3D Laser Scanning For Recording and Monitoring Rock Art Erosion

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Until recently, British prehistoric rock art has been relatively understudied and undervalued. Over the past few years, this position has begun to change. On the one hand this has been the result of new research (Boughey & Vickerman 2003; Bradley 1997; Waddington 1998), and the publication of novel syntheses summarising what has been found so far (Beckensall 1999; van Hoek 2001). On the other, following a number of Historic Scotland initiatives on carved heritage (Yates *et al*. 1999), and more recently English Heritage-led initiatives, set in motion by the Rock Art Pilot Project (RAPP 2000) and its recommendations (RAMASES 2000), the recording, conservation and management of prehistoric rock art is starting to be addressed coherently by heritage agencies. Both strands – research and management – have now been considered when presenting and disseminating rock art to the public. This can be seen in exhibitions focused on or including a significant component of rock art – “Stone Circles and Standing Stones of Eden” exhibition, Penrith 2002; “Art on the Rocks” exhibition, Durham 2002, “Not Set in Stone” workshops and exhibition, Ilkley 2004 – and in the recent conferences in 2003 (Edinburgh and Durham (Rainsbury 2004)), and 2004 (British Academy and Newcastle).

Recording, conservation, and management are not independent from research. A number of recent studies of prehistoric carvings have focused on their landscape contexts (Bradley 1997; Waddington 1998). The landscape perspective is partly dependent on an assumption that has not been assessed fully: that the distribution of sites in a particular area today is the same as in prehistoric times. However, anecdotal evidence from all over the rock art areas in the U.K. suggests that rock art is suffering a high degree of degradation in these areas, and there is a general perception that the rate of erosion had accelerated in recent years (Barnett & Díaz-Andreu forthcoming). Yet, the methods so far used for documenting rock art makes this perception extremely difficult to verify. One of the main reasons for this is the lack of accurate recording, due mainly to documentation in two-dimensions of what are essentially three-dimensional surfaces and volumes. This usually results in inaccuracies that can sometimes be significant (Simpson *et al*. 2004: fig. 1). It is important to address this problem, as rock art recordings are at the core of research and management of rock art sites. They are an essential component of any database formed for research and protection programmes. In recent years, relatively inexpensive commercial software has made possible the consideration of other options such as the creation of precise 3D models from photographs using photogrammetric techniques (Simpson *et al*. 2004). Another option is that of 3D laser scanning, a technique that, despite its great potential, has not been easily available given the high hardware acquisition costs (but see Eklund & Fowles 2003; Goskar *et al*. 2003). The recent trend towards lower prices and the development of software for specialised processing and visualisation of 3D rock art has made this work more accessible and has enabled the technique to be used in the "Fading rock art landscapes project" funded by the British Academy - small grant awards. For this project the prehistoric art interest group based in the Department of Archaeology of the University of Durham formed a partnership with the Department of Computer Sciences of the University of Bristol.

Recording the prehistoric engravings

The rock art site chosen to undertake the fieldwork is situated on Rombald's Moor in West Yorkshire. The area is renowned for its wealth of prehistoric carvings, with over 600 engraved stones currently recorded mainly using rubbing techniques and photography (Boughey & Vickerman 2003). The site selected is in a remote setting on the moor on private land. A rock covered with many cup marks (stone 105 in Boughey & Vickerman 2003, see figure 1) was chosen for 3D laser scanning. The rock is located at an altitude of approximately 288 m OD on local sandstone, Millstone Grit, and in open moorland where it is exposed to the prevailing weather. The surface of the rock is engraved with over 60 individual cup marks each between 1.0 and 0.5 cm depth. The cupules all show signs of significant erosion.

Figure 1: Photograph of rock with cup marks.

The carvings were recorded using black and white print film and a Canon D30 digital camera capable of capturing images in high quality TIF format (3.1 megapixel). The 3D surface of the rock was then digitised using the Minolta 910 laser scanner, with sub-millimetre accuracy and very dense sampling (8.6 million points). The scanning was performed in bright day light in the early afternoon. Initially the scanner had problems recording the surface due to scattering on the rock's surface and the high level of background illumination. This was overcome using a make-shift canopy to cast a shadow on the surface. The scanning was completed within 40 minutes.

The 3D laser scanner was used on this project in conjunction with a laptop for data storage and on site quality control. Each scan requires 2 to 3 seconds to record and a further 30 seconds to transfer to the computer. In addition to 3D data about the structure of the surface a reference digital photograph is taken. For sites such as this, which have difficult accessibility , or which are only available for a short period of time the use of a laptop is essential to ensure that the entire area of interest is covered in adequate density and quality. Once the equipment is set up, each scan takes a matter of minutes to complete.

Data processing for this project involved the trimming of unwanted data and merging the individual scans into a joint 3D surface by registering the individual elements together. This is done first roughly by eye by selecting similar points on the scans to be joined, and then automatically with a closest point alignment algorithm. Once all the points of all scans have been merged, they are globally aligned and are subsequently triangulated into a single mesh. This mesh may then be textured with colour information taken from the digital photograph and saved in one of the common 3D data file formats. The formats we chose to use include still images and vrml1 models in order to be accessible over the internet. Additionally we created several fly-by animations for the data.

The results of the initial laser scanning can be found on the project website: http://www.dur.ac.uk/prehistoric.art. Despite the evident advantages of the method (speed, elimination of the contact with the rock surface, very high information density) and the availability of the data in digital form (data processing, viewing and archiving, automatic pattern recognition, easily distributable) there may be gaps in the data that need to be explained. Due to the nature of the project the decision was taken not to touch the stone. Therefore, no lichens or mosses were removed, despite the ongoing debate on whether they protect or damage the rock art (Barnett & Díaz-Andreu forthcoming). The gridded and rendered 3D surface of the rock is shown in fig. 2 while fig. 3 illustrates the use of elevation contours as examples for 3D rock art visualisation.

Figure 2: Gridded 3D surface.
Figure 3: Elevation contours

The 3D laser scanning method is able to produce a precise digital model of the carved rock and provides accurate geo-referenced data in sub-millimetre resolution, thus allowing the quantitative assessment of surface erosion and deterioration of the rock art by comparison with future recordings. Our project involves a second recording of the same stones after one year, and further recordings may be possible at later points in time subject to funding. Investigations undertaken in Scandinavia, have revealed that prehistoric rock art decays at a significantly faster rate than expected – an average loss of material of 6.0 mm/1000 years on granite compared to the post glacial average for granite decay of 1.5 mm/1000 years (Löfvendahl & Magnusson 2001, 48; Walderhaug & Walderhaug 1998). If rates of rock art decay are similarly high in Britain, even in a single year it should be possible to identify sub-millimetre levels of material loss from the rock surface. The recording undertaken so far and the comparison with future measurements will allow a quantitative and qualitative assessment of the erosion process. This information is needed for the conservation and management of rock art, it will help in protecting and preserving our cultural heritage for future generations as well as providing a digital database for the scientific community.

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Figure 1: Photograph of rock with cup marks.
Figure 2: Gridded 3D surface.
Figure 3: Elevation contours

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Figure 1: Photograph of rock with cup marks.

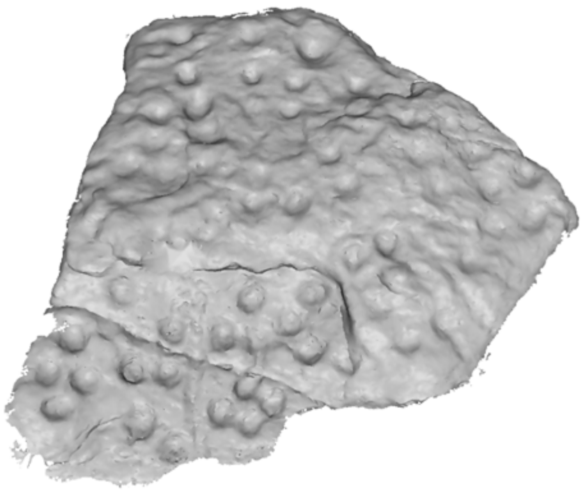

Figure 2: Gridded 3D surface.

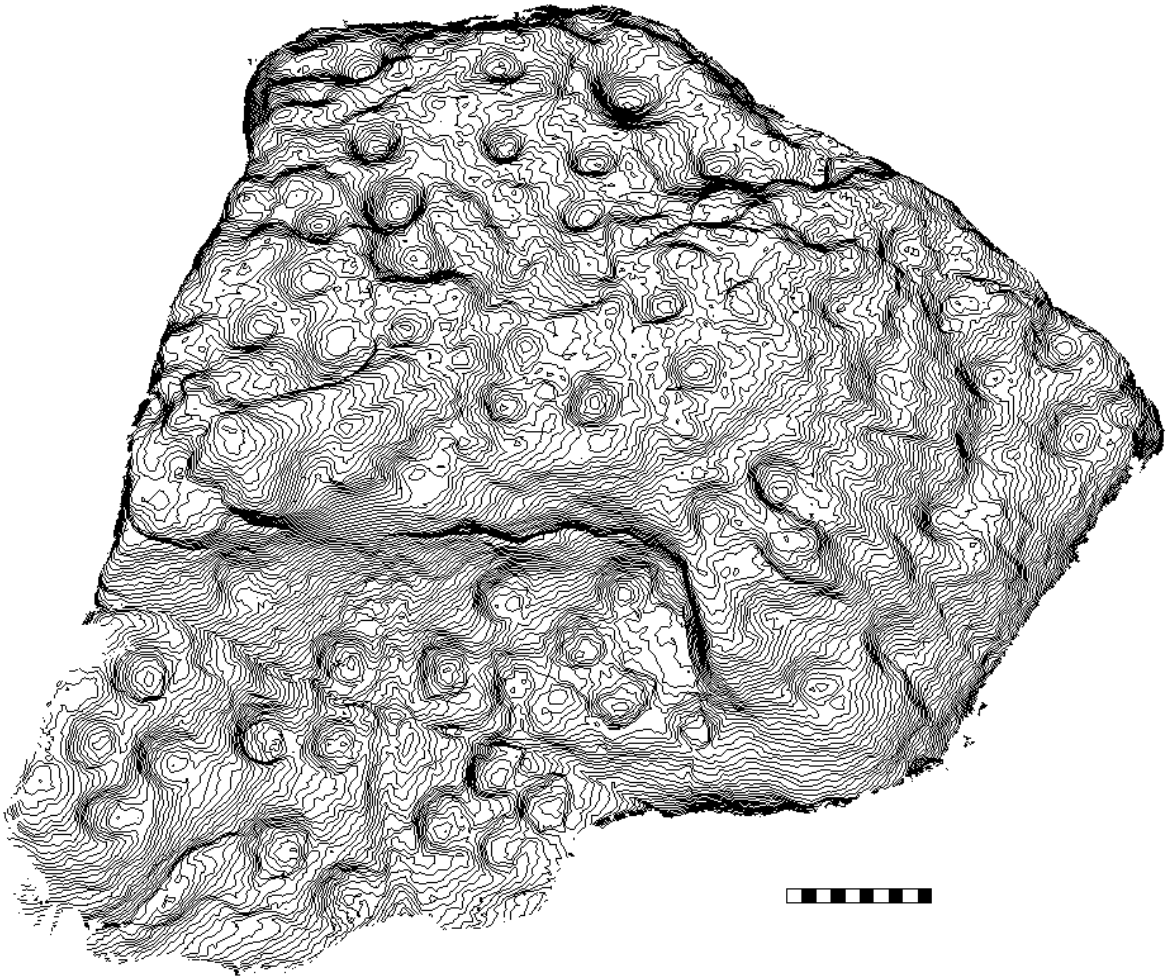

Figure 3: Elevation contours

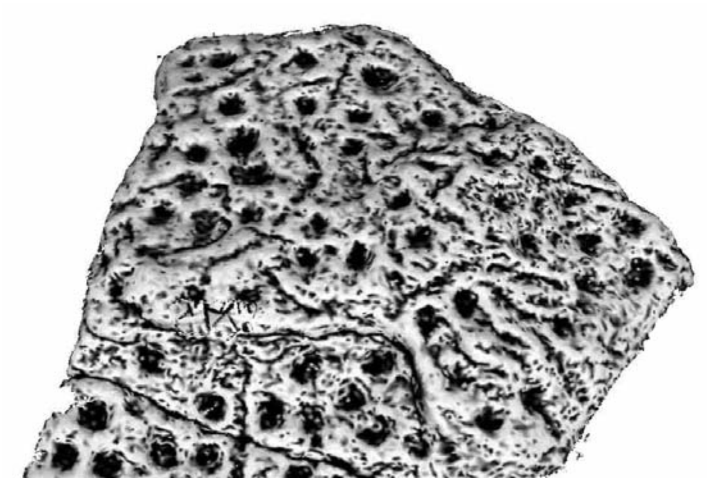

Fig. 4. Maximum curvature colouring