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DEVELOPMENTS IN PETROGLYPH DATING

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Abstract. In the short history of scientific approaches to estimating the age of rock art there have been many fascinating developments already. Here I provide a brief personal account of some of these developments, focussing especially on the more recent, Recent experiences in the use of carbonaceous substances for carbon isotope analysis, the experimental use of field XRF spectrometry to determine the age of mineral crusts covering petroglyphs, recent developments in the use of microerosion analysis in various contexts, and the development of digitised colorimetry to achieve seriation dating of ferromanganese patinae all show promise.

My involvement with rock art dating commenced in 1963, when I recorded two petroglyphs at the entrance to a cave in the eastern Alps of Austria, Kranichberg Cave (Bednarik 2008). There is no rock art inside this limestone cave, located about 70 kilometres south-southeast of Vienna, but on the overhanging wall immediately to the left of its entrance there are the images of a human and what appears to be a Roman numeral in a rectangular frame. The latter suggests the date of '1851', although one of the characters is apparently inverted (Fig. 1). The relatively naturalistic anthropomorph appears to wear a coat resembling a hussar uniform, of a fashion that was still in use in the region at the time. Being the budding young scientist, I examined the grooves closely and marvelled at the advanced state of weathering. The images appeared to be much older than the purported mid-nineteenth century antiquity implied, but limestone in the open obviously is not a good support for rock art. I could see no reason why the numeral, which was of identical weathering, should be misleading, it had been executed with great care, and the entire composition seemed too purposeful to be a simple hoax.

This led me to ask: How would one go about dating a petroglyph if one did not have the luxury of finding a carved date with it? I have been considering that question ever since, and while various methods have been developed since 1963 that can help us in this quest, it is also true that the issue of dating petroglyphs remains one of the most intractable in rock art research and in archaeology. All methods used so far remain experimental, and the interpretations of their results by archaeologists are frequently misleading because of an eagerness to 'over-interpret' data that are subject to complex qualifications (Watchman 1999; Bednarik 2002a).

Estimating the age of pictograms (rock paintings, drawings, stencils and beeswax figures) is not much easier, but at least there is the promise of obtaining results of some kind directly from a substance that 'dates' from the time that the rock art was made: the paint residue. In the case of petroglyphs, rock art motifs made by a reductive process, the substance removed from the rock is not realistically recoverable. That

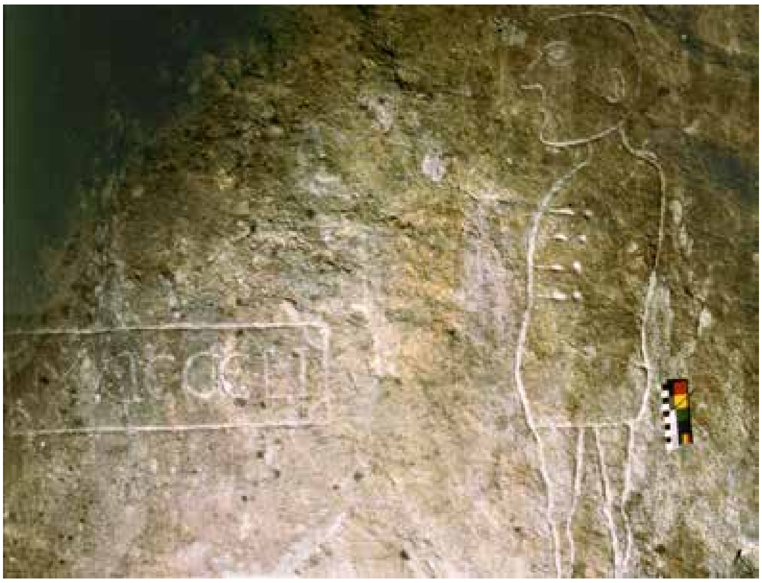

Figure 1. Two petroglyphs at the entrance to a limestone cave in the eastern Alps of Austria, Kranichberg Cave.

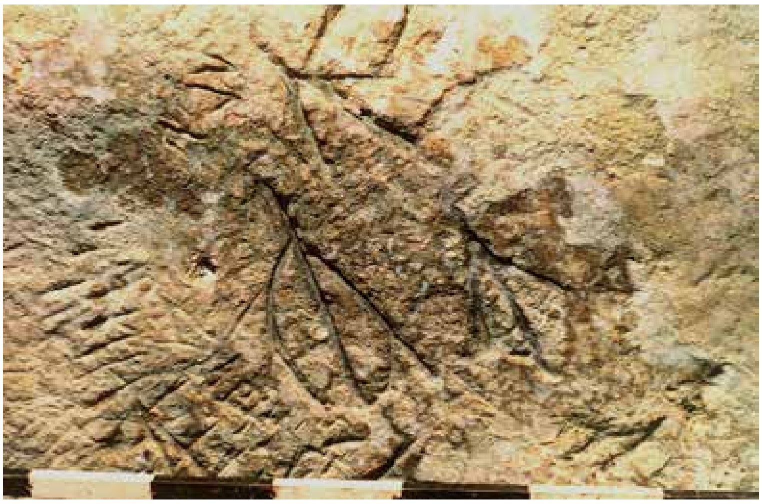

Figure 2. *Ceiling petroglyphs in Malangine Cave, South Australia, exposed by the exfoliation of carbonate lamina postdating them.*

does not mean, however, that we are entirely without means of estimating the antiquity of a petroglyph, but it does mean that this requires considerable ingenuity and understanding of method. The development of experimental methods is therefore essential, and this activity has marked recent decades and will continue for some time. Here I report two aspects of this quest: my personal experiences with it, and some of the most recent developments we have witnessed.

Since re-discovering the huge rock art complex of Dampier in Western Australia and many other Pilbara petroglyph sites during the 1960s, I have maintained my commitment to finding ways of estimating the ages of petroglyphs. This resulted, in the 1970s, in the development of nanostratigraphy and various studies of patinae. When I named Malangine and Koongine Caves in south-eastern South Australia in 1980, I saw what appeared to be a clear-cut way to securing 'direct' dates: here, cave petroglyphs were covered by thick re-precipitated calcite skins, on which much younger petroglyphs had been executed. The age of this ceiling lamina (Fig. 2) therefore had to be between the ages of the two rock art traditions.

Having learnt in the 1960s that calcite can be dated under favourable conditions (if it is of the secondary, re-precipitated, type), because about half of its carbon has been obtained from the atmosphere, I secured carbon isotope as well as uranium-thorium contents from the lamina in 1981. This was the first application of scientific analysis to rock art dating; it marked the beginning of 'direct dating'. But a scientist needs to be self-critical and I have reviewed these approaches critically in subsequent years. I found that the method works very well in theory, but the complicating factors in interpreting results correctly are almost overwhelming (Bednarik 1998).

I had long been aware from microscopic work that the fractures of the crystals exposed by freshly broken or ground rock surfaces showed perfectly sharp edges, but that these became progressively rounded with time. This process of microscopic edge rounding, attributable to the process of solution that proceeds faster at a convex or protruding aspect than on flat or concave surfaces, seemed to proceed so uniformly that I considered how it might be quantified. Every time a petroglyph is made hundreds of grains or crystals are broken or truncated, and if we could relate the degree of edge rounding (called a 'wane') to their age, it would provide a measure of when the initial event occurred. By the late 1980s I had determined the geometrical laws of the process of wane formation. In 1990, I applied the theory to a petroglyph at Lake Onega, in Karelia, Russia (Bednarik 1992). These laws also apply to many other physical phenomena, such as the development of weathering zones, the transfer of heat in a geometric body, and the way a cube of sugar is penetrated by coffee. In its application to microscopic crystal edges, the method is called 'microerosion analysis'. This method has since been used by me in every continent except Antarctica, and also by researchers other than me (Fig. 3).

Figure 3. *Microerosion analysis in progress at Rupe Magna, Grosio, northern Italy.*

Microerosion age estimation is the only method developed so far that seeks to determine the date of the 'target event' (the production of the petroglyph; cf. Dunnell and Readhead 1988) rather than that of some other, physically related phenomenon that is either older or younger. Moreover, it is one of very few approaches to petroglyph dating that involves no contact with the rock art, and no sample removal. Its great limitation is the need to establish local calibration curves from surfaces of known ages, which is often difficult to achieve. For instance, I considered for many years how to apply it in Australia, but it took me ten years to find conditions suitable for calibration. In 2000, I found a large number of dated inscriptions among rock art at Spear Hill, a huge site complex I

Figure 4. *Site 7, Spear Hill site complex, Pilbara, Western Australia.*

Figure 5. *Pictograms 15 and 16, Mladeč Cave, Czech Republic, claimed to be of the Palaeolithic, but according to various evidence of the 19th century.*

had visited more than thirty years previously (Fig. 4). This series of rock surfaces of known ages facilitated the first application of microerosion analysis in Australia (Bednarik 2002b).

In reviewing close-up photographs of many dated inscriptions I noticed that the progressive darkening of the patination in them, caused by the re-patination processes, seemed to proceed quite regularly. They prompted the idea of quantifying these changes experimentally. The possibility of using the degree of repatination is certainly not a new notion, it was first mooted by Belzoni (1820), and in the 1970s I already had cited his observation of the repatination of Egyptian petroglyphs. It is a phenomenon all petroglyph researchers are familiar with, but nobody had ever attempted its quantification by colorimetric determination, let alone any more detailed analysis. I assembled a series of photographs featuring a colour device profile, of carved dates from the Spear Hill complex, and calibrated them digitally. Then I experimented with pixel aliquot sizes to determine the minimum size for representative averages. This led me to favour 36-pixel square aliquots. Next, I determined thousands of precise RGB colour values from these inscriptions of known ages, and experimentally plotted the results in a graph. To my considerable surprise, when plotted on logarithmic scale, the values formed an almost perfect, slightly parabolic curve. I then added a few slightly older values, from motifs whose ages I had estimated by microerosion analysis, to the same curve by the same means, and they fitted perfectly.

The statistical probability that all of this is simply a fluke result is so small that it can be disregarded. It seems that the degree of repatination is a predictable function of time and it can be used to estimate age at a given location and lithology. Moreover, these spectacular results also support the veracity of the microerosion ages used in the experiment, which had been determined previously and independently. Colorimetric analysis (Bednarik 2009) also involves no contact with the imagery, and I have already used it for rock paintings. In determining colour variation in the pigment markings in Mladeč Cave, Czech Republic, which had been suggested to be of the Upper Palaeolithic, I was able to demonstrate that they are all of the 19th century (Fig. 5).

It must be emphasised that, in applying this method to estimate the age of repatination, calibration values from different locations, lithologies, environments and exposures cannot be used indiscriminately. At this stage, one must assume that, for each site and exposure type, local calibration is required. This is a severe limitation, but there are various rock art regions where this does not impair the use of colorimetry. I have begun to use it in Saudi Arabia, after finding a great wealth of datable inscriptions at petroglyph sites all over the country. As part of the first scientific work undertaken with the rock art of Saudi Arabia (Bednarik and Khan 2005, 2009), we attempted preliminary colorimetry. In checking the archaeological sequence of presumed petroglyph traditions at Jabal Qara we found ample evidence that the proposed sequence was essentially false: superimposition and the very numerous historical inscriptions could be used to refute the stylistic chronology entirely. In determining values for five surfaces at the site Najd Sahi, Jabal al Kawbab, we found excellent correspondence between colorimetric determinations, superimposition and juxtaposition with inscriptions (Fig. 6). While we have not attempted absolute age estimates, it is evident from the relative dating results that they are entirely consistent with other age indicators. This work is tentative and

***Figure 6.** Superimposition and juxtaposition of petroglyphs and inscriptions at Najd Sahi, Jabal al Kawbab, that were subjected to colorimetric determinations*

much more fieldwork is required, but it is already evident that colorimetry is much more reliable than previously expected. Its practical limitations remain severe, but they will gradually diminish as work proceeds.

One of the most used methods in the estimation of petroglyph ages is the extraction of organic matter from mineral accretions, usually but not always over the rock art in question (Watchman 1996). There has been much debate about the veracity of such data, concerned primarily with the possibility of contamination from older or younger sources. The same issues also apply to analyses of pictograms. It appears that there are considerable differences between the reliability of such results depending on the type of mineral accretion. For instance one would need to severely question such results from ferromanganous deposits, including rock varnish, whereas those derived from silica skins or oxalate crusts appear far more secure because such deposits tend to seal in the dated matter.

Watchman's (2000) production of several in-sequence dates from a deposit of only 2.11 mm thickness, but spanning 26 000 years, demonstrated the utility of the method. However, there remain difficulties with single dates derived from bulk samples, that is, where it has not been determined precisely what is being analysed (Bednarik 1996). This could be ascertained either at the molecular level (type of substance) or at the object level. Until recently, this had not been achieved, but Ponti and Sinibaldi (2005) have presented the first attempt to use radiocarbon analysis of single substances that they secured from Saharan paint residues. Although their results derive from pictograms, the same principles would apply to deposits relating to petroglyphs, so their work needs to be considered here. They isolated for radiocarbon analysis a protein from a motif at the Lancusi, Tadrart Acacus site in Libya. They also secured monoterpenes (organic compounds) from two Fozzigiart site samples in the same region, and isolated a heavy hydrocarbon in one of them. In both cases, the dated substances were not identified, but are thought to have been derived from binders in the paint. There is promising potential in developing this method, but it involves considerable analytical complexity.

Another recent development in petroglyph dating is the first attempt to estimate the age of motifs by x-ray fluorescence spectrometry (Lytle et al. 2004). In this method, the sample is bombarded with x-rays, and the wavelengths and quanta of the released energy, or fluorescent x-rays, are measured, thus determining the elemental composition of the sample's surface. The technique has long been used in archaeology, but portable XRF equipment has become available only recently. The researchers determined the amounts of Mn and Fe in rock varnish deposits formed on petroglyphs at a site in Utah. Having established a calibration curve based on radiometric dating of geomorphic surfaces, they noted a consistent increase in the Mn+Fe concentration with increasing age. By projecting values taken from a series of petroglyphs into their calibration curve, they acquired age estimates for these ranging from about 500 to 4000 years BP.

This method also involves no sample removal and, apart from contact, is non-invasive, as are microerosion and colorimetry analyses. It takes only about two minutes to take and record one measurement. Even if it were to be found ultimately that it does not provide viable estimates of petroglyph age, the use of portable XRF equipment is still an invaluable addition to the growing arsenal of the rock art scientist. It can be used to identify the composition of accretions and weathering phenomena. If it were also to yield approximate estimates of age (an accuracy of only about ±50% is proposed by Lytle et al.), that would be a welcome bonus. The first claims will need to be examined carefully; some aspects of their initial project are debatable. For instance, several of the calibration points were derived from questionable cosmogenic analyses and unreliable radiocarbon results, and the diagenetic complexity of rock varnishes (in view of re-cycling of cations by microbes, and other causes of degradation) renders the idea of a linear enrichment implausible. Duplication of this work is therefore imperative.

Finally, there is one more development in petroglyph dating that has not found much attention so far. It is a departure from the usual aim of dating a surface or a specific feature directly related to the rock art. Attempts have been made, with promising results, to determine the age of the tools used in making the petroglyphs. Two approaches have been applied. One is to search for the hammerstones in the excavation of sediment deposits below the decorated rock panels, and to determine the time of their deposition by traditional means. This is currently being applied in central India (Bednarik et al. 2005).

The second method perhaps would be applicable only rarely, but it has succeeded at three Bolivian sites. Sometimes, at isolated small petroglyph sites, it may suffice to find either hammerstones or, as happened in one instance, even just tiny spalls of the stone tool that have remained in cracks around the petroglyph (Fig. 7). In either situation it has been shown to be worthwhile to analyse the stone tools or slivers by microerosion study, as long as there is adequate indication that there is a connection between the rock art and the evidence of its making.

Figure 7. *Tiny spalls of white quartz recovered from cracks adjacent to horizontal petroglyphs at the elevated site Kalatrancani 3, near Cochabamba, Bolivia.*

It is evident that the apparently intractable issue of petroglyph dating is being addressed from various angles. While progress may appear to be slow, in the years since 1963, when I first confronted the issue, there have been worthwhile developments. Scientific approaches were not applied to the problems of rock art dating until 1981. By the early 1990s, progress began to accelerate markedly, and in 2010 we can confidently expect further improvements. So far, all work in this field has been experimental. Perhaps it will remain so for many more years, because it is difficult to standardise the required procedures and to establish processes that might be routinely applied. Each site and dating context seems to present different challenges, and this area of research will continue to engender innovative and inventive approaches for many years to come. The nature of the task demands this.

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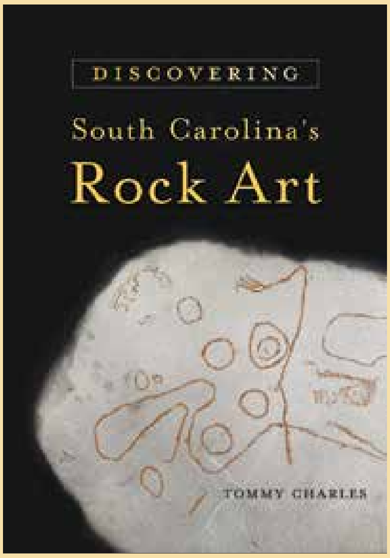

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