

LRCW 4

Late Roman Coarse Wares, Cooking Wares and Amphorae in the Mediterranean

Archaeology and archaeometry

The Mediterranean: a market without frontiers

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ARCHAEOLOGICAL AND ARCHAEOMETRIC INVESTIGATIONS OF THE AMPHORAE CARGO OF A LATE ROMAN SHIPWRECK SUNK NEAR THE CAPE OF PLAKA (CRIMEA, UKRAINE)

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A late Roman shipwreck located off the cape of Plaka (Crimea, Ukraine) during surveys carried two main types of amphorae, LRA1 and 'carrot' amphorae. The typological study lead to propose a dating of the cargo between the second quarter of the 6th and the 3rd quarter of the 7th century. Preliminary results of petrographic and chemical analyses show that the two types of amphorae do not correspond to a single production. The hypothesis that the whole cargo came from the workshops of Sinop or of Seleucia Pieria, possible providers of both types, is thus not supported. An origin in Rhosos/Arsuz might be proposed for most of the LRA1 samples, thanks to reference chemical data provided by previous research carried out by Empereur and Picon. The attribution of Plaka 'carrot' amphorae requests further study, and especially the analysis of comparative material from Sinop. The amphorae in the cargo are shown to have multiple origins, a feature that may be common in the late 6th - 7th centuries.

Introduction

From 1993 onwards, a team of underwater archaeologists from the Centre for Underwater Archaeology, Taras Shevchenko National University of Kiev, led by Dr. Sergiy Zelenko, carried out coastal surveys off the south-eastern part of the Crimean peninsula (Zelenko 2008). In ancient times a small settlement and trade post Lampados mentioned by ancient geographers was situated on Plaka cape. In the medieval period the settlement developed into a big fortified town (Firsov 1990, 96-99). A medieval settlement Partenit was localized nearby to the West. The medieval portolan-charts informed us on an important city and port situated on Partenit site (Parshyna 1991, 65-66). It corresponded to the end-point of one of the maritime trade routes crossing the Black sea, with its other end in Sinop (Fig. 1).

Three shipwrecks, differing in chronology, were discovered off the cape of Plaka at a depth of about 10m amid large stones and rocks (Zelenko 2008, 82-87). One of the shipwrecks is dated back to the late Roman period. It comprises large fragments of LRA1 type and fragments and two complete vessels of 'carrot' amphorae of Sinopean type. It was associated to a fragment of a leaden sheet, such sheets being used as siding or bottom - planking of ships in ancient times. The amphorae cargo had been preliminarily dated to the 7th century AD according to typological parallels (Morozova 2009, 166). This paper presents the material from the shipwreck studied so far, stored in the Alushta museum and in Kiev University, whose origin(s) was investigated by chemical and petrographic analyses.

Typology and dating of amphorae from the Plaka shipwreck (Figs. 2-5)

The cylindrical amphora LRA1 is one of the most common and widespread in the late Roman and early Byzantine period. The type, whose form evolved considerably through the 4th to 7th centuries, was the subject of many studies and recent reviews (Riley 1979; Panella 1986; 2001; Empereur and Picon 1989; Reynolds 2005; Arthur 1998; Pieri 2005; 2007; Williams 2005). Pieri (2005, 69-85) divided LRA1 into types A and B, based on studies of complete and fragmented examples from France. Of particular interest to us was the study by van Alfen on the Yassı Ada shipwreck, because of the precise dating by coins to the beginning of the 7th century (van Alfen 1996, 191). Van Alfen's typology has shown eleven variants for LRA1 among 71 amphorae, based on complete forms and their morphometric characteristics such as capacity (van Alfen 1996, 191). In the Plaka shipwreck there are neither coins nor complete examples as in the Yassı Ada shipwreck. Neither comparison with van Alfen's typology nor independent typology seem possible. Provisionally we will refer to Pieri's typology, with some specific features.

We divided Plaka amphorae into three categories according to their exterior features, handles position, neck, rim and wall shapes and profiles, as well as interior mouth diameters, 5-6cm and 7-8cm respectively.

Category 1: one vessel (BZY 55) with a tall, straight, narrow neck with a small folded band rim. Oval in section, handles have a single finger-made groove and are

attached to the neck in its mid point. The base and body are unavailable. The interior diameter of the mouth is 5cm. Neck height is 11cm. It is suggested that this type corresponds to Pieri's type LRA 1A (2005, pl.1-14). The variant was dated to the late 4th-5th century (Arthur 1998, 164-165; Pieri 2005, 70-75).

Category 2: Vessels (BZY 51, 53, BYZ932-935) with tall, straight and narrow neck, but the handles are attached to a well-defined ridge below the rim. Handles are large and thick and have a right angled profile. The rim is oval in section in most cases, though rims and handles are various in shapes. The interior diameter of mouth is 5-6cm, neck height is 9-11cm. It is suggested that this type corresponds to Pieri's type LRA 1B (2005, 75-77, pl.15-18). Some examples are variations of this type - the neck is tall, not straight but flares toward the rim (BZY 54. mouth diam.-6cm, BZY 8. mouth diam.-6cm, BZY 45. mouth diam.-7cm). The LRA 1B1, vessels with a larger capacity took their 'true LRA1 form' (Arthur 1998, 164) in the 6th and 7th centuries (Pieri 2005, 75-77). Arthur gives the earlier dates for this group of vessels, from the second half of the 5th century (Arthur 1998, 164-165). The LRA 1B has close parallels to those found in the Yassı Ada shipwreck.

Category 3: Vessels (BZY 9-11, 47-49, BYZ930-931) with tall, straight and wide neck, the handles are attached to a well-defined ridge below the rim. The main difference between types 2 and 3 is the diameter of the mouth. The interior diameter of the mouth is 7-8cm, neck height is 8-13cm. The rim is oval in section in most cases, though in this type rims and handles are various in shapes. It is suggested that this type also corresponds to Pieri's type LRA 1B with a dating in the 6th and 7th centuries (2005, 75-77, pl.15-18).

All LRA1 fragments found at Plaka belong to amphorae with cylindrical body. The clay is light yellow, light red or cream-colored. Some fragments contain the remnants of resin lining.

It is very difficult to apply the above mentioned categories and dating to the fragmentary material from the shipwreck site at Plaka. A single sample (BZY 55) belongs to type LRA 1A of the 5th century; however it is met together in one assemblage with LRA1 of category 2, of the 6th-7th century. Was it a residual find or 'new data' for future discussions on chronology, it is hard to state.

The 'carrot' amphorae received their name in archaeological literature after publication by Zemer (1978). A recent contribution to its study is the book by Kassab Tezgör (2010) on the workshops of Demirci next to Sinop, active between the 3rd and the 6th centuries AD and where this type was produced. Kassab Tezgör establishes a typology of the production of the workshop, changing during this long period in shape, size and aspect of the paste. Plaka 'carrot' amphorae are close to Sinopean Group C, types II-3 and III-1a and b that she dates in the 4th-5th century. However, the rim style and

shape of the neck is rather different. The Plaka vessels are also smaller in size than their Demirci analogues, the height of complete vessels are 58 and 56cm for a rim diameter between 3 and 5cm.

The vessels from Plaka were initially seen as homogeneous in type. They have tapered body with two loop handles. The handles are oval in section, sometimes with one groove on the upper flat. A high rounded neck with a heavy knobbed or beak shaped rim flares to the horizontal ribbing body. The handles are attached to the mid of the neck at their upper point and to the shoulder at their lower end, continuing the outline of the body. The conical bases are of two types – tapering one and rounded and hollow inside one. The vessels are made of pale-pinkish clay. The outer surface is covered by patina of brown color with organic impregnations as a result of long-lasting interaction with the seawater environment.

The closest parallels for our examples are vessels from Chersonesos: finds from the well in the north-eastern section of the city (Sazanov 1991, 60-72, fig.9); Hermonassum (Jakobson 1979, 9 fig.1,1), Iliichevka on the Taman Peninsula (Sazanov 1991, 69) and Iatrus in Bulgaria (Kuzmanov 1985, fig. 1,2). In general, they are close to examples from the archaeological assemblages from the Crimean and southern Russian settlements and cities dated by Sazanov to the third quarter of the 6th to the first quarter of the 7th century (Sazanov 1991, 66). LRA1 are present in the same sites as well, sometimes associated in the same archaeological contexts, as in a wine cellar in Chersonesos where they are found together with coins of the emperors Zeno (c. AD 474-475 and AD 476-491) and Justinian I the Great (AD 527-565) (Belov 1950, 118). The 'carrot' amphorae were also found associated in shipwrecks located close to Sinop and investigated during the Deep Water Project, developed and carried out by the Institute for Exploration (IFE) (Ward and Ballard 2005). In cargoes of ships A, B and C 'carrot' amphorae are dominant. In the case of shipwreck B, several LRA1 vessels were found among the piles of 'carrots' (Ward and Horlings 2008, 156, 165, fig. 8.6, 8.7b). The authors dated all vessels to the 4th-7th centuries AD (Ward and Horlings 2008, 170).

Although the dating of 'carrot' amphorae is still controversial, considering the close parallels for 'carrot' amphorae with Chersonesos examples found in reliable archaeological assemblages and for LRA1 with the Yassı Ada shipwreck, a dating of the Plaka cargo between the second quarter of the 6th and the 3rd quarter of the 7th century is proposed.

Origins of amphorae from the Plaka shipwreck

Several production sites of LRA1 amphorae are identified in southern Turkey, especially in Cilicia and Pieria (Empereur and Picon 1989), on Kos (Diamanti 2010; Poulou-Papadimitriou and Didjoumi 2010) and on the southern coast of Cyprus (Demesticha 2003). 'Carrot' amphorae - the term is restricted here to Sinopean types,

excluding other forms of amphorae also called ‘carrot’ (Egyptian and Beirut types, etc.) - are mostly known as the products of the Demirci workshops, near Sinop (Kassab Tezgör 2010), but several other workshops on the southern coast of the Black sea have been hypothesized (Kassab Tezgör 2011). The Demirci workshops also manufactured variant of LRA 1A (Kassab Tezgör 2010, 135) or LRA 1B type (Pieri 2007, 615). As far as we know, the only other site where the manufacture of both LRA1 and ‘carrot’ amphorae has been reported is Seleucia Pieria (‘Séleucie de Piérie’, Empereur and Picon 1989). The actual status as workshop of several of the sites mentioned by Empereur and Picon, and particularly of Seleucia Pieria, was recently questioned (Reynolds 2005, 566); but the careful definition by Picon of criteria of identification of production sites (Ballet *et al.* 1991, 130-134) supports the reliability of his assumptions.

Chemical and petrographic analyses were carried out in order to investigate the possible origin, or origins, of the amphorae cargo of the Plaka shipwreck. We intended to test some of the hypotheses: did both amphora types come from the same workshop? could this workshop be identified to Seleucia Pieria? to Sinop? to one or several other production sites? Fifty samples from Plaka shipwreck were analyzed by Wavelength-Dispersive X-ray fluorescence at the ‘Laboratoire de Céramologie’ in Lyon. Petrographic analysis of a sub-sampling of 17 sherds was carried out at the Geology Department of the ‘Dokuz Eylül’ University in Izmir. Three to four additional sherds from Sinop were analyzed by both methods.

Comparative data, especially chemical analyses of samples from LRA1 workshops located by Empereur and Picon in the 1980s, were available to us through the database of the ‘Laboratoire de Céramologie’. This large corpus of data includes not only amphorae samples, but also in some cases tiles, bricks and clays, which may further support the local character of the wares. The Lyon database, however, does not include material from the more recently discovered LRA1 workshops, especially the Aegean and Cypriot ones (Diamanti 2010; Poulou-Papadimitriou and Didioumi 2010; Demesticha 2003). In addition, only a very limited number of reference samples from Sinop was available to us. We could thus not rely on proper chemical reference groups corresponding to the Sinop/Demirci productions and could only expect initial indications. Other indications could potentially be drawn from previous analyses of sherds from Sinop (Demirci *et al.* 1999; Erten *et al.* 2004). But their use was made difficult either by the lack of archaeological identification of the samples, or by the absence of numerical data.

Besides geological maps, petrographic analyses may now refer to the online facility dedicated to Roman amphorae proposed by Williams, at least for the LRA1 amphorae (including samples provided by Empereur and Picon from their survey material, Williams 2005, http://archaeologydataservice.ac.uk/archives/view/amphora_ahrb_2005).

Petrographic features

The 17 samples from Plaka shipwreck examined may be divided into two main petrographic groups. Group I (samples BZY 4, 8, 42, BZY937-941) consists of dominant pyroxene grains, rounded quartz, plagioclase and volcanic rock fragments (Fig. 6, left). Volcanic rock fragments include fresh pyroxene minerals. This group corresponds to samples of ‘carrot’ amphorae, with the exception of sample BZY 8. Group II (samples BZY 5, 45, BZY930-935) also has pyroxene and volcanic rock fragments, but additional carbonate rocks and fossils fragments differentiate it from group I (Fig. 6, right). This group corresponds to samples of LRA1 amphorae. Three samples from Sinop, considered as local references, show petrographic features similar to those of group I. Volcanic rock fragment and pyroxene contents are typical.

Besides, all these ceramic samples are nearly the same in terms of their minerals and rock fragments as Peacock and Williams Class 44 (i.e. LRA1, Peacock and Williams 1986), but there is no serpentine inclusion in them. The presence of serpentine in ceramics shows that inclusions derived from ultrabasic rocks. There is no ultrabasic outcrop in the region of Sinop, whereas ceramics produced in the region of Antakya could be rich in serpentine inclusions due to the presence of ultrabasic rocks.

Chemical features

Fig. 7 (top) presents the classification according to chemical compositions of ceramics from the Plaka shipwreck, together with reference data for the productions of Seleucia Pieria/ Samandağ (27 samples) and Sinop (4 samples). These two sites were selected within the comparative material as they were potential providers of the whole cargo.

The classification shows in the first place different chemical groups within Plaka samples. Two main groups are distinguished: one including only ‘carrot’ amphorae (Fig. 2), the other one only LRA1 amphorae (Fig. 4). This result confirms and emphasizes the petrographic distinction between petrographic groups I and II, differing mainly by their content in calcareous inclusions. It shows a global distinction between more calcareous pastes with ultrabasic features, corresponding to the LRA1 group, as opposed to less calcareous pastes without or with very limited ultrabasic character, corresponding to the ‘carrot’ group (Fig. 8). This distinction clearly invalidates the hypothesis of a common origin for both types of amphorae.

The chemical groups are not homogeneous, especially the LRA1 one where sub-structures may be distinguished according to concentrations in calcium and related elements, as well as to concentrations of elements related to ultrabasic rocks (Mg, Cr, Ni) (Fig. 8). The three typological LRA1 categories do all appear in the group, and do not seem to be correlated to its possible sub-structures (sub-groups with higher Ca: BZY 10-11, 51, BZY930-931; with higher Mg: BZY 9, 54) (Fig. 4).

The samples analyzed originated from more than two workshops, as several stand out as outliers to the main groups (Fig. 7 (top), Fig. 8). Some may correspond to other types, especially fragments of bases which could have been mistakenly identified as 'carrot' amphorae (Fig. 3), e.g. a small group of four samples (BZY155-157, with higher K and Al), as well as two others with a different base form (BZY 43-44, with higher Fe and Ti and low Ca). The LRA1 outliers (BZY 8, 12, 50, 56, 153, BYZ934; Fig. 5) also correspond to various cases: one sample (BZY 56) is marginal to the main LRA1 group but still belongs to it; others are completely different, characterized by non calcareous pastes (BZY 8, 12) or by high potassium content (BYZ934). The diversity of origins of the LRA1 amphorae, which do not seem to be correlated with typological categories, reminds of the situation observed in the Yassı Ada 7th century shipwreck (Leidwanger this volume).

The classification (Fig. 7, top) also shows that Plaka groups or samples do not mix with Seleucia Pieria LRA1 and 'carrot' amphorae, which constitute a separate chemical group. Its characteristics are however not very different from those of Plaka's main group of 'carrot' amphorae (Fig. 8). Among the samples from Sinop, one (SNO1) is close enough to be included in the latter, while the others (SNO2-4) stand apart, including sample SNO3 which would correspond to Kassab Tezgör's type C (Kassab Tezgör 2010), the closest typologically to Plaka 'carrot' amphorae. These results are ambiguous, and additional reference samples from Sinop would be requested, to find out whether the 'carrot' amphorae from Plaka may correspond to Sinop/Demirci productions, or to another workshop of the southern Black sea coast, and to shed light on the status - workshop or warehouse of Sinopean products - of the remains at Seleucia Pieria.

To look for possible origins of the LRA1 amphorae from Plaka cargo, we used the corpus of data corresponding to Empereur and Picon's prospections (1989). A general picture of the distinction between several workshops in south-eastern Turkey and on Cyprus is presented in Fig. 9. Globally, the CaO/Sr ratio shows different trends in the two regions. The Plaka LRA1 samples would belong to a production from south-eastern Turkey, rather than from Cyprus, with the exception of a few examples with low Ca content (see *supra*). Classifications using the same data show that the closest correspondence is obtained with the productions of Rhosos/Arsuz (Fig. 7, bottom). These include amphorae as well as bricks and tiles; clay samples (BAL144-145) were also considered. Two main groups, both including bricks, tiles or clays may be distinguished, which do not strictly correspond to the three workshops presented by Empereur and Picon (1989), or to the seven locations mentioned in Lyon database (Fig. 10). One of the groups shows noticeably high concentrations in Mg, Cr and Ni. The other one is similar chemically to Plaka's main group of LRA1, and the chemical variability observed may account for the heterogeneity of Plaka's samples. These results suggest that part of Plaka cargo may have come from Rhosos/Arsuz.

Concluding remarks

The late Roman shipwreck located off the cape of Plaka during surveys carried out by the Centre for Underwater Archaeology, Taras Shevchenko National University of Kiev, carried two main types of amphorae, LRA1 and 'carrot' amphorae. The typological study lead to propose a dating of the cargo between the second quarter of the 6th and the 3rd quarter of the 7th century.

The preliminary results of petrographic and chemical analyses of samples from the Plaka shipwreck provide clues as to the origins of the cargo. Firstly, it is clear that the two types of amphorae do not correspond to a single production, as two main chemical and petrographic groups are distinguished, corresponding to the majority of the LRA1 and 'carrot' amphorae, respectively. An initial hypothesis, that the whole cargo could have come either from Sinop or from Seleucia Pieria, the only sites reported as far as we know to have manufactured both types, is thus not supported by our results.

The analyses do not rule out a sinopean origin for Plaka's 'carrot' amphorae, but comparative data are too few to be conclusive. Among the reference samples from Cypriot and Turkish LRA1 workshops available in the chemical database of the 'Laboratoire de Céramologie', Plaka's main group of LRA1 shows a fairly good match with amphorae from Rhosos/Arsuz, in south-eastern Turkey, whose local status is further confirmed by analyses of bricks, tiles and clays. This site may thus be proposed as the origin of part of the cargo. However, the absence of serpentine inclusions in the Plaka samples is questioning, as such inclusions are expected to be part of the typical petrographic features of LRA1.

In any case, the cargo carried amphorae of multiple origins. In addition to the two main groups, other small groups of amphorae or isolated samples are shown to belong to different productions. The diversity of origins of the LRA1 amphorae, which do not seem to be correlated with typological categories, reminds of the situation observed in the Yassı Ada 7th century shipwreck, and might thus be seen as a feature of the economy of the late 6th - 7th centuries.

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Fig 1: Map of the Black sea, with indications of trade routes and location of sites mentioned in the text (Y. Morozova).

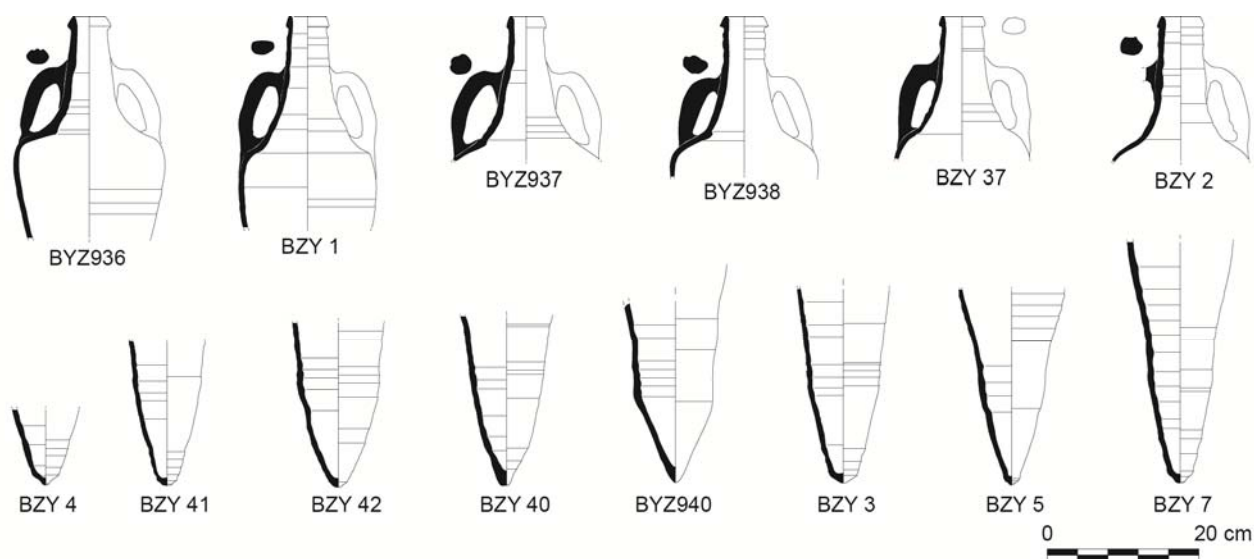


Fig. 2: Carrot amphorae from the Plaka shipwreck, main chemical group (sample numbers are indicated) (Y. Montmessin, N. Sokolchuk, S.Y. Waksman).

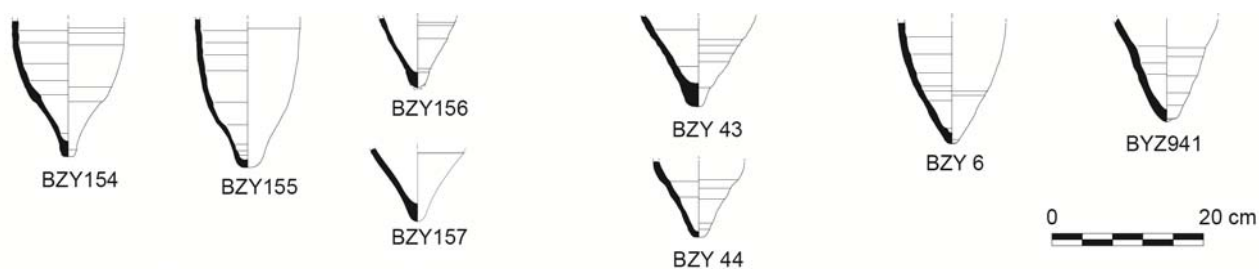


Fig. 3: Carrot (?) amphorae from the Plaka shipwreck, not in the main chemical group (sample numbers are indicated) (Y. Montmessin, N. Sokolchuk, S.Y. Waksman).

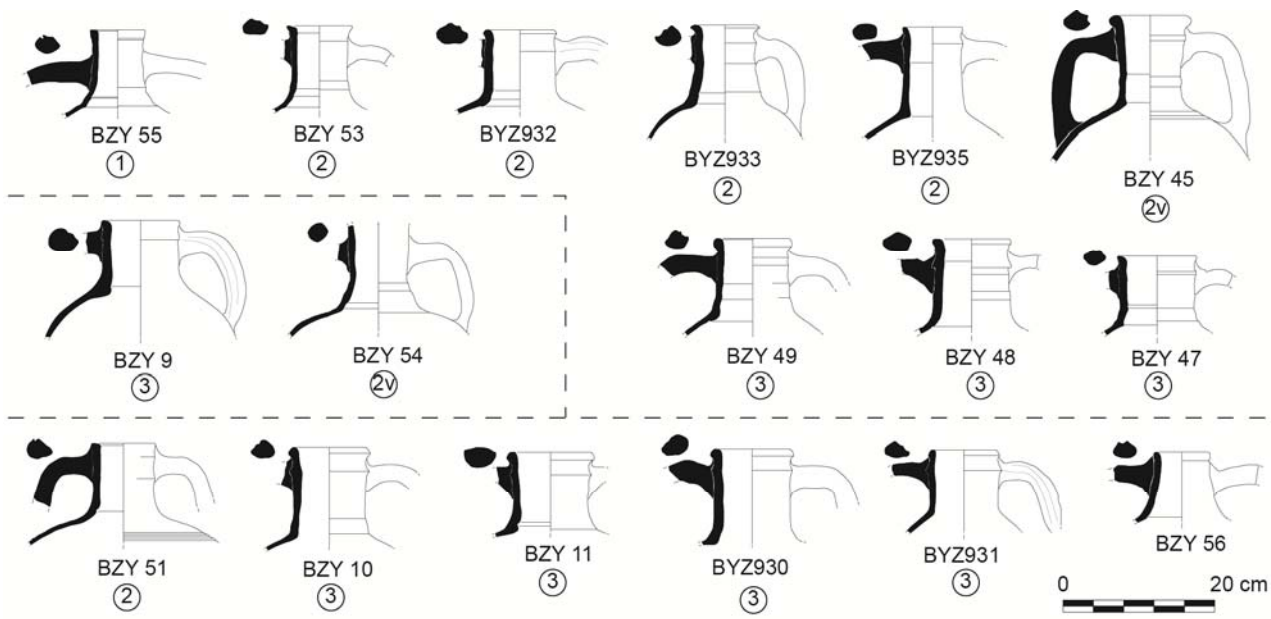


Fig. 4: LRA1 amphorae from the Plaka shipwreck, main chemical group(s). Sample numbers are indicated, as well as typological categories (1, 2, 2v[ariant], 3) and possible chemical sub-groups (lower row: more calcareous; middle row, left: stronger ultrabasic features) (Y. Montmessin, N. Sokolchuk, S.Y. Waksman).



Fig. 5: LRA1 amphorae from the Plaka shipwreck, not in main chemical group(s) (sample numbers are indicated) (Y. Montmessin, N. Sokolchuk, S.Y. Waksman).

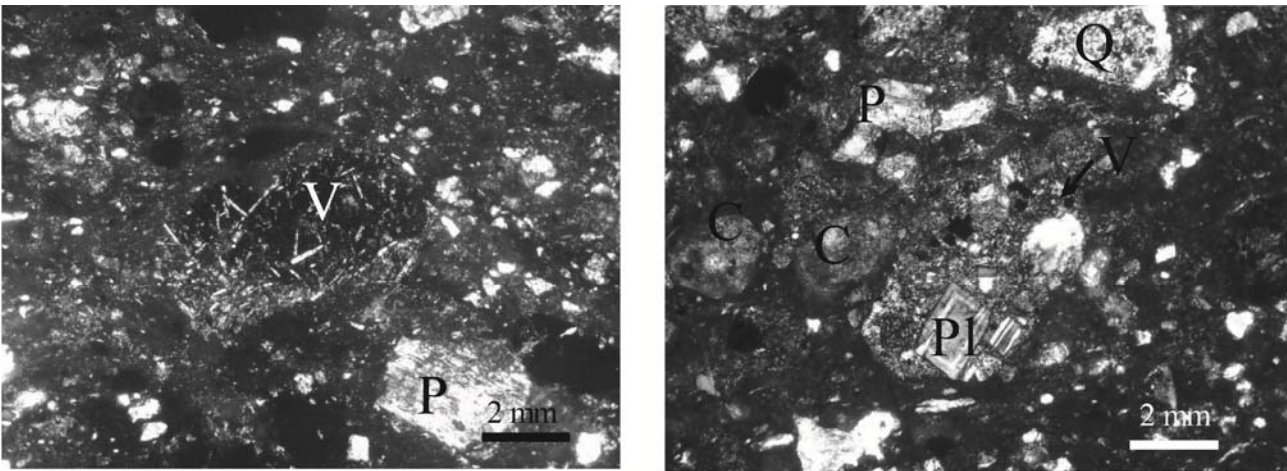


Fig. 6: Microphotographs under the polarizing microscope (crossed polars) of samples belonging to petrographic groups I (left) and II (right); Q: quartz, P: pyroxene, Pl: plagioclase, C: calcareous rock, V: volcanic rock (M. Çolak).

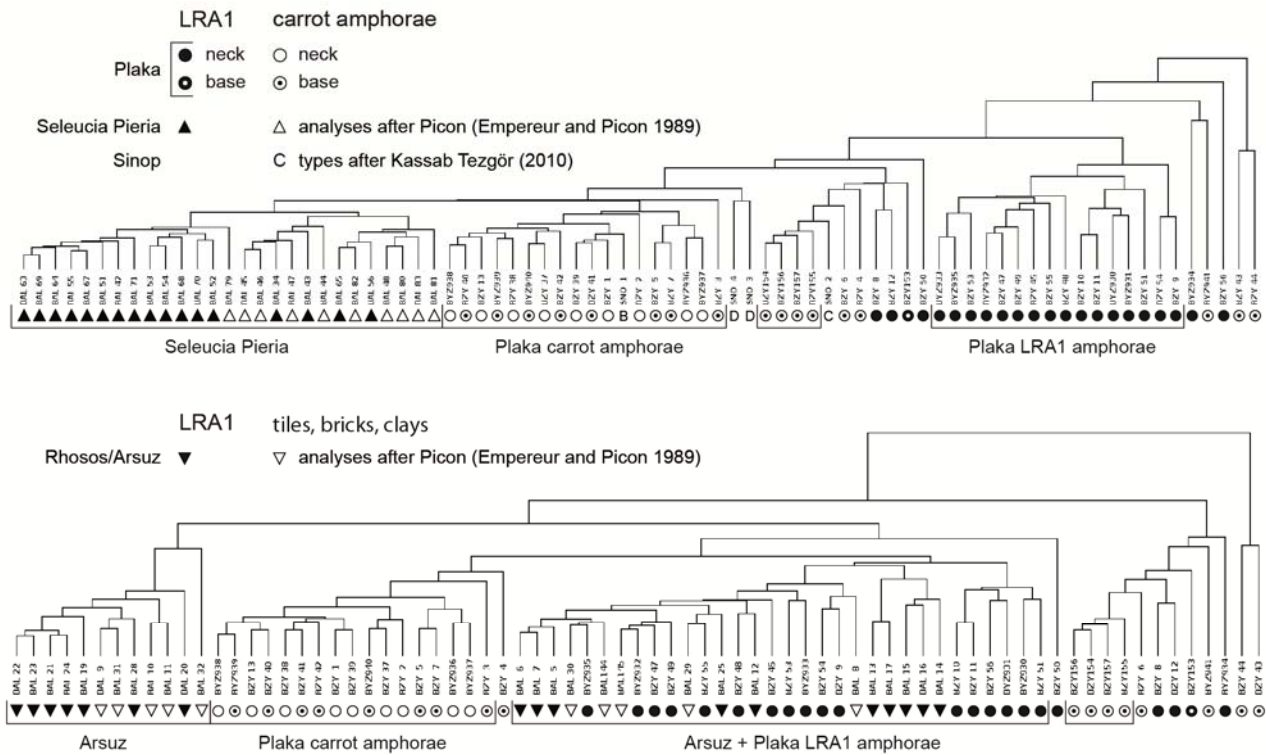


Fig. 7: Classification of the samples according to chemical compositions, based on 17 elements. Amphorae from the Plaka shipwreck are compared to reference samples from Seleucia Pieria/Samandağ and Sinop (top) and from Rhosos/Arsuz (bottom). Provenance and typological features are indicated by symbols, the main chemical groups are underlined; data for Seleucia Pieria/Samandağ and Rhosos/Arsuz after Empereur and Picon (1989) (S.Y. Waksman).

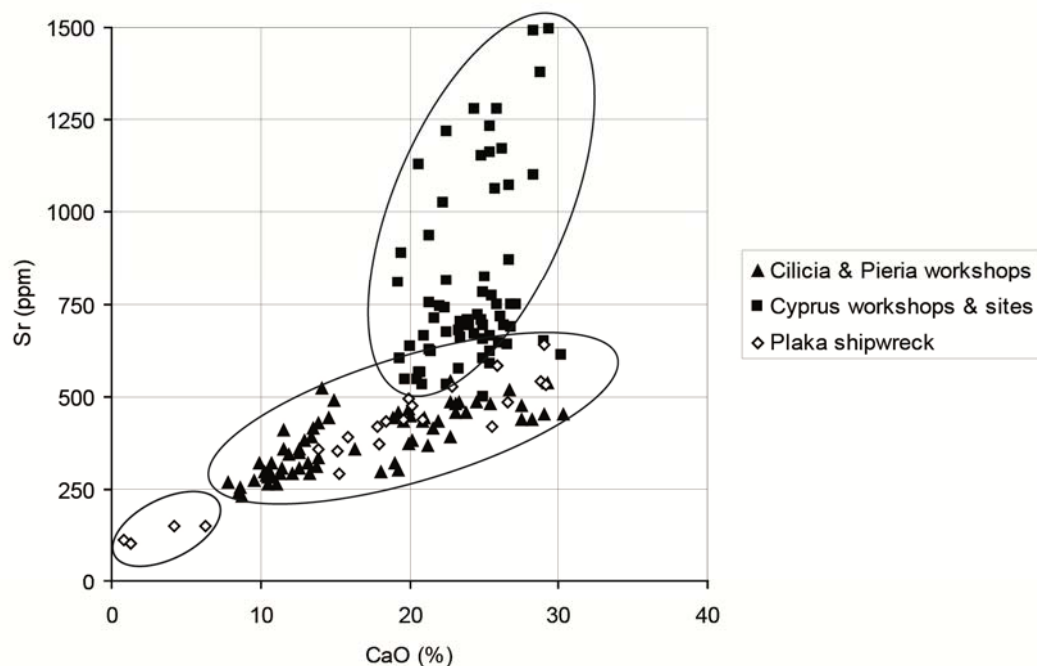


Fig. 9: Binary plot calcium - strontium.

LRA1 amphorae from the Plaka shipwreck and from workshops in south-eastern Turkey and on Cyprus (after Empereur and Picon 1989; south-eastern Turkey: Seleucia Pieria/Samandağ, Rhosos/Arsuz, Aigeai/Yumurtalık, Magarsos/Karataş, Soles, Elaioussa Sebaste/Ayaş; Cyprus: Paphos, Amathous, Kourion). Global trends are shown by ellipses, including respectively samples from Cyprus, samples from Turkey together with the main part of Plaka samples, and low-calcareous Plaka samples (S.Y. Waksman).

sample	CaO	Fe ₂ O ₃	TiO ₂	K ₂ O	SiO ₂	Al ₂ O ₃	MgO	MnO	(Na ₂ O)	(P ₂ O ₅)	Zr	Sr	Rb	Zn	Cr	Ni	Ba	V	Ce
Seleucia Pieria/ Samandağ, local production, after Picon and Empereur 1989																			
BAL 63	13.45	6.93	0.780	1.92	58.03	12.54	4.70	0.0991	1.19	0.17	136	389	81	82	236	99	244	161	62
BAL 69	12.95	6.76	0.790	1.96	58.74	12.90	4.18	0.0876	1.25	0.19	138	381	70	80	232	103	273	157	62
BAL 64	11.40	6.75	0.810	1.94	59.54	13.35	4.32	0.0978	1.45	0.14	138	305	75	82	232	119	259	156	61
BAL 55	12.61	6.56	0.760	2.12	59.37	13.02	3.63	0.0920	1.45	0.20	129	348	64	78	168	91	304	143	62
BAL 67	12.61	6.61	0.780	2.01	59.59	12.84	3.68	0.0819	1.42	0.19	127	358	80	82	211	102	293	151	59
BAL 51	13.23	6.51	0.810	1.99	58.77	13.46	3.44	0.0996	1.32	0.18	135	320	81	89	208	101	312	145	57
BAL 42	11.33	6.51	0.770	2.05	60.49	12.85	4.16	0.0909	1.40	0.16	146	293	91	81	182	81	312	153	61
BAL 71	13.90	7.15	0.810	1.88	57.38	13.21	3.93	0.1150	1.24	0.19	135	332	61	74	235	108	309	164	61
BAL 53	14.57	6.37	0.770	1.84	58.13	12.54	3.98	0.0870	1.29	0.21	139	442	60	69	220	99	304	159	65
BAL 54	14.14	6.22	0.740	1.93	59.10	12.49	3.78	0.0855	1.08	0.23	132	524	67	73	213	101	285	142	63
BAL 68	13.93	6.13	0.730	1.77	59.75	12.14	3.60	0.0824	1.43	0.23	125	430	47	81	192	93	295	135	62
BAL 70	11.56	6.07	0.750	2.05	62.11	12.68	2.93	0.0774	1.40	0.19	147	357	79	73	175	94	307	137	62
BAL 52	11.55	6.25	0.780	1.84	62.03	11.95	3.79	0.0859	1.36	0.17	155	408	54	73	190	95	294	151	60
BAL 79	14.87	6.14	0.740	2.00	58.97	12.91	2.70	0.0964	1.17	0.20	147	491	79	86	169	104	281	130	60
BAL 45	10.61	6.27	0.790	2.07	61.38	14.10	2.93	0.0786	1.42	0.15	167	296	86	71	177	104	308	122	76
BAL 46	10.74	6.19	0.790	2.22	60.82	14.57	2.68	0.0781	1.32	0.40	150	320	97	70	161	108	321	125	72
BAL 34	8.46	6.27	0.810	2.14	63.48	13.90	3.07	0.0785	1.41	0.17	155	239	94	72	219	140	335	132	70
BAL 47	9.56	6.53	0.810	2.31	61.30	14.68	2.57	0.0711	1.61	0.36	149	274	103	79	177	104	355	139	71
BAL 43	11.11	7.07	0.810	2.34	58.82	14.00	3.82	0.1083	1.55	0.17	153	263	105	70	211	103	371	160	76
BAL 44	8.68	6.07	0.760	1.99	64.14	13.58	2.48	0.0752	1.74	0.30	176	253	77	66	161	96	336	128	62
BAL 65	10.74	6.74	0.800	2.17	60.33	14.05	3.25	0.0845	1.47	0.16	154	283	92	86	194	104	331	143	73
BAL 82	10.49	6.48	0.800	2.02	61.81	13.71	2.81	0.1117	1.36	0.23	150	280	82	89	182	109	327	138	66
BAL 56	11.89	6.87	0.770	2.31	59.37	13.08	3.62	0.0884	1.59	0.21	142	341	91	91	179	100	305	149	67
BAL 48	10.22	6.50	0.790	2.27	61.26	14.32	2.67	0.0732	1.53	0.16	156	294	98	96	172	99	362	135	62
BAL 80	10.42	7.14	0.840	2.30	59.95	14.53	2.58	0.0993	1.46	0.49	159	285	106	98	192	126	355	136	61
BAL 83	9.93	6.26	0.790	2.20	62.10	13.86	2.78	0.0712	1.49	0.32	167	318	92	92	178	87	341	125	51
BAL 81	7.80	6.28	0.830	2.19	64.20	14.49	2.29	0.0669	1.49	0.17	167	267	93	101	172	118	297	127	70
m	11.58	6.50	0.786	2.07	60.41	13.40	3.35	0.0875	1.40	0.22	147	337	82	81	194	103	312	142	64
σ	1.90	0.33	0.028	0.16	1.83	0.79	0.66	0.0126	0.14	0.08	13	72	16	10	24	12	31	12	6
Plaka shipwreck, main group of carrot amphorae																			
BYZ938	9.97	7.71	0.812	1.80	58.99	13.92	5.07	0.1552	1.30	0.11	168	279	68	88	155	80	432	141	77
BZY 40	8.46	7.22	0.817	1.79	61.77	14.01	4.27	0.1911	1.23	0.08	179	261	77	86	152	72	423	146	74
BZY 13	9.02	6.79	0.783	1.93	60.35	13.13	5.96	0.2150	1.58	0.09	157	292	76	86	156	69	433	130	72
BYZ939	10.38	7.64	0.752	1.72	58.17	13.39	6.37	0.1407	1.15	0.12	165	291	68	84	138	76	483	135	73
BZY 38	11.35	7.04	0.781	1.71	57.55	13.58	6.05	0.1944	1.49	0.08	165	327	68	77	145	75	494	137	64
BYZ940	12.81	6.87	0.748	1.76	57.04	13.54	5.69	0.2224	1.06	0.10	161	339	76	91	124	77	458	120	85
BZY 37	11.12	6.77	0.751	1.94	58.77	13.56	5.03	0.1717	1.61	0.10	161	331	71	85	122	81	485	118	83
BZY 42	15.33	6.72	0.724	1.79	56.15	13.05	4.47	0.1736	1.32	0.11	154	355	66	84	122	81	460	117	68
BZY 39	13.69	7.64	0.794	1.71	56.60	13.38	4.44	0.1205	1.36	0.10	166	319	69	77	144	81	424	136	67
BZY 41	11.84	7.75	0.823	1.76	58.23	13.08	4.62	0.1823	1.47	0.09	168	306	64	80	165	79	392	138	65
BZY 1	10.62	7.04	0.831	1.79	59.80	13.18	4.82	0.1121	1.56	0.08	178	300	67	82	178	66	420	141	62
SNO 1	11.89	7.13	0.810	1.72	58.17	14.22	4.38	0.1078	1.20	0.20	167	332	57	75	200	94	373	167	70
BZY 2	13.77	7.12	0.708	1.85	57.25	13.83	3.62	0.1665	1.41	0.12	140	349	67	82	129	75	373	129	91
BZY 5	11.59	6.23	0.728	1.93	58.89	13.25	5.38	0.1808	1.58	0.09	156	348	70	81	123	71	465	118	53
BZY 7	12.60	5.71	0.697	1.79	59.29	12.87	5.30	0.1482	1.36	0.08	169	342	72	80	130	61	459	111	44
BYZ936	12.81	5.65	0.685	1.80	59.15	12.74	5.39	0.1187	1.39	0.10	164	349	62	73	129	61	443	106	59
BYZ937	11.30	6.22	0.703	1.95	59.88	12.88	5.11	0.1005	1.61	0.10	168	309	62	76	116	61	420	106	73
BZY 3	10.76	7.62	0.844	1.89	60.00	13.14	3.88	0.0779	1.55	0.09	176	279	75	79	173	58	411	144	42
m	11.63	6.94	0.766	1.81	58.67	13.38	4.99	0.1544	1.40	0.10	165	317	69	81	145	73	436	130	68
σ	1.71	0.65	0.051	0.08	1.43	0.42	0.75	0.0412	0.17	0.03	9	29	5	5	23	9	36	16	13
Plaka shipwreck, minor group of carrot (?) amphorae																			
BZY154	7.53	8.67	0.826	2.81	57.94	16.15	4.02	0.1435	1.56	0.17	178	267	108	92	152	112	476	136	65
BZY156	6.90	8.48	0.851	2.58	57.95	16.36	5.05	0.1549	1.34	0.17	183	241	102	100	168	117	486	151	71
BZY157	8.65	7.92	0.827	2.83	58.53	16.30	3.00	0.1598	1.45	0.15	180	266	118	96	156	101	514	152	79
BZY155	10.93	7.74	0.807	2.81	57.05	15.85	2.74	0.0946	1.66	0.14	172	288	101	92	146	91	500	131	69
m	8.50	8.20	0.828	2.76	57.87	16.17	3.70	0.1382	1.50	0.16	178	266	107	95	156	105	494	143	71
SNO 2	9.01	7.26	0.850	2.74	59.61	15.53	3.24	0.0875	1.32	0.18	171	272	118	86	207	97	437	179	78
BZY 6	7.79	7.45	0.794	2.91	57.39	16.29	5.32	0.0712	1.68	0.14	167	296	125	103	133	101	312	192	70
BZY 4	10.47	8.43	0.888	1.89	59.26	14.59	3.03	0.2715	0.90	0.10	172	290	95	96	166	86	472	152	87
BZY 8	1.25	8.49	0.999	2.26	66.34	16.97	2.33	0.1397	0.98	0.07									

sample	CaO	Fe ₂ O ₃	TiO ₂	K ₂ O	SiO ₂	Al ₂ O ₃	MgO	MnO (Na ₂ O)	(P ₂ O ₅)	Zr	Sr	Rb	Zn	Cr	Ni	Ba	V	Ce	
Plaka shipwreck, main group of LRA1 amphorae																			
BYZ933	19.89	7.97	0.652	1.80	48.32	12.82	6.27	0.2167	1.71	0.16	112	494	53	88	357	217	239	130	61
BYZ935	20.20	7.76	0.666	1.58	47.16	12.81	7.36	0.1496	1.96	0.17	109	473	41	82	294	204	265	130	62
BZY 53	20.90	8.53	0.716	1.55	47.36	12.24	6.14	0.1466	2.06	0.16	117	435	52	85	621	203	215	133	39
BYZ932	17.80	6.66	0.635	1.85	50.76	11.67	8.45	0.0962	1.72	0.13	135	419	60	74	802	172	242	117	66
BZY 47	19.56	6.36	0.627	1.95	49.04	11.83	8.21	0.1463	1.96	0.12	122	439	76	76	573	201	239	106	71
BZY 49	15.12	6.57	0.658	2.02	52.54	11.94	8.69	0.1052	2.03	0.13	144	353	79	73	405	206	258	111	62
BZY 45	22.88	6.99	0.636	2.07	47.90	12.06	4.94	0.1117	2.06	0.12	124	526	79	76	782	188	238	123	53
BZY 55	15.88	7.79	0.699	1.69	50.29	11.93	9.52	0.1330	1.67	0.15	121	391	64	82	1110	250	222	107	68
BZY 48	18.41	7.17	0.658	2.19	49.87	13.80	5.64	0.0802	1.88	0.12	114	432	97	87	291	240	221	140	72
BZY 10	28.99	5.37	0.568	1.56	45.71	10.73	4.85	0.1648	1.74	0.13	121	640	60	68	282	170	267	89	65
BZY 11	25.84	5.85	0.601	1.52	48.37	10.89	4.52	0.2197	1.85	0.14	130	584	57	69	431	185	300	101	62
BYZ930	26.54	6.40	0.562	2.02	47.01	10.66	4.69	0.3147	1.48	0.15	132	483	62	67	344	164	297	87	77
BYZ931	25.49	6.64	0.628	1.90	47.54	11.54	4.58	0.1845	1.18	0.13	140	419	59	75	456	173	287	90	82
BZY 51	28.80	6.70	0.713	1.33	43.16	11.46	5.20	0.3162	1.93	0.14	131	541	47	75	939	197	340	126	70
BZY 54	17.98	5.90	0.621	1.12	46.72	11.20	14.87	0.1397	1.15	0.12	131	371	40	69	412	202	174	106	64
BZY 9	13.88	6.29	0.663	1.28	51.59	12.06	12.57	0.1139	1.25	0.12	147	359	38	69	527	197	258	108	47
m	21.14	6.81	0.644	1.71	48.33	11.85	7.28	0.1649	1.73	0.14	127	460	60	76	539	198	254	113	64
σ	4.79	0.85	0.045	0.31	2.34	0.83	3.02	0.0706	0.31	0.02	11	82	16	7	249	24	40	16	11
BYZ934	4.14	6.87	0.827	4.69	60.27	17.89	3.91	0.0832	0.96	0.19	208	149	183	116	126	67	483	148	90
BYZ941	6.99	11.34	1.006	2.94	56.00	16.42	3.34	0.1031	1.44	0.25	165	262	104	114	206	78	336	241	71
BZY 56	29.11	6.04	0.630	1.73	44.26	10.44	5.81	0.2412	1.28	0.14	110	529	63	83	1788	219	208	104	87
BZY 43	1.20	9.39	1.109	1.18	67.19	17.52	1.28	0.0494	0.83	0.09	274	127	44	73	119	20	426	246	48
BZY 44	1.36	14.26	1.228	0.86	61.63	18.55	1.18	0.0586	0.67	0.06	192	111	37	76	172	32	251	298	35

Fig. 8 (continued): Chemical compositions of amphorae from Plaka, together with comparative material from Seleucia Pieria and Sinop. Samples are ranked as in the classification (Figure 7, top).

sample	description	CaO	Fe ₂ O ₃	TiO ₂	K ₂ O	SiO ₂	Al ₂ O ₃	MgO	MnO (Na ₂ O)	(P ₂ O ₅)	Zr	Sr	Rb	Zn	Cr	Ni	Ba	V	Ce	
Rhosos/Arsuz, after Picon and Empereur 1989																				
BAL 22	LRA1	13.26	8.24	0.610	1.46	48.43	11.88	14.33	0.1172	1.13	0.12	94	293	46	91	2199	648	243	118	65
BAL 23	LRA1	13.75	8.18	0.580	1.47	48.10	11.45	14.80	0.1239	1.01	0.13	89	310	54	84	1949	672	197	119	66
BAL 21	LRA1	10.52	8.74	0.600	1.56	48.97	11.82	16.26	0.1148	0.91	0.12	85	261	47	85	1701	789	218	121	60
BAL 24	LRA1	12.13	8.44	0.610	1.61	48.29	11.88	15.46	0.1171	0.97	0.14	95	293	50	91	1364	716	237	114	60
BAL 19	LRA1	12.63	8.33	0.610	1.71	49.48	11.98	13.71	0.1164	0.90	0.18	95	306	60	94	1307	711	229	71	63
BAL 9	tile	12.51	8.53	0.550	1.31	47.21	10.69	17.41	0.1189	0.97	0.15	77	291	39	91	3401	859	174	107	56
BAL 31	tile	14.01	8.25	0.560	1.63	47.28	10.91	15.55	0.1273	0.90	0.21	82	320	43	95	3427	740	249	116	57
BAL 28	LRA1	13.23	8.44	0.590	1.16	47.24	11.50	15.96	0.1265	1.00	0.17	88	320	20	86	3572	750	334	111	61
BAL 10	brick	20.42	8.00	0.560	0.93	45.72	9.83	12.69	0.1345	1.07	0.13	86	294	44	94	3308	570	176	136	61
BAL 11	brick	19.65	8.10	0.530	0.92	46.29	9.73	12.87	0.1375	1.16	0.11	75	296	25	82	2873	663	185	125	58
BAL 20	LRA1	8.77	9.26	0.570	1.52	48.12	11.06	19.24	0.1178	0.58	0.13	81	231	45	103	3952	963	185	136	59
BAL 32	tile	11.94	9.05	0.520	1.51	45.81	10.44	18.84	0.1267	0.63	0.15	82	267	37	109	7576	935	238	126	53
BAL 6	LRA1	19.61	6.50	0.660	1.54	51.33	12.47	5.53	0.1371	1.76	0.23	111	431	50	76	407	221	308	115	63
BAL 7	LRA1	22.76	6.43	0.660	1.50	49.05	12.45	5.38	0.1355	1.24	0.18	102	392	52	81	445	231	321	122	57
BAL 5	LRA1	21.17	6.66	0.680	1.41	49.50	12.38	6.15	0.1332	1.50	0.19	115	367	35	80	486	296	299	127	69
BAL 30	tile	20.38	7.19	0.620	1.62	48.12	12.49	7.47	0.1461	1.53	0.19	104	499	61	79	658	336	226	108	64
BAL144	clay	23.32	6.94	0.690	1.42	45.40	12.10	8.03	0.1332	1.56	0.19	101	411	45	82	332	314	211	131	68
BAL145	clay	20.31	6.24	0.650	1.57	50.16	11.72	7.06	0.1159	1.78	0.17	113	390	68	75	610	282	229	116	64
BAL 29	tile	18.18	7.32	0.650	1.77	49.00	13.11	7.76	0.1281	1.70	0.17	112	360	62	89	409	303	229	125	70
BAL 25	LRA1	16.27	8.07	0.730	1.91	48.74	14.42	8.29	0.1000	1.09	0.16	112	359	61	99	292	340	211	120	73
BAL 12	LRA1	18.91	7.02	0.670	1.72	50.65	13.96	5.23	0.0858	1.39	0.12	112	442	69	81	387	255	376	127	77
BAL 8	tile	23.40	6.95	0.580	1.24	44.96	11.05	10.18	0.1177	1.08	0.16	88	363	29	75	1058	393	203	121	59
BAL 13	LRA1	25.43	5.46	0.550	1.56	49.44	11.06	4.71	0.0874	1.34	0.13	104	480	61	62	299	220	505	97	73
BAL 17	LRA1	28.18	5.22	0.560	1.56	48.30	10.56	3.97	0.0888	1.23	0.11	114	436	59	68	485	197	348	93	68
BAL 15	LRA1	21.90	6.13	0.600	2.10	50.04	12.24	5.11	0.0876	1.41	0.12	109	433	84	67	358	292	698	101	79
BAL 16	LRA1	21.02	6.51	0.650	1.67	49.90	12.58	5.41	0.1388	1.72	0.14	106	442	60	81	355	235	602	118	71
BAL 14	LRA1	13.58	6.69	0.680	2.31	55.85	13.37	5.30	0.0943	1.73	0.12	142	416	97	78	389	319	704	110	77

Fig. 10: Chemical compositions of LRA1, tiles, bricks and clays from Arsuz and its surroundings. Samples are ranked as in the classification (Figure 7, bottom). Major and minor elements are given in oxides weight %, trace elements in parts per million (ppm); elements between brackets were not taken into account in the classification.