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A geoinformatic approach to the collection of archaeological survey data

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This article explores the integration of GIS technology with archaeological survey, focusing primarily on two case studies from central Anatolia, the Göksu Archaeological Project and the Avkat Archaeological Project. The methodology employed allows for expediency and accuracy in data recording, which enables refined analyses of anthropogenic and environmental phenomena. The approaches outlined in this article allowed the investigators to move from field observation to publication quality results within a single field day, usually within a four-hour window from initial field observation. The techniques described in the article are some of the geoinformatic applications that classical archaeology is implementing increasingly to develop a robust archaeoinformatic tool kit.

Keywords: landscape archaeology; archaeological survey methods; Turkey

Introduction

The methods landscape archaeologists use for collecting data are determined by a variety of factors, but if painted broadly, are chosen to balance the need for accurately identifying anthropogenic and other elements on the landscape with making efficient and satisfactory coverage through the area of interest. The goal is to rectify intensity and sufficient coverage with a satisfactory level of precision to detect a broad array of past activities. To address the balance between intensity and extent, the means by which the area of interest is organized into survey units is an important consideration. Further protocols within a project design implemented to record and identify areas of interest (known variously as sites, features, POSIs, DUs, SIAs, etc.) are also influenced by the need to balance intensity and extent. The decisions made in regards to establishing survey units and protocols for assessing areas of significance have an impact upon project workload, the type of analyses possible in future stages, and the means by which the results can be integrated into other studies. This article begins by briefly discussing the means by which intensive archaeological surveys as practiced in the eastern Mediterranean and Aegean most often address these issues, followed up by a discussion of methods developed for central Anatolia that employ a geoinformatic focus to data collection that streamlines the collection, mapping, and analysis phases of a project.

Recording Units of Analysis

An important part of an archaeological survey is the establishment of survey units within the study area. Within the eastern Mediterranean, several methods are used to establish these basic units of survey. Some projects use natural field boundaries to establish survey units, such as field breaks, roads, terraces, natural contours, and changes in vegetation. This method was applied early in the development of intensive Mediterranean survey, and was employed at projects such as the Nemea Valley Archaeological Project, the Northern Keos Survey, and the Pylos Regional Archaeological Project (Wright et al. 1990; Cherry et al. 1991; Davis et al. 1997). The advantage to this method is that it is easy to establish survey units on the ground (Cherry et al. 1991:22–25). Several limitations include the difficulty in accurately reconstructing the irregular units into a mosaic of coverages once surveyed (whether reconstructed by hand or by GIS personnel in the laboratory); and the irregular size of the survey units, which can make comparisons internal and external to the survey universe difficult (Cherry et al. 1991: 22). Results of the survey can lose specificity when those field observations are recorded by irregularly shaped survey units (Figure 1). The representations are sensitive to the method chosen to represent artifact distributions.

In Figure 1, inset A displays total counts per field, divided by standard deviations from the mean. This method does not take into account density, so larger units will often display larger counts irrespective of actual significance. Insets B and C use a true density measurement that removes the effects of unit size. These insets display the data broken down by standard deviation, and show that the interpretation of the data is sensitive to the number of times the Gaussian curve is divided. Inset D is

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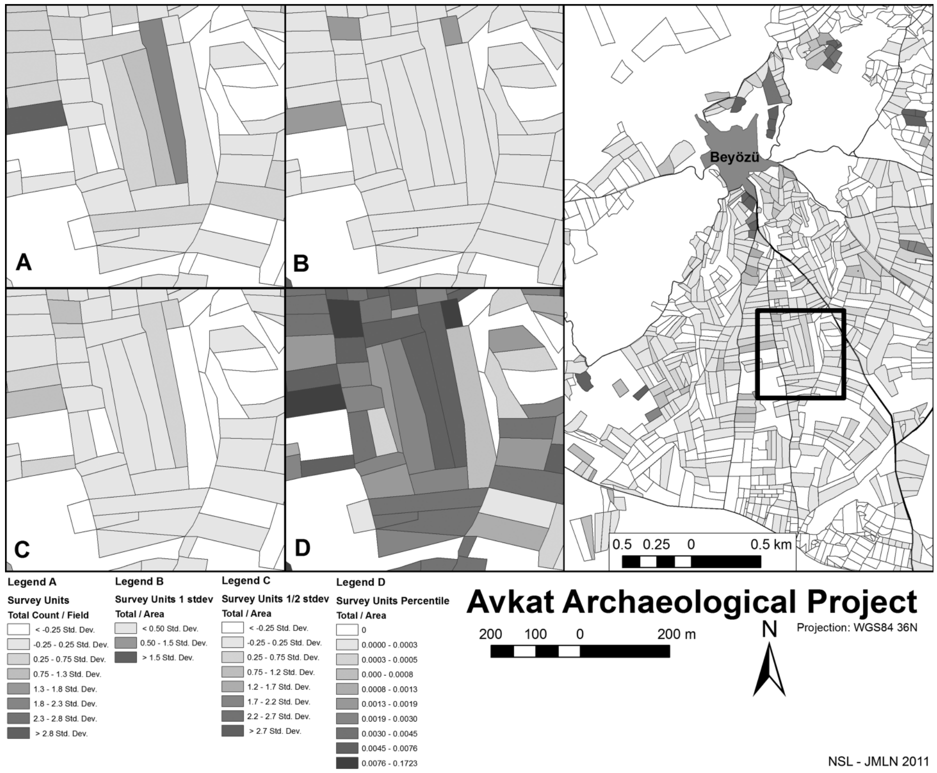

Figure 1. Sample of standard method artifact distribution from the Avkat Archaeological Project. Figure insets A-D show that the major problem with this form of representation is that one is unable to determine the nature of artifact distribution within the unit, or how those distributions may relate to adjacent areas. Furthermore, this figure demonstrates the variability in the visualization of artifact distribution based upon different statistical methods employed.

also a true density display, but uses the percentile technique. In this case, each gradation in the scale represents the percent of the total density of finds in a unit. Inset D suggests where units hold significant quantities of artifacts, but it does not explain how those concentrations relate to the units around them. While this information can be used with other data sets to enhance interpretation, Inset D only shows potential areas of interest in a general fashion.

When using an arbitrary unit strategy, natural topography and landscape features are ignored in favor of establishing a synthetic grid. A predetermined length and width measurement for the unit is established and this is transferred across the entirety of the area of interest. Examples of such projects include the Boeotia Survey, the Sphakia Survey, and the Pyla-Koutsopetria Survey (Bintliff and Snodgrass 1985, 1988; Moody and Nixon 1998; Caraher et al. 2008). In general, this method allows for ease of mapping both within GIS and in the field and removes many problems with units of differing size, but establishing the units on the ground can take longer than other methods. Intensive survey may be at a high level of intensity within the unit, but because densities are assessed at the field level, the resolution is low (such as 50 × 50m). As in the case of surveys using natural topography, features may be obscured by the size of the field, or split between two fields (Figure 2). The use of topographically defined units does allow for the production of density maps which can address interpretations involving on-site vs. off-site scatters and the definition of significant artifact densities (Bevan and Conolly 2002–2004; Caraher et al. 2006; 2008). These densities are still handled at a coarse resolution, however.

A third type of survey minimizes the problems of survey unit non-uniformity found in the topographic-based approach. The Sydney Cyprus Survey Project (SCSP), uses a composite method which employs both modern field boundaries and 100m × 50m sections to delineate survey units (Given and Knapp 2003: 32–34). The Saronic Harbors Archaeological Research Project (SHARP) and Eastern Korinthia Archaeological Survey (EKAS) set survey units within distinct geomorphic features, and established field lengths and uniform walker spacing to further define units (Tartaron et al. 2006: 467; Tartaron et al. 2011: 604–05). The Antikythera Survey similarly arranged their survey units according to natural topography, but sought to standardize

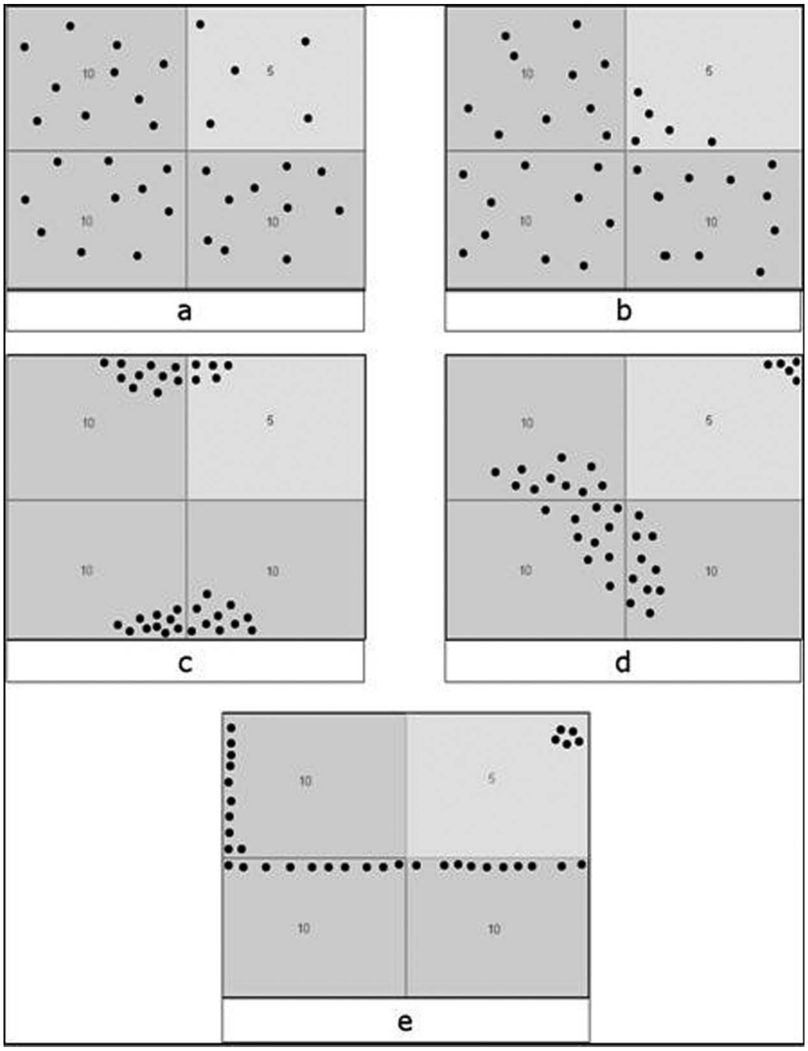

Figure 2. Hypothetical distributions of artifacts across a landscape. Each example has the same number of artifacts in each grid. Distribution (a) shows a random distribution across the entirety of the survey units. Distribution (b) shows an example in which the material in the top-right is seen as associated with the other 3 units. Distributions (c) and (d) present concentrations that are split across survey unit boundaries, but likely not associated with each other. Distribution (e) represents distributions that are associated in a linear fashion, such as a drainage ditch, with a highly localized concentration in the least densely populated unit. The patterns avail themselves to a vast array of interpretations, but the patterns are indistinguishable if densities are considered at the survey unit level alone (as in Figure 2).

the display of collection units as estimated counts per 100m^2 (Bevan and Conolly 2009: 957). As a general principal, this composite type uses natural topography as the means to divide the landscape, but seeks to minimize problems associated with differing sizes of collection areas (Fotheringham and Wong 1991: 1025–26; Bevan and Conolly 2009: 957).

Regardless of how the survey universe is divided, data is aggregated to survey units (also known as transects) such that site definition is lost to the artificial construct of the unit boundary. This leaves the field surveyor with a need to establish a method for identifying areas of interest (labeled by projects as "sites," "features," "places of interest," etc.). In many instances, the identification of areas of interest (within this article, 'features') is first made by the intensive field team. In many instances, the teams stop their regular surveying regime to make a brief description of the feature; estimate size, date, and function; and in some instances collect grab samples of diagnostic ceramics. This initial discovery is followed up by a revisit to the feature (sometimes years later) by the project's senior staff and specialists to assess more accurately the extent, function, and phases of the feature, and to determine if additional intensive collection is warranted (see Broodbank 1999; Cherry et al. 1991; Davis et al. 1997; Given and Knapp 2003; Tartaron et al. 2006). Identifying and relocating the places that require revisits has been problematic, although technological advances (such as GPS receivers and satellite imagery) assist in more accurately marking what has been surveyed. The landscape archaeologist still faces the debate over the boundaries of the concentration, its phases and dates, the extent to which the concentration has been altered by a series of anthropogenic and natural forces (such as plowing and erosion), and whether a concentration is "significant."

Archaeologists increasingly are turning to technology to address these issues. Within the eastern Mediterranean, there are many instances of this occurring. For example, the EKAS project developed a geoinformatic system that allowed for daily updates to the developing dataset, and implemented a post-field resampling regimen to smooth field observations (Tartaron et al. 2006: 457–8; 489). The Kythera Project developed the GIS system prior to fieldwork, and used it as an information repository and analytical tool throughout the project's history (Broodbank 1999; Bevan and Connolly 2002–2004). This system was further augmented with greater use of GIS mapping in the survey on Antikythera (Bevan et al. 2008). In Lydia, surveyors used RTK GPS in combination with Quickbird imagery and intensive collection to render high resolution digital elevation models and other site information (Roosevelt and Luke 2008). In the early 2000s, a series of projects in Anatolia were designed and implemented by the authors with the intention of integrating technology within the collection process to improve data recording, display, and analysis. This paper draws upon work from the Göksu Archaeological Project (2003–2006) and the Avkat Archaeological Project (2007–2009) (Figure 3).

Recent GIS Implementation in Central Anatolia

While conducting fieldwork in Turkey, the authors devised methods to shorten the time between data collection and analysis, provide accurate mapping of artifact concentrations, and allow for the integration of geomorphological and artifactual data. This was accomplished via an intensification of field data collection, the pushing of mapping and geocoding into the field, and post-field data transformations in GIS. The Göksu Archaeological Project (GAP) was an intensive and extensive survey conducted in the Taurus Mountains of south-central Turkey (Elton 2008). The project was established as a diachronic survey of an upper section of the Göksu River Valley, with a focus upon understanding the context of the Alahan Monastery to the surrounding landscape. Between 2003 and 2006, 13km^2 were intensively surveyed within the 68km^2 area, revealing land use practices ranging from the Paleolithic through to Medieval periods (Elton et al. 2006; Elton 2008). From 2007 to 2009, the Avkat Archaeological Project (AAP) investigated via intensive and extensive means a 40km^2 area around the modern town of Avkat, ancient Euchaïta (Elton et al. 2008, 2009; Elton, et al.

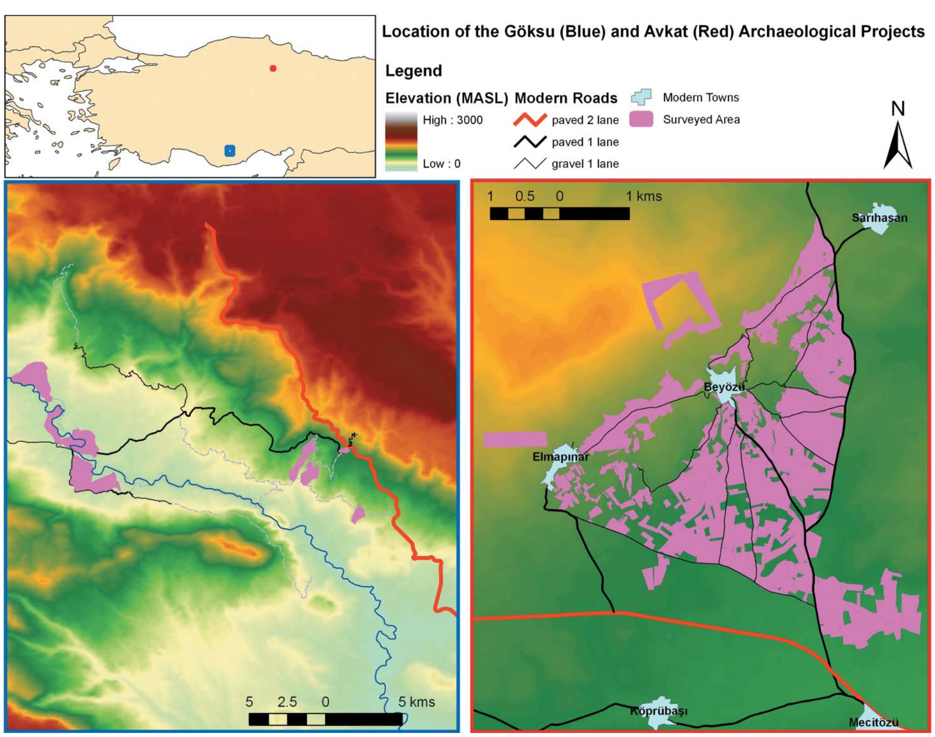

Figure 3. Map showing the location of the Göksu and Avkat Archaeological Projects and their respective survey areas.

2009). Within the project area, 9.2 km^2 were intensively surveyed in a diachronic fashion, with the central aim of understanding the changing habitation and land use practices during the Late Roman, Byzantine, and Ottoman phases (although objects from all periods were recorded).

The methods outlined below present results from work within these two projects,[1] are based in part upon initial techniques developed by Gray & Pape (Purtill et al. 2001), and have been recorded briefly in part in interim reports for these projects. Specific points have also been made elsewhere in presentations at conferences (Newhard and Littlefield 2007; Newhard, Elton, and Haldon 2009). The following is a comprehensive review of the methodologies developed and employed by the authors since 2004.

Hardware, networking, and database

In order to develop a refined dataset and expedite in-field processing, the work required a technological support system capable of multi-user data manipulation, versioning, and seamless or near seamless data transfer. The hardware and software used on the Avkat Archaeological Project (the most advanced permutation of the techniques presented) can be divided into three categories: instruments used in the data collection process, software and applications employed in the lab at the field office capable of merging data transfers to and from the field, and the networking infrastructure established to provide multi-user functionality and ensure a system of data integrity and security.

Data collection was carried out in part with Personal Data Assistants (PDAs). Each of the Hewlett Packard IPACs was equipped with GPS loaded with ArcPad 7.0 – a mobile GIS application produced by ESRI. The ArcPad applications communicated directly with an ArcServer SDE database to allow for multi-user distributed editing and data capture capabilities. The field lab at the project basecamp was equipped with laptop computers linked via both wireless and local area network (LAN) connections that allowed for distributed editing of data and backup to an on-site local drive system. Additionally, the network was outfitted with a DSL connection, allowing it to be connected directly to the ArcServers and master SDE databases back at the College of Charleston for back up and update. Additionally, data was collected from paper forms (consisting of survey unit visibility, land use, and other observation data), and was entered into an SQL database, using a graphic user interface (GUI) built in JavaScript and .php. The GIS that integrated the data within the project (ArcMap 9.0–9.3, ArcCatalog, and other ESRI-based applications as appropriate) ran on a database structure compatible with Structured Query Language (SQL) protocols. These protocols permitted the artifact database to be integrated into the GIS environment. This was an improvement upon the Göksu Archaeological Project, which used Access databases which were limited not only in functionality but also by a maximum storage capacity of 2 gigabytes. In contrast, SQL databases have fewer storage limitations (10 gigabytes while using the Microsoft SQL server Express system on the field laptops) and additional storage was available on the SDE backup systems. Shifting to MySQL system for the paper form information allowed for greater streamlining and flexibility in data management; MySQL is intended for multiple-users, it interfaces with the GIS system, and can be accessed on both PC and Mac platforms. The resulting field lab was a configuration where a laptop could be brought into the network via a LAN or wireless connection, access the database regardless of platform, and access the ESRI-based geospatial database. Multiple users simultaneously could access and add, modify, and delete data based upon their security credentials and permission levels.

In addition to the use of client-server applications for both the GIS and database, the use of high resolution satellite imagery was instrumental in the development of our methods. Satellite images of the project area were uploaded onto the PDAs. SPOT 2.5-m resolution imagery has worked well for most purposes – field boundaries and major physical features are identifiable. Quickbird imagery, at 60 cm resolution and more expensive, was found to be the better value once the multi-spectral qualities of the image were taken into account.

Technology in the Field

One of the accomplishments of the GAP/AAP methods was to decrease the time between initial observation in the field and the analysis of field information by the primary investigators. Field team leaders attended a 1-hour training session, where they were instructed on the use of the PDAs. Despite the brevity of this training, the applications and methods were easily mastered, such that adding this piece of technology brought no disruption to the survey process. While in the field, team leaders deployed field-walkers using topographic features as the primary method of survey unit delineation. Using the high resolution satellite image as a base map for the survey area in the mobile GIS system, the team leader outlined the survey units while in the field – either by outlining the field boundaries manually or by walking along the boundaries of the survey unit and obtaining the points from the GPS unit which was linked to the PDA via a Blue-tooth connection. The field boundary vector polygons created within the mobile GIS system had minimal data attached to them, namely the unit's unique identifying number. The use of satellite images via mobile GIS allowed for accurate recording and orientation, replacing the use of hard-copy maps (Given and Knapp 2003: 34). Detailed information was collected on paper forms, and entered manually into the project database at the lab. The rationale for maintaining a paper-based recording system is largely to provide redundancy, thus serving as a check against system crashes and technical difficulties while in the field. In addition to the demarcation of survey units, the PDAs were also used for marking the locations of features within the landscape. In this regard, the GPS receiver was used to supply a point for the item, which was then given a unique feature identifier. Supplemental information was recorded on paper forms for the same reasons identified for the survey unit data.

Using PDAs in this fashion had several positive outcomes. Team leaders no longer needed to spend time performing advanced reconnaissance ahead of their field teams, the data entry controls on the ArcPads reduced the incidence of user error, and survey units were mapped in the field to a great extent. Data collected with PDAs allowed instantaneous mapping of surveyed areas, and prevented the resurvey of units in later seasons by personnel unfamiliar with the area. During the Avkat Archaeological Project, the field director typically met team leaders upon their return from the field, and with the use of the PDA data, discussed the results of the day's work with them, and reviewed daily or weekly goals. This system provided an easy assessment of expectations for both field director and teams.

After transferring data from field collectors, vector polygons were layered over Quickbird imagery covering the area of interest. The field boundary lines were modified as needed to correct any drawing errors that occurred in the field. Since most of the walked fields were congruous to the visible agricultural features, this was performed accurately and efficiently. Owing to the establishment of the field base geodatabase server, the versioning capabilities within ArcServer were put into effect allowing for multiple users to modify geospatial data simultaneously.

After minor modifications were made to the survey unit's polygons, an updated display of the project's surface coverage was available. Further data entry into the project database (linked to the GIS by the unique identifier of the survey unit or feature) allowed for information on visibility, land use, finds and survey-unit resolution artifact densities to be available within a matter of hours. These coverages were georectified, spatially accurate, and of publication-grade quality. The modified field boundary information was then loaded onto the PDAs, so that the team leaders had the most updated version available for the next day of fieldwork.

Field Collection Intensification

Use of the PDAs and Blue-Tooth equipped GPS receivers assisted greatly with the accurate placement of survey units and features within the landscape, but did little to address the more complex issues of understanding on-site vs. off-site surface scatters, geomorphological or other post-depositional processes or determining areas of significance. As a means to address these issues, methods of documentation developed for Cultural Resource Management survey in the US by Gray & Pape, Inc. (see Purtill et al. 2001) were adapted to the Mediterranean world.

In the Göksu and Avkat projects, intensive survey followed protocols consistent with many other Mediterranean projects. Diagnostic ceramics and other artifacts (chipped stone, ground stone, glass, and other "small finds") were collected from the field, bagged and tagged according to survey unit, and continue to undergo analysis for date, function, and other characteristics. Fieldwalkers walked transect lines within a survey unit (Figure 4a). As they progressed, they were required to subtotal counts of artifacts on fieldwalker forms every 15m. The result was the equivalency of a rough 15m grid (Figure 4b). Once the fieldwalker forms were entered into the project database, the counts for each of the observations were linked to point data generated within the project GIS (called "observation points" or "OPs"–

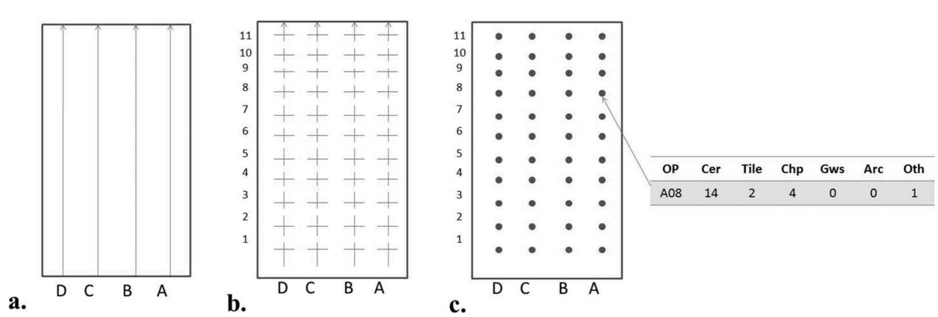

Figure 4. Idealized survey unit, showing the transformation from typical data collection procedures in which fieldwalkers survey at a standard interval (a) to the observation point method in which fieldwalkers subtotal observations every 15m (b) and its linkage with data split by artifact type (c). Once linked to the database, the survey unit boundaries may be removed from the analysis, allowing for spatial analysis to occur without artificial constructs of the survey unit to interfere with interpretation.

Figure 4c). Both Avkat and Göksu projects therefore have field observation data split by observed counts of ceramics, rooftile/pithoi, chipped stone, ground stone, architecture, or other objects at a resolution of approximately 15m. Because the data was tied to the unique identifier (the OP), the field boundaries could be removed, resulting in a regional dataset with 15m resolution that minimized the effects of the arbitrary survey unit shape or size (Figure 5). The Nikopolis Project employed a similar method in the 1990s, spacing fieldwalkers 5m apart and having them subtotal counts every 30 meters, which were presumably recorded in the team leader's notebook for reference (Tartaron 2003: 34–35).

The collection of observation points in the field required additional geospatial processing in the field office.[2] The observation points were configured for each field within the GIS by technicians using the fieldwalker and survey unit forms as a guide. The OPs were derived from a master grid file template containing points spaced at 15 × 15m intervals, which were identical to the spacing practiced in the field. Each point in this file held a unique identifier, which indicated where said points would be located in the survey unit. For each survey unit, the GIS technician copied the points necessary from the master grid, and saved the copied grid according to its survey unit number. The OP files were then positioned over their respective SUs, taking into account the direction walked as recorded on the Survey Unit Form by the team leaders. When the OPs were edited and associated with their SU, they were appended to an OP master file in the project's spatial database and then joined to artifact data stored in the MySQL database. Because of the networking and versioning capabilities, the artifact data entry and the GIS component were completed simultaneously by multiple users. In as little as four hours, the results of the day's survey could be viewed and analyzed.

While observations of artifacts are recorded and displayed in high resolution, collection of diagnostic ceramics (and therefore information about date, function, etc.) is organized at the survey unit level. The reasons for this were largely a function of cost. Separately bagging and organizing ceramics at the observation point level would have slowed fieldwalking to a crawl, and created a backlog in the areas of ceramic and data processing. Dating significant concentrations was therefore carried out using practices common in other surveys when gridded collection is not undertaken – by associating ceramics from survey units to the concentrations in question. Arguably, intensive collection would provide stronger chronological ties to given concentrations, but in many cases the informed judgment of the archaeologists deemed that chronologically dating these concentrations could be accomplished successfully by field-level analysis.

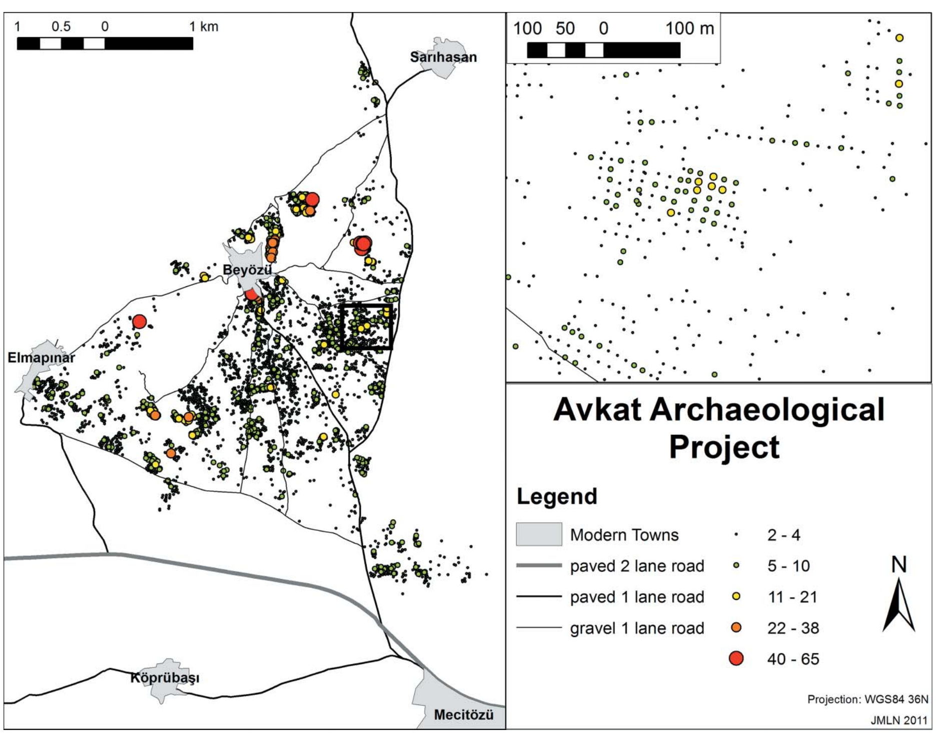

Figure 5. Survey area for the Avkat Archaeological Project displayed with observation points tied to ceramic counts. Since fieldwalkers record several types of artifacts at the level of the observation point (ceramic, tile, pithos, chipped stone, etc.), the artifact distributions can not only be analyzed at a higher resolution, but also by artifact type.

Post-Field Processing

The observation point is a recording of an artifact's position within a 1-2m swath of ground over a 15m stretch of ground. The actual point of original deposition, however, was likely altogether different, its eventual provenience involving a number of site formation processes (Bintliff and Snodgrass 1988). To account for the inherent fuzziness of the data, an interpolation algorithm was used to smooth the point data. The kernel density function (KDF) is one means by which the density of artifacts in a given location can be represented as a raster surface (Conolly and Lake 2006: 175–177). The function within ArcGIS employs the Epanechnikov kernel (Silverman 1986, eq.4.5) as opposed to uniform, normal, biweight, or other kernel functions (Scott 1992, table 6.2). The resulting output is a density that is not dependent upon field boundaries, but upon observation points, allowing for user-determined levels of significance to be displayed, some of which may have otherwise been hidden by the field unit. The kernel density function assists in developing a more effective representation of the artifact distribution through the application of a smoothing algorithm. Other interpolative algorithms are certainly possible, and are used often to disaggregate data collected in differently shaped units or in units larger than desired for a particular analysis (see Kar and Hodgson 2012 for a review and analysis of a wide array of disaggregative interpolation methods; Bevan and Conolly 2009 for a recent example of kriging and regression from the eastern Mediterranean). The appeal of kernel densities is that the algorithm allows for adjustment to cell size and search radius, which was easily manipulated by the end users with no need to evaluate tensioning parameters. This feature makes KDF reproducible based on the cell size parameter, allowing densities from one area to be compared readily to another. Once converted to kernel densities, the data can be manipulated within GIS to represent significant concentrations (Figure 6). Because the observation point data is split by artifact type, comparisons of distributions between separate artifact types can be made, and the artifact distributions displayed in Figure 1 are now further clarified (Figure 7). Use of these approaches improves the resolution and understanding of artifact scatters as they were presented on the ground.

Use of kernel densities or other interpolative methods are not unique to these two projects. Indeed, other projects in the eastern Mediterranean collecting data or reporting results at approximately the same time as GAP and AAP were employing interpolative methods (Bevan and Conolly 2009; Caraher et al. 2006; Tartaron et al. 2006, 2011). Such methods are mentioned in general books on archaeological GIS published during this time (Conolly and Lake 2006) and were suggested as suitable approaches earlier (Baxter et al. 1997). Bevan and Conolly employed geographically weighted regression (GWR) in the Anitkythera Project, which has as its basis a kernel density function, adopted in part for its capability to easily adjust weights of data values and kernel size based upon iterative analyses (2009: 960). EKAS took field unit data,

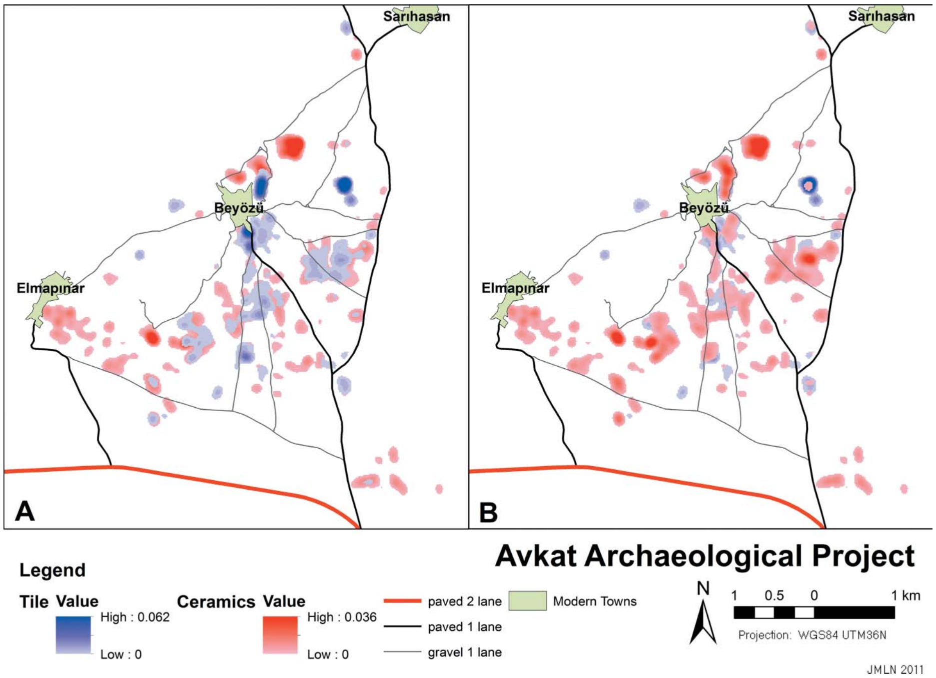

Figure 6. Kernel density distribution of ceramics and tile found in the Avkat area. The left panel (A) places tile over the distribution of ceramics, the right (B) overlays ceramics onto tile. Kernel densities generated at 15m grid cells using a 60m search radius.

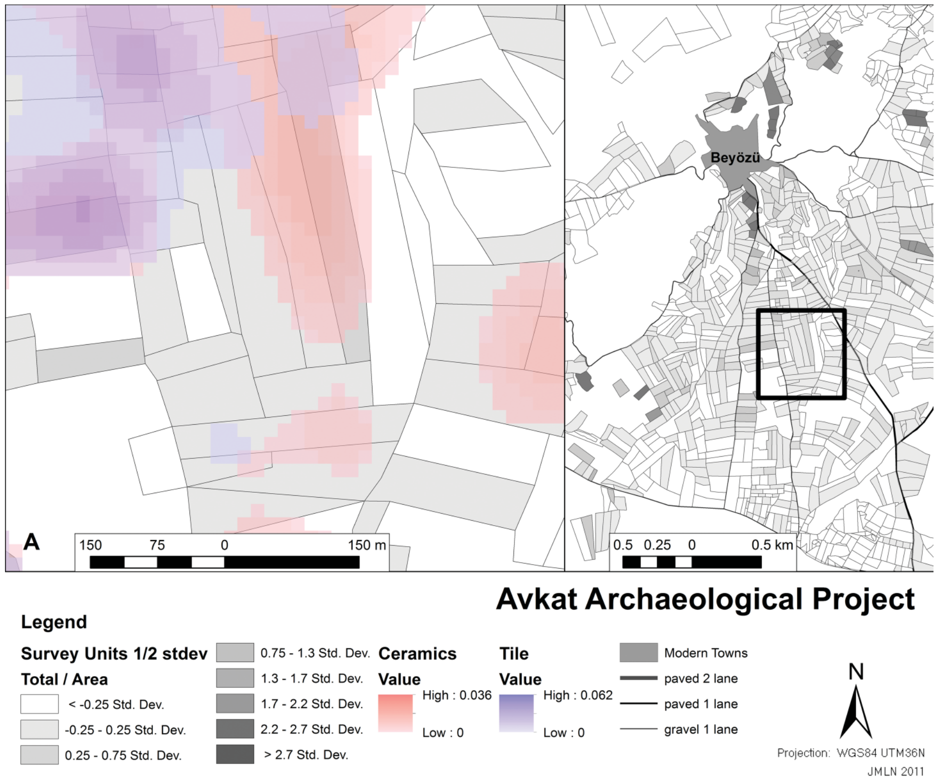

Figure 7. Ceramic and tile concentrations for the area found in Figure 2, displayed as kernel densities. Ceramics (red) and tile (blue) are rendered as semi-transparent, to allow overlapping concentrations to appear as purple. The disaggregated data collection allows the display of different artifact type distributions without the interference of irregularly-shaped or large gridded survey units.

resampled the density of those counts to a raster surface, and performed a nearest neighbor algorithm to provide a sense of smoothing (Tartaron et al. 2006; Caraher et al. 2006). These methods are used as a way to smooth data that was collected at greater or differing scales of analysis, a need commonly seen in the social sciences where aggregate data collected at different levels of resolution from differing sources are being combined (Kar and Hodgson 2012). There is a long and large body of studies and approaches in place that deal with these issues (see reviews in Eicher and Brewer 2001; Fisher and Langford 1996; Holt, Lo and Hodler 2004; Kar and Hodgson 2012). Contrarily, in GAP and AAP the desire was to present a generalized representation of density based upon data collected at a higher resolution, a practice more often encountered in the natural sciences where the locational recording of data at a specific point in space is inherently understood to be an approximation (Aarts et al. 2008; Green et al.2010; Seaman and Powell 1996; Vokoun 2003). In GAP and AAP, the smoothed rasters are based upon data recorded at a higher resolution, thus all smoothed products are developed from generalization of original data and not through interpolation or the creation of missing data. Density rasters in general can be integrated within other raster data types, including elevation and derivative surfaces (such as slope, watershed, etc.), and environmental features such as soil type and vegetation. In this way, artifact and environmental data can be integrated to gain an understanding of the effects of post-depositional processes and land use (Figure 8).

Costs

In terms of project investment, the AAP used GIS capable Hewlett Packard PDAs. The units, when combined with separate GPS receivers are approximately $600 apiece. In 2007, the four field teams and field director were equipped with a PDA per team, for a total cost of roughly $3000. Some intensive surveys call for each surveyor to be equipped with a Garmin GPS unit, making the AAP/GAP comparable in cost. In addition, current technology would realize greater cost effectiveness, given that a team could go out with a single smartphone and be equipped with phone, camera, GPS, and GIS collector for markedly less than the PDAs in 2007. Converting the database and GIS system in the lab required the establishment of an IP address, so the Avkat project invested in a DSL service every season via TurkTelecom (about $180/season). Given the desire for connectivity to home institutions, libraries, and other communication needs, the use of the internet

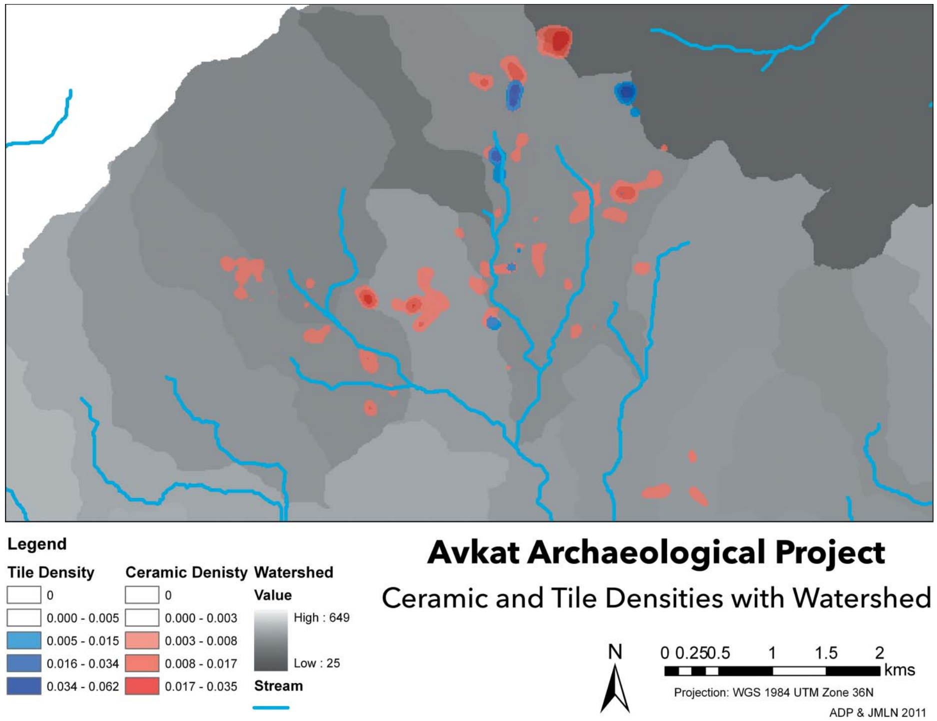

Figure 8. Watershed and stream model with ceramic and tile kernel densities. The hydrology model suggests that certain locales may be better suited to artifact retention owing to their relationship with the stream flow model.

became a real asset for purposes beyond our original desire for an internally networked system.

The additional protocols described required increased staffing in the laboratory. During the Avkat Archaeological Project, the field survey consisted of 3 intensive survey teams and a village-based architectural reconnaissance team. In many field projects, there is a GIS specialist, either part-time or full-time, who is in charge of managing the geospatial components of the project. To handle the added work of entering OP data, downloading ArcPad data, and troubleshooting connectivity between the GIS and database, a GIS manager and full-time assistant were deemed necessary. The increase in GIS laboratory staff is justified given the quality, reliability, and speed of the results. This increase in staffing provided adequate coverage which allowed not only for the swift turnaround times described above, but also for additional GIS-based analysis (i.e. Phebus et al. 2010; Craft 2011) to be conducted while still in the field. During the AAP when the techniques were most developed, the project surveyed 9km^2 over a nine week combined season. This compares well with EKAS, which reports intensively surveying 3.85km^2 over a 9 week period (Tartaron et al. 2006: 464). A study was conducted in the summer of 2006 during the Göksu Project to determine whether the benefits of these new methods outweighed the cost of an increased time expenditure on data entry. Data entry times for survey units were recorded from June 1 to June 12, 2006. These times were then averaged to provide a mean daily time for entering data into the project database, the additional data for the Observation Points, and the parallel processes dealing with the geospatial data. Table 1 shows that adding the time to enter OP data caused an average increase in data entry time of 2 hours 41 minutes – a 51% increase in daily data entry time. This suggests that collecting OP data is time intensive in regards to data entry and GIS data management.

Despite the increased hours required daily in data entry, this methodology, combined with the topographic capabilities of the overlain GIS maps, eliminated many of the field revisits usually required to assess further feature delineation. Cherry (et al.1991:28) refers to these revisits as "'milling about' in order to establish more clearly the size and shape of the site…" In discussing the results of

Table 1. Differences between the average time taken to enter information into both the GIS and database for traditional survey unit level methods and the additional time required for inputting observation point information during the Göksu Archaeological Project.

	Data Entry	GIS	Average Daily Processing Time
Survey Unit	0:26:39	2:06:30	2:33:09
OPs	1:03:32	1:37:45	2:41:17
Total	1:30:11	3:44:15	5:14:26

the Argolid Exploration Project (AEP), Jameson (et al.1994) noted that the AEP placed the responsibility of feature definition in the hands of individual team leaders while in the field (Jameson et al. 1994: 224–225), and used a separate team altogether in later seasons to revisit areas from prior seasons – a practice not uncommon in later projects (Given and Knapp 2003; Tartaron 2003; Tartaron et al. 2006). The methodology outlined here places feature identification and definition in the hands of the end user and allows consistent parameters to be applied for feature definition, yet enables flexibility if local issues of site formation, geomorphology, or other factors are deemed to apply. The use of observation points and kernel densities were so effective that density features could be identified easily with no difficulty several years after the fact by individuals who were not involved with the initial data collection.

Site revisits are still required in some cases: what has been developed is a tool that reduces inherent need and focuses revisits upon cases where extant field, artifact, and/or geomorphological data do not resolve questions of site size, shape, date, and genesis. In these cases the high resolution data assists in isolating and focusing the questions for archaeologists. In addition, the amount of intensive site collection was reduced. Intensive gridded collection and other controlled, intensive survey methods are often viewed as a way to establish the size, date ranges, and possible function of an area of interest once revisits have corroborated the initial findings of the field team (Davis et al. 1997:401–02; Given and Knapp 2003: 34; Jameson et al. 1994: 224–228; Cherry et al. 1991: 29). The estimation of time used for these activities is not possible due to the number of variables involved (including differences in field size, density of artifacts, and team efficiency). However, these more intensive methods of sampling and collection can often involve an entire field team (if not the entire project) for a period of hours if not days, not including the added time required for processing the ceramics in the field laboratory and data entry. The methods outlined here require less intensive site collection, and yield sufficient information to determine site size, location, and date in many cases. Intensive gridded collection was reserved to address specific research-oriented questions (Bikoulis 2011) that extended beyond understanding a site's geographic extent and date, which could be deduced often from the initial survey data.

Examples

The high resolution dataset developed from using observation points can provide information about subsurface characteristics not realized by field-resolution data alone, and conceptualizing the artifactual landscape without the use of field or survey unit boundaries allows for patterns to emerge that would not be readily apparent. Each of these benefits is best shown via concrete examples, taken from the Göksu and Avkat projects.

In 2004, remnants of an Early Bronze Age settlement were surveyed as a part of the Göksu Archaeological Project. The site consisted of a dense scatter of ceramics localized on a hill c. 300m from the Göksu River (Figure 9). When looking at density of artifacts by Survey Unit, the greatest density of artifacts appear in the northeastern section. The same area, viewed at the level of OPs and kernel densities however, suggests a different pattern. Here, the concentration is in two areas near the center, with a long concentration of artifacts to the southwest (Figure 10). The use of the observation points provide a greater understanding of where the site concentrations are. Furthermore, the combination of kernel density and topographic data with erosional modeling could assist with understanding the elongated concentration of artifacts in the southwestern section.

Two additional examples from the Avkat Archaeological Project demonstrate the effectiveness of using observation-point-resolution analysis and kernel density mapping to elucidate potential subsurface features and to visualize land use patterns obscured by modern field boundaries. The first, F0306, is the 'kale' above the town of Beyözü, modern Avkat (Elton et al. 2009). Figure 11 represents the limited distribution of tile and pithos material (11a) compared with ceramic densities for the same area (11b). Overlaying these distributions with the results of magnetometry and ground-penetrating radar (11c) reinforced the suggestion that the extent of pithos and tile distributions represent the core areas of the fortress, and further distribution of this artifact type was limited by the geographical barriers of the remaining city wall to a greater extent than the lighter, smaller, ceramic material. The second feature (F1005), appears in the standard kernel density surface as a light patch, approximately 30 by 45 meters in dimension (12a). This light but marginally significant concentration does not appear in distribution maps using field-resolution data only, demonstrating the benefits of employing these methods to determine significant densities at the survey unit level alone (Figure 12b). In this case, the artifacts are spread over four separate survey units, and would not have been recognized as a significant concentration without the additional refinement of the observation-point-level density analysis. Furthermore, the survey observed rooftile and pithos fragments, but did not collect them, as they were not considered to be diagnostic. The method of OP counting and post-processing via kernel density functions allowed for this concentration (identified as a small late-Roman/Byzantine farm house) to be recognized. Gridded collection of this feature in 2009 (Bikoulis 2011) yielded a size and shape that was congruous to the form calculated by the kernel density function, further highlighting the efficacy of this approach.

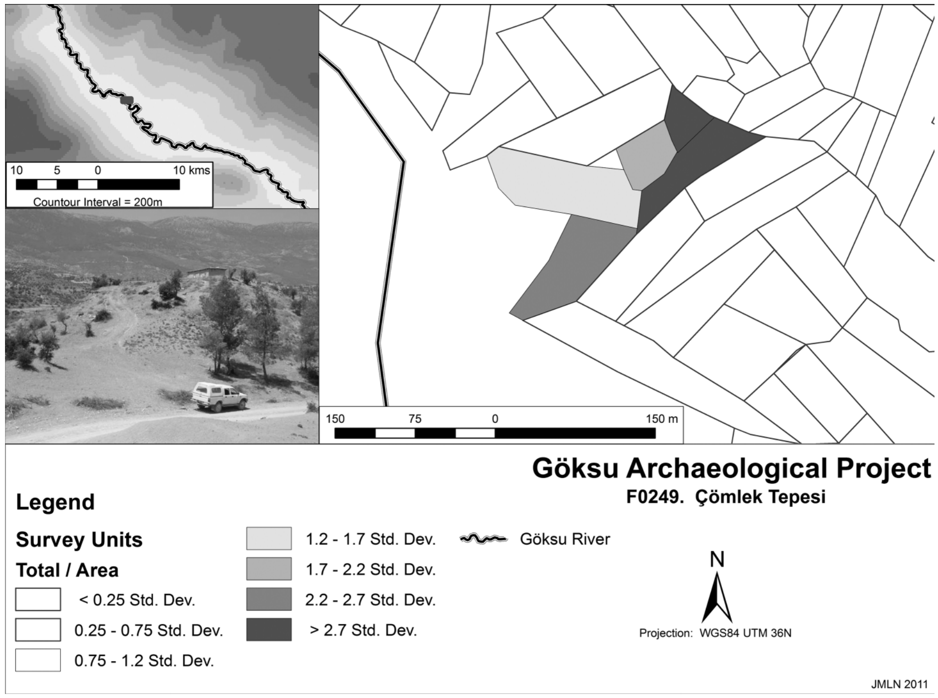

Figure 9. Location of F0249, Çömlek Tepesi, Göksu River Valley, and the density of artifacts at the site, recorded by survey unit. According to the data as presented, artifacts appear to be largely present in the northeastern section, with a possible secondary concentration in the south west. Photo: GAP Archives.

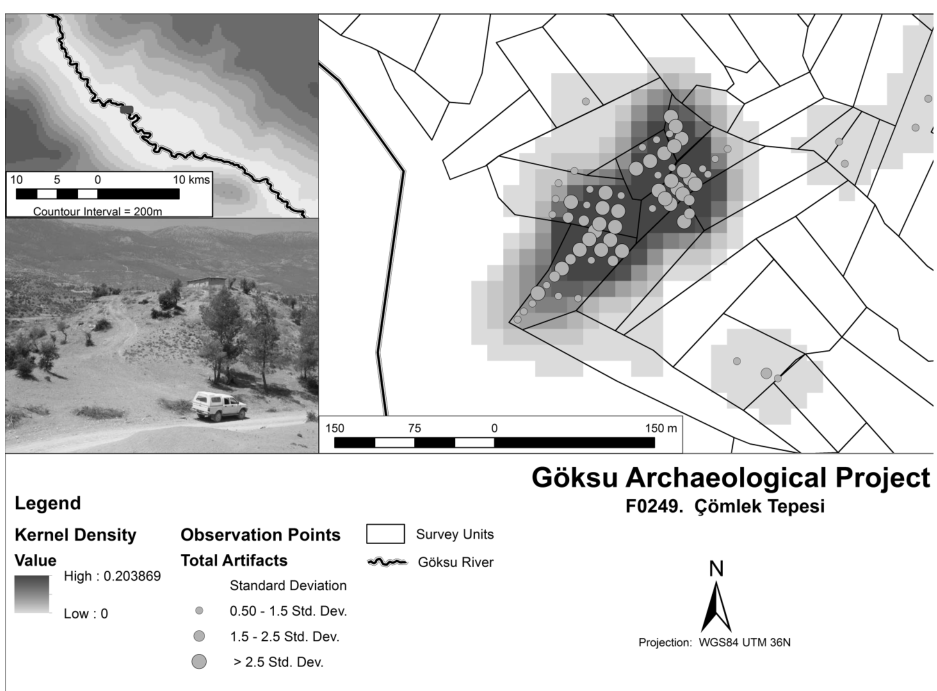

Figure 10. Ceramic densities at Çömlek Tepesi, displaying results by observation point and kernel densities. The single line of densities extending to the southwest suggests a geomorphological explanation, while a more confined 'core' could be defined by concentrations pulled from all five survey units displayed in Figure 9. Kernel densities displayed as 15m grid cells, computed using a 60m search radius. Photo: GAP Archives.

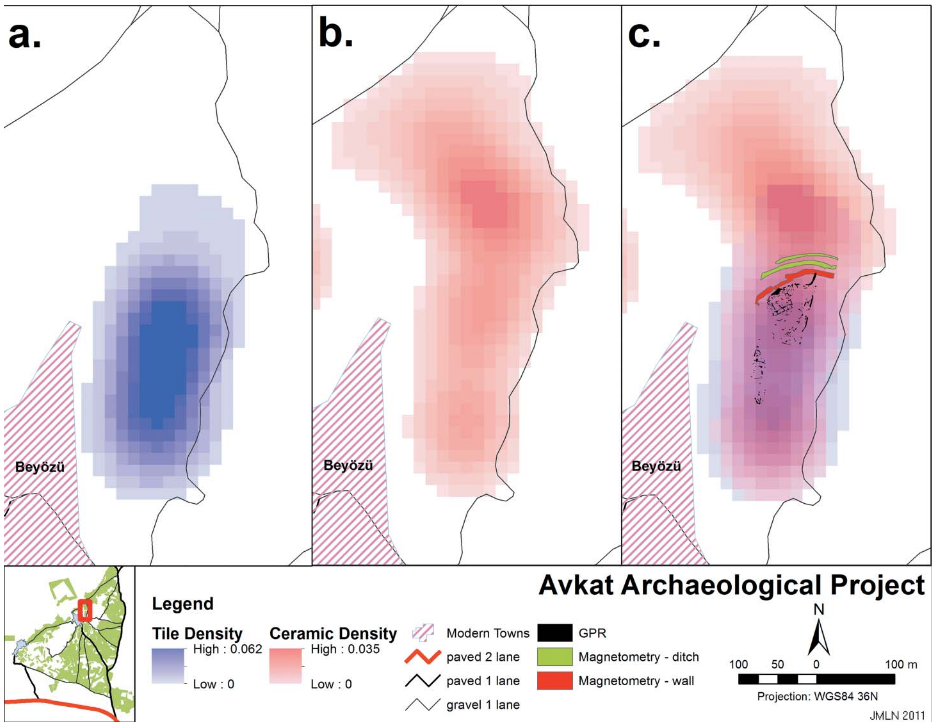

Figure 11. F0306. Avkat 'Kale' showing kernel density concentrations of tile/pithos (a) and ceramics (b), with results from magnetometry and ground-penetrating radar (c). Ceramics (red) and tile (blue) are rendered as semi-transparent, to allow overlapping concentrations to appear as purple. Kernel densities are displayed as 15m grid cells, computed using a 60m search radius. This figure demonstrates the effectiveness of employing the kernel density algorithm to isolate potential areas of significance.

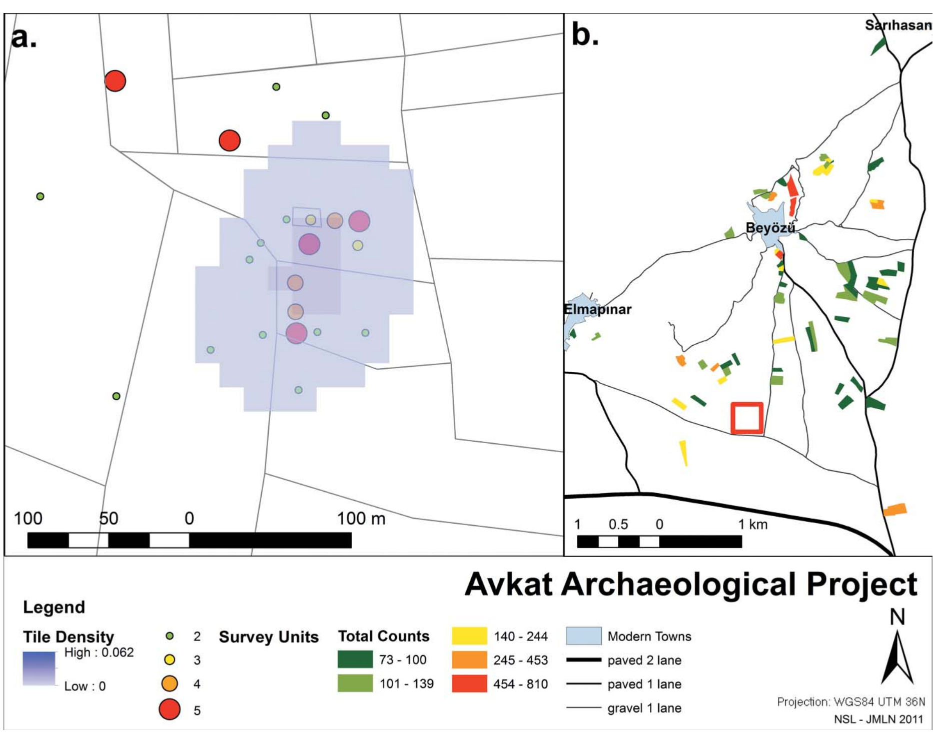

Figure 12. Avkat Archaeological Project, F1005. Kernel density map for pithos/rooftile shows a light concentration (a) in an area not identified via more traditional means (b). The disaggregated nature of the observation points allow for significant concentrations to be identified, irrespective of survey unit boundaries. As bounded by the kernel densities, F1005 includes material found in five adjacent fields, and would not have been identified via more standard means of data collection.

Conclusions

The process of conducting archaeological survey – as is its counterpart investigative method, excavation – is dependent upon context. It requires the ability to accurately record field observations and their geographic location. Recent technological innovations in GIS, satellite imagery, and mobile technology have allowed for greater precision and efficiency in reporting. The methods employed on GAP and AAP serve as additional tools to the repertoire of the landscape archaeologist. When combined in concert with more extensive survey approaches in GAP and AAP, the methods provide a combination of general and high resolution data to the hands of researchers in a short amount of time. The methods serve to define artifact densities without the bias of modern field boundaries, map the location of these densities within the area surveyed, and hold the capacity to integrate geomorphological and archaeological information. While the methods increase the amount of time required for data entry, the increase in GIS processing is offset by the reduced need for field revisits and intensive collection for the purposes of site identification and delineation. These methods, aided by a versioned network and data processing regimen, allow for the time from field observation to a publication-quality product to be reduced to a matter of hours. The added labor deployed in initial GIS processing also allows for additional analysis and modeling – activities usually relegated to the offices and laboratories of home institutions after fieldwork has been completed, leading to increasingly dynamic and active engagement while in the field.

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1. The authors would like to thank at this time the directors and members of the Avkat Archaeological Project (2007–2009) and the Göksu Archaeological Project (2004–2006).
2. The procedures established using the master grid to develop expedient and consistent OP base files were developed by J.Kyer and Elizabeth Kramp during the Göksu Archaeological Project, 2005–2006.

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