Dating Methods (Absolute and Relative) in Archaeology of Art

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Introduction

Chronology of rock art, ranging from Paleolithic to present times, is a key aspect of the archaeology of art and one of the most controversial. It was based for decades in nonscientific methods that used stylistic analysis of imagery to establish one-way evolutionary schemes. Application of scientific methods, also called absolute dating, started to be used in the 1980s and since then has increased more and more its significance, as judged by the large number of papers published in the last two decades on this subject (Rowe 2012).

Definition

Absolute and relative dating methods have been used to establish tentative chronologies for rock art. Relative dating refers to non-chronometric methodologies that produce seriation based on stylistic comparison and stratigraphic assumptions. On the other hand, absolute dating methods are based on scientific techniques that yield a chronometric age for a phenomenon in direct or indirect physical relation to rock art (same age, older, or younger). Dating of some binders in pictographs or the alterations of surfaces by petroglyphs are examples of direct ages related to rock art production. However, it is controversial to consider these dates as “absolute” as they merely reflect experimental propositions, which often lack independent verification (Bednarik 2007; Pettitt & Pike 2007). Most scientific dating methods are indirect because they produce constraining ages for imagery, and the age obtained is of a phenomenon related to but not the actual time of manufacture of the art. If these indirect ages are in a stratigraphic relation to rock art (older or younger), then they produce minimum/maximum direct dates for related imagery (Bednarik 2007; Morwood et al. 2010; Ruiz et al. 2012).

Rock art research has been treated for years as a minor aspect of archaeology. Lack of reliable methods to date ancient imagery, both pictographs and petroglyphs on open-air sites or inside of deep caves, kept it outside of mainstream archaeology. This began to change with the introduction of scientific dating approaches, and there are reasons to feel optimistic about dating rock art at this time. Several dating groups are currently working on this around the world, and it is now possible to hope for interlaboratory comparison tests to help evaluate the reliability and accuracy of the techniques.

Key Issues/Current Debates/Future Directions/Examples

Archaeological studies of rock art demand a temporal framework in which a particular imagery was produced, as it is the only way to relate decontextualized imagery to archaeological cultures. The earlier traditional methods to establish chronologies of rock art sites and imagery were based on assumptions made on iconography, style, and comparison with excavation evidence and technical analysis. For example, Paleolithic mobiliary art from excavated sites in Europe was used as a base for stylistic comparison with cave imagery. These evidences, supported by superimposition analyses, produced the great stylistic schemes for Paleolithic art in Western Europe, which defended a one-way evolution from simple to complex figures, expanding from Aurignacian to Magdalenian times (Pettitt & Pike 2007). These systems lack enough resolution to produce an accurate temporal frame for rock art, above all for styles without consensus on their mobiliary parallels.

Weaknesses of these stylistic paradigms were pointed out (see (Bednarik 2007; Pettitt & Pike 2007) for recent reviews of them), but it is important to recognize that they are still useful for rock art chronology because it is obviously impossible to date every figure in a site and every site all over the world. A well-defined proxy with stylistic, technical, and chemical composition data would be very helpful as a complement to scientific dating. A date archaeologically decontextualized is of little value, so it must be stressed that any dating should be included in archaeological hypotheses.

The first radiocarbon dating on rock paintings was carried out on a charcoal pictograph in South Africa in the late 1980s quickly followed by others in 1990 in Australia, the USA, and Europe, which added to pioneer research on engravings dating. A few years later, a broader conscience about these new possibilities dictated that scientific dating of the passage of time became an alternative to stylistic paradigms (Lorblanchet & Bahn 1993). However, debates on very old AMS ^{14}C dates from Chauvet Cave (France) and very young ones on open-air engravings dated by several methods in Foz Côa (Portugal) showed that style and scientific dates were still necessary for archaeology of art.

The most common technique for dating rock paintings worldwide is the radiocarbon dating of the charcoal pigments often used to construct the drawings. A large number of publications have been collected in the bibliography composed by Rowe (2012). Dating charcoal has been well honed by the radiocarbon community, and the results can be considered to be generally reliable. The main disadvantage to radiocarbon dating charcoal pigments is that the date measured is *NOT* that of the time of execution of the painting. Rather it dates the pigment and there are two caveats that accompany any date of charcoal: old wood and old charcoal (Steelman & Rowe 2012). Old wood phenomena are situations, usually encountered in desert areas where wood decays slowly, in which the wood burned to make charcoal may be up to centuries old. Old charcoal may occur when freshly hewn wood is burned, but not used to construct a painting until much later. Both these caveats should be kept in mind at all times when interpreting charcoal pigment radiocarbon dates.

Dating of charcoal pictographs has been broadly used in French and Spanish Paleolithic caves (Alcolea & Balbín 2007; Steelman & Rowe 2012), but also in North America and Australia, and other regions of the world. The largest part of the charcoal pigment dates is considered reliable but, for example, in Chauvet Cave, dates are controversial because they are unusually old and conflict with stylistic paradigm. Several authors claimed for a likely contamination of datings of Chauvet, as the dates from different samples of one single figure in Peña de Candamo (Asturias, Spain) showed that results by Geochron Lab (USA) were 15,000 years younger than those produced by LSCE (France), responsible of all Chauvet dates (Pettitt & Pike 2007). This situation reflects pitfalls of the method that could be accompanied by contamination of unknown origin, possible repainting for younger dates, mistakes in laboratory treatment of samples, and the presence of carbon of different origin, for example, incomplete dissolution of calcium oxalates. An improved specific protocol to remove contamination produced by calcium oxalates from charcoal paintings has recently been developed (Bonneau et al. 2011).

It is indispensable to follow a strict protocol to collect samples during fieldwork. The protocol described in literature tries to avoid contaminations using sterile latex gloves and surgical masks. Samples are removed from walls with a sterile surgical blade, which is changed and discarded after each sample. They are put inside of a sheet of folded sterile aluminum foil and placed inside of a labeled plastic bag. The exact position where samples were removed should be recorded with photographs. Extreme care ought to be observed on the selection of the sampling points to avoid major visual impact or harm to the pictographs, for example, selecting flakes that appear likely to spall from the walls naturally. The size of samples required is uncertain but around 2 cm^2 is generally used for pictographs with inorganic pigments and much less for charcoal-pigmented paintings, as for AMS ^{14}C dating only 50–100 µg of carbon is needed for an accurate date. For pictographs with inorganic pigments, e.g., iron ochre or manganese oxides, it is essential to take an unpainted rock sample as near to the sample taken as is feasible. That background rock sample should be processed identically to the pictograph sample. A more detailed report on sampling protocol, reporting of radiocarbon results and laboratory pretreatment of samples, has been just published (Steelman & Rowe 2012).

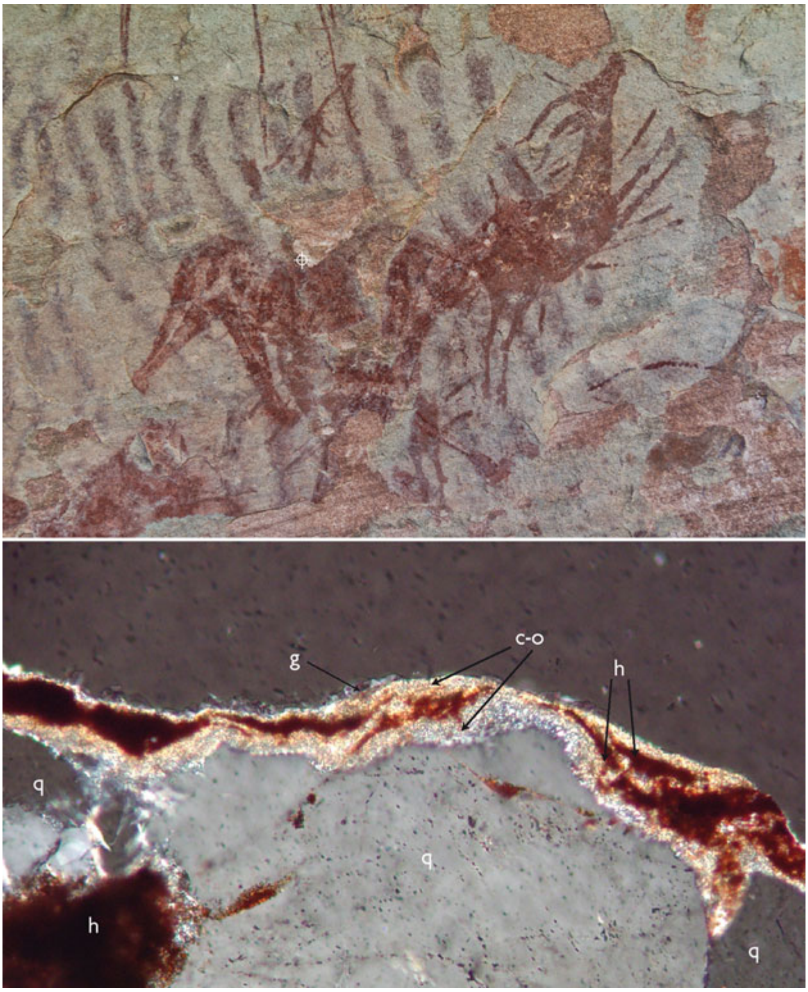
AMS ^{14}C has been used to date any other kind of carbon-bearing substances related to pictographs or petroglyphs (Aubert 2012). The presence of binders has been used to produce direct radiocarbon dates of beeswax paintings in Australia (Morwood et al. 2010). Vegetal resins and wax are binders of these paints. It is considered that wax would have been fresh when applied on walls to construct the drawings, so it should be ambient source of carbon to date rock art. In the Australian Kimberley area, a range of dates from 3,780 ± 60 BP to present times were obtained (Morwood et al. 2010). Rowe and coworkers have dated non-charcoal paintings in several sites in North and South America (Rowe & Steelman 2003; Steelman & Rowe 2012). These pictographs were made with inorganic pigments, mainly iron oxides, so it is assumed that some organic binder must be present in them. Replicate measurements on samples of the same pictograph yield an uncertainty of ±250 years suggesting results are reliable (Steelman & Rowe 2012).

Indirect dating by AMS ^{14}C has been widely used to date carbon-bearing accretionary crusts (like calcium oxalate skins) or organic matter inclusions in mineral coatings (amorphous silica skins). Calcium oxalate dating is a procedure to set a temporal frame on the age of a pictograph or a petroglyph. Calcium oxalate coatings appear naturally on walls in two mineral forms: whewellite and weddellite. The exact process of formation of these accretionary crusts is still unknown, but there is a broad consensus that they form from ambient carbon dioxide and that they are deposited on external faces of rocks after metabolic activity of lichens, microbes, and bacteria. This method was first used in Australia in the early 1990s, and since then it has been used in sites all over the world (see review by Ruiz et al. 2012). It has been shown to be useful to get minimum ages for petroglyphs and minimum/maximum ages for pictographs. On certain locations, researchers has bracketed dates for rock paintings between two oxalate skins, producing a temporal frame for pictographs in agreement with archaeological expectations (Ruiz et al. 2012).

Sample removal procedure is similar to that described for radiocarbon dating (Cole & Watchman 2005). Sample sizes range from 25 mm^2 to 1 cm^2, depending on oxalate content. Oxalate dating demands microstratigraphic analysis and micro-excavation techniques to avoid contamination between upper and lower layers of calcium oxalate. Mechanical procedures and laser ablation have been used so far for this purpose (Watchman 2000). There are two main drawbacks for oxalate dates: (1) radiocarbon age of any calcium oxalate crust is a weighted “average” of oxalate deposited for long periods of time, even into modern times, so (2) they always yield minimum ages, and in consequence the archaeological significance of them is limited by our ignorance of time lapse among rock art creation and formation of the oxalate crust (Fig. 1).

A similar approach can be used with silica skins. These accretionary crusts are formed during evaporation of runoff water solutions containing monomeric silicic acid that after dehydration forms a hard noncrystalline film on the surface of rocks (Watchman 2000). Organic matter like diatoms and other algal has been found inside of finely laminated silica crusts overlying pictographs in Australia, for example, giving a minimum age for related Bradshaw-style figures. The same procedure has been described to date a silicate accreted paint layer.

Calcium carbonate coatings interstratified with pictographs or engravings can be used to obtain constrains on their time of manufacture. U-Th series disequilibrium method is applied to date the formation time of calcite coatings. They are formed from the redeposition of dissolved calcium carbonate from saturated solutions of water that flow across the surfaces of rocks and eventually deposit over rock art. In these flowstone crusts are contained small quantities of



Dating Methods (Absolute and Relative) in Archaeology of Art, Fig. 1 Group of zigzags and Levantine zoomorphs from Cueva del Tío Modesto (Henarejos, Cuenca, Spain). A microsample was collected from point indicated in upper picture. Cross section shows two painting events interstratified with calcium oxalate layers (*down*). Two ^{14}C AMS dates were obtained related to this microstratigraphic packet (*q* quartz, *h* hematite, *g* gypsum, *c-o* calcium oxalate)

uranium (U), an element soluble in water, while they are relatively free of thorium (Th), an insoluble chemical element. The method is based on the radioactive decay chain from parent ^{238}U into the intermediary isotope ^{234}U and finally to daughter ^{230}Th. Relative measurement between these three isotopes in calcium carbonate crusts allows calculation of the age of the carbonate host as the decay rate is known. Detrital materials, such as aeolian dust or silts and clays dissolved into water, incorporated into calcite layers are a potential contaminant that could distort the results producing overestimated ages (Taçon et al. 2012). Low ^{230}Th/^{232}Th ratios are indicative of detrital contamination. This concern can be corrected by measuring the activity of another isotope, ^{232}Th, which can be detected in elevated levels in detritus.

Samples could be extracted by scraping with a surgical blade or with an electric drill. They could be very small (10–150 mg) and very thin (0.5–2 mm), depending on uranium content. Submillimeter-thick laminations can be accurately dated by this method. Two lab treatments are described in literature, an acid wash (Taçon et al. 2012) and a micromill preparation (Hoffmann et al. 2009), after which laser ablation inductively coupled plasma mass spectrometry (LA-ICP-MS) is used to isotopic ratio measurements.

U-Th dating was first used in South Australia to give an estimation of the age of two petroglyphs concealed by speleothems (Bednarik 1999). The result yielded a minimum age for these cupules of 28,000 ± 2,000 years BP. At least two research groups are currently working with this method, one in Australia and Asia (Taçon et al. 2012) and the other one in Europe (Pike et al. 2012). A large-scale U-series dating program has recently been carried out in several Paleolithic caves of northern Spain (Pike et al. 2012); the extremely old results of some of these dates (a red disk in El Castillo has a minimum age of 41,400 ± 570 years BP) are controversial, because the older of these dates are very near to the time when modern humans appeared in that region. (Pike et al. 2012). On the other hand, since we know that modern humans did art and were present in this same time span, there is little reason to introduce Neanderthals as the artists of this art. In southern China, U-Th dating has yielded minimum/maximum ages for naturalistic pictographs in an open-air shelter, and they have been compared with ^{14}C AMS dating of plant debris and microorganisms trapped inside of calcite crust, after an estimation of the contribution of geological carbon in calcium carbonate (Taçon et al. 2012).

OSL (optically stimulated luminescence) dating has been used by several groups. The method is based on an estimation of the time since grains of quartz or feldspar were last exposed to daylight. Stimulating samples with laser produces luminescence signals whose intensity varies depending on the radiation absorbed before last light exposition. Obviously, samples should be collected in absolute darkness. Pioneering work with this method was on quartz grains on mud-wasp nests overlying pictographs in Northern Australia (Aubert 2012). The resultant ages range from present time to 1,530 ± 220 years old but yielded three very old dates between 17,000 years and 24,000 years. These extremely old dates have been criticized as it is very difficult to believe that those fragile structures have survived many millennia (Bednarik 2007). Additional concerns have been expressed by Bednarik (2007) and Aubert (2012). OSL dating has been applied to date petroglyphs in Qurta sites (Nile valley, Egypt). A part of panel QII.4.2 was concealed by aeolian sediment accumulations that yielded dates from 10,000 ± 1,000 years at the top to 16,000 ± 2,000 years at the base of the sequence. This is considered as evidence of Pleistocene age rock art in Egypt (Huyge et al. 2011). Future directions for this technique could try to date individual quartz grains underlying paintings, but many uncertainties have to be resolved first.

At least three techniques are being currently used to date petroglyphs. The older of the more commonly used techniques is that of "*microerosion analysis*" developed by Bednarik who has published widely on the subject (see bibliography Rowe 2012 for references through 2011). The method is based on direct microscopic observations on fractures of crystals in rock surfaces produced by petroglyphs. Newly broken or abraded rock surfaces are very sharp, but over time they become progressively more rounded. Two major advantages of the technique are (1) that it is nondestructive and (2) it measures the date of the targeted event, i.e., the manufacture of the petroglyph. A perceived problem, one shared by all the described dating techniques, is that it has not been independently verified by any other laboratory. Its dependence on calibration from rock surfaces of known age and on weathering assumptions has been criticized.

The other two techniques are as follows: (1) *microlamination analysis* of desert varnish developed by Liu and coworkers (see bibliography Rowe 2012 for Liu et al. complete references through 2011). This has been applied specifically to rock art in only one recent instance (Tratebas & Dorn 2012). Although destructive, only a small sample is needed for the analysis for a date. The method is fairly straightforward for archaeologists and geologists. It is based on stratigraphy of desert varnish formation over a fresh rock surface. Once a rock surface is removed, desert varnish begins to form, but not uniformly in depth. Rather it is varied depending on the climatic conditions that change over time. A situation develops that may be viewed in analogy to tree rings, except that with microlamination that it has far less resolution, changing discernibly on centuries rather than years. Obviously calibration is needed, using studies of rock surfaces dated with independent methods to construct the necessary curve.

The method, developed by Dr. Tanzhuo Liu (see references his geochemical applications in Rowe 2012), has been blind tested and replicated and hence can be viewed with promise for dating petroglyphs. (2) Determining the *buildup of manganese in desert varnish* as it forms over newly exposed petroglyphs over time is the basis for a technique developed by Lytle et al. (Rogers 2010). This technique is also nondestructive; measurements can be carried out on site. It requires construction of a calibration curve. The principle of the method is quite straightforward. In a newly constructed petroglyph, the removed surface exposes fresh rock, usually very low in manganese. As the petroglyph weathers over time, manganese content steadily builds up as a component of the desert varnish that forms over the previously exposed surface over time. Manganese measurements can be performed in a few minutes with pXRF devices without sample removal. Using the calibration curve, the time of formation of the petroglyph is directly measured. Only Lytle's group has measured petroglyph construction dates using the technique. At present, the method claims an uncertainty of $\sim \pm 30\ \%$.

In our opinion, the time has come for the three groups conducting petroglyph dates to compare the methods, one against the other. If all agree, petroglyph dating would at that point be considered viable by all techniques, a very important verification, and a giant step forward in petroglyph dating.

Cross-References

- ▶ Altamira and Paleolithic Cave Art of Northern Spain
- ▶ Art, Paleolithic
- ▶ Australian Rock Art
- ▶ Bednarik, Robert G.
- ▶ Chronological Systems, Establishment of
- ▶ Côa Valley Rock Art Sites
- ▶ Dating Techniques in Archaeological Science
- ▶ Europe: Paleolithic Art
- ▶ Europe: Prehistoric Rock Art
- ▶ Iberian Mediterranean Basin: Rock Art
- ▶ Leroi-Gourhan, André
- ▶ Mobiliary Art, Paleolithic
- ▶ North American Rock Art
- ▶ Organic Residue Analysis in Archaeology
- ▶ Pigment Analysis in Archaeology
- ▶ Radiocarbon Dating in Archaeology
- ▶ South American Rock Art
- ▶ Style: Its Role in the Archaeology of Art
- ▶ Techniques of Paleolithic Art
- ▶ Unilinear Evolution and Lineal Time: A Critique

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Dating Methods in Historical Archaeology

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Introduction and Definition

Dating methods in historical archaeology differ little from the methods of archaeology in general. Both absolute and relative dating approaches are employed. However, historical archaeology has