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Skilled people or specialists? Knowledge and expertise in copper age vessels from central Italy

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ABSTRACT

Studying craft specialisation in archaeology involves investigating and reconstructing how production was organised. This article focuses on prehistoric communities and asks who performed specific tasks. Ceramic specialisation is traditionally approached through models of production organisation that are largely based on ethnoarchaeological case studies and are usually difficult to link with the archaeological evidence. Based on these models, the economic framework plays a key role in associating the emergence of specialisation with the intensification of the demand for goods and identifying specialists by the amount of time required for production. This approach neglects the social value of products and the social context sustaining skills development. This article discusses surface treatments as a means to understand the skills of potters and the social values of specific ceramic products in Copper Age communities from central Italy. The methodology combines the analysis of technological traces and experimental archaeology used to infer craftspeople's expertise and reveals differences in the *chaîne opératoire* and skills involved in the production of domestic and funerary vessels. The results support a hypothesis of *household specialisation* that developed in these communities based upon differences in skills, knowledge and dedication among potters and the recurrent association of skilled productions with ritual contexts.

1. Introduction

A wide body of literature in archaeology and anthropology discusses the concept of craft specialisation. This topic is important because it contributes to understanding the development of social inequality in human groups in terms of the emergence of figures capable of performing novel tasks, reconstructing the economy of ancient societies and characterising human skills and their associated knowledge.

Pottery production has always been strongly connected to social life, such as in the processing and sharing of food or ritual and funerary celebrations. Beyond its use, pottery can reveal social aspects of everyday life through its technology, understood as how vessels were produced. A *chaîne opératoire*-based approach (Lemonnier, 1993; Dobres and Hoffman, 1994; Dobres, 2000; Roux, 2016) allows us to focus on every step of one or more vessels' production sequence, beginning with raw material sourcing and proceeding to firing or post-firing treatments. Although the growing application of scientific analyses has allowed us to characterise craft production in terms of the producers' social organisation, few studies have focused on the production sequence in terms of performance (Budden, 2008; Michelaki, 2008; Budden and Sofaer, 2009; Sofaer, 2015; Kuijpers, 2017; Thomas, 2011). The application of a cognitive approach to the social aspects surrounding pottery production involves primarily ethnoarchaeological contexts (Roux and Corbetta, 1989; Roux, 1990; Wallaert-Pêtre, 1998, 1999, 2001; Crown, 2014). This approach suggests that focusing on performance as a growing interaction between the transmission of knowledge and the development of manual practice plays a key role in understanding the artisans' behaviour and their actual expertise (Sennett, 2008; Minar and Crown, 2001).

Studying craft specialisation in archaeology means investigating and reconstructing how production is organised (Van der Leeuw, 1977; Peacock, 1981; Arnold, 1985). Every craft activity, independent of its complexity, is an entangled system of production, distribution and consumption. Production leads to the transformation of raw materials into objects that can be used by the producer or by other people inside or outside the community. In this system, modes of production, distribution and consumption have pivotal roles in our understanding of craftspeople. Researchers have discussed artisanal identities and the emergence of specialised labour for many years, but the debate continues. Although the importance of specialists for the development of complex societies is accepted (Tosi, 1984), no consensus currently exists concerning how these specific figures arose (Rosen, 1997; Flad and Hruby, 2008; David and Kramer, 2001; Spielmann, 2002). This discordance is primarily due not only to the theoretical backgrounds and

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methodologies of investigation but also to the effective difficulty of tying models of production organisation to archaeological case studies, particularly to studies of prehistoric periods (Rice, 1981).

Models describing the variety of craft specialisation focus on modes of production, understood as how the transformation of raw material into a final object is organised. Based on an evolutionary view of growing complexity, stages of craft production begin with production for oneself in a household environment and develop through intermediate stages to the modern system of large-scale industry (Van der Leeuw, 1977; Peacock, 1981; Costin, 1991; David and Kramer, 2001; Costin and Hagstrum, 1995). The first two theoretical modes of production, *household production* and *household industry* (Van der Leeuw, 1977), are used to describe the organisation of production in prehistoric contexts.

Although these modes define the main features that would have characterised prehistoric productions and suggest variables for investigating household systems, they do not consider equally important aspects such as the skills and expertise usually developed in a specific community of practice (Wenger, 1998; Minar and Crown, 2001) or the social value of some craft products (Appadurai, 1988; Spielmann, 2002), both of which are undeniably important for shaping the craftsperson's social identity in a community (Michelaki, 2008). Their decoding in an archaeological context allows to establish the existing technological levels that supported the role of craftspeople and to ask whether we should think in terms of economy, skills or both to enrich the meaning of the concept of specialisation (Flad and Hruby, 2008).

Beyond the scalar model, which largely derives parameters of production organisation from ethnoarchaeological studies, other approaches have focused on archaeological materials to reveal a variety of knowledge and skills attributable to different technological levels. Such approaches have focused primarily on the effects of specialisation on ceramic production. The standardisation of materials or products and behaviours has usually been considered the most recognised effect of craft specialisation (Rice, 1981, 1987; Roux, 1989, 1990, 1999; Gandon et al., 2014). However, an enrichment of the meaning of craft specialisation in prehistoric communities could benefit from the analysis of the emerging identities of potters who were socially recognised for their skills. In this case, the perception of differences among social identities is not based on the standardisation of their production but is due to their knowledge and practical ability, which was not widely shared in a community. According to studies focused on the technological features of ceramic assemblages, multiple levels of skill in prehistoric communities can be identified in archaeological contexts through a detailed analysis of production sequences (Michelaki, 2008; Forte, 2014). This methodology reveals the presence of multiple levels of technical ability and the difference between technological choices widely shared by the majority of the people in a group and a more restricted number of specific production sequences applied solely by the most skilled individuals of the analysed group (Michelaki, 2008). This approach strengthens the idea that skill in ancient pottery production was an ability developed over time and supported by a specific social context. In cognitive studies focusing on learning processes and psychomotor skills, scholars have shown that underlying any production is a sequence of gestures that can be decoded and associated with specific learning stages. If a repetition of a technical behaviour fits well with the concept of gesture standardisation, this behaviour is not usually recognised as specialised when it is identified in a *household* context but rather is considered an expression of skilful people based on a division of *labour*. Cognitive studies in the ethnoarchaeological field suggest that some implements or activities, more than others, should be considered difficult for untrained people to properly reproduce; such implements or activities require prolonged and intensive apprenticeships (Roux, 1989, 1990; Roux and Corbetta, 1989; Crown, 2014). The ethnoarchaeological literature widely supports this view, with several case studies in American (Arnold, 1989; Crown, 2014), African (Balfet, 1965; Gosselain, 1992; Gosselain and Stark, 1998) and Indian (Roux, 1989) contexts of learning systems and skills development. These case studies highlight how the expertise developed by artisans is a mix of inherited knowledge and a knowledge built by experience (Wallaert-Pêtre, 2001; Crown, 2014) in a supportive social environment (*sensu* Wenger). Such expertise is expressed in the execution of the correct sequence of steps and the ease of gesture reproduction and the capacity to rectify as well as recognise the properties of the raw material and work on it using the most effective approach (Bleed, 2008; Sennett, 2008; Kuijpers, 2017). Although children naturally increase the cognitive and motor skills that enable them to produce balanced gestures (Piaget, 1972; Crown, 2014) and symmetric objects in hand-made works, Crown (2014:72) suggests that "*crafting pots takes more than growing older; it requires repeated practice to attain skills*", such as the dedication to a specific activity and the time to work on a task. Therefore, it is not casual repetition that is required but rather an intentional focus on the manufacturing sequence of production devoted to the creation of an object that is both functional and well-refined and perceived as a "socially valued good" (Spielmann, 2002). According to Spielmann (2002), in archaeological and ethnographic small-scale societies, economic demand is due to the need for "socially valued goods", including food for feasting and a large variety of intentionally refined objects for ritual occasions. The economic demand from the community is not based on a quantity of the goods but the quality of attractive objects involved in social occasions (Spielmann, 2002). Such a scenario suggests that the quality of some ceramic objects, according to the raw material used, the choices of production and the actual use, needs to be reviewed from a more social perspective in which the vessel has social value and the activity of "making a pot" "*is not exactly the same as being a potter*" (Michelaki, 2008:355).

Based on these premises, this article discuss a specific aspect of pottery production in the Copper Age communities of the current Rome area, focusing on the expertise of craftspeople and patterns of skilled behaviours underlying the application of burnishing, a specific surface treatment that was regularly applied on ceramic vessels destined for domestic activities and funerary celebrations.

This contribution aims to improve our understanding of the concept of specialisation in ceramic production by reflecting on what may have usually occurred in prehistoric communities before this activity became full time. Focusing on a traceological analysis of the ceramic assemblages supported by a dedicated experimental framework, a scenario of multiple levels of expertise and a relationship between some skilled productions and their use in ritual occasions emerges. This examination leads us to think about the social context supporting the emergence of highly skilled figures as a consequence of a *household specialisation* system that characterised some contexts that usually fall into the more generic *household production*.

2. Materials and methods

2.1. The copper age pottery from the area of modern Rome (central Italy)

In recent years, several excavations (Anzidei et al., 2011a, 2011b, 2007, 2008, 2012; Carboni and Anzidei, 2013) have documented a significant occupation of the suburban territory of Rome by a number of Copper Age communities dated to the 4th and the 3rd millennium BC. The evidence of settlements, necropolises and material culture confirms

Fig. 1. Locations of Copper Age contexts (4th–3rd millennia BC) of the Rome area involved in the research: 1. Casetta Mistici; 2. Osteria del Curato-Via Cinquefrondi; 3. Tor Pagnotta; 4. Torre della Chiesaccia (Necropolis); 5. Torre della Chiesaccia (Settlement); 6. Ponte delle Sette Miglia; 7. Romanina; 8. Valle dei Morti.

the presence of distinct and, in some cases, coeval communities that succeeded in this area during the entire Copper Age. Although the radiocarbon dating of settlements has proven the occupation of this area in approximately the middle of the 4th millennium BC (Anzidei et al., 2011a, 2011b), the more ancient presence of Copper Age communities is documented by several funerary contexts dated to the first half of the 4th millennium BC (Anzidei et al., 2012). A technological study focusing on ceramic production from the settlements of Osteria del Curato-Via Cinquefrondi, Casetta Mistici, Tor Pagnotta, and Torre della Chiesaccia Valle dei Morti and the necropolises of Romanina, Ponte delle Sette Miglia and Torre della Chiesaccia (Fig. 1, Table 1) highlighted the presence of technological choices of production that were intentionally transmitted over time and several technological levels reflecting differences in the skills and knowledge of craftspeople.

The pottery assemblage dated to the late 4th millennium BC (3330–2900) in the settlements of Casetta Mistici and Tor Pagnotta shows homogeneous characteristics in the shapes' morphology with novel stylistic elements compared to the previous ceramic productions of this area (Anzidei et al., 2011a; Forte, 2014) (Fig. 2). The pottery used in domestic environments by these communities included open vessels with a flat base (e.g., cooking pots or storage vessels), narrow-neck vessels (jugs) and a number of cups (see Fig. 2) (Anzidei et al., 2011a, 2011b). The vessels used as grave goods in the coeval Torre della Chiesaccia's necropolis include a large number of shapes associated with liquid contents, such as jugs and cups, followed by characteristic narrow-neck vessels named "*askoi*" that are usually rare in settlement assemblages, where they are represented only by isolated fragments (Anzidei et al., 2011a) (Fig. 2). These communities transmitted within their ceramic tradition the use of a local clay paste characterised by volcanic rock fragments and grog in a semi-fine granulometry followed by a lower incidence of local clay with sedimentary rock fragments (Forte, 2014; Forte and Medeghini, 2017). Flat-base open vessels, such as cooking pots, were modelled by the superimposition of slabs, and cups exhibit features suggesting the use of slabs or, in some cases, moulds employed to obtain the typical rounded base that was then completed with slabs to form the upper part of the vessel. The most complex shape morphologies of this period, jugs and *askoi*, lead to hypothesise in regard to vessel modelling the use of slabs and moulds, not excluding the use of beating as an additional technique to reinforce walls and favouring the symmetry of the vessel (Table 2) (Forte, 2014). Regarding the firing of the pots, the vessels were fired mainly in mixed or reducing atmospheres.

These shape morphologies and technological choices clearly change during the 3rd millennium BC. The settlement's production is based on the exploitation of local clays characterised by variations in granulometry. Indeed, household shapes such as open vessels with a flat base (e.g., cooking pots, cups) modelled by slabs or, in smaller shapes, by coils were made of clays with volcanic rock fragments or by recipes with sedimentary fragments in both coarse and semi-fine granulometry (Table 2). In this tradition, the use of a fine clay paste with sedimentary rock fragments increased for modelling smaller vessel shapes, such as bowls, often decorated with engraved motifs, which were replaced with impressed and dragged comb motifs during the late 3rd millennium BC (Forte and Medeghini, 2017; Forte, 2014) (Fig. 2). This choice characterised the domestic pottery production of Casetta Mistici, Torre della Chiesaccia, Tor Pagnotta, Osteria del Curato-Via Cinquefrondi and Valle dei Morti until the end of the millennium (2650–2130) (Fig. 2) (Carboni and Anzidei, 2013). Moreover, the use of local clay paste with fine sedimentary fragments for modelling smaller domestic shapes, such as bowls, increased as well in this period (Forte, 2014; Forte and

Table 1
Chronology and function of the archaeological contexts involved in the research.

Site	Casetta Mistici	Tor Pagnotta	Osteria del Curato Via Cinquefrondi	Torre della Chiesaccia	Valle dei Morti	Torre della Chiesaccia	Romanina	Ponte delle Sette Miglia
Function	Settlement	Settlement	Settlement	Settlement	Settlement	Necropolis	Necropolis	Necropolis
Period	Late half 4th millennium-Late 3rd millennium BC	Late half 4th millennium	Early 3rd millennium-Late 3rd millennium BC	Middle 3rd millennium BC	Middle/Late 3rd millennium BC	4th-3rd millennium BC	4th-3rd millennium BC	4th-3rd millennium BC
Date	3330–2131	3090–2870	2760–2450	2580–2515	2490–2350	3030–2910	3640–2030	3510–2030

Medeghini, 2017). During the entire 3rd millennium BC, domestic vessels were fired in oxidising or mixed atmospheres, with exceptions made for fine-grained bowls produced during the late period of the millennium and fired mainly in reducing atmospheres.

The necropolises of Romanina and Ponte delle Sette Miglia have not provided, since the 4th millennium BC, ceramic vessels compatible in shape and technology to the settlement productions described above (Fig. 2). The Copper Age pottery used as grave goods is characteristic and is composed of narrow-neck vessels (flasks), bowls and biconical vessels made of local clay with sedimentary fragments in a fine (or, rarely, semifine) granulometry (Anzidei et al., 2008, 2011a, 2011b, 2012; Forte, 2014; Forte and Medeghini, 2017). The techniques used for modelling these shapes varies and includes moulds and the overlapping of slabs in case of flasks as well as additional beating techniques for strengthening the walls and obtaining symmetry. Moreover, a combination of moulds and slabs or solely overlapping slabs was used in the production of smaller vessel shapes, such as round-based carinated bowls and round-based or flat-based carinated vessels (Table 2). These shapes were intentionally fired in reducing atmospheres (Forte, 2014).

The location, chronology and presence of rare fragments of this kind of pottery in settlements populated during the 3rd millennium BC, such as the site of Osteria del Curato-Via Cinquefrondi (Anzidei et al., 2012), have led researchers to consider these ceramics, commonly described as part of distinct traditions, as a selected production of coeval communities and most likely devoted to rituals (Anzidei et al., 2012, p. 210). These vessels, which were not necessarily associated with single buried people, could have had high symbolic value as objects mainly used in funerary ceremonies and ritual occasions (Miari, 1994). This hypothesis could also be supported by the lack of settlements in this area (Anzidei et al., 2012).

Beyond technological choices of production, including the intentional transmission of clay recipes and their association with specific shapes and modelling techniques, ability and accuracy in modelling and surface refining characterises some domestic vessels, regardless of their shape, and the majority of pottery found in burials. The latter show a high degree of accuracy in surface treatment, as suggested by the frequent application of burnishing techniques and intentional reducing firing atmospheres. As mentioned above, burnishing was used as a refining technique in domestic production to strengthen the product, but in this latter case, it is possible to observe a higher degree of variety in traces associated with this treatment, often occurring with surface anomalies caused by the building techniques, which were not adequately homogenised before the final finishing treatment.

The preservation of ceramic materials and a preliminary study of the technological choices of production makes these contexts a good case study to analyse craft aspects and forms of specialisation in Copper Age ceramics. Considering the treatment of burnishing as a technique commonly used in the selected contexts, shared in communities and transmitted over time, this article focuses on the artisans' expertise in burnishing application based on the actual use of domestic and funerary pottery production. The wide use of this treatment is documented in both types of contexts in the Rome area and is presented here not only as a production choice transmitted in association with specific vessel shapes but also as a means to measure a craftsperson's expertise and dedication in producing vessels with social value shared by the community.

2.2. Methodology

The development of skill in modelling vessels requires repetition over time to achieve higher levels of ability in managing clay pastes and working them to obtain complex vessel shapes while properly managing wall thickness and the vessels' size. The ability and degree of accuracy in the refining steps are closely related to the repetition of intentional gestures and time dedication. Their characterisation in a

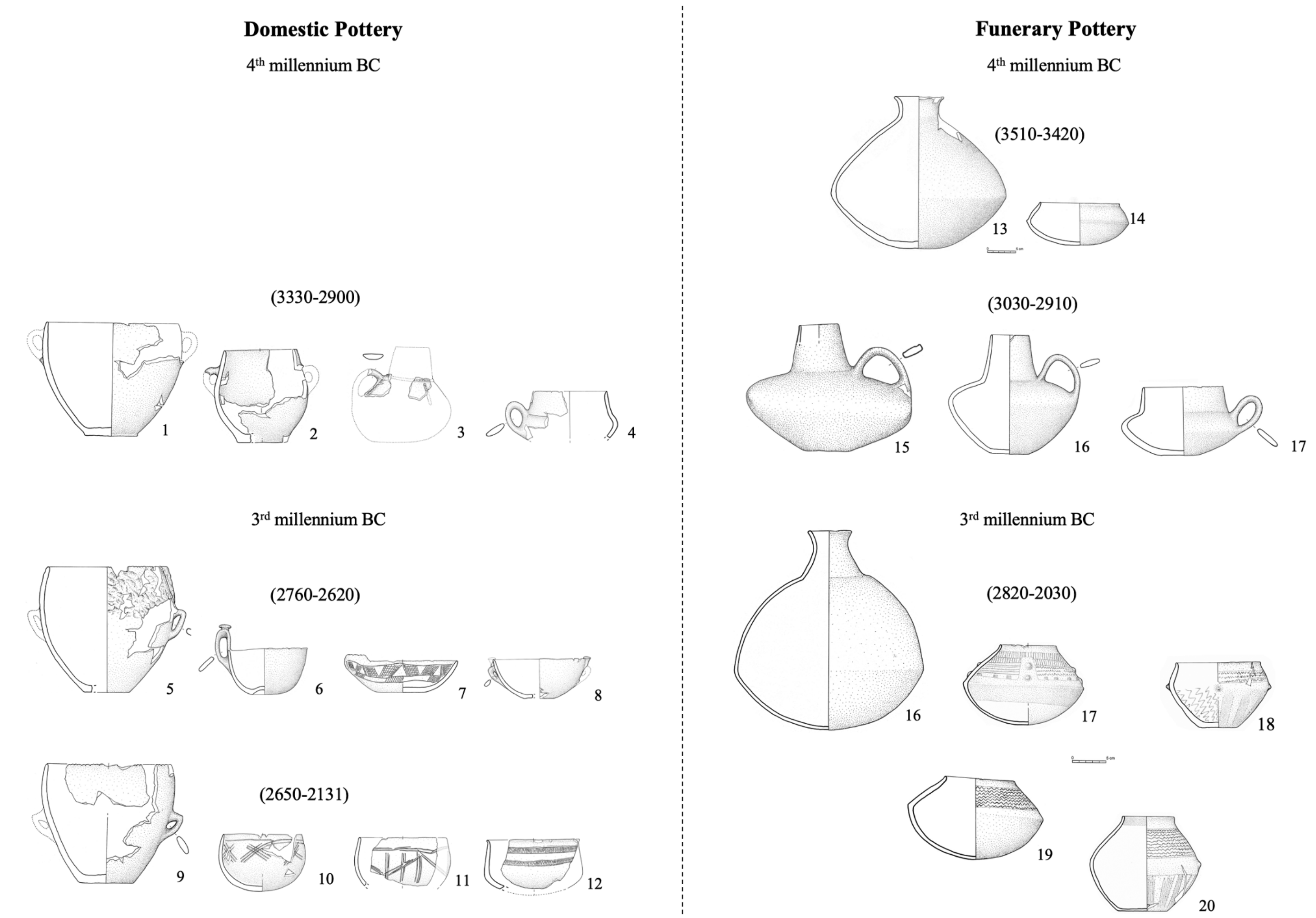

Fig. 2. Copper Age pottery production in the area of modern Rome: 1. Casetta Mistici (Anzidei et al., 2011a); 2. Tor Pagnotta (Anzidei et al., 2011a); 3. Casetta Mistici (Anzidei et al., 2011a); 4. Tor Pagnotta (Anzidei et al., 2011a); 5–12. Osteria del Curato- Via Cinquefrondi (Carboni and Anzidei, 2013); 13–14. Ponte delle Sette Miglia T.3 (Anzidei et al., 2012); 15–17. Torre della Chiesaccia T.4 (Anzidei et al., 2011a); 18. Romanina T.1 (Anzidei et al., 2012); 19. Romanina T.21 (Anzidei et al., 2012); 20. Ponte delle Sette Miglia T.13 (Anzidei et al., 2012); 21. Romanina T.39 (Anzidei et al., 2012); 22. Ponte delle Sette Miglia T.10 (Anzidei et al., 2012).

ceramic production allow us to identify the potter's skill in a specific operational sequence or specific steps within a wider *chaîne opératoire*. Surface treatment is the most evident and generally the last stage of a production process. The homogeneity of its result reveals the actual degree of accuracy behind a surface finishing and highlights the necessary technical skills required for its successful application (e.g., knowledge of the correct technical steps, gesture coordination) and qualitative information regarding the craftsperson who made a specific production, such as his/her specialisation knowledge and amount of time devoted to carry out the work. Integrating trace analysis of archaeological vessels' surfaces and experimental replicas of surface treatments allows us to obtain a dedicated collection for comparison and to relate the resulting surface topographies and textures to specific actions or combinations of technical steps. Dedicated experimental frameworks allow us to isolate which variables in an entire operational sequence depend on knowledge transmission (e.g., a sequence of technical gestures or techniques) or personal ability. Burnishing, as a surface treatment technique, can be subject to high variability of trace combinations, requiring an analytical study of surface topographies and textures to reconstruct the basic operational sequence and to infer the craft behaviour, knowledge and skill underlying the final result.

Combining evidence from an analytical study of technological traces on archaeological ceramic vessels with data from a dedicated experimental framework focusing on burnished surfaces, this article aims to interpret the variability of skill and knowledge underlying surface treatments and the characteristics of the Copper Age vessels of central Italy and to demonstrate how some specialised craft behaviours could be generically defined in a production as *household*.

2.2.1. Burnishing and polished ceramic surfaces

Several specialists in ceramic technology have worked on surface treatments and related techniques. The application of such techniques has not only an aesthetic but also often a practical effect on the physical structure of the object, affecting its functionality and durability over time (Echallier, 1984; Diallo et al., 1995; Lepère, 2014). Regardless of the process, the surface treatment marks the difference between a finished and an unfinished product. The archaeological and ethnoarchaeological literatures provide wide documentation of treatment techniques applicable to objects, many of which are shared among and applied on tools and materials that are apparently different. In this conceptual sharing, the use of the term "burnishing" has grown in the ceramic field to define the technical gesture of rubbing a surface with

Table 2
Building techniques used for producing ceramic vessels found in domestic and funerary contexts of the current Rome area (4th–3rd millennia BC).

Building Techniques	Settlements			Necropolises			
	Flat-base opened vessels (cooking pots)	Bowls	Cups	Narrow-neck vessels (flasks, jugs)	Biconical vessels	Bowls	Cups
	Slab/coiling	Mould, mould/slab, slab	Mould/slab, coiling	Mould/slab, slab	Mould, mould/slab	Mould, mould/slab	Mould/slab, slab

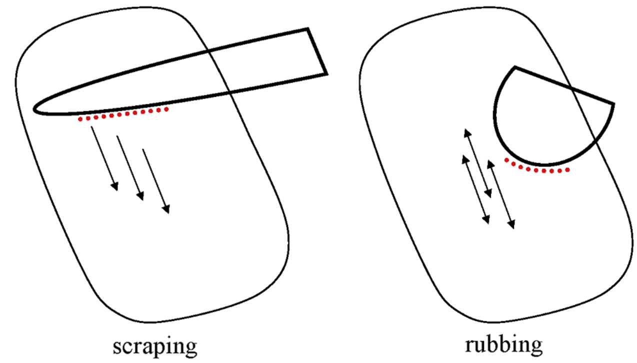

Fig. 3. Difference between a scraping (unidirectional) and a rubbing action (back and forth).

specific tools to produce a smoothed and polished effect. This word is derived from metalworking, but surface finishing is also applied in the leather industry and woodworking. This technique is currently used in industry. In the past and currently, the process is used to affect surface asperities, often at a micro-level, to transform rough topographies to polished surfaces. For this reason, burnishing and polishing can be considered interchangeable terms to define finishing techniques, and burnished and polished surfaces can both be used to define topographies affected by rubbing movements with the purpose of removing superficial irregularities (Fig. 3). The distinctive feature of this technique is the variable shiny effect due to the physical properties of the surface reflecting the light.

In ceramics, as in lithic studies, the polishing formation process remains under study. Some explanations (Fullagar, 1991; Mansur, 1997; Mansur-Framchomme, 1983) attribute this feature to material that is detached during rubbing movements and re-involved in the formation of a coating film with a topography that is sufficiently flat to lead to light reflection. Occasionally, this process does not immediately produce a covering polish because the surface modification first affects the protruding parts and then spreads elsewhere on the surface.

Unlike metal, bone or leather, the polishing of ceramic surfaces occurs when the material remains a clay paste both physically and chemically. Clay objects (e.g., vessels, figurines or spindle-whorls) are modelled at a plastic stage of the raw material. Their surfaces can be finished when the clay remains humid and plastic or when it is starting to dry. At this latter stage, the surface technique can be applied, and the polishing of the clay surface begins to develop.

A series of variables can affect the development of a shiny effect, and their combination can lead to various results that have been interpreted by scholars as the consequences of the intentional application of different techniques. Recent experimental studies provide detailed new data about this variability and confirm that a shiny effect is intentionally achieved by employing a specific gesture (rubbing) and by using a specific tool (hard tools with polished functional edges or soft fibres) on a specific surface topography (rough or smooth) and featuring a specific hygrometry (leather-dry or dry) (Martineau, 2010; Lepère, 2014; Forte, 2014; Roux, 2016).

Although the main features of the burnishing technique are currently known, the application of dedicated experimental protocols to investigate surface treatments in a specific ceramic production is a fruitful occasion to investigate the knowledge and behaviours (e.g., gestures) of craftspeople. The investigation of the technological trace variability and its intentionality, based on the ceramic pastes primarily exploited, provides information about craftspeople's expertise with regard to pots. Applying a smooth burnishing on a clay surface requires skill and practice, including the development of the correct gesture to be performed with the correct pressure, which usually varies based on surface topography, clay hygrometry and the tool's features, to avoid damage to the clay surface or to the tool and to ensure the expected effect. This skill is visible through the burnishing trace variability, which suggests not only how a technique was applied to refine the vessel but also the skill involved in the process.

2.2.2. Low-power approach to ceramic surface treatments

The methodology applied to study a potter's gestures combines the analysis of technological traces and experimental archaeology to infer the abilities and expertise of craftspeople in the selected archaeological contexts. A preliminary observation of vessels leads to the identification of patterns of technological features and to the selection of surfaces for the final interpretation.

The dedicated analysis of ceramic surfaces consists of three steps: (1) the definition of surface topography, (2) the identification of technological traces and (3) the grouping of surfaces showing similar technological features. The analytical observation was performed with a low-power approach using a Dinolite (Dino-Lite Edge AM7915MZT) digital microscope and a Nikon SMZ-U equipped with a 1X objective and with 10X oculars allowing a magnification range from 0.75X to 75X (Tringham et al., 1974; Van Gijn, 2010).

The interpretation of archaeological traces is based on a framework comprising surface treatment data from dedicated experimental protocols and published experimental studies (Martineau, 2010; Lepère, 2014; Roux, 2016). The choice of surface treatment techniques applied to replicate trace variability is based on the archaeological literature addressing this topic (Ronchi et al., 1994; Levi and Recchia, 1995; Lepère, 2014) integrated with variables originating from the analysis of archaeological surfaces from the Copper Age pottery of the area of modern Rome (Forte, 2014).

2.2.3. Experimental framework

Developing a dedicated experimental framework is an essential step for investigating human behaviours through the analysis of technological traces. Applying comparisons among technological traces and published archaeological or ethnoarchaeological collections is usually a valuable part of the interpretative processes, but a better comprehension of the expertise behind a production can be obtained by researchers who develop their own personal experience in terms of skill, time and technical difficulties. Moreover, experimental archaeology shows that different combinations of gestures and tools can occasionally lead to extremely similar traces; at the same time, use wear can be incorrectly interpreted as technological traces. Applying dedicated experimental protocols reduces this risk. Indeed, the reproduction of specific conditions, such as selected raw materials, tools and the degree of skill, is one of the main conditions for the successful application of experiments in archaeology (Coles, 1979, Outram, 2008).

The purpose of the frameworks discussed here was to replicate the conditions and technological features of the polished surfaces that were widely diffused in the area of modern Rome during the Copper Age. The variety in the use of burnishing techniques observed on domestic and funerary ceramic archaeological assemblages supports the hypothesis of diverse but coexistent technological behaviours and expertise, which can be verified through a reconstruction of gestures, procedures, tools, times of intervention and the craftsperson's expertise.

The experimental burnishing framework, developed by the author working as the only experimenter,[1] considered empirical variables derived from the low-power analysis approach of the selected archaeological ceramics (Forte, 2014) and published observations on polished pottery surfaces and burnishing processes (Rye, 1981; Rice, 1987; Gibson and Woods, 1997; Ronchi et al., 1994; Levi and Recchia, 1995; Cuomo di Caprio, 2007; Vidale, 2007; Brodà et al., 2009; Martineau, 2010; Lepère, 2014; Roux, 2016). Based on this information, a series of variables were selected comprising clay paste, the hygrometry of the clay surface, surface topography, tools, and additional substances and gestures (Table 3). The clay pastes comprised raw materials that were selected by considering the composition and granulometry observed on the archaeological productions examined in this study: (1) a fabric with sedimentary inclusions, featuring quartz and feldspar in a fine granulometry; (2) a fabric with sedimentary inclusions and grog in a semi-fine granulometry; and (3) a fabric with volcanic rock fragments and grog in a coarse and semi-fine granulometry (Forte, 2014; Forte and Medeghini, 2017). Hygrometry, the examination of the degree of moisture of the surface, has been expressed in terms of leather/dry[2] and dry surfaces. Topography is defined as the identification of features of the clay surface before the application of burnishing (Fig. 4). The set of tools used comprised cobbles, antler, bone, leather and wool (Fig. 5); additional substances included water, milk and animal fat. The gestures of the experimental craftsperson were recorded by considering movement in terms of pressure (soft/heavy), continuity and covering. In limited cases, additional treatments with a soft material such as leather or wool were applied for further surface finishing (Table 3).

The time of execution was not quantified during the experimentation because trace replicas were reproduced on vessels of different dimensions (6 in total) and on briquettes (31 in total), which usually require different working times. Some works suggest that this operation can constitute one-third of the entire process (Brodà et al., 2009) (see Table 3).

For this reason, a time-based variable was considered and recorded in terms of recognising the correct drying stage to intervene on a surface and to obtain the expected result compatible with the archaeological collection. Working on clay briquettes leads to intervening on a limited and ideal surface portion; however, applying burnishing on an entire vessel involves more complex dynamics of trace development. Vessels can be of variable shapes and dimensions and are subject to different drying stages based on the wall thickness and the environment during the drying stage. For this reason, variable traces can be identified and properly interpreted according to their position on the entire vessel. For example, shallow and isolated grooves might be identified in proximity to the connection between the vessel body and neck as a spot that is still lightly modifiable because it retains residual moisture. The presence of such a localised type of trace should be interpreted as an anomaly in the analysis of a surface treatment. In addition, striations, as the most diffused anomalies, can easily be produced by moving a vessel before firing. By considering these aspects, we can avoid misinterpretations in trace analysis.

2.2.4. Technological traces

The analysis of the technological features of finishing treatments is based on traces left by tools on a surface.

Trace recording begins with a preliminary definition of the surface *topography*, referring to the degree of regularity of a surface as a superimposition of the traces left by different tools or gestures and categorised as *flat*, *sinuous* or *uneven*. *Flat* refers to plane surfaces lacking coarse irregularities, and *sinuous* refers to slightly wavy surfaces lacking coarse irregularities and representing the middle stage between the two main topographies, *flat* and *uneven*. *Uneven* includes all of the surfaces featuring frequent and coarse irregularities, such as rough depressions or deep grooves (Figs. 5 and 6).

[1] The experimental framework is composed of a collection of 18 samples (12 briquettes and 6 ceramic vessels) selected from the experimental collection built by the author during her PhD work (Forte 2014) on domestic pottery production and a comparison collection built during the TraCTUs research project focused on funerary pottery. The first experimental collection is composed of vessels produced indoors and briquettes worked outdoors in the spring season to avoid windy conditions or direct sun. The second comparison collection was built indoors in late summer in conditions comparable to the first experimental session. The entire experimental framework required approximately a month of work.

[2] This stage refers to an intermediate stage between leather and dry, when the surface retains a residual softness.

Table 3
Experimental Framework: the double line divides smooth and rough burnished surfaces resulting from the experiments; dashed lines group the experimental burnishing into flat/smooth, sinuous/smooth, uneven/smooth, flat/rough, sinuous/rough, sinuous/rough, and uneven/rough.

ID	Surface treatment variables							Final result		
	Clay paste	Hygrometry	Topography	1st treatment: Tool	1st treatment: Added substances	Gestures	2nd treatment: Tool	Topography	Texture	Macrotraces
37	fine	dry	flat	cobble	milk	soft, continuous and covering rubbing	leather	flat	smooth	no macrotraces
8	fine	dry	flat	antler	milk	soft, continuous and covering rubbing	/	flat	smooth	no macrotraces
30	fine	dry	flat	antler	milk	soft, continuous and covering rubbing	/	flat	smooth	no macrotraces
2	fine	dry	flat	cobble	milk	soft, continuous and covering rubbing	/	flat	smooth	no macrotraces
9	fine	dry	flat	cobble	/	soft, continuous and covering rubbing	/	flat	smooth	no macrotraces
6	fine	dry	flat	antler	/	soft, continuous and covering rubbing	/	flat	smooth	no macrotraces
1	fine	dry	flat	cobble	animal fat	soft, continuous and covering rubbing	/	flat	smooth	light batches of striations
13	fine	dry	flat	cobble	/	heavy, continuous and covering rubbing	/	flat	smooth	light batches of striations
28	fine	dry	flat	antler	milk	soft, continuous and covering rubbing	/	flat	smooth	light striations
5	semi-fine	leather/dry	flat	antler	/	heavy continuous and covering rubbing	/	flat	smooth	light batches of striations
4	fine	dry	flat	wool	/	soft, continuous and covering rubbing	/	sinuous	smooth	light striations
7	fine	dry	sinuous	antler	animal fat	soft, continuous and covering rubbing	/	sinuous	smooth	light isolated striations
29	fine	dry	sinuous	antler	milk	soft, continuous and covering rubbing	leather	sinuous	smooth	light striations
32	fine	dry	sinuous	antler	milk	soft, continuous and covering rubbing	leather	sinuous	smooth	light isolated striations
36	fine	dry	sinuous	wool	milk	soft, continuous and covering rubbing	/	sinuous	smooth	striations
25	fine	dry	sinuous	antler	water	soft, continuous and covering rubbing	/	sinuous	smooth	batches of striations
26	fine	dry	sinuous	wool	water	soft, continuous and covering rubbing	antler	uneven	smooth	no macrotraces
27	fine	dry	sinuous	wool	milk	soft, continuous and covering rubbing	/	uneven	smooth	striations
23	semi-fine	dry	uneven	bone	clay coating	soft, continuous and covering rubbing	/	uneven	smooth	light batches of striations
12	semi-fine	dry	flat	cobble	milk	heavy continuous and covering rubbing	/	flat	rough	batches of striations
3	fine	dry	flat	wool	animal fat	soft, continuous and covering rubbing	/	flat	rough	striations
35	fine	dry	flat	antler	milk	soft, continuous and covering rubbing	wool	flat	rough	light batches of striations/striations
17	semi-fine	dry	uneven	bone	water	soft, continuous and covering rubbing	/	flat	rough	batches of striations/elongated depressions/residual striations
24	semi-fine	dry	uneven	cobble	water	soft, continuous and covering rubbing	/	flat	rough	batches of striations
18	semi-fine	dry	uneven	antler	water	soft, continuous and covering rubbing	/	flat	rough	batches of striations
19	semi-fine	dry	uneven	bone	water	soft, continuous and covering rubbing	/	flat	rough	batches of striations
20	semi-fine	dry	uneven	antler	water	soft, continuous and covering rubbing	/	flat	rough	batches of striations/residual striations
16	semi-fine	dry	uneven	antler	water	soft, continuous and covering rubbing	/	flat	rough	batches of striations/elongated depressions/residual striations
22	semi-fine	dry	uneven	antler	clay coating	soft, continuous and covering rubbing	/	flat	rough	light batches of striations/elongated depressions
21	semi-fine	dry	uneven	bone	water	soft, continuous and covering rubbing	/	flat	rough	light batches of striations/residual striations
14	semi-fine	dry	sinuous	antler	water	soft, continuous and covering rubbing	/	sinuous	rough	batches of striations/elongated depressions
15	semi-fine	dry	sinuous	bone	water	soft, continuous and covering rubbing soft,	/	sinuous	rough	batches of striations/elongated depressions
34	fine	dry	sinuous	cobble	milk	soft, continuous and covering rubbing	wool	sinuous	rough	striations
33	fine	dry	sinuous	cobble	milk	soft, continuous and covering rubbing	leather	sinuous	rough	light gouges/striations
10	semi-fine	dry	sinuous	wool	milk	soft, continuous and covering rubbing	/	sinuous	rough	striations
31	semi-fine	dry	sinuous	cobble	milk	soft, continuous and covering rubbing	/	sinuous	rough	light gouges striated/light batches of striations
11	coarse	leather/dry	uneven	cobble	/	heavy continuous and covering rubbing	/	uneven	rough	batches of striations

Fig. 4. Tools used for the experimental surface burnishing: leather (soft), wool (soft), cobble (hard), bone (medium hard) and antler (medium hard).

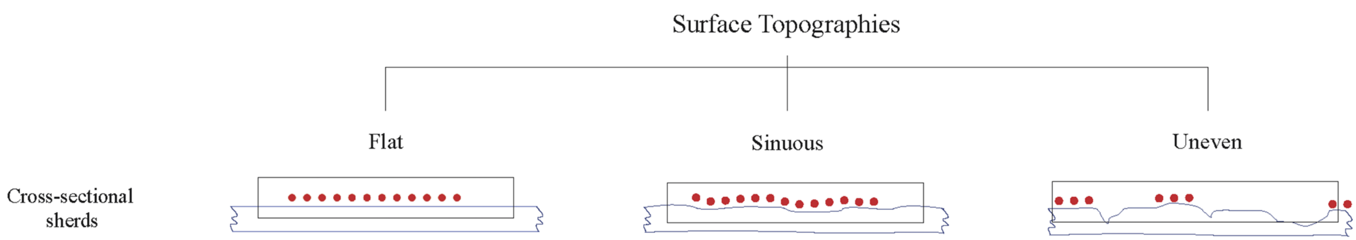

Fig. 5. Red dots indicate the burnishing distribution on flat, sinuous and uneven topographies. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

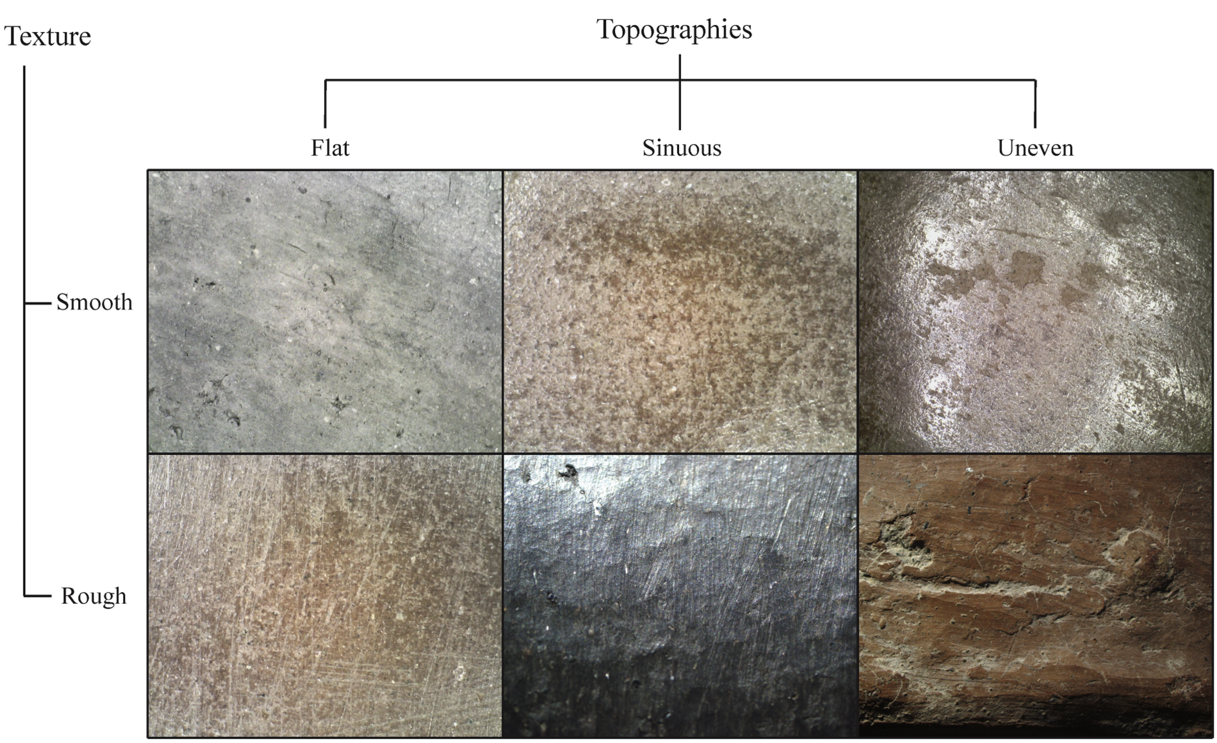

Fig. 6. Texture and topography variables on ceramic surfaces.

Table 4
Variables and features used for the trace analysis.

Trace variables	
Variables	Features
Surface topography	Flat/sinuous/uneven
Texture	Rough/smooth
Shape	Striations/batches of striations/grooves/depressions
Frequency	Isolated/closed/connected
Incidence	Shallow/deep/mixed
Edge morphology	Regular/irregular/rounded/sharp

The following step coincides with the description of burnishing trace textures based on the homogeneity criterion and varying between *rough* and *smooth*. The two main variables of the texture can be associated with a variability of topographies (flat, sinuous or uneven). The texture also varies in its regularity; *smooth* includes textures lacking irregular macrotraces or with the presence of very light occasional traces, whereas *rough* refers to a texture that features visible macrotraces occasionally recurring in different shapes (Fig. 4).

Observation of the texture through multiple magnifications can lead to the identification of additional technological features of burnishing traces by analysing the single traces on the basis of their *shape* (striations, batches of striations, grooves and depressions), *frequency* (indicating the repetitiveness of any trace, such as isolated, closed, or connected), *incidence* (defining the wear depth in relation to the surface: shallow or deep) and *edge* (varying among regular, irregular, rounded and sharp) (Table 4).

Topography and texture analysis play key roles in understanding the overlapped manufacturing steps and the interpretation of tools and gestures related to surface treatments.

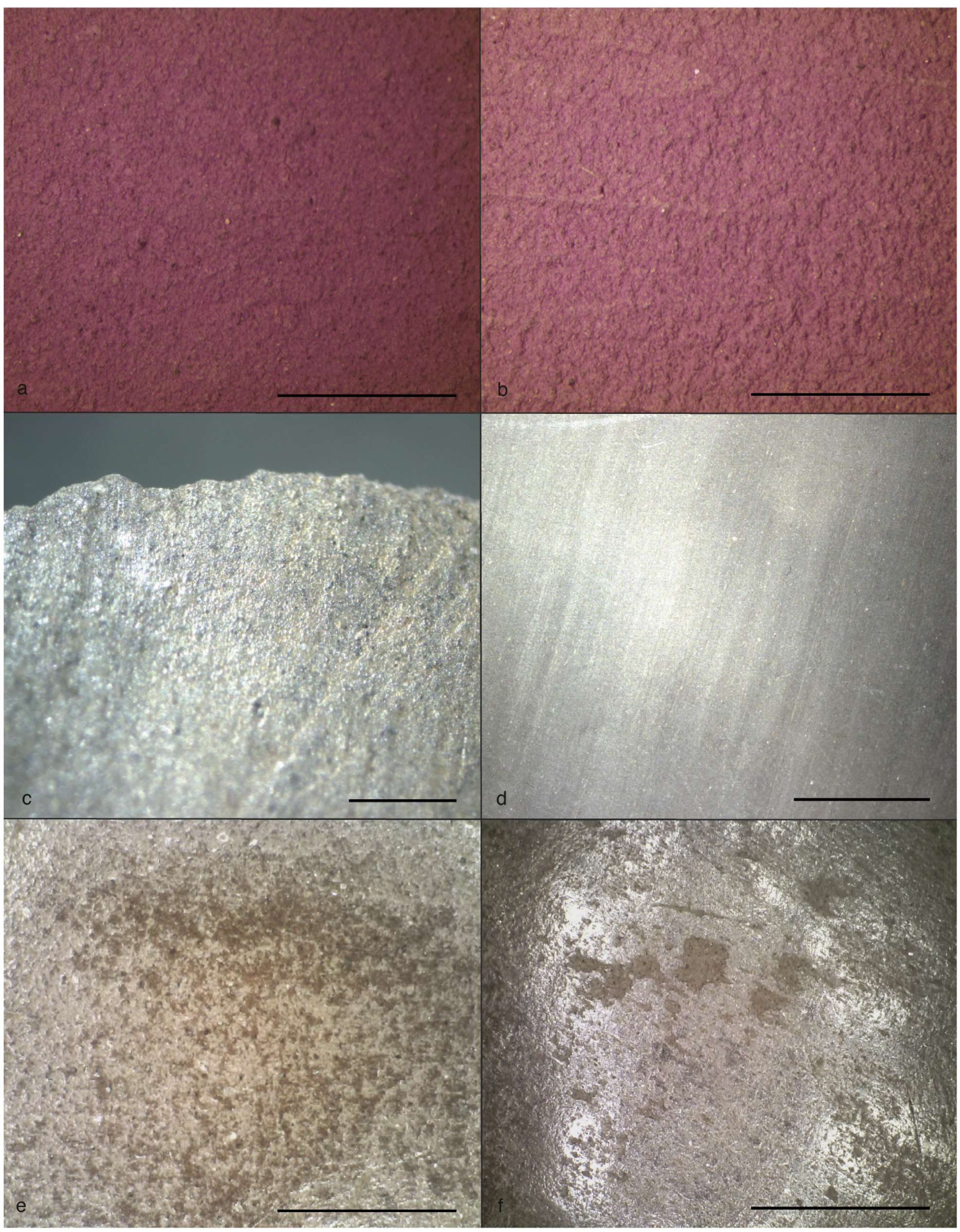

Fig. 7. Examples of experimental burnished surfaces. a: flat, dry and fine-grained clay surface before burnishing application; b: sinuous, dry and fine-grained clay surface before burnishing application; c–d: examples of a smooth burnishing with a flat topography applied at a dry stage; e–f: examples of a rough burnishing with a sinuous and rough surface (black bar is 5 mm).

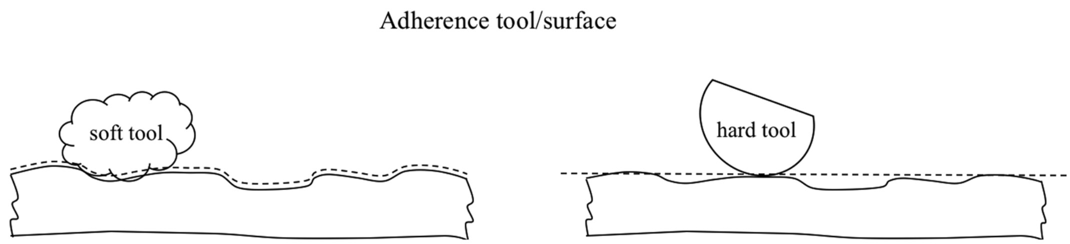

Fig. 8. Adherence tool on surface topography.

3. Results

3.1. Experimental burnishing traces

The experimental framework led to the replication of 37 burnishing treatments, which can be divided into 2 main groups of burnished surfaces, *smooth* and *rough,* on the basis of the degree of texture roughness observed at low magnifications. The variability in each group is due to a multiple combination of raw materials (granulometry and hygrometry), surface topography, tools (nature, shape and edge morphology) and gestures (movement and pressure degree).

3.1.1. Smooth burnished surfaces

This group includes surfaces with a smooth texture featuring the absence of macrotraces or the presence of very light irregularities left by the utilised tools (Fig. 7c–d). This texture can feature flat, sinuous or uneven topographies (Fig. 6).

The experiments show that smooth burnishing can be obtained by soft, continuous and covering rubbing of a hard tool (e.g., cobble or antler) on a flat, dry and fine-grained clay surface (Fig. 7a). Smooth and covering burnishing without macrotraces has been reproduced largely on flat topographies obtained by carefully smoothing the surface before the drying process (Fig. 7a). The experiments showed that an intervention, preferably at a dry stage when the clay has reached a high degree of compactness, facilitates the modification of micro irregularities on the surface, resulting in a smooth texture (Fig. 7c–d). In this case, modifications affect the superficial particles that are dislodged and re-located during the hard-tool rubbing as a re-involvement of superficial material that is then compacted by the hard tool through back and forth movements. Additional substances such as fat liquids (e.g., milk) added on a dry surface work as a lubricant to reduce the friction that usually causes visible traces and leads to an incipient dissolution of superficial clay that is subsequently relocated in imperfections, such as striations or small depressions, left by the previous treatment. This modification leads to the formation of a flat topography favouring light reflection and a shiny effect (compare Fig. 7a–b with c–d).

The experiments indicate that a smooth texture can also be associated with sinuous and uneven topographies, with different results due to the overlapping of the burnishing on irregular surfaces. Rubbing movements first affect the protruding parts of a surface, and the result changes depending upon the shape and hardness of the tool's functional edge. A soft tool (such as leather or wool) usually adapts to the surface with which it comes in contact, easily reaching the irregularities of the topography (e.g., superficial depressions). In contrast, a hard tool primarily affects the protruding parts (Fig. 8).

Although this group features a high degree of surface regularity, it is possible in some cases to observe superficial traces, such as batches of striations or isolated striations, emphasised by light reflection (Fig. 7d).

Batches of striations are the most diffused trace morphology associated with burnishing treatments. These batches comprise parallel striations of variable sizes usually left by a hard tool and are caused by macro- or microtraces on the tool's edge (Fig. 9c–11). The amplitude of traces is due to the width of the functional edge area coming in contact with the surface. The area can also vary depending upon the handling or inclination of the tool during the process.

In some cases, isolated striations have been recorded in association with surfaces rubbed with soft tools such as wool or leather (Fig. 10a–b). These striations consist of isolated traces left by the imperfections in the leather or by the wool fibres occasionally used as additional homogenisation treatments.

3.1.2. Rough burnished surfaces

This group is composed of surfaces with a rough texture characterised by isolated or multiple striations or batches of striations. These traces can develop from rubbing leather-dry or dry surfaces with hard (e.g., cobble or antler) or soft tools (e.g., wool or leather) independently of the paste granulometry and surface topography. The repeated use of a tool on dry paste leads to the development of multiply orientated striations that are variable in size (Fig. 10).

Usually, a high degree of roughness on a clay surface is due to the overlapping of batches of striations and multiple striations on surfaces that are not prepared or smoothed before the burnishing treatment. The application of the latter technique emphasises surface imperfections (Figs. 7f and 10c,e).

Some experiments show how the application of an added substance on a dry uneven surface rubbed with a hard tool can lead to its modification until an almost flat topography is obtained, which also explains some smooth burnished surfaces (fine-grained clay) transformed from sinuous to flat or from uneven to sinuous surfaces (see Table 3). This process also occurs on surfaces in semi-fine-grained clay paste that usually feature evident traces such as grooves or striations developed on a tool's functional edges during its continuous rubbing on clay pastes with exposed inclusions. Although hard tools push the inclusions deep, this interaction affects the tool's topography (Fig. 9), proving that the roughness of a treatment can also be affected by the roughness of a tool's functional edge. As explained above, the application of intermediate substances can reduce the attrition between surfaces and decrease the roughness. Moreover, experiments demonstrated that the degree of surface roughness can be increased by additional treatments

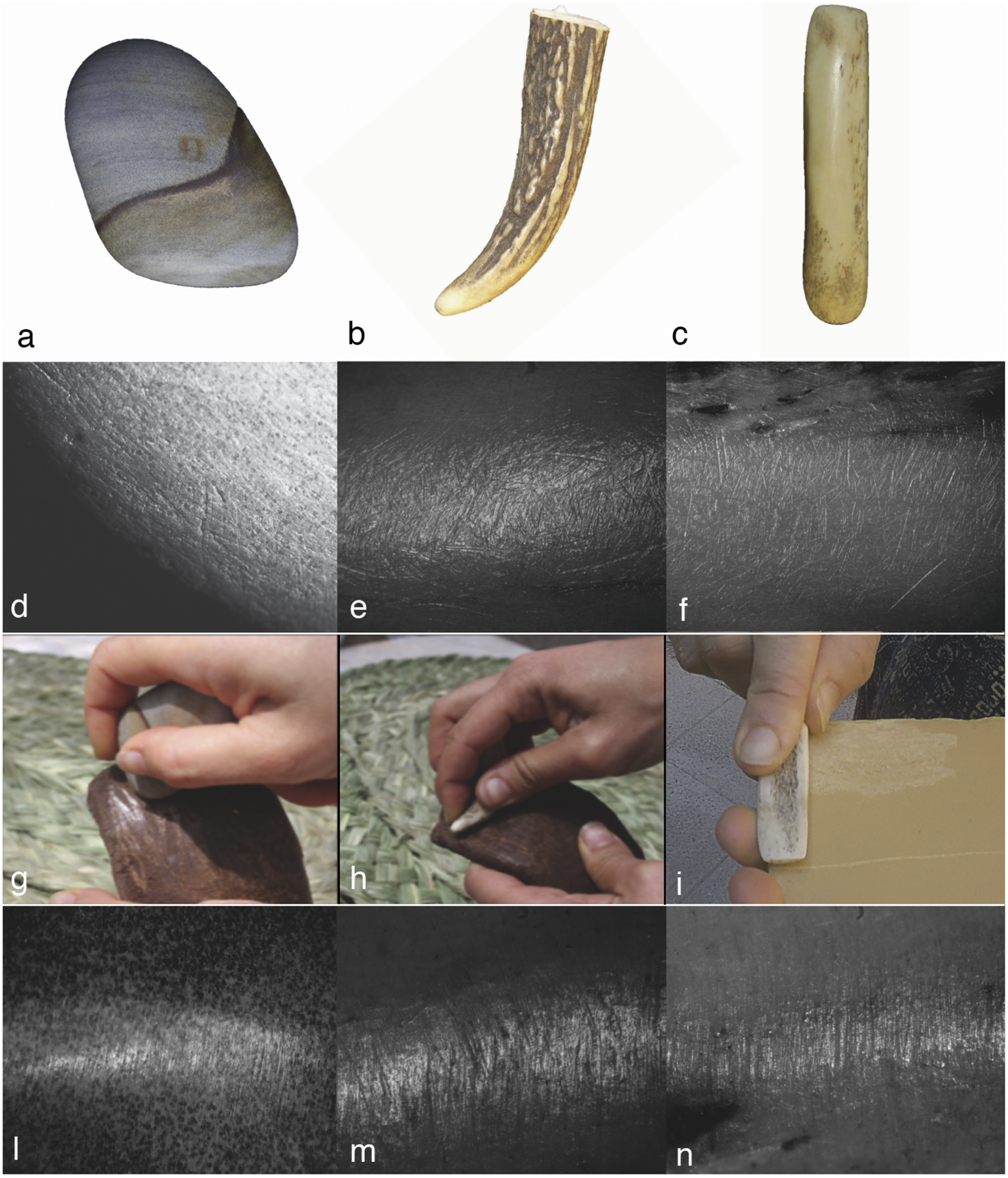

Fig. 9. Traces on tools' edges before and after their use for burnishing clay surfaces. a–c: cobble, antler, bone; d–f: functional edge pre-use of cobble, antler, bone (striations with chaotic orientations) (10x); g–i: use of tools; l–n: use wear on functional edges (rubbing produced parallel oriented striations causing batches of striations on clay surfaces) (10x) (e–f–m–n Ph. Sara Stellacci).

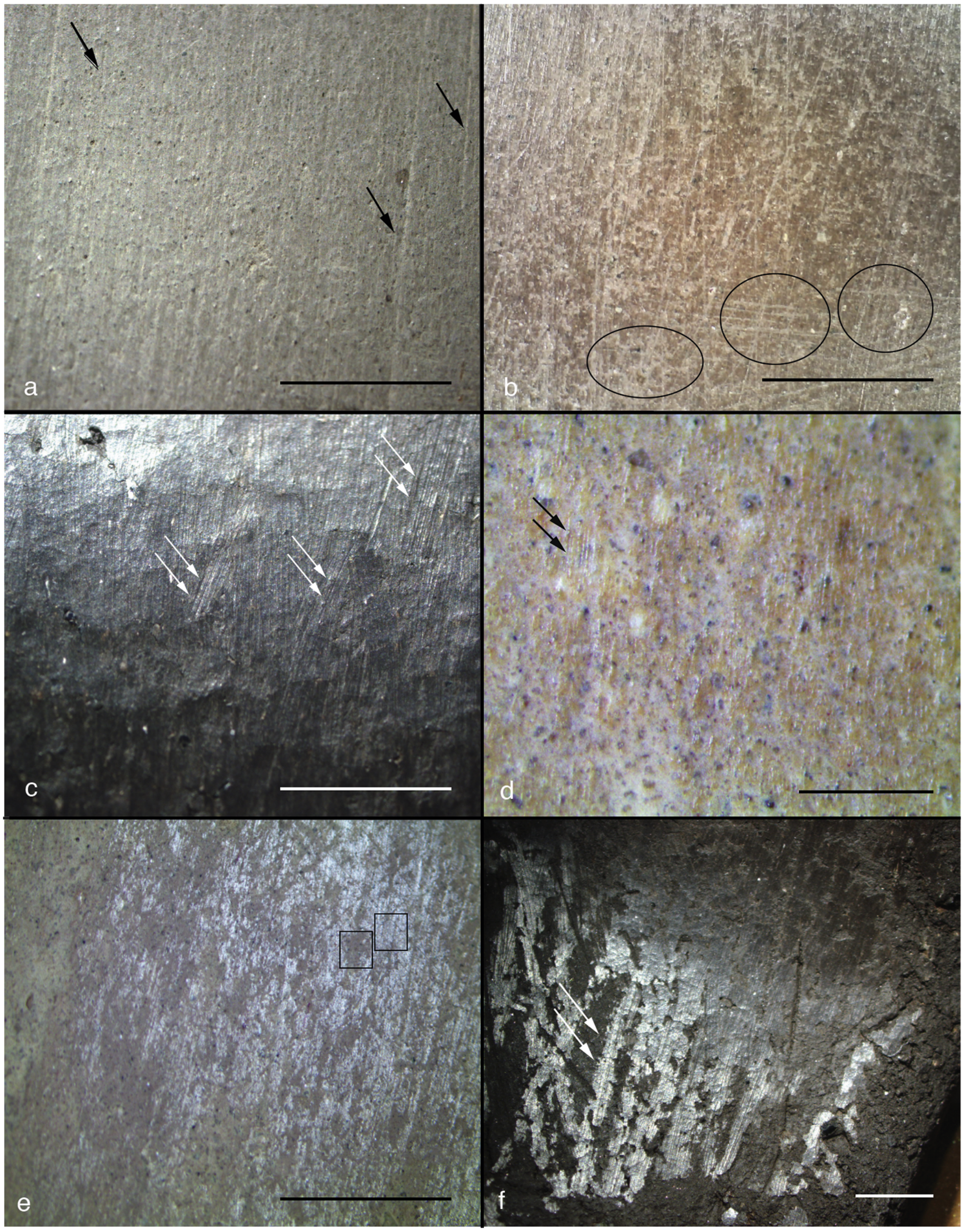

Fig. 10. Experimental burnished surfaces. a: Rough burnishing on a flat topography featuring orientated striations caused by wool; b: Rough burnishing on a flat topography featuring overlapping striations caused by wool rubbed on a surface previously burnished with a hard tool (cobble); c: Rough burnishing on a sinuous surface from rubbing a hard tool (cobble) on an almost dry surface (the tool left evident batches of striations); d: Rough burnishing on a sinuous surface from rubbing a hard tool (cobble) on a dry surface with an added substance; e: Rough burnishing on an uneven surface due to the rubbing of a hard tool (cobble) on a dry surface (see the contrast between shiny and matte areas); f: Rough burnishing on an uneven surface due to a not-covering rubbing of a hard tool (cobble) on a dry surface (black bar is 5 mm, except Fig. 10d is 1 mm).

such as rubbing with soft materials (e.g., wool or leather) (Table 3). Such rubbing apparently can homogenise the entire treatment, in some cases leaving casual and variable isolated depressions or multiple striations due to imperfections in the soft materials or in the pressure applied in rubbing (Fig. 10a–b).

The results of burnishing within the experimental framework confirmed, based on previous studies (Martineau, 2010; Lepère, 2014; Roux, 2016), that shiny surfaces are due to an intervention by rubbing on a clay surface that is not wet. A wet clay surface is plastic and easily modifiable under a tool's pressure due to the high attrition force between clay and the tool's edge. Consequently, scraping (Fig. 1) is the most recurrent action applied at this stage, removing extra clay paste until the expected surface topography is obtained. Although some surfaces appear macroscopically smoother than others do, their roughness topography, which is rich with micro imperfections, is unable to reflect light properly, creating the resulting matte effect.

During the drying stages of the clay surface, the surface reacts differently depending upon its residual hygrometry. The clay becomes difficult to modify as it dries unless superficial particles are compacted under a specific gesture of tool rubbing performed with controlled speed and pressure. Experiments show that the final effect of this treatment depends upon a specific combination of clay paste granulometry, surface preparation before burnishing, hygrometry, eventual intermediate substances, the tool's edge morphology and, possibly, a combination of multiple treatments.

Table 5
Relationship between traces of smooth burnishing and stable/changing variables affecting them.

Smooth burnished surfaces		
No Macrotraces (7 experiments)	Stable variables	Fine clay
		Dry stage
		Tool with a hard and polished functional edge
		Soft, continuous and covering rubbing
	Changing variables	Flat or sinuous topography
		Added substance
		Leather as a second treatment
Light Striations (7 experiments)	Stable variables	Dry stage
		Soft, continuous and covering rubbing
	Changing variables	Fine/semifine clay
		Wool or tool with a hard and polished functional edge
		Flat or sinuous topography
		Leather as a second treatment
		Added substances
Light Batches of Striations (5 experiments)	Stable variables	Tool with a hard and polished functional edge
	Changing variable	Fine/semifine clay
		Dry or leather/dry stage
		Flat/sinuous/uneven topography
		Heavy, continuous and covering rubbing or soft rubbing in presence of any fat added substance (e.g., animal fat)
		Second treatment (leather or wool)

3.2. Experimental burnishing traces and craft skill inferences

The gesture of rubbing is the main parameter that is undeniably connected with burnishing treatments used to compact and orientate superficial clay particles and to close pores to favour light reflection. The homogeneity of the final effect is due to the combination of the remaining variables.

The experiments confirmed how hygrometry affects the development of traces and their morphology (Martineau, 2010; Lepère, 2014; Roux, 2016). A dry surface is primarily modified on the top, changing only the orientation of the particles and not the topography, which explains why surfaces that are not well worked and have macroscopic imperfections (e.g., sinuous or uneven topographies) maintain irregularities emphasised by the shiny/matte effect (Figs. 7f and 10f). In summary, the pre-burnishing preparation treatment of a surface is one of the main prerequisites for a final homogeneous effect. Some experiments showed that intervening at the right moment and identifying the right hygrometric stage (not leather-dry but not completely dry) led to highly homogeneous burnished surfaces, defined here as smooth burnishing on flat topography and known in some references as polished, as defined by Roux (2016), or furbished, as defined by Lepère (2014). This effect is also due to the low imperfections of hard tools (Fig. 7c, d, f). As observed in the experiments, traces associated with burnishing are batches of striations or striations left by the tool's edge on the surface. The visibility of these traces is ruled by two main aspects: the first one is their effect on a tool's functional edge, which could be intentionally regularised by polishing the tool; the second aspect is the presence of an intermediate substance that reduces friction and supports the sliding of the tool, resulting in the development of light traces.

The experiments also showed that it is possible not only to distinguish a specific time of intervention but also to characterise the tool used for burnishing a surface. Hard tools, regardless of their edge morphology and imperfections or surface hygrometry, leave more or less evident batches of striations and are able to compact protruding parts of surface topographies (Fig. 10c–e).

Isolated or multiple striations, occasionally associated with batches of striations, are due to leather (depending upon the effectiveness of the tanning process) or wool (Fig. 10a–b), suggesting that the choice of tools based on the morphology of the functional edge and their eventual adjustment must be considered an important parameter for a homogeneous shiny effect. The expertise and interest of the artisan in selecting and caring for his/her toolkit can be considered an intentional choice for obtaining a well-refined final product.

Gestures in burnishing are determinants of not only the type of movement but also the amount of pressure applied, which must be sufficient to modify the surface without damaging it. High pressure, particularly if concentrated on one area, can lead to abrasive wear of dry surfaces, exposing the clay particles underlying the surface. The capacity to manage the gesture's pressure and modify it based on surface features can be considered one of the effects emerging from the artisan's expertise due to movement repetition over time, improving the gesture efficacy and the awareness to obtain an ever-better effect.

The experimental protocols showed that surface topography and hygrometry are key aspects that enormously affect the results and the trace morphology. Consequently, obtaining a well-refined surface treatment is the result of intentionally planning all of the stages in the *chaîne opératoire*, from the selection of the raw material (the suitable clay recipe for the ultimately desired result) to the identification of the right moment to apply the burnishing technique. The correct sequence of these steps as shown by the experiments infers a transmitted knowledge and an intentionally acquired skill in applying the correct burnishing treatment.

Table 3 shows that it is possible achieve multiple burnishing effects solely through well-planned sequences associated with controlled gestures that lead to highly homogeneous burnishing (Table 3, IDs 37, 8, 30, 2, 9, 6). Multiple subgroups of experiments (Tables 5 and 6) can be identified in the two main groups of smooth and rough burnishing as a series of treatments emerging from different combinations of stable or changing variables. These experiments suggest that the increasing degree of roughness in burnishing is due to a combination of relatively uncontrolled choices in clay selection, tools, times of intervention or unskilled gestures.

Table 6
Relationship between traces of rough burnishing and stable/changing variables affecting them.

Rough burnished surfaces		
Striations (3 experiments)	Stable variables	Fine clay Dry stage Added substance Soft, continuous and covering rubbing
	Changing variables	Wool or tool with a hard and polished functional edge Flat or sinuous topography Second treatment (wool)
Batches of striations (5 experiments)	Stable variables	Dry stage Tool with a hard and polished functional edge
	Changing variable	Semifine/coarse clay Flat or uneven topography Added substance (milk/water) Heavy/soft, continuous and covering rubbing
Light batches of striations/striations (1 experiment)	Stable variables	Fine clay Dry stage Second treatment with wool flat topography Added substance (milk) Second treatment with wool Soft, continuous and covering rubbing
Batches of striations/elongated depressions/residual striations (2 experiments)	Stable variables	Semifine clay Dry stage Uneven topography Tool with a hard and polished functional edge Added substance (water) Tool with a hard and polished functional edge
Batches of striations/elongated depressions (3 experiments)	Stable variables	Semifine clay Dry stage Tool with a hard and polished functional edge Soft, continuous and covering rubbing
	Changing variables	Sinuous/uneven topography added substance (water/clay coating)
Batches of striations/residual striations (2 experiments)	Stable variables	Semifine clay Dry stage Uneven topography Tool with a hard and polished functional edge Added substance (water) soft, continuous and covering rubbing
Light grooves/striations (experiment)	Stable variables	Fine clay Dry stage Sinuous topography Tool with a hard and polished functional edge Added substance (milk) Soft, continuous and covering rubbing Second treatment (leather)
Light grooves striated/ light batches of striation (1 experiment)	Stable variables	Semifine clay Dry stage Sinuous topography Tool with a hard and polished functional edge Added substance (milk) Soft, continuous and covering rubbing

Fig. 11. Copper Age pottery production from the area of modern Rome: a: Osteria del Curato-Via Cinquefrondi settlement; Ponte delle Sette Miglia necropolis; Torre della Chiesaccia necropolis.

3.3. Archaeological burnishing traces

The analysis of burnishing traces on the ceramic assemblages discussed in this research revealed the diffused and growing use of this surface treatment technique by the Copper Age communities that settled in the area of modern Rome (central Italy) and qualitative features of the treatment suggesting multiple levels of skill (Fig. 11; Table 6).

Table 7
Sampling of surface treatments selected for the burnishing techniques study (CM: Casetta Mistici; TP: Tor Pagnotta; OC-VC: Osteria del Curato-Via Cinquefrondi; TCh: Torre della Chiesaccia; VdM: Valle dei Morti; ROM: Romanina; PSM: Ponte delle Sette Miglia.

	Settlements							Necropolises		
	Late half 4th millennium BC (3330–2870)		Early 3rd millennium BC (2760–2620)	Middle/Late 3rd millennium BC (2580–2130)				4th-3rd millennium BC (3640–2030)		
	CM	TP	OC-VC	TCh	OC-VC	VdM	CM	TCh	ROM	PSM
Samples analysed	207	54	36	95	217	194	130	17	30	12
Not burnished	53%	61%	23%	19%	32%	34%	15%	/	23%	8%
Smooth burnished	2%	/	6%	39%	11%	63%	54%	5%	27%	26%
Rough burnished	45%	39%	71%	42%	57%	3%	31%	95%	50%	66%

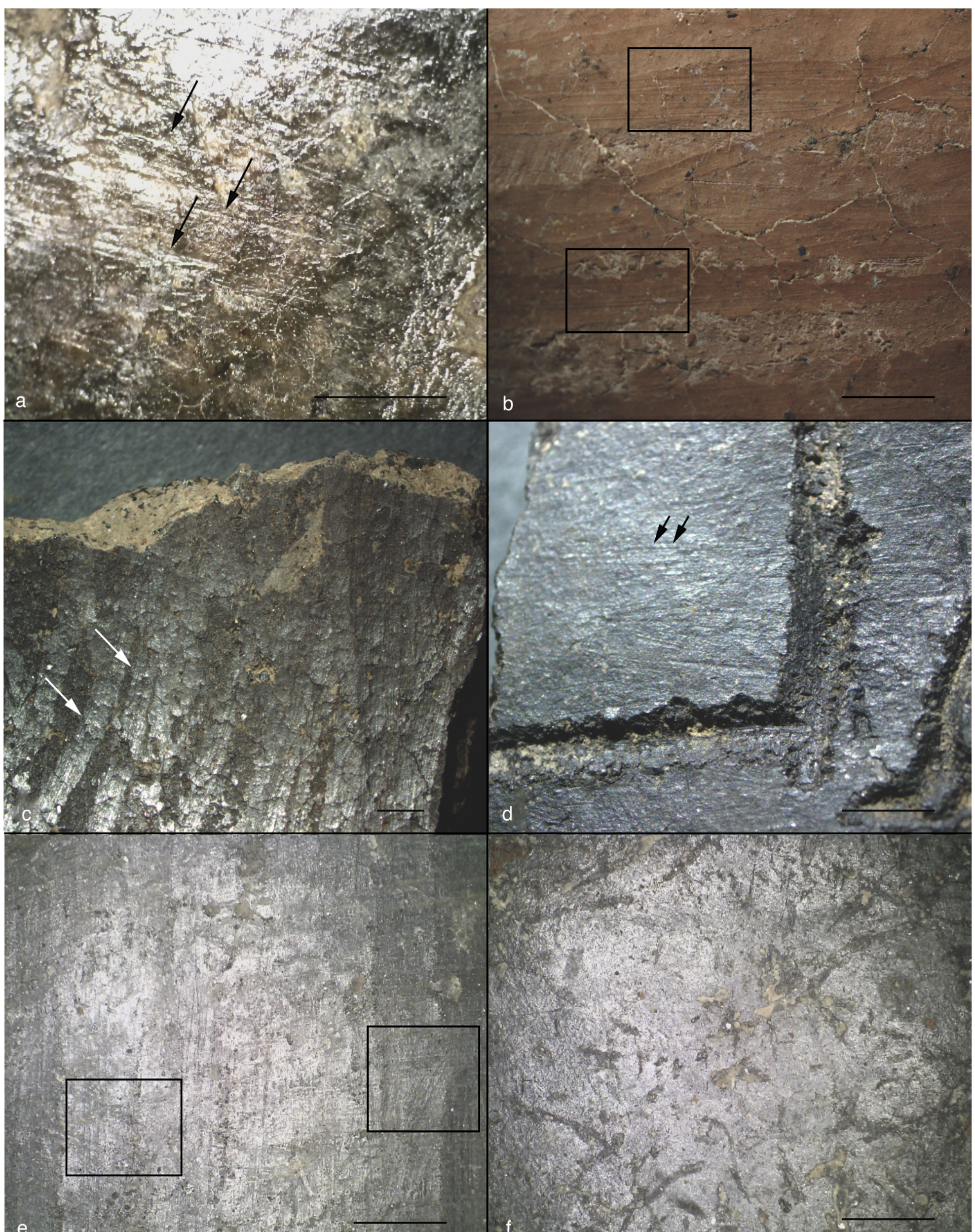

Fig. 12. Archaeological surface treatments: Torre della Chiesaccia necropolis (rough burnishing with striations left by wool); b-c: Osteria del Curato-Via Cinquefrondi (rough burnishing with batches of striations and striated grooves left by a hard or medium-hard edge tool e.g., cobble, antler or bone); d: Osteria del Curato-Via Cinquefrondi (rough burnishing with batches of striations left by a hard or medium-hard edge tool e.g., cobble, antler or bone); e: Romanina Necropolis: Smooth burnishing with light overlapping and multi-directional batches of striations left by a hard or medium-hard edge tool and an additional treatment with a soft tool e.g., leather; f: Smooth burnishing without evident macrotraces; according to the experimental results, it can be produced by more technical sequences, such as the use of a soft tool (e.g., leather) (black bar is 5 mm).

3.3.1. Domestic vessels

Burnishing traces on pottery vessels used in settlements populated during the second half of the 4th millennium BC revealed the association of this technique with all of the vessel shapes used in household environments, such as cooking pots, narrow-neck vessels and cups. Based on traceological analysis, hard tools and soft tools were used to refine clay surfaces. Vessels such as cooking pots were completely or, in some cases, partially rubbed using a tool with a functional hard edge, leaving more or less evident batches of striations (Fig. 12b).

Partial rubbing produced the characteristic polish/matte effect. Based on the few cases of narrow-neck vessels unearthed from the settlements and the cups, they were always refined with covering burnishing. In some cases, the treatment was applied by rubbing the surface at a dry stage with a functional hard edge, leaving parallel and overlapping batches of striations. However, this stage was occasionally followed by a brightening using a soft tool (Fig. 4). The comparison of archaeological and experimental frameworks led to the identification of wool as the soft tool largely used solely by the communities that settled in this area during the second half of the 4th millennium BC and not identified for the following productions. Multiple isolated striations can be left by animal fibres that are naturally rich in grease and that enable the tool to shift on a surface and avoid abrasive processes (Fig. 12a). The study of these vessels revealed a low effect of smooth burnishing and a high incidence of rough burnished surface variables with a degree of roughness. In these cases, the roughness of the treatments derives from the combination of two technological choices. This ceramic production was almost completely obtained by a local clay used in a semi-fine or coarse granulometry affecting the superficial topography. Moreover, the tools used for treatments were hard tools that produced visible batches of striations combined with wool, leaving the characteristic overlapping striations (Fig. 12a). Skilled gestures were identified in limited cases of the rough burnishing application in which the texture is considered rough due to the multiple wool macro traces visible on the surface that occasionally occur on a flat topography. This identification suggests that regularisation processes before burnishing required accuracy and sufficient time to smooth out irregularities from building techniques and asperities corresponding to the superficial temper (e.g., Figs. 7a-b and 10c).

The burnishing techniques identified in settlements populated by the Copper Age groups during the entire 3rd millennium BC suggest the use of tools with hard-functional edges (Figs. 4 and 12b–d) that leave characteristic batches of striations. The majority of the domestic production of cooking pots was refined through a non-covering burnishing (Fig. 12b). The experiments showed that this type of treatment is due to continuous but partial rubbing, leaving multiple but unconnected traces. The final result is a treatment with sinuous or uneven topography (depending upon the accuracy of the previous surface treatment) and rough texture due to irregularities of the functional edge used. Based on the experiments, a rough morphology of cooking pots led to the exclusion of the use of added substances during burnishing or additional refining steps through soft tools (leather).

Clear differences in treatment applications were identified on small vessels such as bowls, usually decorated by a comb. This class, particularly during the second half of the 3rd millennium BC, featured a smooth burnishing showing many similarities with treatments identified on funerary vessels. A comparison with the experimental replicas led to the hypothesis of an intervention on dry surfaces (waiting for the right time of intervention) that were previously well refined and then rubbed with hard tools (Fig. 4) with polished functional edges. The brightness and macroscopic homogeneity of some vessels does not exclude the use of lubricant substances during burnishing or light final rubbing by extremely soft leather. These treatments clearly suggest not only different technological choices (e.g., depurated clay pastes and surface preparation before burnishing) but also skilled manufacturing expertise with regard to embodied technological steps and apparently easy gestures (e.g., rubbing) applied correctly (measuring pressure and speed) at the right stages of the *chaîne opératoire.* These aspects are inferred from a detailed analysis of the recurring flat topographies that often lack evident tool traces.

3.3.2. Funerary vessels

Vessels used in funerary contexts of the late 4th millennium BC show no differences in shape or technology of drinking vessels when compared with similar vessels found in coeval settlements. Indeed, the contemporary funerary contexts (e.g., Torre della Chisaccia) yielded a number of narrow-neck vessels (*askoi* and jugs) and cups of different sizes (Fig. 2). The traceological analysis led to the identification of the use of hard tools and soft tools occasionally combined for refining clay surfaces. All vessels feature covering burnishing, such as smooth surfaces rubbed with hard tools and surfaces brightened with a soft tool identified as wool based on the experimental traces (Fig. 12a). Skilled manufacturing can be hypothesised based on the same technological features observed in some vessels used in settlements. A rough texture due to homogeneous wool use is associated with flat topographies that were previously accurately refined (Fig. 12a). Moreover, these vessels show considerable accuracy in the symmetry of shapes and homogeneity in the rough burnishing application compared with the entire analysed domestic production.

Different variables suggesting multiple levels of skilled behaviours were identified in burnishing treatments applied to the funerary assemblages, such as narrow neck vessels (flasks), bowls or biconical vessels, frequently found in funerary contexts from the early 4th to the 3rd millennium BC and attributed to a different ceramic tradition (see Fig. 2). Vessels used as grave goods were refined through treatments of both rough and smooth burnishing, with a clear preference for the use of smooth burnishing as the final treatment of the narrow neck vessels (flasks) and, in rare cases, bowls and biconical vessels. The application of these treatments was repeatedly and intentionally associated with a reducing firing atmosphere to obtain the effect identified in the small vessels, such as comb-decorated bowls, found in settlements and attributed to skilled manufacturers. Although the use of rough treatment apparently prevails, an accurate, qualitative analysis of the connected traces indicates a higher degree of accuracy that is not observed on the rough surface burnishing associated with most of the cooking pots (Table 3) (see Fig. 12a-b). The traces left by tools are usually light. As identified for some bowls found in coeval domestic productions, the vessels were intentionally and accurately refined with homogeneous treatments applied on almost dry surfaces to produce the correct topography for a final homogeneous burnishing application. The vessels, previously well smoothed until they reached flat topographies, were rubbed with hard tools, leaving light traces (Fig. 12e). In this case, the shiny effect associated with macroscopic homogeneity cannot exclude the use of lubricant substances or light conclusive rubbing with extremely soft leather (Fig. 12f).

4. Discussion

The integrated analysis recently applied to the pottery produced by Copper Age communities suggests differences in the operational sequences and skills involved in the production of domestic pottery and vessels used for rituals.

The study focused on surface treatment traces, confirming variations in the technological choices of production and technical behaviours within coeval ceramic traditions transmitted among communities that settled in the area of modern Rome between the 4th and 3rd millennia BC.

The comparison between the technology and the use of ceramic vessels and the study of ritual practices support the hypothesis about the existence of a social environment able to sustain the development of craft skills that were intentionally transmitted and strengthened over time between people involved in ceramic production. This study explains how some vessels during this period were burnished with a high level of skill. The development of a specialised expertise can be inferred by the repetition of a clear *chaîne opératoire* that appeared as a planned sequence of stages intentionally employed in their work. For example, the choice of selected and well-purified clay pastes was associated with experience in waiting and recognising the right moments to intervene on a surface by properly applying burnishing. This expertise developed because craftspeople had direct experience of the properties of raw materials and knew the variety of technological traces derived from the combination of specific tools on specific clay surfaces. For this reason, studying the variation of topographies of clay surfaces and textures of burnishing treatments on archaeological and experimental items suggests that any variation of results was due not only to a technological choice but also to the ability, knowledge and role of the potter.

Systematic and analytical observations of both collections led to the identification of which features of a surface may be related to a skilled gesture learned by prolonged repetition until it produced a habituated skill. For this reason, analysing the topography and texture of a treatment can be useful to understand the technological choices (the overlapping of specific technical interventions), movements, pressure and efficacy of a human gesture.

The aspect that distinguishes the quality of manufacturing in the burnishing application is the degree of roughness, particularly on coarse and semi-coarse clays. This roughness, observed during the experiments, can usually be reduced with an accurate preparation of the surface before reaching the dry-leather stage (see Table 3). Variable techniques of surface preparation can be identified in beating (e.g., using a wooden paddle) or smoothing the wet surface with a spatula and adding water. These techniques enable the homogenisation of the surface, pushing the surfacing largest grains in deep or dissolving the finest clay grains until a superficial coating[3] is produced and a diffused homogeneity is reached. Vessels featuring a covering burnishing with a low degree of roughness are usually associated with indicators of skilled behaviour as demonstrated by the symmetry of the vessel shape and the regularity and thickness of the walls (Roux, 1989; Wallaert-Pêtre, 2001; Crown, 2014). These abilities were achieved by dedication combined with technical knowledge first acquired through an apprenticeship and strengthened over time by practice.

The experimental framework provided a comparison collection for understanding the variety of treatment traces in the analysed productions and showed how specific and highly refined burnishing was applied on funerary vessels such as flasks or on some bowls in fine clay found in settlements. Both of these types are associated with a reducing firing atmosphere, a process that leaves black or dark-brown shiny surfaces. This result, based on the experiments, has likely been enhanced by the extremely fine granulometry, which was intentionally selected and enabled the preparation of surfaces before rubbing. The expertise of the potter, after the building stage, consists of smoothing the clay, thereby removing any anomalies left by the forming steps. The experiments suggest that every tool, regardless of its nature, can leave traces due to the morphology of its functional edge. Morphology in this case refers not only to the shape of the entire edge but also to the macro and micro imperfections on the surface (see Rodríguez Rodríguez et al., 2017). Experimental tools used for burnishing left batches of striations due to the macro and micro striations on the tool's functional edge (Fig. 9). These striations are caused by a repeated use of the edge on clay surfaces at different hygrometric stages or granulometry. Particles of a dry clay can be responsible for abrasive wear (e.g., striations) along a tool's functional edges.

The absence or low incidence of traces left by a tool on archaeological vessels can suggest a specific level of knowledge and expertise. Both of these were most likely acquired in a social environment, such as the domestic environment, that supported the acquisition of notions concerning raw material management, recipes and their association with vessel shapes. The repetition of specific associations of clay pastes in vessel shapes over time (e.g., coarse clay with volcanic rock fragments and grog for cooking pots and fine clay for narrow-neck vessels used as grave goods) was most likely due to functional needs, such as the use of refractory clay recipes for food processing, fine clay recipes with low porosity for vessels intended to contain liquids, and the diffused application of burnishing, regardless of accuracy, to strengthen the vessel and reduce its permeability (Martineau, 2010; Lepère, 2014; Forte et al., 2018). At the same time, functional needs could be affected by cultural or social aspects such as location of sourcing areas (see Arnold, 2000) or the system of knowledge transmission associated with the prevalent economic system of the production and distribution of vessels (González Urquijo et al., 2001).

A number of human behaviours have been identified with regard to different activities involving ceramic vessels and the recurrent association between specific vessel shapes and the quality of their manufacturing. Different expertise levels have been observed, particularly when comparing the technological features of funerary vessels and cooking pots used in the household environment. For example, frequent variations in wall thickness in a single vessel, asymmetry of the entire shape or repeated anomalies of the building phase visible on surfaces suggest that underlying domestic production was frequently a basic expertise in pottery manufacturing that was usually associated with fast work due to lack of time or interest in obtaining a functional and not necessarily well-refined object (Forte, 2014). Based on the experimental results, the archaeological cooking vessels analysed usually feature rough burnishing and are fired in a mixed atmosphere, causing a high variability of colours. This type of production, most frequent in domestic vessels dated to the 3rd millennium BC, features rough burnishing techniques with evident batches of striations occasionally associated with light striated grooves suggesting an intervention on vessels with surfaces at different hygrometric stages. The rubbing on dried areas left flat batches of striations, and the treatment on leather-dry areas affected the clay, leaving more invasive traces such as light striated grooves (Fig. 12b).

The variety of expertise in vessel manufacturing is clear from the observation of domestic vessels, particularly when compared with vessels used in funerary contexts. However, the communities that settled in the Rome area showed different ritual behaviours. The Copper Age groups that settled in the area in the last part of the 4th millennium BC used as grave goods a class of vessels largely documented in settlements in everyday life. This correspondence has also been observed in the manufacturing technique used, with particular reference to the use of the same clay pastes and burnishing features (e.g., hard tools + wool). The funerary vessels analysed show an expertise beyond the skills involved in the modelling of an open vessel with a flat base and suggest the acquisition of motor skills leading to successfully developing complex shapes and refining the entire surface without mistakes (e.g., narrow-neck vessels such as *askoi* and jars). The presence in the Copper Age communities of a social environment that supported skill development in selected pottery production is primarily suggested by the narrow-neck vessels, called flasks, unearthed from funerary contexts dated to the 4th and 3rd millennium BC. The absence of these shapes in domestic contexts, except for a few potsherds in contemporary settlements (e.g., Osteria del Curato-Via Cinquefrondi), leads to the hypothesis that these funerary vessels were produced for use in ritual and funerary occasions by the same coeval communities that settled in the Rome area during the 3rd millennium BC (Anzidei et al., 2012, p. 210). This hypothesis can also be supported by the raw material exploitation strategies and their selected use for specific vessel shapes such as coarse pastes for cooking pots refined with rough burnishing treatments and fine pastes for narrow-neck vessels refined with smooth burnishing. The technological features of smooth burnishing used for refining funerary vessels show high compatibility with the surface treatment applied to domestic bowls that were produced

[3] The analysis of ceramics from the Rome area led to the exclusion of the application of coating clay before burnishing.

with fine-grained paste and often fired in a reducing atmosphere. The low effect of smooth burnished surfaces in the archaeological sample studied (Table 7) and its association with shapes that were not directly involved in food processing but that recur in the funerary context lead to the hypothesis of an association of such shapes with a limited but socially recognised skilled manufacturers.

5. Conclusion

Based on the traceological analysis of surface treatments applied by craftspeople to Copper Age vessels used in households and burials in the area of modern Rome, a diversification of craft figures has been hypothesised in association with different degrees of practical skills and technical knowledge.

The presence of multiple levels of skills in prehistoric craft productions is expected to be but is not always directly associated with an intentional process of apprenticeship recognised by the community. Indeed, the *household production* model recognises the craftsperson as an *amateur* able to produce simple functional vessel shapes with variable raw materials that are usually subject to a high internal variability. The *household industry* model similarly recognises personal production distinguished by the same technological features as the *household production* model but distinguished by a higher level of skill expressed by a semi-formalised activity. This differentiation does not properly consider the social value of the object produced and then circulated inside and outside the community in a context such as the Copper Age, in which a market economy in association with some ethnoarchaeological cases of *household industry* had not yet replaced an exchange economy. The production discussed in this article, particularly the pottery used as prestige grave goods (Miari, 1994; Negroni Catacchio, 2011), could reflect the emergence of craftspeople who most likely acquired their practical skills and technical knowledge through an apprenticeship carried forward within the village community. This apprenticeship was not formalised as a workshop system but intentionally transmitted, particularly for producing complex vessel shapes. An example is the narrow-neck vessels used on ritual occasions associated with burials but not always in direct connection with specific individuals, as suggested by the presence of a few isolated vessels found in multiple depositions and lacking direct connections to specific buried people (Miari, 1994; Negroni Catacchio, 2011). The majority of these shapes had a low impact on the domestic assemblages and were associated with raw materials selected for composition and granulometry, forming techniques not identified in cooking pot technology, highly refined surfaces and specific firing techniques used to achieve black-shiny surface effects (Forte and Medeghini, 2017). As this article explains, the knowledge (that is, the sequence of correct steps), dedication (time to work) and skill (ease of gesture reproduction and the capacity to rectify gestures) can be observed through the lack of mistakes or anomalies on pottery vessels, reflecting the ability of the potter to recognise the properties of the raw material and work on it using the most effective approach to produce a functional, well-refined object (Bleed, 2008; Sennett, 2008; Kuijpers, 2017). Differences between skilled and unskilled people are easy to observe in large productions in which well-made vessels are distinguished by their symmetry and roughness of surfaces. Independent of the presence of a more or less developed market economy, the technological features of vessels associated with the actual use and supposed social value of a pottery production can be considered indicators of a system of knowledge transmission supported by some members of a community through which the production of ceramic vessels, often used as prestige goods, continued. This article proposes a definition of this type of production system as *household specialisation* based on the emergence of figures through a long and intentional apprenticeship system involving a limited number of people in the group obtaining specific skills in ceramic production that were not achieved by the rest of the community. Their role as potters was socially recognised as having specific abilities, and the amount of time needed to obtain well-refined vessels usually coincided with objects recognised for their high symbolic meaning due to their involvement in shared social occasions (e.g., funerary rituals). Developing knowledge of such a system of production, including other aspects of the *chaîne opératoire,* can enrich our understanding of processes that led to forms of diversification between “skilled figures”, as prehistoric potters in the literature are usually defined, and the commonly accepted “specialists” as institutionalised figures performing novel tasks.

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