# From standard pots to potters' standards

*An integrated approach to ceramic standardization and change in Archaic Satricum (6th–4th century BC)*

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**Publication date**
2024

# Chapter 4
# Analytical Methods

*This chapter illustrates the main tenets underpinning the analytical methods applied to this work. The first section starts off with a brief overview of the major lines of inquiry currently addressed in pottery studies, moving then to the specific challenges and questions posed by the New Perspectives on Ancient Pottery (NPAP) project, within whose theoretical framework this research was developed. The second section of the chapter revisits the multiple levels of analysis commonly adopted to assess ceramic standardization and variability, with particular reference to sampling strategies, choice of variables and analytical techniques. The final section delves into the analytical methods applied to measure both metric and technological standardization for the ceramic assemblage under review here, from statistical analysis (coefficient of variation) to fabric characterization (macroscopic analysis, thin section petrography, geoprospection and raw materials description).*[367]

## 4.1 Of pottery, people, choices and archaeologists: Current lines of inquiry in ceramic studies

In current scholarly work, ancient pottery is commonly viewed as a component of material culture that holds valuable insights into the dynamic interactions among communities or individuals and into their involvement in production, consumption and distribution practices. Consequently, it can provide new perspectives on various aspects of past human behavior, such as political, socioeconomic and cultural relationships, as expressed through material things. The study of pottery in archaeology should not only focus on the intentional/mechanical choices made by makers and users but also consider the mechanisms that influence and are influenced by the decisions of all parties involved within specific sociopolitical, economic and ideological contexts.

Researchers have explored several methodological approaches to gain a deeper understanding and interpret the processes underpinning ceramic manufacture, consumption and discard.[368] While it is not an exhaustive list, the following research avenues represent two prominent traditions in pottery studies: the typo-morphological characterization of ceramic objects (including variations in vessels' forms, shapes, decorative styles and surface treatment) and the study of technological practices drawing on the known notion of *chaîne opératoire*, which is often interpreted differently by scholars. Due to the importance of this concept in the current study, I will provide a brief overview of the significant advancements it has experienced since its initial conception up to its latest understandings.

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367 In this chapter, part of the discussion concerning the contribution of a *chaîne opératoire* approach to pottery studies (section 4.1) has been previously published in Revello Lami, M. 2021, Fluctuation and Stability: Materialising Technological Knowledge among Satricum Potters, in M. Gnade & M. Revello Lami (eds.), *Tracing Technology: Forty Years of Archaeological Research at Satricum*, Louvain, 129–144.

368 Hunt 2016.

Conventionally referred to as *chaîne opératoire*, the concept was first outlined for archaeology by Leroi-Gourhan in the 1960s and applied to the study of Paleolithic technology in France. In his formulation, technology is intended as a "total social phenomenon," where any technological activity is constituted within an influential social and historical context; thus, both realms cannot be analyzed in isolation. When humans create and transform the physical world, they are also creating and transforming themselves. The recognition and analysis of every stage along an operational sequence "becomes therefore relevant, since it provides information about the subject of that action and, moreover, about the society within which the given action is inscribed."[369] From this starting point, the notion of *chaîne opératoire* and its many interpretations is capable of merging opposing epistemologies, such as deterministic and humanistic approaches to the study of the material record. Even in its narrower sense of "a series of technological operations which transforms a raw material into a usable project,"[370] *chaîne opératoire* entails a shift of scholarly attention from the examination of the end product to the process of manufacturing. Previous approaches to technology revolved mostly around the description of ancient tools in order to address issues related to their dissemination through time and space (diffusionism/evolutionism) or to explain the laws of human adaptation to the environment. The spotlight was on the object, while the particular human activity that had originated it was completely missing from the picture. In contrast, the notion of *chaîne opératoire* emphasizes every step, and every choice, of toolmaking. The object of study therefore becomes a longer sequence instead of just one item, thus enhancing the possibility of obtaining more accurate reconstructions of ancient technological systems. Following the works of Sellet, Grace, Sillar and Tite, it is now widely agreed that this conceptual chain does not end with the realization of the manufactured product but ends when the artifact is finally discarded after different uses and reuses.[371] The target of attention lengthens further, and the analysis extends to the whole life cycle of an artifact and its interaction with the community that produced and used it. Along this ordered sequence of actions, gestures and instruments, the agents leading the transformation of a given material toward the manufacture and use of a product through a series of recurrent and predictable steps move to center stage. The two latter components (the relevance of the agent and the degree of predictability of a project) are key topics in assessing technological knowledge. Reconstructing the operational sequence reveals the technical choices made by the individuals in a group, thus enabling the characterization of the technical traditions within a social group.



Over the last three decades, the *chaîne opératoire* ceased to be simply an object of study and became an approach, an interpretative methodology "capable of forging robust inferential links between the material patterning of technical acts and the sociopolitical relations of production accounting them."[372] This approach entails the application of a wide range of analytical techniques, ranging from those borrowed from the hard sciences in order to identify the physical factors influencing the manufacture, shape, use and discard of an object to those grounded in anthropology, ethnography and social sciences in order to identify the cultural factors determining the technological action and charging the resulting end products with meaning. In this light, the dynamic enactment of the technical process takes place

369 Martinón-Torres 2002, 30.
370 Cresswell 1990, 46.
371 Grace 1996; Sellet 1993; Sillar & Tite 2000. A recent overview can be found in Maldonado 2018, 13-16.
372 Dobres 1999, 124.

in connection with static concepts or sets of rules, but it goes beyond the simple interaction between knowledge and skill. The focal point is recognizing that the interaction between the technical gesture (the manner of carrying the body) seats at the confluence of the mind, body, social and material world. Moving from the detailed description of the sequence of motions performed by a potter to shape the rim of a jar, to the more universal narrative of the choices made by a community when it comes to the acquisition of raw materials or the style of a decorative pattern, a *chaîne opératoire* approach enables archaeologists to go beyond the redundancies of the material record and look at the system of values and beliefs that individuals share when shaping and using the material world.

In short, to fully exploit the potential of the theoretical framework defined above, it is crucial to integrate and mend the different interpretations of *chaîne opératoire* known in literature, which can be briefly summarized as follows:

The more conservative one that examines economic and ecological considerations in close connection with technological aspects, viewing culture still as an 'extrasomatic means of adaptation'.[373]

The one centered on the notion of materiality and the biography of objects, often linked, or juxtaposed with materials' science methodologies.[374]

The social technology approach, examining techniques not just as a series of technical actions related to function, economy and environment, but also, as complex practices that encompass social and ideological systems underlying the production, circulation, and consumption of pottery at different scales (from individual producer to micro- and macro-community levels, inter-community or regional contexts).[375]

These differences in approach highlight the urgent need for close collaboration between archaeologists, either working in the field or processing excavated and/or collected materials, and materials' scientists mainly operating in laboratories. Establishing a shared communication protocol that provides robust conceptual and operational tools is crucial for current researchers to cross traditional disciplinary borders, enhance the integration of diverse ideas and methods, thus leading to a more comprehensive perception and understanding of archaeological inquiries concerning any material under examination.

When studying ceramic assemblages, particularly those requiring advanced analytical techniques, it is widely accepted that scholars should follow a methodological approach that starts with simpler tools and progresses to more sophisticated ones.[376] This "bottom-to-top" progression is particularly important when dealing with assemblages that have not been previously analyzed, either on a macroscopic or a microscopic level.

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373 Binford 1965, 209; Gosselain 1998; Roux 2003.
374 Boivin 2004; Gosden & Marshall 1999; Jones 2002; Sillar & Tite 2000.
375 Dietler & Hebrich 1998; Hegmon 1998; Dobres 2009; Kohring 2013.
376 Peacock 1977.

More practically—as amply discussed in the previous chapter—the classification of assemblages into consistent and identifiable categories typically revolves around parameters such as ware (including any given surface treatment and/or decoration), fabric and shape. The choice of parameters depends on the nature of the material under investigation and, most importantly, the research questions being addressed.[377] By simultaneously considering these parameters, meaningful interrelationships within a pottery assemblage can be revealed, suggesting coherent patterns related to production technology, mechanisms of consumption and rejection, and intrasite or regional circulation of both artisanal practices and final products. Ideally, a comprehensive understanding of potting traditions should involve a combination of all aforementioned parameters.

However, such an integrated approach relies on having well-preserved and reasonably fragmented ceramic assemblages that allow for the sound detection of surface treatment, decoration, and shape from just sherds. In cases where ceramics are heavily weathered and fragmented, typically encountered during surveys or excavations at ill-preserved sites, a fabric-based classification coupled with further study at the assemblage level should be regarded as the most appropriate approach.[378]



Fabric characterization, as part of a broader analytical methodology, is normally carried out at two different scales: macroscopic (hand specimen) analysis, usually performed in the field, and the more advanced optical microscopy (thin section analysis), generally conducted in a laboratory, unless the necessary equipment is available on-site.

### 4.1.1 From types to samples: Unlocking potters' and consumers' choices through ceramic analysis

The study of pottery has long coincided with the study of vessels' form and decoration—where present—to build seriations based on morphological features. Already in the 19th century, scholars began to apply the same taxonomic approach used in the natural sciences to organize archaeological artifacts according to types in an attempt to cope with the sheer quantities of pottery produced in the multiple excavations dotting Europe and the Mediterranean. The resulting type series in connection with stratigraphic sequences provided a crucial dating tool, turning typologies into a staple of any archaeological approach to artifacts analysis.

Although the term "type" was given subtly different meanings—the definition of a "typical" pot could refer to its shape, manufacturing technique, decoration, fabric composition etc.—they all entailed the idea of development over time, usually from simple to complex, and could therefore be used to reinforce chronological sequences. However, the risk of such an interpretation of "type" becoming a circular argument has since been discussed at length: it is now widely agreed in fact that the notion of typology should be reserved for a "theoretically oriented" classification system created to address specific research questions.[379] Typological categories are essentially human inventions designed not just to conveniently systematize the material world but also to facilitate our understanding of it. As Barret rightly argued

377 Hitsiou 2003; Joyner 2007; Kiriatzi 2003; Tomkins & Day 2001; Wilson & Day 1994, 1999.
378 Broodbank & Kiriatzi 2007; Kiriatzi 2003; Whitbread et al. 2007.
379 Dunnell 1971; Hill & Evans 1972; Rice 1987, 283.

in the 1990s, the categories created by a specialist to record an archaeological assemblage did not make any sense to those who actually designed, manufactured and used that material.[380] This argument is crucial to consider when developing and interpreting a chosen typology for pottery. The classes that originate from any classificatory effort need to be considered as conventional analytical tools created to aid macroscopic examination, rather than being inherently meaningful to the producers and consumers of these ceramic artifacts.

Along the same lines, Kotsakis argued that every typological system, with its advantages and limitations, can be effectively used as interpretative tool only by the specialist who developed it, while keeping in mind the specific archaeological questions they seek to investigate.[381] Therefore, any new typological system, even if it partly draws on existing ones, should be tailored to the particular themes that the researchers analyzing the material wish to investigate. Even though they are devised to address specific questions, typologies need to meet some basic requirements to validate their development process. The first two pillars of a robust typology are its verifiability and replicability, which enable any archaeologist to identify the same types by examining their main visible characteristics.[382] Second, a sound classification should be organized in a way that allows for statistical analysis. In fact, if the variables and typological characteristics identified in a ceramic assemblage demonstrate some sort of correlation, meaningful patterns for interpretation may emerge. Additionally, a typological model should be flexible, open to including new material when needed and fit it into the already established categories. Last, when selecting the criteria based on which to develop an appropriate typology, it is fundamental to keep in mind that archaeologists mostly work with hundreds of thousands of sherds and not complete vessels. For instance, in case of very fragmented material objects, capacity would not be a viable choice to build a sound typology.

The study of ceramic assemblages of any chronological period intended for petrographic or any other scientific analysis, whether restricted or at a larger scale, typically involves examining selected bodies of the material based on purely archaeological criteria and the issues to be addressed. In the case of petrographic analysis, the examination of pottery usually entails multiple levels of analysis, as described below:

- Typo-morphological analysis: This step involves macroscopic examination of a sufficient and archaeologically meaningful fraction of the estimated total assemblage (usually around 20–25%). The sample can derive from either “closed” contexts (a burial) or activity areas/phases selected based on the main research questions and aims of the project and the different scale of analysis taken into account (intra-/intersite, regional). This process results in a coherent classification that serves as an efficient analytical tool to study pottery in all or some of its aforementioned parameters/attributes (ware, fabric, shape).
- Selection of representative samples: A number of representative samples are chosen for further materials analyses. These should encompass the whole range of pottery types recorded in the

380 Barrett 1991, 204.
381 Kotsakis 1983.
382 Rice 1987; Sinopoli 1991.

first step of analysis, including variations in surface treatment, decoration, fabric and shape (if applicable). The selection procedure should always be guided by the central research questions, the nature of the studied assemblage and any practical limitations encountered during the sampling.
- Petrographic analysis: The representative samples selected on the basis of the already established macroscopic fabric groups are then analyzed petrographically. This stage evaluates the validity of the macroscopic fabrics and may lead to merging or further dividing them.
- Refiring tests: these tests are conducted to explore the effects of firing on the colors and compositions of clays, helping identify homogeneous or inhomogeneous variations.
- Examination of the geological deposits in the vicinity of the investigated areas: This step serves as a proxy to assess the compatibility of raw sources with the geological composition of the ancient ceramics. Geoprospection provides important insights into the provenance of raw materials used.
- Experimental study of modern soil, clay and other organic and inorganic materials: This stage entails conducting experiments using modern raw sources to replicate ancient clay recipes. It also helps establish connections between the modern geology of the area and the ceramic artifacts produced by past communities, facilitating comparative analysis.
- Petrographic analysis of chronologically compatible material: This stage entails the petrographic study of material that aligns with the chronological context investigated. The results serve as reference data for comparative purposes, providing a more complete interpretation of the assemblage under study.
- Chemical analysis: The representative samples selected based on the already established petrographic fabric groups are then analyzed chemically through one (or more) of the many methods at our disposal today. This stage evaluates the validity of the petro-groups and provides a qualitative or quantitative determination of the microcomponents used in the clay paste or in the layers added on the surface of a ceramic object.



The analytical stages described above encompass the notion of ceramic petrology as defined by Ian Whitbread in the mid-1990s, building on the experience of the UK-based Ceramic Petrology Group, founded by Middlestone and Freestone in the 1980s, and further codified by P. Day's work group based at Sheffield and the numerous petrography fellows working at the Fitch Laboratory of the British School of Athens from the late 1980s until the present day.[383] When used in conjunction with other appropriate analytical techniques relevant to the research questions addressed, they significantly contribute to our understanding of technological practices, preferences and conscious and unconscious choices involved in the production of ancient pottery. At an empirical level, all the above stages form the *chaîne opératoire* of a ceramic specialist,[384] supplying a feedback system that makes it possible to control and reassess the output resulting from each stage and ultimately generate new inputs (Figure 52).

383 Day 2014; Middleton & Freestone 1991; Quinn 2009; 2013; Whitbread 1995. A detailed history of the Ceramic Petrology Group can be found in Quinn & Freestone 2017.
384 Expression borrowed from J. Hilditch's apt formulation (Hilditch 2015, lecture Practical in Mediterranean Pottery).

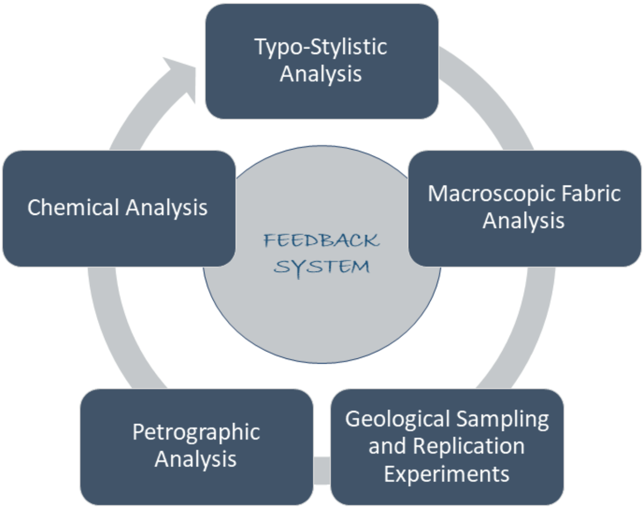


**Figure 52.** A ceramic specialist's ideal feedback system based on Whitbread's analytical stages.

However, using all stages listed above is not always possible, but the system can be—and must be—adapted to suit both the material under study and the practical constraints of a given project. In this sense, the different case studies lying at the core of the New Perspectives on Ancient Pottery (NPAP) project provided a perfect testing ground to assess the flexibility and efficacy of such a multilevel analytical system, which proved to be a valuable tool to bridge the gap between different scholarly traditions in pottery studies.

## 4.2 Integrating different traditions in pottery studies: The NPAP framework

As briefly mentioned in the introduction, this work stems from the wider NPAP research project, based at the Archaeology Department of the University of Amsterdam.[385] The Satricum project, directed by prof. Marijke Gnade, is one of NPAP's main study areas and largely contributed to laying down the foundations of the project.

The NPAP project was launched in 2007 by the Amsterdam Centre for Ancient Studies and Archaeology (ACASA) and funded by the Utopa Foundation and the University of Amsterdam. The project ran for seven years under the direction of prof. V. Stissi and had at its core the study of large bodies of pottery from three different archaeological fieldwork projects: excavation at ancient Satricum, Italy; survey and excavation on the island of Zakynthos;[386] and survey and excavation around ancient Halos, the latter

385 For an introduction to the project, see Stobbe et al. 2008.
386 See most recently on the Zakynthos project van Wijngaarden et al. 2013, 2014, 2017.

two in Greece.[387] The wider scope of the project revolved around the methodology applied to the study of archaeological ceramics, promoting as best practice the combination of different traditions in pottery research. To this end, great effort was put into the search for and implementation of better and faster strategies for recording finds with electronic databases as well as integrating into these data systems direct possibilities for producing meaningful pottery classifications that go beyond traditional typo-chronology and include as much as possible material generally labeled as "nondiagnostic." Such material is often stacked away in storerooms as an archaeological archive that might or might not be studied in some future. The main reason why storerooms are usually the final destination of nondiagnostics is that they come in masses—sherds especially—and studying them would require a major time investment. Taking this legacy data out of the storerooms was one of the great challenges of NPAP, which entailed finding ways to speed up the processing while at the same time paying attention to those aspects that bring the nondiagnostic to the fore as a meaningful material category.

This research was one of the six PhD subprojects included within the scope of NPAP, investigating current issues in Mediterranean pottery research, with each study forming a unique combination of theories, techniques and methodologies. To supplement the empirical research, the research undertaken by senior project members focused on bridging traditional boundaries based on period and region across the three sites under study—Satricum, Halos and Zakynthos—as well as reviewing "operational" aspects of the project, including integration of digital databases and fabric analysis. This combination of innovative approaches, applied at various scales of analysis, aimed to generate new perspectives on ancient pottery that offer the greatest potential for archaeological interpretation.



All case studies within the NPAP project used as a starting point two broad but complementary themes common to ancient pottery studies:

- *From far or nearby?* The relationship between imported and locally produced pottery in different find contexts and periods.
- *Does function follow form?* The correlations between different wares, fabrics and shapes and the contexts in which they were used.

These broad themes invited a range of more sophisticated research questions that have been applied within the individual studies and the NPAP project in general.

Since its inception in 2007, significant progress has been achieved within the NPAP project, not only with respect to the elaboration of the research questions within the two broad themes but also in physical terms, regarding the quantity of pottery processed and studied. All of the chosen NPAP assemblages have been systematically investigated using an integrated program of geological prospection, macroscopic and petrochemical analysis to elucidate behaviors or choices within the production sequence, from raw material exploitation to eventual deposition of finished vessels. Crucially, for most NPAP case studies, these results constitute the first systematic investigation of potting raw materials and production units

387 See most recently on Halos Stissi 2012, 2016; Stissi et al. 2018–2020. About the history of research in Halos, see Dijkstra et al. 2017.

for the areas under study and will provide a valuable foundation for future analytical and archaeological work in these regions.

The following section highlights the development of research questions within the NPAP case studies and gives a summary of the practical achievements to date.

### 4.2.1 From far or nearby?

Establishing precisely what comes "from far or nearby" requires a deeper understanding of many interlocking issues, for instance, the definition of "local" and "import," what constitutes a "local" pot or how to characterize local vs. nonlocal ceramic production traditions. Rather than interpreting this theme as purely concerned with provenance issues, the NPAP case studies draw on recent debates within archaeology on the socially embedded nature of material culture to expand on the concepts of production, distribution and consumption of ceramic assemblages.

Characterizing technological and compositional parameters for "local" pottery is critical for investigating more sophisticated research questions, such as the distribution of local and imported fabrics within a single "analytical unit," transmission and learning of technical knowledge across interaction networks or verifying the validity of current analytical frameworks for assessing technical standardization and ceramic variability, such as the case of the present study. For instance, the program of geological sampling and experimental replication of raw materials carried out in the vicinity of Halos provided an invaluable comparative dataset for establishing exploitation of locally available raw materials and noncompatibility of imported pottery with respect to mineralogical and elemental composition.[388]

As a necessary corollary to local production activities, the distribution and consumption of ceramics have also been addressed across a variety of contexts traditionally studied from a consumption-driven perspective, such as household assemblages, votive deposits and cremation burials. In all cases, the NPAP project's methodology encouraged the study of complete assemblages using an integrated program of macroscopic fabric and typo-stylistic analysis to maximize the quantity and quality of ceramic datasets in which local and imported material can be assessed in a meaningful way. In this way, the character of traditional consumption contexts can be deconstructed with respect to production and distribution activities and reinserted into holistic site interpretations.

Another benefit of seeking to differentiate multiple types of ceramic-related activities is the potential for deconstructing much larger-scale changes in material culture patterning at the three study areas encompassed by the NPAP project. All the case studies seek to question the dynamics of these phenomena through the characterization of production, distribution and consumption activities, relating changes in social behaviors to the movement of pots, people and ideas across the ancient landscape. The broad diachronic occupation of Halos, Satricum and Zakynthos, from the Neolithic to Hellenistic/Early Republican periods across Greece and Italy, has inevitably witnessed major social, economic and political

388 Rückl & Jacobs 2016.

changes, and many of the case studies seek to try and understand these changes in relation to observed patterns in the ceramic record.

Central to any study of larger-scale processes is the continual definition of boundaries, be they technological, social or political. Within the NPAP project, several studies tackled the issue of boundaries from a ceramic perspective, all founded on establishing "local" practices/activities through integrated fabric characterization and typo-stylistic analyses. Defining the geographical extent or sociotechnical boundaries of the local pottery-producing practice is crucial for investigating the mobility of craft knowledge, the distribution of particular ceramic "styles" and how these local pottery-producing communities responded to wider regional interactions or the dynamics of political expansion. The relationship between material-culture patterning and social interactions has also been studied from a multiscalar perspective by mapping sociotechnical boundaries onto physical or "natural" boundaries, such as survey sites within an island or indeed the island itself.

### 4.2.2 Does function follow form?

This question, echoing the modernist dictum "form follows function" (FFF),[389] raises the wider theme of the relationship between ceramics from various find contexts and the development of these connections over time and possibly across regions.[390] As mentioned above, the NPAP methodology promotes the study of entire assemblages so as to bring these complex relationships between different vessel types to light. For instance, new perspectives can be applied to votive deposits to try and discover if past meanings or values can be reconstructed from the choices of vessels being deposited. At Satricum, all the ceramic contents of the Hellenistic votive deposit, from fine ware sherds to coarse ware vessels, are being studied alongside other Hellenistic settlement contexts to characterize the relationship between conspicuous consumption and local production traditions.[391] Likewise, the relationship between forming technique, typology and fabric has been investigated within the ceramic assemblages recovered from the Iron Age huts unearthed on the acropolis.[392] Are particular forming techniques linked to specific vessel forms, general categories of function or even perceived value? In a related vein, my study of the Archaic assemblage from Satricum provides a valuable opportunity to assess whether particular vessel shapes are more susceptible to standardization over time. Are standardized shapes indicators of specific social status, resistance to wider regional shifts in material culture or changes in the organization or technology of pottery production?

Concepts such as value and meaning are traditionally problematic within archaeology, with ongoing debates raging for over 40 years. As such, material culture studies within archaeology are still often criticized for imposing modern norms or expectations on past datasets. Numerous approaches to tackle these mental concepts have been advocated through the years, though no common framework has yet been accepted, allowing for the application of new perspectives to "ancient" problems. Applying a science,

389 First coined by American architect Louis Sullivan in 1896 (Sullivan 1896), the phrase "form (ever) follows function" became the credo of Modernist architects such as Le Corbusier, Walter Gropius and Mies van der Rohe in the 1930s (Guillén 2006).

390 See also Stissi 2009.

391 Louwaard 2014.

392 Stobbe 2007.

technology and society (STS) studies perspective is proposed by one NPAP case study as a means of addressing the ongoing struggle with distant pasts next to reflexive presents within archaeology by studying archaeological practices in relation to the facts that archaeologists produce.[393] This approach is also an explicit call for archaeologists to move away from isolated objects and embrace a relational perspective that includes humans and objects, thereby enabling active, dynamic interpretations of the static material record. The same thread runs through all NPAP subprojects, also advocating the deliberate study of complete ceramic assemblages where traditionally perhaps only particular parts may have been the object of study. Assessing whole assemblages enables a holistic view of the relationships between vessel types and repertoires, shedding light on unexpected and unintended activities where the "multifunctionality," rather than ideal function, of ceramics can be appreciated.

In this sense, the questions raised in this work about different degrees of standardization or variability can be addressed only at an assemblage level, thus embracing the holistic approach to ceramic studies fostered by the NPAP project. How to answer such inquiries in practice and through which analytical techniques will be discussed in the remainder of this chapter.

## 4.3 Scaling ceramic standardization: Choice of variables and attributes

### 4.3.1 Sampling criteria and choice of variables

As pointed out in the first chapter, standardization is commonly referred to as a relative concept. As stated by I. Berg in her work on Aegean late Bronze Age conical cups, "humans cannot produce an exact copy of an artifact without mechanical aid. Due to limitations in our visual perception, memory and motor skills, we identify objects as exact replicas even though they may differ by up to 2-3 per cent in dimensions and weight".[394] From which it follows that, when not relying on external standard tools like a scale, a ruler or a mold, we see artifacts as "equal" regardless their possible minor variations in weight or dimensions. Experiments conducted by Eerkens have shown that when producing items by hand from a mental template a faulty memory may "increase the minimum coefficient of variations above this visual limit".[395] More specifically, Eerkens' research indicates that "coefficients of variation in the range of 3 ± 1% are about as perfect as humans can get under most preindustrial conditions. A uniform population of numbers with a co-efficient of variation of 3% contains all of its sample within 5% of the mean. Thus, 'perfection' for manual production can be interpreted as being within approximately 5% of the intended size".[396]

Eerkens work established a solid foundation for comparing against CV values recorded in any archaeological collection. Such static datasets, however, need to be handled with some caution, as

393 Stobbe 2007.
394 Berg 2004, 75. It is worth noting that the extent of variation not perceived by humans can be mathematically calculated with the so-called Weber fraction (Eerkens 2000; Eerkens & Bettinger 2001).
395 Eerkens 2000, 666.
396 Eerkens 2000, 667.

different materials and different technological systems will allow for different error rates, thus different degrees of standardization. For example, pottery making is regarded as more easily standardized than flintknapping, where errors can only be adjusted by further reducing the core thus impacting the overall size of an object.[397]

Standardization, along with its opposite, variation, will continue to be a relative phenomenon, necessitating definition through the comparative analysis of assemblages. In this respect, the methods to conduct this comparison have received considerable attention. The process of comparing must be regulated systematically in order to set apart studies on digress of variability in ceramic artifacts from elusive treatments of similarity and dissimilarity.

Ceramic standardization (or variability) can be scaled through the study of different attributes, including the chemical or mineralogical composition of pottery fabrics, manufacturing techniques, form and dimensions and surface decoration.[398] Because of the diverse nature of these attributes, the way in which they are analyzed differs accordingly. However, before proceeding with the overview of the most common analytical methods applied in assessments of ceramic variability (see below), the criteria for selecting the ceramic assemblages to be compared need to be explained first.



To choose the appropriate strategy for a case study and avoid having distorted results, scholars dealing with the assessment of variability should take into account a range of considerations. To begin with, one should be aware of any misrepresentations resulting from the formation of the archaeological assemblage and the methods of recovery. This includes the effect of depositional processes and patterns of breakage and of scholarly choices and field research techniques.[399] Distortions may also be caused by the nature of assemblages that manifest rapid technological or other change.[400]

The size of the assemblages to be compared should also be taken into account.[401] Absolute figures for the minimum population (number of sherds of pots) in each assemblage can generally not be given and mainly depend on the research questions and the nature of the material under consideration. Nonetheless, P. Rice has argued (albeit with some reservation) that an assemblage should include no fewer than 30 individuals and suggests that a number of 100 is preferable.[402] Sizable assemblages are clearly to be preferred; small samples tend to leave rarer categories underrepresented or exclude them altogether and therefore alter the degree of variability. Likewise, the relative size is also important in assessments of variation and standardization. This involves comparing assemblages of corresponding, if

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397 Eerkens & Bettinger 2001, 500. About lithic industry and standardization see more recently Bogosavljević Petrović 2018, 89-119.
398 Arnold 1991, 364; Arnold & Nieves 1992, 95; Berg 2004; Blackman, Stein & Vandiver 1993; Eerkens & Bettinger 2001, 493-494; Hegmon et al. 1995, 34-35; London 1991, 183, 187-200; Rice 1981, 220-221; Roux 2003, 768 (see more below, section 4.2.2).
399 Rice 1989, 112, 117.
400 For instance, comparing assemblages derived from community-wide or household inventories, see B.L. Stark 1995, 236.
401 Rice 1989, 112, 116; 1991, 276; B.L. Stark 1995, 236.
402 Rice 1989, 116; 1991, 276.

not equal, size and also ensuring that the categories involved in comparisons, such as wares and shapes, are common to the assemblages.

To ensure the reliability of their results, scholarly assessments of variability should not rely on a single variable: two or more independent sets of variables should normally be taken into account.[403] This said, archaeological ceramics are often very fragmentary, which makes the choice of variables to consider even more problematic.[404]

Another, more controversial consideration regards whether the assemblages to be compared should originate from the same geographical area, cultural context or chronological sequence. Earlier views showed a preference for the temporal or spatial contiguity of the assemblages to be compared but also noted potential problems in identifying different modes of production, which are no reflection of actual developments but rather the product of historical or ecological phenomena.[405] Conversely, it has lately been argued that analytical assessments of variation and standardization should involve cross-cultural comparisons as a means to test archaeological evidence against ethnographic data.[406] However, cross-cultural comparisons do not mean overlooking contextual considerations, which are crucial in determining whether correspondences seen in the degrees of standardization or variation of ceramics from different time periods and cultural contexts represent similar modes of production or consumption.[407]

Last, assessments involving material from more than one production event should take into account that products of such events are normally less standardized than the product of a single event because of natural and cultural processes. Although it was very slight, this effect has recently been evaluated in the metric attributes of vases produced by the same traditional potter over two consecutive days.[408] The effect becomes stronger when the time span is longer. Ethnoarchaeologists have actually observe rapid changes in the morphology of a shape class within a time span of a few years.[409] In the case of archaeological ceramics, the impact of this effect has come to be known as *cumulative blurring* and has best been studied with reference to an assemblage of the 3rd millennium BC from Tel Leilan in Syria.[410] Scholars working with this material have found that stacked wasters of a certain type of bowl, which represent a single production event, are much more standardized than the bowls of the same type that were found throughout the site and represent different production events. Similarly, Fragnoli highlighted the importance of correct sampling strategies in order to mitigate the cumulative blurring effect: her research into the degree of standardization of Late Chalcolithic household wares from Arslantepe demonstrated how strategies "aimed at accounting for the duration of each period and the associated

403 Arnold 1991, 366; Blackman, Stein & Vandiver 1993, 61; Costin 1991, 35; 2000, 389; Rice 1989, 112; 1991, 271.
404 Benco 1988, 60.
405 Arnold & Nieves 1992, 94-95; Crown 1995, 149; Longacre et al. 1988, 106-111; Rice 1981, 221; 1989, 112, 116-117; 1991, 271.
406 B.L. Stark 1995, 240; Roux 2003.
407 Kenoyer et al. 1991, 48.
408 Roux 2003, 776, table 7.
409 Stark et al. 2000, 303-304.
410 Blackman, Stein & Vandiver 1993. The effect of this blurring is also briefly noted in Benco 1988, 68.

amount of materials recovered so far" enabled the researchers to counteract "the higher variability that production events generate along longer time-spans."[411]

### 4.3.2 Intentional vs. mechanical attributes

Having described the issues that should be considered in the choice of variables to make reliable comparisons, what remains is to introduce the range of data analysis techniques that were used in the assessment of the variability in raw material, form and surface treatment. Out of this range of attributes, vessel form and dimensions have received the most attention[412] and have been the subject of different applications. The methods employed in assessments of metrical standardization show considerable variety but can be said to have become increasingly more complex over time, to the extent that they are often not accessible to archaeologists who have no strong familiarity with statistics.

As noted above, the nature of potential attributes to consider when measuring ceramic variability is quite heterogeneous. C.L. Costin and M.B. Hagstrum have discussed the matter in detail. According to the authors, a distinction between intentional and mechanical attributes needs to be made to understand the significance of these parameters for standardization.[413] *Intentional attributes* (whether technological, morphological or stylistic) are those consciously controlled by the potter. As a rule, these attributes are related to the vessel's function in its social and/or economic context. On the other hand, *mechanical attributes* are those introduced by the potter unintentionally and are unrelated to any concern with functional performance. The multiple ceramic features included in these two broad categories enable us to trace different scales of standardization within artifacts' technology, shedding light on the choices of producers and consumers alike, as discussed in the first chapter of this work.[414] However, as Gosselain aptly put it, they all have different degrees of visibility and hence require a diverse range of analytical tools to be detected.[415]

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Coming to the first category of attributes, Hegmon, Hurst and Allison contribute largely to their formulation and understanding: "intentional stylistic components of ceramics (e.g. decoration) are strongly affected by social variables and, thus, have a tenuous relationship to the system of production. In some cases, ceramics with apparently standardized designs were produced at different locations and at a fairly small scale. On the other hand, some specialists created highly variable designs to express their individuality".[416]

Another example of intentional attributes brought forward by Hegmon and colleagues are the so-called gross formal characteristics of a ceramic object. Attributes like size and shape are closely connected to the intended function of ceramics. While their reliability in evaluating modes of production is quite

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411 Fragnoli 2021, 9-10.
412 Benco 1988; Clark 2007; Crown 1995 (with brief notes on fabric and decoration); Longacre 1999, 44, 49-59; Longacre et al. 1988; Rice 1981; Roux 2003; Sinopoli 1988; B.L. Stark 1995, 214-216.
413 Costin & Hagstrum 1995, 622. See also Berg 2004, 74-75, 83; Crown 1995, 147; Roux 2003, 768-769; B.L. Stark 1995, 235.
414 Chapter 1, section 1.2.2.
415 Gosselain 2000.
416 Hegmon et al., 34.

disputed, these attributes can greatly contribute to assess different degrees of standardization. Form and dimension, for instance, play a crucial role in vessels designed for long-distance trade, especially in those regions marked by specialized production. As noted in chapter 1, transportation is more convenient for smaller objects, and containers of standard dimensions that could be piled and nested were likely favored.[417]

Among the intentional attributes of a ceramic assemblage, compositional characteristics hold particular significance. They refer to the material composition of a pot; in other words, to the chemical and mineralogical characteristics of clay and temper. It is commonly accepted that compositional analyses can provide important information on sources of production and may be used to infer the number of production sources. The potential of these kinds of data for assessing standardization is, however, a complex issue and requires a closer look. During the last 20 years, archaeologists have used the evidence of pottery fabrics in order to develop models of manufacture organization, often linking specialized production to a high degree of standardization in ceramic pastes; unfortunately, this link remains highly speculative[418]. Both Rice and Costin have hypothetically related paste standardization to the transition from nonspecialized to specialized production. According to their model, in the final steps of this development, an empowered elite may take control of craft production and restrict the access to clay resources. A limited resource base presumably entails a low level of chemical mineralogical variability in ceramic raw materials, and this change should result in fabrics with greater homogeneity.[419]

In the early 2000s D.E. Arnold—while analyzing geochemical data of ceramic vessels produced at a household level from different communities in Mexico, Peru and Guatemala—underlined the contribution of an ethnoarchaeological perspective to evaluating such promising hypotheses, arguing that "one cannot properly interpret the social implications of paste variability in antiquity unless raw material selection, procurement, and preparation are understood in present-day societies."[420] Moreover, by illustrating the variety of factors responsible for fabric variability and how much we still have to learn about it, Arnold concluded that without more study on the relationship between paste variability and the geological, social and behavioral aspects affecting raw material selection and preparation, using compositional characteristics of pastes to reconstruct modes of production is premature.[421] Paste composition remains therefore a powerful tool to provide information about the geological context, the geographic location of resource areas and the distribution pattern of pottery-making communities, whereas its actual contribution to the discussion on ceramic standardization needs further evaluation.[422]

P. Fragnoli recently challenged Arnold's claim about paste composition providing information primarily on the geological context rather than on production organization. In the already mentioned work on the Late Chalcolithic pottery from Arslantepe, Fragnoli argued instead that "the variations in paste recipes can be used as indicators of production organization at least at an intra-site level. To achieve

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417 Ibidem; Ch. 1, section 1.4.
418 Mills & Crown 1995b; Stark et al. 2000.
419 Costin 1991, 31-34; Rice 1981, 220-222, 1991, 262.
420 Arnold 2000, 335.
421 Arnold 2000, 361.
422 Arnold 1991; Arnold & Nieves 1992; Bishop et al. 1982.

this aim, different compositional analyses—i.e. bulk geochemistry and thin section petrography—have to be integrated with selected technological and typological features."[423] Fragnoli thus calls for an integrated approach to address ceramic standardization while also underlining the importance of the scale of analysis (intrasite) and the nature of the sample chosen for analysis: studies that address modes of production are in fact more likely to benefit from the analysis of diverse "pottery assemblages related to distinct levels of specialization and produced over a long time span marked by drastic socio-economic changes."[424]

The second category of attributes, *mechanical and technological*, are more directly related to productive specialization and are therefore the most often utilized parameters in metrical assessment of standardization. These attributes may reflect how a pot was made, when considering for example the rim shape; how it was decorated, when considering for example the presence or absence of incised lines on the surface and their width; or how it was fired, when considering for instance the paste color. To investigate these factors, the analysis usually focuses on specific attributes of form and design. Especially when dealing with sherds, the best option is to consider several attributes of rim fragments. Most of these attributes (wall thickness, rim shape etc.) likely resulted from the mechanics of the production process and should be closely related to the scale and intensity of production. Studies of artifact variation have employed a sophisticated range of measures, such as standard of deviation, coefficient of variation, Weber's fraction and skewness. To date, the method most commonly used is the coefficient of variation (CV), which is defined as the sample standard deviation divided by sample mean, then multiplied by 100 and expressed as a percentage.[425] This measure is particularly well suited for the assessment of a single ceramic type or assemblages from the same site as well as for cross-cultural comparisons of metrical standardization.[426]

So far, it might be clear that archaeological studies of ceramic standardization and variability should proceed cautiously. Given the variety of factors that can disturb the analysis, any investigation into standardized manufacture should be associated with effective auxiliary data, such as actual production locations and evidence concerning the mode of production and the spatial distribution of pottery. As rightly argued by C. Costin, inferring degrees of standardization from pottery attributes only can be potentially misleading.[427]

Although the actual analytical models are not completely established yet and the construction of a common framework is still ongoing, further morphological studies of pottery from well-stratified sites or from ethnographic contexts may provide a fruitful way to assess the potential of the notion of ceramic standardization in understanding ancient production systems and distribution patterns. In this sense,

423 Fragnoli 2021, 2.
424 Ibid.
425 For the definition, see Eerkens & Bettinger 2001, 495. Examples of the application of this method can be found in Arnold 1991; Benco 1988; Berg 2004, 78; Blackman, Stein & Vandiver 1993; Longacre et al. 1988; Roux 2003; M.T. Stark 1995, 214-216.
426 For a detailed analysis of the range of possible ways to scale artifacts variation and the limits of the CV method, see Eerkens & Bettinger 2001.
427 Costin 1991, 44.

the assemblages sampled at Satricum provide a good opportunity to experiment and eventually set up an analytical standard to test the so-called standardization hypothesis in pottery studies. In the next section of this chapter, I will dive in greater detail into the methods applied to this research.

## 4.4 Analytical approaches to metric and technological standardization

### 4.4.1 Metric standardization and statistical analysis

The analytical approaches employed for metrical standardization analysis may differ, each presenting its own set of gains and difficulties. Concerning variation analysis, as Vuković rightly pointed out, the critical factors include the count of attributes for each variable, such as rim diameters or wall thicknesses, and the occurrence of each individual attribute, like the instances where each recorded rim diameter or wall-thickness is present. Consequently, key statistical indicators for analysis encompass "range of values, mean value and standard deviation. Although different statistical techniques, notably variance analysis, have been used for standardization analysis, the opinion that the most reliable method to determine standardization is the analysis of the standard deviation value and CV is gaining ground".[428]

Already in 2001 J. Eerkens and R. Bettinger advocated for the adoption of the coefficient of variation (CV) as the primary statistical technique for standardization analysis, providing also baseline values for the metrical variability of artifacts.[429] The upper baseline, which represents the maximum standardization that humans can generate without the aid of physical standards such as rulers, displays a CV of no less than 1.7%. On the other hand, the CV for the lower baseline, which represents the maximum of variation in random production, is no more than 57.7%. The values set by Eerkens and Bettinger hold particular significance when it come to the study of archaeological assemblages. When the CV reaches 57.7% or higher values may indicate potential errors made by researchers who have "unknowingly lumped two or more discrete classes of artifacts into a single category, thereby artificially increasing variation".[430] Based on ethnographical work, V. Roux produced a scheme for inferring the scale and intensity of ceramic production and degrees of specialization on the basis of Eerkens and Bettinger's system.[431] According to her scheme, a CV below 3% suggests a large-scale, highly specialized production of 14,000 (or more) pots per year. CV values between 3% and 6% are associated with a scale of production ranging considerably, between 4,000 and 14,000 pots, and a high or low degree of specialization. Last, a high CV (exceeding 6%) is associated with small-scale production and part-time specialists. Certainly, the CV values provided serve as an exemplary illustration. According to Vuković in fact, achieving genuinely low CV values signifying the presence of standardization (up to 5%), is feasible primarily in ethnoarchaeological studies. In such research, it is relatively straightforward to isolate and analyze objects made by individual makers or objects resulting from a specific production cycle.[432] Nevertheless, archaeologists work in markedly

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428 Vuković 2011, 85. Vukovic further specifies that "Standard deviation is the measure of dispersion in the main set; it indicates the average extent to which set elements deviate from the arithmetic mean of the set" (Vuković 2011, 85).

429 Eerkens & Bettinger 2001.

430 Eerkens & Bettinger 2001, 497.

431 Roux 2003.

432 Vuković 2011, 86.

different conditions lacking in most cases such clear and comprehensive data; therefore, CV values, except in extraordinary cases, will be inevitably higher. As briefly noted above, a cumulative blurring effect can undoubtedly be expected when analyzing archaeological ceramics, which may be the result "of depositions of products made by a number of producers or of many production series spanning over a long period."[433]

In consideration of the vast research done on the CV to assess metric standardization, the number of studies adopting it and the resulting remarkable corpus of datasets at our disposal for comparison, I decided to incorporate this analytical device into the study of Archaic Satricum household ware (see Chapter 5).

### 4.4.2 Technological standardization: Compositional variables and materials science analysis

Over the last decades, pottery studies have suggested paste uniformity as an index of product standardization and as possibly the result of a more intense level of specialization. The argument by Rice that paste homogeneity could be interpreted as a consequence of elite control over production is well known. In her view, restricted access to a clay resource presumably corresponds to reduced chemical and mineralogical variability.[434] More recently, Arnold seriously questioned this link, arguing that other factors (environmental, technological, social etc.) may have influenced paste variability.[435] Indeed, social and economic inferences from ceramic pastes need to be understood in relation to numerous factors, such as natural variability of the ceramic raw materials, their procurement and their use in paste preparation. Arnold's ethnographic work in Latin America has showed how paste composition appears to provide information primarily on the geological context and geographic location of pottery-making communities, rather than on production organization. Paste composition, therefore, must be understood in terms of the variability of raw materials available within a community's resource area. The strict connection between paste composition and a community's resource area calls for an appropriate definition of the spatial scale at which the analysis is carried out. In this respect, the models supplied by ethnoarchaeologists point out that aspects related to production organization can hardly be inferred from archaeological paste data below the community resource area level. According to the threshold model of distance to ceramic resources elaborated by Arnold, clay and temper resources occur within a well-defined geographic area that circumscribes the natural causes of paste variability. It is within this resource area, which is usually calculated as less than 7 km, that the potters' community will select, modify and mix raw materials.[436] The "community resource area" approach entails, first, the necessity of designing the research on a regional scale, combining a raw material survey with compositional analyses of sherds from the full range of known vessel shapes and local raw materials (geoprospection). Second, by applying the threshold model of distances to ceramic resources, it is possible to distinguish local from nonlocal ceramic production. Nonlocal production may indicate the occurrence of some kind of exchange, i.e., potters producing above the community needs, and may therefore be a possible indication

433 Ibidem.
434 Rice 1981.
435 Arnold 2000.
436 Arnold 2000, 336.

of specialized production. In turn, once a production community is identified, it is more productive to use compositional analysis and geoprospection on a regional level for understanding the production and distribution dynamics between different communities.

J. Hilditch echoed Arnold's concerns when it comes to characterizing the technological standardization of ceramic artifacts and inferring production behaviors and choices within craft communities. According to Hilditch, the difficulty of devising a robust methodology to quantitatively assess compositional or technological standardization, such as that described above for morphometric standardization, "is due in part to the low visibility or invisibility of compositional and technological behaviors in the finished vessel, but also, perhaps more importantly, because these aspects of ceramic vessels are increasingly recognized as inherently bound up in the learning habits and skills of individual potters within the wider socio-culturally-bounded ceramic producing communities."[437] More broadly, developing quantitative methods that generate static datasets may dangerously lead to unilinear interpretations of the ceramic record, reinforcing evolutionary narratives based on "from-simple-to-complex" models, a biased approached amply discussed in the first chapter of this work.[438]

To disentangle the dynamic sets of interactions between humans, material worlds and social and physical environments, it is necessary to integrate quantitative data with qualitative research methods, chiefly in archaeological ethnographic, experimental and case-study-based work. In this sense, adopting a *chaîne opératoire* approach allows for such an integrated methodology and has proved to "offer a genuinely dynamic perspective through which to characterize and analyze production and consumption activities."[439] By breaking down manufacturing stages and patterns of use and reuse into a sequence of detectable choices and behaviors, the *chaîne opératoire* framework can, when embedded within increasingly sophisticated analytical research programs, draw a more detailed picture of when, how and where change (or lack thereof) occurs in both visible and invisible attributes of a pottery assemblage, making the notions of both metric and technological/compositional standardization a valuable proxy to shed light on potting communities.

Hilditch made a strong case for the potential of applying such an integrated methodology to the study of technological standardization by rediscussing an iconic ceramic vessel—the Minoan conical cup—whose standardized shape spreading across Crete and beyond has been traditionally associated with the impact of the Minoans throughout the Aegean. Whereas scholarship usually derives the overall impression of uniformity from morphometric attributes (size, form, capacity)—what we would call intentional/stylistic thus visible features particularly linked to consumers' choices—Hilditch shifted the focus to less visible characteristics connected with raw materials, paste processing, fashioning and firing techniques observed at Akrotiri on the earliest examples of Minoan-inspired conical cups. The unfolding analytical stages followed the path from macroscopic to chemical analyses (specifically SEM-EDS) described above, including a geological survey and experimental tests, enabling the author to reconstruct the choices and practices of potters working within the local ceramic tradition. By integrating less visible aspects into

437 Hilditch 2014, 27.
438 Kotsonas 2014, 17.
439 Hilditch 2014, 27.

the standardization equation, Hilditch opened up a window into the dynamic interactions between craft people through time and space, placing emphasis on how technological knowledge and innovation traveled instead of limiting the discussion to how established consumption patterns were transmitted from the Minoan world across the Aegean.

Even though it discussed a different chronological and geographical setting, namely Late Chalcolithic Eastern Anatolia, Fragnoli's work reinforced the point made by Hilditch about the potential of evaluating technological standardization to question common explanatory models linking higher production volumes and uniformity in vessel attributes to increased social complexity.[440] However, the analytical strategy adopted by Fragnoli followed a different route than that indicated by Hilditch: Fragnoli in fact applied the same methods used to scale metrical standardization—in this case the aforementioned CV—to measure geochemical variability within potters' communities at Arslantepe from 4700 to 3200 BCE. To overcome the difficulties of interpreting such a static dataset—as stressed by Hilditch—Fragnoli integrated the metric data resulting from the calculation of the CV of main compositional elements present in Arslantepe vessels with nonmetric data derived from petrographic grouping, in addition to the data derived from manufacturing techniques and stylistic and morpho-functional features identified macroscopically. The different levels of analysis applied made it possible to interpret patterns of variability more meaningfully: interestingly, Fragnoli concluded that the higher degree of standardization recorded in raw materials and paste processing was connected to the scale and mode of production, rather than to fashioning methods: "Mass-produced vessels, both the handmade ones (LC1-2 and partially in LC3-4) and the ones shaped on the wheel (partially LC3-4 and LC5), indeed display the lowest compositional variability within each period."[441] In this way, Fragnoli demonstrated how exploring artifacts' standardization within a dynamic analytical framework proves to be a powerful tool to challenge established preconceptions (such as the assumed more standardized nature of vessels built with the aid of the wheel) and gain insights into the complexity of the social organization of the pottery production, from the control over natural resources to labor division, shared behaviors and gestures.



The examples illustrated above provide the framework within which the methodology applied to this research was developed. The potential of integrating qualitative and quantitative data to approach ceramic standardization in its broadest sense calls for the adoption of multiple analytical scales to generate a dynamic dataset that enables us to investigate the interactions between people, things and the environment and to create a feedback system that makes it possible to control and reassess the output resulting from each stage and ultimately generate new inputs. As mentioned earlier, in this work CV was selected to scale metric standardization. In the remainder of this chapter, I will outline the threefold analysis applied to assess technological and compositional standardization, which entailed macroscopic examination of clay paste and surface treatment, petrographic analysis, a raw material survey and replication experiments.

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440 Fragnoli 2021.
441 Fragnoli 2021, 27.

## 4.5 Macroscopic fabric analysis: Definition and analytical strategies

The recognition of the significance of ceramic fabrics (or pastes) in providing essential information about chronology, site function, regional interaction and technology is now widespread. The analysis of ceramic fabric at a microscopic level, also known as ceramic petrography, has a long and exciting history in Mediterranean archaeology.

As early as the late 19th century, F. Fouqué's geological monograph on the volcanic history of Santorini (1879) highlighted the potential of examining archaeological ceramics under a microscope by describing the petrographic characteristics of ceramic thin sections. Subsequently, the influential works of Anna Shepard and Wayne Felts in the 1940s on Rio Grande Glaze Paint pottery from New Mexico and various ceramic assemblages from Troy in western Turkey, respectively, played a fundamental role in firmly establishing petrography within pottery studies.

Since then, microscopic fabric analysis, advocated by many in the 1980s and 1990s and now systematically integrated into archaeological projects, has become a central component of ceramic studies for nearly half a century. On the other hand, macroscopic ceramic fabric analysis has not received the same level of attention.

Defined as the systematic study and characterization of ceramic fabrics using a 10 to 30x hand lens, macroscopic analysis has struggled to be recognized as an essential initial analytical stage among specialists. This lack of recognition has resulted in unclear definitions and unstandardized procedures, which only in the past two decades have undergone a thorough process of standardization. This has led to the wider acceptance of macroscopic fabric analysis as a crucial aspect of pottery processing and study by a larger community of archaeologists. The following section focuses on the first level of analysis, which involves macroscopic examination of selected pottery assemblages, with a particular focus on the characterization of clay pastes. To accomplish this, a detailed and comprehensive definition of the term "macroscopic fabric" will be provided, followed by an exploration of the specific analytical strategies employed in this research.

Early works on macroscopic ceramic characterization were heavily influenced by A. Shepard's book *Ceramics for the Archaeologist* (1956), although the term "fabric" was not explicitly used in connection with pottery. Nonetheless, Shepard illustrated all the basic elements used in fabric analysis, including color, hardness, texture (both paste and surface), luster, porosity, strength, fracture and gravity. The fifth reprinting of her book in 1965 provided a comprehensive account of new developments within the discipline, such as chemical and petrographic analyses, the application of computer technology and the concepts of ceramic ecology and ethnography. The integration of Shepard's approaches and methods became a standard procedure in pottery studies and formed the foundation for most research in ceramic fabric analysis. In the 1970s, a greater emphasis on the informative potential of ceramic analysis expanded the range of research topics addressed by specialists, shifting from typological seriation and chronology to trade networks and, to a lesser extent, technology. Particularly, the interest in tracing exchange patterns shifted the focus from fine tableware to coarse wares and transport containers, which required different analytical methods than those traditionally established for fine wares. At the outset, thin section petrography and chemical analyses were emphasized; however, due to the destructive and costly nature of sampling procedures, alternative and more affordable methods for studying coarse wares became necessary. Despite still lacking a clear formulation and standardized practices, macroscopic ceramic analysis emerged as the most suitable alternative.

In her critical reassessment of the type-variety system, Rice was the first to treat the term "fabric" as a different and independent technological attribute, separate from that of ware. Prior to that, both terms were considered part of a single concept. Following an intense theoretical debate, Peacock, Rye, Kotsakis and Rice reached a consensus on the definition of fabric.[442] They defined it as a purely technological term encompassing various characteristics of fired clay, such as color, hardness, voids and the composition of inclusions. However, they excluded surface treatment and decoration from this definition.

As mentioned at the beginning of this chapter, Whitbread refined and established the definition of fabric analysis by expanding its scope to include both macroscopic and microscopic levels through integrating it into the broader field of ceramic petrology. Whitbread argued that a correct interpretation of ceramic petrography should involve systematic descriptions of ceramic materials, their compositions and their organization in both hand specimens and thin sections. It encompasses a comprehensive interpretation of raw material selection, ceramic technology and determining provenance based on petrographic investigations. This is supported by data from other scientific methods, such as chemical analysis.[443]

In this perspective, petrographic analysis naturally follows the macroscopic examination of pottery and serves as a crucial link between field archaeologists and materials scientists who employ more advanced analytical techniques, such as SEM, XRF, NAA and ICP. Whitbread introduced a detailed system of petrographic fabric descriptions on both macroscopic and microscopic levels in 1995. He incorporated terminology from sedimentary petrology and soil micromorphology into his system. According to Whitbread, the most fundamental form of fabric analysis is the hand specimen description of pottery fabrics, which should be conducted on fresh breaks of sherds.

It is now widely accepted that the initial macroscopic examination of fabrics is typically carried out in the field using a magnifying glass, with magnifications ranging from 10x to 30x, depending on the type of material being analyzed. By employing macroscopic fabric description handouts, which consider specific parameters outlined in Chapter 6, section 6.2, specialists can identify the main fabric groups as well as unique fabric types (loners) while working in the field. Peacock was the first to propose a systematic method for macroscopic fabric description,[444] which was later adopted and further developed by Whitbread in the aforementioned work on Greek transport amphorae.[445] Within the framework of the NPAP research project (see below), a very similar version to that employed by Whitbread has been applied, with some modifications designed ad hoc by E.S. Hitsiou and J.R. Hilditch. In Chapter

442 Kotsakis 1983, 107; Peacock 1977, 29; Rice 1987, 476; Rye 1981, 19.
443 Whitbread 1995, 365-378; 2017, 203-207.
444 Peacock 1977.
445 Whitbread 1995.

6, a detailed description of the handout is given in order to explain the basic criteria around which the macroscopic fabric description is carried out across all NPAP projects.

## 4.6 Thin section petrography: A view from Italy

Among the methods for fabric analysis at our disposal today, the examination of thin sections through a petrographic microscope still holds a central position. Borrowed from earth sciences, thin section analysis makes it possible to characterize the clay matrix and identify the minerals present in the ceramic body and their distribution, size, shape and behavior. After all, ceramics share features with both rocks and sediments, thus "it can be argued that ceramics are best approached in a manner similar to that used in the geological study of the parent raw materials," as Peacock aptly put it.[446] Long before Peacock, the groundbreaking contributions of A. Shepard in the Americas significantly shaped the current approach to fabric characterization in Mediterranean archaeology, whose influence is particularly evident through the publication of *Ceramics for the Archaeologist*.[447] As aptly put by Hilditch:

> Her work reflected her training in both geology and anthropology through the use of petrology to investigate provenance and technology issues for archaeological ceramics. […] Shepard demonstrated the suitability of raw materials for potting and finished clay vessels for petrographic investigation, from characterization of the fine matrix to the shape, density and sorting of the coarser inclusions and their implications for elucidating technological choices within the production sequence. The textural analysis of pottery fabrics remains one of the greatest strengths of ceramic petrography.[448]

In Italy, the utilization of more advanced approaches to pottery analysis gained momentum in the latter half of the 20th century, when A.M. De Angelis, E. Mariani, G. Peco and C. Storti experimented with different analytical methods on a few pre- and protohistoric specimens selected from several regions, namely Lombardy, Liguria, Apulia and Sicily.[449] The techniques used ranged from thin section petrography to differential thermal analysis and measurement of physical properties such as porosity, weight and volume. The use of new scientific methods in the study of pottery was received with great enthusiasm, to the detriment of a clear formulation of the archaeological questions substantiating the research program, which led to results that were not very coherent. Shortly after, G. Guerreschi argued in favor of a different analytical strategy revolving around the examination of consistent bodies of pottery—selected from several settlements in Lombardy (Isolino Varese, Belforte and Lagozza)—to be carried out on a fresh break through the use of a stereomicroscope.[450] As mentioned in the opening section of this chapter, such a macroscopic technique makes it possible to gather substantial information on clay recipes and propose an initial subdivision according to fabric in a relatively short time, causing little

446 Peacock 1977, 26.
447 Shepard 1956.
448 Hilditch 2008, 105, commenting on Shepard's works on pottery from Pecos (1936) and Yucatan (1965).
449 De Angelis 1956/1957; De Angelis et al. 1960; Mariani et al. 1956/1957.
450 Guerreschi 1964-1966; Guerreschi & Mesturini 1980-1981.

damage and using low-tech equipment. However, the resulting observations should then be supported by more sophisticated means of analysis.

In 1967, J.Ll. Williams conducted truly pioneering work on a large sample of ceramics spanning the Neolithic and Bronze Age from the Aeolian Islands: based on the analysis of over 350 thin sections mostly from Lipari but also from the smaller islands of Filicudi, Panarea and Salina, Williams was able to highlight a surprisingly complex situation in terms of raw materials and final product circulation across the archipelago and beyond. Unfortunately, the long publication time—a first overview of the results was released in 1980, a second one in 1991—watered down the impact of the research on later studies; in fact, for much of the 1970s, petrography applied to pottery studies was confined to the realm of the sciences subsidiary to archaeology.

We owe much to T. Mannoni if the contribution that petrography can make to archaeology as a discipline is finally acknowledged. Mannoni's petrographic work focused particularly on Roman and post-Roman ceramic production in Liguria and other key sites for the Roman period, such as Luni, Pompei and Ostia, and brought to the attention of the scientific community several methodological issues, particularly important among which are those related to the sampling strategies operated within a research program, often not explicitly illustrated nor systematically applied.[451] The rigorous methodological protocols established by Mannoni and his school led to a more standardized description of thin sections and to the characterization and classification of petrographic groups that can be compared and connected with different production areas across Italy.[452]



Since the 1980s, Italy has been at the core of a large project led by R. Jones and L. Vagnetti aimed at the characterization of ceramic material originating from or inspired by Aegean products in a Mediterranean perspective. Within this framework, the research conducted at Sibaris contributed greatly to the creation of a consistent archive of especially chemical data, often coupled with petrographic descriptions, that made it possible to single out and distinguish imported from local pottery manufacture.[453] Over time, more than 700 samples of Mycenean and Italo-Mycenean pottery have been analyzed, alongside an equally consistent sample of other ware classes derived from Aegean prototypes (gray ware, *dolia*, protogeometric) from approximately 50 sites, among which Coppa Nevigata, Rocavecchia, Scoglio del Tonno and Broglio Trebisacce are particularly relevant.

In 1985, the volume by N. Cuomo di Caprio *La ceramica in archeologia* was released. This was the first Italian handbook systematically addressing science-based pottery analysis using a very accessible language and an interdisciplinary approach. The book consists of three sections dedicated respectively to potting technology, analytical methods and ancient sources. Most of the examples provided by Cuomo di Caprio derived from the Greek and Roman worlds; however, all time periods and different artisanal techniques are addressed. The work by Cuomo di Caprio (re-edited in 2007 with extensive additions)

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451 Mannoni 1994.
452 Capelli & Mannoni 1996, 1998.
453 An overview can be found in Bettelli et al. 2006; Guglielmino et al. 2010; Jones et al. 2002; Jones et al. 2005, 2014; Levi et al. 2006; Vagnetti et al. 2006, 2009.

has been and still is an indispensable didactic tool, an encyclopedia that changed and greatly stimulated both the understanding and the spread of pottery studies.

Following Mannoni's and Cuomo di Caprio's contributions, the growing interest in materials science applied to ceramic analysis led to more diversified research avenues and increased attention for the methodological issues first raised by Mannoni. This is the period when seminars, conferences and workshops dedicated to archaeometry became established occasions to take stock of the advances in the discipline. In 1991, Rome hosted the first European Workshop on Archaeological Ceramics (EMAC), organized by the Department of Earth Sciences at Sapienza University of Rome, inauguring the series of the biennial EMAC meetings that took place three other times in Italy: in Riccione in 1995, Padova in 2013 and last Pisa in 2023.

In the same period, the Associazione Italiana di Archeometria was founded (1993); however, archaeologists did not feature among the members at first but were finally included only after a rather heated debate. The initial exclusion of archaeology from the disciplines participating in the association reflects the traditional divide between humanities and hard sciences, where archaeology is still perceived as a branch of art history, hence not sharing the same techniques and methodologies as natural science. Archaeologists voiced their unanimous discontent with such a shortsighted disciplinary confinement during the first meeting fully dedicated to the advancements made in the study of Roman pottery thanks to the application of archaeometry, held in Montegufoni in 1993, the same year in which the Italian Association for Archaeometry was established. G. Olcese and the many contributors gathered on that occasion, among which D. Manacorda, T. Mannoni and M. Maggetti, stressed the need to better embed archaeometry within archaeological research programs to provide more systematic and standardized output and hence lay the foundations for the creation of shareable and comparable datasets. The resulting proceedings also shed light on the advancements made thanks to the integration of materials science methods into the study of Roman pottery, especially for the most common fine wares such as black gloss (Morel and Picon) and *terra sigillata* wares (Picon, Schneider and Hoffmann).[454] Within this framework, the work of Olcese on Republican household ware (*ceramica comune*) represented one of the earliest efforts to typologically, technologically and compositionally systematize a category of objects typically neglected due to their elusive nature and shape conservatism, as amply discussed in the previous chapter about Archaic household ware. Olcese underlined in fact the need to integrate different scales of analysis, especially in the case of this category of artifacts, where the greater informative potential resides in their technological characteristics rather than their morpho-typological features.[455]

Since the 1990s, the integration of thin section petrography and/or chemical analysis within any study involving pottery assemblages has become a staple of archaeological research in Italy. Over the last decades, training in thin section petrography and archaeometry in a broader sense is offered at several Italian archaeology and conservation departments, and works encompassing all analytical stages—part of what J. Hilditch aptly defined as the *chaîne opératoire* of a ceramic specialist (see above section

454 Olcese 1995.

455 Olcese 1995, 89-91. The contribution of archaeometry to the study of Roman *ceramica comune* is further discussed in the volume dedicated to Rome and Lazio published in 2003 (Olcese 2003).

4.1.1)—have increased exponentially. Among the main topics addressed, technology and production organization, potters' technological choices, the exploitation and circulation of clays and tempers, the distribution of finished products, the circulation of transport containers and the circulation of knowledge and artisans hold a central position.

The proliferation of archaeometric studies, however, has kept the methodological debate on best practices, limitations and potentialities of the discipline quite lively. Particularly relevant for the methodological choices operated in this work is the renewed interest for aspects connected to the macroscopic examination of ceramics brought forward by Chelini, Sarti and Pallecchi, as well as Capelli, Mannoni, Starnini and Cabella. Both contributions emphasized the importance of adding this first stage of analysis more organically into any research program aiming at fabric characterization and compositional analysis, as the resulting sampling strategy highly depends on the first macroscopic assessment of clay recipes.[456] Also, the plea for the adoption of an internationally recognized standardized fabric description made by both Chelini, Sarti and Pellechi et al. and Capelli et al. gave voice to a much felt need in the scientific community and remained a topical subject for much of the 2000s.[457]



Currently, the debate has moved from codified description protocols to the risk of data fragmentation generated by the increasing number of research projects operating separately. Especially when the matter of study is concerned with how technology, knowledge or products traveled, robust coordination and collaboration between different research groups are pivotal, as Levi and Muntoni warned already in 2014. This concern has as a corollary the issue of a rather heterogeneous presentation of data, which often hinders comparison and thus intrasite or intraregional analysis. Accessibility, interoperability and openness of thin section archives is certainly another matter of concern: despite the growing trend to make data available, the vast majority of information stored in digital archives—be they images or fabric descriptions—remain unshared. Typically, an overview of the methodology and platform used is published together with a summary of the results, but access to core data is password-protected, often due to research being still ongoing and ownership matters.

For the Mediterranean area, there are however notable exceptions to the rule, such as the FACEM (Fabrics of the CEntral Mediterranean) online repository launched in 2011 by V. Gassner, M. Trapichler and B. Bechtold (University of Vienna) and now at its ninth release. Here, data originating from the macroscopic examination of thousands of ceramic fabrics gathered across the Central and Southern Mediterranean dated between the 7th century BC and the 7th century AD are openly accessible and coherently systematized, with the ultimate goal of supporting cross-comparison when it comes to the identification of the provenance, distribution and technology of ancient pottery.[458] The web-based archive ceraDAT, which stems from the collaboration between the Institute of Materials Science at N.C.S.R. "Demokritos" (IMS-DEMO) and the Helmholtz-Institute of Radiation and Nuclear Physics at the

456 Capelli et al. 2006; Chelini et al. 2006.
457 Cau et al. 2004; Cuomo di Caprio 2007; Levi 2010; Levi & Muntoni 2014; Muntoni 2004; Quinn 2013; Tite 2008; Vidale 2007; Whitbread 2017.
458 Gassner et al. 2011. For the latest releases of the database, see https://facem.at/project/about.php (accessed September 2023).

University of Bonn, shares the same concerns about standardization and comparability of chemical data when it comes to pottery studies. Coordinated by A. Hein and V. Kilikoglou, ceraDAT was set to provide an open platform that could gather the elemental compositions of several thousand ceramic artifacts from the Eastern Mediterranean, analyzed by means of neutron activation analysis (NAA) at different laboratories. Over time, ceraDAT has started incorporating petrographic and mineralogical data alongside elemental analysis, expanding the geographical focus to the Western Mediterranean, namely Sardinia and Sicily.[459]

In the past decade, experiences comparable to FACEM and ceraDAT have multiplied. On the Italian front, an early example is provided by G. Olcese's (University of Milan) Immensa Aequora project launched in 2010. The project's main aim was to gather and systematically present archaeological and archaeometric data for the Tyrrhenian region (Etruria-Lazio-Campania-Sicilia) with a particular emphasis on pottery production and trade between the 4th BC and the 1st AD.[460] Alongside traditional publications, the team led by Olcese developed an online database, access to which, however, remains password-protected.[461]

More recently, it is worth mentioning the ArchAIDE project, a fully open-access, AI-based application to recognize archaeological pottery developed by G. Gattiglia,[462] and its extension Open Fabric, curated by E. Odelli.[463] The latter database was realized to manage and make available the archaeological and archaeometric data collected from bodies of ceramics recovered from Tuscan contexts spanning over a long period from Late Antiquity to the Early Renaissance. For all sites, data derived from petrographic analysis, micro-Raman spectroscopy, portable X-ray spectroscopy and microscopy cathodoluminescence, "together with their excavation site coordinates and provenance hypothesis, are made available and downloadable for scholars willing to compare and reuse those data to improve research."[464] To date, Open Fabric is one of the few examples of a truly shared ceramic digital archive in Italy and certainly the way forward for a proficient approach to pottery analysis in the future.

## 4.7 Geological prospection and characterization of ceramic raw materials

Geology and archaeology cross and are interconnected in many ways. On the one hand, "an understanding of geology deepens the appreciation of any archaeological site, be it the context, the artifacts present, or the activities carried out there."[465] On the other hand, archaeology brings depth and the human factor into time, revealing how the most diverse landscapes have been managed and changed over time,

459 Hein & Kilikoglou 2021. Database available at https://ceradat.net/ (accessed September 2023).
460 Olcese 2010, 2011/2012.
461 https://www.immensaaequora.org/en/content/database (accessed September 2023).
462 Gattiglia 2018; Gualandi, Gattiglia & Anichini 2021.
463 Odelli 2023. The Open Fabric pottery database (see Supplementary Materials) is available on Mappa Open Data repositories under CC BY SA license (https://creativecommons.org/).
464 Odelli 2023, 141.
465 Allen 2017, 3.

thus enhancing our knowledge of the planet's dynamic history and the intricate relationship between human groups and Earth's geological processes. Exploring how geological materials were exploited by humans for farming, building, finding fuel, making tools or fashioning weapons is an essential part of any archaeological research into ancient technology, a realm where—as we will see—pottery manufacture takes center stage.

All artifact or material characterization studies within archaeology, be they from the 1950s or today, assume that chemical differences within a single source of material must be fewer than the chemical differences between different sources. They both use this basic assumption as their analytical starting point.[466] Hilditch, however, warns about the challenges that emerge when distinct sources generate identical signatures within the resolution of the analysis. In her view, this similarity could either indicate genuine resemblances in the composition of raw materials and the subsequent technical processes executed by ancient artisans, or it may stem from the limitations of the analytical technique itself.[467] This aspect has led to the extensive use of various analytical techniques in the ongoing efforts to characterize materials in the field of pottery studies. Echoing Hilditch "To the nonspecialist, these studies may present a bewildering range of acronyms and technical terms, but essentially (and reassuringly), they seek to answer the same questions: is this artifact compatible with locally available raw materials and, if not, where is it from?".[468] In this sense, provenance determination studies were "responsible for the initial application of compositional analyses, be they macroscopic fabric classification, thin section petrography and bulk geochemistry, to archaeological ceramics and their rapid growth in the latter part of last century."[469]

Any ceramic artifact represents the result of a highly variable mixture of several geological components, which are typically distinguished according to granulometry in clay, silt and sand.[470] When characterizing a ceramic fabric, clay and silt are referred to as *matrix*, while sand is referred to as *clasts* or *skeleton*. These components are included in the wider category of *geomaterials* that "include all the materials of geological origin, such as rock, sediment, or soil, which could be advantageously utilized for the manufacture of artifacts in their natural state or after man-made processing."[471] Hence, any geomaterial is connected to a specific raw source in the landscape and to a specific way of making things. Especially in the case of pottery, geomaterials will undergo an elaborate modification process, ranging from extraction—levigation, tempering, shape forming, surface finishing, drying, firing and cooling off—to being converted into a finished product.

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466 Renfrew et al. 1965; Weigand et al. 1977.
467 Hilditch 2008, 109.
468 Hilditch 2008, 109-110.
469 Quinn 2013, 117.
470 According to the international scale set by ISO-14688: 2002, in geomorphology sand ranges in grain size from 2 mm (very coarse) to 62·50 (very fine) µm, silt from 62·50 to 1·953 µm, clay < 1·953 µm (Blott & Pye 2012, 2083, fig. 5). In thin section analysis, Whitbread (1995)—though advocating for a more flexible distinction between "micromass" (clay) and "inclusions" (sand, silt) determined according to the assemblage at hand—suggested 10 micron as the limit between silt and clay (micron = 1/1000 mm).
471 Montana 2017, 88.

Thin section petrography applied to ceramics and modern clay samples enables us to pin down the region where the geomaterials were sourced and the sequence of actions (technology) carried out to transform them into artifacts. The underlying principle is that the petrography of a ceramic object is connected to the geology of the area where it was manufactured. In other words, pottery originating from a specific production center should exhibit distinctive compositional and textural attributes when contrasted with pottery manufactured elsewhere. Broadly speaking, a high concentration of metamorphic inclusions is likely to indicate that the ceramic object in question was made in a region where such rocks are abundantly present, just like calcareous and fossiliferous fabrics probably originate from marine or lagoonal outcrops. The "geological provenance" of a ceramic sample can be further narrowed down when specific lithologies or aplastic inclusions are present: considered in the literature as mineralogical-petrographic markers, such distinctive components enable us to more precisely measure the correspondence between raw clayey materials and ceramic pastes. A chief example is provided by so-called Pantellerian ware, Late Roman cooking vessels whose production has been associated with the volcanic island of Pantelleria, located 100 km southwest of Sicily and 60 km east of the Tunisian coastline. In their comprehensive review of the archaeometric data available for this ware class, Montana and colleagues were in fact able to identify the recurrence of several mineralogical-petrographic markers that could be associated unequivocally with the peculiar volcanic affinities and lithological signature (peralkaline magmatism) of the island.[472] The distinctiveness of such ceramic material, in terms of both chemical and petrographic composition, has made it possible not only to associate the production of Pantellerian ware with a very limited area of the island but also, perhaps most remarkably, to confidently identify the trade network of such vessels widely distributed over the central and western Mediterranean basin.[473]

Generally, volcanic geological environments, such as that of Pantelleria, lend themselves well to provenance determination studies, as they tend to be more extensively examined through mineralogical, petrographic and geochemical analyses, resulting in the availability of comprehensive databases for comparative purposes. Volcanic minerals can be precisely categorized using optical microscopy and linked to specific geological contexts;[474] however, archaeometric results are not always as straightforward as in the case of Pantelleria. High concentrations of volcanic clasts do not always provide exact geological attribution, as shown in several studies dealing with ceramic production in areas characterized by intense volcanic activity, such as the Eastern Aegean or the Tyrrhenian region, which is also the object of this work. Case studies from Campania and Lazio in fact have amply demonstrated how far extrusive, pyroclastic material can travel.[475] Sudden changes in airstreams and weathering in general can disperse ashes and other by-products of eruptive events over a wide area, "and the proximity of different volcanic sources with a similar petrogenesis can further complicate matters."[476]

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472 The recurrence of aplastic inclusions such as anorthoclase, aenigmatite and primary quartz in association with trachytic-rhyolitic lithic fragments constitutes the petrographic signature of Pantellerian ware. Ample discussion is in Montana et al. 2007.

473 Montana et al. 2007, 476.

474 See for instance the case of Campana A ware retrieved from the Hellenistic workshop at Piazza Nicola Amore, which is characterized by the petrographic markers (leucite and garnet-bearing temper) typically associated with the environment pertaining to the adjacent Somma Volcano. Such components, however, were added to calcareous clays most likely originating from the island of Ischia, thus indicating a more composite clay recipe (De Bonis et al. 2016).

475 About Campania, see Thierrin-Michael & Galetti 1996 and Olcese & Picon 1998. About Lazio see Borgers et al. 2018.

476 Montana 2020, 5.

Volcanic components are but one example of how mineralogical-petrographic markers may contribute to assigning a ceramic assemblage to a (more or less specific) geological environment, like any other mineralogical phase that can be directly associated with specific lithologies would also make possible. Aside from the connection between certain geological components and certain landscapes, provenance studies rely on another key tenet that adds the human factor to the equation. In fact, when trying to pin down the exact location of suitable raw materials, the distance potters traveled to obtain their clays plays a significant role. As previously noted when discussing technological standardization and paste variability, it is commonly assumed that potters exploit sources within relatively limited range, variably estimated within a 7–9 km radius from the production center, according to Arnold's threshold model of distance from raw sources.[477] Based on ethnographic comparison, such a limited catchment area has been confirmed at least among sedentary, non-industrial craft communities who typically collect their clays and temper within a few kilometers from their workshop. By applying this resource zone model to ceramics containing distinctive petrographic characteristics proper to known geological deposits, it is sometimes possible to more precisely delimit the supply area and perhaps more importantly the time and energy spent to reach it. Such information enables us not only to trace different modes of production, labor division and seasonality (in case of sources accessible only in specific periods) but also to set a baseline to distinguish between local and nonlocal sourcing.



Evidence for the provenance and selection of raw materials of archaeological ceramics needs to be supplemented with a rigorous geological prospection program, through which compositional data inferred from thin section analysis can be compared with the compositional and textural characteristics of locally available clayey materials. This final stage of analysis entails the acquisition of geological maps to investigate the territory under scrutiny. Once potential outcrops are located, their extension, accessibility and suitability for potting need to be assessed through sampling, usually by means of coring or superficial digging. The clayey sources collected should then go through the modification process put in place by a potter to transform earth into a durable artifact. From refinement—in order to remove aplastic inclusions—to the addition of temper or the mixing of different clays, all these stages impact the natural composition of the raw sources, thus the need to replicate the same sequence with the modern material collected during the geoprospection. The same applies to the last dramatic change that clay will be subjected to in order to transform into a solid, nonplastic state: thermal treatment. To this end, samples will be processed to obtain clay recipes comparable to those recorded at the site and modeled in small briquettes that—once fully dried—will be fired under controlled conditions. Experimental firing is usually carried out "at temperatures roughly close to those inferred by the study of the ceramics,"[478] in some cases also replicating ancient firing methods (bonfire, pit kiln, kiln). Finally, thin sections will be prepared from the firing briquettes to then be examined under a polarizing microscope. Such an analytical procedure allows for a more detailed definition of the determination of raw materials supplies, while at the same time conveying fundamental information on the human factor involved in the manufacturing process.[479]

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477 See above, section 4.4.2.
478 Montana 2020, 9.
479 Hein & Kilikoglou 2017, 567.

To conclude this brief review about the salient steps involved in tracing raw material sources used by ancient potters, I would like to recall Hilditch words of caution according to which "many geological deposits transcend archaeological occupation in terms of their age. This allows any detailed geological prospection programme to provide useful information on available raw materials for any period of human occupation [...] *given rigorous geological prospection, reference to published geological maps and an understanding of the palaeolandscape during the period under question*."[480] Hilditch raises here a critical point for the analysis of ancient ceramics, which is also relevant for the case study addressed in this work, the Pontine Plain. In fact, the massive volcanic eruption of the Volcano Laziale laid thick volcanic deposits over the entire region and the gradual erosion of such layers has resulted into "a different raw material signature for modern sediment deposits [.... Thus reinforcing] the danger of not accounting for short-term landscape processes".[481]

This chapter concludes the first part of this work in which the theoretical framework (Chapter 1) and analytical techniques (Chapter 4) have been illustrated and discussed against the background of the archeological evidence (Chapter 2) and ceramic dataset (Chapter 3) here under review. The next part will dive into the standardization analysis conducted on materials recovered from both the acropolis and the lower settlement of Satricum to gain insights into the production system of a flourishing Central Italian site between the Archaic and the Post-Archaic period.

480 Hilditch 2008, 111-112 (emphasis is mine).
481 Hilditch 2008, 112.