ARCHAEOMETRIC RESEARCH ON THE FIRST POTTERY PRODUCTION IN THE CARPATHIAN BASIN: MANUFACTURING TRADITIONS OF THE EARLY NEOLITHIC, KÖRÖS CULTURE CERAMICS

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Kivonat

A cikk a Kárpát-medencében legkorábban letelepedett földművelő népek kerámiáinak archeometriai vizsgálati eredményeit mutatja be. A kerámiák a kora neolit Körös kultúrából (Kr.e. VII. évezred, uncal. BP) származnak. A feldolgozás során a kerámiák mellett a lelőhely környékéről mint potenciális nyersanyagforrásból gyűjtött agyagos talajminták vizsgálatára is sor került. Továbbá a területről néhány későneolit kerámiát is megvizsgáltunk abból a célból, hogy megnézzük volt-e valami változás a kerámiák gyártási technológiájában az idők során.

A kutatás az egyik legelső archeometriai vizsgálat a Körös kultúra leletein. A vizsgálatok során vékonycsiszolatos petrográfiai vizsgálatokat végeztünk, amelyet ásványtani (röntgen-pordiffrakciós), geokémiai (XRF, NAA módszerekkel) és pásztázó elektronmikroszkópos vizsgálatokkal egészítettünk ki. Ez a cikk elsősorban a kerámiák és az agyagos üledékek részletes petrográfiai vizsgálati eredményeivel, és az eredmények értelmezésével foglalkozik, ami alapján kimutatható volt, hogy a kora neolitikus fazekasok a Körös folyó agyagos üledékeit közvetlenül használták a kerámiák készítéséhez. A fazekasok ehhez elsősorban a karbonátmentes, esetleg nagyon kis karbonáttartalmú agyagokat választották ki nyersanyagnak. A vizsgált kerámiák mind nem plasztikus elegyrészeiket, mind szöveti-szerkezeti jellegeiket tekintve hasonlóak egymáshoz, vagyis egy csoportot alkotnak, azonban, kisebb különbségek alapján négy alcsoportot azért meg lehetett különböztetni. Az ugyanerről a területről származó, a Vonaldíszes Kultúrába tartozó néhány kerámia petrográfiai vizsgálata azt mutatja, hogy időben a kerámia készítés technológiája változott.

Abstract

The paper presents the results of an archaeometric study on the first pottery production of the earliest farmers of the Carpathian Basin. The ceramic samples belong to the Early Neolithic Körös Culture, radiocarbon dated to the beginning of the 7th millennium uncal. BP. The samples comprise both sherds and soils, as potential raw materials, which were collected from surroundings of the Neolithic sites from various geological deposits. In addition, some samples from later Neolithic phases were analysed in order to study possible technological changes trough time.

This research represents the very first archaeometric study for the Körös Culture in Hungary. The methods of investigation include a petrographic study of thin sections under a polarising microscope, combined with mineralogical (XRD), geochemical (XRF, NAA) and SEM-EDS analyses. This paper will present and discuss mainly the results of petrographic analysis of clayey sediments and pottery, which allowed us to establish that Early Neolithic potters exploited local clay deposits of the Körös river, with the addition of vegetal temper. Among the possible raw materials, only those with no or very little primary carbonates were selected for pottery production. The ceramic fabrics of the various sites are very similar. Well-defined groups cannot be distinguished, but sherds belong to the same fabric group, which could be subdivided into four subgroups on the basis of minor textural differences. Finally, some ceramic samples of the Linear Pottery Culture from the same area are compared to those of the Körös Culture, which show technological changes in the pottery production through time.

KULCSSZAVAK: ARCHEOMETRIA, KERÁMIAKÉSZÍTÉS, KORA NEOLITIKUM KÖRÖS KULTÚRA, KÁRPÁT-MEDENCE, FITOLIT

KEYWORDS: ARCHAEOMETRIC ANALYSES, POTTERY PRODUCTION, EARLY NEOLITHIC KÖRÖS CULTURE, CARPATHIAN BASIN, PHYTOLITHS

The archaeological framework

The introduction of pottery in the Carpathian Basin was part of a larger economic and social phenomenon that occurred with the transition to farming in Southeast Europe. By the 6th millennium cal BC cereal cultivation and ceramic production spread in this area and a great number of open-air villages were located along the main river valleys. Vessel shapes and decorations are quite similar within a large geographical area, denoting a common cultural tradition of the settlers.

Early Neolithic potters were not dependent on potting for their livelihood. Many indicators, among which the lack of workshops and other specialised sites, suggest that pottery production was a household-scale industry. Household production is the first system state of ceramic production, where potters are all the adult females, who have learned the craft in their youth and have the same potential to make pots (Arnold 1985; Crown 1999). Domestic mode of production is in general typical of societies without social stratification and craft specialisation, where the makers of the pots were also the users. It has also been argued that in small-scale societies technological practices are inseparable from ideas of spiritual or ancestral involvement in the production process (Tilley 1999: 57).

An interdisciplinary research project was started by the authors some years ago in order to characterise the oldest pottery production of Early Neolithic sites of the Great Hungarian Plain and to test the hypothesis that similarities in ceramic style and technological practices resulted from similar cultural traditions and choices rather than from raw material availability or trade and exchange of ceramic products. The ceramic samples studied in this paper belong to the Körös Culture, which is radiocarbon-dated between the first half and middle of the 6th millennium cal BC (Makkay 1989, 1992; Kalicz et al. 1998; Whittle et al. 2002; Biagi and Spataro 2005) and represents the first food-producing communities in the Carpathian Basin. The Körös Culture belongs to the Early Neolithic complex of the Central Balkans together with the Starčevo and the Criş cultural groups. The Körös, Starčevo and Criş Cultures share a great deal of similarity and overlaps in terms of their material culture and cultural traits. It is undoubtedly significant that the boundaries between the various cultural groups correspond to modern political boundaries. In particular, the eponyms of the cultures Criş and Körös are respectively the Romanian and Hungarian names of the same river, which flows east-westwards from Transylvania through the Great Hungarian Plain before joining the Tisza River. The characteristic pottery of this period is homogenous both in form and macroscopic features over a wide area, suggesting a high degree of cultural contacts and transmission of technological skills (Szakmány et al. 2004; 2006). Given that similarities in material culture, style and technological traditions can be related to cultural identity, it seemed to be a good case to investigate. The present research focuses on both ceramic products and raw materials in order to better understand the technology of ceramic production. The analyses carried out represent the first archaeometric study for the Körös Culture ceramics in Hungary; they allow a comparison with datasets obtained by similar analytical methods from neighbouring areas (Manson 1995; Spataro 2003; 2004; 2006).

Sampling strategy

Representative pottery samples and other fired clay artefacts (net-weights, loom-weights, floors and wall plasters) were collected from five Körös Culture Neolithic settlements, located near the present towns of Endrőd and Szarvas (**Figs. 1, 2**), in the Körös River Valley.

The majority of the studied sherds refer to the Early Neolithic, Körös Culture, although a smaller number belong to the Middle Neolithic Linear Pottery Culture (Alföld LP and Szakálhát). The latter ones were selected in order to investigate possible temporal changes in potting traditions (Szakmány et al. 2005). In terms of geomorphology, the Neolithic sites from which the pottery was studied, lie in the Holocene flood-plain of the Körös River Valley, where the watercourse energy is moderate and the river begins meandering. The basin surface of the river is covered by Holocene alluvial silt and clay sediments with remnants of Pleistocene surfaces with loess, infusion loess and clay deposits (Rónai 1985; Gyalog 2005; Nádor et al. 2007).

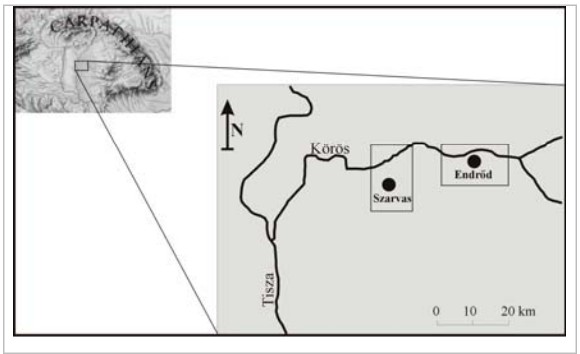

Fig. 1

Location of the studied area

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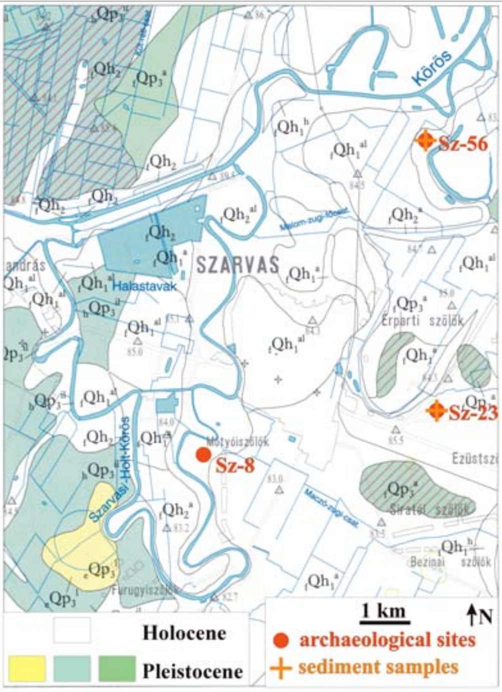

Fig. 2a
Geological map of the Szarvas area with the location of the soil sampling and the Neolithic sites (after Gyalog ed. 2005)

On the contrary, stone material is not available locally, not even in the form of secondarily-deposited gravel, which might have influenced technological choices in pottery production. Besides soil samples, collected by hand coring down to a maximum depth of 2.5 metres in the proximity of the Neolithic sites, plaster samples (fired wattle and daub wall and floor plaster fragments) were also studied with in order to better characterising the composition of local raw materials and compare them to that of the pottery (Starnini and Szakmány in press).

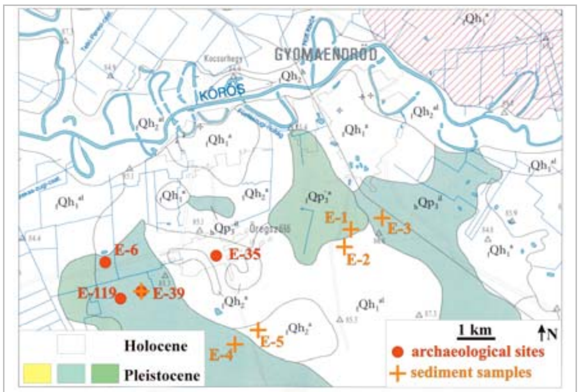

Fig. 2b

Geological map of the Endrőd area with the location of the soil sampling and the Neolithic sites (after Gyalog ed. 2005)

It is assumed that for logistic reasons and ethnographic comparisons, the raw materials for plastering the settlements structures were gathered from sources located close to the sites (Moffa 2005).

Soil samples were collected with different strategies in order to cover every possible raw material source available to the Neolithic potters. Samples were collected in undisturbed areas of the Neolithic settlements (i.e. Szarvas sites Sz-23 and Sz-56, Endrőd site E-39) and within their immediate surroundings, considering the different geological characteristics (Upper Pleistocene, Holocene sediments) mapped by the Hungarian Geological Institute (Gyalog 2005) (**Figs. 2a, 2b**).

Ceramic samples were selected only from well-known vessel shapes (open and globular bowls, small and large storage jars, etc.), on the basis of macroscopic characteristics of their paste (fine-medium-coarse wares), decorations and surface treatments (pinched decorations, barbotine, burnishing, etc.). Paste texture and surface finishing were considered the major criteria for the definition of ware types.

54 potsherds, 26 samples of net-weights, loom-weights, burnt wall and floor plasters and 18 local, natural soil samples were studied. Furthermore, from each soil core, test briquettes were prepared using the clayey horizons, which were considered to be the most suitable for pottery production. The briquettes were experimentally fired at 700 °C, in an oxidising atmosphere for ca. 4 or 8 hours in an electric kiln. They were subsequently analysed by thin section petrography, XRF and NAA. The aim of the preparation of the test samples, fired under almost the same conditions as the prehistoric pottery (Szakmány et al. 2005), was to obtain a comparative dataset for chemical and petrographic analyses, which better matches the physico-chemical transformations which might occur in the raw materials during the firing.

Analytical methods

All the pottery, fired clay artefacts and the fired natural soil samples were analysed in thin section under the polarising microscope. Fabric and quantitative analyses (volume percentage) of the non-plastic inclusions were made. Mineralogical composition of the paste was revealed by X-ray powder diffraction analysis (Szakmány et al. 2005) on 34 artefacts. X-ray fluorescence (XRF, performed at the University of Tübingen, Germany) and instrumental neutron activation analyses (INAA, performed at ACME labs., Canada) were used to determine the major and trace elements (Si, Ti, Al, Fe, Mn, Mg, Ca, Na, K, P, Rb, Sr, Ba, Pb, Th, Zr, Hf, Nb, Y, V, Cr, Co, Ni and REE) of 55 representative clay artefacts and 34

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soil samples. Preliminary geochemical information is presently available for 15 samples (Starnini and Szakmány in press).

Small, rounded nodules were often observed in the pottery samples, which were examined under a Scanning Electron microscope (SEM-EDS). Their chemical composition was determined through an electron microprobe analysis (Szakmány et al. 2004).

Prompt Gamma Activation Analysis (PGAA), a new non-destructive analytical method useful for detecting major and some trace elements in ceramics, will be experimentally performed on some samples in the future.

Description of the samples

Ceramic samples

Körös ceramic samples were selected from the following sites:

Endrőd site E-6: 3 samples (2 Körös + 1 ALP)
Endrőd site E-39: 12 samples
Endrőd site E-119: 4 samples
Szarvas site Sz-8: 9 (3 Körös + 6 Szakálhát)
Szarvas site Sz-23: 25 samples

From 2 sites, namely Endrőd 6 and Szarvas 8, a few ceramic samples were selected from subsequent periods such as Middle Neolithic, Alföld Linear Pottery and Szakálhát Cultures, in order to assess possible variations in pottery technology and raw material choices through the time.

The number of analysed sherds for each site is uneven; nevertheless, each site is represented by a significant number of samples of standard pottery production. Samples from Endrőd 39, 119, Szarvas 8 and 23 represent the so-called classic phase of the Körös Culture, while those from Endrőd 6 belong to the latest phase of the same culture (Makkay 2007).

Soil samples

As mentioned above, the soil samples were collected by hand coring in the Körös Valley localities listed below (**Figs. 2a, 2b**), with the aim of representing all the possible variants of raw materials available in the micro-region, according to the geological map of the area (MÁFI: Gyalog 2005):

Late Pleistocene Infusion Loess (LPIL) sediments: Endrőd-site 39 (E-39), Endrőd-core-3 (E-3) and Endrőd-core-4 (E-4)
Late Pleistocene (LP) clay sediments: Endrőd-core-1 (E-1)
Early Holocene (EH) silt sediments: Endrőd-core-2 (E-2)
Early Holocene (EH) clay sediments: Szarvas, site 23 (Sz-23)
Holocene (H) clay sediments: Szarvas, site 56 (Sz-56) and Endrőd-core-5 (E-5)

Coring was made in undisturbed areas, e.g. in fields where only superficial agricultural activity was going on, avoiding anthropogenic buried deposits and zones around recent constructions. Some of the cores were collected in correspondence of the Early Neolithic sites, while the others were collected in their immediate surroundings where the different types (age, texture) of sediments could be sampled. For each type of sediment such as LPIL, EH clay and silt, at least one core was collected.

In order to extract coherent sediment samples, coring was made as deep as the present water-table was not encountered. The average depth reached with coring was about 2-2.5 m below the present surface, which is more or less the same depth reached by the Neolithic structures (storage pits and rubbish pits found during the archaeological excavations), which might have functioned, at their first use, as clay pits for the extraction of raw material for pottery and plastering.

Results

In the present paper we will discuss mainly the petrographic results of the pottery samples. The analytical results of the "non-ceramic" fired clay artefacts will be published in a forthcoming paper (Starnini and Szakmány in preparation). The preliminary results of petrographic and X-ray powder diffraction analyses, made on the first set of samples, have already been published by Szakmány et al. (2005), while the results of preliminary geochemical analyses are in press (Starnini and Szakmány in press; Starnini et al. in press).

In general, the Körös samples are mostly very porous and have serial, or in some cases weakly hiatal, fabric with variable amounts of fine-grained, non-plastic inclusions. The clasts are mainly angular-subangular, rarely subrounded or rounded. In general, the amount of non-plastic inclusions does not exceed 25% of the total volume, although in some samples it does not even reach 10 %. Grain-size of the inclusions is generally fine, smaller than 200 μm, the maximum-grain size is between 200-450 μm, and the inclusions are moderately well, well or very well sorted. It was observed that pottery pastes are characterised by a rather similar non-plastic content. Non-plastic inclusions occur almost in the same proportion and predominantly are composed of mono-crystalline quartz (with both wavy and normal extinction) and rare polycrystalline quartz, plagioclase, K-feldspar, very fine-grained white mica (muscovite-sericite) in variable amounts, in some samples also a few biotite, fine grained opaque minerals and variable quantities of accessories [tourmaline (green), zircon (monazite?), rutile, clinozoisite-zoisite, epidote, hornblende (brown and green), clinopyroxene, garnet, kyanite]. Apart from these, occasionally individual fragments of rocks also appear such as granitoid, metasedimentary (metasiltstone or metasandstone), vulcanite, greenschists or greenstones.

Fabric grouping of ceramic samples was difficult to define due to the extreme homogeneity of the fabrics. However, we observed the occurrence of at least two sub-groups (sG1 and sG2), on the basis of the amount and the size of non-plastic inclusions (dominant ranging and maximum grain size), sorting and proportion between the fine and coarse fractions:

- sG1: besides fine grained clasts (150 µm) it also contains common/very common amounts of coarse-grained clasts. The latter are medium-large in size (250-400 µm); moderately or poorly sorted, weakly hiatal, with bimodal distributions.

- sG2: the grain size is finer (in general below 100 µm), only a few coarse clasts are present, and grains are well or very well sorted, in general with unimodal distribution.

These 2 sub-groups can further be subdivided (**Table 1**) according to the same principles mentioned above, respectively into two slightly different variants, namely:

- sub-Group 1a (sG1a) is characterised by medium-sized clasts, ranging between 10-20%, and the non-plastic inclusions are moderately sorted (**Figs. 3a, 3b**);

- sub-Group 1b (sG1b) has larger amounts (>20%) of clasts, which are coarser than in the previous sub-group; the non-plastic inclusions are poorly sorted (**Figs. 3c, 3d**);

- sub-Group 2c (sG2c) generally has little amounts of clasts (<10%), which are small-sized (below 100 µm) and with a few or none coarser-grained clasts; the non-plastic inclusions are well or very well sorted (**Figs. 3e, 3f**);

- sub-Group 2d (sG2d) has medium or large amounts of clasts (>10%) although some coarser grained clasts also occur, however, the size of the clasts is fine-grained; the non-plastic inclusions are always well sorted (**Figs. 3g, 3h**).

Primary carbonates were often observed in fired clay artefacts, although they very rarely occur in the ceramic samples. They are present in the form of sparite in 2 samples only from Endrőd-39 and in the form of bioclast (fossil shell fragment) in one sample from Szarvas-23. Interestingly, the presence of micritic carbonates in the pottery paste characterises both the 2 Late Körös samples from Endrőd-6.

Finally, small, rounded limonitic nodules were often observed, even macroscopically, in the ceramic samples, in variable quantities and different sizes (mean: 100-500 µm; rarely up to 5 mm) (**Fig. 4**).

Porosity of the ceramic body is usually high, due to the use of organic (vegetal) temper that left voids after firing. The shape of the voids is usually elongated, although there are also rounded, sub-rounded and branched pores. The elongated ones are usually parallel to the walls. The boundaries are normally regular, but in some rare cases they might be slightly wavy or irregular. Their shape and, sometimes, the presence of phytoliths inside, suggests that the organic temper mostly derived from the upper part of cereals (glumes, chaff) (**Fig. 3e**).

Phytoliths were usually observed in the pores of many samples, especially in wall plaster and net weights, sometimes still in anatomical order.

Sub Group 1		**Sub Group 2**	
Sub-Group 1a (site-n. of samples)	*Sub-Group 1b (site-n. of samples)*	*Sub-Group 2c (site-n. of samples)*	*Sub-Group 2d (site-n. of samples)*
Szarvas-23 (13)	Szarvas-23 (3)	Szarvas-23 (7)	Szarvas-23 (2)
-	-	-	Szarvas-8 (3)
-	Endrőd-6 (2)	-	-
-	-	Endrőd-39 (2)	Endrőd-39 (10)
-	-	Endrőd-119 (3)	Endrőd-119 (1)

Table 1: distribution of Körös ceramic samples according to groups.

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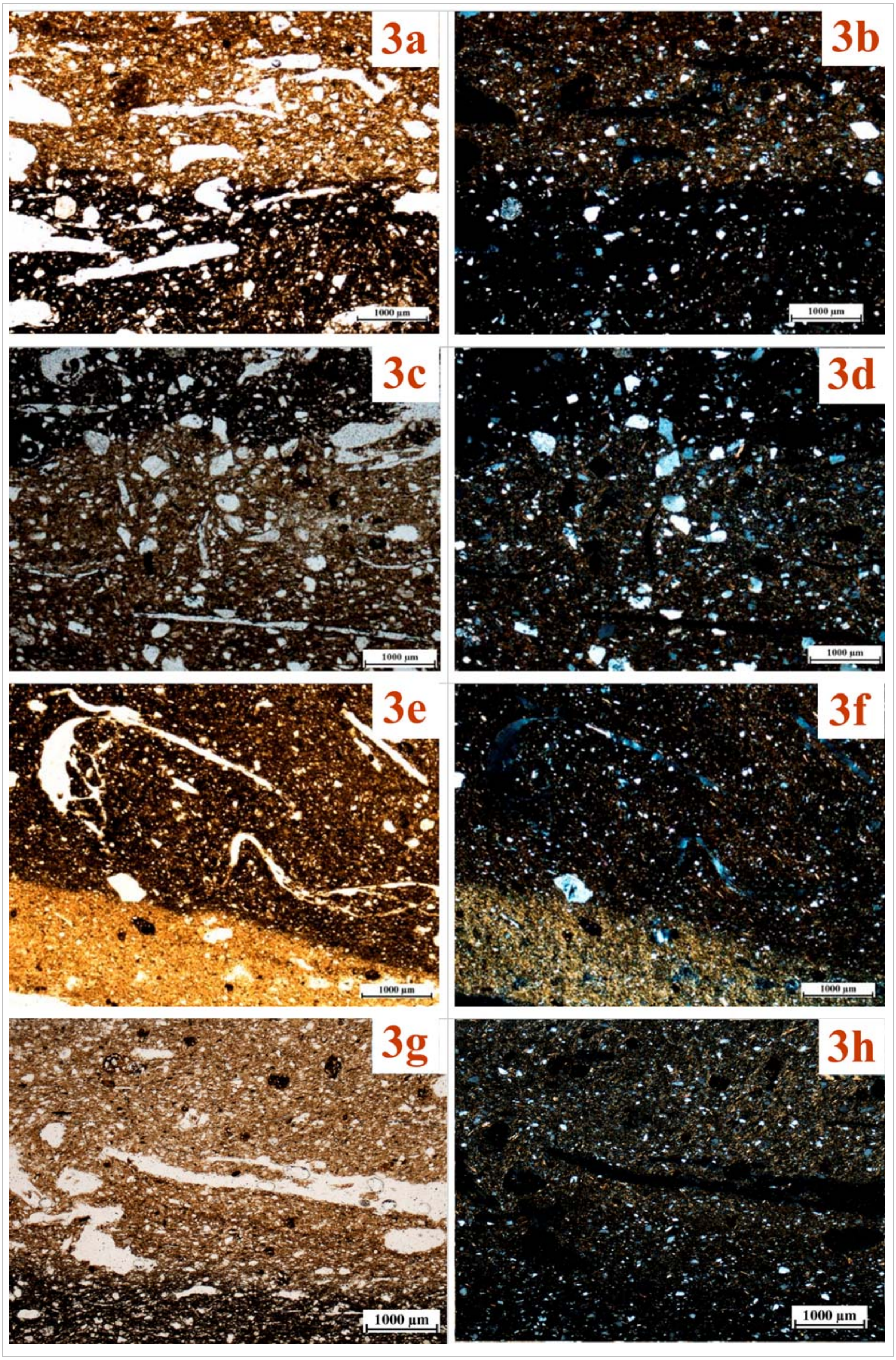
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Fig. 3 (previous page)

Fig. 3a-b

Micrographs of Körös Culture ceramic sub-group sG1a from Szarvas- 23

a) sample A71a3 1N; b) the same, +N.

Fig. 3c-d

Micrographs of Körös Culture ceramic sub-group sG1b from Szarvas- 23

c) sample A20c 1N; d) the same, +N.

Fig. 3e-f

Micrographs of Körös Culture ceramic sub-group sG2c from Szarvas- 23

e) sample A95, with characteristic voids left by the burnt off chaff 1N; f) the same, +N.

Fig. 3g-h

Micrographs of Körös Culture ceramic sub-group sG2d from Endrőd-39

g) sample E39/7 1N; h) the same, +N.

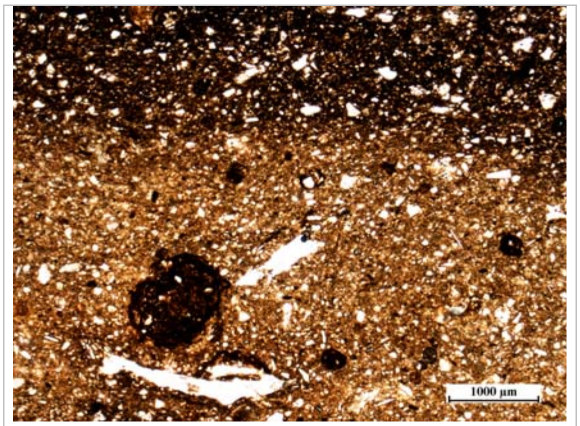

Fig. 4

Micrograph of a Körös Culture sherd from Szarvas-23 showing limonitic nodules in the paste (sample A64b4 1N).

Their quantity and preservation are variable. Only a few ceramic samples show many and well preserved phytoliths (**Figs. 5a-d**), and in general they are rare and not always in good conditions.

The experimentally fired soil samples manufactured from local raw material, which were analysed contain the same type of non-plastic inclusions of the archaeological samples and their grain size distribution is similar to that of the prehistoric artefacts.

The few sherds so far analysed from the Szakálhát Culture from Szarvas 8 (**Figs. 6a-d**) show the use of raw materials similar to those of the Körös ceramics, even though the Szakálhát sherds also show different amounts of ARF (Argillaceous Rock Fragments; Whitbread 1996) inclusions. Moreover, the Szakálhát samples also show in thin sections a mixture of at least two different clay types, one of which more massive. Another difference that was noticed from the Körös ceramics is the size and shape of the pores, which might suggest the use of a different type of organic temper. Finally, only a few phytoliths were recognised, which were almost embedded in the matrix (**Fig. 6d**).

In general, the soil samples did not show any significant difference in terms of the range, quality and quantity of minerals and grain size and distribution between the different geological units that were sampled (LP, EH, H), and among the layers recorded at different depths of the cores, except for the deepest part of the coring of the Late Pleistocene Infusion Loess (LPIL), whose clasts grain-size is above the larger average size observed in the pottery (**Fig. 7a-f**).

Another difference is the primary carbonate content, which is almost absent in the ceramics, while it is high in some soil profiles.

Minerals in the soil samples are of the same type of those observed in pottery. However, each sampled locality showed some specific characteristic except for Szarvas-56, which is more similar to the Pleistocene deposit (despite the fact that it is a Holocene unit in the geological map). The comparison of all the other soil samples shows that the Holocene soils are generally slightly coarser-grained than the Pleistocene ones. Moreover, samples from the Holocene soils are moderately and poorly sorted in general and richer in clasts (20-25%, rarely 40%) than the Pleistocene ones (max 15%), which are in turn well sorted. The two different cores from the LPIL units (E-3 and E-4), show a similar stratigraphic pattern: the upper layers are slightly different from the lower ones in terms of percentage of the clasts and their distribution, which is weakly hiatal. However, the

Fig. 5a

Micrograph of a Körös Culture sherd from Endrőd-site 39 showing phytoliths in the voids (sample E39/9 1N)

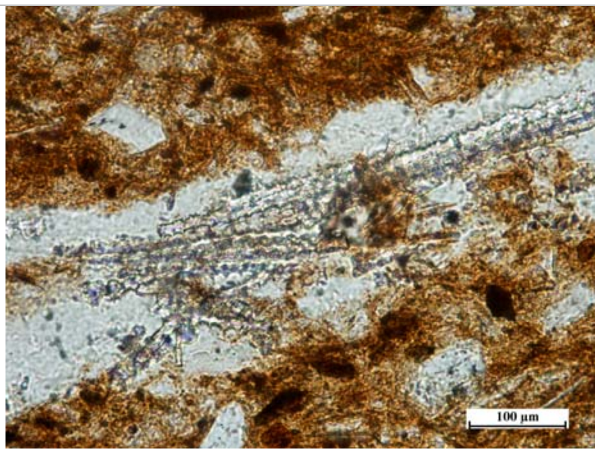

Fig. 5b

Micrograph of a Körös Culture sherd from Endrőd-site 39 showing phytoliths in the voids (sample E39/9 1N).

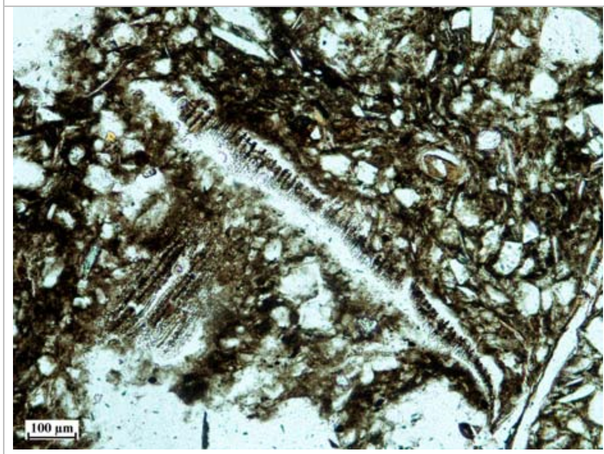

Fig. 5c

Micrograph of a Körös Culture sherd from Endrőd-site 39 showing phytoliths in the voids (sample E39/9 1N).

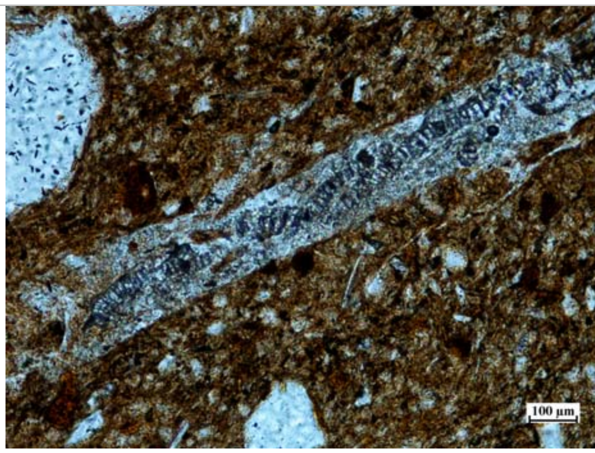

Fig. 5d

Micrograph of a Körös Culture sherd from Szarvas-site 23 showing phytoliths in the voids (sample Sz23/A20a 1N).

lower part of the core contains much more coarse than fine grains, which is the opposite of what was observed both in the upper layers of the same drill and in the other cores.

Holocene sediments always contain carbonates (both primary and secondary), just as the Pleistocene clay deposits; on the contrary, they are not present in the LPIL sediments and at Szarvas 56. Primary carbonates are in the form of bioclasts (shell fragments), sparite or micritic nodules. This observation might be important because it seems that carbonate-free clayey soils were preferred for pottery production.

The soil sample from Endrőd-39 represents a characteristic sandy-silty LPIL sediment (**Fig. 7g-h**), which was analysed to study the mineral composition of the sediments of that area. Also in this case, its mineral composition is similar to that of the other types of soils.

Also the presence/absence of limonitic nodules in the archaeological sample reflects the natural variability of the local soil deposits.

Discussion

At the present stage of the research, the comparison between the samples from the different sites shows a micro-regional variability within the pottery production. For instance, the pottery fabrics from Endrőd-119 are more similar to those from Szarvas-23, while Endrőd-6 fabrics differ from the others. One of the samples might have been tempered with sand. It is interesting to note that these samples

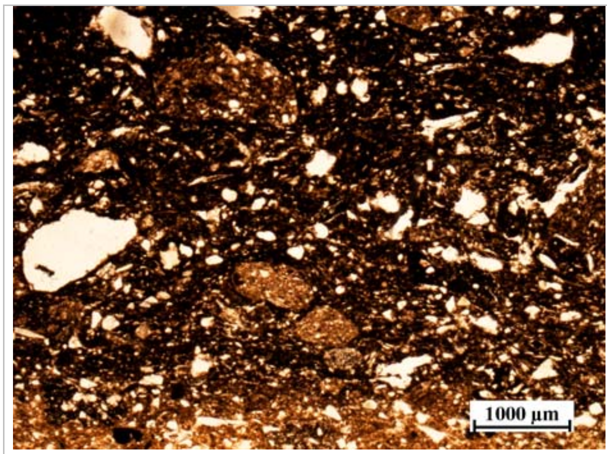

Fig. 6a

Micrographs of a Szakálhát Culture sherd from Szarvas-8, showing ARF in the paste a) sample Sz8/2 1N

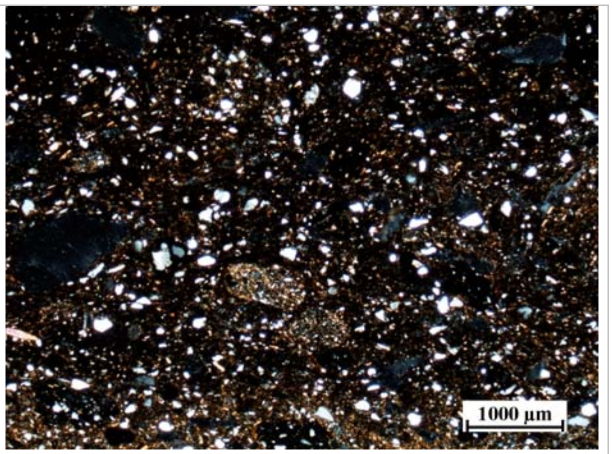

Fig. 6b

Micrographs of a Szakálhát Culture sherd from Szarvas-8, showing ARF in the paste b) sample Sz8/2 +N.

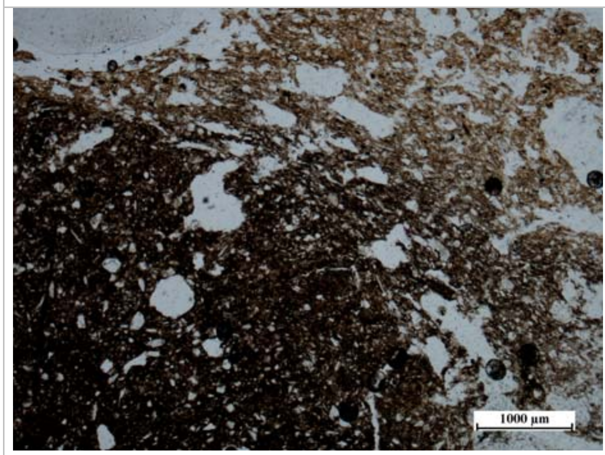

Fig. 6c

Micrograph of a Szakálhát Culture sherd from Szarvas- 8, showing the admixture of two different clays (sample Sz8/5c 1N)

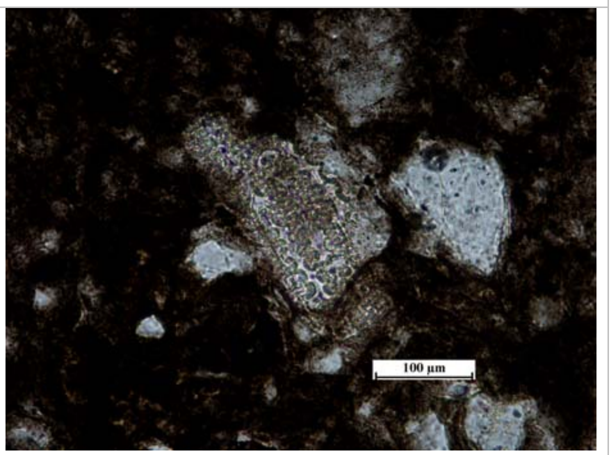

Fig. 6d

Micrograph of a Szakálhát Culture sherd from Szarvas- 8, showing phytolihs in the paste (sample Sz8/5d 1N).

represent a Late Körös ceramic production (Makkay 2007). The main difference noticed at Endrőd-39 is the use of a finer grained local raw material.

The first attempt at comparing soil types and ceramic sub-groups is given in **Table 2.** Holocene soil deposits might represent the raw material source for ceramic sub-Group 1, except for the soil sample from Szarvas-56, which is more similar to ceramic sub-Group 2.

Pleistocene deposits better correlate with sub-Group 2, except for the upper core samples of E-3 and E-4, which are more similar to sub-Group 1.

The next and last level of our analyses will be to understand if the similarities/differences discussed above are connected to the local raw material sources micro-variability, or to the slightly different chronology of the samples (Körös-Early Neolithic, Alföld Linear Pottery (ALP) / Szakálhát-Middle Neolithic), or perhaps they are connected to the different functions of the analysed artefacts (i.e., for instance, storage/daily use pottery, fine/coarse ware).

Macroscopically, almost all the sherds have a „sandwich-like" structure, i.e. their cross section shows a black core with red–brownish red rims corresponding to the inner and outer surfaces. The boundary between the lighter margins and the dark core is usually not sharp, but the colour changes gradually from yellow to red and then to black. X-ray powder diffraction analyses taken from the cores and the margins showed compositional differences between the parts. The most striking feature is the presence of chlorite in the core and its absence in the margin (Szakmány et al. 2005).

drill-core	soil age	ceramic sub-Group
Szarvas, site 56 (Sz-56)	Holocene clay sediments	sG2c/d
Endrőd-core-5 (E-5)	Holocene clay sediments	sG1b ?
Szarvas, site 23 (Sz-23)	Early Holocene clay sediments	sG1b
Endrőd-core-2 (E-2)	Early Holocene clay sediments	sG1a
Endrőd-core-1 (E-1)	Late Pleistocene clay sediments	sG2c ?
Endrőd, site 39 (E-39)	Late Pleistocene Infusion Loess	~sG2d
Endrőd-core-3 (E-3)-upper part	Late Pleistocene Infusion Loess	sG1a
Endrőd-core-3 (E-3)-lower part	Late Pleistocene Infusion Loess	sG2c
Endrőd-core-4 (E-4)-upper part	Late Pleistocene Infusion Loess	sG1a
Endrőd-core-4 (E-4)-lower part	Late Pleistocene Infusion Loess	sG2c

Table 2

Correlation between the ceramic sub-groups and the soil types recorded in the drills.

These results compared with Livingstone's ethnoarchaeological survey of pyrotechnological practices (Livingstone Smith 2001), suggest that the pottery was fired at low temperatures (700–750ºC), with high heating rates and short soaking times. Moreover, the survival of opal silica in the form of identifiable phytoliths also suggests that the temperatures were below 800°C (Vrydaghs, pers. comm.). The presence of dark cores also indicates low firing temperatures, an insufficient length of firing and a reducing atmosphere since the core would be lighter if the carbonised organic temper was removed through oxidation. Furthermore, the reduced core can suggest firing in the open without the use of a kiln (Matson 1963).

Some of the sherds show rounded, pebble-like, almost opaque nodules as inclusions, with a diameter of few millimetres (max. 5 mm). Under the polarising microscope these nodules are dark brownish red or almost opaque, containing mineral inclusions predominantly quartz, which are similar in quality to those observed in the pottery matrix.

These nodules were studied under a scanning electron microscope and their geochemical composition was determined with the help of an electron microprobe analysis (Szakmány et al. 2004). Backscattered electron images show that the nodules usually have a concentric structure. Geochemical analyses revealed that iron poor (4–5%) and iron rich (30–40%) zones can be distinguished. The contact lines between the zones are sharp and the iron content at the borderline can be very high (60–70%) (Szakmány et al. 2004). Structures similar to those discussed above are common in clay rich soils of marshlands or floodplains or in meadow soils close to the water-table level (Szendrei 2001). This suggests that the Körös Culture potters most probably used raw materials from these environments.

During traditional archaeological classification, fine-medium-coarse wares could be distinguished only on the base of the quantity of vegetal temper and the quality of surface finish. Textural analyses revealed that vegetal material was intentionally added as temper in a variable quantity, according to the thickness of the vessel body and the quality of the fabric (fine-coarse).

The vegetal inclusions are still quite clearly observable in thin section in the form of voids left by burnt off vegetal material, burnt plant parts and, more rarely by phytoliths (**Fig. 5a-d**). It is important to point out that, at present, in the scientific literature, there are only a few cases of phytoliths evidence provided by ceramic petrographic thin sections (De Paepe et al. 2003; Vrydaghs et al. in press) and plaster analyses (Kajale 2004).

The phytolith morphotypes (dendritics) observed in the Körös samples, the morphology of the voids and the clear imprints of plant parts (glumes, kernels, caryopses and spikelet forks) on the pottery surfaces and breaks, which can be observed at a macroscopic level, allow to identify the majority of the vegetal material as chaff resulting from crop(cereals)-processing, (Starnini et al. in press) and therefore as the waste from routine processing of ears. Considering that chaff remains are both on the surface and inside the pottery paste, they must have been intentionally added during pottery production as organic temper. Finally, there seems to be no real difference, at least from information gathered from the observations carried out up to now in the composition of tempers between different ceramic material culture remains like vessels, net and loom weights.

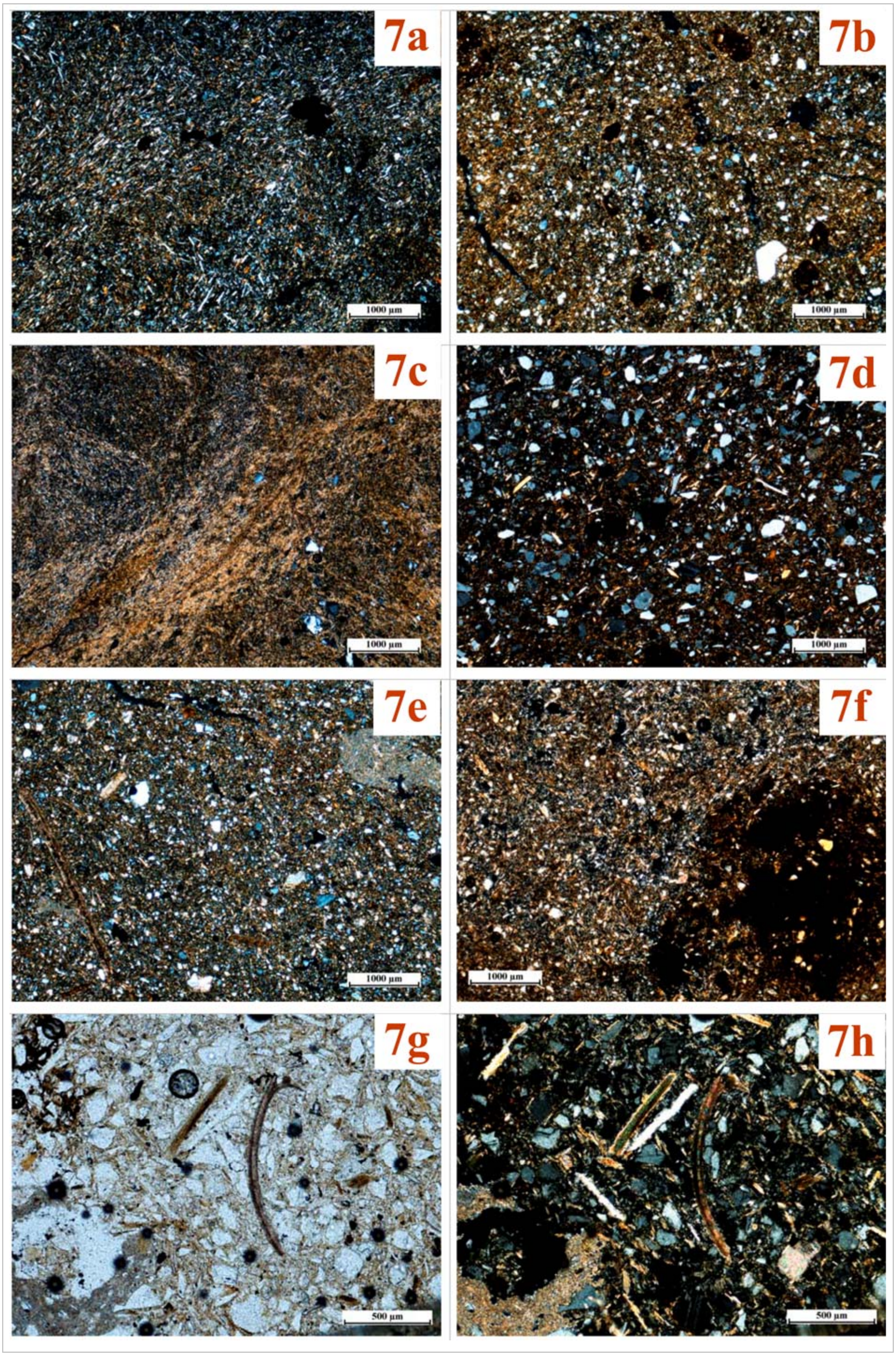
7a
1000 µm
7b
1000 µm
7c
1000 µm
7d
1000 µm
7e
1000 µm
7f
1000 µm
7g
500 µm
7h
500 µm

Fig. 7 (previous page)

Fig. 7a

Micrograph of a Pleistocene clayey soil sample from E-1 drill, at a depth of 185-200 cm (+N).

Fig. 7b

Micrograph of a Pleistocene infusion Loess soil sample from E-4 drill, from the upper part of the core (+N).

Fig. 7c

Micrograph of a Pleistocene infusion Loess soil sample from E-4 drill, from the lower part of the core (+N).

Fig. 7d

Micrograph of an Early Holocene soil sample from Sz-23 drill, -1m (+N).

Fig. 7e

Micrograph of a Holocene soil sample from EN-5 drill (+N).

Fig. 7f

Micrograph of a Holocene soil sample (very similar to the Pleistocene deposit) from Sz-56 drill (+N).

Fig. 7g-h

Micrographs of a sandy soil sample from E-39 drill

g) 1N; h) +N.

Finally, geochemical analyses (XRF-INAA) on representative samples of ceramics, plasters, net weights and soil samples from the sites are in progress. Preliminary results of chemical data processing are published in Starnini et al. (in press) and seem to confirm the petrographic results.

Conclusions

This study of the pottery production of the Körös Culture sites of the Szarvas and Endrőd districts revealed that the Early Neolithic wares have similar macroscopic features and also similar mineralogical and geochemical composition. It is suggested that argillaceous silt or silty clay already subjected to pedogenesis was tempered with vegetal material and used as raw material for pottery manufacture. X-ray powder diffraction analyses of the paste showed that the pottery was fired at low temperatures (about 700–750ºC) in a reducing atmosphere, with high heating rates and low soaking times, most probably in open fires, followed by a fast oxidising process and then cooling. Relatively low, equivalent firing temperatures are also indicated by the absence of vitrification in the clay matrix and the quite good survival of phytoliths in some of the samples, which represent the remains of the vegetal temper intentionally added during pottery production. The soil analyses demonstrated that local silty clay was a well suitable raw material for pottery production and that it was employed for the manufacture of ceramics and other fired clay artefacts without much manipulation, except for the addition of vegetal (chaff) temper. Moreover, petrographic and chemical analyses showed that Neolithic potters most probably intentionally selected the richest clay layers from the deposits available in the area, and systematically avoided layers with carbonate, or carbonate-nodules.

The main temper in the fabric was organic (chaff), probably because on the surface of the Körös Valley the Holocene alluvial sediments are mainly represented by clay, silty clay and silt; coarse-grained mineral temper was not available. Thus, it seems that the absence of mineral/lithic temper was the main constraint for the development of an expedient ceramic technology, and the local clay with naturally present small-sized, non plastic inclusions, was a very good raw material. However, we cannot exclude that this choice was due to technological traditions and perhaps techno-functional advantages, because organic tempering increases clay workability during manufacture, gives lighter weight and good maintenance of adequate cooling of the content in fired vessels (Skibo et al. 1989). Moreover, chaff temper and sequential slab construction, both employed in the pottery manufacture of Körös Culture, have been explained as adaptations to highly plastic clays (Neff 1993).

The data available so far seem to confirm the great homogeneity of the ceramic production (e.g. raw material, tempering, firing) of the Early Neolithic in Hungary throughout a long period, as already noticed at stylistic level (e.g. vessel shapes, decorations). This homogeneity most probably indicates cultural transmission within groups belonging to a traditionally-structured, technologically stable society. If we compare our archaeometric data with those available from the few Early Neolithic sites studied in other areas of the Carpathian Basin such as in Romania and Serbia (Manson 1995; Spataro 2003; 2004; 2006), it turns out that stylistic similarities of pottery are coupled with similar production techniques over a wide area of the Central Balkans. The origins of the Early Neolithic pottery pyrotechnology of the Carpathian Basin can be traced in Anatolia and the Levant, where the earliest local pottery productions are characterised by the use of vegetal temper (Vandiver 1987; Aureche and Kozłowski 1999; Lichter 2005), resulting from the harvesting and threshing of the first domesticated cereals.

Moreover, it is well known that the weather and the climate can affect pottery production; thus pottery is produced preferably during the dry season. It was already proposed (Starnini in press) that the high content of chaff temper in the Körös pottery might indicate that pottery production took place seasonally, according to which we can infer that ceramic was probably manufactured soon after the harvest. This suggestion is in accordance with the assumption that pottery production can be linked more directly to agricultural activities, when agricultural by-products such as chaff are incorporated into ceramics (Fuller et al. in press). To support this hypothesis there are several cases from which it has been suggested that, especially in temperate areas, harvest time might have roughly coincided with ceramic production, and the latter, to some extent, can be considered as a seasonal activity (Howard 1981; Fuller et al. in press).

To conclude, preliminary comparisons between the Körös and the Linear Pottery Culture ceramic production show a change in terms of raw material preparation and organic temper. In particular the Late Körös and Early ALP samples from Endrőd-6 are much more similar than the Classic Körös and Szakálhát ceramic samples. The appearance of ARF in the ceramic paste and the combination of at least two different clayey raw materials is observed only in the Szakálhát pottery samples. This means that it is easier to assess technological changes through a long period, rather than within a short time and that technological changes were not progressive, but rather a slow process.

However, to confirm this observed trend and to better define patterns of technological change trough time, in the future it will be necessary to enlarge the analytical database of pottery samples.

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