Preliminary Stages in the Development of a Real-Time Digital Data Recording System for Archaeological Excavation Using ArcView GIS 3.1

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Introduction

This paper describes the development of a system for real-time recording of archaeological excavation into an ArcView GIS 3.1 database. While the accomplishments described in this paper are largely methodological, excavation of the site is still in progress and aspects of the system are still evolving. However, we wish to highlight exciting new developments in the way that archaeological excavations can be recorded. We are confident that the methods described here could be applied to nearly any excavation context. We will discuss real-time digital data collection methods as they have been and continue to be applied to the excavation of a stratigraphically complex Archaic high-elevation site from the south-central Andes in Peru named Jiskairumoko.

The site of Jiskairumoko was first discovered in 1995 during an archaeological survey of the region directed by Aldenderfer (Figure 1). He initially recorded the site based on the presence of surface artifacts that were diagnostic of the Archaic Period. Projectile points from the Early, Late, and Terminal Archaic were all found on the surface. Formative projectile points and Late Horizon ceramics were also observed along with some collapsed stone walls and what appeared to be the remains of a corral.

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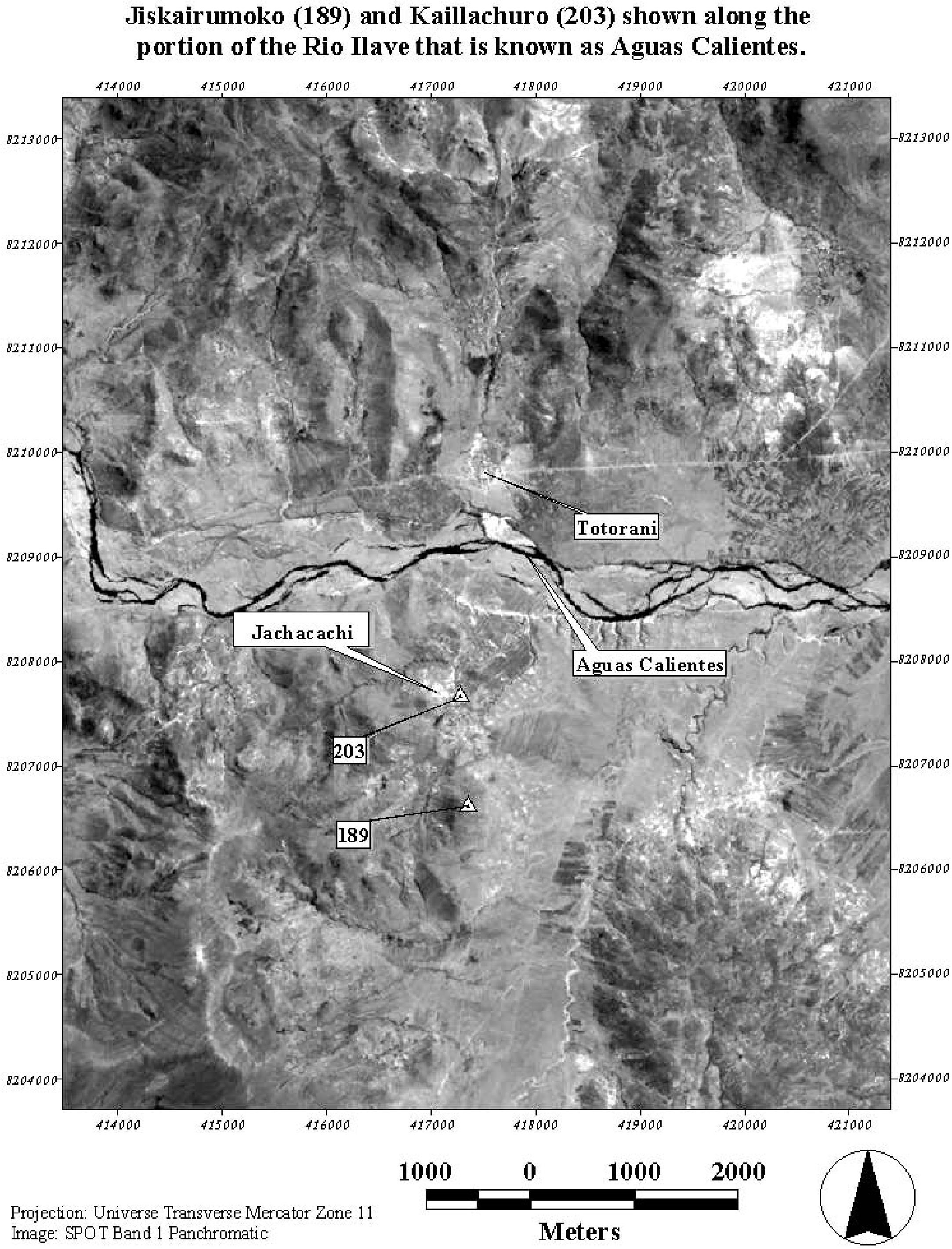
Figure 1
The location of Jiskairumoko is shown here as site number 189. The site has been plotted on a georeferenced SPOT Band 1 Panchromatic image.



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One of the key theoretical questions driving the excavation of Jiskairumoko involves investigation into the kinds of social changes that occur when domesticated camelids and plants are incorporated into the economies of societies in this part of the Andes. We sought to know more about the nature of the hunting and gathering societies that existed prior to the incorporation of these domesticates as well as to develop a more refined picture of the agropastoral societies that inhabited the region after domesticates became central economic resources. While these theoretical questions are what primarily drive the project, we saw that addressing social dimensions of these questions would require extremely high-resolution archaeological data. In an attempt to recover the highest quality archaeological data possible, we also sought to tackle some significant methodological problems as part of this project. Specifically, we sought to develop a system for constructing extremely accurate computer models of archaeological sites in real time that would be tied to a database allowing researchers to retrieve information about various portions of the deposit.

The information recovered from archaeological excavations is highly spatial in nature (Aldenderfer 1991, 1998). Horizontal associations and vertical relationships that are recorded during excavation are fundamental to how archaeologists develop an understanding of the past. Given the highly spatial nature of archaeological data, GIS is a logical choice when attempting to envision the kind of computer database that would be used to store this kind of information.

Modern Archaeological Site Excavation Technologies

One of the features of modern archaeological research is that many different kinds of data are relied on or collected during the process of excavation. Data collection or sources of data relied on to build information about a site increasingly are in digital form. These sources of data may include use of

- Space-borne remote sensing detectors for aiding in the establishment of a site within the larger landscape context.
- Geophysical survey instruments for subsurface remote sensing. These may include magnetometers and ground-penetrating radar instruments.
- Electronic total stations for mapping of both surface features and features exposed during excavation.
- Digital cameras for photographic documentation of excavation.

These methods of data collection improve our ability to rapidly and accurately record a deposit during the process of excavation. Space-borne remote sensing permits us to view a site and its surroundings from a perspective that is not obtainable from the ground. Geophysical instruments give us a view below the surface that allows us to guide the prospect of excavation. Total stations permit extremely accurate and rapid collection of spatial data, and digital cameras permit excavators to review photographs in the field so that one can be assured of the photographs' quality.

Each of these pieces of equipment significantly improves the process of site excavation by enhancing the means by which these data categories can be combined during the process of excavation. However, finding ways of using these different kinds of data together expands the scope of recording even further. In using traditional paper methods of recording site excavations, even when these other automated data collection devices are employed, it is difficult to synthesize disparate sources of data so that the information collected by these devices can truly be capitalized on.

If one develops a field strategy where the results of excavation are recorded directly in digital form, there are expanded possibilities for incorporating different sources of digital data. Use of ArcView GIS 3.1 has permitted us to incorporate data from each of the different sources of data described above. The ability to incorporate data from different sources permits forms of visualization and analysis that are simply not possible with traditional methods of field recording. We must emphasize that the system we are describing is only in the initial stages.

Digital Data Collected at Jiskairumoko

The HLA methodology has developed from the seminal work carried out in Cornwall (Herring 1998), which mapped the landscapes according to "Historic Character Types," a paper-based exercise. Work in Scotland further developed the approach by mapping "Historic Landuse" using a geographic information system (GIS) (Dyson–Bruce, 1998; Dyson–Bruce, et al, 1999). Wales defined a "Register of Landscapes" of specific or outstanding interest (Cadw, 1998). English Heritage (EH) has used a wide variety of paper or increasingly GIS-based methodologies to determine "Historic Landscape Character" in different counties (Fairclough, 1999).

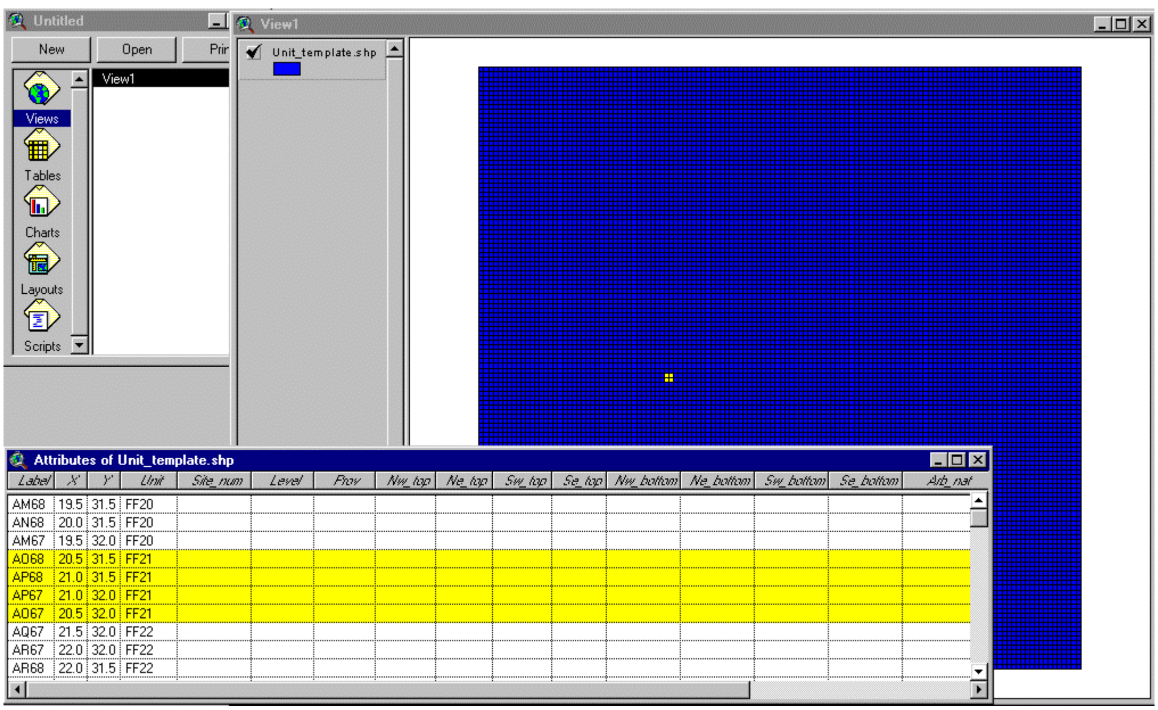
Topographic mapping of the site was completed by Aldenderfer in 1997 as part of the process of recording the site. The topographic data was collected with a Topcon total station. Initial topographic maps of the site were created using the Surfer software package. However, when we decided to develop a real-time digital data recording system that would revolve around the use of ArcView GIS 3.1, we re-created the topographic map in ArcView GIS so that the elevation data could be used in concert with the other forms of data that had been and would be collected. The topographic data from the Topcon total station was subsequently imported into ArcView GIS as an array of points and then converted to a grid format using the Spline interpolator. Once in grid form, it was possible to interpolate contour lines.

A magnetic survey had been conducted at Jiskairumoko in 1997 using a Geometrics G-858 cesium vapor magnetometer. Initial processing of the survey results in Surfer indicated the presence of several magnetic anomalies typical of soil that has been heated or baked. Previous excavations by Aldenderfer (1998) at Asana, another south-central Andean Preceramic site, had exposed heat-treated house floors. Initial test excavations at Jiskairumoko in 1997 discovered similar house floors that were spatially associated with the anomalies seen in the magnetic survey. Further examination and subsequent processing of the magnetometric data in ArcView GIS 3.1 (described below) showed that there were several other anomalies that were distributed throughout the area of the magnetic survey covering an extent of about 50 m east-west by about 60 m north-south.

In 1999, Aldenderfer obtained an equipment grant from the National Science Foundation to develop a system for digitally recording the results of archaeological excavations in the field. As a result of this grant, Aldenderfer was able to purchase five Fujitsu Stylistic 2300 pentop computers and two Nikon CoolPix 950 digital cameras.

We returned to Jiskairumoko later in 1999 to further explore the social changes related to the incorporation of domesticated plants and camelids into the diet, wanting to improve the way in which archaeological data was collected so that we could attack this anthropological problem in new ways. Preparation for fieldwork involved the construction of a site matrix in ArcView GIS. This matrix would serve as the coordinate system and organizational scheme around which the excavation would take place. To construct this matrix we used the Gridmaker.ave script developed by ESRI, available in the ArcScripts section of their Web site (http://www.esri.com/). Aldenderfer excavated 1 m x 1 m units in four 0.5 m x 0.5 m minimum provenience units. Since the extent of the magnetic survey conducted in 1997 was 50 m x 60 m, we set parameters in the GridMaker.ave script to make a matrix that was 65 m x 65 m and composed of 0.5 m cells. Once the site matrix was constructed, we added each of the fields from the paper-level records of the matrix as additional columns. This matrix and table serves as our template for the construction of new units (Figure 2).

Figure 2
The site excavation matrix for Jiskairumoko, created with the GridMaker.ave script, is shown above in the View1 window. The associated attribute table is also shown. The four selected records in the attribute table correspond to the four selected cells in the excavation matrix and the additional columns related to fields from the paper records that had previously been used to record the site during excavation.



Given that a magnetic survey had been conducted at the site in 1997, we wanted to be able to use this information to guide us in making decisions about where to place excavation units. To improve our ability to select excavation units based on the presence of magnetic anomalies, data from the magnetic survey was imported into ArcView GIS as an array of points. A grid was then interpolated from these points using the Inverse

Weighted Distance interpolator. Once the magnetic survey had been rasterized in ArcView GIS, it was possible to georeference this grid to our site excavation matrix.

As users of magnetometric data are aware, magnetic anomalies of interest to archaeologists are often obscured by the magnetic properties of the surrounding matrix (Breiner 1993). Magnetic anomalies are often not visible without additional postprocessing. One technique that does not involve changing the actual values recorded by the magnetometer relies on how colors are distributed as variation in values of the data. Typically, colors are mapped to equal intervals of whatever continuous value is being represented by a raster layer. However, this does not tend to be an effective method of representing magnetometric data. A common solution to the problem is "Color Equalizing" (GeoMetrics 2000: 71) or mapping each color to an equal number of pixels in the raster representation of the magnetic survey. The ArcView GIS equal area palette function performs this task quite well and represented numerous anomalies in the magnetometric data (Figure 3).

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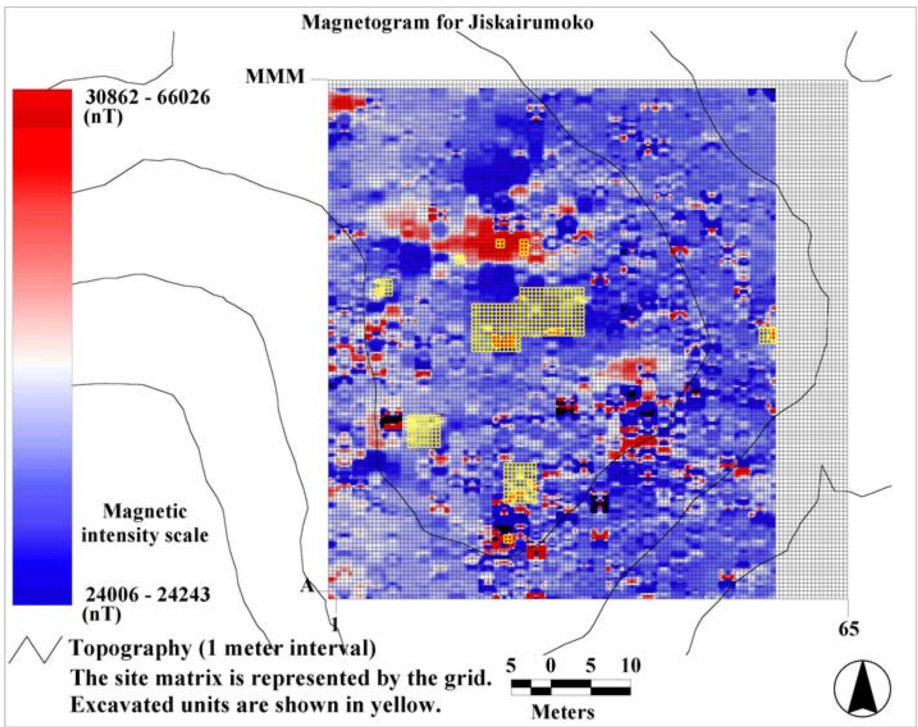
Figure 3
The magnetic survey is shown georeferenced to the site excavation matrix. The magnetic survey was imported from the MagMap96 software as an array of points and then rasterized in ArcView GIS 3.1 using the IDW interpolator. The rasterized magnetic survey was then rubber sheeted to the site excavation matrix using the Warp.avx extension. An equal area color lookup table was then applied to the magnetic survey. Topography of the site was constructed with data collected using a Topcon total station. This data was imported into ArcView GIS as an array of points, rasterized using the spline interpolator, and 1 m contour lines were interpolated and saved as a shapefile.



One of the primary goals of any excavation is to accurately record features that are exposed while digging. Traditional methods of feature recording involve the use of a tape to collect points that are then transcribed to paper. Measurements of the features are made in the unit, and these are transferred onto graph paper on the level record. Using GIS to directly record levels as they are excavated permits fundamentally new techniques of documenting features. One could replicate traditional paper methods of feature recording by taking measurements in the unit and then using standard measurement tools within a GIS to make measurements and plot points so that features could be digitized in much the same way one would draw the feature on a paper-level record form. However, this method is quite time-consuming and is prone to introducing new errors into the data. Instead, we used ArcView GIS in concert with the Nikon CoolPix 950 digital cameras to record each level of the site excavation. We took photographs of surfaces excavated within each unit and georeferenced each photograph to its proper place within the site excavation matrix using the Warp.avx sample extension.

A purely raster representation of the surface is not a sufficient documentation of the top of a level. The photograph very accurately represents what can be seen on the surface, but the features need to be defined and delineated as individual objects that can contain information about the artifacts that are found within a particular feature or section of matrix. To generate the necessary thematic objects, we displayed a georeferenced version of the photograph and then digitized the features directly on the screen of one of the Fujitsu Stylistic 2300 pentop computers. Each polygon was a new record in the theme, and we could attach information (soil Munsell color, number of flakes, etc.) to each of those polygons in the theme's attribute table.

Figure 4a
The georeferenced photograph for Unit T11 level iii is shown with the minimum provenience cells. Polygons representing archaeological features are shown as they were digitized in the field on top of the georeferenced unit photograph.

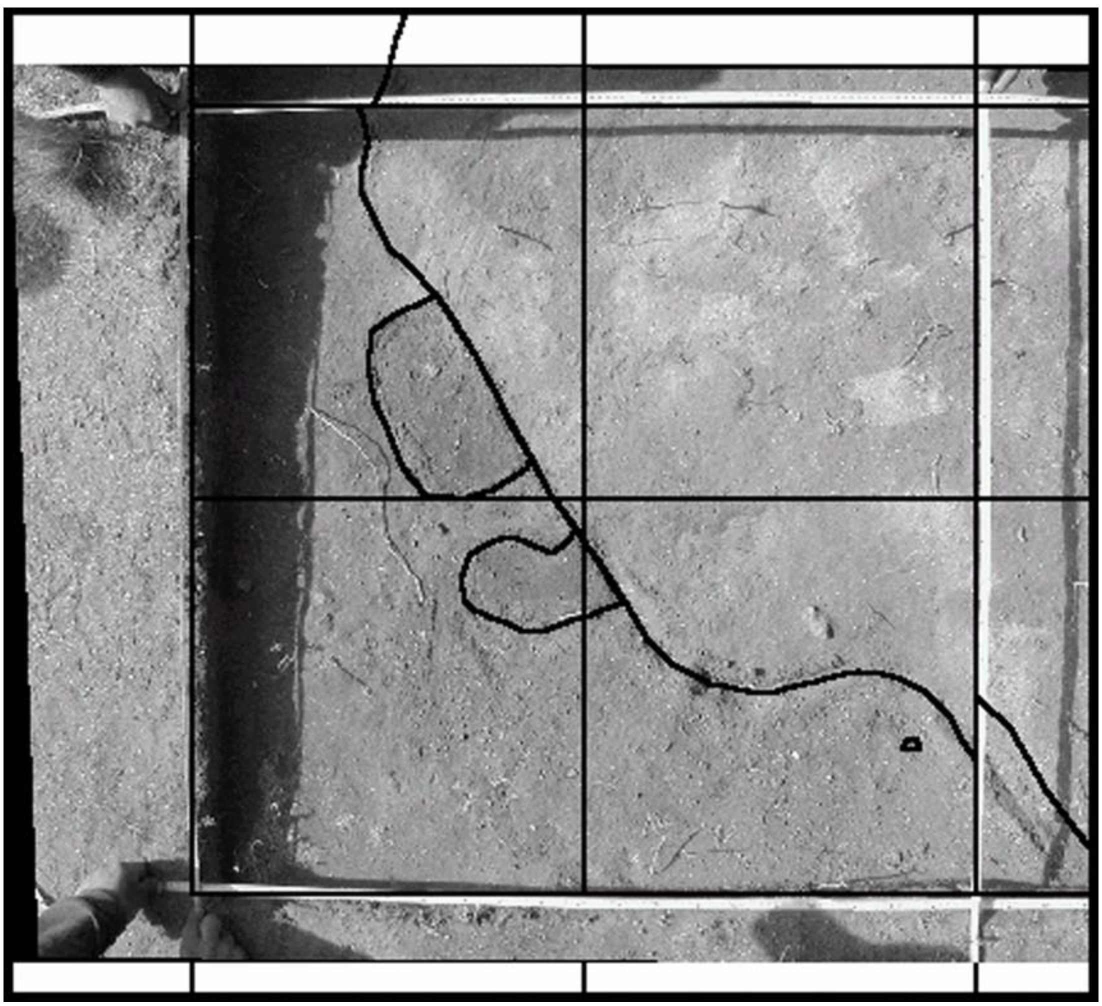


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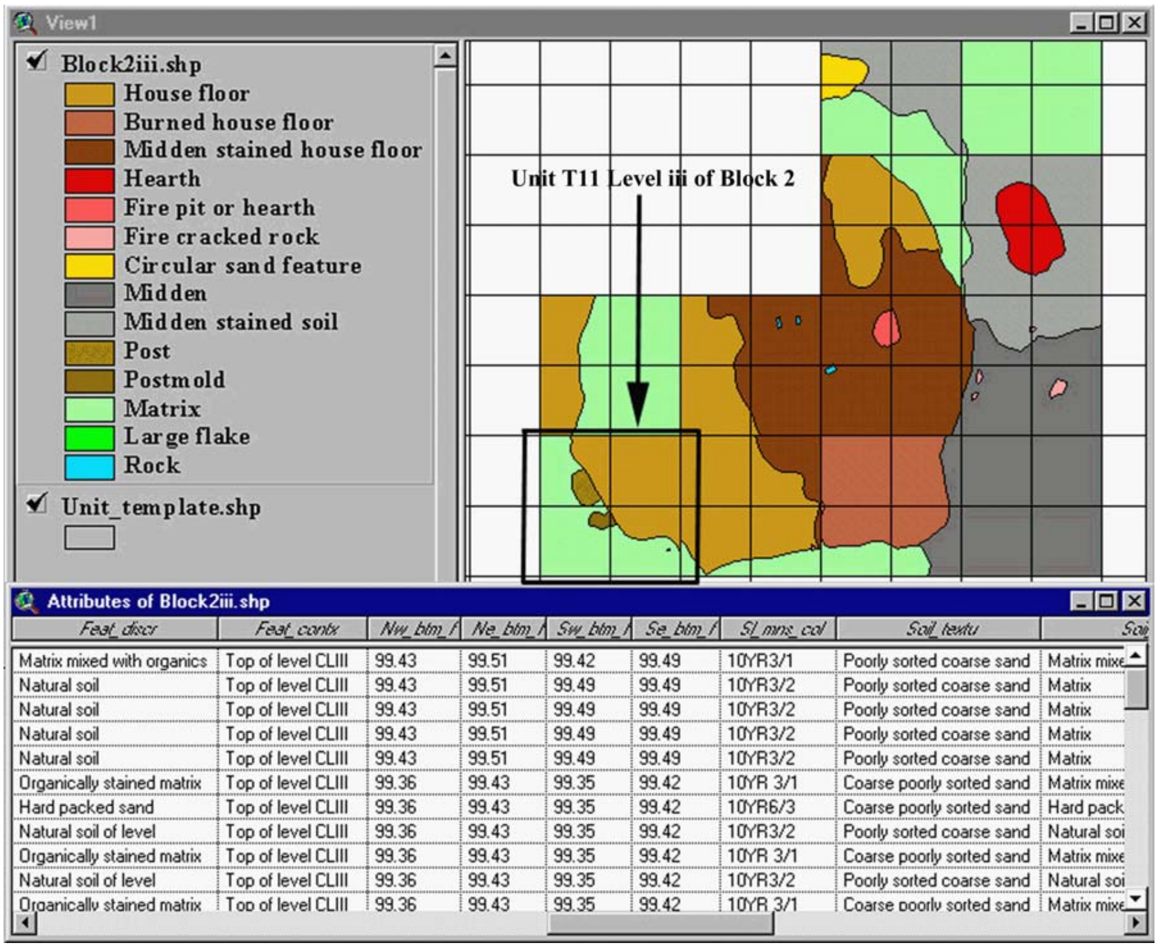
Figure 4b
Shows all of the units of Level iii in Block 2. Only the site excavation matrix and the digitized features are shown in this figure. Note the location of Unit T11 Level iii that was shown in Figure 4a. Each of the features digitized during the excavation was drawn from georeferenced photographs. The attribute table for Block 2 Level iii is also shown.



Feat_discr	Feat_contx	Nw_btm_f	Ne_btm_f	Sw_btm_f	Se_btm_f	Sl_mns_col	Soil_textu	Soi
Matrix mixed with organics	Top of level CLIII	99.43	99.51	99.42	99.49	10YR3/1	Poorly sorted coarse sand	Matrix mixe
Natural soil	Top of level CLIII	99.43	99.51	99.49	99.49	10YR3/2	Poorly sorted coarse sand	Matrix
Natural soil	Top of level CLIII	99.43	99.51	99.49	99.49	10YR3/2	Poorly sorted coarse sand	Matrix
Natural soil	Top of level CLIII	99.43	99.51	99.49	99.49	10YR3/2	Poorly sorted coarse sand	Matrix
Natural soil	Top of level CLIII	99.43	99.51	99.49	99.49	10YR3/2	Poorly sorted coarse sand	Matrix
Organically stained matrix	Top of level CLIII	99.36	99.43	99.35	99.42	10YR 3/1	Coarse poorly sorted sand	Matrix mixe
Hard packed sand	Top of level CLIII	99.36	99.43	99.35	99.42	10YR6/3	Coarse poorly sorted sand	Hard pack
Natural soil of level	Top of level CLIII	99.36	99.43	99.35	99.42	10YR3/2	Poorly sorted coarse sand	Natural soi
Organically stained matrix	Top of level CLIII	99.36	99.43	99.35	99.42	10YR 3/1	Coarse poorly sorted sand	Matrix mixe
Natural soil of level	Top of level CLIII	99.36	99.43	99.35	99.42	10YR3/2	Poorly sorted coarse sand	Natural soi
Organically stained matrix	Top of level CLIII	99.36	99.43	99.35	99.42	10YR 3/1	Coarse poorly sorted sand	Matrix mixe

Preliminary Results From the 1999 Field Season

While excavations are still in progress at Jiskairumoko, preliminary results from the new methods developed are quite encouraging. Recording the excavation of Jiskairumoko in digital form using ArcView GIS 3.1 has allowed us to easily plot the location of the site onto space-borne remotely sensed imagery. We have been able to incorporate topographic mapping data from a total station and georeference the rasterized results of magnetometric surveys. Perhaps the most exciting result has been our ability to georeference photographs of each level we excavate. This has permitted us to accurately and rapidly record features and surfaces in great detail. Once photographs are rubber sheeted in the field, we can easily digitize features and entities observable in the excavation units. Using this method it was possible to excavate a total of 227 individual layers that were contained in a total of 113 units. Collecting this kind of data in a consistent coordinate system that is tied to the entire site matrix allows us to build mosaics of large blocks of excavation units

The large-scale excavation of residential features is one of the most effective ways in which variation in activity performance can be defined for an occupation of a site and allows us to track changes in activity performance through time in a more effective and rapid manner. For instance, using this system we can more quickly and accurately measure the size of houses and the ways in which people used their residential spaces. This may help us create models of the size of the family or social group that occupied the site during different periods. The system also allows us to examine differential density of various artifact classes across the site both vertically and horizontally. We may find, for instance, that artifact densities are lower in the levels of the site occupied by hunters and gatherers, suggesting a short-term occupation, as compared to those levels occupied by agropastoralists. Although one can do this with traditional methods of infield recording, our system allows us to visualize the data far more rapidly and clearly.

The application of intrasite GIS using infield data recording is still in its infancy, but we remain convinced that systems like the one we have described in this paper are the future of archaeological excavation. Such systems will allow the investigator to move from the field to the lab to publication rapidly, and will enhance the sharing of data between archaeologists interested in the same problem or region.

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