Three-Dimensional Gigapan Views of Archaeological Sites and Artifacts: Examples from the Paleolithic of Southwest France

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ABSTRACT

The use of Gigapan imagery in an archaeological context allows for quick, very high resolution recording of excavation surfaces, artifacts and surrounding areas. At the Paleolithic site of Abri Castanet (France), we have, since 2008, used a Gigapan imager mounted horizontally to record lateral variation across our active excavation surface. Using GIS software and topographic data from our onsite Total Station, we can then minimize distortion, plot the image relative to artifact and feature locations and display all of these data in three-dimensions. This gives us a unique way to record and analyze patterns of variation across a constrained archaeological horizon. In addition, we have recently began a project using this technique to record, process and project imagery of early Upper Paleolithic engraved blocks and rockshelter ceilings, representing some of the earliest examples of cave art in Europe.

Keywords

Archaeology, Paleolithic, Excavation Techniques, Origins of Art

INTRODUCTION

This paper focuses on the use of Gigapixel imagery in recording and analyzing archaeological data from the site of Abri Castanet in the Dordogne region of Southwest France (Figure 1). The Dordogne region has been the focus of archaeological research since the nascence of archaeological inquiry and contains some of the best-known Paleolithic sites, including Lascaux and Cro-Magnon (1).

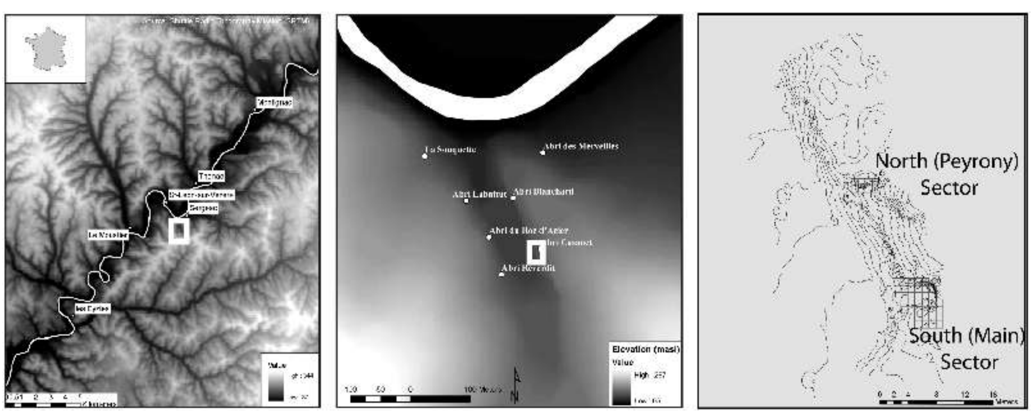

Figure 1: Location of Abri Castanet

Abri Castanet dates to the Aurignacian period (~38,000 – 30,000 years before present) of the Upper Paleolithic. This period is widely considered to represent the first wave of modern humans (*Homo sapiens*) moving from Africa into

Europe and replacing the indigenous Neanderthal populations. During its occupation, Castanet was a several meter deep rockshelter located on the east bank of the Vézère River (2,3,4). Today, it is a dense archaeological layer preserved by large limestone blocks from the collapsed rock shelter. The site was initially excavated during the early 20th century and was found to preserve a striking number of stone tools, animal bones, and an extensive series of some of the earliest beads and jewelry (4).

When excavations resumed in 2005 the goals were twofold: first, to recover material related to the production of jewelry and second, to study the site's single archaeological layer and associated combustion feature in as much detail as possible. To address these goals, the site is excavated in a way that maximizes horizontal exposure. This allows us to recover lateral variation of geological facies associated with the combustion feature and to facilitate characterization of the anthropic and/or geological origin of these variations.

METHODOLOGY

At Castanet, we use a Total Station (a laser theodolite and electronic distance measurer) to record the three-dimensional coordinates of all archaeological objects. A well referenced Total Station can give the location of a point with a combined error of less than 0.5 centimeters in all dimensions. Total Stations are commonly used to register the locations of artifacts and features in archaeological excavations (5,6), but at Castanet, we also record the surface topography of each stratigraphic unit and how it corresponds to lateral variation in sedimentary facies (7). With the combined influences of waterflow, anthropic modifications and only partial protection from the elements, the stratigraphy of rockshelter sites is notoriously complex. This methodology is particularly useful for this type of site because it allows for direct correlations between stratigraphic units and greatly facilitates correlations over multiple years of excavation. It also allows for the three-dimensional display of artifact data and photographs of features in relation to the geological strata.

Once topographic points have been recorded with a Total Station, they are imported into ESRI ArcGIS as a vector shapefile (Figure 2: I). These topographic points are then used to create an interpolated surface (Figure 2: II). This generally consists of a topographic surface of the entire excavation area with vector polygons distinguishing different sediment types. This gives us a ‘working surface’ for the excavation in process, while preserving a detailed and accurate record of the topography of each sedimentary unit even after it has been completely excavated. The accuracy of the interpolation is tested both by qualitatively comparing the interpolated surface to the actual surface and by computing a variance of prediction (Figure 2: III). If the interpolation does not match in a given area, then more topographic points can be recorded with the Total Station in that area before excavation resumes.

The corrected interpolated surfaces are then exported into ESRI ArcScene, a GIS program designed to display three dimensional data. Due to the fact that raster digital elevation model (DEM) images can be difficult to view simultaneously and do not display an easily interpretable scale, a 2 cm vector grid is created based on the DEMs (Figure 2: VII). The polygons representing the extent of each sedimentary unit are then vertically projected based on the interpolated surface. This projection is not a systematic resampling technique and it should be noted that both of these processes result in some smoothing of the original surface. However, this error between the projected vectors and the original interpolation rarely exceeds 1 cm and can be overcome with further processing.

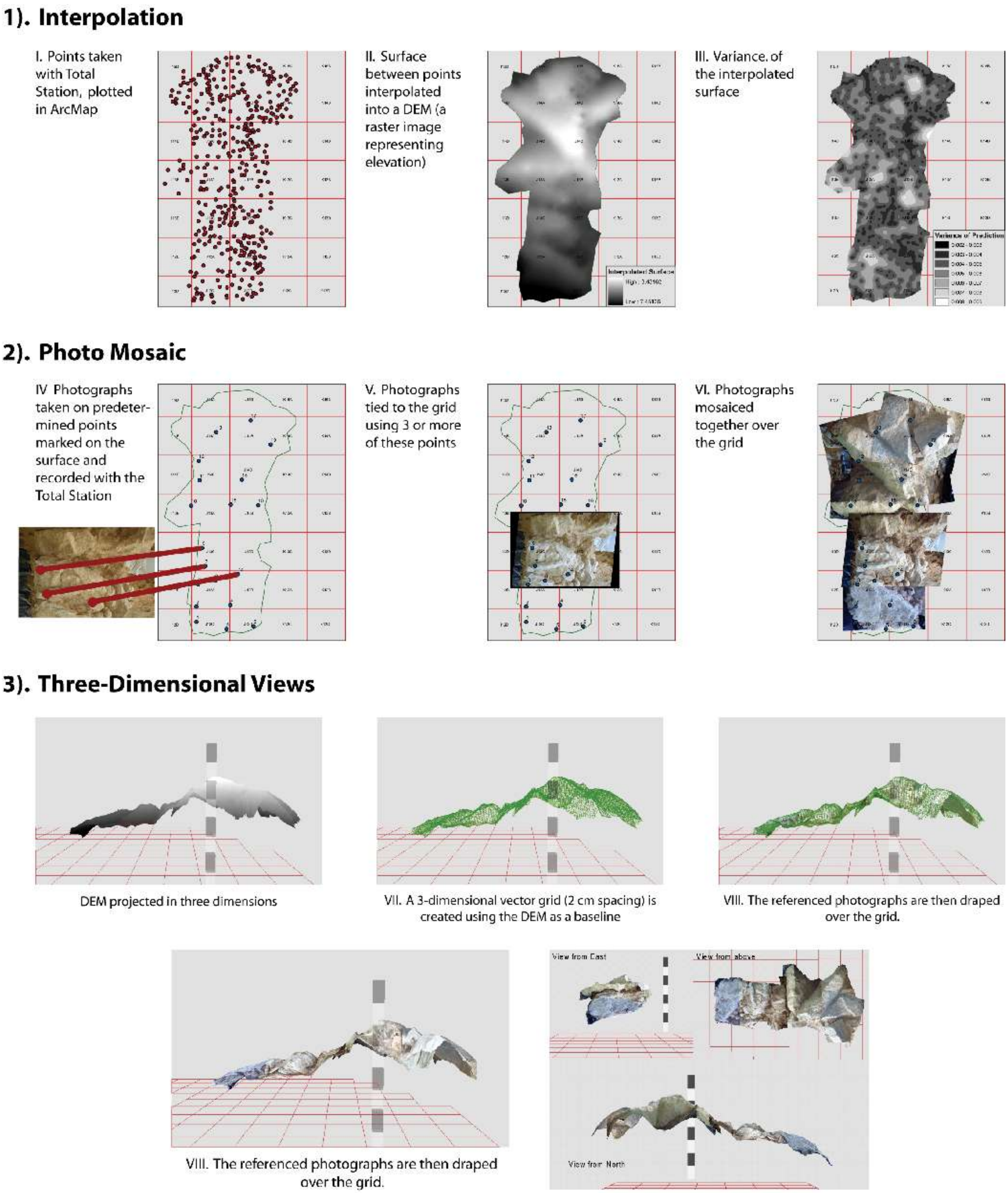

Figure 2: Methodology

For the registration of photographs we mark a series of points on the top of each stratigraphic unit. These points are recorded with the Total Station and exported into a separate registration shapefile. In our initial method, photographs were taken facing down with at least three of the points visible in each (Figure 2: IV). Using these points the photos are warped to match the excavation grid (Figure 2: V) and mosaicked into one image (Figure 2: VI).

Since 2008, we have used pre-mosaicked, high resolution images recorded using the Gigapan imager. At Castanet, the we mount the imager parallel to the excavation surface on a Manfrotto 055CX3 tripod with a counterweight. The center of the imager's field of view is roughly aligned with the center of the area to be recorded. Images are taken in the morning with natural light. Exposure setting are locked using an area including both the reflective limestone bedrock and the darker soils (usually ISO 400-800; f 4.3-5.6; shutter speed 1/10 – 1/25).

This equipment has greatly facilitated photographing the entire excavation surface in precise detail. It is, however, designed for capturing panoramic images of larger phenomena. When used facing downwards and panning over a small excavation area, the results in distortion at the margins of the image. Georeferencing these images with a spline method allows for overcoming distortion in these images. The spline method is a form of interpolation which effectively locks the image to the registration points while maintaining a systematic warp for areas in between points (Figure 3).

The resolution of these images is sufficient to view changes in soil color and consistency, the locations of objects, and even some indication of grain size . The images can the be visualized with all excavation data, including excavated objects and different sediment types (Figure 3) and can be projected in three dimensions (Figure 4).

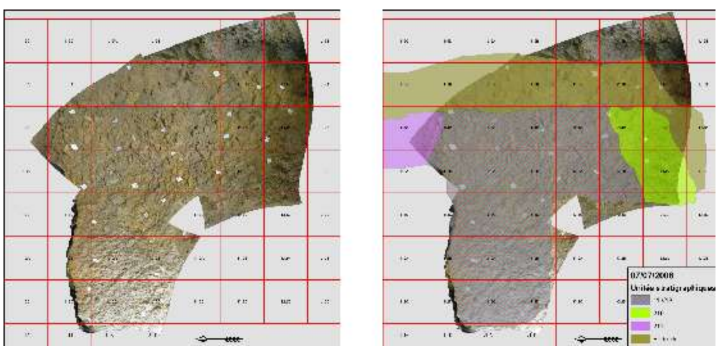

Figure 3: Gigapan Image Fit to Site Grid (2008)

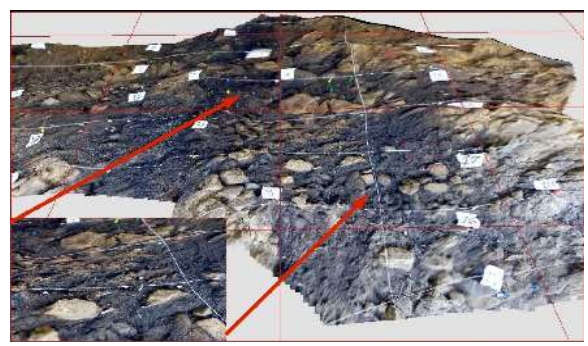

Figure 4: Gigapan Image Displayed with Topographic Data in 3d (2009)

EXAMPLES

Example 1: Excavating a 32,000 year old hearth

The last two years of excavation (2009-2010) at Abri Castanet have focused on a very systematic excavation of a presumed 32,000 year old hearth in the center of the site. It was previously covered by a witness section (seen in Figure 2), and the very dark upper surface can be seen clearly in Figure 4. However, as the approximately one by two meter feature was exposed it became clear that it was far more complex than a single well-outlined hearth. Densities of burnt material, color, characteristics of the sediment and the presence of limestone cobbles all varied across the surface. This level of complexity is not outside the norm for archaeological excavations, but using Gigapixel imagery to record periodic views of the exposed surface gave us a way to quickly re-access data across the entire surface and with a resolution that exceeds other current methods. One of these images is shown in Figure 5, but a time series of relevant images from 2010 can be found at *http://www.gigapan.org/viewProfile.php?userid=4885*. Each of the 2010 surface images consists of between 350-425 images, resulting in a resolution that suffices to show not only details of individual artifacts (Figures 6 and 7) but also some indication of the character of the sedimentary matrix (Figure 8). All of these images have corresponding reference points (the tacks seen in Figure 5) and topographic surfaces allowing them to be, as outlined above, referenced to the site grid and projected in three dimensions (Figure 9).

Figure 5: Untreated Gigapan of Abri Castanet Excavation Surface: June 25, 2010.
For zoomable version, see http://www.gigapan.org/gigapans/55787/

Figure 6: Reindeer Teeth

Figure 7: Stone Tool

Figure 8: Soil Detail

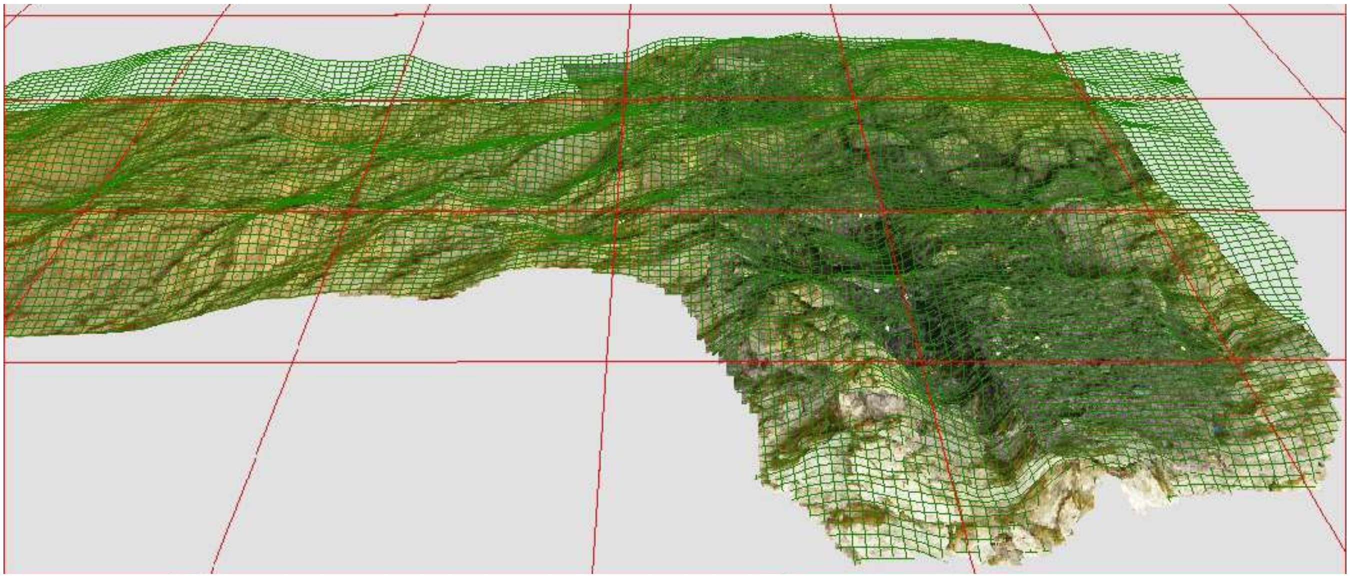

Figure 9: Gigapan of Abri Castanet excavation surface projected in 3d. The larger grid is at 50 cm intervals. The smaller topographic grid is 2 cm.

Example 2: Documenting and analyzing ancient rock art

In addition to the now completed excavation of the fire-feature in the south section, the northern Peyrony section (Figure 1) of Abri Castanet has yielded some of the oldest artistic representations in the world. In 2008, we discovered an engraved block, formerly a section of the rock shelter's ceiling, that had fallen in antiquity onto the archaeological layer (4). While the dating and full publication of this find is forthcoming (9), significant work restoring and analyzing the engraving has been undertaken. Due to both its fall in antiquity and the method used to extract it, the block itself is broken into several pieces. The digital refitting of the various pieces of the block is critical the reconstructing and analyzing the engravings. This, of course, entails registering in three-dimensions, and at extremely high resolution, the entire surface of the block. Using a modified version of the methodology outlined above, we have referenced a series of gigapixel images (Figure 10 is a representative image) of each piece. These are then mosaicked and draped over a three-dimensional surface to illustrate what the block would have looked like before its breakage (Figure 11).

Figure 10: One of several Gigapans focusing on the engraved surface of Bloc K

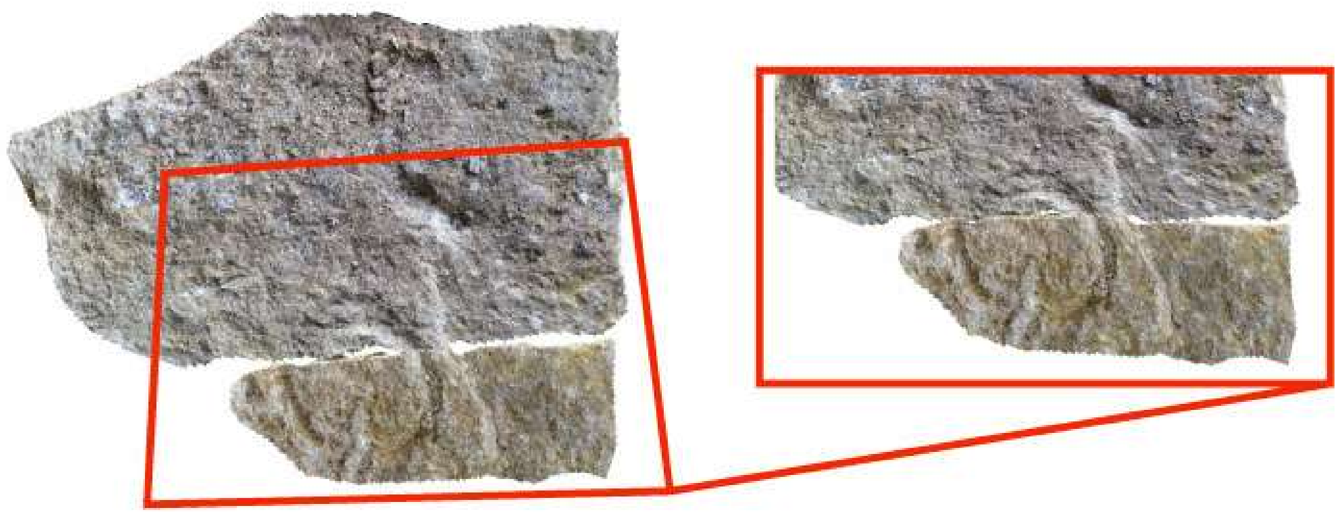

Figure 11: Detail of two refitting blocks in 3d

CONCLUSION

Using the Gigapan and the resulting imagery at Abri Castanet has been a rewarding experience. From a strictly methodological standpoint it has given us a way to record ongoing excavation data at a level of detail that would never have been previously possible. Additionally, the high-resolution images not only compliment our preexisting process of topographic interpolation, but have also significantly simplify the process. Although, the Gigapan is not designed for capturing images of flat surfaces without distortion, we feel that through a relatively simple GIS-based process this limitation can be overcome. Thus, this tool is an exciting first step towards gigapixel recording of archaeological excavation data. In addition, the Gigapan has important potential for recording early art. Gigapixel imagery can be combined with three-dimensional data (from Total Stations or 3d scanners) to provide a complete view of an object's morphology and context. This technique will allow more individuals (both researchers and the public) to view and analyze detailed digital recreations of these objects in their original context.

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