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Four centuries of cooking wares at Priene: Tracing transformation in supply and trade patterns in western Asia minor (Turkey)

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ABSTRACT

This paper presents the results of a diachronic and multidisciplinary investigation into the production and consumption of cooking ware in the ancient city of Priene (Turkey). Three major chronological horizons are considered, covering the fourth to the first century BCE: the late Classical/early Hellenistic period, the middle Hellenistic period, and the late Hellenistic/early Roman Imperial period. Following a thorough typological and macroscopic study of fabrics, an integrated analytical approach combining petrography and elemental analysis (wavelength dispersive X-ray fluorescence) was applied to investigate the main macroscopic types and fabrics that characterised cooking wares. Integration of the results from the typological study with the subsequent analyses of 90 representative samples has provided high-resolution insights into cooking ware production and consumption at Priene over the study period. In addition to tracing transformations in local and regional manufacture over time, the results show that cooking wares were imported to the city from several places and, moreover, at a scale at least equivalent to that for other categories of ceramic vessels at that time. Changes in the manufacturing technology of local and regional products and the origin of imports are discussed in the context of significant historical developments that took place in this region over the period covered by the study.

1. Introduction

The last decades have seen increasing interest in using material culture to investigate ancient economies, both complementing and expanding the picture presented by the historical sources (Bresson 2016; Jones 2014; for the lack of information regarding the trade of pottery specifically, see also Stissi 2002:320–24). Amongst the material remains from the Greek and Roman eras that can be investigated for this purpose, pottery products hold a special position for several reasons. Firstly, pottery is durable and often the most abundant material found during archaeological fieldwork. Further, ceramic vessels are a well-known trade commodity—serving either as containers (e.g., amphorae) for the product traded, or as products in their own right (e.g., fine wares or cooking wares)—and were often transported over vast distances across the Mediterranean (cf. Briese and Vaag 2005; Fenn and Römer-Strehl 2013).

Fine wares and transport amphorae usually attract the most attention in such pottery-based studies, and the mechanisms behind their trade are relatively well understood. More recently, other types of utilitarian wares, specifically cooking wares, have begun to receive attention (e.g., Spataro and Villing 2015 and literature therein). These are often neglected in investigations of Greek and Roman trade networks due to an implicit assumption that they were predominantly locally produced (e.g., Edwards 1975:117) or that their role within ancient trade networks was rather insignificant. However, through time and at different locations across the Mediterranean, several well-known production centres specialised in the manufacture of cooking wares, distributing their products widely in different periods (Borgers et al., 2017 and literature therein). Systematic fabric studies of pottery assemblages from well-connected sites suggest that in many instances, a considerable proportion of cooking wares may have been imported

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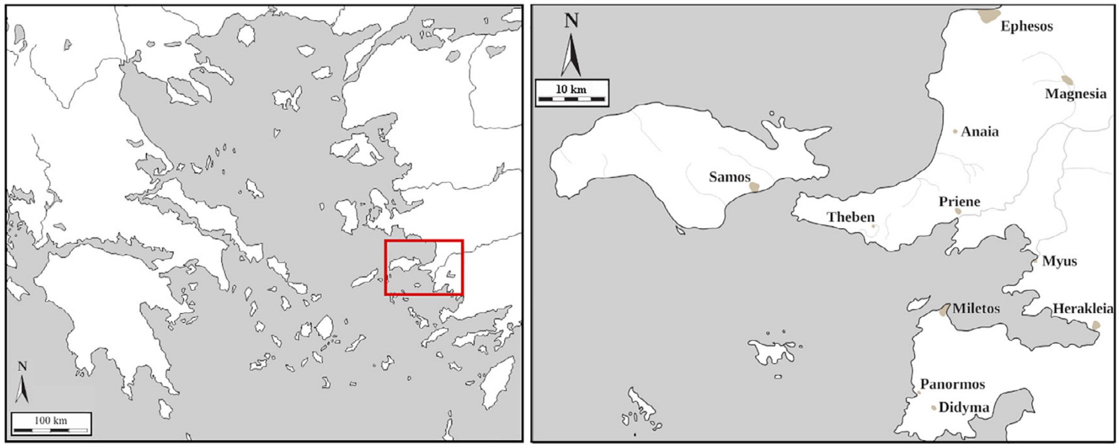

Fig. 1. Location of Priene in western Asia Minor (left) and on the Latmian Gulf, with the estimated shoreline of the Classical/Hellenistic period (right). (Lars Heinze; colour on the web and black and white in print).

from outside the region. In the case of the Athenian Agora for example, macroscopic studies (Rotroff 2006:61–65, 2015) attest that cooking pottery occurred in a variety of different fabrics and throughout time included varied numbers of imported vessels, as well as vessels that could have been produced by migrant potters, as suggested by Klebinder-Gauß and Strack (2015). The increased interest in cooking wares over the last decades led to an intensification of studies integrating material analysis (e.g., Spataro and Villing 2015 and literature therein). These have showcased the great potential of research on these everyday items to contribute to our knowledge of ancient societies by helping to trace both networks of distribution and exchange and the movement of ideas, traditions, and people (e.g., Cau Ontiveros et al., 2019; Klebinder-Gauß and Strack 2015; Müller et al., 2015; see also the various articles deriving from the Late Roman Coarse Ware conferences since 2002).

In this article, we investigate the cooking wares produced and consumed at Priene in western Turkey (Fig. 1), a Greek city-state that, due to its extended excavation history, is of crucial importance for the understanding of socioeconomic developments within Asia Minor. The archaeological investigations at Priene (cf. Raeck 2020) have unearthed large portions of the ancient settlement and revealed an exceptional stratigraphic sequence of deposits spanning from the late Classical to the early Imperial Roman period. The rich material culture from this site offers an opportunity to trace developments in production and consumption of cooking wares over four centuries (mid-fourth to mid-first century BCE). Preceding research at the site (Amicone et al., 2014; Fenn 2016; Heinze, in press; Neumann 2012) has indicated that a significant proportion of the cooking wares found at Priene was potentially imported.

In this study we aimed to trace the provenance of imported vessels and to identify changes in their origin over time. In addition, we explored phenomena of continuity and change in the local and regional production of cooking wares at Priene. In the context of the present study, the term *local production* refers to that taking place at Priene or its *chora*, while *regional production* indicates that taking place in the lower Meander Valley region of the former Latmian Gulf or, more broadly, in an area around Priene characterised by similar geological formations.

Thin section petrography and elemental analysis were applied to a carefully selected set of samples to identify and characterise the ceramic fabrics of cooking wares consumed at Priene over the span of nearly half a millennium. Analytical results were integrated with archaeological data to examine the relationship between local and non-local products, allowing us to present the results within the broader social context of that period.

1.1. *Archaeological and historical background*

While the exact location of the Archaic city of Priene is unknown, the later settlement, founded during the fourth century BCE, lies on previously uninhabited land on the southern slope of the Mykale Mountains (Figs. 2 and 3). In western Asia Minor, the middle of the fourth century BCE was marked by tension between the emerging Macedonian Kingdom and the Persian Empire, a conflict that culminated in the latter being conquered by the young Macedonian king Alexander the Great during the third quarter of the fourth century BCE. Priene was established as a new city around the time of this conquest, and Alexander himself is prominently mentioned in the dedication inscription at the temple of Athena Polias, the city's central sanctuary (Rumscheid 1998).

This scenario provides an important terminus post quem of ca. 350/330 BCE for all the material found at the site (Heinze in press; Prillwitz 2020). The urban development of the city up until the early to the middle Imperial Roman period is well understood, thanks to large-scale excavations that took place during the late nineteenth century (Wiegand and Schrader 1904) and to ongoing investigations that began in 1998 (for an overview, see Raeck 2020).

The excavations carried out over the last two decades have provided a vast number of stratified and well-dated contexts spanning the period from the city's foundation until the early Imperial Roman period, and many of these contexts have been subjected to thorough material studies by multiple ceramic specialists (Fenn 2016; Heinze 2006; 2020; in press; Junghans 2015; Neumann 2012; Picht 2012; Yilmaz 2020).

1.2. *Geomorphological and geological background*

The late Classical city of Priene is situated within the Menderes Massif at the mouth of the Meander River (modern-day Büyük Menderes). The Menderes Massif (Bozkurt and Oberhänsli 2001:Fig. 1; Régnier et al., 2007) is derived from the collision of the African and Eurasian tectonic plates towards the end of the Tertiary period. The Meander River later made its way through one of the larger rift valleys formed by this process (Müllenhoff 2005:17–23).

The river valley (Fig. 3) is flanked to the north by the Mykale Mountains (modern-day Dilek Dağı or Samsun Dağları), which protrude to the west as a narrow peninsula towards Samos (Gödecken 1984:261–64). The city of Priene is located on the southern slope of the mountain range, facing south towards the Latmian Gulf, with line of sight to the neighbouring city of Miletos. The constant silting of the river mouth has pushed the sea back about 30 km since Archaic/Classical times, so the former Latmian Gulf has now been replaced by the alluvial silt of the Meander River delta.

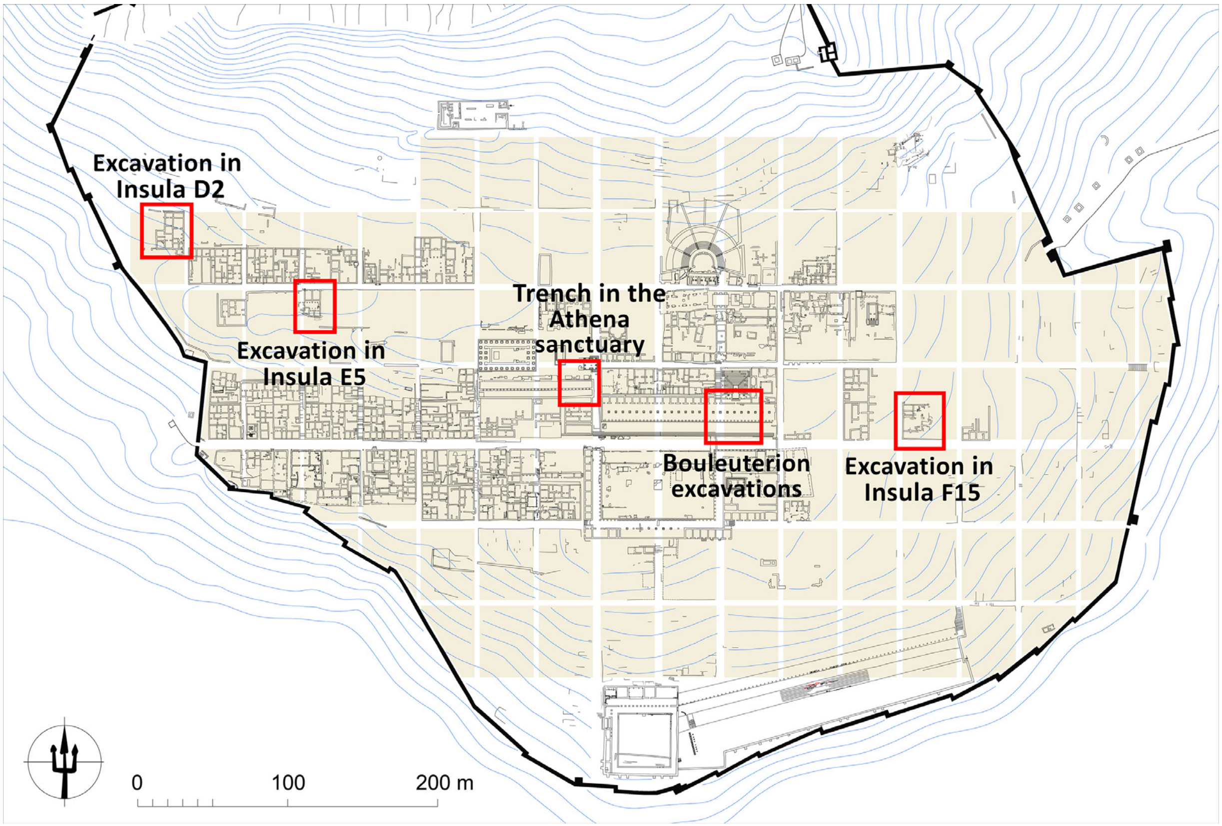

Fig. 2. Plan of the excavated areas of Priene with the location of contexts considered in this study. (Courtesy of U. Mania; colour on the web and black and white in print).

The Mykale Mountains are generally characterised by marble, which forms the outermost part of the Menderes Massif and covers a metamorphic formation consisting of schist (chlorite schist, epidote schist) and gneiss (Fig. 4). At Priene itself, the southern slope of the Mykale Mountains forms a steep cliff, called the Teloneia, which has been incorporated into the city's fortifications. This formation consists of marble, with mica-schist emerging towards the mountain foot. Marble has been used extensively for the construction of buildings throughout the city.

The Söke basin occupies the area to the east of the Mykale Mountains and comprises young tertiary freshwater deposits. It consists of a coarse conglomerate covered by fine grey marly limestone deposits marked by freshwater mussels and lignite layers. Above this is a layer of grey sand with limestone, into which volcanic rock formations (andesite and dacite) are embedded.

The area to the south of the Meander Valley is bounded by two parallel mountain ranges: the Latmos, consisting mostly of granite, and the Grion, which is formed mainly of marble and mica-schist. Towards the west, a tertiary basin forms the land mass where both Miletos and Didyma are located. This platform comprises alternating layers of tufa, white limestone, and clayey or calcareous sandstone, with occasional deposits of volcanic tuff.

1.3. Contexts and chronology

1.3.1. Contexts of the fourth–third centuries BCE

The earliest known deposits in Priene comprise large amounts of well-stratified pottery deriving from fills below the later Hellenistic *bouleuterion* and below two excavated houses in the western (Insula D2) and eastern (Insula F15) quarters of the city (Fig. 2). These three contexts have been investigated by L. Heinze (in press), who suggests that the material found in these levelling deposits might derive from domestic contexts belonging to the earliest decades of the newly founded city. Cooking wares consistently formed about 10% of the diagnostic sherds within these early contexts, providing more than 100 vessels and devices for the present investigation.

It can be assumed that cooking pots found in these earliest layers included vessels brought from the original settlement, as well as newly acquired ones. Since cooking vessels are generally used for only a limited time (Tani and Longacre 1999), it can be expected that even the older pots were not produced much earlier than the foundation of Priene in the middle of the fourth century BCE.

Based on the datable material (e.g., Attic fine ware), the group of contexts from beneath the *bouleuterion* (Bu 4, Bu 6, Bu 7) and the deposit in Insula F15 (F15/11) have closing dates of around 300 BCE or slightly thereafter, while the material from Insula D2 (D2/22) seems to reach further into the third century BCE, probably ending towards the middle of that century. If treated as one horizon, these contexts represent the development of cooking wares within the first century of the new settlement (mid-fourth to mid-third century BCE).

The range of cooking vessels and devices reflects the full spectrum expected of late Classical and early Hellenistic cooking wares (Fig. 5). Cooking pots occur as deep (*chytrai*) and shallow (*lopades*) vessels—each with two different typological subsets—and are found next to a variety of pans (Fig. 5h–i). Cooking stands (*lasana*) and, less frequently, shallow grilling trays (*escharai*) are found in place of the large portable braziers known from later periods. All these vessels range from fine to coarse in their macro fabrics and are often difficult to classify in the hand.

1.3.2. Contexts of the second century BCE

In the middle of the second century BCE, large parts of the western quarters of the city were destroyed, most likely in the aftermath of an earthquake that destabilised huge boulders from the steep gradient of the Teloneia in the northern part of the city (Raeck 2020; Rumscheid 2015). Many of the buildings that were hit during this

Fig. 3. Map showing the silting evolution of Miletos Bay due to alluvium brought by the Meander River during antiquity. (Courtesy of Eric Gaba/Wikimedia; colour on the web and black and white in print).

event were later abandoned, preserving at least some of the destruction layers in these quarters. In recent years, a team led by F. Rumscheid re-examined the western city quarters (Fig. 2) and excavated an undisturbed domestic context and its destruction horizon in Insula D2 (Rumscheid 2003; 2014). It contained a rich assemblage of ceramic vessels that were used by the owners of this house up until its destruction in around 140/130 BCE, providing a closely dated range of vessels spanning one or two decades around the middle of the second century BCE. The cooking ware assemblage from this context has been investigated by S. Neumann (2012) and will be presented in its entirety as part of future publication on the insula. About 200 cooking vessels and braziers from this context were studied; almost 30 have been preserved to such a degree that there is no doubt that they were found in situ at the final location in which they had been used before the destruction and abandonment events.

Cooking wares and kitchen utensils were found in almost all excavated rooms, although they were more abundant in those where cooking activities were attested. A surprising result of the investigation was the large array of shapes and macro fabrics that were apparently in use at the same time, as revealed by the "snapshot" nature of this destruction deposit, which captured a moment in the life of this house.

The range of shapes, including *chytrai, lopades,* and pans (Fig. 5), is similar to that found in contexts of the fourth and third centuries BCE, but certain morphological changes to some of the vessel types can be observed. The necked *chytrai* (Fig. 5b) that are common in contexts from the first 100 years after the city's foundation are replaced by the so-called Phokaian type of cooking pots and pans (Fenn 2016:154–57). Phokaian-type *chytrai* and *lopades* (Fig. 5c and g) have very thin walls, and both are marked by more articulated rims that enable precise rim fitting.

Phokaian pans (Fig. 5j) have an angular profile with a straight rim and smoothed inner surface. The set of pans found in Insula D2 is complemented by deep pans, often with a flanged rim or a narrow groove on top of the rim, a feature known from *orlo bifido* pans originating in the western Mediterranean (Berlin 1993; Rotroff 2006:192–93). There are no *lasana* and *eschara* found in this context. Instead, a wider range of braziers (e.g., Fig. 5n–o) is attested, including the horseshoe type (Rotroff 2006:220–21) and braziers combined with grill platforms similar to the Bakalakis type (Bakalakis 1934; Rumscheid 2008).

1.3.3. *Contexts of the first century BCE/First century CE*

The transition of cooking ware shapes and macro fabrics from late Hellenistic to early Imperial Roman times can be better understood by exploring two substantial contexts (Fig. 2) studied by N. Fenn (Fenn 2016), both of which represent levelling fills. The earlier of the two originates from the southern stoa of the sanctuary of Athena Polias. The small trench at the south eastern end of the stoa was densely packed with pottery, 10%–15% of which consisted of cooking wares. Despite being found within the sanctuary, the pottery from these levelling fills seems to derive entirely from domestic contexts and, based on the associated fine wares, can be dated primarily to the late second century and the first half of the first century BCE (Fenn 2016). The range of pottery used for cooking shows interesting continuities when compared to that of the assemblage recovered from the destruction layer in Insula D2. *Chytrai, lopades*, and pans appear as two distinct subtypes: the Phokaian type and local/regional products (Fig. 5), both having clearly distinguishable macro fabrics (Fenn 2016). Phokaian-type products are strongly represented amongst *chytrai* and *lopades*, and Phokaian pans seem to dominate the Prienian market. There is also a large number of braziers of the well-known and often richly decorated Aegean type

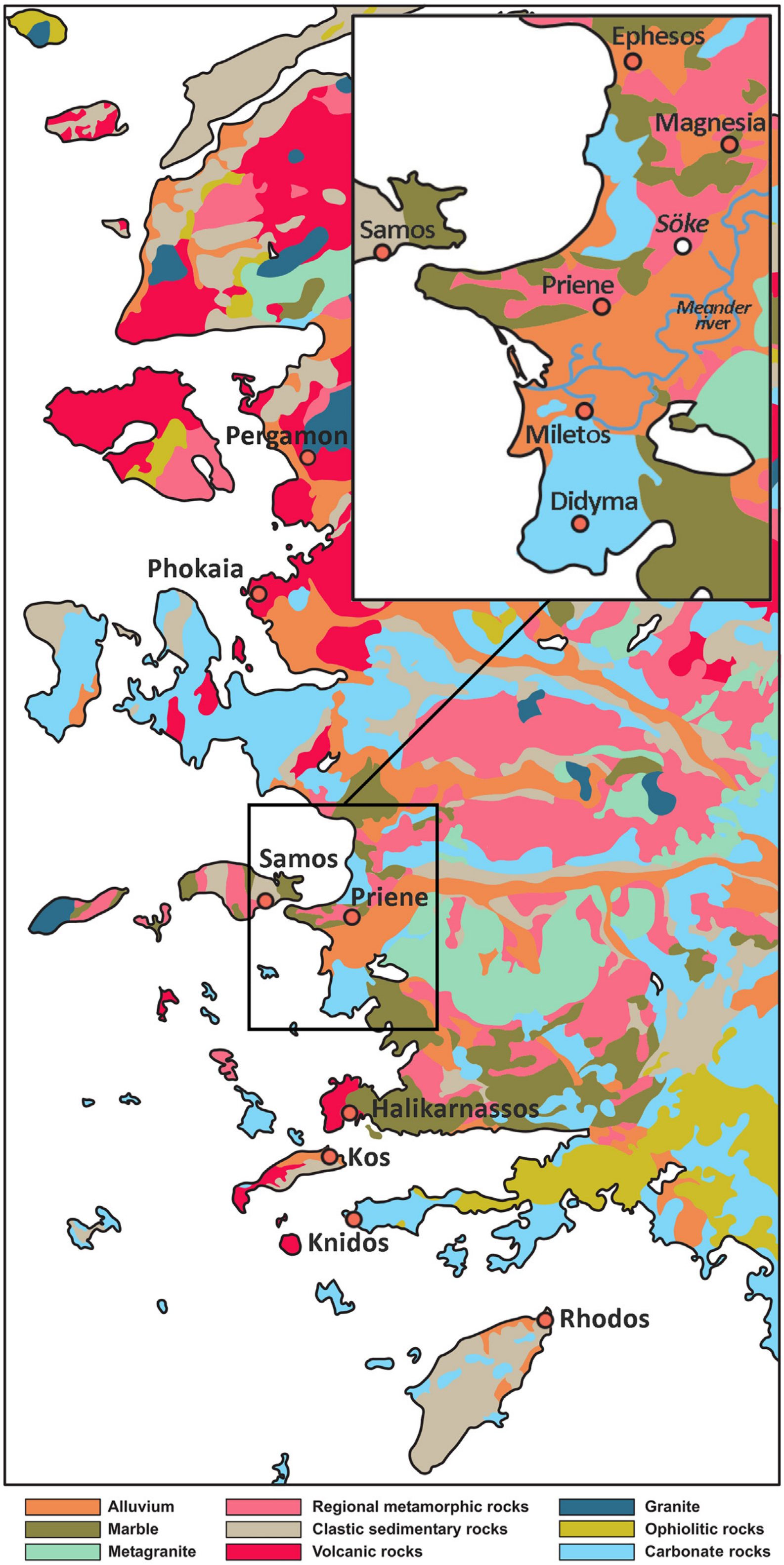

Fig. 4. Simplified geological map of the western coast of Asia Minor (Lars Heinze, based on the geological map of Turkey (1:250.000) by the Turkish General Directorate of Mineral Research and Exploration; colour on the web and black and white in print).

(Fig. 5p) in a distinctive non-local macro fabric (Fenn 2016:230–32), while vessels used for other means of cooking, such as *lasana* and *eschara*, are again missing from the archaeological record.

The other, later context of the early Imperial Roman period (Insula E5), with an end date around the middle of the first century CE, is similar in composition to that from the Athena sanctuary (10%–15% cooking ware), containing *chytrai, lopades,* and pans of the Phokaian type as well as other local/regional products. *Chytrai* and Phokaian pans begin to appear more frequently in the local/regional macro fabrics (Fenn 2016:170–72). This is accompanied by a significant drop in the amount of imported cooking wares in comparison to the slightly earlier context (Fenn 2016:190), and we now also see large, Aegean-type braziers made in the local/regional macro fabric (Amicone et al., 2014; Fenn 2016:177).

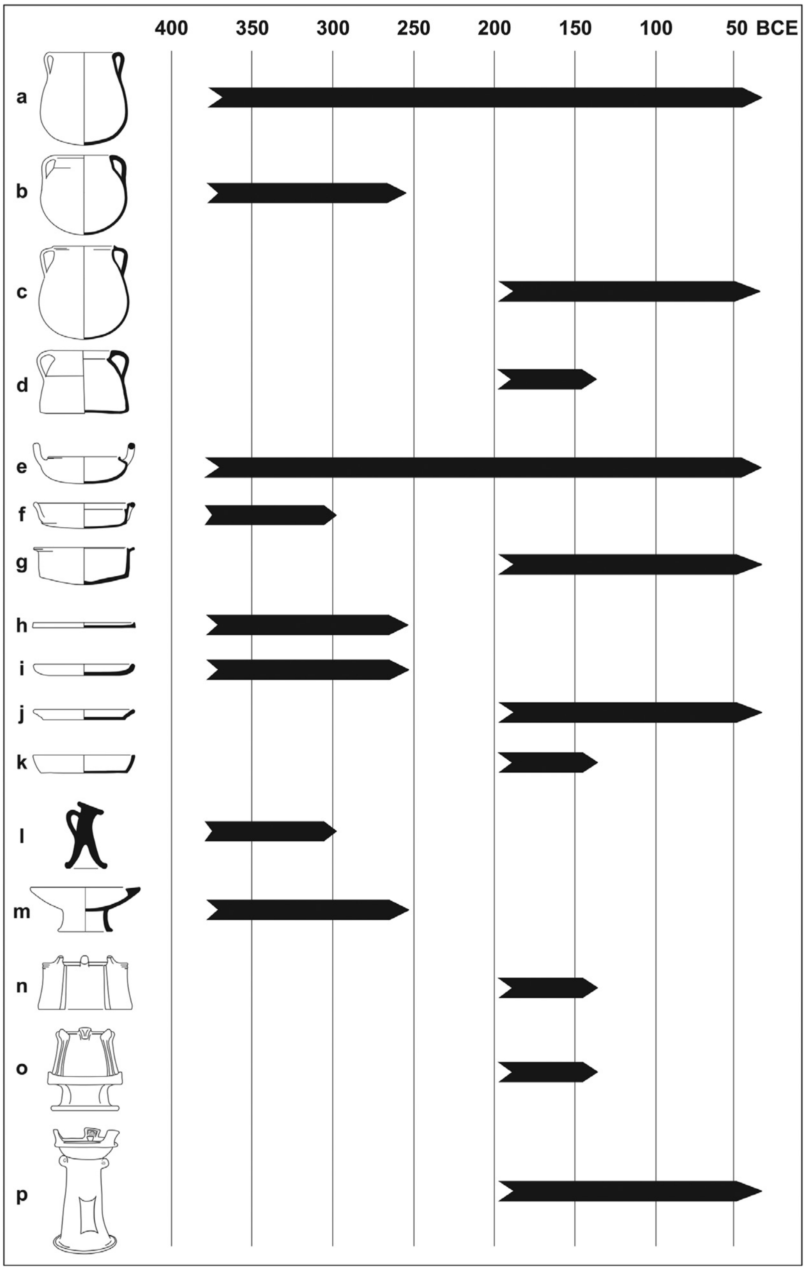

Fig. 5. Main types of cooking vessels (a–k) and cooking devices (l–p) mentioned in this article, with timelines representing the presence of these shapes in studied contexts from Priene: (a) belly *chytra*; (b) necked *chytra*; (c) Phokaian-type *chytra*; (d) flat-bottom *chytra*; (e) lebes-type *lopas*; (f) mainland-type *lopas*; (g) Phokaian-type *lopas*; (h) flat pan; (i) bevelled pan; (j) Phokaian-type pan; (k) *orlo bifido* pan; (l) *lasana*; (m) *eschara*; (n) horseshoe-type brazier; (o) Bakalakis-type brazier; (p) Aegean-type brazier. (Black and white on the web and in print).

2. Sampling strategy and analytical techniques

A total of 90 samples (44 from the fourth/third century BCE, 24 from the second century BCE, and 22 from the first century BCE/first century CE) were analysed in the present study.

Of these, 36 had been included in a previous preliminary study, the results of which emphasised the need to expand and supplement sampling in a more systematic investigation of the technology and provenance of the cooking ware repertoire of the city of Priene (Amicone et al., 2014). The 90 samples (Table 1) were selected to represent the dominant trends with respect to fabric (covering both macroscopic main groups, characterised by the presence or absence of white mica; see below) and vessel shape variation within the periods considered. As the macro fabrics of vessels from context E5 were identical to those identified in the Athena sanctuary deposit, only one sample was taken from E5. This specimen (Pri172) represents an Aegean-type brazier that appeared macroscopically to have been made in the local/regional fabric and was selected solely to verify whether this was indeed the case.

The overall macroscopic assessment of the fabrics (Supplementary Materials 1 and 2) that make up the cooking ware assemblages allowed us to divide them into two groups. The first includes vessels made from a wide range of fabrics, from very coarse to fine, (Fig. 6), characterised by the occurrence of glittering silver inclusions (white mica). This is assumed to be the local/regional fabric on both macroscopic and analytical grounds (Amicone et al., 2014; Fenn 2016).

The second group also includes a range of fabric textures from coarse to fine, but its most striking characteristic is the absence of white mica. Vessels assigned to the latter group are assumed to have been imported to the site (Amicone et al., 2014; Fenn 2016). Macroscopic examination revealed a greater degree of fabric standardisation amongst the cooking pots of the second century BCE and the first century BCE/first century CE. Amongst the pottery of these periods, coarse Phokaian fabrics (associated with pans), fine Phokaian fabrics (associated with *chytrai*

Table 1
List of samples.

Sample Number	Inventory Number	Published catalogue Number	Type	Period	Context	C.G.	Petrography	WD-XRF Fitch	WD-XRF ARCHEA	Amicone et al., 2014, Petro-fabrics	Amicone et al., 2014, XRF Fenn	Amicone et al., 2014, XRF ARCHEA
Pri148	PR00 K379	Fenn 2016, A 422	chytra, Phokaian type	1st cent. BCE	Athena sanct.	1a	X			A	X	
Pri150	PR00 K385	Fenn 2016, A 435	lopas, lebes type	1st cent. BCE	Athena sanct.	1a	X				X	
Pri151	PR00 K378	Fenn 2016, A 423	belly chytra	1st cent. BCE	Athena sanct.	1a	X				X	
Pri152	PR00 K383	Fenn 2016, A 432	lopas, lebes type	1st cent. BCE	Athena sanct.	1a	X	X		A	X	
Pri153	PR00 K387	Fenn 2016, A 436	lopas, lebes type	1st cent. BCE	Athena sanct.	1a	X	X		A	X	
Pri154	PR00 K511	Fenn 2016, A 425	chytra, unspecific type	1st cent. BCE	Athena sanct.	1a	X			A	X	
Pri155	PR00 K512	Fenn 2016, A 426	chytra, Phokaian type	1st cent. BCE	Athena sanct.	1a	X				X	
Pri172	PR03 K107	Fenn 2016, B 362	brazier, Aegean type	1st cent. BCE/CE	E5	1a	X	X				
Pri515	PR01 K017	Heinze in press, A1.311	lopas, standard type	4th cent. BCE	Buleuterion	1a	X	X		A		
Pri519	PR01 K038	Heinze in press, A1.303	belly chytra	4th cent. BCE	Buleuterion	1a	X			A		
Pri598	PR02 K486	Heinze in press, C.285	lopas, lebes type	4th/3rd cent BCE	D2, early phase	1a	X		X	A		X
Pri608	PR05 K056	Heinze in press, B.133	lopas, lebes type	4th cent. BCE	F15, early phase	1a	X		X	A		X
Pri614	PR07 K261	Heinze in press, A3.325	belly chytra	4th cent. BCE	Buleuterion	1a	X	X		A		
Pri616	PR07 K160	Heinze in press, A3.330	belly chytra	4th cent. BCE	Buleuterion	1a	X	X		A		
Pri626	PR07 K044	Heinze in press, A3.350	pan, rounded rim	4th cent. BCE	Buleuterion	1a	X	X		A		
Pri627	PR07 K042	Heinze in press, A3.352	pan, rounded rim	4th cent. BCE	Buleuterion	1a	X	X		A		
Pri631	PR02 K536	Heinze in press, C.181	storage bowl	4th/3rd cent BCE	D2, early phase	1a	X	X				
Pri632	PR02 K478	Heinze in press, C.256	belly chytra	4th/3rd cent BCE	D2, early phase	1a	X	X				
Pri638	PR07 K010	Heinze in press, A3.340	lopas, lebes type	4th cent. BCE	Buleuterion	1a	X					
Pri640	PR07 K009	Heinze in press, A3.341	lopas, lebes type	4th cent. BCE	Buleuterion	1a	X	X				
Pri645	PR02 K460	Heinze in press, C.278	lopas, lebes type	4th/3rd cent BCE	D2, early phase	1a	X	X				
Pri649	PR01 K156	Heinze in press, A1.312	lid	4th cent. BCE	Buleuterion	1a	X	X				
Pri700	PR01 K501	unpublished	chytra, flat-bottom type	2nd cent. BCE	D2, destr. layer	1a	X		X			
Pri706	PR02 K282	unpublished	chytra, flat-bottom type	2nd cent. BCE	D2, destr. layer	1a	X		X			
Pri714		unpublished	belly chytra	2nd cent. BCE	D2, destr. layer	1a	X		X			
Pri720	PR02 K663	unpublished	pan, orlo bifido type	2nd cent. BCE	D2, destr. layer	1a	X		X			
Pri726	PR03 K367	unpublished	lid	2nd cent. BCE	D2, destr. layer	1a	X		X			
Pri728	PR03 K452	unpublished	pan, orlo bifido type	2nd cent. BCE	D2, destr. layer	1a	X		X			
Pri743	PR08 K035	unpublished	lopas, lebes type	2nd cent. BCE	D2, destr. layer	1a	X		X			
Pri747	PR08 K088	unpublished	lopas, lebes type	2nd cent. BCE	D2, destr. layer	1a	X		X			
Pri748	PR08 K091	unpublished	lopas, lebes type	2nd cent. BCE	D2, destr. layer	1a	X		X			
Pri750	PR08 K104	unpublished	lopas, lebes type	2nd cent. BCE	D2, destr. layer	1a	X		X			
Pri751	PR08 K116	unpublished	brazier, barrel type	2nd cent. BCE	D2, destr. layer	1a	X		X			
Pri752	PR08 K118	unpublished	brazier?	2nd cent. BCE	D2, destr. layer	1a	X		X			
Pri753	PR08 K119	unpublished	belly chytra	2nd cent. BCE	D2, destr. layer	1a	X		X			
Pri759	PR09 K183	unpublished	belly chytra, Phokaian type?	2nd cent. BCE	D2, destr. layer	1a	X		X			
Pri760	PR09 K184	unpublished	pan, deep type	2nd cent. BCE	D2, destr. layer	1a	X		X			
Pri149	PR00 K386	Fenn 2016, A 431	lopas, lebes type	1st cent. BCE	Athena sanct.	1a	X				X	
Pri605	PR02 K462	Heinze in press, C.273	necked chytra	4th/3rd cent BCE	D2, early phase	1b	X		X	A		X
Pri636	PR02 K500	Heinze in press, C.274	necked chytra	4th/3rd cent BCE	D2, early phase	1b	X	X				
Pri641	PR02 K502	Heinze in press, C.283	lopas, lebes type	4th/3rd cent BCE	D2, early phase	1b	X	X				
Pri642	PR02 K694	Heinze in press, C.303	bowl/lid	4th/3rd cent BCE	D2, early phase	1b	X	X				
Pri644	PR02 K455	Heinze in press, C.276	lopas, lebes type	4th/3rd cent BCE	D2, early phase	1b	X	X				
Pri648	PR02 K472	Heinze in press, C.289	lid	4th/3rd cent BCE	D2, early phase	1b	X	X				
Pri512	PR01 K087	Heinze in press, A1.320	pan, rounded rim	4th cent. BCE	Buleuterion	1c	X	X		A		
Pri628	PR05 K097	Heinze in press, B.135	pan, flat bottom	4th cent. BCE	F15, early phase	1c	X	X		A		
Pri629	PR01 K690	Heinze in press, A1.317	pan, flat	4th cent. BCE	Buleuterion	1c	X	X				
Pri630	PR01 K161	Heinze in press, A1.33	belly chytra	4th cent. BCE	Buleuterion	1c	X					
Pri633	PR02 K518	Heinze in press, C.261	belly chytra	4th/3rd cent BCE	D2, early phase	1c	X	X				

(*continued on next page*)

Table 1 (*continued*)

Sample Number	Inventory Number	Published catalogue Number	Type	Period	Context	C.G.	Petrography	WD-XRF Fitch	WD-XRF ARCHEA	Amicone et al., 2014, Petro-fabrics	Amicone et al., 2014, XRF Fenn	Amicone et al., 2014, XRF ARCHEA
Pri634	PR05 K120	Heinze in press, B.132	belly chytra	4th cent. BCE	F15, early phase	1c	X	X				
Pri647	PR02 K464	Heinze in press, C.288	lid	4th/3rd cent BCE	D2, early phase	1c	X	X				
Pri145	PR00 K360	Fenn 2016, A 443	pan, Phokaian type	1st cent. BCE	Athena sanct.	2a	X			B1	X	
Pri146	PR00 K359	Fenn 2016, A 440	pan, Phokaian type	1st cent. BCE	Athena sanct.	2a	X	X		B1	X	
Pri147	PR00 K514	Fenn 2016, A 441	pan, Phokaian type	1st cent. BCE	Athena sanct.	2a	X	X		B1	X	
Pri169	PR00 K361	Fenn 2016, A 442	pan, Phokaian type	1st cent. BCE	Athena sanct.	2a	X	X		B1	X	
Pri712	PR02 K646	unpublished	pan, Phokaian type	2nd cent. BCE	D2, destr. layer	2a	X		X			
Pri715	PR02 K650	unpublished	pan, orlo bifido type	2nd cent. BCE	D2, destr. layer	2a	X		X			
Pri761	PR09 K201	unpublished	basin	2nd cent. BCE	D2, destr. layer	2	X		X			
Pri156	PR00 K513	Fenn 2016, A 427	lopas, Phokaian type	1st cent. BCE	Athena sanct.	2b	X	X		B2	X	
Pri157	PR00 K362	Fenn 2016, A 420	chytra, Phokaian type	1st cent. BCE	Athena sanct.	2b	X			B2	X	
Pri158	PR00 K364	Fenn 2016, A 417	chytra, Phokaian type	1st cent. BCE	Athena sanct.	2b	X	X		B2	X	
Pri159	PR00 K467	Fenn 2016, A 419	chytra, Phokaian type	1st cent. BCE	Athena sanct.	2b	X	X		B2	X	
Pri160	PR00 K366	Fenn 2016, A 414	chytra, Phokaian type	1st cent. BCE	Athena sanct.	2b	X			B2	X	
Pri162	PR00 K367	Fenn 2016, A 415	chytra, Phokaian type	1st cent. BCE	Athena sanct.	2b	X			B2	X	
Pri744	PR08 K036	unpublished	chytra, Phokaian type (imitation?)	2nd cent. BCE	D2, destr. layer	2b	X		X			
Pri768	PR04 K015	unpublished	pan, deep type	2nd cent. BCE	D2, destr. layer	2b	X		X			
Pri511	PR02 K430	Heinze in press, C.292	fragment of lid = Pri599	4th/3rd cent BCE	D2, early phase	2c	X	X		B3		
Pri599	PR02 K145	Heinze in press, C.272	necked chytra	4th/3rd cent BCE	D2, early phase	2c	X		X	B3		X
Pri625	PR02 K373	Heinze in press, C.298	pan, rounded rim	4th/3rd cent BCE	D2, early phase	2c	X	X		B3		
Pri635	PR02 K382	Heinze in press, C.265	belly chytra	4th/3rd cent BCE	D2, early phase	2c	X	X				
Pri643	PR02 K387	Heinze in press, C.281	lopas, lebes type	4th/3rd cent BCE	D2, early phase	2c	X	X				
Pri510	PR01 K567	unpublished	brazier, unknown type	4th cent. BCE	Buleuterion	2d	X		X			
Pri517	PR01 K020	unpublished	lasana (cooking stand)	4th cent. BCE	Buleuterion	2d	X	X				
Pri518	PR01 K153	Heinze in press, A1.34	cooking jar	4th cent. BCE	Buleuterion	2d	X	X				
Pri161	PR00 K372	Fenn 2016, A 453	brazier, Aegean type	1st cent. BCE	Athena sanct.	2e	X	X				
Pri163	PR00 K437	Fenn 2016, A 454	brazier, Aegean type	1st cent. BCE	Athena sanct.	2e	X	X				
Pri164	PR00 K374	Fenn 2016, A 457	brazier, Aegean type	1st cent. BCE	Athena sanct.	2e	X	X				
Pri702	PR01 K520	unpublished	brazier, Bakalakis type	2nd cent. BCE	D2, destr. layer	2e var	X		X			
Pri725	PR02 K705	unpublished	lid	2nd cent. BCE	D2, destr. layer	2b var	X		X			
Pri727	PR03 K414	unpublished	lopas, Phokaian type	2nd cent. BCE	D2, destr. layer	2b var	X		X			
Pri740	PR04 K010	unpublished	brazier, unknown type	2nd cent. BCE	D2, destr. layer	2e var	X		X			
Pri639	PR07 K011	Heinze in press, A3.342	lopas, standard type	4th cent. BCE	Buleuterion	2f	X	X				
Pri650	PR07 K132	Heinze in press, A3.344	lid	4th cent. BCE	Buleuterion	2f	X	X				
Pri513	PR01 K018	Heinze in press, A1.310	lopas, lebes type	4th cent. BCE	Buleuterion	2 g	X	X		B4		
Pri514	PR01 K039	Heinze in press, A1.306	necked chytra	4th cent. BCE	Buleuterion	2 g	X	X		B4		
Pri637	PR01 K171	Heinze in press, A1.4	necked chytra?	4th cent. BCE	Buleuterion	2 g	X	X				
Pri646	PR01 K035	Heinze in press, A1.315	lid(?), maybe for a brazier	4th cent. BCE	Buleuterion	2 g	X	X				
Pri651	PR01 K072	Heinze in press, A1.322	cooking jar	4th cent. BCE	Buleuterion	2 g	X	X				
Pri516	PR01 K157	Heinze in press, A1.321	pan, rounded rim	4th cent. BCE	Buleuterion	2 g var	X	X		B4		
Pri652	PR01 K079	Heinze in press, A1.309	lopas, lebes type	4th cent. BCE	Buleuterion	2 g var	X	X				

Note: C.G. = compositional group; Athena sanct. = Athena sanctuary; destr. layer = destruction layer.

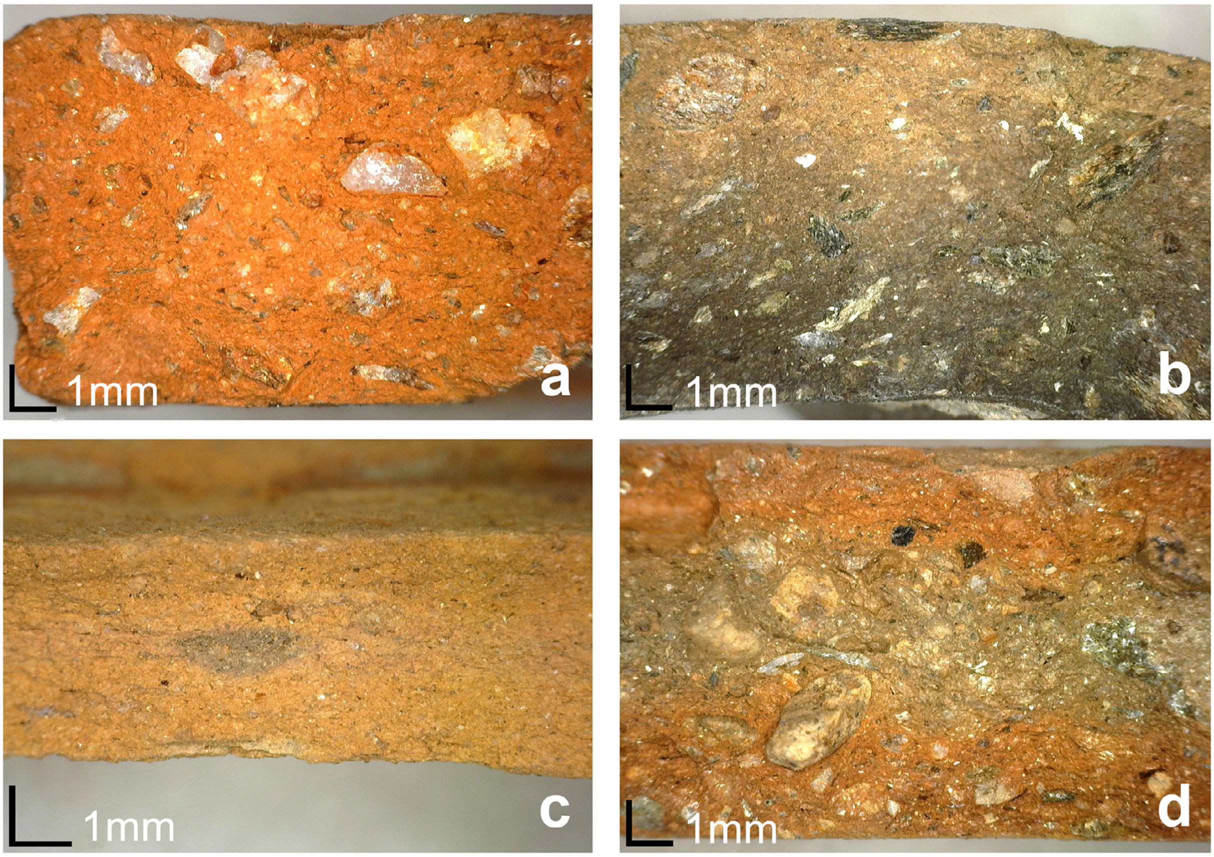

Fig. 6. Overview of macro fabrics from Priene, marked by the presence of glittering silver inclusions (white mica) and assumed to be local or regional products: (a) Pri151; (b) Pri615; (c) Pri641; (d) Pri628. Pictures were taken with a USB microscope (DinoLite AM4113T). (Colour on the web and black and white in print).

and *lopades*), and Aegean-type brazier fabric were identified and sampled (Amicone et al., 2014; Fenn 2016:177). Pastes used for fourth/third century BCE cooking pots are characterised by greater variability in the coarseness, abundance of inclusions, and grain size distribution. This made a systematic macroscopic fabric classification more challenging and required more extensive sampling of cooking wares from this period.

All 90 samples were analysed using ceramic petrography with a Leica (2500 P) polarising microscope equipped with a Pixe Link Camera D655CU (Quinn 2013:23–33; Whitbread 1989); 77 specimens were also examined using wavelength dispersive X-ray fluorescence spectrometry (WD-XRF). The different patterns resulting from these two methods exemplifies how the combination and integration of elemental and petrographic datasets provides more insights than either approach used in isolation. In addition, and particularly for coarser fabrics, petrography shows whether different clusters identified via statistical analysis correspond to provenance, technological groups, or a combination of both. Elemental analysis also helps to confirm and further elucidate the results of the petrographic analysis (e.g., Day et al., 1999; Stoltman 1989). The petrographic results were compared to those for samples from various Mediterranean sites analysed and archived at the Fitch Laboratory.

The WD-XRF analyses were carried out at the Fitch Laboratory (cf. Georgakopoulou et al., 2017: WD-XRF Bruker S8-TIGER wavelength dispersive spectrometer with Rh excitation source) and at ARCHEA (cf. Daszkiewicz and Schneider 2021: WD-XRF Panalytical Axios wavelength dispersive spectrometer with Rh excitation source).[1] At the Fitch Laboratory, 26 elements were determined (Na, Mg, Al, Si, P, K, Ca, Ti, Fe, V, Cr, Mn, Co, Ni, Cu, Zn, Rb, Sr, Y, Zr, Ba, La, Ce, Nd, Pb, Th); at ARCHEA, 25 were determined (Na, Mg, Al, Si, P, K, Ca, Ti, Fe, V, Cr, Mn, Ni, Cu, Zn, Rb, Sr, Y, Zr, Ba, La, Ce, Nb, Pb, Th). In both cases, samples were prepared as fused beads using 1 g of the ignited sample and 6 g (4 g at ARCHEA) of a mixture of lithium metaborate/lithium tetraborate. Direct comparability of results obtained from the two different setups was ensured by comparing the measurements of a certified reference material and an in-house standard, neither included in calibration by either setup (see Supplementary Materials 3). This confirmed a very good agreement between the two setups, with no systematic differences. Accordingly, while the origin of the data is indicated for every sample (Table 2), for the statistical treatment and formation of group averages, the two datasets were merged. To explore patterns in the elemental dataset, multivariate statistical analyses (cluster and principal component analyses) were performed on log transformed element concentrations (using the commonly measured elements and excluding Pb, Cu, and P) using both the R and STATISTICA software packages. Additional analyses were also run on the dataset transformed with a centred log ratio (CLR) and an asymmetric log ratio (ALR) (Buxeda i Garrigós 1999:300). Potential clusters in the elemental dataset were subsequently examined considering petrographic fabrics and macroscopic information.

3. Results of petrographic and elemental analyses

Based on the petrographic analysis of thin sections, the samples were divided into two main petro fabrics: metamorphic (1) and volcanic (2).

[1] The use of two different labs and setups was due to practicalities related to the development of the overall project. An early set of analyses was performed at ARCHEA, and this was later complemented by data obtained at the Fitch Laboratory.

Table 2
Results of the WD-XRF Analysis.

Sample	C.G.	SiO_2	TiO_2	Al_2O_3	Fe_2O_3	MnO	MgO	CaO	Na_2O	K_2O	P_2O_5	V	Cr	Co	Ni	Cu	Zn	Rb	Sr	Y	Zr	Nd	Nb	Ba	La	Ce	Pb	Th	LOI	Sum	FITCH	ARCHEA
Pri152	1a	59.78	0.75	17.80	7.66	0.07	2.28	2.31	0.92	2.86	0.12	131	194	23	138	58	96	141	154	29	183	34	n.m.	635	44	80	41	16	4.77	99.50	X	
Pri153	1a	63.54	0.78	15.90	6.61	0.05	1.83	2.44	1.14	2.28	0.10	124	219	22	188	50	78	97	122	26	171	29	n.m.	479	33	70	40	14	4.68	99.53	X	
Pri172	1a	57.40	0.66	15.78	5.52	0.09	3.39	5.30	1.28	3.46	0.20	80	176	22	226	30	70	154	141	38	240	42	n.m.	673	47	90	31	24	6.50	99.76	X	
Pri515	1a	60.42	0.60	13.17	9.18	0.12	3.66	4.07	1.33	2.67	0.22	88	1079	63	880	37	93	114	170	24	211	31	n.m.	475	37	69	28	16	3.81	99.56	X	
Pri608	1a	60.08	1.36	17.74	8.42	0.11	1.67	5.75	1.35	3.11	0.13	133	122	n.m.	63	35	96	122	276	36	324	n.m.	27	721	38	104	23	22	4.44	99.72		X
Pri614	1a	58.80	0.94	15.61	6.98	0.08	2.21	5.26	1.13	2.82	0.16	115	136	20	122	56	89	106	228	39	304	51	n.m.	592	52	97	30	17	5.69	99.87	X	
Pri626	1a	57.53	0.69	14.55	7.19	0.10	5.84	3.36	1.07	2.36	0.14	128	424	32	330	41	93	96	148	23	179	31	n.m.	379	31	64	25	12	6.64	99.64	X	
Pri627	1a	62.26	0.81	16.69	7.93	0.09	2.81	1.01	1.02	3.21	0.12	113	669	41	487	38	78	127	115	28	218	40	n.m.	470	44	88	17	17	3.65	99.84	X	
Pri631	1a	59.64	0.69	15.34	6.09	0.08	4.38	5.33	1.34	4.00	0.26	83	227	24	245	30	65	147	135	32	223	36	n.m.	563	46	89	21	17	2.25	99.58	X	
Pri632	1a	51.48	0.70	17.21	7.88	0.14	10.36	4.23	0.56	1.68	0.10	111	567	39	515	32	93	90	88	21	156	26	n.m.	613	32	60	22	11	5.29	99.86	X	
Pri640	1a	61.67	0.80	16.04	8.03	0.11	3.02	2.47	1.27	3.37	0.18	103	536	36	349	28	78	129	87	30	197	40	n.m.	518	47	82	28	15	2.37	99.53	X	
Pri645	1a	56.81	0.96	15.05	7.44	0.09	2.57	6.01	0.88	2.14	0.14	107	191	26	192	39	80	98	176	35	295	43	n.m.	619	41	97	26	15	7.23	99.51	X	
Pri750	1a	74.14	0.80	13.71	4.68	0.05	1.40	1.42	0.32	3.03	0.11	76	146	n.m.	96	11	42	128	57	21	356	n.m.	15	592	36	83	140	25	3.02	99.66		X
Pri747	1a	67.26	1.02	17.26	7.00	0.07	1.95	0.82	1.60	2.37	0.08	96	230	n.m.	142	47	77	106	85	27	256	n.m.	17	466	27	86	30	20	1.94	99.43		X
Pri753	1a	63.74	0.89	20.71	8.09	0.05	1.73	1.00	0.88	3.06	0.08	153	240	n.m.	161	46	102	145	76	27	216	n.m.	16	578	38	82	18	20	5.18	100.24		X
Pri706	1a	64.83	0.93	18.70	8.20	0.07	1.86	1.96	0.83	2.75	0.28	110	227	n.m.	143	33	74	113	89	28	249	n.m.	12	638	34	61	24	27	2.95	100.41		X
Pri720	1a	65.51	0.68	17.67	6.20	0.08	2.28	3.21	1.17	3.33	0.14	78	146	n.m.	170	33	67	187	89	29	288	n.m.	17	813	48	93	49	32	5.02	100.27		X
Pri743	1a	61.96	0.84	19.67	6.86	0.08	2.99	2.16	1.17	3.92	0.19	83	255	n.m.	275	30	76	186	121	36	302	n.m.	23	968	47	120	51	37	3.82	99.85		X
Pri760	1a	59.18	0.95	19.76	8.57	0.09	3.12	4.33	1.02	2.95	0.18	119	303	n.m.	231	40	97	138	133	31	252	n.m.	18	808	47	100	21	24	6.08	100.16		X
Pri726	1a	63.46	0.80	17.30	6.11	0.08	3.23	3.61	1.26	3.77	0.15	93	204	n.m.	228	92	65	182	124	31	290	n.m.	19	575	53	88	31	34	2.56	99.76		X
Pri759	1a	63.17	0.87	19.41	7.55	0.10	3.27	1.40	1.27	3.46	0.20	80	257	n.m.	335	43	81	182	94	38	320	n.m.	23	961	64	108	38	45	4.26	100.70		X
Pri714	1a	61.79	0.81	18.32	8.04	0.09	3.51	2.79	1.38	2.79	0.27	116	288	n.m.	231	51	90	127	97	29	200	n.m.	15	545	34	81	60	26	3.45	99.79		X
Pri700	1a	62.12	0.95	19.37	8.00	0.07	3.65	1.84	0.80	3.17	0.16	116	388	n.m.	282	39	89	159	87	32	288	n.m.	19	786	35	95	37	31	4.03	100.13		X
Pri751	1a	57.00	0.86	18.12	8.57	0.11	3.64	7.28	0.84	2.94	0.15	120	209	n.m.	256	51	94	154	221	39	233	n.m.	19	695	36	137	28	31	8.37	99.52		X
Pri748	1a	60.36	0.92	17.62	8.73	0.11	3.81	4.43	0.74	2.80	0.20	105	226	n.m.	265	55	98	127	212	36	239	n.m.	24	897	47	96	45	30	4.77	99.73		X
Pri649	1a	52.48	0.78	15.91	7.01	0.08	2.98	7.39	1.40	2.83	0.30	114	206	27	201	60	104	114	252	35	214	45	n.m.	631	47	91	29	15	8.16	99.54	X	
Pri752	1a	60.27	0.85	19.55	9.56	0.11	3.51	2.11	0.71	3.11	0.17	120	209	n.m.	274	46	91	136	156	43	241	n.m.	19	701	53	114	38	32	4.76	99.94		X
Pri598	1a	60.87	0.59	15.62	5.24	0.09	4.26	7.73	2.28	3.34	0.23	59	259	n.m.	272	14	56	162	198	31	272	n.m.	19	531	37	76	16	31	0.78	100.24		X
Pri728	1a	67.75	0.89	13.90	8.09	0.14	3.95	3.63	0.72	1.33	0.10	99	423	n.m.	331	31	70	70	77	18	243	n.m.	19	516	10	63	30	24	4.05	100.50		X
Pri616	1a	55.95	0.59	12.81	8.33	0.09	8.53	4.30	1.29	1.60	0.15	137	1131	26	503	39	92	77	119	19	137	19	n.m.	289	23	49	17	10	6.04	99.92	X	
Pri605	1b	58.13	1.07	19.97	9.59	0.14	3.79	3.77	0.80	2.95	0.19	125	266	n.m.	256	36	95	134	217	42	300	n.m.	23	557	45	100	28	27	1.57	100.39		X
Pri636	1b	54.23	0.97	18.77	9.20	0.14	4.10	4.93	1.12	3.02	0.19	137	257	33	272	45	106	126	234	41	243	47	n.m.	628	55	121	34	19	2.46	99.33	X	
Pri641	1b	58.44	0.60	15.82	5.46	0.09	3.72	5.65	2.01	3.21	0.26	69	243	23	286	35	76	149	184	34	252	37	n.m.	741	49	86	40	24	4.30	99.76	X	
Pri642	1b	59.44	0.57	15.53	5.57	0.09	4.26	6.23	1.78	3.23	0.25	64	285	27	345	34	68	142	189	35	246	41	n.m.	571	44	85	38	22	2.35	99.50	X	
Pri644	1b	55.38	0.90	15.51	7.33	0.09	3.05	5.13	1.02	2.17	0.15	117	224	28	247	45	89	90	163	34	279	41	n.m.	595	47	104	29	13	8.63	99.56	X	
Pri648	1b	58.92	0.61	15.62	5.77	0.09	3.81	5.99	1.36	3.38	0.37	67	242	23	256	37	82	148	180	37	227	40	n.m.	572	54	96	38	24	3.43	99.55	X	
Pri512	1c	52.05	1.13	10.15	9.37	0.15	13.40	4.34	0.89	0.83	0.23	122	1492	72	1103	35	88	47	134	20	141	14	n.m.	192	16	39	20	7	6.62	99.48	X	
Pri628	1c	50.62	0.51	9.16	11.26	0.13	21.08	2.78	0.47	0.51	0.11	119	2090	103	1979	31	84	28	73	14	92	10	n.m.	156	10	17	11	5	3.14	100.20	X	
Pri629	1c	53.94	0.70	9.54	9.35	0.13	15.26	3.85	0.86	0.80	0.53	115	1547	69	1164	44	86	39	103	19	122	12	n.m.	224	14	23	16	6	4.69	99.97	X	
Pri633	1c	49.66	0.71	9.72	11.19	0.15	22.91	2.34	0.72	0.45	0.12	105	2108	109	1984	40	87	21	50	19	121	10	n.m.	170	10	30	15	4	1.53	99.95	X	
Pri634	1c	49.77	0.49	10.10	11.27	0.17	18.48	3.29	0.54	0.56	0.20	108	2368	100	1395	32	92	27	88	15	105	14	n.m.	300	11	23	14	7	4.83	100.12	X	
Pri647	1c	52.03	0.66	9.63	10.42	0.15	20.15	3.06	0.80	0.69	0.12	110	2005	97	1704	39	83	36	58	17	107	15	n.m.	199	17	25	17	5	1.67	99.79	X	
Pri146	2a	60.06	0.29	20.62	5.37	0.12	0.55	0.66	3.88	6.49	0.06	25	33	6	9	18	109	292	110	40	412	61	n.m.	230	111	202	112	45	1.17	99.43	X	
Pri147	2a	59.03	0.34	20.24	5.41	0.13	0.60	1.33	3.58	6.37	0.07	27	40	7	14	22	110	284	158	42	429	64	n.m.	284	112	187	73	49	2.28	99.54	X	

(*continued on next page*)

Table 2 (*continued*)

Sample	C.G.	SiO_2	TiO_2	Al_2O_3	Fe_2O_3	MnO	MgO	CaO	Na_2O	K_2O	P_2O_5	V	Cr	Co	Ni	Cu	Zn	Rb	Sr	Y	Zr	Nd	Nb	Ba	La	Ce	Pb	Th	LOI	Sum	FITCH	ARCHEA
Pri169	2a	60.78	0.33	20.28	5.03	0.13	0.57	0.64	3.66	6.48	0.07	27	41	7	13	22	105	296	115	37	450	58	n.m.	213	95	190	86	46	1.39	99.50	X	
Pri715	2a	60.24	0.32	22.00	5.79	0.10	0.38	0.83	3.53	5.94	0.08	17	43	n.m.	25	8	94	306	122	29	534	n.m.	69	426	109	206	66	69	2.03	99.21		X
Pri712	2a	60.96	0.40	21.72	5.92	0.15	0.52	0.78	3.18	6.10	0.08	29	66	n.m.	23	9	106	310	117	32	603	n.m.	69	305	87	187	86	73	1.79	99.81		X
Pri761	2a	61.88	0.61	20.91	5.99	0.11	1.05	1.46	3.26	4.77	0.09	57	85	n.m.	41	11	85	224	209	28	434	n.m.	39	491	72	163	61	53	0.84	100.13		X
Pri156	2b	59.06	0.41	20.02	5.31	0.09	0.74	2.03	2.84	4.83	0.11	40	92	11	34	26	88	211	128	32	512	46	n.m.	358	80	181	94	49	3.79	99.41	X	
Pri158	2b	59.85	0.53	21.45	6.29	0.11	1.10	0.87	2.32	5.95	0.06	51	68	12	29	16	89	224	242	34	430	55	n.m.	450	90	176	78	40	0.74	99.45	X	
Pri159	2b	59.94	0.57	21.75	6.48	0.09	0.91	0.95	2.03	5.13	0.05	56	75	14	55	27	86	179	232	22	390	41	n.m.	485	55	144	76	37	1.08	99.15	X	
Pri744	2b	58.69	0.45	24.16	6.18	0.11	0.94	1.29	2.10	5.77	0.07	35	58	n.m.	34	7	86	220	289	34	410	n.m.	33	496	106	173	47	53	1.46	99.77		X
Pri768	2b	58.54	0.46	24.17	6.26	0.09	0.50	1.68	2.09	5.69	0.11	38	58	n.m.	61	9	69	191	275	36	415	n.m.	35	672	101	167	75	55	4.81	99.59		X
Pri725	2b/var	66.80	0.71	18.14	5.05	0.09	1.21	1.35	1.95	3.59	0.05	59	137	n.m.	50	7	54	181	182	25	406	n.m.	31	495	51	119	44	40	1.92	98.94		X
Pri727	2b/var	66.54	0.74	19.08	5.08	0.10	0.68	1.45	2.18	3.82	0.15	62	169	n.m.	48	7	57	158	209	24	483	n.m.	34	651	66	146	58	44	3.73	99.82		X
Pri511	2c	63.31	0.73	18.52	5.53	0.09	0.96	2.30	2.37	2.35	0.07	67	115	13	65	27	66	83	251	22	284	27	n.m.	800	40	74	29	19	3.15	99.56	X	
Pri599	2c	65.87	0.78	18.77	5.77	0.09	1.18	2.99	2.10	2.30	0.08	84	131	n.m.	65	17	62	103	257	18	300	n.m.	19	713	39	66	26	25	2.24	99.93		X
Pri625	2c	64.49	0.71	17.41	5.38	0.12	1.03	2.28	2.38	2.49	0.07	74	131	16	63	28	65	88	245	22	268	31	n.m.	876	43	83	36	17	3.30	99.83	X	
Pri635	2c	61.69	0.80	19.16	6.03	0.08	1.06	2.53	2.17	2.30	0.07	82	133	13	66	24	72	86	254	25	317	33	n.m.	854	43	73	33	19	4.02	100.11	X	
Pri643	2c	62.31	0.85	18.87	6.06	0.08	1.21	2.01	2.16	2.44	0.07	80	121	14	64	29	80	95	237	26	291	38	n.m.	669	51	75	41	18	3.28	99.50	X	
Pri510	2d	70.66	0.60	15.19	4.95	0.08	1.12	3.16	0.99	3.22	0.14	78	174	n.m.	100	30	51	164	131	17	248	n.m.	13	415	32	99	20	31	2.18	100.11		X
Pri517	2d	68.07	0.69	15.46	5.35	0.10	1.23	3.29	0.97	3.35	0.11	87	192	20	121	28	64	172	123	27	240	36	n.m.	419	45	83	25	18	1.10	99.87	X	
Pri518	2d	65.06	0.80	17.55	7.06	0.13	2.53	1.48	0.71	2.80	0.25	129	193	23	134	56	98	111	152	31	227	40	n.m.	572	46	78	38	19	1.09	99.63	X	
Pri161	2e	62.38	0.75	19.76	6.24	0.06	1.16	1.19	2.31	3.99	0.09	92	121	16	56	30	75	159	330	23	380	36	n.m.	998	53	101	71	42	1.65	99.82	X	
Pri163	2e	62.28	0.64	19.68	5.57	0.05	1.11	1.91	2.33	2.68	0.09	78	101	12	61	37	66	102	300	17	258	27	n.m.	976	41	69	50	27	3.29	99.85	X	
Pri164	2e	62.10	0.68	21.32	5.91	0.09	1.21	1.35	2.53	3.24	0.09	88	79	15	57	27	74	140	305	21	292	26	n.m.	905	52	99	72	34	0.78	99.50	X	
Pri702	2e/var	62.09	0.75	21.23	8.02	0.12	1.42	1.76	1.28	3.30	0.12	129	202	n.m.	155	57	101	137	208	23	279	n.m.	18	959	46	83	70	31	4.39	100.08		X
Pri740	2e/var	60.70	0.93	22.87	7.86	0.16	1.30	1.62	1.65	3.06	0.12	84	185	n.m.	116	28	116	141	262	24	361	n.m.	27	1039	70	104	68	42	3.69	100.28		X
Pri639	2f	57.42	0.65	20.79	6.79	0.14	1.24	4.37	2.17	1.28	0.10	87	307	20	169	35	83	64	368	28	240	32	n.m.	514	38	64	39	12	4.39	99.52	X	
Pri650	2f	56.50	0.64	21.21	6.27	0.12	1.36	4.30	2.52	1.17	0.16	78	146	18	108	42	86	53	429	27	229	30	n.m.	579	42	72	26	12	4.90	99.30	X	
Pri513	2 g	56.08	0.91	18.59	7.08	0.09	1.64	4.83	2.41	3.22	0.23	114	89	19	34	55	79	132	656	27	364	53	n.m.	1041	75	151	76	56	4.14	99.51	X	
Pri514	2 g	58.39	0.93	20.96	7.68	0.12	1.81	2.32	2.23	3.58	0.24	123	113	22	65	39	92	178	495	34	437	63	n.m.	1082	92	168	76	68	0.74	99.31	X	
Pri637	2 g	57.32	0.92	20.39	7.67	0.11	2.12	3.56	2.39	3.07	0.21	129	94	22	40	39	83	139	630	29	366	56	n.m.	999	73	146	84	50	1.40	99.43	X	
Pri646	2 g	57.74	0.85	19.19	7.08	0.07	1.78	2.43	1.97	3.54	0.18	108	95	18	58	57	92	156	464	30	353	56	n.m.	913	74	129	75	54	4.16	99.24	X	
Pri651	2 g	59.16	0.91	20.26	7.50	0.09	1.72	2.46	2.50	3.93	0.16	122	76	21	36	41	85	185	562	33	467	64	n.m.	1096	92	179	87	75	0.76	99.74	X	
Pri516	2 g/var	60.84	0.78	17.33	6.69	0.11	2.24	2.09	1.09	2.90	0.20	133	162	22	95	46	89	123	269	28	243	36	n.m.	709	45	80	43	22	5.39	99.85	X	
Pri652	2 g/var	59.90	0.87	18.80	7.13	0.09	2.05	2.34	1.58	3.23	0.15	128	153	23	73	49	93	127	413	26	265	42	n.m.	879	58	106	56	28	3.32	99.68	X	

Notes: Elements reported as oxides are given in percentages, as are loss on ignition (LOI) and the sum total. All other elements are given in ppm. C.G. = compositional group. The laboratory in which each measurement was conducted is indicated. Co and Nd are measured only at the Fitch Laboratory, while Nb is measured only at ARCHEA; for each sample, elements that were not measured are indicated as n.m. (not measured).

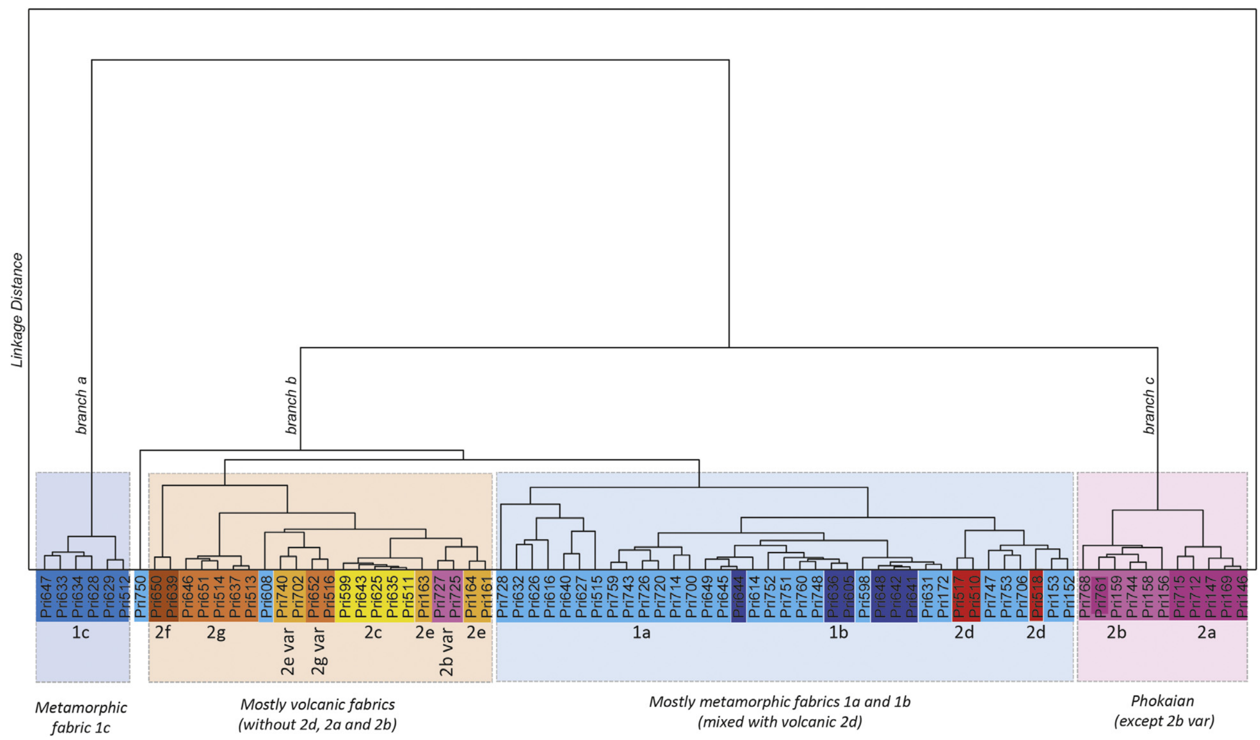

Fig. 7. Dendrogram resulting from cluster analysis performed on log transformed data, excluding P, Cu, and Pb, using unweighted pair-group averages and squared Euclidian distances, with fabric groups indicated (blue tones: metamorphic fabrics, red-yellow tones: volcanic fabrics). (Colour on the web and black and white in print).

The integration of the petrographic and elemental data allowed these to be further divided into several groups based on compositional and textural criteria (Table 1).

The results of petrographic and elemental analysis corroborate the two macro fabrics originally defined through examination of the sherds by eye. The macro fabric with glittering silver inclusions (silver mica) is characterised by fragments of metamorphic rocks and corresponded to fabric groups 1a–1c, while the second, characterised by the presence of volcanic rock fragments, corresponded to fabric groups 2a–2f.

This distinction based on rock type/origin of inclusions was less clear-cut in the results from the elemental analysis. Hierarchical clustering results in a dendrogram where samples are allocated to three main branches (Fig. 7): Branch a: 1c samples (a metamorphic fabric); Branch c: the majority of the 2a and 2b samples (two volcanic fabrics); and Branch b: the remainder of the metamorphic and volcanic fabrics.

While there is a clear tendency for metamorphic and volcanic fabrics to group apart, there is no complete separation between the two major categories of fabric groups and occasionally between fabrics themselves, since the variations in element composition within different volcanic or metamorphic groups are in some instances much greater than those between certain volcanic and metamorphic fabrics.

Nevertheless, the very distinct elemental composition of some groups results in most samples in Group 1c and those in Groups 2a and 2b plotting separately from the remaining samples, forming two distinct clusters, the first (1c in Branch a) characterised by very high levels of Mg, Cr, Ni, and Co and the second (2a and 2b in Branch c) characterised by high levels of K and Na. Differences in elemental composition between the bulk of the remaining metamorphic fabrics on the one hand and volcanic samples on the other are less stark, reflected in a relatively low linkage distance between the two sub-clusters of Branch b. Samples assigned to volcanic fabric Group 2d, which contain both volcanic and metamorphic fragments, cluster together with the metamorphic Group 1a and 1b samples. Below is a short account of these groups, identified by integrating results of petrography and elemental analysis as well as their correlation to different periods and vessel shapes.

3.1. Metamorphic groups

Three of the fabric groups identified by integration of the petrographic (Supplementary Materials 4) and elemental data are characterised by the occurrence of metamorphic rocks (Fig. 8). Group 1a is a very heterogeneous group of fabrics, in terms of both petrography and elemental composition, with all fabrics being of coarse texture and characterised by the same type of metamorphic rock (mica-schist). Group 1b samples, which are finer, form a more homogenous group that appears to be compatible with Group 1a samples, both petrographically and elementally. Finally, samples assigned to Group 1c differ from 1a and 1b samples in that they contain common serpentinite and talc. This is also reflected in a distinct elemental composition, characterised by elevated Cr, Ni, Co, and Mg contents (Tables 2 and 3).

Compositional Group 1a (Fig. 8a–h) comprises 36 vessels from late Classical to late Hellenistic contexts, thus covering the entire time span taken into consideration. Vessel shapes include the belly *chytrai* with out-turned rim and the lebes-type *lopades* but also a variety of pans and one Phokaian-type *chytra*. One standard-type *lopas* with internal flange and one Aegean-type brazier are also attested in this fabric.

Samples were included in Group 1a because they reflect a similar geology, marked by the presence of fragments of foliated metamorphic rocks. While the coarse fabric of these specimens shows considerable variation in thin section, both in texture and composition, there is no clear-cut separation possible between different fabrics assigned to the group. The dominant mineral inclusions are quartz, muscovite, and fragments of foliated metamorphic rocks composed of the same minerals (probably mica-schist).

Samples Pri519, Pri614, Pri632, and Pri714 also contain small amounts of phyllite. Biotite is common, and there are occasional inclusions of calcite (as seen in Pri645 and Pri728, most likely deriving from marble), epidote (more abundant in Pri519 and Pri608), amphibole (e.g., actinolite, hornblende, and tremolite), feldspars (K-feldspar and plagioclase), and opaques.

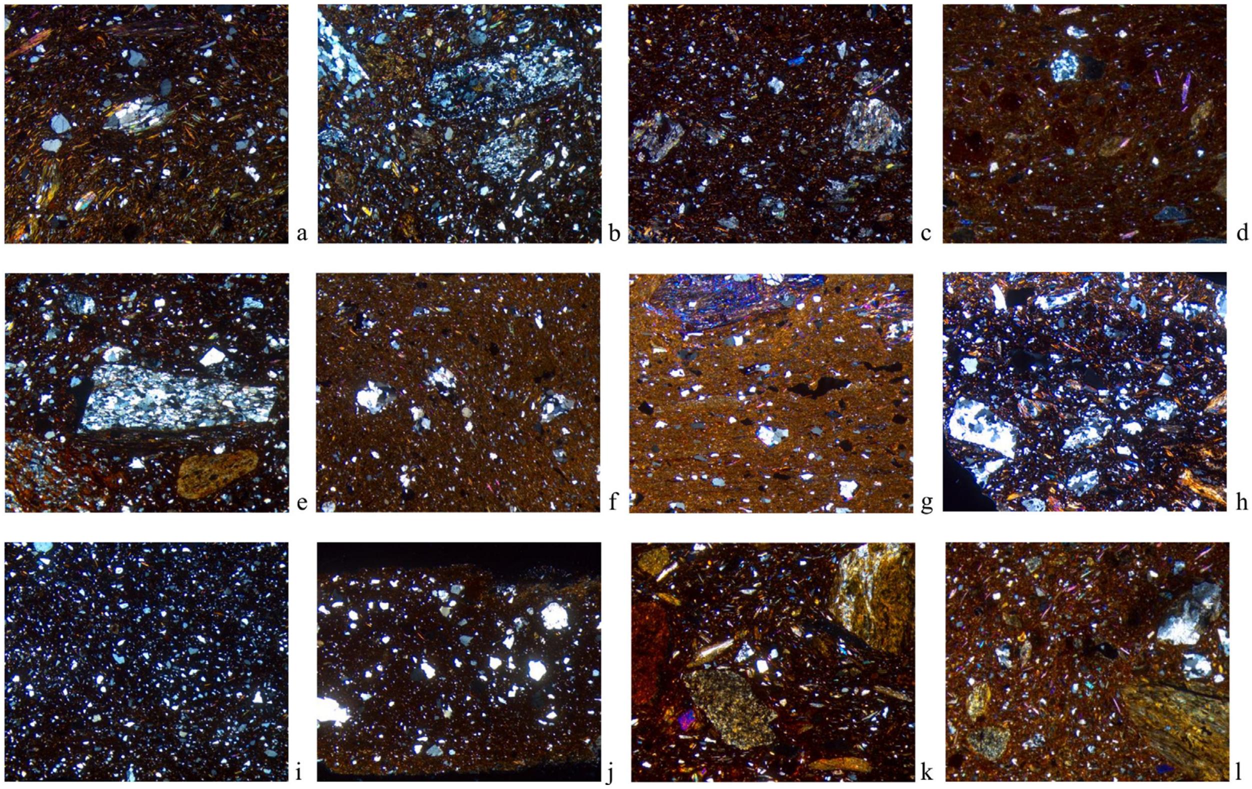

Fig. 8. Thin section micrographs of selected samples with metamorphic fabrics: (a) Pri631 (1a, fourth/third century BCE); (b) Pri608 (1a, fourth/third century BCE); (c) Pri626 (1a, fourth/third century BCE); (d) Pri632 (1a, fourth/third century BCE); (e) Pri751 a (1a, second century BCE); (f) Pri753 (1a, second century BCE); (g) Pri153 (1a, first century BCE); (h) Pri172 a (1a, first century BCE /CE); (i) Pri642 (1b, fourth/third century BCE); (j) Pri648 (1b, fourth/third century BCE); (k) Pri628 (1c, fourth/third century BCE); (l) Pri629 (1c, fourth/third century BCE). Field of view 6 mm. (Colour on the web and black and white in print).

Some samples (e.g., Pri149, Pri616, Pri626, Pri632, and Pri743) additionally seem to contain talc and stilpnomelane. Finally, in Pri149 and Pri626, serpentinite was observed, and a possible inclusion of grog was identified in Pri632. Most of these samples are also characterised by higher concentrations of Cr, Ni, and Mg. Another subgroup of samples included in Group 1a displays higher amounts of Cr and Ni.

These include late Classical to early Hellenistic *lopades* (Pri515 and Pri627) and a pan (Pri640) that from a petrographic point of view do not show any characteristic that could differentiate them from the other samples, apart from two possible inclusions of glaucophane in Pri627. Two other specimens can be distinguished due to their elemental compositions: Pri750, a second century BCE *lopas*, has the highest concentration of Si and Zr; Pri608, a late Classical to early Hellenistic *lopas*, marked by a higher amount of epidote, has the lowest content of Mg, Cr, and Ni of the entire dataset.

Most of the samples are coarse and show a bimodal grain size distribution. However, the sorting, grain size, and abundance of inclusions vary from specimen to specimen. There is also considerable variability in the appearance of the matrix and the birefringence, but most of the samples display optical activity, indicating relatively low firing temperatures. The bimodality observed in most samples assigned to this group may suggest, at least in some cases, tempering with metamorphic rock fragments. The compositional and textural variability could then reflect different strategies of cleaning and tempering of a low-calcareous clay base. Heterogeneities in elemental composition not reflected in petrography (Pri515, Pri627, and Pri640) may be indicative of additional variation in the base clays employed in ceramic manufacture. This notable compositional and textural diversity is particularly evident in the late Classical and early Hellenistic period, while in the late Hellenistic period, the composition of cooking pots appears to be less diverse.

Compositional Group 1b (Fig. 8i–j) includes seven vessels from Context D2, amongst them necked *chytrai*, lebes-type *lopades*, and two fragments of lids. It is noteworthy that this fabric appears temporally restricted, as it is not attested in the earliest contexts of Priene (*bouleuterion* and F15); nor is it found in the late Hellenistic or early Imperial Roman periods.

All samples of this group are characterised by rather fine fabrics that form a quite homogenous compositional group marked by the presence of quartz, muscovite, plagioclase, and small fragments of foliated rocks composed of quartz and muscovite. A low calcareous clay was used to produce these vessels. In terms of elemental composition, all samples are compatible with the composition of Group 1a samples, particularly those from the third and fourth centuries (not containing talc or otherwise distinct). Group 1b samples plot in a subfield of the 1a compositional field (see Fig. 9). However, later 1a samples tend to show more overall variation in their calcium contents and therefore plot in a comparatively wider field.

The fineness of this fabric could potentially indicate that the collected raw material was cleaned via sieving or levigation prior to use, or simply that naturally fine sediment resources were exploited. Moderate to very low optical activity of the matrix reflects firing of these vessels at higher temperatures compared to those of Group 1a.

Compositional Group 1c (Fig. 8k–l) comprises nine vessels, including *chytrai*, pans, a lebes-type *lopas*, and a lid. These vessels are attested only in the late Classical and early Hellenistic periods. The fabric is characterised by the presence of fragments of serpentinite and foliated metamorphic rocks, including mica, epidote, and talc schist fragments. Common mineral inclusions are quartz and muscovite. Unlike in samples assigned to Group 1a, serpentinite and amphibole (e.g., actinolite, hornblende, and tremolite) are also common, and there are also a few inclusions of biotite, calcite, epidote, opaques, stilpnomelane, and

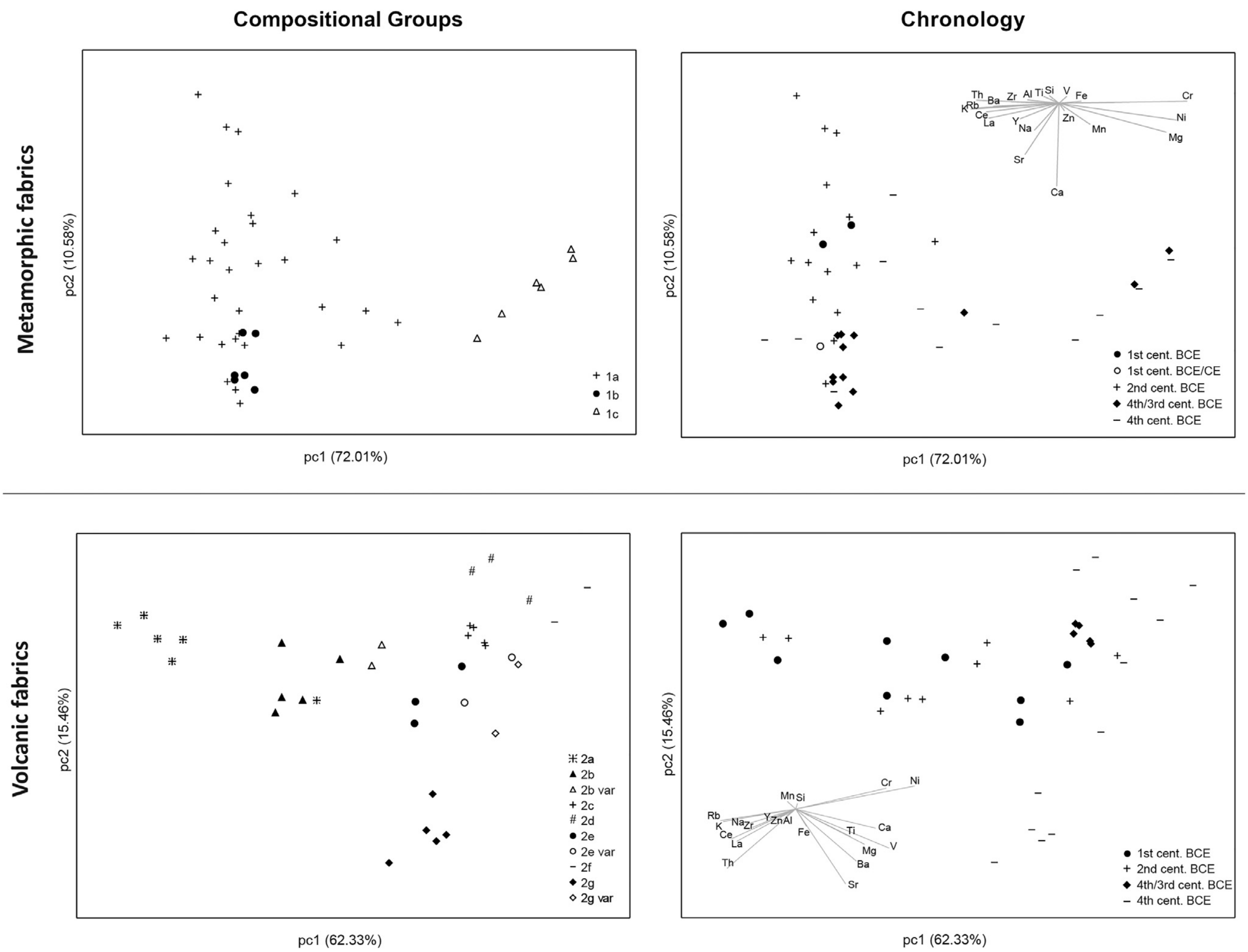

Fig. 9. Results of principal component analysis performed for samples assigned to metamorphic (top of figure) and volcanic (bottom of figure) fabrics. Plots of factor 1 versus factor 2, with loadings for variables included in each analysis, are given in the plot to the right. Compositional groups are indicated in the plots to the left, while chronological information is given in the plots to the right. (Black and white on the web and in print).

feldspars (K-feldspar and plagioclase). The six samples subjected to elemental analysis via WD-XRF are characterised by high concentrations of Co, Cr, Ni, and Mg. For this reason, they form a separate group both when subjected to hierarchical clustering and in principal component analysis parameters (Figs. 7 and 9).

The matrix of most samples displays optical activity, indicating relatively low firing temperatures, and appears low in calcareous content. The bimodality of the samples assigned to Group 1c indicates that they could have been made with a clay tempered with a sand rich in metamorphic minerals and rock fragments.

3.2. Volcanic groups

About 50% of the analysed samples are characterised by volcanic rock fragments (Fig. 10). Clearly, these do not form a single compositional group, but based on petrographic characteristics (Supplementary Materials 4) in combination with variability in elemental composition (Table 2 and 4), they could be assigned to seven distinct compositional groups, described below.

Compositional Group 2a (Fig. 10a) includes five Phokaian-type pans, one *orlo bifido*–type pan, and one basin of the middle/late Hellenistic period. All samples are characterised by a coarse, tempered fabric with fragments of acidic volcanic rocks. Dominant mineral inclusions are K-feldspar and plagioclase, while quartz is common. Muscovite occurs rarely. This fabric also displays a very distinct elemental composition: it is characterised by very high K but also by Ce, Th, and high levels of Na and Zr.

Compositional Group 2b (Fig. 10b–d) includes eight late Hellenistic cooking pots, namely the Phokaian-type *chytrai*, two Phokaian-type *lopades*, and one deep pan. This group comprises specimens with a fine fabric. Like 2a, it is marked by fragments of acidic volcanic rocks. K-feldspar and plagioclase are the dominant mineral inclusions. Quartz is common while muscovite occurs rarely. Again, this fabric is characterised by elevated contents of K, Ce, and Th compared to other fabrics but perhaps slightly less than samples assigned to 2a. Samples Pri725 and Pri727 have a lower Al:Si ratio, reduced K, and elevated Cr and V content compared to other samples in the group. In thin section, these samples have slightly more quartz than other 2b samples.

Compositional Group 2c (Fig. 10e) includes late Classical to early Hellenistic cooking vessels, namely necked and belly *chytrai*, a lid, a pan, and *lopas* of the lebes type. Samples assigned to this compositional group are marked by a fine fabric with fragments of acidic-intermediate volcanic rocks. Dominant mineral inclusions are plagioclase and quartz, while K-feldspar and pumice are common. Muscovite, chert, micrite, pyroxene, amphibole, and fragments of metamorphic rocks are rare. In terms of elemental composition, this is quite a tight group of low calcareous (c. 2.5% CaO) samples.

Compositional Group 2d (Fig. 10f) includes three vessels of late Classical to early Hellenistic date: a brazier, a cooking stand, and a cook-

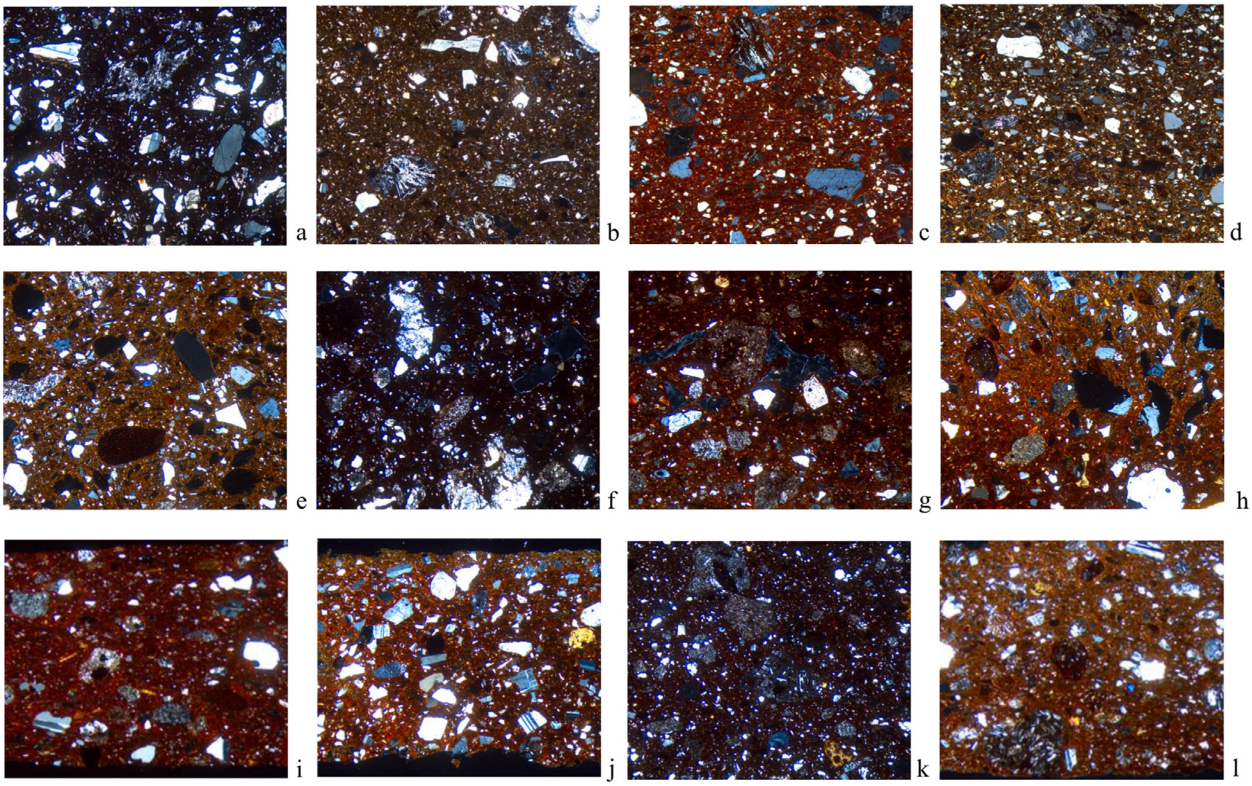

Fig. 10. Thin section micrographs of selected samples with volcanic fabrics (a) Pri145 (2a, first century BCE); (b) Pri162 (2b, first century BCE); (c) Pri725 (2b var, second century BCE); (d) Pri727 (2b var, second century BCE); (e) Pri625 (2c, fourth/third century BCE); (f) Pri518 (2d, fourth/third century BCE); (g) Pri161 (2e, first century BCE); (h) Pri163 (2e, first century BCE); (i) Pri702 (2e var, second century BCE); (j) Pri650 (2f, fourth/third century BCE); (k) Pri651 (2 g, fourth/third century BCE); (l) Pri652 (2 g var, fourth/third century BCE). Field of view 6 mm (except a, c, and d, where field of view is 3 mm). (Colour on the web and black and white in print).

ing jar. The specimens have a coarse, most likely tempered fabric characterised by fragments of acidic-intermediate volcanic and metamorphic rocks. Common mineral inclusions are plagioclase and quartz. Muscovite and chert are rare. Compared to all other volcanic groups, samples assigned to Group 2d have the lowest Na content and lowest Al:Si ratio and have comparatively low Ce, Th, Zr, and Sr values.

Compositional Group 2e (Fig. 10g–i) is attested in the middle and late Hellenistic period and includes five braziers of the Aegean type. Samples are characterised by a coarse fabric with very weathered, acidic-intermediate volcanic rocks. Dominant mineral inclusions are plagioclase. Muscovite, epidote, and serpentinite are rarely present. The absence of optical activity suggests relatively high firing temperatures. Overall, this is a somewhat variable group in terms of elemental composition: samples of the middle Hellenistic period (Pri702 and Pri740) show slightly different elemental compositions, with elevated Fe, Cr, Ni, and Zn and lower Na and Sr contents.

Compositional Group 2f (Fig. 10j) includes two samples: a late Classical to early Hellenistic *lopas* of the standard type and a lid. These are characterised by a medium-coarse, likely tempered fabric containing abundant plagioclase. K-feldspar, pyroxene, quartz, and chert are common, and it should be noted that these minerals could derive from the weathering of volcanic rocks. Muscovite and fragments of metamorphic rocks are rare. In terms of elemental composition, while still considered low calcareous, samples of this group have the highest calcium content of all the volcanic group samples and do not show the increased Ce, Th, and Zr signature indicative of felsic intrusive rocks.

Compositional Group 2g (Fig. 10k–l) includes seven vessels, namely late Classical to early Hellenistic *lopades* of the lebes type, necked *chytrai*, a pan, a lid, and a jar. This compositional group comprises specimens with a coarse, most likely tempered fabric marked by the presence of weathered, acidic-intermediate volcanic rocks. Dominant mineral inclusions are quartz and plagioclase. Chert, K-feldspars, pyroxene, and amphibole are common. Mudstone, foliated metamorphic rocks (Pri516 and Pri652), muscovite, and serpentinite are rare. Like Groups 2a and 2b, Group 2g is marked by elevated Ce and high Th content, but samples contain somewhat elevated Ca and higher Sr, V, and Ba contents than these groups. Again, Group 2g is quite variable in terms of elemental composition, with two samples (Pri516 and Pri652) marked by lower Zr, Ce, and Ba contents alongside somewhat higher levels of Cr and Ni. From a petrographic point of view, however, they do not show significant differences apart from having slightly more fragments of sedimentary and foliated metamorphic rocks. Pri652 is also a little coarser in comparison to the other samples in this group.

4. Discussion

4.1. Provenance of the metamorphic compositional groups

The petrographic characteristics of compositional Groups 1a and 1b fit well with the geology of the region around Priene, which is marked by the presence of a metamorphic formation consisting of schist (chlorite schist, epidote schist) and gneiss. These specimens could therefore be considered local or at least to represent the output of workshops potentially located in the *chora* around Priene. Unfortunately, no direct evidence for pottery production has yet been found in Priene and its territories for the time span considered in this study. While Group 1a covers the entire period, samples assigned to Group 1b, marked by a very fine paste, could instead reflect local production restricted to the late Classical and early Hellenistic periods. Earlier analyses have shown that samples assigned to Group 1a match the Prienian local reference group, as corroborated by stamped tiles and medicine vessels that have

Table 3
Average composition (M) and relative standard deviation (RSD) of metamorphic fabric groups.

	Priene 1a*		Priene 1b		Priene 1c	
	(n = 28)		(n = 6)		(n = 6)	
	M	RSD (%)	M	RSD (%)	M	RSD (%)
SiO_2 (%)	60.59	6	57.42	4	51.35	3
TiO_2 (%)	0.83	19	0.79	28	0.70	33
Al_2O_3 (%)	16.99	12	16.87	12	9.72	4
Fe_2O_3 (%)	7.55	14	7.15	26	10.48	9
MnO (%)	0.09	24	0.11	22	0.15	10
MgO (%)	3.53	53	3.79	11	18.55	19
CaO (%)	3.71	52	5.28	17	3.28	22
Na_2O (%)	1.13	30	1.35	35	0.71	24
K_2O (%)	2.88	22	2.99	14	0.64	25
P_2O_5 (%)	0.17	34	0.23	33	0.22	74
V (ppm)	107	19	97	35	113	6
Cr (ppm)	336	73	253	8	1935	18
Ni (ppm)	277	57	277	13	1555	25
Cu (ppm)	42	33	39	13	37	14
Zn (ppm)	84	15	86	16	87	4
Rb (ppm)	131	24	131	17	33	29
Sr (ppm)	140	39	194	13	84	37
Y (ppm)	31	20	37	9	17	14
Zr (ppm)	239	20	258	10	115	15
Ba (ppm)	625	25	611	11	207	25
La (ppm)	40	26	49	9	13	24
Ce (ppm)	87	22	99	13	26	29
Pb (ppm)	31	35	31	35	16	19
Th (ppm)	23	38	23	38	6	21

* Not including Pri750.

been analysed both petrographically and chemically (Amicone et al., 2014:6).

While samples in Groups 1a and 1b seem to be of a local origin, it cannot be ruled out that the variability within these groups could reflect the existence of several regional production centres. Other important cities, such as Samos, Ephesos, and Magnesia, and some parts of the vast *chora* of Miletos, lie in areas characterised by a geological environment comparable to that of Priene. Therefore it cannot be excluded that workshops in one or more of these cities established cooking ware production centres that exploited clay sources very similar to those available in Priene and were successfully exporting their products. Petrographic analysis of prehistoric materials from Samos (Menelaou and Kouka 2021) and Ephesos (Betina 2019; Peloschek 2016) has shown that it is difficult to separate the products from these sites from the typical "Prienian" fabric based solely on petrographic analysis. Nevertheless, previous elemental analysis of Augustan cooking pots from Ephesos (Zabehlicky-Scheffenegger and Schneider 2005) suggests that elemental composition may help to distinguish products from Priene and Ephesos, as while they are overall very similar (Supplementary Materials 5), these plot separately on selected biplots (Amicone et al., 2014:23) of elemental data. In the absence of further systematic analysis of pottery production in the wider Meander Massif region, we cannot further clarify these issues at this time.

The minerals observed in Group 1c correlate with metamorphic formations that outcrop around the modern city of Söke, an area that is still within the *chora* of the ancient city of Priene. These formations include the Selçuk and Lycian nappes, both containing ophiolite and peridotite-serpentinite (Rimmelé et al., 2005; Ring et al., 2007). Outcrops of these formations can also be found, however, in various other places of western Asia Minor, such as Ephesos, and even to the south on the Bodrum Peninsula, where Halikarnassos was located. Outcrops of the Selçuk nappe can also be found on the island of Samos. It is not surprising, therefore, that very similar fabrics have been identified in pottery from Ephesos (EPH-SERP_02, Betina 2019) and Samos (Fabric 1; Menelaou and Kouka 2021), and these similarities should be considered.

4.2. *Provenance of the volcanic compositional groups*

The variability observed amongst the volcanic fabric groups suggests the presence of different production centres marked by diverse volcanic geological environments.

Western Anatolia witnessed intensive magmatic intrusions during the Oligocene-Miocene and widespread volcanic activity from the Early Miocene (see Fig. 3). The volcanism in this area developed on the metamorphic rocks of the Menderes Massif as well as on ophiolitic rocks. This resulted in several basic, intermediate, and, more frequently, acidic and pyroclastic formations that outcrop in western Anatolia and on the nearby Greek islands (Aydar 1998).

In the following section, the different compositional groups identified through petrographic (Supplementary Materials 4) and chemical analysis are discussed in chronological order rather than by group labels; we also consider geological and archaeological information and previous analytical studies to correlate them with potential production centres.

4.2.1. *Late classical and early Hellenistic period*

The lack of reference data for cooking wares renders it difficult to formulate suggestions regarding the origin of the volcanic fabrics of this period. Previously (Amicone et al., 2014), Groups 2c and 2d were tentatively connected to the city of Phokaia; however, the detailed petrographic and elemental analyses carried out in the current research project show that this hypothesis should be discarded, as these late Classical and early Hellenistic volcanic groups display a composition that is clearly different from the Phokaian production (Lemaître et al., 2013; Mayet and Picon 1986:Table 1). Lacking reference data, the study of the spatial distribution of certain pottery shapes could give some clues about the possible provenance of at least some of these earlier fabrics. The majority of necked *chytrai* belong to Groups 2c and 2g. According to current evidence, the life span of this vessel shape seems to be rather limited, as necked *chytrai* appear to be attested only until the first half of the third century BCE. In addition, Priene seems to be the northernmost place in Asia Minor where this shape appears, while it has been identified more frequently in southwestern Asia Minor—for example at Halikarnassos and Rhodos (Heinze in press). While clearly different from Koan amphorae fabrics (Hein et al., 2008a), a parallel for Group 2c can be found in a late Hellenistic cooking ware assemblage from Kos (Edyta Marzec, personal communication). It may be suggested, therefore, that Groups 2c and 2g are connected to centres of production in southwestern Asia Minor that are set in a volcanic environment, such as those found at Halikarnassos, Kos, or—more restricted—Rhodes (Lekkas et al., 2018). It is important to mention that two necked *chytrai* found in Priene belong to Group 1b, for which a local/regional production can be assumed. However, this shape does not occur in association with Group 1b in the earliest contexts of Priene (*bouleuterion* and F15). This may indicate that these vessels are connected to a short-lived early Hellenistic adoption of this shape in Priene after it had been introduced to the city in the late Classical period, presumably from southwestern Asia Minor.

For now, it is almost impossible to present a hypothesis for the origin of the other two compositional groups, 2d and 2f. Group 2f is represented in only two samples, one of which is a very good example of the type of *lopas* that usually occurs in mainland Greece in the Classical period. It was not possible to find comparisons for this fabric, but this is not unexpected as few production centres are known outside of the well-studied Aeginetan one (Gauß et al., 2015 and literature therein). Additionally, no reference materials were found for Group 2d, reflecting a geological environment in which both volcanic and metamorphic rocks are present. This fabric seems to be typical for cooking stands (*lasana*) found in the earliest contexts, as well as a distinctive jar type that may have been used to boil liquids in open fireplaces.

Table 4
Average composition (M) and relative standard deviation (RSD) of volcanic fabric groups.

	Priene 2a ($n = 6$)		Priene 2b ($n = 5$)		Priene 2b var		Priene 2c ($n = 5$)		Priene 2d ($n = 3$)		Priene 2e ($n = 3$)		Priene 2e var		Priene 2f		Priene 2 g ($n = 5$)		Priene 2 g var	
	M	RSD (%)	M	RSD (%)	Pri725	Pri727	M	RSD (%)	M	RSD (%)	M	RSD (%)	Pri702	Pri740	Pri639	Pri650	M	RSD (%)	Pri516	Pri652
SiO_2 (%)	60.49	2	59.22	1	66.80	66.54	63.53	3	67.93	4	62.25	1	62.09	60.70	57.42	56.50	57.74	2	60.84	59.90
TiO_2 (%)	0.38	31	0.49	13	0.71	0.74	0.78	7	0.70	15	0.69	8	0.75	0.93	0.65	0.64	0.90	4	0.78	0.87
Al_2O_3 (%)	20.96	4	22.31	8	18.14	19.08	18.55	4	16.07	8	20.25	5	21.23	22.87	20.79	21.21	19.88	5	17.33	18.80
Fe_2O_3 (%)	5.59	7	6.10	7	5.05	5.08	5.75	5	5.79	19	5.91	6	8.02	7.86	6.79	6.27	7.40	4	6.69	7.13
MnO (%)	0.12	15	0.10	13	0.09	0.10	0.09	19	0.11	25	0.07	31	0.12	0.16	0.14	0.12	0.10	22	0.11	0.09
MgO (%)	0.61	38	0.84	27	1.21	0.68	1.09	10	1.63	48	1.16	4	1.42	1.30	1.24	1.36	1.81	10	2.24	2.05
CaO (%)	0.95	37	1.36	36	1.35	1.45	2.42	15	2.64	38	1.48	25	1.76	1.62	4.37	4.30	3.12	35	2.09	2.34
Na_2O (%)	3.51	7	2.27	15	1.95	2.18	2.24	6	0.89	18	2.39	5	1.28	1.65	2.17	2.52	2.30	9	1.09	1.58
K_2O (%)	6.02	11	5.47	9	3.59	3.82	2.38	4	3.12	9	3.30	20	3.30	3.06	1.28	1.17	3.47	10	2.90	3.23
P_2O_5 (%)	0.08	15	0.09	39	0.05	0.15	0.07	8	0.17	43	0.09	1	0.12	0.12	0.10	0.16	0.20	18	0.20	0.15
V (ppm)	30	45	44	20	59	62	77	9	98	28	86	8	129	84	87	78	119	7	133	128
Cr (ppm)	51	39	70	20	137	169	126	6	186	6	100	21	202	185	307	146	93	14	162	153
Ni (ppm)	21	56	43	34	50	48	65	2	118	15	58	5	155	116	169	108	47	30	95	73
Cu (ppm)	15	45	17	54	7	7	25	19	38	42	31	16	57	28	35	42	46	20	46	49
Zn (ppm)	101	10	84	10	54	57	69	10	71	34	72	7	101	116	83	86	86	7	89	93
Rb (ppm)	285	11	205	9	181	158	91	9	149	22	134	22	137	141	64	53	158	15	123	127
Sr (ppm)	139	28	233	27	182	209	249	3	135	11	312	5	208	262	368	429	561	15	269	413
Y (ppm)	35	17	31	17	25	24	23	14	25	20	20	15	23	24	28	27	31	9	28	26
Zr (ppm)	477	16	431	11	406	483	292	6	283	4	310	20	279	361	240	229	397	13	243	265
Ba (ppm)	325	34	492	23	495	651	782	11	469	19	960	5	959	1039	514	579	1026	7	709	879
La (ppm)	98	16	86	23	51	66	43	11	41	19	49	14	46	70	38	42	81	12	45	58
Ce (ppm)	189	8	168	9	119	146	74	8	87	13	90	20	83	107	64	72	155	13	80	106
Pb (ppm)	81	23	74	23	44	58	33	18	28	34	64	19	70	68	39	26	80	7	43	56
Th (ppm)	56	22	47	17	40	44	20	16	23	31	34	22	31	32	12	12	61	17	22	28

4.2.2. Middle/Late Hellenistic period

More robust hypotheses can be formulated for the provenance of fabrics of the later phases in Priene. Compositional Groups 2a and 2b have a very similar petrographic and elemental composition, and they seem to have been produced from similar raw materials. The striking characteristics of Group 2a are that the inclusions are coarser and have a bimodal distribution, suggestive of tempering, and that it includes exclusively pans, while Group 2b contains mainly *chytrai* and *lopades*. We could perhaps speculate that the apparently different paste recipes for these two types of Phocaean cooking vessels are related to different demands on the vessels due to differences in use. For example, the greater toughness imparted by coarse tempering (Kilikoglou et al., 1998) may have been important for pans, as this made them more resilient to frequent subcritical impact, but it could also be thought to impart greater resistance to thermal shock (Müller et al., 2014), while a finer fabric with potentially increased thermal conductivity (Hein et al., 2008b) would be better suited for the production of *lopades and chytrai*. The absence of optical activity in both compositional groups indicates that vessels produced using these fabrics were consistently fired at fairly high temperatures. The samples in Groups 2a and 2b stand out for their relatively high levels of Na and K, and this probably correlates to the abundant presence of plagioclase and K-feldspar. These characteristics, alongside very high Ce, Th, and Zr contents, isolate these groups from the other volcanic groups. The concentration of Na and K is lower in Group 2b compared to 2a, especially in samples Pri725 and Pri727 (a lid and *lopas,* respectively) from the middle Hellenistic period.

The distinctive and recognisable elemental composition of these samples corresponds to that reported previously for Phokaian cooking wares (Lemaître et al., 2013; Mayet and Picon 1986:Table 1; Supplementary Materials 5). It also matches the elemental composition of Phokaian cooking vessels from late Hellenistic and early Roman Paphos that have recently been analysed at the Fitch Laboratory (Marzec et al., forthcoming; Fabric 4). In previous studies (Amicone et al., 2014; Fenn 2016), samples assigned to these compositional groups were correlated to the Phokaian production, based on typological characteristics but also on the comparative analysis of reference samples from Phokaia itself and from Ephesos, Aquileia (Italy), Emona (Slovenia), and Pergamon, as well as Aguntum (Austria) and Gadara (Jordania) (Amicone et al., 2014). Geochemical analysis of the volcanic rocks of the Foça region identified samples with high Ce, Th, and Zr contents (Agostini et al., 2010), compatible to levels observed in Phokaian pottery sherds.

It is of note that few samples of pots with the characteristic morphological traits of Phokaian types (see Section 1.3.2) were produced in the metamorphic fabric of Group 1a. This points to a phenomenon of imitation of Phokaian production by the local/regional workshops around Priene (Fenn 2016:153–54, 275–76) and may be indicative of a high reputation attached to Phokaian cooking pots, likely rooted in their quality, or a perception thereof, as discussed further below.

Finally, the shapes associated with Group 2e have traditionally been connected to Knidos, on the Datça Peninsula (Şahin 2003). Comparison with fabrics of amphorae from that region do not allow confirmation of this hypothesis (Whitbread 1995). Nevertheless, the Datça Peninsula is characterised by considerable geological variability, and the cooking ware workshops may well have been located in different areas or have exploited different clay beds than those producing amphorae (Empereur et al., 1999). From a purely geological point of view, the composition of the samples in the present study could be compatible with that of samples attested in the Datça Peninsula, which also include volcanic-acidic formations (Ercan et al., 1982; Şimşek et al., 2017).

4.3. Cooking ware supply patterns at Priene over time

4.3.1. Organisation of production

The results presented above, together with the interpretation of the possible provenance of the different compositional groups identified, suggest several possibilities. One clear pattern emerging is that the number of metamorphic groups decreases over time. For example, two of the earlier compositional groups (1b and 1c) are no longer attested from the middle Hellenistic period onwards. In addition, the composition of Group 1a samples increases in homogeneity with time.

These observations could be associated with various alternative scenarios. If all the metamorphic fabrics reflect local products, or they are at least related to workshops operating within the *chora* of Priene, the disappearance of Groups 1b and 1c and the decreasing variability of paste in Group 1a over time could reflect a transition from a dispersed to a more centralised organisation of production in Priene. The latter would exploit a more limited range of raw material sources and would follow a more standardised routine for their preparation. However, in the absence of any identified ceramic workshop area in Priene and its *chora* for the period considered, it is not currently possible to confirm this hypothesis.

If, on the other hand, the variability of the metamorphic fabrics observed in the late Classical and early Hellenistic period reflects production centres located in different areas of the Menderes Massif beyond the *chora* of Priene, then the decreasing complexity could reflect the emergence of a specialised production centre in this region, which perhaps started to operate from the middle/late Hellenistic period and replaced the smaller dispersed centres that are attested earlier. This hypothesis could be tested through a systematic study of cooking ware production in the broader area of the Meander Valley.

A similar pattern of decreasing variability is also observed in the clearly imported volcanic ware. It is important to note that while the presence and abundance of non-local cooking wares are constant over the entire time span considered, the temporal distribution of the various non-local compositional groups identified does vary. The late Classical and early Hellenistic periods are characterised by a variety of products that are difficult to connect to precise production centres. Instead, in the late Hellenistic period, the vast majority of imports can be traced to Phokaia, the only exception being the braziers, whose secure origin of production remains unknown.

These changes in the consumption (and supply) of cooking wares in Priene seem to parallel changes in the supply of other wares in the city (Fig. 11). Most apparent is the rise of new and often highly specialised centres of production in Asia Minor (e.g., Pergamon, Ephesos, Knidos) that became leading producers for fine wares and dominated the markets of that region after the decline of Attic imports during the third century BCE. It is remarkable that these transformations of trade networks seem to follow the disruption that probably occurred during the early Hellenistic period. An obvious explanation for this could be that the political and social unrest that followed the conquest by Alexander the Great, as reflected in the continuous wars and conflicts that shaped the Diadochi period, created complications for certain long-range trade activities for the previously well-established commercial centres and hubs (Heinze in press).

4.3.2. Dietary habits

The increasing presence of Romans in Asia Minor may have affected the dietary habits of the region. Certain vessels had distinct functions within the Greek and Roman kitchen, so the introduction of new shapes could be the manifestation of such a development. Few innovations were observed, however, in the samples covering the transition from the early to the late Hellenistic period at Priene. The only changes of note are a thinning of the walls of the *chytrai* and *lopades* and possible higher firing temperatures. Thinning is a typical trait of Phokaian products and their imitations, which dominate the later assemblage in Priene. It is tempting to connect this trait to the apparent popularity of Phokaian cooking vessels. Thinner walls alongside increased vitrification resulting from higher firing temperatures would affect a vessel's heat transfer properties, which could be beneficial for cooking activities such as boiling, allowing contents to heat more quickly (Hein et al., 2008b; Müller et al., 2013). Further, given the substantial scale of production and widespread trade of Phokaian cooking ware, the reduced

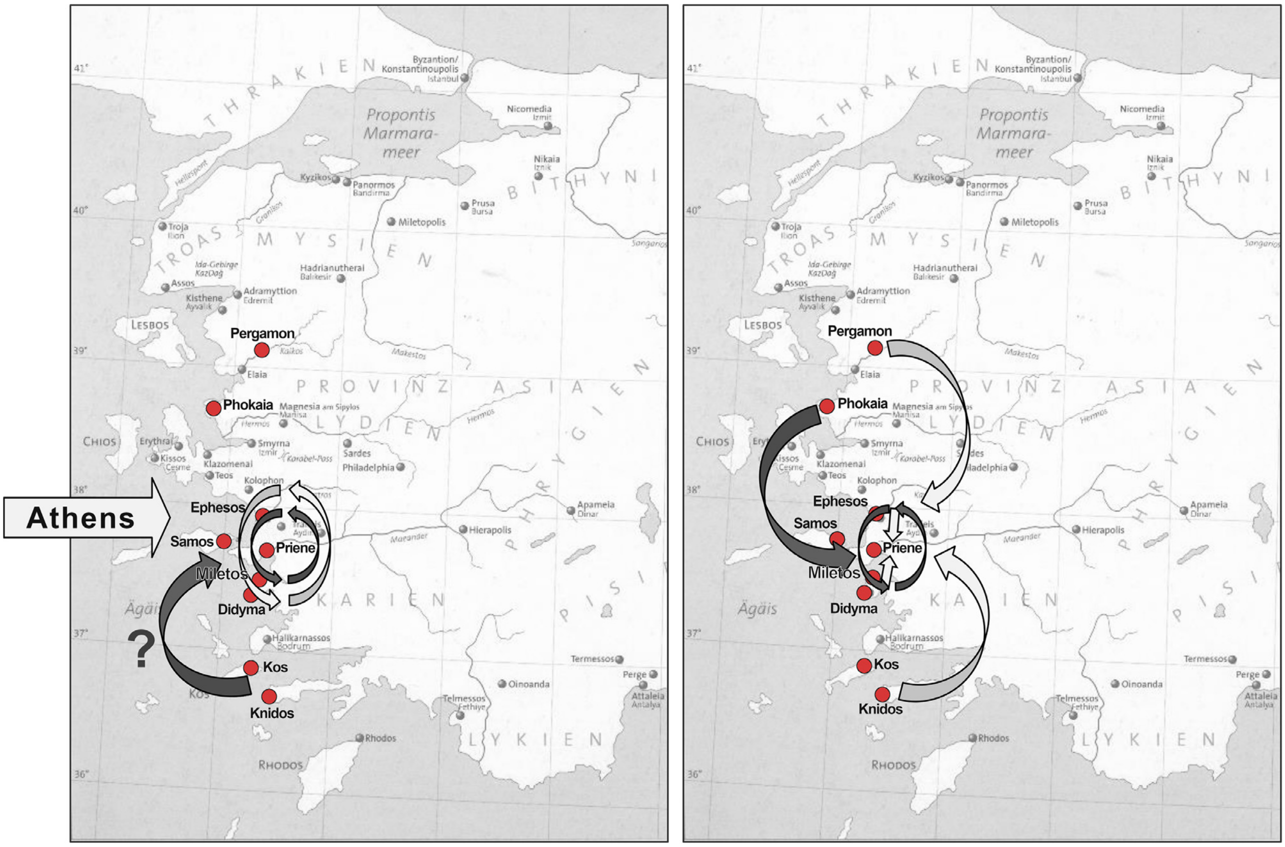

Fig. 11. General import patterns of fine wares (light grey) and cooking wares (dark grey) at Priene in the early Hellenistic (left) and late Hellenistic (right) periods. (Colour on the web and black and white in print).

weight achieved by thinning the walls might also have been favoured for products intended for export. Higher firing temperatures would increase the material's strength (e.g., Tite et al., 2001), compensating for the thinner walls and allowing the vessels to withstand loads during transportation and use.

Other than the thinner walls, both the general shapes and dimensions of the vessels connected to cooking remain stable over the time span considered. The only new shape appearing from the middle Hellenistic period is the *orlo bifido* type, originating in the Italian Peninsula during the second century BCE (Berlin 1993; Rotroff 2006). This type is deeper than the standard pans and can be closed with a lid. Its appearance therefore seems to be connected to a tradition typical of Roman cuisine. It is noteworthy, however, that this type of pan had little impact on the Prienian market, as indicated by the fact that it is found only as isolated imports and does not seem to have been included in the repertoire of local and regional manufacturers.

It may be concluded, therefore, that the key to understanding developments observed in the Priene assemblage is not changes in dietary habits but rather the emergence of specialised centres of production for cooking wares, such as those in Knidos (Doksanaltı and Tekocak 2014) and Phokaia (Firat 2012a; 2012b; 2014; Özyigit 1998). This was part of the general phenomenon of reorganisation of ceramic production described above. It does not imply that dietary habits remained unchanged in Priene over the time span considered, but this is not reflected in the patterns observed in this study. To identify possible changes in dietary habits, the integration of different proxies—in particular the analysis of organic residues as well as the remains of fauna and flora in relation to cooking areas—promises to be more rewarding. To date, very little information of this nature is available, but such research will be able to build upon the single published study (Benecke 2020) that examines faunal remains in a more general way without temporal resolution.

4.3.3. *Trade*

A significant compositional variability marks the cooking ware assemblages of Priene from the late Classical to the late Hellenistic period. Metamorphic fabrics can be recognised along with volcanic fabrics across the entire time span considered, with the latter apparently imported from more distant production centres. Not only are a substantial number of imported cooking vessels consumed at Priene, but these seem to come from a variety of sources (Fig. 12).

It has been suggested that cooking wares were occasionally transported along with other ceramic wares (Rotroff 2006:193). However, it is quite clear that, for Priene at least, fine ware imports followed different routes than those of cooking wares (Heinze in press). Kitchen wares are usually more voluminous than fine wares, so they would have taken up a considerable proportion of the space available for cargo shipped between cities. The decision to sell this type of ware would therefore need to be carefully planned and calculated.

Cooking wares were important vessels in ancient households. They were intensively used and would have needed regular replacement (Tani and Longacre 1999). The study of the contexts excavated at Priene shows that cooking wares constitute a large part of the pottery assemblages of the city, frequently accounting for between 10% and 20%. The need to import cooking vessels might therefore be linked to the fact that local/regional workshops could not meet the apparently high demand. An alternative hypothesis would be that vessels made in the local/regional metamorphic fabric, with foliated inclusions, performed poorly and were not held in very high regard, so consumers sought to obtain imported vessels. Although foliated inclusions can be argued to impart an increased use-life to fabrics due to increased toughness, they also reduce thermal conductivity and therefore are not ideal for cooking vessels (Hein et al., 2008b; Müller et al., 2010).

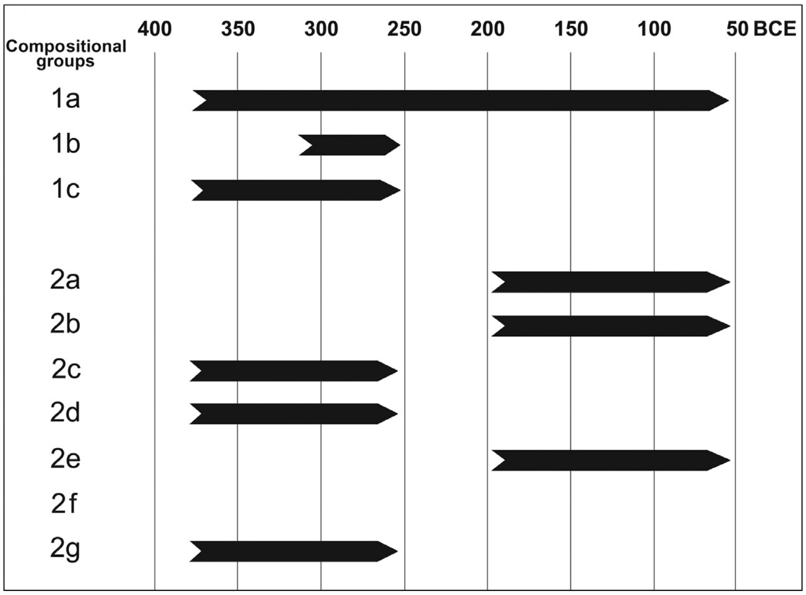

Fig. 12. Temporal distribution of the various cooking ware compositional groups identified in this study. (Black and white on the web and in print).

Other factors may have played a role in the trends reported here. However, one of these is the coastal location of Priene. The city had a functioning harbour until at least the late Hellenistic period (Fenn 2016; Müllenhoff 2005) and therefore had relatively easy access to a wide range of commodities, including cooking wares, whose transport by land would have been far more expensive. An ongoing study of cooking pots from the city of Sardis, situated about 85 km from the sea (Amicone et al., 2019; for fine ware, see Berlin 2019; Rotroff 2019), shows that in this case imported cooking pots are relatively rare in comparison to fine ware and started to appear only in the late Hellenistic period. The location of Priene would certainly have favoured imports of bulkier commodities such as cooking pots.

Nonetheless, it is important to discuss the other reasons behind the specific points of origin of imports and their development through time. Specialised centres of production of cooking ware emerged in various parts of the Mediterranean from at least the Archaic period onwards (e.g., Gauß et al., 2015). This phenomenon is occasionally also attested by finds from shipwrecks, such as that recovered close to the French coast near Var with a cargo containing at least 300 *orlo bifido* pans of Italic origins (cf. Berlin 1993).

The proximity to suitable raw materials and the adoption of specific manufacturing practices could lie behind the success of certain cooking ware production centres, with the quality of their products having been (or at least being perceived as) superior,[2] as hypothesised in the previous section with regard to the Phokaian cooking vessels imported to Priene. In addition to use-related parameters, tactile, visual, and acoustic qualities could also have appealed to consumers and could potentially have been connected to the actual performance of the pots (e.g., Longacre et al., 2000). It is likely that a complex mixture of all these and other nonmaterial factors (e.g., site location governing access to trade routes, socioeconomic dynamics) determined the range and popularity of cooking ware production centres and the appearance of local imitations of these popular products (Gauß et al., 2015).

[2] Cooking vessels should be able to withstand thermal stresses they are exposed to during use and be reasonably resistant to subcritical impacts endured in frequent handling (e.g., Tite and Kilikoglou 2002). Depending on the mode of cooking, different demands are placed on thermal conductivity (Müller et al., 2013). These properties can be steered in manufacture as they are affected by composition and microstructure, which in turn depend on the raw materials and manufacturing techniques used in manufacture (Müller 2017).

5. Conclusions

This study allows us to explore patterns of consumption, supply, and trade, in addition to the potential production of cooking ware, in the city of Priene. The combination of petrographic and elemental analysis reveals that local/regional products are present alongside imports from a variety of production sites. The results indicate a decreasing diversity in local/regional production and imports, which may suggest a centralisation of production. This closely parallels developments seen for other commodities consumed at Priene, such as fine wares. The general continuity in the functional shapes of cooking ware present at the site over the study period implies that the developments observed are unlikely to be connected to major changes in dietary habits. Instead, the observed patterns and discontinuities in ceramic fabric may be explained in light of the reorganisation of production in the wider area in the wake of disruptive historical developments in Asia Minor during the transition to the late Hellenistic period and Romanisation.

Further systematic analysis on the production and consumption of cooking ware from the broader region, including sites such as Miletos, Samos, and Didyma, will allow us to examine this phenomenon on a larger scale and aid understanding of this transitional phase. Our study clearly demonstrates the potential of investigating major historical events through the interdisciplinary study of cooking ware. This is particularly significant given that this category of material culture is often neglected or included only in specialised ceramic studies that are not considered relevant to a broader archaeological audience.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

CRediT authorship contribution statement

Silvia Amicone: Conceptualization, Methodology, Formal analysis, Investigation, Writing – original draft, Writing – review & editing, Visualization, Project administration, Funding acquisition. **Noémi S. Müller:** Methodology, Formal analysis, Investigation, Writing – review & editing, Visualization. **Lars Heinze:** Conceptualization, Methodology, Investigation, Writing – review & editing, Visualization. **Gerwulf**

Schneider: Methodology, Formal analysis, Writing – review & editing. **Svenja Neumann:** Investigation, Writing – review & editing. **Nina Fenn:** Investigation, Writing – review & editing. **Evangelia Kiriatzi:** Methodology, Supervision, Formal analysis, Investigation, Writing – review & editing, Resources.

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Supplementary materials

Supplementary material associated with this article can be found, in the online version, at doi:10.1016/j.aia.2023.05.002. Additional data that support the findings of the study are also openly available at: doi:10.7910/DVN/E1O3NB.

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