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Simonetta Menchelli[*/§], Elisabetta Starnini[*], Roberto Cabella[**], Claudio Capelli[**], Michele Piazza[**]

* DCFS – Department of Civilizations and Forms of Knowledge, University of Pisa, Italy.
** DISTAV – Dipartimento di Scienze della Terra, dell'Ambiente e della Vita, University of Genoa, Italy.
§ Corresponding Author.

CERAMIC PRODUCTION AND RAW MATERIALS IN THE TUSCAN-LIGURIAN REGION: AN ARCHAEOLOGICAL AND PETROGRAPHIC APPROACH IN A DIACHRONIC PERSPECTIVE

Abstract: This contribution focuses on the history of ceramic production of a large geographic area of NW Italy summarized from an archaeological point of view but employing a petrographic approach. In this work we will briefly summarize the data and acquisitions mainly relating to the area between western Liguria and north-western Tuscany, also considering comparisons with the Central-South Italian volcanic area (S-Tuscany, Latium and Campania). The scope of our research is to reconstruct the productive districts combining information from Prehistory to the late Roman, Medieval, and post-medieval ages in a diachronic perspective. The region under study is characterized by a marked geodiversity allowing the definition of specific production areas based on minero-petrographic (including paleontological) data. Our long-term research combines information collected from different archaeological sources, from prehistoric ceramics to Roman pottery workshops identified in the region. This diachronic approach allows the definition of subregional productive districts characterized by the mineralogical-petrographic content of the products, that can be considered as fingerprints for pottery provenance. Our goal is to promote a «green archaeometry/green archaeology» approach, recycling and reusing old samples for reanalysis, rather than resample for new analyses and to limit new sampling to the strict necessary.

Keywords: 1) ceramic sourcing; 2) Tosco-Ligurian region; 3) petrographic approach; 4) production markers.

1. Introduction

This paper presents one of the achievements of a long-term research project based on the mineralogical-petrographic (including paleontological aspects) analysis of a large thin section dataset, encompassing prehistoric (from the early Neolithic to the Iron Age), Roman and post-Roman age ceramics produced and/or imported in

fig. 1. Petrographic slide storage boxes in metal drawer conserving the collection of DISTAV-University of Genoa (photograph by the Authors).

Liguria and Tuscany. This research benefits from two main pillars: the legacy of the pioneer studies in the field of archaeometrical analyses applied to ceramics of the late Prof. Tiziano Mannoni and the thin sections Database of Mediterranean ceramics, that he started to set up in the 1960s at the University of Genoa (Mannoni, 1994; Capelli & Mannoni, 1999; Capelli et al., 2006; Starnini, 2011; Levi & Muntoni, 2014; Menchelli, 2018; Pesce et al., 2020) and it is constantly implemented by the research group of the DISTAV (Dipartimento di Scienza della Terra, dell'Ambiente e della Vita, Università di Genova).

It is a long-lasting project, following the principle that can be called "slow science" (Stengers, 2018) and for which we still consider some of T. Mannoni's remarks important. For example, the need for continuous dialogue between Archaeologists and Archaeometrists, starting from the archaeological-historical question asked by the "Humanists", and subsequently in the sampling phase to choose the potsherds to be analysed and finally in the interpretation of the data (Mannoni, 1987).

Thanks to about 60 years of continuous research, over 13.000 thin sections of Mediterranean ceramics from Prehistory (early Neolithic) to the 19th century, and several hundreds of thin sections of clays and sands samples as comparative materials are currently stored at the Genoa University (DISTAV Department) (fig. 1). Moreover, XRD and SEM-EDS analyses have been carried out whenever necessary to get insight into specific problems. Chemical bulk analyses have been performed in some cases in cooperation with specialized Laboratories (namely the Laboratoire de Céramologie of Lyon, founded by Maurice Picon).

So far only samples of prehistoric and protohistoric ceramics have been included in a digitized database (Capelli et al., 2006), which we intend to continue implementing with samples from post-prehistoric periods. Among them, some thousand samples are from the Ligurian-Tuscan area.

The project involves several approaches, in a holistic perspective, among which:

- the mineralogical-petrographic and archaeological-typological integrated study
- the comparison and integration with works published by other research groups
- the continuous implementation of the collection with new samples

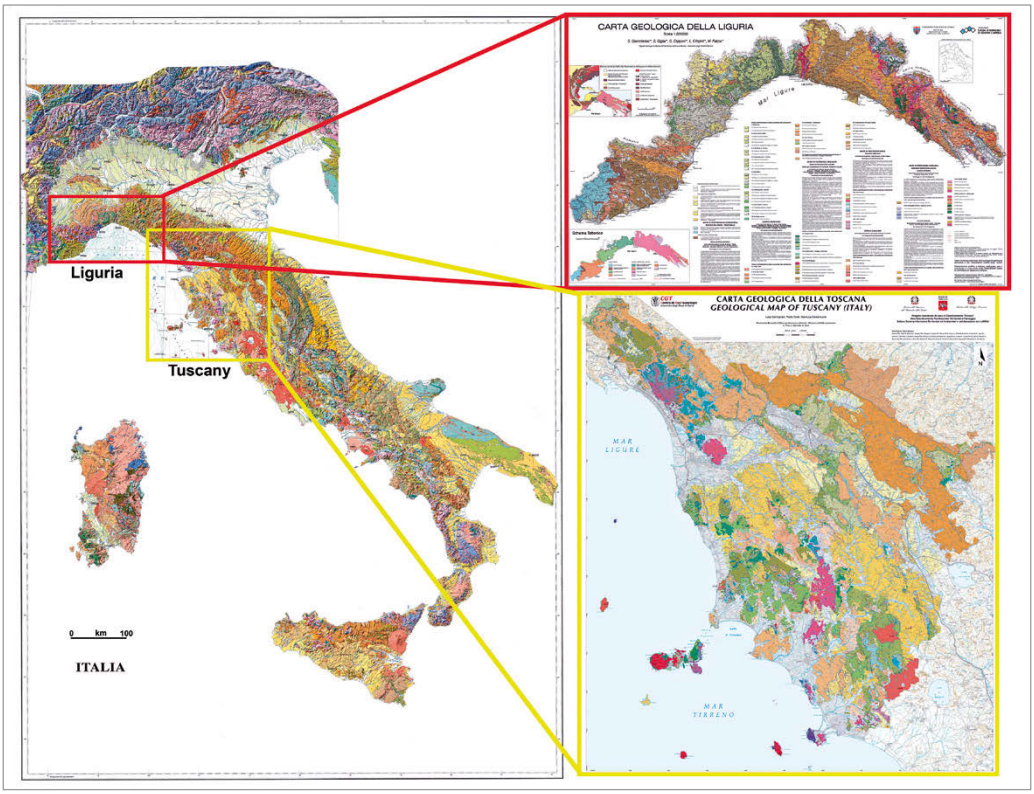

fig. 2. Geological maps of Liguria (modified after Giammarino et al., 2002) and Tuscany (modified after Carmignani et al., 2013) and their location on the geological map of Italy (modified after Compagnoni et al., 2004).

On these bases, it is now possible to distinguish with good reliability several ceramic production districts especially in the territorial transect encompassing Liguria and Tuscany.

The characterization of these districts is based on the identification of compositional markers of the fabrics directly related to the sub-regional geology. The identification of local productions also allows us to better distinguish the regional and extra-regional imported ceramics, characterized by raw materials incompatible with the local geology.

2. Geographical, geological features and discriminant petrographic markers of the ceramic productions of the study area

The focus-area of the present synthesis (i.e. Liguria and NW Tuscany) (fig. 2) is geologically characterized by a high lithological diversity that includes the entire range of magmatic, sedimentary, and metamorphic rocks (Giammarino et al., 2002; Conti et al., 2020). The transect comprises the Ligurian Alps and Northern Apennine orogenic systems, with rocks belonging to the pre-Alpine, Alpine and Apennine geological history, and the related late- to post-orogenic sedimentary covers. The central

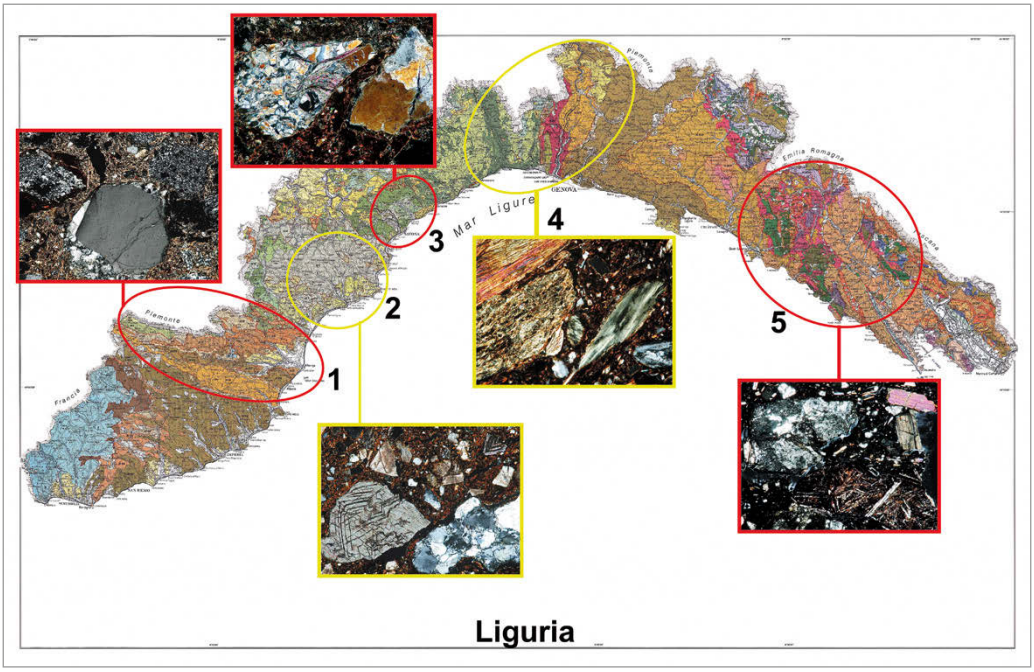

fig. 3. Location of the production districts on the Liguria geological map and ceramic thin section photomicrographs showing their characteristic minero-petrographic markers: 1) Albenga hinterland markers: acidic meta-volcanic and meta-sedimentary rocks, in the microphoto meta-rhyolite, fine-grained quartz-micaschist; 2) Finalese area markers: acidic and basic metavolcanites and spathic calcite, in the microphoto spathic calcite and meta-quartzarenite; 3) Savona-Albisola markers: ortho- and paragneisses, amphibolites, serpentinites, calcareous and siliceous microfossils, in the microphoto: gneiss; 4) central-western Liguria markers: ophiolithes and calcschists/quartz-micaschists, in the microphoto: serpentinite; 5) eastern Liguria markers: ophiolites without Alpine metamorphism, in the microphoto: gabbro, basalt and "diallage" clinopyroxene (the actual area of the microphotographs is 1.3×1 mm, crossed polars) (map modified by the Authors after Giammarino et al., 2002).

Tyrrhenian sector comprising the volcanic area encompassing S-Tuscany, Latium and Campania will be briefly discussed too, especially regarding the presence of peculiar volcanic markers that can be used to trace long-distance imported ceramics.

So far, the Ligurian geological areas that can be fingerprinted by the presence of peculiar rocks and associations of minerals and petrographic markers that have been identified are listed below (fig. 3):

Albenga hinterland markers (fig. 3, 1):

This microregion is located in western Liguria and encompasses the plain of Albenga, the Centa River basin and the Pennavaire Valley. This area shows a notable geological variety, due to presence of several tectonic units piled in the Ligurian Alps and of late- to post-orogenic and Quaternary sedimentary deposits (Lanteaume, 1968; Lorenz, 1968; Boni et al., 1970; Boni et al., 1971; Dallagiovanna & Seno, 1984; Vanossi et al., 1984; Marini, 2004; Gaggero et al., 2004; Decarlis et al., 2013). Overall, the units are

made up of acidic metamorphites, acidic to intermediate volcanites, quartz-arenites, quartz-conglomerates, polygenic breccias, dolomites, limestones, arenaceous-conglomeratic and calcareous-marly turbidites, clayey and calcareous-clayey pelites, basaltic olistoliths (Lanteaume, 1968; Boni et al., 1970; Boni et al., 1971; Dallagiovanna & Seno, 1984; Marini & Terranova, 1985; Marini, 1988; Di Giulio, 1992; Gaggero et al., 2004; Decarlis et al., 2013). The late- to post-orogenic and Quaternary deposits are represented by very fine to very coarse clastic deposits feed by the Alpine rocks of this sector: it is to be noted the presence of the Pliocene fossiliferous marine pelites of the Ortovero Clay (Lorenz, 1968; Boni et al., 1970; Boni et al., 1971; Fanucci et al., 1980; Boni, 1984; Marini, 2004).

A recent work provided a preliminary definition of the origin markers of this ceramic production district (Capelli et al., 2023). The fabrics are mainly characterized by inclusions related to the Permian metamorphic quartz-conglomerates and quartz-arenites, meta-rhyolites, fine-grained quartz-micaschists.

Finalese area markers (fig. 3, 2):

This area corresponds to a karstic highland characterised by Mesozoic Briançonnais dolostones and limestones (and minor siliciclastic sedimentary rocks and acidic metavolcanites) and Miocenic biocalcarenites/biocalcirudites of the *Pietra di Finale* (Boni et al., 1968; Bonci et al., 2019; Dallagiovanna et al., 2011; Decarlis et al., 2013; Baucon et al., 2020) overlying the Paleozoic crystalline and sedimentary Units.

In this area the main rocks and minerals characterising the local productions derive from the Permian acidic and basic metavolcanites, and acidic metasediments, along with spathic calcite from Mesozoic and Miocene limestones (Capelli et al., 2018; Capelli & Starnini, 2019).

Savona-Albisola area markers (fig. 3, 3):

This area is largely characterized by the occurrence of Paleozoic gneiss, metagranitoids, amphibolites and associated metasediments as well as metaophiolites outcropping in the eastern part (Dallagiovanna & Seno, 1984; Vanossi et al., 1984; Marini, 2004; Gaggero et al., 2004; Dallagiovanna et al., 2011; Decarlis et al., 2013; Federico et al., 2014; Capponi et al., 2016; Federico et al., 2022). These crystalline units are locally covered by Oligocene mainly siliciclastic, fine to very coarse sediments (Molare Formation) and Pliocene pelitic deposits (mainly marls and clays, Ortovero Formation) (Lorenz, 1968; Boni et al., 1970; Boni et al., 1971; Fanucci et al., 1980; Boni, 1984; Marini, 2004; Federico et al., 2014; Capponi et al., 2016; Federico et al., 2022).

The studied fabrics of all ages and typologies, from the Iron Age (Bulgarelli et al., 2023) to the modern age (Capelli, 2001; Capelli et al., 2013; Capelli & Cabella, 2015) are strongly distinguished by a complex association of inclusions derived from the Paleozoic basement (gneisses and amphibolites), minor Jurassic metaophiolites, and both calcareous (foraminifera) and siliceous (sponge spiculae, diatoms, radiolarians) microfossils from the Pliocene clays. This association is recognizable not only in the coarse fabrics, partly or completely made from alluvial sediments, but also in the Ligurian majolica, made with Pliocene clays (Capelli & Cabella, 2013).

Central-W Liguria markers (fig. 3, 4):

This microregion, encompassing the basin of Rio Sanda to the west and the Polcevera River Valley to the East is distinguished by the presence of Jurassic meta-ophiolites affected by Alpine HP – and greenschist – facies metamorphism (mainly serpentinites, metagabbros, metabasites, prasinites, eclogites) and of the related oceanic metasediments (calcschists, metacherts, marbles, minor dolomitic marbles and fine-grained siliciclastic and carbonate turbidites) (Federico et al., 2014; Capponi et al., 2016; Federico et al., 2022).

Inclusions derived from metaophiolites and calcschists/quartz-micaschists characterise the fabrics of this area (Mannoni, 1970/71; Capelli, 2006).

Eastern Liguria markers (fig. 3, 5):

This area, located between the Entella River Valley and the border with Tuscany, is mainly composed of ophiolites (gabbros, basalts, peridotites) without Alpine metamorphism and related pelagic sedimentary rocks (cherts, micritic limestones, marly to clayey pelites) and of siliciclastic and carbonate turbidites (claystones, sandstones, conglomerates, calcilutites and calcarenites) pertaining to the Internal and External Ligurian Units (Elter & Marroni, 1991; Marroni et al., 1992; Marroni & Pandolfi, 1996; Catanzariti & Perilli, 2011; Conti et al., 2020). In the easternmost part of this area, the Tuscan units, which are described in the following lines, also occur.

The fabrics are well distinguished by the presence of the Jurassic ophiolitic inclusions, including "diallage" clinopyroxene and Ca-rich plagioclase, sometimes associated to sandstone clasts.

In the adjacent NW part of the Tuscany region, the main geo-petrographic markers are the following (fig. 4):

Luni-Massa microregion markers (fig.4, 1):

Located on the border between Liguria and NW Tuscany, this area that includes the Magra river basin and the westernmost stretch of the Apuan Alps, is characterized by the occurrence of a large variety of lithotypes, including pre-Alpine acidic metamorphic rocks (Tuscan Metamorphic Unit), Meso-Cenozoic sedimentary rocks of the Tuscan Nappe Auctt. (cherts, claystones, siltstone, sandstones, marls, conglomerates, vacuolar to micritic to bioclastic limestones) and the corresponding metamorphic terms (Tuscan Metamorphic Unit), Ligurian ophiolites (peridotites/serpentinites, gabbros, basalts), and Pliocene to Recent sandstones and shales (Carmignani & Kliegfield, 1990; Elter & Marroni, 1991; Marroni et al., 1992; Marroni & Pandolfi, 1996; Carmignani et al., 1978; Carmignani et al., 2013; Catanzariti & Perilli, 2011; Carmignani et al., 2013; Conti et al., 2020).

The fabrics of the various productions of this area contain polygenic inclusions derived from ophiolitic, acidic metamorphic, and sedimentary rocks (Capelli et al., 2022; Genovesi & Capelli, 2016)

Serchio valley markers (fig. 4, 2):

The Serchio is the second largest river in Tuscany; here, several geological units belonging to different paleogeographic domains crop out: from SW to NE, occur

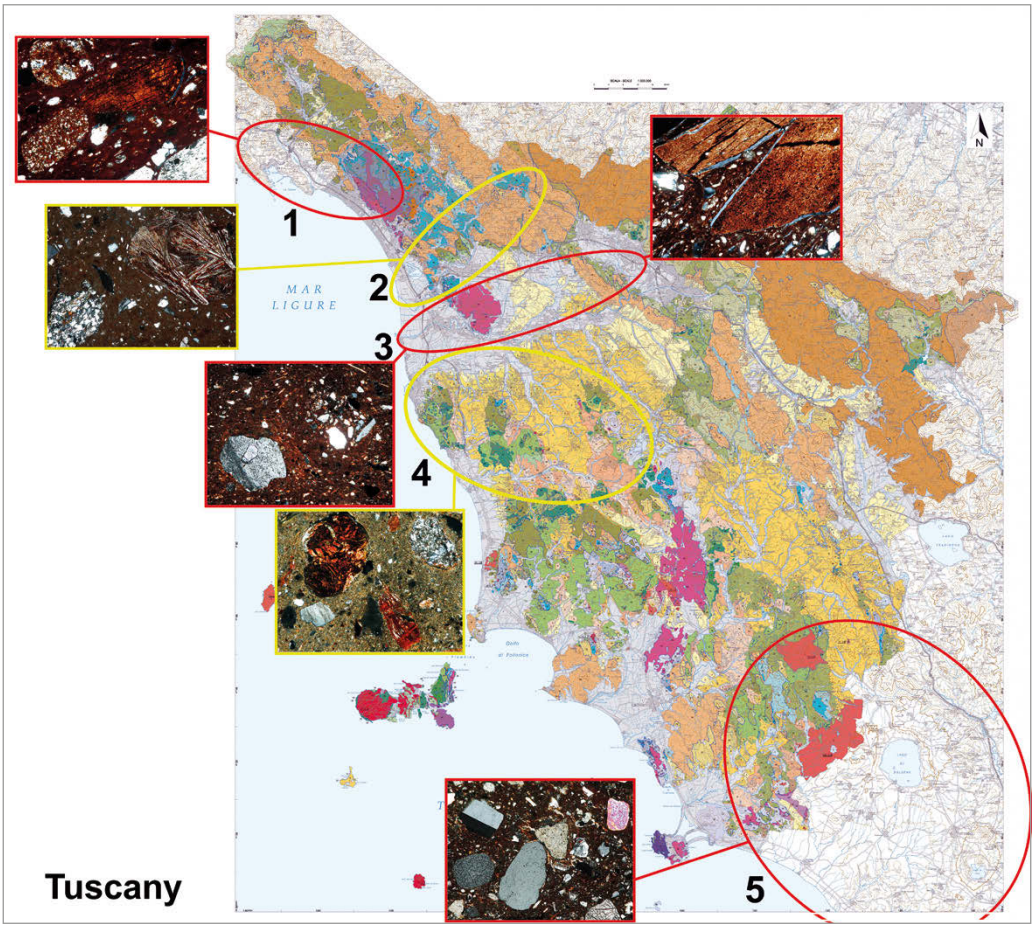

fig. 4. Location of the production districts on Tuscany geological map and ceramic thin section photomicrographs showing their minero-petrographic markers: 1) Luni-Massa makers: ophiolites, acid metamorphites, sedimentary rocks, in the microphoto: serpentinite, metasiltite; 2) Serchio Valley markers: acidic metamorphites, ophiolithic basalts, shales, and sandstones, in the microphoto: quartz-micaschist, basalt; 3) Mid-lower Arno Valley markers: fine grained fabrics with acidic metamorphic elements, sandstones, calcareous microfossils (echinoid spines), in the microphoto: feldspar, sandstone; 4) Livorno-Vada markers: ophiolites, sedimentary rocks, siliciclastic elements, calcareous microfossils, in the microphoto: serpentinite, basalt, plagioclase, quartzite; 5) volcanic area extending from southern Tuscany, to Latium and Campania: markers: alkali-potassic volcanic rocks, in the microphoto sanidine feldspar, clinopyroxene, limestone, quartz (the actual area of the microphotographs is 1.3×1 mm) (map modified by the Authors after Carmignani et al., 2013).

the Ligurian, Subligurian and Tuscan domains (Nardi et al., 1986; 1987; Carmignani et al., 2013; Conti et al., 2020); for the lithological aspect refer to the information reported in the above lines (i.e., Eastern Liguria and Luni-Massa areas). Fluvio-lacustrine, siliciclastic, fine- to coarse-grained deposits ("Villafranchian" continental deposits Auctt.) crop out too in tectonic depressions: they are part of the Barga and Castelnuovo di Garfagnana fluvial-lacustrine basins (Perilli et al., 2004).

The fabrics of the productions located in the mid and lower valley are characterised by an association of inclusions derived from acidic metamorphites, ophiolitic basalts, shales, and sandstones (Menchelli et al., 2001; Capelli et al., 2017a).

Mid-lower Arno River Valley markers (fig. 4, 3):

This hydrographic basin is located in the northern Apennines and it is characterized by the occurrence of sedimentary siliciclastic and calcareous rocks and minor acidic metamorphites pertaining to Ligurian, Subligurian and Tuscan domains, as well as Cervarola and Mt Modino siliciclastic turbidites. All these units are part of the Northern Apennines tectonic pile (for a lithological view refer to the information reported in the above lines, i.e., Eastern Liguria and Luni-Massa areas, and to Carmignani & Kligfield, 1990; Cencetti & Tacconi, 2005; Nisi et al., 2008); Plio-Pleistocene fine-grained, marine to alluvial sediments also occur (Aruta et al., 2003; Nisi et al., 2008; Conti et al., 2020).

The lower part of the basin is characterised by Fe-rich alluvial clays, extensively used and generally poorly modified for the pottery production in all ages (Capelli, 2001; Menchelli et al., 2001). The fabrics generally show fine, generic inclusions (acidic metamorphic elements, sandstones, calcareous microfossils from Pliocene sediments; among which, echinoid spines in the Empoli area: Bulgarelli et al., 2018).

Livorno-Vada markers (fig. 4, 4):

The Vada plain, which belongs to the coastal sector between the port cities of Livorno and Piombino, falls within the wider plain south of the Fine River valley. The area is part of the Castiglioncello-San Vincenzo sedimentary basin. It is characterised by a succession of marine sediments, including transgressive coastal conglomerates of Villa Magrini; Santernian-Emilian sands and clays with *Arctica islandica* of the Morrona Formation; the Montescudaio Limestones, transgressive sediments of a shallow environment dated to the Emilian; and the Riparbella Conglomerates, found at the roof of the succession only in this locality. The bedrock of the area of interest is formed by the units of the Tuscan Nappe and the Ligurian Domain. The former is composed of a marine succession of Mesozoic to Eocene sedimentary rocks, overlain by Oligo-Miocene turbidite deposits. The Ligurian Units here include deep to very deep marine deposits, such as limestones, marls, and cherts, and rare ophiolitic terms (Pasquinucci et al., 2001; Bosellini, 2005; Carmignani et al., 2013).

The ceramics of this area are distinguished by inclusions derived from the Jurassic ophiolites (serpentinites, gabbros, basalts) associated with sedimentary rocks, siliciclastic elements, and Pliocene microfossils (Pasquinucci et al. 1997; Boschian, 2000; Cabella et al., 2023).

Central-S Italian volcanic area (S-Tuscany, Latium, and Campania) (fig. 4, 5).

This large coastal region is composed of a number of units forming the tectonic pile of the Apennines on which rest a large variety of volcanic and sedimentary rocks and unlithified sediments (Messinian to Recent), but it is strongly characterised by the presence of the volcanic complexes of Plio-Pleistocene age (Conticelli et al., 1986; Cosentino et al., 1993; Peccerillo, 2005; Carmignani et al., 2013; Fedele et al., 2016;

Conti et al., 2020, 2022). According to the just cited Authors, the Apenninic units include virtually all types of clastic and carbonate sedimentary rocks and also some metasediments (Permian to Oligocene in age). The Messinian to Recent sedimentary cover is composed of fine to coarse grained siliciclastic sediments deposited in marine to subaerial environments as well as of chemical deposits (e.g., travertine). The volcanic rocks have mainly alkaline (from K-alkaline to high-K-alkaline) and calcalkaline composition (Conticelli et al., 1986; Cosentino et al., 1993; Peccerillo, 2005; Fedele et al., 2016; Conti et al., 2020, 2022) and contain very discriminant minerals (among which: sanidine feldspar, clinopyroxene, biotite, leucite, "melanitic" garnet), that allow the provenance identification of the various pottery productions distributed in the area (for example: Capelli & Iliopoulos, 2021; Izzo et. al., 2021; 2023).

3. Aims and methods

Our research has been designed to build a reference dataset of local productions for provenance studies on ceramics from the Neolithic to historical periods. This can be achieved by the identification of mineralogical-petrographic markers of origin in the fabric aplastic inclusions, independent of their frequency, their morphological-dimensional characters, the typology, and chronology of the ceramics, considering the hypothesis/assumption that, in general with rare exceptions, the raw materials for the ceramic production were not traded from long distance in ancient times (about this topic see: Grifa et al., 2021).

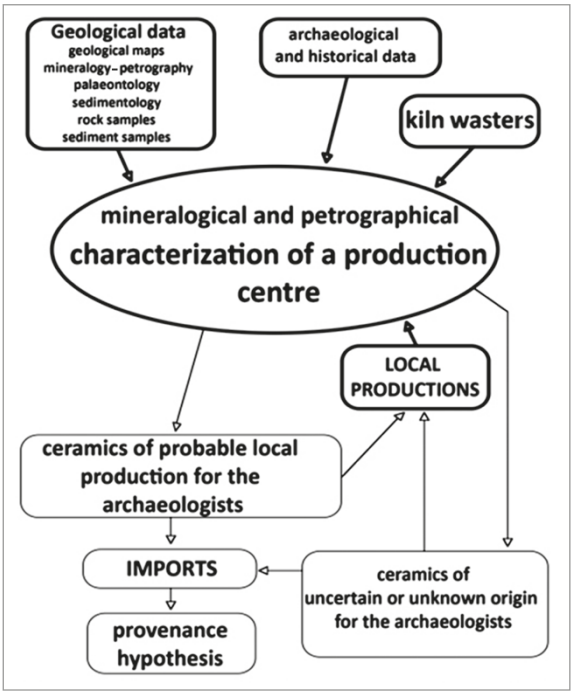

fig. 5. A model of the relationships between the components involved in ceramic sourcing studies (modified and translated by the Authors from Capelli & Mannoni 1999, fig. 1).

The compositional and technological comparison between the samples of the database allows to obtain information on the technological evolution and use of raw materials in the same production centre or district over a wide chronological span and to recognize the distribution area of products, traditions, and technological knowledge (Capelli & Mannoni, 1999; Spataro & Villing, 2015) (fig. 5).

For provenance studies, comparisons with reference groups of certain origin are fundamental, particularly the kiln wastes.

The analytical methods systematically employed in our research are Optical microscopy, with both stereomicroscope and magnifying lens, followed by thin section analyses under polarizing microscope of representative samples selected on the base of typology, fabrics, and technology. However, other techniques (e.g., Scanning Electron Microscopy and microanalysis, X Ray Diffraction, X-Ray Fluorescence) are also used when necessary to solve specific problems (as well as bulk chemistry) in collaboration with specialized Labs.

As mentioned before, the final goal of the research is to identify the minero-petrographic markers of provenance in the paste, independently from their frequency, morpho-dimensions, and typo-chronology of the pottery. The advantage of the petrographic approach versus the geochemical one is that petrography gives provenance indications even when archaeological hypotheses and reference materials are lacking, as the comparison between the petrography of the inclusions and the geological cartography always gives some results, in both positive (the inclusions are compatible with the local geology) and negative (the inclusions are incompatible with the local geology) ways.

4. Achievements

Beside the identification of regional-subregional markers, an important result of the exam of the collection was obtained from the comparison of prehistoric potsherds with historical ceramic samples from the same area present in the database. It emerged that the origins of some technological traditions and the use of particular raw materials can be traced back to Prehistory or Protohistory, such as the utilisation of ground spathic calcite or gabbro as a temper found also in later period in some Roman and medieval productions of Eastern Liguria and Northern Tuscany, for the cooking wares in particular (Boschian, 2000; Capelli et al., 2006; Cagnana et al., 2008; Capelli et al., 2022; Cabella et al., 2023, 86; Menchelli & Bianchini, 2023, 236) .

Moreover, prehistoric ceramic circulation along the Tyrrhenian coasts could be traced and can be used as a proxy to infer the existence of Neolithic production centres filling voids in the knowledge and predicting the presence of sites that have yet to be found (Capelli et al., 2017b). In particular, the research revealed the earliest, long-distance circulation of ceramic products in the Mediterranean during the early Neolithic (ca. 5800 BC). In some Prehistoric and Roman potsherds, long distance exotic markers such as Apennine gabbro as well as volcanic components (sanidine and basalts) have been identified by thin section analyses (Capelli et al., 2011; 2017b; Cabella et al., 2023, 87-90) (fig. 6, 1-2).

fig. 6. Imported fabrics found in Liguria and Tuscany from Neolithic and Roman age sites, with volcanic inclusions in the paste: 1) Early Neolithic impressed pottery from Pian del Ciliegio (Liguria, Finalese); 2) Graeco-Italic and Dressel 1 amphorae forms found in the *Portus Pisans* seabed (the actual area of the microphotographs is 1.3×1 mm) (photographs by the Authors).

For later periods, samples from pottery workshops are represented in the database, along with samples from sites distributed along the northern coastal Tuscany and dated to Etruscan and Roman times.

In fact, the geological features and the many workshops identified in the Pisan-Volaterran area made possible the mineralogical-petrographic characterization of their products, dated from the late 7th cent. BC to the Late Roman period (Menchelli et al., 2011; Cabella et al., 2023). In this district the Isola di Migliarino site, located at the mouth of the Serchio River, was particularly important because it was a port belonging to the Pisa Harbour System (Pasquinucci & Menchelli, 2010) and included a manufacturing centre of Italian Sigillata vases (mainly cups and dishes) that, according to the archaeological and epigraphical findings, was active from 20 BC to 150 AD (Menchelli et al., 2001; Menchelli & Sangriso, 2017). These fine wares were made of alluvial clay, while the spacers feature an alluvial sandy temper (acidic metamorphic rocks + sandstones + basalts) added to the same clay (Menchelli et al., 2001) (fig. 7, 1). Based on the comparison with these reference materials, rectangular sesquipedalians bricks (Augustan age – 1st century AD) found in various contexts in Pisa and in the hinterland of the Arno River Valley (Sant'Ippolito di Anniano, Oratoio) were attributed to the workshops located in the Isola di Migliarino district (Capelli & Cabella, 2022).

Workshops of Italian Sigillata, producing the same vases forms as those from Isola di Migliarino, were also located in the northern suburbs of the Roman Pisa, as documented by significant discharges of kiln wasters as well as kiln furniture (Menchelli et al., 2001; Menchelli et al., 2020). However, the Pisa products show quite different, more refined and generic, fabrics and thus can be distinguished from those of the lower Serchio River Valley workshops.

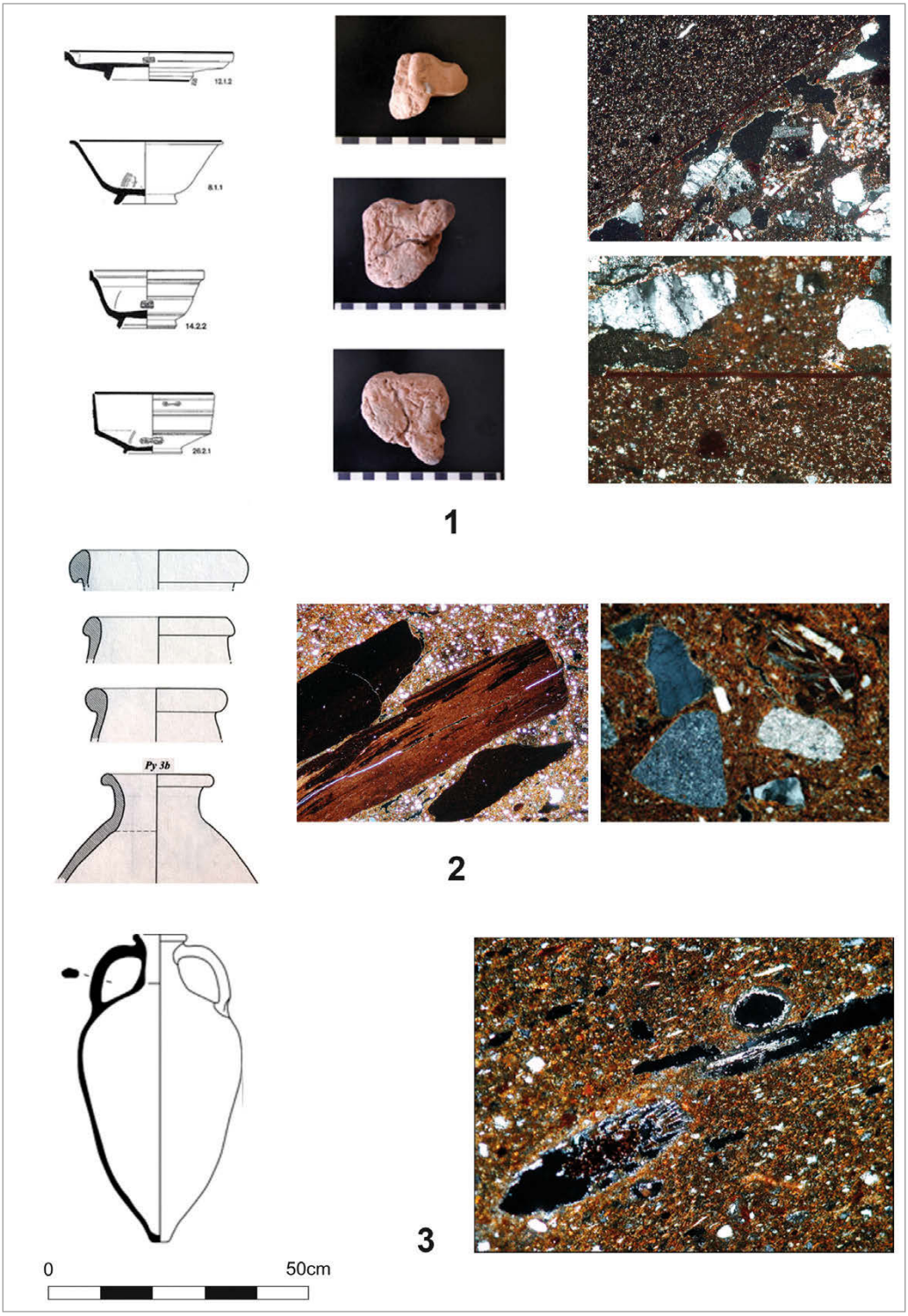

fig. 7. 1) Dishes, cups, and spacers from the Isola di Migliarino Workshops; 2) Etruscan amphorae and pots produced in the Pisan territory; 3) Empoli type Amphora (the actual area of the microphotographs is 1.3×1 mm) (photographs by the Authors).

Moreover, the minero-petrographic analyses demonstrated to be also effective, along with the more employed chemical analyses, for particularly fine ware productions such as the black-gloss ware (4th-1st century BC). The productions that have been identified in the Serchio valley as well as in Pisan area can be distinguished from the central and southern Tyrrhenian ones for the absence of volcanic inclusions (Capelli, 1998).

Regarding the amphorae, a Pisan Etruscan wine container production (type Py 3a dating to the late 7th-6th cent. BC), with alluvial sands or ground shales as added temper in the paste has been identified (Capelli et al., 2017a) (fig. 7, 2).

This is a typical fabric of the Pisan territory and, thanks to mineral-petrographic analyses, these Etruscan amphorae together with pots of the same ware have been recognised in Genoa (Monte Castello: Mannoni, 1975, classe II, tipo I; Portofranco: Capelli, 2006; San Silvestro: Milanese & Mannoni, 1984, Gruppo XII), thus documenting the marketing of Pisan goods towards the north during the Archaic age.

Concerning Roman Amphorae, the Empoli type wine containers were produced throughout the Arno River valley and in other Tuscan districts from the late 2nd to the late 5th/early 6th cent. AD (fig. 7, 3). These amphorae were traded both to the Rome's markets and along the western Mediterranean coasts and to Corsica, Sardinia and the other minor islands (Menchelli, 2022). Thanks to the finding of kilns and wasters and to geo-archaeological and minero-petrographic studies, three main production areas have been identified:

a) Empoli area (mid-Arno River Valley). Markers: calcareous microfossils (echinoid radioles) from Pliocene sediments.
b) Pisan district (low Arno River Valley). Markers: fine-grained alluvial clays, fine-grained inclusions: acidic metamorphic elements + sandstones and shales.
c) Coastal Volaterran district (Low Fine and Cecina Rivers areas). Markers: Jurassic ophiolites (serpentinites, gabbros, basalts) + sedimentary rocks + Pliocene microfossils.

The morphological peculiarities of the Empoli type Amphorae were very similar in the various districts/workshops, but the specific markers of their fabrics allow identifying the precise provenance of their products in the consumer sites (Capelli et al., 1999; Bulgarelli et al., 2018; Del Rio, 2023).

In the same way, the characterisation of the local and regional fabrics allowed the distinction of the Graeco-Italic and Dressel 1 wine amphorae imported from central and southern Italy from those produced locally, for example in the case-study of a sector of the *Portus Pisanus* seabed (Menchelli et al., 2013) (fig. 8, 1)

In fact, starting from the 3rd cent. BC, *Portus Pisanus*, the main centre of the Pisan Harbour system (immediately north of Livorno), became the military base for the Roman army during its expansion towards the north-west. Therefore, a remarkable quantity of Graeco-Italic (3rd-2nd cent. BC) and Dressel 1 (late 2nd-1st cent. BC) amphorae were sent from Latium and Campania to the Pisan area, and the presence of the armies stimulated the local production of wine amphorae as demonstrated by the pottery kilns found in the hinterland of *Portus Pisanus* (fig. 8, 2-3). Therefore, the minero-petrographic analyses, not only distinguished various imported products, but also identified the presence in the port of local amphorae ready for the trade of the local wine (fig. 8, 4) documenting significant import-export activities during the Romanization process in the Pisan district.

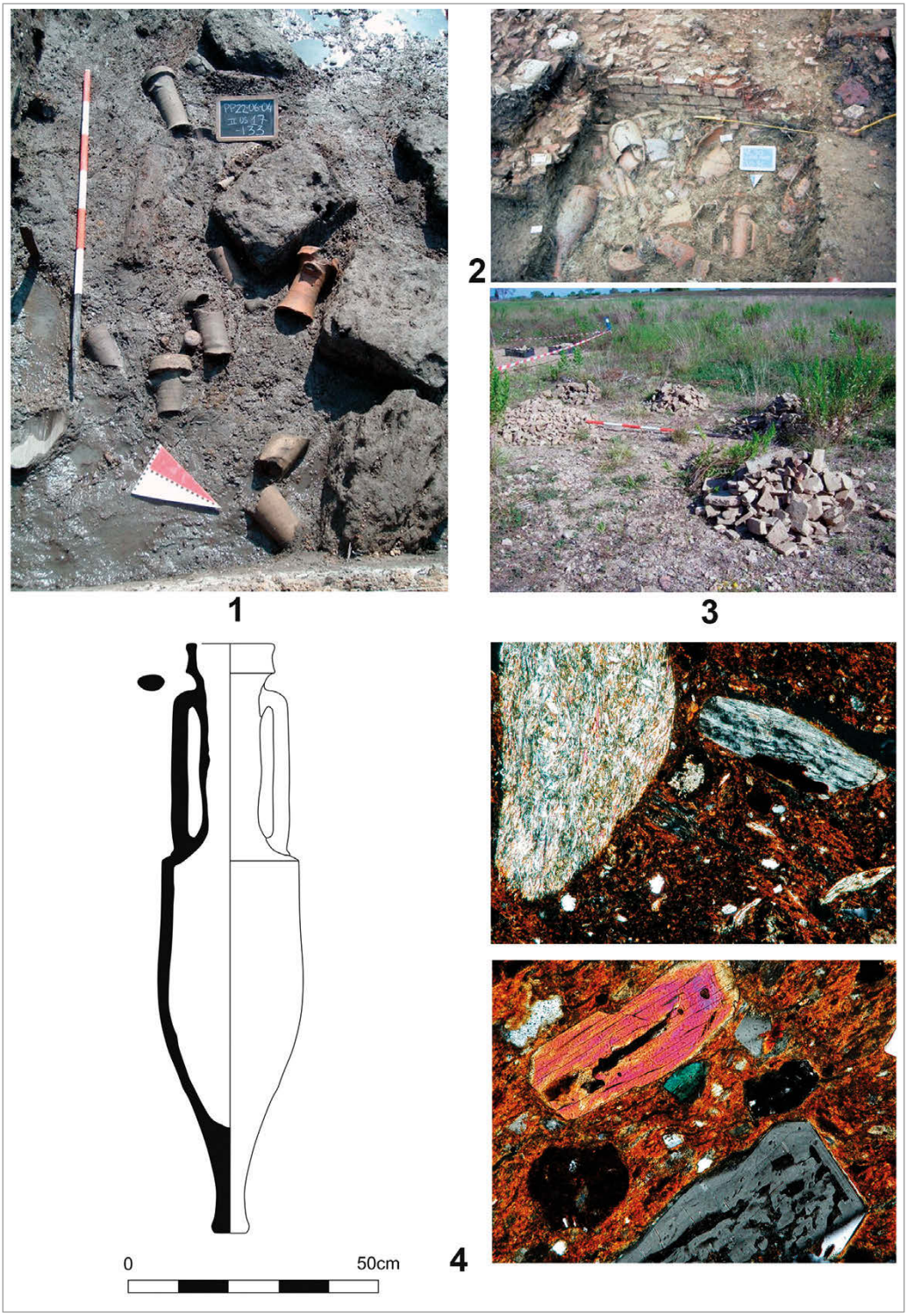

fig. 8. *Portus Pisanus* area. 1) The seabed being excavated (2004); 2-3) amphorae workshops; 4) locally produced Dressel 1 amphora form (the actual area of the microphotographs is 1.3×1 mm) (photographs by the Laboratory of Ancient Topography, University of Pisa, & microphotographs by the Authors).

5. Conclusive remarks

Our goal is a «green archaeometry», that is: sustainable as aimed at providing the archaeologists with tools for recognizing the combination of the compositional, technological, and typological macroscopical markers, for identifying a specific production without destructive and expensive analyses. Moreover, in the spirit of «green archaeology» (Costanzo et al., 2024) our aim is to recycle and reuse old samples for reanalysis, rather than resample for new analyses and to limit new sampling to the strict necessary. In many cases, new and groundbreaking information have been achieved simply restudying old collections of thin sections in the light of new knowledge and with new, holistic approaches.

Considering the large amount of data collected so far by our research group, with samples spanning from the Neolithic to the post-Medieval period, it will be necessary in the future to create a digital database to store information, possibly with open data access, in the policy of Open Science (European Commission, 2015:33). Ideally, the database should include contextual, typological, chrono-cultural, geographic, and petrographic information for each sampled potsherd. This database will let us archive previously acquired data and to input new and ongoing research. It will be conceived for searching through queries the information among the individual samples and ceramic pastes at a Mediterranean scale and *longue-durée* perspective. There are already several Databases accessible on the net (Tomber & Dore, 1996; 1998; Odelli, 2023, tab. 1; Stilborg et al., 2023). Nevertheless, we do believe that our thin section collection deserves a further effort for its digitalization due to its unique characteristics that reside precisely in its geographical and chronological breadth, the result of a long work of over 50 years of analysis.

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Bibliography

Aruta, G., Bruni, P., Cecchi, G., Cipriani, N., & Tredici, Y. (2003). Pliocene and Pleistocene unconformity bounded units (UBSU) Val di Chiana. In D. Morini & P. Bruni (eds.) *The Regione Toscana Project of Geological Mapping Case Histories and Data Acquisition* (pp. 133-136) Regione Toscana.

Baucon, A., Piazza, M., Cabella, R., Bonci, M.C., Capponi, L., Neto de Carvalho, C. & Briguglio, A. (2020). Buildings that 'Speak': Ichnological Geoheritage in 1930s Buildings in Piazza della Vittoria (Genova, Italy). *Geoheritage*, 12 (70), 1-22.

Bonci, M. C., Cabella, R., Faccini, F., Firpo, M., Mandarino, A., & Piazza, M. (2019). Geologia, paleontologia e geomorfologia della Pietra di Finale. In G. Murialdo, R. Cabella, & D. Arobba (eds.) *La Pietra di Finale. Una risorsa naturale e storica del Ponente ligure* (pp. 11-32). Istituto Internazionale di Studi Liguri.

Boni, A. (1984). Il Pliocene e la Neotettonica nelle Alpi Liguri. *Memorie della Società Geologica Italiana*, 28, 229-265.

Boni, A., Boni, P., Cavallaro, E., Cerro, A., Gianotti, R., Perotto, G., & Vanossi, M. (1970). *Carta Geologica d'Italia, Foglio 92-93 Albenga-Savona. Servizio Geologico d'Italia*. Istituto Italiano d'Arti Grafiche.

Boni, A., Cerro, A., Giannotti, R., & Vanossi, M. (1971). *Note illustrative della Carta Geologica d'Italia. Foglio 92-93 "Albenga-Savona"*. Roma: Servizio Geologico d'Italia.

Boni, P., Mosna, S. & Vanossi, M. (1968). La Pietra di Finale (Liguria Occidentale). *Atti dell'Istituto di Geologia dell'Università di Pavia,* XVIII, 102-150.

Boschian, G. (2000). Analisi mineralogico-petrografica delle ceramiche di Casa Querciolaia (LI). In C. Tozzi & M.C. Weiss (eds.) *Les premier peuplements Olocenes* (sic !) *de l'aire Corso-Toscane* (pp. 239-240). Edizioni ETS.

Bosellini, A. (2005). *Storia geologica d'Italia*. Zanichelli.

Bulgarelli, F., Capelli, C., & Cabella R. (2023). La necropoli di Albisola Superiore tra archeologia e archeometria. Le origini della produzione ceramica albisolese. In F. Negrino & V. Tiné (eds.) *Preistoria e Protostoria della Liguria. Rivista di Scienze Preistoriche*, LXXIII, S3, 959-968.

Bulgarelli, F., Cascarini, L., Dell'Amico, P., Gervasini, L., Capelli, C., & Cabella, R. (2018). Notizie preliminari sulla presenza dell'Anfora di Empoli in Liguria. *Archeologia in Liguria*, nuova serie, volume VI, 2014-2015, 87-109.

Cabella, R., Capelli, C., & Piazza, M. (2023). Le analisi archeometriche in microscopia ottica sulle ceramiche di San Gaetano di Vada. In S. Menchelli, M. Pasquinucci & P. Sangriso (eds.) *Vada Volaterrana: gli horrea. Strutture, stratigrafie, materiali* (pp. 83-90). Instrumenta, 5. Pisa University press.

Cagnana, A., Cabella, R., Capelli, C., Castiglioni, E., Marrazzo, D., Piazza, M., & Spinetti, A. (2008) (2008). L'abitato d'altura di X-XI secolo a Corvara di Beverino (SP). Contributo all'archeologia del paesaggio altomedievale in Lunigiana. In A. Del Lucchese & L. Gambaro (eds.), *Archeologia in Liguria*, Nuova Serie, 1, 2004-2005. De Ferrari, 123-151.

Capelli, C. (1998). Analisi archeometriche, in M. Pasquinucci et al., Ceramica a vernice nera dall'Etruria settentrionale costiera. Primo contributo alla caratterizzazione delle produzioni locali e delle importazioni. In P. Frontini & M.T. Grassi (eds.) *Indagini archeometriche relative alla ceramica a vernice nera: nuovi dati sulla provenienza e la diffusione* (pp. 101-104). New Press.

Capelli, C. (2001). Il contributo delle analisi minero-petrografiche per le caratteristiche delle produzioni savonesi e pisane: considerazioni preliminari sulle maioliche arcaiche. In *Atti XXXII Convegno Internazionale della Ceramica, Albisola, 1999* (pp. 43-48). All'Insegna del Giglio.

Capelli, C. (2006). Analisi minero-petrografiche su ceramiche di Portofranco (Appendice a Melli P., L'emporio di Genova. Riflessioni e problemi aperti alla luce dei nuovi ritrovamenti). In *Gli Etruschi da Genova ad Ampurias. Atti del XXIV Convegno di Studi Etruschi ed Italici, Marseille-Lattes, 26 settembre-1 ottobre* 2002 (pp. 609-637). Istituti editoriali e poligrafici internazionali).

Capelli, C., & Cabella, R. (2013). Il contributo delle analisi archeometriche alla conoscenza della maiolica ligure: risultati recenti e problemi aperti. In *Atti XLV Convegno Internazionale della Ceramica 2012. Maiolica e dintorni. Giornata di studi in ricordo di Arrigo Cameirana, Savona, 24 maggio 2012* (pp. 373-382). Bacchetta.

Capelli, C., & Cabella, R. (2015). Technological transfer and trade routes of glazed wares in Medieval and post-Medieval times in the western Mediterranean. "Global pottery" from Savona and Albisola (Liguria, Italy). In J. Buxeda i Garrigos J., M. Madrid i Fernández & J. G. Ibañez (eds.), *Global Pottery 1. Historical Archaeology and Archaeometry for Societies in Contact* (pp. 27-36). BAR International Series 2761. Archaeopress.

Capelli, C., Cabella, R. (2022). Scheda. Le analisi archeometriche. In F. Fabiani & S. Genovesi (eds.) Tecniche edilizie e tradizione ellenistica. I mattoni sesquipedali rettangolari a Pisa. *Studi Classici ed Orientali*, 68, 322-324.

Capelli, C., Cabella, R., & Piazza, M. (2022). Analisi archeometriche in sezione sottile della ceramica. In A.M. Durante & S. Landi (eds.). *La necropoli di Ameglia Cafaggio* (pp. 436-447). Sagep Editori.

Capelli, C., Del Rio, A., Menchelli, S., & Pasquinucci, M. (1999). Integrazione fra dati archeologici e mineropetrografici per l'individuazione dei centri produttivi delle "anfore di Empoli", (II-V sec. d.C.). In *V Giornata "Le Scienze della Terra e l'Archeometria", Bari, 1998*, Pàtron, 29-35.

Capelli, C., & Iliopoulos, I. (2021). V.2. Catalogo dei dati mineralogici relativi alle anfore dei relitti considerati. In G. Olcese (Ed.) *Relitti dell'Italia tirrenica nel Mediterraneo Occidentale (fine IV secolo a.C. – I d.C.). Archeologia e archeometria delle anfore* (pp. 205-231). Immensa Aequora, 7, (Per Incerta Maris 2). Edizioni Quasar.

Capelli, C., & Mannoni, T. (1999). Evoluzione metodologica nelle ricerche archeometriche di provenienza. Il riesame delle ceramiche medievali di Castel Delfino nel quadro delle produzioni e delle importazioni liguri. *Archeologia Medievale,* XXVI, 387-394.

Capelli, C., Mannoni, T., Starnini, E., & Cabella, R. (2006). Le produzioni preistoriche e protostoriche italiane nella Banca Dati delle Ceramiche Mediterranee di Genova: storia delle ricerche archeometriche e stato attuale delle conoscenze, in *Atti dell'8° Giornata di Archeometria della Ceramica, La Ceramica in Italia quando l'Italia non c'era*, *Vietri, 27-28 aprile 2004* (pp. 57-62), Edipuglia.

Capelli, C., Piazza M., & Cabella, R. (2017a). Appendice. Analisi petrografiche preliminari su ceramiche etrusche di area pisana. In F. Marucci (Ed.) *La ceramica d'impasto ad argilloscisti a Pisa e nell'Agro Pisano* (pp. 209-217). Biblioteca di «Studi Etruschi», 58. Giorgio Bretschneider ed.

Capelli, C., Richez, F., Vallauri, L., Cabella, R., & Di Febo, R. (2013). L'épave du Grand Congloué 4: caractérisation archéologique et archéométrique d'un lot de céramiques à taches noires de Albisola-Savona. In *Atti XLV Convegno Internazionale della Ceramica 2012*, *Savona, 25-26 maggio 2012* (pp. 7-16). Bacchetta.

Capelli, C., & Starnini, E. (2019). La Pietra di Finale e la produzione ceramica nel Neolitico: una visione archeometrica. In G. Murialdo, R. Cabella, & D. Arobba (eds.) *La Pietra di Finale. Una risorsa naturale e storica del Ponente ligure* (pp. 119-121). Istituto Internazionale di Studi Liguri.

Capelli, C., Starnini, E., Cabella, R., Del Lucchese, A., & Piazza, M. (2011). La prima circolazione di ceramica nel Mediterraneo: una sintesi dei nuovi dati archeometrici sulla Ceramica Impressa della Liguria. In S. Gualtieri, E. Starnini, R. Cabella, C. Capelli, & B. Fabbri (eds.) *La ceramica e il mare, Atti 12ma Giornata di Archeometria della ceramica* (pp. 15-28). ARACNE editrice.

Capelli, C., Starnini, E., Cabella, R., & Piazza, M. (2017b). The circulation of Early Neolithic pottery in the Mediterranean: A synthesis of new archaeometric data from the Impressed Ware Culture of Liguria (NW Italy). *Journal of Archaeological Sciences: Reports,* 16, 532-541.

Capelli, C., Starnini, E., Cabella, R., & Piazza, M. (2018). Analisi archeometriche in microscopia ottica di ceramiche neolitiche dall'Arma dell'Aquila (Finale Ligure, Savona) nel quadro delle produzioni preistoriche del Finalese, In P. Biagi & E. Starnini (eds.) *Gli Scavi nell'Arma dell'Aquila (Finale Ligure, Savona): Le Ricerche e i Materiali degli Scavi del Novecento* (pp. 97-112). Società per la Preistoria e Protostoria della Regione Friuli-Venezia Giulia, Quaderno 15, Print and Graph.

Capelli, C., Starnini, E., Cabella, R., & Piazza, M. (2023). Archeometria delle produzioni fittili preistoriche e protostoriche della Liguria: primo contributo per una definizione dei markers petrografici del distretto produttivo Albenga-Centa-Val Pennavaire (SV). In F. Negrino, V. Tiné (eds.) *Preistoria e Protostoria della Liguria. Rivista di Scienze Preistoriche*, LXXIII, S3, 921-928.

Capponi, G., Crispini, L., Federico, L., & Malatesta, C. (2016). Geology of the Eastern Ligurian Alps: a review of the tectonic units. *Italian Journal of Geosciences*, *135*(1), 157-169.

Carmignani, L., Conti, P., Cornamusini, G., & Pirro, A. (2013). Geological map of Tuscany (Italy). *Journal of Maps*, 9(4), 487-497.

Carmignani, L., Giglia, G., & Kligfield, R. (1978). Structural evolution of the Apuane Alps: an example of continental margin deformation in the Northern Apennines, Italy. *Journal of Geology,* 86, 487-504.

Carmignani, L., & Kligfield, R. (1990). Crustal extension in the Northern Apennines: the transition from compression to extension in the Alpi Apuane core complex. *Tectonics*, 9(6), 1275-1303.

Catanzariti, R., & Perilli, N. (2011). Chronostratigraphic framework of the External Ligurian Units (Late Cretaceous; Northern Apennines; Italy) based on calcareous nannofossils. *Ofioliti,* 36(1), 37-57.

Cencetti, C., & Tacconi, P. (2005). The Fluvial Dynamics of the Arno River. *Giornale di Geologia Applicata,* 1 (2005), 193-202, https://doi.org/10.1474/GGA.2005-01.0-19.0019

Compagnoni, B., Galluzzo, F., Bonomo, R., Capotorti, F., D'Ambrogi, C., Di Stefano, R., Graziano, R., Martarelli, L., Pampaloni, M. L., Pantaloni, M., Ricci, V., Tacchia, D., Masella, G., Pannuti, V., Ventura, R., & Vitale, V. (2004). *Carta Geologica d'Italia in scala 1:1.250.000*. Servizio Geologico d'Italia/Dipartimento Difesa del Suolo-APAT.

Conti, P., Conticelli, S., Cornamusini, G., & Marroni, M. (2022). *Guide Geologiche Regionali 15-Toscana*. Società Geologica Italiana.

Conti, P., Cornamusini, G., & Carmignani, L. (2020). An outline of the geology of the Northern Apennines (Italy), with geological map at 1: 250,000 scale. *Italian Journal of Geosciences*, 139 (2), 149-194.

Conticelli, S., Manetti, P., Peccerillo, A., & Santo, A. (1986). Caratteri petrologici delle vulcaniti potassiche italiane: considerazioni genetiche e geodinamiche. *Memorie della Società Geologica Italiana*, 35, 775-783.

Cosentino, D., Parotto, M., & Praturlon, A. (1993). *Guide geologiche regionali 5 – Lazio*. Società Geologica Italiana.

Costanzo, S., Pappalardo, M., Starnini, E., Rossoni-Notter, E., Notter, O., Moussous, A., Soares-Remiseiro, M., Fermo, P., Cremaschi, M., & Zerboni, A. (2004). Integrating musealized archaeological sediment collections into current geoarchaeological analytical frameworks for sustainable research practices, *MethodsX*, 13, 102897, https://doi.org/10.1016/j.mex.2024.102897

Dallagiovanna, G., & Seno, S. (1984). Rilevamento geologico ed analisi strutturale del settore meridionale dell'unità di Arnasco-Castelbianco (Alpi Marittime). *Memorie della Società Geologica Italiana*, 28, 441-445.

Dallagiovanna, G., Gaggero, L., Seno, S., Felletti, A., Maino, M. & Toscani, G. (2011). *Note illustrative della Carta Geologica d'Italia alla scala 1:50.000 – foglio 228 Cairo Montenotte*. ISPRA – Regione Liguria, Litografia Artistica Cartografica s.r.l.

Decarlis, A., Dallagiovanna, G., Lualdi, A., Maino, M., & Seno, S. (2013). Stratigraphic evolution in the LigurianAlps between Variscan heritages and the Alpine Tethys opening: A review. *Earth-Science Reviews,* 125, 43-68.

Del Rio, A. (2023). Anfore italiche. In S. Menchelli, M. Pasquinucci & Sangriso P. (eds.) *Vada Volaterrana: gli horrea. Strutture, stratigrafie, materiali* (pp. 357-381). Instrumenta, 5. Pisa University press.

Di Giulio, A. (1992). The evolution of the Western Ligurian Flysch Units and the role of mud diapirism in ancient accretionary prisms (Maritime Alps, Northwestern Italy). *Geologische Rundschau,* 81 (3), 655-668.

Elter, P., & Marroni, M. (1991). Le Unità Liguri dell'Appennino Settentrionale: sintesi dei dati e nuove interpretazioni. *Memorie Descrittive della Carta Geologica d'Italia,* 46, 121-138.

European Commission: Directorate-General for Research and Innovation (2015), Open innovation, open science, open to the world – A vision for Europe, Publications Office, https://data.europa.eu/doi/10.2777/061652

Fanucci, F., Giammarino, S., & Tedeschi, D. (1980). Il Pliocene della costa e del margine continentale dell'Appennino ligure in rapporto alla neotettonica. *Memorie della Società Geologica Italiana,* 21, 259-265.

Fedele, L., Esposito, C., Franciosi, L., Morra, V., Perrotta, A., Santangelo, N., & Scarpati, C. (2016). *Guide Geologiche Regionali – Campania e Molise*. Società Geologica Italiana, 11.

Federico, L., Crispini, L., Malatesta, C., Torchio, S., & Capponi, G. (2014). Geology of the Pontinvrea area (Ligurian Alps, Italy): structural setting of the contact between Montenotte and Voltri units. *Journal of Maps*, 11:1, 101-113, https://doi.org/10.1080/17445647.2014.945749

Federico, L., Crispini, L., Scarsi, M., Capponi, G., & Piazza, M. (2022). Late orogenic tectonics in the Ligurian Alps (Italy): constraints from syntectonic sedimentary deposits at the top of an exhumed plate interface. *Journal of Maps*, *18*(2), 178-189.

Gaggero, L., Cortesogno, L., & Bertrand, M. (2004). The pre-Namurian basement of the Ligurian Alps: a review of the lithostratigraphy, pre-Alpine metamorphic evolution, and regional comparisons. *Periodico di Mineralogia,* 73, 85-96.

Genovesi, S., & Capelli, C. (2016). L'analisi archeometrica di manufatti ceramici. In F. Fabiani & E. Paribeni (eds.) *Archeologia a Massa. Scavi all'ombra del Mercurio* (pp. 87-90). Ed. Nuova Cultura.

Giammarino, S., Giglia, G., Capponi, G., Crispini, L., & Piazza, M. (2002). *Carta Geologica della Liguria, a scala 1: 200.000*. Laboratorio di Cartografia Digitale e GIS, Dipartimento di Scienze della Terra dell'Università di Siena.

Grifa, C., Germinario, C., de Bonis, A., Cavassa, L., Izzo, F., Mercurio, M., Langella, A., Kakoulli, I., Fischer, C., Barra, D., Aiello, G., Soricelli, G., Vyhnal, C., & Morra, V. (2021). A pottery workshop in Pompeii unveils new insights on the Roman ceramics crafting tradition and raw materials trade. *Journal of Archaeological Science*, 105305, https://doi.org/10.1016/j.jas.2020.105305

Izzo, F., Guarino, V., Ciotola, A., Verde, M., De Bonis, A., Capaldi, C., & Morra, V. (2021). An archaeometric investigation in a consumption context: Exotic, imitation and traditional ceramic productions from the Forum of Cumae (southern Italy). *Journal of Archaeological Science: Reports*, 35, 102768, https://doi.org/10.1016/j.jasrep.2020.102768

Izzo, F., Ciotola, A., Guarino, V., Verde, M., De Bonis, A., Germinario, C., Capaldi, C., & Morra, V. (2023). Focusing on red and black engobes in Roman pottery from Cumae (southern Italy): Pompeian Red Ware and Graue Platten ceramic productions. *Journal of Archaeological Science: Reports*, 47, 103778, https://doi.org/10.1016/j.jasrep.2022.103778

Lanteaume, M. (1968). *Contribution à l'étude géologique des Alpes Maritimes franco-italiennes*. Imprimerie Nationale.

Levi, T., & Muntoni, I. (2014). L'archeometria della ceramica in Italia: storia degli studi, risultati e prospettive della ricerca. In A. Guidi (Ed.) *150 anni di Preistoria e Protostoria in Italia*, (pp. 535-542), Studi di Preistoria e Protostoria 1.

Lorenz, C. (1968). Contribution a l'étude stratigraphique de l'oligocene e du miocene inferieur des confins ligure-piemontais (Italie). *Atti dell'Istituto di Geologia dell'Università di Genova*, 6 (2), 273-889.

Mannoni, T. (1970/71). La ceramica dell'età del Ferro nel Genovesato. Saggio di studio mineralogico. *Studi Genuensi*, VIII, 3-29.

Mannoni, T. (1975). Studio mineralogico di alcuni tipi ceramici provenienti dall'abitato preromano di Genova. In *Archaeologica, Scritti in onore di Aldo Neppi Modona* (pp. 373-386). Olschki.

Mannoni, T. (1987). Archeometria ed archeologia. *Notiziario di Archeologia Medievale*, 46, 21-23.

Mannoni, T. (1994). *5. Archeometria, Geoarcheologia dei Manufatti*. Venticinque Anni di Archeologia Globale, ESCUM-Sagep.

Marini, M. (1984). Le deformazioni fragili del Pliocene in Liguria. Implicazione nella geodinamica alpina, *Memorie della Società Geologica Italiana,* 29, 157-169.

Marini, M. (1988). Evoluzione tettonico-sedimentaria e geodinamica dei flysch cretacico-eocenici della Liguria Occidentale. *Bollettino della Società Geologica Italiana,* 107 (1), 193-218.

Marini, M. (2004). *Carta Geologica del Pliocene Ligure di Albenga (Alpi Marittime Liguri – Provincia di Savona), a scala 1: 25.000*. S.E.L.CA.

Marini, M., & Terranova, R. (1985). Osservazioni sugli olistostromi presenti nei flysch della Liguria occidentale (valle del Torrente Arroscia): problemi e prospettive interpretative. *Bollettino della Società Geologica Italiana*, 104 (1), 143-150.

Marroni, M., Monechi, S., Perilli, N., Principi, G., & Treves, B. (1992). Late Cretaceous Flysch Deposits of the Northern Apennines, Italy: Age of Inception of Orogenesis-Controlled Sedimentation. *Cretaceous Research*, 13, 487-504.

Marroni, M., & Pandolfi, L. (1996). The Deformation History of an Accreted Ophiolite Sequence: The Internal Liguride Units (Northern Apennines, Italy). *Geodinamica Acta*, 9, 13-29.

Menchelli, S. (2018). Figli di un dio minore. Ceramica e archeometria in Italia. Le origini, le tendenze, i risultati nelle ricerche più recenti: alcuni casi di studio. In M. Cavalieri & C. Boschetti (eds.) *MVLTA PER ÆQVORA. Il polisemico significato della moderna ricerca archeologica. Omaggio a Sara Santoro* (pp. 191-206). UCL Louvain.

Menchelli, S. (2023). Western regional contexts and their interconnectivity in the Late Roman Mediterranean: some case studies, In V. Cammineci, E. Giannitrapani, M.C. Parello & M.S. Rizzon (eds.) *Late Roman Coarse Wares 6, Cooking Wares and Amphorae in the Mediterranean: Archaeology and Archaeometry, Land and Sea: Pottery Routes* (pp. 313-330). Archaeopress.

Menchelli, S., & Bianchini, S. (2023). Vasellame di uso comune. In S. Menchelli, M. Pasquinucci & P. Sangriso (eds.) *Vada Volaterrana: gli horrea. Strutture, stratigrafie, materiali* (pp. 231-344). Instrumenta, 5. Pisa University press.

Menchelli, S., Capelli, C., Del Rio, A., Pasquinucci, M., Thirion-Merle, V., & Picon, M. (2001). Ateliers de céramiques sigillées de L'Etrurie septentrionale maritime: données archéologiques et archéométriques. *Rei Cretariae Romanae Fautorum Acta*, 37, 89-105.

Menchelli, S., Capelli, C., Pasquinucci, M., Picchi, G., Cabella, R., & Piazza, M. (2013). Nuove scoperte d'ateliers di anfore repubblicane nell'Etruria settentrionale costiera. In *Itinéraires des vins romains en Gaule, iiie-ier siècles avant J.-C. confrontation de faciès, Actes du colloque européen Lattes, 30 janvier-2 février 2007* (pp. 471-478). UMR 5140 du CNRS.

Menchelli, S., Pasquinucci, M., Cabella, R., Capelli, C., Piazza, M., & Picchi, G. (2011). La ceramica, l'archeometria e il mare: storie di traffici fra l'Etruria settentrionale e il Mediterraneo. In *La ceramica e il mare. Il contributo dell'archeometria allo studio della circolazione dei prodotti nel Mediterraneo. Atti della XII Giornata di Archeometria della ceramica. Genova 2008*, (pp. 149-160). Aracne.

Menchelli, S., & Sangriso, P. (2017). Pisan sigillata: Augustan Ideology with a few Images. In M. Flecker (Ed.) *Neue Bilderwelten zu Ikonographie und Hermeneutik Italischer Sigillata* (pp. 53-72). Tübinger Archäologische Forschungen, vol. 23.

Menchelli, S., Sangriso, P., & Baronti, T. (2020). Gli scavi in via Galluppi. In F. Cantini, F. Fabiani, M.L. Gualandi, & C. Rizzitelli (eds.) *Le Case di Pisa. Edilizia privata fra età romana e Medioevo* (pp. 57-64). All'Insegna del Giglio.

Milanese, M., & Mannoni, T. (1984). Gli Etruschi a Genova e il commercio mediterraneo. *Studi Etruschi*, 52, 117-146.

Nardi, R., Pochini, A., Puccinelli, A., D'Amato Avanzi, G., & Trivellini, M. (1986). Valutazione del rischio da frana in Garfagnana e nella Media Valle del Serchio (Lucca). Carta geologica e carta della franosità degli elementi «Gragnana», «Piazza al Serchio», «Casciana» e «Ceserana» (scala 1:10 000). *Bollettino Società Geologica Italiana,* 104, 585-599.

Nardi, R., Puccinelli, A., D'Amato Avanzi, G., & Trivellini, M. (1987). Valutazione del rischio da frana in Garfagnana e nella Media Valle del Serchio (Lucca). Carta geologica e carta della franosità degli elementi «Sillico», «Castelnuovo Garfagnana», «Cascio», «Castelvecchio Pascoli», «Gallicano», «Barga», «Fornaci di Barga» e «Ghivizzano» (scala 1:10 000). *Bollettino Società Geologica Italiana,* 106, 819-832.

Nisi, B., Buccianti, A., Vaselli, O., Perini, G., Tassi, F., Minissale, A., & Montegrossi, G. (2008). Hydrogeochemistry and strontium isotopes in the Arno River Basin (Tuscany, Italy): constraints on natural controls by statistical modeling. *Journal of Hydrology*, 360(1-4), 166-183.

Odelli, E. (2023). Openfabric ceramic database: an overview. *Archeologica Data*, III, 139-144, DOI http://doi.org/10.13131/unipi/dgzm-ym38; Dataset: DOI http://doi.org/10.13131/unipi/archelogicadata/28k2-hn40

Pasquinucci, M., Capelli, C., Del Rio, A., & Menchelli, S. (1997). Analisi morfologiche, archeometriche e funzionali sulle ceramiche comuni di età romana dagli horrea di Vada Volterrana (Rosignano M.mo – Livorno). In S. Santoro Bianchi & B. Fabbri (eds.) *Il contributo delle analisi archeometriche allo studio delle ceramiche grezze e comuni* (pp. 214-222), Atti della 1a Giornata di archeometria della ceramica, Bologna, 28 febbraio 1997. Bologna University Press.

Pasquinucci, M., Mazzanti, R., Menchelli, S., Marchisio, M., & D'Onofrio, L. (2001). Coastal Archaeology in North Etruria. Geomorphologic, archaeological, archive, magnetometric and geoelectrical Research. *Revue d'Archeometrie*, 25, 187-201.

Pasquinucci, M., & Menchelli, S. (2010). Il sistema portuale di Pisa: dinamiche costiere, import-export, interazioni economiche e culturali (VII sec. a.C.-I sec. d.C.). *Bollettino di Archeologia Online* I, 2010/Volume Speciale B /B6/1, 1-13.

Peccerillo, A. (2005). *Plio-Quaternary Volcanism in Italy – Petrology, Geochemistry, Geodynamics*. Springer-Verlag.

Perilli, N., Puccinelli, A., Sarti, G., & D'Amato Avanzi, G. (2004). Lithostratigraphy of the Plio-Pleistocene continental deposits of the Barga and Castelnuovo Garfagnana tectonic depressions. In D. Morini, & P. Bruni (eds.) *The Regione Toscana project of geological mapping. Case histories and data acquisition* (pp. 121-132). Special Volume for the 32nd IGC Congress, Florence. Regione Toscana.

Pesce, G. L., Capelli, C., Del Soldato, M., & Starnini, E. (2020). L'approccio di Tiziano Mannoni all'Archaeometria. Dalla caratterizzazione dei materiali alla loro datazione e provenienza. *Notiziario di Archeologia Medievale,* 87, 11-20.

Spataro, M., & Villing, A. (2015). *Ceramics, Cuisine and Culture: The Archaeology and Science of Kitchen Pottery in the Ancient Mediterranean World*. Oxbow.

Starnini, E. (2011). Presentazione. In S. Gualtieri, E. Starnini, R. Cabella, C. Capelli, & B. Fabbri (eds.) *La ceramica e il mare, Atti 12ma Giornata di Archeometria della ceramica,* (pp. 9-11). ARACNE editrice.

Stengers, I. (2018). *Another science is possible: A manifesto for slow science*. John Wiley & Sons.
Tomber, R. S., & Dore, J. (1996). A 'National Roman Fabric Collection', *Britannia,* 27, 368-382.
Tomber R., & Dore, J. (1998). *The National Roman Fabric Reference Collection: a Handbook.* Museum of London Archaeology Service Monograph 2.
Vanossi, M., Cortesogno, L., Galbiati, B., Messiga, B., Piccardo, G.B., & Vannucci, R. (1984). Geologia delle Alpi Liguri: dati, problemi, ipotesi. *Memorie della Società Geologica Italiana,* 28, 5-75.