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NEW IMAGING TECHNIQUES AND POLISH ARCHAEOLOGY IMPRESSIONS ON RTI AND SLOW-MOTION TECHNIQUES IN ARCHAEOLOGY

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Abstract

Digital imaging techniques have found wide usage for documenting archaeological work. On some occasions, the use of specialised techniques yields results that differ from traditional digital photography or videography. In this presentation I am presenting two techniques that appear to require an introduction for polish archaeologists. Reflective Transformation Imaging (RTI or PTM – Polynomial Texture Mapping) is very efficient for documenting and analysing carved and relief bearing monuments. PTM uses a series of images and transforms them into a single image file. This allows the researcher to record an object in different lighting conditions and use a computer to transform the light while viewing. This enables very precise documentation of the surface features of the heritage object that then facilitates further archaeological analysis. Another use of serial imagery is taking slow motion digital videos in experimental archaeological documentation. The technique allows archaeologists to observe and document dynamic phenomena that are difficult to observe with the naked eye.

Keywords: digital imaging, documentation in archaeology, photography, videography

Resumen

Las técnicas de toma de imágenes digitales han encontrado una amplia aplicación en la documentación del trabajo arqueológico. En algunas ocasiones el uso de las técnicas especializadas aporta resultados que difieren de los de la fotografía digital tradicional o la videografía. En el presente artículo se comentan dos técnicas que parecen requerir una introducción para los arqueólogos polacos. La técnica de Reflective Transformation Imaging (RTI, Imágenes de Transformación Reflectiva, o Polynomial Texture Mapping, PTM, Mapeamento de Textura Polinomial) es muy eficaz en la documentación y el análisis de los monumentos escultóricos o decorados con relieves. El PTM aprovecha una serie de imágenes y las transforma en un archivo de imagen único. Esto permite al investigador grabar un objeto en diferentes condiciones de luz y usar el ordenador para transformar la luz durante la visualización. De esta manera es posible conseguir una documentación muy precisa de las características de la superficie de los objetos de patrimonio cultural, lo cual facilita un análisis arqueológico posterior. Otro uso de la imaginería en serie consiste en aprovechar los vídeos digitales a cámara lenta en la documentación arqueológica digital. Dicha técnica permite a los arqueólogos observar y documentar los fenómenos dinámicos que son difíciles de observar a simple vista.

Palabras clave: imágenes digitales, documentación del trabajo arqueológico, fotografía, videografía

INTRODUCTION

This article is an expanded version of a talk that I presented in Warsaw, Poland in June 2015. The goal was to raise awareness of the new technologies in digital imaging among Polish archaeologists. Because of my experience, I chose two techniques that I am familiar with. The first is Reflectance Transformation Imaging (or Polynomial Texture Mapping), which is rarely applied in Polish archaeology and cultural heritage management, but has a long history of use in other countries (see recent examples Artal-Isbrand *et al.* 2011; Artal-Isbrand and Klausmeyer 2013; Earl *et al.* 2010). The second technique is slow motion video (or high speed video/photography). Both techniques are based on the principle of capturing much more information than is recorded through traditional imaging methods.

One shared characteristic of these techniques is that their output is based on the use of multiple images. Reflective Transformation images are based on a series of pictures taken by a static, fixed camera of a static, fixed object. The original images are recorded in changing light conditions. This is equivalent to observing a dynamic process – in this case the changing light. Slow-motion video is composed by sequencing high speed photography stills of an object in motion or engaged in some other dynamic process.

Below I will provide short presentations of each technique and report my experiences.

DIGITAL IMAGING

The history of photographic documentation in archaeology is very extensive (e.g. Dorrell 1994: 1-7). Recently, this practice was revolutionised by digital photography; this is not only much easier to handle and store than analogue photography, but is also much cheaper than traditional photography which requires costly rolls of film. In the past, taking a large series of photographs or video clips was expensive; however, with digital photography, the cost of recording a single image is negligible. This low cost is one reason that RTI and slow motion are appropriate for use in archaeology . In fact, both techniques require only a single, relatively small investment in photographic equipment.

The RTI's advantage lies in the fact that no specialised equipment is needed to perform this kind of photography (see below). This is also true of slow motion, which in the past required specific technologies.

Reflective Transformation Imaging – history and technical aspects

Reflectance Transformation Imaging (RTI) was developed by researchers from Hewlett-Packard Laboratory and released in 2001 (Malzbender *et al.* 2000, 2001; Archaeology and Polynomial Texture Mapping... 2014). Since its initial development, this technique has been used for documenting cultural heritage. One of the most famous and early uses of this technique was to document the remains of the complex, brass mechanisms of the ancient calculating device, the Antikithera mechanism (after Freeth 2009: 79)[1].

The technology utilises the concept of Polynomial Texture Mapping (an alternate name for this technique) (Malzbender *et al.* 2001). As the name suggests, PTM uses multiple data sets for every

[1] Please note that is a very abbreviated description of the procedure. My main aim is to popularise this efficient and low-cost technique of documentation among Polish audiences. Excellent more detailed procedures, guidelines, tutorials (and software) are available from other authors who have much more experience and were among the developers of this technology. See Goskar and Earl 2010; especially Duffy et al. 2013, please see websites http://culturalheritageimaging.org/ and http://www.hpl.hp.com/research/ptm/

point in an image. Traditional raster or bitmap images are composed of points that are attributed a value that relates to the location and a value that describes the colour. In PTM, each point may be given several additional values (Malzbender *et al.* 2001). In other words, this technique combines several pictures into a single raster. In the most standard archaeological use of RTI, it is usually used to record the point's colour value in varying lighting conditions. Therefore, while viewing a PTM file, the viewer can browse through visualisations of this PTM that relate to all recorded lighting conditions (Figure 1). The presence of this data allows users to measure characteristics of reflectance and to mathematically enhance a surface to "highlight" specific features not visible to the naked eye or in traditional photographs. Other types of PTM imagery have been produced that feature alternate visual aspects, such as images shot with differing focal lengths (Malzbender *et al.* 2 001).

RTI is very useful for documenting carvings and other marks. Carved surfaces are important parts of archaeological finds and artefacts, but at the same time are difficult to photograph well. To visualise the carved details, the object is usually lit from a low angle at one location, so that the raking light casts a shadow to help distinguish details from the background (Dorrell 1994: 185-191). The process is highly selective because such shading from one location and angle helps to highlight a range of detail while others are obscured. RTI images help capture various lighting conditions ranging from heavily raked light to full frontal. In addition, this additional data allows for significant image enhancements.

The most important items required for RTI imaging are a good camera fixed on a tripod, a separate flash mounted on a monopod, a remote trigger, and a reflective target (a polished black sphere) that must be included in the photograph's frame (Duffy *et al.* 2013; Goskar and Earl 2010). The sphere will be used by the software to identify the light source positions in each image. The difficulties of RTI lie in keeping the camera and object in a fixed position throughout the documentation and in using sources of light other than the camera flash. To keep the object illuminated only by the light source, photos should be taken in a dark room, at night or using specific aperture/shutter speed/film sensitivity settings that only detect light from the light source.

The photos should be produced with a flash mounted on a monopod or tripod and positioned by an assistant, while the camera is triggered remotely to avoid altering its position. The positioning and framing of the object are identical to standard archaeological photography. To illustrate this, several series of photographs were taken of a cast of a Maya stela (Figure 2). During each series, shots were taken with light coming from different directions and angles — for example, twelve photos, each with light coming at the same angle to the surface of the object from twelve o'clock positions. Each series should document a different angle of light — for example, 30°, 45°, and 60° to the surface perpendicular to the camera and parallel to the surface of the object (Figure 3). The light source should be located at a constant distance from the object. A string can be used to secure this[2].

After applying proper software solutions, the result is a single file containing an RTI image which can be opened by one of the several RTI image viewers that are now available[3]. With such software, interactive lighting can be applied to manipulate: the lighting conditions (Figure 1).

The procedure is relatively straightforward. I had a chance to practice producing RTI images during a workshop organised by Carlos Pallan Gayol and Nikolai Grube at the University of Bonn in August 2012. It took two hours to present the procedure and carefully go through the process. After a quick set-up (fixing the camera in position and preparing the equipment) as a team of three (myself and my colleagues, Laura Stelson and, Mike Lyons), the process of taking a series of 68 photos took us

[2] It is also possible to use a specially constructed dome, a lighting rig that features lights at fixed positions, but this is not so low-cost or field trip friendly (Malzbender *et al.* 2001: 521).

[3] For software solutions (ptmbuilder or rtibuilder for creating RTI images and ptmviewer or rtiviewer for viewing) please see please see websites http://culturalheritageimaging.org/ and http://www.hpl.hp.com/research/ptm/. A software postprocessing can be applied for the images (see Duffy *et al.* 2013: 9).

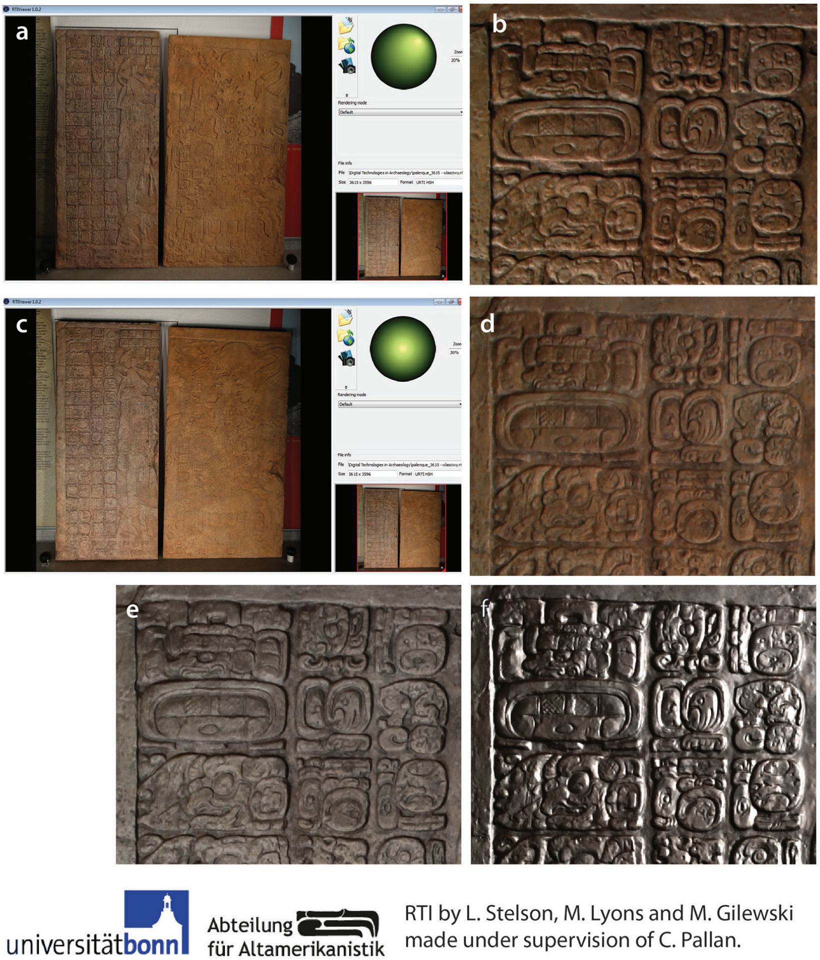

Figure 1. Selected imagery from an RTI image of a cast of a Maya stela. Screenshots from RTI viewer software (a, c); enlargements showing fragments of the inscription in different lighting (b, d); and with the specular enhancement (e, f).

less than forty minutes (Figure 2). During the workshop, I witnessed first-hand that this technique uses few resources and money: the most basic DSLR cameras, heavy old tripods, cheap remote triggers and improvised shiny black spheres that some students brought to the workshop worked just fine (compare Goskar and Earl 2010).

This emphasises an important advantage of this technique. Very little equipment is of required and the equipment that is necessary, is lightweight and inexpensive, and thus expendable. This is of extreme importance for archaeological fieldwork conducted during expeditions to extremely remote locations. For example, Carlos Pallan and Nikolai Grube, as Maya archaeologists and epigraphers, work with recovered Maya epigraphic stone monuments. Because they are in very remote locations in tropical rain forests, there are certain specific problems with documenting them and their recovery. These artefacts have sophisticated carvings and, at the same time, are very prone to rain induced

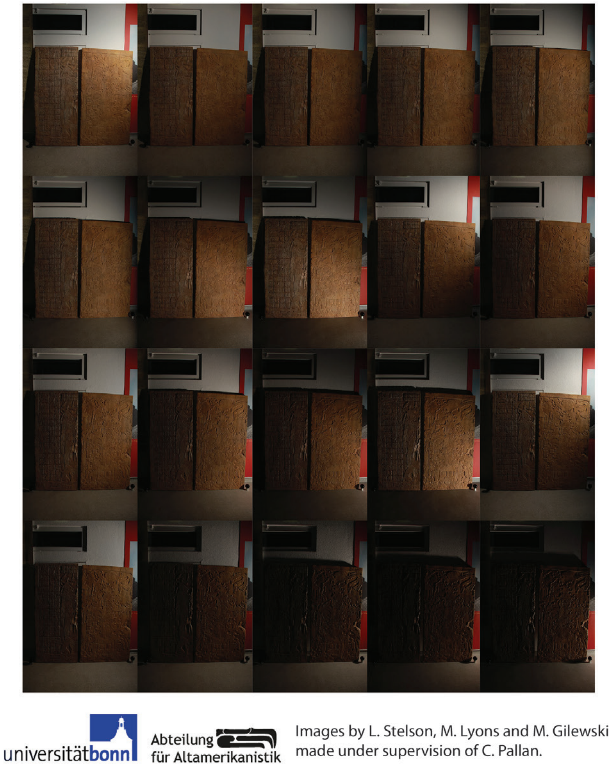

Figure 2. 20 (of 68 total) digital images (with various light direction) taken to produce the RTI image shown in Figure 1.

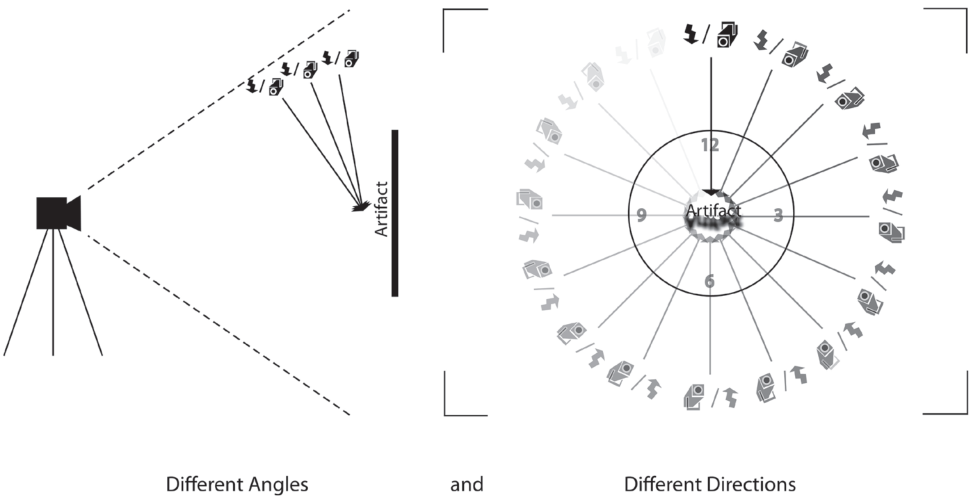

Figure 3. Photos has to be taken with light coming from different directions and angles. Drawing by M. Gilewski.

erosion. Maya epigraphy perfectly exemplifies a great comfort that RTI brings to the work of an epigrapher: not only does it greatly increase the visibility of inscriptions, but it also allows some portion of their work to be done remotely, out of the difficult tropical rainforest environment.

DISCUSSION

RTI use and Polish Archaeology

RTI technology is surprisingly little-known and rarely used in Poland[4]. While preparing this presentation, I asked a few photographers and archaeologists about their opinion on these techniques. Some noted that applying photogrammetric or laser scan-based 3D modelling and studying 3D models may be an alternative to RTI imaging. An anonymous photographer suggested that photogrammetry-based 3D modelling reproduces a similar level of details that is recorded with RTI and that 3D models may provide even better results. I would argue that RTI remains a viable alternative to those techniques because RTI is based on photography and raster images, and thus inherits certain advantages from traditional and digital photography.

Both 3D models and photographic documentation are interpretations and reproductions of reality. 3D models, even when done with laser scanning, are the results of large amounts of post-processing to achieve accurate results (e.g. Remondino and El-Hakim 2006). This is particularly true when archaeologists want to use these models for surface measurement (Remondino and El-Hakim 2006: 276-278). PTM makes it quick and easy not only to produce, but also view and share very adequate surface models (Earl *et al.* 2010: 220). This advantage stems from the fact that RTI is a type of photography. It is very clear how the image was framed and thus how it relates to the real object. Earl and his colleagues (2010) suggest that the use of photogrammetry based 3D modelling is complementary to PTM and that it is good to combine both techniques. They mention field research where they managed to capture a large 80 m rock art panel using photogrammetry based 3D modelling, while also producing PTM images (close-ups) of smaller fragments of the panel. They report that the PTM was very good for the analysis of smaller fragments and that great results can be achieved by comparing/combining PTM images with 3D models. They also demonstrate that high resolution 3D models can be used to create PTM images (see Earl *et al.* 2010: 221, for comparison of PTM and 3D model).

On the other hand, I would like to add that technical efficiency and the amount of reproduced details is not the only factor. While laser scan modelling and photogrammetry have different record different resolutions, the finest reproductions are still produced by using casts. However, casts, laser scans and heavy 3D modelling are resource-intensive and demand specialised and expensive equipment (laser scanner and computer workstations) for processing and storage, while RTI, is a very handy resource and cost efficient technique.

Slow Motion video - technical aspects

In contrast to RTI, serial images (in the form of videos) can be also used to document dynamic processes that are thought to be related to the material remains of the past. Archaeology frequently deals with dynamic processes, either when it is trying to reconstruct them, or when modern dynamic

[4] It seems that the only Polish researchers utilising this technique are my colleagues from University of Warsaw, Piotr Witkowski, Wojciech Ejsmond, Julia Chyla from El Gebelein research (Piotr Witkowski, personal communication, see "Polish archaeologists discovered an unknown temple of Hatshepsut" PAP News of Polish science).

processes are used to analogise past ones and thus, slow motion imaginge techniques (or high speed video) is a good solution.

Videography has a long history of application in social sciences (sociology and ethnography). It is used as a research tool for studying such dynamic processes as social behaviour and other similar phenomena (e.g. Beale and Healy 1975; Knoblauch and Tuma 2011). Slow motion video (or high speed videography) is a technique that has frequently been used in the past to study industrial endurance experiments and by athletes interested in studying their movements to improve their results (Vollmer and Möllmann 2011; Verrall *et al.* 2005). My literature survey indicates that the use of slow motion videos in archaeology has been very limited. Some videography and slow motion video was conducted in the past for documenting the movement and technical aspects of experiments with the use of the atlatl (spear-throwing devices) (Whittaker 2010). Additionally, some flintknapping experiments by Donald Crabtree were filmed in slow-motion for demonstrative purposes (after Beale and Healy 1975: 892; Marks 1975).

Put simply, slow motion video is a series of many pictures taken in a short period of time. These photographs are taken with a very fast shutter speed and at a high frequency. In regular videos, the number of pictures that are taken and then reproduced is 25 or 30 per second. In slow motion video, the video is reproduced at this speed of 25 or 30 frames per second (fps), but the frequency of pictures recorded is greater. This can range from 60 fps to millions of pictures being recorded per second (Motion Picture:: Cinema Time... 2014). As a result, when such video is replayed at the standard speed of 30fps, because many more than 30 pictures were taken, the playback of the recording will last much longer. The videos that I described below were shot at 1200fps, so a 5 second recording replayed at 30fps would be 40 times slower and thus run for 3 minutes and 20 seconds.

Slow motion videography is an extremely simple task for mechanical cameras that use analogue film. They can be easily adjusted to operate at high speeds. However, the use of analogue film makes it very costly. Unfortunately, digital equipment with such capabilities for long time remained extremely specialised and expensive until the not-too-distant past. Only recently have some models of consumer grade electronic cameras been given additional features for shooting slow motion videos. They are limited in terms of the resolution and the length of the clip that can be produced and stored in the camera, but many cost less than 250 euros. However, as proven by the case described below, even such inexpensive devices can be successfully applied for the documentation of archaeological experiments.

Slow motion videography in Archaeology – an example from South Guatemala

In August 2013, I supervised a small excavation unit in the National Archaeological Park Tak'alik Ab'aj in Guatemala. In the course of this work, an interesting find was uncovered. It was a cavity formed with borders of fired baked clay and filled with artefacts and stones including some showing charred surfaces and thermal fragmentation. Such finds have previously been recognised at this and other sites as the results of a fireplace. However, it was not precisely clear how the find had come to be, even though a very careful and reflective excavation procedure was undertaken. The research director of the project, Christa Schieber de Lavarreda, suggested an experimental recreation of the find. This was carried out by Jose Pineda and his workers. Other archaeologists (Carlos Espigares, Victor Flores, Geremias Claudio and the author) participated as observers. To create a visual documentation of this process, I produced various videos of it, which I will present in the following section. A Nikon 1 V1 series with a dedicated 1 Nikkor 10-30mm (F/3.5-5.6) interchangeable lens was used.

The experiment was conducted in field conditions next to the excavation unit. Firstly, the cavity was reproduced as a small model and a fire was set up with wood and then mostly traditional resins such as copal were used. The stones were also inserted at various times, some before the start of fire and some during the process. Stones inserted later in the process cracked and pieces of their surface would fragment at very great speed in multiple directions. Such rapid and forceful movements also meant that other material from the fireplace was ejected at high velocities (Figure 3). The spatial pattern of the deposition of fragments that were later found was recorded by Jose Pineda. The process proceeded very quickly, and I started to use the slow motion recording function of my camera to capture it. Specifically, I recorded the moments of surface fragmentation of the stones.

Slow Motion - Discussion

In this paper, however, I would like to argue that the presented case is a good example of how slow motion videos can be used in archaeology. Slow motion video allows archaeologists to observe rapid phenomena occurring in the experiment. Some important portions of the process lasted approximately 0.075 seconds, which makes them extremely difficult to observe with the naked eye. The video also allowed for measuring the timing of those phenomena, and thanks to the video, it is clear how much material was blown out of the fireplace and in which directions (Figure 4). My colleague, Miguel Medina, noted that such spatial patterns of stone fragments deposition have been observed in other locations at the site, often in contexts where no other fireplace was found. He suggested that they might be explained as fireplaces that had been carefully cleaned up and removed. However, tiny fragments that dispersed at great speed could not be located. Even the ten observers located at the experiment area could not see where they went.

Slow motion videography seems to be a very promising technique for documenting archaeological experiments. I must admit that I had never thought about the use of such a technique in archaeology. However, I became interested due to my above-mentioned experience where the technique proved to be a very adequate method of documentation.

After some time, I came to the conclusion that this method of documentation can be useful for many types of experimental archaeology. Thanks to the technological developments and great reduction in cost, this technique may be applied more often. Studies of lithic tool technologies are a perfect example. The production, sequence and even the movements can be carefully examined. A very large amount of research is done through the experimental recreation of artefacts. Some portion of the research relates to the movements involved in the production of such artefacts. Slow motion videography, often used by athletes and their coaches to study their own movements, may be a perfect documentation technique and research tool for such studies.

I also believe that the ability to replay and re-experience the experiment multiple times and also at a slower pace, is also highly relevant to archaeological experiments. T here is a good custom among archaeologists to promote careful and thoughtful work for even the most basic procedures of data recording. Slow motion videography is in line with such ideas. It facilitates more reflective and insightful analyses of archaeological experiments.

CONCLUSIONS

Overall, it must be said that RTI and slow motion are very efficient ways of documenting and analysing archaeological data. These techniques represent a great advantage to archaeology as the highly sophisticated and specialised results each relate to a specific field of archaeology and to a specific category of data, and furthermore, they are simple to use and readily available.

Of course, it must be understood how these techniques are meant to be used. All techniques should be applied carefully, with a good awareness and understanding of their applications. RTI is a very good technique for documenting artefacts with carved or non-flat surfaces. These photographed surfaces

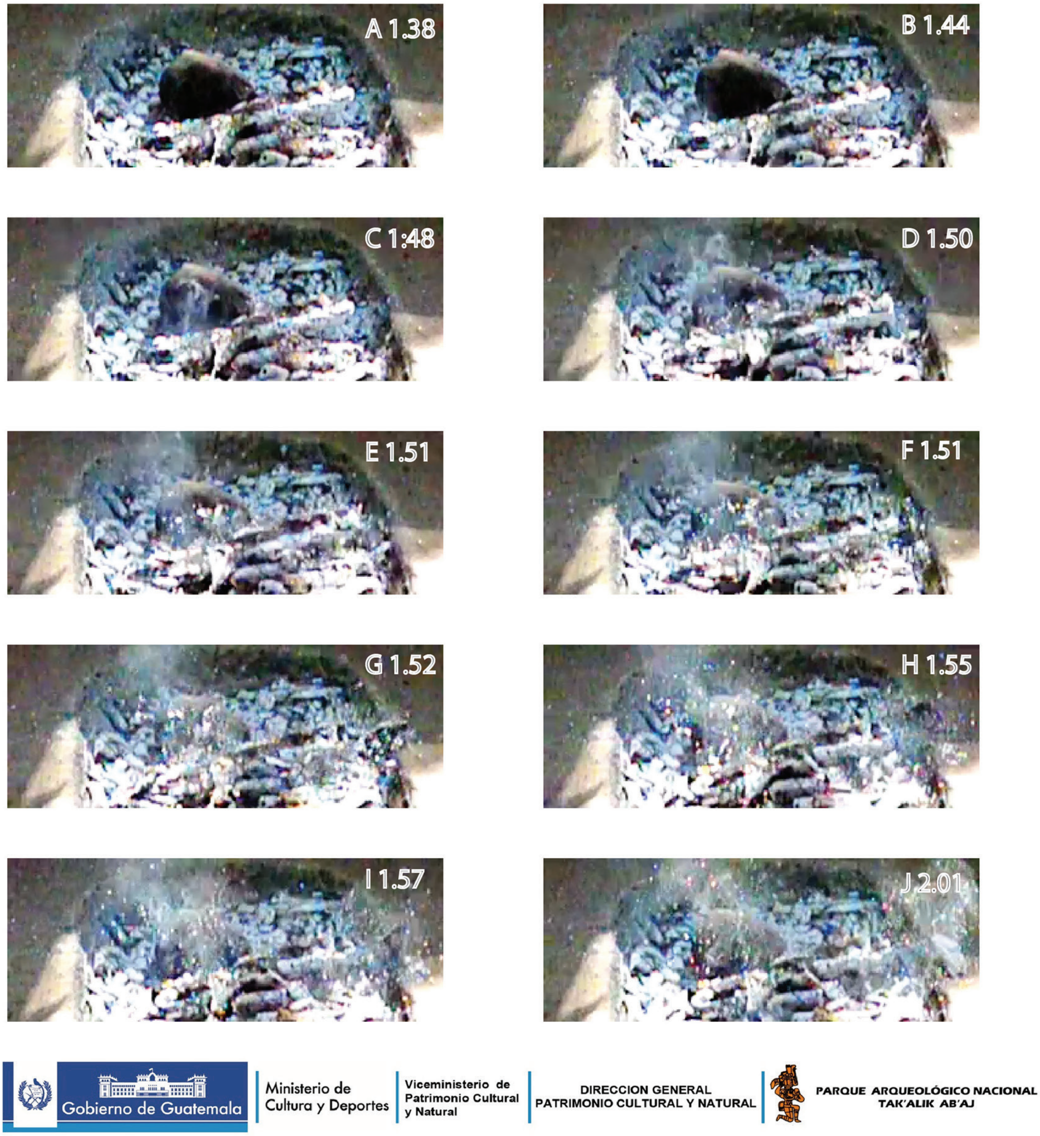

Figure 4. Selected still frames from slow motion video of an archaeological experiment presenting a rapidly occuring phenomenon (c-j). Author Michał Gilewski,courtesy of National Archaeological Park Tak'alik Ab'aj (Ministry of Culture and Sports of Guatemala).

can be carefully studied on a computer while the produced imagery keeps the aesthetic values of conventional photography.

Slow motion is an excellent aid for measuring, interpreting and understanding archaeological experiments that deal with dynamic processes. Slow motion is not the best method of videography to document the slow and already lengthy process of excavation.

When applied with appropriate goals in mind, these techniques may yield great results. They can allow greater amounts of information to be recorded and used in the process of analysis, making archaeological interpretation richer and sounder.

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