Making Digital Top Plans: A Pilot Test of the Overhead Photographic System Used At Karsola 2011-12

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Introduction:

Plans and photographs are essential components of archaeological documentation. Each preserves contextual relationships between cultural materials encountered during an excavation. Unfortunately creating precise top plans by hand in the field can be a drain on an excavation's time and resources, limiting the area that can be accurately recorded. This paper discusses a new way to generate precise plans and photographs that requires less time in the field and yields more flexibility during analysis. Archaeologists have made major improvements to techniques for collecting overhead photographs of archaeological features during excavation (Schlitz 2004). In addition, advances in digital image processing makes removing lens distortion, improving the quality of images, and creating rich mosaics simpler and more efficient than it was in the past (Akar 2009).

This year at Karsola (Shinde and Sengar in press), we assembled a system that takes advantage of these developments. Our system reduced the need for costly hand-drawn illustrations, allowing us to produce digital imagery that could be converted into illustrations when needed. It is efficient, stable, and cost effective. Though we are in the process of refining and improving it, our initial results are promising. We have been able to produce accurate, scale illustrations from our overhead photographs. We were also able to produce accurate overhead photo mosaics and create georeferenced raster layers in ArcGIS. It is our hope that our preliminary results will inspire others to begin experimenting with these techniques on their own projects.

Overheard Photography at Archaeological Sites

Since the birth of the discipline archaeologists have drawn upon new technologies to visually record their sites. By adapting surveying techniques from geography and cartography, early archaeologists created detailed illustrations and plans during their initial work in the Near East (Fagan 1979) and South Asia (Possehl 2002). As photography developed, archaeologists quickly adapted it for documenting sites.

Verhoeven (2009) argues that archaeologists have been producing overhead views of their sites since the 1890's, when Giacomo Boni produced a plan image of the Roman forum using a camera attached to a balloon. Similar methods remain an important tool for archaeologists in South Asia, as Jansen (1984) and his team demonstrated with balloon photography during their work on the surface of Mohenjo-daro.

At Karsola, we wanted to develop a system that provided a high degree of control over the camera's location and produce predictable overlap between images. There are many effective techniques for creating such images that draw upon devices that are stabilized and controlled from the ground (Myers 1990, Poulter and Kerslake 1997, Schlitz 2004, Sterud and Pratt 1975, Verhoeven 2009, Whittlesey 1975). These systems maintain a camera's position at a fixed point, and can thus be used to systematically photograph a desired feature through a series of shots (Schlitz 2004). They need not be expensive and typically require few people to operate.

Whittlesey (1975) is one of the earliest advocates of bipedal photographic systems for the creation of overhead mosaics. Horizontal excavations are ideal subjects for overhead photographic techniques, which cover a large area quickly and accurately. Whittlesey's apparatus stands on two arched legs that are supported a camera on a crossbeam at their apex. The camera can be moved into two positions by adjusting the top bar. Like subsequent systems based on its design, Whittlesey's bipod is easy to move and adjust and can be operated with minimum labor.

Digital photography has greatly enhanced the utility of such devices. It is cheap; a thousand digital images can be produced for a fraction of the time and resources as a single analog print. Digital images can be imported directly to a project's information infrastructure (Verhoeven 2009). This makes a variety of tools, such as ArcGIS, Adobe Photoshop, and Adobe Illustrator immediately available for post-processing. Digital images are also easier to share and distribute, making it possible to conduct collaborative research even when members of a project's team are on other sides of the planet. Advances in the software that powers Adobe Photoshop and ArcGIS make it simple to remove lens distortion and georectify overhead shots, which can then be added to a Geographic Information System (GIS). In sum, digital photography is one of the fastest and most precise methods of collecting data on the spatial relationships between exposed artifacts and features.

Mr. Murat Akar (2009), the senior field supervisor at the Alalakh Excavation in Hatay, Turkey, has made improvements to the bipedal photographic system by simplifying its design and incorporating the advantages of digital photography. He has written a detailed overview of the Alalakh system at www.alalakh.org, and encourages other projects to adopt and improve the system. The Alalakh Photo System consists of two light aluminum rods that are 9 meters in length. They are pointed on the bottom and joined by ropes and a metal cable at the top. When deployed, they are positioned on either side of an exposure to be photographed. The metal cable provides a track for a pulley attached to a camera box that can be moved back and forth by pulling ropes attached to either side. Another set of ropes attaches at the top of each rod to provide tension, pulling the support cable tight. The system requires eleven people to operate; three stabilize each of the support rods, two manage the control ropes and two manage the tension ropes. The DSLR housed in the camera box is triggered using a remote control. The resulting photos are then processed in Adobe Photoshop and added to the site's GIS.

The Karsola Excavation

The Karsola Excavation Project took place during the 2010-11 Season. It was a joint endeavor by Deccan College Postgraduate Institute of Archaeology and the Archaeological Survey of India's Institute of Archaeology, directed by Professor Vasant Shinde and Professor P. B. S. Sengar. The aim of the Karsola Project was to address some of the research questions raised during the last season at the nearby Harappan site of Farmana. Karsola was chosen because surface work produced a collection of Mature, Late Harappan, and Painted Grey Ware (PGW) ceramics, suggesting that the site may have been occupied during a transition period between the Harappan and PGW Periods. The directors wanted to test an interpretation asserted by J. P. Joshi based on his excavations at Bhagwanpura (Joshi and Madhu 1993). He argued that there was significant overlap between the Late Harappan and PGW Periods. The Farmana Project had already provided some data on the development of the Mature Harappan in the Ghaggar Basin (Shinde et al. 2008); it was hoped that excavations at Karsola would help fill out the sequence. Additionally, Karsola was almost entirely intact.

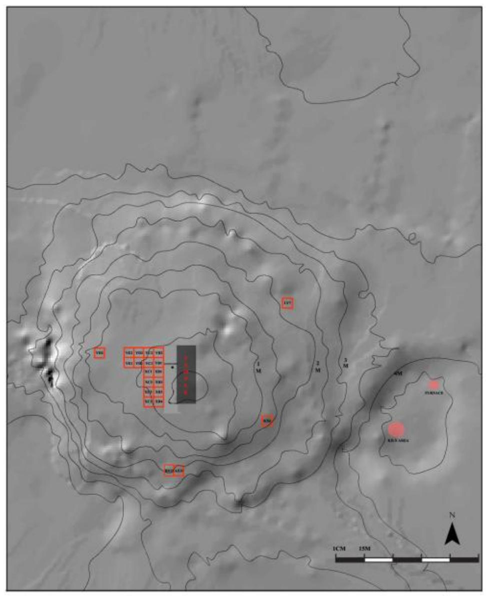

Figure 1: DEM and Contour Map of Karsola Kheda, with Trench Locations and Features Labeled. From Shinde and Sengar (in press)

The site of Karsola (Figure 1) consists of a low mound spread over approximately 17 hectares. It is near the village of Karsola in the Julan Tehsil of the Jind District in Haryana (Shinde and Sengar in press). The mound rises to around five meters above the level of the Ghaggar Basin flood plain. The surface of the mound is covered with Protohistoric Artifacts, including ceramic assemblages as well as carnelian and terra cotta beads and animal bones. When the team began work, the mound was almost entirely intact, save for some small pits the villagers had dug on the surface to plant trees or dispose of rubbish. A small Hanuman Temple is also located on top of the mound, along with a water reservoir, bathhouse, and several small garden plots.

East of the main mound, farmers were in the process of leveling a portion of the mound to improve the flow of water to adjacent fields. They used tractors to loosen large tracts of soil, which was then removed from the site. Unfortunately, similar forms of site destruction are common in Haryana, (Shaffer 1987, Shinde 2010, Shinde et al. 2008), further necessitating the development of tools that can be used to rapidly record spatial data.

As this was the opening season at Karsola, a large horizontal excavation area was established west of the temple. To the south, east, and north of the horizontal exposure, index trenches were established to sample all the different temporal periods during which the site was occupied. These types of exposures provide an ideal environment for working with bipedal overhead photography systems.

Developing the System

The overhead photographic system we developed at Karsola was modeled on the one used by the Alalakh Excavation. We planned to use the system to make top plans and photo mosaics of one or more 5x5 meter trenches as features or occupation phases were exposed. As such, it was necessary to lift and hold a camera that could be operated remotely over an excavated trench.

To help assemble the system, New York University donated a Nikon D3000, an entry level DSLR with an 18-55mm kit lens. The D3000 is a robust camera that can be purchased for around 25,000 rupees. The body of the camera comes with all of the features necessary for producing sharp overhead images, as well as an automatic self-cleaning feature for the image senor. Its kit lens comes with an auto-focus that takes advantage of the software Nikon supplies in the D3000 body. The lens also has vibration reduction, which stabilizes the lens to produce sharper images. The most important component of the DSLR is a remote-operated shutter setting.

Note that any DSLR could be used in an overhead photographic system, so long as it can produce clear images in non-ideal circumstances and can be operated remotely.

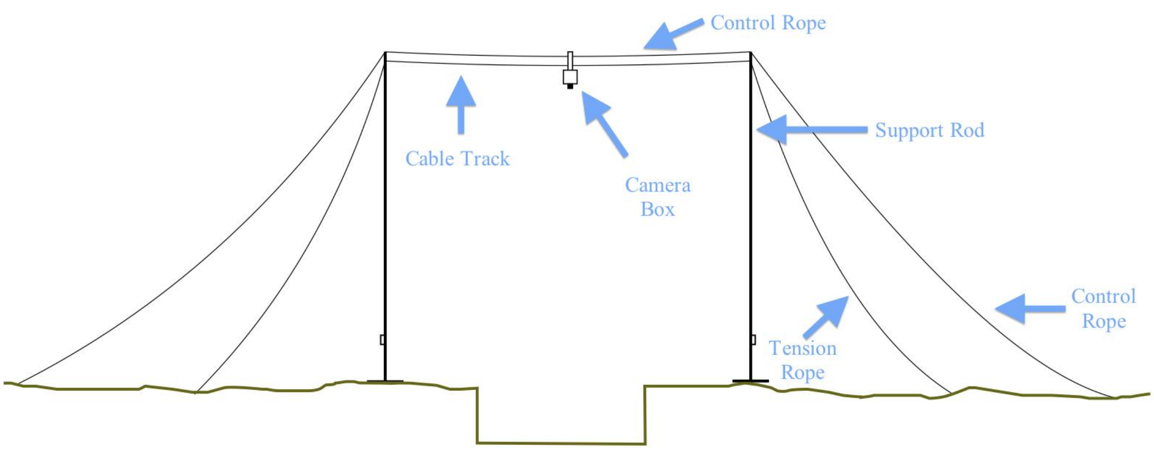

Figure 2: Schematic of the Karsola Overhead Photography System

Figure 2 is a schematic of the system we used at Karsola. It consists of a bipedal apparatus that suspends the D3000 around 9 meters above the surface of the mound. It was assembled by myself and Mr. Nilesh Jadhav, a PhD candidate from Deccan College. The total cost of the system, minus the camera and software, was around Rs 2000.

No aluminum was available, so we constructed our system from iron. Its support rods are made of iron pipes cut to 9 meters in length. On one side of each pipe is a square metal bracket approximately 1 meter up that serves as a handle for lifting the apparatus. At the base of each pipe is a short horizontal bar that provides a foothold for stabilizing the system after it has been lifted. As they are made of iron, the support rods are heavy and require two to three people to stabilize. However, once they have been lifted, they are extremely stable and are not prone to bending or shaking.

We had initially planned to use a steel cable as a track for the camera, but this material was not available, so we used a 12 meter length of fiber optic cable sheathed in plastic. We found to our satisfaction that the plastic sheath reduced the friction between the cable support and the camera box, obviating the need for pulleys. Our camera box simply slides back and fourth along the camera support. Instead of permanently attaching the camera track to the tops of the support rods, we tied the cable to the tops of the rods whenever we wanted to use the system, allowing us to adjust the length of the track based on the exposure that we wanted to photograph. For large exposures, we could extend the cable almost 11 meters; for smaller exposures, we could tie it off at 7 or 8 meters for added stability.

Opposite of the cable track, we attached tension ropes to each of the support rods. Once the support rods had been lifted, these ropes could provide tension to the top of the support rods, which would otherwise be difficult to stabilize at that height. This simple innovation was developed by Sterud and Pratt (1975) for their bipedal system and incorporated into a broader design by Akar (2009). It allows us to simplify the design of the whole system, removing some ofo the complicated components used to support Whittlesey's system.

Above the tension ropes we attached a set of control ropes, each running from a team member on the ground through a track at the top of the photo system to one side of the camera box. As the cable support supplies minimal friction the to camera box, these control ropes could easily move the camera box back and forth so long as their operators acted in concert.

Figure 3: Camera Box, Photo by Aadil Brar

The camera box was made by a carpenter in Karsola village. It is made of light plywood cut to the dimensions of the DSLR. Its base is made from a small sheet of thin acrylic with holes for the camera's lens, part of its body, and the sensor that operates the remote shutter. When positioned inside the camera box, the D3000 hangs vertical, allowing it to capture exposures at 90° from the ground. The top of the box consists of a mast that connects to the fiber optic cable in the middle and the control ropes at the top.

Operating the System

Once the crew had practiced a bit, operating the overhead photographic system was easy. The biggest constraint was time of day: ideal lighting conditions for field photography of any kind are in the early morning and just before sunset. At these times, soil contrasts are clear and there are minimal shadows in the trenches.

Once a feature had been identified for photography, we carefully cleaned and leveled the trench and set time aside to take the photos. For simple illustrations no additional preparations are necessary, though it is useful to measure visible features to control for accuracy in the photos. For scale mosaics, control points must be established to rectify the image to a geographical coordinate system. In a systematic excavation, the corner pegs of the trenches can be used by collecting their three dimensional coordinates using a total station. It is also helps to establish additional control points by creating tags in the trench that can later be identified in the photographs. Control points should be spaced evenly throughout the trench. This step only takes a couple of minutes to complete.

Once control points have been established, the team sets up the photo system for operation. The photo system takes approximately ten people to operate safely. A support rod is placed on either side of the feature or trench that is to be photographed. Two or three people wait at the base of either support rod to help left it. The cable is then run through the camera box and tied to the top of either support rod. The control ropes are attached to the box at the top and strung through the top of the rods. The end of each control rope is placed at either side of the apparatus in line with the rope on the other side. Tension ropes are then attached to the top of either support rod; their ends are placed between the base of the control ropes and the base of the support rods. It is important that the bases of the rods and ropes all form a single straight line extending from either side of the trench or feature to be photographed.

The camera is placed inside the camera box after ideal exposure and focus settings have been inputted. The camera is also switched into a remote shutter mode. An ideal zoom is selected for the lens. After some experimentation, we decided to take most of our photographs at the 24 mm focus level. At this level it takes around three photographs to cover a 5x5 meter trench. Higher zoom settings produce less distortion, but require more shots to cover the entire exposure, which can be difficult to stitch together. Camera settings need to be adjusted according to the requirements of the subject of the photographed; if smaller features are the subject of the shot closer zooms can be used, but if entire trenches are to be stitched together middle zoom settings tend to work better. The camera box is then held above the ground until it is lifted into the air by its cables.

Once the system is fully assembled and everyone is in place, those operating the support rods slowly lift the apparatus into place. When the control rods are vertical one person stands on either of the footrests and holds the support bar. The tension ropes are then pulled taught, and the camera box may be moved back and forth using the control ropes. At the 24 mm zoom level, the camera should be moved to either side of the trench, a number of shots taken, and then to the middle. Plenty of overlap ensures a better mosaic once everything has been stitched together.

The whole process rarely takes no more than ten or fifteen minutes for a single exposure, and all image processing was undertaken outside of excavation hours at the field camp on crew laptops. Once the photos have been produced, a number of different processes can be undertaken.

Pit Illustrations in LY7

One of the simplest uses of the overhead photo system is the rapid production of accurate feature illustrations. This process does not require the use of control points, and the only software required to undertake it is Adobe Photoshop and Adobe Illustrator.

This is one of the first photographs we took using the system. Early during the excavation season the northernmost index trench produced a cluster of circular pits filled with Early Historic pottery. We decided to produce a basic illustration of the pits using the system. As such, no control points were used, though we did measure the pits beforehand and placed a scale in the neighboring photograph to assist in confirming our results.

Figure 4: Western half of LYZ showing Early Historic Pit Cluster

Figure 4 is an overhead shot of the west side of index trench LY7. Note the exposured pits in the northwestern quadrant of the trench. This photograph was captured at the 24 mm zoom level and depicts approximately one third of the trench. It was then adjusted for barrel distortion using Adobe Photoshop. This photograph was not taken during an ideal time of day, which resulted in shadows falling across some of its features, but all of the desired detail was recorded.

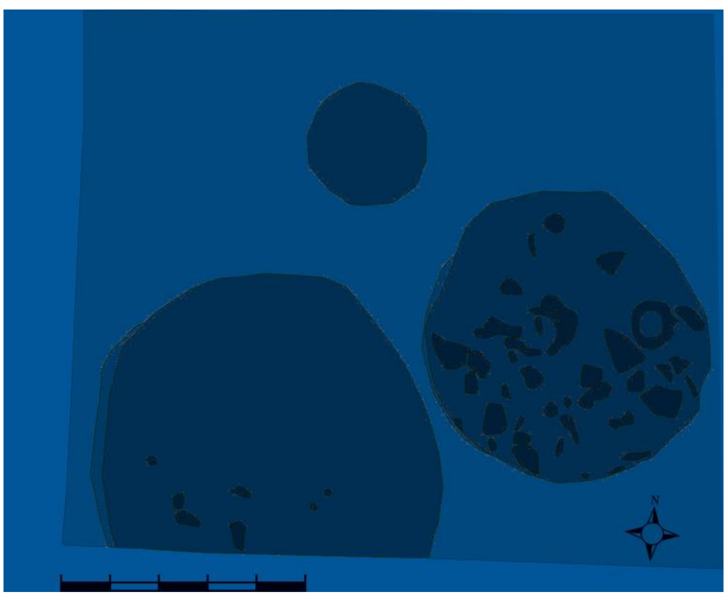

Figure 5: Illustration of Pits made using photograph

After removing lens distortion, we produced this illustration of the three pits using Adobe Illustrator by tracing pottery fragments and the pit's edges. This process took about 20 minutes. This basic illustration highlights the relationship of the pits to one another and to the edges of the trench. A scale bar was added by superimposing it on the scale provided in the neighboring photograph after lens distortion had been removed. Any variety of shading techniques or colors could be added to facilitate interpretation of the image.

Documenting the Off-grid Kiln Features

Fieldwork in Haryana is often a race between the archaeologist and the farmer. This season we were placed in the unfortunate position of having to hastily record a number of features that were under threat. While we were conducting systematic excavations on the west side of the mound, local farmers were leveling a portion of the east side of the mound. As they were cutting through the mound they came upon a number of archaeological features. After notifying Mr. Kanti Pawar of what they found, they offered to suspend their work for a short time so that we could document them before they were completely destroyed.

The most important of these features was a series of burnt circular clay features that may have belonged to a kiln complex in the past. There is a full discussion and description of these features in Shinde and Sengar (in press).

When the farmers notified the team of the features' existence it placed us in a difficult position: they were located over 150 meters from the gridded excavation and had been cut in half before they were identified. Still, their burnt walls suggested that they may have been kilns, and their clustering suggests intensive use. We wanted to collect information on the features before they were destroyed, so we recorded their three dimensional coordinates in reference to the site grid and conducted a quick systematic excavation. We also took some overhead shots to document them before and after excavation.

Below is the first round of photographs we collected. The circular feature that has been halfway exposed has an ashy interior filled with large early historic pottery fragments and burnt clay walls. The others have not yet unexcavated, but their location in relation to the central pit is clear.

The next photograph was taken after the pits had been excavated. This series of overhead shots did not turn out as well as hoped. Due to time constraints, we had to take them as the sun was setting, and the lower light levels produced a small amount of blurring. However, they are properly georectified and have been entered into the site GIS, so it is remains possible to consider their relationship to features that we were able to properly recorded in the gridded excavation. Additionally, distortion has been removed so even the blurred images may be used to produce illustrations.

Figure 6: Features after their initial discovery

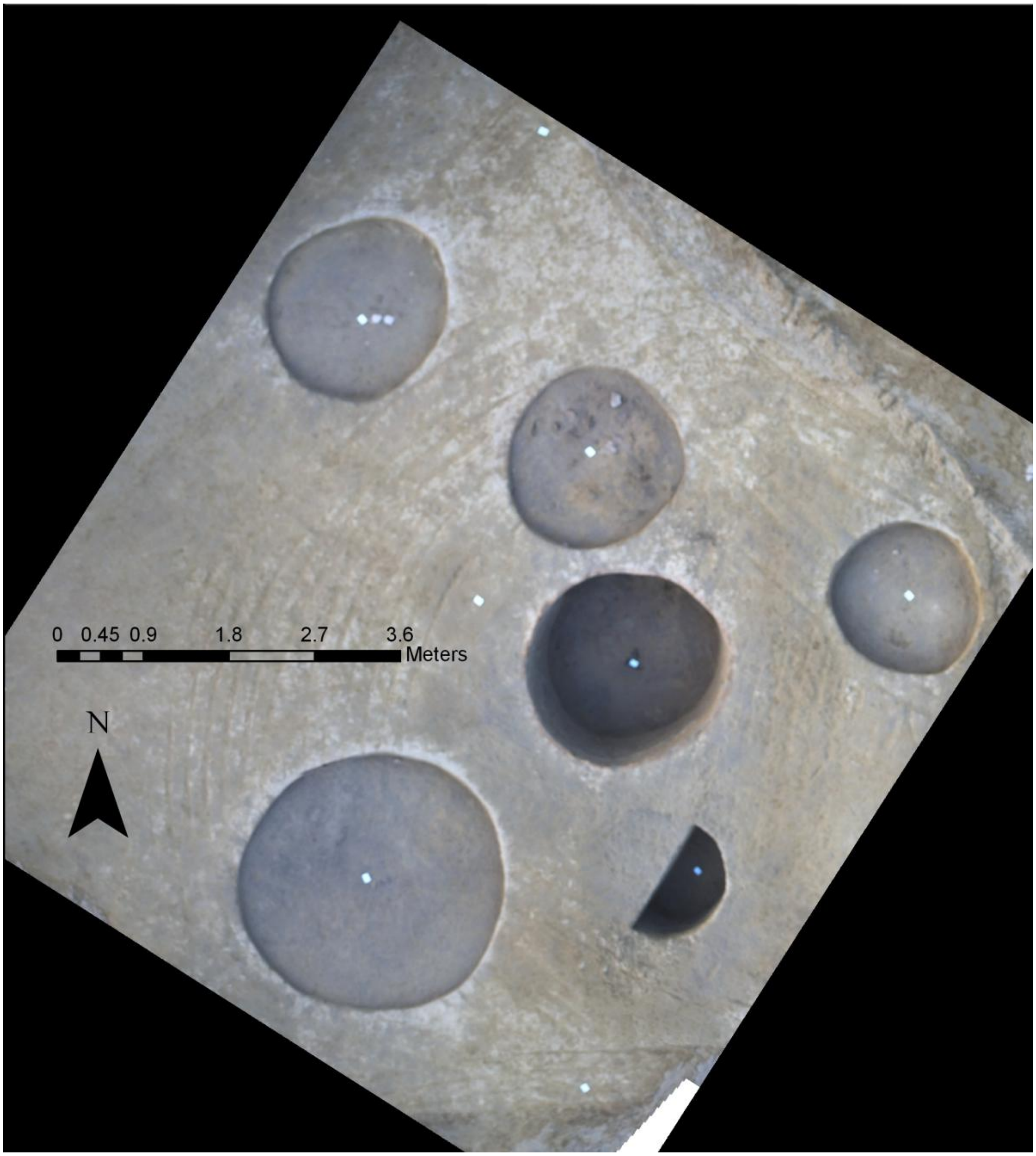

Figure 7: Rough mosaic after excavation

Georectified Trench Plans

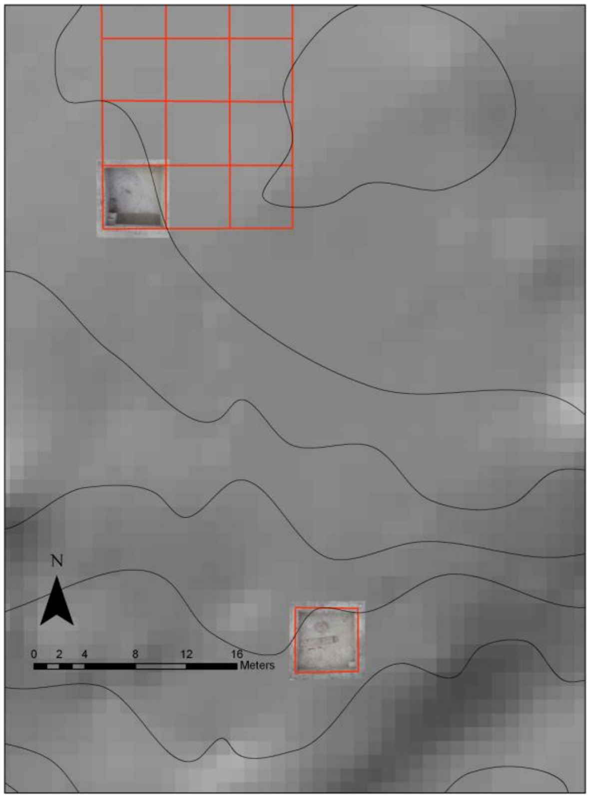

Figure 8: Mosaics of Excavated Features Georectified and Added to Site GIS

The system's most important ability is to provide georectified overhead photos and plans for the site's GIS during excavation. At its full capacity, the system could be used to create georectified photographic mosaics of exposures and features that can be analyzed in reference to other data from the site. Eventually, as we move toward a fully digitized workflow, it will be possible to conduct detailed contextual studies involving artifact density, mound topography, architecture and other parameters in the field as we excavate. Capturing overhead images allows us to create rapidly create plans of excavated features in the field, and creating digital top plans in the field is an important step towards fully digitizing excavation data as it is produced, speeding interpretation and publication.

The following is an example of this process. One of our trenches in the main horizontal excavation west of the temple produced a large, circular feature with multiple layers of floor material, including plaster remnants and ash. Once we had exposed the entirety of this feature, we decided to document it with a series of overhead photographs. As this feature was excavated on the grid, it was a simple task to georectify it and add it to our GIS.

Figure 9: Georectified trench with circular floor feature. Photo series collected by Mr. Nilesh Jadhav

This image is was produced using a series of three photographs taken at a zoom level of 24 mm. The images were then stitched together using Adobe Photoshop. In the process, barrel distortion was removed, and the exposure level of each photograph was matched to its neighbors. The resulting mosaic was saved as a .tif, and imported into our GIS using ArcMap 9.3.

For this image, we used only the center of the trench and the four corner pegs as control points. After rectifying it, we measured known features in order to assess its accuracy. We found that this image is accurate to just under 3 centimeters. The circular feature is clearly visible, and should we decide to create mosaics for the surrounding trenches we could create a mosaic for the entire occupation level. Alternatively, the images could be opened in Adobe Illustrator to trace accurate publication quality illustrations of the circular feature.

Figure 10: Georectified trench with furnace and possible drainage canal. Photo series collected by Mr. Nilesh Jadhav

This image (Figure 10) was created using the same procedure as the above photograph. This pyrotechnical feature was identified in the index trench to the south of the main horizontal exposure. In is located next to a sort of drainage canal that may have been used for water to quench metal during metal production.

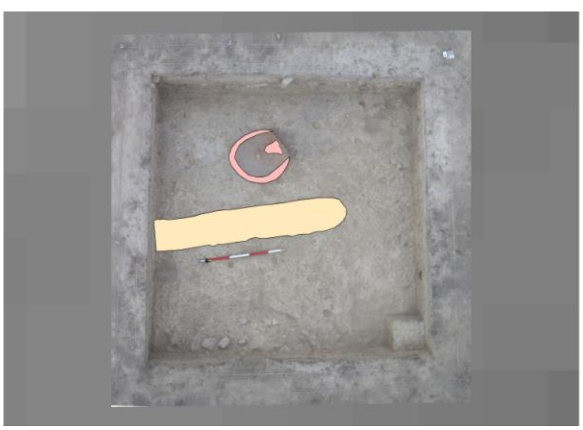

Figure 11: GIS layers for polygons representing the furnace and drainage canal

The primary advantage of this technique is that the raster data can be used to rapidly trace important features and artifacts in a georectified environment. The resulting shape files are already in the database, and can be used for subsequent contextual analyses. Though we have not yet processed enough of this imagery to conduct one of these contextual analyses, we have taken these initial steps as a test of the system, and as more materials are exposed, it is a simple matter to add them to the digital environment that has already been developed for the site.

Summary

To summarize, the Karsola Overhead Photographic system represents an important step toward a streamlined digital workflow that saves time in the field, allowing the rapid production of accurate archaeological illustrations, beautiful overhead mosaics of archaeological features and exposures. This work was possible in the field, and only required suspending excavation in a particular area for the ten to fifteen minutes it takes to produce a series of overhead images. The system can be adapted to a variety of field and time constraints. During our first season with the system we produced a number of illustrations, panoramas, and GIS layers that aided our understanding of the site and provided a foundation for future work. We will continue to improve and refine the system, integrating it into our excavation procedures to save time and speed interpretation and publication. I have tried to describe the system and the procedures for processing its imagery in as much detail as possible, in hopes that others will adapt it to their own sites and use it where possible. I will be happy to provide further details should anyone contact me with questions, and I would also like to again refer people to Murat Akar's write up at www.alalakh.org for further information.

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