COST-EFFECTIVE ROCK-ART RECORDING WITHIN A NON-SPECIALIST ENVIRONMENT

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ABSTRACT:

At the recent CIPA 2007 Congress, the authors presented a paper which described the development, application and refinement of a simple, cost effective method to record and document rock-art (Chandler and Bryan, 2007). This was based on prior development of a recording methodology for capturing Aboriginal rock-art (Chandler et al., 2005a), including both pictographs and petroglyphs, at a range of sites and scales in Australia. The recent work focused on developing an approach that was simple enough for non-expert volunteers to capture stereo-imagery using low-cost, consumer-grade digital cameras and establish survey control through a range of simple scale bars. Once captured this 'field package' could be processed using commercially available photogrammetric software, both high-level and emerging lower-cost solutions.Following initial training conducted by both authors, in both the capture and processing approaches, the technique has been adopted and successfully used within a non-specialist, production environment by the Northumberland and Durham Rock Art Project. This three year English Heritage funded project, due for completion in July 2008, had the original objective of piloting a scheme to create a georeferenced index of around 1500 known rock art panels located in the north-east of England. It also sought to test a number of different techniques for recording the rock art, compare different techniques (both image and laser based) and make recommendations on those most suitable for routine monitoring in the field. However rather than use a specialist work-force experienced in photogrammetric survey, the project recruited around 60 volunteers from the local community who were trained using the recording methodology designed for them to use with ease. As well as highlighting the recording work undertaken by the project volunteers, this paper will describe the methodological development and how, through training and education, the volunteers have come to terms with using it. It will also introduce a number of ideas and approaches that should be considered for future development including application across the full range of carved panels that might typically be experienced 'out in the field'. A key point is to demonstrate that it is only simple recording methods which allow non specialist volunteers to carry out the substantive fieldwork and data acquisition required. Mobilizing the voluntary sector accrues significant political benefits beyond the obvious labour cost savings. In the UK four of the corporate strategies identified in English Heritage's Research Strategy document (English Heritage, 2005) emphasize the role of local people becoming involved in caring for and taking responsibility for their historic environment. Only simple approaches similar to those developed in this project can stimulate and harness the enthusiasm of the voluntary worker necessary to begin to record the world's heritage.

1. INTRODUCTION

It is an unfortunate fact that even in 2008 a significant proportion of the methodologies, often reported within academic literature, are still rarely utilised within a production environment. A limiting factor has traditionally been the gap in expertise between specialist exponent and potential user. However this paper is able to successfully demonstrate that 'simple' research methodologies can indeed be readily adopted by other practitioners to create accurate information suitable for recording purposes. Significantly, this work demonstrates that if these methodologies incorporate "low-cost" approaches, then even the voluntary, non-specialist sector can begin to embrace these innovations and start contributing to their long-term development.

The application area described in this paper is in the field of rock-art, which is found throughout the world. The creation of a facsimile is desirable, allowing for scientific study and providing some protection against loss in the event of destruction. During a six-month period of study leave spent in Australia, the first author developed a simple methodology for recording aboriginal rock art, (Chandler and Fryer, 2005; Chandler et al., 2005a; Chandler et al., 2007) including both petroglyphs and pictographs (engraved and painted images respectively).

This combined the use of consumer-grade digital cameras, simple control and commercial digital photogrammetric software to extract digital elevation models (DEMs), orthophotographs and create fly-through models. The technique has subsequently been adopted and successfully used in production by the Northumberland and Durham Rock Art Project (N&DRAP) to capture over 1500 known rock-art motifs located across northeast England (Chandler and Bryan, 2007). (Figure 1). The work has been achieved through collaboration between Loughborough University, Northumberland & Durham County Councils and English Heritage, who have played both a critical funding and coordinating role. This project was originally of two year duration, but is now due for completion in July 2008. It has developed a toolkit to enable the non-intrusive, digital recording of both the rock art and the host surface upon which it is located. A significant element of the project has been the recruitment of over 60 volunteers from the surrounding, local communities to carry out the actual recording activities. Initial training, education and early field experiences proved critical in refining both the technical and logistical aspects of the methodology. Even though this has been successfully used by the volunteers, the paper will highlight areas for development and further refinement to enable it to be applicable for future rock-art recording projects.

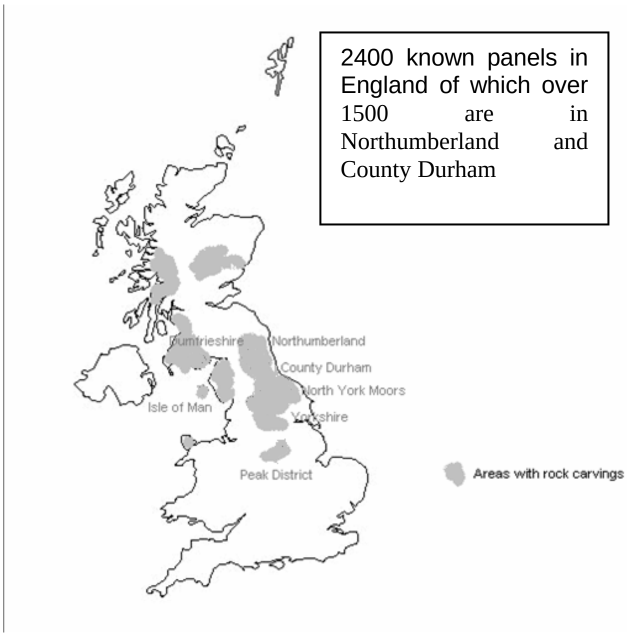

Figure 1 Distribution of Prehistoric Rock-Art across UK (courtesy of Tertia Barnett, RCAHMS)

2. PAST USE OF PHOTOGRAMMETRY FOR ROCK ART RECORDING

An early example of photogrammetry being used to record rock surfaces is reported by Atkinson (1968) where a special stereo-metric camera system was used to manually measure contours at Stonehenge in the UK. In a series of related projects, Rivett (1979) and Ogleby and Rivett (1985) demonstrated the benefits of photogrammetry for recording aboriginal rock-art, including both petroglyphs and pictographs. Fieldwork was conducted at a series of sites around Australia, including Kakadu National Park, Northern Territory; Whale Cave, NSW; Quinkin, Queensland; Hawkesbury, NSW; and various cave sites in Western Australia. Their “Handbook of Photogrammetry” (Ogleby and Rivett, 1985) was a key text at that time, describing how to conduct a photogrammetric survey for field archaeology. More recently, Ogleby (1995; 1999; 2001) has continued to demonstrate the benefits of photogrammetry to a wider archaeological audience, including the Ayutthaya temple in Thailand (Ogleby, 1999) and Mount Olympus in Greece (Ogleby, 2001). In these two examples, an important final product has been the virtual model, enabling the visualization of the site from any perspective. Virtual model creation is now recognised by the archaeological community as beneficial, particularly for providing contextual information (eg Winterbottom and Long, 2006).

The International Committee for Architectural Photogrammetry (CIPA) was established to improve the recording of cultural monuments using photogrammetry and related methods. The conference proceedings of CIPA provide ample examples where imagery is being used to record our heritage (Peipe and Stephani, 2003; El-Hakim et al., 2005). Patias (2007) provides a full review for the heritage sector and Remondino and El-Hakim (2006) review the current status of three-dimensional image-based modelling. One of important recommendations of CIPA is the “3x3” principle (Waldhäusl and Ogleby, 1994), which promotes the acquisition of photography suitable for photogrammetric measurement. The principles include three geometrical rules (control, base/distance ratio, normal photography); three photographic rules (constant camera geometry, soft illumination, film type); and three organisational rules (sketches, care, checks). It is disappointing that these principles and photogrammetric methods have not been adopted more widely outside the CIPA community. Indeed, one of the tasks identified by CIPA is to “bridge the gap” (Letellier, 2001) between the information user and the information provider. In rock-art recording, Palumbo and Ogleby (2004) note that the impediment preventing wider adoption of photogrammetry is the lack of inexpensive, portable, automated and easy to use systems. It is believed that the simple methodology described briefly below and reported upon more fully prior (Chandler and Fryer, 2005; Chandler et al., 2005b) and now being used in production, (Chandler et al., 2007) demonstrate that a significant step towards achieving that objective has now been realised.

3. THE TECHNIQUE

Key aspects of the technique have been reported prior (Chandler et al., 2005a; Chandler et al., 2007) and only a brief summary is required here.

3.1 Image acquisition

The methodology uses the simple stereopair to provide stereoscopic coverage. For many simple sites, a single pair is theoretically all that is required, but multiple pairs provide redundancy, increased coverage and additional viewpoints. If lighting permits, images can be acquired using a handheld camera, otherwise a modest camera tripod is required. A wide variety of consumer-grade digital cameras can be used, normally equipped with a variable zoom and auto-focus lens. By adopting the widest zoom setting and maintaining a camera-object distance > 0.5m, both the largest object coverage is provided and the required camera calibration procedures are simplified (Chandler et al., 2007).

3.2 Control

Control can be of two forms. The simplest and by far the cheapest is to employ a single scale bar (Figure 2), which allows data to be extracted and output to a known scale.

If the object is too large to be captured using a single stereopair, or extracted data needs to be precisely oriented to the local vertical or other reference datum, then targeted control should be adopted. Whilst taking note of local conservation requirements, small targets can be temporarily attached to non-engraved sections of the rock surface using clear, silicone bathroom sealant and then subsequently removed following acquisition of the photography. Ideally the three-dimensional coordinates of each target need to be determined using theodolite intersection or reflectorless EDM (Chandler et al., 2007).

Figure 2 Petroglyph and simple scale control (courtesy of Tertia Barnett, RCAHMS)

3.3 Photogrammetric data processing

Data processing was originally carried out using the Leica Photogrammetry Suite (LPS). However since the project started other commercial digital photogrammetric packages, such as Topcon's PI-3000 'Image Surveying Station' and most recently Photomodeler 'Scanner', have subsequently proved suitable for creating DEMs and orthophotographs from each stereopair, after satisfactory exterior orientations have been achieved. Once generated these two files can be used to create flythrough visualizations (Chandler et al., 2007), which convey the nature of the derived datasets very simply. Such visualizations are particularly important to the layperson and non-expert user.

4. APPLICATION WITHIN A NON-SPECIALIST ENVIRONMENT

The two year, Northumberland and Durham Rock-Art Project (N&DRAP) was originally established in August 2004 to create an index of rock art across the two counties in NE England. A prime objective was to provide a geo-referenced dataset of the 1500 known panels, complete with drawn and photographic records of the motifs. The project would also test and compare a number of different recording techniques, including laser scanning and photogrammetry, so as to make recommendations on those most suitable for routine recording and monitoring in the field. Subsequently extended from two to three years, it has involved close collaboration between the authors, the county councils of Northumberland and Durham and the 60 non-specialist volunteers recruited to undertake the work.

During the early stages of the project (January, 2005) a decision was made to purchase six Nikon Coolpix 5400 digital cameras, following successful use of the Nikon Coolpix 3100 in Australia. The near doubling of image resolution to 5 Mega-pixel was perceived to be particularly valuable for recording rock-art panels. The six digital cameras were subsequently calibrated at Loughborough University. The calibration procedure involved acquiring six images of a 3D and planar testfield specifically constructed for this project. The control field design was similar to that used previously (Chandler et al., 2005b) but was slightly larger (1.2×0.9m) to allow the cameras to be calibrated at an object distance of 1.5m.

4.1 Initial training and education

In April 2005 the second author ran a one-day workshop attended by 50 enthusiastic rock-art volunteers. The aboriginal work and purpose of recording was identified and presented, raising various issues including: the accuracy and density of extracted data and the natural division of tasks/roles between fieldwork and data extraction. The basic controls of the Nikon Coolpix camera were explained alongside CIPA's 3 x 3 principles (Waldhäusl and Ogleby, 1994). A particular focus was an explanation of how to acquire appropriate stereo-imagery. Here the simple recommendation was to emphasize the benefits of a "base to distance ratio" method of acquisition, combined with slight camera convergence to provide overlaps of approximately 95%. Methods of providing photogrammetric control were then discussed, a scale-bar for simple objects (Figure 2) and 3D control for more complex, but included the relative strengths and weaknesses of the two approaches. The final presentation focused on how to use LPS to extract DEMs and orthophotos, although emphasizing the archival importance of the stereo-imagery which could itself remain as the record, rather than any extracted data. This workshop was crucial to the project in 'firing' enthusiasm amongst the volunteers, whom within weeks had begun to acquire their own imagery 'in the field'.

4.2 Early field experience

Since the project started back in 2004, the main focus had been on recruiting, training and allocating the volunteers, all of diverse ages and technical abilities, into six regional recording teams. Although most could, given time, operate a digital camera to capture an acceptable image of a rock-art panel, not all could engage with the unfamiliar concept of stereo-photography. Some immediately embraced it whilst others showed considerable reticence, so it was subsequently decided to allocate photogrammetric recording to two volunteers per group. Site work commenced in June 2005 following a series of on-site training courses provided by the first author.

Figure 3 Stereo-photography training at Bowes, Co Durham (courtesy of Tertia Barnett, RCAHMS)

These emphasized how to acquire suitable stereo-photography using the Nikon 5400 and providing simple control configuration using scale-bars. (Figure 3). Working initially at the calibrated range of 1.5m, a 'primary' stereo-pair of each panel was taken as normal to the object as practically possible, alongside four convergent (normal) pairs at suitable viewpoints around each panel.

When attempting to use any recording technique 'in the field', the variable weather and lighting conditions can create problems for image exposure. Although narrative photographic approaches typically use 'raking-light', either natural or artificial, to accentuate the three-dimensional relief of the carvings, it was decided to limit stereo-photography within 'square-on', evenly lit conditions.

Figure 4 Stereo-photography training at Doddington, Northumberland (courtesy of Tertia Barnett, RCAHMS)

By limiting exposure variation between image-pairs, and hence minimise shadow creation, it was hoped this would improve photogrammetric processing results. Although both narrative and stereo-photography required 'conflicting' approaches to illumination, in practise the latter was adequately controlled using a variety of shading devices including umbrellas, boards, sheets…..or whatever the volunteers had at their disposal! (Figure 4).

The original project aim was to concentrate volunteer input into acquiring stereo-photography of as many of the known rock-art panels as possible. In doing so, great interest developed across all teams in processing their own imagery to generate 3D surface models, orthophotographs and visualizations, as introduced during the opening workshop. At the time English Heritage were researching other 'lower-cost' photogrammetric software packages and although many could theoretically process the level of field package acquired by the volunteers, the combined ability of Topcon's PI-3000 'Image Surveying Station' proved to be particularly suitable for rock-art recording. This included the ability to import 'consumer-grade' imagery, set it up solely using observed scaled distances, view the stereo-pairs in 3D and, using its own correlation algorithm to generate, output and visualize surface models of the rock carved panels. It has also proved to be more 'user-friendly' than other processing packages of a similar level.

Therefore following acquisition by English Heritage of a number of PI-3000 licences and a period of further education, training and 'step-by-step' guidance during February 2006 on photogrammetric recording, several of the volunteers quickly became adept at processing their own stereo-imagery using this software. Despite the considerable increase in technical content to the project, the majority had surprisingly few problems in using the software and quickly started generating a range of outputs including 3D surface models (Figure 5).

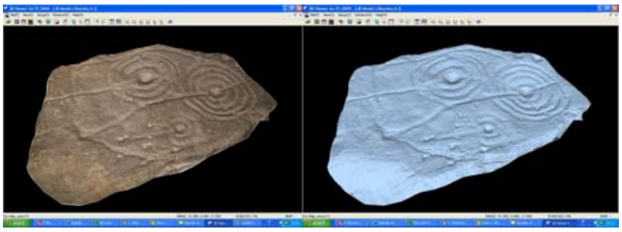

Figure 5 3D Surface Model of Beanley Moor Rock Art, Northumberland (courtesy of Richard Stroud, N&DRAP)

4.3 Further refinement

Although the use of simple scaling approaches, such as scale bars, triangles and scaled measurements between targets has proved suitable for providing control, there may be other low-cost approaches worthy of consideration. The volunteers did find the use of Total Stations difficult and alternatives may include the use of fixed based 'stereo-cameras' in conjunction with GPS and orientation sensors to provide camera location, perhaps derived via virtual networks. If conventional control is utilized, the ease of processing can certainly be improved by use of coded targets. It is pleasing to see the inclusion of such automated processing options within the latest release of the low-cost digital photogrammetry software Photomodeler – 'Scanner'.

4.4 Camera calibration

The original methodology was based around using the Nikon Coolpix 5400 to record a rock-art panel of up to 1m x 1m dimensions from a range of 1.5m. Although camera calibration was successfully performed at this range, and the majority of panels recorded in this manner, the volunteers did find adherence to just one "calibrated object distance" setting rather restrictive, as rock-art panels do vary greatly in size and shape. One advantage of utilizing consumer-grade digital cameras is the very short focal length which should theoretically mean that the calibrated focal length is valid for a very wide range of camera to object distances (Chandler et al, 2007). Suitably accurate data did seem to be generated for all sites but tests have not been conducted to specifically quantify this affect. One option could include providing a range of calibrated settings for the chosen digital camera. Alongside the use of digital cameras with even greater pixel resolutions, this would enable both smaller, portable stones as well as larger, more complex panels to be recorded at more appropriate detail. However the provision of accurate calibration information for a specific camera can be problematic, particularly for the non-specialist who may not have access to calibration facilities or routines.

The stability of the recovered inner orientation parameters always needs to be considered when using consumer grade digital cameras but experience has demonstrated that the recovered lens model is generally stable for medium accuracy measurement (Wackrow et al., 2007). The focal length and principal point offset tends to be less stable but these primary parameters can also be less significant, particularly if the object field itself is planar and parallel to the focal plane. For really high accuracy work using oblique imagery it is necessary to recover these parameters *in-situ.* One suggested methodology is to utilize the laboratory calibrated lens model, but estimate principal point offset and focal length for each camera using captured imagery. However, insufficient imagery/control may mean that this approach is not always practicable.

Finally, although the ‘primary’ stereo-photography for the project has been acquired using near-parallel camera axes, recent research (Wackrow and Chandler, 2008) has shown that convergent imagery eradicates the impact of a slightly inaccurate lens model, which improves accuracy. Therefore future recording projects should always consider acquiring mildly convergent stereo-imagery.

5. DISCUSSION

5.1 Line drawing or surface model?

As well as introducing an accurate ‘third dimension’ to the recording process, additional benefits include the provision of a an accurate stereo-record from which both line drawings and 3D surface models can be generated at user-selectable resolutions. Although packages like PI-3000 and LPS allow the user to extract line drawings little use of this feature has been made by the volunteers, due principally to the perceived introduction of subjectivity into the digitising process. Instead volunteers have preferred to generate more objective, 3D models in both textured & untextured forms. Although rock-art recording output has traditionally been supplied in vector form, the ability to digitally remove the texture from such VRML models, leaving just the host rock surface, has proved of enormous benefit to the volunteers in attempting to understand the underlying carvings. However as with laser scanning, further tools (preferably automated) need development to enable the end-user to accurately extract any man-made features from those occurring naturally, based on objectively acquired 3D data sets.

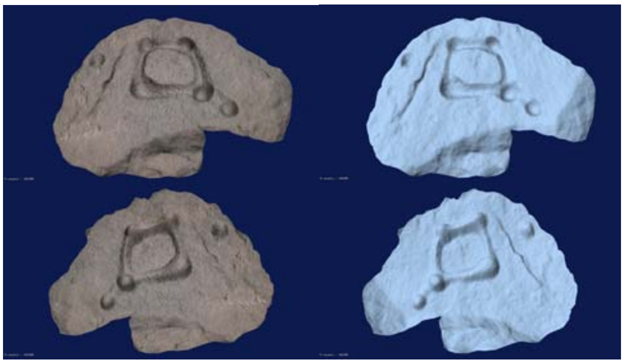

Figure 6 3D Surface Model, including inverted VRML view, of Ouston Pike Hill Rock Art, Northumberland (courtesy of Dave Tuck, N&DRAP)

5.2 Future initiatives and applications

Following completion of the project in July 2008 the outputs from the N&DRAP will be made available to other potential users. These include a new Rock-Art web-site and database which are being constructed to enable quick and easy access to all recorded data for each individual panel. For the photogrammetric element this includes:

- Original stereo-photographs - supplied either as .tif, where already existing in this format, or .jpg images.
- Camera calibration file for each project – supplied in .cmr format (ASCII) as used by PI-3000 software.
- Scaling information – specific information about the scale bars used within the stereo-photographs.
- Photogrammetry recording sheet for each panel – supplied as a scanned ‘tif file, this will provide the ‘metadata’ for each panel.
- 3D surface information – supplied in VRML format these models, including the appropriate texture file, are to be the primary dissemination format of the photogrammetry derived datasets.

As well as encouraging the development of other large-scale recording initiatives, providing on-line access to both the original stereo-photogrammetry and processed outputs will hopeful lead to further research work specifically related to rock-art recording. Although some software tools already exist it is hoped to encourage use of the available data-sets towards development of semi-automated filtering routines so as to extract the host-rock surface from the man-made interventions. Used alongside manual input from the expert end-user this will hopefully aid understanding of the various motifs and symbols that typically comprise a rock-carved surface.

Expert interpretation of captured data has to be a key outcome and benefit of creating these 3D datasets. The volunteers, all of which share a common interest in rock-art, are already using the processed data for interpretive purposes. As two of the expert volunteers, Richard Stroud and Joe Gibson, explain:
“*In addition to 3D viewing and movement of carved panels, which in itself brings a greater reality than standard photography, the ability to remove distracting surface textures to better distinguish and assess artificiality and design components within markings is very useful. Previously undetected motif and design components within markings have been revealed. Cup depth and shape can be better analyzed and measured accurately on screen for comparison purposes. Digital Elevation Models (DEM’s) of a reversed surface model can further clarify motif patterns and relationships. Essentially the photogrammetric process allows detailed desk based research on an accurate surface model without intrusion, removal or otherwise endangering easily damaged and irreparable panels. However photogrammetry should not be used in isolation as an interpretive tool for rock art and should be used in conjunction with field visits*”

Finally, although laser scanning has specifically been used throughout the duration of the project to monitor the condition of five panels, it has become increasingly clear that photogrammetry, albeit in this simple low-cost form, also has monitoring potential. Adjacent research has already demonstrated that calibrated 5MPixel digital cameras can supply three dimensional data with accuracies up to $\pm$1.5mm. Therefore it is hoped that use of digital compact cameras with higher resolutions and Digital SLR’s with larger sensors will both provide monitoring potential.

6. CONCLUSION

A very pleasing outcome of the project is how a significant number of the volunteers have learned to carry out the photogrammetric processing tasks themselves. Originally it was envisaged that volunteers would only carry out photo acquisition, and a 'specialist' photogrammetrist would subsequently post-process the imagery to create DEMs and orthophotos for just a few exemplar sites. However out of the 1100 panels so far recorded on site, 600 have been photogrammetrically processed by the volunteers alone. This ably demonstrates that photogrammetry, albeit in a simple low-cost form, can indeed provide a cost-effective approach to recording within a non-specialist environment.

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