UNRAVELLING THE GORDIAN KNOT: COMBINING TECHNOLOGIES TO ANALYSE ROCK ART IN PLEITO CAVE

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Pleito Cave is situated in the Wind Wolves Preserve in South Central California and contains complex polychrome rock art which the authors are currently analysing. The analysis utilises a range of technologies including pXRF, portable Raman, 3D laser scanning, RTI and layer separation to examine chemical composition, relative positions of rock art panels and elements, and the order of pigment layers. This paper describes the approaches being taken in this analysis, summarises the results so far and outlines the plan for the project.

Pleito Cave in the Wind Wolves Preserve, south central California, contains polychrome rock art which is arguably the most complex rock art site in North America. It has 12 panels containing red, orange, yellow, blue, green, black and white pigments (Figure 1). It is of great cultural and archaeological importance and it is crucial that this site is protected. Unfortunately, Pleito is subject to continuous natural erosion, and the rock art is becoming more fragile over time. The Wind Wolves Preserve mission statements include both conservation and education and the fragility of this site presents a conflict between these mission statements. The Gordian Knot project aims to thoroughly record the site using a range of technologies including 3D laser scanning, D-stretch, Reflectance Transformation Imaging, portable XRF (pXRF) and portable Raman, and to use these records to allow people to experience the site without needing to visit it, thereby minimising footfall within the cave and reducing further resulting erosion.

The research aims to use experimental work to establish the effect of source materials, background surfaces, binders, superimposition of pigments and taphonomic processes on the readings acquired in situ at rock art sites. Conclusions drawn from this experimental work will then be used to establish a methodology for identifying pigment and binder materials in situ, which will be applied to the site of Pleito in order to determine the pigments used. The analysis aims to examine source materials, processing techniques and binders used in rock art production at the site and potentially to inform on the date at which it was produced.

Within the Wind Wolves Preserve extensive work has already been undertaken to examine the social context of rock art. Great debate surrounds the nature and purpose of rock art with some arguing that it is the result of Shamanistic ceremony of a largely private nature (Keyser and Whitley 2006; Whitley 1998) whereas others challenge this view (McCall 2007; Quinlan 2000). Some such as Robinson (2006; 2010a; 2010b; 2011) and Hyder (1989) and argue that it had a more public role and that it was involved in communication and boundaries. At Pleito specifically debate surrounds the origin of the pigments used and whether they were of local origin or came from the missions (Bury et al. 2003). Establishment of the origin of these pigments may provide an indication of the age of the rock art. A variety of exfoliated paint samples have previously been examined at this site (Scott et al. 2002) and this analysis has identified some of the principal pigment materials used in the rock art present. However, an in situ analysis of this rock art using non-destructive techniques would allow a comparison of rock art elements within the site, the identification of any changes in materials within panels and further discussion about the range of materials and technologies used in rock art production. Some preliminary pXRF analysis has already been undertaken in Pleito Cave (Robinson et al. 2015) and the results are discussed in the preliminary results section below.

Figure 1. Panels A, G, and H forming the Gordian Knot (photograph by Robinson).

METHODS

The Gordian Knot project plans to employ layer separation pXRF, Raman spectrometry, D-stretch, Reflectance Transformation Imaging and 3D laser scanning to examine and record Pleito cave.

Portable XRF is a method which uses temporary irradiation by X-Rays to identify the chemical elements that make up a material, and which has been applied to a wide range of archaeological materials such as obsidian (Jia et al. 2010; Craig et al. 2007; Nazaroff et al. 2010), lithics (Williams-Thorpe et al. 1999; Jones, G. T. et al., 1997), ceramics (Terenzi et al. 2010; Papachristodoulou et al. 2010), glass (Kato et al. 2009), bronze (Dungworth 1997), iron (Mentovich et al. 2010) as well as pigment materials (Nuevo et al. 2011; Roldan et al. 2010; Olivares et al. 2013). Portable XRF developed from lab-based XRF devices but does not need the sample preparation that is required by lab based instruments. The portable devices can therefore be used in situ without causing any damage to the material being examined.

Previous studies by D’Errico, McGil, Jercher and Gialanella have already characterised the chemical composition of ochre and have established that it is a complex material which occurs in pockets of varying quality (Jercher et al. 1998:386) which is predominantly iron oxide but which contains a number of trace elements such as arsenic, lead, copper and zinc which could provide a chemical fingerprint for different ochre samples (Gil et al. 2007:728). It has also been established that the appearance of ochre can be affected by heating and that red ochre may have been produced by heating yellow ochre (d’Errico et al. 2010; Gialanella et al. 2011). Studies by Roldan et al. (2010), Nuevo et al. (2011) and Olivares et al. (2013) have shown that pXRF is effective for examining the composition of in situ rock art and have used the technique to characterise the materials present, demonstrating that the red pigment used is iron oxide and that black pigments tend to be either charcoal or manganese based (Nuevo et al. 2011:4; Olivares et al. 2013). Roldan et al. (2010) also presented the idea that fluctuating trace levels of manganese may allow the identification of different preparation techniques, and that the absence of manganese in some pigments may indicate different ochre source materials (Roldan et al. 2010:248). Nuevo et al. (2011) also noted that the relatively high level of iron in one pigment may indicate a different material (Nuevo et al. 2011:4).

The papers above touch on the possibility of differentiating between in situ pigments and Huntley et al. (2015) discuss differentiation between pigments and comparison with materials from quarry sites. This project will further explore the potential for this technique to be used to compare in situ pigment materials within and between panels and sites, to identify ochre deposits from which these pigments were sourced, and to examine the processing techniques and technology used to produce rock art.

The pXRF results will be supplemented by Raman spectrometry using a laser set at 78 nm and Fourier Transform Infrared (FTIR) spectrometry. These instruments examine bond energies and so will provide information on the compounds used within the rock art. In addition, they can be used to identify organic compounds, which are not detected by pXRF.

Data from the analytical methods outlined above will be combined with information from D-stretch, Reflectance Transformation Imaging (RTI) and layer separation to establish a sequence for rock art elements within the panels at Pleito. D-stretch uses a decorrelation method to increase contrast in the visible spectrum, thereby allowing faint images or subtle contrasts between rock art elements or materials to be seen more clearly. RTI uses photography with light from various angles in order to view the superimposition of layers of paint. Layer separation, started by Dan Reeves uses visual examination of rock art panels to establish which pigments were painted over others.

PRELIMINARY RESULTS

Initial work on panel C (Figure 2) included analysis using pXRF, D-stretch, RTI and layer separation and demonstrated variations between pigments within the panel.

Panel C was examined using a Bruker Tracer III hand held XRF. The panel contains red, orange, black, white and green pigments. A total of 275 readings were taken from this panel, and so far the readings from green and red pigment have been examined using principal component analysis in order to establish variation in chemical composition across the panel, and to identify contrasting pigment materials used to produce the same colour. Portable XRF readings from red and green pigments in panel C at Pleito were examined and the points from which these were taken are shown in Figure 3.

The initial processing and deconvolutions used ARTAX software with results exported into Excel where they were converted into percentages of the total number of counts. The principal component analysis was performed using PAST software (Hammer et al. 2001), using a variance-covariance matrix and included counts of Si, K, Ti, V, Cr, Mn, Fe, Ni, Rb, Sr, Y, Zr and Nb.

Both the red and green pigments showed high iron counts, and there is an absence of copper in the green, indicating that the red is ochre and that the green is most likely a green earth compound. This is corroborated by work undertaken by Scott et al. (2002), who described the green pigment on fragments collected from Pleito as green earth. Typically, black rock art pigments consist either of charcoal or a manganese based material (Nuevo et al. 2011, Olivares et al. 2012). The absence of an elevated manganese level compared with the bare rock therefore suggests that a charcoal based black pigment is likely.

Analysis of the green pigments showed no significant groupings of contrasting readings between different areas of green pigment within the panel (Figure 4), but more variation was present in the red pigments.

Three areas of red pigment (elements A, B and D) showed the same chemical composition as each other, but contrasted with others in the panel. Areas C and E showed similar chemical composition but area F contrasts with all the other areas of red (Figure 5). Area F shows much more widely dispersed readings than A, B and D which are more neatly clustered. This may demonstrate a difference in the quality of ochre used.

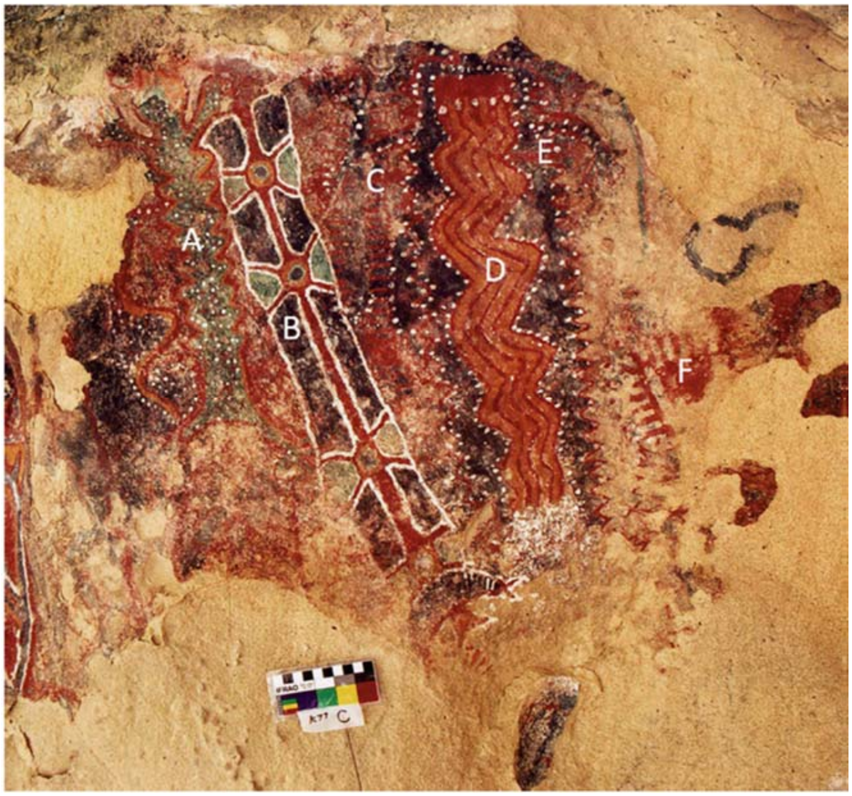

Figure 2. Panel C in Pleito Cave, with elements labelled. Photograph by Rick Bury.

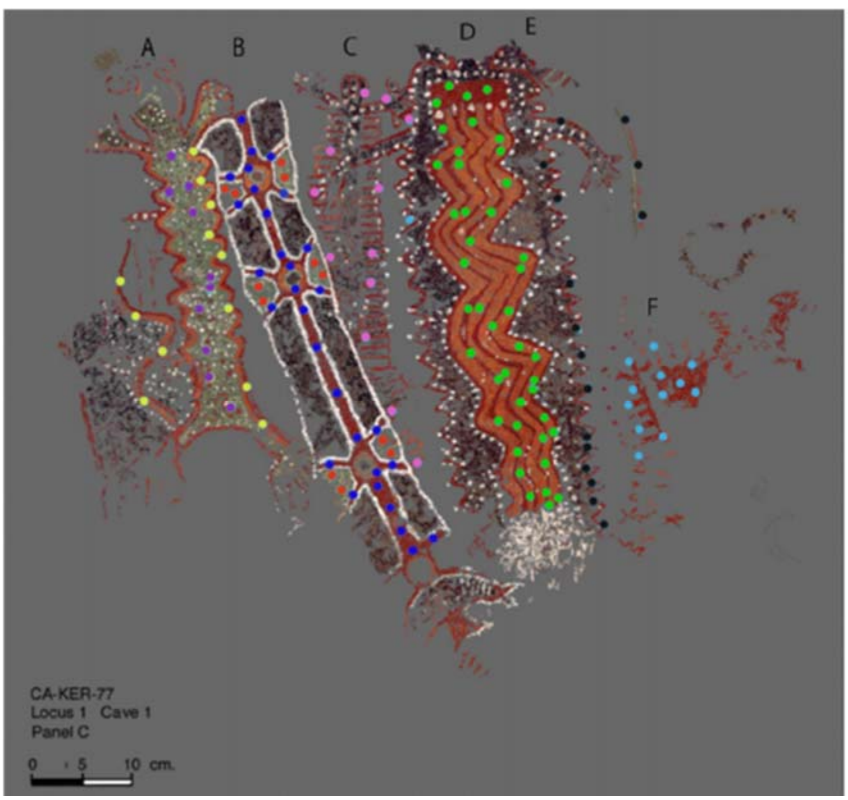

Figure 3. Panel C at Pleito with points for red and green pigment pXRF readings marked.

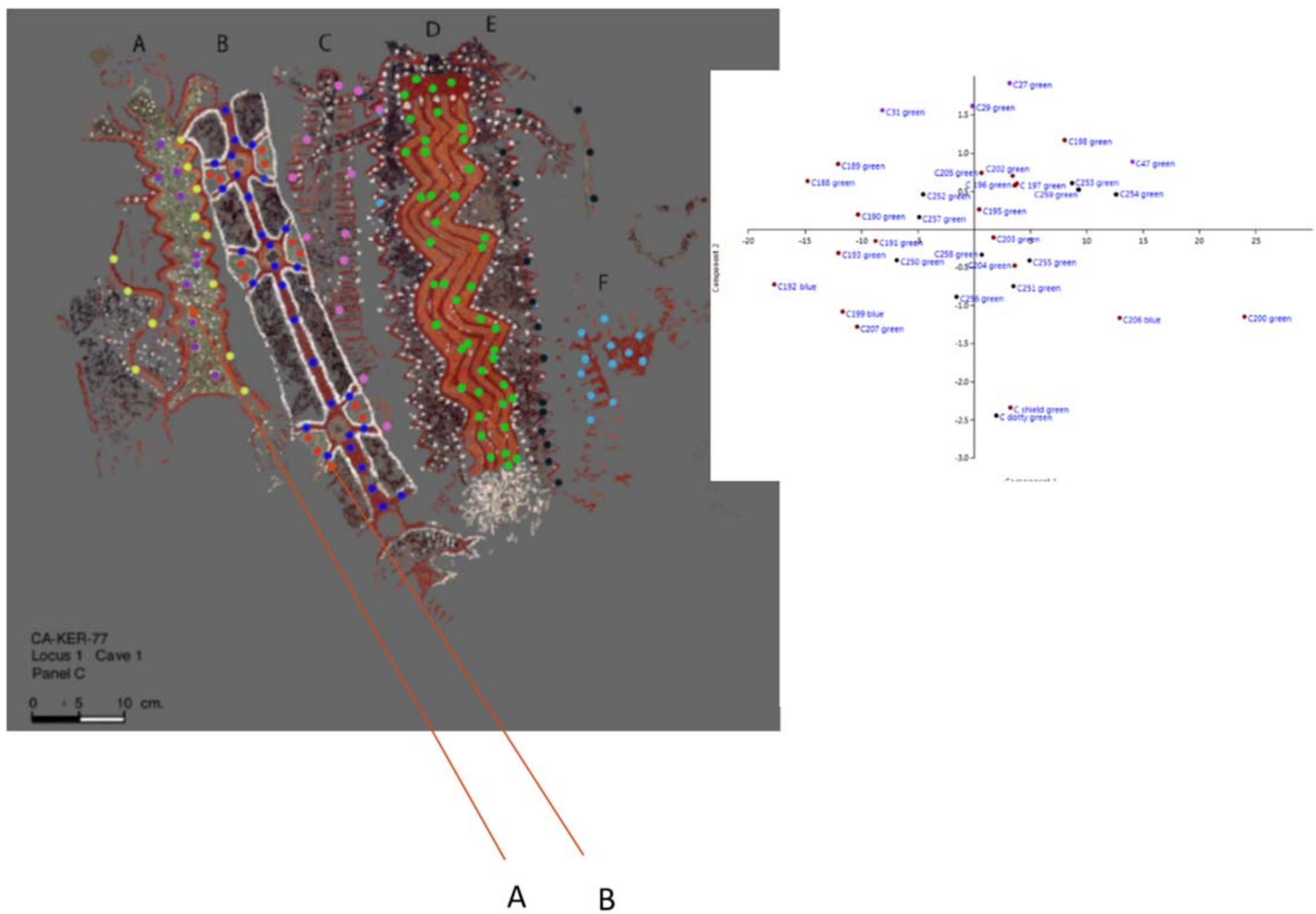

Figure 4. PCA plot of panel C green pigments.

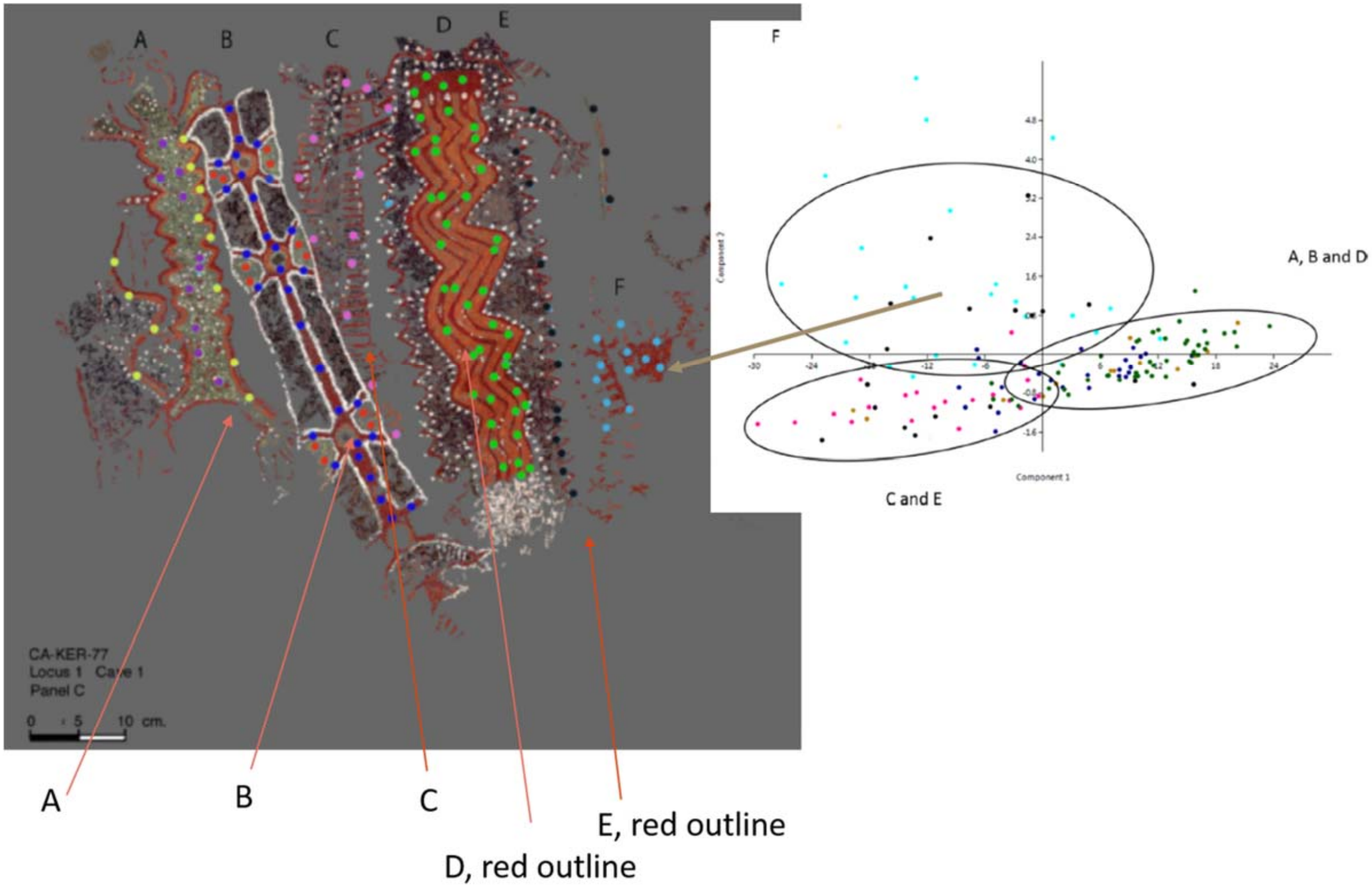

Figure 5. PCA plot of panel C red pigment readings.

Figure 6 shows the sequence of paintings based on layer separation work by Dan Reeves. The XRF results indicate a minimum of three different red pigments at Pleito. The distribution of these pigments according to the XRF results was used in conjunction with layer separation techniques to establish an order of rock art production in this panel. Figure 6 below shows the likely order in which this panel was produced based on layer separation and XRF data.

Layer separation indicates that it is most likely that element F was produced first, followed by elements A and C, then elements B and D. However, given the compositional contrast between A and C shown by pXRF it is likely that these were also produced at different times indicating a fourth layer in this chronological order. In addition to this, the compositional similarity between A and B may indicate that a short time passed between the production of these elements, or that during this time there was consistency in the artist, the ochre source or the method of pigment processing used here.

Results from the RTI examination of the site largely support the order established using layer separation and pXRF. RTI examination showed that element F presented a similar surface texture to the background material beneath other elements, indicating that it was produced first. The results support the sequence of superimposition of the other elements and demonstrate a black layer beneath element A. Figure 7 shows the most likely sequence when layer separation, pXRF and RTI are combined. D-stretch revealed a sun-shaped element below element A (Figure 8) which is difficult to see under normal light. This will be revisited to accumulate further pXRF readings and to examine where it fits into the sequence.

FUTURE DIRECTIONS

During this project each panel will be examined in the same way as panel C, with the addition of Raman and FTIR data. The project will also include controlled experimental work to determine the effect that the background substrate, binders, source material and processing techniques have on the pXRF readings which are gathered in situ. A number of factors may present complications in the examination of pigment materials. These include taphonomic influences such as erosion, naturally occurring biological agents and the seeping of chemical compounds through the rock substrate.

This experimental work will use raw pigment materials including red, yellow, green, blue and black pigments from multiple sources in order to allow comparison between sources. Each material will then be processed and analysed for its main components and proportions of trace elements. Each pigment material is to be applied to multiple stone surfaces including granite, sandstone, limestone and gritstone in raw and powdered forms, with and without binders.

XRF, Raman and FTIR readings will be taken from each material at each stage of processing in order to establish the characteristic elements of each material, the relative proportions of which can be used to compare in situ pigments to with each other and with possible source materials. Handheld Raman will be used to supplement the pXRF analysis by identifying organic materials such as binders. The establishment of the presence or absence of binders will inform the interpretation of the chemical data from Pleito, giving greater confidence to conclusions drawn when examining in situ rock art.

Once all the information about Pleito is gathered a virtual reality version of the cave will be produced which will allow visitors to experience and explore features of the site without needing to access the cave itself. The virtual reality cave will be based on a 3D model produced by James Miles using a FARO Focus 3D laser scanner (Figure 9).

This study will add to the large body of work already undertaken concerning Chumash rock art in the Wind Wolves Preserve and will contribute to the ongoing discussion about the nature and purpose of rock art (Blackburn 1977; Hyder 1989; Hyder and Oliver 1986; Insoll 2012; Lee and Hyder 1991; McCall 2007; Quinlan 2000; Robinson 2010; Whitley 1987). This project will provide valuable information about the potential for non-destructive, portable devices to be used to analyse these features of rock art and provide a robust methodology for in situ polychrome rock art analysis which can be applied to sites around the globe. It presents an approach which will allow the public to appreciate and interact with sites remotely. This approach reduces the potential erosion from visitors whilst still communicating information about the sites. It also helps to keep the exact location secret and allows those who would struggle to access the site to learn about it in way that is applicable to many other fragile and inaccessible archaeological sites.

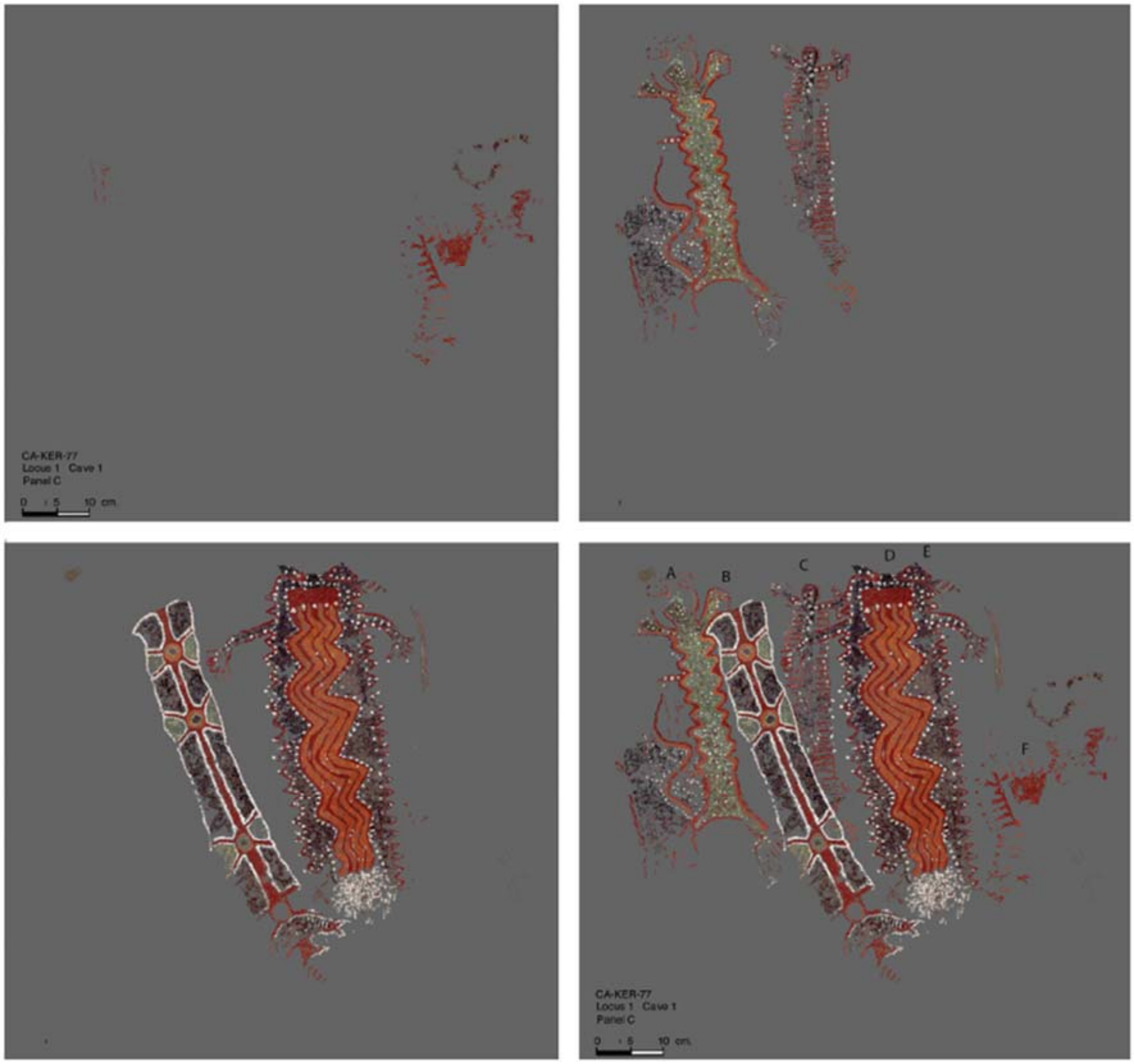

Figure 6. Sequence of rock art production according to layer separation work by Dan Reeves.

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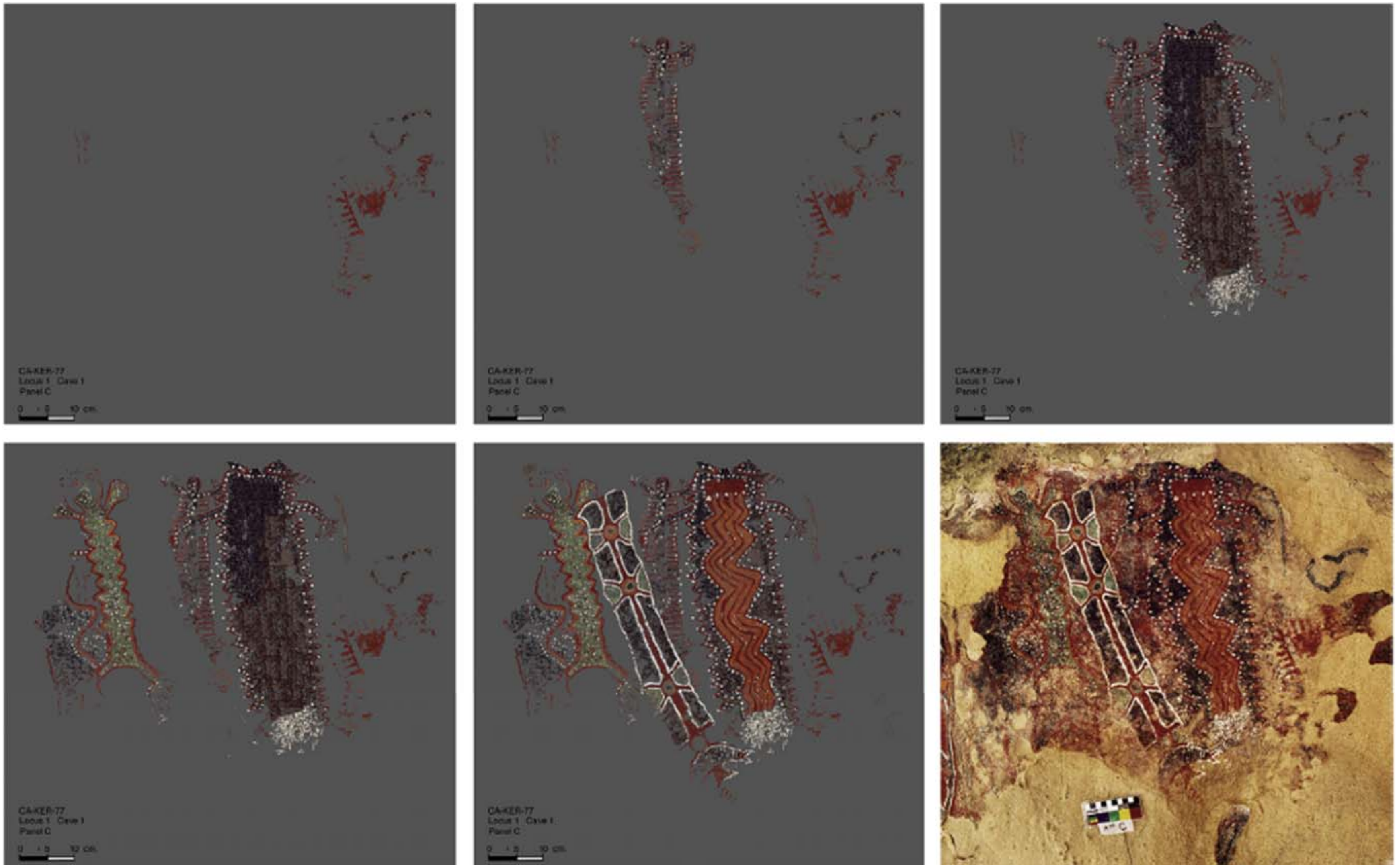

Figure 7. Sequence of production in panel C using combined techniques. David Robinson and Dan Reeves.

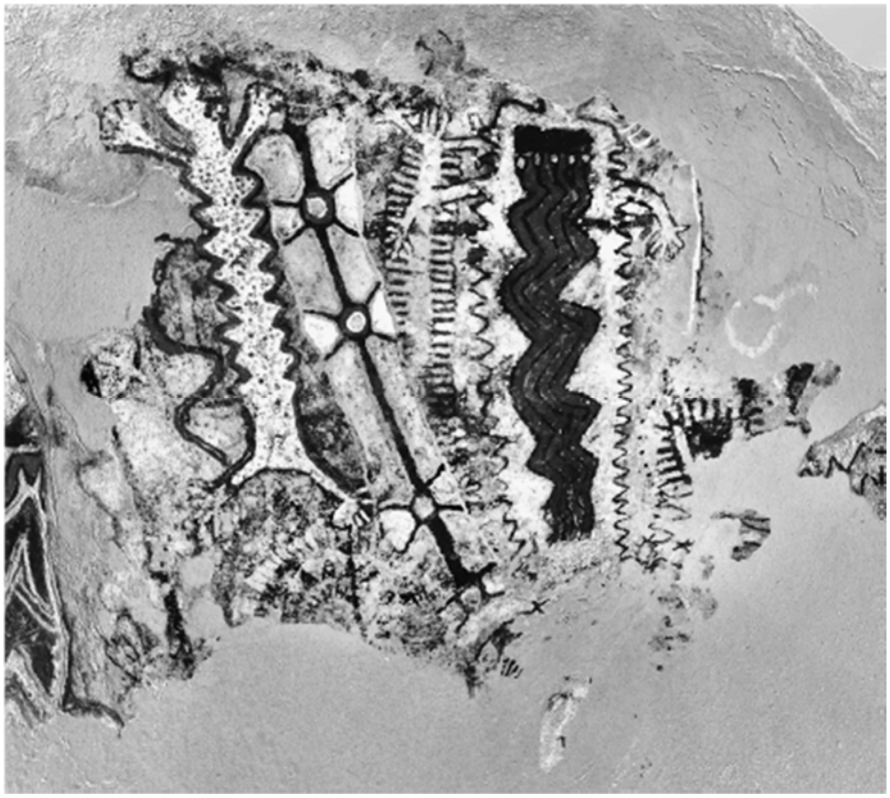

Figure 8. D-stretch image of Pleito panel C.

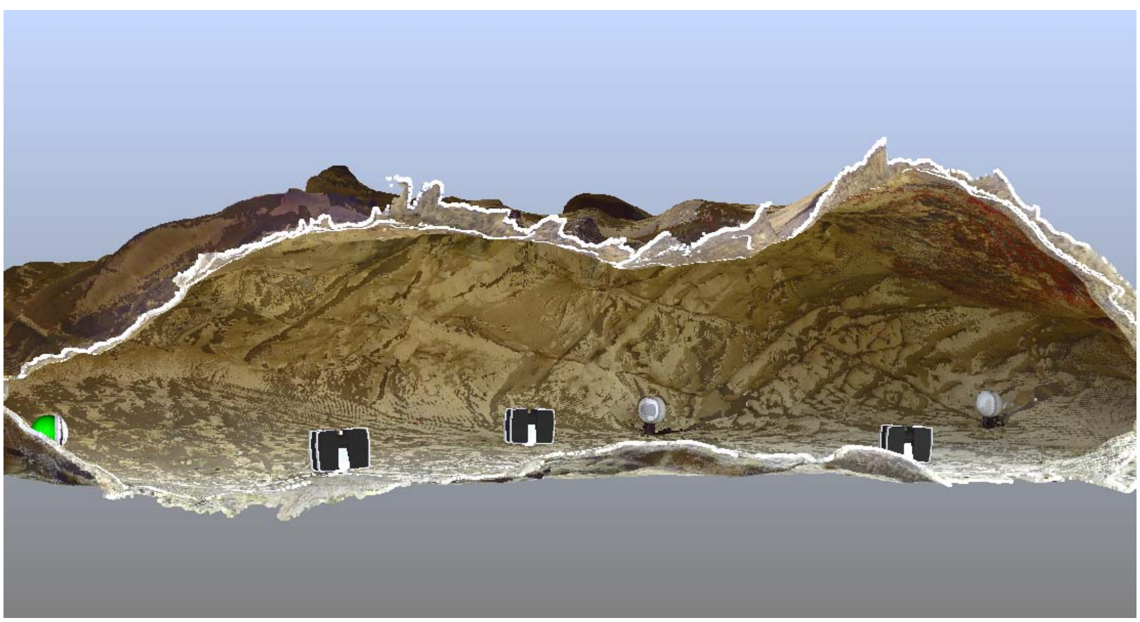

Figure 9. 3D model of Pleito Cave by Michelle Wienhold and James Miles.

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