphs. *Rock Art Research*, 8:127-130.

LOY T.H., R. JONES, D.E. NELSON, B. MEEHAN, J. VOGEL, J. SOUTHON AND R. COSGROVE, 1990. Accelerator radiocarbon dating of human blood proteins in pigments from Late Pleistocene art sites in Australia. *Antiquity*, 64: 110-116.

MORGAN V., 1993. Ice core dating and climatic records. *The Artefact*, 16: 8-11.

MORWOOD M.J., G.L. WALSH AND A. WATCHMAN, 1994. The dating potential of rock art in the Kimberley, N.W. Australia. *Rock Art Research*, 11: 79-87.

MURRAY-WALLACE C.V., 1993. A review of the application of the amino acid racemisation reaction to archaeological dating. *The Artefact*, 16: 19-26.

NELSON D.E., 1993. Second thoughts on a rock-art date. *Antiquity*, 67: 893-895.

NELSON D.E., C. CHIPPINDALE, G. CHALOUPKA, P. TAÇON AND J. SOUTHON, 1993. AMS dating of bees wax rock art in northern Australia. *The Artefact*, 16: 52.

PINEDA C.A., M. PEISACH AND L. JACOBSON, 1989. The time-clock of aged patinas. *Nuclear Active*, 41: 17-24.

ROBINSON J.M., 1994. Atmospheric CO_2 and plants. *Nature*, 368: 105-106.

SOLEILHAVOUP F., 1985. Les paysages de l'art rupestre de plein air: vers une normalisation des méthodes d'étude et de conservation. *Rock Art Research*, 2: 119-139.

SOLEILHAVOUP F., 1988. Découvertes archéologiques exceptionnelles au sud de l'Ahaggar. *Sahara*, 1: 49-71.

SOLEILHAVOUP F., 1990. Nouvelles stations rupestres à l'Ouest de l'Ahaggar. *Sahara*, 3: 71-82.

SOLEILHAVOUP F., 1992-93. Art rupestre du Tassili de Ti-n-Reroh (Sud-Ouest de l'Ahaggar). Premières données paléoculturelles. *Sahara*, 5: 59-70.

WATCHMAN A., 1993. The use of laser technology in rock art dating. *The Artefact*, 16: 39-45.

WATCHMAN A., 1995. Recent petroglyphs, Foz Côa, Portugal. *Rock Art Research*, 12: 104-108.