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Ceramic traditions and technological choices revealed by early Iron Age vessels: the case of Vetulonia (southern Tuscany)

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ABSTRACT
Early Iron Age pottery from central Italian regions has so far largely been studied with a particular emphasis on typological and stylistical features. However, an analytical approach to ancient ceramic technology can reveal a wealth of data on the know-how of early Iron Age central Italian craftspeople and their production choices. With this aim we conducted archaeometric analyses of forty vessels from one of the main protohistoric cemeteries of Vetulonia, coupled with geological surveys of the territory around the settlement and the collection of raw materials. The occurrence of a ceramic fabric marked by fragments of metasedimentary rocks, as opposed to a fabric tempered with flint fragments, indicates the existence of separate traditions, characterised by distinct processes and the addition of specific tempers, probably reflecting different technological practices. The significance of our findings is briefly discussed within the historical and social scenario of early Iron Age Vetulonia, at the dawn of urbanisation.

KEYWORDS
Pottery technology; archaeometry; petrography; raw materials; early Iron Age Etruria; Villanovan culture

1. Introduction

Central Italian pottery productions of Etruria during the early Iron Age (c. late tenth to late eighth centuries BCE) have been extensively studied typologically and stylistically, mainly focusing on vessel morphology and decoration. The detection of morphological and decorative attributes (*sensu* Clarke 1968 and Peroni 1998) characterising different ceramic "types" has allowed a better understanding of their chronological development, especially when vessels are included in grave-good associations (Toms 1986; Iaia 1999; Pacciarelli 2000). The often elaborate decorative patterns typical of this period (Bettelli and Di Pillo 2000) have enabled insights into the ritual meaning of the motifs engraved on the surface (Iaia 2002: Donati 2005; Delpino 2009), considerations on the geographical distribution of iconographies, reflecting the style of different areas (De Angelis 2001), and the possible social value of particular representations (Guidi 1980).

The approaches highlighted above can be of undeniable significance, and their intensive application since the 1980s has produced meaningful results. However, this remarkable ceramic production (usually referred to as "Villanovan pottery") has great potential also in terms of understanding early Iron Age ceramic technology, the use of landscape resources and the circulation of pottery in Etruria at the dawn of the historical period.

Over the last decades, several works have emphasised the importance of studying ancient artefacts as an expression of a complex traditional craft, which is socially constructed and in continuous evolution (e.g. Roux 2019 and literature therein). Within this field of technological study, material science has revealed the enormous potential to enhance the understanding of archaeomaterials technology, as it allows a degree of resolution that cannot be obtained solely with macroscopic inspections (Martinón-Torres and Rehren 2008). Archaeometric analyses can disclose crucial details regarding the provenance of objects, thus enabling the reconstruction of networks of circulation of finished products.

In addition, the application of scientific analyses to archaeomaterials helps to trace the technological know-how and its place within the broader social, economic, and environmental spheres.

For ceramic of the early Iron Age period in central Italy, these kinds of studies are generally limited in number. One of the few extensive investigations on ceramic production technology is based on

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finds from Osteria dell'Osa in *Latium Vetus* (Cuomo di Caprio 1992). This is probably also due to the relatively scarce evidence of pottery production areas for this period (see Biella et al. 2017; Bartoloni 2009), as archaeologists often only use direct evidence, such as production loci and debris, to study technology and organisation of production (Costin 1991). Especially, pottery from Etruria of this period has been investigated only sporadically with this approach (analyses by P. Pallecchi, reported by Cygielman and Pagnini 2002; Morandi, Porta, and Ribechini 2018; Amicone et al. 2020 and literature therein).

To address these issues, widely unexplored for this cultural and chronological context, we have adopted a technological approach to the study of vessels from one of the largest early Iron Age cemeteries of Vetulonia, namely Colle Baroncio (Morandi 2013; 2022).

Specifically, our study aims to obtain a first understanding of early Iron Age ceramic technology in this region, with an emphasis on exploring the different strategies of collection and manipulation of raw materials in one of the most important sites of northern Etruria. To achieve this, we applied ceramic petrography to forty vessels carefully selected after a macroscopic examination. The investigation was coupled with a survey and analysis of the raw materials around the site, aimed to identify potential clay and temper sources for pottery making. The interpretation of the results within their environmental and cultural context allowed us to explore for the first time the technological choices employed at Vetulonia during the early Iron Age and to define the geological characteristics of the potential raw materials used for pottery production at this site.

1.1. Archaeological background

Vetulonia (c. 330 m a.s.l.) lies on a small group of hills at the margins of the plain of Grosseto (southern Tuscany), once occupied by a shallow lagoon directly connected to the sea (Figure 1). At the turn of the Iron Age, the site emerged as an important proto-Etruscan centre of "Villanovan culture" (c. 925–720 BCE), which established a remarkable transmarine connection with Sardinia (Milletti 2012; Cygielman et al. 2015), and from the seventh to the third century BCE it flourished as one of the main Etruscan cities. It is therefore a site of great importance to advance our knowledge of early Iron Age ceramic production, and a first step towards a comprehensive study of Villanovan pottery.

There is no agreed meaning among the scholars as regards the use and validity of the term "Villanovan"; in this paper, it is simply employed to indicate the early Iron Age period in Etruria and the related material culture (for the Villanovan archaeological *facies* as a culture see Bietti Sestieri 2012 and de Marinis 2020; *contra* Peroni 1992). Villanovan sites were characterised by a widespread adoption of the cremation rite coupled with specific ceramic and metal objects, and were distributed over a vast territory extending from northern to southern Italy, overlapping with most of the future Etruscan-speaking areas (Figure 2(a)).

No dwelling zones are known for this period in Vetulonia, but extensive archaeological fieldwork during the nineteenth century brought to light several cemeteries on the hills all around the village, the largest of which, Poggio alla Guardia and Colle Baroncio, included up to more than a thousand burials (Figure 1). Typically, the graves consisted of circular pits filled with the ashes of the pyre and the cinerary urn covered by an upturned bowl (Figure 2(b)). Inside the urns the cremated remains of the deceased were placed, often along with a few grave goods.

Excavation reports are available for the eastern cemeteries (Falchi 1891), while the western necropolis of Colle Baroncio was privately dug by the landowners during the 1880s, so that no contextual information is available (Morandi 2013; 2022). Nonetheless, a wealth of finds from this cemetery – currently stored at the archaeological museum of Grosseto – provides precious material for a pioneering archaeometrical study of Villanovan pottery from Vetulonia.

1.2. Geological and palaeoenvironmental setting

The hills of Vetulonia lie at the western margin of the reclaimed plain of Grosseto, on non-metamorphic Tuscan units. The hilltop occupied by the ancient settlement and the slopes surrounding the site consists consist of a flysch formation composed by sandstone and siltstone (Formation 31: Macigno, Mt. Modino Sandstones), with the exception of Colle Baroncio, also partly consisting of shale, siltstone and limestone (Formation 27: Canetolo Clays and Limestones, Groppo del Vescovo Limestones) (Carmignani et al. 2004) (Figure 3). The area southeast of the site, now occupied by sediments forming the alluvial plain of the river Ombrone (Formation 1) (Gliozzo 2020, 2022), was home to marine and lagoonal environments throughout most of the Holocene, directly linked to the Tyrrhenian Sea (Colombi 2021). Around 2800 BCE, approximately the period of production of the artefacts analysed in this work, a change occurred from shallow brackish to shallow freshwater lagoon, and the situation was reversed again multiple times (Biserni and van Geel 2005). In the Roman Age, due to the development of the tombolo, the lagoon had become a lake separated from the sea (known as *Lacus Prilius* in ancient Roman sources),

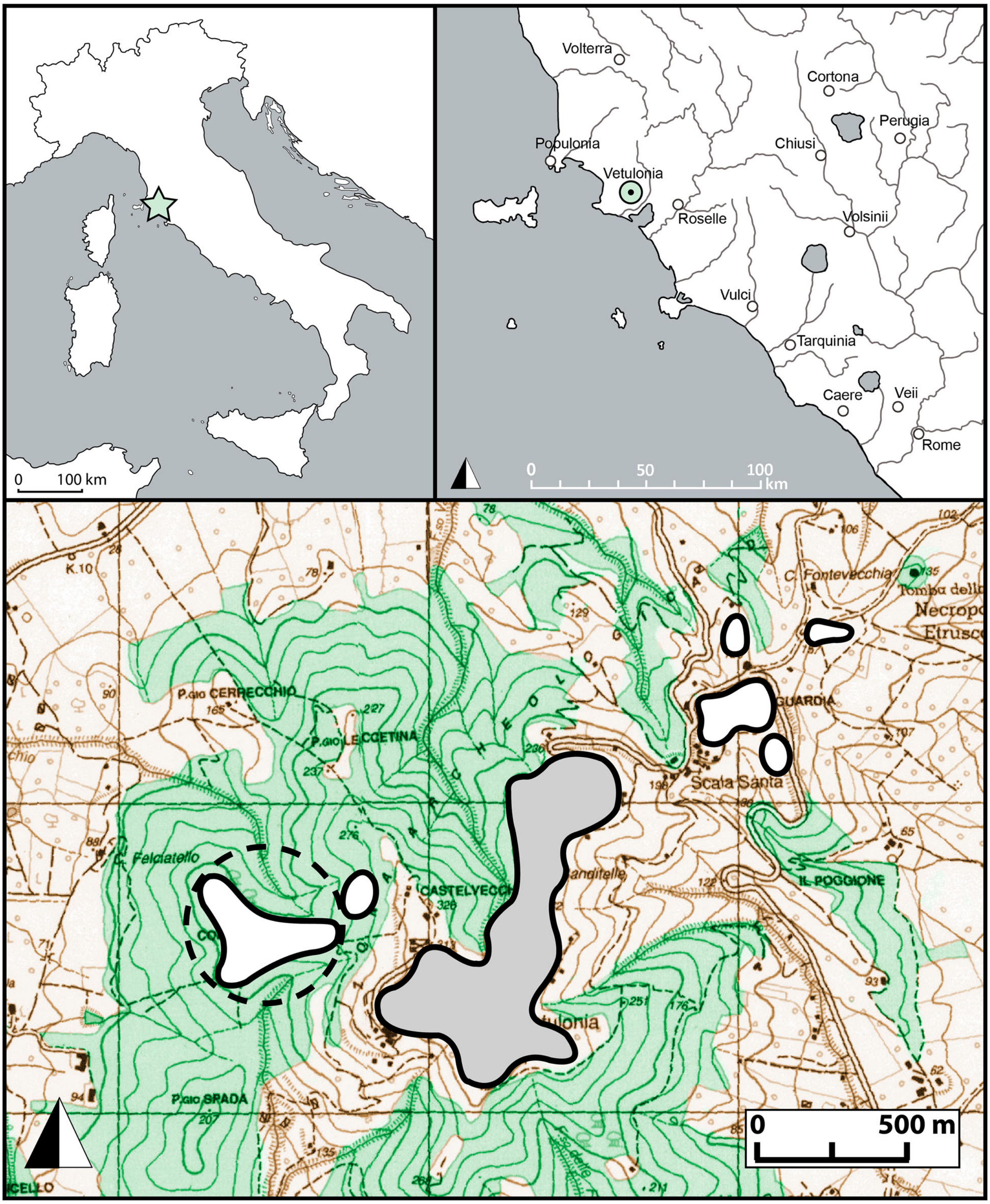

Figure 1. Map of Etruria showing the location of Vetulonia (the shoreline reflects the geo-morphological situation during the early 1st millennium BCE). Bottom image: grey = hypothetical settled area; white = early Iron Age cemeteries (Colle Baroncio encircled by the dashed line).

until the area was reclaimed in the eighteenth century (Barsanti and Rombai 1987; Morandi 2022). However, towards the coastal side of the plain of Grosseto, a natural reserve consisting of a small saltmarsh known as Diaccia Botrona survived the reclamation of the ancient basin, and is considered to be the last remnant of the ancient lagoon (Luti et al. 2000; Arnoldus-Huyzendveld 2007).

2. Materials and methods

2.1. Archaeological samples

After an accurate macroscopic observation, a total of 40 vessels were selected for petrographic analysis. In order to ensure representativity of the results, the majority of the samples were taken from ceramic types which were particularly frequent in the cemetery

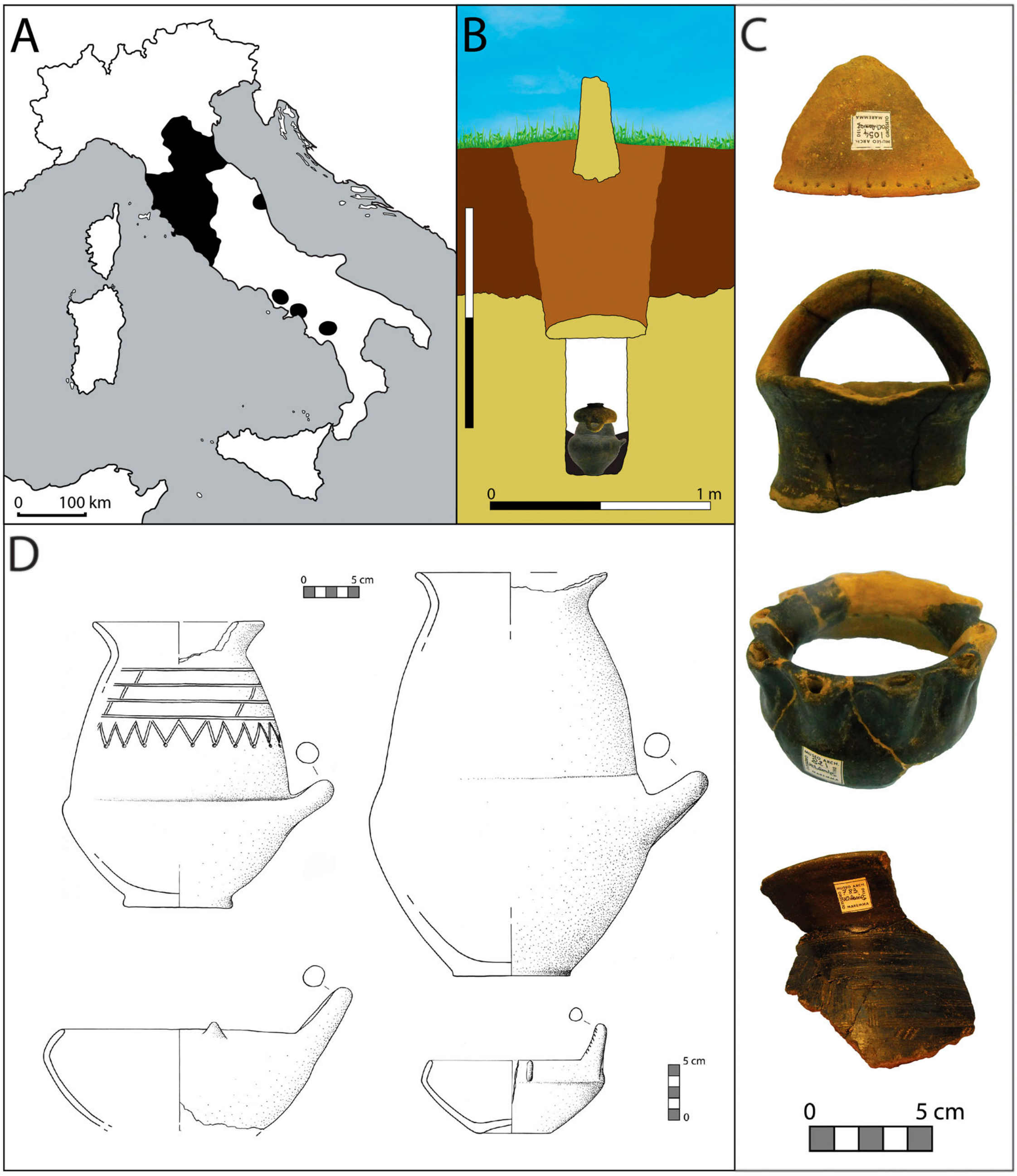

Figure 2. (A) Distribution of the Villanovan culture in the Italian peninsula (black areas). (B) Section of a typical early Iron Age grave of Vetulonia, based on the descriptions by Helbig (1885), Falchi and Pasqui (1885) and Falchi (1891). At Colle Baroncio, the burials were commonly marked by a vertical slab. (C) Photographs of pottery from the cemetery of Colle Baroncio. From top to bottom, the finds from which samples VT-CB 2, VT-CB 27, VT-CB 40 and VT-CB 3 were taken. (D) Examples of biconical urns and cover-bowls typical of Vetulonia. Clockwise from top left, the vessels used to take samples VT-CB 30, VT-CB 39, VT-CB 14 and VT-CB 18.

of Colle Baroncio (Morandi 2022) and are widely considered as markers of Villanovan culture, namely biconically-shaped cinerary urns and the bowls used to cover the mouth of the vase (Peroni 1992; Bietti Sestieri 2012). A number of finds were too fragmentary to determine the initial ceramic form, but rather larger and flat sherds were almost certainly fragmented walls of biconical urns. The remaining samples were chosen from vessels that stand out for particular reasons, e.g. rare shape, possible ritual function, unusual decoration (Table 1).

2.2. Geological samples

Geological samples were taken from specific locations of Vetulonia and from the surroundings of the settlement, where clay and tempering materials were likely to be collected by early Iron Age potters (Figures 3 and 4). Sediments were taken from a remnant of the ancient *Lacus Prilius*, now a lagoonal environment (Figure 4(a)), and from the riverbed or bank of three watercourses: river Ombrone (the largest river in the area of Grosseto) and the small streams running at the foot of the hills of Vetulonia (the stream Sovata, the stream Bruna, and

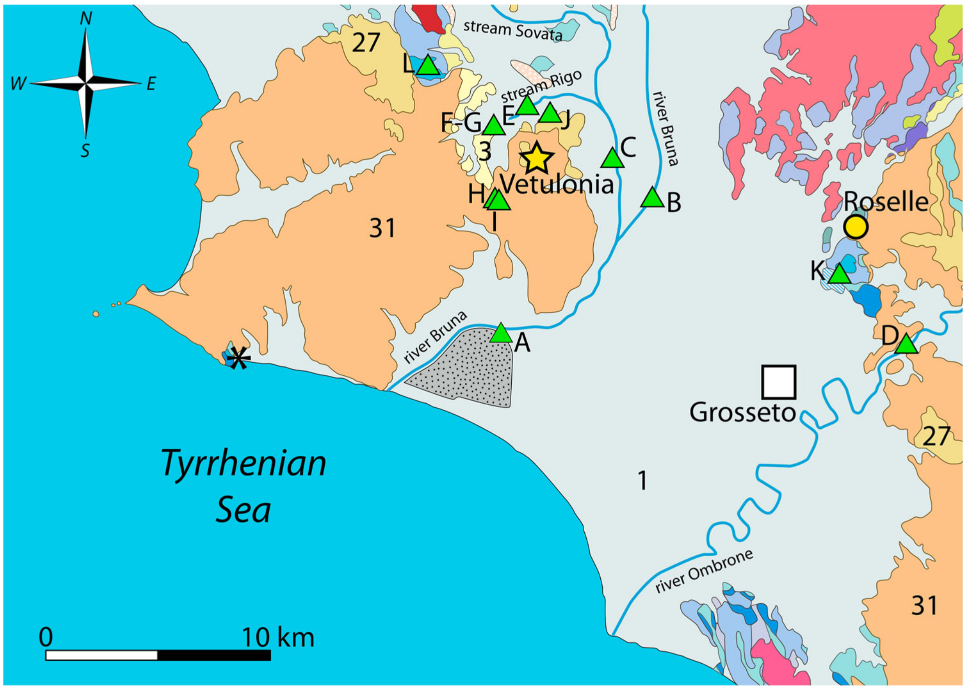

Figure 3. Geological map showing the main units in the territory around Vetulonia (numbers) and the location of the geological samples analysed in this study (letters). Formation 1: sands, pebbles and muds (alluvial, aeolian, lacustrine, palustrine, lagoonal, shore deposits) (Quaternary). Formation 3: conglomerates, sandstones, siltstones, clays and limestones of fluvio-lacustrine environment (Ruscinian-Villafranchian). Formation 27: shales, limestones and siltstones (Paleocene-Eocene). Formation 31: internal sandstone flysch: sandstones, siltstones with olistostromes (Chattian-Aquitanian). The colours used for all units refer to the official geological map of Tuscany (Carmignani et al. 2004). The dotted grey area marks the wetland of Diaccia Botrona, and the asterisk marks the formation with flint nodules south of Punta Ala. For the letters marking the geological samples collected for analysis, see Figure 4.

a tributary of the stream Rigo) (Figure 4(b–e)); the main course of this latter stream could not be sampled directly due to modern embankments. Other outcrops in the territory around the settlement and the former lagoon were also sampled (Figure 4(f–l)). These contained a variety of rocks and sandy clays.

2.3. Petrographic analysis

The archaeological samples and geological samples were then prepared as thin sections. A slice from the vertical cross-section of each sherd and rocks was cut, consolidated with epoxy resin and pasted over a glass slide and then ground to approximately 30 µm thickness. The thin sections for the petrographic analysis of the sandy clayey samples were prepared from briquettes obtained by mixing 20 g of clay with deionised water. These briquettes were fired in oxidising conditions in a furnace (Nabertherm P 300) at 700°C (2 h to reach the maximum temperature, 1 h at maximum temperature, 2 h of cooling).

All the thin sections were studied under a polarising microscope (Leica DM2500 P) to identify the compositional and technological characteristics of the materials under investigation (Whitbread 1989; Quinn 2013, 23–33). In addition, the effect of firing in reducing conditions on the colour of the pink flint collected during the survey (Figures 3 and 4(k, l)) was tested. The samples were topped by charcoal, placed in closed crucibles and fired in a furnace (Nabertherm P 300) at 800 °C (2 h to reach the maximum temperature, 1 h at maximum temperature, 2 h of cooling).

3. Results

3.1. Macroscopic inspection of archaeological vessels

The vessels' fabric is relatively soft, medium to coarse in texture, and marked by the presence of white/grey and more rarely black inclusions. Most of the pots show a dark grey surface (Figure 5(a)) and fabric colour which ranges from dark grey to orange, indicating firing under variable atmospheric conditions. The study of the macro-traces left by the potters indicates that the primary forming technique in Vetulonia was coiling. Macro-traces indicative of this technique include point of connections between adjacent coils (Figure 5(b)) and the presence of preferential fractures that follow the joints between the coils. Another typical feature indicative for coiling is the variable thickness of the walls of the pots (Roux 2017, 200–206). After being formed, the surface of the vessel was finished via

Table 1. Association between vessel morphology and ceramic fabric of the sampled sherds.

Sample	Vessel type	Fabric type	Inventory number	Reference	Notes on the vessel type
VT-CB 1	Biconical urn	B	2284	Morandi (2022), cat. no. 45	
VT-CB 2	Bell-helmet cover	C	1054	Morandi (2022), cat. no. 110	Symbolic function
VT-CB 3	Biconical urn	A	783	Morandi (2022), cat. no. 48	
VT-CB 4	Biconical urn	A	773		
VT-CB 5	Biconical urn	A	782		
VT-CB 6	Biconical urn	B	777		
VT-CB 7	Jar/Jug	A	822	Morandi (2022), cat. no. 101	
VT-CB 8	Biconical urn	B	826		
VT-CB 9	Jar	A	824	Morandi (2022), cat. no. 51	
VT-CB 10	Cup	A	814	Morandi (2022), cat. no. 105	
VT-CB 11	Biconical urn	B	827		
VT-CB 12	Biconical urn	A	799		
VT-CB 13	Biconical urn	A	775–823		
VT-CB 14	Bowl	A	813	Morandi (2022), cat. no. 53	
VT-CB 15	Bowl	A	802	Morandi (2022), cat. no. 76	
VT-CB 16	Biconical urn	A	776		
VT-CB 17	Biconical urn	A	786		
VT-CB 18	Bowl	A	803	Morandi (2022), cat. no. 62	
VT-CB 19	Jug/Jar	A	828	Morandi (2022), cat. no. 113	
VT-CB 20	Bell-helmet cover	B	1053	Morandi (2022), cat. no. 109	Symbolic function
VT-CB 21	Bowl	A	833		
VT-CB 22	Bowl	A	812	Morandi (2022), cat. no. 54	
VT-CB 23	Bowl	A	1316	Morandi (2022), cat. no. 88	
VT-CB 24	Biconical urn	B	3957		
VT-CB 25	Biconical urn	A	832		
VT-CB 26	Biconical urn	A	3938		
VT-CB 27	Situla	A	810	Morandi (2022), cat. no. 100	
VT-CB 28	Biconical urn	B	772	Morandi (2022), cat. no. 46	
VT-CB 29	Bowl	A	801	Morandi (2022), cat. no. 81	
VT-CB 30	Biconical urn	A	1313	Morandi (2022), cat. no. 36	Local type
VT-CB 31	Biconical urn	A	825	Morandi (2022), cat. no. 43	Local type
VT-CB 32	Jar/Jug	B	818	Morandi (2022), cat. no. 114	
VT-CB 33	Biconical urn	A	1327	Morandi (2022), cat. no. 50	
VT-CB 34	Biconical urn	A	785	Morandi (2022), cat. no. 40	
VT-CB 35	Biconical urn	A	784	Morandi (2022), cat. no. 49	
VT-CB 36	Cup	B	811	Morandi (2022), cat. no. 104	
VT-CB 37	Bowl	B	1318	Morandi (2022), cat. no. 58	
VT-CB 38	Biconical urn	A	5356	Morandi (2022), cat. no. 47	
VT-CB 39	Biconical urn	A	792	Morandi (2022), cat. no. 39	
VT-CB 40	Multi-spouted jug	A	821	Morandi (2022), cat. no. 99	Rare type, possible ritual use

smoothing and/or burnishing (Martineau 2010) (Figure 5(a)), though it has been observed in some cases that a slip could have been applied to the surface of the vessel.

3.2. Petrographic analysis of archaeological samples

Based on their composition, the samples were grouped into three distinct fabrics: pottery characterised by a non-tempered paste marked by metasedimentary rocks (A), a paste tempered with flint (B) and a paste rich in muscovite (C) (Table 2).

Fabric A (Figure 6(1–6)) is heterogeneous, polymodal and marked by the natural occurrence of fragments of metasedimentary rocks. Other inclusions observed are quartz, feldspars, clay pellets, opaques and more rarely mica. The matrix is non-calcareous, dark to light brown/orange with moderate optical activity. Voids are by the great majority planar and parallelly oriented to the edges of the sherds. Samples VT-CB 5, VT-CB 7 and VT-CB 30 show the presence of a distinctive slip layer applied to the surface of the vessel.

Fabric B (Figure 6(7–9)) is heterogeneous, bimodal and characterised by large and angular brownish/reddish flint fragments whose identification was also confirmed by micro XRD analysis (see Supplementary materials). Other inclusions observed are metasedimentary rocks, quartz, feldspars, clay pellets, opaques and more rarely mica. The matrix is non-calcareous, dark to light brown/orange with moderate optical activity. Voids are by the great majority planar and parallelly oriented to the edges of the sherds. Samples VT-CB 24 and VT-CB 28 show the presence of a distinctive slip layer applied to the surface of the vessel.

Fabric C (Figure 6(10–12)) is heterogeneous, bimodal and marked by abundant muscovite. Other inclusions observed are metasedimentary rocks, quartz, feldspars, clay pellets, opaques and more rarely biotite. The matrix is non-calcareous, dark to light brown/orange with moderate optical activity. Voids are by the great majority planar and parallelly oriented to the edges of the sherds.

3.3. Petrographic analysis of geological samples

The grain size of modern sediment samples collected from streambeds in the territory of Vetulonia ranged from fine to coarse sandy clay. In particular, the

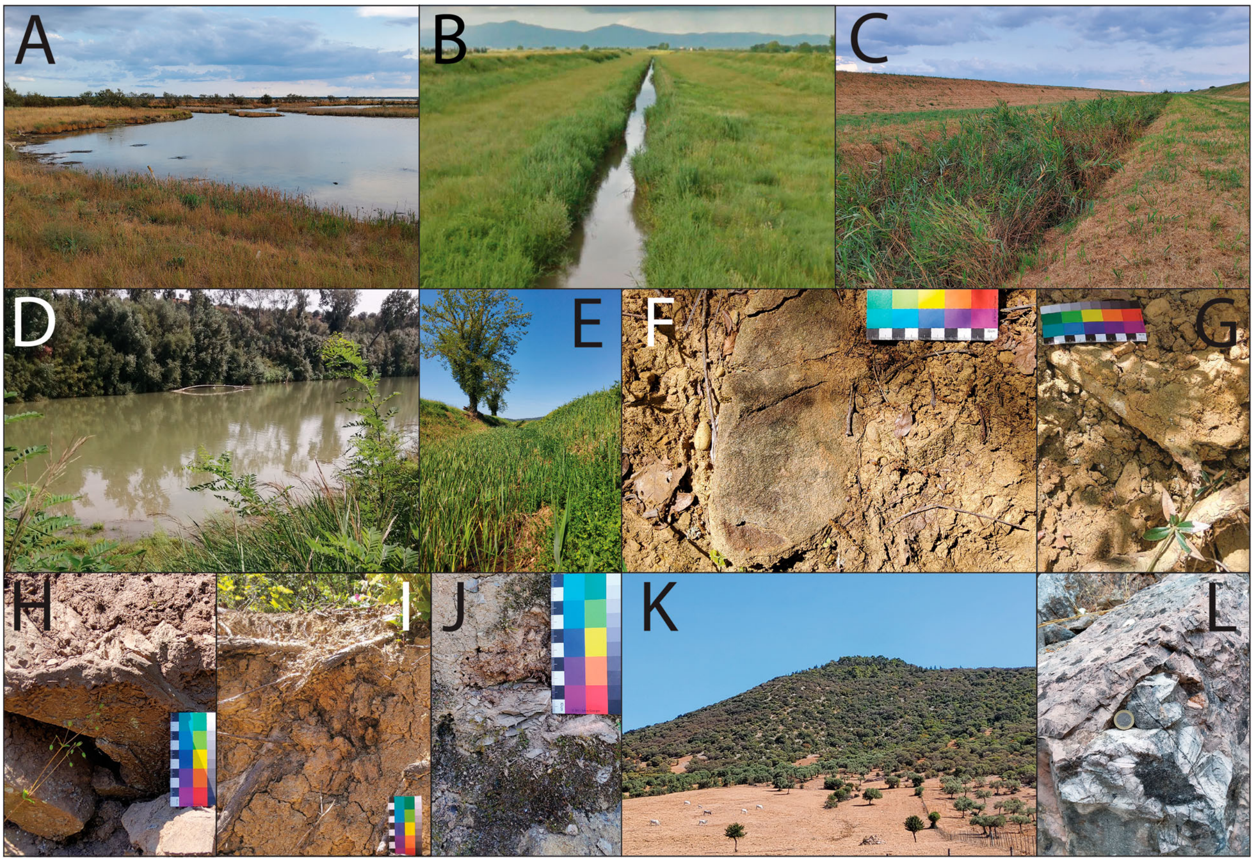

Figure 4. Location of the geological samples taken to produce comparative thin sections. A: Brackish wetland of Diaccia Botrona; B: River Bruna; C: River Sovata; D: River Ombrone; E: Tributary of stream Rigo; F: Sandstone from Formation 3; G: Clay from Formation 3; H: Sandstone from Formation 31; I: Clay from Formation 31; J: Claystone from Formation 27; K: Hill of Poggio Moscona containing flint nodules (Formation 33); L: Flint nodules from Poggio Paganella (Formation 33).

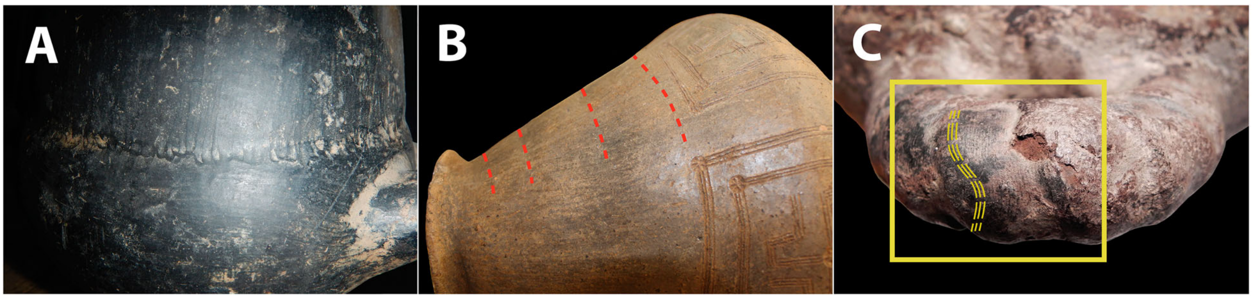

Figure 5. Colour, evidence for forming techniques and surface treatment of Villanovan vessels from Colle Baroncio. A: blackish/dark grey surface of pottery fired under reducing conditions; B: Coiling traces on a biconical urn; C: Parallel marks left by surface treatment on the handle of a biconical urn.

samples from river Ombrone (Figure 7(1–2)) are characterised by a fine sandy clay (min. 0.01 mm, max. 0.5 mm, av. 0.1 mm) dominated by quartz, with frequent plagioclase and opaques. Biotite, muscovite, chert and calcite are here common, while fragments of metasedimentary rocks are rare. The sediment from the stream Bruna (Figure 7(3)) is medium-coarse-grained, sandy clayey (min. 0.01 mm, max. 0.5 mm., av. 0.2 mm) and dominated by quartz, with frequent and often seriticised plagioclase. Muscovite and chert are frequent and few inclusions of sanidine and tiny fragments of metasedimentary rocks can also be observed. The sediment from the stream Sovata (Figure 7(4–5)) is a coarse sandy clay (min. 0.05 mm, max. 3.6 mm, av. 0.5 mm) dominated by fragments of metasedimentary rocks, with frequent fragments of sedimentary rocks. Plagioclase, chert, microcline and perthite are common to few, while sanidine, biotite and muscovite are rare. The sediment from a tributary of the stream Rigo (Figure 7(6)) is a medium-coarse sandy clay (min. 0.01 mm, max. 0.9 mm., av. 0.2 mm) dominated by quartz, with frequent and often seriticised plagioclase. Muscovite and chert are frequent, with sporadic inclusions of

Table 2. Characteristics of ceramic fabrics.

A – Fabric with metasedimentary rocks	VT-CB 3, VT-CB 4,VT-CB 5, VT-CB 7, VT-CB 9, VT-CB 10, VT-CB 12, VT-CB 13, VT-CB 14, VT-CB 15, VT-CB 16, VT-CB 17, VT-CB 18, VT-CB 19, VT-CB 21, VT-CB 22, VT-CB 23, VT-CB 25,VT-CB 26, VT-CB 27, VT-CB 29, VT-CB 30, VT-CB 31, VT-CB 33, VT-CB 34, VT-CB 35, VT-CB 38, VT-CB 39, VT-CB 40
Inclusions	40%, equant or elongate, angular, poorly/moderately sorted, randomly oriented, weakly bimodal
Coarse fraction	40–50%, moderately well sorted (min. 0.2 mm, max. 0.8 mm, average 0.5 mm)
Dominant	Quartz (sub-angular) (max. 0.75 mm, av. 0.3 mm)
Frequent	Fragments of metasedimentary rocks mostly composed of quartz and rarely muscovite (sub-angular) (max. 2.20 mm, av. 0.7 mm)
Common to few	Fragments of sedimentary rocks (sandstone, mudstones) (sub-angular) (max. 0.7 mm, av. 0.25 mm)
	Plagioclase (ang. to sub-angular) (max. 0.35 mm, av. 0.2 mm)
	Sanidine (ang. to sub-angular) (max. 1.00 mm, av. 0.3 mm)
	Microcline (ang. to sub-angular) (max. 0.6 mm, av. 0.2 mm)
	Perthite (ang. to sub-angular) (, max. 1.10 mm, av. 0.6 mm)
	Chert (sub-angular to sub-rounded) (max. 0.5 mm, av. 0.25 mm)
	Textural features: reddish clay pellets, marked frequently by quartz and feldspars
	Opaques (rounded to sub-angular) (max. 0.25 mm, av. 0.1 mm)
Rare	Muscovite (elongate) (max. 0.3 mm, av. 0.2 mm)
Fine fraction	50–60%, well sorted (min. 0.03 mm, max. 0.12 mm, av. 0.07 mm)
Predominant	Quartz (sub-angular) (max. 0.1 mm, av. 0.05 mm)
Rare	Muscovite (elongate) (max. 0.08 mm, av. 0.02 mm)
Matrix	50%, non-calcareous, dark to light brown/orange
Voids	10%, mostly planar (c. 0.1–0.2 mm), few vesicles (c. 0.1–0.2 mm)
B – Flint-tempered fabric	VT-CB 1, VT-CB 6, VT-CB 8, VT-CB 11, VT-CB 20, VT-CB 24, VT-CB 28, VT-CB 32, VT-CB 36, VT-CB 37
Inclusions	40%, equant or elongate, angular, moderately sorted, randomly oriented, bimodal
Coarse fraction	40–50%, moderately well sorted (min. 0.5 mm, max. 3.5 mm, av. 0.5 mm)
Dominant	Flint, 0.5–3.5 mm (sub-angular to elongate) (max. 4.0 mm, av. 2.5 mm)
Frequent	Quartz (sub-angular) (max. 1.1 mm, av. 0.6 mm)
	Fragments of metasedimentary rocks mostly composed of quartz and rarely muscovite (sub-angular) (max. 3.0 mm, av. 1.0–1.5 mm)
Common to few	Fragments of sedimentary rocks (sandstone, mudstones) (sub-angular) (max. 2.0 mm, av. 0.7 mm)
	Plagioclase (ang. to sub-angular) (max. 0.5 mm, av. 0.4 mm)
	Sanidine (ang. to sub-angular) (max. 0.6 mm, av. 0.3 mm)
	Microcline (ang. to sub-angular) (max. 0.8 mm, av. 0.4 mm)
	Perthite (ang. to sub-angular) (max. 0.8 mm, av. 0.5 mm)
	Chert (sub-angular to sub-rounded) (max. 1 mm, av. 0.4 mm)
	Textural features: reddish clay pellets, marked frequently by quartz and feldspars (max. 0.8 mm, av. 0.5 mm)
	Opaques (rounded to sub-angular) (max. 0.3 mm, av. 0.25 mm)
Rare	Muscovite (elongate) (max. 0.4 mm, av. 0.2)
Fine fraction	50–60%, moderately well sorted (min. 0.03 mm, max. 0.12 mm, av. 0.07 mm)
Predominant	Quartz (sub-angular) (av. 0.05–0.08 mm, max. 0.2 mm)
	Opaques (rounded to sub-angular) (max. 0.1 mm, av. 0.02 mm)
	Muscovite (elongate) (max. 0.12 mm, av. 0.05 mm)
Rare	Biotite (elongate) (max. 0.1 mm, av. 0.05 mm)
Matrix	50%, non-calcareous, dark to light brown/orange
Voids	10%, planar (c. 0.25–0.5 mm)
C – Muscovite-rich fabric	VT-CB 2
Inclusions	40%, equant or elongate, angular, moderately sorted, randomly oriented, bimodal
Coarse fraction	40–50%, moderately well sorted (min. 0.5 mm, max. 3.5 mm, av. 0.5 mm)
Dominant	Muscovite (elongate) (max. 2.5 mm, av. 0.5 mm)
Frequent	Quartz (sub-angular) (max. 0.4 mm, av. 0.2 mm)
	Fragments of metasedimentary rocks mostly composed of quartz and muscovite (sub-angular) (max. 3.5 mm, av. 0.7 mm)
Common	Fragments of sedimentary rocks (sub-angular): Sandstone (max. 1.2 mm, av. 0.6 mm) Mudstone (max. 1.5 mm, av. 0.3 mm)
	Plagioclase (ang. to sub-angular) (max. 0.5 mm, av. 0.25 mm)
	Sanidine (ang. to sub-angular) (max. 0.6 mm, av. 0.4 mm)
Few	Perthite (ang. to sub-angular) (max. 1.20 mm, av. 0.7 mm)
Rare	Biotite (ang. to sub-angular) (max. 0.2 mm, av. 0.08 mm)
	Amphibole (angular) (max. 0.2 mm)
Fine fraction	50–60%, moderately well sorted (min. 0.03 mm, max. 0.12 mm, av. 0.07 mm)
Predominant	Quartz (sub-angular) (max. 0.1 mm, av. 0.07 mm)
Rare	Muscovite (elongate) (max. 0.1 mm, av. 0.04 mm)
	Biotite (elongate) (max. 0.15, av. 0.05 mm)
	Opaques (rounded to sub-angular) (max. 0.05 mm, av. 0.04 mm)
Matrix	50% non-calcareous, dark to light brown/orange
Voids	10%, planar (c. 0.25–0.50 mm), vughs (c. 0.5–1 mm), vesicles (c. 0.5–1 mm)

sanidine and tiny fragments of metasedimentary rocks.

A sediment typical of a low-energy environment characterises the sample from the wetland of Diaccia Botrona (Figure 7(7)), consisting of a very fine sandy clay (min. 0.01 mm, max 0.2 mm, av. 0.02 mm) containing quartz and calcareous microfossils.

The sandstone and clay from Formation 3 and Formation 31 (Figure 7(8–11)) consist of metasedimentary rocks, quartz, plagioclase, perthite, microcline, biotite and muscovite, while feldspars are often seriticised. The same range of inclusions can be observed in the clay sample collected in this formation, probably deriving from the erosion of the sandstone.

A reddish cryptocrystalline flint with calcitic veins occurs at Poggio Paganella near Caldana (municipality of Gavorrano) and at Poggio Moscona next to Roselle (Formation 33) (Figure 7(12)). After firing in

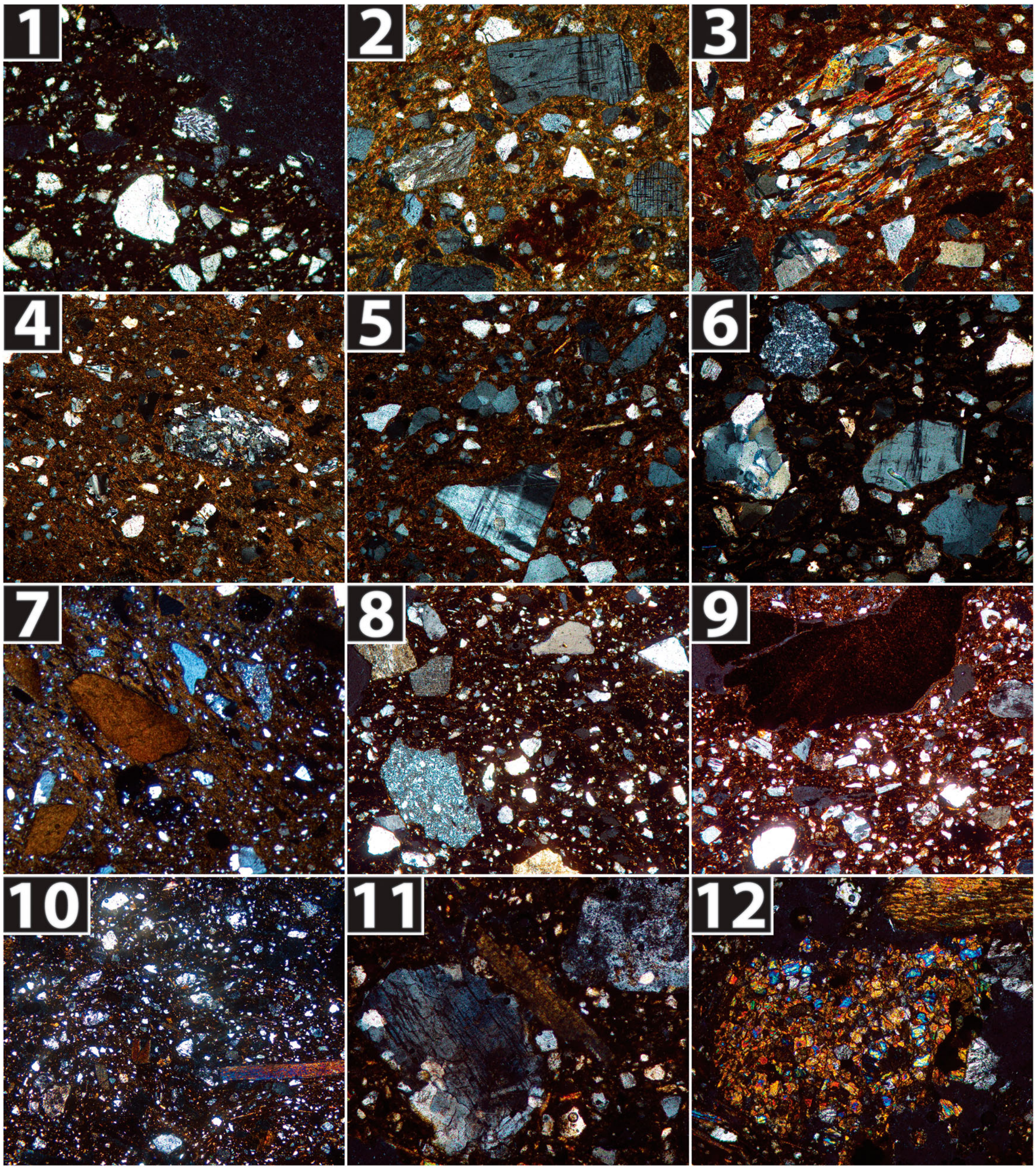

Figure 6. Thin-section photomicrographs of selected archaeological ceramic samples from the Villanovan cemetery of Colle Baroncio. Fabric A (non-tempered clay): 1. VT-CB 4; 2. VT-CB 5; 3. VT-CB 10; 4. VT-CB 14; 5. VT-CB 15; 6. VT-CB 31. Fabric B (clay tempered with flint): 7. VT-CB 8; C: 8. VT-CB 36; 9. VT-CB 37. Fabric C (clay tempered with metasedimentary rocks): 10. VT-CB 2; 11. VT-CB 2; 12. VT-CB 2. All pictures taken under XP; field of view: nos. 1–3, 5–6, 8–9, 11–12 = 1.5 mm; nos. 4 = 3 mm; nos. 7, 10 = 6 mm.

reducing conditions, the flint samples underwent a rather marked darkening (Figure 8).

4. Discussion

4.1. Selection of raw materials

The results of this study allowed us to explore different aspects of ceramic production at the site of Vetulonia, with a particular emphasis on how the potters navigated their landscape to select a variety of raw materials.

A non-tempered fabric characterises the majority of potsherds (Fabric A) and points to the use of a sandy clay rich in metasedimentary inclusions. The presence of inclusions of various sizes and heterogeneous compositions, compatible with the geology of the territory of inner southern Tuscany between the hills of the Crete Senesi and Mt. Amiata, suggests that these clasts naturally occurred in the clay deposits, as a result of fluvial erosion and transportation.

Nowadays, the area north of the ancient Lake Prile is cut by a few small watercourses (Bruna, Sovata, Rigo; Figure 3). Although their current path is the result of recent landscape modifications, they run through the same geological formations characterising the Holocene geology of the area, eroding and transporting the same rock and mineral components, so

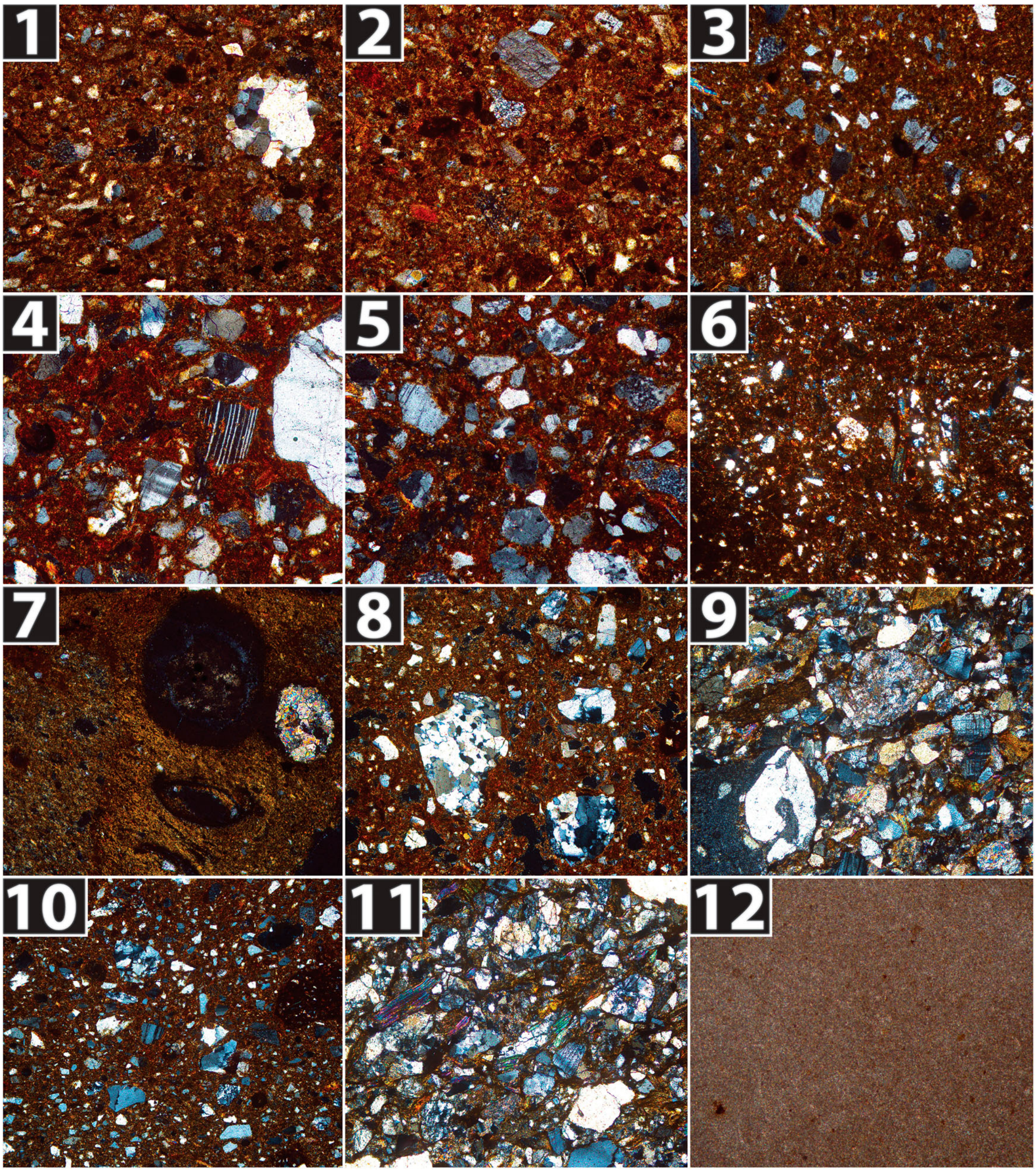

Figure 7. Thin-section photomicrographs of geological samples from the territory of Vetulonia. 1. Fine sediment fraction from River Ombrone; 2. Fine sediment fraction from River Ombrone; 3. Fine sediment fraction from River Bruna; 4. Fine sediment fraction from Stream Sovata; 5. Fine sediment fraction from Stream Sovata; 6. Fine sediment fraction from a tributary of stream Rigo; 7. Fine sediment fraction from the brackish wetland of Diaccia Botrona; 8. Clay from Formation 3; 9. Sedimentary rock from Formation 3; 10. Clay from Formation 31; 11. Sedimentary rock from Formation 31; 12. Flint from Formation 33 near Caldana. All pictures taken under XP; field of view: nos. 1–5, 7, 12 = 1.5 mm; nos. 6, 8–11 = 3 mm.

that they have been taken as analogues for early Iron Age clay sources. Among the geological samples collected from the above-mentioned water courses, the briquettes produced with clay from the banks of the stream Sovata indicate a very strong compositional similarity with the archaeological sherds of Fabric A, characterised by abundant angular inclusions of metasedimentary rocks (average size 0.5 mm). This stream runs north and east of Vetulonia, c. 1–3 km from the site, and also collects the water from another small stream (Rigo). This latter runs through sedimentary formations rich in clasts very similar to those identified in the ceramic materials. The secondary clays transported by the streams around Vetulonia may have been a convenient source of raw matter for early Iron Age potters, and very likely were used to produce all vessels characterised by Fabric A. On the other hand, we cannot completely rule out the possibility that residual sandy clays forming from the weathering of rocks within the sedimentary formation (e.g. Formations 3 and 31) may have also been used. However, given their coarser inclusions, they might have been less plastic in comparison to alluvial secondary clays. As regards the clay used to produce Fabric B and Fabric C, its petrographic characteristics suggest the use of a similar material as the one

Figure 8. Unfired flint (left) and flint subjected to firing in a reducing atmosphere (right). Scale bar = 4 cm.

employed for the production of Fabric A. However, the bimodal distribution of the inclusions observed in both fabrics is a strong indication for the addition of aplastic tempers within the ceramic paste, as it will be discussed in the following section. Finally, the clay collected from the residual wetlands in the area of the prehistoric marine gulf and later Lake Prile, bordering the area of the settlement between the 2nd and 1st Millennium BCE, is markedly different, showing only small quartz inclusions and an abundance of calcareous microfossils (Figure 7(7)). This composition, which never occurs among the archaeological potsherds analysed in this study, is typical of brackish/marine sedimentary environments, largely attested in the area throughout the Holocene (Biserni and van Geel 2005).

4.2. Tempering

A widespread adoption of flint tempering at Vetulonia, a procedure well documented in pottery making (see e.g. Mullin and Brown 2012; Thomas 2014), is clearly testified by several potsherds characterised by well-sorted angular flint inclusions (Fabric B). However, Vetulonia does not lie in close proximity to any geological formations with flint nodules (Carmignani et al. 2004). In the vicinity of the settlement, these only occur: in a small area c. 6 km northeast of the site (Poggio Paganella, Formation 33; Figure 3, point L); at Roselle (Poggio Moscona, Formation 33; Figure 3, point K), a settlement c. 15 km southeast of Vetulonia which flourished slightly later and controlled the western side of the former Lake Prile; in a very small area at the northernmost end of the Gulf of Grosseto, c. 17 km southwest of Vetulonia (Promontory of Punta Ala, Formation 33; Figure 3, asterisk). It is also worth mentioning that flint was virtually long out of use in cultures of the late Metal Age in the Italian peninsula (see e.g. Cocchi Genick 2009; Bietti Sestieri 2010).

Interestingly, the outcrop of Poggio Paganella lies in the immediate surroundings of the final Bronze Age-early Iron Age settlement of Scarlino (Bartoloni and Rossetti 1984). This village, connected to a series of production sites located along the coast (Aranguren et al. 2014), is known for the finding of a large ceramic workshop (Aranguren 2009). However, at least as regards reddish coarse ware jars, the production sites near Scarlino are characterised by the use of clasts deriving from the Gavorrano granite formations outcropping near Puntone di Scarlino, marked by a leucogranite facies with schorl tourmaline (Aranguren et al. 2014), while flint only occurs sporadically as natural inclusions in the sherds, suggesting a tempering tradition different from those documented in Vetulonia.

Further away, c. 30 km northwest of Vetulonia, flint outcrops occur inland from the Gulf of Follonica and the promontory of Piombino near Populonia, and become large and very common in northern Tuscany, around the area of Pisa. However, given the frequency of Fabric B and its occurrence in typically local ceramic types, an importation of pottery having this fabric from northern Tuscany must be ruled out. The natural occurrence of the flint in the clay used to make the vases should also be excluded, given the presence of large angular fragments which indicate a deliberate fragmentation.

The flint outcrops from Poggio Paganella and Poggio Moscona were sampled and analysed in thin section, to assess a possible correlation with the fragments observed in pottery. In their natural state, they are both characterised by a pinkish/grey type of flint, lighter in colour than the dark-greenish flint frequent in the archaeological sherds (Figures 6(7–9) and 7(12)). However, it is possible that the darker colouration of the flint fragments observed in pottery samples derived from firing ceramics in a reducing atmosphere up to c. 800 °C. Varying and not fully oxidising atmospheric conditions would be frequently met in open firings (bonfires, pit firings) or simple kilns (e.g. Amicone et al. 2021). Our experiments showed that firing under reducing conditions can indeed produce colour changes in this type of flint, which from pinkish/white became greyish/black, probably due to iron reduction or carbon black deposition (Figure 8).

If Villanovan pottery made in Vetulonia was tempered using flint from the nearest sources available according to the geological map, it should be assumed that Vetulonian potters were engaged in periodic visits to Poggio Paganella (which is however rather isolated and distant from strategic areas) or, more likely, to the southeastern limit of the Promontory of Punta Ala (c. 5 km form the northern edge of the ancient Lake Prile) or to Roselle (Poggio Moscona), to obtain suitable tempering material. This latter option suggests a possible collaboration between the two settlements during the earliest occupation of Roselle, finalised to an efficient exploitation of the natural resources of the territory. However, the existence of a route linking Vetulonia and Punta Ala, along which are the seventh to sixth centuries BCE sites of Val Berretta and Pian d'Alma (Cygielman 2002), further suggests the use of flint form the area of Punta Ala. Unless the material was transported to ceramic workshops located in Vetulonia, this hypothesis may also find some support in the decentralisation to which artisan workshops can be subjected in antiquity, which for practical (and sometimes even religious) purposes implies exclusion from the urban space (e.g. Goodman 2016).

As the abundant sandstone from the hill of the settlement can serve the same purpose as flint tempering (see below, Fabric C), the deliberate addition of flint sourced from a few kilometres is highly significant. Urns and cover-bowls show both Fabric A and Fabric B (Table 1), therefore, in the absence of any vessel type/fabric type relationships, the occurrence of flint tempering points to the existence of an established ceramic tradition, which did not follow the same procedure used to produce Fabric A pottery. This tradition probably reflects the activity of a different production unit using flint as tempering material, responsible for the diffusion of Fabric B.

Fabric C, characterised by abundant muscovite inclusions (probably tempered with local sandstone), matches well with the local geology of the settlement and shows the use of sedimentary rocks, such as the sandstone found in Formations 3 and 31, as tempering agents. This choice, however, within our (albeit limited) sample set only occurs once, probably because natural clay deposits exploited by local potters were already sufficiently rich in natural inclusions to guarantee improved mechanical and thermal properties (Müller 2017).

4.3. Forming, finishing and firing

This study has also produced new evidence on the manufacturing methods used by Villanovan potters. Provided that there may have been significant inter-site differences within the Villanovan milieu (ranging from the Po Valley to the Campanian region), macroscopic examination of intact vessels and sherds from Colle Baroncio has allowed identification of coiling, as evidenced by regular thinning of the walls, marking the coil joints. The coils are c. 3–5 cm wide and were observed on biconical urns (Figure 5(b)).

As regards surface treatments, in addition to common polishing marks of Villanovan *impasto* (coarse ware pottery), the application of clay slips has been observed on a few samples (VT-CB 5, VT-CB 7, VT-CB 24, VT-CB 28b, VT-CB 30) pertaining to both Fabric A and B. Further mineralogical and chemical analysis will be important in defining the nature of this slip and its technological characteristics.

Moreover, peculiar traces were observed on a biconical urn which was not sampled for thin-section examination. The vessel, coated with birch bark tar over a large portion (Morandi, Porta, and Ribechini 2018; Morandi 2022), shows the presence of parallel and curved thin lines, c. 1 mm apart, especially evident on the vase handle (Figure 5(c)). The pattern is visible on the ceramic surface underneath the tar, in spots where the coating has come off. The absence of a grid-like pattern seems to rule out the possibility of a textile impression (M. Gleba, pers. comm.). It is not easy to determine which type of tool or material may have left these parallel traces, which might be the result of a surface preparation prior to the application of the birch bark tar.

Considering the softness of the paste and the high variability in the colour of the vessels when observed both macroscopically and in thin sections and the high optical activity of the matrix, the potsherds analysed may have been fired under variable conditions at a relative low temperature. For this period there is a general lack of information for ceramic pyrotechnological installations used in Etruria, except for the context of Veio Campetti, where a horizontal draft kiln was found (Boitani, Neri, and Biagi 2009; 2017). This is not surprising, given the paucity of systematically excavated settlements for this chronological period. In addition, this kiln type is a very simple structure, and might not result in any immediate, clearly recognisable archaeological evidence.

In any case, a firing procedure marked by lower temperatures and uncontrolled atmospheric conditions could have been achieved using both an open fire or a relatively simple kiln such as the one discovered in Veio Campetti, where a direct contact between the flames and the vessels occurs, making it quite challenging to distinguish between fully reducing and oxidising conditions.

5. Conclusions

By analysing forty vessels from a major cremation cemetery, this study has provided comprehensive archaeometric data on early Iron Age pottery from a Villanovan site of Etruria. Three types of ceramic fabrics, dominated respectively by fragments of metasedimentary rocks, flint and muscovite have been identified, and no correlations occur between vessel shape and fabric type. Petrographic analysis of experimental briquettes produced using raw materials collected in the territory of Vetulonia have shown that the compositional characteristics of clay sources around the site are compatible with the mineralogical features of several potsherds analysed. However, the most unexpected and interesting result concerns the widespread use of flint fragments as tempering agents in archaeological potsherds (Fabric B), in spite of the absence of this rock in the settlement area, which therefore must have been sourced from at least c. 5–15 km, where the closest flint outcrops occur (from the area of Roselle, Punta Ala or from the area of Poggio Paganella near Caldana), and in spite of the high local availability of another equally functional tempering material (sandstone). The reasons for this technological choice are not clear, but it is likely that in the early Iron Age potters from Vetulonia had access either to the small formation with flint nodules located southeast of Punta Ala, which was also a possible location for an ancient docking place near the margins of Lake Prile (Cygielman 2002), or to the sources of raw matter in the territory of Roselle, which was settled only during the second phase of the early Iron Age and did not become a competitor of Vetulonia until the archaic and classical phases (Luti et al. 2000; Cygielman 2002).

It is difficult to infer general statements on Villanovan pottery technology from this single context. Nevertheless, it is noteworthy to notice the presence of different traditions of selection and processing of raw materials, which may suggest the co-existence of different communities of practice at Vetulonia (Lave 1991; Squires and Van De Vanter 2012). The discovery of Villanovan reddish coarse ware in the island of Tavolara (Sardinia) already showed the presence of a variety of pastes that may be related to different production centres in Etruria (Amicone et al. 2020; Di Gennaro et al. 2023). These are definitely the outcome of an interplay between ecological constraints and cultural choices dictated by consolidated manufacturing traditions, and further analyses on other contexts from Vetulonia and from the rest of Etruria will allow us to gain an improved understanding of this complex picture.

Establishing the main compositional features of early Iron Age pottery from Colle Baroncio at Vetulonia, this work marks a first step towards the archaeometric characterisation of ceramics from all the main Villanovan sites of Etruria, an endeavour which has the potential to advance our knowledge of pottery circulation and technology transfer not only within the Italian peninsula but also between Etruria, Sardinia and other Mediterranean regions.

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Authors' contributions

L. F. M. conceptualised the whole article, devised the methodology, conducted a formal analysis, investigated the data, wrote the original draft, reviewed and edited the first and final draft, and visualised the article. S. A. conceptualised the whole article, devised the methodology, supervised the formal analysis, investigated the data, reviewed and edited the first and final draft, visualised the data; administered the project, brought the resources, conducted funding acquisition.

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