Towards three-dimensional non-invasive recording of incised rock art

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Ancient art cut into rock is difficult to research and manage off-site without precise three-dimensional records. Experiments with photographic modelling by the authors led to a relatively accessible and economical way of making them.

Keywords: Rock art, petroglyphs, field recording, conservation

Traditional recording methods and problems associated with them

Recording is the essential prerequisite of any database compiled for research and conservation programmes for rock art. In the British Isles several methods have been employed which can be grouped into two major categories: two-dimensional and three- dimensional recordings. The first one includes techniques already in use in the nineteenth century such as free hand drawing and casts, and others appearing later: tracing, rubbing (Beckensall 1983: 32), photographs and digital image processing (Donnan 1999). Three major problems affect these techniques. Firstly, they document in two dimensions what are essentially three-dimensional surfaces and volumes which usually results in inaccuracies that can sometimes be important (Figure 1, see also Coles 2003). A second major problem, as Loendorf has recently highlighted, mentioning rubbing in particular, is that it is proven to have a damaging effect in samples taken for dating (Loendorf 2001: 57). Given the difficulties with dating engravings experienced in Foz Côa (Zilhão 1996) this is a problem liable to affect British rock art in the future, even if it does not now. Finally, casting, tracing and rubbing are invasive techniques and may affect rock art preservation. Although in his article on recording Loendorf considers invasive techniques (especially in this case tracing) as potentially harmful, he acknowledges petroglyphs are usually more durable. However, this is not always the case, as the condition of some rock art surfaces in Britain (such as Achnabreck) shows. Preservation is a major concern. In the main report of the *Rock Art Pilot Project* commissioned by English Heritage, photography was recommended as a non-invasive technique (RAPP 2000: 88). Historic Scotland follows a policy of non-contact techniques for recording rock carvings (Yates *et al*. 1999).

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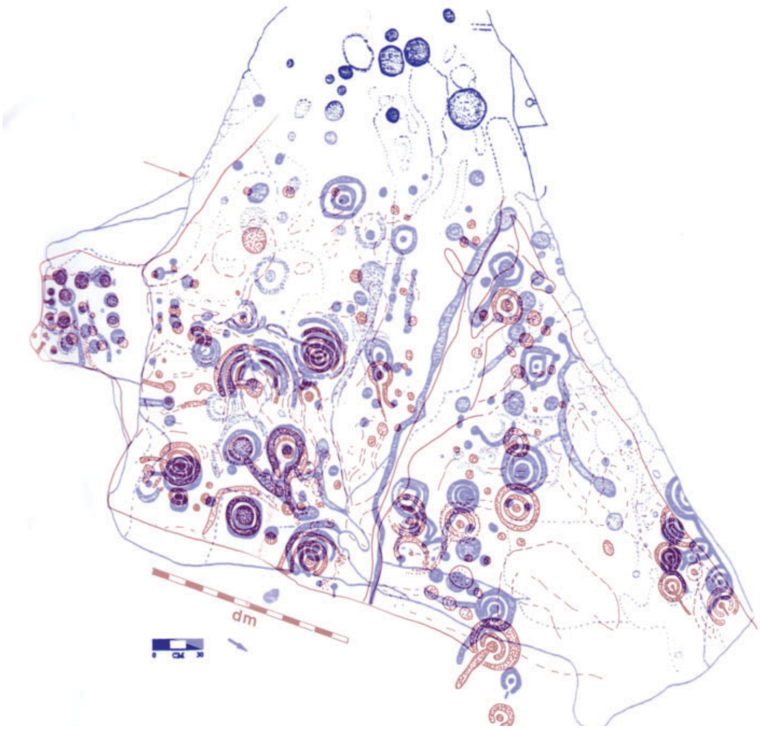

Figure 1. Comparison between Beckensall (1983: fig. p. 204), Beckensall (1992: fig. p. 25) and Beckensall (1999: fig. 39).

The second category of techniques used in recording prehistoric carvings in the British Isles comprise those recording in three dimensions: laser scanning (Eklund & Fowles 2003) and three-dimensional modelling from photographs. Both are still in an experimental stage. They have the advantage of overcoming the problems associated with 2D recording mentioned above and require no contact. Despite the potential of laser scanning, it is still a high cost option and therefore the opportunity for its use is currently restricted. 3D modelling from photographs, however, is more accessible at low cost. In order to investigate its potential a programme of study was established at the Department of Archaeology, University of Durham, England. The aim of the project was to test the feasibility and accuracy of a method of recording rock art in 3D, in order to maintain the "real-world" spatial relationship between motifs overcoming the inaccuracies of 2D recording.

3D recording of the Horseshoe rock

Relatively inexpensive commercial software, mostly based on single camera photogrammetric techniques, is now available for creating precise 3D models from photographs. *Photomodeler* (produced by Eos Systems, Canada) is an example of such a programme and its use is illustrated in a number of archaeological examples on the manufacturers website. (www.photomodeler.com and www.3dphoto.dk). In England a project developing methodologies for 3D visual representations of megalithic monuments was also based on the use of a previous version of *Photomodeler* (Gillings 2000). The study presented here is an investigation into the suitability of Photomodeler (version 4) for the recording of rock art.

Photomodeler uses identifiable points within a series of overlapping photographs to calculate the position of the camera. If the characteristics of the camera and lens combination are known, then the 3D co-ordinates of those points can be determined and a wire frame model can be constructed. Visual detail can then be laid over the wire-frame model from photographs taken without the control points. After the control points are put in place, photographs are taken from several positions around the object to establish a high degree of coverage. The control points should be visible in at least three of the images. These criteria can be covered in most situations using the concepts of "rings" i.e. camera stations encircling the object, positioned an equal distance from a known control point on the object. At least one dimension between two known points is required in order to calibrate the model. For this project all the images were taken at a 3.2 megapixel resolution with a Sony DSC-P71 digital camera using a focal length of 8.0mm. The focal length must remain constant for all images. All digital images were produced with the camera mounted on a tripod.

A series of laboratory based experiments were initially conducted to establish the procedures and the degree of control required (e.g. camera position, location of points, lighting etc.) for the successful production a 3D model. The initial experiments were undertaken under laboratory conditions on a carved stone from Alnmouth, published as a rock art stone by Gladys Bettess (Bettess 1995) (Figure 2). From the initial experiments, a laser aiming device was designed and developed to aid in the accurate alignment of the camera (Figure 3) and the position of the camera stations were established on the ground. Although not essential, this stage was undertaken in order to reduce the risk of not photographing the entire surface of stone, and so that subsequent photographs could be taken from the same positions but without the targets.

One of the major problems encountered with our previous research in 3D modelling of rock art was the

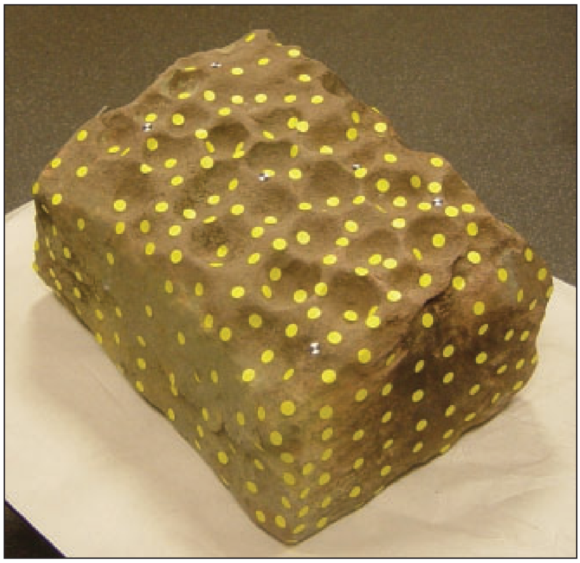

Figure 2. Alnmouth stone used in initial experiments. Yellow stickers are used as targets (Photograph: Alice Simpson).

Figure 3. Laser spotting device mounted in front of camera (Photograph: Alice Simpson).

difficulty of accurately identifying a suitable number of control points or targets within the photographs. Due to time and financial constraints imposed on the reported research this problem was addressed through the use of 0.5cm diameter yellow self-adhesive circles, positioned on a regular grid system. This solution was considered far from ideal as their use raises the issues previously discussed concerning invasive recording techniques. However their use proved to be highly successful in producing an accurate rendition of the rock shape. The use of a second series of images taken from the established camera stations but without targets proved to be successful for laying visual detail over the measured model. The impact of different lighting conditions were also investigated and it was concluded that the effect of lighting on the object would only be of major concern when the angle caused the motifs to cast elongated shadows over the rock face.

Figure 4. Horseshoe rock, Lordenshaw, Northumberland (Photograph: Alice Simpson).

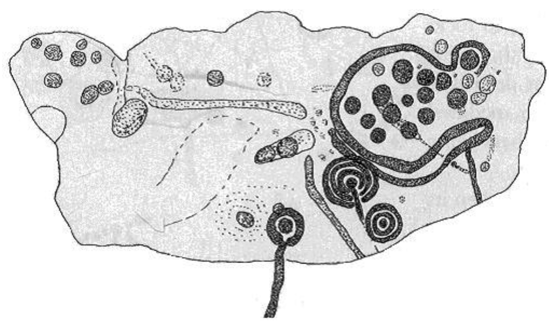

Figure 5. Recording based on rubbing made on the Horseshoe rock (Beckensall 2001: 90, fig. 103)

Figure 6. Horseshoe rock with stickers used as targets (Photograph: Alice Simpson).

Procedures and parameters having been established within the laboratory, it was now necessary to test them in the field. The site chosen was the Horseshoe rock at Lordenshaws (Figure 4). The rock measures approximately 190 x 120 cm, there is a relatively unrestricted view from all directions and the motifs are clearly visible. These features allowed us to concentrate on the recording methods rather than the processing of the data. As a drawing and description of the rock had been published by Stan Beckensall (2001: 90, fig. 103, see Figure 5), a comparison of the details produced by the two recording methods was possible.

Method

The first phase of the recording of the Horseshoe rock at Lordenshaws was to take the photographs in the field. Yellow self-adhesive circular targets were used to cover the majority of the rock surface, as with the initial laboratory-based recording following a regular grid system, whilst quartered black and white targets were used at key points on the rock (Figure 6). Step two of the fieldwork phase was the establishment of the camera stations to ensure the entire rock was photographically covered. As the rock is situated on uneven ground it was necessary to establish the first camera station at the highest point in the terrain.

The laser aimer was used to measure the distance from the camera station to the alignment target (307.5cm) and eight camera stations were then established 307.5cm away from the target on the rock, with a good angle of separation between each station. The tripod was positioned accurately over the station using the laser in the central support beam. The camera angle remained constant, and the tripod was levelled at each station. The laser aiming device was used at every station to align the camera with the predetermined target. The final stage of the fieldwork was the removal of the targets and the production of digital images of the rock surface without them. Close-up images were produced using the same focal length as those already created (8mm) and with a high degree of overlap. These would be used to add high resolution detail to the final model.

The digital images were now ready for processing in Photomodeler. Calibration of the camera and lens combination, to ensure accurate calculation of the camera positions, was undertaken following the procedures outlined in the Photomodeler manual. Initially, four images were selected for processing which collectively covered the entire rock surface. All the control points were identified manually and referenced to their corresponding points within the other images. Once "processed" a basic model was produced showing the three dimensional position of the points in space. Additional images were then introduced, increasing the number of control points and hence the detail within the model (Figure 7). The model was then scaled using the recorded "real world" dimensions between a number of known points. The digital images taken of the rock without the targets were then imported into the model. These images were used to produce a detailed rendering of the surface of the rock.

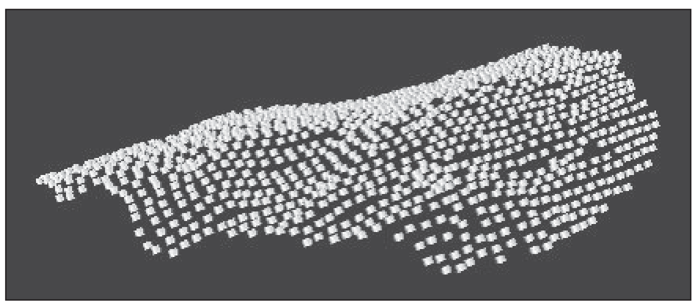

Figure 7. Marked and referenced targets in Photomodeler.

The measurements calculated by Photomodeler were compared to a series of measurements taken from easily identifiable points across the surface of the rock, showing the accuracy of the model to be better than 1%. A VRML version of the final model can be seen at www.dur.ac.uk/prehistoric.art and two screen shots have been selected for display here (Figures 8 and 9).

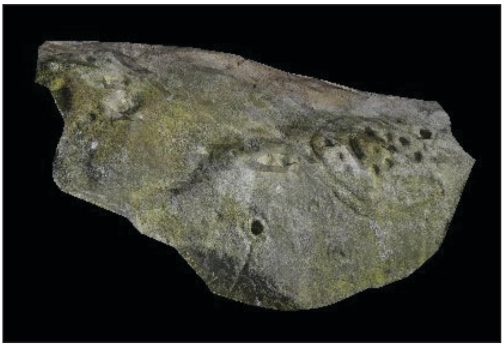

Figure 8. Detail of the 3D model of the Horseshoe rock.

Figure 9. Detail of the 3D model of the Horseshoe rock.

Discussion

Three-dimensional photographic modelling is a useful addition to the range of techniques used for recording rock art. It can produce an accurate and precise rendition of the surface features in three dimensions which can be viewed repeatedly and at leisure making possible continual reassessment of the interrelationship of motifs, their association with natural features of the rock and their three-dimensional location on the rock surface. Precise measurements of the motif size, and the distance between motifs can also be recorded. In addition, the images can be utilised for presentation purposes and they help to build public interest in rock art. The model can be exported in an number of different formats, including DXF, 3DS and VRML, for use in other CAD and rendering software packages. The level of precision and detail is dependent upon the resolution of the digital camera, the quality of the lens and the density of control points or targets across the surface. The greater the density of points the more precise and detailed the final model.

Further development is however required in a number of aspects. The method requires a sufficient number of recognisable and measurable points on a rock surface to provide a detailed three-dimensional image. However the nature of a rock surface is such that easily identifiable ancient points of suitable density are not often present. The problem was overcome here with the use of self-adhesive dots, but this undermines the principle that the technique should be non-invasive. This problem could be perhaps be overcome through the use of points of light projected onto the surface or the use of a fine flexible net draped over the surface.

Although the rock art site chosen for the field experiment was only of medium size and its motifs clearly visible, we are confident that the recording of larger stones would not represent a problem. However surfaces in which features are highly degraded may require the help of raking light, or perhaps computer-enhancement (always to be explicitly declared), to bring out detail. Our photographic modelling has not yet succeeded in recording the relative depths of the incisions or other marks, such as is required for research (Coles 2003) and for the assessment of degradation. This is where 3D laser scanning may offer advantages as a recording system. However, in the meantime, three-dimensional photographic modelling, together with traditional routine measurement and note-taking, represents a convenient, portable and economic alternative.

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