Long Meg: Rock Art Recording using 3D Laser Scanning

M. Díaz-Andreu*, R. Hobbs†, N. Rosser#, K. Sharpe**, I. Trinks†.

*Department of Archaeology. University of Durham. Project leader.

† Department of Earth Sciences. University of Durham.

Geography Department, University of Durham, Durham DH1 3LE.

**Department of Archaeology. University of Durham. Research Assistant.

For more than a century the documentation of most British prehistoric rock art has been undertaken by a small number of antiquarians and avocational archaeologists including James Simpson (1865, in *Proceedings of the Society of Antiquaries of Scotland* 6: 1-140; 1867, *Archaic Sculpturings of Cups, Circles &c. upon Stones and Rocks in Scotland, England & other countries.* Edinburgh), Ronald Morris (1981, *The Prehistoric Rock Art of Southern Scotland, except Argyll,* Oxford) and, more recently, Stan Beckensall (1999, *British Prehistoric Rock Art.* Stroud) and the Ilkley Archaeology Group (Boughey & Vickerman 2003, *Prehistoric Rock Art of the West Riding,* Leeds). Techniques used to record the carvings have varied from tracing, free-hand drawing, to photography and wax rubbing, the latter being that most commonly used during the last three decades. Although these approaches provide adequate information to identify each carving and give an impression of the designs, they cannot reproduce the degree of detail and accuracy required by today's researchers and conservationists. The traditional techniques are inherently subjective; they rely heavily on the skill and experience of the recorder as well as on prevailing lighting conditions. The process of transferring a 3D object onto a 2D piece of paper also has obvious limitations. Even the most experienced protagonists acknowledge that different results may result on repeated visits to the same site. 3D laser scanning has the potential to revolutionise rock art recording. It produces highly objective and accurate 3D models providing reliable, detailed information for both researchers and conservationists. Laser recordings may even identify previously unknown carvings as occurred recently at Stonehenge (Goskar *et al.* 2003, in *British Archaeology* 73: 9-15).

The project "Breaking through rock art recording: three dimensional laser scanning of megalithic rock art", sponsored by the Arts and Humanities Research Board (now the Arts and Humanities Research Council), under the Innovation Awards scheme, aimed to explore the potential of this novel technique. The one year project was undertaken by the University of Durham, led by Margarita Díaz-Andreu, and began in March 2004. The main sites analysed were the stone circle at Castlerigg and the standing stone of Long Meg in Cumbria, in addition to the Copt Howe panel, also in Cumbria and the Horseshoe Rock site in Northumberland where an investigation on 3D representations had been previously undertaken (Simpson, Díaz-Andreu *et al.* 2004 in *Antiquity* 78: 692-8; Trinks, Díaz-Andreu *et al.* forthcoming, *Rock Art Research*). This article focuses on the results obtained at Long Meg (NY56933716, CCSMR6154, NMR 23663), comparing two different methods to visualise the rock art data, one developed by Hobbs and Trinks using freely available software, and the other one undertaken by Nick Rosser employing software especially developed for archaeology but not anymore commercially available unless the scanning service is also appointed. Two previous recordings existed of the carvings on the western face of the pillar: an early recording first published in 1867 by Simpson in the form of a lithograph by A. Ritchie (Simpson 1867: plate VII), and a wax rubbing produced by Beckensall (2002, *Prehistoric rock art in Cumbria. Landscapes and monuments.* Stroud, fig. 70).

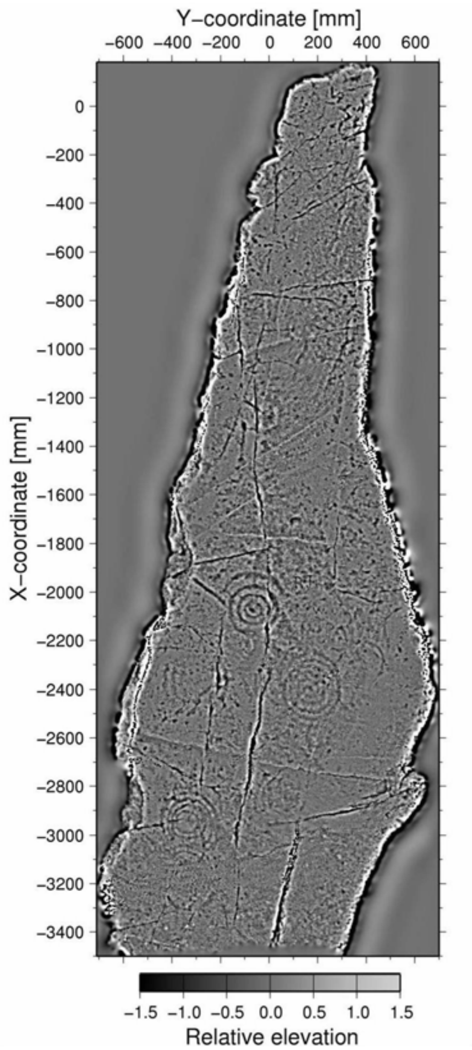
The recording of Long Meg with 3D laser scanning was undertaken in several phases. The first phase included the laser scanning and pre-processing of data. This was undertaken by a team led by Dr Alan Chalmers, University of Bristol. The data set acquired with a Minolta 910 laser scanner consisted of roughly 45 million points (26 million of which came from the north-easterly facing panel where the carvings are located), with overlaps in excess of 25 % between the coverage of each scan. The recording took approximately twelve hours and involved the creation of 102 ‘patches’ of rock surface which were then ‘stitched’ together electronically to create the complete 3D model.

The second phase was the development of new processing and 3D visualisation methods to visualize the rock art contained in the data. This was undertaken by two different approaches. A new method was developed by Immo Trinks and Richard Hobbs of the Department of Earth Sciences at the University of Durham using the Visualization Toolkit (VTK) and Generic Mapping Tools (GMT) software. The original data was resampled to 645,432 points since the overlapping scan areas contained a large amount of redundant information. The carved front face of Long Meg was transformed into horizontal orientation and the data points were gridded using a 2D triangulation algorithm (Wessel & Smith 1991, in *EOS Transactions of the AGU* 72/441, 445-446). Subsequently a spatial highpass frequency filter was applied to the 3D surface data, removing the long-wavelength surface structure of the rock (Trinks *et al.* forthcoming). Thus, the relative local elevation could be rendered using colour intensity values (Fig. 1a). Figure 1b shows that elevation rendering without the removal of the low-frequency content, which represents the large-scale topography of the rock, would fail to highlight the rock carvings. It is possible to map the relative elevation colour values onto a digital 3D rock model, in order to visualize small scale variations in the rock surface. This option is particularly interesting should the rock have strong 3D structure. Due to the relatively plane structure of the front face of Long Meg this step was not considered necessary (fig 1b).

A second method of visualising the data was undertaken by Nick Rosser, Geography Department, University of Durham. Data was processed using firstly Demon3D (Archaeoptics Ltd) and then ENVI RT 4.0 (RSI). The initial stage of the processing involved trimming the point cloud of the data beyond the area of interest to reduce data processing time. The point cloud was then triangulated using a 2.5 dimension view dependant triangulation algorithm. This was conducted from a view angle which was normal to the dominant plane of the rock face. The triangulated surface was edited, with long triangles removed to reduce interpolative errors on the surface. The meshed surface was then rendered and light from 3 directions applied to enhance the differentiation of surface texture and features for visualisation. The second stage of the data processing involved the detection of surface features. Given the curvature of the rock face a simple contour or height rendering does not represent the surface detail well. To overcome this remote sensing image analysis techniques were applied, using ENVI RT 4.0 (RSI). The edited point cloud data from Demon3D was imported into ENVI, and gridded at 0.0005 m resolution, which derived a raster of the rock surface topography. A high pass convolution filter with kernel width 29 mm was then applied to the image to remove long wavelength surface curvature, but retain surface detail (fig. 2a left). This kernel size was found to remove the general rock surface topography but maintain surface detail well. A triangulation threshold algorithm was then applied to the resulting image. The level of the threshold revealed different levels of detail on the image and was tailored to filter out noise (fig. 2a right). Three profiles cut vertically through the surface were extracted using Demon3D. Profile 1 illustrates profiles across a human made carving, where the carved grooves have a rounded cross sectional form but are distinct indentations on the profile. Profile 2 shows a natural fracture, which is deeper, weathered, and non-symmetrical. Profile 3 shows a weathered carved surface, and here it is noticeable that the surface definition is less clear than that seen in Profiles 1 and 2, with less differentiation between the carved grooves and surrounding surface (fig. 2b).

The results of the analysis of 3D laser scanning data shown in figures 1 and 2 demonstrate the power of 3D laser scanning to capture the features accurately and objectively. Both methods have provided very similar results. In order to describe them we have superimposed the image with a grid. Because of the limitation in the number of words, a detailed description is not possible here. In brief, our recording has identified four certain cup and ring motifs and another four possible cup and ring motifs. The first are located, from top to bottom and left to right, in 45C, 67BC, 78CD and 9AB. The possible cup and ring motifs are placed in 78BC, D7, 89C, 910B. No grooves other than those connected with the cup and ring motifs have been detected. The analysis of profiles taken across the surface show distinct differences between natural and human made surface features. Additionally, there are considerable differences in the degree of angularity and rounding across the ring motifs identified, which has potential to act as a measure of the relative age of the carvings. In comparison with previous recordings laser scanning really represents a quantum leap in rock art recording. The technique offers significant advantages over previous methods of recording, namely: objectivity in recording is hugely improved in relation to traditional techniques such as rubbing; results are reliable and reproducible; the level of precision achieved is much greater than that obtained with any other method currently available, including photogrammetry; and the recording process is non-invasive and so not detrimental to fragile rock surfaces.

Fig. 1. Long Meg 3D laser scanner data coloured according to relative elevation.



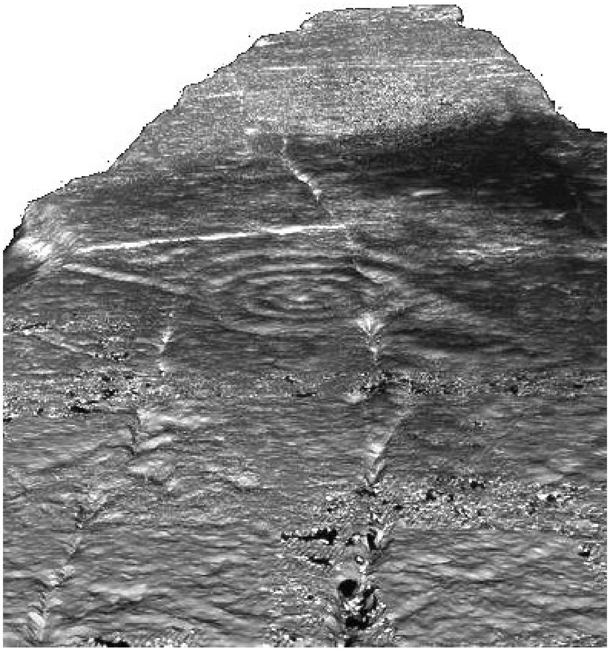
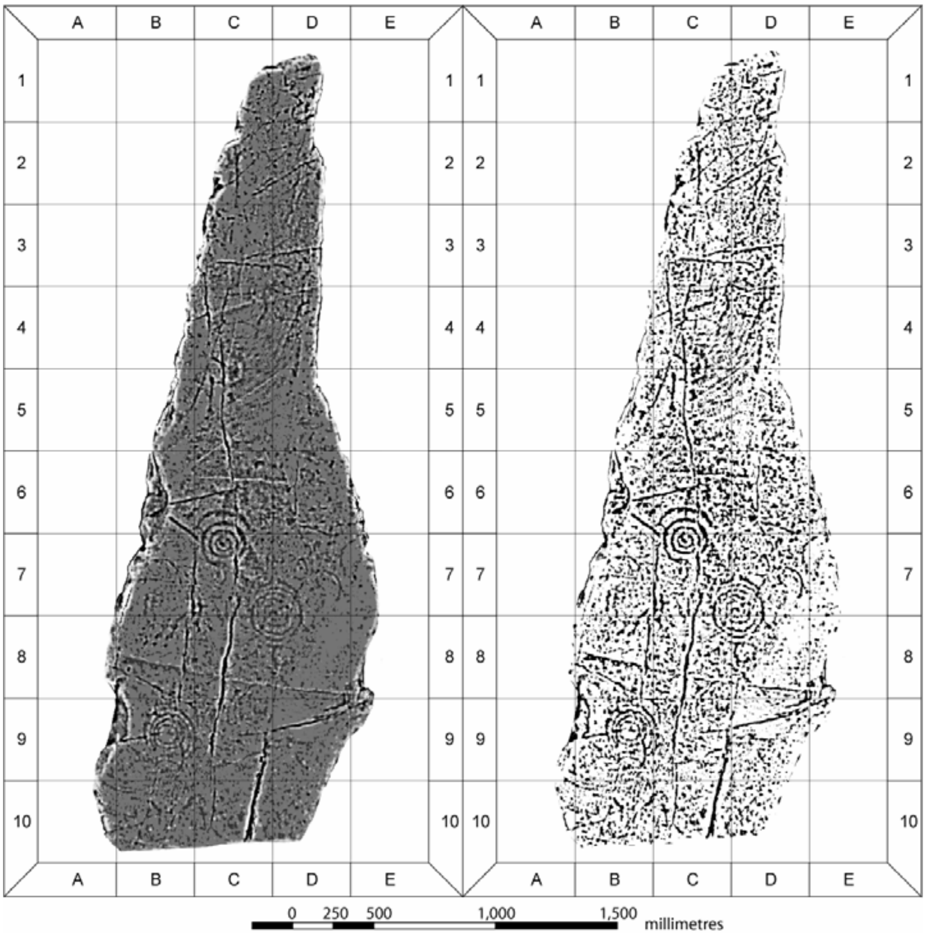
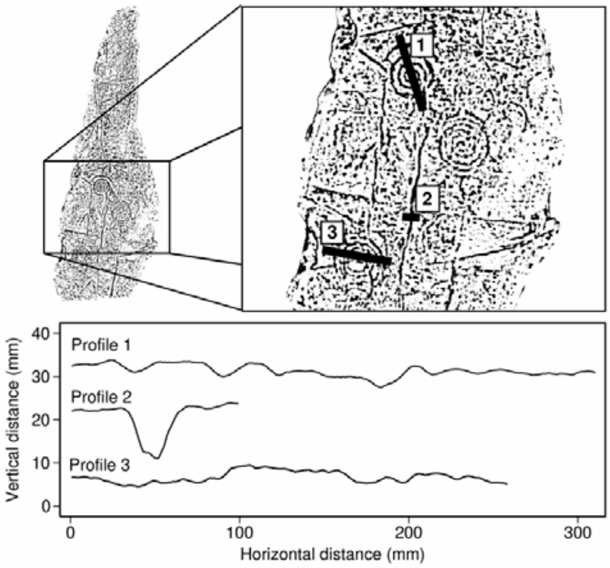


Fig. 1b. Perspective view of Long Meg laser scanner data using absolute elevation rendering relative to the average rock face plane. The dark region has a higher elevation than the top and bottom region of the face.

Figure 2. 2a. left: Front face of Long Meg, showing the result of the high-pass convolution filter. The grey scales indicate the degree of surface indentation, with black areas showing the deepest cuts. Right: shows the result of the threshold filter applied to the processed surface image. The threshold removes noise from the surface topography and identifies significant features. 2b. Top, diagram showing the location of profiles 1, 2 and 3 on the carved face of Long Meg. Bottom, graphs showing the three profiles extracted. 1.) well defined human made carving; 2.) natural rock fracture; and 3.) degraded man made carving.





1
2
3
Profile 1
Profile 2
Profile 3
Vertical distance (mm)
40
30
20
10
0
0
100
200
300
Horizontal distance (mm)