Direct Rock Art Dating in China

Subjects: Archaeology
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This paper summarizes the scientific study of rock art in China, focusing on the direct dating of rock art. It pays particular attention to the recent work of the International Centre for Rock Art Dating (ICRAD) at Hebei Normal University and explains the problems of the uranium-thorium analysis of reprecipitated calcium-carbonate skins related to rock art.

rock art petroglyph China

1. Introduction

Immovable cultural heritage occurs throughout the world and in many forms, of which rock art is the most numerous of manifestations. In the case of China, the connection between rock art and other such heritage is particularly important because features such as statues, religious and secular structures or rock inscriptions of known ages have been used extensively to calibrate the direct dating of rock art. Estimating the ages of rock art is one of the most challenging tasks of archaeology and is riddled with controversies [1]. Many approaches have been tried, and it has become evident that the methodology of 'direct' dating is the most dependable of them. It is characterized by a direct physical relationship between the rock art in question and the dating criterion, and the falsifiability of the propositions concerning that relationship.

Figure 1. Tang Huisheng conducting the first replicable direct dating of rock art in China in 1997 at the Lushan petroglyph site in Qinghai Province (photograph by Gao Zhiwei, with permission).

A wide range of potential 'dating criteria' has been appraised, but there are difficulties with many of them. Most importantly, the demand for falsifiability renders it is essential that the analysis should be repeatable: another researcher must be able to test the claim by repeating the experiment. Such replication is not possible with many methods proposed or already used because they involve the removal of physical samples that are sacrificed in the process of analysis. Such methods may also be challenged on ethical grounds by arguing that these interventions damage the integrity of the rock art or its relationship with contiguous features, such as mineral accretions. Examples include extracting carbon-bearing substances contained in rock art paint residues, cations present in rock varnishes covering petroglyphs, or determining the nature of uranium and thorium components of reprecipitated carbonates. Many of these applications are severely hampered by the significant variations of the concentrations of the dating criteria elements in coeval mineral skins on a millimetre-scale, which may be well above 100% [2][3].

2. Direct Rock Art Dating in China

These first two direct dating attempts of Chinese rock art refer to endeavours that were not testable by replicating the experiments on which they were based. The subsequent results were derived from Tang Huisheng, who, in 1997–1998, introduced the use of microerosion analysis in Qinghai Province [4]. He collected microerosion calibration data from three petroglyph sites: Shuixia, Lebogou and Kexiaotu. These were then used to place petroglyphs from three more sites chronologically: Lushan, Lumanggou and Yeniugou. These were found to be approximately E2000, E2300 and E3200 years old, respectively (the 'E' prefix indicates that the age estimate was derived from erosion data). Since these measurements are repeatable, they fully comply with the requirements of direct rock art dating (**Figure 1**). Tang then secured age estimates from three cupules at the Jiangjunya site at Lianyungang City, Jiangsu Province, ranging from E4300 to c. E11,000 years BP, using calibration obtained from a Buddhist inscription at nearby Kongwang Hill, dating from April 61 CE [5].

All methods currently used to estimate the ages of rock art are experimental, and that includes microerosion analysis [1]. However, that method offers significant advantages, such as full replicability and lack of physical intervention. Microerosion-derived age estimates of petroglyphs can only be approximate because precipitation can vary as a function of time. Nevertheless, the results of seven 'blind tests' conducted in Russia, Portugal, Italy, Bolivia, Australia (2) and China matched archaeological expectations very well [6][7][8][9][10][11][12]. In terms of their magnitude, results from this method are fully reliable. Radiocarbon analysis, by contrast, can provide very precise results, but when obtained from rock art these may be entirely false. Those obtained from paint residues can only be accepted if the substance analyzed has been identified and separated, be it at the molecular or at the object level [13].

The discovery of a major rock art concentration in Henan Province [14] prompted a very successful rock art dating expedition in that region and Ningxia and Jiangsu Provinces during June and July 2014 [15]. It utilized China's wealth of rock surfaces suitable for microerosion calibration, especially soundly dated rock inscriptions. Several calibration curves, as well as twenty-seven age estimates from petroglyphs, were secured.

The microerosion method endeavours to ascertain when crystals in the grooves of percussion grooves were fractured by impact during petroglyph production. At that time, the edges of these fractures were totally sharp, but erosion gradually rounds them at the microscopic level in a quantifiable process that is a function of time. The resulting micro-wanes reflect the time since the fractures occurred [6][7]. In contrast to most other known direct dating methods, it refers to criteria that are functions of actual age rather than minimum or maximum ages. It is also non-invasive and involves no contact with the rock art and there are no contaminating factors. The method even allows age determinations in the field. However, it also entails several disadvantages: it has so far only been applied to two minerals (quartz and feldspar); it requires minimum grain sizes of about 1.5 mm with fractures of about 90° between the cleavage surfaces, orientated so that the micro-wane faces the microscope; and the rock surface must have been exposed to precipitation ever since the petroglyph was created. Microerosion analysis provides very reliable but imprecise age estimates, with tolerances often in the order of 20–25%. The significant differences in rainfall in different environments can be accounted for by calibration against the microerosion of surfaces of known ages. In recent years a universal calibration has been created that is based on relative regional precipitation and can be applied where local calibration is not possible [16][17]. The only minerals calibrated so far are quartz and feldspar and the former is thought to have a range of up to maximal 50 ka.

3. The International Centre of Rock Art Dating (ICRAD)

The ICRAD established a simple ground rule to ascertain the scientific integrity of records: they must be presented so that another researcher can try to duplicate (or refute) the reported results, be it by the same or another method. Therefore, the dating criterion must be described so that the second researcher can re-locate the criterion reliably. ICRAD also emphasizes the need to establish protocols that would stand the test of time and will not need to be significantly modified in the future.

To facilitate the implementation of these protocols, ICRAD has established a system of numbering each rock art age determination attempt with a unique code, much in the way radiocarbon dating results are identified. Without such a system, the growing mass of uncollated and incompatible data would eventually become unmanageable. ICRAD’s direct dating register will eventually be made available publicly to facilitate its use globally.

Since the establishment of ICRAD, the efforts of direct-dating Chinese have continued unabated—in fact, they appear to be accelerating. In 2017, a large team conducted the first rock art dating program undertaken in Hubei Province, focusing on a mountainous area east of Tongbai [18]. Huai River rock art corpus includes numerous sites that generally resemble the Henan rock art to the north. Eight of them yielded age estimates, which in all cases derive from cupules. They all fall under 1270 years, ranging down to about 650 years, indicating that the extensive rock art complex is relatively young. The results of this work were interpreted according to the recently established universal calibration curve (UCC) [16][17].

4. The Trouble with U–Th Dating of Rock Art

The first application of U–Th analysis to estimate the age of rock art relates to petroglyphs on the ceiling of Malangine Cave in South Australia [19]. A speleothem lamina covers one generation of them that in turn bears another tradition of petroglyphs, thus providing a minimum date for one and maximum date for the other. Its radiocarbon age was 5550 ± 55 years bp, but the sample's U–Th date was five times greater, 28.0 ± 2.0 ka. All subsequently dated similar carbonate speleothems subjected to both tests showed a similar pattern: the U–Th results were always older and, in most cases, significantly older than ^{14}C or archaeological estimates (**Figure 2**) [20][21][22][23][24][25][26]. Indeed, in two cases, both from China, the U–Th dates were more than one hundred times as old. A reprecipitated carbonate film at Yilin in Heilongjiang that can only be a few centuries old at most has provided a U–Th raw age of 134.6 ka, i.e., hundreds of times its realistic age [2]. An international team recently discovered a few hand and foot impressions of juveniles in a hardened travertine deposit at the Quesang Hot Spring site in Tibet. They correctly proposed that the age of these prints should approximate the rock's age, which must have been soft and still forming at the time they were produced. They secured U–Th 'dates' from the travertine that would place the age of the formation between 169 ka and 226 ka. On that basis, they claimed to have found the oldest known rock art globally, probably made by Denisovans [27].

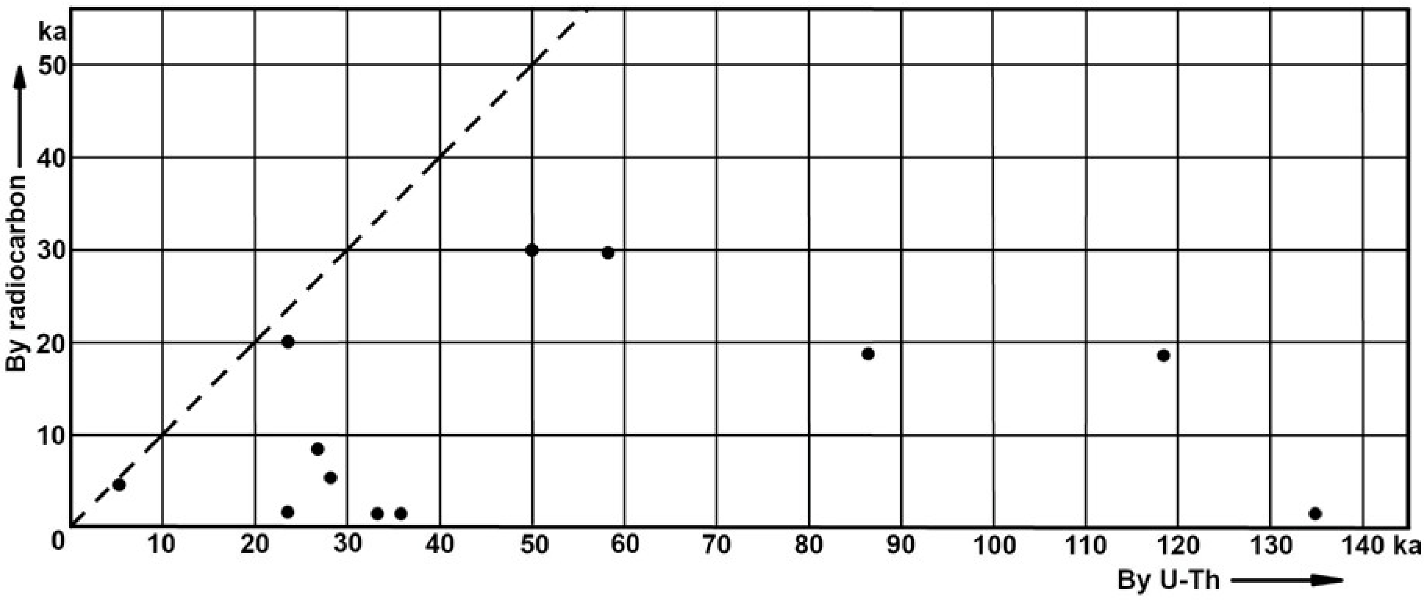

Figure 2. U–Th age determinations of speleothems compared with archaeologically realistic or radiocarbon ages of these same deposits.

This follows similarly spectacular claims from several cave sites in Spain, also based on U–Th data, that paintings thought to be of the late Upper Paleolithic were much older and were made by Neanderthals [28][29][30]. Due to these many concerns about the credibility of U–Th dates from non-crystalline reprecipitated carbonates, an intensive debate of the method when applied to thin or porous carbonates has developed over the last decade [31][32][33][34][35][36][37][38][39][40]. The primary cause of the excessive ages attributed to reprecipitated carbonate deposits is the depletion of U by moisture. Solution may also remove detrital Th, there may be a transformation of aragonite to calcite, or samples may be contaminated by components of the support rock [41][42][43].

Two other factors are of great concern. One issue needing more attention is the significant variation of U concentrations in coeval calcite skins demonstrated to occur on a millimetre-scale that may be greater than 100% [2][3]. The second concern stems from the 'blind tests' we conducted due to the grossly incongruous U–Th results from Heilongjiang sites Mohe and Yilin 2 [2]. We split four samples from Yunnan Jinshajiang sites and submitted the two sets to two different U–Th laboratories [44]. Not only did this yield two entirely different sets of results, but the reporting protocols also differed profoundly. Moreover, three results produced negative values, probably attributable to significant leaching of U and other contaminating factors (**Table 1**). The stochastic distribution of the dates in **Figure 2** suggests that the distortion is not systematic but seems to be a random function of taphonomic processes distorting the U–Th ratios. Most notably, the water-soluble U can be readily mobilized when the deposit is subjected to moisture. This frequently occurs with speleothems and even more so with travertine that is fully exposed to precipitation. Travertines are not dense crystalline formations like stalagmites; they have varying degrees of porosity which assists the reaction with carbonic acid to revert to their soluble (bicarbonate) phase.

Table 1. Comparison of the raw U–Th ages of four split samples provided by two laboratories: all ages in ka.

Sample	MR-1	HY-1	YDG-1	YDG-2
Laboratory 1	1.359 ± 0.179	2.362 ± 2.573	4.674 ± 5.118	20.077 ± 2.742
Laboratory 2	−7 +21/−26	−20 +26/−35	−14 +33/−45	0.4 ± 7.7

There are also a few more minor issues related to extraordinary claims of this nature about rock art. Although we have no reliable information on soft tissue dimensions of any robust humans, especially not on Denisovans, we assume that Neanderthals had thicker fingers than moderns, and we know that their feet differed from those of gracile humans [45][46].

5. Summary and Outlook

It needs to be emphasized that U–Th results of the Holocene, especially the second half of that period, seem to match ^{14}C dates from the same deposits frequently. It is only as we approach the Pleistocene that the results of the two methods diverge. By the time 30,000 carbon years is reached, the corresponding U–Th ages are around 50,000 years—and this also appears to apply to fossil bone [47]. Nevertheless, the $^{230}Th/^{234}U$ method has been widely used to date carbonate speleothems, and when it produces extraordinary results, its advocates reject the need for checking these with another method [38]. One of the most consequential outcomes of the work by the International Centre for Rock Art Dating (ICRAD) is that it has found a path to test the results of U–Th analysis and thereby help resolve the deadlock between the opposing parties. First, it has begun to take multiple samples of coeval carbonate skins, confirming dramatic differences [2]. Second, the processing of split samples by multiple laboratories has shown no correspondence whatsoever, be it in actual dates or reporting protocols [44]. Direct rock art dating results that cannot be verified are questionable, and if different laboratories deliver wildly diverging dates of split samples, there is no basis for even the most rudimentary comparison. The refusal of the advocates of exclusive use of U–Th dating to consider applying a second method [38] also deprives the discipline of the most crucial attribute of good science—the facility of testability.

The method of microerosion analysis has become the most intensively used by ICRAD researchers, despite its lack of high precision. It offers reliability instead, simplicity of application, unlimited repeatability, the benefit of obtaining target dates rather than maximum or minimum ages, and its lack of physical intervention. In China, with so many historical sources, rock inscriptions and archaeological sources of dating information, the method has already been widely applied. Its results have, in many cases, been verified independently by archaeologically derived information of several types. By comparison, the exclusive application of U–Th analysis, especially in presumed Pleistocene contexts, has universally provided ages that are archaeologically far too great, and the reasons for this are well understood.

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