Margaret Morris

KRAP Summer 2004

Spatial Analysis

Spatial analysis is a very important aspect to any archaeological excavation and subsequent interpretation of data. Whether of a local (site) scale or regional scale, there are a variety of methodologies, models and tools that one can utilize in order to assist in the organization and reconstruction of archaeological data. Many of these models have been utilized within the field for many years, others, especially new technology such as satellite imagery and geographic information systems (GIS) are newcomers to archaeology. The facilitators, graduate, and undergraduate students working with the Körös Regional Archaeological Project (KRAP) have been utilizing various spatial analysis models and technology since the project's inception in 2001. KRAP, a continuation of the work started by Dr. William A. Parkinson, has enjoyed great success in regards to this type of analysis. The following paper will briefly outline some important methods in spatial analysis, discuss the remote sensing associated with the Körös Regional Archaeological Project, introduce GIS and what has been done thus far with it, and discuss possible areas of analysis these tools would be useful for in the future.

Spatial analysis, in general, is made up of "a set of techniques whose results are dependent upon locations of the objects of analysis". (Goodchild 1996:241) Using this definition, spatial analysis is a way of relating one or more object(s) to another one or more object(s). As spatial analysis seems to be an almost inherent aspect of archaeological analysis today, it is difficult to imagine a time when archaeology did not involve the relation of such space elements. Yet, some aspects of spatial analysis are relatively new to archaeology.

Though it t would be possible to list all of the contributors to spatial analysis in archaeology; such a feat is well beyond the scope of this paper, not only because the list would be vast, but because spatial analysis itself varies upon the "space" one chooses to examine and dividing up the importance of various contributions would be difficult. There are a few people worthy of mention, however, as they have paved the way for the utilization of the technology discussed here. Primarily, there are classic "founders" of settlement pattern and regional analysis – Gordon Willey and Robert McCormick Adams, both of whom took to identifying the bigger picture outside individual sites.

Dunnell and Dancey are also very important mentions as their "siteless survey" approach for archaeological field research took the focus of analysis off of "the site" and demonstrated how regional survey, done with surface collection and limited excavation, could provide valuable archaeological information. (Dunnell and Dancey 1983 (1973)) E.S. Higgs and C. Vita-Finzi took environmental surroundings into consideration while reconstructing past economies and territorial systems of prehistoric societies utilizing site catchment analysis. (Higgs and Vita-Finzi 19) Kenneth Kvamme is a worthy mention for his various work on both the subject of GIS and archaeology and his use of GIS and various remote sensing techniques on a wide variety of his archaeological research.

Additional contributors can be found in the wide range of various "methodologies" that can be used for spatial analysis and variety of models and paradigms that incorporate various settlement pattern analysis and spatial data into an archaeological context. There are paradigmatic approaches, which take to identifying particular landscapes or regions and then reconstructing archaeological evidence and history around said defined area. (Barker 1995), models used to reconstruct hunter and gatherer group sizes, theories that allow for analysis of regional trade networks and their spatial distribution as related to “settlement hierarchies” (Johnson 494), and spatial analysis that focuses on the smaller scale, such as quantitative access analysis which is used to help understand “the relationship between spatial configuration and purposeful movement” within and between residential units. (Cutting 2003, 1)

With KRAP, not all spatial analysis models and remote sensing techniques are appropriate or will produce useful outcomes. As archaeological sites can be found on every continent, ranging all human history, in every climate and on every terrain, archaeologists will be limited, prior to even digging, by a variety of circumstances. This is certainly the case with the Körös Regional Archaeological Project, whose unique focus of study limits the usefulness of some of these techniques.

Discussion of Spatial Analysis on the Great Hungarian Plain

Much of the analysis that has been done with the project can be attributed to the work done by the Hungarians themselves. Hungarians have taken a very active role in measuring and recording archaeological sites around the country. These data are translated into maps, published by county, and made available to the public. This information has allowed for many aspects of the history of Hungary, and in particular, the Great Hungarian Plain to be reconstructed with varying degrees of clarity. Spatial analysis (and GIS) has been used in a wide range of studies on the Great Hungarian Plain for over the last 20 years, a display of the success and importance of such methodology and technology in spatial analysis.

Sherratt, in a study done during the 1980’s, used spatial analysis on the Great Hungarian Plain as a tool for reconstructing settlement organization on the plain. This analysis showed a change in the arrangement of sites over time – from a linear/shoreline distribution during the

Körös culture (6th millennium BC) to an aggregated clustering of sites during the Tisza period (5th millennium BC) and finally a dispersed settlement arrangement during the Tiszapolgar period, which is the focus of study for the Körös Regional Archaeological Project. (Sherratt 1983---) Sherratt then incorporated various geomorphological information (soil, hydrological, geological and environmental) with archaeological information to view regional and local changes on the plain during the previous mentioned time span. (Sherratt 1983)

Parkinson used GIS to complete cluster analysis for Late Neolithic and Early Copper Age sites on a section of the Great Hungarian Plain. The archaeological sites were mapped into a GIS program and nonparametric bivariate cluster analysis was performed for both time periods to reveal the relationships between the sites during their respective times and the changes between the two time periods. Analysis revealed that Late Neolithic settlements were structured in discrete clusters (meaning they were closely associated with each other – often in relation to a core site, in this case a tell site). Early Copper Age sites were much more dispersed across the area, revealing that the clusters that had previously existed and presumably the social arrangements associated with them, had been either destroyed or replaced with a new type of settlement and social strategy. (Parkinson 1999)

Gillings incorporated GIS in an active attempt to reconstruct the paleoenvironment and hydrology and model the possible flood dynamics on the Tisza basin of the Great Hungarian Plain. Drainage information was added as a layer to topographic information and hypothetical flood water was added to locate possible locations of pooling and heavy flood water accumulations. Although this study (introduced in 1993) initially did not produce any definite results, the premise behind the study offers a look at the potential for GIS in archaeology. (Gillings ---)

Remote sensing and GIS have also been used in other areas of science and social science pertaining to the Great Hungarian Plain. The Hungarian counterpart to the United States Geological Survey (USGS) – FÖMI, has been using GIS to complete civilian and military base maps of Hungary (of varying scales) since the late 1990's. They too incorporate satellite imagery and a wide range of remote sensing for such work as planning roads and dams and the expansion of cities and towns. Recently, at the May 2004 EARSeL Symposium in Croatia, various papers and posters were presented on work being done utilizing remote sensing, satellite imagery, and GIS. Topics ranged from the use of remote sensing techniques in an archaeological context to satellite imagery monitoring changes on the polar ice caps. Two posters presented current work being done on the Great Hungarian Plain and surrounding countryside using satellite imagery and GIS. Both of these posters, one presenting work targeted on the Upper Tisza River Basin and the other the Hungarian-Romanian border, discussed how this technology was being used to monitor flooding events in the regions over time. Both studies are seeking a better understanding of the underlying factors that cause such damaging floods on the plains and are looking for ways to not only provide area river authorities with monitoring technology, but ways of improving the landscape to possibly prevent damaging floods in the future. (Kostyuchenko, et al. 2004, Kerényi and Putsay 2004)

The Körös Regional Archaeological Project Background

The site of Vészt_-Bikeri (also known as Vészt_-20 or V-20) is located outside the town of Vészt_ on the SE portion of the Great Hungarian Plain. As there have been numerous other summaries written that provide a background on the geomorphological nature of the plain itself, the description here will be very limited. The Great Hungarian Plain is essentially one gigantic floodplain criss-crossed with a few major rivers (the Körös, Danube, and Tísza) and a system of canals and waterways – some of which were naturally occurring, others which are anthropogenic modifications to the plain made over the last 150 years in an effort to prevent the biennial flooding which used to cause problems for residents of the plain. This modification has altered the "original character" of the plain as levees, dams and other parts of the rivers and secondary waterways have been built up or moved to ensure limited breeching events. Currently, the alluvial soils are home to a wide variety of agriculture, fed by canals and irrigation systems.

One of the very unique aspects of the Plain is its geology – specifically it's lack of stone and rocks in the sedimentary layers. The loess and alluvial soil layers run thick, and in some areas of the Carpathian Basin (of which the Great Hungarian Basin is a small part), the layers can run a 100m deep. (Pésci 1999) Although this might have presented some challenges for Paleolithic and Neolithic peoples, it presents archaeologists with a unique opportunity to study trade as chert or stone found within sites were not found locally, they were brought onto the plain from elsewhere.

Another unique aspect of the plain is it's lack of relief – namely it has little to none. This type of situation can present some problems in regards to spatial analysis as there are no geomorphological landmarks that divide the plain into separate areas. On the flip side, the absence of such barriers allow for opportunities for reconstruction of interaction and settlement patterning and clustering over time on the plain.

One of the main questions being asked by the Körös Regional Archaeological Project is what happened on the plain between the Late Neolithic and Early Copper Ages (5000-4000 BC respectively). Archaeological evidence points to "dramatic changes" (Parkinson 1999) occurring during this time that resulted in changes in settlement organization, trade networks and intragroup relationships. Namely, three geographically discrete cultural groups on the plain during the Late Neolithic were dissolved and replaced by one relatively uniform culture. Whether a structural change as a result of conflict, environmental issues, or other is not clear. The change in social structure on the plain was accompanied by changes in settlement patterning, namely discrete clusters of sites during the Late Neolithic, often aggregated around tells being replaced by more evenly dispersed settlements. Late Neolithic multi-family domiciles were replaced by much smaller houses during the Early Copper Age, and a change in trade routes also accompanied this settlement pattern change. As numerous publications have discussed the changes on the Great Hungarian Plain, the preceding will be all that is included in this paper. Additional information, specifically focusing on the changes during this time, viewed from a regional and social perspective, can be found in Parkinson 1999.

Remote Sensing and KRAP

Many types of remote sensing have been done in association with the Körös Regional Archaeological Project including aerial photography, phosphate analysis, magnetometry, analysis of satellite imagery, and soil analysis. In the following sections, each of these types of remote sensing will be discussed including when and where the analysis was performed and what contributions each has made to the project.

Magnetometry

By far, magnetometry has produced the most useful information regarding individual sites over all other spatial analysis done in affiliation with KRAP. Unlike DEMs or satellite imagery processing, magnetometry takes a detailed look at a relatively small area within the region. KRAP has done magnetometry at two sites – V-20 and Korosdalany 14 (K-14), a smaller site a few hundred meters from V-20. Considered a non-invasive archaeological tool (as readings are taken above the ground and no excavation is required for preliminary analysis), magnetometry at V-20 and K-14 have added in identifying particular areas of interest for excavation as well as helping establish the size of the sites themselves.

Magnetometry measures the magnetic properties of the soil and is useful for locating burned soils, habitation locations, and ditches filled with organic material. (Sarris 2004) Buried features are identified by their variation in magnetic values in relation to the rest of the soil in the area. For both V-20 and K-14, areas around the sites were identified and magnetometry readings were taken for 20m x 20m grids using a Geoscan FM36 fluxgate gradiometer. At V-20, certain parts of the site were unable to have magnetometry done as excavation was begun in 2001 and magnetometry for V-20 was done in 2002. However, magnetometry done at the site revealed circular ditches around the site as well as additional habitation units that were excavated in 2003.

Magnetometry at K-14 occurred in 2003 during the summer field season. Although K-14 is smaller than V-20, similarities in site structure was revealed, most notably the circular ditches surrounding both sites. (Fig. 2 – INSERT BOTH SITES MAP) Fieldwork, set to begin again in 2005, will take advantage of the magnetometry analysis and certain aspects of K-14 will be targeted for excavation investigation. Although magnetometry does not complete the archaeological picture, as it does not identify specifically what is located under the ground, in the case of KRAP magnetometry the imagery provides a base map on which future excavation locations can be specifically targeted. Magnetometry will be used in future years with KRAP in hopes that future work will continue to reveal the same type of results.

Soil Phosphate Analysis

ASTER

Originally, the initial goals of utilizing satellite imagery on the KRAP project during the summer field season 2003 was much wider in scope and included the investigation of questions such as how the contemporary environment differs from the paleoenvironment and whether satellite imagery would be a useful tool in the location and identification of paleodrainages on the plain. However, as the summer progressed and due the highly technical and difficult nature of the project's questions (namely GIS and satellite imagery) – the project was cut down to one task – process an original 60km x 60km ASTER image for the Vészt_-20 area and then rectify the image to the topographic map of the site that had been digitized earlier.

ASTER (Advanced Spaceborne Thermal Emission and Reflection Radiometer) is an instrument loaded on the Terra spacecraft, which is part of NASA's Earth Observing System (EOS). The purpose of EOS, which has both a science component and a data information system (EOSDIS), is to monitor long-term global aspects of land surface, the biosphere, atmosphere, and the oceans. (ASTER crap) This is accomplished through the coordination of several satellites, each equipped with different imagery equipment, positioned at varying altitudes and orbit locations around the earth. (ASTER crap)

ASTER takes about 650 images per day, each of the images are 60km x 60km. There are two types of ASTER images processed out of the 650 taken daily – levels 1A and 1B. 1A images have less information available (digitally) in them and are referred to as lower-level data products. Level 1B, which are used for DEM extraction and other more advanced analyses, are called “higher-level data products” and require more processing work on the part of the EROS Data Center Land Processes Distributed Active Archive Center (a.k.a. LP-DAAC), and on average only 150 out of the 650 original images make it to the 1B level. All ASTER products are stored on Hierarchical Data Format (HDF-EOS), which is translatable into ArcGIS and a variety of other GIS programs.

ASTER images come divided into “importable” bands, essentially meaning that each band can be imported as a layer into a GIS. Each band represents a particular part of the spectral image. All together, there are 14 bands per ASTER image. These are divided into visible and infrared radar (VNIR), short wave infrared (SWIR), and thermal infrared (TIR). Each of these bands allow for a different aspect of light reflected off of the earth to be collected. Some of the bands are useful when dealing with polar caps, others when dealing oceans. For all said purposes in Hungary, bands 1,2 and 3N (3 out of 7 from the VNIR group) created an image, which allowed for viewing of the geomorphological aspects of the landscape.

The data for bands 1,2, and 3N, called layers, were imported into ArcGIS. After being imported, the site (Vészt_-20) was located within the 60km x 60km swath and the area was “cut and paste” into another ArcGIS file. This cut area matched the area of a topographic map which had been digitized earlier (Magyar Nepkoszatarsasag #48-244 Vészt_) and nine points, visible both on the topographic map and the ASTER image were selected for geo-referencing. Geo-referencing is basically tying an image or map to actual geo-coordinates. This step has to be completed in order to rectify the image because images of the earth, especially satellite images, are taken at an angle, which skew, in a sense, the reality of the curvature of the planet. Maps are also guilty of lack of proper projection as they are drawn “flat” and do not take into account the curvature either.

These points were entered onto both images as geocoordinates. Both “corrected” images could then be layered together (the previously entered geocoordinates linking them) to create a rectified image. The final image produce a rough looking DEM (the result of the topographic map) overlaid with the ASTER image.

In this particular instance, ASTER works much like an aerial photo as it produces stereo-paired images. Unlike an aerial photo, ASTER images, and other satellite images, are essentially images created from the collection of reflected light off the earth’s surface. There are several types of satellite imagery – some which employ a radar type method of bouncing a signal off the earth and collecting the reflection, and others which simply collect the natural radiation from the earth’s surface. All satellite imagery information is collected as a set of numbers. These numbers are then translated by a computer into a variety of information including the layers of the images. This process can be very, very technical (FIG. 1) and there are many opportunities for errors to occur in the processing.

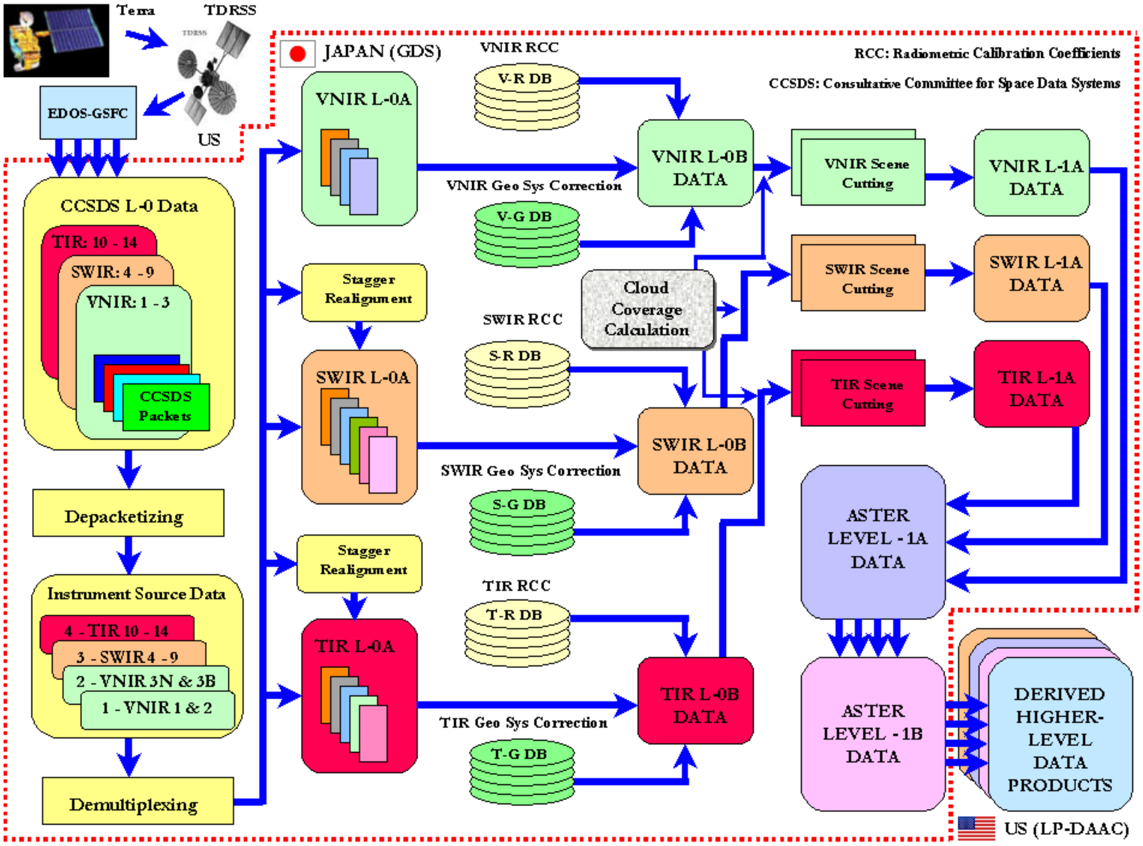

Fig.1

ASTER imagery is not the best imagery available for every kind of work, but it is free, which makes it an ideal option for archaeologists. For those not capable of extracting a DEM using ASTER imagery, DEMs that have already been created are accessible through EROS LP-DAAC (EOS data storage center). If a DEM is not available for an available ASTER image, one can be requested. The ASTER image delivers accuracy of information regarding geomorphological features and works tremendously well on a large scale as it provides 15m resolution (generally). However, many of the images can range from 15m-90m depending upon the wavelength being used for analysis, the resolution should be 15m for VNIR.

GIS – Geographical Information Systems

GIS is essentially a program that consolidates various data that can be correlated spatially (maps). (Ormsby 2003) GIS can provide analysis ranging from population statistics correlated with percentages of urban suicide to natural resources available at various altitude ranges. GIS itself does not provide answers to questions – it is simply a way to organize data that allows the user to ask questions or view information and interpret their questions. Data is organized into thematic or theme layers – for example, topography might be one layer, early Copper Age sites might be another layer, and Late Neolithic sites might be a third. These layers can be combined or view separately, allowing for questions of varying complexity to be asked.

For example, an archaeologist might ask if more Early Copper Age sites were located on higher elevations of a landscape vs. Late Neolithic sites. This archaeologist could utilize GIS to answer this question by creating two maps out of three thematic layers. First, the thematic layers would be entered into the GIS program – the topographic base map of the region of interest, the location of Late Neolithic sites within the region and the location of Early Copper Age sites. Using these layers, the archaeologist would next combine the maps to create two maps – one map containing the topographic base map and Late Neolithic sites and the second containing the topographic map and Early Copper Age sites. Finally, the archaeologist could choose to a particular statistical analysis on both maps to compare the relationship between the location sites and elevation.

GIS performs a wide variety of statistical analyses that are of benefit to archaeologists including nearest neighbor, cluster analysis, Theisson polygons, things such as temperature or climatic variations over particular regions, and population density estimates. GIS can answer simple or complex questions, varying in the amount of information provided to the system by the archaeologist. The more complete a picture an archaeologist wants on a particular region, the more information would have to be collected and inputted in order for analysis to be run. If an archaeologist only wants distances computed between sites, only geographical locations of these sites would need to be added to the program. If the archaeologist wants to reconstruct the changing paleoenvironment over a period of one thousand years in conjunction with subsequent changes in settlement patterning and trade networks, this would require MUCH more information added to the program.

The DEM (Digital Elevation Model)

A DEM is essentially a 3-D model of the relief of a particular region of the earth's surface. Also called "digital terrain models", these are very useful in spatial analysis and visually help "bring together" aspects of study, which could potentially be missed by analyzing a regular, flat map. (Wheatley and Gillings 2002) Thus far, this paper has discussed KRAP's attempt to obtain their DEM through satellite imagery. It should be noted that there are several ways to obtain DEMs. The two that will be discussed here are:

1. Digitization of a region's topographic maps and creation of the DEM based off the digitized information.
2. Extraction of the topographical information from the satellite imagery and subsequent creation of a DEM based upon the elevation information provided by the image.

Both methods provide DEMs with varying resolutions and, depending upon the project's goal, one particular method might be more feasible than another. For archaeologists working in the US, digitized topographic base maps are available through the United States Geological

Survey (USGS) website, which eliminates much of the work involved in obtaining a DEM or even maps for a project. Archaeologists working overseas might have more difficulty obtaining already digitized information, although most European countries and some Asian and African countries do have digitized topographic base maps for purchase if a project can afford the price. If looking to create a DEM, the digitized topographic maps might be the more efficient option.

If no digitized maps are available, satellite extraction can save time in the process of obtaining a DEM, however, a working knowledge of the GIS programs as well as the various kinds of satellite imagery is a must. Satellite imagery can also be extremely costly, and in order to obtain images for necessary regions, interested parties should not be surprised at seeing costs between $500-$750 per image. Another notable downfall to satellite imagery is that some of it does not have global coverage, and other kinds are not available to the general public for security reasons.

The most time consuming, yet seemingly most reliable, method of obtaining a DEM is the digitization of paper topographic maps. Once digitized, these maps can be turned into a DEM. The advantage of digitizing maps is that the user controls and decides what types of information to include and not to include on the layers. Roads, rivers, crop types, or soil types can also be digitized. Currently, soil and topographic maps of areas in Northern Bekes County are being digitized for the KRAP project and although this method is time consuming, the results will hopefully be beneficial to those needing the information on the project.

Satellite Imagery, GIS and KRAP

It is difficult to predict what future spatial analysis and remote sensing will reveal to the participants of KRAP. As spatial analysis associated with the project progresses, more detailed questions regarding settlement pattern, social structure, and paleoenvironmental changes on the Plain could be made available. Thus far, combinations of Magnetometry and phosphate soil analysis have revealed similarities between the two sites and future work using these two valuable methods may further understanding of site structure during the Tiszapolgar period on the Plain. Additional work with GIS, on varying scales, has the opportunity to describe intrasite relationships at each site, create a linear reconstruction of environmental changes on the Plain, and provide invaluable data to help answer the questions pertaining to the changes that occurred between the Late Neolithic and Early Copper Age. GIS will also be helpful in determining changes in trade networks and how inhabitants of the area interacted and changed their landscape.

Suffice to say, GIS and remote sensing will continue to remain an important part of the Körös Regional Archaeological Project due partly to the success it has enjoyed and to the fact that the individuals who have worked on the project employing various techniques realize the value of utilizing such technology. Although the ASTER imagery has thus far failed to produce a DEM, this has not deterred interested parties from researching other forms of imagery as a potential source for topographic information (e.g. RADARSAT). It should be noted that ASTER imagery does produce effective DEMs, and that there are many possible reasons why the image did not produce a successful DEM in this particular case, including the image itself (the data) being flawed.

Although KRAP is in no way unique in regards to its use of remote sensing and GIS in an archaeological context, it is among a few projects utilizing GIS in a relatively long-term study. This is where the Körös Regional Archaeological Project has the potential to contribute not only to the important archaeological knowledge of changes on the Great Hungarian Plain in the past, but to archaeology itself – as both a science and as a discipline. As GIS has been a part of KRAP since the onset and is used at a variety of levels, from the site to the region, future contributors to the project will be able to add to the already existing information, identify new problems and perform new analyses, which, without GIS, might not be noticed or initially asked.

As far as GIS itself, there are many publications, written with much more clarity than this simple paper, that discuss the grand potential for this technology as a spatial analysis and data organizational tool. One notable advantage to using such technology, rarely discussed, is it's potential to aid in the sharing of archaeological information in the future. Archaeologists completing work with GIS today are also creating easily referenced and organized maps and spatial analysis for the archaeologists of the future. Future researchers, 25 years from now, wishing to further examine this particular area and time period on the Great Hungarian Plain will be able to build upon the existing information (or delete from it). One can hope that as technology improves creating thematic layers and using GIS will become easier, making it accessible to all archaeologists as a tool for analysis.