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Marcin Matera, Merab Khalvashi, Małgorzata Daszkiewicz, Lasha Aslanishvili

A BYZANTINE KILN FOR AMPHORA PRODUCTION AT GONIO-APSAROS (GEORGIA)

Abstract: The location of the production sites of brown-clay amphorae is the subject of lively scientific discussion. So far, it has not been possible to determine with certainty where such amphorae were produced. This paper publishes a kiln for the production of brown-clay amphorae discovered by the Polish-Georgian expedition at Gonio (ancient Apsaros). The kiln was used in the Byzantine period, but at the current stage of research it is not possible to provide a more detailed chronology for this workshop's activity.

Keywords: amphorae, brown-clay amphorae, Colchian amphorae, kiln, archaeometric analysis, production, production centre, Gonio, Apsaros

Brown-clay amphorae were produced for a very long time, from the fourth century BC up to the seventh¹ or even eighth century AD.² These containers comprised one long-lived type divided into four chronological variants and several subvariants.³ Their finds are extremely common on the eastern shores of the Black Sea,⁴ and are also quite numerous on the sites located along the northern Black Sea coast.⁵

Iraida Zeest was the first researcher who typologically identified these amphorae, having only diagnostic fragments coming from Bosporan sites at her disposal.⁶ She believed that the place of their production were centres located on the southern shores of the Black Sea.⁷ Later, Boris Mihlin divided brown-clay amphorae into three types. In his opinion, two of them were produced in the centres of southern Pontus, while the third was produced on the territory of Colchis.⁸ Yuriy Vinogradov and Nadezhda Onajko linked these amphorae with the production of Heraclea Pontica.⁹

Almost at the same time as Zeest's theory, a hypothesis on the production of this type of amphorae in the territory of ancient Colchis was formed by Boris Kuftin.¹⁰ Other Georgian

¹ VNUKOV 2003, p. 160; VNUKOV 2010, p. 29; ОПАИТ 2015, p. 286; EROL, TAMER 2020, p. 527.

² GAMKRELIDZE 2012, p. 91.

³ TSETSKHLADZE, VNUKOV 1992, p. 361; VNUKOV 2003, pp. 160–166; VNUKOV 2010, p. 29; VNUKOV 2011, p. 271; EROL, TAMER 2020, p. 527.

⁴ GAMKRELIDZE 2009, p. 197: 'Colchian amphorae have been discovered in large numbers on settlement sites [...] all over the territory of historical Colchis. There is almost no former settlement site here with such amphorae not coming to light'.

⁵ TSETSKHLADZE, VNUKOV 1992, p. 359.

⁶ ZEEST 1951, p. 114 and p. 115, fig. 7.

⁷ ZEEST 1960, p. 108 and p. 162, tab. XXVI:60. Later, Iraida Zeest agreed with the idea proposed by Georgian archaeologists regarding the Colchian provenance of these amphorae: ZEEST 1967, p. 13.

⁸ MIHLIN 1974, pp. 64–65.

⁹ VINOGRADOV, ONAJKO 1975, pp. 89–90.

¹⁰ KUFTIN 1950, p. 84.

archaeologists, including Ketevan Berdzenishvili,¹¹ Nino Choshtariya,¹² and Otar Lordkipanidze,¹³ have also argued for this possibility, referring to the similarities in the mineral composition of the clay of these amphorae with local pottery, the presence of similar incised marks left by potters in the wet clay wet clay, and the densest concentration of finds in this area.

This hypothesis was accepted by some specialists,¹⁴ although the information on the discovery of the kilns and production centres of brown-clay amphorae in the area of modern Sukhumi (ancient Dioscurias)¹⁵ was not entirely convincing.¹⁶ Despite that, Gocha Tsetskhladze and Sergej Vnukov strongly supported the concept of brown-clay amphorae production in the area of ancient Colchis.¹⁷

Other researchers criticised this concept by pointing to the possibility of producing brown-clay amphorae (depending on the ceramic fabric) in different centres also in the territory of Colchis, e.g. Trapezus.¹⁸

In this light, Irina Kruglikova's observations are very interesting. In her opinion, amphorae corresponding to the morphological features of brown-clay containers defined in Vnukov's typology as Ch IB₂–Ch IC were produced in Gorgippia.¹⁹ The possibility of producing such amphorae in Gorgippia in the first centuries of our era is also considered by Ekaterina Alekseeva.²⁰

Dominique Kassab Tezgör and Mustafa Akkaya mention a similar situation when describing containers from the Samsun Museum, which they called pseudo-Colchian.²¹ In their opinion, these may have come from one of the centres on the southern coast of the Black Sea. Kassab Tezgör and Akkaya mention the area of Borçka, where ceramic production was still present in recent times.²²

In 2002, Merab Khalvashi published information about the ceramic workshop discovered at Gonio (ancient Apsaros) [Fig. 1]. There was a kiln at the workshop, of which only part of the combustion chamber has been preserved. The maximum dimensions of the preserved part were 1.20 × 1.10 m. The kiln was close to circular, built of orthostatic stone slabs. Ceramic wasters, including amphorae, were also discovered near the kiln. According to Khalvashi, this kiln was used for the production of brown-clay amphorae, and dated to the second half of the second century and first half of the third century AD.²³ However its dimensions seem rather too small for amphora production, especially when we take into account that the kiln dome in the firing section was even smaller. The workshop and the kiln was undoubtedly used for producing pottery, but these were probably smaller forms, e.g. tableware or lamps.

New data on the production of brown-clay amphorae were revealed by Polish-Georgian excavations at Gonio. These are conducted in cooperation with the Polish Centre of Mediterranean Archaeology, the University of Warsaw, and the Cultural Heritage Protection Agency of Ajara under the supervision of Radosław Karasiewicz-Szczypiorski.²⁴

¹¹ PUTURIDZE 1977, p. 68 and p. 71, n. 2.

¹² HOŠTARIA 1955, p. 61; after: TSETSKHLADZE 1992, p. 90.

¹³ LORDKIPANIDZE 1966, pp. 137–140; LORDKIPANIDZE 1968, pp. 235–236.

¹⁴ See: TSETSKHLADZE 1992, p. 91, n. 6 with bibliographic references.

¹⁵ TRAPŠ 1969, p. 225; VORONOV 1969, p. 50, no. 85, p. 51, no. 98 and p. 52, no. 112; VORONOV 1977; ŠAMBA 2005, pp. 78–82.

¹⁶ VNUKOV 2001, p. 161; VNUKOV 2012, p. 5; GERASIMOVA 2024, p. 299.

¹⁷ SOZNIK, TSETSKHLADZE 1991; TSETSKHLADZE 1990; TSETSKHLADZE 1991; TSETSKHLADZE, VNUKOV, SOZNIK 1991; TSETSKHLADZE 1992; VNUKOV 1992; TSETSKHLADZE, VNUKOV 1992; TSETSKHLADZE, VNUKOV 1993; VNUKOV 2001; VNUKOV 2010; VNUKOV 2011.

¹⁸ EFREMOV (JEFREMOV) 1994; KAC 2001; 2007, pp. 107–110; 2008; EFREMOV 2011; OPAIŤ 2015.

¹⁹ KRUGLIKOVA 1966, p. 150; cf. VNUKOV 2001, p. 147, fig. 1 and p. 149.

²⁰ ALEKSEEVA 2008, pp. 19–23.

²¹ KASSAB TEZGÖR, AKKAYA 2000; cf. KASSAB TEZGÖR 2002, pp. 205–207.

²² KASSAB TEZGÖR, AKKAYA 2000, p. 134.

²³ KHALVASHI (HALVAŠI) 2002, pp. 16–17; KHALVASHI 2010, p. 33; KHALVASHI, KAKHIDZE 2014, p. 192.

²⁴ For more on the results of the Polish-Georgian research, see: MISIEWICZ, KARASIEWICZ-SZCZYPIORSKI 2012; KARASIEWICZ-SZCZYPIORSKI 2016; KARASIEWICZ-SZCZYPIORSKI *et alii* 2016; MAMULADZE *et alii* 2016; KARASIEWICZ-SZCZYPIORSKI 2018; KARASIEWICZ-SZCZYPIORSKI, MAMULADZE 2019; MAMULADZE, KAMADADZE 2019; ŁĘCZYŃSKI *et alii* 2021.

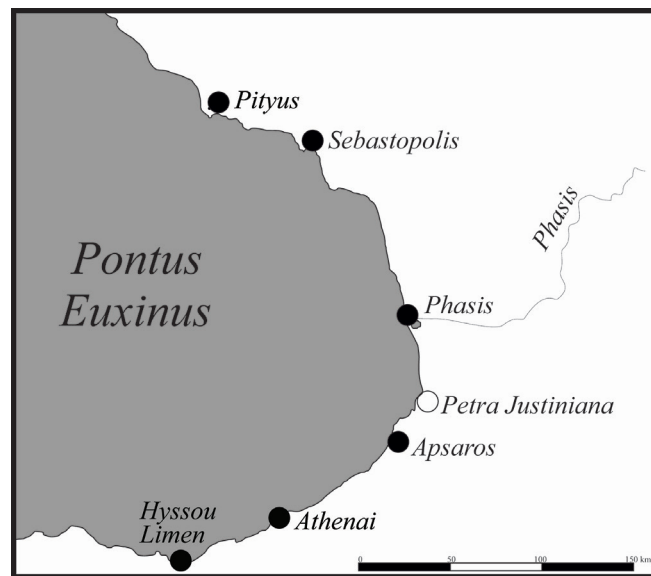


Fig. 1. Map of the eastern shores of the Black Sea, showing the location of Gonio/Apsaros and other Roman forts from the Principate period. Confirmed sites are marked as black dots, presumed locations are in white. Drawing by O. Kubrak

An important achievement of this joint work is undoubtedly the new perspective gained from refining the chronology of the history of Roman military presence in this place, showing periods of intensive occupation of the fort that correspond with the main building phases at the site.²⁵

Earlier, a general scheme for the chronology of the site had been proposed in the publication of the results of the Georgian-German expedition²⁶ and in the publications of Georgian archaeologists.²⁷ According to this scheme, the Roman garrison at Apsaros was already functioning in the 60s AD, probably right after the annexation of Polemon's Pontus by the Roman Empire.²⁸ The next two phases of lively activity occurred during the reign of Trajan and then Hadrian. The decline and abandonment of the fort seems to have been linked with the Boranoi raiding of the Colchian littoral in the 250s AD.²⁹ The traces of violent conflagration at Apsaros are almost certainly the result of the second Boran invasion,³⁰ dated to AD 257/258.³¹ Very little is known about the later period. The written and archaeological sources confirm that a Roman army was no longer stationed at Apsaros.³² Over this entire later period, the army units stationed at Apsaros changed;³³ however, apart from a few periods of intensive occupation of the fort, the garrison must have been extremely small.³⁴ So far it has been impossible to establish whether there were any gaps when the garrison changed, and if so, of what possible duration.³⁵

²⁵ JAWORSKI 2021; JAWORSKI, KARASIEWICZ-SZCZYPIORSKI, MAMULADZE 2021; KARASIEWICZ-SZCZYPIORSKI *forthcoming*.

²⁶ PLONTKE-LÜNING 2003, pp. 8–9 and pp. 11–16.

²⁷ E.g. KAKHIDZE 2008, pp. 304–314.

²⁸ KARASIEWICZ-SZCZYPIORSKI *forthcoming*.

²⁹ Zos., *Hist. nova* 1.31–33; KAKHIDZE 2008, p. 313.

³⁰ KARASIEWICZ-SZCZYPIORSKI *forthcoming*.

³¹ See: MYZGIN, DIDENKO 2021, p. 318 with literature on the discussion of the date of the second Boran invasion.

³² KARASIEWICZ-SZCZYPIORSKI *forthcoming*.

³³ On the units stationed at Apsaros, see: KARASIEWICZ-SZCZYPIORSKI, MAMULADZE, SPEIDEL 2021; cf. MAMULADZE, KHALVASHI (HALVAŠI), ASLANISHVILI (ASLANIŠVILI) 2002; KHALVASHI, ASLANISHVILI, KAKHIDZE 2018.

³⁴ JAWORSKI 2021, pp. 133–134; JAWORSKI, KARASIEWICZ-SZCZYPIORSKI, MAMULADZE 2021, p. 292.

³⁵ KARASIEWICZ-SZCZYPIORSKI, MAMULADZE 2019, pp. 67–68; KARASIEWICZ-SZCZYPIORSKI *forthcoming*.

A new chapter in the history of Apsaros begins in the Byzantine period. The written sources of that time, relating to the history of the site, are quite contradictory.³⁶ However, researchers generally agreed that it was not rebuilt before the second half of the sixth century AD.³⁷ However, Tamaz Darchidze draws attention to the fact that when the people of Lazica revolted against the Persians in AD 549 and asked the Byzantines for help, the answer came relatively soon.³⁸

During the Middle Ages, the name of the town was changed to the one used today: Gonio. In the opinion of Fedor Uspenskij, this name appeared no earlier than the twelfth century.³⁹ It certainly appears in the fourteenth-century *Chronicle* by Michael Panaretos, and on nautical maps from the thirteenth to sixteenth centuries.⁴⁰ In the second half of the sixteenth century, Gonio was captured by the Ottomans.⁴¹ An garrison and military administration were stationed there. In 1878, as a result of the Russo-Turkish War, Gonio was annexed by the Russian Empire, which at that time occupied the territory of Georgia.⁴²

In the last three years of archaeological research at Gonio, five kilns for ceramic production have been discovered during the excavations in Sectors NO 2 and NO 12. In these sectors, remains of *principia* built in Trajan's time and a building with an apse, dating most probably to the time of Justinian, have been located [Figs. 2–3]. Four of the kilns (numbers 1, 3, 4, and 5) should be dated

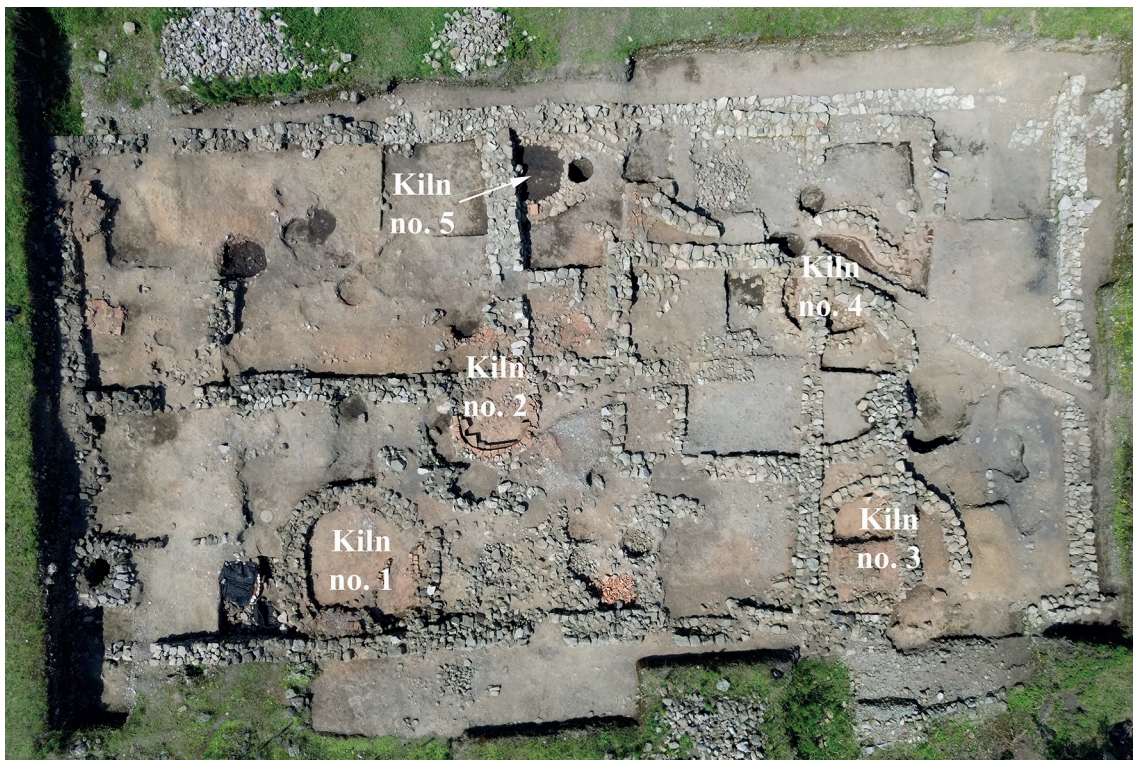


Fig. 2. *Principia*, building with an apse, and amphora kilns in Sectors NO 2 and NO 12. Aerial photography. Photo by F. Szemiet

³⁶ USPENSKIJ 1917, pp. 166–167; LEKVINADZE 1961, pp. 227–228; PLONTKE-LÜNING 2005, pp. 134–135; KAKHIDZE 2008, p. 314.

³⁷ JAWORSKI, KARASIEWICZ-SZCZYPIORSKI, MAMULADZE 2021, p. 292.

³⁸ DARCHIDZE 2024, p. 24.

³⁹ USPENSKIJ 1917, p. 167.

⁴⁰ PLONTKE-LÜNING 2005, p. 135.

⁴¹ For more on Gonio in the Ottoman period, see: KAKHIDZE, IBRAHIMZADE, VARSHANIDZE 2023.

⁴² LEKVINADZE 1961, pp. 229–230; KAMADADZE 2018, p. 261.

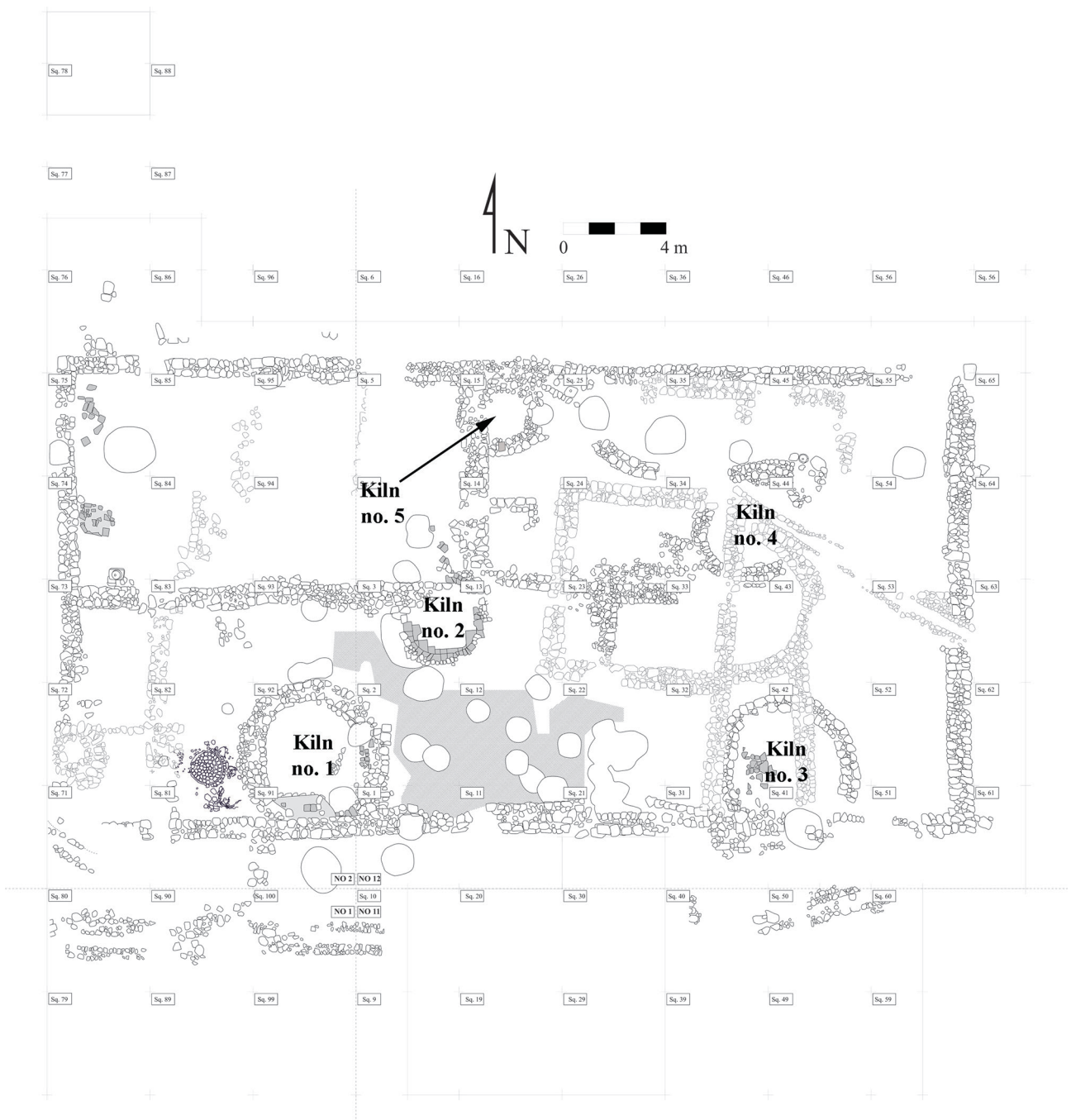


Fig. 3. *Principia*, building with an apse, and amphora kilns in Sectors NO 2 and NO 12.
Plan. Drawing by M. Marciniak

to the period preceding the construction of the *principia* in Trajan's time.⁴³ Kiln number 2 was a later construction [Figs. 4–5], as evidenced by the fact that it partially destroyed the western wall of the above-mentioned building with an apse.



Fig. 4. Kiln number 2. View from the north. Photo by M. Matera



Fig. 5. Kiln number 2. Plan. Drawing by A. Deptuła

⁴³ These kilns will be the subject of a separate publication.

Only the lowest part of this kiln, constituting its foundations, and part of the combustion chamber have been preserved. It was built on a stone foundation of height *c.* 0.65 m [Fig. 6]. Its form was close to circular, with a maximum diameter of 3.40 m. The upper part of the kiln was built from recycled bricks and roof tiles [Fig. 7]. Bricks had probably also formed the bottom of the combustion chamber; however, they were later destroyed. The entrance, which also acted as the stoking vent, was probably located at the south-west. Its width was 0.40 m. There was a layer



Fig. 6. Stone foundation of kiln number 2. Photo by M. Matera



Fig. 7. Upper part of kiln number 2. Photo by M. Matera

of stones and pebbles below the floor of the combustion chamber, which constituted the substructure layer inside the kiln [Fig. 8]. The width of the kiln walls was approximately 0.40 m. Inside the kiln, waste remains from production were recorded [Fig. 9]. They belonged to brown-clay amphorae. Unfortunately, only non-diagnostic fragments were recovered, which do not allow for a closer consideration of the typology of the containers produced at Apsaros. Taking into account that the kiln was functioning in the Byzantine period, these were probably amphorae of the Ch ID type. The poor state of preservation of the kiln does not allow for any conclusions to be drawn about the construction of the dome or the perforated floor separating the firing and combustion chambers. There are also no data that would allow us to even approximately estimate the production capacity of the kiln, and thus to mathematically calculate how many amphorae could have been fired in it at one time.



Fig. 8. Layer of stones and pebbles below the floor of the combustion chamber inside kiln number 2. Photo by M. Matera



Fig. 9. Waste remains of production inside kiln number 2. Photo by M. Matera

Despite the discovery of the kiln for brown-clay amphorae, many issues concerning their production still remain unresolved. This applies both to the activity of the workshop at Apsaros, and to the broader problem of the location, chronology, typology, etc. of production of this type of amphorae. Unfortunately, we cannot say anything about the organisation of production, as only the remains of the kiln were recorded. There are also no data on the length and intensity of its use. Therefore, nothing can be said about the scale of production. At the current stage of research, it is not possible to establish the exact chronology of the activity period of the workshop and the kiln.

Although everything indicates that Apsaros was a local centre of amphora production in Roman and Byzantine times, at present, however, we are unable to distinguish any features that would allow us to identify the products of this centre within the general corpus of Colchian amphorae. Unfortunately, many other questions will also remain unanswered, as there is a lack of data to answer them. Considering the fact that the production of amphorae took place before the construction of the *principia* on the one hand, and after the end of the functioning of the building with an apse on the other, it did not have to be related to the presence of the army.

The mere discovery of brown-clay amphorae kilns in Gonio does not rule out the possibility of their production in other places. Apsaros could have been, and likely was, one of many sites where such amphorae were produced.

A sample was taken for laboratory analysis from one of the amphorae found in kiln number 2 (laboratory number MD8133). This sample was analysed at the same laboratory as the samples taken from ceramic building materials (CBM) used in the construction of the fort at Apsaros, as well as four Colchian amphorae sherds (found within the confines of the fort, but not in association with any of the kilns) and fine ware vessels.⁴⁴

The aim of this analysis was to determine whether the chemical and phase composition of the amphora fabric from kiln number 2 is analogous to the Apsaros (Aps) reference group or to any local or regional clay mineral reference groups. Figure 10 shows a cross-section through the amphora wall, taken perpendicular to the vessel's main axis both before and after refiring at 1100, 1150, and 1200 °C [Fig. 10]. The matrix of the original sample was brownish-orange,⁴⁵

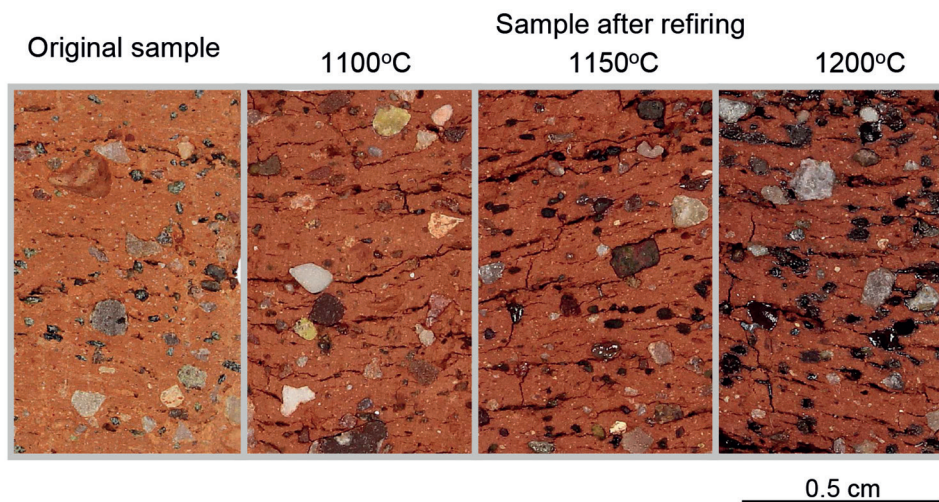


Fig. 10. Sample MD8133. Cross-section through amphora wall, taken perpendicular to the vessel's main axis both before and after refiring at 1100, 1150, and 1200 °C.

Prepared by H. Baranowska

⁴⁴ KARASIEWICZ-SZCZYPIORSKI *et alii* 2018.

⁴⁵ 7C7 in *Methuen Handbook of Colour*: KORNERUP, WANSCHER 1967.

and after refiring at 1200 °C it changed colour to a brownish-red.⁴⁶ This is an SN-type matrix,⁴⁷ which means that the clay fraction of the ceramic body was dominated by clay minerals of the kaolinite group. Inclusions of rock fragments (feldspar, intergrown quartz), plagioclase, weathered feldspars, hornblende and other iron-rich silicates, a few silt-sized grains of quartz, and very fine iron-rich inclusions can be observed in thin section [Fig. 11]. Elongated pores (up to *c.* 1.5 mm long), partially filled with uncombusted organic matter, are also observed.

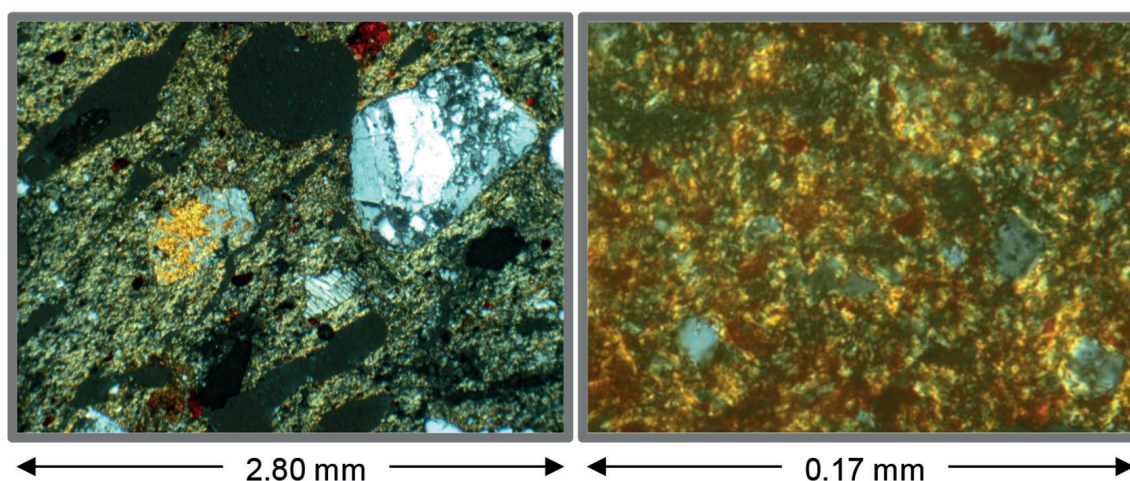


Fig. 11. Sample MD8133. Thin section, Photomicrographs, crossed-polarisers.
Prepared by M. Daszkiewicz

The chemical composition of the amphora from kiln number 2 is shown in Table 1. The chemical composition of this amphora differs significantly from that of the clay daub sample from the fort at Apsaros, as well as from the chemical composition of local and regional clay raw materials [Tab. 1]. Taking into consideration both the firing test results of the clay raw materials and their chemical composition, the analysed amphora from kiln number 2 was not made from any of the currently known clay raw materials (even if one takes into account the possibility of the raw materials having undergone technological processing, such as slurring and/or tempering with non-plastic particles).

Comparison with the results of analyses performed on CBM samples, fragments of four Colchian amphorae (not associated with any kiln) and fine ware vessels, as well as fine wares analysed in Leiden by Andria Rogava⁴⁸ showed, as expected, that the pottery was made from different raw materials to those used for the CBM.

The results of discriminant analysis, taking into account the content of Si, Ti, Al, Fe, Mn, Mg, Ca, Na, K, V, Cr, Ni, Cu, Sr, Y, Zr, and Ba,⁴⁹ show very good discrimination between these two categories of ceramics and clay raw materials [Fig. 12].

⁴⁶ 9C8 catalogue as above.

⁴⁷ Sintered matrix type (SN) = the sherd is well compacted; it may or may not become smaller in size in comparison to the original sample, whilst its edges remain sharp.

⁴⁸ ROGAVA 2016.

⁴⁹ Zn, Rb, Nb, and Ce levels are not included, as the concentration of these elements was not determined for the fine ware analysed by A. Rogava.

Lab. No.	SiO ₂	TiO ₂	Al ₂ O ₃	Fe ₂ O ₃	MnO	MgO	CaO	Na ₂ O	K ₂ O	P ₂ O ₅	V	Cr	Ni	Cu	Zn	Rb	Sr	Y	Zr	Nb	Ba	La	Ce	Pb	I.o.i. %	
Colchian amphora, kiln No. 2																										
MD8133	68.22	1.29	15.08	8.00	0.047	2.06	3.03	0.52	0.67	1.07	164	241	30	65	63	48	97	22	229	19	272	<5	29	38	4.67	
clay daub*																										
MD215	53.40	1.10	21.43	11.48	0.178	4.42	4.15	1.47	1.83	0.55	313	192	67	158	107	52	385	23	107	5	433	15	36	16	1.07	
clays collected in the area of the fort of Apsaros**																										
MD7534	52.32	1.31	23.78	12.12	0.108	4.49	3.19	0.84	1.49	0.34	447	157	68	220	144	42	354	26	92	4	413	18	48	17	15.13	
MD7532	50.47	1.36	22.30	13.69	0.119	5.51	3.98	1.01	1.23	0.32	491	249	92	204	112	38	296	24	94	5	333	<5	43	11	9.21	
MD7533	56.47	1.18	23.72	11.38	0.142	2.59	1.53	1.12	1.54	0.33	315	173	66	212	99	51	238	33	125	6	553	52	72	17	9.39	
MD7531	57.50	1.12	22.63	10.06	0.088	2.65	2.74	1.15	1.72	0.35	273	157	55	198	111	66	228	29	118	6	450	46	45	23	8.43	
MD6728	54.04	1.14	25.95	11.36	0.104	2.79	1.59	0.78	1.69	0.55	337	140	55	194	106	46	272	28	113	10	435	26	48	15	14.20	
MD6727	52.12	1.28	27.49	11.04	0.094	3.01	2.13	0.69	1.63	0.52	342	144	74	226	121	31	205	27	100	14	659	5	11	13	11.19	
MD7535	51.40	1.25	25.31	13.53	0.177	3.55	2.24	0.67	1.48	0.39	373	131	65	235	114	44	289	26	101	5	452	11	63	14	11.36	
MD7536	52.39	1.24	25.01	13.41	0.124	3.56	1.46	0.79	1.76	0.26	367	139	68	257	117	51	271	29	98	5	468	35	62	7	9.40	
MD7529	54.55	1.21	22.95	13.10	0.112	3.29	2.03	1.03	1.32	0.41	360	182	69	234	120	41	243	30	113	6	392	23	57	56	9.51	
MD7530	51.81	1.29	24.84	14.90	0.141	3.11	1.34	0.77	1.48	0.32	362	150	78	247	115	48	210	27	113	7	479	47	49	13	9.87	
clays collected in the vicinity of Apsaros*																										
MD5942	50.10	1.77	28.02	15.65	0.144	2.10	0.50	0.15	1.39	0.19	504	169	85	199	132	61	143	22	141	12	426	33	39	13	12.08	
MD5943	47.96	1.63	28.21	16.50	0.128	2.76	0.85	0.22	1.44	0.30	486	128	77	206	128	50	137	29	121	9	468	30	44	15	10.64	
MD5940	51.02	1.47	24.74	16.68	0.154	1.89	0.41	0.09	3.31	0.24	438	392	83	186	116	99	309	20	123	10	758	38	25	14	9.16	
MD5941	55.07	1.56	28.50	13.09	0.038	0.79	0.08	0.00	0.76	0.11	330	163	73	192	88	64	64	29	229	20	179	38	66	21	11.20	
MD5784	58.75	1.49	23.73	12.28	0.109	1.28	0.64	0.14	1.15	0.43	380	220	79	118	83	90	90	20	234	21	228	40	47	22	9.03	
MD5939	56.80	1.59	26.04	12.96	0.222	1.03	0.08	0.06	1.04	0.18	348	263	143	154	105	81	67	23	247	24	262	41	85	30	10.06	
MD5944	47.41	1.51	32.07	16.44	0.097	1.58	0.00	0.01	0.64	0.25	426	150	54	264	92	39	39	55	108	5	188	31	56	8	12.23	
MD6176	44.44	1.73	32.02	19.00	0.228	1.73	0.09	0.01	0.46	0.29	546	333	470	491	111	26	56	37	101	6	249	49	57	15	12.87	

Tab. 1. Results of chemical analysis by WD-XRF, analysis of melted samples after loss on ignition (l.o.i.) at 900 °C. Content of major elements calculated to oxides and normalised to 100%. * = published in KARASIEWICZ-SZCZYPIORSKI *et alii* 2018, p. 509; ** published in KARASIEWICZ-SZCZYPIORSKI *forthcoming*, appendix 15. Prepared by M. Daszkiewicz

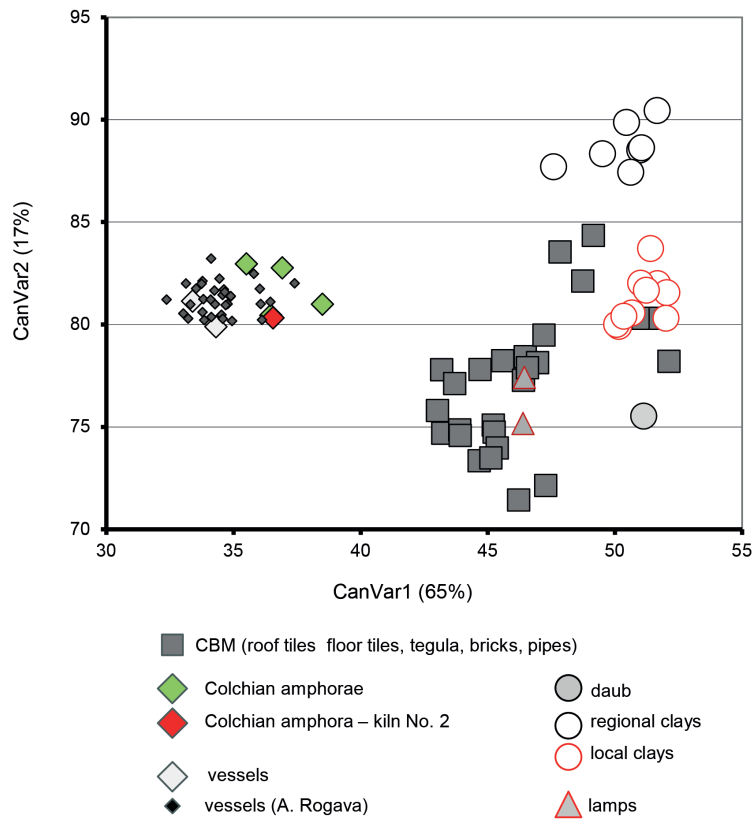


Fig. 12. Results of discriminant analysis using concentrations of Si, Ti, Al, Fe, Mn, Mg, Ca, Na, K, V, Cr, Ni, Cu, Sr, Y, Zr, and Ba. Prepared by M. Daszkiewicz

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