ARCHAEOMETRIC STUDIES ON EARLY BRONZE AGE POTTERY FROM VÖRS-MÁRIAASSZONY-SZIGET

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Kivonat

Cikkünk a Vörs-Máriaasszony-sziget régészeti lelőhelyen feltárt, Kisapostag kultúrába tartozó kora bronzkori kerámiák (tárolóedények: fazekak vagy urnaalakú edények töredékei) petrográfiai, ásványtani és geokémiai vizsgálatának eredményeit mutatja be. A vizsgálatok egy multidiszciplináris kutatás részét képezik, amelynek során történeti szempontból értékeljük a lelőhely anyagát. Összehasonlításul egy közeli lelőhely, Vörs-Tótok dombja egykorú településének kerámiáit használtuk. A vizsgálatra szánt kerámiákat a formájuk és a szövetük makroszkópos megfigyelése során válogattuk ki. A vizsgálatok kiindulópontját a kerámiák és a potenciális nyersanyagok petrográfiai elemzése jelentette, amit röntgen-fluoreszcens analízissel, neutronaktivációs analízissel és röntgen-pordiffrakciós elemzéssel egészítettünk ki. A kerámiák ásványtani, kőzettani és geokémiai jellemzőit összevetettük a lelőhelyen feltárt, zárt régészeti objektumokból származó talajmintákéval, a Máriaasszony-szigeten mélyített sekélyfúrásokból származó homokos üledékekével, és a közeli Vörs-Battyánpuszta agyagbányájából nyert agyagmintákéval. Az összehasonlítások során felhasználtuk a lelőhely legkorábbi kerámiáit is: a Kisapostag kultúra kerámiaanyagát petrográfiai és geokémiai szempontból is összevetettük a Starčevo kultúra Máriaasszony-szigeten feltárt kerámiáival.

Azt találtuk, hogy a kerámiák zömét Máriaasszony-szigeten és Tótok dombján is összetört kerámiadarabokkal soványították. Két Máriaasszony-szigetről származó mintában azonban nem találhatók kerámiatöredékek, ezeket a korabeli fazekas karbonátos homokkal soványította. Azaz a vizsgált időszakban legalább két kerámikészítési recept volt forgalomban. A kerámiák és a potenciális nyersanyagok ásványos összetétele nagyon hasonló, a geokémiai összetételben azonban különbségek mutatkoznak mind a főelem-, mind a nyomelem-összetételben. A lelőhelyről származó homokos üledékek és a Battyánpusztáról származó agyagminták petrográfiai vizsgálatának eredményei azt mutatják, hogy a Kisapostag-kerámiák fő tömegének nyersanyagát Máriaasszony-sziget lelőhely közvetlen közeléből szerezték be. A két karbonátos homokkal soványított kerámia petrográfiai és geokémiai tulajdonságai egyaránt utalhatnak ennek az elterjedten használt nyersanyagnak a kezelésére és más nyersanyagforrás használatára is.

Abstract

This study presents the results of the petrographic, mineralogical and geochemical analysis of Kisapostag Culture (Early Bronze Age) pottery (jars or urns/amphorae) from Vörs-Máriaasszony-sziget. This study forms a part of a major project on pottery analysis at a multi-period archaeological site. Pottery samples were chosen through macroscopic examination of fabric and form and the investigations were based on thin section petrography, X-ray Powder Diffraction (XRPD), X-ray Fluorescence Analysis (XRF) and Instrumental Neutron Activation Analysis (INAA). For comparison, coeval samples from a nearby settlement site – Vörs-Tótok dombja – were examined. The petrographic, mineralogical and geochemical properties of the sherds were compared to potential raw materials, obtained from closed archaeological units at Vörs-Máriaasszony-sziget (soil samples), from shallow boreholes drilled on Máriaasszony-sziget (sand samples), and from a nearby clay mine in Vörs-Battyánpuszta, 2 km north-east of the site (clay samples). The petrographic and geochemical characteristics of Kisapostag ceramics were also compared to that of the earliest ceramics of the site of Starčevo culture.

It was found that most of the ceramics both from Máriaaszony-sziget and Tótok dombja were tempered with grog, while in the case of two sherds from Máriaasszony-sziget carbonate sand was used as temper. That clearly reflects the use of two distinct pottery making recipes. Mineralogical composition of the ceramics and the potential raw materials are very similar, however, there are differences in geochemical composition, concerning both major and trace elements. The results of the petrographic analysis of sandy sediments of the site and clays from Battyánpuszta suggest that the raw material source of the majority of the ceramics was most probably in the closest vicinity of Máriaasszony-sziget.

HU ISSN 1786-271X; urn:nbn:hu-4106

The petrographic and geochemical composition of the two carbonate sand tempered sherds might reflect either the use of a different raw material source or the treatment of the extensively used natural sediment.

KULCSSZAVAK: KORA BRONZKOR, KISAPOSTAG KULTÚRA, NYERSANYAG, PETROGRÁFIA, GEOKÉMIA, RÖNTGEN PORDIFFRAKCIÓS ELEMZÉS

KEYWORDS: EARLY BRONZE AGE, KISAPOSTAG CULTURE, RAW MATERIALS, PETROGRAPHY, GEOCHEMISTRY, X-RAY POWDER DIFFRACTION ANALYSIS

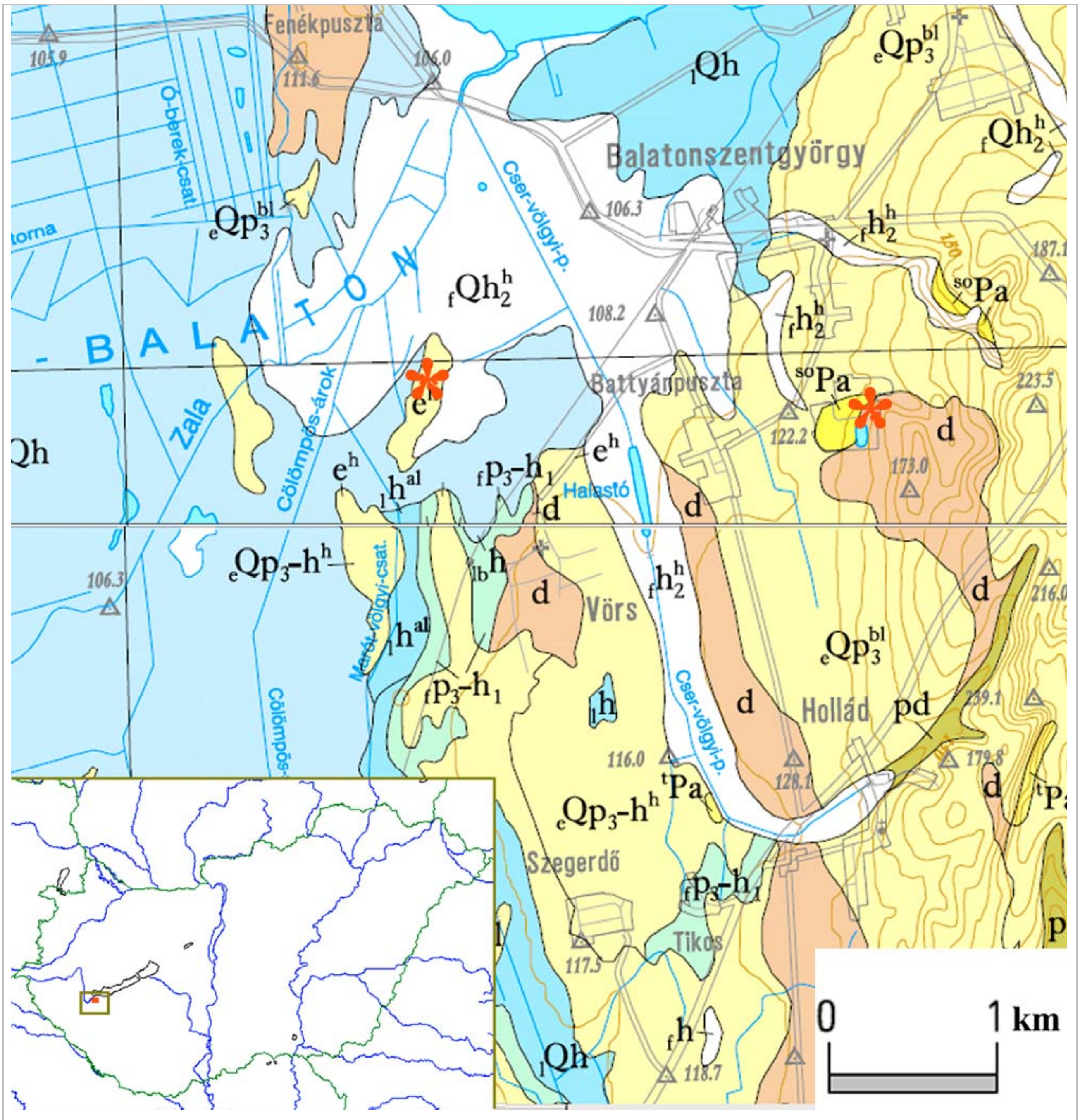


Figure 1.

Map of the region with the location of Vörs and Battyánpuszta. Sampling points marked with red asterisk. Details from the Geological Map of Hungary: courtesy of P. Scharek, Hungarian Geological Institute

Introduction

Vörs is a small village located at the eastern margin of Little-Balaton, very close to Lake Balaton, in Southwest Hungary. The site, Máriaasszony-sziget lies northwest of the village on a sandy peninsula protruding the former lake (**Fig. 1**).

Archaeological investigations of the region started fairly early and were renewed following the rescue excavations performed in connection with the reconstruction of the former Little-Balaton marshes. Archaeological survey and excavations between 1989-1991 provided rich material from an Early Neolithic settlement on the site Máriaasszony-sziget (M. Aradi 1992). The significance of the prehistoric finds urged further research (Kalicz et al 1998). Thus the excavations were continued in 1999-2000.

The excavations revealed that the territory was very popular for inhabitation from the Early Neolithic (cca. 5500 BC) until Early Mediaeval period; there were at least 8 distinct periods of habitation distinguished on the basis of traditional archaeological methods. Finds were identified from the Early Neolithic Starčevo culture, Early Copper Age Lengyel III culture, Middle Copper Age Balaton-Lasinja culture, Late Copper Age Kostolac culture, Early Bronze Age Kisapostag culture, Late Celtic, Early Roman period and Early Mediaeval Árpád-dynasty period.

The site Máriaasszony-sziget is a sandy peninsula extending 1400-1600 m long in northern direction on the eastern margin of Little-Balaton marshes, connected to the south-western corner of Lake Balaton. Its highest point is elevated some 3-5 meters above the surrounding marshes. On the basis of shallow boreholes drilled in the marshes, and the evidence of old maps it can be stated that the peninsula used to be surrounded by the open lake.

This study focuses on the petrographic, mineralogical and geochemical analysis of the finds of the Early Bronze Age Kisapostag culture.

Methods

24 ceramic samples, representing all macroscopic varieties, were selected for petrographic analysis. 16 of the examined sherds belong to the settlement material of the Kisapostag culture at Vörs-Máriaasszony-sziget (75/a; 75/b; 75/c; 75/01; 75/02; 75/03; 75/04, 75/05; 75/06; 00/1a/a; 00/1a/b; 00/1a/c; xx2a, xx2b; xx//b; 80/a). 8 control samples were also taken from Vörs-Tótok dombja (xx1/3/a; xx/1/3/b; xx/1/3/c; xx1/3/d; xx/c; xx/d, xx/e, xx/f), a nearby coeval settlement, from the excavation of Viktória Kiss (Kiss 2003; Kiss & Kulcsár in press). Most of the pottery samples selected for the analysis belong to coarse wares (jars or urns/amphorae), with brushing or vertical incised lines on the surface. Only 2 rim fragments have 'reeled stick' decoration (xx/c, xx/f), that is the special characteristic of the Kisapostag culture (Torma 1978, Fig. 11-12).

The samples selected for analysis were described macroscopically according to type/function and physical qualities, using the system suggested by Orton et al. (1994, 269).

Thin section analysis included the examination of fabric (grain-size distribution, description of the roundness, sphericity and orientation of the grains, the colour and isotropy of the groundmass) and the qualitative and quantitative analysis of the non-plastic inclusions. Samples and control samples were grouped according to their petrographic properties.

Potential raw materials were also investigated. One representative sand sample (V2-10) was chosen from the 24 sand samples collected from 3 shallow boreholes drilled at the archaeological site, Vörs-Máriaasszony-sziget, and two clay samples out of 5 from the clay mine at Battyánpuszta (B1-02, B1-04) were examined under the polarizing microscope. Sediments were formed into bricks and fired at 700°C for 4 hours in an electric oven. Thin sections were obtained from the fired bricks.

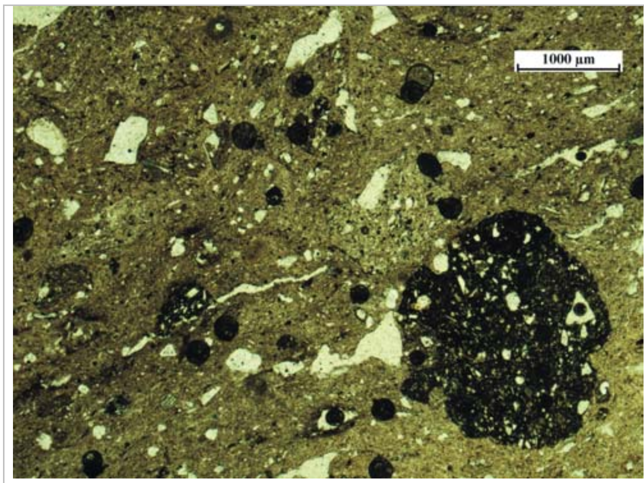
Soils samples (collected from closed archaeological units 62, 70, 71, 75 and 80) were dispersed in water and mounted on glass slides and examined under the polarizing microscope, in order to investigate grain size distribution.

Based on the results of petrographic analyses 20 ceramics (15 sherds from Vörs-Máraasszony-sziget, 5 sherds from Vörs-Tótok dombja) representing all petrographic varieties, together with 5 soil samples (from archaeological units 62, 70, 71, 75 and 80) and 5 sand samples from Vörs-Máriaasszony-sziget and 4 clay samples from Battyánpuszta were selected for geochemical analysis performed by XRF, in order to determine the following major and trace elements: Si, Ti, Al, Fe, Mn, Mg, Ca, Na, K, P, Rb, Sr, Ba, Zr, Nb, Y, V, Cr, Co, Ni, Zn. Considering the results of petrographic and XRF analysis, a smaller set of samples were chosen for INAA. 13 ceramics from Vörs-Máriaasszony-sziget, 5 sherds from Vörs-Tótok dombja, 2 soil samples (from archaeological units 70 and 71), 3 sand samples from Vörs-Máriaasszony-sziget and 4 clay samples from Battyánpuszta were investigated.

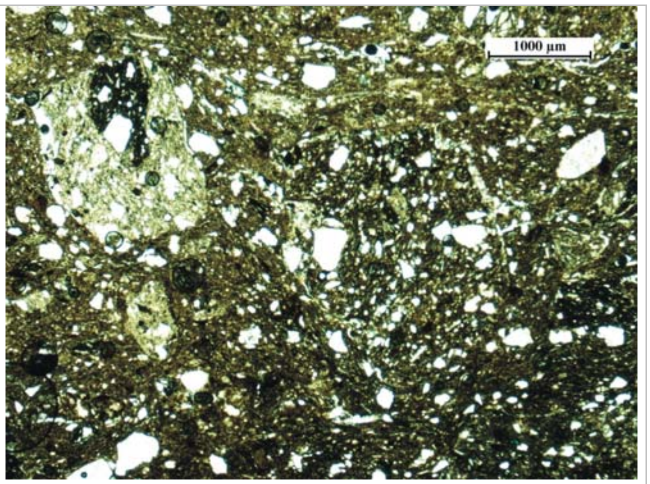
XRF analysis was carried out at the Department of Geochemistry of the University of Tübingen (Germany). The pressed powder pellets were analyzed using a Bruker AXS S4 Pioneer instrument with a rhodium X-ray source. Samples were prepared as fused disks, using a mixture of 7.5 g Merck A12 di-lithium tetraborate/lithium metaborate (66:34) flux and 1.5 g sample. Total Fe content is reported as Fe_2O_3. Loss on ignition (LOI) was determined after heating powdered samples at a temperature of 1000°C for an hour.

Instrumental neutron activation analysis was done at the training reactor of the Institute of Nuclear Techniques (Budapest University of Technology and Economics).

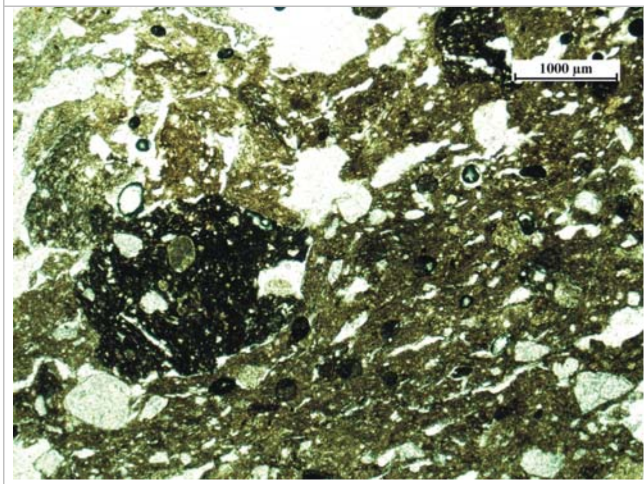
Figure 2. Polarization microscopic micrographs of pottery samples



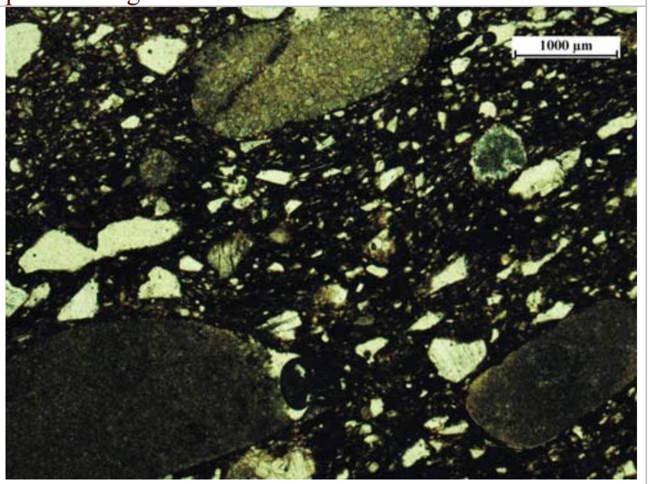
a) Grog fragment in pottery sample 75a (Group Ib). Plain polarized light.



b) Argillaceous fragment (probably grog) in a grog fragment in pottery sample xx2b (Group Ia). Plain polarized light.



c) Low sphericity, well rounded carbonate rock fragment in grog in pottery sample 75/04 (Group Ib). Plain polarized light.



d) Low sphericity, well rounded carbonate rock fragments in pottery sample 75/b. Plain polarized light.

It has a maximal power of 100 kW and the maximum thermal neutron flux is $2x10^{12}$ $ncm^{-2}s^{-1}$. The irradiation time was 8 hours. Gamma-spectroscopy measurements were performed after 7 days; a second count was conducted after a 30-day decay. The measuring system consists of an HPGe well-type detector (Canberra, FWHM: 1.95 keV, rel. efficiency: 20.5 %); an amplifier (Canberra Model 2020); and an analyzer (Canberra S100, 16k). The counting time is 5000-10000 seconds, respectively.

The chemical composition of the ceramics were compared to the geochemical composition of a natural fine grained argillaceous sediment, the Post Archaean Australian Shale (PAAS, generally used normalization data for mud and clay) (McLennan, 1989, 2001; Taylor & McLennan, 1995), to the investigated potential raw materials and to the earliest pottery Starčevo culture finds of the site. In this latter case geochemical comparison was made by using average element concentrations of Starčevo ceramics after excluding a possibly non-local sherd (Gherdán et al, 2005).

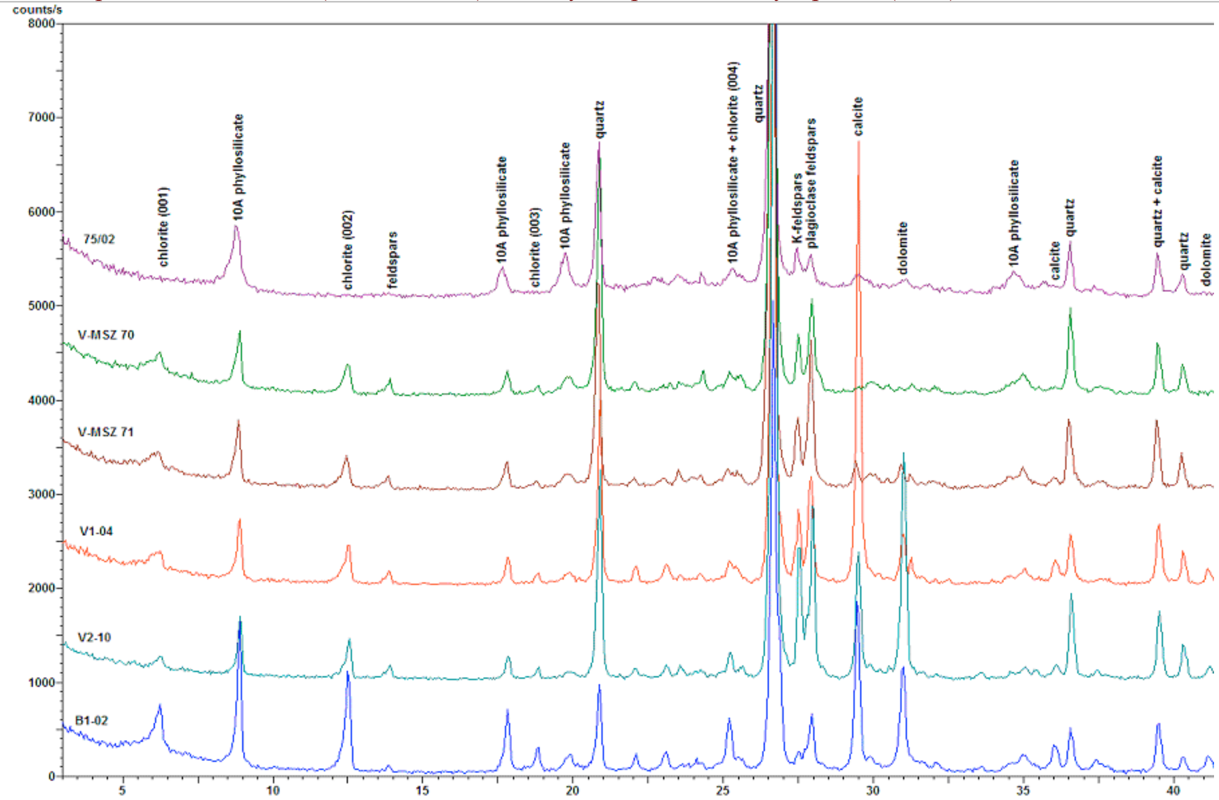
Mineralogical composition of 1 pottery sample (75/02), five soil samples from archaeological units 62, 70, 71, 75 and 80, 4 sand samples from Vörs-Máriaasszony-sziget and 4 clay samples from Battyánpuszta were determined by XRPD analysis.

Analyses were carried out at the Institute for Geochemical Research, Budapest on a Philips PW 1730 diffractometer with a Bragg-Brentano alignment. CuK (radiation, 45kV tension, 35 mA intensity, 0.05° - 0.01° 2Θ step size, time constant 1 sec, and graphite monochromator were used.

HU ISSN 1786-271X; urn:nbn:hu-4106 © by the author(s)

Figure 3. X-ray powder diffraction patterns of EBA pottery and soil samples

From top to bottom:EBA pottery (75/02), soil samples from Vörs-Máriaasszony-sziget (V-MSZ 70, V-MSZ 71), soil samples from core drills (V1-04, V2-10) and clay sample from Battyánpuszta (B1-0).



Results

Petrography

Ceramics

Concerning the petrologic properties the examined 24 sherds (16 samples from Vörs-Máriaasszony-sziget and 8 comparative samples from Vörs-Tótok dombja) could be divided into two groups, one of which was divided further into two subgroups. Detailed petrographic description is presented in the **Supplement.**

Group I

The majority of the samples, 22 sherds, belong to this group. All of these ceramics are grog tempered, and have bimodal grain size distribution. The main difference among them is in the amount of non-plastic inclusions. According to the fabric properties of the clay matrix this group could be divided into two subgroups.

Group Ia

16 samples belong to this group, 9 from Vörs-Máriaasszony-sziget (75/01; 75/03; 75/05; 75/06; 00/1a/a; 00/1a/b; 00/1a/c; xx2b; xx/b) and 7 comparative samples from Vörs-Tótok dombja (xx/1/3/b; xx/1/3/c; xx1/3/d; xx/c; xx/d; xx/e; xx/f).

These ceramics have hiatal fabric. The amount of non-plastic inclusions varies between 15 and 25 volume percent, the grain-size distribution is bimodal. The matrix is fine sand-containing clay, which is tempered with grog. The matrix contains dominantly fine sand sized, rarely medium sand sized low sphericity, angular monocrystalline quartz grains, feldspars (both potassium and plagioclase feldspars) and low sphericity, subrounded polycrystalline quartz, accompanied by traces of accessories and mica.

Low sphericity, well rounded, medium sand-sized carbonate fragments also occur. They are present in less than 1 volume percent. Grog fragments (**Fig. 2a**) dominantly contain monocrystalline quartz, and in some cases other argillaceous fragments (probably grog) (**Fig. 2b**). The amount of grog varies considerably. Most of the samples contain large (1000-4000 µm) grog fragments in relatively great amounts (making up to 80 volume percent of the non-plastic inclusions), but there are also sherds in which there are only a few, smaller (500-1000 µm) ceramic fragments. Grain-size distribution is bimodal and according to the amount of grog fragments it can be of two types (**see Supplement,** http://www.ace.hu/am/2007_2/AM-2007-02-GHK-supplement.pdf).

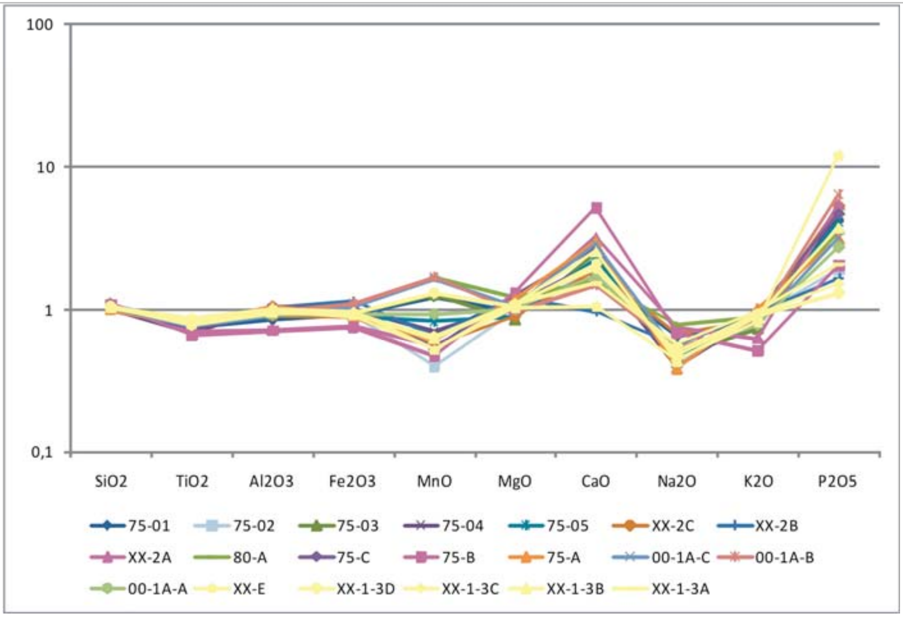


Figure 4a

Major element patterns of pottery samples. Concentration values are normalized to PAAS (Taylor & McLennan, 1995). Signs and lines of various colours represent pottery samples from Vörs-Máriaasszony-sziget, yellow signs and lines correspond to ceramics from Tótok dombja. The two sherds marked with purple signs and lines are the carbonate sand tempered ceramics from Máriaasszony-sziget.

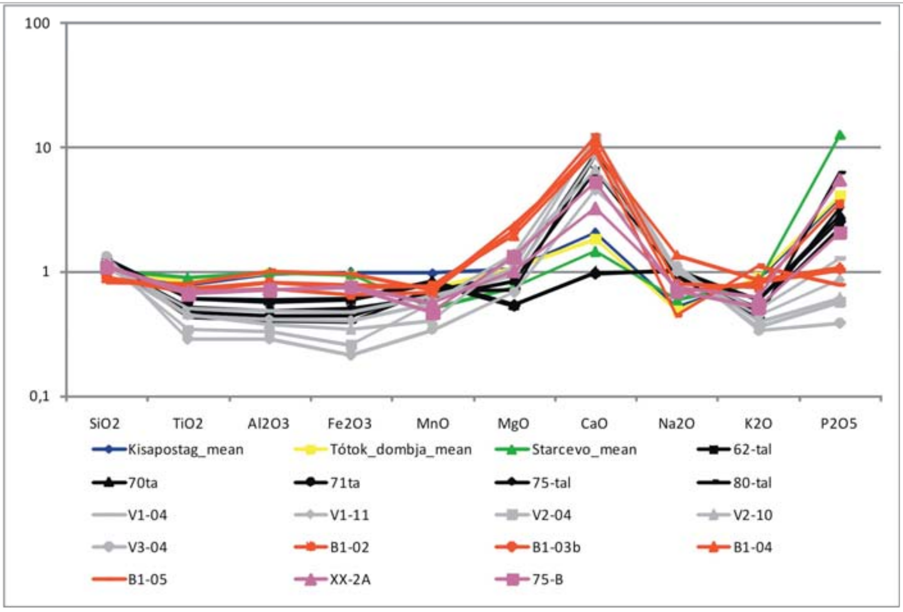


Figure 4b

Average values of major element concentrations of Kisapostag ceramics from Máriaasszony-sziget (blue line and signs), of ceramics from Tótok dombja (yellow line and signs), of Starčevo ceramics from Máriaasszony-sziget (green line and signs). Major element concentrations of soil samples (black lines and signs), sand samples (grey lines and signs) from Máriaasszony-sziget. Major element concentrations of clay samples from Battyánpuszta are marked in red. Composition of the two carbonate sand tempered sherds from Máriaasszony-sziget are shown by purple line and signs. Concentration values are normalized to PAAS (Taylor & McLennan, 1995).

Group Ib

6 samples, 5 from Vörs-Máriaasszony-sziget (75/a; 75/c; 80/a; 75/02; 75/04), and 1 (xx1/3/a) from Vörs-Tótok dombja form this subgroup.

Ceramics of this subgroup have hiatal fabric. The amount of non-plastic inclusions is generally less than 10 volume percent, except for sample 80/a (where it is 25 volume percent), that contains large grog fragments in greater amounts. The grain-size distribution is bimodal (supplement 1). The matrix is fine, often inhomogeneous clay which contains only small amounts of fine and medium sand sized mineral grains and is tempered with grog. Fine sand sized grains include low sphericity, angular monocrystalline quartz, feldspars (potassium and plagioclase feldspars), low sphericity, angular, subrounded polycrystalline quartz, and accessories. Medium sand sized, low sphericity, well rounded carbonate grains are also present in minor amounts. Their size in most cases is in the range of 200-650 µm, but there are some grains that are as big as 1500 µm. Grog fragments (250-3000 µm) contain monocrystalline quartz and in some cases low sphericity, subrounded carbonate grains (**Fig. 2c**). Their size, sphericity and roundness are similar to that of carbonate rock fragments in the pottery itself.

In this group of ceramics narrow, elongated pores parallel to the surface are very characteristic.

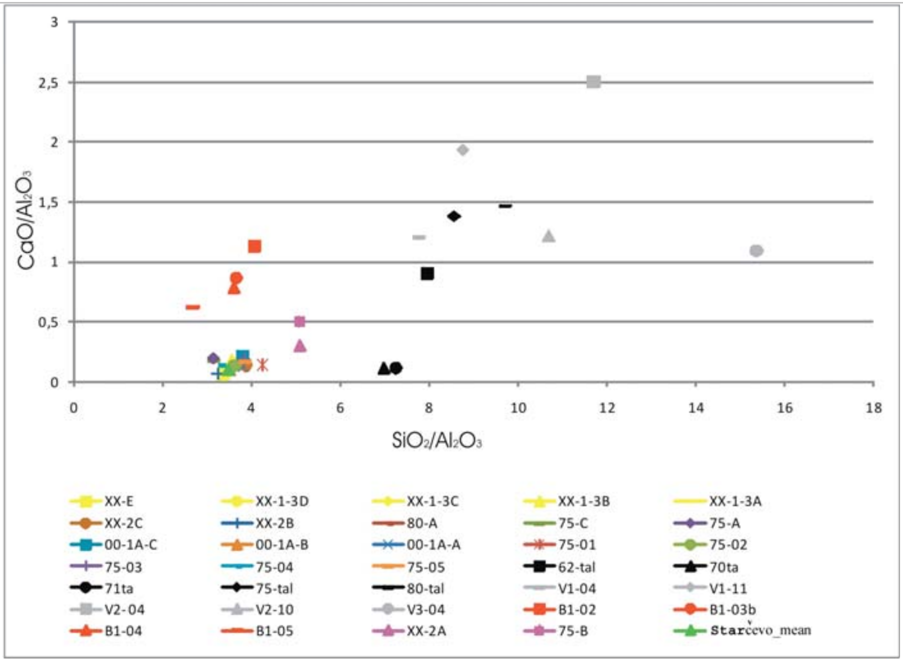


Figure 5

CaO/Al_2O_3 versus SiO_2/Al_2O_3 bivariant diagram. Signs of various colours represent pottery samples from Máriaasszony-sziget, ceramics from Tótok dombja are marked in yellow. Black signs stand for soil samples and grey signs for sand samples from Máriaasszony-sziget. Red signs show the composition of clay samples from Battyánpuszta. The two carbonate sand ceramics are marked in purple.

Group II

Only two samples (75/b; xx2a) from Vörs-Máriaasszony-sziget can be found in this group.

These ceramics have hiatal fabric, the non-plastic inclusions make up 20-30 volume percent. The grain-size distribution is bimodal in both samples, but not the same (supplement 1).

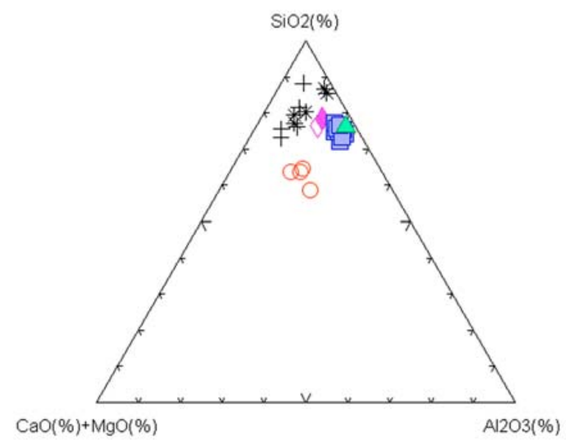


Figure 6. - Ternary diagram of compounds $CaO+MgO/Al_2O_3/SiO_2$.

Blue squares stand for pottery samples from Máriaasszony-sziget, yellow stars for pottery samples from Vörs-Tótok dombja; black stars for soil samples from Máriaasszony-sziget, black crosses for sand samples from Máriaasszony-sziget and empty red circles for clay samples from Battyánpuszta. Purple diamonds stand for the two carbonate sand tempered ceramics from Máriaasszony-sziget. Green triangle represent average concentration of Starčevo samples.

The composition of the two sherds are very similar, but the amounts of constituents differ.

In sample xx2a dominant grain size is 50-400 µm, these grains are dominantly mineral fragments, while in sherd 75/b dominant grain size is 400-2000 µm, these grains are monocrystalline and polycrystalline quartz grains and carbonate rock fragments. Fine and medium sand sized grains include low sphericity, angular monocrystalline quartz, feldspars, accessories accompanied by larger (500-600 µm) high sphericity, well rounded polycrystalline quartz and low sphericity, well rounded carbonate rock fragments (1500-2500 µm) (**Fig. 2d**). These ceramics do not contain grog.

Raw materials

V2-10

Yellowish grey fine sand from a shallow borehole at the site Máriaasszony-sziget from the depth of 2.1-2.4 m.

Grain supported sand. The matrix is composed of clay, containing 10 A phyllosilicates and chlorite (see the results of XRPD analysis below). Sorting is good, non-plastic grains are present in 50-60%. Dominant grain size is 100-250 µm. This fraction is composed mainly of low sphericity, angular, monocrystalline quartz grains, dominantly with normal extinction. Low or high sphericity, subrounded, subangular polycrystalline quartz grains are of various size, with a maximum of 650 µm. Other mineral fragments include potassium feldspar, plagioclase feldspar, muscovite, biotite, calcite and accessories (zircon, epidote as most common). The sediment also contains low sphericity, well rounded carbonate rock fragments, that are dominantly in the range of 200-400 µm, with a maximum diameter of 2000 µm.

B1-02

Grey clay from the clay mine in Battyánpuszta, from 4 metres under the surface.

Matrix supported clay. The matrix is composed of 10A phyllosilicates and chlorite (see the results of XRPD analysis below). Sorting is very good. Non-plastic grains are present in less than 5 %. Dominant grain-size is <50 µm. This fraction mainly consists of low sphericity, angular monocrystalline quartz grains with normal extinction. Other components are feldspars, muscovite, calcite and carbonate shell fragments.

B1-04

Yellowish grey clay from the clay mine in Battyánpuszta, from 2 metres under the surface.

Matrix supported clay. The matrix is made up of 10A phyllosilicates and chlorite (see the results of XRPD analysis below). Sorting is poor. Non-plastic grains, argillaceous rock fragments are present in 20%. Their size is between 250-4000 µm. The rock fragments are low sphericity, angular and contain monocrystalline quartz grains, that are <50 µm.

Other components of the sediments are low sphericity, angular monocrystalline quartz, <50 µm, feldspars, muscovite and calcite.

Soils

All soil samples (from units 62, 70, 71, 75 and 80) are dominated by low sphericity, angular, colourless, transparent grains of 50-300 µm. In addition sample 80 contains low sphericity, angular or subangular 500-1000 µm opaque grains.

X-ray powder diffraction analysis

Pottery sample 75/02 from petrographic Group Ib, five soil samples obtained from closed units of the site Vörs-Máriaasszony-sziget, together with 4 sand samples from Máriaasszony-sziget and four clay samples from the clay mine in Battyánpuszta were subjected to analysis. The composition of representative samples is presented on **Fig. 3**.

The examined pottery consists of quartz, 10 A phyllosilicates, potassium and plagioclase feldspars and hematite.

Most of the soil samples (62ta, 71ta, 75ta, 80ta) dominantly consist of quartz, 10 A phyllosilicates, chlorite, plagioclase and potassium feldspars, calcite and dolomite. Sample 70ta has similar composition concerning quartz, phyllosilicates and feldspars, but it proved to be carbonate free.

Sand samples (V1-04, V1-11, V2-04, V2-10 and V3-04) consist mainly of quartz, potassium and plagioclase feldspars, calcite and dolomite. In smaller amounts, compared to soil and clay samples, they contain 10 A phyllosilicates and chlorite.

Clay samples from Battyánpuszta have the same mineralogical composition to carbonate rich soil samples from Vörs. They consist of quartz, 10 A phyllosilicates, chlorite, plagioclase and potassium feldspars, calcite and dolomite. Carbonates are in greater amounts in the clay samples than in the soil and sand samples.

Geochemistry

20 pottery samples (15 from Máriaasszony-sziget and 5 comparative samples from Tótok dombja), 5 soil samples and 5 sand samples from Vörs and 4 clay samples from Battyánpuszta were examined by XRF.

Concerning the results of major element analysis and petrographic properties, selected pottery samples from Máriaasszony-sziget (13 samples) and Tótok dombja (5 samples) together with selected soil samples (2 samples) and sand samples (3 samples) from Máriaasszony-sziget, accompanied by clay samples (4 samples) from Battyánpuszta were subjected to INAA.

Concerning major elements pottery values are around PAAS concentrations (**Fig. 4a**), and keep together, however there is a bit greater variability in the amount of mobile elements, such as Na. Also there is greater variance in FeO and MnO contents, which might be the result of the geographical position of the site, that it is situated in a marshy area, where water level could change cyclically. Almost all sherds (except for two samples) are enriched in CaO, whereas CaO concentration of the two exceptions (xx2b from Máriaasszony-sziget and xxe from Tótok dombja) is similar to PAAS. The two petrographically different samples (75b and xx2a) which contain carbonate sand, are the most enriched in CaO, 75b having the highest concentration. Carbonate sand containing sherds are slightly more depleted in K_2O. All sherds are strongly enriched in P_2O_5.

Starčevo ceramics - considered to be local as a result of previous investigations (Gherdán et al) - shows that ceramics of Kisapostag culture have very similar geochemical composition to Starčevo ceramics concerning both major and trace elements (**Fig. 4b**).

Soil samples from Vörs - compared to PAAS - have stronger negative anomalies in TiO_2 and Al_2O_3, however - except for two samples (70ta, 71ta) - they are strongly enriched in CaO. These two samples have CaO concentrations similar to PAAS. P_2O_5 content is similar to that of pottery samples (**Fig. 4b**).

Sand samples from Vörs-Máriaasszony-sziget follow similar pattern to soil samples, however, according to their different grain-size and much smaller amount of phyllosilicates, they are more depleted in TiO_2, Al_2O_3 and, Fe_2O_3. These sediments do not have positive P_2O_5 anomalies (**Fig. 4b**).

HU ISSN 1786-271X; urn:nbn:hu-4106

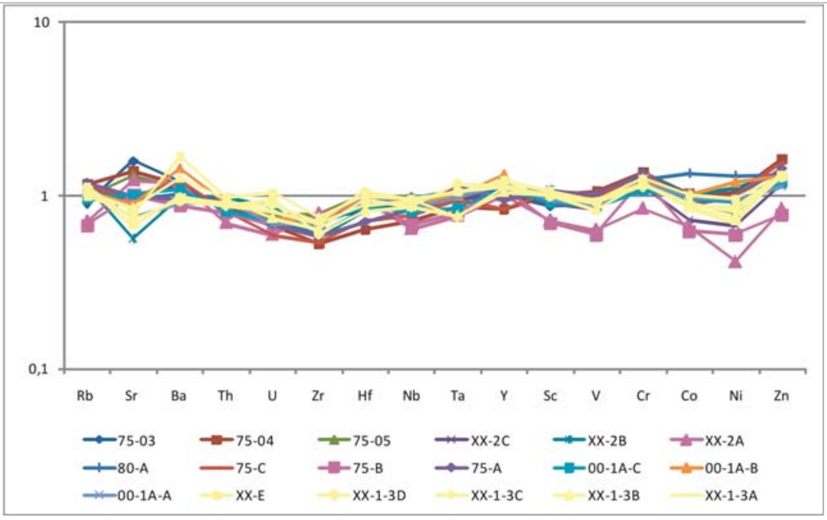


Figure 7a

Trace element patterns of pottery samples.

Concentration values are normalized to PAAS (Taylor & McLennan, 1995). Signs and lines of various colours represent pottery samples from Vörs-Máriaasszony-sziget, yellow signs and lines correspond to ceramics from Tótok dombja. The two sherds marked with purple signs and lines are the carbonate sand tempered ceramics from Máriaasszony-sziget.

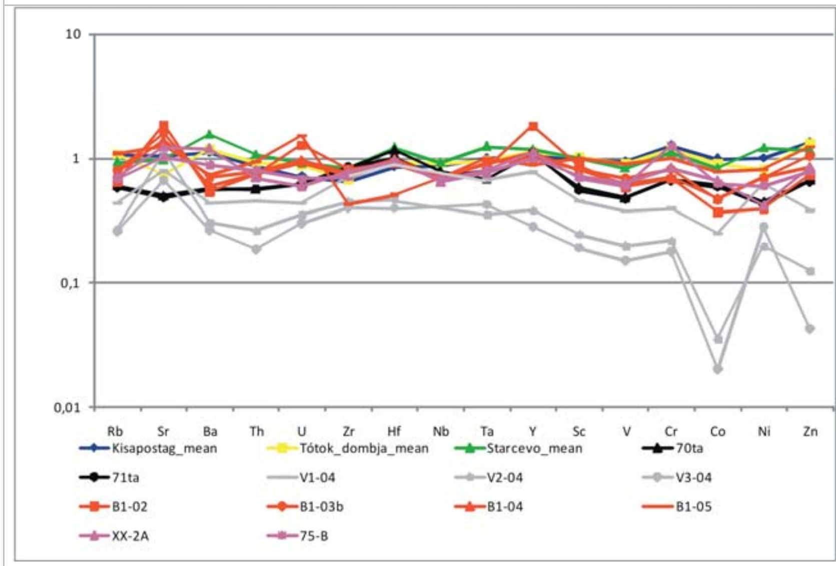


Figure 7b

Average values of trace element concentrations of Kisapostag ceramics from Máriaasszony-sziget (blue line and signs), of ceramics from Tótok dombja (yellow line and signs), of Starčevo ceramics from Máriaasszony-sziget (green line and signs). Trace element concentrations of soil samples (black lines and signs), sand samples (grey lines and signs) from Máriaasszony-sziget. Trace element concentrations of clay samples from Battyánpuszta are marked in red. Composition of the two carbonate sand tempered sherds from Máriaasszony-sziget are shown by purple line and signs. Concentration values are normalized to PAAS (Taylor & McLennan, 1995).

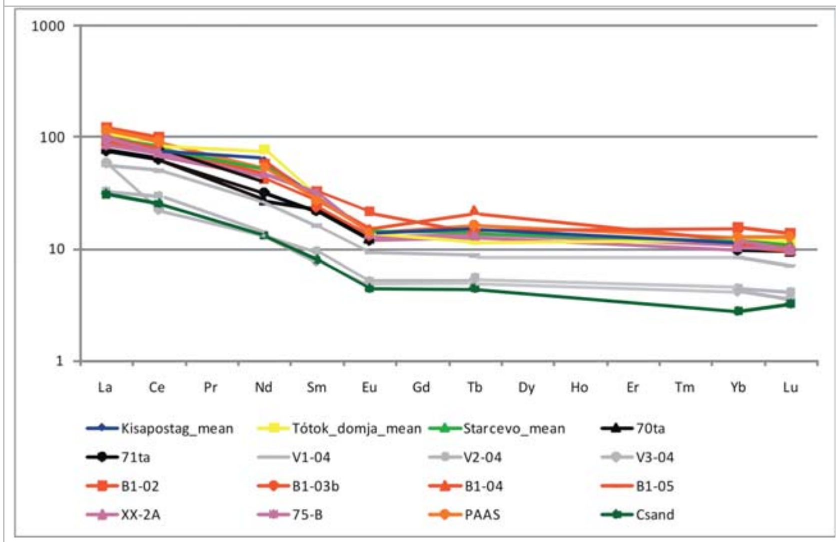


Figure 7c

Rare Earth Element patterns (normalized to Nakamura 1974) of pottery samples (various, soil and sand samples from Máriaasszony-sziget. Average concentrations of ceramics from Máriaasszony-sziget are marked in blue. Ceramics from Tótok dombja are shown by yellow lines and signs. Green lines and signs stand for average concentrations of Starčevo ceramics. Soil samples from Máriaasszony-sziget are marked in black, while sand samples from Máriaasszony-sziget in grey. Clays from Battyánpuszta are represented by red signs and lines. For comparison patterns of the PAAS and an average sandstone composition (Csand, average phanerozoic sandstone (Condie, 1993)) are shown.

Clay samples from Battyánpuszta have similar major element composition to ceramics, however they are enriched both in MgO and CaO (**Fig. 4b**). This phenomenon is better shown in the bivariant diagram CaO/Al_2O_3 versus SiO_2/Al_2O_3 (**Fig. 5**) and the ternary diagram on the main components of the samples. $(CaO+MgO)/Al_2O_3/SiO_2$ (**Fig. 6**). Pottery samples from the two sites fall closely together, while raw materials scatter away from them. Only the two carbonate sand tempered ceramics (75/b; xx2a from group II) have higher CaO content. Their composition falls between the fields of the raw materials and the majority of the potteries.

Concerning minor and trace elements pottery values also keep together. Differences can be observed in mobile element concentrations, such as Sr, Ba, U, and the petrographically different two sherds show differences in the concentration of Sc, V, Cr (only xx2a), Co and Zn. They are more depleted in these elements (**Fig. 7a**).

Comparison with raw materials show that soil samples from Máriaasszony-sziget with either low or high CaO content are much more depleted in Th, Sc, V, Cr, Co, Ni and Zn than the majority of the pottery samples. The two petrographically different sherds (75b, xx2a), however, follow a similar pattern concerning these elements (see above) (**Fig. 7b**).

Sand samples from Máriaasszony-sziget due to their different grain-size and the smaller amount of phyllosilicates present, are depleted in all minor and trace elements (**Fig. 7b**).

Minor and trace element composition of clay samples from Battyánpuszta are similar to pottery samples, however element concentrations vary in a wider range, with most of the samples being depleted in V, Cr, Co and Ni. B1-05 is different, as it has V, Cr, Co and Ni concentrations similar to the majority of the ceramics, but is strongly depleted in Zr and Hf compared either to ceramics or to other clay samples from Battyánpuszta (**Fig. 7b**).

Rare Earth Element patterns are similar for both potteries and raw material samples (soils and clay) and follow the pattern of PAAS, except for sand samples from Máriaasszony-sziget, whose REE patterns are similar to natural sands (**Fig. 7c**).

Discussion

Petrographic investigations showed that the Early Bronze Age ceramics from Vörs-Máriaasszony-sziget are of two kinds. The majority of the samples (14 out of 16 samples) are grog-tempered (which was a common phenomenon in Early Bronze Age (Kreiter in press b)), however carbonate sand containing sherds were also found (2 samples). The latter ones were most probably tempered with a carbonate sand. The fact that these ceramics do not contain grog fragments clearly reflects the use of two different pottery making recipes.

Coeval control samples from Vörs-Tótok dombja from a petrographic point of view, are closely related to the majority of the sherds from Máriaasszony-sziget: they were also tempered with grog.

The composition (especially the presence of low sphericity, well rounded carbonate rock fragments) and grain size of non-plastic inclusions in grog fragments (both in sherds from Máriaasszony-sziget and Tótok dombja) is similar to that of the matrix. The amount of grog varies considerably from 80 volume percent to only a few fragments. This phenomenon - as it has already been suggested by Kreiter (Kreiter in press a) - might lead to the conclusion that potters did not always use grog because of technological or functional purposes but also because of tradition.

Comparison of the petrographical and mineralogical characteristics of the ceramics and the potential raw materials revealed that sandy sediments found at the site of Máriaasszony-sziget have similar mineralogical composition, grain size, grain sphericity and roundness to the sand size non-plastic constituents of the majority of the sherds found at the site and at Tótok dombja.

Geochemical composition of all the ceramics (both local and control samples) are also very similar, except for the two carbonate sand tempered sherds which differ both in their major and minor element content. The majority of Kisapostag ceramics both from Máriaasszony-sziget and Tótok dombja have very similar major and minor element concentrations to Starčevo ceramics of the site.

The results of comparison with potential raw materials from the site and a nearby clay mine are not so straightforward. Investigations have not lead to a clear answer to the question of where ancient potters of Máriaasszony-sziget collected their clayey raw materials.

As seen above, mineralogical composition of the raw materials and the ceramics is very similar, however there are differences in both major and trace element content. Concerning major elements the most striking is the difference in CaO, MgO, SiO2 and Al2O3 content.

However, the results of the petrographic analysis of sandy sediments of the site and clays from Battyánpuszta suggest that the raw material source of the majority of the ceramics was most probably in the closest vicinity of the site.

The petrographical and geochemical composition of the two carbonate sand tempered sherds might reflect either the use of a different raw material source or the treatment of the extensively used natural sediment.

HU ISSN 1786-271X; urn:nbn:hu-4106 © by the author(s)

Acknowledgements

The interdisciplinary elaboration of Vörs finds is realised in the framework of OTKA project T-046297.

The authors are grateful for Dr. Heinrich Taubald for X-ray Fluorescence Analysis of the samples and Dr. Márta Balla for Instrumental Neutron Activation Analysis.

Raw material analysis was conducted in the framework of the 2005-2006 MÖB-DAAD project with the title of Archaeometrical analysis of Neolithic pottery and comparison to potential sources of raw materials in their immediate environment.

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