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THE 2014 MICROEROSION DATING PROJECT IN CHINA

Tang Huisheng, Giriraj Kumar, Liu Wuyi, Xiao Bo, Yang Huiling, Zhang Jiaxin, Lu Xiao Hong, Yue Jianhua, Li Yingnian, Gao Wei and Robert G. Bednarik

Abstract. A survey conducted in June and July 2014 in three regions of China, Henan, Ningxia and Jiangsu Provinces, has profitably utilised the country's wealth of rock surfaces suitable for microerosion calibration, especially soundly dated rock inscriptions. A large team has managed to secure several calibration curves and twenty-seven age estimates from petroglyphs of these regions. While these results offer no more than a preliminary glimpse of the time depth of Chinese rock art, they do provide a first opportunity to test previous archaeological age estimates for some of the best-known Chinese petroglyph complexes, such as those of Helanshan and Jiangjunya. The findings are briefly presented and some of their implications are offered for consideration.

1. Introduction

The credible age estimation of rock art, often called 'rock art dating', remains a ferociously complex subject and has spawned scores of misinterpreted results, mostly because the scientific qualifications attached to them tend to be disregarded (Bednarik 1996, 2002; Watchman 1999). Typically, scientists provide empirical information relating to the age of the rock art in question, using a variety of methods, and archaeologists then over-interpret these data in their desire to secure 'absolute ages'. Here we present a project begun in China that attempts a comprehensive and systematic approach of securing testable data from petroglyphs from several regions in that large country, and avoids the opportunistic sampling strategies often guiding projects of this kind.

The principal advantages of microerosion analysis as a method of age estimation of petroglyphs are that it is relatively inexpensive and simple; that in contrast to all other known 'direct' rock art dating methods it refers to criteria that are functions of actual age of the petroglyphs in question (all other methods so far applied refer to entities that, while directly related to the rock art, are either older or younger than it, usually without indication of the probable margin of difference); that in contrast to most other methods it is entirely non-invasive and involves no contact at all with the rock art; and that the process it is based on is entirely irreversible. Concerning the latter factor it is noted that in other rock art dating methods applied so far, the possibility of reversibility in the variable being determined cannot be

excluded with certainty. The analysis of microerosion is in most cases concerned with the process of micro-wane formation as a freshly broken edge of a mineral crystal gradually becomes rounded with time, as material is dissolved at the surface of a crystal that was fractured at the moment of petroglyph production. The rounding process follows specific geometric laws that determine how certain dimensions are linear functions of time (Bednarik 1992, 1993).

The practical application of the method is constrained by a significant number of limiting factors. Although it has been used in all continents except Antarctica, the method of measuring micro-wanes has been applied only to two minerals so far, feldspar and especially quartz. Obviously, its application is limited to petroglyphs on which crystals or grains fractured by percussion have remained intact, which excludes all relatively rapidly eroding rock types (such as most sedimentary facies) from consideration, as well as rocks lacking quartz or feldspar. Even if these conditions can be met, the edges whose micro-wanes are measured must be fractured at close to 90° to be amenable to meaningful measurement. Moreover, the method can only be applied to rock surfaces that have been fully exposed to precipitation for as long as they existed. These factors limit the applicability of micro-wane analysis quite severely: in practical terms much less than 1% of the world's petroglyph population could possibly present suitable conditions. Finally, the solution process whose results are measured is variable according to environmental conditions, especially the availability of solvent (usu-



Figure 1. Map of China indicating the three regions the 2014 microerosion survey focused on.

ally meteoric water, i.e. derived from precipitation). Therefore for each region, calibration curves need to be established for the minerals the method is applied to, by ascertaining the degree of microerosion from rock surfaces of known antiquity. For this purpose a variety of suitable calibration surfaces have been used, including those of gravestones, Roman bridges and inscriptions, monuments or stone structures, even final Pleistocene glacial striae. The most precise calibration references are provided by dated inscriptions, a factor that immediately illustrates the importance of a focus on China. That country features numerous rock inscriptions of ages known *precisely to the day*, and in addition many more approximately dateable surfaces on natural rock. Written records date back further than in most other countries, and China also has large numbers of petroglyphs on supports likely to be susceptible to successful microerosion analysis. This would include especially granitic and gneissic rocks, and quartz-containing facies such as schists, phyllites, coarse-grain sandstones, conglomerates and breccias.

The work of one of us (TH), which includes the first direct dating results from China, has established the great potential of microerosion analysis of Chinese petroglyphs (2012; Tang and Gao 2004; Tang and Mei 2008). In 1997 and 1998 he applied the method in embryonic form (employing wire gauges for measurement estimates), using a stone lion sculpture and inscriptions of known ages as reference points (Tang and Gao 2004). He secured age estimates for three petroglyphs, one each for Lushan, Lumanggou and Yeniugou sites in Qinghai Province, ranging from E2000 to E3200 years

BP. Subsequently he obtained age estimates from three cupules at Jiangjunya site at Lianyungang City, Jiangsu Province, ranging from 4300 to c. 11000 years BP, using calibration from a Buddhist inscription at nearby Kongwang Hill dating from April 61 CE (Tang 2008). Tang's studies have provided the impetus for a systematic program of securing a series of calibration curves and applying microerosion analysis more widely across China, and of taking advantage of the many opportunities to obtain calibration values. The recent discovery of a large corpus of cupule sites in Henan Province (Tang 2012) added a significant incentive to embark on such a major study program with the aim of securing broadly based rock art age estimates. In 2013, plans for this project began to be made, and the first field campaign took place in June and July 2014. It involved the collaboration of almost thirty people and focused on three regions: Henan Province in central China, the semi-arid Ningxia Province in central-northern China; and the coastal Jiangsu Province in the east (Fig. 1). The strategy was to acquire calibration data from these regions, with their different climates; to design a standard protocol for processing the results of this work (Tang et al. 2014); and to subject numerous suitable petroglyphs to microerosion analysis.

Cupules represent the most common form of petroglyphs in the world (Bednarik 2008). They are found in all continents except Antarctica, often in groups of large numbers. They are mostly circular features that have been found pounded into horizontal, somewhat inclined, or vertical rock surfaces and they have the shape of a spherical cap or dome. In size they tend to

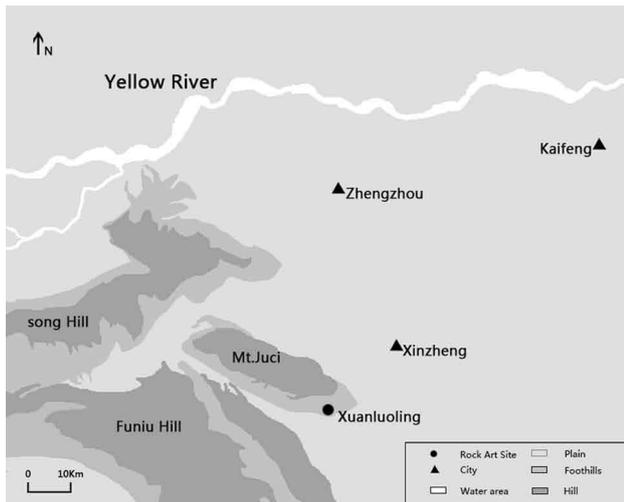


Figure 2. The setting of Mt Juci near Xinzheng, Henan Province.

range from 2 cm to about 10 cm diameter, but larger specimens do occur. They can resemble several other phenomena, and small potholes especially have often been misidentified as cupules. Their purpose is essentially unknown, despite a few ethnographic glimpses of their significance (Bednarik 2010). But one of their most astonishing characteristics is that cupules have been produced by numerous human societies for hundreds of millennia, up to cultures of the 20th century. They are in fact the oldest surviving rock art known, with examples in southern Africa thought to be about 410 000 years old (Beaumont and Bednarik 2015) and others in central India suspected of being even older than that (Bednarik et al. 2005).

2. The sites

2.1 Henan Province

Mt Juci is a steep and rocky mountain southwest of Xinzheng, in the central region of Henan Province (Fig. 2), its distinctive southern cliffs rising several

hundred metres above the surrounding hilly landscape. The mountain is protected as a conservation park. Its schistose rocks contain extensive veins of crystalline quartz that offer opportunities for microerosion analysis where affected by anthropogenic impact. Two clusters of petroglyph sites, both dominated by cupules, were examined: one at high elevations along mountain ridges beyond the main peak, the other comprising a group of sites found in the lower parts of the main cliff defining Mt Juci, and on the slopes below. There are also a few rock inscriptions, two of which were investigated. One of them, the First Gate Site, yielded a poor calibration curve.

Guanyinshan is a granite hill with major rock exposures southeast of Fangcheng (Fig. 3). In one steep panel is a large Buddhist petroglyph on the near-vertical rock, which is not readily accessible. Above it on a flat, vertical rock occurs an engraved inscription in a rectangular frame, 68 cm wide and 108 cm high. It provided calibration curves for both quartz and feldspar. At the upper left the date of execution is defined as being 8 April 1578 CE.

Cupule sites occurring on a group of granite 'whalebacks' at the Xiaomazhuang site complex, next to a small village and near the river Xiang He, were subjected to close examination and provided reliable data from several cupules. These sites are approximately 42 km from Fangsheng and offered ideal conditions for analysis due to their granitic geology.

About 20 km from the city of Yahe, in the Nanyang Yahe District of Henan Province, occurs the Huihuimo Site. There are numerous cupules on gently sloping granite rock exposures above a reservoir lake, again providing excellent data from several of the cupules. In one case this included the measurement of a feldspar micro-wane.

Next, the two inscriptions at Deyunshan, Fangcheng County, were analysed. They are located near the top of a hill crowned by an ancient Buddhist monastery, side by side on the near-vertical, flat fracture of a large granite block, 1.6 m high and 1.4 m wide. The left inscription commemorates the visit of a high official on 1 April 1001 CE, the right dates from 10 February 1004 CE. A calibration curve was obtained from the uppermost character in the second row from the left of the left-hand text.

Wufuling is a hill about 9 km from Fangsheng, topped by an unusual lithology. Its outcrops of pinkish-brown quartzite containing well-metamorphosed silica breccia with angular white quartz clasts and patches of haematite include a small rock tower, on

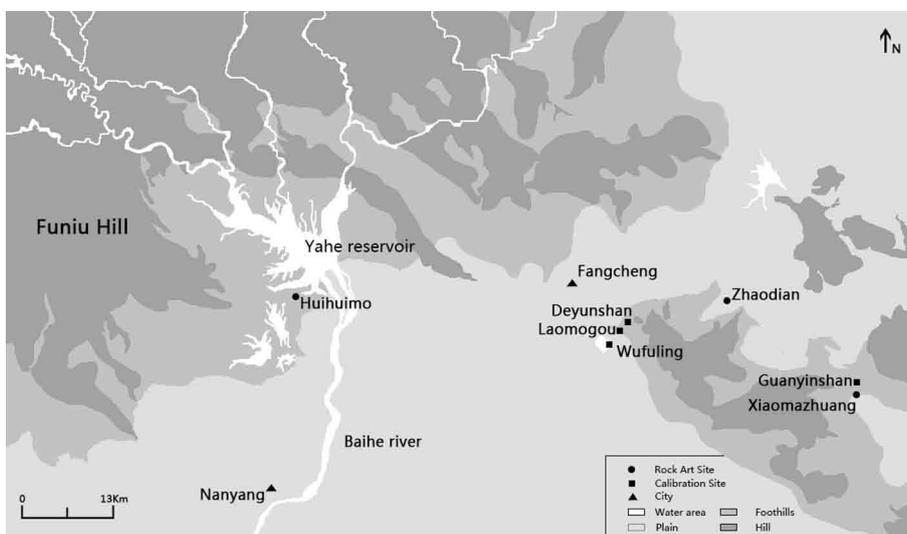


Figure 3. The study area in central Henan Province.

which occur three cupules. Five more are found on an adjacent outcrop and two more nearby. These are of very ancient appearance, but a thorough search failed to locate any fracture edges of an age commensurate with the old appearance of all the cupules. Nevertheless, a relatively recent age estimation was secured from one of the cupules, but perhaps it refers to a retouch event.

The Zhaodian valley in Fangcheng County features extensive granite hills and rock outcrops. A group of dissected rocks amidst a rural community features seven cupules on one of the rocks. Approximately 800 m up the mountain slope, at Shipenggou, is a prominent group of small granite tors that features several sets of cupules. Central to the group is a 'phallic' bedrock outcrop, bearing an unusually large cupule centrally on its top. There are extensive percussion marks on its sides, suggesting that the shape was deliberately emphasised. The highest point of the group features a second granite column and its top bears two smaller cupules. Thus the entire complex is suggestive of some form of ritualistic activities. The site features three main groups of cupules, which include random groups as well as sets of double rows of six cupules, the latter being common in the region. The highest panel, just below the upper column, includes such a double row comprising a dozen cupules, one of which yielded excellent microerosion data.

In the high part of a mountain range near Fangcheng, in the Laomogou valley, occurs a rock inscription on a flat panel inclined at 22° from vertical. It was created in 1510 CE, and the character stating the actual number of the date features a prismatically fractured quartz crystal displaying several edges. The micro-wane of one of these was successfully measured, providing a fourth calibration curve for Henan Province.

The last cluster of petroglyph sites investigated in Henan during the 2014 campaign was Xuanluoling, which is about 30 km southwest of Xinzheng (Fig. 2). A chain of hills overlooks a rural landscape with many gravel pits. It features old stonewall-supported agricultural terraces almost up to the ridge crests. The hills' phyllite contains occasional small quartz veins, and there are several groups of cupules on the larger rocks along the ridge. They comprise up to a few dozen cupules, of which three were found to feature quartz veins. However, visible fracture edges were scarce. One of them offered five micro-wanes, semi-parallel but slightly convergent, one of which yielded credible microerosion data.

2.2 Ningxia Province

Ningxia Province is a semi-arid region (Fig. 4), dominated by the Helanshan ranges which rise to

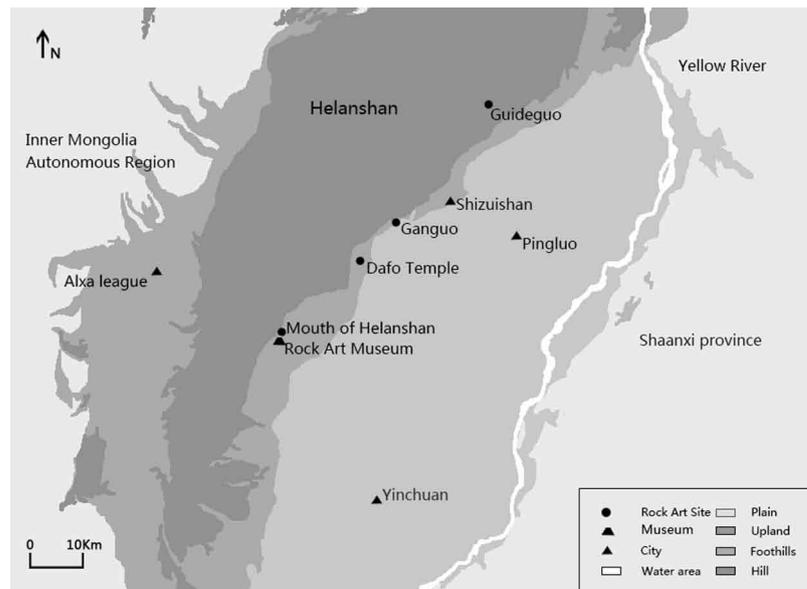


Figure 4. The study area in Ningxia Province.

3626 m a.s.l. At their foot, 32 km north of Yinchuan and overlooking the Yinchuan graben, is one of China's best known rock art sites, occupying the mouth of a canyon. The Helanshan Rock Art Park is a very well developed public site, attracting approximately 200 000 visitors per year. The Park features substantial and extensive board walks and CCTV security cameras along the visitors' route, much of which is defined by steel barriers. There is an impressive museum building nearby, and electric trolleys are used to transport people to the entrance of the tourist circuit. Among the thousands of petroglyphs, the so-called masks are perhaps the most prominent. The metamorphosed Permian (Ritts et al. 2006) fluvial sandstones and conglomerates of the site contain numerous quartz pebbles and coarse sand-fraction grains, sometimes impacted on by the production of petroglyphs. A total of five microerosion determinations were obtained from four petroglyph motifs. The first derives from a single quartz nodule in the groove of a partially exfoliated large 'mask' motif about 12 m above the boardwalk, above the first major petroglyph concentration along the tourist route. Two motifs were sampled about 200 m further into the valley, about 5 m above the boardwalk and to its right, where a major concentration of quartz nodules was noted in the rock. Just outside the mouth of the canyon, alongside the cobble bed of the alluvial fan and roughly below the entrance to the tourist route, is a large block. It is c. 4 m long and bears on its sloping upper surface several petroglyphs. In the central part of the decorated surface one motif has a white quartz pebble among its conglomerate schlieren that has been modified by impact. Ten more quartz inclusions in petroglyphs were observed in the Helanshan Rock Art Park but failed to yield measurable micro-wanes, and two rock inscriptions examined lacked quartz grains.

Further fieldwork was conducted in a number of valleys in the vicinity of Shizuishan, north of Yinchuan.

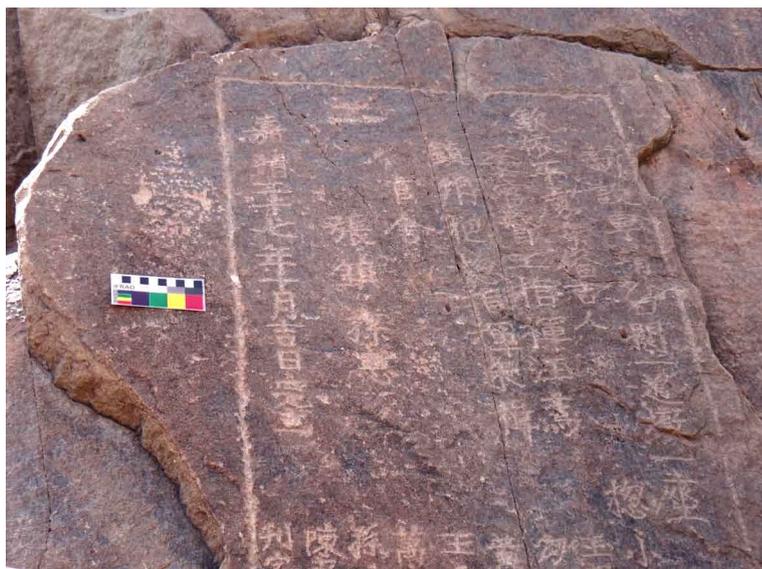


Figure 5. Part of the Gangou inscription of 1548 CE; poor calibration was obtained from the quartz pebble visible to the right of the IFRAO Scale.

A calibration determination was effected at an inscription in Gangou valley, where the establishment of a communication beacon along the Great Wall had been commemorated in 1548 CE. The inscription occurs on a steep cliff about 10 m from the floor, some 5 km from the entrance of the very arid valley (Fig. 5). As all other rock inscriptions examined in the course of this project, it is enclosed by a rectangular surround, the left vertical groove of which runs over a rounded quartz pebble in the schistose rock. Most of this stone has been affected by impact and it bears several good micro-wanes. Unfortunately the steepness of the site and the lack of standing support renders microscopy extremely difficult, but one wane was measured.

The Dafo Temple at Dashui valley, in Ping Luo County, is a Buddhist monastery in a remote valley just north of the remains of a section of the Great Wall, made here of loess bricks. There is a huge Buddha statue next to the traditional-style monastery. Below it, just above the river, a panel of petroglyphs occurs on a small phyllite cliff. These were made with rather pointed metal tools (probably steel) as shown by the characteristically narrow pits. The lack of quartz inclusions prevented the use of microerosion analysis. The floor shelf may have been more extensive to the left, where the petroglyphs are now out of reach. A large scar in the lower part of the flat panel seems to be fire caused and truncates petroglyphs. It shows reddening and is maximal 10–15 mm deep in the central part, with distinctive thinning towards the margins of the exfoliated flake.

Another valley examined in the vicinity of Shizuishan is Guidegou, 17 km long and its entrance is 15 km from Shizuishan. There is an isolated farm c. 8 km from the mouth of the valley. The area features many spectacular examples of folded geological strata in its massive

metamorphic facies, contorted in every possible way. Four sites were investigated in this remarkable valley system, but due to the absence of quartz inclusions none of them has provided microerosion data. The four sites were Sankeshu, Zhuanwankou, Sanchashan and Lvkuangmen.

Sankeshu, on the northern side of the main valley, features a jaggedly fractured sandstone layer about 40 m above the valley's floor. It bears numerous deeply patinated petroglyphs on small panels located mostly along this seam, and there are also a few graffiti-like recent engravings that look quite fresh. The older motifs at Sankeshu were made with pointed metal implements as well as stone tools, as indicated by the variability of the pit shapes and profiles and their lack of steepness. The metal-caused pits are close to circular and characteristically deep; the stone-tool-produced marks were made with great precision, suggesting traditional competence in manipulating such tools.

Zhuanwankou is a schistose, flat, steeply inclined panel of several segments, bearing a dense concentration of petroglyphs: at its bottom some zoomorphs, for the rest mostly 'faces', some of them quite elaborate. The level of manganese-dominated patination, quite uniform across the site, seems to be about 20% to 25% of the accretion evident in the older motifs at Sankeshu, which is the earliest of these four sites of Guide Valley. Sanchashan is a vertical cliff of slightly metamorphosed sandstone in a side valley, immediately above the dry creek bed, featuring a small number of petroglyphs, including face-like motifs and zoomorphs. The rock art seems to be more recent than that of Zhuanwankou. Lvkuangmen consists of a slate ridge in the main valley on which a flat panel occurs, inclined at 45° and about 15 m long, elevated about 20 m above the valley floor. The light-coloured panel bears inscriptions, slogans and imagery, including some indistinct zoomorphs. One of the inscriptions is dated 1944, and it appears that the rest of the panel also is of the 20th century. Erosion of the motifs is minimal, perhaps 10% of the adjacent, probably also relatively recent exfoliation surface.

2.3 Jiangsu Province

Located on the mid-latitude eastern seaboard of China, Jiangsu Province is another repository of many granitic formations that are particularly amenable to microerosion analysis (Fig. 6). Probably the best known petroglyph site in Jiangsu is Jiangjunya, the General's Cliff. Located at Lianyungang City, close to residential suburbs, this is a major rock art site on a gneissic exposure at the foot of rocky hills overlooking a coastal plain that apparently was covered by sea in Historic times. The feldspar-dominated rock of Jinping Hill contains numerous inclusions of crystalline quartz, including long and substantial veins, which in

various cases cross petroglyphs. This is a major rock art site comprising hundreds of cupules and numerous iconic and aniconic motifs which appear to be of a range of greatly different ages. The site is elevated 20 or 30 m above the plain and consists essentially of a gently sloping pavement, around 40 m wide and 20 m long. It features in its upper part a group of much eroded large rocks that seem to have been positioned to form a dolmen, although this is not certain. Jiangjunya is a public site with extensive boardwalk and signage, and it is supervised by a residential caretaker.

Besides this major rock art site, several other locations were also examined in the vicinity of Lianyungang. Just 250 m north of Jiangjunya, on the hillside above a valley with heavy vegetation, is the site of the former Duijiu Nunnery at deliberately positioned blocks forming a dolmen (Fig. 7). Next to it occurs a large cupule made right over major quartz inclusions that yielded good microerosion data. A further 17 m up the valley is a short rock inscription with two well-made animal sculptures. Because there is no certainty that these features are of identical ages it was decided to analyse a very short micro-wane (390 μm long) in the specific character of the inscription that defines its age, 1051 CE, the 2nd or 3rd year of the Song Dynasty. Other cupule sites in the area were also visited, but no attempt was made to conduct analytical work there. However, about 35 km from Jiangjunya is the Song Pan inscription, at the site of the former Bei Gu Hill monastery. It is on the side of a rock supporting a precariously balanced massive rounded boulder and occurs at 57 m elevation a.s.l. As determined from its content, the inscription dates from the 14th year of the Dading Period, Jin Dynasty,

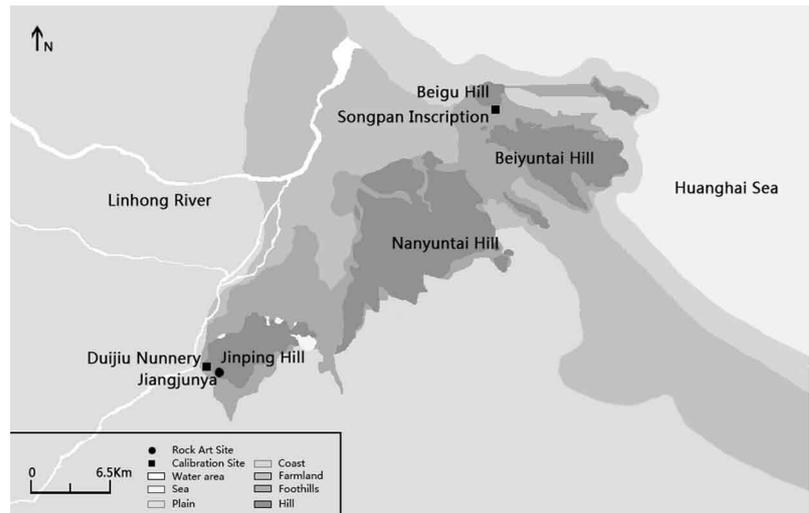


Figure 6. The study area in Jiangsu Province.

i.e. from 1174 CE. A few isolated cupules within a few metres of the inscription were checked too, but the silica in them was not adequately crystalline. The rock is gneissic, silica occurs either as crystalline quartz or as a lumpy product of metamorphism. The site is located on a rocky hillside immediately adjacent to major residential areas today.

3. The empirical field data

3.1. Henan Province

Four rock inscriptions in Henan Province have provided calibration data of varying quality for microerosion analysis. The First Gate Site in the southern cliff of Mt Juci features an inscription dating from the 1st of Wanli, 12th year of Ming Dynasty, which is the 4 March 1584 CE. The upper line of the rectangular surround features a very angular quartz vein, with several fracture edges at c. 90°. One of them yielded these micro-wane widths: 2, 2, 3, 2, 3 = $12/5 = 2.4 \mu\text{m}$.

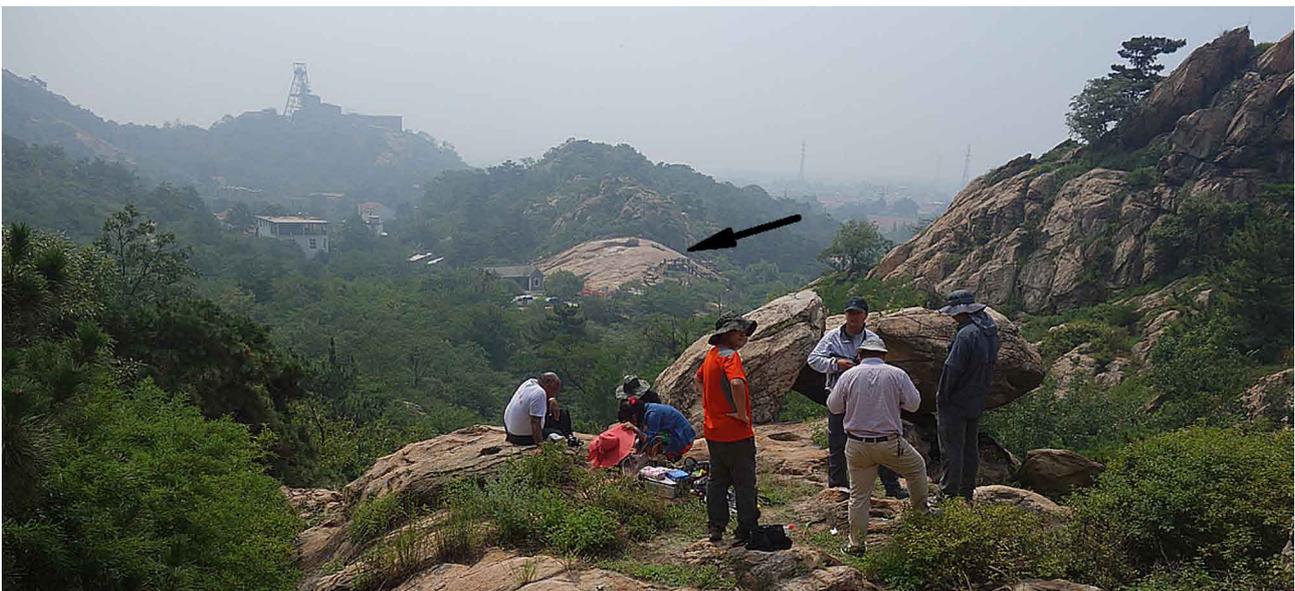


Figure 7. The Jiangjunya site, Jiangsu Province, in the central background, as seen from the dolmen at the former Duijiu Nunnery site.



Figure 8. Part of the Deyunshan inscription, showing the character used for analysis. The calibration micro-wane is located just above the middle of the upper edge of the IFRAO Scale.

The result is, however, considered unreliable due to extensive mineral accretions. Similarly, the prominent inscription at Dragon Mother Spring, in an eastern valley, is protected under a rock shelf, and therefore cannot provide useful microerosion results. This is despite the highly suitable quartz fracture edges found in three locations of the inscription and its rectangular surround.

The Guanyinshan rock inscription of 1578 CE includes a 55-mm-long horizontal line, in which a short quartz fracture yields these micro-wane widths: 3, 3, 4, 3, 4, 3 = $20/6 = 3.33 \mu\text{m}$. Just a little to the right of it is an excellent micro-wane of feldspar, occurring along the lower edge of the groove in a pentagon-shaped feldspar body. The ridge runs down vertically and provided these values: 25, 23, 28, 28, 25, 30, 23 = $182/7 = 26.0 \mu\text{m}$.



Figure 9. The vertical micro-wane measured in the Deyunshan inscription, Henan Province. The wane is 47 microns long and vertical, on a fracture of just under 90° that was made on 1 April 1001 CE, and it has yielded six wane-width measurements.

The Deyunshan inscription of 1001 CE yielded from the first character in the second row from the left, from its right-hand lower right groove (Fig. 8), the following micro-wane widths from quartz: 7, 6, 7, 6, 7, 7 = $40/6 = 6.66 \mu\text{m}$. The micro-wane is orientated vertically and is $47 \mu\text{m}$ long (Fig. 9). It is difficult to find any micro-wanes in both these inscriptions as the quartz is extensively crushed and fracture edges are generally very short.

Finally, the 1510 inscription high in Lao Mo valley provided a reasonably secure set of micro-wane measurements from the very character stating the actual number of the date. It features a prismatic fractured quartz crystal with several short edges, the longest being $125 \mu\text{m}$ long. It yields just three micro-wane widths: 3, 3, 3 = $9/3 = 3.0 \mu\text{m}$.

The lower slopes of Mt Juci below the main cliff feature several sites of cupules on horizontal surfaces. One of these furnished a long fracture edge of $\sim 90^\circ$, c. 1.4 mm long, with these wane widths: 25, 20, 22, 18, 20, 20, 20, 22 = $167/8 = 20.9 \mu\text{m}$.

Xiaomazhuang Site 1, the biggest of a series of granite 'whalebacks', features four deep cupules on a sloping surface. The largest of them yielded the following wane widths from a $280\text{-}\mu\text{m}$ -long micro-wane on quartz: 8, 8, 9, 8, 10, 8, 7, 8, 8 = $74/9 = 8.2 \mu\text{m}$. Next to it, on its right, a second cupule produced from feldspar: 90, 95, 90 = $275/3 = 91.7 \mu\text{m}$. A third cupule just above the previous contains a relatively long micro-wane on feldspar, $490 \mu\text{m}$ long, yields: 85, 80, 85, 90, 90, 85, 90 = $605/7 = 86.4 \mu\text{m}$. The same third cupule, below its upper rim, has several angularly broken quartz crystals. On one $280\text{-}\mu\text{m}$ -long quartz micro-wane, the following excellent values are determined: 10, 12, 11, 11, 10, 11, 9 = $74/7 = 10.6 \mu\text{m}$. The cupule contains also some very recent damage, though not extensive. The fourth of this distinctive group of cupules, contains a block of quartz extensively broken up with several measurable edges that measure generally about $2 \mu\text{m}$. It has clearly been extensively modified relatively recently.

Xiaomazhuang Site 2, 250 m SSE of Site 1, features numerous cupules, including a group of geometrically arranged smaller specimens, the deeper ones being 13–15 mm deep. One cupule features a $390\text{-}\mu\text{m}$ -long micro-wane on feldspar with these wane widths: 180, 175, 170, 170, 170, 175, 165, 170, 170, 160, 155 = $1860/11 = 169.1 \mu\text{m}$. Two other cupules in the same set show recent damage, which in one provides micro-wane widths of 2–3 μm .

At the Huihuimo Site, the cupule closest to the lake provides good data from a distinctive quartz mass with a pronounced conchoidal fracture. The impact has created a long convex fracture across the middle of the quartz. The right-angle micro-wane is $670 \mu\text{m}$ long and yields: 15, 20, 14, 16, 14, 14, 15, 14, 12 = $134/9 = 14.9 \mu\text{m}$. A nearby medium-size cupule with a short 'flow-

out' groove has fractured horizontal surfaces close to its floor that offer good 90° fractures on both quartz and feldspar. A large quartz grain measuring 800–900 µm comprises a concave fracture with a long edge, providing: 18, 20, 20, 20, 18, 16, 20, 20, 20, 22, 20 = 214/11 = 19.5 µm. In its immediate vicinity occurs a large eroded feldspar edge with coarse micro-wane on the floor of the cupule that yields: 189, 195, 185, 180 = 749/4 = 187.2 µm. Then there is a set of geometrically arranged cupules and interconnecting grooves forming a rectangular grid of four by six cupules, one of which yields particularly reliable micro-wane measurements from quartz: 20, 20, 20, 18, 18, 18, 16, 18, 18, 20, 22, 22, 20, 18, 18, 20 = 306/16 = 19.1 µm. This is from a micro-wane length of only 380 µm, which is barely more than about a third of the 1-mm-long wane. Below the edge and parallel to it runs a distinctive step-flaked flaking scar that resembles horsehoof core-type flaking, and the quality of the micro-wane is superb.

The cupules on the top of the hill Wufuling were thoroughly searched and only one suitable wane was detected. Its quartz yielded these values: 5, 5, 6, 6, 8, 6 = 36/6 = 6.0 µm.

At the cupule site in Zhaodian valley, the NNE-most cupule contains c. 8 mm from its western rim a very corroded micro-wane on a 90° quartz edge, yielding the following wane widths: 28, 26, 30, 30, 30, 32, 30, 32, 30 = 268/9 = 29.8 µm. The age is broadly confirmed by another, larger cupule 15 cm to its south. At the nearby Shipenggou site (Fig. 10), the double row of a dozen cupules at the highest point includes one such feature that comprises an excellent ~90° quartz fracture of 760 µm length. Its micro-wane possesses these widths: 15, 16, 18, 18, 15, 16, 18, 18, 20, 20, 20, 18, 17, 18, 17, 17, 18, 18, 16 = 333/19 = 17.5 µm.

One of the many cupules at the Xuanluoling site complex offered a set of semi-parallel micro-wanes, one of which provided good conditions of measurement. It yielded the following widths: 13, 13, 13, 12, 12, 12, 10 = 85/7 = 12.1 µm.

3.2 Ningxia Province

The Helanshan Rock Art Park has provided several microerosion determinations, but so far lacks a calibration curve. The attempted calibration analysis of the 1548 CE inscription in Gangou valley is geographically certainly close enough to be relevant, but its micro-wane widths are quite small and difficult to measure, being in the order of 2 µm wide and providing only coarse resolution.

The first petroglyph sampled successfully in the Helanshan Rock Art Park, a large 'mask' motif, comprises a large quartz nodule

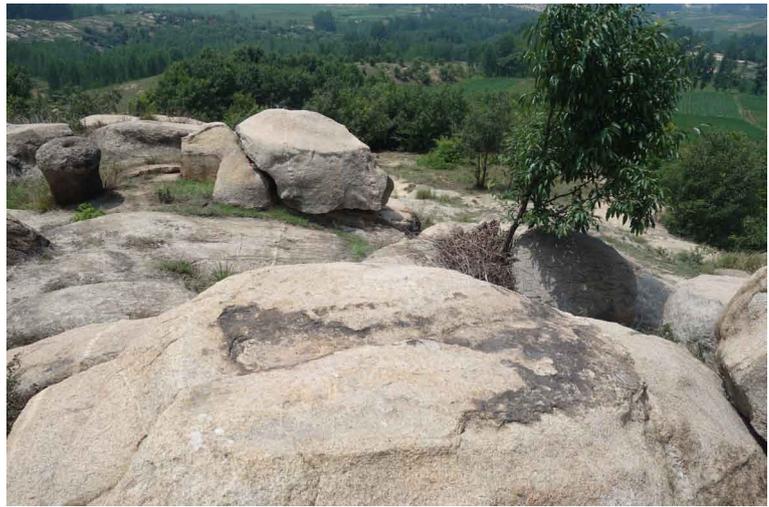


Figure 10. The possibly ritualistic site Shipenggou, seen from its highest point; the presumed phallic rock, c. 1.5 m high, is visible on the left.

in the middle of the petroglyph (Fig. 11). It is 17 mm long and bears extensive battering due to two thirds of it being in a groove forming part of the image. On one short, 150-µm-long fracture edge, the following micro-wane widths were measured: 14, 14, 14, 12, 12 = 66/5 = 13.2 µm. Further into the canyon, to the right of the path, is a major concentration of quartz nodules in the rock, providing suitable fracture edges in two motifs. The first motif yielded: 12, 12, 11, 11, 11, 12, 11, 10, 10, 10 = 110/10 = 11 µm. In the second motif, two micro-wanes occur in alignment with each other, less than 1 mm apart. One micro-wane, 180 µm long, yields: 15, 15, 14, 14, 14, 13, 14, 16 = 115/8 = 14.2 µm. The second, 260 µm long, produces: 16, 16, 14, 14, 13, 13, 12, 13, 12 = 123/9 = 13.7 µm. Finally, the petroglyph sampled on a large block just outside the mouth of the valley (Fig. 12) provided a very short micro-wane, c. 100 µm long, yielding a series of wane widths: 14, 15, 16, 16, 16, 15, 16



Figure 11. Partly exfoliated mask-like petroglyph, Helanshan. The microerosion measurements derive from the white quartz pebble visible below the blue chip of the IFRAO Scale.



Figure 12. Part of a complex petroglyph design just outside the mouth of the Helanshan valley. The extensively fractured quartz pebble above the scale provided the microerosion data.

= $108/7 = 15.4 \mu\text{m}$. All the values secured at Helanshan Park were taken from quartz.

3.3 Jiangsu Province

This project obtained two calibration curves from Jiangsu Province. The first is from the 1051 CE inscription located at the former nunnery site near Jiangjunya. A relatively short quartz micro-wane, 390 μm long, was analysed in the specific character of the inscription that defines its age. It yielded the following wane widths: 6, 6, 6, 5, 5 = $28/5 = 5.6 \mu\text{m}$. The Song Pan inscription, at the site of the former Bei Gu monastery, is of 1174 CE, and presented the following microerosion values on quartz: 5, 5, 5, 6, 5, 5, 4 = $35/7 = 5.0 \mu\text{m}$.

Analytical work at Jiangjunya, the General's Cliff, was commenced at the right-hand, southern section where the groove of a prominent rectangle has extensively damaged a distinctive quartz vein. However, there are only few fracture edges and they



Figure 13. Floor of large cupule at the site of the former Duijiu Nunnery near Jiangjunya, showing the massive impact damage to the quartz inclusion.

are very short, none of them more than 50 μm long. One of these provides the following micro-wane widths: 10, 10, 11, 12 = $43/4 = 10.75 \mu\text{m}$. The central pit of a sun-like motif 4.5 m higher up is of 40 mm diameter and in its very centre is a deeply fractured quartz crystal, providing many excellent fracture edges along a canyon-like feature. One 520- μm -long straight micro-wane provided these reliable wane-width measurements: 24, 22, 22, 21, 22, 20, 20, 20, 21, 21, 20, 20 = $253/12 = 21.1 \mu\text{m}$. There are also numerous small bodies of silica but they are of variable quality; best are clear crystalline zones lacking 'lumpy' texture.

Two of the cupules on the probable dolmen in the upper part of the site are also checked but were found to be too granular. Then attention turned to the right-hand part of the main petroglyph panel below to focus on quartz bodies in petroglyph grooves. In one location, white quartz provided: 14, 15, 14, 14, 14, 15, 16 = $102/7 = 14.6 \mu\text{m}$. A greyish quartz in the same motif yielded: 3, 2, 2, 3, 3, 2, 2 = $17/7 = 2.4 \mu\text{m}$, possibly suggesting more recent damage. The central deep groove dividing this panel (called 'meridian' by rock art interpreters) dissecting one of the 'face' motifs centrally has been extensively abraded, so the 'lumpy' quartz retains fracture edges from the abrasive process. One of these edges is 460 μm long and yields: 5, 6, 6, 6, 6, 7, 7 = $43/7 = 6.1 \mu\text{m}$. In the upper part of the main panel occurs a prominent diagonal groove, from upper right to lower left, that does not seem to have been modified recently, providing: 18, 16, 18, 18 = $70/4 = 17.5 \mu\text{m}$. This is not a very good micro-wane, but it is probably reliable because there is no evidence of recent damage.

In the northern part of the site's pavement occurs one very large cupule literally across a thick quartz vein of about 3 cm width running roughly east-west. The unusually large cupule measures 21 cm north-south and 19 cm east-west and it is 59.6 mm deep. Its eastern part comprises an excellent straight impact fracture on crystalline quartz, broken at 90° , near the bottom of the cupule. It yields the following secure micro-wane widths: 36, 38, 38, 36, 34, 36, 34, 32 = $284/8 = 35.5 \mu\text{m}$. There would be ample opportunities for further wane studies but the extensively impacted quartz in the eastern zone of the cupule's floor is coated by a black deposit, apparently of dead algae. Nevertheless, in places the accretion is thin enough to show that the wane widths recorded are consistent with other micro-wanes in the vicinity.

About 250 m north of Jiangjunya, next to the dolmen at a former nunnery site, another exceptionally large cupule has been made right over major quartz inclusions (Fig. 13). It measures 21.5 cm by 20.0 cm, depth 32.0 mm, and the quartz body exposed in it measures 2.75×6.5 cm, yielding these micro-wane widths from a fracture edge of $\sim 90^\circ$: 6, 7, 5, 6, 5, 5, 5, 6 = $45/8 = 5.6 \mu\text{m}$.

4. Interpretation of the data

4.1 The calibration curves

The data from one of the four calibration sites analysed in Henan Province, the First Gate Site at Mt Juci, is disregarded because it is considered unreliable, due to subsequent modifications. These include mineral accretion deposition, which may cause either acceleration (due to prolonged moisture and chemical reactions) or deceleration (due to concealment). Also, the site is not well exposed to precipitation. This leaves three calibrations in Henan, and two more from Jiangsu Province.

The Guanyinshan rock inscription of 1578 CE (Henan) has yielded a mean micro-wane width of $3.33 \mu\text{m}$ from quartz, which corresponds to a microerosion coefficient of $7.6 \mu\text{m/ka}$. Although this result is just as reliable as that from Deyunshan, because both are based on six primary readings, the latter curve was preferred because of its much longer range. The Deyunshan curve has a time range more than double that from Guanyinshan. The feldspar curve from Guanyinshan produced a microerosion coefficient of $59.6 \mu\text{m/ka}$, or almost eight times that of quartz. This differs significantly from the ratio reported from Lake Onega, Karelia, where it was about 1:12. The explanation for this difference very probably lies in the unusually wet conditions of the Lake Onega site, located 1–2 m above the water level of the lake, and as noted previously (Bednarik 1992: 286), the feldspar is significantly more affected by this factor than the quartz.

The Deyunshan inscription of 1001 CE (Henan) provides a longer-range estimate, which is always preferred in calibration. It is therefore the basis of all age estimates for quartz from Henan Province presented below. Its microerosion coefficient of $6.6 \mu\text{m/ka}$ compares reasonably well with that of Guanyinshan, providing the calibration effort with some confidence (Fig. 14).

The microerosion coefficient of about $6 \mu\text{m/ka}$ obtained from Laomo valley inscription of 1510 CE, also in Henan Province, lacks precision (short range combined with $n = 3$), but it also suggests that the Deyunshan calibration curve is the most representative.

In Jiangsu Province, the rock inscription at the former nunnery site near Jiangjunya, dating from 1051 CE, has provided a calibration curve for quartz, based on a mean wane width of $5.6 \mu\text{m}$, which yields a microerosion coefficient of $5.8 \mu\text{m/ka}$. The Song Pan inscription of 1174 CE in Jiangsu has produced a very similar microerosion coefficient of $5.9 \mu\text{m/ka}$, but because it represents a slightly larger number of measurements it is the preferred calibration curve for Jiangsu Province — until a better one becomes available (Fig. 15).

4.2 The dating attempts in Henan Province

The preferred calibration for the Henan Province determinations is the Deyunshan calibration curve,

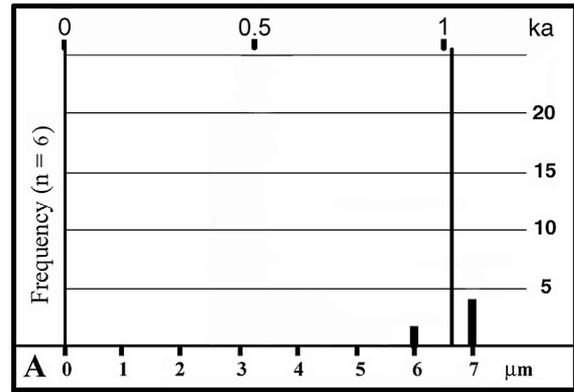


Figure 14. The Deyunshan microerosion calibration curve for quartz, used as the standard for Henan Province.

which was used for all Henan and Ningxia age estimates on quartz. For the estimates on feldspar, the Guanyinshan calibration was used in Henan Province (no micro-wanes on feldspar were measured in Ningxia and Jiangsu Provinces).

The cupule Juci1 at Mt Juci has provided an age estimate of $E3170 + 620 / - 440$ years bp (throughout this paper, 'bp' refers to 'before 2014 CE', not to the radiocarbon reference point). Despite the relatively low number of measurements, this result is credible, because the histogram features a distinctive peak and the age is matched by the level of weathering of the schistose matrix.

Several cupules provided good data from the Xiaomazhuang petroglyph complex and measured micro-wanes were numbered Xiaomazhuang1 to 5. The first cupule analysed yielded a date of only $E1240 + 280 / - 180$ years bp. The cupule next to it, Xiaomazhuang2, provided a poor date from feldspar of $E1540 + 70 / - 30$ years bp. A better-based result from feldspar in Xiaomazhuang3, another cupule just above the former, was $E1450 + 60 / - 110$ years bp. The same cupule in this prominent group of four also provided an age estimate from quartz, numbered Xiaomazhuang4, which is $E1610 + 210 / - 250$ year bp. The apparent discrepancy between the latter two results from the same petroglyph is most probably attributable to inherent imprecision in

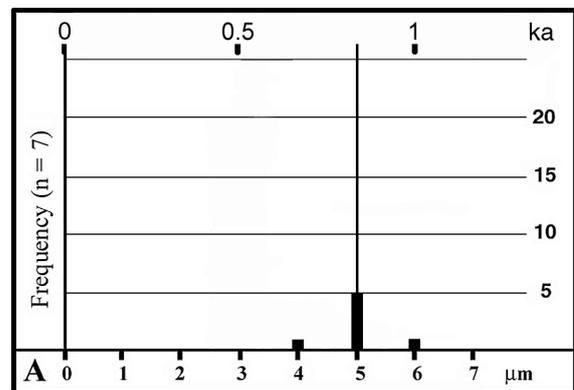


Figure 15. The Song Pan microerosion calibration curve for quartz, used as the standard for Jiangsu Province.

the calibration curves, and it is evident that the tolerance ranges of the two results in fact overlap by 150 years. What is clear from these results is that the group of cupules appear to be of slightly different antiquities, but could quite well still date from a single event of production around 1500 years ago.

However, the result secured from one cupule at the nearby Xiaomazhuang Site 2 shows it to be clearly almost twice the age of the first group. Being part of a set of geometrically arranged cupules, it yielded an age estimate of $E2840 + 180 / - 240$ years bp. This well-defined result from cupule Xiaomazhuang5 is based on a good number of determinations and can be considered relatively reliable. It shows that the practice of creating cupules has been ongoing in the region, and it warns against the generic assumption that structured cupule arrangements postdate random arrangements.

At the Huihuimo Site, three cupules have provided microerosion age estimates, and the micro-wanes were numbered Huihuimo1 to 4. The first wane measured yielded a somewhat diffuse histogram indicating a date of $E2260 + 770 / - 440$ years bp. Similarly, Huihuimo2 provided an age estimate with large tolerance definitions, of $E2950 + 380 / - 540$ years bp, from quartz. However, a feldspar micro-wane within millimetres of the site, from the same cupule, broadly confirmed that date at $E3140 + 130 / - 120$ years bp. That second result is numbered Huihuimo2a. Of particular reliability is the age estimate of a third cupule, from an excellent micro-wane on quartz, Huihuimo3. Albeit burdened with large tolerance margin of about 15%, with sixteen measurements this is one of the best results in this study. The dimensions generated an age determination of $E2890 + 440 / - 470$ years bp, a result resembling the two from the previous cupule rather closely. Clearly these two petroglyphs are in the order of E3000 years old, while Huihuimo1 is likely to be somewhat more recent.

The one cupule at the hill Wufuling that provided a

suitable micro-wane is estimated to be only $E910 + 300 / - 150$ years old, despite its relatively ancient appearance. Of much greater age is one of the cupules on a granite outcrop in Zhaodian valley, in which a quartz micro-wane provided an estimate of $E4520 + 330 / - 580$ years bp. At the nearby Shipengguo site, which is thought to have been used for ritualistic purposes, excellent micro-wane measurements were secured from a cupule of a geometrically structured group of twelve, indicating an age of $E2650 \pm 380$ years bp. The montane site complex of Xuanluoling provided one micro-wane from quartz whose measurements imply an antiquity of just under two millennia. At $E1830 + 140 / - 310$ years bp, this is one of the most recent cupules dated in China so far.

4.3 The dating attempts in Ningxia Province

Although numerous petroglyph sites were examined in Ningxia Province, only the Helanshan site complex has yielded age estimates, and so far only for a few motifs. However, of the five dates secured from only four motifs, four are quite tightly clustered between 2400 and 2000 years bp, which does provide valuable insights about the traditions represented (see below). In the absence of a calibration curve for the region, the Deyunshan curve was provisionally used as reference point, which means that should a calibration curve from the Yinchuan region become available, the following estimates may need to be adjusted upwards by some centuries.

The large 'mask' motif high on the cliff provided a date of $E2000 + 120 / - 180$ years bp. The first of two adjacent motifs analysed further into the canyon is $E1670 \pm 150$ years old. The following pair of estimates is of particular interest as they derive not only from the same motif, but are from micro-wanes that are less than 1 mm apart. They provide therefore a convenient internal check. The first date is $E2180 + 240 / - 210$ years bp, the second is $E2080 + 340 / - 260$ years bp. Although these two results do differ somewhat, they are certainly

well within the tolerance values attached to them, which range from almost 10% to over 16%. Finally, the motif sampled outside the valley yielded a microerosion result of $E2330 + 90 / - 210$ years before 2014 CE (Fig. 16).

4.4 The dating attempts in Jiangsu Province

All except one of the petroglyph datings secured in Jiangsu Province derive from the Jiangjunya site at Lianyungang City, but in contrast to the tightly clustered results from Helanshan Rock Art Park, those from the similarly well-known Jiangjunya site are of much greater range, implying that the site has been in use for many millennia.

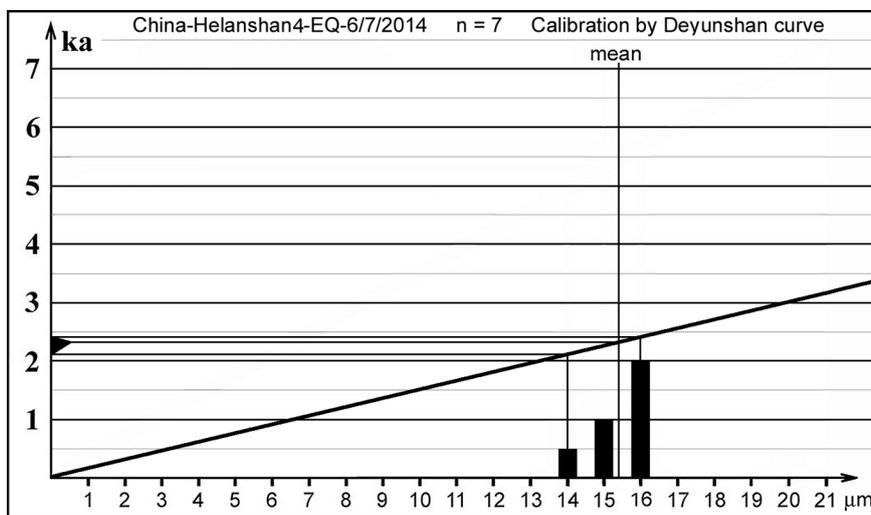


Figure 16. Microerosion age estimate of the Helanshan petroglyph shown in Figure 12.

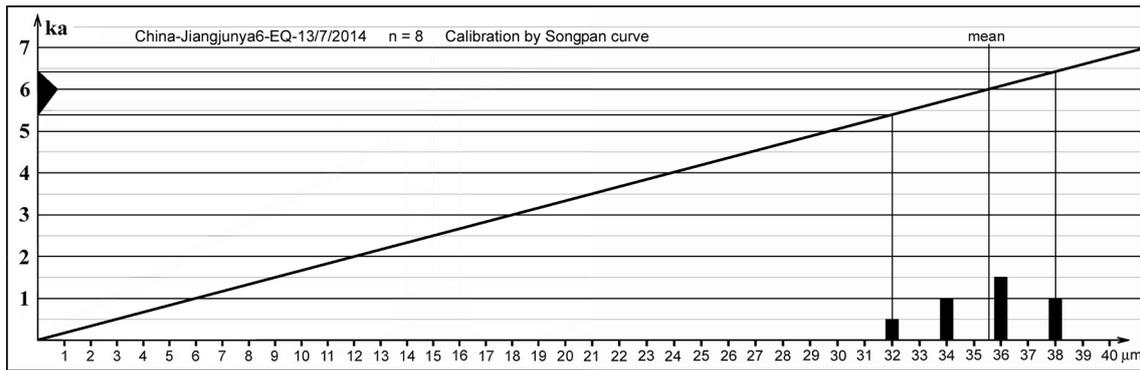


Figure 17. Microerosion age estimate of large cupule with substantial quartz vein in the northern sector of Jiangjunya.

The large rectangle crossed by a long quartz vein is relatively young, at E1630 + 190 / - 110 years bp. The central cupule in a sun-like motif provided a considerably more reliable date of E3200 + 440 / - 170 years bp. Two significantly different results from two quartz micro-wanes in the same motif of the main petroglyph panel demonstrated unambiguously the presence of recent damage. An early hammering of the motif occurred E2210 + 210 / - 90 years bp, but it was partially retouched only E360 + 90 / - 60 years ago. The so-called 'meridian', dissecting the petroglyph panel vertically, is either E920 + 140 / - 160 years old, or its most recent retouch by abrasion occurred at that time. A prominent diagonal groove in the upper part of the main panel was made E2650 + 80 / - 230 years ago. The earliest secure date came from a large cupule in the northern sector of the site, which yielded a reliable date of E5380 + 380 / - 530 years bp (Fig. 17).

Another large cupule with a major quartz vein, from the former nunnery 250 m north of the Jiangjunya main site, at Duijiu Nunnery, proved to be significantly younger, at E850 + 210 / - 90 years before 2014 CE (Fig. 18).

5. Discussion

The above results represent the largest collection of petroglyph dates secured by a single project, but in terms of establishing comprehensive scientific dating for Chinese rock art they have not a great impact. For a wide-ranging understanding of rock art traditions in this great country, thousands of such data would be required. Therefore what can be said about the results of this project is limited, but a few pertinent observations are possible. This work has included the first scientific and direct dating of one of China's best-known and most valued rock art properties, the Helanshan site complex. That renders it possible to review previous, archaeologically derived propositions of antiquity for this major collection of petroglyphs, and this will be attempted here.

Scientific dating of Helanshan (or

Helankou) petroglyphs is hampered by the attention lavished on this site in past decades, which has resulted in contamination by various outdated recording processes, ranging from taking rubbings to the application of enhancing substances, and to latex casting in some cases; and then secondarily by the application of chemicals to remove the traces of these misguided practices of yesteryear. Fortunately, microerosion analysis is much less affected by these contaminating procedures than any other direct dating method, being probably the most robust among them. It relies mostly on a chemically inert mineral, quartz. Previous age estimates of the Helanshan petroglyphs have ranged from the Pleistocene to recent centuries, i.e. they covered the entire possible range (e.g. Gai 1986; Li 2010). However, attribution to pre-Neolithic times is rare, and late Holocene attributions are generally preferred. Chinese proposals of rock art chronologies are largely based on notions of style, purported subject matter and inscriptions, of which only the last-named can be regarded as scientifically relevant. Xu and Wei (1993) have advanced a tripartite chronology for Helanshan petroglyphs, comprising a phase 1, 1600–200 BCE;

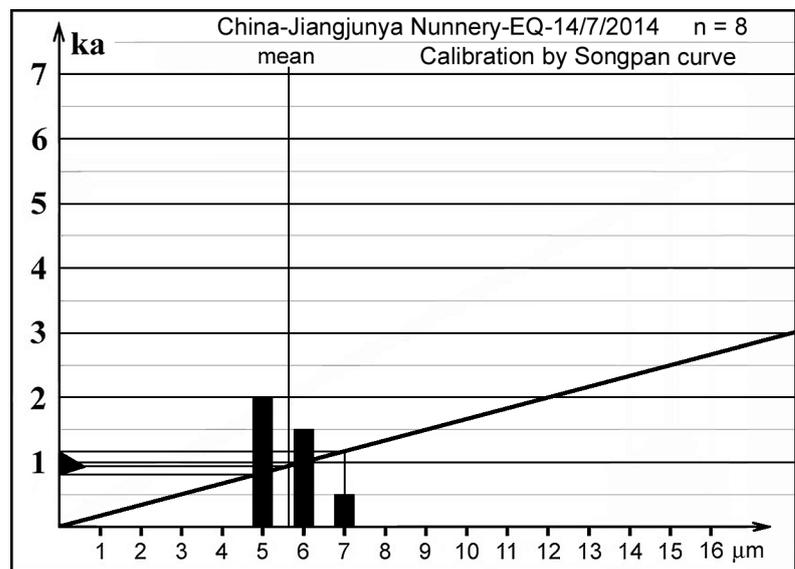


Figure 18. Microerosion age estimate of the cupule at the former Duijiu Nunnery near Jiangjunya shown in Figure 13.

phase 2, 200 BCE–600 CE; and phase 3, 200 BCE–600 CE. It is derived from the dynastic succession in China, even though the region was rarely under imperial control. The only attempt of direct dating Ningxia rock art so far has been by Li and Zhu (1993), who proposed lichenometric ages of 2000–1000 BCE. However, the reliability of these results can be questioned (Bednarik 2007: 127–129; Tang 2005), for instance by reference to the lichenometric dates reported by Su and Li (2007) from Damaidi, which at up to 15000 bp are arguably not credible. Demattè (2011) has presented another archaeologically derived but more carefully formulated chronology comprising four phases, ranging from pre-500 BCE to post-800 CE. However, while her sequence is essentially tied to iconography, it is rather vague and ambiguous. For instance she finds ‘face’ (or ‘mask’) motifs in all of her first three phases, and zoomorphs in the first two phases. The only definitive part of Demattè’s sequence is her statement that the bulk of the Helankou rock art belongs to her phase 3, dated 200–800 CE.

Most of the few microerosion age estimates so far secured from the Helanshan corpus are tightly clustered between about 2400 to 2000 bp, except one ‘face’ motif dated to $E1670 \pm 150$. Although not a statistically conclusive finding, it does imply that Demattè’s

estimates were somewhat too conservative. Fairly typical motifs were sampled by the project reported here, suggesting that the main corpus is more likely to date from the time of her second phase. Nevertheless, in a more general sense, her prediction of an essentially final Holocene range of ages is probably correct, and the claims for a much longer time range are likely to be false. To test this proposition further is possible, as there are thousands of potentially suitable petroglyphs at the Helanshan petroglyph complex, and the only way to establish a sound chronological system for them is to greatly increase the data base of directly dated motifs.

Much the same applies at the similarly prominent Jiangjunya site, but here the microerosion data imply a much longer use of the site, especially if the one end-Pleistocene date obtained by Tang (2012) is included. Even the results reported here present a site use as ranging from the Neolithic period to just 360 years ago. Clearly this site has been in use for many millennia and to untangle its long and complex history requires the collection of far more data than are presently available. It needs to be emphasised that the one-month campaign of this project could only spend one day each at both Helanshan and Jiangjunya, therefore campaigns of several weeks at each site are likely to yield much more

Region	Site	Motif	Micro-wane	Age estimate
Henan Province	Mt Juci	Cupule Juci1	China-Juci1-EQ-27/6/2014	$E3170 + 620 / - 440$
	Xiaomazhuang 1	Cupule Mazhuang1	China-Mazhuang1-EQ-29/6/2014	$E1240 + 280 / - 180$
	Xiaomazhuang 1	Cupule Mazhuang2	China-Mazhuang2-EF-29/6/2014	$E1540 + 70 / - 30$
	Xiaomazhuang 1	Cupule Mazhuang3	China-Mazhuang3a-EF-29/6/2014	$E1450 + 60 / - 110$
	Xiaomazhuang 1	Cupule Mazhuang3	China-Mazhuang3b-EQ-29/6/2014	$E1610 + 210 / - 250$
	Xiaomazhuang 2	Cupule Mazhuang4	China-Mazhuang4-EQ-29/6/2014	$E2840 + 180 / - 240$
	Huihuimo	Cupule Huihuimo1	China-Huihuimo1-EQ-30/6/2014	$E2260 + 770 / - 440$
	Huihuimo	Cupule Huihuimo2	China-Huihuimo2a-EQ-30/6/2014	$E2950 + 380 / - 540$
	Huihuimo	Cupule Huihuimo2	China-Huihuimo2b-EF-30/6/2014	$E3140 + 130 / - 120$
	Huihuimo	Cupule Huihuimo3	China-Huihuimo1-EQ-30/6/2014	$E2890 + 440 / - 470$
	Wufuling	Wufuling1	China-Wufeling1-EQ-1/7/2014	$E910 + 300 / - 150$
	Zhaodian	Zhaodian1	China-Zhaodian1-EQ-2/7/2014	$E4520 + 330 / - 580$
	Shipengguo	Shipengguo1	China-Shipengguo1-EQ-2/7/2014	$E2650 \pm 380$
Xuanluoling	Xuanluoling1	China-Xuanluoling1-EQ-4/7/2014	$E1830 + 140 / - 310$	
Ningxia Province	Helanshan	‘Mask’1	China-Helanshan1-EQ-6/7/2014	$E2000 + 120 / - 180$
	Helanshan	Petroglyph2	China-Helanshan2-EQ-6/7/2014	$E1670 \pm 150$
	Helanshan	Petroglyph3	China-Helanshan3a-EQ-6/7/2014	$E2180 + 240 / - 210$
	Helanshan	Petroglyph3	China-Helanshan3b-EQ-6/7/2014	$E2080 + 340 / - 260$
	Helanshan	Petroglyph4	China-Helanshan4-EQ-6/7/2014	$E2330 + 90 / - 210$
Jiangsu Province	Jiangjunya	Rectangle	China-Jiangjunya1-EQ-13/7/2014	$E1630 + 190 / - 110$
	Jiangjunya	Cupule in ‘sun’	China-Jiangjunya2-EQ-13/7/2014	$E3200 + 440 / - 170$
	Jiangjunya	Petroglyph1	China-Jiangjunya3a-EQ-13/7/2014	$E2210 + 210 / - 90$
	Jiangjunya	Petroglyph1	China-Jiangjunya3b-EQ-13/7/2014	$E360 + 90 / - 60$
	Jiangjunya	‘Meridian’	China-Jiangjunya4-EQ-13/7/2014	$E920 + 140 / - 160$
	Jiangjunya	Diagonal groove	China-Jiangjunya5-EQ-13/7/2014	$E2650 + 80 / - 230$
	Jiangjunya	Large cupule	China-Jiangjunya6-EQ-13/7/2014	$E5380 + 380 / - 530$
	Duijiu Nunnery	Large cupule	China-Duijiu1-EQ-14/7/2014	$E850 + 210 / - 90$

Table 1. The microerosion dating results from China of the survey conducted in June and July 2014.

comprehensive chronological models.

The need for further microerosion analyses is even more apparent for Henan Province, whose vast body of cupule sites has been subjected to research only in most recent times. The first international report of these many sites (Tang 2012) implies that the work of the present project has only scratched the surface of what appears to be a major concentration of cupule sites that in some cases date from Neolithic times, in others from the Bronze Age and even more recent times.

7. Conclusion

The first intensive program to apply a direct dating method to Chinese rock art has resulted in detailed age information about petroglyph corpora in three regions, Henan, Ningxia and Jiangsu Provinces. China is particularly susceptible to effective microerosion analysis, because of the country's rich heritage of calibration resources, especially precisely and absolutely dated rock inscriptions. Based on a series of such historical dedications found on various rock facies, six initial microerosion calibration coefficients have been secured from five inscriptions, and applied to a total of 23 petroglyphs in the three regions investigated. This has secured 27 age estimates from a total of 11 sites out of over 20 examined (Table 1). The analytical work also confirmed the authenticity of all inscriptions surveyed.

While this represents an impressive initial data bank about the time depth of Chinese petroglyph corpora, it does not amount to more than a preliminary perspective on the ages of major rock art traditions, dating from Neolithic times to most recent centuries. It also shows the effectiveness of multiple age determinations from single motifs, including the use of different minerals (quartz and feldspar), and of establishing the ages of multiple uses of motifs (i.e. retouch of older motifs). Both these potentials of the microerosion method have already been demonstrated in both Asia other continents. Of particular relevance is the comparison of the new Chinese data with other calibration microerosion coefficients which has recently shown a strong correlation between them and mean annual rainfall for a range of greatly varying environments. This new insight will be presented elsewhere; suffice it to say that the present state of global information suggests that the great dependency of microerosion analysis on regional calibrations can be progressively phased out.

Within China, microerosion analysis has a great future, for two reasons. First, the country's great wealth of very precisely dated natural but anthropogenically modified rock surfaces provides obviously favourable conditions for the application of this method. Second, the recent establishment of the International Centre for Rock Art Dating and Conservation (ICRAD) at a major Chinese university (Hebei University) by one of us (TH), intended to become a world repository of all direct dating results, promises a surge and

consolidation of scientific rock art dating work in the People's Republic of China.

Professor Tang Huisheng
International Centre for Rock Art Dating (ICRAD)
Hebei Normal University
20 Nanerhuandonglu
Shijiazhuang
Hebei Province
China
tanghuisheng@163.com

Professor Giriraj Kumar, girirajrasi.india@gmail.com

Dr Liu Wuyi, 13903716651@163.com

Dr Xiao Bo, 2007010576@163.com

Dr Yang Huiling, yang.hll@163.com

Zhang Jiabin, 2801514899@qq.com

Lu Xiaohong, rockartlxh@hotmail.com

Yue Jianhua, 448768797@qq.com

Li Yingnian, Fwupc@163.com

Gao Wei, 4536300@qq.com

Robert G. Bednarik, robertbednarik@hotmail.com

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