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Lydian pottery in the Roman tradition: An archaeometric study of production at Sardis

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Abstract

The emergence of Sardis as an urban centre in the early Iron Age coincided with local production of fine painted pottery in a distinctive regional idiom. Examples of Lydian-style pottery found across western Anatolia from the eighth century BC attest the city's growing cultural and economic contacts as well as consistent materials and craft methods. Archaeometric study using neutron activation analysis (NAA) at the University of Missouri Research Reactor (MURR) examined representative specimens of Lydian-style ceramics from Sardis and compared their composition with later examples of red-gloss and red-slipped pottery, fine grey wares and transport jars commonly found at the site. The results confirm the sustained activity of local workshops from the early Iron Age into later historical periods, as Lydia became part of the Seleucid and Roman empires and Sardis a centre of regional innovation.

Özet

Sardes'in Erken Demir Çağı'nda bir kent merkezi olarak ortaya çıkışı, kendine özgü bölgesel bir üslupta yapılmış yerel ince boyalı seramik üretimiyle aynı zamana denk gelmektedir. MÖ sekizinci yüzyıldan itibaren Batı Anadolu'da bulunan Lydia tarzı seramik örnekleri, kentin artan kültürel ve ekonomik ilişkilerinin yanı sıra aynı malzeme ve üretim yöntemlerinin kullanıldığını da kanıtlamaktadır. Missouri Üniversitesi Araştırma Reaktörü'nde (MURR) nötron aktivasyon analizi (NAA) kullanılarak yapılan arkeometrik çalışmada, Sardes'ten Lydia tarzı seramiklerin temsili örnekleri incelenmiş ve bu seramik grubu, yerleşim yerinde yaygın olarak bulunan parlak kırmızı ve kırmızı astarlı seramikler, ince gri seramikler ve taşıma kaplarının daha sonraki örnekleriyle karşılaştırılmıştır. Sonuçlar, erken Demir Çağı'ndan, Lydia'nın Seleukos ve Roma imparatorluklarının bir parçası haline geldiği ve Sardes'in bölgesel yeniliklerin merkezi olduğu sonraki tarihsel dönemlere kadar yerel atölyelerin faaliyetlerinin devam ettiğini doğrulamaktadır.

Ancient Lydia lay at the heart of western Anatolia, along both sides of the Hermus (Gediz) river as it descends from the high plateau of inland Phrygia to the Aegean coast. The fertile river valley with freshwater Gygaean Lake near its centre had a long history of settlement, and by the Late Bronze Age this included continuous occupation of the site of Sardis (Fig. 1). For over a millennium, between the eighth century BC and early seventh century AD, Sardis served in turn as the centre of the Lydian empire, seat of a Persian satrap, strategic Seleucid polis and Late Roman provincial capital. Excavations carried out since 1958 by the Archaeological Exploration of Sardis have made clear that the site was a regional focus of habitation, exchange and consumption, and home to enduring customs of craft and production (Hanfmann 1983; Cahill 2010).

The economic importance and political status of Sardis, together with its distance from sea lanes and coastal highways, contributed to significant continuity in pottery-making traditions. Diachronic regional survey has noted broad similarity among local ceramic fabrics and shapes during the Bronze Age, with increasing standardisation of the kinds of fine pottery known at Sardis appearing in the early Iron Age (Luke et al. 2015: 445–46). While paths of interregional exchange came to focus on the city, the volume they carried remained limited by its location three

travel-days from Aegean ports and major settlements on the Anatolian plateau. In town and country alike, potters relied on nearby resources and familiar technologies to make vessels for preparing, consuming and storing food and other commodities (Peacock 1982: 52–74; for transport in late antiquity, Bandow 2013). Sixty years of excavation and study at Sardis have clarified the emergence of distinctive fine and utility wares during the Archaic Lydian and Late Lydian periods, as well as their transformation by contact with Persian, Hellenistic and Roman markets. Morphological and microscopic study of selected wares has underscored the general similarities of clays, potting methods and firing temperatures used at different times in the site's history (Scott, Kamilli 1981; Rotroff, Oliver 2003: 96–97, 134; Raubolt 2019; Ramage et al. 2020: 1–18).

This paper builds on earlier compositional investigations to explore the production of pottery at Sardis during the Roman (mid-first century BC to mid-third century AD) and Late Roman (late third century to mid-seventh century AD) periods. Over 200 representative examples of early Iron Age through modern ceramics and soils from the site and environs were selected, prepared and subjected to neutron activation analysis (NAA) at the University of Missouri Research Reactor (MURR). Previous analytical projects have focused on the Bronze Age and early Iron Age, but have paid little attention to Lydia after the time of Alexander; for this reason, the objective of sampling was to confirm the material parameters of Archaic Lydian and Late Lydian ceramics while examining the range of local production in the early first millennium AD. As in other parts of western Anatolia, the region's distinctive geomorphology is well suited to the analytical strengths of NAA, which can quantify a broad range of diagnostic elements in ceramic specimens (Perlman, Asaro 1969; Glascock 1992; Riehle et al. 2023; for the local geology Roosevelt 2009: 46–47; Kealhofer et al. 2013: 1923). Coordination of results obtained by multiple projects carried out by independent laboratories, moreover, allows comparison within a growing field of provenance research spanning the east Mediterranean region (see Appendix). MURR's analysis of 39 specimens of Lydian-style pottery (about 20% of the total sample) and seven local sediments broadly confirms the findings of earlier investigations and establishes the scope of local production, which has been the subject of recent discussion (Kealhofer et al. 2013; Luke et al. 2015; Gürtekin-Demir et al. 2022). The 163 examples of late Hellenistic, Roman and Late Roman

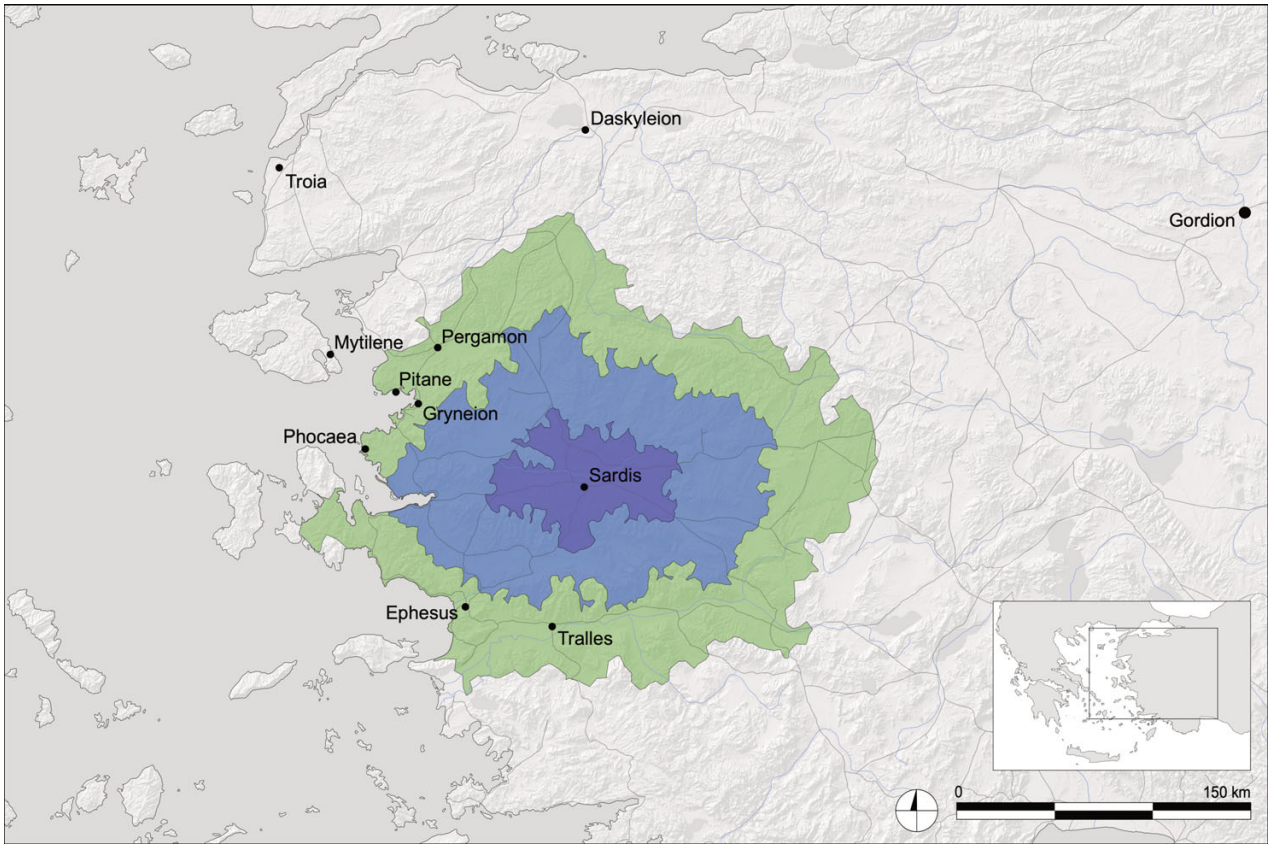

Figure 1. Map of western Anatolia with 50km isodistance intervals from Sardis, and other sites mentioned in text (by B. Bricker).

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wares presented in this report include fine red-gloss pottery, moldmade relief bowls and serving dishes in grey fabric, red-slipped tableware and one-handled transport jars. Smaller numbers of moldmade ampullae, Asia Minor-type lamps, utility pottery and ceramic building materials were included for comparison. Compositional analysis demonstrates that many of these representative objects were made close to Sardis by potters who introduced new ideas to this late phase of regional production.

Previous materials analysis of Lydian pottery

The diverse geology of western Anatolia, a seismically active metamorphic landscape underlain by a series of east-west grabens, offers an attractive environment for provenance studies of archaeological materials. Evolving methods of petrographic, heavy mineral and X-ray diffraction and fluorescence analyses (XRD, XRF) were among the first to draw attention to the geologic composition and processing of clays into suitable ceramic pastes in the early Iron Age (twelfth to sixth centuries BC). Most of this research grew out of long-term exploration of coastal sites like Ephesus, Miletus and Pergamon, with the primary goal of distinguishing imported wares from local products (Sauer 1995; Schneider 2000; Ladstätter, Sauer 2005; Schneider, Japp 2009). Turning inland to Sardis, XRF analysis of 40 specimens of Lydian-style painted pottery and clays assembled in the late 1970s identified a homogenous chemical structure that was shared with similarly decorated vessels found elsewhere (Dupont, Lungu 2010; 2020). Petrographic and XRD study and scanning electron microscopy (SEM) have established the basic characteristics of fine and coarse ceramics used in different parts of the Archaic city (Kamilli 1978; Scott, Kamilli 1981; Middleton et al. 2010).

NAA offers a more exacting approach to sorting closely related archaeological materials (Glascock 1992; Neff 2000; Riehle et al. 2023). One of the earliest applications of NAA to ceramics from ancient Lydia centred on moldmade Asia Minor lamps and related materials now in the collections of the British Museum (Hughes 1988). Nine lamps recovered by early exploration at Sardis were available for study by the British Museum Research Laboratory, along with ten lamps from later excavations, eight examples of Lydian-style pottery and eight coarse-ware sherds of uncertain date from nearby Bin Tepe. Cluster analysis of 23 elements identified by NAA at Amersham International PLC (Harwell, Oxfordshire) established the broad homogeneity of these varied samples. Most of the Sardis lamps and Lydian-style wares were assigned to four closely related sub-clusters, which differed from morphologically similar lamps found at Ephesus and other sites in the region. Compositional differences between the Sardis and Ephesus clusters appeared mainly among Cs, Na and Fe, which are present in greater concentrations among the Sardis specimens, while Hf is more strongly represented among lamps from Ephesus. Four Sardis lamps were associated with a related but distinct compositional group and may have come from another workshop in the vicinity (Hughes 1988: 479).

Long-term investigations begun in the early 1980s at the Helmholtz-Institut für Strahlen- und Kernphysik (HISKP) at the University of Bonn have used NAA to explore several well-known classes of late Bronze Age and early Iron Age pottery in western Anatolia. Analysis of up to 30 trace and minor elements identified nine regional groups within the initial collection of 107 specimens (Akurgal et al. 2002). The groups have been refined and considerably expanded by analysis of additional specimens, which now number over 12,500. At least two compositional groups have been distinguished among contemporary products of both Ephesus and Miletus. Further study has proposed production areas in Aeolis, north and south Ionia, Samos and elsewhere in the Aegean region (Kerschner 2005; 2006; Kerschner, Mommsen 2009; for geographic boundaries, Apostolou 2023). Two of these compositional groups (SarP and SarQ, combined n=59) comprise specimens of Lydian-style wares commonly found at Sardis, as well as a burnt or misfired Hellenistic bowl excavated at the site (Gürtekin-Demir et al. 2022: 102–04).

Another large-scale application of NAA to the study of regional ceramics was conducted in Canada at Becquerel Laboratories (Mississauga, Ontario) on behalf of the Anatolian Iron Age Ceramics project (AIA). Drawing on earlier examination of clays and ceramics at Gordion in Phrygia, the AIA project has tested nearly a thousand representative samples from sites in western and central Anatolia spanning the eighth through sixth centuries BC (Henrickson, Blackman 1996; Grave et al. 2009; Kealhofer et al. 2013; 2023). Analysis of principal components (PC) and canonical variates (CV) for the 24 elements measured by both laboratories proposed compositional groups associated with different production centres, of which Sardis was one of the most important. Twenty sediments and 255 ceramic specimens from the Sardis vicinity offered evidence for two macrogroups, A and B. Two sediments and more than half of the pottery samples (combined n=148) were assigned to a primary local group (A 1.1). Other sediments and ceramics were attributed to related groups (A 1.2–6, B 2.01–05), whose variations apparently reflect different clay sources or methods of preparation. After reducing the dataset to 13 diagnostic elements, 27 of these specimens could be associated with previously identified sources in Aeolis, Ionia and elsewhere (Kealhofer et al. 2013).

More recently, petrographic and NAA study of Chalcolithic through Iron Age ceramics from the wider

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environs of Sardis has been carried out as part of the Central Lydia Archaeological Survey (CLAS). The survey area encompasses the valley floor and surrounding foothills within a half-day walking distance of the Gygaean Lake, which lies about 15km north of the city (Luke et al. 2015: 428–30; Roosevelt, Luke 2017: 123–28). A selection of 387 ceramics representing different fabrics, shapes, finishes and dates was subjected to NAA at MURR. Multivariate analysis of 30 elements, selectively refined by petrographic scrutiny, defined four related compositional groups within the area's general geochemical homogeneity. The preponderance (nearly 90%) of increasingly standardised Iron Age wares assigned to group 4 apparently reflects the selective quarrying and processing of local clays around the time that fine Lydian-style pottery and architectural terracottas appeared at Sardis (Luke et al. 2015: 445–46, tab. 2).

Compositional analysis and interpretation at MURR

Research undertaken at MURR extends the findings of these earlier investigations of Bronze Age and early Iron Age Lydia into the first millennium AD. Sardis was a major population centre of the region throughout the late Hellenistic and Roman periods, and survived earthquakes and social upheaval to become the capital of the province of Lydia during the later Roman empire (Hanfmann 1983; Rautman 2011). Ongoing excavations have made clear the city's economic vitality and political importance between the later first and sixth centuries, when local potters turned out specialised wares for cooking, eating, storage and transport. Imported fine ware, cooking pots and amphorae trace complex connections with other regional cities and the wider Mediterranean (Rautman 1995; Raubolt 2019).

It has generally been assumed that much of the pottery used at Sardis in the early Iron Age was made in the vicinity of the site (Hanfmann 1983: 78–79). Painted, plain and coarse ceramics found in Archaic Lydian and Late Lydian contexts present fabrics that resemble local sediments and clays. The ceramic body is normally fine in texture with mostly silt-sized grains, and was fired light red to reddish yellow in colour (about 2.5YR 5/6 to 5YR 5/6–6/6 on the Munsell scale). Abundant mica is invariably present and often appears in sizeable gold flecks. Coarser fabrics can have a soft, flaky texture and include small stony particles, such as quartz, untwinned feldspar and chert, which in some cases were reduced by levigation (well described by Kamilli 1978; Middleton et al. 2010: 158; Gürtekin-Demir 2021: 1–8; Ramage et al. 2021: 9). Petrographic study of ceramics found around the Gygaean Lake has explored the close relation of early Iron Age pottery with wares of the Middle and Late Bronze ages (Luke et al. 2015: 444). Visually similar fabrics appear in Lydian-style vessels and rooftiles like those known at Sardis. Compositional analysis offers a way to track the emergence of new Roman-style wares against this broad chronological background.

Archaeological materials from Sardis analysed by NAA at MURR comprise 202 historical ceramics, seven sediments (four in both bulk and clay fraction) and two commercially manufactured tiles from a nearby factory (Tab. 1). Examples of Archaic Lydian (n=28) and Late Lydian ceramics (n=11) represent painted wares commonly found at the site: cups and skyphoi, bowls, stemmed dishes, jugs, kraters, amphorae and tiles (for a recent overview of shapes and styles, Ramage et al. 2021: 1–18). Late Hellenistic and early Roman materials (combined n=38) consist of fine red- and black-gloss pottery and moldmade relief bowls. Late Roman ceramics (n=125) include red-slipped tableware, utility pottery, roof tiles and a few specialised objects like moldmade ampullae and Asia Minor lamps. Sediments did not come from systematic surface sampling but were acquired in the course of unrelated projects. Materials were processed and analysed at MURR according to procedures described by Glascock (1992; 2018). Compositional data and group assignments are presented in Czujko et al. (2024).

Broader interpretation of the results was made possible by incorporating data from previous analyses carried out at MURR and other laboratories. A piece of red-gloss Eastern Sigillata B (ESB) ware from Tel Anafa, Israel, and an example of Phocaean Red Slip/Late Roman C (PRS/LRC) ware and five Late Roman 1 (LR1) amphorae from Kalavasos-*Kopetra*, Cyprus, were analysed at MURR in the late 1980s (Slane et al. 1997; Rautman et al. 2003). Sixteen Sardis ceramics were analysed by the British Museum (BMS- and W-series) around the same time. One example of red-slipped LRC ware from Sardis was included by the AIA project undertaken at Becquerel Laboratories. Fifty specimens of local and non-local wares from Troia were studied at the University of Mainz (K-series; Tekkök, Pernicka 2012). One Hellenistic sample from Sardis and forty specimens of Archaic through Late Roman pottery from Phocaea were analysed at Bonn (Phok-series; Kerschner 2006; Mommsen, Japp 2009). Altogether, 332 ceramics and soils were available for quantified analysis (Tab. 1).

Statistical interpretation of the combined dataset followed recognised procedures for PC analysis and calculation of group membership assignments based on Mahalanobis distance-based probabilities (Glascock 1992; Neff 2000). PC analysis offers an efficient way to characterise the elemental compositions of multiple ceramic specimens and distinguish compositional clusters in their patterning. Group boundaries were evaluated by trends seen across scatterplots of different variables, and associations between individual samples were observed and clusters grouped;

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confidence ellipses were drawn at 90%. Group membership was further evaluated using Mahalanobis distance calculations on the first three PCs, which account for 76.73% of variance, and the first four PCs, which account for 84.03% of variance within the PC-transformed dataset. All samples were grouped and tested as unknown values against the compositional reference groups. Ten primary reference groups emerged from this statistical analysis.

Compositional groups of local origin (A, B and D)

The local origin of most Archaic Lydian through Late Roman specimens appears clearly in the structure of two large and closely related groups (Fig. 2). Forty-five percent of the Sardis ceramic specimens analysed at MURR (combined n=202) were assigned to the Local A group, whose 91 members consist of 30% Lydian-style and 70% Hellenistic through Late Roman samples. Ten members of the closely related Local B group comprise 30% Archaic and 70% later specimens as well. Together the two groups include 30 of 33 assigned specimens of Lydian-style pottery, 19 of 24 assigned late Hellenistic fine wares and various Roman and Late Roman fine, plain and coarse ceramics commonly found at the site. The connection of these groups with Sardis is supported by analysis of a subsurface sediment (SRD145A/B) collected in 1997 by coring at Mersindere, about 5km west of Sardis, for which Mahalanobis probability calculations show a strong likelihood of assignment to Local A. Two soil samples (SRD143A/B, 144A/B) obtained in 1981 from a modern pottery workshop near Urganlı, about 20km west of Sardis, show moderate agreement with six ceramic specimens assigned to group D, and these can provisionally be assigned to the vicinity. While the historical scope of 'local' can vary, and in late antiquity may have approached a long day's travel distance (up to 50km, see Fig. 1; Morrisson 2012: 4–5; Lavan 2013), most samples in these three groups seem to have originated within a short distance of the site (Kealhofer et al. 2013: 1924–27).

The identification of two or more local groups resembles the findings of earlier NAA investigations of

Dataset / Compositional group	**Total**	**Local A**	**Local B**	**C**	**D**	**E**	**F**	**G**	**H**	**J**	**K**	**Unassig.**
Archaic Lydian	28	17	3								2	6
Late Lydian	11	10						1				
Hellenistic	25	15	4					5				1
Roman	13	10						2	1			
Late Roman	125	39	3	6	6	4	5	30	6	13		13
Sum: Sardis MURR ceramic dataset	202	91	10	6	6	4	5	38	7	13	2	20
MURR: Mytilene, Tel Anafa, Cyprus	9			1				2	4	1		1
Becquerel Laboratories: Anatolian Iron Age Project	1									1		
British Museum Research Laboratory	16	9	2									5
Helmholtz-Institut, University of Bonn	41	1								4		36
University of Mainz	50			32								18
Sum: Combined ceramic dataset	319	101	12	39	6	4	5	40	11	19	2	80
Archaic Lydian and Late Lydian	55	36	5					1			2	11
Hellenistic through Late Roman	212	65	7	39	6	4	5	39	11	19		17
Unknown	52											52

Table 1. Group assignments of Sardis ceramics analyzed at MURR, and related ceramics from other projects included in Figs 4, 6, 8 and 10.

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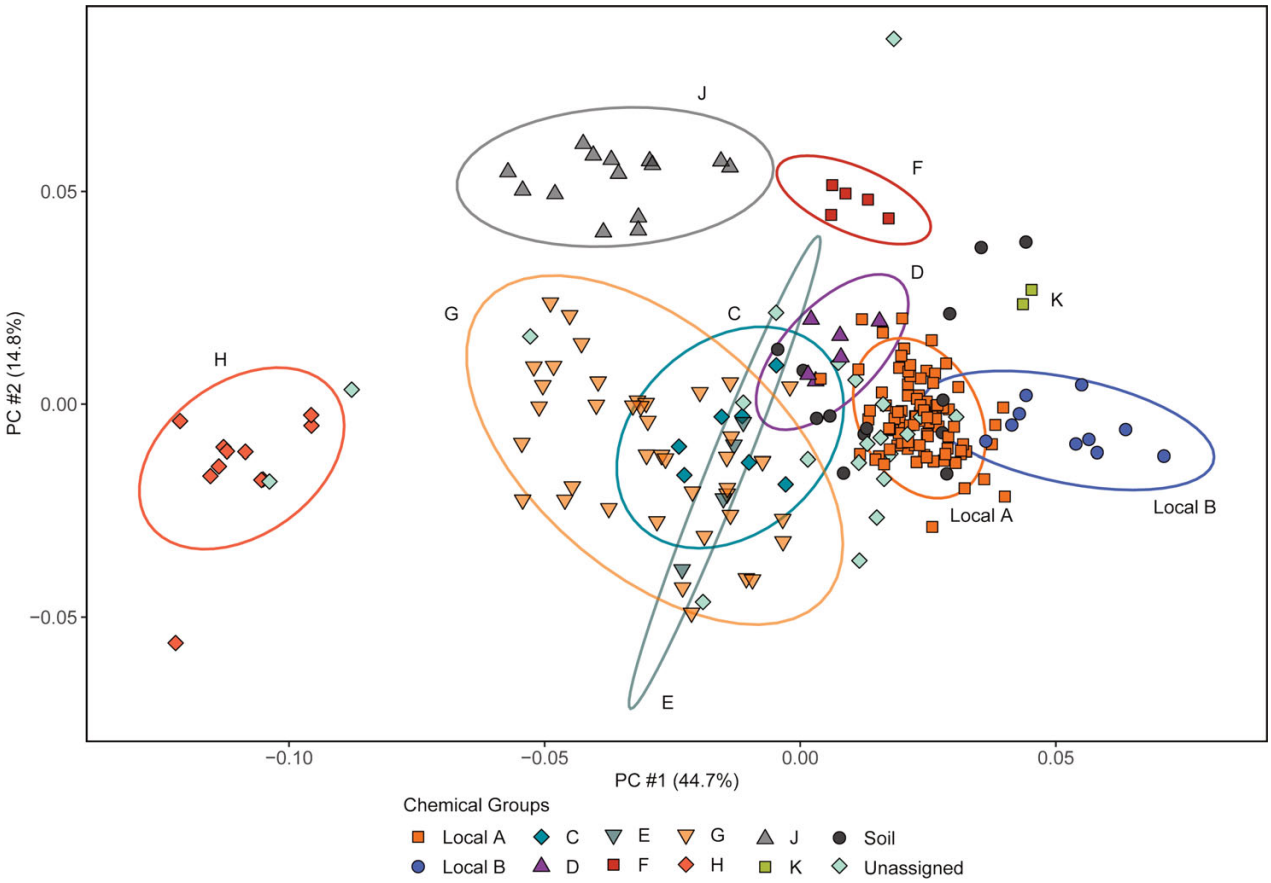

Figure 2. Scatterplot of compositional reference groups Local A and B and groups C, D, E, F, G, H, J and K based on NAA carried out at MURR.

Sardis-area ceramics (Tab. 2; see Appendix). The British Museum's fourth cluster analysis of Lydian-style pottery and Roman lamps found four closely related subclusters among the samples (combined n=24; Hughes 1988: 479, tab. 5), although changes in measuring elemental concentrations since the 1980s preclude direct comparison with MURR data. Analysis at Bonn distinguished two primary groups, SarP and the closely related SarQ, among the 58 Lydian-style and one Hellenistic specimens associated with the site (Gürtekin-Demir et al. 2022: 102–03, tab. 1). Five of the SarQ specimens (Sard73–77) were also analysed by the British Museum (as W45692T, W45693R, W45694P, W45695Y, W45698S, respectively), and these data can be assigned to the Local A group at MURR. The AIA project attributed 203 ceramic specimens and three sediments (AIA3901, 3903, 3905) collected within 15km of Sardis to the local macrogroup A ('Pactolus group'), and assigned 69 ceramics and 17 sediments to the geographically broader macrogroup B (Kealhofer et al. 2013: tab. 2a). While Becquerel data are based on a different compositional standard, the broad patterning of Lydian-style ceramics and local sediments resembled observations at MURR. Forty-two specimens of Iron Age pottery analysed at MURR for the CLAS regional survey were assigned to compositional group 4 (Luke et al. 2015: 442, tab. 2). Table 4a (see online supplementary materials) summarises intercalibrated average elemental values for local reference groups determined by these four projects. Correspondences among primary and secondary groups are complex and deserve further sampling and study.

Compositional groups of non-local origin (C, E, F, G, H, J and K)

Three Lydian-style ceramics and 72 Hellenistic through Late Roman specimens from Sardis were distributed among seven other compositional groups (Fig. 2, Tab. 2; Czujko et al. 2024). The approximate location of four of these groups can be established by the presence of familiar ceramic wares of known origin (Hayes 1997). Group H includes Eastern Sigillata A (ESA) ware and LR1 amphorae, which are understood to come from Cilicia and north Syria. Six examples of ESB ware place the source of group C near Tralles in south Ionia. Ten samples of PRS/LRC ware locate group J in the coastland of Aeolis. The assignment of Eastern Sigillata C (ESC), including Pergamene, Çandarlı and related wares, suggests that the large group G originates

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Local A: Sardis vicinity (combined n=101)		
26	Archaic Lydian	Black-on-red stemmed dish, wave-line hydria/krater, oinochoe, banded/streaky skyphos, tile
10	Late Lydian	Achaemenid bowl, skyphos, tile
16	Hellenistic	Local, grey and red moldmade relief bowl, red- and black-gloss Ionian platter
10	Roman	Local red-gloss Sardian Sigillata, red-slipped dish
39	Late Roman	Local red-slipped/LRC, red-slipped dish, grey serving dish, MWJ-B, plain utility, brick, pipe, tile
Local B: Sardis vicinity (combined n=12)		
5	Archaic Lydian	Black-on-red dish, wave-line krater/hydria, oinochoe, tile
4	Hellenistic	Local moldmade relief bowl
3	Late Roman	Local red-slipped/LRC, red-slipped dish, moldmade Asia Minor lamp
Group C: South Ionia, Tralles vicinity (combined n=39)		
39	Roman	Red-gloss (and grey-fired) ESB
Group D: Central Lydia (n=6)		
6	Late Roman	Red-slipped/LRC, AMLC, moldmade Asia Minor lamp, MWJ
Group E: Unlocated (n=4)		
4	Late Roman	ESC-Çandarlı, AMLC
Group F: Unlocated (n=5)		
5	Late Roman	MWJ-C (grey fabric)
Group G: Aeolis (combined n=40)		
1	Late Lydian	Achaemenid bowl
7	Hellenistic	Pergamene Appliqué, black-gloss Ionian platter
2	Roman	Pergamene Sigillata/ESC, red-gloss ESB
30	Late Roman	Çandarlı/ESC, AMLC, red-slipped/LRC, moldmade ampulla and Asia Minor lamp, MWJ-A, MWJ-B
Group H: Cilicia-North Syria (combined n=11)		
1	Roman	Red-gloss ESA
10	Late Roman	LR1 amphora
Group J: Aeolis, Phocaea vicinity (combined n=19)		
19	Late Roman	PRS/LRC, LR unguentarium
Group K: Unlocated (n=2)		
2	Lydian	Brown-on-buff cup/jar
Unassigned (combined n=80)		
11	Archaic Lydian	Brown-on-buff cup/jug, black-on-red dish/krater, greyware jug, marbled fruitstand
6	Hellenistic	Grey moldmade relief bowl, black-gloss dish
4	Roman	Troia red-gloss ESB
14	Late Roman	Red-slipped dish, AMLC, LR unguentarium, MWJ-A, MWJ-B, LR1 amphora, plain utility
45	Uncertain	(Phocaea vicinity and Troia)

Table 2. Group assignments and proposed sources of combined ceramic dataset (n=319).

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in the same general region. In addition to these major ceramic sources, three small groups represent unidentified and perhaps short-lived regional workshops: group K with two brown-on-buff Lydian wares, group E with two examples each of ESC and Asia Minor Light Colored (AMLC) wares, and five grey-fabric transport jars of group F. Drawing on earlier work by other laboratories, the combined dataset reinforces these compositional groups and expands the membership of MURR groups C, G, H and J. About 15% (6 of 39) of the Archaic and 9% (14 of 163) of Hellenistic through Late Roman specimens in the Sardis MURR ceramic dataset remain unassigned.

The Roman tradition at Sardis

The attribution of both local and non-local provenance to ceramics of similar form and finish reflects the economic and social networks that joined Sardis with other cities of the Roman East. A growing urban population and developing markets in the first centuries AD stimulated demand for commodities and encouraged local workshops to adapt their practice to new economic and social circumstances. Significant changes included the production and use of fine red-gloss pottery, grey-fabric relief bowls and serving dishes, red-slipped tableware and slender transport jars around Sardis and its environs.

Eastern Sigillata B ware and Sardian Sigillata

Red-gloss pottery was one of the most distinctive innovations of the early Roman period in the east Mediterranean. Following the introduction of high-quality table wares from Italy during the late republic, a variety of fine plates, dishes, bowls and cups spread across the Aegean coastlands in the late first century BC. The most widespread series of red-gloss ceramics in western Anatolia are known as Eastern Sigillata B (ESB) ware. The earliest production of ESB ware is unsettled but its appearance and general development are clear (Hayes 1985: 49–70; Lund 2003; Fenn 2013; Bes 2015: 16–17). The light red fabric appears consistently fine grained with a little mica, was evenly fired and usually carried a dark-red glossy or waxy slip; grey-fired versions of some early forms are known as well. The fine fabric, thin-wall construction and smooth finish show that vessels were made in well-organised workshops that shared raw materials and kiln technologies. Literary sources and recent fieldwork suggest that early production centred on the city of Tralles in the lower Meander valley (modern Aydın; Takaoğlu 2006; Civelek 2010). Growing demand in the first and second centuries AD encouraged potters across western Anatolia to turn out similar vessels in the new red-gloss tradition (Poblome, Zelle 2002).

ESB ware has received much archaeometric attention, which has documented its compositional consistency at Tralles, throughout western Anatolia and across the Aegean. Thin-section and XRF analyses have suggested a geological environment favouring Ca-enriched soils and metamorphic rocks (Sauer 1995; Schneider 2000; Fenn 2016). Chemical study by inductively coupled plasma mass spectrometry (ICP-MS) and inductively coupled plasma atomic emission spectroscopy (ICP-ES) has confirmed the ware's chemical uniformity and close relation to soils near Tralles (Takaoğlu 2006). Compositional outliers are generally seen to reflect production experiments and imitations made elsewhere, especially during the later first and second centuries.

A few examples of ESB ware have been included in early NAA studies of non-Anatolian materials (e.g.,

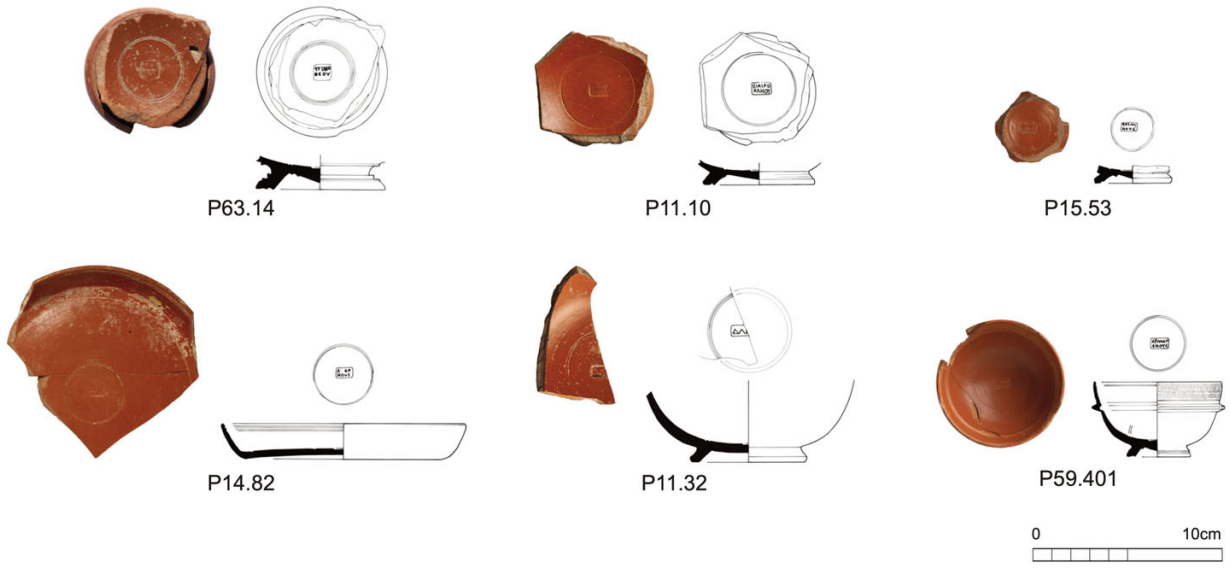

Figure 3. Sardian Sigillata, representative examples (by C.S. Alexander and B. Bricker; © Archaeological Exploration of Sardis/President and Fellows of Harvard College).

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Hatcher et al. 1980; Slane et al. 1997). Recent study at the University of Mainz used NAA to examine red-gloss and related pottery from excavations at Troia, near the Dardanelles along the north Aegean coast. Cluster analysis found a high level of uniformity among 29 non-local red-gloss vessels and three grey-fired examples of the same forms, which supported their visual identification as ESB ware. By contrast, the fabric of three other red-gloss bowls resembled local sediments and pre-Roman pottery at the site, confirming the long-term use of homogeneous clays by local potters (Tekkök, Pernicka 2012: 353; Grave et al. 2013: 1774–76). A larger NAA investigation of ESB and related wares is underway in Vienna.

Research at MURR took a similar approach to red-gloss wares from Sardis. A recent study of representative shapes and potters' stamps proposed that a limited series of vessels was made by local workshops (Rotroff et al. 2018; Fig. 3 for representative examples). Wavelength dispersive X-ray fluorescence (WD-XRF) analysis of 23 red-gloss bowls and dishes found at the site confirmed the distinctive fabric of this 'Sardian Sigillata'. Six specimens bearing stamps of local potters were clearly separated from 17 examples with different names, and which presented higher values of Cr and Ni consistent with ESB ware (Rotroff et al. 2018: appendix C). In most cases the geochemistry agreed with observed differences in fabric colours, with local vessels appearing slightly redder (near 2.5YR 5/6) than the non-local wares (5YR 6/6; Rotroff et al. 2018: 135–36, fig. 1).

Eighteen different specimens of red-gloss vessels from Sardis were available for NAA at MURR. Fabrics ranged from red to reddish yellow in colour (about 2.5YR 5/6–6/6) and included varying amounts of fine mica. All examples had a glossy red or mottled red/black surface. No name was preserved but one base was stamped with a rosette. PC analysis found that the fabric of ten small dishes and bowls (SRD047, 048, 127, 130, 151, 152, 161, 162, 165, 166) closely resembled the Local A reference group, supporting their identification as Sardian Sigillata (Fig. 4).

Six visually similar specimens (SRD046, 049, 050, 128, 153, 163) present a distinct chemical profile marked by higher levels of Cr and lower levels of Cs, and together form compositional group C. Comparison with previously analysed materials at MURR found a match with an ESB vessel from Tel Anafa in Israel (analysed as two specimens, ISR027 and 028; Slane et al. 1997). Elemental values of these non-local vessels appear similar to the 29 non-local red-gloss specimens from Troia and reinforces their identification as ESB ware from Tralles (Tekkök, Pernicka 2012). The contribution of another unidentified source is implied by a single red-gloss specimen (SRD160) assigned to the large group G.

West Anatolian and local grey wares

Fine reduction-fired pottery has a long history in western Anatolia, which was continued or selectively revived in the Iron Age (Bayne 2000; Dikbaş 2008; Pavuk 2008;

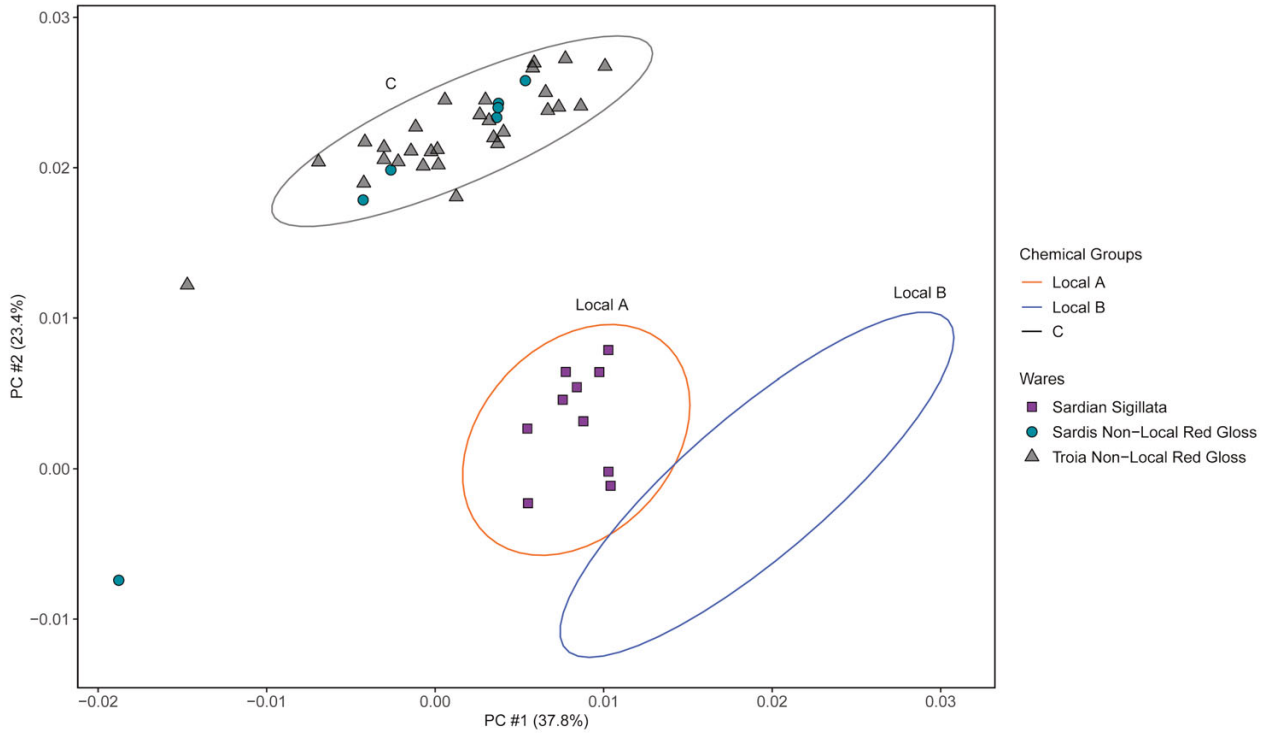

Figure 4. Scatterplot of groups Local A and B, Sardian Sigillata and non-local red-gloss ware (group C, ESB).

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Luke et al. 2015). In the late Hellenistic period, south Ionia emerged as a primary source of moldmade lamps and tableware, whose grey body and black-gloss finish suggest metal prototypes. Large workshops near Ephesus and Knidos turned out a distinctive series of decorated lamps, platters and dishes with micaceous grey-fired fabrics. Petrographic and geochemical study using WD-XRF analysis has confirmed the mineralogical similarity of lamps and pottery from the Ephesus area (Sauer 1995; Zabehlicky-Scheffenegger et al. 1996).

Previous NAA study of late Hellenistic and Roman grey wares has focused on differentiating ceramics made near Ephesus from imitations made elsewhere. Twenty late Hellenistic moldmade lamps excavated at Ephesus were the recent subject of both thin-section petrography and NAA at the Atomsinstitut in Vienna. Comparative analysis confirmed their close relationship with local grey wares and associated both with group I in the Bonn database (Kerschner 2007; Fragnoli et al. 2022: 18–19, tab. 1). The same study found no connection between these grey-fabric ceramics and 47 unpublished specimens of ESB ware previously analysed in Vienna (Fragnoli et al. 2022: 18). Similarly, the Mainz analysis of pottery from Troia confirmed the non-local origin of five black-gloss plates and trays as well as their compositional difference from ESB imports, which included three grey-fired black-gloss dishes of standard shapes (Hayes 1995: 185; Tekkök, Pernicka 2012).

Fourteen pieces of grey-fabric tableware were studied at MURR (Fig. 5 for representative examples). Five specimens belong to a class of moldmade hemispherical relief bowls often found in late Hellenistic contexts at Sardis (Rotroff, Oliver 2003: 142–48). The micaceous fabric was fired grey to dark grey in colour (about 10YR 5/1 to 5Y 4/1) and carries a thin, slightly darker slip. Five more specimens from Sardis are from large, flat platters with low, thick rims, a long-lived shape made by Ionian workshops throughout the late Hellenistic and early Roman periods (Zabehlicky-Scheffenegger et al. 1996; Rotroff, Oliver 2003: 31–37; Raubolt 2019: 194–97). Fabrics are generally friable and very micaceous, dark grey to yellowish brown in colour (10YR 4/1–5/3) and covered by a glossy dark grey or black slip; one example was fired red (2.5YR 5/8). All present similar palmette stamps and some have fine rouletting. Two similar platters from excavations at Mytilene (Lesbos) were included for comparison. Two more specimens from Sardis represent a distinctive type of serving dish that is usually found in contexts of the fourth century AD. The best-known examples have a sloping wall with gouged radial fluting, outturned, notched rim, and horizontal handles. Fine white and stony inclusions are visible in the micaceous fabric, which was covered with a matt wash and fired grey (about 5YR 5/1–6/1).

Figure 6 shows the chemical homogeneity of the 12 Sardis specimens. The grey-fabric moldmade relief bowls (SRD016–020), platters (SRD021–025) and late dishes (SRD123, 124) match the Local A reference group, although SRD019, with a computed <5% probability for group membership, was left unassigned. Local production of grey-fabric moldmade bowls supports previous analysis at Bonn of a burnt or misfired relief fragment from Sardis, which was assigned to Bonn group SarP (Sard 57F = P98.94; Rotroff, Oliver 2003: no. 461; Gürtekin-Demir et al. 2022: 102–03), and shows good agreement with Local A.

The two platters from Mytilene (SRD138, 139) show relatively higher levels of Cr and lower levels of Cs than Local A specimens, and were assigned to the large group G. Differences with the local reference groups and previously reported data from Ephesus and Troia, also included in Figure 6, point to an unidentified source, perhaps on Lesbos itself.

Phocaean Red Slip/Late Roman C ware and local red-slipped pottery

The Roman empire's economic recovery in the fourth century stimulated broad demand for affordable table service in east Mediterranean cities. Western Anatolia emerged as a major source of red-slipped pottery, with potters in the wider Aeolis region turning out dishes and bowls that were distributed in large quantities across the late empire. Examples of this regional LRC ware generally have a light-red fabric with scarce mica, occasional lime or other white particles, and thin matt slip. Ten primary shapes were developed between the early fifth and seventh centuries (Hayes 1972: 325–46). The discovery of kiln debris and much surface pottery has suggested that a large workshop was located near Phocaea (Eski Foça; Langlotz 1969: 379–81; Özelce 2022). Similar shapes in different fabrics have been reported at Gryneion, Pitane (Çandarlı), and other nearby sites that may have seen smaller operations (Hayes 1980: lix–lx; Vaag 2005; Bes 2015: 24–26; Bes, Keweloh-Kaletta 2021).

Petrographic and mineralogical study has demonstrated the relative consistency of LRC ware from these sites. XRF analysis has confirmed the wide export of red-slipped vessels similar to those made near Phocaea, which are usually identified as PRS/LRC ware (Semiz et al. 2023). The more limited distribution of related wares, such as those found near Gryneion and Pitane, suggests different products may have served mainly local markets (Mayet, Picon 1986). Petrographic and WD-XRF analysis of pottery at Ephesus, about 100km to the southeast, has identified the proposed products of Phocaea and Pitane, as well as similar shapes in three local fabrics. The Ephesian market was apparently dominated by PRS/LRC vessels,

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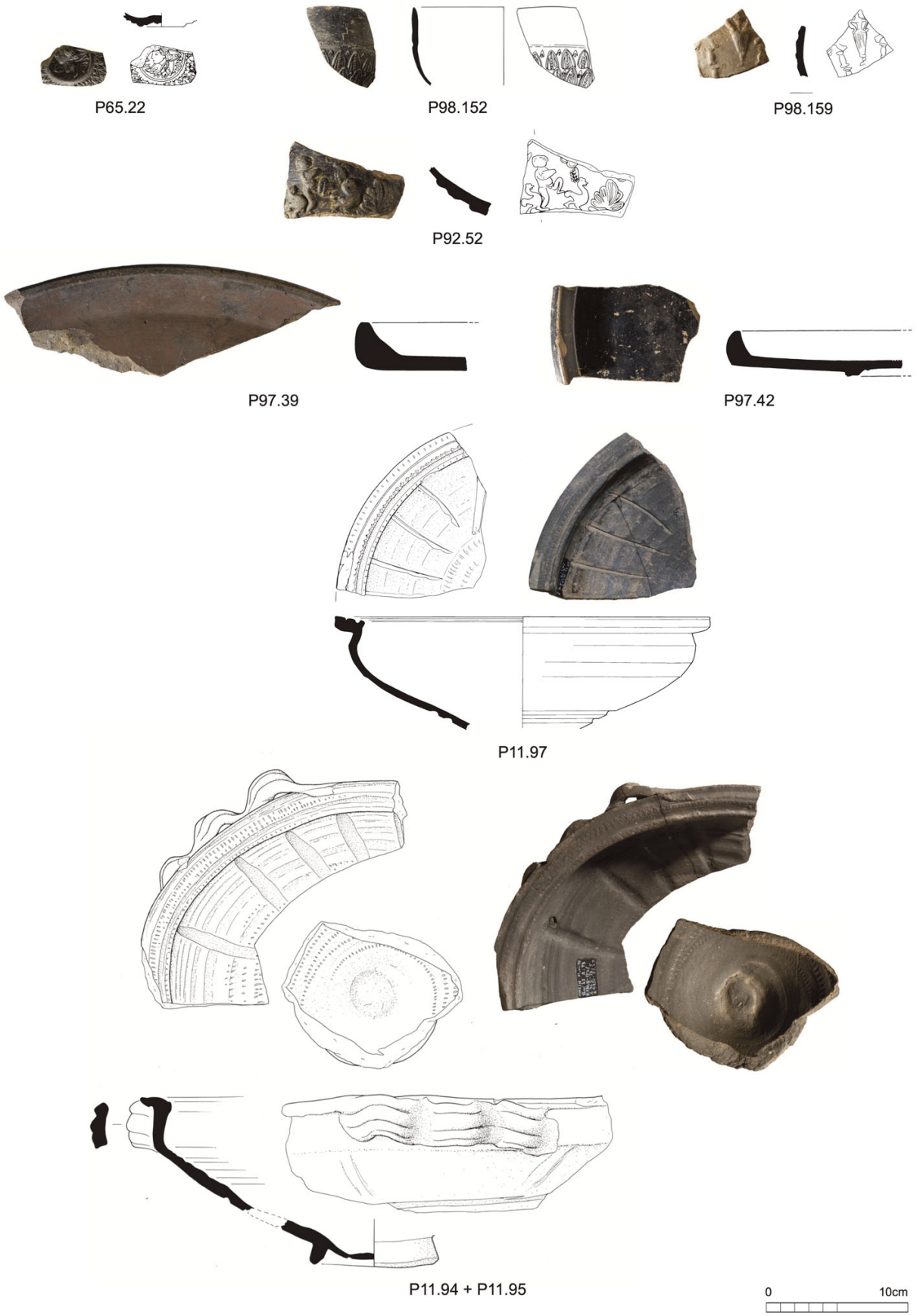

Figure 5. Local grey-fabric ceramics, representative examples (by C.S. Alexander and B. Bricker; © Archaeological Exploration of Sardis/President and Fellows of Harvard College).

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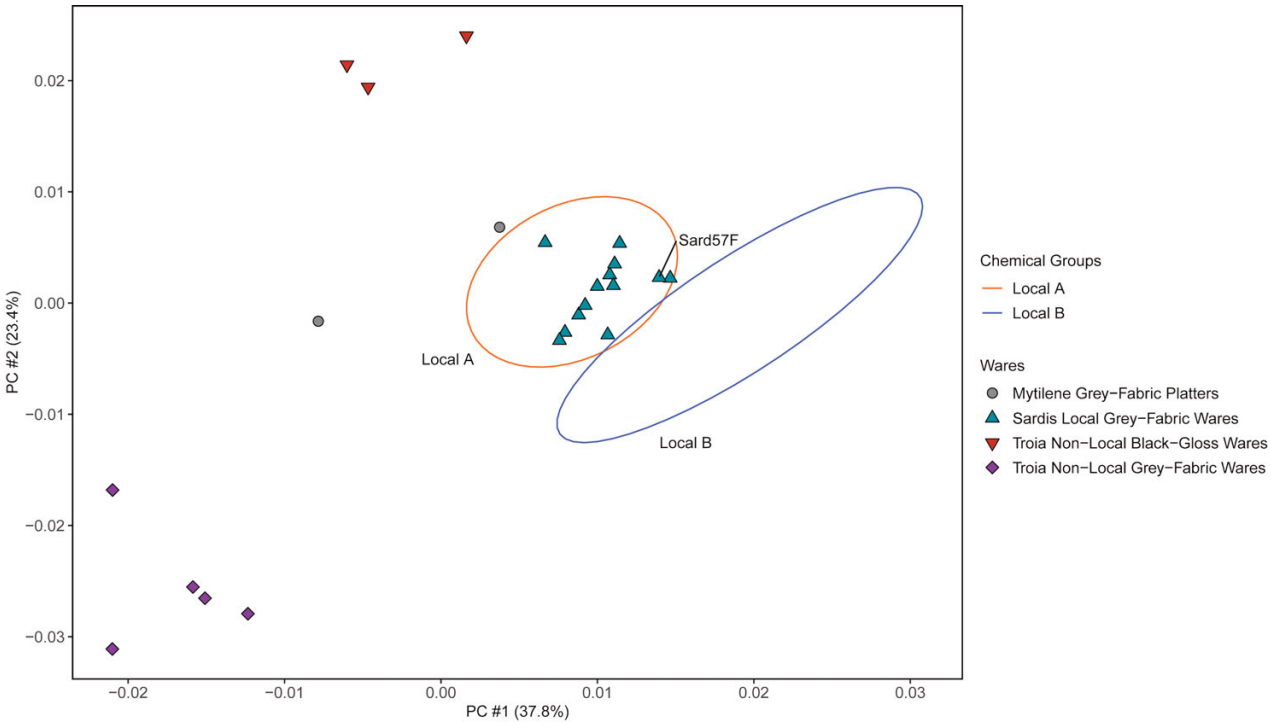

Figure 6. Scatterplot of groups Local A and B, local and non-local grey-fabric wares.

while local potters contributed dishes and bowls in similar shapes (forms 3, 4, 6, 10; Ladstätter, Sauer 2002; 2005; Waldner, Ladstätter 2014). The copresence of PRS/LRC ware and local imitations has been reported in many places in the region; for example, at Anemurium, Aphrodisias, Cilicia, Emporio, Hierapolis, Priene and Sardis (Hayes 1972: 370; 1992: 63; Boardman 1989: 90–96; Williams 1989: 52–53; Yilmaz 2007; Hudson 2008: 332; Bes 2015: 24–26; Francis 2015; Toniolo 2019: 360).

Several pieces of LRC wares were included in Bonn's NAA investigation of ceramic production in the wider Aeolis region (Kerschner 2006). At least 11 examples of LRC forms 3 and 10 were reportedly found at Elaia, Gryneion, Phocaea and Pitane. Five specimens have been associated with group Phot as likely products of Phocaean workshops (Ela 11, Phok 61F, 62F, 63F, 65F; Japp 2009: 204; Mommsen, Japp 2009: 276, tab. 1). One sample came from a well-known stack of six fused LRC form 3C bowls excavated at the site (Phok 05; Langlotz 1969: 280, figs 4–6; Kerschner 2006: fig. 32).

Thirty examples of red-slipped dishes and bowls in the LRC tradition were analysed at MURR. Nineteen specimens have fabrics that visually resemble pre-Roman pottery at Sardis: fine-grained, light red to reddish yellow in colour (about 2.5YR 5/6 to 5YR 6/6), with much mica and occasional fine white particles (Hayes 1972: 410; Rautman 1995: 41–42). Most pieces preserve traces of a thin slip; a few have decorative stamps or an externally rouletted rim. Identified shapes include LRC forms 1, 3, 5 and variations (Fig. 7 for representative examples). Examples of the standard-fabric PRS/LRC ware include ten specimens from Sardis and one from Cyprus; a single Sardis specimen analysed by the AIA project was included as well. The distinctive clay body appears finely speckled with lime but little mica, and usually pale or weak red to reddish yellow in colour (10R 6/4 to 5YR 7/6). Recognised shapes include LRC forms 3 (B, C, D, F), 5A and 10.

PC analysis found that 16 specimens of micaceous red-slipped vessels in LRC shapes (SRD026–030, 201–207, 213–216) match the Local A and B groups (Fig. 8). Two examples (SRD209, 225) were attributed to group D, which suggests that another workshop in central Lydia made similar pottery. A single specimen (SRD223) was placed in the large group G.

Ten examples of the standard-fabric PRS/LRC found at Sardis (SRD041–045, 077–079, 224, 226) and one from Cyprus (KKP197) make up the well-defined non-local group J. Three Late Roman unguentaria (SRD085, 086, 088) share the same composition, which is distinguished from Sardis products by relatively lower levels of rare earth elements, Ce and Cr. Five similar samples in the combined dataset were added to group J: the AIA specimen from Sardis (AIA3693 = P22.21), previously analysed by Becquerel, and four PRS/LRC vessels reportedly found at Phocaea (Phok 20, 61F, 62F, 63F), which Bonn assigned to group Phot. The connection with Phocaea is reinforced by two unassigned examples of Phocaean cooking pots that show similar if distinct elemental values (Phok 64 and 66F; Japp 2009: 266–

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67). Two other examples of LRC analysed at Bonn (Phok 65F and the fused waster Phok 05; Mommsen, Japp 2009: 276) match group Phot but diverge from group J in terms of Ni, Zn, As, Tb and U. The consistent fabric, shapes and firing of most standard-fabric vessels found at Sardis suggest they came from workshops near Phocaea.

West Anatolian and local micaceous water jars

Thin-walled transport containers, commonly called micaceous water jars, were used for carrying and storing liquid commodities across western Anatolia and the Aegean region from late Hellenistic to Late Roman times. Reported fabrics are notably fine grained and micaceous with particles of quartz and igneous and metamorphic rock; most examples range from light red or reddish yellow to reddish brown in colour. Early jars were relatively large and ovoid in shape with a narrow rim, small handle and self-supporting base. Later examples tend to be shorter and more slender with a pointed foot and sometimes a second handle. Petrographic and WD-XRF study has associated some of the most common fabrics with the environs of Ephesus. Considerable variation in fabric, shape and chronology reflects a wide production area that included wine-producing lands in the lower

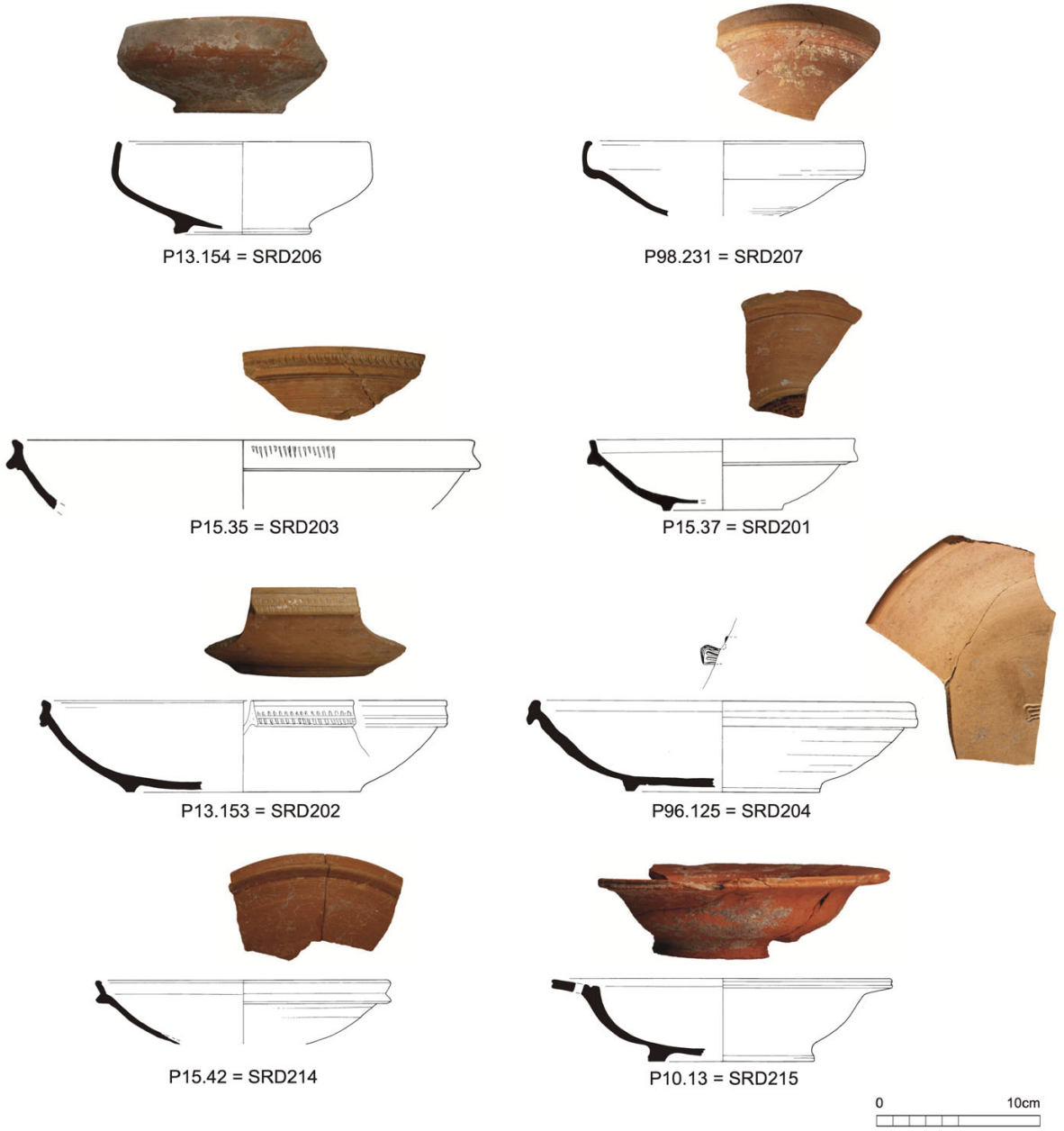

Figure 7. Local red-slipped ware, representative examples (by C.S. Alexander and B. Bricker; © Archaeological Exploration of Sardis/President and Fellows of Harvard College).

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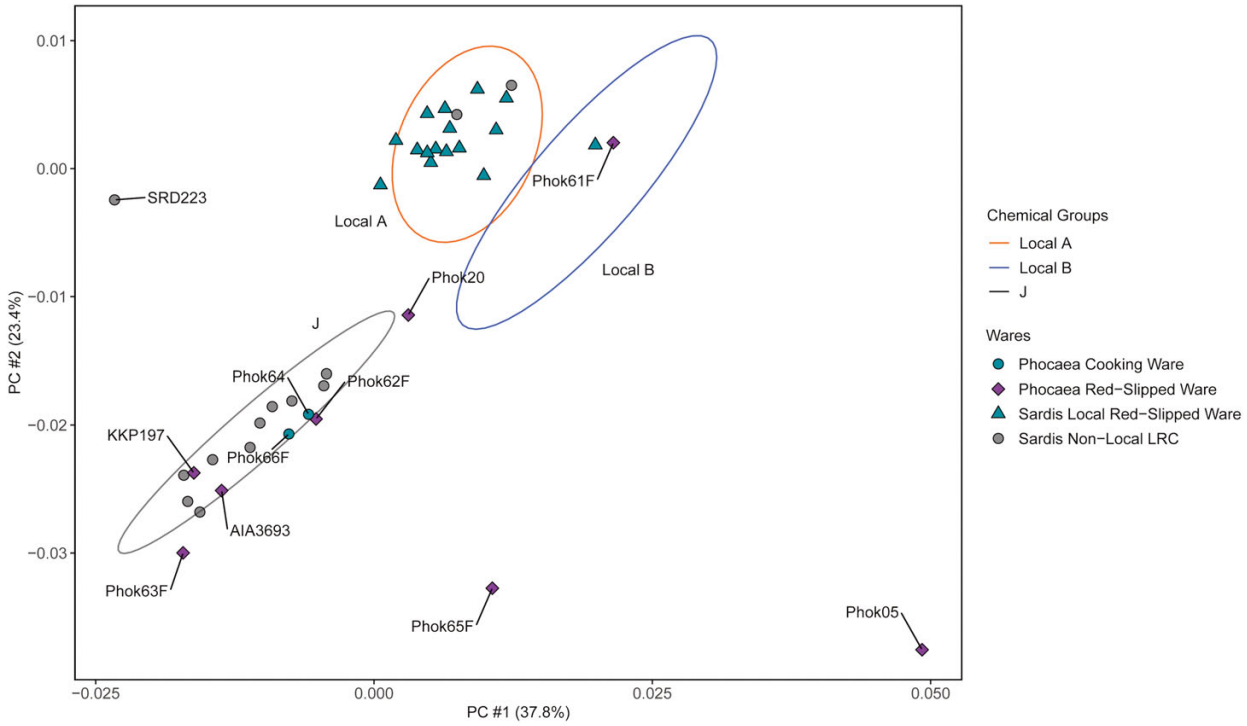

Figure 8. Scatterplot of groups Local A and B, local and non-local red-slipped wares (group J, PRS/LRC ware).

Meander, Caystros and Hermus valleys (Pieri 2005: 94–101; Bezeczky 2013: 28–31, 164–67; Kara 2020).

Analysis at MURR included 18 specimens of micaceous water jars from Sardis. Thirteen examples represent a local shape common in sixth-century contexts: slender jars with a narrow, rounded rim, solid toe and small handle; reconstructed examples stand about 0.4–0.5m high (MWJ-B; Fig. 9 for representative examples). Most body sherds have a lightly ridged surface with traces of a light wash or slip, as often noted on local plain ware pottery. The micaceous fabric resembles pre-Roman pottery at Sardis, ranging from light red to reddish yellow in colour (about 2.5YR 6/8 to 5YR 7/6) with few obvious inclusions. Five specimens represent a distinctive variation in a smooth fabric that is very micaceous and dark grey to olive (5Y 4/1–5/3) in colour (MWJ-C). Incomplete examples have a plain narrow rim, lightly ridged wall, hollow foot and one or two handles (Rautman 1995: 80–81).

PC analysis assigned ten red-fabric specimens of micaceous water jars (SRD061–063, 066–070, 082, 083) to the Local A group (Fig. 10). Three visually similar examples apparently came from different places: one forms part of the small group D (SRD084), one belongs to group G (SRD064) and one was unassigned (SRD065). The five grey-fabric specimens (SRD071–075) share a well-defined chemical profile with relatively higher levels of Sc and Fe (group F). These specimens stand apart from all other ceramics analysed at MURR and represent an unlocated source in the wider region.

Provenance and production in western Asia

The prominence of the Local A and B reference groups in the combined ceramic dataset (113 of 319 total specimens) establishes the continuity and diversity of pottery making at Sardis over more than 1200 years (Fig. 2, Tab. 2). Analysis at MURR and the British Museum attributed the greater number of specimens to Local A, yet both groups include a similar range of Lydian-style wares, such as black-on-red stemmed dishes, wave-line hydria/kraters, banded or streaky skyphoi and architectural terracottas. The absence of Late Lydian samples in Local B hints at a possible narrowing of production areas or practices during the later sixth and fifth centuries. Late Hellenistic and early Roman moldmade relief bowls and Ionian platters also appear mainly in Local A, as do the six examples of red-gloss Sardian Sigillata. Most Late Roman ceramics, including grey-fabric serving dishes, red-slipped LRC ware, utility pottery, transport jars and building materials were assigned to Local A. A few red-slipped dishes and a single moldmade Asia Minor lamp show lingering activity in the area or working habit of Local B.

Six Late Roman samples assigned to group D offer tentative evidence of production in the wider environs of Sardis, perhaps near clay sources about 20km west of the city. Two of these specimens reflect the broad popularity of red-slipped LRC ware; two more belong to the poorly understood tradition of fine light-coloured regional fabrics (AMLC; Hayes 1972: 408–10; Ergürer 2014; Japp 2014: 19–21). The compositional similarity of a single

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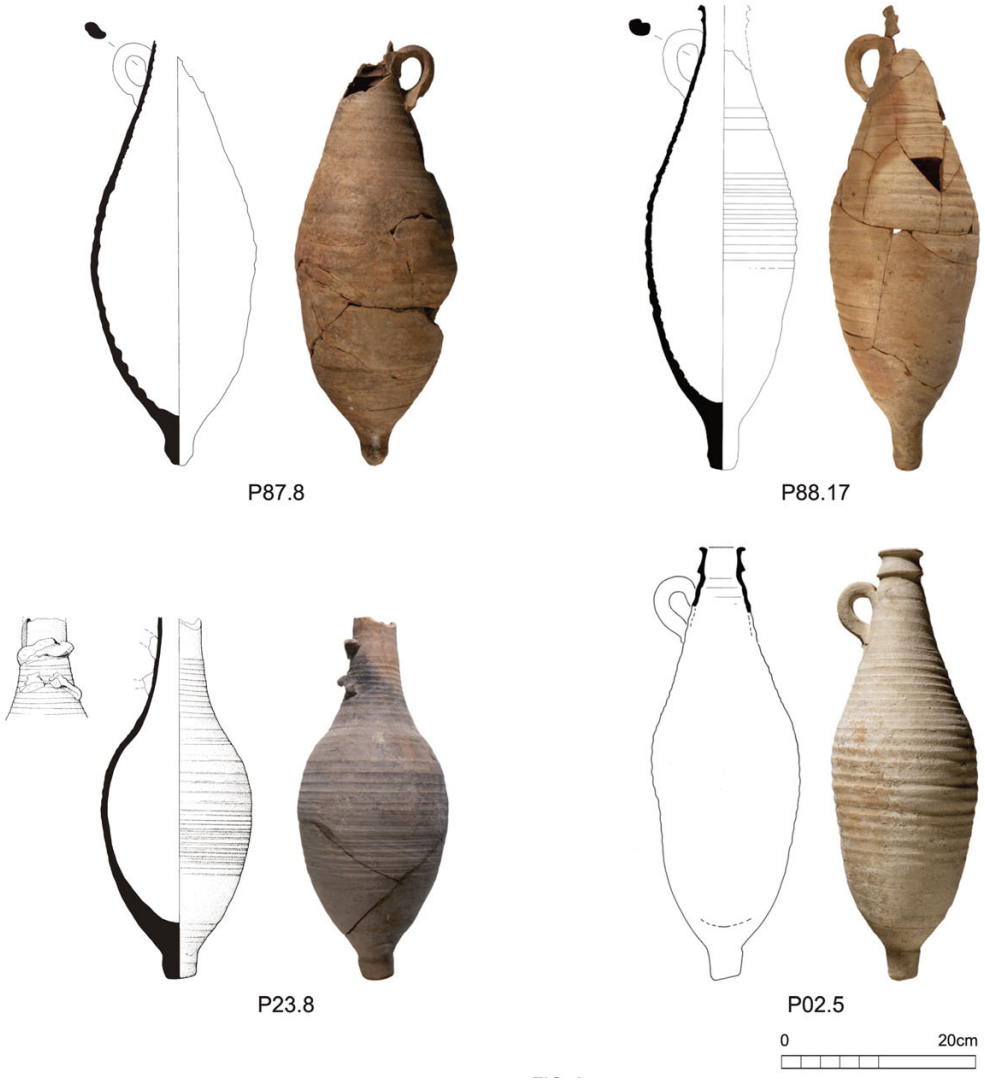

Figure 9. Local transport jars, representative examples of micaceous water jar B (by C.S. Alexander and B. Bricker; © Archaeological Exploration of Sardis/President and Fellows of Harvard College).

micaceous water jar and moldmade Asia Minor lamp suggests that the area's output may have been diverse but was not widely distributed in late antiquity.

Two small, unlocalised groups probably represent contact with other regions. Group K, which is known only by two Lydian-style brown-on-buff cups or jars, may be one of many unidentified workshops that operated within the wider territory of the Lydian empire (Kealhofer 2013: 1931–33; Dupont, Lungu 2020: 136–38; Gürtekin et al. 2022: 107–08). The five grey-fabric transport jars (MWJ-C) of group F likely originated in a wine-producing coastal area, from which similar vessels were shipped throughout the Roman and Late Roman periods (Rautman 1995: 81; Bezeczky 2013: 28–31, 164–67).

The remaining four groups in the combined dataset reflect exchange networks spanning the Roman East and can be located on the basis of previous study. Group H includes a single piece of red-gloss ESA ware from the first century AD and ten LR1 amphorae from the fifth or sixth century, and appears far apart from other groups in PC space (Fig. 2). Other examples of these wares found at Sardis suggest a low but persistent level of contact with the source area in coastal Cilicia and north Syria (Rautman 1995: 81; Bes 2015: 12–16; Raubolt 2019: 118–21). Six Sardis specimens of red-gloss ESB ware assigned to group C are joined by a single example from Tel Anafa, Israel, and 32 red- and grey-fired specimens from Troia (Fig. 4; Slane 1997; Tekkök, Pernicka 2012). While reduced versions of similar shapes are known at Sardis, the resemblance of local and non-local red-gloss vessels suggests that early production was carefully managed during the first and early second centuries (Poblome, Zelle 2002: 280–81; Rotroff 2018: 153, 167–70; Raubolt 2019: 135–39).

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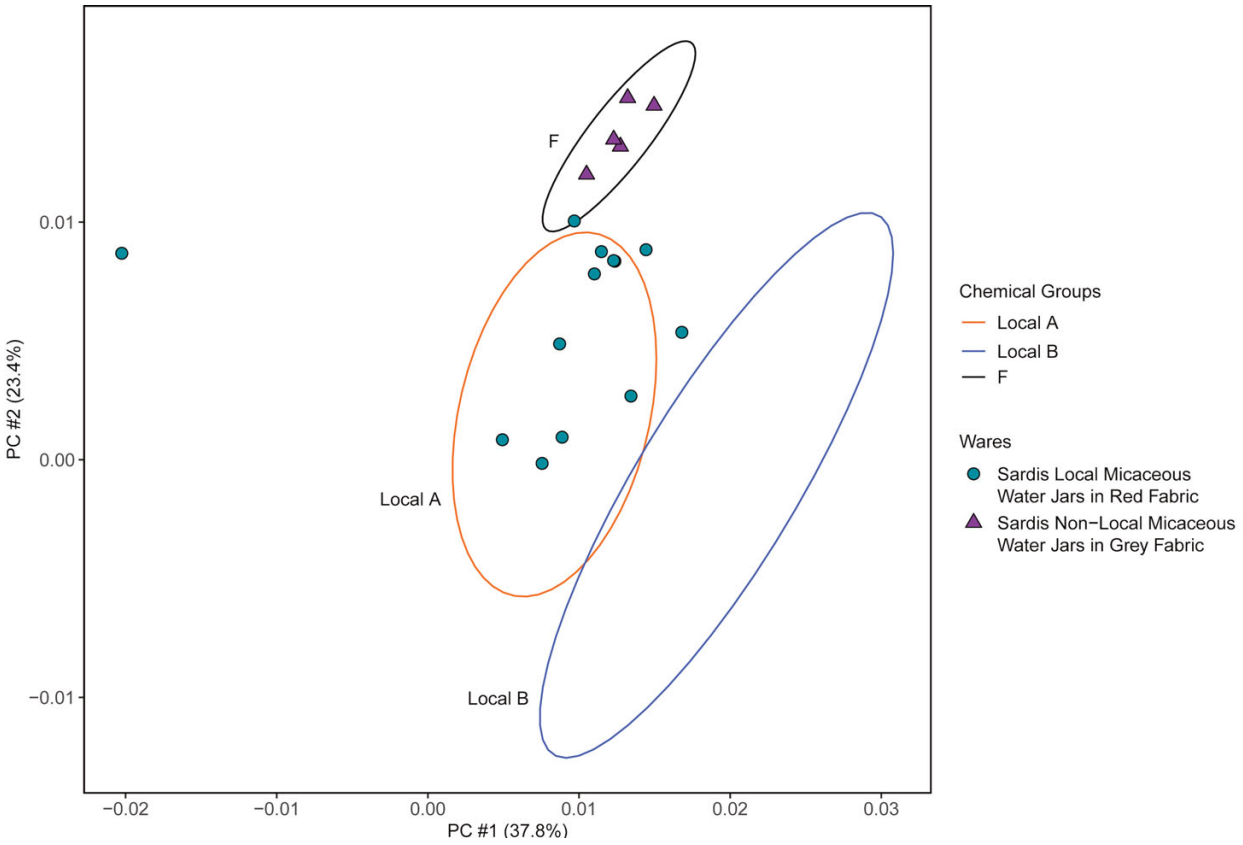

Figure 10. Scatterplot of groups Local A and B, local and non-local micaceous water jars (group F, MWJ-C).

The well-defined group J includes all ten examples of the standard-fabric PRS/LRC ware found at Sardis as well as a single specimen from Cyprus. Another example from the AIA survey and four specimens from Phocaea reported by Bonn were added in the combined dataset, which ties the group closely to the ware's main place of production (Fig. 8). The assignment of three of six sampled Late Roman unguentaria to the same compositional group suggests that other distinctive vessels came from nearby, and like Phocaean cooking pots, accompanied shipments of tableware to Sardis.

The number and variety of specimens assigned to groups E and G demonstrate the importance of the wider Aeolis region as a supplier of wider markets through late antiquity (Tab. 2). Apart from a single Achaemenid bowl fragment, samples range from late Hellenistic to Late Roman in date. Red-gloss pottery associated with nearby Pergamon and Pitane include five pieces of Pergamene Appliqué and seven ESC wares. The two Ionian platters from Mytilene match the broad parameters of group G, which also includes LRC bowls in micaceous non-standard fabric, moldmade ampullae, Asia Minor lamps and transport jars (MWJ-A and B). The attribution of two AMLC samples to group E and 17 specimens to group G suggests that many of the distinctive light-fabric vessels found at Sardis originated in the area. Archaeometric study of ceramics and soils has established the complexity of local materials and production (Kerschner 2006; Japp 2009; 2014; Mommsen, Japp 2009; Bes 2015: 17–19). Further formal and compositional study of the wares will clarify the contribution of this region to ceramic use at Sardis.

Twenty specimens comprising nearly 10% of the MURR dataset remain unassigned. Six Lydian-style samples may reflect experiments by local potters or unlocated production in the region. Unassigned examples of Late Roman unguentaria (3), micaceous red-slipped dishes (4) and fine AMLC wares (3) suggest the wider compass of the local market and the present limitations of research.

Persistence and change in the pottery of Roman Sardis

The materials and methods of making pottery at Sardis during the early Iron Age lasted well into the first millennium AD. Inhabitants knew where to find suitable clays in nearby river valleys and how to use them with minimal processing. Compositional study shows that most Lydian-style pottery can be associated with two main sources, Local A and B, which lay close to the city and continued into Roman times. Within these production areas, multiple workshops apparently shared raw materials, preparation,

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shaping and finishing methods and kiln technologies to turn out a growing variety of wares for domestic and commercial purposes.

The emergence of new traditions within this stable ceramic environment reflected larger changes in the economic and social life of Sardis. As elsewhere in western Anatolia, the arrival of ESB ware from Tralles in the late first century BC encouraged specialised workshops to make similar red-gloss vessels. Capital investment and technological expertise from outside the city soon found their place among existing producers, particularly during reconstruction after the great earthquake of AD 17. The smooth transmission of ideas appears in the similarity of fine dishes and bowls that were made elsewhere (group C) and at Sardis (Local A). At least six potters' names have been identified on Sardian Sigillata plates, cups and bowls (Rotroff et al. 2018: 167–70). The ware may not have been widely distributed outside the city, yet red-gloss vessels of uneven quality continued to be made locally into the second and even third century (Raubolt 2019: 225–26).

Other innovations seem well suited to local experience with reduction-fired grey pottery. Multiple workshops made red and grey moulded-relief bowls in the second and first centuries BC. Minor variations of fabric, with four grey bowls assigned to the Local A group and four red bowls to Local B, suggest different production areas or ways of refining clay for use with detailed moulds. Ionian-style platters with stamps and glossy black slip were made at Sardis (Local A) around the turn of the millennium, although with inconsistent results likely caused by their thick floors and broad diameters. Limited production of small dishes and bowls continued into late antiquity, with a distinctive series of serving bowls reflecting prototypes in metal (Local A).

As Sardis grew in political and economic importance in the fourth century, local workshops responded to the appearance of red-slipped pottery in regional markets. Some local tablewares depended on late forms of the ESB series or African Red Slip (ARS) ware. Other products looked to the LRC tradition with special interest in forms 1, 3 and 5. As elsewhere, the form 3 dish/bowl with flanged rim was made in large numbers with varying faithfulness to the original PRS/LRC series (group J). Close imitations had stamped floors, thin walls and neatly rouletted rims; more perfunctory examples rested on heavy bases and had undulating rims of vague profile. Slips ranged from a thick red coating, which often flaked badly, to a thin wash that fused with the clay body. Variations in forming, trimming and firing suggest red-slipped tableware was made in multiple workshops around the city (Local A, B) and the urban environs (group D).

While red-gloss, grey-fabric and red-slipped tableware showed Rome's growing presence at Sardis, containers for storage and transport reflect broader regional trends. Ovoid, single-handled jars had been used across western Anatolia from the second and first centuries BC, with different wine-making areas shipping their products across the Aegean region. Thin-walled vessels with a narrow body, mouth and foot presented clear advantages for transport and became increasingly common as trade expanded in later antiquity. A small handle joining the upper wall and neck typified most of these micaceous water jars; some producers added a second handle in the fifth and sixth centuries (group F). Potters in the Sardis environs followed a similar path between the first and sixth centuries, making smaller, more slender jars but with only a single handle (Local A). The demands of overland transport apparently encouraged the use of such small, sturdy vessels for shipping goods, even if they are infrequently reported abroad.

The pottery of Sardis constitutes an exceptional record of habitation, economic life and cultural activity in western Anatolia. The inland location and natural resources supported continuity of urban settlement for over 1200 years, from the early Iron Age well into the first millennium AD. Between the eighth and fourth centuries BC, local potters turned out plain and decorated ceramics befitting the capital of an independent Lydian state and maintained many features during the years of Persian rule. Their successors in the first through sixth centuries AD combined similar materials and practices with new ceramic models to meet the needs of this growing city and Late Roman provincial capital of Lydia *après* Lydia. Together with visual assessment of fabric, form and finish, the methods of compositional analysis make clear the resources of this enduring cultural landscape and the craft and technology it sustained.

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Appendix: Coordination of laboratory data

Data cited in this paper were generated in five laboratories using different standard reference materials and reporting varying numbers of elements. Conversion factors were determined to make the data compatible (see Tab. 3 in online supplemental materials; Czujko et al., 2024). All data from MURR were standardised relative to SRM-1633a Fly Ash. Data from the University of Bonn were standardised relative to the Perlman-Asaro Standard Pottery (1969, 1971). Data from the British Museum were standardised relative to the British Museum standard pottery (Hughes 1988). Intercalibration factors for elements measured at Bonn and the British Museum were determined by measuring their standards at MURR relative to SRM-1633a. Intercalibration factors for elements measured by the Becquerel Laboratories relative to MURR were reported by MacDonald et al. 2018. Intercalibration factors for data from the University of Mainz (Tekkök, Pernicka 2012) relative to MURR were calculated by ratioing the mean concentrations of compositional groups identified in common with MURR. Among elements measured in all laboratories, only 19 showed strong agreement in mean concentrations and were used for further statistical treatment: K, Sc, Cr, Fe, Co, Rb, Cs, La, Ce, Nd, Sm, Eu, Tb, Yb, Lu, Hf, Ta, Th and U. Fourteen elements (Na, Al, Ca, Ti, V, Mn, Ni, Zn, As, Sr, Zr, Sb, Ba and Dy) were not measured at all labs and were excluded from comparison.

Table 4a (see online supplemental materials) compares averaged intercalibrated data for Sardis reference groups Local A and Local B, groups SarP and SarQ previously reported by Bonn and AIA group A1.1 identified at Becquerel. Local A and SarP show good agreement for 24 out of 27 elements detected at both laboratories: As, Ba, Ca, Ce, Co, Cr, Eu, Fe, Hf, K, La, Lu, Na, Nd, Rb, Sc, Sm, Ta, Tb, Th, U, Yb, Zn and Zr; poorer agreement was shown by Cs, Ni and Sb. Local B and SarQ show poor agreement overall: 20 out of 27 measured elements broadly agree, but Ca, Cs, Eu, Lu, Na, Ni and Zn compare weakly. It is possible that Sardis Local B is distinct, representing some previously unknown compositional group. Alternatively, this group may represent a smaller subset of Sardis Local A or of Bonn's SarQ. Note that published values were converted to standard deviation (σ) for consistency. Table 4b (see online supplemental materials) reports averaged data for Sardis groups C, D, F, G and J.

Supplementary material

Supplementary material may be found online at https://doi.org/10.1017/S0066154624000073 and consists of the following:

Table 3.
Conversion factors for interlaboratory comparison of data.
Table 4a.
Average elemental values for Sardis reference groups Local A and Local B, Bonn SarP and SarQ (Gürtekin-Demir et al. 2022, table 1), AIA Macrogroup A 1.1 (Kealhofer et al. 2013, table 4a) and CLAS Group 4 (Luke et al. 2015, table 2)
Table 4b.
Average elemental values for selected compositional groups in combined dataset analyzed at MURR: group C (non-local red-gloss ware, ESB), group D (various Late Roman wares), group F (non-local gray-fabric jars, MWJ-C), group G (ESC, AMLC, and other Late Roman wares) and group J (non-local red-slipped ware, PRS/LRC).

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