Geophysical and Geochemical Investigations at Two Early Copper Age Settlements in the Körös River Valley, Southeastern Hungary

Richard W. Yerkes,[1],* Apostolos Sarris,[2] Tod Frolking,[3] William A. Parkinson,[4] Attila Gyucha,[5] Meredith Hardy,[4] and Luigi Catanoso[2]

[1] *Department of Anthropology, Ohio State University, Columbus, OH 43210-1364*
[2] *Foundation for Research and Technology–Hellas, Rethymnon, Greece*
[3] *Denison University, Granville, OH, USA*
[4] *Florida State University, Tallahassee, FL, USA*
[5] *Munkácsy Mihály Múzeum, Békéscsaba, Hungary*

Geophysical and geochemical analyses conducted at the Early Copper Age (ECA, ca. 6500–5900 B.P.) sites of Vésztő-Bikeri and Körösladány-Bikeri in southeastern Hungary located and mapped subsurface features and activity areas. Vertical magnetic gradient measurements defined the extent and layout of structures and features and revealed previously unidentified concentric ditches enclosing both sites. Soil chemical surveys recorded high concentrations of phosphorus in "ring middens" around the sites' perimeters, but low concentrations around structures. Magnetic susceptibility measurements supported and enhanced the results from other surveys. Excavations confirmed the locations of the features detected in the geophysical and geochemical surveys. The layouts of the two sites were different. Vésztő-Bikeri was "nucleated," with central longhouses surrounded by pits and a ring midden. At Körösladány-Bikeri, smaller structures were dispersed and intermixed with other features, including post-Copper Age pits. The nondestructive investigations helped us refine our models of settlement organization during the Neolithic–Copper Age transition. © 2007 Wiley Periodicals, Inc.

INTRODUCTION

Geophysical and geochemical investigations of two Early Copper Age settlements in the Körös Region of the Great Hungarian Plain by the Körös Regional Archaeological Project[1] (Figure 1) provided new details on the changes in settlement

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[1] An international team of archaeologists and earth scientists who have been investigating the transition from the Neolithic to the Copper Age on the Great Hungarian Plain (*Nagy Alföld*) in the eastern Carpathian Basin since 2000 (Parkinson, Gyucha, & Yerkes, 2004; Parkinson et al., 2002, 2004; Gyucha, Parkinson, & Yerkes, 2004; Sarris et al., 2004).

*Corresponding author; E-mail: yerkes.1@osu.edu

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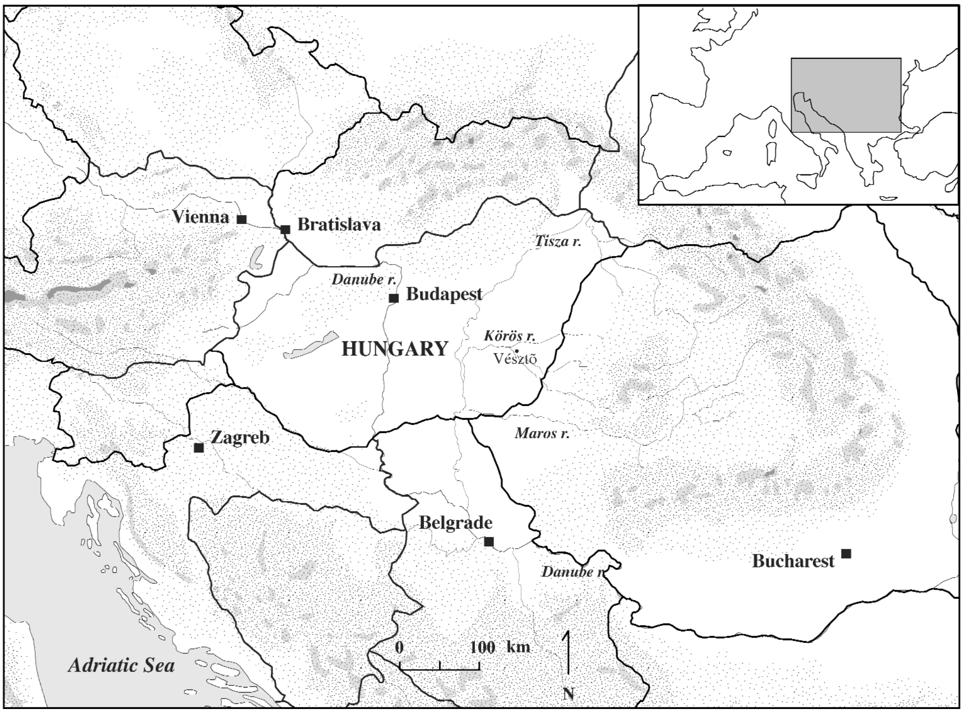

Figure 1. Map of the Carpathian Basin in central and southeast Europe (inset). The Great Hungarian Plain is east of the Danube. The KRAP study area is just west of the town of Vésztő. The middle channel of the three branches of the Körös River is the Sebes Körös River.

patterns and site organization that were implemented by southeast European agricultural societies during the Late Neolithic (LN, ca. 8500–6500 B.P.) to Early Copper Age (ECA, ca. 6500–5000 B.P.) transition. The discovery of palisades and ditches surrounding the small, dispersed ECA sites forces us to abandon the idea that defensive features became "superfluous" at the end of the Neolithic (Bognár-Kutzián, 1972). It seems that the ECA may not have been so peaceful after all. Large longhouse structures were found, suggesting that there was more continuity in house construction methods during the LN–ECA transition than was previously thought.

However, most of our results support the LN–ECA transformation models of changing socioeconomic organization marked by new house forms, site layouts, settlement distributions, and mortuary customs. These models are based on the results of surface surveys and test excavations on the Great Hungarian Plain by Hungarian, British, and American archaeologists (Bognár-Kutzián, 1963, 1972; Ecsedy et al., 1982; Sherratt, 1983, 1984; Raczky, 1987; Jankovich, Makkay, & Szőke, 1989, 1998; Parkinson, 2002) that have been combined with GIS-based topographic and hydrological reconstructions (Parkinson, 2002; Frolking, 2004; Harrower & Morris, 2004).

Similar changes occurred across most of southeastern Europe at this time as populations dispersed and abandoned the large villages and tells that had been inhabited for generations. On the Great Hungarian Plain, this transition affected nearly every aspect of social organization, from households and villages to regional settlement systems, but our understanding of these changes is hindered by a lack of systematically excavated Early Copper Age settlements. Although several large tells and Late Neolithic settlements have been excavated recently (e.g., Raczky, 1987; Raczky et al., 1994), before the launching of the Körös Regional Archaeological Project, there were no systematically excavated Early Copper Age sites.

To gain a better understanding of these socioeconomic changes, two Early Copper Age sites, Vésztő-Bikeri and Körösladány-Bikeri (Tiszapolgár culture, ca. 6500–6000 B.P.) were selected for intensive study (Figure 2). Both sites are located on low rises overlooking an old channel of the Körös River near the modern town of Vésztő, Hungary. The sites are only 60 m apart, but are separated by a modern drainage canal. Construction of this canal seems to have damaged the western edge of the Vésztő-Bikeri site and the eastern edge of Körösladány-Bikeri (Parkinson, Yerkes, & Gyucha, 2004; Sarris, 2004; Sarris & Catanoso, 2005). While cultural deposits at many shallow Tiszapolgár settlements have been destroyed by plowing, the surface material at Vésztő-Bikeri and Körösladány-Bikeri retained their spatial integrity, and suggested that sub-surface features were intact (Parkinson, 1999: 201–202, 208–210; Parkinson, Gyucha, & Yerkes, 2002; Parkinson, Yerkes, & Gyucha, 2004). Nondestructive

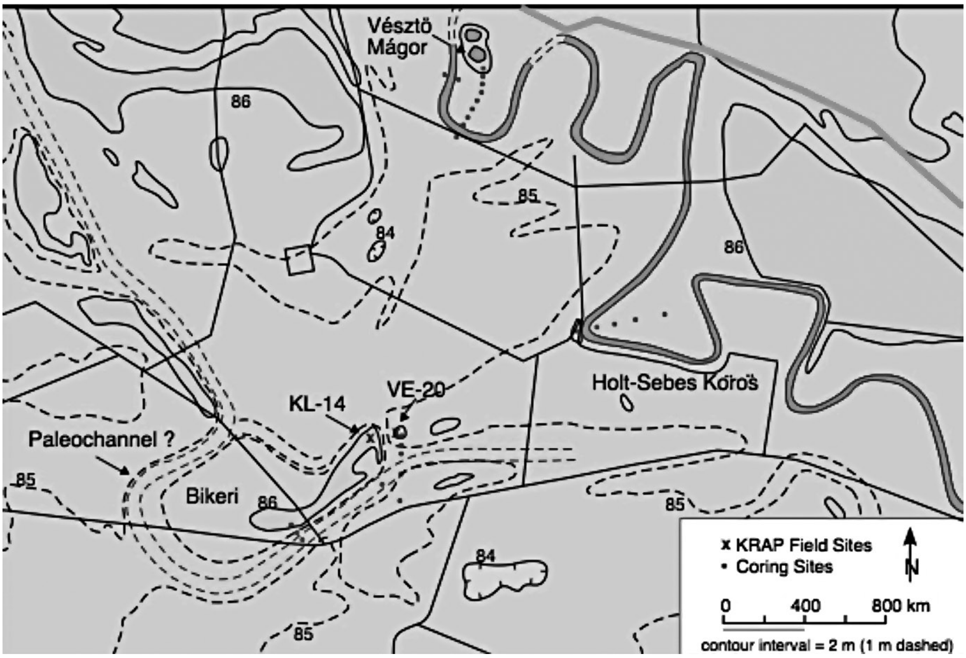

Figure 2. Locations of the Early Copper Age Vésztő-Bikeri (VE-20) and Körösladány-Bikeri (KL-14) sites on the flatlands south of the Vésztő Magor tell and SW of the pre-canal channel of the Sebes Körös branch of the Körös river (Holt Sebes Körös). Locations of the cores used to reconstruct paleochannel dimensions are also shown (after Frolking, 2004).

geophysical and geochemical surveys were conducted at the two ECA settlements to locate and map subsurface features and activity areas. Excavations at the two sites by Hungarian and American archaeologists and field school students between 2000 and 2006 confirmed the locations of most of the wall trenches, postholes, ditches, and pits detected during the nondestructive surveys and also established spatial and stratigraphic contexts for the features, artifacts, and ecofacts. Vertical magnetic gradient measurements defined the extent and layout of the features within the two sites, including a series of concentric circular anomalies that enclosed each site (Figure 3). Excavations revealed that these anomalies were palisades and ditches, but no traces of the circular features were visible on the modern surfaces of the sites or apparent in the surface artifact distribution patterns (Sarris et al., 2004; Parkinson et al., 2004).

The soil chemical surveys recorded high concentrations of phosphate around the perimeters of each site (some of which were associated with ring middens), and showed a contrast between the "cleaner" centers of the sites (near several wattle-and-daub structures at Vésztő-Bikeri) and the ring of debris at the edges of the sites

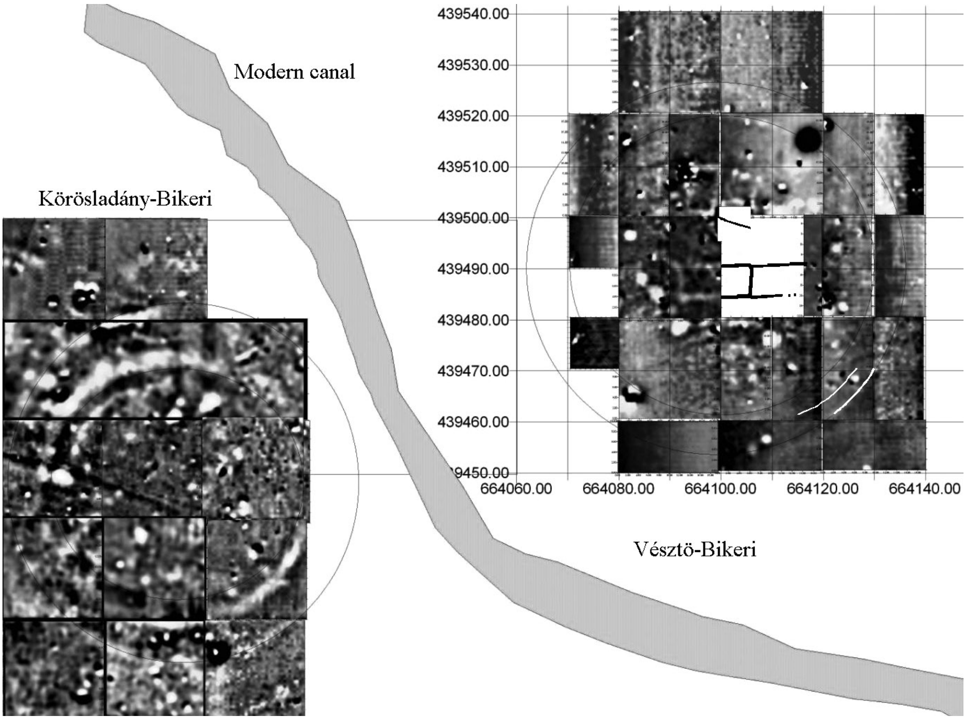

Figure 3. Magnetic Anomalies recorded at the Körösladány-Bikeri (left) and Vésztő-Bikeri (right) sites. Raw vertical gradient measurements within the Hungarian national grid system are shown. Locations of the excavated longhouses in the center of the Vésztő-Bikeri site (black lines) and the excavated segments the circular enclosures along the southeast edge of the site (white lines) are superimposed (after Sarris 2004; Sarris et al. 2004). The large dark circle in the northeast quadrant of the Vésztő-Bikeri site is the iron rod that served as the site datum.

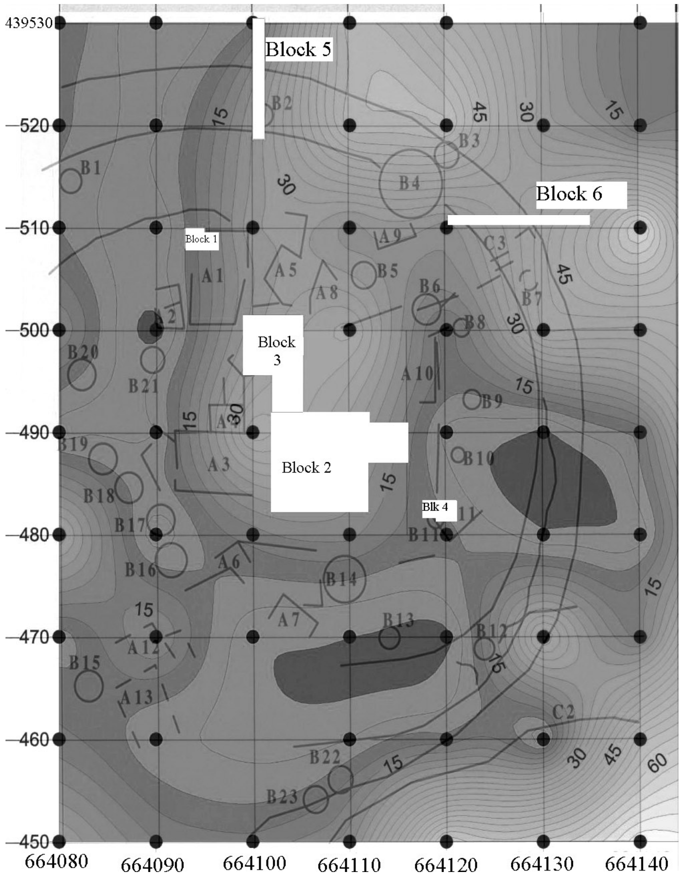

Figure 4. Map showing the location of phosphate samples (black dots), phosphate levels, diagrammatic representations of the magnetic anomalies, and excavation blocks from the 2000–2002 field seasons at Vésztő-Bikeri. Higher phosphate values are represented by darker colors, lower values are indicated by lighter colors. Note the low phosphate values in the center of the site near Blocks 2 and 3 where several longhouses (A3, A4) were located. The highest phosphate values are at the E and S edges of the site near the circular anomalies (C1, C2, C3, ditches and palisade), High phosphate values were also recorded near the circular anomalies B9, B10, B14, B16, B17, B18, B19, B20 and B21, which may be cooking features or storage pits.

(near the circular palisades and ditches, see Figures 4 and 5). Magnetic susceptibility measurements from the two Early Copper Age settlements were analysed by Apostolos Sarris and Luigi Catanoso (2005) and compared with the earlier geomagnetic and geochemical survey results.

Nondestructive surveys are not a substitute for systematic excavation, but they provide spatial information that can be used to construct models of settlement organization that can be tested with efficient excavations limited to specific targets of interest. These results are an important component of our ongoing investigations

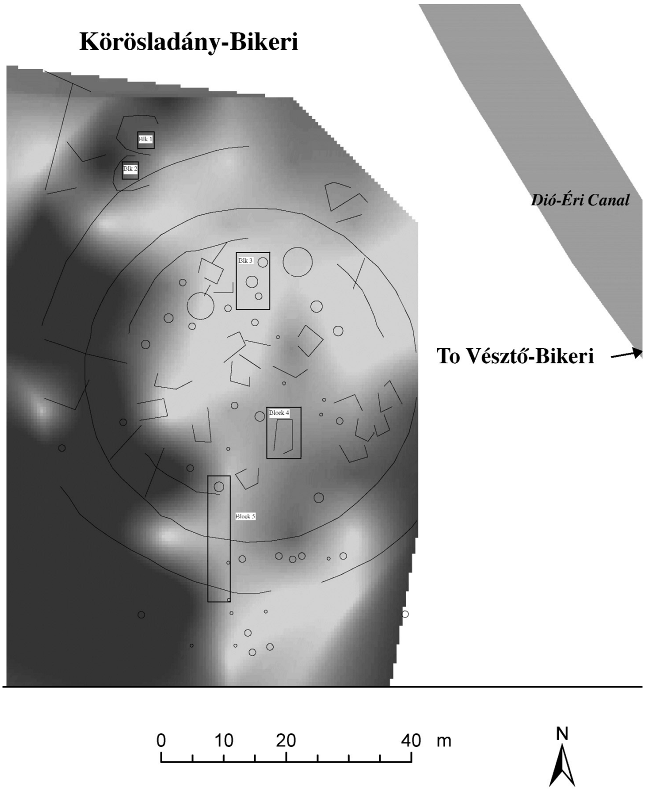

Figure 5. Map showing phosphate levels, diagrammatic representations of magnetic anomalies, and excavation blocks from the 2001 and 2005 field seasons at Körösladány-Bikeri. Higher phosphate values are represented by darker colors, lower values are indicated by lighter colors.

and have changed the way we view the Neolithic–Copper Age transition. These methods should provide equally valuable information when they are applied in other archaeological contexts.

THE ENVIRONMENT OF THE EARLY COPPER AGE SETTLEMENTS

The Körös Basin of the Great Hungarian Plain contains Quaternary fluvial deposits overlain in some places by aeolian loess and sands (Pécsi & Sárfalvi, 1964; Pécsi, 1970; Kosse, 1979; Várallyay, 1993). In the last 720,000 years, over 150 m of clays, silts, and fine sands have been deposited in the KRAP study area (Rónai, 1997; Frolking, 2004). There are no local sources of stone (or copper) for tools. Flint, obsidian, and copper implements (or raw materials) had to be imported. The small rivers in the Körös Basin flow west ca. 175 km from the foothills of the Apuseni and Bihor Mountains of the Western Carpathians across the low-gradient Körös plain until they merge and form the main channel of the Körös, which flows another 45 km southwest and joins the Tisza River (a large tributary of the Danube) (Figure 1). In eastern Hungary, these streams meander over an extremely low relief (1–2 m) landscape. Numerous sets of weakly expressed meander scars and levees are visible near the modern river channels in the study area.

The climate of the region has been characterized as semiarid "Mediterranean" or semiarid-semihumid (Pécsi & Sárfalvi, 1964; Kosse, 1979; Szujkó-Lacza, 1981: 16, 1982: 7–13; Borhidi, 1993), marked by seasonal droughts and wet periods. There is no evidence for significant climate change during the Neolithic–Copper Age transition in southeast Europe (Starkel, 1997; Magyari et al., 2001), but unfortunately no pollen records or other proxy climate data are available for the immediate region. The ECA Vésztő-Bikeri and Körösladány-Bikeri sites were established on relatively well-drained, low hills or rises adjacent to poorly-drained flats and depressions within 1 km of the active channel of the Sebes Körös River and 2 km south of the tell site at Vésztő-Magor (Figure 2). The low-lying areas of the Körös floodplain are characterized by seasonally inundated "meadow clays" that seem to have been avoided by Neolithic and Copper Age groups (Kosse, 1979; Ecsedy et al., 1982; Sherratt, 1983; Raczky, 1987; Jankovich, Makkay, & Szőke, 1989, 1998; Parkinson, 2002).

Our ongoing paleoenvironmental investigations suggest that the landscape around these sites was stable. Although we do not have enough data for a detailed reconstruction of the flora and fauna of the site environs, it appears that the ECA inhabitants seem to have cleared some forestlands to obtain wood for their wattle-and-daub houses and palisades (and for cooking and pottery production). This would have opened up areas for cultivation and grazing. They also fished and hunted in the wetlands, forests, and streams (Kasper, 2003; Nicodemus, 2003; Frolking, 2004; Parkinson, Gyucha, & Yerkes, 2004; Parkinson et al., 2004). To understand the internal organization of these small domestic settlements, we need to look at the results of the geophysical and geochemical surveys and our excavations of specific features identified in these surveys.

GEOPHYSICAL AND GEOCHEMICAL METHODS

Nondestructive geophysical and geochemical surveys can detect subsurface features such as pits, middens, walls, foundations, ditches, hearths, kilns, animal pens, pottery concentrations, and burned structures. This is accomplished by measuring the physical properties of soils and by recording concentrations of magnetic minerals and chemicals such as phosphorus, nitrogen, calcium, and carbon (Eidt, 1973; Aitken, 1974; Sjöberg, 1976; Bethell & Máté, 1989; Spoerry, 1992; Becker, 1996; Bjelajac, Luby, & Ray, 1996; Eder-Hinderleitner, Neubauer, & Melichar, 1996; Lambert, 1997; Schlezinger & Howes, 2000; Kvamme, 2001; Parnell, Terry, & Golden, 2001).

In 2002, a high-resolution (0.25–0.5m sampling interval) magnetic survey covering more than 5000 sq. m of the area surrounding the central excavation blocks at Vésztő-Bikeri was conducted (Sarris et al., 2004), followed by a similar survey at Körösladány-Bikeri, where an area of 5600 sq. m was covered (Sarris, 2004). A Geoscan FM36 Fluxgate Gradiometer was employed during the investigations to record the vertical magnetic gradient, namely the difference of the vertical component of the magnetic field at two different heights from the surface. The two sensors of the gradiometer consist of two coils spaced 0.5 m apart that are very sensitive to features located with 50–100 cm of the surface. The instrument is able to read the vertical gradient of the magnetic field with an accuracy of 0.1 nT/m. The magnetic survey was conducted by walking from south to north along 0.5 m spaced transects and taking measurements every 0.5 m or 0.25 m.

Magnetic Data Processing Procedures

Although the magnetic data did not need to be corrected for diurnal variations of the earth's magnetic field because both sensors read simultaneously the vertical component of the field, all data were characterized by a constant shift of the average value within each survey grid. This was because of the shifting of base/reference stations at the two sites and the balancing of the instrument when walking along the grid lines. For this reason, preprocessing of the raw data was needed in order to create a common base level (0-level base line) for all survey grids. These data were downloaded into a portable personal computer right after fieldwork and each data set was coded by a survey grid number and given the appropriate coordinates within the site grid system. Statistical analysis of the magnetic values in the common rows and the calculation of the average magnetic intensity levels of adjacent grids were carried out in order to provide a correction factor for each new grid. These correction factors were used to create a mosaic of the data collection grids and allowed data from adjacent grids to be processed simultaneously (Sarris, 2004).

Kriging interpolation was used for gridding the data. In some cases, selective despiking techniques were used to isolate the extreme values that marked the anomalies of interest (Sarris, 2004; Sarris et al., 2004). Selective compression of the dynamic range of values was also employed to isolate anomalies close to the background level. A mask file was created to isolate the areas of the two sites where magnetic survey was not conducted. Other filters such as high-pass (gradient) or calculation of first horizontal derivatives were used to emphasize the high frequency components of the geophysical maps of each site (Figure 3). Finally, interpretation maps were made based on the features that were identified during the different processing steps. Color and gray-scale geophysical maps were produced. Hot colors (red shades) in color maps and light (white) colors in gray-scale maps represent areas of high (positive) magnetic intensity. Cold colors (blue shades) and dark (black) colors represent low intensity anomalies (Sarris, 2004).

Methods of Soil Chemical Analysis

Soil samples were collected with an Oakfield hand soil probe at 10 m intervals within a 9400 square-meter grid covering the Vésztő-Bikeri site and from transects extending 100 m east and 100 m south of the edges of site. Cores were also taken at nine control points that were sampled to establish the natural background levels of phosphorus to be expected in the area near the site (Sarris et al., 2004). Similar sampling methods were employed at Körösladány-Bikeri within a grid covering an area of 4800 sq m, along transects extending 100 m west and 110 m south of the site, and at six randomly selected points (Figure 5). The samples were extracted from both the plow zone (Ap, 15–20 cm below surface) and subplow horizons (45–50 cm below surface), and were analysed for total phosphorus, percent of organic content, magnetic susceptibility, and pH (Lee, Galaty, & Hardy, 2004; Sarris et al., 2004; Hardy, 2005).

Phosphate Analysis

In the ground, phosphorus may be in two forms: available or unavailable for plants. This availability may also be thought of as extractable (available) and total (unavailable). Total phosphorus is what is found primarily in the subsoil and is removed from the soil only by erosion. The "stable" total phosphorous values can be used as proxies for past human activities (Eidt, 1973). The soil's pH is a determining factor for phosphorus availability, as is particle size. Alkaline soils form calcium carbonates, which are easily absorbed by plants, whereas acidic soils form aluminum and iron phosphates that are slowly available for plant use. Phosphate fixation is high in clayey soils and low in coarse-grained soils (Sjöberg, 1976: 448). Increased levels of phosphorus tend to be present around areas of human settlement where organic materials were stored or left to decay (e.g., houses or villages, animal enclosures, middens, burials, and places of food preparation). Different activities result in a variable distribution of phosphorous across settlements. For example, high phosphorus concentrations can be indicative of animal pens or middens, with slightly lower concentrations possibly indicating food storage facilities and cooking areas (Sjöberg, 1976: 452; Conway, 1983; Bethell & Máté, 1989; Lambert, 1997; Schlezinger & Howes, 2000; Parnell, Terry, & Golden, 2001; Sarris et al., 2004; Parkinson et al., 2004). Very low levels of phosphorous are often indicative of places that were intentionally cleaned, such as plazas or courtyards.

Plow zone and subplow zone samples from Vésztő-Bikeri and Körösladány-Bikeri were tested for extractable phosphorus to assess the effect of modern activities on archaeological chemical signatures. The samples from both sites were tested with a colorimetric technique for Molybdate Reactive Phosphorus (MRP) based on a modification of the methods outlined by Murphy and Riley (1962), which reduces the sample to a molybdenum blue with a color intensity that is proportional to phosphate concentrations (Lee, Galaty, & Hardy, 2004; Sarris et al., 2004).

However, additional analyses were conducted on 84 of the 105 subplow zone soil samples from Körösladány-Bikeri (Hardy, 2005). These 84 samples were tested for total phosphorus, extractable phosphorus, percent organic content, and pH. All tests were in accordance with procedures for the processing and testing of sediments as established by the U.S. Environmental Protection Agency and the U.S. Army Corps of Engineers (Plumb, 1981). Total phosphorus is measured in micrograms per kilogram in dry weight (μb P/kg). Organic loss is conducted as a loss of ignition (LOI %), in which samples are dried and combusted. The pH was determined for selected samples that were associated with different types of magnetic anomalies. Total phosphate for dry weight was calculated as follows:

$$\text{Total phosphate mg/kg (dry weight)} = \frac{(x)\,(y)\,(1000)}{(g)\,(\%\,S)}$$

where

x = phosphate concentration in sediment digest (mg/l)
y = final volume of sediment digest (l)
g = wet weight of sample digest (g)
$\%\,S$ = percent solids in sediment sample as a decimal fraction

Magnetic Susceptibility

Frequently, anthropogenic soils have magnetic properties distinct from those of the background values found at archaeological sites. Surface magnetic susceptibility variations produced by plowing and scatters of small iron or ceramic objects can be quite easily identified (Tucker, 1952; Le Borgne, 1955, 1960; Scollar, 1965). Susceptibility enhancement is also correlated with duration and intensity of human activity. It can provide information on the extent and dating of human occupation, the type of vegetation cover once present, and even predict the potential of a site for magnetometer survey by examining the average level of susceptibility of the topsoil and the corresponding contrast between features and their soil context (Sarris, 1992).

A dual frequency susceptibility sensor was employed to measure samples from Vésztő-Bikeri and Körösladány-Bikeri to see if the multidomain grains most likely derived from natural parent materials could be distinguished from the single-domain (larger frequency dependent) grains of soil affected by human-activity (Clark, 1988, 1990: 99–117; Sarris & Catanoso, 2005). Mullins and Tite (1973: 804) have shown that a significant variation of susceptibility with frequency is observed in single domain grains in contrast to the multidomain grains (no quadrature susceptibility, no frequency variation of susceptibility and very small magnetic viscosity). As the frequency of the AC field is increased, susceptibility is expected to decrease due to the fact that magnetic viscosity slows down the reaction of the magnetic grains to the changing direction of the AC field. Soil grains around the SD/SPD boundary display a magnetic viscosity resistance to high frequency measurements and thus their apparent susceptibility falls off sharply with increasing frequency (i.e., there is a high frequency dependence inversely proportional to the susceptibility).

Human habitation is characterized by high variations of the surface distribution of topsoil susceptibility in combination with high frequency dependence. By contrast, naturally derived magnetic minerals of multidomain character exhibit low frequency dependence. As a general conclusion, human activity, weathering, and burning would enhance the conversion of magnetic particles to a smaller size characterized by high frequency dependent susceptibility and thus measurements of the susceptibility at two or more frequencies can be used as a guide for the location of areas of archaeological interest. The "frequency dependent susceptibility" ($FDS\% = \chi fd\% = ((\chi low - \chi high)\ \chi low) \times 100$) can be used as a relative measure distinguishing ancient human activity from modern disturbances (Oldfield et al., 1983: 37–44; Clark, 1990: 103–104).

Even if there are strong variations of the magnetic susceptibility, a low frequency dependent susceptibility shows that these variations might be a result of the parent magnetic minerals of the soil.

Magnetic Susceptibility Measurements

A dual frequency sensor MS2B (Bartington Instruments, 1988) was employed in the measurements of the soil magnetic susceptibility. Accurate measurements (in units of 1×10^{-6} cgs/gr) of the mass susceptibility were obtained in two frequencies ($f_{low} = 0.43$KHz and $f_{high} = 4.3$KHz). Each measurement was normalized for a mass of 10 gr, to be compatible with the initial calibration of the instrument. A total of about 180 samples from the two sites were measured and processed.[2] Both coordinates of the position from where the samples were extracted, and the corresponding susceptibility measurements (in both frequencies) were recorded and processed with ArcGIS software. The results of the magnetic survey were also processed through rectification of the final maps in the same coordinate system and digitization of the potential anomalies.

RESULTS

The results of the magnetic surveys defined the extent and layout of the structures and features across the two ECA settlements. It seems that both of the fields where the sites are located have almost always been used to grow crops or graze animals, since there were no known historic/modern farmsteads or other buildings at these locations.

Vésztő-Bikeri

Excavations at Vésztő-Bikeri verified most of the features with distinct geophysical signatures, such as wall trenches, ditches, pits, and a system of concentric ditches enclosing the site (Sarris et al., 2004; Parkinson et al., 2004, Parkinson, Yerkes, & Gyucha, 2004). Vésztő-Bikeri is a single component ECA Tiszapolgár settlement. Virtually all of the ceramics from the site date to the Early Copper Age,[3] and the only excavated features at the site that are *not* Tiszapolgár are two intrusive equestrian burials from the Hungarian conquest period (10th century A.D., see Lichtenstein, 2004; Gyucha, Parkinson, & Yerkes, 2004; Parkinson et al., 2004).

The three concentric circular anomalies that were identified during the magnetic survey at Vésztő-Bikeri enclosed a 0.7 ha—area that contained large rectilinear anomalies associated with several wattle-and-daub "longhouse" structures in the center

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[2] Measurements of the magnetic susceptibility were carried out in summer 2004 at the Institute for Mediterranean Studies—FORTH, with the assistance of Luigi Catanoso, under the auspices of a Leonardo Da Vinci Training program.

[3] Of the more than 75,000 Tiszapolgár ceramics collected from Vészt-Bikeri, only a handful show stylistic similarities with Late Neolithic Tisza and Herpály Culture sites in the region. No diagnostic sherds from any other cultural period were recovered. Radiocarbon dates on charcoal and organic remains from several features at the site concentrate between 6500 and 6200 B.P.

of the site. A dozen isolated circular monopole magnetic anomalies (vertical gradient ranging from 7nT/m to 30nT/m) were recorded in a circle around the central longhouse structures. These were identified as possible pits, hearths, and/or kiln features, the largest of these features may have been a well or cistern that was filled in with burned daub (Sarris et al., 2004, also see later). Excavations of segments of the circular anomalies in the north, east, and southeast edges of the Vésztő-Bikeri site showed that the outermost anomaly is a "U" or "V" shaped ditch (Figure 6b) that is 1.6 m deep, and 1.6 m wide (it narrows to 0.4 m in some places). In the northern and eastern excavation trenches (Figure 6a), a shallow narrow trench (0.4 m wide, 0.8 m deep) lies about 2 m inside of the outer ditch, but this shallow trench was not visible below the plow zone in the larger excavation block in the southeast. A narrow (0.4–0.75 m) deep ditch that contained many large posts sunk 1.7 m below the modern surface was exposed five meters inside of the wide, deep outer trench in all three of these excavation blocks. The inner palisade wall seems to have been covered with daub. About 0.8–2 m inside the palisade, several large postholes spaced about 3 m apart (and sunk 1 m below the surface) were found at the southern end of the site. The large posts may have supported a platform that was raised on the inside of the palisade (Parkinson et al., 2004). After one of these large posts was removed and the posthole was filled in, an adult Tiszapolgár burial was placed over the posthole (Giblin & Hughes, 2004).

Two of the "longhouse" features in the center of the site were oriented east–west and contained no internal hearths or storage features (Figures 7a and 8). The western wattle-and-daub structure measured 14 × 6 m. Its earthen floor was clean, and no internal activity areas could be identified. When it was abandoned, it was dismantled and mounded over with midden trash and dirt, but its eastern wall trench was re-used as the western wall trench of the eastern wattle-and-daub structure (Figure 7b). The western structure measured 10 × 6m, and contained a few ceramic vessels and several antler and bone projectile points that were burned *in situ* when the house was destroyed. The distribution of these materials suggests that the large structure contained discrete activity areas. The several dozen antler and bone arrowheads (and debitage associated with their manufacture) were found in a 1.5 m^2 area, and a few meters to the east, several nearly identical ceramic mugs were found. A few meters east of the mugs, several large storage vessels were recovered. This western structure had no eastern wall trench. It was burned, taken down and mounded over with midden debris after it was abandoned (Figure 8).

Another possible rectangular structure was exposed north of the two large wattle-and-daub "longhouses." It was oriented northwest–southeast and its floor was preserved, but only the northeast wall trench has been identified. It contained a large deposit of ceramic vessels and several loom weights and shuttles associated with textile production. A child burial was found just outside the wall trench. Part of another rectangular structure was confirmed in one of the test excavation units excavated in 2000 (Block 1), but only part of one of its wall trenches was exposed.

The largest circular monopole magnetic anomaly (vertical magnetic gradient up to 30nT/m) was excavated, just south of the longhouse structures. It was a very deep (ca. 1.5 m) slightly bell-shaped pit that was filled with burned daub fragments,

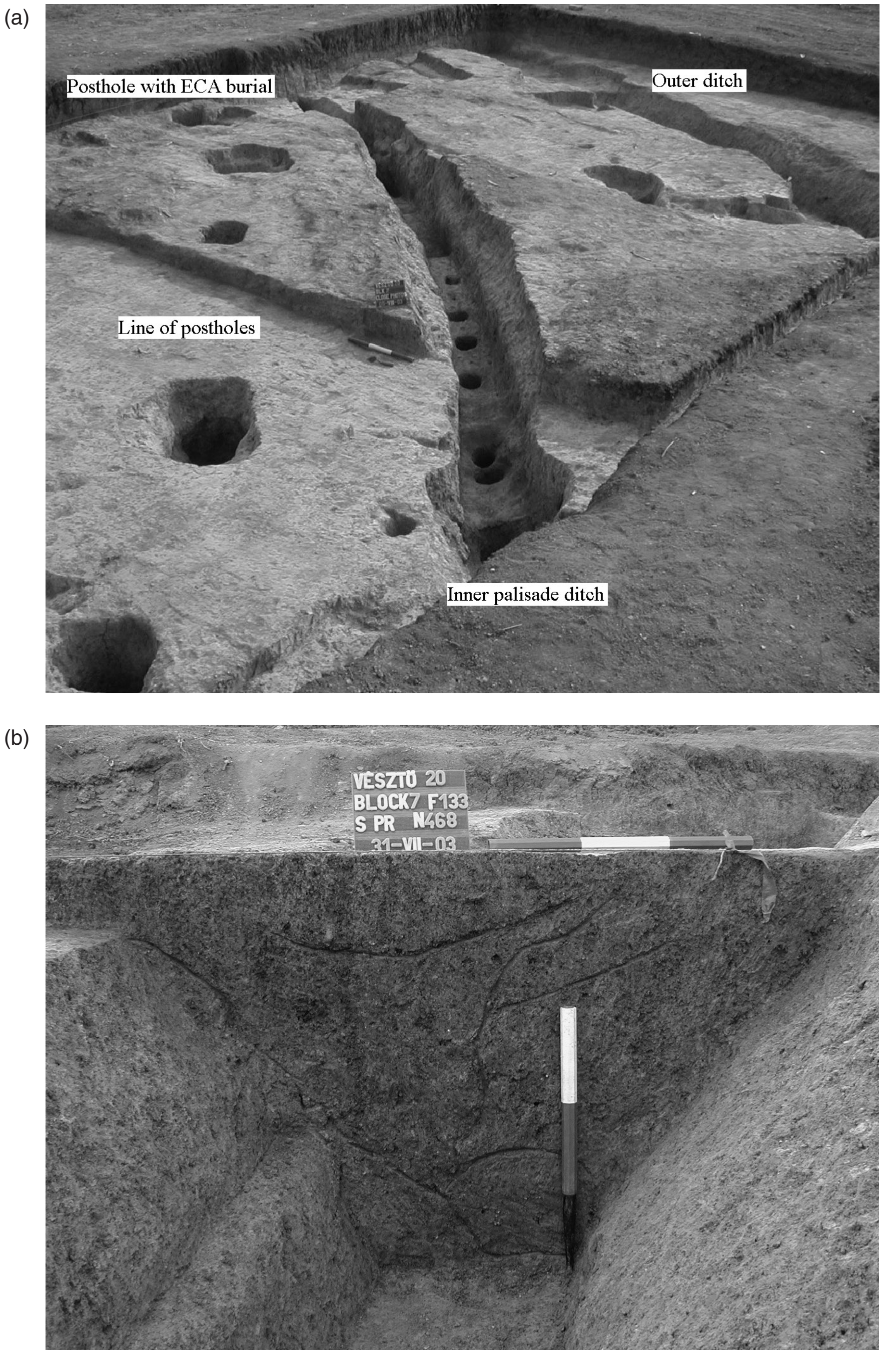

Figure 6. a) Circular ditches and postholes in Excavation Block 7, southeastern edge of the Vésztő-Bikeri site. Trowel points north, scale is 60 cm long; b) Section of outer ditch in Excavation Block 7 at Vésztő-Bikeri. View to north, scales are 60cm long.

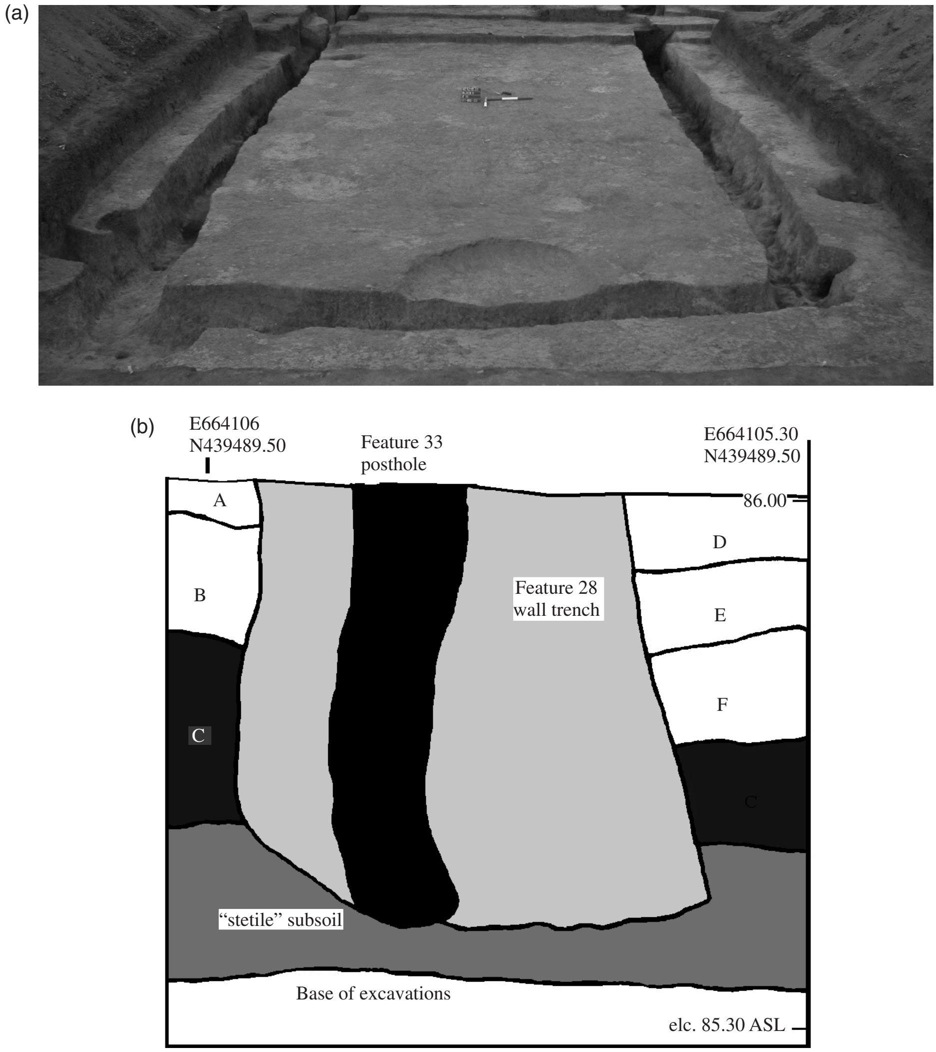

Figure 7. a) The western "longhouse" wattle-and-daub wall trench structure (Feature 15) in the center of the Vésztő-Bikeri site. View to the E, scale is 60cm long;
b) Section of Feature 28, the eastern wall trench of the western longhouse (Feature 15) that was filled in and reused as the western wall of the eastern longhouse (Fea. 4/14). Feature 33 is a posthole in the western wall of Feature 4/14 that was dug into the filled-in E wall trench of Feature 15. A is the floor of the eastern longhouse. B is a cultural layer below the floor. C is a transitional zone between the cultural layers and subsoil. D is the floor of Feature 15 (the western longhouse). E and F are subfloor layers.

and then had a series of small rectangular ovens or kilns constructed just below the surface inside of the pit (Figure 8). The feature may have originally been used as a well or cistern, because some thin gray clay "gleyed" deposits were found in oakfield cores from the feature's basal fill layers (Parkinson et al., 2004).

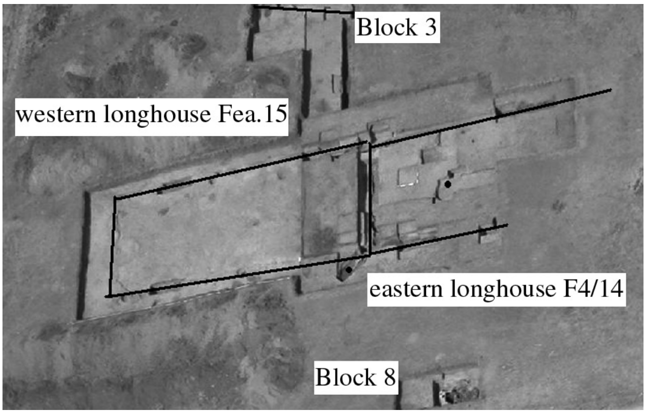

Figure 8. Aerial view of the center of the Vésztő-Bikeri site showing the partially excavated wattle-and-daub longhouses, the wall trench in Block 3, and the superimposed ovens or kilns in Block 8 (where a well or cistern was filled in with burned daub before the ovens or kilns were constructed). Black lines show the alignment of the wall trenches. Black dots show locations of the two intrusive equestrian burials from the Hungarian Conquest period. North is at the top, scales are 1 m long.

Magnetic Survey Results at Körösladány-Bikeri

The surface collections from Körösladány-Bikeri included some ceramics dating to the Late Bronze Age (3500–2800 B.P.), Iron Age (Sarmatian Period, 2nd to 4th century A.D.), and Árpádian periods (end of the 1st millennium A.D.), so we cannot assume that all of the anomalies identified in the magnetic survey are associated with ECA features. Nonetheless, many of the same types of magnetic anomalies found at Vésztő-Bikeri were recorded at Körösladány-Bikeri (Figure 3).

The two ECA settlements are nearly identical in size. At both sites, three concentric circular anomalies enclosed a 0.7 ha area with many high magnetic gradient rectilinear and smaller circular monopole and dipole anomalies (Sarris, 2004). However, at Körösladány-Bikeri, the rectangular features are smaller, and more dispersed than they were at Vésztő-Bikeri (Sarris, 2004; Sarris et al., 2004). The small isolated monopole anomalies that were associated with burned features and pits at Vésztő-Bikeri also are more dispersed at Körösladány-Bikeri, and some of them are located outside of the outermost concentric anomaly (Figure 9). Extreme dipole anomalies that were caused by the presence of metal objects in the soil are more common at Körösladány-Bikeri, and there are at least three large monopole anomalies with magnetic signatures that are not like any of the pits or thermal features recorded at Vésztő-Bikeri. A rectangular anomaly outside of the concentric circles (to the northwest) was also identified in the magnetic survey (Figure 9). Several linear low magnetic gradient anomalies were also found at Körösladány-Bikeri (Sarris, 2004). These features may be associated with the post-ECA components at the site.

During our first full season of excavations at Körösladány-Bikeri in summer 2005, we investigated one of the large monopole anomalies, and found that it was an intrusive Sarmatian pit over 2 m deep with an irregular outline and a width of ca. 3 m

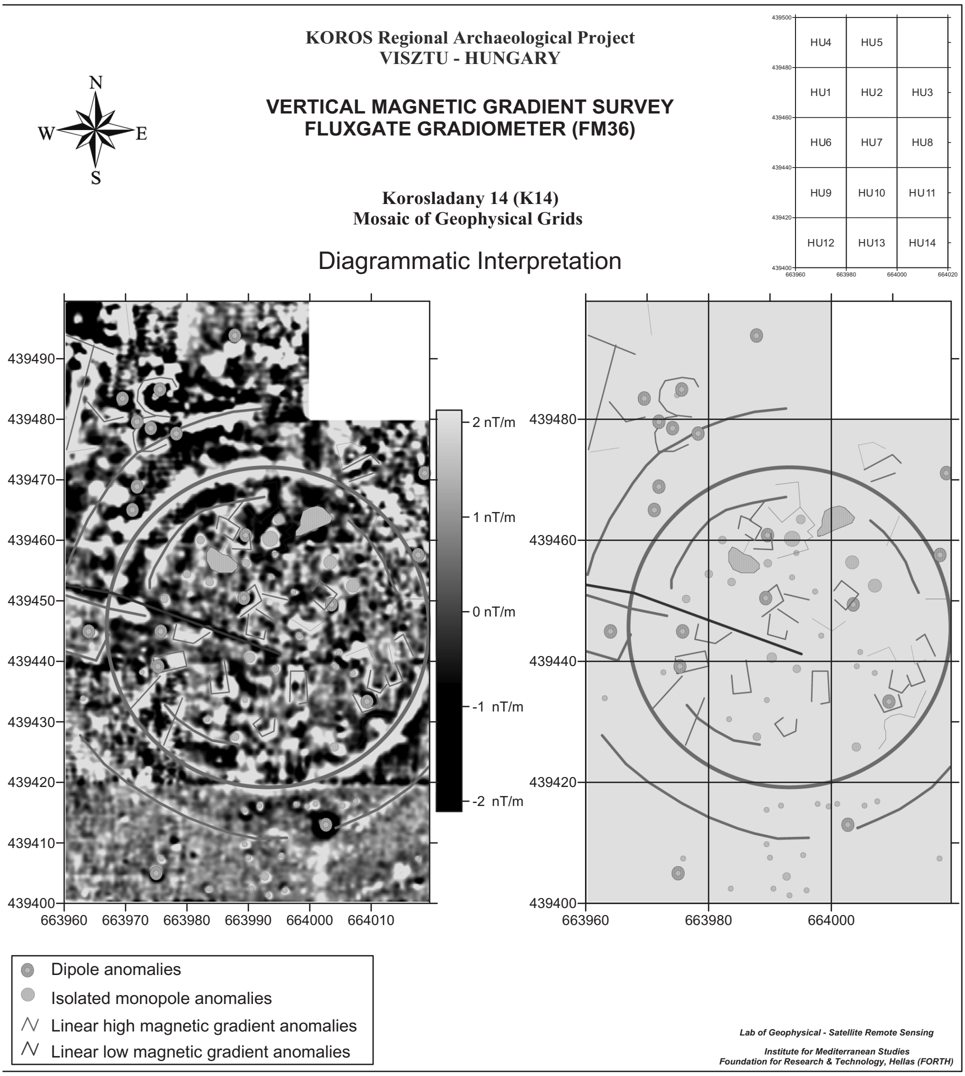

Figure 9. Diagrammatic interpretation of magnetic survey results from Körösladány-Bikeri.

(Figure 10a). A smaller monopole anomaly located northeast of the Sarmatian pit turned out to be an intrusive Late Bronze Age pit or “hoard” that contained three nested Gava Culture ceramic drinking vessels (Figure 10b). The remains of an infant were found in a “sheet midden” deposit near these pits. Another small monopole anomaly was excavated just inside of the innermost large circular anomaly (Figure 11). A nearly square intrusive pit measuring 1.2 m across and 1.4 m deep was found in this location, with Late Bronze Age ceramics in the fill. Even though more than 90% of the diagnostic sherds found on the surface of the Körösladány-Bikeri site are ECA

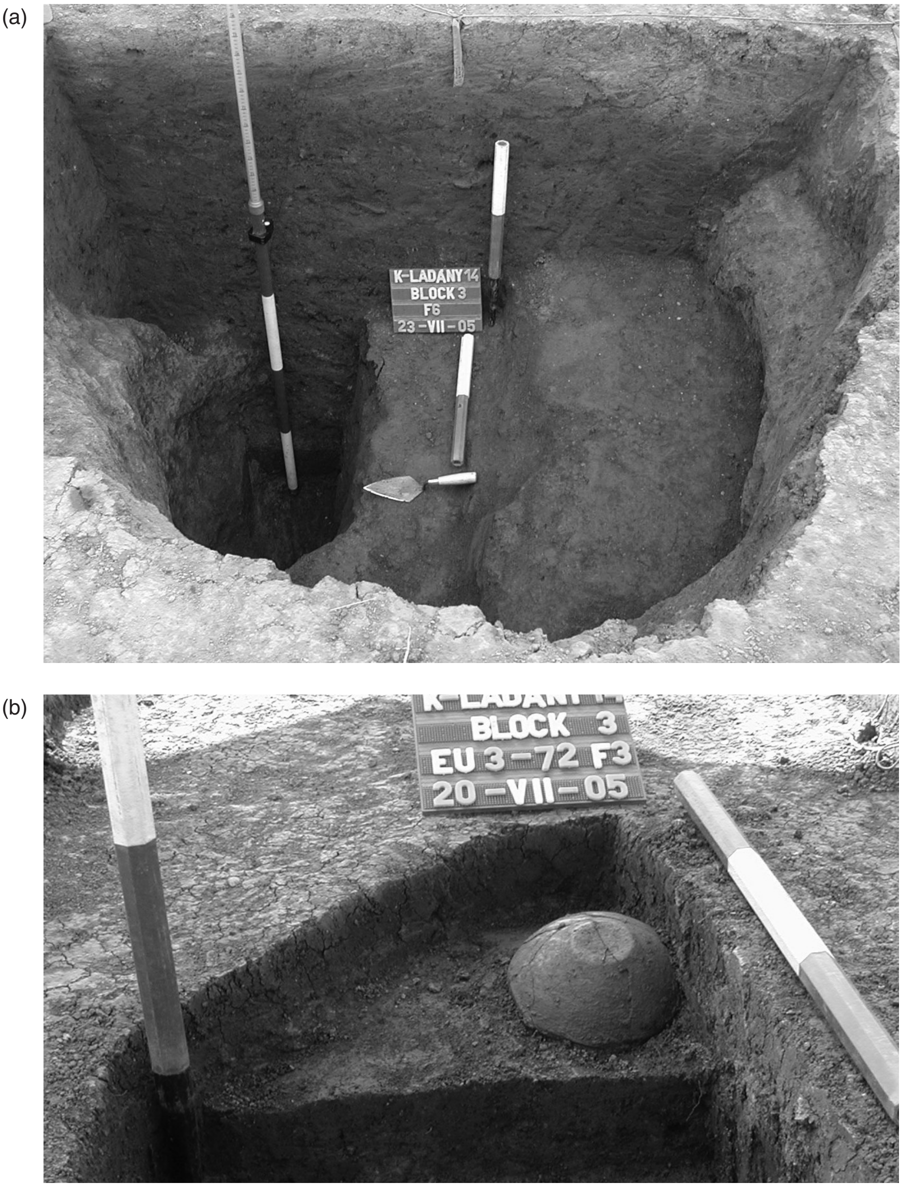

Figure 10. a) Intrusive Sarmatian pit in Block 3 at Körösladány-Bikeri located where a large monopole magnetic anomaly was recorded. The pit fill on the right had not been removed when the photo was taken. Another possible Sarmatian pit can be seen in the left end of the section; b) eastern half of the intrusive Late Bronze Age pit with the nested Gava Culture drinking vessels in block 3 at Körösladány-Bikeri. Horizontal scale in 60 cm long.

Figure 11. a) Segment of the inner palisade ditch at Körösladány-Bikeri. Postholes are visble in the base of the ditch. The posts were removed before the ditch was filled in. Vertical scale is 60 cm high, horizontal scale is 40 cm long; b) Segment of the wide outer ditch at Körösladány-Bikeri. Note flat steps at base of the ditch.

Tiszapolgár types,[4] our excavations have shown that several of the magnetic anomalies are associated with later components. Further excavation is needed to separate the Tiszapolgár features from the Bronze Age and Iron Age pits, but our 2005 excavations showed that the three concentric circular anomalies are associated with the Tiszapolgár settlement at Körösladány-Bikeri.

Excavation of a 2.5 m segment of the prominent middle circular anomaly in summer, 2006, revealed that it is a 3.8 m wide and 2.2 m deep trapezoidal ditch (in the magnetic survey, the diameter of the middle circle was 50 m). We also excavated two 3 m segments of the narrow (0.4 m wide) inner trench, and found that it is similar to the inner palisade trench at Vésztő-Bikeri (Figure 11a). Sixteen large postholes were exposed, and most of them also were sunk 1.7 m below the modern ground surface (the same depth as the posts in the inner trench at Vésztő-Bikeri). The center of the inner trench was about 5 m from the center of the middle ditch, the same distance that separated the inner palisade and outer ditch at Vésztő-Bikeri (no shallow narrow ditch was found between the two at Körösladány-Bikeri). A sheet midden deposit that contained only Tiszapolgár ceramics covered the inner palisade trench and middle ditch at Körösladány-Bikeri, suggesting that the palisade was taken up and the ditches were filled in before the settlement was abandoned. The magnetic survey also showed several breaks in the innermost circle and many features were located where the palisade once stood (Figure 9). This also suggests that the palisade was taken down when the settlement was expanded out to the far edge of the middle ditch.

Excavation of a small segment of the outermost circular anomaly at Körösladány-Bikeri (Figure 11b) revealed that it was located about 7 m outside of the middle ditch, and had a diameter of 70 m (Sarris, 2004). This outermost ditch was 2.0–2.3 m wide and 1.6 m deep, the same depth as the outer ditch at Vésztő-Bikeri, but a little wider. It also was trapzoidal in section, with a flat bottom, that was excavated in terrace-like steps each about 1.3 m long (Figure 11b).

In 2005, we also opened an excavation block where one of the small rectangular high gradient anomalies was located (Figure 5); while we did not find a wall-trench structure here, several large bell-shaped Tiszapolgár storage/refuse pits (rich in faunal remains) and two infant burials were exposed (Figure 12a and 12b). In summer 2006, excavations in Block 7 where a large monopole anomaly was recorded,[5] exposed an ECA well that was over 2 m deep. The well had been filled in after it had gone dry. The deep pit in Block 8 at Vésztő-Bikeri was nearly the same size as this well (see earlier).

Results of the Geochemical Surveys

The soil chemical surveys (Sarris et al., 2004; Lee, Galaty, & Hardy, 2004; Hardy, 2005) recorded high concentrations of phosphate around the perimeter of Vésztő-Bikeri (near the circular enclosures). Lower levels were measured in the central

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[4] The ceramic assemblages from both sites are virtually identical, with typical Tiszapolgár vessel types, dominated by bowls with everted rims and straight-walled pots, both with flat and pedestal bases (Bognár-Kutzián, 1963, 1972).

[5] At N 439440 E 663978 on the grid on Figure 9.

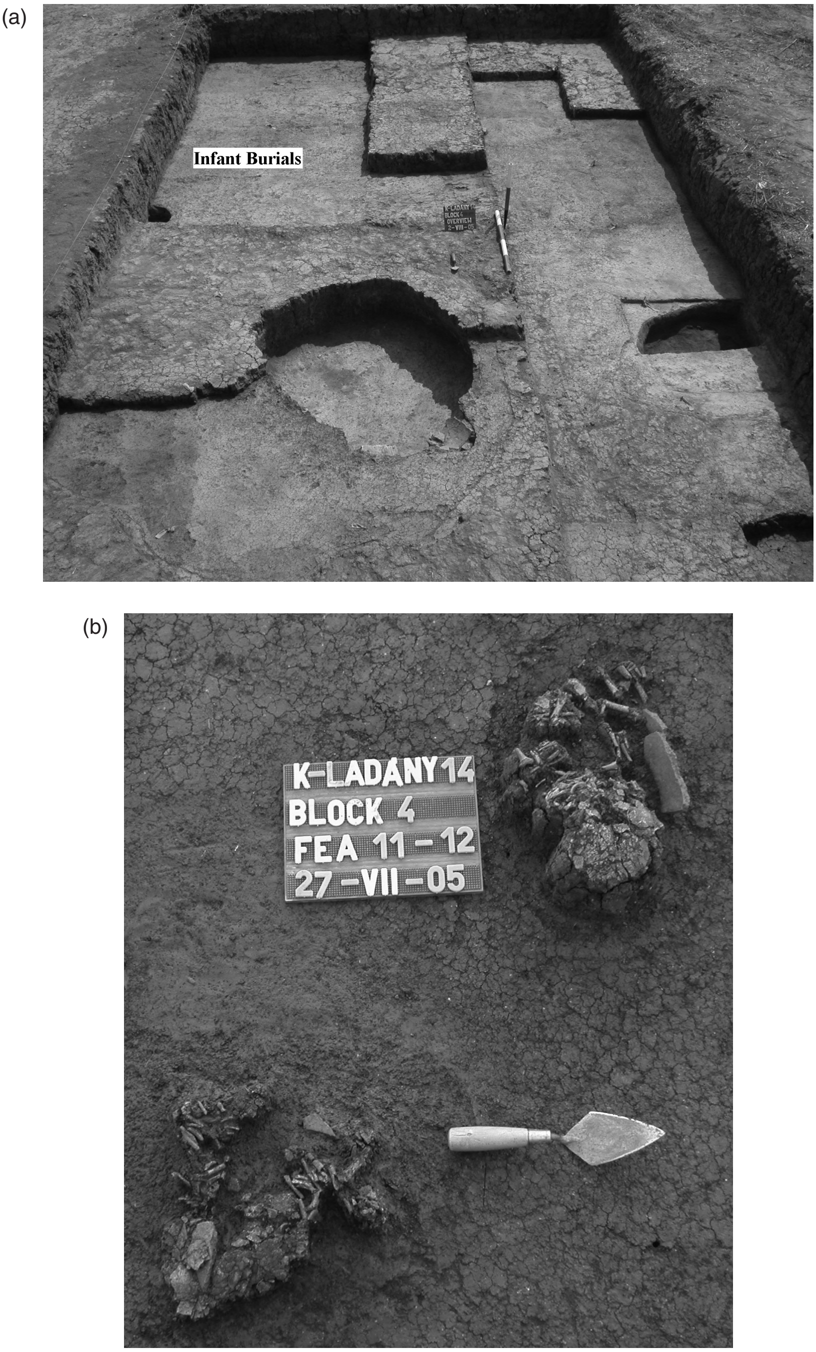

Figure 12. a) Excavated pits in block 4 at Körösladány-Bikeri. Location of the burials is noted; b) Infant burials laid on the ancient surface in Block 4 of the Körösladány-Bikeri site.

area of the site. This pattern fits the model for agricultural settlements where residents removed organic waste from living quarters and deposited their trash in “ring middens” at the perimeter of the site. The low phosphorus levels near the structures suggest that organic waste was not a constituent of the daub employed in the manufacture of the buildings at Vésztő-Bikeri. By contrast, higher levels of phosphorus were recorded where possible kilns, ovens, pits, or hearths were mapped during the magnetic survey, probably associated with the residues of organic material used in cooking, food storage, and ceramic production.

A different pattern was found in the soil samples from Körösladány-Bikeri (Figure 5).

The highest Total Phosphorous (TP) values were concentrated in the northern half of the site, but elevated levels were distributed across the site. Total Phosphorous values lower than those for off-site areas were located near the site’s interior; however, a second area of even lower values was located near the site’s southern perimeter. Higher extractable phosphorous values seemed to correlate with the higher TP results (Hardy, 2005). The representative samples tested for pH across the site varied from 5.87 to 9.7.

Contour maps were created based on both the magnetometry survey and the phosphorus results (Figures 4 and 5). Boundaries for both Vésztő-Bikeri and Körösladány-Bikeri were established. The highest values of extractable phosphorus were typically located in close proximity to the site’s perimeter, whereas high levels were also recorded in areas identified in the magnetometry survey and tentatively interpreted as kilns, ovens, pits, or hearths. At Körösladány-Bikeri soil phosphate levels were higher near the circular magnetic anomalies, while lower levels were associated with the rectilinear features. Breaks in the high-value phosphate contours around the perimeters of the two sites may represent entryways (Sarris, 2004; Parkinson et al., 2004).

Magnetic Susceptibility Results

The majority of the soil samples collected at Vésztő-Bikeri appear to be of a relatively lower magnetic susceptibility level compared with those of Körösladány-Bikeri (93% of the samples from Vésztő-Bikeri are below the level of 30×10^{-6} cgs/gr, and only 16% exhibit high frequency dependent susceptibilities (above 10%), whereas 64% of the soil samples from Körösladány-Bikeri are below that level, and 28% exhibit high frequency dependent susceptibilities (Sarris & Catanoso, 2005). The high magnetic susceptibility values from Vésztő-Bikeri are concentrated inside of the settlement, and decay to background values outside of the concentric ditches. Similar high values are shown for the frequency dependent susceptibility, which reaches its highest value at the edges of the settlement, where the circular ditches are located.

A different picture is suggested by the susceptibility measurements from Körösladány-Bikeri. Although the levels of the magnetic susceptibility values are higher than those from Vésztő-Bikeri, the highest values are not located within the limits of the settlement, but rather outside of them, concentrated in the northwest and west directions where a cluster of high vertical gradient dipole magnetic anomalies

(−130 to 135nT/m) were recorded (Sarris, 2004; Sarris & Catanoso, 2005). These values may be associated with kilns or ovens that were located outside of the ECA settlement, or they may be features from the Bronze Age and Iron Age components at the site.

The weaker magnetic signals of the interior of the Körösladány-Bikeri ECA settlement may be because the smaller rectangular structures were not burned before they were dismantled (like some of the longhouses at Vésztő-Bikeri). It is also possible that the Early Copper Age settlement at Körösladány-Bikeri was not occupied as long as Vésztő-Bikeri. Susceptibility measurements along the south–north and east–west transects across and beyond the Körösladány-Bikeri site do not define the limits of the settlement as clearly as they did at Vésztő-Bikeri. The peak values along the east–west transect are located about 60–100 m to the east of the settlement. Similar results exist for the FDS 20–40 m to the south of the Körösladány-Bikeri site. It is not clear if the high levels of FDS in these off-site areas represent Early Copper Age activities, or features created by Bronze Age, Iron Age, or later groups.

CONCLUSIONS

The results of our geophysical and geochemical investigations at the two Early Copper settlements on the Great Hungarian Plain provided data on site location and organization that support some, but not all, of the current interpretations of the Late Neolithic–Early Copper Age transition. We were surprised to find palisades and ditches surrounding these small ECA settlements. If the ECA dispersal from tells and large nucleated LN sites was associated with increased mobility by herder-farmers involved in the “secondary products revolution” (Sherratt, 1981), why did they invest so much time and effort in the construction of palisades and ditches? If the ECA groups were increasing the size of their herds and raising cattle, sheep, and goats for milk, wool, and labor as well as meat, hides, bone, and marrow (the “secondary” products of animal domestication), they may have needed more lands for pastures and forage crops, but their small dispersed settlements seem to be more permanent than current models allow, and the need for defense from human and nonhuman predators may not have diminished (contra Bognár-Kutzián, 1972).

The large longhouse structures found at the single component ECA Vésztő-Bikeri site show that there was more continuity in house construction methods during the LN–ECA transition than was previously thought. In current models, large multi–family houses are associated with large nucleated late Neolithic settlements (including tells), while small single family houses were associated with small dispersed Early Copper Age settlements (Bognár-Kutzián, 1972; Raczky, 1987; Parkinson, 2002). The longhouses at Vésztő-Bikeri are large, and the radiocarbon dates associated with these wattle-and-daub structures (6500-6200 B.P.) are early for Tiszapolgár settlements (Gyucha, Parkinson, & Yerkes, 2004; Parkinson et al., 2004), suggesting close chronological and social affinities with Late Neolithic cultures in the region. However, no large structures were found at the Körösladány-Bikeri site, and the houses there may have been the more "typical" smaller Copper Age types. If Körösladány-Bikeri was occupied later in the Early Copper Age than Vésztő-Bikeri, then it would seem that the dispersal of settlements and the reduction of settlement size took place before households were reorganized and nuclear families replaced extended families as the primary economic units in ECA societies.

The geophysical and geochemical surveys show that the sizes of the two Early Copper Age sites are much smaller than the earlier nucleated Late Neolithic sites. Pairs of dispersed ECA settlements seem to have been established, and each of the paired sites is nearly identical in size. We believe that these two fortified ECA sites were not strictly contemporary, but were occupied in sequence. A nearly identical system of palisade and ditches was constructed at each site, but the internal organization of the settlements changed. At the earlier Vésztő-Bikeri site, we see a centralized pattern where a sequence of longhouses were built in the center and surrounded by an inner ring of pits, kilns, and cooking features, and an outer ring just inside the palisade where animals were kept and trash was discarded. At Körösladány-Bikeri (which we believe was occupied later), houses and features are less centralized, the smaller structures are intermixed with the other features, and extend out to the "ring midden" area where the animals may have been kept.

At both sites, we found evidence that houses and palisades were taken down, posts were removed, and trenches, postholes, and pit features were filled in and mounded over before the sites were abandoned. Some of the structures at Vésztő-Bikeri seem to have been intentionally burned when they were taken down, whereas others were not (we have not yet found any evidence for intentional burning of structures at Körösladány-Bikeri and geophysical investigations suggest that there was less "thermal activity" at that site). This leveling and mounding over of abandoned structures and features is reminiscent of the tell-building during the Middle and Late Neolithic on the Great Hungarian Plain, but instead of building on top of the abandoned structures and features, the Copper Age people seem to have built next to them.

We still do not know why the Late Neolithic populations abandoned their large nucleated settlements near major rivers and dispersed across the flatlands. It appears that each of the large household groups that lived together at tells and large nucleated sites moved to a new location and established a separate settlement. Our data suggest that the household clusters at large Late Neolithic sites become separate Early Copper Age sites (hence the sevenfold increase in site numbers from the LN to ECA periods in the Körös River Valley (Parkinson, 2002; Parkinson, Gyucha, & Yerkes, 2004; Parkinson et al., 2004; Sarris et al., 2004). The geophysical and geochemical surveys and excavations at Vésztő-Bikeri and Körösladány-Bikeri show us how this fragmentation and dispersal continued at Early Copper Age settlements. The large nucleated Late Neolithic villages broke up and dispersed. The resulting small Early Copper Age settlements were the residences of longhouse-centered households or lineages. Later in the Copper Age, the central longhouses were replaced with small, dispersed houses, suggesting that the ECA households broke up into nuclear family groups. The changes in settlement organization in the Körös region may be an expression of the general trend toward household specialization and economic intensification in southeast Europe and the Near East during the LN–ECA transition (Kaiser & Voytek, 1983). However, whereas in the Near East competition between households led to social differentiation and ranking (Flannery, 2002), on the Great Hungarian Plain the Copper Age settlements continued to function as independent, integrated segments of prehistoric tribal societies (Parkinson, 2002; Gyucha, Parkinson, & Yerkes, 2004; Parkinson, Gyucha, & Yerkes, 2004; Parkinson et al., 2004).

Our interpretations of the Late Neolithic–Early Copper Age transition will surely change as we continue our excavations at Körösladány-Bikeri and conduct nondestructive geophysical and geochemical surveys at other sites in the region. However, by combining the results of nondestructive surveys with limited excavations at specific "targets" at two Early Copper Age sites, we have been able reconstruct their layout and internal organization after only a few field seasons—something that would have taken us decades to accomplish if we had to rely on excavations to expose the site plans.

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