Volume 39 Number 2 February 2012 ISSN 0305-4403

Published in association with the Society for Archaeological Sciences

Journal of Archaeological SCIENCE

Journal of Archaeological Science 39 (2012) 458–466

Contents lists available at SciVerse ScienceDirect

Journal of Archaeological Science

journal homepage: http://www.elsevier.com/locate/jas

Modeling Late Copper Age demographics on the Great Hungarian Plain using ceramic petrography

Timothy A. Parsons*

National Park Service Southeast Archeological Center, 2035 E. Paul Dirac Drive, Johnson Building, Suite 120, Tallahassee, FL 32310, USA

ARTICLE INFO

Article history:
Received 11 March 2011
Received in revised form
10 September 2011
Accepted 1 October 2011

Keywords:
Ceramic petrography
Migration
Kurgans
Late Copper Age
Baden
Hungarian Plain
European prehistory

ABSTRACT

Ceramic petrography can be an effective method for studying demographic shifts and the possibility of migration into a region. This is based on the principle that ceramic manufacturing technology is resistant to change over time, while form and decoration can change quickly even in times of demographic continuity. As such, sudden shifts in raw material preparation and methods of pottery manufacture may be indicative of the arrival of new people in a region. The manufacturing characteristics indicative of such a demographic change are observable and measurable microscopically. Petrography was used to describe and measure paste characteristics of 114 Middle Copper Age, Late Copper Age, Early Bronze Age, and Middle Bronze Age sherds from the Körös region of the Great Hungarian Plain to determine if changes in manufacturing techniques accompanied changes in ceramic form and decoration at the beginning of the Late Copper Age Baden period (ca. cal. 3500 B.C.). A comparison of the petrographic results from the cultural phases showed that little manufacturing and technology change occurred during the time period covered by the study. Migration of new people into the region is therefore not supported, and changes in ceramic form and decoration associated with the Late Copper Age occurred during an extended period of demographic continuity.

1. Introduction

This study demonstrates the utility of ceramic petrography for the synchronic and diachronic study of ceramic technology, and for testing the migratory or indigenous origins of a regional archaeological culture traditionally defined by its ceramic design. In a wider methodological sense, it utilizes a “technology of style” approach (Stark, 1998a, b) to measure changes in pottery manufacturing techniques in a geographically bounded area over the long-term.

Traditional petrographic studies address issues of compositional grouping (see Day and Kiriatzi, 1999) and provenance (see Ferring and Perttula, 1987), often to assess pottery produced locally versus imported ceramic material (Jordan and Schrire, 1999). The method utilized here differs in that it diachronically measures change in ceramic production technology in a spatially bounded study region. The analytical focus includes the observation of sudden changes in manufacturing behavior at specific points in time, rather than focusing solely on identification and characterization of unique ceramic fabrics at the synchronous geographic and cultural level.

A combined synchronous and diachronic approach to ceramic compositional variability allows for the assessment of the indigenous or migratory nature of material culture change. Pottery form and decoration can change quickly even in times of population continuity, while production technologies are highly resistant to change (Lemmonier, 1992). In this case study, a shift in production methods at the beginning of the Late Copper Age would suggest a migratory origin for the Baden material culture on the Great Hungarian Plain, while continuity in production methods would suggest population continuity in the region at this time. Similarly, contemporaneous compositional variability within the Körös region during the Late Copper Age could indicate multiple populations creating pottery of similar form and decoration.

2. Archaeological background

The Holocene prehistory of the Great Hungarian Plain is traditionally divided into three phases: The Neolithic (ca. 8000–4600 cal. B.C.), Copper Age (ca. 4600–2800 cal. B.C.), and the Bronze Age (ca. 3000–1400 cal. B.C.) (Duffy, 2010; Gyucha, 2010; Parkinson, 2006) (Fig. 1). The Copper Age, of particular interest in this study, is a period uniquely delineated in the relative chronology of the Carpathian Basin. Whereas most European chronologies include only general

---

* Tel.: +1 (850) 766 4088; fax: +1 (850) 580 2884.
E-mail address: timothy.parsons@gmail.com.

0305-4403/$ – see front matter © 2011 Elsevier Ltd. All rights reserved.
doi:10.1016/j.jas.2011.10.001

Absolute chronology (CAL B.C.)	*European chronology*	*Central and Southern Plain*	*Northern Plain*	*Eastern Plain and Körös Region*
ca. 2,200-1,600	Middle Bronze Age	Gyulavarsand Ottomány	Gyulavarsand Ottomány	Gyulavarsand Ottomány
ca. 2,800-2,200	Early Bronze Age	Nyírség Makó	Nyírség Makó	Nyírség Makó
ca. 3,500-2,800	Late Copper Age	Baden Boleráz	Baden Boleráz	Baden Boleráz
ca. 4,000-3,500	Middle Copper Age	Bodrogkeresztúr Hunyadihalom	Bodrogkeresztúr Ludanice Hunyadihalom	Bodrogkeresztúr Hunyadihalom
ca. 4,600-4,000	Early Copper Age	Tiszapolgár	Tiszapolgár	Tiszapolgár
ca. 5,000-4,600	Late Neolithic	Tisza	Tisza Csőszhalom	Tisza Herpály

Fig. 1. Prehistoric chronology of Europe and the Great Hungarian Plain (after Parkinson, 2006; Gyucha, 2010; Duffy, 2010).

characterizations of a Chalcolithic period, archaeologists working in Eastern and Central Europe – and the Hungarian Plain in particular – have seen fit to recognize a Copper Age distinct from the preceding Neolithic and subsequent Bronze Age. This is due to differences in ceramic design and settlement patterns between the Late Neolithic Tisza-Herpály-Csőszhalom complex and the Early Copper Age Tiszapolgár phase, in addition to the more frequent appearance of copper in the material record (Kalicz and Raczky, 1987; Parkinson, 1999). Despite this material and settlement discontinuity, Sherratt (1997a, b), Parkinson (2002) and Gyucha (2010) have demonstrated that archaeological cultures on the Hungarian Plain, from the Neolithic to the Copper Age, possessed material culture and settlement characteristics indicative of long-term continuity in the region.

The Late Copper Age Baden phase (ca. 3500–2800 cal. B.C.) on the Great Hungarian Plain experienced a more severe discontinuity in the archaeological record, evidenced by dramatic changes in the way that local populations decorated pottery and organized their settlements. At this time, the entire Carpathian Basin was integrated into the wider Baden material culture horizon that stretched from eastern Austria to the central Balkans (Fig. 2). This is most clearly illustrated in the archaeological record by an abrupt shift in the form, design, and decoration of ceramics, which are superficially similar throughout the Baden distribution (see Furholt, 2008).

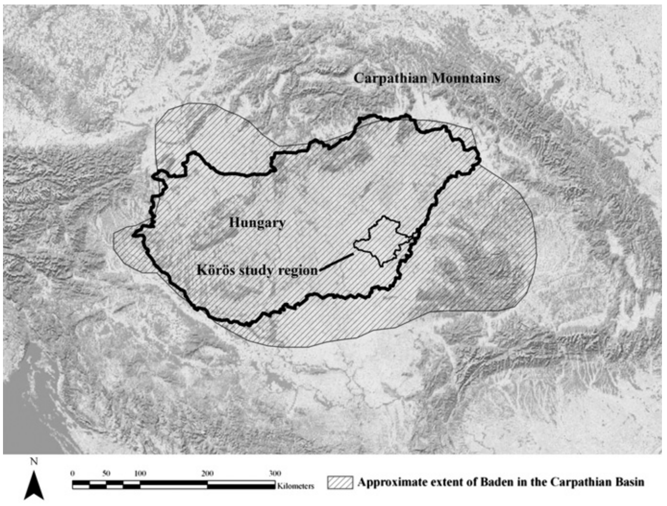

Fig. 2. Map of the Carpathian Basin, depicting the approximate extent of Baden material culture distribution during the Late Copper Age, the modern Hungarian political boundary, and the boundary of the Körös River watershed study region.

The region's archaeological palimpsest is complicated by the appearance of thousands of kurgan burial tumuli almost simultaneously with the Baden horizon around 3500 B.C. The timing of the kurgans' construction has long been a question of interest to archaeologists working in the region (see Ecsedy and Bökönyi, 1979; Gimbutas, 1977, 1979, 1980). Sherratt (1997a, b) noted that Late Copper Age archaeological sites and kurgans occur in a complementary distribution on the Hungarian Plain. This led him to suggest that two separate populations occupied the region simultaneously, largely avoiding each other and exploiting different characteristics of the local environment. Recent research (Parsons, 2011) supported Sherratt's conclusions regarding the distribution of kurgans across the landscape, though lack of extensive stratigraphic evidence or radiocarbon dates means that exact temporal and social affiliations remain uncertain.

2.1. Baden and the "culture concept"

Due to their contemporaneity, kurgan builders and the makers of Baden pottery remain linked in the archaeological record. The apparent collision of interaction spheres and their presumed coexistence on the Hungarian Plain led to a great deal of discussion on the origins of both Baden and the kurgans. For decades a monolithic foreign origin for Baden was standard fare (Němejcová-Pavuková, 1981, 1984; see Sochacki, 1985), and invasions and migrations were used as explanatory mechanisms for the co-development of Baden and the "kurgan culture" (Gimbutas, 1963). Despite the fact that most archaeologists have eclipsed the presumption that pottery styles correspond to distinct social or ethnic groups, the "traditional concept of Baden culture" (Furholt, 2008: 617) has remained entrenched in Childe's so-called "pots equals people" culture concept (see Childe, 1950). Indeed, the stylistic similarity of Baden ceramic assemblages throughout central Europe led few to question the existence of a Baden archaeological culture, and a generalized Baden culture played a key role in connecting central Europe to the Aegean and Anatolian Bronze Age (Kalicz, 1963) and in Sherratt's "secondary products revolution" (1981, 1997a, b).

Recent research demonstrated that Baden pottery does not have a discrete distribution with sharp boundaries (Furholt, 2008). Nor does Baden pottery distribution correspond to the distribution of other categories of material culture or cultural practice. For example, flint industries throughout the Baden pottery distribution lack uniformity (Balcer, 1988; Pelisiak, 1991), and burial customs, including cremation and inhumation, vary throughout the Baden pottery region (Sachße, 2005). In citing several other examples, Furholt (2008: 619) stated, “it is impossible to find any sphere of [Baden] material culture that shows a distribution corresponding to that of the pottery style.” Furthermore, recent studies in neighboring regions identified regional variability in Baden pottery that suggests the retention of earlier local design characteristics (Furholt, 2008; see also Roman and Diamandi, 2001), and de Capitani (2002) noted the coexistence of “local” coursewares and Boleráz (early Baden) fine wares in the Lake Constance area. These studies call into question two common assumptions: first, that Baden constitutes a homogeneous cultural unit, and second, that migratory population groups produced Baden ceramics.

2.2. *A tale of two models: migration versus economy*

Much like the traditional idea of Baden itself, models developed to explain the appearance of the regionally similar Late Copper Age horizon remain heavily dependent on the overly simplified culture concept, and ultimately form a much too simplistic dichotomy of local versus foreign influence. Though one goal of this study is to advance the discussion beyond the archetypical definition of archaeological culture, the research must be properly contextualized in light of previous work.

Two primary models have explained the appearance of the Baden material culture on the Hungarian Plain, and its ubiquity throughout the Carpathian Basin. The model for migratory origins of Baden on the Plain draws heavily from the work of Gimbutas (1963, 1977, 1979, 1980), and posits a scenario by which indigenous populations were replaced by a migratory one carrying the Baden ceramic tradition with them. The economic model, most closely associated with Sherratt (1997a, b), suggests that interplay of indigenous social trajectory and pan-eastern European economic interaction led to Baden’s ubiquity throughout the Carpathian Basin. Though both perspectives largely ignore the possibility of material culture variability on the local level, they form the foundation of Late Copper Age knowledge on the Hungarian Plain and serve as testable models for the present study.

2.3. *The migration hypothesis*

Gimbutas’ (1963, 1970, 1977, 1979) model for social change on the Hungarian Plain focused on the appearance of thousands of kurgans in the region during the Middle and Late Copper Age, and drew upon her encyclopedic knowledge of little known Pontic Steppe and Black Sea regional chronologies. It can be summarized in three points: 1) Yamnaya pastoralists from the Pontic Steppe arrived on the Hungarian Plain ca. 3000 B.C., 2) the kurgan builders’ entrance marked the arrival of the Indo-European language, culture, and religion in Europe, and 3) the arrival brought about sudden, drastic culture change.

Gimbutas’ argument is appealing, as kurgans on the Hungarian Plain are identical to Yamnaya burials on the Eurasian Steppe. Indeed, kurgan burial tumuli stretch from the steppe near the Dnieper River west into the Hungarian Plain, and even further into central and western Europe (Anthony, 1986). However, it remains unclear how the tumuli developed across the landscape of the Plain. Though many kurgans have been excavated (see Ecsedy and Bökönyi, 1979), no radiometric data exist to accurately describe their spread or the nature of their relationship with indigenous cultural phases.

2.4. *The economic hypothesis*

Sherratt (1997b: 292) emphasized a “considerable measure of continuity” on the Hungarian Plain between the Neolithic and the Early Bronze Age. His analysis of site distribution on the eastern Hungarian Plain led him to argue for a depopulation event around 4000 B.C. during the Middle Copper Age due to a shifting emphasis on the importance of goods and raw materials from outside of the Plain. This may have opened a niche for the pastoral kurgan builders to move into the now less densely occupied region. However, it was the Plain’s incorporation into a broader economic sphere that ushered in the appearance of Baden in the region, and not the influence of a migratory population.

3. Research design

Lemmonier (1992) described how characteristics of material culture can quickly change during times of population continuity as well as during times of rapid social, economic, or political change. The technology that produces material culture, however, is more conservative and is less prone to sudden changes. As such, approaching culture change through pottery typologies emphasizing formal variation is not the most reliable method by which to model migration or other demographic shifts. Archaeologically, Lemmonier’s perspective is well suited to petrographic pottery analysis, which is uniquely able to describe methods of ceramic production technology – including raw material preparation, the addition of tempers, and firing techniques – in the context of broader geographic and diachronic comparison.

Although the goal of petrographic analysis is often the characterization of contemporaneous sherds or wares and their classification into fabric types to address issues of provenance (Reedy, 2008: 151; see Chandler, 2001; Freestone, 1995; Peacock, 1968), several studies have illustrated the utility of petrography for investigating questions of manufacture, technology, and cultural implications of varying methods of vessel construction (see Beynon et al., 1986; Kreiter, 2005).

This study tests the migration hypothesis of Baden material culture origins on the Great Hungarian Plain during the Late Copper Age. Rather than approaching the question of migration through analysis of ceramic form and decoration, ceramic petrography is used to compare ceramic paste and body composition in two ways: 1) a synchronic geographic analysis of Late Copper Age compositional variability in the 3000 km^2 Körös River study region of the southeastern Hungarian Plain (see Fig. 2), and 2) a diachronic petrographic study of Middle Copper Age, Late Copper Age, Early Bronze Age, and Middle Bronze Age ceramics from within the study area to observe changes in compositional variability over time. The study focuses on petrographic characteristics indicative of raw material preparation, vessel forming, and firing technologies, as well as identifying changes in clay preparation and ceramic manufacturing technology.

This research design serves two main purposes: 1) to identify geographic compositional variability that could indicate the presence of more than one ethnic group in the region producing similar styles of pottery during the Late Copper Age, and 2) to identify diachronic compositional variability that could indicate the arrival of a foreign population on the Plain. Since manufacturing technologies are both resistant to sudden change and often differ between discrete populations, any notable variability in vessel composition related to manufacturing techniques might suggest the presence of a migratory population producing pottery using different methods. Such a pattern could also indicate the adoption of foreign techniques by the region’s indigenous population, or if observed synchronously could indicate a high degree of localized technique in ceramic production (including the collection of clay from geologically distinct sources, see Frolking, 2009). Though not impossible, the latter possibility seems unlikely due to the homogeneous geology of the eastern Hungarian Plain (Frolking, 2009; Hoekman-Sites et al., 2007).

4. Sample selection and analytical procedures

4.1. Samples

Ceramic samples for this study came from two sources: 1) a sample of the ceramic material collected from the surface of archaeological sites in the Körös River valley study area during the Hungarian Archaeological Topography surveys of the 1970s, 1980s and 1990s (Ecsedy et al., 1982; Jankovich et al., 1989, 1998), and 2) surface collections conducted at Late Copper Age archaeological sites in the Körös River valley in the autumn of 2009 by the Late Copper Age Körös Archaeological Project (Parsons, 2011) (Fig. 3).

A total of 114 sherds from 28 sites in the Körös region were selected for petrographic analysis (Table 1). Since all ceramics in the study originate from surface contexts, samples were chosen based on diagnostic characteristics – primarily incised decoration and patterns of punctuation – that unambiguously assigned them to known chronological phases. Although the use of only stylistically diagnostic material limited sample size, this criterion was necessary to ensure chronological control. Ideally, the study would have included ceramic samples from Yamnaya-style kurgan interments. Unfortunately, the destructive nature of petrographic ceramic analysis precluded such materials from inclusion.

4.2. Sample preparation

Sherds were thin sectioned at the laboratory of the Field Service for Cultural Heritage (KÖSZ) in Budapest, Hungary. Thin sectioning involved removing a small fragment from the sherd, polishing the fresh break, and mounting the fragment onto a glass slide using an impregnative epoxy. The samples were then ground to a thickness of 0.02–0.03 mm, the point at which light characteristically passes through clay groundmass and mineral inclusions, allowing for their specific description and identification.

4.3. Petrographic analysis

Thin sections were analyzed under a polarizing light microscope under plane polarized light and with crossed-polars. Counts were made at 2 mm intervals as per Stoltman's (1989, 1991, 2001) methodology. Between three and five transects and as many as 150, but never fewer than 100, points were counted per slide. A critical aspect of this method of petrographic analysis is the differentiation between a ceramic's paste (the aggregate of natural minerals) and body (the bulk composition of a vessel). Comparison of paste values over space and time can shed light on raw material preparation techniques that result in the removal of large naturally occurring mineral grains, while body values account for temper materials intentionally added to the paste by the potter during the production sequence.

Fig. 3. Locations of archaeological sites within the Körös River watershed study region from which petrographic samples were collected.

Table 1
Provenience of petrographic ceramic samples, and sums of samples from each site and chronological phase. Letters next to site names correspond to the plotted samples in Figs. 4 and 5.

Site	Middle Copper Age	Late Copper Age	Early Bronze Age	Middle Bronze Age	Total
Békés178 (a)	–	4	4	2	10
Békés26 (b)	–	2	3	2	7
Békés39 (c)	–	5	–	–	5
Békés75 (d)	–	1	–	–	1
Bélmegyer56 (e)	–	6	–	–	6
Bélmegyer82 (f)	–	2	–	–	2
Biharugra33 (g)	3	5	1	3	12
Biharugra53 (h)	–	1	–	–	1
Busca13 (i)	–	2	–	1	3
Dévaványa166	1	–	–	–	1
Füzesgyarmat97 (j)	–	5	–	–	5
Gerla64 (k)	–	2	1	–	3
Körösladány16	2	–	–	–	2
Körösladány21 (l)	–	1	–	–	1
Körösladány33 (m)	–	1	–	–	1
Mezőberény34 (n)	–	2	–	–	2
Okány43 (o)	–	1	–	–	1
Szeghalom112 (p)	–	1	–	–	1
Szeghalom168 (q)	3	3	–	–	6
Szeghalom60 (r)	–	4	–	–	4
Szeghalom80 (s)	4	8	6	2	20
Szeghalom89 (t)	–	3	–	–	3
Tarhos67 (u)	–	12	–	–	12
Vésztő119 (v)	–	1	–	–	1
Vésztő17 (w)	–	1	–	–	1
Vésztő49 (x)	–	2	–	–	2
Vésztő65	1	–	–	–	1
Total	*14*	*75*	*15*	*10*	*114*

Recorded quantitative data included point counts for matrix, void space, natural mineral inclusions, and intentionally added temper inclusions. Both natural and temper inclusions were tallied by size: ranging from silt at <0.25 mm, fine sand from 0.25 mm to 1 mm, and medium sand from 1 mm to 2 mm. No inclusions larger than 2 mm were observed in any of the samples. These data were used to generate ratios of matrix, sand, and temper for body and paste compositions of the samples. Qualitative description followed Whitbread's (1989, 1995) methodology and classification scheme. General qualitative description included characterization of void shape and size, kneading, sorting of natural mineral inclusions, groundmass description (including crystallitic birefringence and birefringent fabric description, or inactive groundmass description), and color.

For synchronous analysis of all Late Copper Age sherds ($n = 75$), paste and body compositions of each sample were calculated and plotted to measure geographic compositional variability. For the diachronic analysis, compositions were similarly calculated and plotted. Body and paste compositional variability of Middle Copper Age, Early Bronze Age, and Middle Bronze Age samples were then compared with the Late Copper Age samples to observe any possible changes in composition through time.

5. Results

Both Late Copper Age synchronous and multi-period diachronic analysis failed to identify anything beyond modest compositional variability (Tables 2 and 3). Though no dramatic changes in paste or body composition were identified geographically or temporally, long-term trends in body composition indicate some level of manufacturing change in the Körös region during the period covered by this study.

5.1. Late Copper Age variability in the Körös region

No discrete geographic patterning in paste or body composition was observed in the Late Copper Age samples. Although the samples expressed a range of variability in paste composition (specifically the percentage of silt-sized mineral grains, which ranged from 5% to 23%), none of the samples clustered in a way indicative of a relationship between geography and ceramic paste composition (Fig. 4). Only one site – Tarhos67 – clustered discretely from the other samples, with 11 of 12 samples containing silt in amounts greater than 15%. The ceramics from this site could generally be described as slightly sandier than most other samples. However, the size of the mineral grains (<0.25 mm, predominately monocrystalline quartz) and their shape (rounded, rather than with the sharp edges indicative of intentional crushing) point to their unintentional inclusion in the clay. No such clustering of samples from Tarhos67 or any other site was inferred in the body composition of Late Copper Age sherds (Fig. 5).

All Late Copper Age samples shared qualitative characteristics indicative of similar raw material processing and vessel firing techniques. All exhibited an optically active birefringent groundmass and all contained calcite as angular grit, indicating low firing temperatures of <800 °C (Barone et al., 2003; Damjanović et al., 2010). Void space was characterized similarly in all Late Copper Age samples. Large and small vughs (irregular voids) were ubiquitous, planer voids (thin, linear voids that formed as the pot dried) were nearly universal, and vesicles and channel voids (evidence for organic materials burned away during firing) were extremely rare. Muscovite mica lathes were present in all samples, and nearly always expressed a preferred orientation of between 25° and 45° to the surface of the sherd. The universal presence of vughs indicates a moderate level of raw clay kneading, while planar voids commonly indicate folding and pressing of the clay before formation of the vessel (Whitbread, 1995).

Table 2
Summary statistics of point counts from Late Copper Age archaeological sites.

		Paste			Body		
		% Matrix	% Sand	% Silt	% Mat/Silt	% Sand	% Temp
Site							
Békés178	Average	80.78	0.75	18.48	93.55	5.70	0.75
(*n* = 4)	Std. dev.	5.93	1.50	5.98	6.14	6.69	1.50
Békés39	Average	88.26	0.00	11.74	97.24	2.76	0.00
(*n* = 5)	Std. dev.	5.44	0.00	5.44	2.57	2.57	0.00
Bélmegyer56	Average	84.17	1.92	13.92	95.42	2.17	1.92
(*n* = 6)	Std. dev.	5.18	2.68	4.61	4.81	4.05	2.68
Biharugra33	Average	86.58	0.00	13.42	94.53	5.47	0.00
(*n* = 6)	Std. dev.	3.39	0.00	3.39	4.94	4.94	0.00
Füzesgyarmat97	Average	82.46	0.00	17.54	97.24	2.76	0.00
(*n* = 5)	Std. dev.	3.43	0.00	3.43	2.92	2.92	0.00
Szeghalom168	Average	88.83	0.00	11.17	95.37	4.63	0.00
(*n* = 3)	Std. dev.	7.09	0.00	7.09	4.39	4.39	0.00
Szeghalom60	Average	87.98	0.00	12.03	97.25	2.75	0.00
(*n* = 4)	Std. dev.	6.20	0.00	6.20	1.85	1.85	0.00
Szeghalom80	Average	80.51	0.14	19.35	92.25	7.50	0.13
(*n* = 8)	Std. dev.	5.84	0.39	5.77	5.95	5.87	0.35
Szeghalom89	Average	79.13	0.30	20.57	96.17	3.53	0.30
(*n* = 3)	Std. dev.	14.62	0.52	14.94	5.88	6.12	0.52
Tarhos67	Average	74.81	0.95	24.24	95.21	3.87	0.93
(*n* = 12)	Std. dev.	9.09	1.83	9.35	3.13	3.16	1.78

Table 3
Summary statistics of Middle Copper Age (MCA), Late Copper Age (LCA), Early Bronze Age (EBA), and Middle Bronze Age (MBA) petrographic point counts. The more restricted compositional variability of MBA samples is reflected in the variation from the mean, and may be an indicator of increased specialization in pottery production by the middle of the Bronze Age (Budden and Sofaer, 2009).

		Paste			Body		
		% Matrix	% Sand	% Silt	% Mat/Silt	% Sand	% Temp
Period							
MCA	Average	85.42	0	14.58	98.4	0	2.6
(*n* = 14)	Std. dev.	6.16	0	6.16	2.65	0	2.75
LCA	Average	83.14	0.54	16.32	94.21	0.53	4.1
(*n* = 75)	Std. dev.	8.67	1.67	8.55	11	4.01	1.65
EBA	Average	82.12	0.13	18.75	91.57	0.11	6.52
(*n* = 15)	Std. dev.	6.42	0.35	6.42	8.33	0.29	4.21
MBA	Average	84.2	0.61	15.19	89.29	1.61	9.1
(*n* = 10)	Std. dev.	2.92	1.29	2.86	5.63	3.26	6.12

5.2. Diachronic variability in the Körös region

Middle Copper Age, Late Copper Age, Early Bronze Age, and Middle Bronze Age ceramic samples were all compositionally similar. Most petrographic characteristics were ubiquitous throughout the four phases, with nearly all samples possessing a mosaic-speckled and striated optically active birefringent fabric. Void spaces were characterized primarily as large irregular vughs,

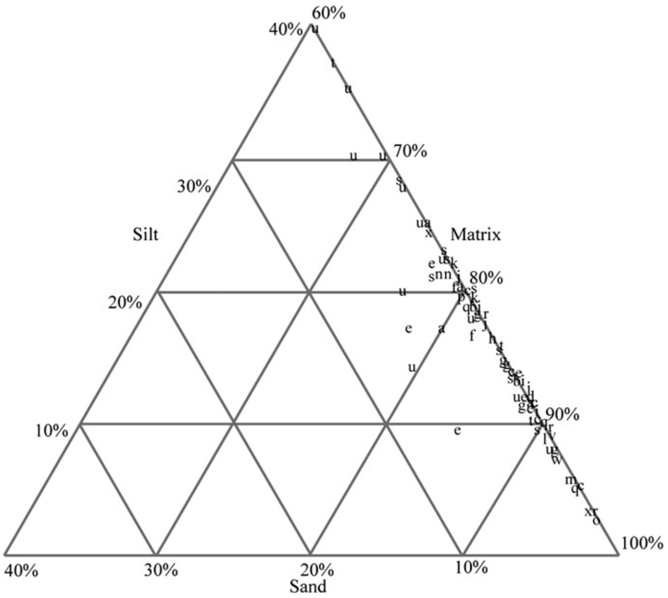

Fig. 4. Ternary plot of paste compositional variability in Late Copper Age samples. Letters correspond to the sample's provenience: Békés178 (a), Békés26 (b), Békés39 (c), Békés75 (d), Bélmegyer56 (e), Bélmegyer82 (f), Biharugra33 (g), Biharugra53 (h), Busca13 (i), Füzesgyarmat97 (j), Gerla64 (k), Körösladány21 (l), Körösladány33 (m), Mezőberény34 (n), Okány43 (o), Szeghalom112 (p), Szeghalom168 (q), Szeghalom60 (r), Szeghalom80 (s), Szeghalom89 (t), Tarhos67 (u), Vésztő119 (v), Vésztő17 (w), Vésztő49 (x).

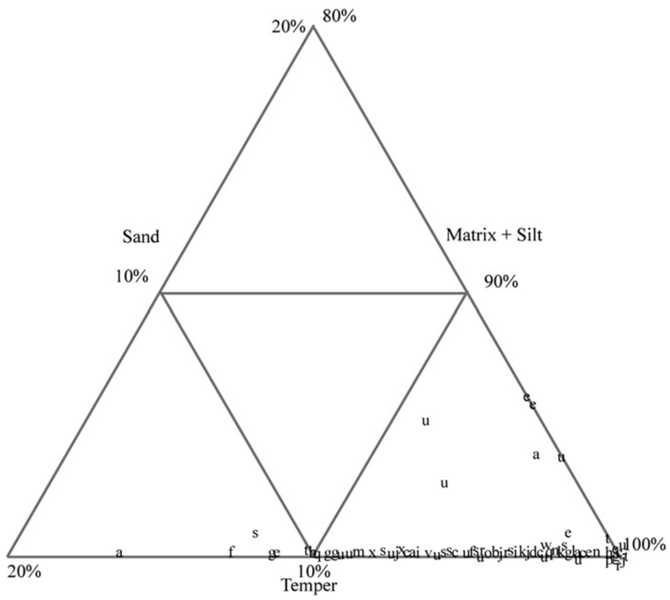

Fig. 5. Ternary plot of body compositional variability in Late Copper Age samples. Letters correspond to the sample's provenience: Békés178 (a), Békés26 (b), Békés39 (c), Békés75 (d), Bélmegyer56 (e), Bélmegyer82 (f), Biharugra33 (g), Biharugra53 (h), Busca13 (i), Füzesgyarmat97 (j), Gerla64 (k), Körösladány21 (l), Körösladány33 (m), Mezőberény34 (n), Okány43 (o), Szeghalom112 (p), Szeghalom168 (q), Szeghalom60 (r), Szeghalom80 (s), Szeghalom89 (t), Tarhos67 (u), Vésztő119 (v), Vésztő17 (w), Vésztő49 (x).

with planar voids less common. Vesicles and channels were extremely rare across all phases. Naturally occurring mineral inclusions in the clay paste were consistent throughout all phases, and consisted primarily of monocrystalline quartz, potassium feldspar, and muscovite mica. Angular grits of calcite were almost ubiquitously observed. Plagioclase feldspar, calcite, pyroxene, and amphibole were less common, while epidote, olivine, chlorite, and serpentine were observed very rarely. These general characteristics indicate that ceramics from all temporal phases were produced using similar raw material processing, vessel forming, and firing techniques (described above).

Quantitative results largely reinforce conclusions drawn from the qualitative diachronic petrographic characteristics. Only modest variability was observed in paste and body composition within and between phases (Figs. 6 and 7). Samples did not cluster by site in terms of paste composition. Samples from no period existed outside of the range of variability expressed by Late Copper Age samples, and no clustering indicative of discrete fabric types was observed. However, Middle Bronze Age ceramics existed within a restricted range of variability compared to all other phases, and deviated less from the mean than samples from other periods (see Table 1). In other studies, similar patterns have been interpreted as a sign of specialization in pottery manufacture (see Budden and Sofaer, 2009). Middle Bronze Age samples are also differentiated by the more frequent relative occurrence of grog (crushed pottery) temper ($n = 6$ of 10, 60% of the samples).

5.3. *Long-term trends in Körös region ceramic compositional variability*

Despite the relative homogeneity in diachronic paste and body composition, and the lack of discrete ceramic fabrics both geographically and temporally, subtle long-term general changes in composition were observed. The general trend of the approximately 2000 years encompassing the temporal phases included in this study is a subtle, but steady increase in the presence of grog temper (Fig. 8). However, grog must compose 20%–50% to enhance the physical properties of a vessel (Rye, 1981: 39). None of the ceramics in this study consisted of greater than 20% temper material, so grog did not play a functional role during the production sequence. Though unusual, Kreiter (2005) noted a similar phenomenon in Transdanubian Bronze Age ceramics. While it is possible that grog in such small amounts resulted inadvertently as a byproduct of the production sequence, this seems doubtful since the presence of grog increases steadily over time. Similarly, the presence of sand-sized unintentional mineral inclusions increases slightly between the Middle Copper Age and Middle Bronze Age (Fig. 9), suggesting slight changes in the processing of raw clay through time.

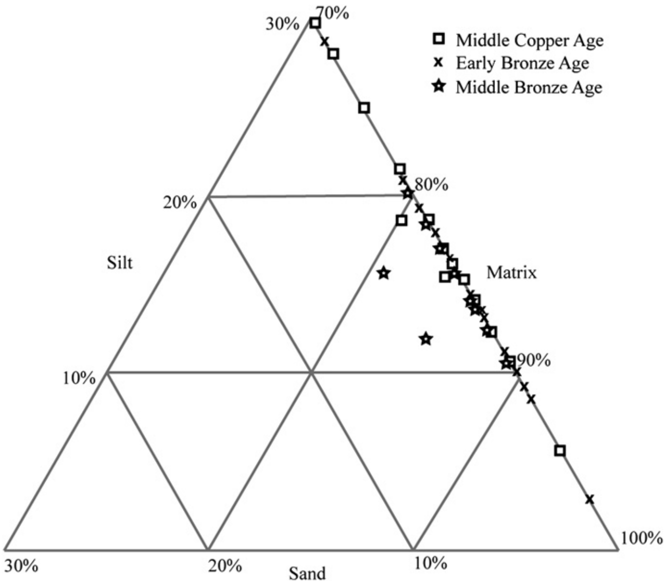

Fig. 6. Paste composition ternary plot of Middle Copper Age, Early Bronze Age, and Middle Bronze Age ceramic samples. Note the restricted range of compositional variability in the Middle Bronze Age samples.

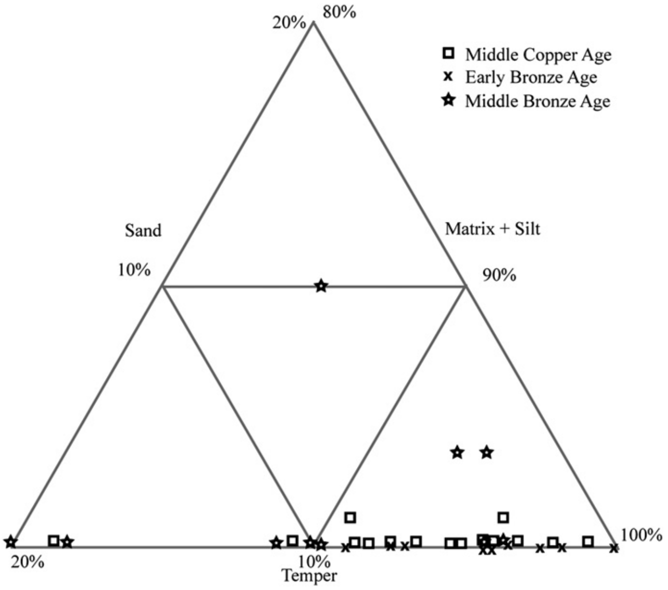

Fig. 7. Body composition ternary plot of Middle Copper Age, Early Bronze Age, and Middle Bronze Age ceramic samples.

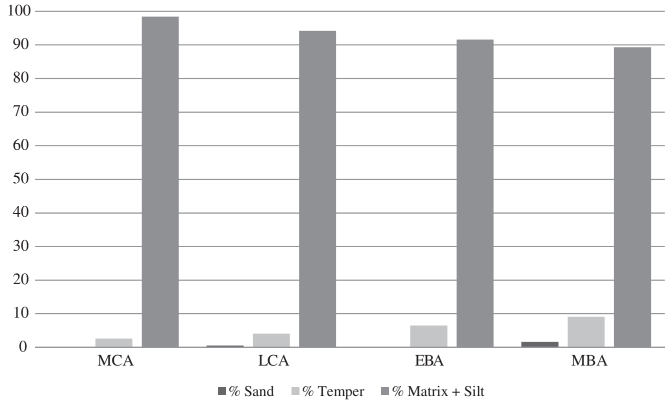

Fig. 8. Body composition of Middle Copper Age, Late Copper Age, Early Bronze Age, and Middle Bronze Age ceramic samples. A steady shift in the ratio of temper (including grog) to sand and matrix plus silt is observable over time. This shift is subtle, but important, as it indicates minor, continuous change in vessel manufacturing rather than an abrupt change. Such a trend indicates continuity in manufacturing technology over the long-term.

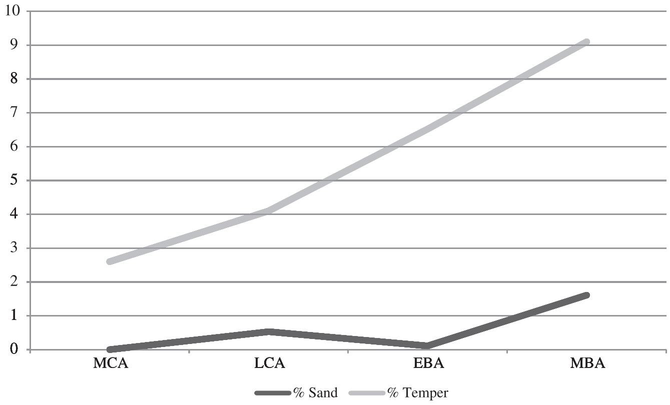

Fig. 9. Percentage of temper and sand observed in point counted Middle Copper Age, Late Copper Age, Early Bronze Age, and Middle Bronze Age ceramic samples. Note the marked trend of an increased appearance of temper (especially grog) over time.

6. Discussion and conclusions

6.1. Discussion: implications of the results for modeling the Late Copper Age

The results of the petrographic analysis point to continuity in ceramic production technology during the time period covering the Middle Copper Age, Late Copper Age, Early Bronze Age, and Middle Bronze Age. A migratory explanation for the appearance of the Baden material culture on the Hungarian Plain is therefore not supported. Although long-term shifts in body composition were noted, and limited clustering was observed in Late Copper Age samples, the abrupt changes in compositional variability that might result from migratory influence were not observed (Stark, 1998a, b). The modest diachronic compositional shift and very slight synchronic geographic compositional grouping observed in this study dovetail well with Furholt's (2008) belief that Baden pottery consisted of regionally diverse fabric types that shared certain common design motifs. In this sense, Furholt's use of the term material culture "coherence" seems more appropriate than material culture homogeneity. In the Körös region during the Late Copper Age, an argument can be made for coherence within the region given the limited range of synchronic compositional variability. Similarly, measured, rather than abrupt, diachronic change points toward population continuity over the time periods covered in this study.

Ultimately, Sherratt's (1997a, b) contention that a population of Yamnaya kurgan builders co-existed with the indigenous Middle and Late Copper Age population in the region is more tenable than Gimbutas's (1970) scenario of invasion, subjugation, and replacement. That said, the physical evidence for migration onto the Hungarian Plain should not be ignored. The presence of Yamnaya-style burial tumuli and inhumations in the study region is a strong indicator of a foreign presence. Stratigraphic data indicate that at least some of the kurgans were constructed around the time of the Middle/Late Copper Age transition (Ecsedy and Bökönyi, 1979), though a lack of radiometric dates for the tumuli makes their association with specific temporal phases impossible. Furthermore, no archaeological evidence other than kurgans exists to indicate Yamnaya presence on the Plain. In spite of this, it is reasonable to suggest that immigrants were quickly incorporated into indigenous populations and had a negligible impact on the material record (Snow, 2009; Thompson, 1996). So, while the kurgans themselves may have left a significant impression on the landscape of the Plain, it is possible that the people that created them did not (Parsons, 2011: 196).

The results of this study show that the migration/economy dichotomy is too simplistic a framework in which to discuss the material culture changes that occurred during the Late Copper Age on the Hungarian Plain. Though a migration into the Plain likely began around 3500 B.C., the material culture changes observed at the advent of the Late Copper Age are more likely a conscious or unconscious adaptation on the part of the people of the Hungarian Plain to align themselves economically and socially with their trading partners beyond the Carpathian Mountains. As the acquisition of raw materials and finished goods (especially metals) became more common in the Late Copper Age and Early Bronze Age (Bóna, 1975; O'Shea, 1978; Sherratt, 1997b), inhabitants of the Plain might have adopted one of the most visual expressions of cultural or economic identity – pottery form and decoration – while retaining local traditions of ceramic manufacturing process, mortuary practices, and house construction. Although further research into Baden social organization on the eastern Plain is necessary to fully support this hypothesis, Sochacki (1985) and Furholt (2008) made similar arguments for regions outside of the Carpathian Basin.

6.2. Conclusions

The framework presented here places Baden firmly within established diachronic models of change for the prehistory of the Hungarian Plain. A social trajectory featuring population continuity and increasing importation of raw and finished stone and copper items existed as far back as the Middle Neolithic, continuing through the Middle Copper Age Bodrogkeresztúr phase (Gyucha, 2010; Parkinson, 2006). This study concludes that the Late Copper Age Baden phase is part of this continuous social and economic trajectory, and that migration and invasion scenarios for the appearance of Baden ceramics on the Hungarian Plain are not tenable.

Methodologically, this study illustrates how ceramic petrography remains useful for the geographic synchronic and diachronic study of changes in ceramic manufacturing technology. Furthermore, the results demonstrate how ceramic types must be viewed independently of cultures or ethnicities in the prehistory of eastern and central Europe. Though it remains temping to equate material culture assemblages with overly simplistic conceptualizations of cultural affiliation, such assumptions contribute to equally simplistic *deus ex machina* models of change. Technological approaches to material culture change, and ceramic petrography in particular, have a role in clarifying the nature of stylistic coherence and can contribute to refining the culture concept in archaeology.

Acknowledgements

I would like to thank Dr. Attila Krieter of the Field Service for Cultural Heritage (KÖSZ) in Budapest, Hungary, for his assistance and guidance in making petrographic thin sections. Dr. Attila Gyucha of the Hungarian National Museum provided invaluable logistical support, and Dr. William Parkinson of the Field Museum of Natural History provided guidance on research design and structure. Annalee Shum, Nicole DeFrancisco (University of California Riverside), Virginia Carr (University of Florida), and Alexandra Parsons (Florida State University) assisted in sample collection and ceramic analysis. Ms. Parsons also provided feedback on an early draft of the paper. Dr. William Parker (Florida State University) allowed me access to his laboratory and a petrographic microscope in the Department of Geology. Dr. Guy Prentice of the National Park Service Southeast Archeological Center provided advice and feedback as the paper developed. Finally, the comments of three anonymous reviewers were invaluable to the production of this report. This study was funded by the National Science Foundation (Doctoral Dissertation Improvement Grant Award Number BCS-0910071).

References

Anthony, D.W., 1986. The "Kurgan culture," Indo-European origins, and the domestication of the horse: a reconsideration. Current Anthropology 27, 291–313.

Balcer, B., 1988. The Neolithic flint industries in the Vistula and Odra basins. Perzigląd Archaeologczny 35, 49–100.

Barone, G., Crupi, V., Galli, S., Majolino, D., Migliardo, P., Venuti, V., 2003. Spectroscopic investigation of Greek ceramic artefacts. Journal of Molecular Structure 651–653, 449–458.

Beynon, D.W., Donahue, J., Shaub, R.T., Johnston, R.A., 1986. Tempering types and sources for Early Bronze Age ceramics from Bab edh-Dhra' and Numeria, Jordon. Journal of Field Archaeology 13, 297–305.

Bóna, I., 1975. Die Mittlere Bronzezeit Ungarns und ihre südöstlichen Beziehungen. Akadémiai Kiadó, Budapest.

Budden, S., Sofaer, J., 2009. Non-discursive knowledge and the construction of identity: potters, potting, and performance at the Bronze Age tell of Százhalombatta, Hungary. Cambridge Archaeological Journal 19, 203–220.

Chandler, G., 2001. Development of a Field Petrographic Analysis System and Its Application to the Study of Socioeconomic Interaction Networks of the Early Harappan Northwestern Indus Valley of Pakistan. In: British Archaeological Reports 995 Oxford.

Childe, V.G., 1950. Prehistoric Migrations in Europe. Instituttet for Sammenlignende Kulturforskning, Oosterhout N.B., The Netherlands.

Damjanović, L., Holclajtner-Antunović, I., Mioč, U.B., Bikić, V., Milovanović, D., Evans, I.R., 2010. Archaeometric study of medieval pottery excavated at Stari (Old) Ras, Serbia. Journal of Archaeological Science 37, 1–11.

Day, P.M., Kiriatzi, E., 1999. Group therapy in Crete: a comparison between analyses by NAA and thin section petrography of early Minoan pottery. Journal of Archaeological Science 26, 1025–1036.

de Capitani, A., 2002. Gefässkeramik. In: de Capitani, A. (Ed.), Die jungsteinzeitliche Siedlung Arbon-Bleiche 3. Funde, Archäologie im Thurgau Frauenfeld, pp. 135–276.

Duffy, P.R., 2010. Complexity and Autonomy in Bronze Age Europe: Assessing Cultural Developments in Eastern Hungary, Anthropology. University of Michigan, Ann Arbor, MI.

Ecsedy, I., Bökönyi, S., 1979. The People of the Pit Grave Kurgans in Eastern Hungary. Akadémiai Kiadó, Budapest.

Ecsedy, I., Kovács, L., Maraz, B., Torma, I., 1982. Magyarország Régészeti Topográfiája. Akadémiai Kiadó, Budapest.

Ferring, C.R., Perttula, T.K., 1987. Defining the provenance of Red Slipped pottery from Texas and Oklahoma by petrographic methods. Journal of Archaeological Science 14, 437–456.

Freestone, I.C., 1995. Ceramic petrography. American Journal of Archaeology 99, 111–117.

Frolking, T., 2009. Holocene Hydrology, Soil Development and Landscape Evolution of the Bikeri Area in the Körös Basin of Eastern Hungary. Denison University, Granville, Ohio.

Furholt, M., 2008. Pottery, cultures, people? The European Baden material re-examined. Antiquity 82, 617–628.

Gimbutas, M., 1963. The Indo-Europeans: archaeological problems. American Anthropologist 54, 602–611.

Gimbutas, M., 1970. Proto-Indo-European culture: the Kurgan culture during the Fifth, Fourth, and Third Millenia B.C. In: Cardona, G., Hoeningswald, H.M., Senn, A. (Eds.), Indo-European and Indo-Europeans. University of Pennsylvania Press, Philadelphia.

Gimbutas, M., 1977. The first wave of Eurasian steppe pastoralists into Copper Age Europe. Journal of Indo-European Studies 5, 277–331.

Gimbutas, M., 1979. The three waves of the Kurgan people into Old Europe, 4500–2500 B.C. Archives Suisses d'anthropologie genéral 43, 113–137.

Gimbutas, M., 1980. The Kurgan wave #2 (c. 3400–3200 B.C.) into Europe and the following transformation of culture. Journal of Indo-European Studies 8, 273–315.

Gyucha, A., 2010. A Körös-vidék Kora Rézkora. (The Early Copper Age in the Körös region). Eötvös Loránd Science University, Budapest.

Hoekman-Sites, H., Parsons, T., Duwe, S., 2007. Elemental interaction: stylistic, composition, and residue analyses of Copper Age ceramics on the Great Hungarian Plain. SAS Bulletin 29.

Jankovich, D., Makkay, J., Szoke, M., 1989. Magyarország Régészeti Topográfiája. Akadémiai Kiadó, Budapest.

Jankovich, D., Medgyesi, P., Nikolin, E., Szatmári, I., Torma, I., 1998. Magyarország Régészeti Topográfiája. Akadémiai Kiadó, Budapest.

Jordan, S.C., Schrire, C., 1999. Petrography of locally produced pottery from the Dutch Colonial Cape of Good Hope, Africa. Journal of Archaeological Science 26, 1327–1337.

Kalicz, N., 1963. Die Péceler (Badener) Kultur und Alatolien Studia Archaeologica, Budapest.

Kalicz, N., Raczky, P., 1987. The Late Neolithic of the Tisza region: a survey of recent archaeological research. In: Tálas, L., Raczky, P. (Eds.), The Late Neolithic of the Tisza Region: A Survey of Recent Excavations and Their Findings. Szolnok County Museums, Budapest-Szolnok, pp. 11–30.

Kreiter, A., 2005. Technological Choices and Material Meanings: Analyses of Early and Middle Bronze Age Ceramics from Hungary. School of Humanities, University of Southampton, Southampton.

Lemmonier, P., 1992. Elements for an Anthropology of Technology. University of Michigan Museum of Anthropology, Ann Arbor, MI.

Němejcová-Pavuková, V., 1981. Náčrt Periodizácie Badenskej Kultúry a jej chronologických vztahov k juhový chodeney Europe. (An outline of the periodical system of Baden culture and its chronological relations to southeast Europe). Slovenská Archeológia 29, 261–296.

Němejcová-Pavuková, V., 1984. K problematike trvania a konca boleazkej skupiny na Slovensku. Slovenská Archeológia 34, 133–176.

O'Shea, J., 1978. Mortuary Variability: An Archaeological Investigation with Case Studies from the Nineteenth Century Central Plain of North America and the Early Bronze Age of Southern Hungary. University of Cambridge, Cambridge.

Parkinson, W.A., 1999. The Social Organization of Early Copper Age Tribes on the Great Hungarian Plain. Department of Anthropology, The University of Michigan, Ann Arbor.

Parkinson, W.A., 2002. Integration, interaction, and tribal 'cycling': the transition to the Copper Age on the Great Hungarian Plain. In: Parkinson, W.A. (Ed.), The Archaeology of Tribal Societies, International Monographs in Prehistory, Ann Arbor.

Parkinson, W.A., 2006. Tribal boundaries: stylistic variability and boundary maintenance during the transition to the Copper Age on the Great Hungarian Plain. Journal of Anthropological Archaeology 25, 33–58.

Parsons, T.A., 2011. Places, Pots, and Kurgans: Late Copper Age Patterns of Settlement and Material Culture on the Great Hungarian Plain, Anthropology. Florida State University, Tallahassee, FL.

Peacock, D.P.S., 1968. A petrological study of certain Iron Age pottery from western England. Proceedings of the Prehistoric Society 34.

Pelisiak, A., 1991. Ze Studiów nad wytwórczością kamieniarską kręgu kultury badeńskiej. Archaeologica Carpatica 30, 17–54.

Reedy, C., 2008. Thin-section Petrography of Stone and Ceramic Cultural Materials. Archetype Publications, London.

Roman, P., Diamandi, S., 2001. Cernavodă III-Boleráz. Ein Vorgeschichliches Phänomen zwischen dem Oberrhein und der unteren Donau, Vavila, Bucharest.

Rye, O., 1981. Pottery Technology: Principles and Reconstruction. Taraxucum, Washington, D.C.

Sachße, C., 2005. Untersuchungen zu den Bestattungssitten der Badener Kultur in ihrem räumlichen und zeitlichen Umfeld. University of Heidelberg, Heidelberg.

Sherratt, A., 1981. Plough and pastoralism: aspects of the secondary products revolution. In: Hammond, N., Hodder, I., Isaac, G. (Eds.), Patterns of the Past: Studies in Honour of David Clarke. Cambridge University Press, Cambridge.

Sherratt, A., 1997a. The Development of Neolithic and Copper Age Settlement in the Great Hungarian Plain I: The Regional Setting, Economy and Society in Prehistoric Europe: Changing Perspectives. Princeton University Press, Princeton, New Jersey, pp. 270–292.

Sherratt, A., 1997b. The Development of Neolithic and Copper Age Settlement in the Great Hungarian Plain II: Site Survey and Settlement Dynamics, Economy and Society in Prehistoric Europe: Changing Perspectives. Princeton University Press, Princeton, NJ.

Snow, D., 2009. The multidisciplinary study of Human migration: problems and principles. In: Peregrine, P.N., Peiros, I., Feldman, M. (Eds.), Ancient Human Migrations: a Multidisciplinary Approach. The University of Utah Press, Salt Lake City.

Sochacki, Z., 1985. The relationship between the Baden culture and the south-east European cultures. Journal of Indo-European Studies 13, 257–268.

Stark, M., 1998a. The Archaeology of Social Boundaries. Smithsonian Institution Press, Washington, D.C.

Stark, M., 1998b. Technical choices and social boundaries in material culture patterning: an introduction. In: Stark, M. (Ed.), The Archaeology of Social Boundaries. Smithsonian Institution Press, Washington, D.C.

Stoltman, J., 1989. A quantitative approach to the petrographic analysis of ceramic thin section. American Antiquity 54, 147–160.

Stoltman, J., 1991. Ceramic petrography as a technique for documenting cultural interaction: an example from the Upper Mississippi valley. American Antiquity 56, 103–120.

Stoltman, J., 2001. The role of petrography in the study of archaeological ceramics. In: Goldberg, P., Holliday, V.T., Ferring, C.R. (Eds.), Earth Sciences and Archaeology. Kluwer/Plenum, New York, pp. 297–326.

Thompson, E., 1996. The Huns. Blackwell, Oxford.

Whitbread, I., 1989. A proposal for the systematic description of this sections towards the study of Ancient ceramic technology. In: Maniatis, Y. (Ed.), Archaeometry: Proceedings of the 25th International Symposium. Elsevier, Amsterdam.

Whitbread, I., 1995. Greek Transport Amphorae: A Petrological and Archaeological Study. British School at Athens, Athens.