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Late 6th – early 4th century BCE western Greek amphorae produced in Selinunte (western Sicily): Ceramic paste characterisation by an integrated archaeometric approach

G. Montana [a], M. Gasparo Morticelli [a], A. Bonfardeci [a], B. Bechtold [b,*], L. Randazzo [a]

[a] Department of Earth and Marine Sciences, University of Palermo, Italy
[b] Institut für Klassische Archäologie, Universität Wien, Austria

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ABSTRACT

This paper aims at an interdisciplinary, archaeological and archaeometric characterisation of the western Greek amphorae series produced in late Archaic and Classical-period at Selinunte (southwestern Sicily). Furthermore, it seeks for archaeometric parameters useful for its distinction from the morphologically very similar production of nearby Agrigento.

The research is based on a macroscopic examination, according to the standardised methods of Fabrics of the Central Mediterranean (FACEM), combined with petrographic analyses of 25 amphorae samples and eight coarse ware samples of presumed local fabric found mostly in Selinunte, in the artisanal quarter, in the western town, and in the major sanctuary on the acropolis. Furthermore, a small selection of three amphorae has been unearthed in the western necropolis of Himera and at *Cossyra*/Pantelleria. Chemical analyses have been undertaken on a group of ten amphorae and four coarse ware samples.

As a result, our study confirms the local manufacture of the entire selection of 33 samples and the more than acceptable petrographic and chemical homogeneity of the ceramic pastes produced with locally sourced clays. Some slight but significant compositional, textural and micro-paleontological differences between Selinuntine and Agrigento productions were pointed out.

The identification of a production of western Greek wine-carrying (?) amphorae in Selinunte dating from the late 6th-earlier 4th century BCE supports earlier archaeometric analyses and breaks ground for a better understanding of the colony's economic development during the late Archaic and Classical periods. The present research will help to clarify the distribution of the class especially in Selinunte's territory, while its supra-regional circulation seems to have been quite limited.

1. Introduction

Selinunte was founded by colonists from Megara Hyblaea in the second half of the 7th century BCE and was the westernmost Sicilian Greek town (Fig. 1a). Located on top of a multiple hill system, the city is flanked to the West by the River *Selinus* (present-day *Modione*) and to the East by the *Gorgo Cotone* (Fig. 1b). Archaic-Classical Selinunte controlled a wide and fertile hinterland delimited to the West and the East by the modern rivers Mazaro and Verdura respectively, and extending to the North until the territories of native sites like Segesta (De Angelis, 2019 with earlier references). From its beginning, the colony's remote position on the southwestern coast favored close economic and cross-cultural relations with the neighboring indigenous and Phoenician-Punic communities (Orsingher et al., 2020; Spatafora, 2018). The probably partly navigable river Hypsas-Belice constituted the most privileged trade axis between the colony and the native *milieux* of inner western Sicily (Spatafora, 2012).

After almost two centuries of overall economic and demographic growth and prosperity, Selinunte was conquered by the troupes of *Hannibal Mago* during the military conflict between the Sicilian *poleis* and Carthage at the end of the 5th century BCE, in 409 BCE. In contrast to Greek Himera on the northwestern coast, after its massive destruction the town was resettled almost immediately by a mixed population directed by *Hermokrates* (for 4th-century BCE *Selinus*: Marconi, 2021; De

* Corresponding author at: Institut für Klassische Archäologie, Universität Wien, Franz-Klein-Gasse 1, 1190 Wien, Austria.
E-mail address: babette.bechtold@univie.ac.at (B. Bechtold).

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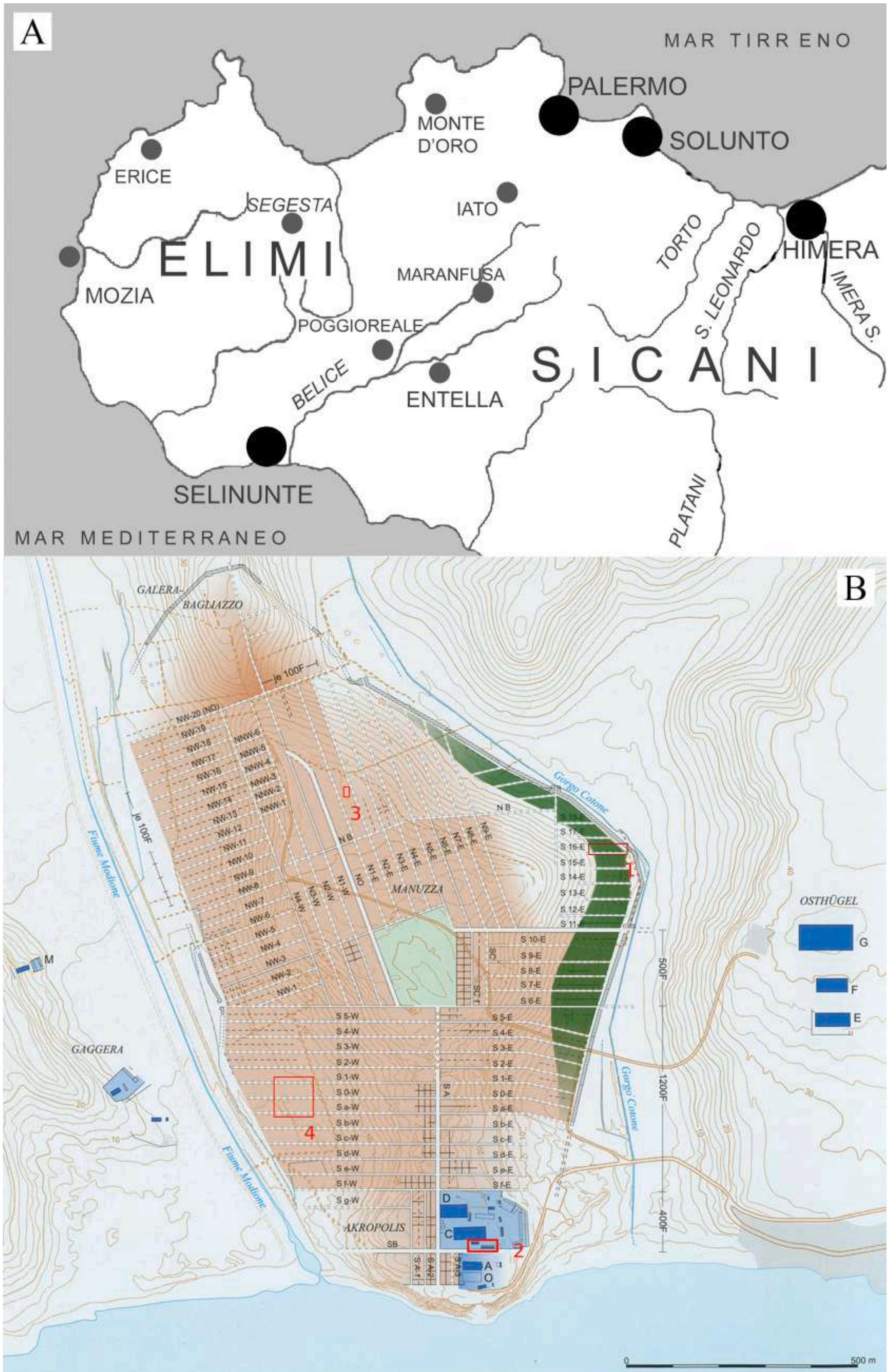

Fig. 1. A) Geographical localization of Selinunte within the regional context of western Sicily (courtesy of S. Vassallo, Soprintendenza BBCCAA di Palermo); (B) Planimetry of Selinunte with indication of the excavation areas which have yielded the analysed materials (courtesy of M. Bentz, Universität Bonn).

Vido, 2018; Greco, 2018). As a result of the Syracusanian-Carthaginian treaty of 405 BCE *Selinus* passed to Punic control as a multi-ethnic community typical of this frontier area. However, only with the consolidation of the *eparchia* in the late 4th century BCE did the site develop into a significant Carthaginian stronghold, which was captured by the Romans in 250 BCE. It was only partially reoccupied from the late Antiquity onwards.

Fully in line with the general aspects of a wealthy and productive town, pottery manufacturing activity took place for most of Selinunte's existence. Archaeological evidence suggests its beginning already in the early Archaic period in the western part of the acropolis and in the area of the *agora* (a synthesis in: Montana et al., 2018a). Within the scope of a general urban monumentalisation around the mid-6th century BCE, a new potter's quarter was created in the *Cotone* valley, situated just inside the fortifications (in detail, see Section 2.1).

Three kilns discovered in 'Isolato FF1′ located in the western part of the acropolis, can be dated to the Carthaginian phase of the site. According to published archaeological evidence, this production area was active during the last decades of the town, which was destroyed during the Roman attack of 250 BCE (overview in: Caruso and Fourmont, 2017; Montana et al., 2018b; Bechtold, 2020a).

By discussing the probable main components of *Selinus*' gross domestic product, M. Bentz considers hypothetical large-scale wheat production in the city's hinterland as one of the most – or even the most? – important contributors (Bentz, 2017, 36 with references). However, its commercialisation did not require the use of transport amphorae. Given the lack of topographical prospections in the hinterland and the rareness of archaeobotanical studies, there is still no data at our disposal for the cultivation of olive plants or grapevines (Bechtold, 2020a), which were typical crops for distribution in commercial containers (for the general issue of scarcity in literary sources on this matter, see Sourisseau, 2011).

The class of 'western Greek' amphorae under focus denotes 6th-4th century BCE transport vessels manufactured by export-orientated Greek colonies in *Magna Graecia* and Sicily (latest: Gassner, 2015, Sacchetti, 2012; Sourisseau, 2011). The most probable primary content of these vessels seems to have been wine (Brun, 2020; Sourisseau, 2011).

Regarding previous archaeometric research on pottery manufacturing in *Selinus*, the first petrographic and chemical investigations were undertaken in 2006 of 42 western Greek and Punic amphorae, kiln wasters, and tiles. In particular, eight samples of 5th-century BCE 'Ionian Massaliote' and 'Pseudo-Chian' vessels were attributed to the finer 'fabric I' which perfectly matches the archaeometric fingerprint of the presumably local reference samples composed by kiln wasters and tiles, and some raw materials taken in the vicinity of the town (Azzaro et al., 2006).

In 2018, a second paper was published aiming to characterise the Pleistocene clayey deposit outcrops outside the fortification line and worked by the local potters (Montana et al., 2018a). Contemporaneously, minero-petrographic and chemical analyses of 29 samples selected from coarse wares found in kilns F2 and F3 of the aforementioned block FF1, in addition to eight samples of overfired structural elements of these furnaces, allowed for the definition of the textural and compositional characteristic features of the pottery production during the Carthaginian period of the site (Montana et al., 2018b). Moreover, further interdisciplinary, archaeometric (Montana and Randazzo, 2015) and archaeological (Bechtold, 2015) analyses of six Punic amphorae – two of them from the kiln area of isolate FF1 – and two coarse wares permitted to establish 'Impasto SLN-I'. As part of the eight edition of FACEM, which focuses on Sicilian western Greek amphorae series, G. Montana and L. Randazzo conducted petrographic analysis on a first selection of seven samples discovered in Selinunte and Pantelleria (preliminary observations in Bechtold, 2020b, section 4).

Furthemore, X-ray fluorescence analyses (P-ED-XRF analysis) undertaken on 55 ceramic samples of fine wares, coarse wares, and transport containers from the *agora* excavations, isolated one possible 'Pseudo-Chian' amphora of local production (Helfert, 2017).

This paper intends to characterise the archaeometric fingerprint of the western Greek amphorae series manufactured at *Selinus* from the late 6th to the late 5th or earlier 4th century BCE. Our research is based on detailed petrographic and chemical analyses of 25 samples of transport amphorae and eight samples of coarse wares, all hypothetically linked to Selinuntinian workshops on the grounds of archaeological considerations (see Section 2). The studied pottery has been cross-referenced with its archaeological record (Table 1) and compared with the results of an earlier archaeometric investigation of 18 local bricks and tiles and ten local raw materials (Montana et al., 2018a).

With this in mind, particular attention has also been paid to establish a satisfactory distinction between the western Greek amphorae productions of *Selinus* and those contemporaneously produced in *Akragas* (already described in detail by Montana et al., 2022). In fact, previous archaeological studies on presumed local amphorae found in the two colonies (Bechtold, 2021; Bechtold, 2020a; Bechtold, 2020c) has underlined the difficulty to distinguish, by the means of archaeological methods only, between the two productions. This is caused by the similarity of the raw materials used in the two sites for amphora production. In dead, both consist in clay of marine origin, with more or less abundant detrital medium-fine sand and calcareous microfauna, even deposited in a fairly overlapping chronological interval.

Thus, in this paper, the clayey raw materials of *Selinus* and *Akragas*, already characterised from a mineralogical, petrographic and chemical point of view in previous works, are also studied from a micropaleontological point of view, in order to accomplish at their accurate relative dating. In this way, the comparison will be possible to evaluate, through a complete comparative evaluation between ceramic materials and raw materials from both sites in terms of abundance and nature of aplastic grains, microfossil type and relative occurrence (if recognizable after firing) and even bulk chemical composition (major and trace elements). It would thus be possible to highlight an acceptable 'production marker' capable of representing an 'archaeometric fingerprint' functional to determining the provenance.

The scientific outcome of this interdisciplinary research will set a benchmark for a more detailed understanding of Greek Selinunte's economic development and its role within the network of regional trade during the late Archaic and Classical periods. Furthermore, it will significantly integrate the series of archaeometric studies on transport containers manufactured in 6th-4th century BCE western Sicily (for the non-Hellenic *milieux*: Montana and Randazzo, 2015; Corretti et al., 2017; for the Greek colonies: Barone et al., 2011; Barone et al., 2012; Montana et al., 2020; Montana et al., 2022).

2. Archaeological materials and methods

Against the background of in-depth, multidisciplinary provenance studies of c. 1200 western Greek amphorae found in mainly western Sicilian sites (for this project, see funding), a batch of 126 fragments of this class has been discovered in recent investigations undertaken in Selinunte. Ceramic samples chipped from these materials were subdivided into macrofabrics using hand lens. In the following, all the samples were analysed according to the standardised methods of 'Fabrics of the Central Mediterranean' (FACEM) database and compared with reference samples of fabrics already defined by former archaeological-archaeometric research (for Selinunte, see specifically: Bechtold, 2020a).

From the above *corpus* of 126 individuals, the utilisation of a stereomicroscope and macro-photos in triple magnification (x8, x16, x25) led to the identification of a major group (N=84) of presumably imported amphorae against a minor selection of 42 samples tentatively attributed to a local production. This latter, relatively homogeneous group labelled 'SEL-A-4′ (Fig. 2) is distinguished by a pinkish-orange or reddish-yellow, carbonatic matrix of rather fine texture (for the macroscopic description: Ferlito, 2020). The external surfaces often preserve a creamy coating.

Table 1
Synopsis of data related to western Greek amphorae and coarse wares produced in Selinunte and provided with petrographical analysis. Typological identification of the amphorae referred to (Gassner, 2003 where 'Randform' intends 'rim shape'). Items of the second column marked with '*' are in phase with their archaeological contexts (see Section 2).

Discovery site	Site inventory	Inv. FACEM	Pottery type	Dat. object	Chemistry	Published	Figgs
Himera western necropolis	W4716	M 179/ 168	*Randform* 3	520–490	X	Bechtold and Vassallo, 2023, 301 cat. 425 here still considered a production of Akragas	3a-b
Selinunte artisanal quarter	SL 38187	M 154/ 318	*Randform* 3	510–480	X		3c
Pantelleria suburban survey	PN04 RIC UT 130.1-2	M 119/ 142	*Randform* 2	510–480		Bechtold, 2020a, Fig. 1,8	
Pantelleria acropolis	PN08 ACRX9376-10	M 119/ 266	*Randform* 2	510–480			3d
Selinunte Manuzza Nord	SL 48379	M 154/ 266	*Randform* 3	500–470	X		3e
Selinunte artisanal quarter	SL 38202	M 154/ 316	*Randform* 3	500–470			
Selinunte survey western town	SL 48018	M 154/ 270	*Randform* 3 late	470–450	X		3f
Selinunte temple R sag Q	SL 43290	M 154/ 209	*Randform* 2/6?	470–440		Bechtold, 2021, tab. 1,74 Fig. 6,8	
Selinunte temple R sag P	SL 42051	M 154/ 141	*Randform* 2/6	470–440		Bechtold, 2021, tab. 1,23 Fig. 3,7	4a
Selinunte artisanal quarter	SL 31807*	M 154/ 312	*Randform* 2/6	460–430			4b
Selinunte artisanal quarter	SL 31502	M 154/ 314	*Randform* 5	470–425			
Selinunte artisanal quarter	SL 29718	M 154/ 315	*Randform* 5	470–425			4f
Selinunte artisanal quarter	SL 35134	M 154/ 286	*Randform* 7.1	440–420	X		
Selinunte Manuzza Nord	SL 48289	M 154/ 264	*Randform* 7.1	440–420	X		5a
Selinunte survey western town	SL 48021	M 154/ 273	*Randform* 7.1	440–420			5b
Selinunte artisanal quarter	SL 36457*	M 154/ 296	*Randform* 7.1	440–420			5c
Selinunte artisanal quarter	SL 31514*	M 154/ 284	*Randform* 6	430–409	X		4c-d
Selinunte Manuzza Nord	SL 48342*	M 154/ 265	*Randform* 6	430–409	X		4e
Selinunte temple R sag Q	SL 43290	M 154/ 210	*Randform* 7.2	425–400		Bechtold, 2021, tab. 1,21	
Selinunte temple B sag H	SL 33690	M 154/30	*Randform* 7.2	425–400		Bechtold, 2021, tab. 1,20	
Selinunte temple R sag O	SL 41190	M 154/ 126	*Randform* 7.2	425–400		Bechtold, 2021, tab. 1,25 Fig. 3,6	
Selinunte artisanal quarter	SL 40989*	M 154/ 317	*Randform* 7.2	425–400	X		5d
Selinunte temple R sag P	SL 42666	M 154/ 150	*Randform* 7.3	409–350		Bechtold, 2021, tab. 1,24 Fig. 3,5	5e
Selinunte artisanal quarter	SL 35138*	M 154/ 285	*Randform* 7.3	409–350	X		5f
Selinunte temple R sag O	SL 42079*	M 154/ 155	*Randform* 7 (peg)	440–350		Bechtold, 2021, tab. 2,9 Fig. 3,8	
Selinunte temple B sag H	SL 33449*	M 184/9	Domestic amphora 'tesa inclinata'	Late Classical period		Bechtold, forthcoming, cat. 213; Montana and Randazzo, 2015 SLN-II	6a
Selinunte temple R sag M	SL 40351	M 154/ 107	Domestic amphora 'tesa orizzontale'	Late Classica period			
Selinunte artisanal quarter	SL 31453	M 154/ 306	Domestic amphora 'tesa orizzontale'	Late Classical period		Bentz et al., 2013, 84-85 Fig. 13	6b
Selinunte artisanal quarter	SL 31847	M 154/ 308	Domestic amphora 'tesa orizzontale'	Late Classical period	X		6c
Selinunte artisanal quarter	SL 38307	M 154/ 311	Domestic amphora 'orlo concavo'	Classical period			6d
Selinunte artisanal quarter	SL 31776	M 154/ 313	Closed shape painted	Classical period	X		6e
Selinunte temple B sag E	SL 33812	M 184/1	Basin	350–250	X	FACEM – http://facem.at/m-184-1; Montana and Randazzo, 2015, 143 SLN-II	6f
Selinunte temple B sag H	SL 33810*	M 184/2	Mortar	400–250	X	FACEM – https://facem.at/sel-c-1; Montana and Randazzo, 2015, 143 SLN-II	6 g

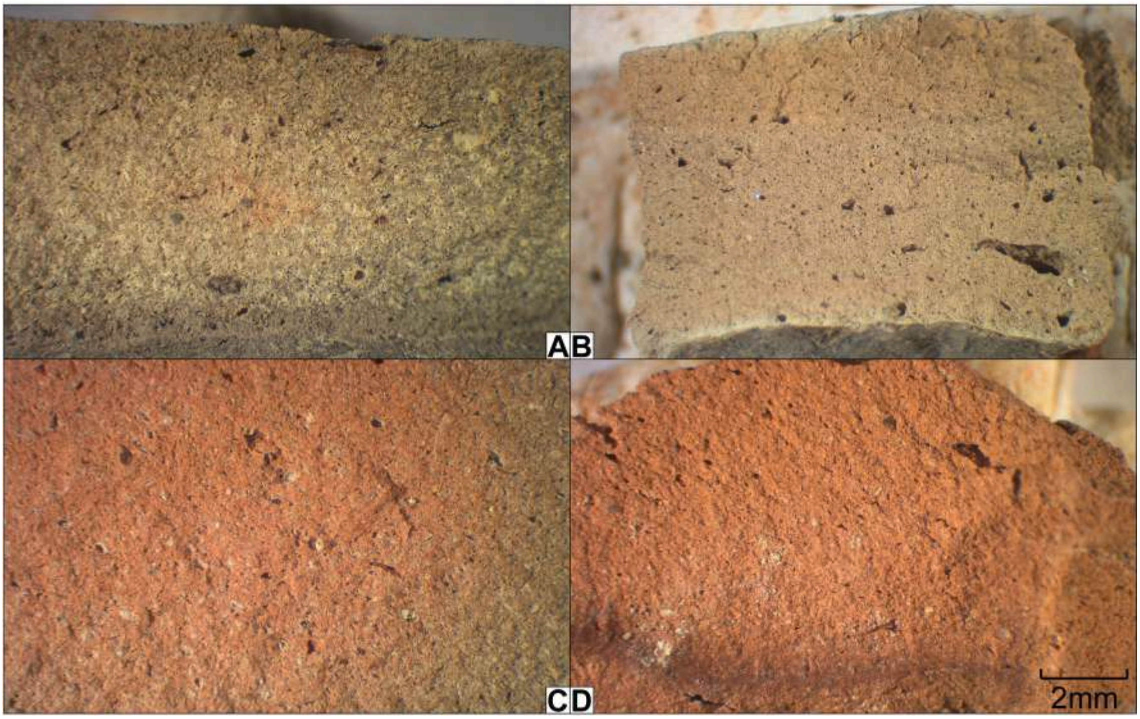

Fig. 2. Microphotos of fabrics of Selinunte at x8 magnification. (A) M 154/285; (B) M 154/264; (C) M 154/317; (D) M 154/315.

Amongst this presumed local assemblage, 29 fragments stem from the Universität Bonn excavations in the artisanal area (see Section 2.1), eight fragments from the American-Italian investigations in the major urban sanctuary (see Section 2.2), and five from the recent DAI Rome trenches/surveys in the residential area on the Manuzza hill (see Section 2.3). Moreover, three samples come from the Universität Tübingen excavations at *Cossyra*/Pantelleria, and one almost entirely preserved amphora has been found in the western necropolis of Himera (see Section 2.4).

In the following, 25 samples selected from these hypothetically local western Greek amphorae were submitted to mineral-petrographic analysis, and ten samples underwent additional chemical analysis (see Section 4). Furthermore, eight samples chipped from presumably local domestic amphorae and mortars/basins have been investigated for comparison with the archaeometric features of the post-Classical Selinuntian coarse wares (see Table 1).

2.1. The amphorae and coarse wares found in the artisanal quarter in the Cotone valley

More than half of the analysed presumably local materials, that is to say, 14 transport amphorae, three domestic amphorae, and one large closed shape, have been found in the investigations of the Universität Bonn (2010–2016) in the mid-6th-5th century BCE artisanal quarter along the *Gorgo Cotone* (Fig. 1b,1), just inside the Archaic-Classical fortifications (Bentz et al., 2016; Bentz et al., 2014 and references therein). Selinunte's 'industrial belt' became the largest manufacturing area of pottery currently known for the Archaic-Classical world, measuring more than 1 km in length. According to M. Bentz' estimation, during the 5th century BCE roughly 15 %-25 % of the urban population lived off ceramic production (Bentz, 2017).

Based on previous geophysical surveys, which identified 84 kilns, large-scale excavations in *insula* S 16/17-E have unearthed ten furnaces and several production structures distributed on four terraces (for all technological aspects: Bentz, 2020; Bentz, 2017). Three of these excavated kilns date to the second half of the 6th century BCE (Bentz et al., 2016), while seven refer to the 5th-century BCE phase of the workshop. None of them preserved the original pottery load and the installations appear to have been heavily damaged or even destroyed during the Carthaginian attack in 409 BCE. After this dramatical episode, the area has occasionally been re-visited for looting activities in the 4th century BCE, but never again systematically occupied.

The supposedly local amphorae found in the workshop currently represent the largest assemblage (N=29) of western Greek vessels identified in Selinunte. Its in-depth study will be presented in the framework of the forthcoming monograph on the *kerameikos* of the Cotone valley. The ten samples selected for archaeometric analyses cover the entire typological repertoire of western Greek amphorae currently documented for the Megarian colony, which can be dated between the late 6th and the end of the 5th century BCE, and the first half of the 4th century BCE (first remarks in: Bechtold, 2020a).

M 154/318 (Fig. 3c) and M 154/316 represent a variant of the late Archaic *Randform* 3 (typological identifications in this paper are referred to: Gassner, 2003, 180-182) with only a slightly moulded, inferior edge. Both items are residuals in late 5th-4th century BCE deposits. On morphological grounds, M 154/315 (Fig. 4f) and M 154/314 from surface contexts can be referred to as *Randform* 5/Corinthian B-type amphorae dating roughly to the second third of the 5th century BCE. A similar chronological range can be attributed to M 154/312, an intermediate shape between *Randform* 2 and *Randform* 6 with an already slightly convex neck (Fig. 4b) from a second half of the 5th-century BCE level. M 154/284, an almond-shaped, clearly everted rim, matches *Randform* 6 (Fig. 4c-d). This probably late 5th-century BCE fragment was found in a 4th-century BCE level excavated in front of the fortification.

The most numerous selection comprises rims underlined by a ridge above convex necks like *Randform* 7. M 154/286 and M 154/296 (Fig. 5c) represent the earliest variant, distinguished by almost vertical lips with a straight inner profile, thickening in the upper third and a hight-to-thickness ratio of 1.6–1.8. M 154/296 was found in the occupation level of room A2 dated to the second half of the 5th century BCE. As a working hypothesis, we assume the above selection of local *Randform* 7-rims should be dated c. 440–420 BCE.

The amphorae from the last quarter of the 5th century BCE feature rims that are noticeably thinner with concave inner profiles that gently

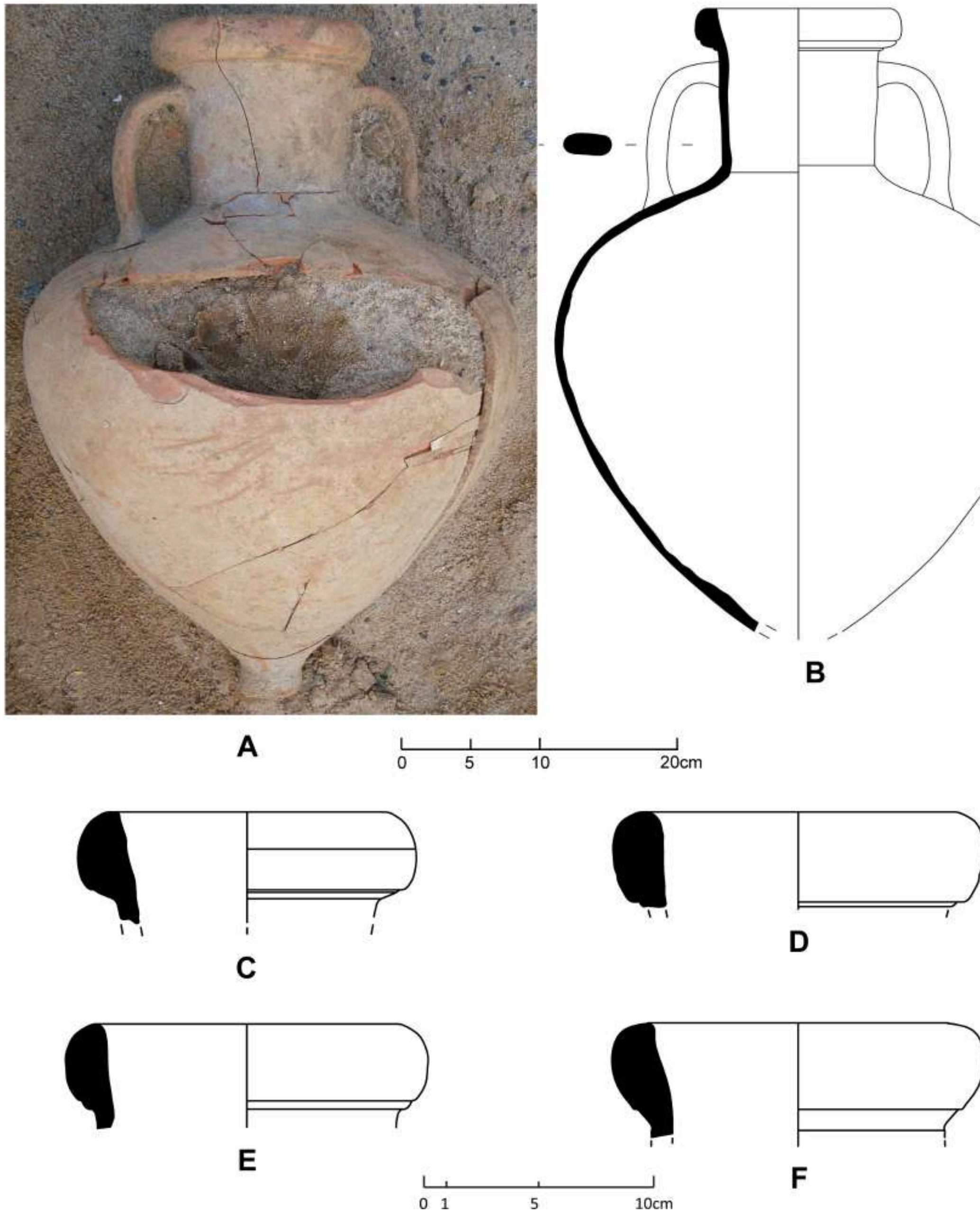

Fig. 3. Late Archaic and early Classical-period amphorae produced in Selinunte. (A)-(B) M 179/168; (C) M 154/318; (D) M 119/266; (E) M 154/266; (F) M 154/270.

slope outwards and have an increased ratio of 2.4–2.7 (Fig. 5d). M 154/317 was found in a street layer excavated before terrace C, dating to the second half of the 5th century BCE. This shape has also been documented in levels relating to the destruction of the workshop in 409 BCE.

Finally, the last group is characterised by clearly everted rims with an angle of at least 20°. Fragment M 154/285 (Fig. 5f), and seven other items from *insula* S 16/17-E belong to phase 6-contexts, which correspond to the catastrophic events of 409 BCE or the re-visitation of the area during the 4th century BCE.

A selection of ten domestic amphorae with large protruding rims 'a tesa' also come from phase 6-levels. Among these, M 154/306 and M 154/308 (Fig. 6b-c) have been submitted for archaeometric investigations. Additionally, the analysed coarse ware assemblage includes M 154/311, a second type of domestic amphora with a concave rim (Fig. 6d) from an earlier 5th-century BCE layer, and M 154/313, a rim of a big closed shape (Fig. 6e) with internal painted lines, which was discovered by a second half of the 5th-century BCE deposit unearthed close to the fortification.

2.2. *The amphorae and coarse wares found in the major urban sanctuary on the acropolis of Selinunte*

Since 2006, excavations have been carried out by the Institute of Fine Arts-NYU, led by C. Marconi, and joined in 2018 by the Università degli Studi di Milano, in the major urban sanctuary, in the area of temples B and R (Fig. 1b, 2), in the southern part of the acropolis (preliminary reports with full references: Marconi and Ward, 2022 for temple R; Marconi, 2012 for temple B).

In view of the present archaeometric research, seven samples of transport amphorae, two domestic amphorae, one basin sample, and one mortar sample have been selected for analysis.

The two earliest local commercial vessels, M 154/141 (Fig. 4a) and M 154/209, found in the urban sanctuary, can be classified as a transitional type of *Randform* 2/6 and can be dated to the second third of the

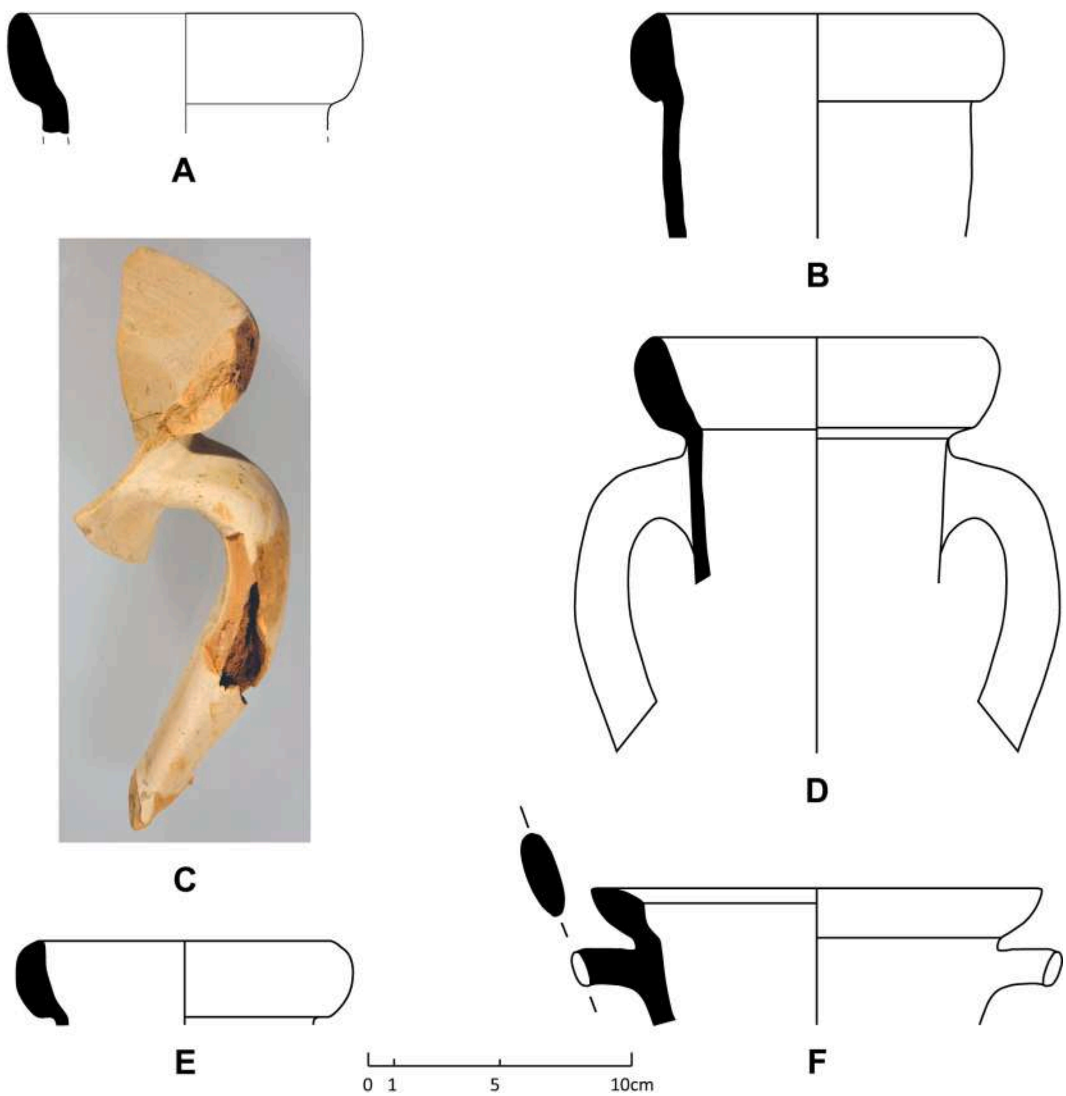

Fig. 4. Classical-period amphorae produced in Selinunte. (A) M 154/141 (B) M 154/312; (C)-(D) M 154/284; (E) M 154/265; (F) M 154/315.

5th century BCE on morphological grounds. The fragments were found as residual elements in the Hellenistic fill of phase X (around 300 BCE), discovered in the *cella* and the *adyton* of temple R.

Three fragments can be attributed to the intermediate state of the local *Randform* 7 with slightly everted rims (see Section 2.1) and date to the last quarter of the 5th century BCE. While M 154/126 and M 154/210 are residuals within the Hellenistic phase X -fill of the *cella* and the *adyton* of temple R, M 154/30 comes from the pre-Hellenistic accumulation layer (540–340 BCE) unearthed outside the altar of temple B.

M 154/150 (Fig. 5e) represents the presumably latest step of the local evolution of *Randform* 7 (see Section 2.1) in the late 5th-first half of the 4th century BCE. It was found in the Hellenistic fill of temple R's *adyton*. Additionally, the peg M 154/155 likely belongs to a *Randform* 7 amphora. It is in phase with the late Archaic-Classical-period surface preparation layer of the *cella* of temple R.

One domestic amphora with a large protruding rim (Fig. 6a) and a mortar (Fig. 6g) come from the foundation fill (around 300 BCE) of the altar of temple B. A second domestic '*a tesa*'-amphora M 154/107 and a basin (Fig. 6f) belong to the massive phase X-Hellenistic fill unearthed in the whole area around temple B.

2.3. The amphorae found in the urban contexts of Selinunte

Three of the analysed samples were found in trench M (Fig. 1b, 3), opened in 2021 by the DAI Rome in the northern part of Manuzza Hill (Jonasch et al., 2022, 32-33). During the Archaic-Classical period, this area of the town was occupied by residential quarters. M 154/266 (Fig. 3e), a residual from a context related to the destruction in 409 BCE, shows the late Archaic *Randform* 3. M 154/264 (Fig. 5a) exemplifies the earliest local version with *Randform* 7 (c. 440–420 BCE, see Section 2.1) and was discovered in an early Hellenistic level. Late 5th-century BCE M 154/265 featuring *Randform* 6 (Fig. 4e), was unearthed in a collapse connected to the catastrophe in 409 BCE, is contemporaneous with its archaeological deposit.

Finally, M 154/270 (Fig. 3f), characterised by a late variant of *Randform* 3, and M 154/273 (Fig. 5b) with an early variant of *Randform* 7, were discovered during the Università di Palermo surveys undertaken in the southern section of the western part of the town (Fig. 1b, 4, see Jonasch et al., 2022, 27-30).

2.4. The Selinuntine amphorae found in Himera and on Pantelleria

An almost entirely preserved amphora (Fig. 3a-b) of Sourisseau's late Archaic form 2 (Sourisseau, 2011) with *Randform* 3 represents the earliest item among the analysed selection of vessels manufactured in Selinunte. It has been reused in an *enchytrismos* grave discovered by the Soprintendenza di Palermo in the western necropolis of Himera (for the most recent update on this research: Vassallo, 2018). In an earlier stage

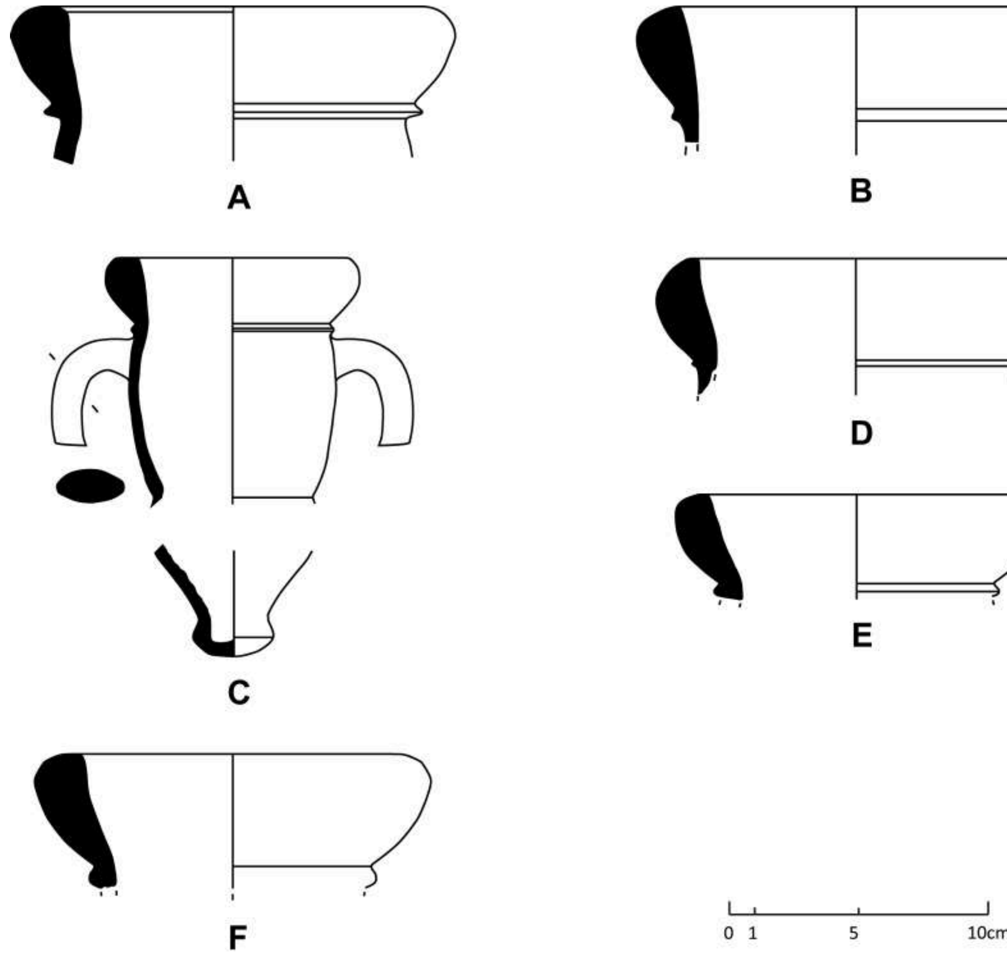

Fig. 5. Late Classical-period amphorae produced in Selinunte. (A) M 154/264 (B) M 154/273; (C) M 154/296; (D) M 154/317; (E) M 154/150; (F) M 154/285.

of the present archaeometric research, this item has been attributed to the production of near-by Agrigento (Bechtold, 2020c, 3-5, Fig. 1,5; FACEM – http://facem.at/m-179-168).

Finally, two late Archaic *Randform* 2-fragments have been identified at *Cossyra*/Pantelleria. M 119/142 was found during the suburban survey in UT 130, a site included in the urban area at least from the 5th century BCE onwards (Almonte, 2013, 175). M 119/266 (Fig. 3d) stems from trench X opened by the Universität Tübingen at the north-western edge of the acropolis, which has been interpreted as a residential zone.

3. Geological context and raw clay sampling

The main sedimentary succession outcropping near Agrigento and Selinunte archaeological sites represent the quaternary syn-tectonic deposit filling wedge top basin on outer sector of the Sicilian Fold and Thrust Belt (FTB). In particular, the Agrigento sector is located in a sin-tectonic basin growing above the westernmost portion of the neogenic Gela Thrust System (GTS) (Catalano et al., 2013; Ghisetti et al., 2009) while the Selinunte sector is located in a syn-tectonic depositional area above the Meso-Cenozoic thrust wedge. In this sector, the Sicilian FTB is constituted by Meso-Cenozoic) south-verging carbonate tectonic units (Saccense and Sicanian Domains), unconformably covered by middle Miocene to Pleistocene deposits. The GTS is formed by late Miocene-lower Pliocene deformed syntectonic successions (Gasparo Morticelli et al., 2015). Both the Sicilian FTB and GTS are covered by Plio-Pleistocene deposits that highlight continuous syndepositional tectonics of the Sicilian FTB evolution (Fig. 7).

The territory of Agrigento is located in the regional tectonic structure named "Caltanissetta synform" (Catalano et al., 2013), where upper Miocene evaporitic deposits pertaining to the Gessoso-Solfifera series, together with Plio-Pleistocene marly clay and biocalcarenites, are widely exposed. The area of the *Valle dei Templi* is specifically characterised by the extensive presence of Pleistocene biocalcarenites and greyish clays. These latter crop out at the base of the southeastern slope below the *Tempio di Giunone*, being characterised by levels rich in planktonic foraminifera and marine mollusks as well. In very recent previous work clay sampling was carried out in the gullies between the *Tempio di Giunone* and the *Tempio della Concordia*, just below Gate III and up to 12 samples were collected (Fig. 7 and Table 2). These samples have been characterised from a minero-petrographic and chemical point of view, through X-ray analysis (XRPD), microscopic analysis of thin sections (after experimental firings) and chemical analysis using ICP-OES/Coupled ICP-MS (Montana et al., 2022). In this research, the sandy fraction of the same samples was separated after careful washing to be subjected to detailed paleontological analyses, with the aim of detecting the associations of microfossils and obtaining a correct relative dating of the sediment.

The area surrounding the archaeological park of Selinunte is characterised by wide out-crops of Pleistocenic clays with variable content of medium-fine sand. These deposits are covered by Holocene marine to coastal terrace deposits and unconformably cover Jurassic-Pliocene carbonate and silico-carbonate succession representing the southern offshoot of the Sicani Mountains (D'Angelo et al., 2001). Although different types of clayey materials are potentially available in the area, Pleistocene clay deposits have been traditionally exploited for ceramic production. As in the case of Agrigento, these clayey materials have also been the subject of minero-petrographic and chemical characterisation in a fairly recent work (Montana et al., 2018a) and in this new research,

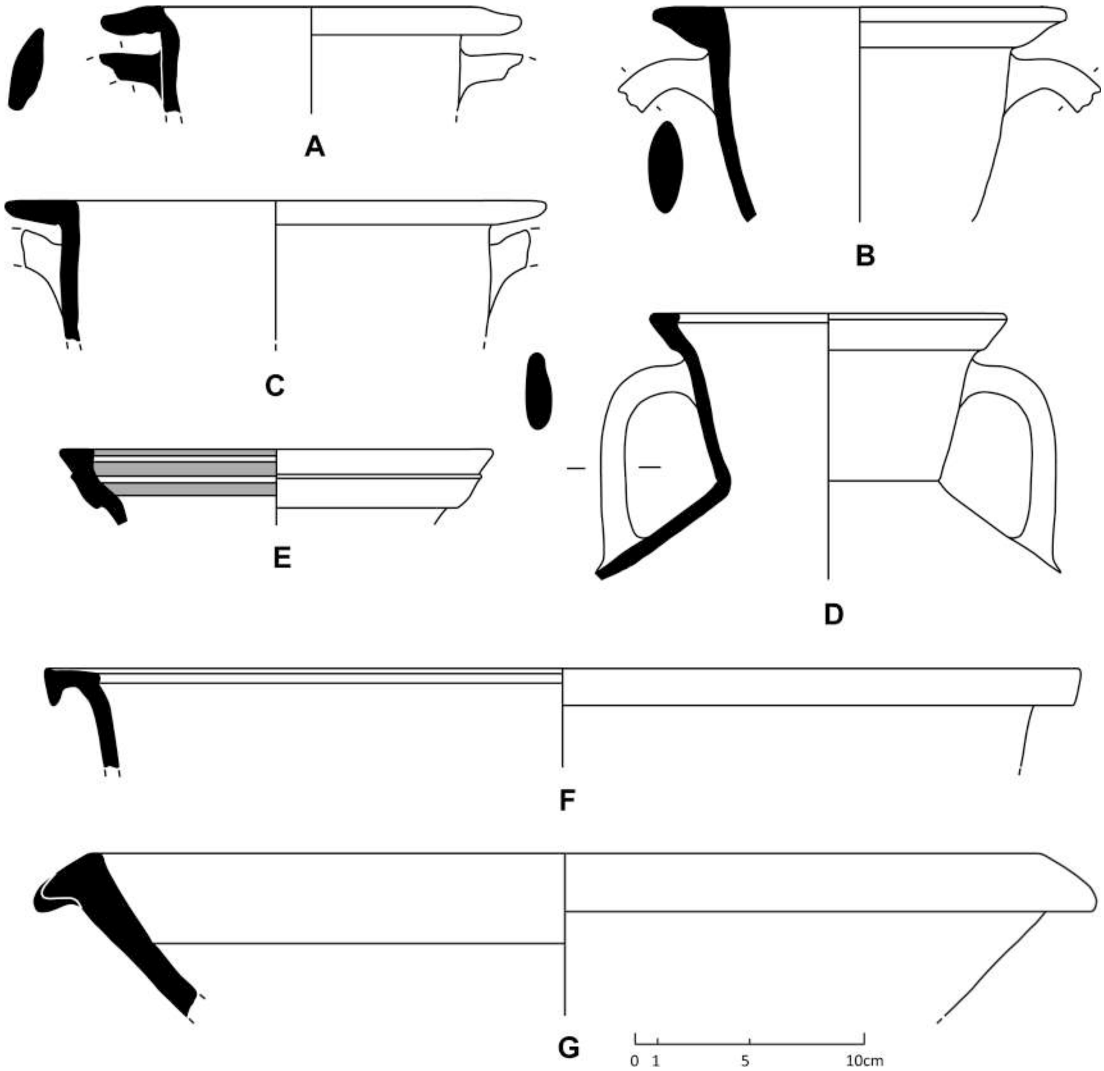

Fig. 6. Classical and late Classical-period coarse wares produced in Selinunte. (A) M 184/9 (B) M 154/306; (C) M 154/308; (D) M 154/311; (E) M 154/313; (F) M 184/1; (G) M 184/2.

investigated in detail from a micropaleontological point of view. Up to eight sample were collected within the Archaeological Park Selinunte and in immediately adjacent locations (Fig. 7 and Table 2).

Clay raw materials were chosen after a detailed field survey, within the boundaries of the present-day archaeological park, as well as from two locations near the village of Marinella di Selinunte and to the east of the mouth of the River Belice at Contrada Gurra di Mare. All clayey materials were collected from a fresh surface and any agricultural land or soil covers were removed beforehand.

4. Experimental procedures and analytical methods

The sediment portion used for microfossils characterisation resulted from the granulometric analysis after sieving, separation and washing (Montana et al., 2018a, 2022). The microfossils subject to specific micropaleontological characterisation were picked up from the sandy fraction (0.06—–2 mm) by means of a fine brush and observed under reflected light binocular microscope.

Thin section obtained from the selected amphora samples were observed through a Leica DM LSP polarizing microscope equipped with a digital camera (Leica DC 200) in order to obtain minero-petrographic description of each sample. The relative abundance of non-plastic inclusions (expressed as area %) was determined by conventional point-counting procedures and comparative tables (after Matthew et al., 1991).

Finally, bulk chemical data of selected ceramics (14 samples) were determined using the fusion inductively coupled plasma optical emission spectrometry (ICP-OES) technique for major oxides and inductively coupled plasma mass spectrometry (ICP-MS) for trace elements at the Activation Laboratories Ltd (Ontario, Canada) and compared with those of clay samples and ceramics beforehand acquired (Montana et al., 2018a, 2018b, 2022). Sample preparation methods, operating conditions, precision and accuracy values can also be found in the previously published papers by the same authors.

5. Results

5.1. Biostratigraphy of the raw clay samples from Selinunte and Agrigento

As regards the clays and sandy-clays samples collected in the area between Selinunte and Porto Palo di Menfi, the biostratigraphic analyses allowed to ascribe them to the latest part of the Lower Pleistocene, but they could be even more recent. Some samples (SEL-1, SEL-6, SGM, AG) were attributed to the interval between the upper part of the MPle1 biozone “*Globigerina cariacoensis* Interval Zone” and to the lower part of the MPle2 biozone “*Globorotalia truncatulinoides excelsa* Interval Zone” (Lirer et al., 2019), late Calabrian in age (Sicilian sub-stage). This attribution is due to the presence of *Globorotalia truncatulinoides*,

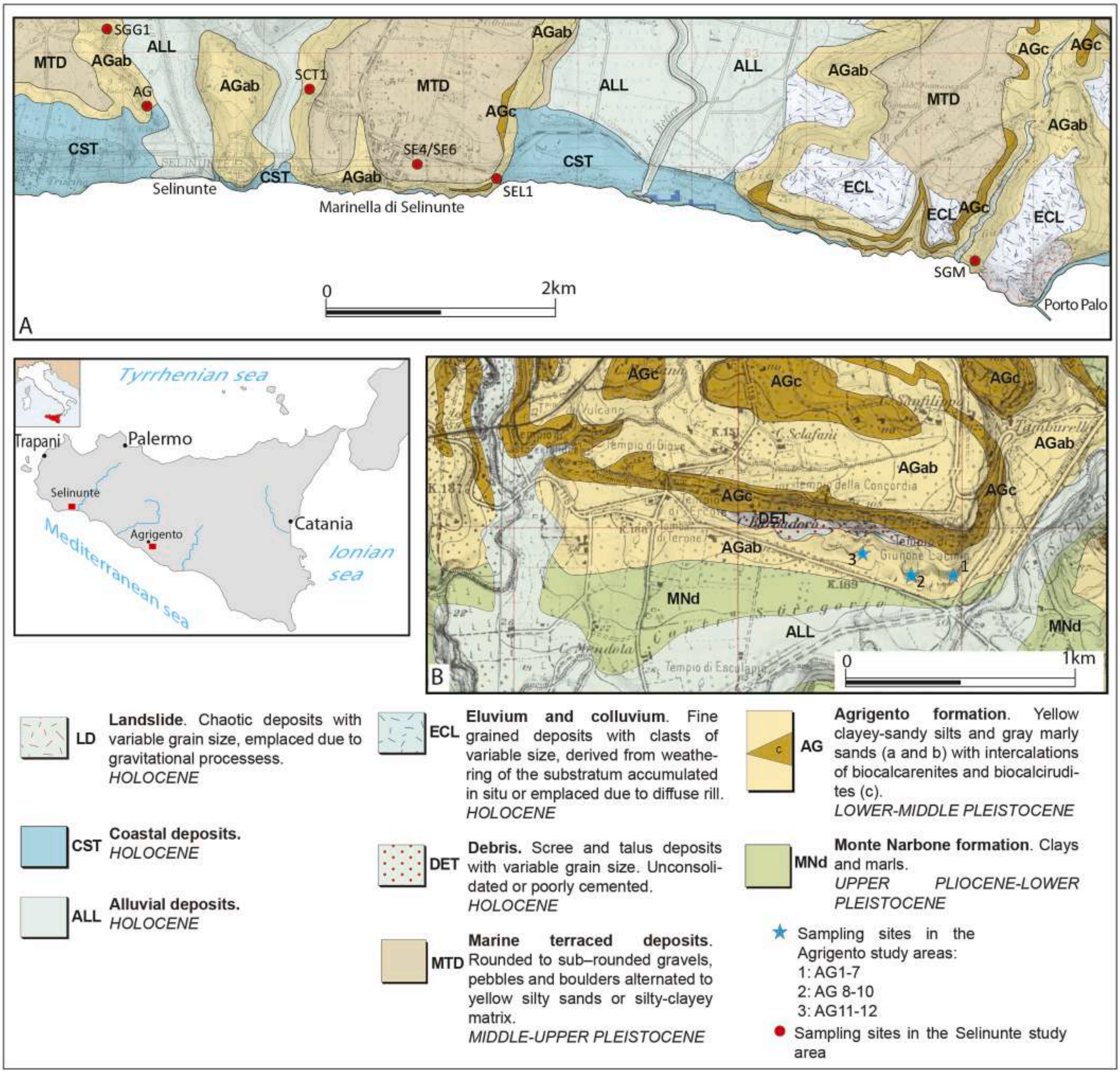

Fig. 7. Geological map of the studied area: Selinunte (A) and Agrigento (B) sectors. Modified from Pucci et al. 2023 and Montana et al. 2022.

together with *Globorotalia inflata*, *Globigerinoides elongatus*, *Globigerinoides tenellus*, *Neogloboquadrina* spp. dx (right coiling). The remaining samples were instead attributed to the upper part of MPle1a and MPle1b, middle Calabrian in age, based on the co-occurrence of *Globorotalia inflata*, *Globoturborotalita rubescens*, *Globigerinoides elongatus*, *Globigerinoides tenellus*, *Neogloboquadrina* spp. dx and sx (right and left coiling), together with the benthic foraminifer *Hyalinea balthica*. Furthermore, the first occurrence of this latter specimen *(Hyalinea balthica)* in the Mediterranean Sea is considered as indicative of the beginning of the Emilian sub-stage (Azzaroli et al., 1997; Caruso, 2004; Cita et al., 2008). Therefore, the biostratigraphic analyses carried out on samples coming from Selinunte and Porto Palo di Menfi indicate an age compatible with the middle-late Calabrian interval (Emilian and Sicilian sub-stages), although it is not possible to exclude that they were deposited more recently, reaching the base of the Middle Pleistocene (Fig. 8a-b). Furthermore, as suggested by Catalano et al., (1998) and Pucci et al., (2023), the clays outcropping in the area between Selinunte, Marinella di Selinunte and Porto Palo di Menfi can be considered as homogeneous from the lithological and micropalontological/biostratigraphic point of view. These authors indeed ascribed these lithotypes to the interval comprised between the middle-upper part of the Calabrian and the Middle Pleistocene.

The biostratigraphic analysis carried out on the clay-marly samples collected in archaeological park of Agrigento allowed to refer this sedimentary record to the Lower Pleistocene. Based on planktonic foraminiferal assemblages analysed, some samples (AG-1, AG-8, AG-11, AG-12) were ascribed to the MPl6 biozone "*Globorotalia inflata* Interval Zone" (Lirer et al., 2019), late Gelasian in age. The co-occurrence of *Globorotalia inflata*, *Globoturborotalita rubescens*, *Neogloboquadrina* spp. dx (right coiling) is indeed typical of the latest part of the Gelasian period. Conversely, the planktonic foraminiferal assemblages observed in the other samples (AG.6, AG.7, AG.10) are compatible with the lower

Table 2
Clay sampling details (WGS84/UTM zone 33N – EPSG:32633 Projected coordinate system).

Sample code	Sampling point	Description	GPS Coordinates (E, N)
SEL1	Marinella di Selinunte (Via della Pineta)	greenish grey level	310231, 4161705
SE4	Marinella di Selinunte	pale yellow level	309528, 4161829
SE6	Marinella di Selinunte	pale yellow level	309528, 4161829
SGG1	Gaggera spring	light brownish grey level	306806, 4163016
SCT1	Cottone valley	ligth yellowish brown level	308580, 4162488
AG	Gaggera spring	grey level	307157, 4162337
SGM	Gurra di Mare	light grey level	314433, 4160979
AG-1	at the base of the gully under the *Tempio di Giunone*	whitish level	375901, 4127595
AG-2	under the *Tempio di Giunone*	yellowish-whitish level	
AG-3	under the *Tempio di Giunone*	light yellow level	
AG-4	under the *Tempio di Giunone*	yellowish level	
AG-5	under the *Tempio di Giunone*	light grey level	
AG-6	under the *Tempio di Giunone*	greysh level	
AG-7	under the *Tempio di Giunone*	yellowish level	
AG-8	at the base of the gully between the *Tempio di Giunone* and the *Tempio della Concordia*	yellowish level	375715, 4127587
AG-9	between the *Tempio di Giunone* and the *Tempio della Concordia*	yellowish level	
AG-10	between the *Tempio di Giunone* and the *Tempio della Concordia*	grey level	
AG-11	taken from the top level, under the *Tempio della Concordia*	grey-yellowish level	375502, 4127694
AG-12	clayey hill just below the *Tempio della Concordia* (paleo-landslide)	grey-yellowish level	

part of the MPle1 biozone "*Globigerina cariacoensis* Interval Zone" (Lirer et al., 2019), Calabrian in age. Furthermore, due to the presence of *Globigerina cariacoensis* and *Globigerinoides tenellus*, as well as to the increase in abundance of *Neogloboquadrina* spp. sx (left coiling) is possible to ascribe these latter samples to the early Calabrian (MPle1a sub-zone), more precisely to the Santernian sub-stage (Fig. 8c-d).

The results relating to the individual samples, both for Agrigento and Selinunte, are shown in Fig. 9 and described in detail in Supplementary Table 1.

5.2. Optical microscopy observations of western Greek amphorae produced in Selinunte

The whole set of ceramic samples shows a good uniformity in terms of petrographic features. In Supplementary Tables 2a and 2b, details of microscopic observations have been reported. They have petrographic characteristics that are very similar to each other and perfectly comparable with local raw materials, both in terms of grain size distribution, relative abundance of the aplastic inclusions and the mineralogical composition (Montana et al., 2018b). As regards the textural aspects, all the finds, regardless of their specific intended use, show serial distribution and a relative abundance of aplastic granules between 15 and 25 % (area), with a notable predominance of coarse silt (0.04–0.06 mm) and very fine sand (0.06–0.125 mm), as well as smaller quantities of fine sand (0.125–0.25 mm). Granules with dimensions between the upper limit of fine sand (0.25 mm) and that of medium sand (0.5 mm) are sporadic to common, while those with an average diameter greater than 0.5 mm are rare or absent. For what concerns the mineralogical composition, single crystal of quartz appears to be by far the most abundant aplastic component. Bioclasts and limestone fragments are common constituents, even if almost completely decomposed after the firing process. They are evident however in the form of *micritic clots* sometimes with a sub-rounded profile, or with an irregular shape (Cau Ontiveros et al., 2002). Polycrystalline quartz and feldspars (K-feldspar and less frequently plagioclase) are common to sporadic components. Very often the crystals of alkaline feldspar and plagioclase appear altered and sericitized (incoming transformation in clay). Among the subordinate or trace aplastic constituents there are fragments of sandstones (quartz-feldspar-mica). White mica (mainly 0.04–0.1 mm), in the form of minute lamellae, chiefly appears to be a rare constituent in terms of abundance, although it is homogeneously distributed in the ceramic body. Secondary deposits of microcrystalline calcite, developed during the burial phase (not only outside but also within the ceramic body), are quite common. Even the petrographic observations of the coarse wares have made it possible to highlight comparable textural and compositional aspects found in the transport amphorae. A significant quantity of granules falls into the classes of coarse silt and fine sand, inclusions with dimensions up to medium sand are common to sporadic, while inclusions with dimensions greater than 0.5 mm are sporadic to rare. Compositionally, monocrystalline quartz prevails. The bioclasts and calcareous lithic fragments are well represented constituents (abundant to common), although for the most part decayed by the firing process and replaced by lumps composed of secondary microcrystalline calcite (micritic clots) or pore casts (Montana et al., 2012). Polycrystalline quartz, feldspars, quartzarenite fragments, chert and mica flakes are sporadic to rare constituents (Fig. 10).

5.3. Chemical analysis of western Greek amphorae produced in Selinunte

The chemical composition of the analyzed ceramics is in good agreement with the results obtained by the microscopic observations of thin section (Supplementary Table 3a and 3b). In fact, within the locally produced amphora, an acceptably homogeneous bulk composition can be highlighted. Only weak variations in concentration of major and trace elements seem to be correlated to slight differences in some textural parameters (packing and prevalent size of the aplastic inclusions) rather than to the nature of minerals or lithic fragments. The concentration of SiO_2 ranges between 53 and 60 % (average value = 58.19 %), while the concentration of CaO varies between 7.5 and 22.9 % (average value = 16.09 %). The average abundance of Fe_2O_3 is 5.84 %, i.e. slightly lower than the average value previously recorded for the "ceramic clays" of western Sicily (Montana, 2011; Montana et al., 2011). The concentrations of the other major elements are absolutely compatible with the mineralogical composition and the proportions of the aplastic inclusions (monomineralic grains and rock fragments). The percentage of MgO (average 2.24 %) is relatively low and reflects the small quantities or absence of magnesium-bearing carbonate rocks in the studied ceramic pastes as well as mafic minerals and opaque oxides. Similarly, concentrations of K_2O (average 1.65 %) arise from the relatively small quantities of silt-sized white mica lamellae dispersed in the groundmass and sporadic feldspar grains (both K-feldspar and plagioclase). Finally, the percentages of Al_2O_3 (average value = 13.92 %) and Na_2O (average value = 0.86 %) are compatible with Sicilian clay ceramic raw materials. Considering the abundances of trace elements, it should be noted that the concentration ranges of Rb, Ba and Sr appear well correlated with the abundances of the geochemically linked major elements (K and Ca). The same considerations can be made for V and the other transition metals (geochemically similar to Fe and Mn), but also for the abundance of the < 2 μm fraction (clay particles) in the ceramic body, as well as for the light rare earth elements (La and Ce) and the other incompatible elements (Zr, Y, Nb). Even the chemical matching with local raw

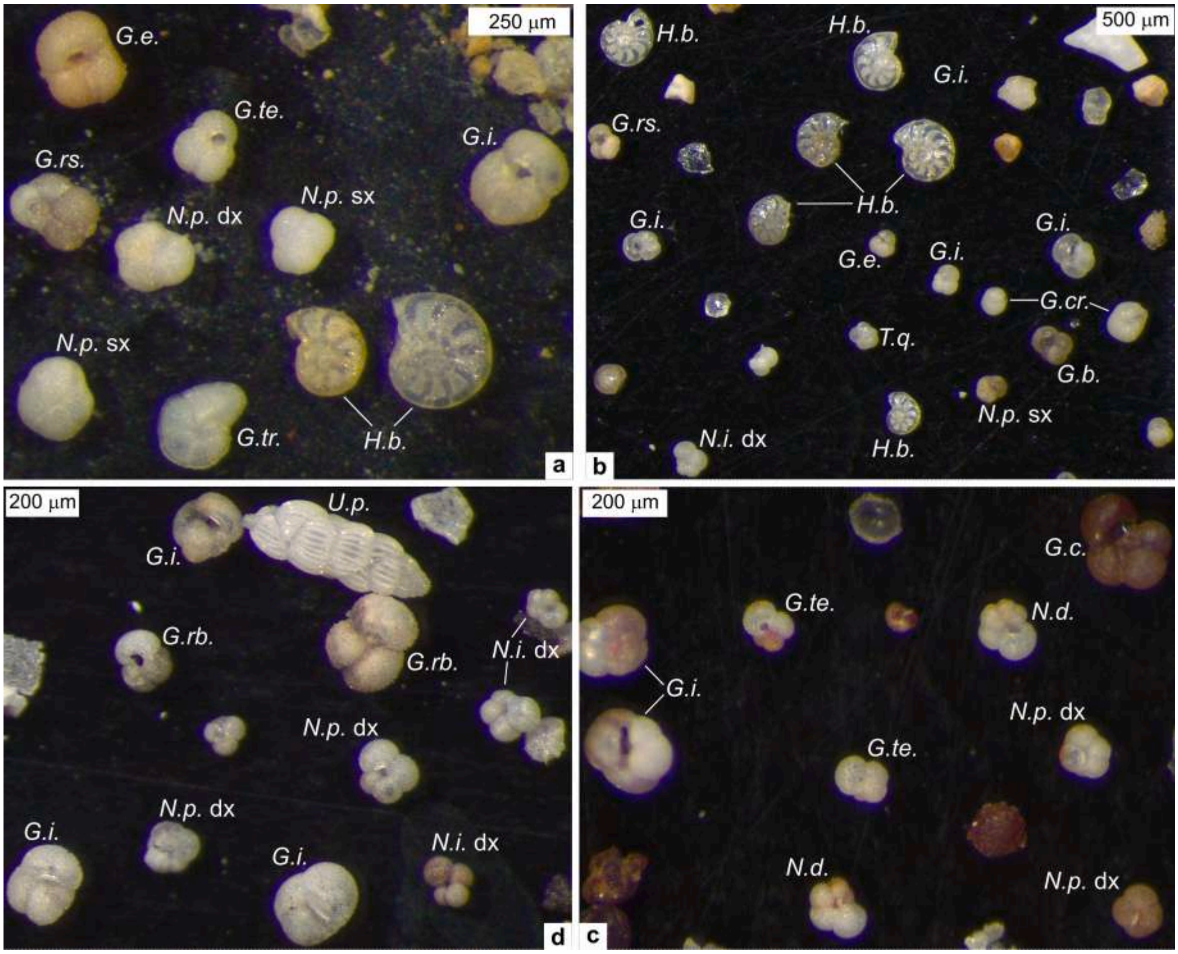

Fig. 8. Micropaleontological analyses carried out on samples collected in the Selinunte and Agrigento areas, two for each one, respectively. The sediment fraction greater than 63 µm has been analysed. a) Sample SEL-6; b) Sample SEL-4; c) Sample AG-6; d) Sample AG-1. The white labels refer to the recognized taxa, indicating the abbreviated genus and species of each of them, as well as for the coiling direction of the test (dx = right; sx = left) in some cases: *G.c.* = *Globigerina calabra*; *G.e.* = *Globigerinoides elongatus*; *G.rb.* = *Globigerinoides ruber*; *G.te.* = Globigerinoides tenellus; *G.rs.* = *Globoturborotalita rubescens*; *G.cr.* = *Globorotalia crassaformis*; *G.i.* = *Globorotalia inflata*; *G.tr.* = *Globorotalia truncatulinoides*; *N.a.* = *Neogloboquadrina acostaensis*; *N.d.* = *Neogloboquadrina dutertrei*; *N.i.* = *Neogloboquadrina incompta*; N. p. = *Neogloboquadrina pachyderma*; *T.q.* = *Turborotalita quinqueloba*; *H.b.* = *Hyalinea balthica* (benthic foraminifera); *U.p.* = *Uvigerina peregrina* (benthic foraminifera).

materials, and other ceramic finds of certain Selinuntine production, is more than satisfactory and leaves only few doubts about their use since the archaic age (Montana et al., 2018a; Montana et al., 2018b).

6. Discussion

The present research has fully confirmed the minero-petrographic and chemical compatibility of a group of 25 transport amphorae and eight coarse wares of supposed local fabric with the Pleistocene clayey deposits of Selinunte outcropping in the river valleys of *Modione* and *Cotone*. As seen in the previous result section, the western Greek amphorae produced in Selinunte are characterised by a medium–high packing (15–25 % area) and an aplastic fraction mainly with very fine grains (0.04–0.15 mm) and medium-coarse ones (0.3–1 mm) in relatively smaller quantities. Probably the fraction of aplastic granules with dimensions greater than 0.5 can be considered as temper, sourced by potters from the coastal dunes and intentionally added (even if in small quantities) to the raw clay. This technological solution has already been highlighted in the case of tiles and bricks produced locally starting from the 5th century BCE (Montana et al., 2018a). This temper by 'dilution effect' may have produced some differences in the abundance ratios of different elements between raw materials and ceramics. Also, regarding the mineralogical composition of the aplastic granules, the correspondence between the paste of the amphorae and that of the local bricks and tiles is more than acceptable. As regards the siliciclastic component, monocrystalline quartz by far prevails over polycrystalline quartz, feldspars, chert, quartzarenite fragments, and mica (rare). The carbonate component is well represented (from abundant to common) by shells of microorganisms (planktonic and benthic), fragments of macrofossils and limestones, even if intensely transformed by the firing process.

In addition to the compositional characterisation of the western Greek transport amphorae produced in Selinunte, one of the aims of this paper consists in the search for possible parameters (textural and/or compositional) useful for the distinction between vessels of the above class manufactured contemporaneously in Agrigento. Concerning this point, it is important to remember that from the late Archaic to the late Classical period, both colonies show an almost identical morphological repertoire and macroscopically very similar ceramic fabrics. However, the reliable differentiation of the two series appears to be of particular relevance for a better understanding of the economic role of the two cities within the wider framework of late 6th-earlier 4th century BCE regional trade.

The comparison in terms of minero-petrographic parameters between the contemporary Selinunte and Agrigento productions highlights some slight but significant differences, if considered in the light of the small stratigraphic discrepancy of the corresponding clayey deposits used as raw materials. In fact, the biostratigraphic analyses carried out on the clay samples from Selinunte indicate an age corresponding to the

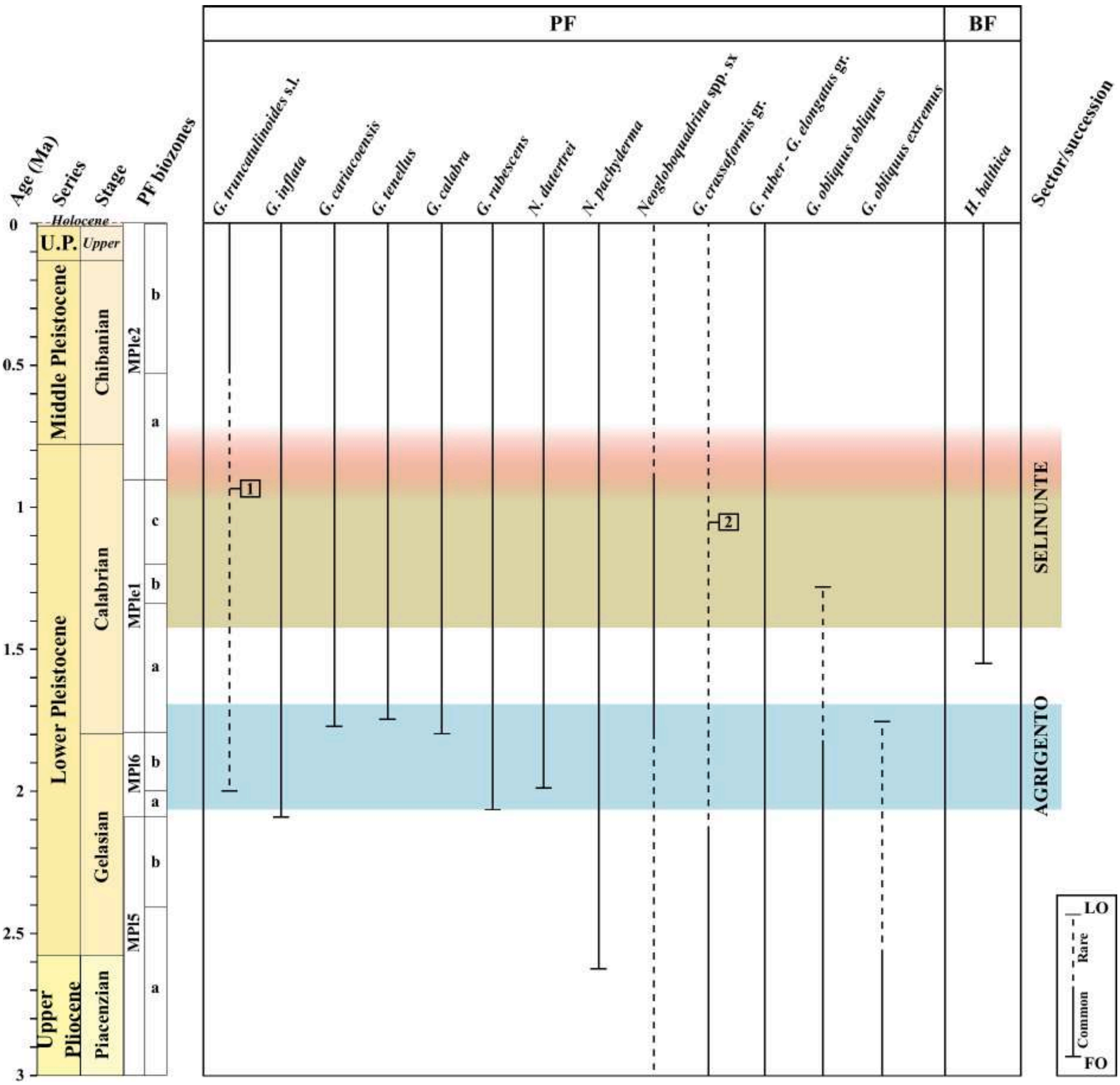

Fig. 9. Biostratigraphic scheme illustrating the distribution of the significant planktonic (PF) and benthic (BF) foraminiferal taxa. The abbreviation U.P. refers to the Upper Pleistocene series. The planktonic foraminiferal biozonal scheme is that proposed by Lirer et al. (2019), whereas the range distribution of the taxa has been derived from Cita et al. (2008), Cita et al. (2012) and Lirer et al. (2019). Numbers into the squares refers to biostratigraphically significant influxes of Globorotalia truncatulinoides s.l. (1) and Globorotalia crassaformis gr. (2). For the taxonomic name (genus and species/subspecies) of the illustrated specimens see Supplementary Table 1. Horizontal bands indicate the chronostratigraphic intervals identified through the samples analysed in the Agrigento (light blue) and Selinunte (beige to light red) sectors. As regard to the Selinunte sector, the fill color is shaded upwards indicating that the age of these deposits could also be more recent than the Calabrian. In the rectangle at the bottom right the legend of the taxa distributions is shown. In this legend the First Occurrence (FO) and Last Occurrence (LO) of the taxa are indicated, as well as if they are common (solid line) or rare (dashed line) within the biostratigraphic range of each one. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

middle-late Calabrian interval (Emilian and Sicilian sub-stages), while the clay samples collected in the archaeological park of Agrigento allowed to refer this sedimentary record to the Gelasian stage. Thus, it is clear that the ceramic raw materials used in these two important production centers both belong to the Lower Pleistocene, but that the clays of Agrigento are slightly older than those of Selinunte. Even with regards to the granulometric characteristics of the clay deposits themselves, there are some minor differences. The clays used in Agrigento can be classified as slightly sandy clayey silts (average percentage values by weight: sand = 8 %; silt = 47 %; clay = 45 %). The raw materials available in Selinunte can be classified as slightly sandy silty clays (average percentage values by weight: sand = 12 %; silt = 40 %; clay = 48 %). The relatively greater theoretical plasticity of the Selinunte clays, due to a larger abundance of clay particles mainly composed by illite and swelling lattice phyllosilicates (i.e. smectite and I/S mixed layer, after Montana et al., 2018a) may have encouraged the use of small quantities of medium sand temper in the ceramic paste mixing to improve the performance of the fired finished products. Another difference found between the ceramic clays of Selinunte and those of Agrigento consists in the type and abundance of fossil microfauna. The latter (Agrigento clays) are in fact characterised by a clear prevalence of planktonic foraminifers compared to benthic ones, which, instead, are very well represented in the Selinunte clays, especially with the exclusive presence of *Hyalinea balthica*, which is absent in the Agrigento succession (Fig. 8). The planktonic foraminifer *Globorotalia truncatulinoides* s.l., typical of the Selinunte clays and absent in Agrigento, is also indicative of the upper part of the Calabrian stage (Sicilian sub-stage).

However, while it was relatively easy to distinguish the two clays for

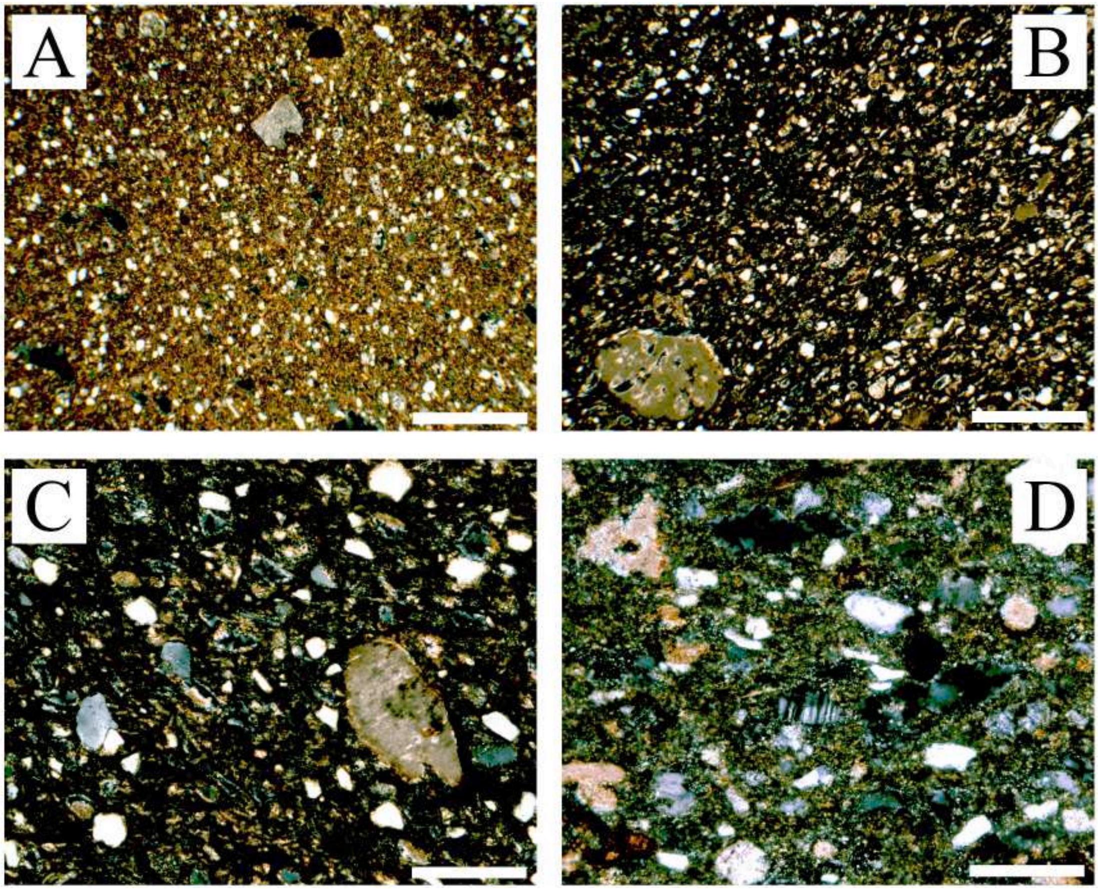

Fig. 10. Thin section microphotographs of some representative ceramic samples (XPL), overview of the characterizing textural and compositional aspects: (A-B) samples M 154/315 and M 154/308, (scale bar = 0.5 mm); (C) sample M 154/296 (scale bar = 0. 2 mm); (D) sample M 154/286 (scale bar = 0.1 mm).

ceramic use thanks to the micropaleontological study, unfortunately the firing process tends to erase the morphological characteristics of the shell of the diagnostic species mentioned above, making their recognition very doubtful. *Hyalinea balthica*, for example, despite being a benthic foraminifer, has small dimensions (similar to those of plankton) and a very thin calcareous shell, which, therefore, is easily degraded if heated to temperatures above 700 °C. In few cases and only in ceramic products from Selinunte fired at low temperatures (ground mass with evident optical activity) microfossils have been identified with a good margin of certainty, even if specifically, they are not diagnostic species (Fig. 11).

The microfabric of the Agrigento amphorae is for several aspects rather similar to that described above for the coeval productions of Selinunte. In fact, it is also characterised by a variable content of aplastic inclusions (from 10 % to 25 % area), with dimensions mainly distributed between 0.04 and 0.3 mm. The calcareous component, relatively less abundant than what was found in the Selinuntine amphorae, is mainly represented by planktonic foraminifera shells significantly modified by the firing process. Monocrystalline quartz is once again the most abundant constituent followed by polycrystalline quartz, while, the tiny lamellae of white mica are relatively more abundant than in the Selinuntine ceramic pastes.

Theoretically, these weak but perceptible differences in the relative abundances of calcareous microfossils and mica between the ceramic products of Selinunte and Agrigento, appreciated by the polarizing microscope observations, should also be replicated by the bulk chemical analysis. However, the chemical compositions of the respective raw materials, at first glance, may appear relatively similar. As regards CaO, although the thin-section observations clearly show a greater content of fossil microfauna in the case of Selinunte, the two amphorae productions are characterised by comparable average values: 16.09 % wt for Selinunte and 15.51 % for Agrigento. This apparently contradictory result is justified by considering that in the Agrigento clays there is detrital gypsum ($CaSO_4 \cdot 2H_2O$) leached from the Messinian evaporite deposits, which transforms into anhydrite ($CaSO_4$) after firing, as found in recent studies (Montana et al., 2022), which certainly contributes to the total CaO content of the ceramic paste. Consequently, the only chemical markers that can be used and justified in light of the minero-petrographic verification are K and Rb (geochemically related to potassium), whose difference in concentration is correlated to the greater content of very fine mica flakes in the clays and amphorae of Agrigento (Fig. 12 and Fig. 13). In particular, the average K_2O content in Agrigento (2.10 %) is approximately 30 % higher than in Selinunte (1.65 %) and the average Rb concentration (76 ppm) is approximately 40 % higher than that of Selinunte (57 ppm).

Coming back to the archaeological study based on morphological and stratigraphic criteria and now integrated by the above archaeometric research, our interdisciplinary investigation offers a more reliable possibility to trace a typological development of *Selinus*' transport amphorae from the late 6th to the end of the 5th-first half of the 4th century BCE.

The earliest specimens match Sourisseau's form 2 (Fig. 3a-b) and feature *Randform* 2 or, more often, *Randform* 3, the overall key type of the late Archaic western Greek world (Sourisseau, 2011). Owing to the new materials found in isolate S 16/17-E and in the Manuzza plain, we are now able to make some assessment on the repertoire of the local workshops during the second third of the fifth century BCE: Alongside with late versions of *Randform* 3 (Fig. 3f) are documented transitional items of *Randform* 2/6 with still vertical (Fig. 4a) or already slightly convex necks (Fig. 4b) and *Randform* 5-amphorae (Fig. 4f).

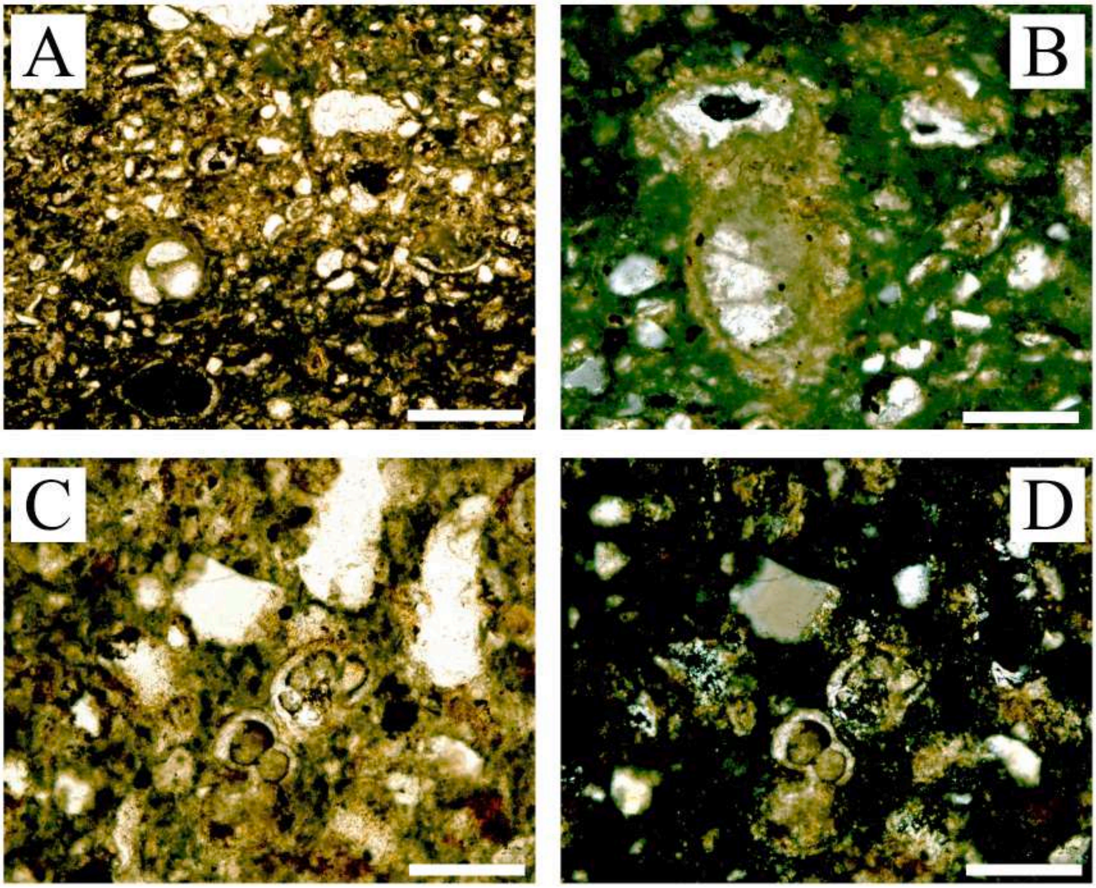

Fig. 11. Thin section microphotographs of some representative ceramic samples with remains of calcareous microfossils: (A) M 154/312 (PPL, scale bar = 0.2 mm), planktonic foraminifera shell (*Globigerinoides* sp.); (B) M 154/312 (XPL, scale bar = 0.1 mm) benthic foraminifera shell (likely *Gyroidina* sp.); (C-D) M 154/316 (PPL and XPL, respectively, scale bar = 0.2 mm), planktonic foraminifera shell (*Globigerinoides* sp.) and benthic foraminifera shell (*Hyalinea balthica*?).

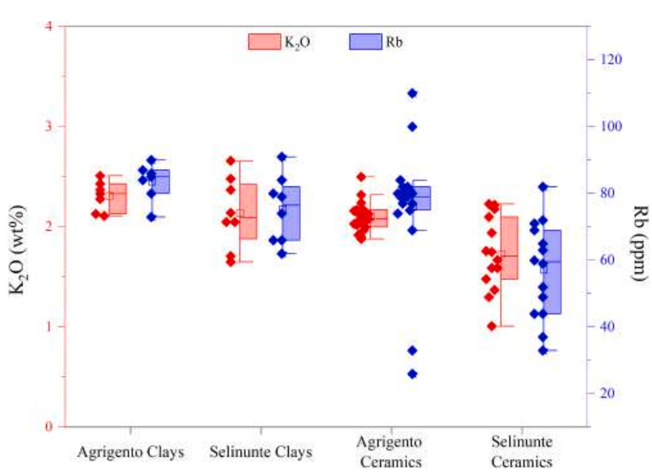

Fig. 12. Double Y-axis box plot diagram showing the comparison between Agrigento and Selinunte ceramics and clays.

A key type of the full 5th-century BCE Sicilian productions, distinguished by *Randform* 7 with an underlying ridge and distinctly convex neck, appears towards the late second third of the 5th century BCE or slightly later (Bechtold, 2021). In Selinunte, probably three variants of this shape carried on from the later Classical (Fig. 5a-d) to the post-Classical period. Based on archaeological considerations, which will be detailed in the monograph on the artisanal quarter, we suspect the latest subtype with a clearly everted rim (Fig. 5e-f) was produced after the city's destruction in 409 BCE.

Finally, amphorae with almond-shape rim like *Randform* 6 (Fig. 4c-e) should be attributed to the last decades before the Carthaginian attack.

The aforementioned diachronic repertoire appears to be aligned with the overall picture currently emerging for Sicily as a whole. Except for early form 1α-forerunners produced in Himera and perhaps in a few other Greek towns (Montana et al., 2020; Bechtold et al., 2019), almost all of the Sicilian colonies (and some non-Hellenic communities) started manufacturing form 2-amphorae destined for extra-local market commercialisation in the late Archaic period (for this issue, preliminarily: Bechtold, 2020b; Montana et al., 2022). The wide-spread dimension of this phenomenon attests to a dramatic demographic and economic increase documented for almost all of the Sicilian communities during the later Archaic period (Vassallo, 2020 with full references).

Regarding Sicily's southern coast, Selinunte represents the third Greek colony, alongside Gela (Spagnolo, 2018) and Agrigento (Montana et al., 2022), to have undergone interdisciplinary research on its local amphorae production between the late 6th and late 5th century BCE. While the Carthaginian conquest of 405 BCE interrupted production in Gela, an ongoing manufacturing activity during the first decades of the 4th century BCE seems likely for both Agrigento, and Selinunte.

The documentation of *Randform* 5/Corinthian B-type vessels among the series of Gela and *Selinus* is of special interest. These Sicilian pots imitate wine-carrying amphorae originating from the Ionian-Adriatic area, particularly Corcyra, which are well-documented in 5th-century BCE deposits excavated in Selinunte's major urban sanctuary on the acropolis (Bechtold, 2021). This phenomenon can be attributed to the emergence of 'shared regional styles' (Lawall, 2011).

The so far rather sporadic documentation of almond-shaped rims in

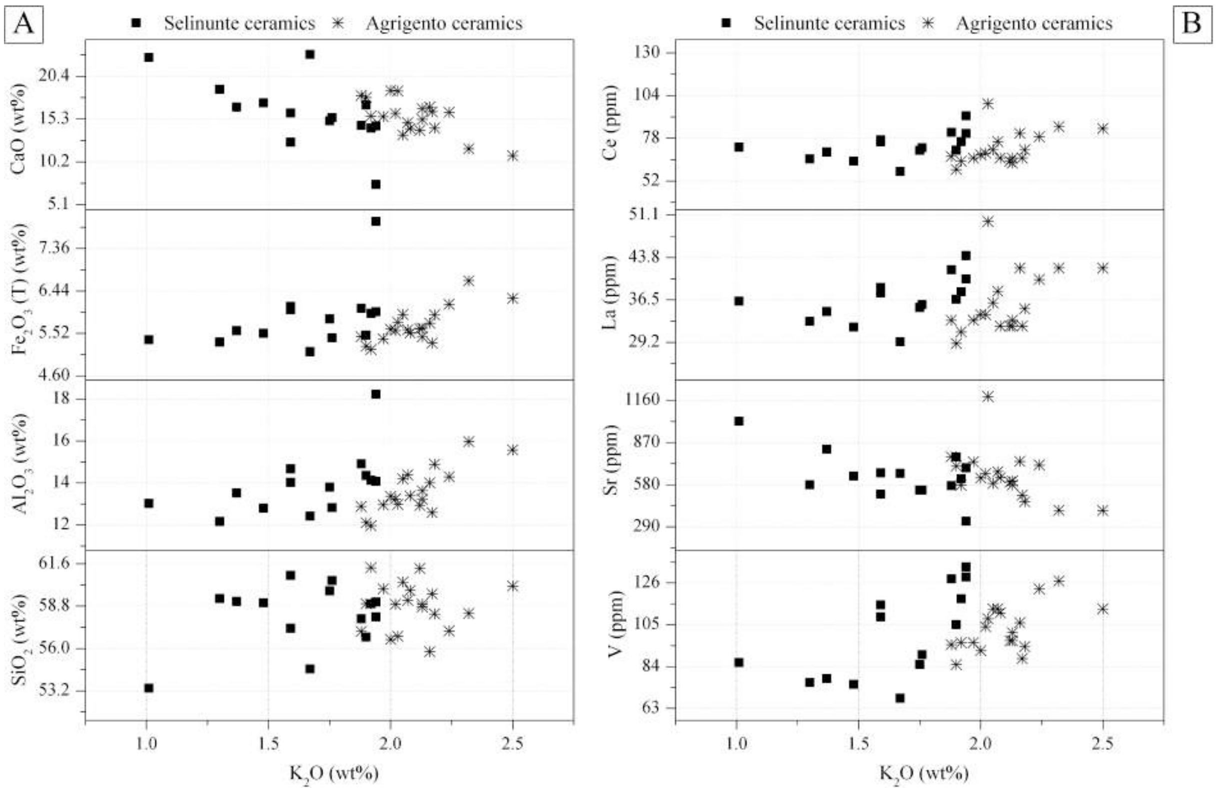

Fig. 13. Binary diagrams of some major and trace elements for the studied ceramic samples. (Data on Agrigento ceramics are taken from Montana et al., 2022).

Agrigento and Selinunte might more easily be addressed as an 'on–off imitation' (Lawall, 2011) of the widely distributed southern Calabrian *Randform* 6-amphorae from the later 5th to the first half of the 4th century BCE (for a Sicilian distribution pattern: Bechtold, 2013).

7. Conclusions and perspective for further research

The archaeometric-based differentiation between the amphorae productions of Agrigento and Selinunte has refined and integrated the fabric identification according to the FACEM method (see Section 2). It underlines the persisting difficulty in macroscopically distinguishing between the two pottery productions.

The archaeometric characterisation of the Selinuntine series of western Greek amphorae mainly focused on materials discovered in the colony itself where the class seems very frequent in the artisanal quarter and in the residential area on Manuzza. By contrast, commercial vessels produced in *Selinus* but found outside the colony are still extremely rare. Amongst c. 1200 western Greek containers studied in the scope of the below project (see funding), items attributed to Selinunte on the grounds of FACEM-fabric studies have only been identified in the Grotta Vanella dump at Segesta (de Cesare et al., 2020: M 165/80 still needs archaeometric analysis), at Pantelleria, and at Himera (see Section 2.4).

The almost complete lack of Selinuntine amphorae among the extensive assortment of 556 western Greek vessels discovered in Himera's necropolises appears to reflect the limited significance of this category in 5th-century BCE regional trade. This is further reinforced by the current absence of evidence for *Selinus*-manufactured western Greek amphorae in nearby Agrigento (Bechtold, 2022a) and Punic Palermo (Bechtold, 2022b).

The overall amphorae data collected from Sicily in recent years seems to hint at a very limited distribution of *Selinus*' transport containers outside the colony's territory. We might suppose that, at least in the coastal towns, their liquid commodities could not compete with the majority of amphorae-born goods imported from extra-regional areas (first remarks in: Bechtold, 2020b).

Further research should focus on sampling and analysing western Greek amphorae from inland sites situated in Selinunte's hinterland to corroborate the former hypothesis on the principal destination of the class to the native *milieu* (Bechtold, 2020a). Consequently, an in-depth fabric study of the quite limited 5th-early 4th century BCE amphorae panorama documented in Entella and its *chora* might become particularly relevant (Michelini, 2021, 55). As a result of the strong commercial and cultural ties between this major native site and the Megarian colony, facilitated by the primary communication route of the Belice valley (latest: Serra, 2021 with references), it is possible that Selinunte's amphora-borne goods were consumed by some of the indigenous communities in this inner western region of Sicily.

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CRediT authorship contribution statement

G. Montana: Writing – original draft, Visualization, Supervision, Resources, Investigation, Conceptualization. **M. Gasparo Morticelli:** Writing – review & editing, Writing – original draft, Visualization, Investigation. **A. Bonfardeci:** Writing – review & editing, Writing – original draft, Visualization, Investigation. **B. Bechtold:** Writing – review & editing, Writing – original draft, Visualization, Supervision, Resources, Investigation, Funding acquisition, Conceptualization. **L. Randazzo:** Writing – review & editing, Writing – original draft, Visualization, Supervision, Resources, Investigation, Conceptualization.

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.

Data availability

Research data are contained in the manuscript.

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Appendix A. Supplementary data

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