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DEVELOPMENTS IN ROCK ART DATING

by

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INTRODUCTION

The scientific study of rock art is crucially dependent upon some form of reliable absolute dating of the art. Without it, different art bodies cannot be convincingly related to one another, nor can the rock art be correlated with any archaeological evidence, and reliable chronological models will remain elusive.

To those who investigate rock art the need to know its age has always been paramount. Over 170 years ago, Belzoni speculated about the possibility of establishing chronological petroglyph sequence from the varying degrees of patination he observed on the Nile (Belzoni 1820). Methods of dating the Palaeolithic cave art of western Europe were explored within 20 years of its discovery in Spain, even before its authenticity was finally acknowledged by a hostile academic establishment in France. In 1896 Daleau exposed petroglyphs at Pair-non-Pair which were concealed by Gravettian occupation deposits. Ampoulange succeeded eight years later at La Gréze Cave. Other dating evidence, in most cases of art panels that had been covered, comes from Sainte-Eulalie, Gargas, Laussel, Cap Blanc, Angles-sur-l'Anglin, Teyjat and Isturitz. The most recent dating of this type is that of the first Palaeolithic rock art sites ever discovered in Germany (Hahn 1990) which have been tentatively attributed to the Aurignacian and Gravettian.

However, none of these cases can be considered to provide indisputable relative dating, let alone absolute dating; they are merely cases of 'archaeological minimum dating'. Claims for correlative relationships between rock art and archaeological finds will always remain asserted propositions, they depend on frequently unfalsifiable assumptions, especially that of stratigraphical integrity. At a few of the western European cave sites it has been postulated that figures on portable art objects appear to be copies or models of parietal art, and must therefore be of similar age, for instance at Altamira and Castillo (Bahn & Vertut 1988). It should be self-evident that such claims are subjective, not only because they rely heavily on iconographically based observation, but also because there is no logical reason why an artist could not copy an already ancient design from a wall, or find an ancient portable object (Upper Palaeolithic people sometimes quarried cave deposits to recover earlier flint tools), to offer just one possible explanation and copy its design onto the rock wall.

The attempts of dating depicted faunas by attributing them to either warm or cold climatic phases (e.g. Gonzalez Echegaray 1972) are similarly in vain: it would have to be shown that art traditions reflect the prevailing ecologies accurately in their motif range and frequency. Such a statistical correlation between excavated faunal remains and animal pictures has not been demonstrated, however (Begouën & Clottes 1985). A somewhat more convincing claim for dating of French 'cave art' comes from Tête-du-Lion, where ochre traces excavated from nearly 22,000-year old charcoal produced similar analytical results as the paint of a nearby wall painting of an aurochs (Combier 1984). Correlative studies of speleomorphological phenomena and parietal art (such as Bednarik 1986a, concerning Baume Latrone, Croze à Gontran, Pech Merle and other sites), which could provide a relative framework, have rarely been attempted in western Europe, they are better established in Australia (Bednarik 1986b, 1990a). A different variation of the dating of rock art by means of the depicted fauna has been pioneered by Chaloupka (1984) in Australia, where it is widely accepted. Chaloupka noted the predominance of, alternatively, coastal and non-coastal species in different art phases, and related these to past sea level fluctuations in Arnhem Land.

Just as a chronology has been created without much substantial scientific evidence for the Upper Palaeolithic rock art of western Europe, based largely on stylistic argument, ideas of distribution and preconceived evolutionary models (i.e., on fundamentally unscientific criteria), in the Sahara we have a chronological framework of rock art that remains the subject of intense debate (e.g. Muzzolini 1990). The claim that petroglyphs of the so-called 'bubaline period' are attributable to the final Pleistocene (Mori 1974, 1978) has been all but abandoned, but the current consensus model still seems incongruous. Its 'bubaline' or 'hunter period' prior to 8,000 years BP is said to be followed by a 'cattle period' which continued to about 3,500 BP, leading to 'horse' and 'camel periods' (using here the 'less ornate' terminology). However, the most prominent motifs of the first phase, besides *bubalus*, are the 'adorned rams', which are clearly domestic. Muzzolini (1990) therefore argues forcefully that all Saharan rock arts postdate the introduction of domesticated sheep, which on present indications occurred around 6,000 years BP.

It is frequently evident from the debates about Saharan rock art that its chronologies were based on circular confirmationist arguments, non sequiturs or stylistic claims of correspondence, i.e. on unscientific models. Apart from some archaeological minimum dates from art that has fallen from shelter walls and become stratified in floor deposits (Mori 1965; Barich 1987), there is no more than a vague attribution of the earliest component of Saharan rock art to the Neolithic, and scientifically credible dating is not available for a single motif of a pre-literate period. This is despite the attribution of ostrich eggshell objects, decorated with geometric as well as iconic engravings, to the epi-Palaeolithic Capsian (Camps-Fabrer 1966).

Attempts to date rock art in southern Africa have been even less successful in most cases. For instance, Denninger's (1971) analyses of amino acids in the protein of supposed organic binders, intended to cover a maximum time span of about 1,800 years, have not been accepted as being valid under field conditions (cf. Goods 1990). Recent attempts to apply the cation-ratio dating method exemplify its misuses: Pineda *et al.* (1989) present data on what is obviously not rock varnish, but are altered surface layers of sedimentary silicas (cf. Bednarik 1980 for details), treating them as if they were varnish. Their error is quite evident from the photographs of the samples and the analytical results: the 'patina surface' in their X-ray diffraction curve is clearly not a rock varnish.

Very early use (Klein 1978) and mining (Beaumont & Boshier 1972) of ochre have been reported in southern Africa, and Middle Stone Age portable paintings have been dated to about 26,000 to 28,000 years BP in Apollo 11 Cave, Namibia (Wendt 1974), and to the Holocene at the Cape (Singer & Wymer 1969; Rudner & Rudner 1973; Deacon *et al.* 1976). Zimbabwean portable stone plaquettes or palettes come from the Middle Stone Age of Pomongwe Cave, and they seem to be over 40,000 years old at Nswatugi (Walker 1987). A recently excavated painted pebble was dated to 760 BP in the Upper Karoo, South Africa (Sampson & Vogel 1989). Engraved stones of the final Pleistocene or the Holocene have been reported from Angola (Clark 1959: 92), South Africa (e.g. Beater 1967; Holm 1958; Humphreys & Humphreys 1973; Malan 1956; Rudner 1953; Thackeray *et al.* 1981), Zaire (Van Noten 1977) and Zimbabwe (Walker 1987). However, the extensive rock art of southern Africa remains essentially undated, and not even a broad chronological model such as that of Saharan rock art is available for the continent's southern half. In one of the very few convincing dating attempts, Pager (1989) has been able to archaeologically minimum-date an exfoliating painting in Amis Gorge, Namibia. It should be noted here that the widely shared belief that southern African rock art was generally produced by the Bushmen or San has never been proved (Hromnik 1991).

Almost no credible dating evidence has been presented for the many rock art traditions of North America. Leaving aside the dating work of R.I. Dorn and colleagues (see below), there are only few published attempts. Ricks and Cannon (1985) provide a radiometric date of 6,700 years BP for volcanic material covering petroglyphs at Long Lake, Oregon, but Steinbring *et al.* (1987, 155-156) describe the sample as 'patently unacceptable', due to previous uncontrolled digging at the site.

It is of historical interest that Grant attempted almost 30 years ago to date a highly eroded Chumash painting near Santa Barbara, California, via radiocarbon content, but obtained only 5% of the sample quantity required in those days. He recognized that the Chumash had frequently retouched paintings, which would complicate dating by this method (Grant 1965). Loendorf (1986) attempted to date what he thought was a red painting at the main petroglyph panel of the Rochester Creek site, Utah, via 2,000-year old charcoal from nearby. This was refuted when I identified the 'pigment' as a discolouration of ferromanganese patina, probably through the dehydration of the patina's goethite to haematite through a fire which had also caused a thermal fracture (Bednarik 1987). In 1974, W. Turner and R. Reynolds tried to date two tufa layers at Salton Sea, and petroglyphs sandwiched between them seem to be bracketed by dates of about 6,400 and 17,000 years BP. However, these results were seriously criticized subsequently. Parkman (1990) has recently proposed that an early cupule tradition of western North America might be of the final Pleistocene, if not older, and while this is an intriguing possibility, it does require substantiation.

The most comprehensive archaeological rock art dating effort in North America is that of Steinbring *et al.* (1987) who excavated major occupation deposits over an area of 81 m^2, covering a petroglyph pavement at Mud Portage, Lake-of-the-Woods, Canada. On the basis of radiocarbon dates, stratigraphy and local geology they argue convincingly that the art is probably between 5,000 and 9,000 years old.

South America has provided somewhat better data. A claim that 32,000 and 17,000-year old rock fragments with pigment traces from Toca do Boqueirão do Sítio da Pedra Furada (Piauí, Brazil) provide minimum ages for the extensive rock art at that shelter (Guidon & Delibrias 1985, 1986) has been examined without confirmation (Bednarik 1989). Several possible explanations to account for the evidence would need to be refuted before this claim could be accepted. However, I found that the currently oldest securely dated rock art of the Americas exists in the same district. At the rockshelter Toca do Baixão do Perna I, a panel of small red paintings was concealed under very dry, coarse sand deposits, commencing almost immediately above a massive layer of charcoal which provided a date of about 9,500 years BP. This stratigraphic minimum age can be regarded as indisputable because of the nature of the stratum it comes from, and is likely to represent the actual approximate age of the art (Bednarik 1989).

At Santana de Riacho, also in Brazil, Prous (1989) has dated one motif between 3,700 and 4,400 years. A detached block from the shelter ceiling came to rest on a hearth, while the figure on the fracture face became itself partly covered by a layer that contained a second hearth. Prous has also provided archaeological minimum dating of 3,700 years at Lapa Vermelha IV.

There have been further attempts in Brazil and other South American countries to date art with the help of archaeological stratigraphy (e.g. Vialou & Vilhena-Vialou 1984). In Peru, a partly dated sequence of traditions of portable art objects is noteworthy (Linares Málaga 1988), which has been claimed to extend back as much as 7,000 years. I have examined components of this sequence, especially the *lajas* occurring in pairs which are termed 'sandwiches'. Not having examined the claims relating to the oldest site, Abrigo de Quebrada Cimarrona, I can merely confirm the evidence relating to finds of between about 1,900 and 1,500 years BP.

No pre-writing rock art anywhere in Asia has been firmly dated, and even broad cultural attribution is often most tenuous. For instance, a Palaeolithic antiquity of Indian rock paintings (Wakankar 1983) is widely rejected by Indian scholars today. Wakankar's claim for the universal superimposition precedence of the green dynamic paintings of central India has been negated by Tyagi (1988), whose findings I have been able to verify on various occasions. Having refuted the engravings on 44 ostrich eggshell fragments from Palaeolithic sites in India by demonstrating that they are natural markings (Bednarik 1991), and having also determined that the Upper Palaeolithic so-called 'mother goddess' of Lohanda Nala, Belan valley (Misra 1977), is in fact a damaged bone harpoon with four symmetrically arranged barbs (Bednarik 1990b), I have had to reject most evidence advanced in favour of Palaeolithic art in India; solid proof is limited to the engraved ostrich eggshell specimen from Patne and a few perforated disc beads (Bednarik 1991), and the Hunsgi evidence of the use of ochre crayons in the Acheulian (Bednarik 1990c). However, there is a possibility that the first petroglyphs discovered in central India (Bednarik *et al.* 1991) include specimens of a Pleistocene tradition, but this proposal is in need of stringent testing (Bednarik 1990b). The vast corpus of Indian rock paintings is attributed mostly to the Mesolithic and Chalcolithic periods, but it must be emphasized that not a single motif is actually dated, nor does the attribution seem to be based on objective and falsifiable reasoning or evidence. In fact not a single Indian rock art site has even been properly recorded (S. Chakraverty, pers. comm.).

Two Siberian rock art sites have been claimed to include motifs from the Palaeolithic period. They are Shishkino and Tal'ma, located on the upper Lena and one of its tributaries (e.g. Okladnikov 1977). In both cases the basis of the dating is intuitive stylistic reasoning. Okladnikov's identification of one figure at Tal'ma as a rhinoceros is without any factual basis (Bednarik 1990b; Bednarik and Devlet 1991). Among the thousands of animal figures of the region not a single one depicts a species that did not occur in that part of Siberia during the Historical periods. Most recognizable motifs appear to be Historical and the geomorphology of the sites confirms that most art must be comparatively recent (Bednarik & Devlet 1991). The only confirmed Palaeolithic rock art site in the Soviet Union is therefore Kapovaya Cave in the Urals (Bader 1965; I do not regard markings in Ignatiev Cave as authenticated, and the newly discovered markings at Serpievskoi Peshchere are yet to be evaluated).

Archaeologically dated portable art of the final Pleistocene has been recovered in the cave of Kamikuroiwa, Japan (Aikens & Higuchi 1982). Rock paintings at Huashan Hill, Guangxi Province, China, have been dated to between 2,370 and 2,115 years BP, via carbonate precipitate (Qin Shengmin *et al.* 1987). In 1989, You Yu-zhu excavated a portable engraving on antler at a Palaeolithic site in China (Bednarik in prep.). Some of the most tantalizing very early 'art' evidence comes from Israel, in the form of portable objects of the Middle Pleistocene (Goren-Inbar 1986; Goren-Inbar *et al.* 1991; Belitzky *et al.* 1991; also more recent finds of the Mousterian, Goren-Inbar 1990).

Anati has produced chronological sequences for the rich rock art regions of the Negev Desert (1963) and of central Arabia (1968). They are based on such factors as superimposition, method of execution, patination, style, motifs or identifiable and illustrated objects, and, for the protohistoric and historic periods, written characters. Anati used the same approach to construct a rough chronological framework for the petroglyphs of Valcamonica, Italy (Anati 1960, 1961, 1975). The chronologies of the Scandinavian rock art bodies are similarly based on technological aspects, on depicted objects and *Leitmotifs*, and to some degree on sea or lake level fluctuations during the Holocene.

In general, this approach appears to have the considerable benefit of being based on several quite different sources of information, which should provide some protection against biases in the data. But in reality it is still fraught with uncertainties. To begin with, the inconographic identification of objects, including tools or weapons, can always be questioned, it is unfalsifiable (Tangri 1989) and can at best be afforded the status of circumstantial evidence. Secondly, this type of evidence is inevitably tied to archaeological models, the reliability of which is itself open to questioning in many cases. It may therefore be judicious to maintain a healthy scepticism concerning at least some aspects of regional sequences derived from this approach.

An excellent example of how entrenched such dating models can become before they are finally refuted is provided by the Levantine art in the rockshelters of eastern Spain. Considered to be of the most dynamic style in Europe, this corpus of paintings, first assigned to the final Pleistocene by H. Breuil, has become widely accepted as being Mesolithic, thus providing a convenient link between Upper Palaeolithic art and the art forms of the ceramic periods. Yet recent discoveries in the Valencian region have shown that the chronology of the Levantine art was false (Hernández *et al.* 1988). New sites in Alicante present essentially four phases in the district's rock art, including the new 'macroschematic art', which is pre-Levantine (as shown by superimpositioning at La Sarga I and Barranc de Beniali IV). Its motifs occur also on potsherds of the local early Neolithic. Therefore the dynamic Levantine paintings are not likely to predate the Neolithic, despite the apparent prominence of hunting scenes. It is to be cautioned, however, that this pronouncement relies on relating rock art to portable objects.

There is an ominous sound about this fundamental revision, in that it coincides with a similar development in the Sahara. Here, too, an apparent phase of 'hunter's art' is turning out to be of the Neolithic, postdating the advent of domestication! Mesolithic rock art is also claimed to exist in Scandinavia, and as mentioned in India. On the other hand, the petroglyphs of northern England are generally assumed to be Neolithic, while a recent analysis of some sites has questioned this attribution; Steinbring and Lanteigne (1991) have argued that in some instances a greater age should not be ruled out. It may be timely to re-examine traditional claims of this type critically.

In Australia, archaeological minimum ages have been ascribed to the rock art of several sites: through a fallen slab at Devon Downs (Hale & Tindale 1930), several engraved fragments from Ingaladdi (Mulvaney 1975: 184-9), or a piece of sandstone possibly bearing a design from near Santa Teresa Mission (Stockton 1971); while Morwood (1981) has presented the evidence from Ken's Cave as providing maximum dating for the art on a boulder (which is, however, contradicted by his own section drawing). A maximum age has also been suggested for Cathedral Cave (Beaton & Walsh 1977), but without published justification.

The most comprehensive Australian evidence for archaeologically derived rock art dating is that from Early Man Shelter, north Queensland (Rosenfeld 1975; Rosenfeld *et al.* 1981), which provides persuasive proof that the oldest surviving petroglyphs at that site are over 13,000 years old.

THE 'DIRECT DATING' OF ROCK ART

It will be apparent from this introduction that by about 1980, practically no pre-Historic rock art in the world had been firmly dated. Wherever regional chronological sequences had been created, they were not entirely free of speculation, circular or tautological argument, wishful thinking and the idiosyncrasies of specific research traditions or individual scholars. They were often based on such subjective notions as the identification of ambiguous objects, or the belief that a researcher can reliably perceive the intent of an artist from an alien graphic tradition. Archaeological dating was available from several world regions, but it referred in nearly all cases to minimum ages, and it was generally contingent upon inferred relationships of different classes of data, which were inaccessible to refutation or independent testing. In short, 160 years after Belzoni's observations, there remained a distinct lack of scientific knowledge about the age of rock art, and a lack of an appropriate methodology promising an improvement.

Not only had archaeology failed to develop appropriate alternative dating techniques, over the past century rock art had increasingly become of peripheral concern to professional archaeologists the world over (cf. Lewis-Williams 1983). Today, many believe that studies of early art are either of no relevance to 'proper archaeological practice', or that they can only be of very limited use in archaeological interpretation (Bednarik in press a). Yet archaeological interpretation is itself a basically unscientific procedure (Bednarik 1990d, 1990e, 1990f), generally unfalsifiable (Tangri 1989, and the work cited therein), and the traditional association of 'prehistoric' art studies with archaeology has done little to enhance the former's credibility or status.

But archaeologists were clearly right that without at least the crudest regional chronologies, rock art studies would continue to languish. By about 1976 I realized that alternatives had to be found to archaeological dating if any real progress was to be made. I intensified my studies of weathering phenomena and patinae and developed a concept of '*direct dating of rock art*', contrasting it with the traditional 'archaeological dating methods' (Bednarik 1979, 1981, 1984, 1985a, 1988a), and defining it thus: "... the most reliable means for determining the antiquity of rock art remains the investigation of features related to the art itself, which either date it (e.g. pigment), predate it (e.g. the rock art's medium, or the particular surface it was executed on), or postdate it (e.g. later cracks dissecting a motif, or precipitates deposited over the rock art)" (Bednarik 1981).

After first examining the potential of patinae, rock varnish and weathering wanes to provide 'direct dating' information relating to the age of petroglyphs, I concentrated my efforts on the rock art stratigraphies of several caves near Mount Gambier, South Australia. Not only was the 'stratigraphical relationship' of the rock art phases (in the sense of Anati 1961) here a physical, indisputable stratigraphy of rock art and laminar layers of reprecipitated calcite (Fig. 1), the latter are datable by various quantitative methods: through the biological origin of one half of the carbon content which renders the deposit susceptible to radiocarbon dating; by the uranium-thorium method for radioactive isotopes present in the speleothem; and by the determination of its oxygen isotope ratio, which can provide palaeoclimatic information.

At about the same time as I experimented with secondary carbonate dating in Australia, Dorn and colleagues developed the cation-ratio (CR) dating method in south-western U.S.A. (Dorn 1983, 1986; Dorn & Whitley 1984). It utilizes the selective leaching of cations from a ferromanganese accretion deposit of supposedly biological origin (Scheffer *et al.* 1963), rock varnish. This is a very distinctive phenomenon (Engel & Sharp 1958) which archaeologists regularly confuse with other types of ferruginous skins. The readily soluble cations K and Ca are compared with the comparatively stable Ti. To establish the local rate of leaching, several large calibration samples, suitable for AMS radiocarbon dating, have to be obtained before the petroglyphs of a site can themselves be minimum-dated via the cation-ratio of varnish formed in their grooves.

The CR method gained considerable support between 1984 and 1988, and I arranged a project in which R.I. Dorn co-operates with M. Nobbs in Australia (Nobbs & Dorn 1988). The great antiquity of Australian rock art was suggested with minimum ages exceeding 30,000 years. The project's spectacular results led to a detailed debate of the method's inherent problems (Bednarik 1988b; Clarke 1989; Clegg 1988; Dragovich 1988a; Lanteigne 1989; Reneau & Harrington 1988; Watchman 1989), and a specialist seminar in Canberra in June 1990 questioned the degree of reliability and accuracy of the method (Bednarik 1990g).

In the meantime, Watchman (1987) had identified oxalate deposits at a series of Australian rock art sites in Kakadu National Park. He recognized their potential to provide minimum or maximum dating where they are in physical contact with rock art. The oxalates whewellite and weddellite are salts of oxalic acid, contain organic carbon, and are susceptible to the radiocarbon dating method (Watchman 1990). The oxalate dating method is thus similar to the carbonate dating method, but it has perhaps wider application and it may not share the serious limitation imposed on the carbonate method by the rejuvenation potential of more recent exchange or deposition (Bednarik 1981).

Several more 'direct' methods have been tried or suggested. Besides true rock varnish, various other ferruginous accretionary deposits are found on rock surfaces (Bednarik 1979). Their dating potential remains largely unexplored, perhaps their polymorphous origins and development are a deterrent for researchers. Lichenometry is among the earliest methods explored (Beschel 1961; Joubert *et al.* 1983). Based on the presumed stable growth pat-

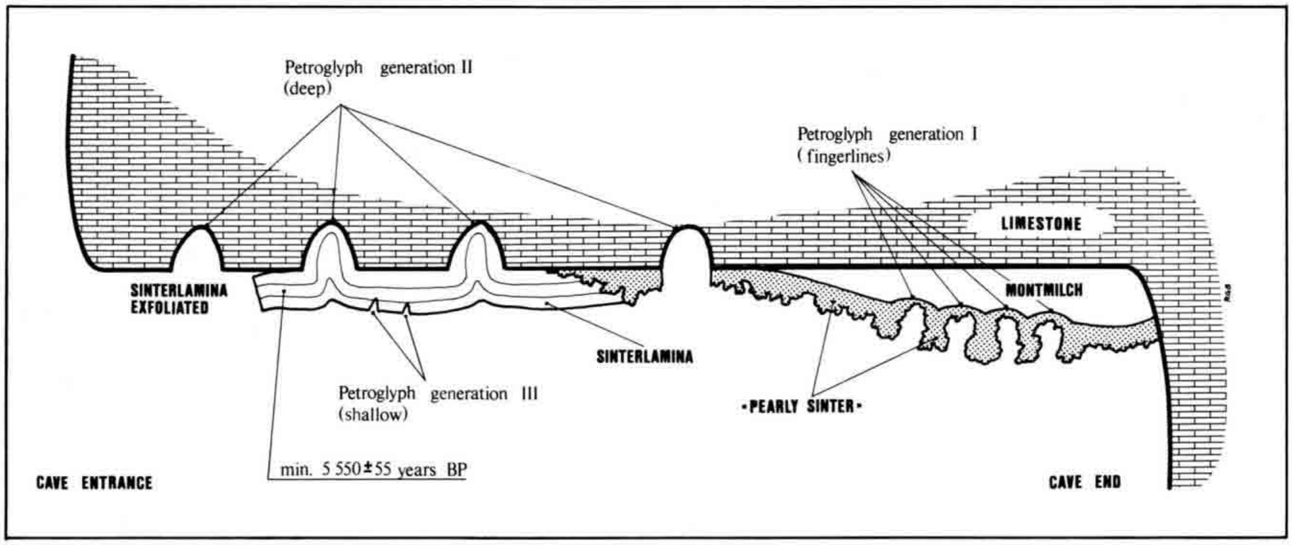

Fig. 1. Schematic depiction of the relationships between three carbonate speleothem formations and three petroglyph 'generations' on the ceiling of Malangine Cave, South Australia. The *Montmilch* deposit was first marked with fingers, then covered by the 'pearly sinter' precipitate in the deep part of the cave. The laminated speleothem ('sinterlamina') near the entrance separates the two more recent petroglyph phases and has provided a 'very conservative' minimum age. On this basis it was argued that the shallow incisions are of the middle Holocene, the deep grooves possibly of the erly Holocene. Recent excavation has confirmed the presence of occupation in the region at mid-Holocene, and between 9000 and 10,000 years BP (Frankel 1986). The age of the oldest marks, the fingerlines, remains unknown, but they are in excess of 20,000 years old elsewhere in Australia. Adapted from Bednarik (1984).

terns of lichen thalli, it has been found to be of only limited utility. Watchman identified organic matter enclosed in silica skins (precipitates of colloid silica commonly found at Australian rock art sites), from which it might be possible to extract AMS dates (Watchman 1985), but considerable uncertainties would apply to such dates. For instance, airborne organic matter may significantly predate a mineral skin in which it is deposited. I have described a process in which potash reacts with silica to produce glass during brush fires (Bednarik 1979: 31), which would almost certainly be datable by various methods, but I have not yet observed such a deposit over rock art.

DATING ROCK PAINTINGS SCIENTIFICALLY

By the late 1980s, 'direct dating' methods had thus established themselves as a viable, if not preferred, alternative to traditional approaches in rock art dating. The first radiocarbon date obtained directly from a rock painting was presented in South Africa by Van der Merwe *et al.* (1987), on comparatively recent charcoal pigment. During 1990, innovative archaeologists began adopting the new methodology on a major scale. Several multidisciplinary research teams in Australia and France succeeded in obtaining absolute dating of painting pigments, publishing their results within a few months of each other.

In Australia, Pleistocene rock paintings were for the first time dated by Loy *et al.* (1990), who obtained three AMS (accelerator mass spectrometry) radiocarbon dates from human blood protein identified in paint samples. A sample from Laurie Creek, Northern Territory, seems to be about 20,000 years old while two samples from Judds Cavern, Tasmania, are believed to be around 9,000 or 10,000 years old.

Palaeolithic rock art was for the first time dated by absolute and 'direct' means when Lorblanchet *et al.* (1990) subjected charcoal-based paint from the cave of Cougnac, Quercy, to AMS dating, obtaining an age of about 14,300 years. Thus at least part of the art in Cougnac, which had been attributed to the Lower Magdalenian, belongs in fact to the Middle Magdalenian.

McDonald and Officer applied AMS dating to charcoal drawings in the Sydney region, obtaining surprising results at the site Gnatalia Creek (McDonald *et al.* 1990). All rock art of the Sydney region had so far been assumed to be less than 2,000-3,000 years old, and the two dates of about 6,000 and 30,000 years BP (obtained from a single motif, a large lattice pattern) have prompted further analyses. There are several possibilities to account for the significant difference between the results and it has to be established which one of them applies in this instance (McDonald *et al.* 1990: 90).

More recently, the AMS method produced a date of about 3,800 years BP from a naturally exfoliated painting fragment from a limestone shelter in Seminole Canyon, Texas (Russ *et al.* 1990). These authors are confident that organic carbon is a ubiquitous component of rock art paints, in the form of binders.

The idea of extracting 'direct dates' from rock art or from contiguous datable mineral deposits has found the support of archaeologists, and the most obvious application of the principle, the dating of paintings via some substance contained in the paint, will in due course revolutionize rock art studies. While few paints would contain charcoal or organic binders, methods to date non-organic components of rock paints will no doubt appear. For instance, Lorblanchet *et al.* (1990) report that their red pigments are apparently not of ochre, but were prepared from locally occurring siderolithic clays which may have been mixed with water, decanted to separate the sand fraction, dried and then roasted at a fire to dehydrate the iron minerals to a red colour. Heat treatment of ochreous substances may have been practised by rock artists more frequently than had been through (Bednarik 1987), and it appears that such paints ought to be datable via the thermoluminescence method. The identification of distinctive paint recipes at Niaux and other French caves is also highly relevant, and appears to have chronological connotations (Clottes *et al.* 1990).

Moreover, the use of organic pigments or binders was perhaps more widespread than has been reported, despite Rosenfeld's (1987) pessimism. For instance, animal proteins have been observed in red rock paint from southern China recently (Li Fushun 1991). Barnes (1982) has shown that in the Four Corners region of Arizona, Utah, Colorado and New Mexico, binders used in rock paintings include blood, eggs, seed and animal oil, plant resins and juices, milk, honey and urine. Several ethnographic accounts attest the use of animal blood for paint preparation in southern Africa (e.g. How 1962; Prins 1990), and of human blood in Australia. Presumed manganese pigments have been found to be of charcoal, and I have identified several types of organic pigments. In India, at least three occur: a distinctive maroon-coloured substance which is thought to be produced by micro-organisms; a white pigment which is transformed into black with time (e.g. at Jaora, Madhya Pradesh); and charcoal. A white pigment turning into black also occurs in the Victoria River district, northern Australia, and I believe the conversion process may be attributable to bacteria or fungi. Some rock paint in South Australia and Victoria consists of bird droppings, and the use of charcoal is widespread in Australia and in other continents. I have seen red cochineal pigment in the Andes, and I have found organic paints in North America and Europe as well. All of these, and all paints containing organic binders or organic carbon, can presumably be dated accurately, within the limitations imposed by sample sizes and the inherent tolerances of techniques.

Recent work by Watchman (1991) has opened several exciting new avenues for analytical work on rock paints: he has detected plant fibres in paint from Laura, north Queensland, which are datable by AMS, and he determined one plant species from brush fibres. Watchman also located up to about ten layers of paint stratified between accretionary geomorphic layers, even on rock panels that appeared not decorated on the surface.

Even if only a minute proportion of all rock paintings became datable, this would suffice to establish a framework of absolute dating into which undated paintings could be slotted on the basis of superimposition and other traditional criteria. It is therefore perhaps only a matter of time before the current, experimental work gives way to a reasonably comprehensive methodology for the dating of rock paintings.

THE DATING OF PETROGLYPHS

While an absolute chronology of some rock painting traditions may no longer seem utopian, the outlook for similar developments with petroglyphs remains bleak. Although there are likely to be improvements in the methods of dating surface encrustations, accretions or patinae that cover and postdate petroglyphs, the present preoccupation with focussing on the ages of such deposits imposes a severe limitation: they can only provide minimum dates for the petroglyphs covered. After all, the art may be just marginally older than the mineral skin, or it may be many times as old! The fundamental difference between pictographs and petroglyphs is that the former are the result of an additive process, which is likely to have taken place when the paint was prepared, whereas the latter, being the result of a deductive process, cannot be readily related to a specific substance. Admittedly, the age of a component of a paint is not necessarily the same as the paint's own age; for instance, one must expect that occasionally the charcoal selected to provide black pigment was not fresh, but was already thousands of years old when it was added to a paint. Nevertheless, this is an inherent risk and one would hope to obtain valid dates in the great majority of cases.

With the exception of parietal finger flutings (Bednarik 1986a), which are made by reshaping a soft surface, all petroglyphs are attributable to a deductive process, such as abrasion, percussion, drilling, or etching (with corrosive agents). The material removed is hardly recoverable, which is why all 'direct' dating methods so far applied to petroglyphs relate to features concealing them, such as carbonate precipitates, rock varnish and oxalate skins.

Most attention has been given to CR dating of rock varnish, but recent developments have not been favourable for it. Subsequent to the developments in Australia during the late 1980s, there have been further critiques, for instance concerning the lack of statistical controls (Lanteigne 1990). Dorn has responded to the various reactions by stressing that CR dating is an experimental method, which would always remain a 'weaker sister' of other approaches due to the many environmental influences that must be allowed for (Dorn 1990). He is revising previous calibration curves, and he certainly prefers direct AMS dating of the organic matter contained in the varnish to CR dating (only the restriction of sample size prevents the use of simple AMS dating of petroglyphs). Dorn is also expressing much interest in an alternative method, which relates to the accumulation of cosmogenic isotopes (^{3}He, ^{10}Be, ^{14}C, ^{26}Al, ^{36}Cl, ^{41}Ca) in exposed rock as a function of time (R.I. Dorn, pers. comm.). This phenomenon is a result of cosmic radiation, but its potential applicability to rock art dating seems remote.

The declining interest in the CR method has rekindled interest in alternative dating techniques for petroglyphs. For instance, my carbonate dating method is being refined by A. Rosenfeld and myself. A substantial cave deposit of numerous thin, successive layers of precipitate, consisting of alternative white and grey laminae, has been located in a Mount Gambier cave. Embedded in this deposit, between two of its layers, occur petroglyphs, and the grey colour of some layers is thought to derive from organic matter. Several analytical possibilities are being explored currently, and the project has received a boost from my discovery of further datable deposits in January 1991.

However, the possibilities of utilizing calcium carbonates in petroglyph dating remain limited. Only a few of the currently known 310 sites of 'cave art' in western Europe and southern Australia (Bahn & Vertut 1988; Bednarik 1990a) feature speleothems that are physically related to art, and there are none in the many sites of cave art I have examined in the Caribbean. Calcite encrustations related to soils, as they are found at petroglyph sites in various world regions (e.g. Bednarik 1987; Dragovich 1988b), are more common than suitable speleothems, but they may have been subjected to a greater number of variables.

Carbonate, CR and oxalate dating all belong to the same class of dating techniques, and our preoccupation with them illustrates one difficulty in rock art dating: a preference for techniques that can be developed or neatly packaged into standard procedures, or that in some form lend themselves to standardization. Such procedures are seen as maintaining a semblance of the replicability science demands, whereas exploratory or tentative methods

Fig. 2. The location of the study site, Besov Nos, at Lake Onega, Karelia.

are more likely to be frowned upon by scientistic archaeologists. Petroglyph dating, one of the most intractable problems in this discipline, remains a largely opportunistic pursuit demanding considerable methodological creativity. It will, I predict, remain a scientific frontier for quite some time.

INTO THE FUTURE

It has become clear from recent petroglyph dating work that the approaches utilizing mineral deposits, irrespective of the accuracy of their results, can only produce associative data. To illustrate that we may have been biased in favour of complex, and perhaps over-sophisticated, methods, I return to my original proposal for 'direct dating': phenomena that predate or postdate petroglyphs are certainly not restricted to mineral accretions. When considering various options (Bednarik 1979) I gave in fact less space to rock varnish and other deposits, than to integrated or cross-referential approaches that would involve the assessment of various types of phenomena on a site-specific basis, particularly rock fracturing, weathering, patination of all forms, physical surface formation processes and erosion wanes ('wanes' are the product of the progressive rounding of rock edges with time, through slow weathering rather than spalling). Soleilhavoup (1985) advocates a recording technique of including relevant information on the geomorphological microtopography, and developed a standard system of depicting such details in the fashion of a geographic map. An expansion of his method (e.g., radii of all rock edges should be recorded) and its general adoption would do much to enlarge the scientific base of this discipline.

I have previously referred to a method for determining the ages of blunted edges on sandstone (Černohouz & Solč 1966), in which the angle of the edge and the distance of retreat at the edge are assessed. Although theoretically valid, the method would lack significantly in accuracy, partly because the two surfaces forming an edge also retreat (Bednarik 1979: 28).

The chronological relationship between rock art and the cracks dissecting it can often be determined. Such a crack results in the formation of two edges separating the art from two new surfaces, and these four features are all of the same age. Edges become progressively blunt and rounded with time, surfaces become patinated or they are subjected to granular or laminar exfoliation, to the deposition of accretions, scratching by animals (in caves) and other processes. Many phenomena could be utilized in dating, depending on local circumstances: the wanes on rock edges; multifacetted boulders that are the result of progressive insolation or brush fire spalling, and bear a patination of different age on every facet (Bednarik 1979: Fig. 1); differential patination, fracture sequences, and their relation to the different art phases present at a site; carved dates, inscriptions and historically datable symbols; the spatial relationship of the art to specific topographic aspects of the site, such as subsided floors, roof falls (in caves and shelters), changes in sediment levels or in accessibility may all be datable in some way.

While it is true that such processes are often susceptible to intractable variables (for instance, climatic factors and environmental pH can accelerate, delay or completely inhibit the formation of patinae; Bednarik 1979: 30), it is also true that most petroglyph panels present a complex record of many time-related processes and events, and the relative position of the art within these chronological sequences is often readily apparent. Archaeologists have traditionally ignored these clear sequences of geomorphological events and processes as a source of information, trying instead to correlate the art with *archaeological data*. Very few petroglyph sites offer any means of relating archaeological 'data' to the art, yet at each and every site the art can be related to at least some of a multitude of geological, geochemical and geomorphological phenomena, all of which refer to specific events or periods, and many of which may be datable in some way. As one would have expected, much of archaeology's effort in providing a chronological framework for rock art has resulted in distinctly ahistorical models (Bednarik 1988a). Instead of being so absorbed in archaeological contexts of rock art, those who study it would do well to concentrate on its medium: the rock surfaces!

I complete this paper with the introduction of the latest petroglyph dating method. Microerosion analysis was conceived while I was working under the auspices of the U.S.S.R. Academy of Sciences on the east shore of Lake Onega, Karelia (Fig. 2), in 1990 (Bednarik in press b). The task of reviewing the age assigned to a series of petroglyph sites on granite pavements (Savvateyev 1984, based on nearby settlements and on assumed lake level fluctuations) proved most frustrating: I found no accretionary deposits or datable sediment strata covering the art, and there is almost no patination. The motifs themselves provide no clues for dating, and the extensive nearby occupation evidence seems to be fairly continuous from the Mesolithic onwards.

Using primarily the micro-wanes on individual crystal cleavage faces that had been exposed when the petroglyphs were fashioned, I noted the differential wear of the feldspar and the quartz components. I thus established a dual calibration curve (starting with feldspar erosion, and continuing with quartz erosion where the former became too excessive to estimate) from several marks of known, or approximately known, historical ages, at the site of Besov Nos (Fig. 3), and using the most recent, final Pleistocene glacial striae as the furthest reference point (the glaciers withdrew about 9,000 years ago, and

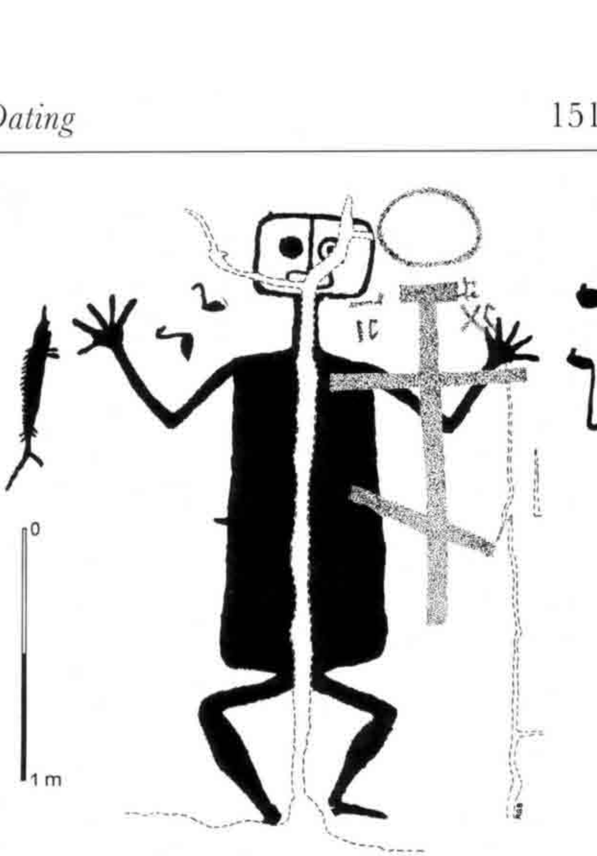

Fig. 3. Petroglyph of antropomorph known as the 'demon' of Besov Nos, Lake Onega. A Russian Orthodox cross, inscription and 'halo' have been superimposed at a later time.

I found that the relative age of striae, as evident from superimposition, is consistently confirmed by their relative degree of microerosion). When the early petroglyphs are placed into this tentative calibration curve according to their solution wear, they appear to be between 3,000 and 5,000 years old, the median age being the most probable (Fig. 4). This almost agrees with the tentative dating of Savvateyev, to the final Neolithic, i.e. to 4,000-4,800 years BP, the time marking the introduction of cold-hammered copper in the region (Savvateyev 1984).

I regard this as the first result of a new and certainly experimental method, and not yet as a valid confirmation of Savvateyev's hypothesis. Nevertheless, there is much to be said in favour of microerosion analysis. It is the only petroglyph dating method that seeks to date the event of petroglyph manufacture rather than the age of some related phenomenon which is inevitably older or younger than the art. It is in fact the purest form of 'direct dating' possible for petroglyphs.

Microerosion analysis is the only viable dating

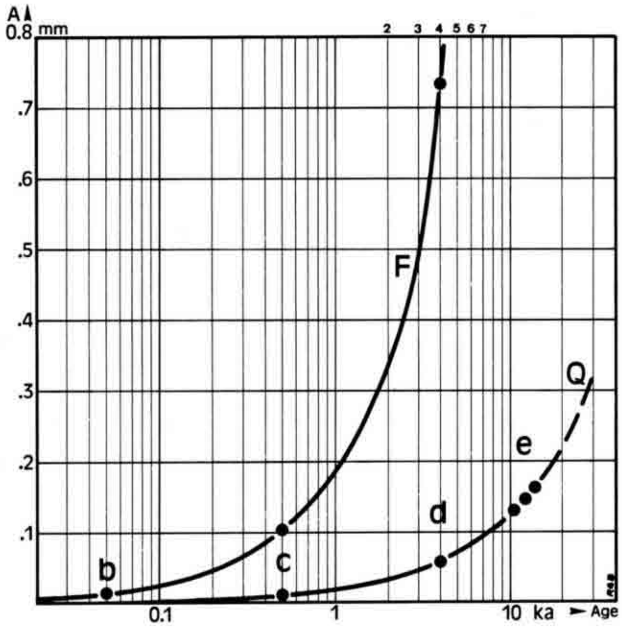

Fig. 4. Model of microerosion calibration curves, using the experimental Besov Nos data. The surface ages b, c and e are known, or approximately known. The age of d, the surface of the Besov Nos 'demon' motif, is to be determined. Curve F represents the feldspar component, curve Q the quartz component, A is the wane width at $\alpha = 90°$, and the age of the samples is shown logarithmically in ka (thousand years) (Bednarik in press b).

technique currently available that involves no damage of the art or a related feature; it requires no contact at all with the motif. The method involves no expensive or sophisticated equipment, handling of samples, possibility of contamination, laboratory costs or waiting for results. Although the theory is somewhat complex (Bednarik in press b), the technique as such does not require a great deal of specialist knowledge or training; extensive field experience, competence in microscopy and a working knowledge of geology are sufficient.

Initially, applications of the method should focus on rock art regions where suitable rocks occur together with rich concentrations of historically datable surfaces and inscriptions, such as the granite zones in India and on the Nile; or on datable lava flows associated with petroglyphs, as in Hawaii. As reliable calibration becomes available for various climate and rock types, many regions throughout the world would become eligible.

The accuracy of microerosion dating may initially correspond roughly to that of earlier petroglyph dating methods, but its reliability cannot be matched by them, nor can its simplicity.

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