# BETTER LATE (ROMAN) THAN NEVER! A POSSIBLE AMPHORA FRAGMENT FROM 6TH CENTURY BALATONLELLE, WESTERN HUNGARY

## EGY LEHETSÉGES AMPHORA TÖREDÉK A 6. SZÁZADI BALATONLELLÉRŐL •

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## Abstract

*This study reports on a unique finding connected to the re-examination of the ceramic assemblage recovered from the Langobard age (6th century AD) settlement of Balatonlelle, situated in the territory of the former Roman province of Pannonia (now in western Hungary). An undecorated body sherd, not picked up by either the initial typological evaluation of the ceramics or by the preliminary petrographic analysis, was now reassessed by thin section ceramic petrography and scanning electron microscopy. The new analyses revealed that this sherd contains rock and mineral inclusions originated from ophiolites, including slightly serpentinised peridotite fragments. Such rocks do not occur on the surface in Hungary, whereas they are commonly found in the Eastern Mediterranean. The presence of ophiolites in the potsherd indicates that this vessel was produced in a distant territory. The macroscopic characteristics of the sherd combined with its petrographic fingerprint suggest that this pot might have been a transport amphora produced in the Eastern Mediterranean. Although rarely found in Pannonia in the Migration Period, several amphora types, including the most frequently found LRA 1 type, were produced in numerous production centres in the Eastern Mediterranean, in territories geologically congruous with the aplastic inclusions found in the fabric of the Balatonlelle sherd.*

*The significance of this finding is that from Langobard age Pannonia, amphorae occur only sporadically, connected mainly to former Roman settlements. While any conclusions drawn from a single sherd must necessarily remain tentative, this sherd nonetheless provides some material evidence for the existence of some sort of contact between Balatonlelle and the Eastern Mediterranean during the 6th century, be it economic, political or cultural.*

*This study also aims to celebrate the career of György Szakmány, who was one of the key figures to establish ceramic petrographic research and education in Hungary, and trained many generations of petrographers – including the present authors. As such, it also serves as an example how ceramic petrography can bring a new dimension of information to archaeological research.*

## Kivonat

*Ez a tanulmány egy olyan különleges leletről számol be, amelyre az egykori Pannonia provincia területén fekvő Balatonlelle langobard kori (Kr. u. 6. század) településén előkerült kerámiaanyag újabb vizsgálata közben derült fény. Egy díszítetlen oldaltöredék, amely sem a kerámiaanyag formai-tipológiai kiértékelése során, sem az előzetes petrográfiai elemzés alatt nem hívta fel magára a figyelmet, most újra kiértékelésre került vékonycsiszolatos kerámia petrográfiával és pásztázó elektronmikroszkópiával. Az új vizsgálatok kimutatták, hogy ez az edénytöredék ofiolit sorozatból származó kőzet- és ásványtörmelékeket tartalmaz, köztük kevéssé szerpentinesedett peridotit töredékekkel. Ilyen kőzetek Magyarország területén nem találhatóak meg a felszínen, míg a Földközi-tenger keleti partvidékén gyakran előfordulnak. Az ofiolitok jelenléte a töredékben arra utal, hogy az edényt a lelőhelyétől távoli területen készítették. A petrográfiai jellemzők és a makroszkopikus jegyek alapján lehetséges, hogy ez az edény egy Kelet-Mediterráneumban gyártott amphora volt. Bár Pannoniában a*

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*népvándorláskorban ritkán fordul elő, a korszakban több amphora típust, köztük a leggyakrabban előkerülő LRA 1 típust is a Földközi-tenger keleti részén, több fazekasközpontban is gyártottak, olyan területeken, amelyek geológiailag is összeegyeztethetők a balatonlellei töredék anyagával.*

*Az eredmény jelentősége, hogy a langobard kori Pannoniából csak szórványosan ismerünk amphorákat, amelyek főként egykori római településeken kerültek elő. Bár az egyetlen edénytöredékből levonható következtetések szükségszerűen korlátozottak, ez a töredék mégis tárgyi bizonyítékot szolgáltat arra, hogy a 6. században Balatonlelle és a Kelet-Mediterráneum között valamiféle kapcsolat állt fenn, legyen az gazdasági, politikai vagy kulturális.*

*Ezzel a tanulmánnyal Szakmány György pályafutását is szeretnénk megünnepelni, aki egyike volt azoknak, akik megalapozták a magyarországi kerámia petrográfiai oktatást és kutatást, és aki petrográfiában jártas kutatók több nemzedékét nevelte ki – köztük e tanulmány szerzőit is. Mint ilyen, arra is példaként szolgál, hogy hogyan nyithat a kerámia petrográfia új dimenziókat a régészeti kutatásban.*

KEYWORDS: AMPHORA, LANGOBARD KOR, KERÁMIA PETROGRÁFIA, SEM-EDS

KULCSSZAVAK: AMPHORA, LANGOBARD AGE, CERAMIC PETROGRAPHY, SEM-EDS

## *Introduction*

This study re-examines a ceramic sherd from Balatonlelle, Felső-Gamász, a 6th century AD settlement in the former Roman province of Pannonia (now in western Hungary, **Fig. 1.**), and considers how even an isolated sherd can nonetheless provide a glimpse into past economic and cultural life of the site. For many decades, archaeological research of Langobard age Pannonia was faced with the problem that, whereas several cemeteries were known from this period (e.g. Bóna & B. Horváth 2009), settlements have not been found connected to the Langobard era. Excavated between 2002–2003, Balatonlelle was in fact one of the first settlements found to be dated to the second third of the 6th century AD. This excavation provided a new view on the every-day life of this period, especially through the analysis of pottery wares.

During the rescue excavations connected to the construction of the M7 motorway, three semi-subterranean buildings were unearthed as part of the remains of a settlement (Skriba 2006; Skriba & Sófalvi 2004; Sófalvi et al. 2007). Based on the large number of loom weights recovered, the buildings were interpreted as having been used for both domestic purposes as well as serving as weaving workshops (Skriba & Sófalvi 2004). The majority of the materials found in the buildings, apart from the loom weights, were potsherds. In this assemblage we can find vessel types well-known from Langobard age cemeteries, such as grey pattern-burnished wares, pear-shaped stamped wares, and closed hole-mouth jars (*Kumpf*, also known as *swebische Topf*). In addition to these types, a significant amount of sherds showing strong Late Antique traditions were recovered. These vessels are predominantly coarse-grained cooking pots, typically with an everted rim and globular body (Skriba & Sófalvi 2004). Although Late Antique elements can be detected in the known cemeteries as well (e.g. Szólád (Bajnok et al. 2022), Kajdacs (Bóna & B. Horváth 2009)), their relative abundance in these first excavated settlements was substantially higher.

The first, preliminary petrographic results about the pottery of Balatonlelle were published a decade ago, examining 38 sherds from this site, in addition to other 5th–6th century ceramics from settlements and cemeteries (Pánczél-Bajnok et al. 2014). The analysis showed rich technological traditions with regard to the diversity of raw material selection and clay preparation processes. The tradition of adding crushed marble as a temper to Late Antique style cooking pots was described for the first time in Pannonia based on the Balatonlelle material. As part of a wider project studying 4th–6th century pottery production in Pannonia, the Balatonlelle samples recently underwent a more detailed re-examination. During this reassessment, one body sherd (Inv. nr. 13.4/346.2) was discovered to be more interesting than had been thought before. Based on its macroscopic characteristics and mineralogical composition, it is suggested now that this sherd belonged to an imported transport vessel, possibly an amphora. In this study we present the arguments that point towards this interpretation, and additionally, we attempt to narrow down the region where it was manufactured. We contrast this information with the amphora types that were known to be in circulation in the 6th century. Amphorae are seldom found in Migration Period Pannonia; their quantities drop significantly from the end of the 2nd century AD (*c.f.* Magyar-Hárshegyi 2016), even in those former Roman settlements still inhabited at later times. Their sporadic occurrences from after the decline of the Roman province are therefore an important aspect of current understandings of the post-Roman period in Pannonia.

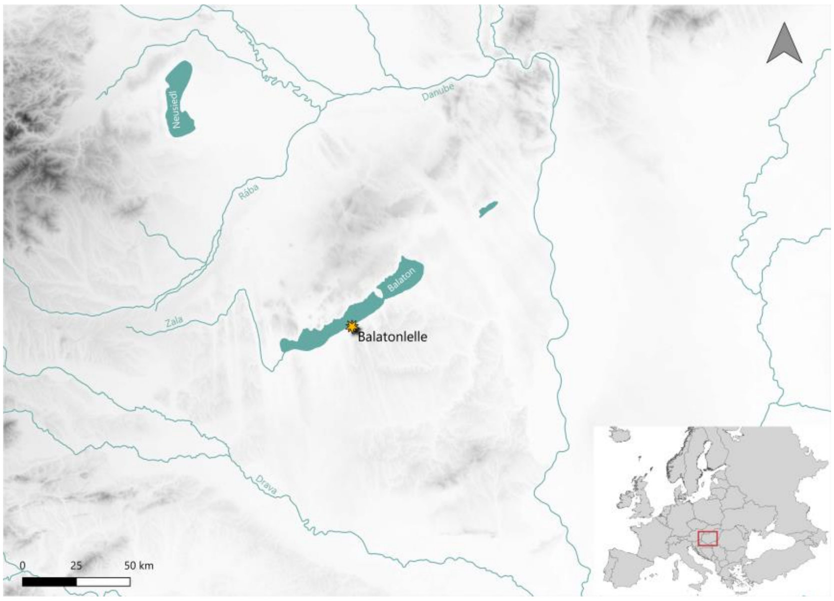


**Fig. 1:** Map showing the location of Balatonlelle

**1. ábra:** Balatonlelle földrajzi elhelyezkedése

## Archaeological context and dating

The first question to clarify is the context in which the examined sherd was found. The fragment was recovered from the filling 10–15 cm above the floor level of House 2 (Skriba & Sófalvi 2004, 127–128, figs. 6–7). The remains recovered from this layer (mainly potsherds and loom weights) appeared chronologically homogenous, showing no sign of mixing with materials from either earlier or later archaeological periods. Upon the examination of the whole excavated area including the material from all three buildings, analysis concluded that they can be dated to the middle third of the 6$^{th}$ century AD (Skriba & Sófalvi 2004, 157–158). The floor layer showed no sign of disturbance by later occupations. The preceding occupation layer below the floor of the house, belonging to an entirely separate archaeological feature, was from the Copper Age; Roman age features were not observed on the site. Based on the archaeological context, we have no reason to question that our examined potsherd was buried together with the rest of the material found at the site. This means that at least the end of its use can be dated to the second third of the 6$^{th}$ century.

## Methodology

For the characterisation of our sherd in question, a conventional archaeological science approach was applied. The first step was the macroscopic examination, which included the description of the dimensions, features of the surface, fresh break and cut surface of the cross-section. For this purpose, we used a Zeiss SteREO Discovery.V8 stereo microscope with a Zeiss AxioCam MRc5 digital camera and the Zeiss AxioVision 4.9.1 camera software tool at the Institute of Archaeological Sciences, Eötvös Loránd University, Budapest. During petrographic analysis, the fundamental characteristics of the fabric of the sherd were examined, including the type, shape, size, abundance, sorting, and distribution of the aplastic components and voids. This provides information about the geological environment from where the raw material used for the production originated, and additionally, certain technological choices made during the manufacture of the pot can be revealed (e.g. clay preparation and processing, firing). In the description, we followed the guidelines and terminology of the systematic description proposed by Whitbread (1995, Appendix 3). The polished petrographic thin section prepared from the potsherd was analysed with a Nikon Eclipse LV100N polarised light optical microscope (OM) using a Nikon DS-Fi3 microscope camera and the NIS Elements BR software at the Neutron Spectroscopy Department of the HUN-REN Centre for Energy Research. During the analysis, the magnification was set between ×20 and ×500.

Finally, the thin section was further analysed by scanning electron microscopy coupled with energy dispersive spectrometry (SEM-EDS) in order to measure the elemental compositions of selected aplastic components locally, as well as areas of the matrix. The SEM-EDS analysis was carried out at the Nanosensors Laboratory of the HUN-REN Centre for Energy Research using a Zeiss LEO 1540 XB electron microscope equipped with an Oxford Instrument Ultim Max 40 energy dispersive spectrometer. Carbon coating was applied to the surface of the thin section. The analysis was performed under$10^{-4}$ Pa vacuum. The measurement conditions were as follows: 21 kV accelerating voltage, 7 nA beam current, and 60 s measurement time of each analysis. The results are normalised and expressed in oxide weight%. One or two points per inclusion were measured, whereas for matrix measurements, areas that appeared homogenous in the backscattered electron images were set manually to ca. 5–10 µm$^2$.

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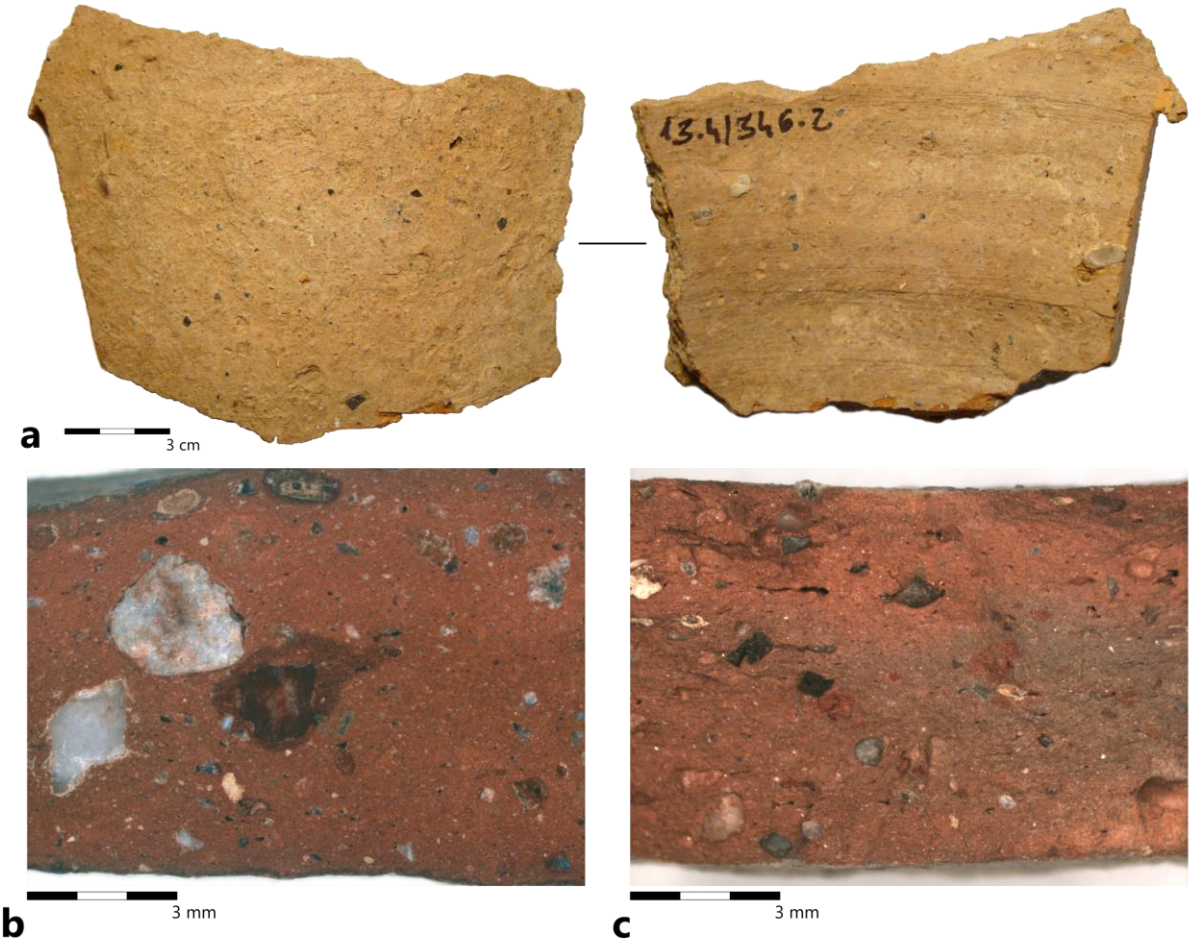


**Fig. 2:** The examined sherd from Balatonlelle, Felső-Gamász. (a) Photographs of the external and internal surfaces of the hand specimen (photo credit: Péter Skriba); (b) cut surface of the cross-section (stereo microscopic image); (c) fresh break surface of the cross-section (stereo microscopic image)

**2. ábra:** A vizsgált töredék Balatonlelle, Felső-Gamász lelőhelyről. (a) a töredék külső és belső felszínéről készült fénykép (fénykép: Skriba Péter); (b) vágott felszínű keresztmetszeti kép (sztereomikroszkópos felvétel); (c) a keresztmetszet friss törésfelületi képe (sztereomikroszkópos felvétel)

## *Results*

### Macroscopic description

The sherd is approximately 14.2 cm high by 11 cm wide, and 6–9 mm thick, and belonged to the body of the vessel. The external and internal surface is covered with a thin (ca. 50 µm), light yellowish brown (10YR 7/4) layer, possibly a slip (**Fig. 2.a**). The external surface is lightly smoothed. The external and the internal surfaces both often exhibit inclusions similar to those also seen in the cross-section of the sherd (described below). On the internal surface, rilling marks are visible, indicative of wheel-use during the manufacture, however, the macroscopic inspection is not sufficient to further distinguish whether the pot was wheel-thrown, or initially made with a hand-building technique and then shaped on a wheel. The hard feel of the sherd suggests a high firing temperature.

Below the thin slip layer, the colour of the cross-section is almost completely homogeneous light red (2.5YR 6/6), with a barely discernible, diffuse light greyish band in the middle (**Fig. 2b-c**). In cross-section, it can be observed that the fabric contains few to common, very poorly sorted inclusions of various colours. Their size varies from a few tens of micrometres to 3 mm (medium to very coarse-grained sand), the dominant size being ca. 1 mm, and their shape is typically well-rounded to rounded. The inclusions display white, greyish white, dark grey, black, reddish orange and reddish brown colours. Few voids can be observed, mainly channels and vughs, the latter possibly relics after inclusions.

The size of the sherd together with the relatively mild curvature indicates that the vessel to which it belonged to was comparatively large. Moreover, it does not exhibit any signs of being used as a cooking pot (carbonised food remains, soot or locally burnt areas). The coarseness of the fabric and the lack of decoration also make it improbable of it being a fine table ware. Based on this information, the vessel can most probably be defined as a large storage vessel.

### Petrographic fabric description by polarised light optical microscopy

The sample displays a homogenous, completely optically inactive groundmass, medium brown in colour in plain polarised light (PPL) (**Fig. 3.c**), and dark reddish-orange colour with crossed polars (XP) (**Fig. 2.d-h**). Few voids can be observed, which are, as discussed in the macroscopic description, mainly meso- and macrochannels and vughs. The inclusions are single to double spaced, the fine and coarse fractions together form approximately 40% of the field of view. It displays a strong bimodal grain-size frequency distribution, the ratio of the coarse and fine fraction, and the voids (c:f:v) is ca. 30:65:5.

The fine fraction is very well sorted with coarse silt-sized inclusions (20–60 μm), which predominantly consist of lamellae of muscovite and dominant angular to sub-angular monocrystalline quartz, while K-feldspar (sometimes perthitic), polycrystalline quartz, plagioclase (often sericitic) and biotite is also common. Rarely chlorite, pyroxene, amphibole, zoisite, epidote, tourmaline, opaque mineral phases, and garnet can be observed as well.

The coarse fraction consists of very poorly sorted, fine to very coarse sand sized inclusions (60–2000 μm). The shape of the inclusions is somewhat variable; while the grains are dominantly well rounded to rounded, sub-angular ones are also common. In this fraction, rock and mineral fragments of several origins can be found. The most dominant inclusions are cherts; their size is typically between 200–500 μm, and their shape is rounded to sub-angular. Most grains are microcrystalline, appearing transparent in PPL and dark to light grey in XP. In many cases, remains of radiolarians can be seen within the inclusions (**Fig. 3.e-f**). Another type of inclusions has light brown colour in PPL, while they are almost isotropic in XP (**Fig. 3.a-b**). Based on their chemical composition measured by SEM-EDS (90–100% $SiO_2$), these are amorphous silica grains most probably originating from crypto- to microcrystalline chert inclusions, which vitrified due to the high firing temperature. Common serpentinite inclusions, or peridotites altering into serpentinite are identified (**Fig. 3.a-e, g**). They vary in size between 100–500 μm and are well-rounded. The serpentinised areas in these inclusions display bright orange colour in PPL and bright orange to dark red in XP. The degree of serpentinisation is varied, in some cases the original, unaltered mineral phases such as pyroxenes, olivines and spinels are well discernible (e.g. **Fig. 3.g** and **4.a-b**), while in other cases the alteration into serpentinite is nearly complete (e.g. **Fig. 3.d**). Monocrystalline quartz (with both straight and undulating extinction), polycrystalline quartz and plagioclase (not zoned) are common, they are sub-angular to sub-rounded. Few, but varied metamorphic rock fragments occur in the sample, among them quartzite, gneiss (sometimes chlorite-bearing) muscovite-schist and meta-siltstone are identified. Their size varies between 200 μm and 1 mm. Rare sub-angular granitoid fragments were also identified, containing sub-angular perthitic K- feldspars within (**Fig. 3.h**). A large, ca. 2 mm long, very well rounded, poly-mictic sandstone fragment was observed (**Fig. 3.a-b**), consisting predominantly of sub-angular to rounded quartz, and rarely chert and chlorite-schist fragments.

Few clay pellets and argillaceous rock fragments (ARF)/grog inclusions also occur in the sample. Clay pellets appear very well-rounded, their colour does not differ significantly from the surrounding clay, and whereas the composition and size of the fine-grained mineral clasts within them is similar to the fine fraction in other parts of the sample, their frequency is lower (**Fig. 3.a-b**). These inclusions are most probably the result of incomplete homogenisation of the clay. The ARF/grog inclusions present in the sample display more complex shapes, furthermore, their clay fraction displays significantly different colours compared to the rest of the sample: they are very light brown in PPL, and black (isotropic) in XP (**Fig. 3.g**). Nevertheless, the suite, size and sorting of inclusions within them matches very closely to the surrounding matrix. The analysis was not conclusive whether these inclusions are present in the sample naturally, or they might be deliberately added crushed ceramic fragments (grog).

### SEM-EDS

The aim of the SEM-EDS analysis was to gain more information about the composition of the aplastic inclusions identified in the sample by polarising microscopy, as this may help us better understand the geological environment from where the raw materials originated, and ultimately, where most probably the vessel was made. The elemental compositions of the different phases in the ultramafic rock fragments, pyroxenes, amphiboles, garnets and plagioclases and a series of accessory minerals were measured. Additionally, matrix measurements were also carried out, where ca. 5–10 $\mu m^2$ areas of clay within the groundmass and in the ARF/grog inclusions were measured. The measured compositions are available in the **Appendix**.

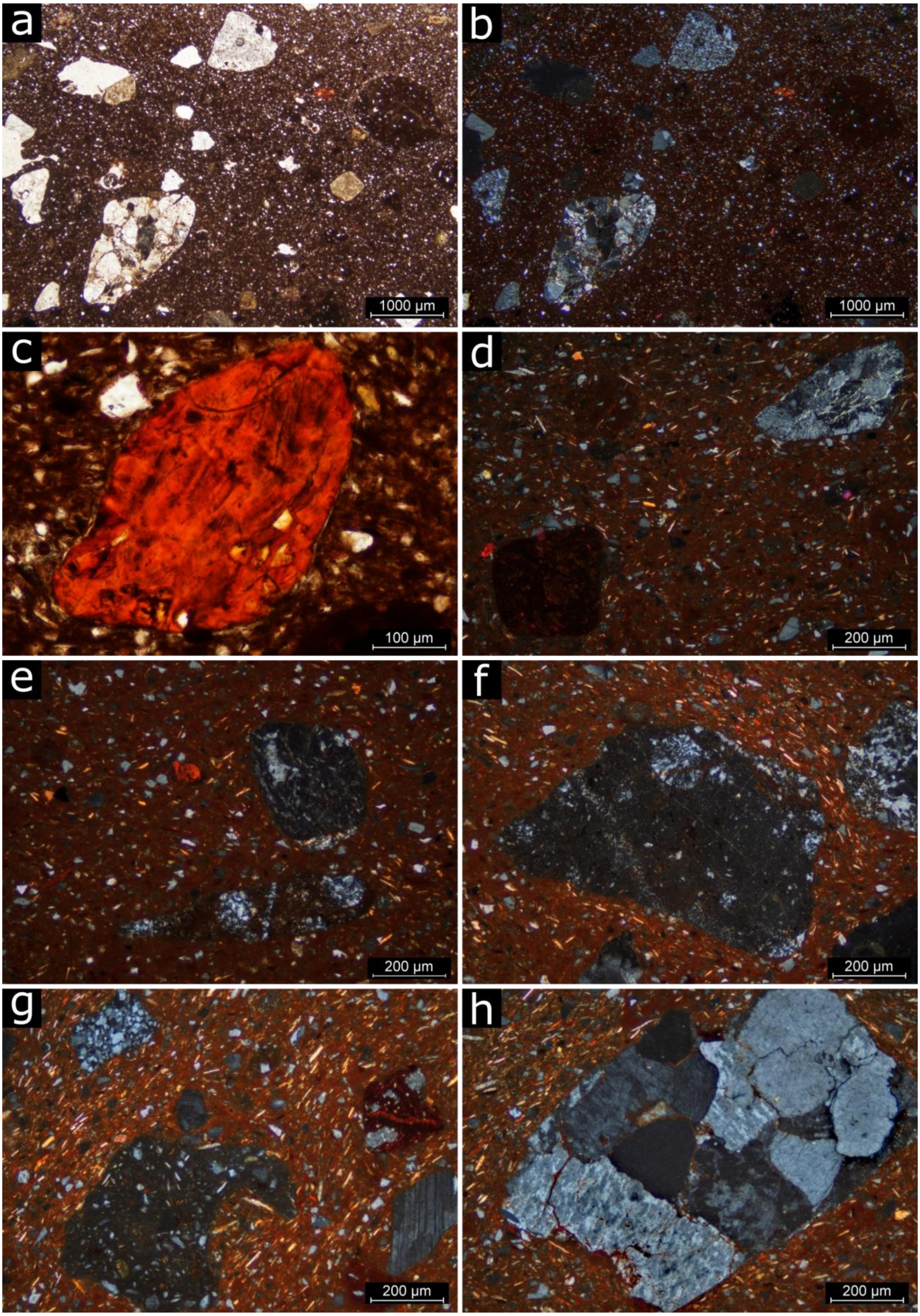


**Fig. 3.:** See captions on next page

**3. ábra:** A képek feliratai a következő oldalon

**Fig. 3. (see previous page):** Photomicrographs of the Balatonlelle sample at various magnifications. Note the optically inactive matrix and the muscovite-rich raw material. (a–b) PPL and XP, respectively, magnification: ×20. The largest inclusion is a very well-rounded sandstone fragment, composed of quartz, chert and a chlorite-schist fragment. Additionally, many vitrified amorphous (often light brown in PPL, near-isotropic in XP) and microcrystalline chert fragments (left and top centre), a serpentinite fragment (orange) and a clay pellet (top right) can be seen; (c) serpentinising peridotite with small clinopyroxene (diopside) inclusions within (XP, ×200); (d) a serpentinite (bottom left) and a muscovite-schist (top right) fragment (XP, ×100); (e) two large radiolarian chert fragments and a small serpentinite (orange) (XP, ×100); (f) a large radiolarian chert fragment (XP, ×100); (g) a large ARF/grog (bottom left); the composition, size and sorting of inclusions within agrees well with the surrounding matrix. Other inclusions in the field of view are plagioclase (albite; bottom right), serpentinising peridotite with ortho- and clinopyroxene inclusions (centre right) and polycrystalline quartz (top left) (XP, ×100); (h) large granitoid fragment composed of quartz and perthitic feldspar (XP, ×100)

**3. ábra (előző oldalon):** Különböző nagyítással készült polarizációs mikroszkópos felvételek a balatonlellei mintáról. A felvételeken jól megfigyelhető az optikailag inaktív mátrix, illetve a muszkovit csillámban gazdag alapanyag. (a–b) 1 N, ill. + N; nagyítás: ×20. A legnagyobb szemcse egy nagyon jól kerekített homokkő törmelék, amely túlnyomóan kvarcból, illetve kisebb részt kovából és egy kloritpala szemcséből áll. Ezen kívül sok különálló üvegesedett amorf (1 N-lal gyakran világosbarna, + N-lal pedig közel izotróp) és mikrokristályos szövetű kovaszemcse, valamint egy szerpentinit és egy agyag pellet látható (jobb felül); (c) szerpentinesedő peridotit, benne kisméretű klinopiroxén (diopszid) szemcsék (1 N, ×200); (d) szerpentinit (bal alul) és muszkovitpala (jobb felül) (+ N, ×100); (e) két radioláriás tűzkő, illetve egy szerpentinit szemcse (+ N, ×100); (f) nagyméretű radioláriás tűzkő szemcse (+ N, ×100); (g) nagyméretű ARF/grog (bal alul). A benne levő törmelékes elegyrészek összetétele, mérete és osztályozottsága nagyon jól megegyezik a körülötte levő agyagos alapanyag törmelékes elegyrészeivel. Jobb alul egy plagioklász (albit) törmelék, egy szerpentinesedő peridotit orto- és klinopiroxén szemcsékkel (jobb középen), illetve egy polikristályos kvarc (bal felül) szemcse látható (+ N, ×100); (h) nagyméretű, kvarcból és pertites földpátból álló granitoid szemcse (+ N; nagyítás: ×100)

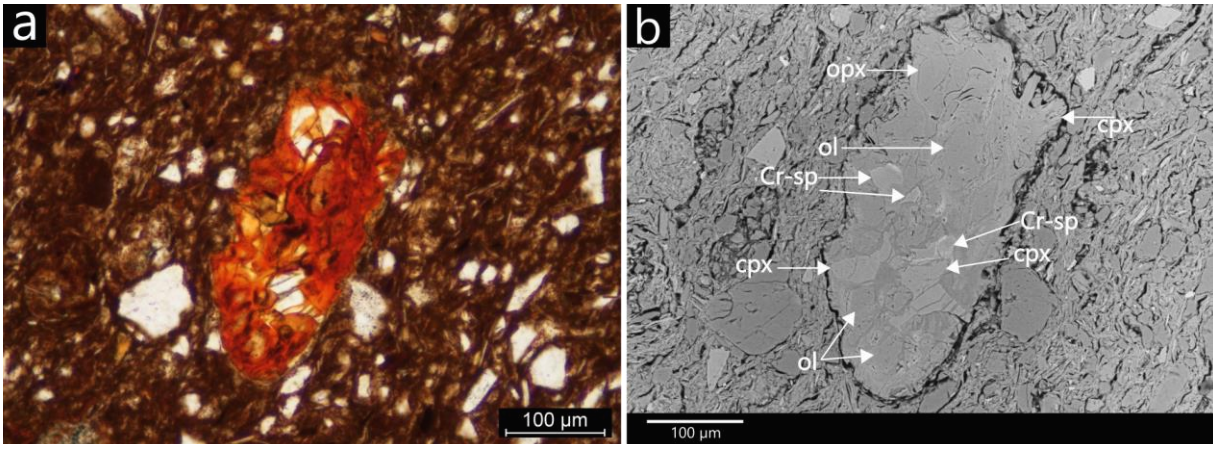


**Fig. 4:** Peridotite inclusion altering into serpentinite. Remains of orthopyroxene (enstatite), clinopyroxene (diopside), olivine and Cr-spinel phases are visible. (a) photomicrograph by polarising microscope (PPL); (b) SEM backscattered electron image. Note that the serpentine minerals (darkest grey shade) only occur in a small amount between the original peridotitic minerals. Abbreviations: cpx = clinopyroxene; Cr-sp = Cr-spinel; ol = olivine; opx = orthopyroxene

**4. ábra:** Szerpentinesedő peridotit szemcse, amelyben jól láthatók az ortopiroxén (ensztatit), klinopiroxén (diopszid), olivin és króm-spinell fázisok. (a) polarizációs mikroszkópos felvétel (1 N); (b) SEM visszaszórt elektron kép. Megfigyelhető, hogy a szerpentinásványok (legsötétebb szürke árnyalattal) csak kis térfogatszázalékban jelennek meg az eredeti, peridotitos ásványok közötti térrészekben. Rövidítések: cpx = klinopiroxén; Cr-sp = króm-spinell; ol = olivin; opx = ortopiroxén

The most unique inclusions were the ultramafic mineral and rock fragments. Among them, we found partially (e.g. **Fig. 3.g**) and completely (e.g. **Fig. 3.d**) serpentinised peridotite fragments identified during the petrographic analysis. In the least altered peridotite inclusions (e.g. **Fig. 4.a-b**), several original mineral phases were visible, i.e. olivines (**Appendix – Table 4.**), ortho- and clinopyroxenes (**Appendix – Table 2.**) and Cr-spinels (**Appendix – Table 5.**). These indicate a lherzolite as the protolith of this fragment, which was affected by only a low degree of hydrous alteration, as serpentine (**Appendix – Table 3.**) only occurs interstitially between the original peridotitic minerals (**Fig. 4.b**). The orthopyroxenes and clinopyroxenes (of those both appearing in the peridotite inclusions and as separate mineral inclusions) are enstatites and diopsides, respectively (**Fig. 5.**). Mg-numbers (Mg#=Mg/(Mg+$Fe^{2+}$)) of the pyroxenes and olivines (89.4–96.2, see **Appendix – Table 2.** and **4.**) resemble upper mantle values (Griffin et al. 2009). The Cr-spinels are rich in Al and Mg and poor in Cr and Fe (**Appendix – Table 5., Fig. 6.**), which resembles fertile mantle volumes, that experienced very low degree or no partial melting in its recent history. This is in good agreement with its modal composition, i.e. being lherzolite, as increasing partial melting rates would result in clinopyroxene loss and a shift towards harzburgite modal composition (Arai 1987).

Furthermore, several individual amphibole inclusions were analysed in the sample; their composition is presented in **Fig. 7.** According to the classification of Hawthorne (2012), among them we find actinolite, magnesio-hornblende and ferro-ferri-tschermakite (**Appendix – Table 1.**).

The variability of amphiboles reflect the diversity of rock types identified during the petrographic analysis, where fragments of sedimentary, metamorphic and granitoid origin were described. Additionally, two individual garnet inclusions were also measured, they can be classified as almandines (**Appendix – Table 6.**).

The ARF/grog inclusions with their matrix being light brown in PPL and isotropic in XP described in the petrographic analysis were further investigated by SEM-EDS. We measured the clay fraction of these inclusions and compared the results with the clay fraction of the rest of the sample (see **Appendix – Table 7–8.**). We found that in these ARF/grog inclusions the clay contained significantly more CaO (7.12–15.87 w%), while $P_2O_5$ and Cl were present consistently in low quantities (1.22–5.55 w% and 1.36–2.32 w%, respectively), whereas these latter two constituents were below the detection limit of the EDS in the host matrix.

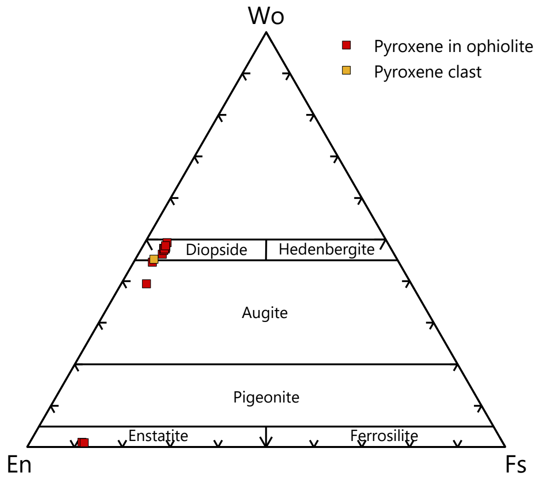


**Fig. 5.:**Ternary diagram displaying the pyroxenes in the sample, based on their composition measured by SEM-EDS. Red squares represent pyroxenes within ophiolite inclusions in the sample, while yellow square shows an individual pyroxene inclusion within the ceramic matrix. Abbreviations: En = enstatite; Wo = wollastonite; Fs = ferrosilite

**5. ábra:** A mintában található piroxének ábrázolása háromszög diagramon SEM-EDS-sel mért elemösszetételük alapján. A piros négyzetek ofiolit szemcséken belül található piroxének, míg a sárga négyszög egy, a kerámia szövetében különállóan található piroxén szemcsét jelez. Rövidítések: En = ensztatit; Wo = wollastonit; Fs = ferroszilit

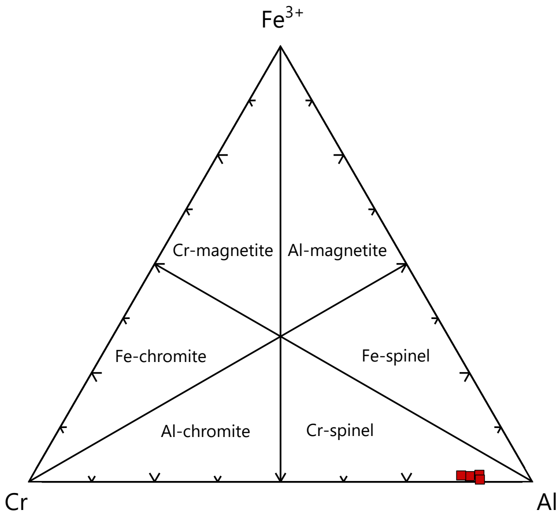


**Fig. 6.**: Ternary diagram displaying the cations occupying the octahedral site (B position in the general formula $AB_2O_4$) in the structure of the spinels found in the Balatonlelle sample based on SEM-EDS measurements (modified after Stevens 1944, fig. 5)

**6. ábra**: A Balatonlelle mintában található spinellek oktaéderes kristálypozíciójában (az általános $AB_2O_4$ képlet B helyén) található kationok megoszlása SEM-EDS-sel mért összetételeik alapján (Stevens 1944, 5. ábra alapján)

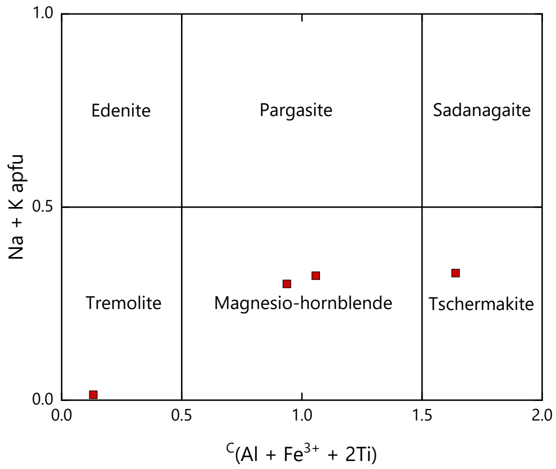


**Fig. 7.:** Chemical composition of amphiboles in the Balatonlelle sample based on the diagram of Hawthorne et al. (2012). The inclusion falling into the tremolite field can be defined as an actinolite, while the one in the tschermakite field is a ferro-ferri-tschermakite according to the classification of Locock (2014).

**7. ábra:** A balatonlellei mintában mért amfibolok elemösszetételének ábrázolása Hawthorne és munkatársainak (2012) diagramja alapján. Locock (2014) alapján a tremolit mezőben levő szemcse aktinolitnak határozható meg, míg a tschermakit mezőben levő ferro-ferri-tschermakitnak

On the basis of our analysis it was not possible to conclude whether these fragments can be interpreted as grog or ARF, as these elements may enrich locally due to natural processes, nevertheless deliberate grog tempering cannot be excluded either. Higher concentration of CaO within their clay fraction might be responsible for their isotropic matrix caused by the high firing temperature, as opposed to the optically inactive, but not isotropic host matrix, as calcareous clays are known to start to vitrify at a lower temperature compared to non-calcareous clays (Quinn 2022, 266–269).

## *Discussion*

From its macroscopic and petrographic characteristics, the following information can be derived about the examined sherd. Based on its size and curvature, this sample belonged to a large vessel with a large body diameter. It was made of a very well-sorted, inclusion-rich, micaceous silty clay, suggesting that the raw clay was levigated first, and then coarse to very coarse sand was added to improve its workability. This resulted in a decidedly coarse-textured vessel. The rilling marks on the interior surface suggest that it was thrown or shaped on a wheel. On the interior and exterior surface, a light brown slip layer was applied. The vessel was evenly fired at a high temperature in an oxidising atmosphere, suggesting well-controlled conditions and advanced firing technology. The large size, lack of decoration and coarse texture together suggest a utilitarian function. Of such vessels, a cooking function may be discounted as unlikely, due to the lack of any soot stain on the exterior. Accordingly, it may be reasonably argued that the sherd probably belongs to a large storage/transport vessel.

The composition of the mineral suite identified in our sample allows us to recognise some aspects of the geological environment from where the raw materials originated, narrowing down the number of probable regions in which it may have been produced. Further confirming that the raw clay was deliberately tempered, differences in composition between the fine and coarse-grained fractions can be observed, the former being characterised by the abundance of muscovite, quartz and feldspars, while the latter displaying great variety comprising fragments of ultramafic, sedimentary, metamorphic and granitoid origin.

The most distinctive characteristic feature in the sample was the presence of ultramafic rock and mineral inclusions, i.e. serpentinising peridotite fragments and radiolarian-rich cherts. Such rocks usually appear on the surface as part of ophiolitic nappes, which are formed when the oceanic lithosphere is obducted, or in other words, uplifted and placed onto another tectonic plate during collision (Dilek & Furnes 2014). As such, ophiolite series comprise a variety of rock types connected to both the upper mantle and the whole crustal section, including ultramafic rocks as part of the former and radiolarites as the deep marine sedimentary cover of the oceanic crust (Haldar 2020). The SW Bükk Mountains is the only place in Hungary, where ophiolitic rocks series can be found (Harangi et al. 1996). However, it is not complete; only parts of the igneous crustal section and the deep marine sediments are present, upper mantle rocks (fresh or serpentinised) are completely missing. Serpentinites occur in the Bódva Valley (Less et al. 2006, 19–20) and the Mecsek Mountains (Szederkényi 1996), but these are small (up to a few hundred meters), isolated bodies in tectonically disturbed successions. Therefore, we assume that the examined sherd, in a rather broad sense, was not made in the vicinity of Balatonlelle. This finding is consistent with the macroscopic evidence that the sherd might have been a transport vessel. Kürthy and colleagues (2018) and Pegán (2023) recently summarised the outcrops of ultrabasic-basic rocks and serpentinites closest to Hungary. According to their work, even the nearest outcrops of ophiolites in the Eastern Alpine region (Melcher et al. 2002), in the Gogołów–Jordanów Massif in Poland (Mydłowski 2009), in the Piedmont-Ligurian Basin (Yegorova & Murovskaya 2023), and, in smaller quantities, in the Maros Valley of the south Carpathians in Romania (Savu 2012), lie several hundred kilometres away from Balatonlelle. It may be added that Kürthy and colleagues (2018) also mention the description of an outcrop in south Slovakia (Putiš et al. 2015), although we find the Slovakian outcrop in our case less likely, as, according to their description, mainly harzburgites were identified, while in our case the peridotites appear to be lherzolites. However, ophiolites are more abundantly found in the Dinarides and the Vardar zone along the Balkan peninsula, and along the Eastern Mediterranean including the east and southeast Aegean and Anatolia (Robertson 2002).

As we can see, even the closest geologically probable sources mean that the vessel was imported from a large distance. If we consider the possible areas listed above, we find that in the Eastern Mediterranean extensive amphora production was taking place in the Early Migration (Early Byzantine) Period; their products reached even the furthest corners of the former Roman Empire (e.g. Pieri 2005, figs. 32, 47). Conversely, such extensive export activities are not identified from the other known outcrops of serpentinites listed above. Combining the results derived from the macroscopic and petrographic analysis with the historical context, we suggest that our sherd might have belonged to a transport amphora produced in the Eastern Mediterranean.

One of the most common amphora types in circulation in the 6th century was the Late Roman Amphora 1 type (LRA 1), which was produced in many workshops in the Eastern Mediterranean between the 4th and the 7th centuries (Reynolds 2005). According to a recent study, seventeen LRA 1 production centres are presently known, most of them located along the Cilician coast (south-eastern Anatolia) and in Cyprus, with further workshops suggested in southwest Anatolia (İçmeler), on several Aegean islands (Cos, Rhodes, Lipsi and Paros), northern Anatolia (Sinop) and in the Roman province of Syria (*Seleucia Pieria* / Çevlik, Alexandretta-Iskenderun) (Gillett 2023, 10). Further centres reported in literature producing imitations include the island of Karpathos (Didioumi 2014), North Africa (Nacef 2007; Pieri 2007), and Egypt (Pieri 2007). Most scholars agree that this type of amphora was used for transporting wine (Komar 2016), which product reached, among others, territories even as far as Britannia (Tomber & Williams 1986) and Hispania (Fantuzzi et al. 2017) provinces. Some petrographic studies have been published about LRA 1 type amphorae (e.g. Fantuzzi et al. 2017; Gillett 2023; Leidwanger 2014; Nagy 2023; Peacock & Williams 1991, 187); these all report on ophiolitic sand tempered fabrics being the predominant fabric for this amphora type, which is not surprising in the light of the known production centres, most of which lie close to ophiolite outcrops. Although the serpentinite-rich fabrics are most commonly described also containing carbonates (limestone, micrite), these were not observed in our Balatonlelle sample. It is possible that originally it did contain a low amount of carbonate inclusions, but if so, they burnt out during the firing, or dissolved in the soil, as some large voids visible in thin section (see **Fig. 3.a-b**) may be interpreted as "calcite ghosts" (c.f. Gilstrap et al. 2021, figs. 6–7). The LRA 1 type sample with the fabric most similar to the Balatonlelle sherd was found in Kinet Höyük (now Türkiye) ('LCP - Sample CAS142' 2012), where the size and sorting of inclusions, including ophiolitic sand fragments, agreed well with our examined sherd. Additionally, it also resembles sample #36 (defined as LRA 1B1, according to the classification of Pieri (2005)) described by Gillett, which is characterised by a fabric rich in serpentinite, chert, limestone and large voids probably connected to dissolved carbonates, and to a lesser amount, quartz, feldspar, pyroxene, mica, sandstone inclusions and clay pellets (Gillett 2023, fig. 29i; 'LCP - Sample Sepphoris 77.1686.1.1' 2022).

Therefore, based on the information available from previous studies, it is possible to suggest that the Balatonlelle sample might have belonged to an LRA 1 type vessel, and although its texture differs slightly from the most commonly presented LRA 1 fabrics, it is nonetheless congruent with the geological environment where these amphorae were produced. However, it is also worth adding that, at present, scientific data has yet to be published from many LRA 1 production centres, and that future information from these sites may cast new light on the origin of the Balatonlelle sherd.

Although we consider LRA 1 type amphorae as a possible source of the Balatonlelle sherd, it is important to emphasise that there were other amphora types produced in the Eastern Mediterranean, which might display similar petrographic characteristics. Indeed, in the absence of characteristic stylistic traits visible on the sherd, we cannot suggest a definite match with any specific types. Nonetheless, we found it important to point out that one of the most common and wide-spread amphora types of the period, the LRA 1 is a possible source for our sherd.

In the 5th–6th centuries, amphorae can be found only sporadically in the former Roman province of Pannonia. On the one hand, it is clear that the number of amphora imports started to drop considerably from the end of the 2nd century AD (Magyar-Hárshegyi 2016), and by the Migration Period, they are considered particularly rare. On the other hand, recent studies on newly recovered material and more refined dating of older finds show that their quantity is slightly higher than had

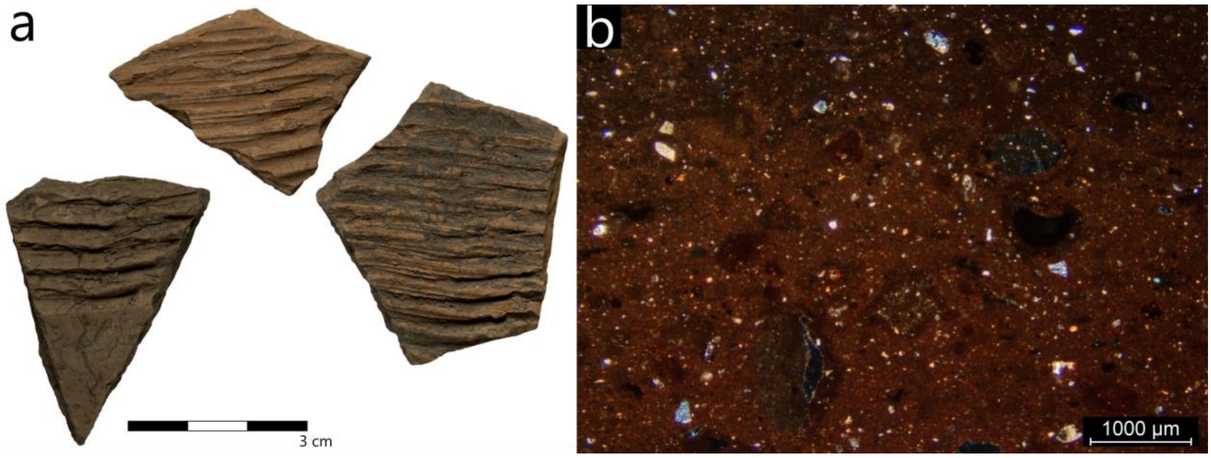


**Fig. 8.**: LRA 2 amphora from Keszthely-Fenékpuszta (unpublished, Inv. nr. 2015.7.1.80). (a) hand specimen; (b) photomicrograph (XP, ×20). The fabric is comparable to petro-fabric 3 described by Fantuzzi et al. (2016)

**8. ábra**: LRA 2 amphora Keszthely-Fenékpusztáról (publikálatlan, ltsz.: 2015.7.1.80). (a) töredékek; (b) polarizációs mikroszkópos felvétel (+ N, ×20). A minta szövete jó egyezést mutat a Fantuzzi et al. (2016) által leírt 3. szöveti csoport jellemzőivel

been thought before (Nagy 2023, 341). Amphorae from Pannonia and its vicinity dated exclusively to the post-provincial, Early Migration Period are known from *Cibalae* / Vinkovci, *Sirmium* / Sremska Mitrovica (Nagy 2023, 341–42), Keszthely-Fenékpuszta (Horváth 2011, 597–602) and *Poetovio* / Ptuj (Hárshegyi and Ottományi 2013, 485–86). They were also present in 6th century Langobard contexts in the East Alpine region (Ciglenečki 2000, 148–149). On some occasions, amphorae were found also in the Avar Age, although mainly used as grave goods (Csiky & Magyar-Hárshegyi 2015), with the exception of the settlement of Kölked-Feketekapu (Hajnal 2005). From Keszthely-Fenékpuszta, the late Roman inner fortification merely ca. 40 km from Balatonlelle, new, as yet unpublished research proves that LRA 2 amphorae, stylistically dated to the mid-6th–mid-7th centuries (Pieri 2005, 88), did reach Pannonia (**Fig. 8.**). Their dating is further confirmed by the stratigraphy, as they were recovered from a feature dated to the period following Building Phase B in Building 25 (Building Phase C is suggested to be dated to the 6th century) (Heinrich-Tamáska & Prien 2017, 141).

In the light of the above mentioned cultural environment amphorae might have also reached Balatonlelle in the 6th century. While owing to the lack of stylistic characteristics on the examined sherd it is not possible to determine its origin beyond any doubt, integrated archaeological science analysis combining macroscopic and petrographic methods provided us a possible explanation as to how we can interpret this sherd. Providing that it was in fact an amphora fragment from the Eastern Mediterranean, many further questions arise, for instance, about the cultural and economic connections of the people from the Balatonlelle site. Although we have no information on the nature of the connection, it is nevertheless interesting that an indirect route might have existed between these territories. Little is known presently about the consumers of the goods transported in the amphorae arriving to Pannonia in the post-provincial period. Understanding the social status and cultural identities of people connected to this later amphora consumption is an exciting new territory of research.

## *Conclusions…*

In this study we reported on a single ceramic sherd from a 6th century site in Balatonlelle, which was suggested to have belonged to a transport vessel. The technology and quality of the sherd may be indicative of industrial production environment (advanced clay preparation and firing technology). It was tempered with coarse-grained ophiolitic sand containing relatively fresh peridotite fragments, which do not outcrop in Hungary. In a geological sense, even the closest of such outcrops lie several hundreds of kilometres away from where the sherd was found. However, we propose that this sherd may originate from even further, from the Eastern Mediterranean, where ophiolites are commonly found, and where Late Roman amphora types (especially LRA 1) were produced in large quantities in the 6th century.

Any discussion of a single sherd necessarily suffers the inevitable deficiencies of small datasets regarding representativeness to the wider archaeo-logical and historical contexts. Accordingly, any conclusions drawn, including those presented here must necessarily be somewhat tentative. None-theless, small-scale social/economic interactions, such as 6th century amphora circulation in Pannonia, remain important phenomena to identify, and as such, we found it important to report on this new finding in detail. It was our aim to provide comprehensive macroscopic and petrographic descriptions, to enable comparisons to be made in the future and help archaeologists to recognise such sherds that only rarely occur in such late contexts.

## *…and some personal closing remarks*

With this study we would like to celebrate the career of György Szakmány, who was one of the key figures establishing modern ceramic petrographic research and education in Hungary, and who started a closer dialogue between archaeologists and geologists in this regard. With the topic of this paper, we intended to evoke one of his first involvements with archaeological ceramics, which was a petrographic contribution to the research of Roman amphorae along the Amber Road in western Pannonia (Bezeczky 1987). Following Gyuri's own lead, we hope that this study will serve as an example of how a combination of archaeological science methods, and a dialogue between researchers of different backgrounds, can be integrated in order to open a new dimension of information.

## *Contribution of authors*

**Katalin Bajnok** Conceptualisation, Methodology, Validation, Formal Analysis, Investigation, Resources, Data Curation, Writing - Original Draft, Writing - Review & Editing, Visualisation, Project Administration, Funding acquisition. **Zoltán Kovács** Methodology, Validation, Formal Analysis, Investigation, Resources, Data Curation, Writing - Original Draft, Writing - Review & Editing. **Anna Andrea Nagy** Conceptualisation, Resources, Writing - Original Draft, Writing - Review & Editing.

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