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# An assessment of Early Farmers' pottery, pastes and raw materials transfers in the Ligurian-Provençal region (*Impressa*, first half of the 6th millennium BCE)

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**Abstract:** Over the last two decades the neolithisation of the Liguro-Provençal arc has been studied mainly through the characterisation and provenance of long-distance materials, which are likely to provide information about the settlement dynamics of the very first Neolithic societies. Like obsidian, the circulation of raw materials and ceramics makes it possible to trace the itineraries of mobile populations and their exchanges between different places at different cultural, spatial and temporal scales. An integrated assessment of the results of provenance studies on pottery, carried out in the framework of a comparative and dynamic exchange of the CIMO Project, currently makes it possible to define a complex socio-cultural framework for the first phases of the Neolithic in the North-Western Mediterranean. In general, due to the contrasting geology of the Ligurian-Provençal arc, pottery pastes can be very diverse and have very specific technological aspects; for example, rock alteration soils are often preferred to alluvial sediments and the use of grog is already characteristic of the very earliest pioneer settlements, unlike in south-eastern Italy. Moreover, some sites are characterised by a higher proportion of non-local pottery. In general, the non-local production is imports over long distances from east to west, but surprisingly also from west to east on a smaller spatial scale. An exception, for example, is the site of Pendimoun, where significant imports of raw materials rather than pots are attested and the intentional mixing in the preparation of pottery pastes is highlight. This framework of mobility on a regional and multidirectional scale results in a complex and dynamic Neolithic process that needs to be refined. At the same time, the presence of multiple imports from the same geological mountain source on several sites in the studied area raises the question of the control of a very extended landscape and a deep knowledge of the resource availability, as early as the pioneer Neolithic stage, and/or the possibilities of connexion between earliest farmers and late hunter-gatherers.

**Keywords:** Impressa Ware, Mediterranean Neolithic, regional networks, ceramic technology, ceramic petrography, intentional mixing, vertical mobility, mountain environment, shared sources

**Résumé :** Depuis deux décennies, les processus de néolithisation de l'arc liguro-provençal ont été abordés en particulier à partir de la caractérisation de matériaux circulant sur de grandes distances. C'est ainsi que l'identification des sources d'obsidienne a fourni des informations sur les dynamiques de peuplement au cours du tout premier Néolithique. De la même façon, les circulations de terres et/ou de vases permettent de retracer non seulement les itinéraires de ces populations et de leurs échanges mais également de discuter des identités culturelles à différentes échelles spatio-temporelles.

Un bilan intégré des études sur ces céramiques et de nouvelles recherches mises en œuvre dans le cadre du projet CIMO participent à la description, pour les premières étapes du Néolithique en Méditerranée nord-occidentale, d'un contexte socio-culturel complexe, avec des aspects insoupçonnés jusqu'ici. L'approche comparative – qualitative et quantitative – retenue ici pour les études technologiques et de provenance révèle en effet de nouveaux aspects de ces productions potières et soulève de nouvelles questions sur l'importance des transferts et sur les réseaux sociaux qui leur sont liés.

L'étude présentée ici s'appuie sur les données pétrographiques acquises par l'analyse exhaustive de trois assemblages céramiques clés pour les systèmes techniques de cette période que sont : la grotte des Arene Candide (Finale Ligure, Savone), l'abri de Pendimoun (Castellar, Alpes-Maritimes) et le site de plein air de Caucade (Nice, Alpes-Maritimes). Elle met en évidence des aspects techniques de préparation des pâtes et des systèmes de mobilité multidirectionnelles dans différents milieux.

Un premier constat d'importance est la forte diversité des matières premières utilisées et des contextes géologiques exploités, diversité qui s'amenuise au fil du temps. Sur les trois assemblages céramiques considérés, nous avons en effet pu identifier seize groupes de pâtes présentant des marqueurs exogènes. Il s'agit, d'une part, de pâtes entièrement composées de matières premières non locales et, d'autre part, de pâtes associant des matériaux tirés de l'environnement proche des sites à de la chamotte fabriquée à partir de pots produits avec des matériaux étrangers aux contextes des sites de découverte. Bien que chaque site révèle un schéma spécifique, avec des groupes de pâtes particuliers ainsi que des variabilités intra-groupe singulières, des similitudes ont été reconnues entre les sites.

Au cours de la première étape del'Impressa, les sites de Caucade et Arene Candide présentent une grande diversité de pâtes céramiques et de matières premières non locales, lesquelles orientent vers au moins sept contextes géologiques : le massif des Maures-Tanneron, les affleurements andésitiques côtiers, les affleurements crétacés de la Provence orientale, le massif de l'Argentera-Mercantour, le massif de Savona-Calizzano, le groupe de Voltri et les formations ophiolitiques de basse pression de Ligurie orientale. Le massif de l'Argentera-Mercantour est la seule zone d'origine commune aux deux sites. Dans l'ensemble, les zones sources identifiées dessinent un réseau de circulations et de contacts multidirectionnels sur de moyennes et longues distances.

Pendant les étapes suivantes de l'Impressa, les assemblages de Pendimoun et des Arene Candide montrent moins de diversit,é avec des réseaux concentrés sur un nombre plus restreint de zones géologiques concernées. Parmi celles-ci, on observe le maintien de deux sources déjà exploitées pendant la phase précédente, les Massifs de l'Argentera-Mercantour et de Savona-Calizzano. La situation révélée par ces deux sites montre également une augmentation des transferts de l'ouest vers l'est, augmentation qui pourrait illustrer une consolidation des contacts intrarégionaux.

L'exploitation du massif de l'Argentera-Mercantour apporte des informations inédites sur l'utilisation, encore sous-estimée, des milieux montagnards au début du Néolithique. La fréquentation de ce massif, seule zone d'affleurement commune aux trois sites-clés de notre étude, témoigne d'une connaissance approfondie de la disponibilité des ressources, et ceci dès le stade pionnier du Néolithique, ce qui soulève la question des connexions entre ces premiers agriculteurs et les derniers chasseurs-cueilleurs susceptible de peupler ces territoires.

Outre la pluralité des territoires dessinée par l'identification des zones sources, l'analyse pétro-archéologique révèle une diversité de choix dans le traitement des pâtes, avec l'emploi conjoint de matières premières homogènes et de matières premières hétérogènes, elles-mêmes issues de mélanges naturels ou anthropiques (mélange de terres et ajout de dégraissants). La démonstration d'un mélange anthropique de terres locales et non locales est l'une des rares situations attestant à la fois d'une production locale de céramique et du transfert de matières premières plutôt que de produits finis. L'exemple de Pendimoun est assez éloquent à cet égard. Sur ce site, trois types de pâtes céramiques ont été identifiés : l'un correspond à une terre locale à glauconie, un autre à une terre mylonitique exogène provenant de l'Argentera-Mercantour et une troisième montre l'association de glauconie et de mylonite. Cette dernière, qui ne peut être produite naturellement dans le système géomorphologique environnant, fournit un témoignage unique d'un mélange intentionnel de matériaux d'origines différentes, pour une production à proximité immédiate du site.

Si la circulation des produits finis est le plus souvent envisagée à partir de la présence sporadique de récipients exogènes dans les assemblages céramiques, un autre argument peut être considéré : celui de la présence, dans un même contexte chrono-culturel et spatial, de productions locales comparables aux productions importées sur le plan typologique et dans celui des compositions. Cela pourrait être le cas sur les sites de Pertusello et Pollera (Ligurie) qui ont livré des pots fabriqués à partir de terres non locales (à glauconie) et présentant des similitudes stylistiques avec les productions locales de Pendimoun.

Le transfert de poteries en tant que produits finis est aussi indirectement attesté par la réutilisation de récipients non locaux pour la production de chamotte utilisée dans les productions locales. Aux Arene Candide, l'utilisation de chamotte dérivée de pots produits avec des matières premières provenant de régions situées plus à l'est, à longue voire très longue distance, comme les terres ophiolitiques de basse pression ou les terres volcaniques potassiques, suggère la circulation de produits finis plutôt que de matières premières.

Ainsi, les différentes modalités de préparation des pâtes céramiques sont en mesure de fournir des informations : (i) sur le transfert des matières premières et des produits finis ; (ii) sur les contextes locaux ou non de production ; (iii) sur les pratiques techniques, et potentiellement les traditions techniques, intégrées dans la préparation des pâtes céramiques.

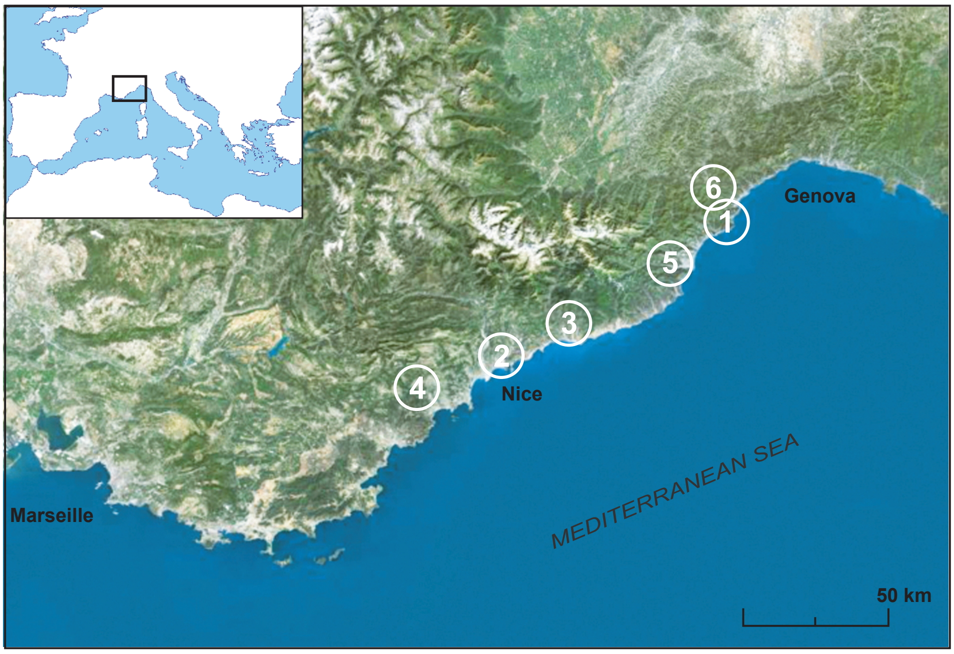
**Mots-clés :** Céramique Impressa, Néolithique méditerranéen, réseaux régionaux, technologie céramique, pétrographie céramique, mélange intentionnel, mobilité verticale, environnement montagneux, sources partagées.

## INTRODUCTION

In the frame of the pioneer Impressed Wares Neolithic dispersal in the Central and Western Mediterranean, mainly during the first half of the 6th millennium BCE, transfers of raw materials, by-products, tools and vessels, play a key-role for tracing potential routes and milestones of diffusion (Binder, Gomart *et al.*, this volume, with references therein). Among those materials and goods, obsidians from Western Mediterranean Islands have revealed Early Neolithic networking throughout a wide area, supporting the idea that maritime voyages were the backbone of this scheme, which lead to an extended Neolithic settlement web mainly confined to coastal environments (Ammerman and Polglase, 1997; Lugliè *et al.*, 2007; Le Bourdonnec *et al.*, 2010; Binder *et al.*, 2012). Recent studies in pottery technology and high-resolution sourcing reinforced those data, demonstrating transfers at similar scales and along the same presumed roads; in addition, they revealed the frequentation of areas where there was previously no other evidence of farmer's settlement (Gabriele *et al.*, 2019).

In parallel, recent developments in the analysis of manufacturing processes in the Central and Western Mediterranean have shown a strong cultural opposition between the Adriatic and Tyrrhenian areas, based on radically different technical traditions regarding pottery forming (Gomart *et al.*, 2017 and Gomart, Binder, Gabriele *et al.*, this volume). Those distinct technical behaviours, revealing distinct communities of practice, are in line with several other distinctive markers, *e.g.* pottery decoration techniques (Manen *et al.*, this volume), symbolic representations (Radi, 2010; Binder *et al.*, 2014), herding and agricultural choices and practices (Vigne, 2007; Rowley-Conwy *et al.*, 2013; Binder *et al.*, 2020), settlement pattern and density, craft specialisation (Guilbeau, 2010; Binder, 2013; Mazzucco *et al.*, 2020). In addition, current data concerning the genomics of the first farmers in Southern France demonstrate the importance of biological admixture between incoming Aegean-Anatolian farmers and western hunter-gatherers (Rivollat *et al.*, 2020), an admixture that could be at the roots of the cultural shift observed on either side of the Apennines.

Looking at the initial steps of pottery "*chaînes opératoires*", *i.e.* raw-material procurement and pastes processing, both regions also seem to provide differences during the first half of the 6th millennium BCE. In Apulia and Dalmatia, potters used to collect local clayey deposits, generally avoiding non-plastic rich geomaterials (Spataro, 2002; Muntoni, 2003; Laviano and Muntoni, 2006; Muntoni, 2012), while in most of the western regions, pottery assemblages provide a wider diversity of pastes often bearing a significant mineral charge (Échallier and Courtin, 1994; Martini *et al.*, 1996; Capelli *et al.*, 2006a; Binder *et al.*, 2010; Convertini, 2010; Paolini-Saez, 2010; Gabriele, 2014; Capelli *et al.*, 2017). This diversity, which reflects the complexity of the Western Mediterranean geological mosaic compared to the Adriatic plaque, also questions the specific skills and technical choices of the potters from both areas, and the specificity of technical gestures attached to such different types of raw materials.




1 - Arene Candide cave　2 - Caucade settlement　3 - Pendimoun rockshelter
4 - Grasse settlement　5 - Pertusello cave　6 - Pollera cave

**Fig. 1** – Area of interest and distribution of archaeological sites for this study.
***Fig. 1*** *– Région considérée et distribution des sites archéologiques dans cette étude.*

Beyond this, this western diversity highlights the possible transfers of raw-materials, pastes or vessels as well as the social networks that could have supported them.

Between the Gapeau river (Var district) to the west, and the Arno river (Northern Tuscany) to the east, the Ligurian-Provençal arc which this paper focusses on (fig. 1), is a hotspot for the pioneer wave of farming dispersal as soon as *c.* 5850 BCE. This area displays a small but rather consistent set of *Impressa* sites, including caves, rock shelters and few open air sites, placed in a robust chronocultural sequence (Binder and Maggi, 2001; Biagi and Starnini, 2016; Binder *et al.*, 2017; Manen *et al.*, 2019; Panelli, 2019; Binder, Gomart *et al.*, this volume).

This region also offers an ideal geological framework (fig. 2) for the sourcing of geomaterials, thanks to a patchwork of tectonically juxtaposed structural units, of different genesis, age and lithology (Kerckhove *et al.*, 1979; Rouire *et al.*, 1980; Vannossi *et al.*, 1984; Bigi *et al.*, 1990; Carmignani *et al.*, 2013).

Accordingly, since the 1990s, this area benefited from several petro-archaeological pottery studies focussed on the first stages of the Neolithic (Mannoni, 1983; Échallier, 1991; Échallier and Courtin, 1994; Ferraris and Ottomano, 1997; Mannoni, 1999; Capelli *et al.*, 2006b; Manen *et al.*, 2006; Capelli *et al.*, 2008; Gabriele, 2014; Capelli *et al.*, 2017; Gabriele *et al.*, 2020). Most of these studies have concluded to a high degree of diversity of the pottery assemblages and have pinpointed the importance of transfers at different scales, including long or even very long distance ones. Further on, petro-archaeological data have been used among other proxies for assessing sites' status, regimes of mobility and territorial patterns, as well as networking practices in the first stages of the Neolithic transition (Martini *et al.*, 1996; Binder, 1998; Gabriele and Boschian, 2009; Manen and Convertini, 2012; Capelli *et al.*, 2017).

This paper presents the petrographic and mineralogical data acquired from the exhaustive analysis of three key pottery assemblages which are considered today as references for the early farmers' technical systems in this part of the North-Western Mediterranean: principally the cave of Arene Candide (Finale Ligure, Savona) and the rock shelter of Pendimoun (Castellar, Alpes-Maritimes), and secondary the open air settlement of Caucade (Nice, Alpes-Maritimes). Punctual data offered by sites surveys or older excavations will be added to the discussion.

These data are used as proxies for the sourcing of geomaterials involved in pottery production and beyond as proxies for networking patterns. In this perspective, it is critical to consider the successive technical operations that potters could have realised between the raw-materials acquisition and the roughing-out of pots, *i.e.* paste processing, including the addition of temper and even the mixing of different geomaterials. This operational

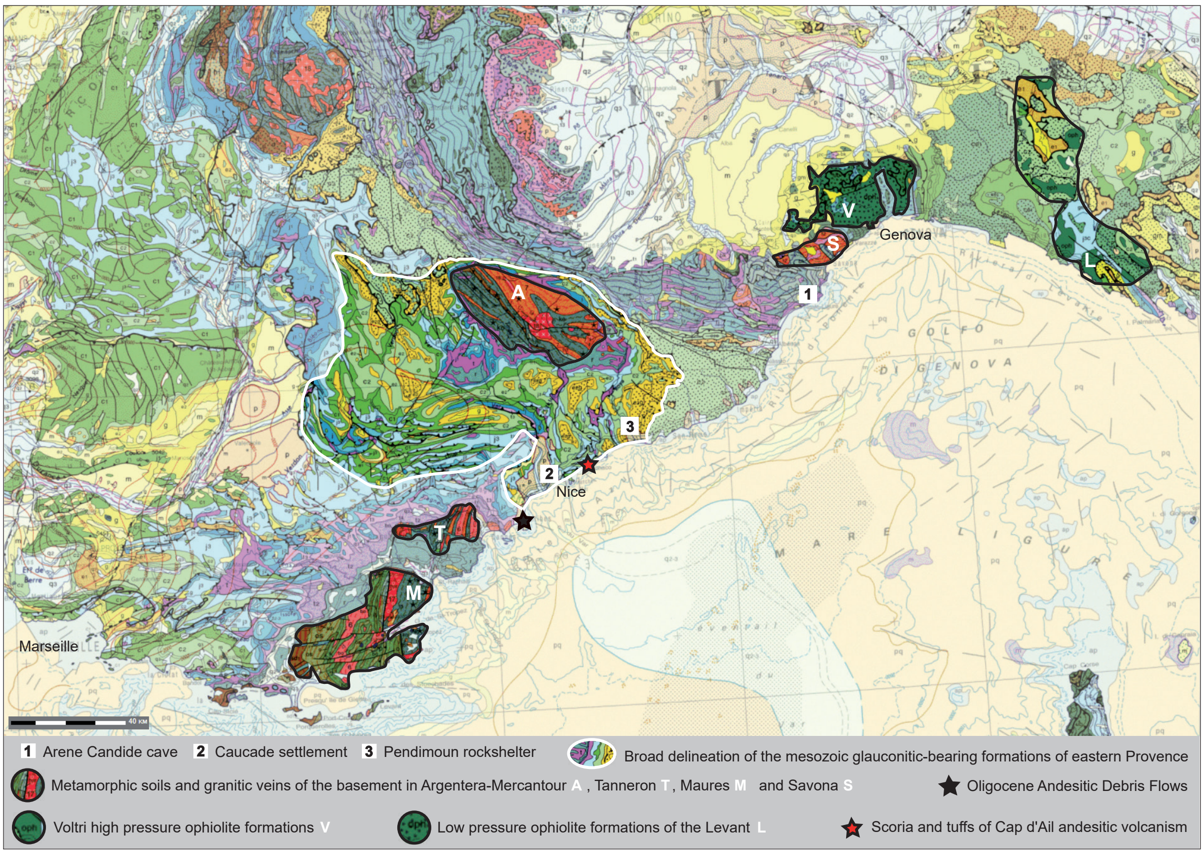



**Fig. 2** – Geological map of the considered region highlighting the geological districts of particular relevance for this study.
***Fig. 2*** – *Carte géologique de la région considérée. Les districts géologiques présentant un intérêt particulier pour cette étude sont mis en évidence.*

complexity is compounded by the difficulties of identifying mixtures of materials of different geological origins that may have occurred in the natural environment.

## SAMPLING STRATEGY AND ANALYTICAL METHODS

Pottery pastes can be produced from one or more raw materials, at least one of which must have the plastic properties to obtain a given shape (*e.g.* Rye, 1981; Rice, 1987; Santacreu, 2014; Roux, 2016).

Raw materials used are usually clayey sediments from diverse geological origins – *e.g. in situ* marls, soils, colluvial or alluvial deposits – for which we use hereafter the generic term of *terrae* (following Échallier, 1984; Mannoni, 1990). To those *terrae,* the potters may have added a wide range of other mineral or biological elements that increase the inherent heterogeneity of the composition (Eramo, 2020). Considering the difficulty of discriminating between anthropogenic and natural microstructures, such as in the case of tempering and clay mixing (Ho and Quinn, 2021), at this level of investigation, we refer in this study to the composition of the pottery pastes and not to their fabric when addressing their "homogeneity" or "heterogeneity". Thus, this study focuses on the nature of non-plastic inclusions, considering their high proportions within coarse or very coarse pastes that are the most common in the study area.

### Observation and description

The characterisation of the raw materials used for pottery production is first based on the stereomicroscopic examination (with magnifications up to 50X) of the entire pottery assemblages available for the studied sites. The corpus consists in sherds, whatever their size, decorated or not, bearing morphologic elements or not, isolated or belonging to reconstructed pot. In exceptional cases, crude paste residues have been observed and studied the same way. This step of the study was carried out in the different museums and archaeological depots with various available stereomicroscopes.

As a result, the sampling for thin section analyses is representative of paste families identified on a mesoscopic scale. In very few cases, for which destructive analysis had to be excluded, the stereomicroscopic observation is the sole source of information accessible. The number of samples is correlated to the abundance of each family and its informative potential; thus the thin sections were obtained from typologically and compositionally representative sherds or pots. At least one thin section per pot has been made; but in some cases a second one (covered/uncovered and perpendicular/tangential) has been cut in order to allow specific analyses using scanning electron microscope coupled with energy dispersive X-ray spectroscopy (Gabriele *et al.*, 2019; Gomart, Binder, Blanc-Féraud *et al.*, this volume). The analyses of thin sections have been performed at the CEPAM laboratory with a Leica MD2700 optical microscope. Besides, all observations broadly follow the guidelines of soil micromorphology (Stoops, 2003) and ceramic petrography (Whitbread, 1989; Quinn, 2013).

In many cases, a mesoscopic check was carried out on the material after examination of the thin sections.

The identified paste groups and families were named on the basis of the observation of distinctive and characteristic rock fragments, individual minerals and/or anthropogenic inclusions.

### Sourcing interpretation

The identification of potential sources relies on an extended geological knowledge and databases available in the different areas concerned by this study, and thanks to an active interaction between geologists and archaeologists.

Since the study region was dramatically affected by sea level rise during the considered archaeological period (*c.* 10-15m; Dubar and Anthony, 1995), the question of ignored outcrops, currently submerged, may seem legitimate. However, the extremely steep shape of the coastal relief and the excellent knowledge of regional geodynamics make it possible to exclude this eventuality.

Basically, for rejecting the hypothesis of local raw material procurement, and consequently for making the assumption of a regional or exogenous procurement, the decision was generally first made by exclusion, considering all the possibilities offered by geological and geomorphological contexts around the consumption sites.

The distinction between a natural and anthropogenic mixture of raw materials, based on their composition and textural criteria, is very challenging with the exception of the inclusion of anthropogenic particles (*e.g.* grog, crushed calcite, etc.). For rejecting the hypothesis of natural mixing, the decision is also made by exclusion on the same contextual bases than *supra*. In this perspective, particular attention will be paid in this paper to mixed pastes, resulting from mixtures of *terrae* of different geological origins.

In addition of the exploitation of geological data, major raw material surveys and samplings, and subsequent firing experimentations, have been carried out in order to reduce the most challenging issues, and especially in order to obtain robust documentation for demonstrating exogenous procurement (*e.g.* this paper fig. 3; Lardeaux *et al.*, this volume; Mouralis *et al.*, this volume).

### Sourcing *vs* production place

When part of the pottery assemblage is defined as exogenous, the most frequent hypothesis is that of the circulation of finished products, *i.e.* pots; indeed, local production made from imported raw materials is rarely documented (Arnold, 2005 and 2017). Specific cases of pastes that give evidence of an exogenous provenience of finished products, are the pottery tempered with non-local grog (Convertini, 2007 and 2010; Capelli *et al.*, 2017; Gabriele *et al.*, 2020 and *infra*) or other non-local material *(e.g.* crushed spathic calcite, Binder *et al.*, 2010).

The assumption of the local production of pottery is generally based on the principle of parsimony for the provenience of the raw materials observed.

The definition of production sites is based on concrete criteria demonstrating which segment(s) of the "chaîne opératoire" are attested *in situ* and which are not, as theorized for chipped stone productions (Perlès 1991; Tixier, 2012). In the case of the stage of pottery forming, it is the presence of production remains which attests of the processing of the raw material on site, particularly in the form of paste aggregates or residues on tools dedicated to pottery making (Binder *et al.*, 1994).

Robust evidence for local pottery production is scarce in the North-Western Mediterranean Impresso-Cardial contexts. First-rate evidence is provided at the Lombard cave (residues of crude paste with crushed calcite temper; Binder, 1991b) and Pendimoun rock-shelter (crude blocks of kneaded paste; this paper fig. 3). Second-order evidence is provided by tools involved in pottery making at Arene Candide as blades used for shaping (De Stefanis, 2018; Binder, De Stefanis *et al.*, this volume) or burnishers used for final surface treatments (De Stefanis, 2018; De Stefanis *et al.*, in press). Beyond these strong arguments, firing structures are sometimes allocated to pottery production but such inferences are sometimes questionable: *e.g.* in the *Impressa* site of Portonovo Fossa Fontanaccia (Ancona, Marche, 6th millennium BCE) recent analyses denied the initial interpretation of structures as being pottery kilns (Conati Barbaro *et al.*, 2019).

## Mobility range

The basis for tracing provenience of raw materials and finished products, and more specifically to define the geographical limits of sources and pottery productions, is the "resource area model" of D. E. Arnold, drawn on the basis of ethnographic observations (Arnold, 2005), which we adapted to our study area. We therefore consider as local the raw materials available in a radius of 7km around the site, and as non-local those that are found in geological outcrops outside this area. Beyond this "local" area one can fix the radius of 30km as a limit for the "neighbouring area/medium distance", based on the Home range defined within farming populations (Higgs and Vita-Finzi, 1972; Gallay, 1983). Further, the radius of 100km is conserved as the limit between "long" and "very long" distances, *i.e.* "regional" and "exotic" areas (Binder, 1998).

We are aware of the unsatisfactory - and therefore tentative - nature of the current representation of these territories in the form of circular acquisition areas. It is obvious that, in a maritime region with a particularly contrasting relief (0 to 3297m asl), the acquisition areas must be modelled taking into account access times and not estimations of distance as the crow flies.

# PETRO-ARCHAEOLOGIC STUDY OF *IMPRESSA* KEY SITES IN THE LIGURO-PROVENÇAL ARC

For our study, the key sites of Castellar – Pendimoun (Binder *et al.*, 1993) and Finale Ligure – Arene Candide (Bernabò Brea, 1946; Maggi, 1997), meet the following conditions: well understood archaeological contexts, fully extended *Impressa* chronology; extensive petrographic studies of pottery pastes.

A third site, Nice – Caucade, has been retained because it is clearly linked to the considered chronocultural *Impressa* sequence (cf. Arene Candide, early *Impressa* phase ACN-1A) and had already benefited from extensive pottery analyses (Manen *et al.*, 2006).

We also considered other sites on the basis of typological arguments, but as complementary information due to the absence of robust contextual data, among them Aquila d'Arroscia – Pertusello cave (Leale Anfossi, 1961a and 1961b; Panelli, 2019) and Finale Ligure – Pollera cave (Odetti, 1990; Panelli, 2019).

The presentation of each key-site includes first, brief outlines of the archaeological and geological contexts, second, extensive descriptions of the non-local pottery pastes, conceived as references for future regional studies and third, sourcing of raw materials.

## Finale Ligure – Arene Candide cave

### *Context*

#### Archaeological context

The Arene Candide cave (Finale Ligure, Savona) is located in Western Liguria, in the Finalese karstic area, giving a complete archaeological stratigraphy spanning from the Upper Palaeolithic to the Byzantine Age (fig. 1). Recent investigations (1997 to 2012) have provided more detail on the Neolithic stratigraphic sequence, which is attributable to the *Impresso*-Cardial Complex (ICC) and to the Square Mouth Pottery Culture (SMP; Maggi *et al.*, 2020).

The earliest Neolithic occupation of the site is associated with ceramics attributed to the *Impressa* horizon, divided into two chronocultural phases: phase ACN-1A, dated to 5830-5640 BCE is characterised by *sillon d'impressions* pottery decoration and phase ACN-1B, dated to 5710-5540 BCE is characterised by instrumental or finger-nail impressed decorations and related to Pendimoun phases PND-1A and PND-1B (Panelli, 2019).

Previous petrographic studies have shown evidence of medium- to long-distance pottery mobility/imports (Ferraris and Ottomano, 1997; Capelli *et al.*, 2017). Our study partly confirms the latter and adds some new elements, both in the circulation patterns and in the quantitative data for chronocultural stratigraphic phase (Gabriele *et al.*, 2020).

For the *Impressa* horizon, we took into account 125 pots, equivalent to more than 700 ceramic fragments,

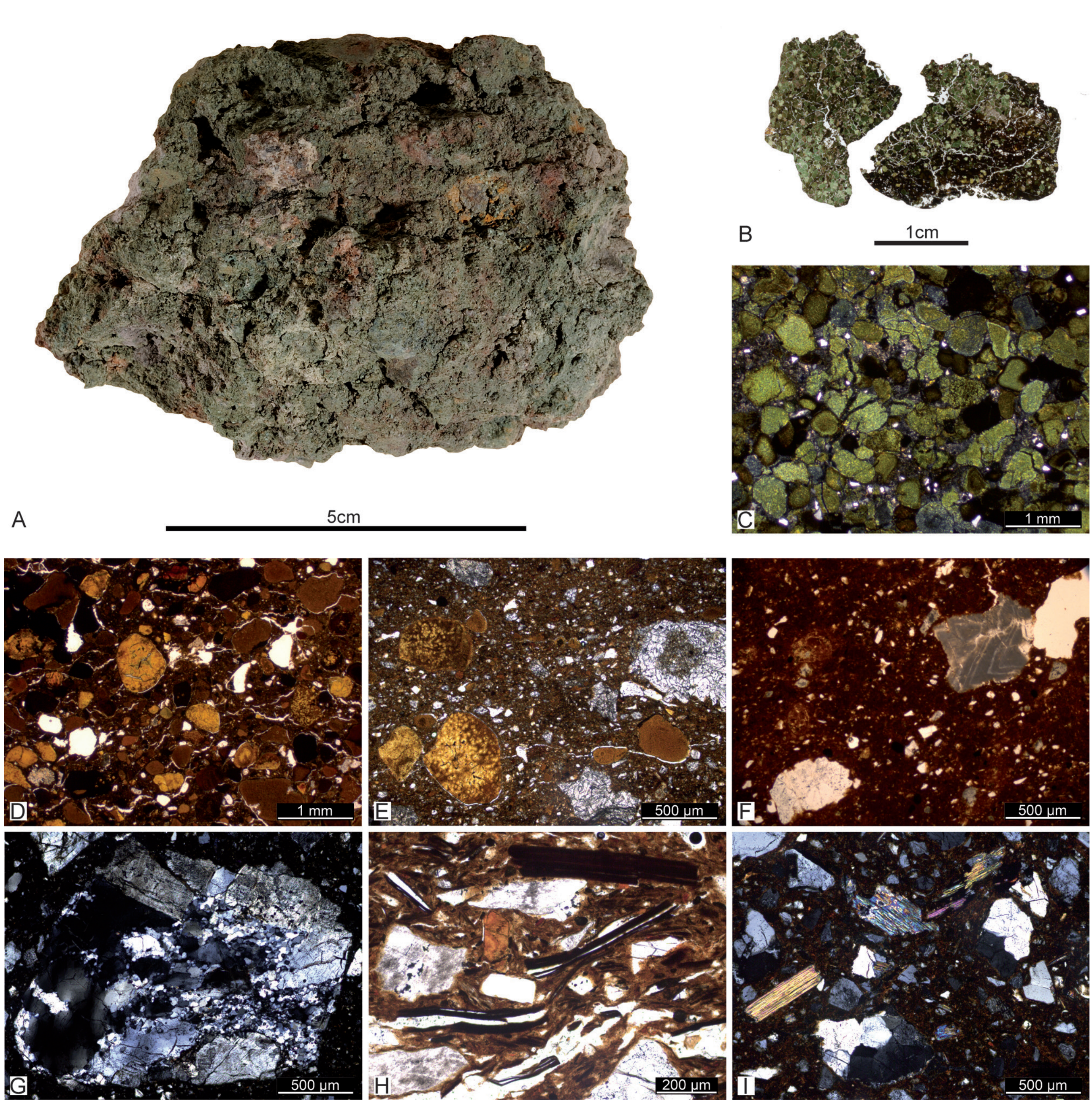



**Fig. 3 –** A) Crude block of kneaded glauconitic paste from Pendimoun rock-shelter; B) High-Resolution scan of a thin section from one of the glauconitic crude blocks (sample APMCLM01NC; PPL); C) microphotograph of one glauconitic crude block's thin section (sample APMCLM01NC; XPL); D) microphotograph of an experimental briquette's thin section of glauconitic paste made from one of the crude blocks (sample APEXPLM02; PPL); E) microphotograph of an experimental briquette's thin section of glauconitic clay sampled near Pendimoun rockshelter (sample ORM03a 500°C; PPL); F) microphotograph of an experimental briquette's thin section made from terra rossa sampled near Pendimoun rockshelter (sample APS14IISP 650°C; PPL); G) microphotograph of an experimental briquette's thin section of mylonitic granite earth from the Argentera Massif rich in deformed granite grains (sample ARG44 700°C; XPL); H) microphotograph of an experimental briquette's thin section of granitic earth from the Maures Massif rich in biotite inclusions (sample MAU01 700°C; PPL); I) microphotograph of an experimental briquette's thin section of granitic earth from the Tanneron Massif rich in muscovite inclusions (sample TAN04 700°C; XPL). PPL: Plane Polarized Light. XPL: Cross Polarized Light.

***Fig. 3 –** A) Pain de pâte glauconieuse malaxée provenant de l'abri Pendimoun ; B) Scanner à haute résolution d'une lame mince de pain de pâte glauconieuse malaxée (échantillon APMCLM01NC; LPNA) ; C) Microphotographie de lame mince de pain de pâte glauconieuse (cfr B ; LPA) ; D) Microphotographie d'une lame mince de briquette expérimentale de pâte glauconieuse provenant d'un des pains (échantillon APEXPLM02; LPNA) ; E) Microphotographie d'une lame mince de briquette expérimentale de terre glauconieuse prélevée près de l'abri Pendimoun (échantillon ORM03a 500°C; LPNA) ; F) Microphotographie d'une lame mince de briquette expérimentale de terra rossa près de l'abri Pendimoun (échantillon APS14II SP 650°C; LPNA) ; G) Microphotographie d'une lame mince de briquettes expérimentales de terre du Massif de l'Argentera riches en grains de granite mylonitique (échantillon ARG44 700°C; LPA); H) microphotographie d'une lame mince d'une briquette expérimentale de terre granitique du Massif des Maures riche en inclusions de biotite (échantillon MAU01 700°C; LPNA) ; I) microphotographie d'une lame mince d'une briquette expérimentale de terre granitique du Massif du Tanneron riche en inclusions de muscovite (échantillon TAN04 700°C; LPA). LPNA : Lumière Polarisée Non Analysée. LPA : Lumière Polarisée Analysée.*

analysed in stereoscopic microscope, and 52 thin sections, analysed in optical microscopy. Thin sections have been obtained from 36 pots (maximum two sections per pot), of which 16 from phase AC1A and 20 from phase AC1B. However, in this research, we focus particularly on pottery with non-local paste features allowing inter-sites comparison and tracing transfer.

### Local geology

The cave of interest is located in the Ligurian “Briançonnais zone”, a major internal tectonic unit of the Alpine belt (Cortesogno *et al.*, 1982; Vannossi *et al.*, 1984).

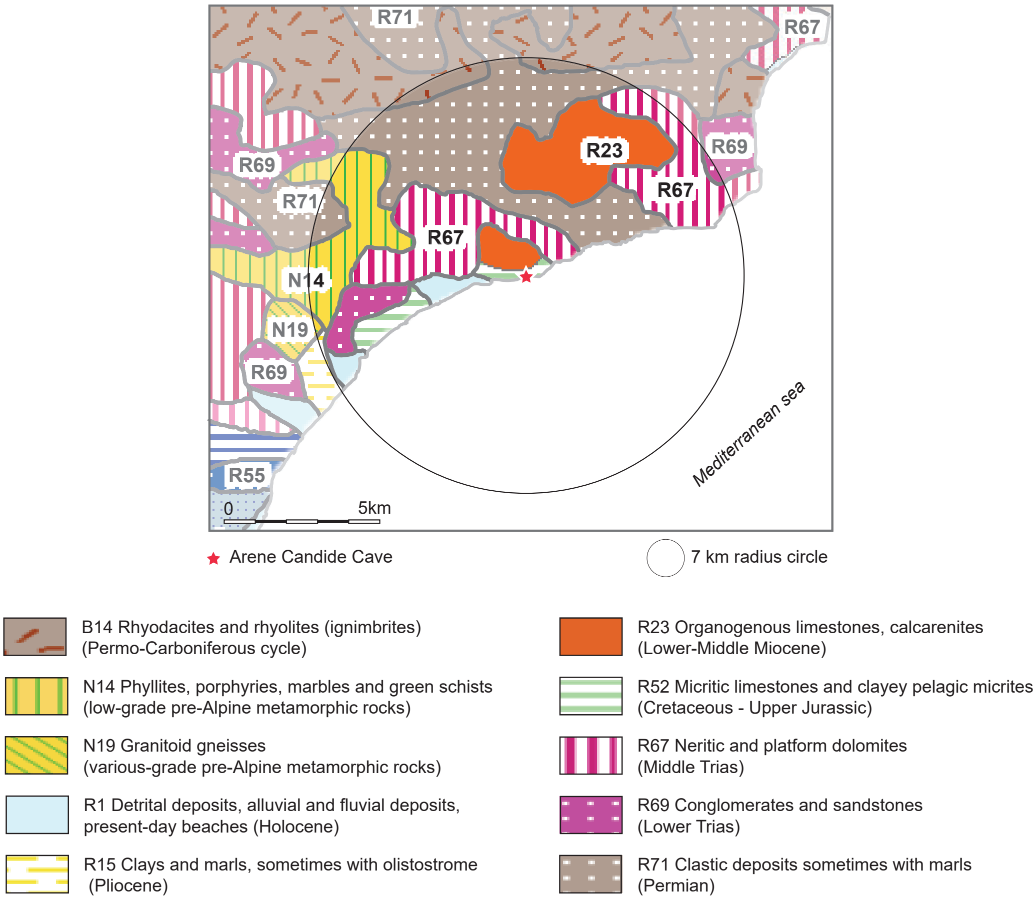
In this area the observed Briançonnais sequences include (see Vannossi, 1990 and Goffé *et al.*, 2004 with references therein):

– pieces of a polymetamorphic crystalline basement, thus Variscan (pre-Pennsylvanian) metamorphic and magmatic rocks (ortho and paragneisses, micaschists, amphibolites, etc.) reworked under High-Pressure/Low-Temperature (HP/LT) conditions during Alpine orogeny;
– the so-called “Briançonnais tegument” composed of Upper Carboniferous-Lower Triassic volcano-sedimentary units metamorphosed under Alpine HP/LT conditions (meta-rhyolites, prasinites, phyllites, quartzites, quartz-schists, porphyroids, etc.);
– low grade to non-metamorphic Lower Triassic-Paleogene sedimentary units (dolostones, dolomitic limestones, limestones, sandstones and conglomerates).

Post-tectonic marine sediments unconformably overlie the Briançonnais sequences (Giammarino *et al.*, 2002), with first Upper Oligocene-Middle Miocene deposits (marly and sandy clays, bioclastic limestones, sandstones and conglomerates) and second Pliocene sediments (marly and silty to sandy clays and rare conglomerates). Lastly, the occurrence of Holocene sedimentary deposits (alluvial, eluvial, colluvial and beach deposits) should be noted (fig. 4).

### *Pottery pastes description*

Petrographic observation reveals high differences within non-local pottery pastes and raw materials. At least six pottery pastes, made from non-local raw materials or by adding non-local grog-temper to local raw materials, indicate transfers (fig. 5-7 ; table 1).




According to : http http://www.pcn.minambiente.it/viewer/

**Fig. 4** – Local geological map of Finale Ligure - Arene Candide site.

***Fig. 4** – Carte de la géologie locale du site de Finale Ligure - Arene Candide.*

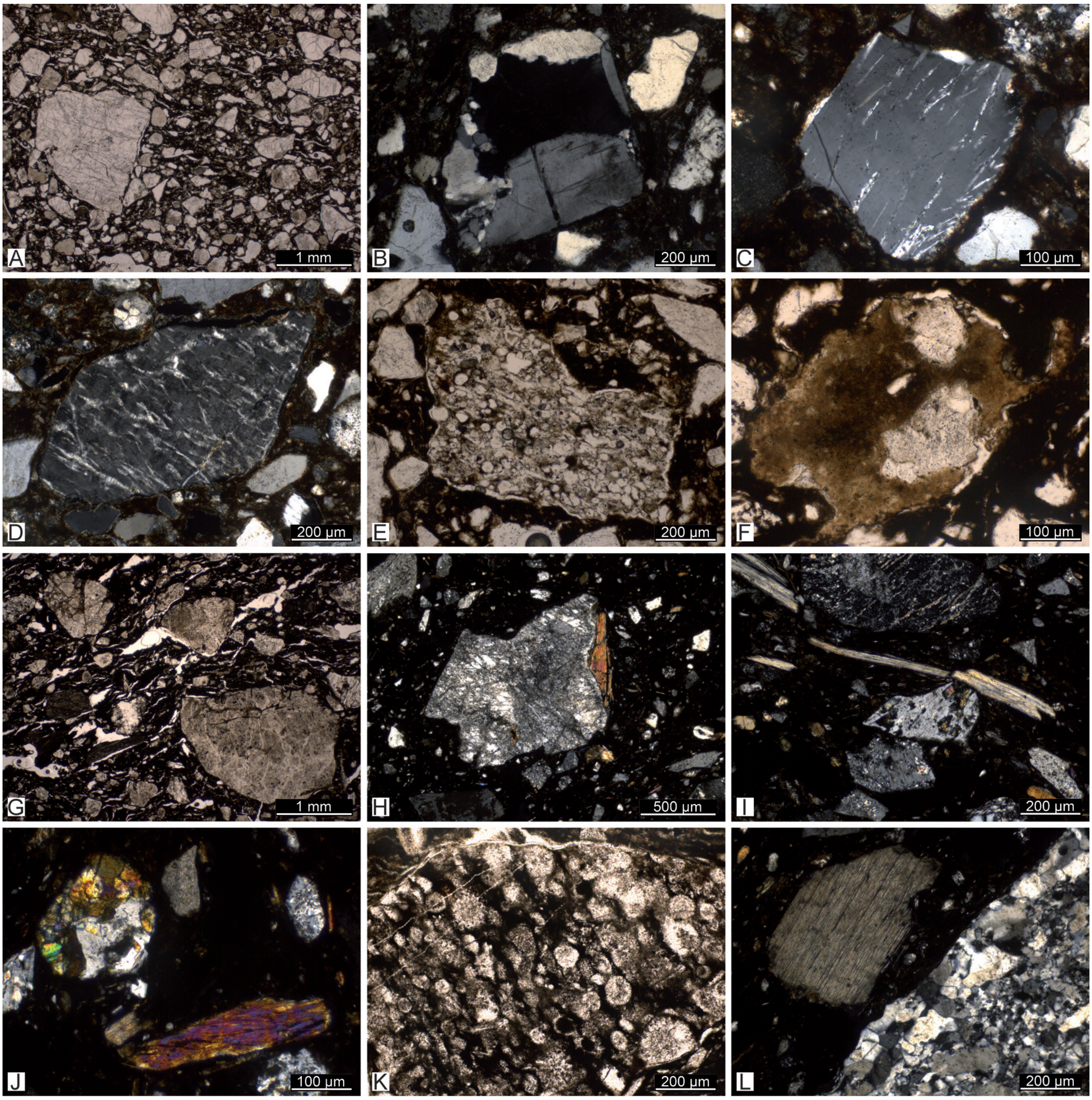



**Fig. 5** – Thin section microphotographs of archaeological pottery pastes from the site of Finale Ligure-Arene Candide. A-F: *Mylonitic meta-granite and sedimentary inclusions paste*. A: general view and inclusion textural features (PPL); B: Quartz with undulatory extinction, amoeboid boundaries, recrystallization and intragranular deformation (XPL); C: quartz associated with sillimanite (XPL); D: perthite (XPL); E: spongolite (PPL); F: amorphous aggregate include quartz and micrite (PPL). G-L: *Diallage-bearing gabbro paste*. G: general view and inclusion textural features (PPL); H: gabbroic rock fragment composed by feldspars and diallage (XPL); I: diallage often fractured and weathered, ophiolitic rocks (XPL); J: amphibole, epidosite, feldspar and very fine diallage inclusions (XPL); K: radiolarite (PPL); L: diallage and quartzite (XPL). PPL: Plane Polarized Light. XPL: Cross Polarized Light.

***Fig. 5** – Microphotographies en lame mince des pâtes de céramiques archéologiques du site de Finale Ligure-Arene Candide. A-F : Pâte à méta-granite mylonitique et inclusions sédimentaires. A : vue générale et caractéristiques texturales des inclusions (LPNA) ; B : quartz à extinction roulante, à limites amiboïdes, recristallisation et déformation intragranulaire (LPA) ; C : quartz à sillimanite (LPA) ; D : perthite (LPA) ; E : spongolite (LPNA) ; F : agrégat amorphe comprenant du quartz et de la micrite (LPNA). G-L : Pâte à gabbro à diallage. G : vue générale et caractéristiques texturales des inclusions (LPNA) ; H : fragment de roche gabbroïque composé de feldspaths et de diallage (LPA) ; I : diallage fracturé, roches ophiolitiques (LPA) ; J : amphibole, épidosite, feldspath et inclusions très fines de diallage (LPA) ; K : radiolarite (LPNA) ; L : diallage et quartzite (LPA). LPNA : Lumière Polarisée Non Analysée. LPA : Lumière Polarisée Analysée.*

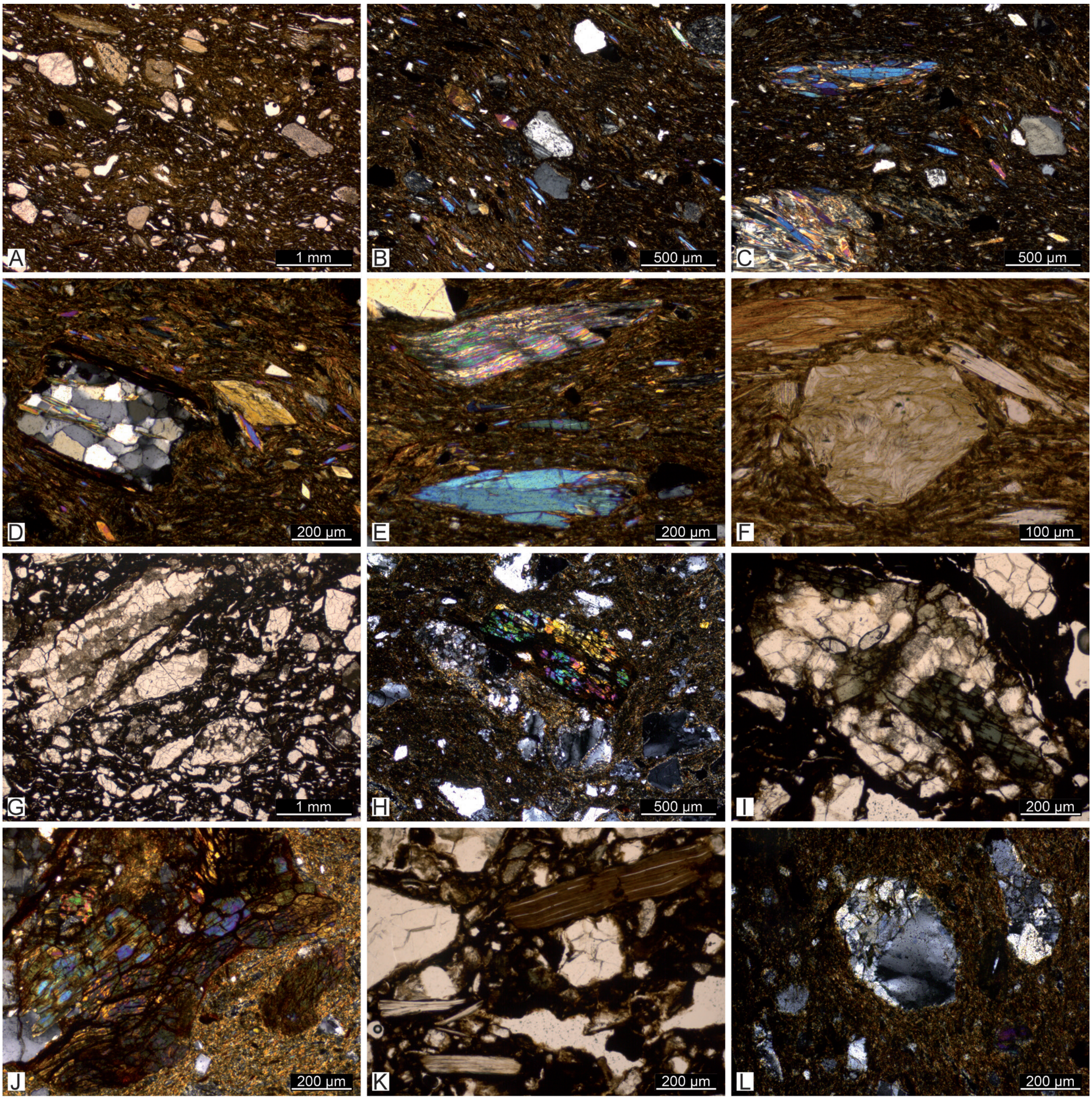



**Fig. 6** – Thin section microphotographs of archaeological pottery pastes from the site of Finale Ligure-Arene Candide. A-F: *Serpentinite and amphibole-bearing schist paste*. A: general view and inclusion textural features (PPL); B: amphiboles (probably tremolite-actinolite series), feldspar and quartz (XPL); C: amphibole-bearing schists, amphiboles and quartz; D: metamorphic micas-rich rocks fragment and amphiboles (XPL); E: mica-bearing schist, amphiboles and quartz (XPL); F: serpentinite, amphibole-bearing schist and amphiboles (XPL). G-L: *Amphiboles-bearing gneiss paste*. G: general view and inclusion textural features (PPL); H: metamorphic rock fragments (quartz, clinopyroxene) and deformed quartz (XPL); I: metamorphic rock fragments (quartz, amphibole and titanite) (PPL); J: metamorphic rock fragments (quartz and amphibole) (XPL); K: quartz, black and white micas (PPL); L: metamorphic rock fragments (deformed quartz with rutile) (XPL). PPL: Plane Polarized Light. XPL: Cross Polarized Light.

***Fig. 6** – Microphotographies en lame mince des pâtes de céramiques archéologiques du site de Finale Ligure - Arene Candide. A-F : Pâte à serpentinite et schiste à amphiboles. A : vue générale et caractéristiques texturales des inclusions (LPNA) ; B : amphiboles (probablement série trémolite-actinote), feldspath et quartz (LPA) ; C : schistes à amphiboles, amphiboles et quartz ; D : amphiboles et roche métamorphique riche en micas (XPL) ; E : schiste micacé, amphiboles et quartz (LPA) ; F : serpentinite, schiste amphibolique et amphiboles (LPA). G-L : Pâte à gneiss à amphiboles. G : vue générale et caractéristiques texturales des inclusions (LPNA) ; H : fragments de roche métamorphique (quartz et clinopyroxène) et quartz déformé (LPA) ; I : fragments de roche métamorphique (quartz, amphibole et titanite) (LPNA) ; J : fragments de roche métamorphique (quartz et amphibole) (LPA) ; K : quartz, micas noirs et blancs (LPNA) ; L : fragments de roche métamorphique (quartz déformé avec rutile) (LPA). LPNA : Lumière Polarisée Non Analysée. LPA : Lumière Polarisée Analysée.*

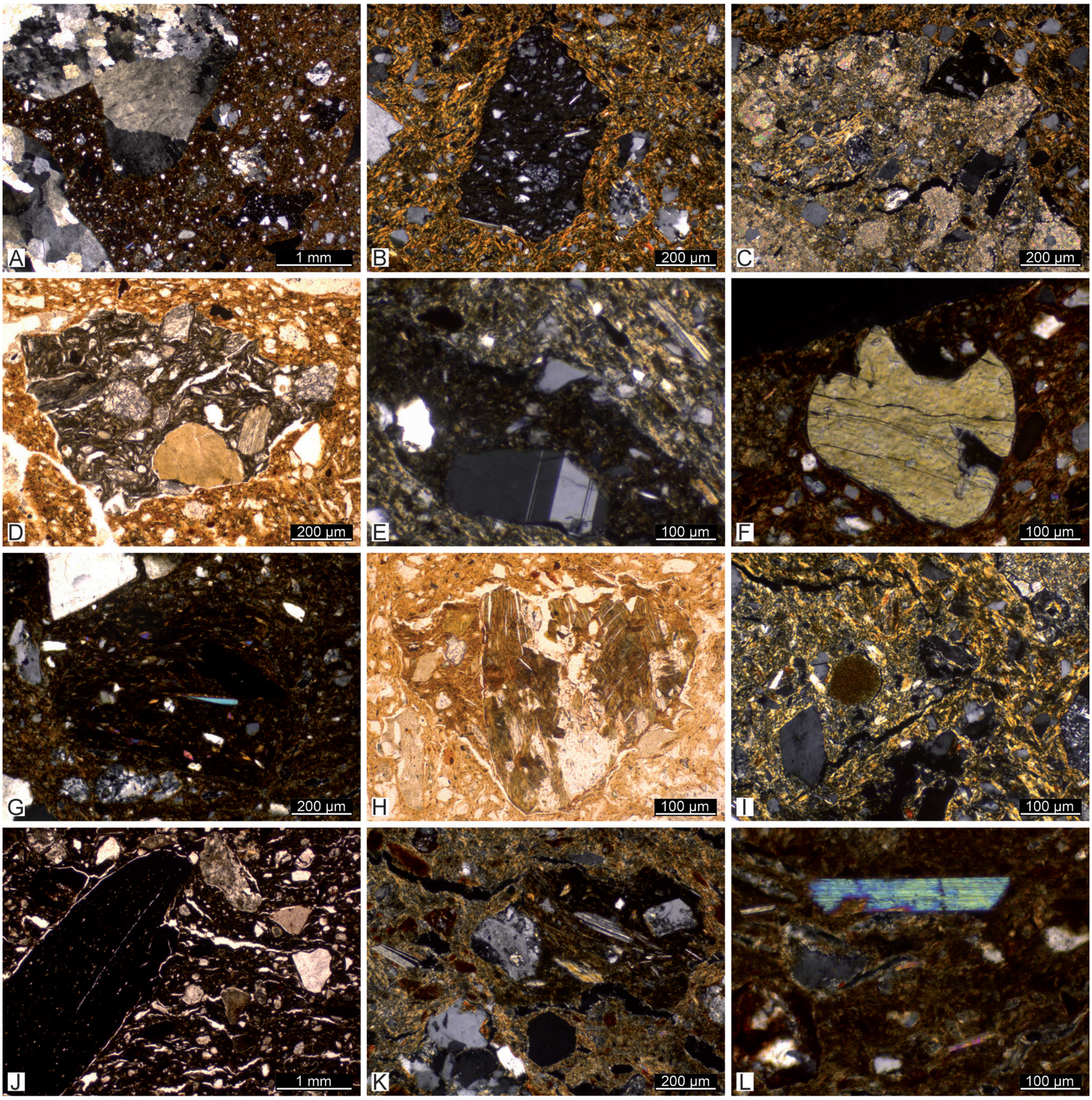



**Fig. 7** – Thin section microphotographs of archaeological pottery pastes from the site of Finale Ligure - Arene Candide. A-I: *Acid metamorphic rocks with carbonatic, metamorphic, ophiolitic and volcanic grog-temper paste.* A: general view and inclusion textural features (XPL); B: acid metamorphic grog-temper paste, iron-rich amorphous matrix and low-birefringence white micas (XPL); C: carbonatic grog-temper paste with second grog generations (XPL); D: ophiolitic grog-temper paste (PPL); E: volcanic grog-temper paste (XPL); F: inclusion of rounded clinopyroxene (XPL); G: metabasite grog-temper paste, characterized by fine elongated non colored and high birefringent minerals, probably actinolite amphibole (XPL); H: Gneiss grog-temper paste with biotite gneiss (PPL); I: glauconite and metamorphic rocks grog-temper paste represented only by a grog inclusion with only a supposed glauconite grain (XPL). J-L: *Sedimentary rocks with diallage grog-temper paste.* J: general view and inclusion textural features: rounded and angular sedimentary rocks, quartz and feldspar (PPL); K: ophiolitic grog-temper paste, generally consisting of a diallage-rich paste, quartz and diallage inclusions (XPL); L: diallage monomineral grains, scattered in the matrix, probably comes from the grog production and addition process (XPL). PPL: Plane Polarized Light. XPL: Cross Polarized Light.

***Fig. 7** – Microphotographies en lame mince des pâtes de céramiques archéologiques du site de Finale Ligure - Arene Candide. A-I : Roches métamorphiques acides avec chamotte à pâte carbonatée, métamorphique, ophiolitique et volcanique. A : vue générale et caractéristiques texturales des inclusions (LPA) ; B : chamotte à pâte métamorphique acide, matrice amorphe et micas blancs à faible biréfringence (LPA) ; C : chamotte à pâte carbonatée avec inclusion de chamotte (LPA) ; D : chamotte à pâte ophiolitique (LPNA) ; E : chamotte à pâte volcanique (LPA) ; F : inclusion de clinopyroxène arrondi (LPA) ; G : chamotte à pâte à métabasites, caractérisée par des minéraux allongés non colorés et à une biréfringence élevée, probablement des amphiboles (LPA) ; H : chamotte à pâte à gneiss à biotite (LPNA) ; I : chamotte à pâte à probable glauconite et roches métamorphiques (LPA). J-L : Roches sédimentaires avec chamotte à pâte à diallage. J : vue générale et caractéristiques texturales des inclusions, roches sédimentaires arrondies et anguleuses, quartz et feldspath (LPNA) ; K : chamotte à pâte ophiolitique, généralement constituée d'une pâte riche en diallage, inclusions de quartz et diallage (LPA) ; L : grain de diallage, dispersés dans la matrice, provenant probablement du processus de production et d'ajout de la chamotte (LPA). LPNA : Lumière Polarisée Non Analysée. LPA : Lumière Polarisée Analysée.*

| Pottery pastes groups | Non Plastic Inclusions | | | | | | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Minerals | | | | | | | | | | | | | | | Rocks | | | | | | | | | | | Bioclasts | Anthropic |
| | NPI % | Qtz | T Qtz | Kfs | Pl | Px/Cpx | Am | Ms | Bt | Glt | Sil | Grt | Tur | Zrn/Ttn | Ep | Cal | Granite | Mylonitic meta-granite | Sil-rich gneiss | Am-bearing gneiss | Am-bearing schist | Serpentinite | Diallage-bearing gabbro | Andesite | Silicites | Terrigenous clastic sedimentary rocks | Glt-rich rocks | Microfossils | Grog |
| Mylonitic meta-granite | 30-40% | •••• | – | ••• | •• | – | – | •• | • | – | + | + | + | + | – | – | • | •• | – | – | – | – | – | – | – | – | – | – | – |
| Mylonitic meta-granite and glauconite | 30-40% | •••• | – | ••• | •• | – | – | •• | • | ••• | + | + | + | + | – | + | + | •• | – | – | – | – | – | – | – | – | + | – | – |
| Mylonitic meta-granite, glauconite and grog-temper | 30-40% | •••• | – | ••• | •• | – | – | •• | • | ••• | + | – | + | + | – | + | + | •• | – | – | – | – | – | – | – | + | + | – | ••• |
| Mylonitic meta-granite and sedimentary inclusions | 30-40% | •••• | – | ••• | • | – | – | • | • | – | + | – | + | + | + | – | • | ••• | – | – | – | – | – | – | + | – | – | + | – |
| Mylonitic meta-granite, carbonates and Triassic quartz | 20% | •• | + | • | + | – | – | • | – | •• | – | – | – | – | – | + | – | ••• | – | – | – | – | – | – | – | – | ••• | – | – |
| Gneiss, meta-granite and sedimentary inclusions ± grog-temper | 30-40% | ••• | + | ••• | •• | + | – | •• | ••• | – | + | – | – | + | – | – | •• | •• | •• | – | – | – | – | – | • | – | – | + | • |
| Gneiss, meta-granite and glauconite ±grog-temper | 30-40% | ••• | + | ••• | •• | + | – | •• | ••• | ••• | + | + | – | + | – | – | •• | •• | •• | – | – | – | – | – | • | – | – | + | •• |
| Granitic | 30-40% | •••• | – | ••• | • | – | – | ••• | •• | – | – | – | – | – | – | – | •• | – | – | – | – | – | – | – | – | – | – | – | – |
| Granitic and two micas | 30-40% | ••• | – | •• | • | – | – | •••• | ••••• | – | – | – | – | – | – | – | •• | – | – | – | – | – | – | – | – | – | – | – | – |
| Glauconite | 40-60% | •• | – | • | • | – | – | + | + | ••••• | – | – | – | + | – | + | – | – | – | – | – | – | – | – | – | – | •• | + | – |
| Diallage-bearing gabbro | 30-40% | + | – | • | ••• | ••• | • | + | + | – | – | + | – | – | + | – | – | – | – | – | – | + | ••• | – | + | + | – | – | – |
| Serpentinite and amphibole-bearing schist | 20% | • | – | – | + | – | •••• | • | + | – | – | + | – | – | + | – | – | – | – | – | ••• | • | – | – | – | – | – | – | – |
| Amphiboles-bearing gneiss | 30-40% | ••• | – | • | •• | • | ••• | ••• | ••• | – | – | + | + | + | • | – | – | – | – | ••• | – | – | – | – | – | – | – | – | – |
| Andesitic | 30-40% | – | – | – | •••• | ••• | • | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | ••• | – | – | – | – | – |
| Andesitic and deformed quartz | 20-30% | • | – | – | •••• | ••• | • | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | •• | – | – | – | – | – |
| Acid metamorphic rocks with local and non-local grog-temper | 30-40% | ••• | – | • | • | • | • | • | • | – | – | – | – | – | – | – | – | – | – | • | • | • | – | – | – | – | – | – | ••• |
| Sedimentary rocks with diallage grog-temper | 30% | •• | – | •• | • | •• | – | • | • | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | •• | ••• | – | – | ••• |

**Table 1** – Summary table of the major non-local ceramic pastes identified for the different sites. Qtz: Quartz; T Qtz: Triassic Quartz; Kfs: KFeldspar; Pl: Plagioclase; Px/Cpx: Pyroxene/Clinopyroxene; Am: Amphibole; Ms: Muscovite; Bt: Biotite; Glt: Glauconite; Sil: Sillimanite; Grt: Garnet; Tur: Tourmaline; Zrn/Ttn: Zircon/Titanite; Ep: Epidote; Cal: Calcite. NPI: Non Plastic Inclusions. ••••••: very dominant (>70%); •••••: dominant (50-70%); ••••: frequent (30-50%); •••: common (15-30%); ••: few (5-15%); •: very few (<5%); +: occasional; - : absent.

***Tabl. 1** – Tableau récapitulatif des principales pâtes céramiques non locales identifiées pour les différents sites. Qtz: Quartz; T Qtz: Triassic Quartz; Kfs: KFeldspath; Pl: Plagioclase; Px/Cpx: Pyroxène/clinopyroxène; Am: Amphibole; Ms: Muscovite; Bt: Biotite; Glt: Glauconite; Sil: Sillimanite; Grt: Garnet; Tur: Tourmaline; Zrn/Ttn: Zircon/Titanite; Ep: Epidote;Cal: Calcite. NPI : Inclusions non plastiques. •••••• : très dominant (>70%) ; •••••:  dominant (50-70%) ; •••• : fréquent (30-50%) ; •••: commun (15-30%) ; •• : rare (5-15%) ; • : très rare (<5%) ; + : occasionnel ; - : absent.*

### Mylonitic meta-granite and sedimentary inclusions paste

Non-plastic inclusions occur with a frequency of 30-40%, with a grain size generally up to coarse and very coarse sand, rarely very fine gravel, angular-subangular and poorly sorted (fig. 5A-F).

Grains mainly consist of frequent metamorphic mono- and polycrystalline quartz and less abundant alkali feldspar and deformed meta-granite (mylonitic granite). Quartz typically show undulatory extinction, amoeboid boundaries, dynamic recrystallization and intragranular deformation (fig. 5B). Quartz may occasionally be associated with sillimanite (fig. 5C) or be undeformed with straight extinction.

Orthoclase is commonly pertitic (fig. 5D), with different degree of alteration (non-alteration; phyllosilicates or opaques). Granitic rock fragments (quartz ± feldspars ± micas) show different degree of deformation features (*i.e.* dynamic recrystallization), as intragranular deformation, recrystallization and decreasing mineral size. Related to granitic rocks, graphic texture, granophyre and aplite are also sporadically attested.

Inclusions comprise other very rare minerals and lithic grains such as plagioclase, occasionally deformed and weathered, as well as microcline, sillimanite, white mica, biotite, accessory minerals (*e.g*. epidotes, tourmaline and titanite), chalcedony, micro-cryptocrystalline silica and spongolite (fig. 5E). Black mica can reach the grain size of fine sand, whereas white mica is usually present in the grain size of silt. In addition, sporadic microfossils (*e.g.* radiolarian?) and plant remains are present.

Pedofeatures are certainly represented by concentric or clay nodules, while the origin of carbonate (often-identified micrite and microsparite) and amorphous nodules and aggregates remains uncertain. These may or may not include mineral grains (*e.g.* quartz; fig. 5F).

### Diallage-bearing gabbro paste

Non-plastic inclusions occur with a frequency of 30-40%, generally with a grain size up to coarse and very coarse sand, rarely very fine gravel, angular-subrounded and unsorted (fig. 5G-L).

Mineral grains are mainly composed of abundant feldspars, clinopyroxene and gabbroic rock fragments. Feldspars are frequent and made up of plagioclase and in a lesser extent of alkali feldspar. Weathering often affects feldspars in different ways (clays, phyllosilicates and opaque concentrations). Diallage is the common mafic mineral, often fractured and weathered (fig. 5I-L); moreover, yellow-green amphibole is rarely present, also showing red color (fig. 5J). Gabbroic rock fragments, composed by feldspars and diallage grains, are common, weathered and can reach the maximum grain size (fig. 5H).

Further non-plastic inclusions also include very few or occasionally green to yellow epidote (probably pistacite), quartz, micas and opaque minerals, as well as fragments, often sub-rounded, of rocks such as serpentinite, epidosite, radiolarite, chert-like, basalt (pillow-lavas), quartzite and probably argillaceous rocks (fig. 5J-L).

Lastly, very few plant remains are identified in elongated and rounded section, also associated to probably short cell phytoliths.

### Serpentinite and amphibole-bearing schist paste

Non-plastic inclusions occur with low frequency, *c.* 20%, generally with a grain size up to medium sand, and more rarely up to coarse sand-very fine gravel, angular to subrounded, low-high sphericity, and moderately-poorly sorted (fig. 6A-F).

Grains are mainly composed by non-coloured or slightly green amphibole (probably tremolite-actinolite series), which can also occur as fibrous and reddish-brown in colour, as well as amphibole-, serpentine- and minor micaschists (fig. 6A-F). Among mineral inclusions, the following also appear with different textural features: deformed quartz, plagioclase, epidotes, garnet, and white and black micas. Finally, occasionally plant and indeterminate organic remains are also present.

### Amphiboles-bearing gneiss paste

This paste group includes three samples that, although similar in composition, show variable textural patterns. At this level of investigation, it was preferred to consider them as a single group, given also the compositional variability that seems to fade from sample to sample (fig. 6G-L).

In sample ACC20 and ACC07, non-plastic inclusions occur with a frequency of 30-40%, with a grain size generally up to coarse and very coarse sand, rarely very fine gravel, angular-subangular and poorly/unsorted (fig. 6G-H). In sample ACC52, the non-plastic fraction occurs with lower frequency, smaller particle size (up to medium-coarse sand) and higher sorting.

White and black micas are common (fig. 6K), with a grain size up to medium-coarse sand in sample ACC20, while decreasing in the other two samples: in particular, white mica is very rare and silt-sized in sample ACC52. Generally, oxidized black mica shows low or no pleochroism and birefringence, especially in ACC52, and can occurs in red colour, as well as some amphibole grains.

Other common components of this paste are amphiboles (green/yellow-green, brown and green-blue amphiboles; fig. 6I-J), deformed quartz, as well as metamorphic rock fragments with varying compositions (quartz ± rutile ± amphiboles ± clinopyroxenes ± feldspars ± micas ± epidote ± garnet ± titanite ± opaques; fig. 6G-L).

Other inclusions are present in smaller quantities, as feldspars (especially plagioclase), epidotes, clinopyroxenes and occasionally tourmaline. Plagioclase and epidotes are particularly presents in samples ACC07 and ACC20. Finally, bioclasts, as plant remains were also found in very small quantities in all samples.

### Acid metamorphic rocks with carbonate, metamorphic, ophiolitic and volcanic grog-temper paste

Despite the similar paste composition of the samples of this group, marked textural differences exist: e.g. in sample ACC06 the mineral inclusions can be rounded and up to very fine gravel in size (fig. 7A), whereas in ACC09 they are more angular and smaller. Nevertheless, for this study, and at this level of investigation, we prefer to consider these samples in the same group, due to the presence of various kinds of grog-temper (fig. 7A-I). Indeed, different compositional paste features marked grog-temper. Overall at least six grog-temper pastes have been definitely recognized:

– Acid metamorphic paste, mainly characterized by deformed quartz and white mica; moreover, this grog-temper paste may present typical features of high temperature firing, such as iron-rich amorphous matrix and low-birefringence white mica (fig. 7B); this grog paste looks like the including pottery paste (fig. 7A);
– Carbonate paste, mainly characterized by calcium carbonate matrix and inclusions. In turn, this paste can also contain other different grog-temper pastes, namely second grog generations are attested (fig. 7C);
– Ophiolitic paste, mainly characterized by serpentinite fragments, diallage, yellow-green amphibole and weathered plagioclase (fig. 7D); this paste looks like the "diallage-bearing gabbro paste" (fig. 5G-L);
– Volcanic paste, mainly characterized by plagioclase, sanidine, clinopyroxene and glassy rock; this paste looks like the one found in other coeval sites (Gabriele *et al.*, 2019; here fig. 7E-F);
– Metabasite paste, mainly characterized by fine elongated non colored and high birefringent minerals, typically amphibole (actinolite) (fig. 7G); this paste looks like the "serpentinite and amphibole-bearing schist paste" (fig. 6A-F);
– Gneiss paste, mainly characterized by biotite-rich gneiss, green-blue amphiboles bearing gneiss and biotite (fig. 7H); this paste looks like "Amphiboles bearing gneiss paste" (fig. 6G-L);

Moreover, one more grog-temper paste could be supposed:

– Glauconite and metamorphic rocks paste; this is represented only by a grog inclusion with only a supposed glauconite grain (fig. 7I).

In this pottery paste group in addition to the grog-temper, the analysed samples mainly include acid metamorphic rocks (e.g. quartz-schists, micaschists and quartzites) and derived minerals, as well as rock and mineral inclusions possibly derived from the different grog-temper pastes (green-blue amphibole bearing gneiss, serpentinite, amphibole-schist, volcanic rocks, glass, diallage, rounded green clinopyroxene (fig. 7F), sanidine, plagioclase and micas).

Finally, bioclasts and pedofeatures, such as plant remains and concentric nodules, are also occasionally present.

**Sedimentary rocks with diallage grog-temper paste**

In this paste group, the non-plastic inclusions are about 30%, with a grain size up to very fine gravel, unsorted, angular to rounded and with medium to low sphericity (fig. 7J-L).

In particular, inclusions mainly consist of rock fragments, such as argillites and phyllites, subrounded-rounded, and chert-like (micro-cryptocrystalline silica), angular-subangular (fig. 7J). Occasional grains of carbonate rocks are also present. Among the monomineralic grains, metamorphic quartz, diallage, feldspars and in smaller quantities white and black mica are present. Micas are very rare and silt size, occasionally up to fine sand. In addition, grog is common, generally consisting of a diallage-rich paste (fig. 7K). Indeed, diallage monomineral grains, scattered in the matrix, probably comes from the grog production and addition process (fig. 7L). Finally, occasional plant remains are observed.

## *Sourcing raw materials*

Alpine metamorphic, low-pressure ophiolite and volcanic formations are suitable sources for the above-mentioned pottery and grog pastes. Such geological formations are not present within a radius of 7km around the site (fig. 4).

One of the sources of raw material for the silicate component of the pottery pastes should be a deformed meta-granite with two feldspars (subsolvus). This type of outcrop is not identified in the Maures-Tanneron massif towards the west or of the Savona-Calizzano massif, towards the east, but rather in the Argentera-Mercantour massif towards the north-west. In fact, here mylonitic subsolvus meta-granites are involved within ductile shear zones, linked to the Alpine orogeny (Sanchez *et al.*, 2011; Lardeaux *et al.*, this volume). Moreover, the absence of Alpine HP/LT minerals and meta-granites deformed under HT conditions in pottery pastes leads to exclude the Savona-Calizzano massif (Chantraine *et al.*, 1996) and Maures-Tanneron massif (Schneider *et al.*, 2014 with references therein) as sources respectively.

Source outcrop for the raw materials of mylonitic meta-granite and sedimentary paste could be identified in the deformed meta-granite of the Argentera-Mercantour massif, about 90km north-west of the site (fig. 2 and fig. 3G). However, the occasional presence of bio-sedimentary inclusions raises the possibility of different source, even if it is difficult to circumscribe geographically. In fact, there is no geographical area close to the Argentera-Mercantour massif, where it is possible to find such a natural mixing of *terrae*. Moreover, the presence of concentric nodules, markers of evolved soils, leads us to look for the source of the raw material, not in a mountain environment or to consider the possibility of an intentional mixing. Evolved soils could be found e.g. in the Maures-Tanneron massif, where it would be possible to find them on granitic formations. However, the mineralogical composition and the absence of marked metamorphic imprint on these formations lead to its exclusion as the source of raw materials.

Unlike the mylonitic meta-granite and sedimentary paste, the other ones were probably produced with raw materials from source outcrops mainly to the east of the site.

In particular, alpine metamorphic raw materials characterized by amphibole-bearing schist and serpentinite (fig. 6A-F) or by amphiboles-bearing gneiss (fig. 6G-H) could come from the formations of the Voltri group and the Savona Calizzano Massif (fig. 2). Indeed, crystalline basement formations with green-blue amphiboles-bearing gneiss and amphibolite are present around 15km to the north and northeast from the site, in the Savona-Calizzano Massif. Instead, alpine meta-ophiolites with serpentinites and actinolite-schists outcrops are extensively present more than 30km to the east in the Voltri group in central Liguria. However, we cannot completely exclude north-eastern Corsica as a possible source area for these "Alpine metamorphic" raw materials.

With regard to diallage-bearing gabbro pastes, Apennine ophiolites characterised by a metamorphic low-pressure footprint, could be the source of the raw materials used in such a pottery production. These outcrops are present in eastern Liguria, more than 90km from the site, but also further afield in central Tuscany and in Tuscan Archipelago.

Finally, it is more difficult to circumscribe the sources of raw material for volcanic and glauconite components of grog pastes. For the glauconite grog pastes, it is possible to consider outcrops in eastern Provence (more than 50km); while for the volcanic pastes, the most indicative minerals (green clinopyroxene and sanidine) suggest the volcanic-potassic outcrops between southern Tuscany and Campania, more than 300km southeast from the site (Peccerillo, 2005). Even if at this research level it is not possible to completely exclude another provenance or multiple sources.

As for technological features, it must be pointed out that two local pottery production, made with local raw materials (acid metamorphic and sedimentary rocks respectively), present the use of non-local and local grog-temper; moreover, these local grog, made of carbonates or deformed quartz ± white mica raw materials, may present some significant technological features, such as second-generation grog and overcooking.

## Nice – Caucade

### *Context*

#### Archaeological context

Caucade (Nice) is a stratified coastal open-air site (fig. 1). In the late seventies, rescue excavations have uncovered an *Impressa* layer corresponding to the first half of the 6th millennium BCE, beneath series of structures belonging to the Chassey culture, mainly dated from the very beginning of the 4th millennium BCE. The *Impressa* horizon is as early as the first phase of the Arene Candide, based on a typological comparison of pottery (Binder and Maggi, 2001; Binder, Gomart *et al.*, this volume).

The small *Impressa* pottery assemblage consist of 67 small sherds after refitting; and the minimum number of pottery individuals (MNI) is to be considered as least equal to the number of decorated rests; to these can be added another six undecorated pots, identified according to the their pottery paste composition. Among the twenty-seven decorated fragments fourteen show typical geometric decoration obtained by the *sillon d'impressions* technique (Binder and Maggi, 2001).

The first petrographic observations (Manen *et al.*, 2006) have shown a great variety in pottery pastes and raw materials, beside a high mobility pattern. In this study, we have considered the previous data and increased the number of samples for thin sections analysis.

Overall, petrographic analyses were carried out on the entire ceramics set and on twenty-nine thin sections from twenty-three representative shard samples.

#### Local geology

The studied site is located in an area within which numerous sedimentary series are well defined (Gèze and Nestéroff, 1968) and particularly Triassic marls and gypsum, Jurassic limestones, Cretaceous marly limestones, including Upper Cretaceous glauconitic deposits and Quaternary alluvial formations (Irr, 1984; Dubar, 2012; fig. 8).

Limestones, marls, sandstones, pelites, magmatic and metamorphic elements, mainly compose the Quaternary alluvial deposits of the Var valley (Irr, 1984) and the terraces of Nice (Dubar, 2012).

### *Pottery paste description*

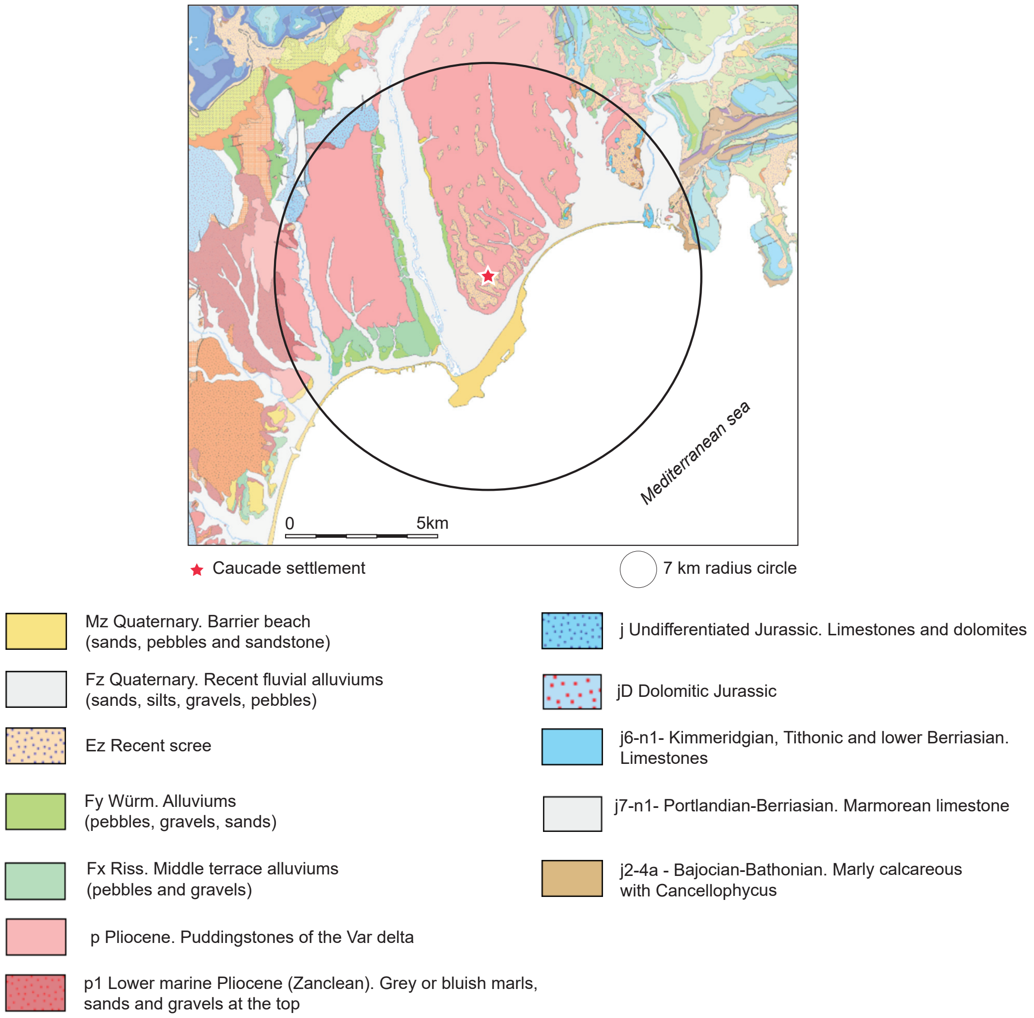
Petrographic observations show great differences among pottery pastes and raw materials, as for the Arene Candide cave. Specifically, with regard to non-local sources, at least six pastes can be outlined (fig. 9-10 and table 1). Some of these pastes have strong similarities in their petrographic composition, fading into each other, thus making it difficult to differentiate them clearly (fig. 9-10; table 1).

#### Gneiss, meta-granite and sedimentary inclusions paste

This pottery paste includes sedimentary, plutonic and metamorphic elements (fig. 9A-F). As a heterogeneous group, it includes all three petrographic components in varying proportions and textural features.

At this level of investigation, it is not possible to clearly identify several pastes in this heterogeneous group, but some differences in composition are highlighted below:

– Mica-rich pastes: micas represent an important but never dominant fraction. Generally, biotite is more abundant than white mica, except for one sample (Cau16). In one case, black and white micas can reach the size of the medium sand (Cau08). Other inclusions are present, angular to rounded and generally up to very coarse sand. Among them, quartz is frequent, generally with intra-crystalline deformation (fig. 9A). In at least in one sample (Cau02) euhedral




Geological Map 1/50 000 (BRGM) Sheet N°1579 - Project: Alpes-Maritimes modified according to Dubar 2012.

**Fig. 8** – Local geological map of the Nice - Caucade site.
***Fig. 8** – Carte de la géologie locale du site de Nice - Caucade.*

Triassic quartz grains are also present (fig. 9D-E). Alkali feldspars are common, while plagioclase is rare. Some of which show microstructures of plastic deformation. Other minerals are occasionally present, such as Fe-Mg minerals and sillimanite. Lithic granules are common, such as plutonic and metamorphic rock fragments and to a lesser extent sedimentary ones. Lithoclasts include granite, meta-granite, sillimanite-rich gneiss (fig. 9B), silicite and spongolites. Finally, microfossils, as likely spicules, were identified in at least three samples (Cau04, 07 and 08). With regard to anthropic inclusions, grog is difficult to identify, but may be present in at least one sample (Cau04; fig. 9C). Clay aggregates are generally present in other samples (*e.g.* Cau08 and 16);

– Mica-poor pastes: in four samples micas are rare with respect to the previously described ones. However, the other components of the non-plastic fraction have different textural aspects. In particular, while sample Cau09 is very similar to the samples described above, but with less abundant inclusions, sample Cau11 has both frequent and well-rounded inclusions. In this sample, the plutonic component seems to be more important than in the other samples. In fact, straight undeformed quartz (fig. 9F), feldspars and aplites are present in this sample. In sample Cau20, the matrix appears to be different, with very few micas and fine fraction. In this sample, non-plastic inclusions may be up to very fine gravel and rounded, with an apparent bimodal distribution. In addition, in this sub-group, Triassic quartz (fig. 9E), Fe-Mg minerals and sedimentary siliceous rocks have also been identified. Finally, pedofeatures concentric nodules are also present.

## Gneiss, meta-granite and glauconite paste

This paste is characterized by very similar mineral and lithic inclusions as those found in the previous paste group, but here associated with glauconite peloids, glauconite-rich rocks, glauconite clay aggregates and grog-temper (fig. 9G-L). Even in this case, the textural features of

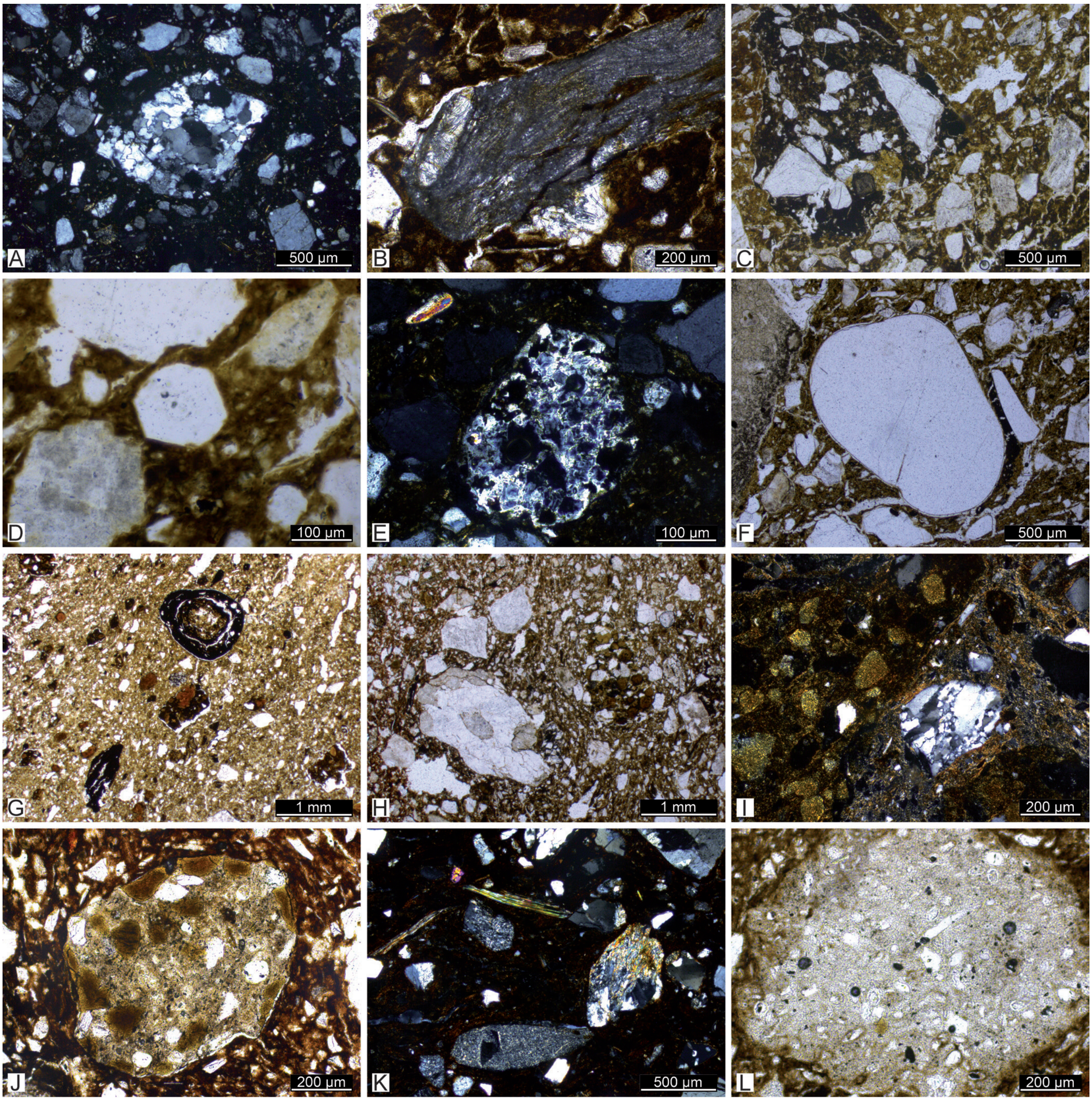



**Fig. 9** – Thin section microphotographs of archaeological pottery pastes from the site of Nice - Caucade. A-F: *Gneiss, meta-granite and sedimentary inclusions paste*. A: quartz with intra-crystalline deformation (XPL); B: sillimanite gneiss (PPL); C: grog-temper with similar composition to the embedded pottery, and probably with second generation grog (PPL); D: Triassic quartz, feldspar and quartz (PPL); E: Triassic cariated quartz, feldspar, quartz and white mica (XPL); F: rounded straight undeformed quartz (PPL). G-L: *Gneiss, meta-granite and glauconite* paste. G: general view and inclusion textural features: glauconite, glauconitic rocks and concentric nodule (PPL); H: glauconite, glauconitic rocks and gneiss fragments (PPL); I: glauconitic grog-temper and quartz with intra-crystalline deformation (XPL); J: phosphate cement glauconite rock (PPL); K: deformed quartz, white mica and gneiss inclusions (XPL); L: bio-sedimentary rock, probably spongolite (PPL). PPL: Plane Polarized Light. XPL: Crossed Polarized Light.

***Fig. 9** – Microphotographies en lame mince des pâtes de céramiques archéologiques du site de Nice - Caucade. A-F : Pâte à gneiss, méta-granite et inclusions sédimentaires. A : quartz avec déformation intra-cristalline (LPA) ; B : gneiss à sillimanite (LPNA) ; C : chamotte à pâte de composition similaire à celle de la pâte de la poterie au sein de laquelle elle a été incorporée, et incluant elle-même probablement de la chamotte (LPNA) ; D : inclusions de quartz, feldspath et quartz du Trias (LPNA) ; E : quartz carié du Trias, feldspath, quartz et mica blanc (LPA) ; F : quartz arrondi non déformé (LPNA). G-L : Pâte à Gneiss, méta-granite et glauconite. G : vue générale et caractéristiques texturales des inclusions, glauconite, roches glauconitiques et nodule concentrique (LPNA) ; H : glauconite, roches glauconitiques et fragments de gneiss (LPNA) ; I : chamotte glauconitique et quartz avec déformation intra-cristalline (LPA) ; J : roche glauconitique à ciment phosphaté (LPNA) ; K : inclusions de quartz déformé, mica blanc et gneiss (LPA) ; L : roche bio-sédimentaire, probable spongolite (LPNA). LPNA : Lumière Polarisée Non Analysée. LPA : Lumière Polarisée Analysée.*

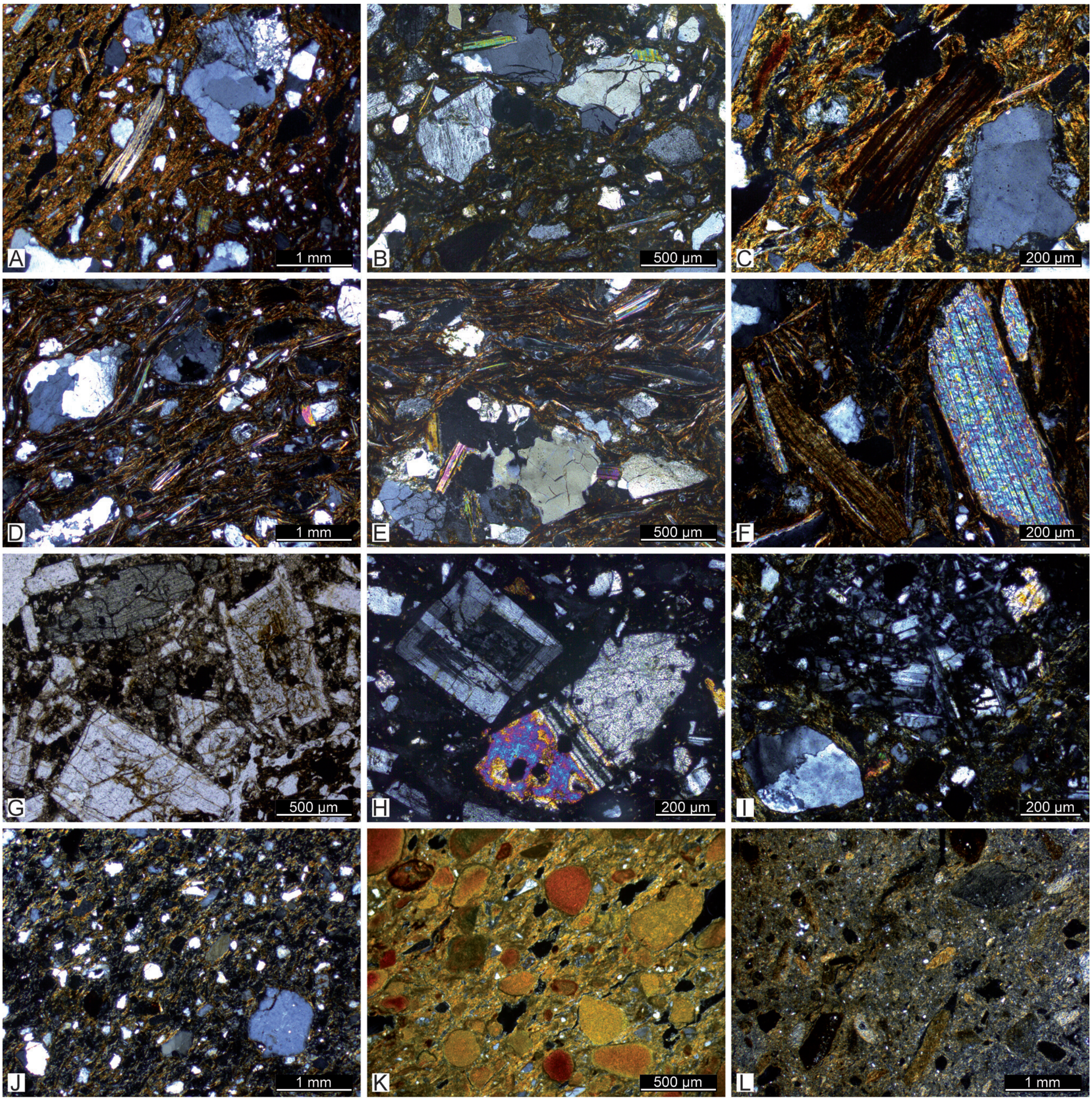



**Fig. 10** – Thin section microphotographs of archaeological pottery pastes from the site of Nice-Caucade. A-C: *Granitic paste*. A: general view and inclusion textural features: common quartz, granitic rock and white mica (up to coarse sand sizes) (XPL); B: white mica granite, white mica, quartz and feldspar (XPL); C: oxidised black mica, granitic rock, quartz and feldspar (XPL). D-F: *Granitic and two micas paste*. D: general view and inclusion textural features, dominant black mica and, to a lesser extent, white mica, granitic rock and quartz (XPL); E: white mica granitic rock, black and white micas, quartz and feldspar (XPL); F: preserved white and black micas (XPL). G-H: *Andesitic paste*. G: andesitic rock with andesine plagioclase, pyroxenes in plagioclases-oxydes groundmass (PPL); H) zoned plagioclase and twinned clinopyroxene (XPL). I-L: *Andesitic and deformed quartz paste.* I: andesitic rock and dynamically recrystallised quartz (XPL); J: Pottery paste characterised by the presence of common quartz (XPL); K: glauconite paste (XPL); L: sedimentary rock paste. PPL: Plane Polarized Light. XPL: Cross Polarized Light.

***Fig. 10** – Microphotographies en lame mince des pâtes de céramiques archéologiques du site de Nice-Caucade. A-C : Pâte granitique. A : vue générale et caractéristiques texturales des inclusions : quartz, roche granitique et mica blanc (jusqu'à des tailles de sable grossier) (LPA) ; B : granite à mica blanc, mica blanc, quartz et feldspath (LPA) ; C : mica noir oxydé, roche granitique, quartz et feldspath (LPA). D-F : Pâte granitique et deux micas. D : vue générale et caractéristiques texturales de l'inclusion, mica noir dominant, suivi par mica blanc, roche granitique et quartz (LPA) ; E : roche granitique à mica blanc, micas noirs et blancs, quartz et feldspath (LPA) ; F : micas blancs et noirs (LPA). G-H : Pâte andésitique. G : roche andésitique avec plagioclase, pyroxènes dans une matrice à plagioclases-oxydes (LPNA) ; H : plagioclase zoné et clinopyroxène maclé (LPA). I-L : Pâte à andésitique et à quartz déformé. I : roche andésitique et quartz recristallisé (LPA) ; J : Pâte à quartz (LPA) ; K : Pâte à glauconite (LPA) ; L : Pâte à roche sédimentaire. LPNA : Lumière Polarisée Non Analysée. LPA : Lumière Polarisée Analysée.*

mineral components can be very different from sample to sample, although plutonic, metamorphic (fig. 9H-I and K), and sedimentary (fig. 9J and L) components are always present. For example, sample Cau01 has abundant inclusions, with common glauconite and black mica, and less abundant white mica, heavy minerals (*e.g.* garnet, zircon, clinopyroxene) and chalcedony spongolite. Samples Cau14 has only one glauconite granule. Sample Cau12 has rare inclusions, including silicite, chalcedony, microfossils (spicules) and pedofeatures (concentric nodules; fig. 9G).

#### Granitic paste

The non-plastic inclusions have a content of 30-40% and a grain size up to the very coarse sand, with rare elements to fine gravel; these are poorly sorted or unsorted, generally angular with low sphericity (fig. 10A-C). Grains consist of frequent quartz and subordinated alkali feldspar. Plagioclase is very few and often much weathered. White and black micas are also present: white mica are common and up to coarse sand sizes, whereas black mica is smaller in size and abundance (fig. 10A-C). In addition, the black mica appears to be oxidised, without colour or birefringence, making it sometimes difficult to recognise (fig. 10C). Lithic grains of white mica granite are present and can reach the largest size.

#### Granitic and two micas paste

This paste is very similar to the previous one as regards the composition of the non-plastic inclusions (fig. 10D-F). Nevertheless, it deserves to be distinguished from the previous one by the presence of dominant black mica and, to a lesser extent, white mica (fig. 10D-F). These, of very variable size generally up to medium sand size, characterise and constitute a large part of the matrix.

#### Andesitic paste

Non-plastic inclusions are abundant, approximately 30-40%, of a grain size up to the very coarse sand, rarely to fine gravel, unsorted and generally angular with low sphericity (fig. 10G-H).

Inclusions are apparently exclusively of volcanic origin. Among them highly zoned and generally angular andesine plagioclase dominates (fig. 10G-H). Green and yellowish-brown clinopyroxene (fig. 10H) is common while colourless orthopyroxene is less abundant. Brown amphibole is rare. Rock fragments of andesite are common, consisting in the association of phenocrysts of plagioclases and pyroxenes in a plagioclases-oxydes groundmass (fig. 10G). Finally, fragments of volcanic glass are also present.

#### Andesitic and deformed quartz paste

Unlike the previous one, this paste is composed of volcanic and metamorphic inclusions. In addition to andesite rocks grains and derived minerals, such as plagioclase and clinopyroxene, mainly inclusions of dynamically recrystallised quartz are present (fig. 10I). It is difficult to propose a certain origin, but it could be compared to metamorphic elements found in other pottery pastes.

### *Sourcing raw materials*

Analysed pottery pastes with plutonic, metamorphic and volcanic inclusions refer to geological contexts more than 7km away from the Caucade site. The only mineral component that refers to local outcrops is glauconite clay. This is associated with material that is not available locally, such as meta-granite, or used as is to produce glauconite pottery paste (fig. 10K). Other local pastes, consisting of only local raw materials, are not considered in detail in this study, as not indicative of transfers (fig. 10J and L).

Plutonic and metamorphic rocks, as well as derived minerals, although possibly present in the quaternary alluvial deposits of the Var valley and the Nice terraces, are here always associated with inclusions of different origin, such as calcareous rocks and tertiary pelites. Indeed, the composition of these alluvial formations, which may have provided raw material for ceramic production, closely mirrors the formations present along the Var valley and its tributaries. This set of rocks is never found in the analysed pottery pastes. In particular, pelites and limestones are not found: even assuming the use of highly leached and evolved soils as raw materials, as shown by concentric nodules, at least occasionally pelites grains should be present and recognized.

As is the case for the Arene Candide site, the closest possible source to Caucade site could be the Argentera-Mercantour massif, for pastes with plutonic and metamorphic components (fig. 3G). In addition, also in these pastes the presence of sedimentary elements, leads to exclude source areas close to the Argentera-Mercantour massif where it is no possible to find a natural mixing of the above-mentioned components, and to consider the possibility of an intentional mixing.

Instead, for pastes with granite and micas, the most likely source seems to be the Maures-Tanneron massif that displays the requested diagnostic mineral-petrographic compositions (fig. 3H-I).

On the other hand, for the andesitic volcanic component, it is possible to propose as a source the outcrops present to the east and west of the site along the coast at a relatively short distance (around 15 km). Finally, the association of andesite with plastically deformed quartz grains does not allow for a secure determination of a possible source of raw material. Whatever, it is not possible to identify a natural heterogeneous source for this type of pottery paste and seems fair to consider an intentional mixing by the potter.

## Castellar – Pendimoun

### *Context*

#### Archaeological context

Pendimoun (Castellar, Alpes Maritimes) is a rock shelter distant about 3km from the sea (fig. 1). This stratified site was occupied from the Early Mesolithic (9th millennium BCE) to the Bell Beakers (end of the 3rd millennium BCE (Binder *et al.*, 1993). Excavations have brought to light a detailed and extensive Neolithic sequence date to the 6th millennium BCE, from the Impresso-Cardial Complex (ICC) and the transition to the Square Mouth Pottery Culture (SMP) (Binder and Sénépart, 2010; Binder *et al.*, 2020).

For the earliest Neolithic occupations, associated with the *Impressa* wares, two successive phases have been identified: PND-1A dated from 5720-5660 BCE and characterized by instrumental and digital-ungual decoration technique; PND-1B dated from 5650-5440 BCE and characterized by digital-ungual and instrumental decoration with addition of few pots in the Basi-Filiestru-Pienza style (Binder, Gomart *et al.*, this volume; Cassard, 2020 and this volume; Manen *et al.*, this volume).

Among a total of 125 *Impressa* pots (MNI), we took into account for this study a total of 104 pots from phases PND-1A and 1B, and eleven individuals attributed to the phase PND-1-undivided; the studied pots are equivalent to several hundreds of sherds, stereo-microscopically analysed.

The first phase of occupation yielded a low number of potteries, compared to the second phase: pots represent 17% and 83% of the total analysed, respectively. Optical microscope observations involved fourteen pots (MNI) and twenty-five thin sections (maximum two sections per pot). In addition, remnants of molded clay blocks and experimental briquettes were sampled for thin-section comparative analysis of as-is material (fig. 3A-D).

**Local geology**

Outcrops 7km around the site are characterised by different geological formations, principally by Upper Cretaceous (marly–calcareous rocks), Lower Cretaceous units (marly limestones, calcareous marls and layered marls interbedded with glauconite-rich layers), Tithonian units (massive limestones), Upper Jurassic units (pseudo-oolitic massive limestone) and Triassic units (limestone, dolomite and marl; Gèze and Nestéroff, 1968; here: fig. 11).

In particularly, the geology of the Pendimoun site area is mainly characterised by limestone outcrops of the Upper Jurassic and by marly limestones, marls and schistose marls with glauconitic beds of the Lower Cretaceous. These outcrops form the top and base of the shelter respectively (Gèze and Nestéroff, 1968).

In front of the site, less than 1km as the crow flies, are the extensive undifferentiated Upper Cretaceous marl-limestone formations, in which limestones can be found in small beds, containing silicites or with glauconitic horizons (fig. 3E). In addition, residual karst clay deposits (*terra rossa*) are common in the local area of the site in association with carbonate rocks (fig. 3F).

Other different formations are present more than 1km as the crow flies from the site: to the north-east and west there are limited outcrops of Triassic marl; to the south and east outcrops of Neocene limestone and marl; to the south-west the extensive formations of the Eocene- Oligocene Annot Sandstone system (Lanteaume, 1962). The latter sedimentary formation is characterized by quartz, feldspars, micas and various fragments of rocks, such as granitic rocks (*e.g.* Hercynian leucogranites and two-micas granites, Permian alkaline granites and syenites), metamorphic rocks (*e.g.* gneiss and micaschists), volcanic rocks (*e.g.* rhyolite, andesite, alkaline basalts and ignimbrites) and sedimentary rocks (*e.g.* limestone and marl). Glauconite is also occasionally present (Stanley, 1961).

## *Pottery paste description*

For the *Impressa* horizon, pastes analyses in thin sections show few differences within the pottery assemblage since only five pottery pastes have been identified (fig. 12-13 ; table 1), among which four present non-local markers.

**Mylonitic meta-granite paste**

The non-plastic inclusions generally occur in percentages varying from 30-40%, with grain sizes up to very coarse sand, rarely very fine gravel; the roundness and sphericity are variable, generally angular-subangular with medium-low sphericity (fig. 12A-B).

Grains are composed of frequent quartz, followed by orthoclase, plagioclase, microcline, micas and accessory minerals. The latter, such as zircon and tourmaline, are scarce but always present (fig. 12A-C). Monomineral grains of anhedral quartz show, in rare cases, inclusions of sillimanite (fig. 12E). K-feldspars can be perthitic while plagioclase can be altered (sericitized). Typical microstructures such as graphic/granophiric texture and myrmekite are also present (fig. 12D). White mica is apparently more abundant and bigger than black mica; which is often altered, with low or no birefringence. All these minerals display intra-crystalline deformation textures indicating ductile behaviour for quartz and ductile/brittle conditions of deformation for feldspars (see detailed discussion in Lardeaux *et al.*, this volume).

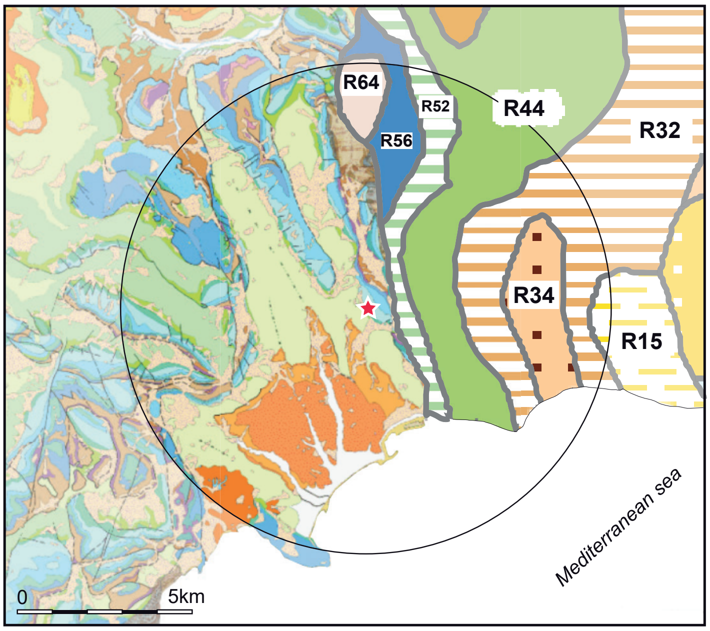
Fragments of meta-granite (quartz ± feldspath ± micas ± zircon) are abundant and are severely deformed and transformed into mylonites under Greenschist facies conditions (see Lardeaux *et al.*, this volume). The presence of granophyre and aplite is recorded. Plant bioclasts, i.e. plant remains and probably short cell phytoliths, are also sporadically present.

Additionally, indeterminate and generally optically inactive (amorphous) aggregates (also associated with micrite) are presents (fig. 12F). Finally, as far as pedofeatures are concerned, iron, clay nodules (also with mineral inclusions) and incomplete dense calcite infillings (neoformations) are also occasional.

**Glauconite paste**

The non-plastic inclusions have a variable content of up to more than 50%, grain size up to the medium sand, rarely coarse and very coarse sand, moderately to poorly sorted, sub-rounded to rounded and medium to high sphericity (fig. 12G-H).

Grains consist of dominant glauconite, in the form of peloids, ooids, with a vermiform aspect or with a nucleus of other minerals such as quartz, at various stages of




★ Pendimoun rockshelter

7 km radius circle

Mz Quaternary: barrier beach (sands, pebbles and sandstone)

Fz Quaternary: recent fluvial alluviums (sands, silts, gravels, pebbles)

Ez Recent scree

m5_P Marine Tortonian: very coarse molasse or molasse poudingues

e7_gA Priabonian: "Annot sandstone"

e7_ca Priabonian: clayey limestones and marls

e5c-6a Upper Lutetian - Auversian: Nummulitic limestone with N. striatus and large Nummulites

c2-3 Turonian-Coniacian: limestones with echinoderm and sponge, grey marls

c2 Turonian: limestones

c1-2_(3) Cenomanian-Turonian: limestones, marly limestones, marls

n1-3_mc Neocomian: undifferentiated marly calcareous

j Undifferentiated Jurassic: limestones and dolomites

j5-7_(2) Malm: limestones

j7 Portlandian: tithonian facies, sublithographic limestones

j6-n1- Kimmeridgian, Tithonic and lower Berriasian: limestones

j5-6 Oxfordian et Kimmeridgian: sublithographic limestones

j1-5b Dogger and middle Oxfordian: limestones and marls

j4-5 Undifferentiated Callovian et Oxfordian: limestones and marly calcareous

j2-4a Bajocian-Bathonian: marly calcareous with Cancellophycus

t7 Rhétian: platy limestones, cargneuls, green marls

t6-7 Keuper: red clays, gypsum, dolomites, cargneuls

According to the Geological Map 1/50 000 (BRGM) Sheet N°1579 - Project: Alpes-Maritimes

R15 Clays and marls, sometimes with olistostrome (Pliocene)

R32 Pelagic marls and calcareous marls (Paleogene)

R34 Arenaceous and arenaceo-marly units (turbidites) (Paleogene)

R44 Organogenic and biodetritic neritic and platform limestones (Upper Cretace)

R52 Pelagic micritic limestones and claye micrites (Cretace - Upper Jurassic)

R56 Limestones and sometimes neritic and platform dolomites (Jurassic)

R64 Evaporites often with marls (Upper Trias)

According to : http http://www.pcn.minambiente.it/viewer/

**Fig. 11** – Local geological map of the Castellar - Pendimoun site.

***Fig. 11*** *– Carte de la géologie locale du site de Castellar - Pendimoun.*

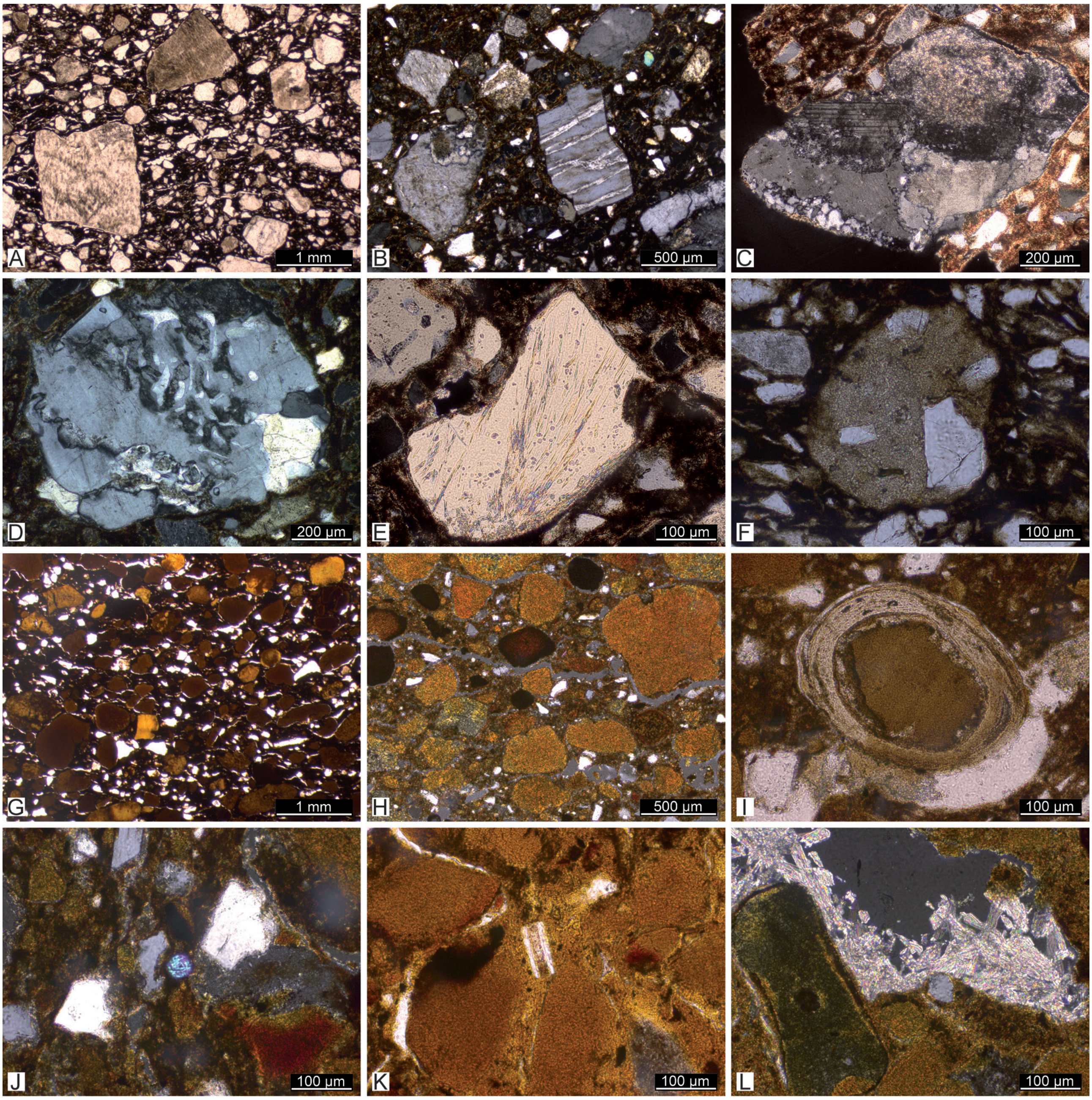



**Fig. 12** – Thin section microphotographs of archaeological pottery pastes from the site of Castellar-Pendimoun. A-F: *Mylonitic meta-granite paste*. A: general view and inclusion textural features: meta-granitic rock, feldspar and quartz (PPL); B: Perthite, quartz and tourmaline (XPL); C: mylonitic meta-granite rocks (XPL); D: intergrowth of quartz in feldspar, probably myrmekite microstructure (XPL); E: quartz with sillimanite inclusions (XPL); F: amorphous aggregate also associated with quartz and micrite (PPL). G-L: *Glauconite paste*. G: general view and inclusion textural features (PPL); H: glauconite birefringence range from orange to orange-brown, more rarely from green to yellow or from dark red-brown to black (XPL); I: phosphate nodule (PPL); J: glauconite, angular quartz and zircon (XPL); K: undetermined microfossil (PPL); L: infilling of neoformed calcite in porosity and glauconite (XPL). PPL: Plane Polarized Light. XPL: Cross Polarized Light.

***Fig. 12** – Microphotographies en lame mince des pâtes de céramiques archéologiques du site de Castellar - Pendimoun. A-F : Pâte à méta-granitique mylonitique. A : vue générale et caractéristiques texturales des inclusions méta-granitique, feldspath et quartz (LPNA) ; B : Perthite, quartz et tourmaline (LPA) ; C : méta-granite mylonitiques (LPA) ; D : intercroissance de quartz dans le feldspath, probable myrmékite (LPA) ; E : quartz à sillimanite (LPA) ; F : agrégat amorphe associé à quartz et micrite (LPNA). G-L : Pâte à glauconite. G : vue générale et caractéristiques texturales des inclusions (LPNA) ; H : biréfringence de la glauconite allant de l'orange au brun-orange, plus rarement du vert au jaune ou du brun-rouge foncé au noir (LPA) ; I : nodule de phosphate (LPNA) ; J : glauconite, quartz anguleux et zircon (LPA) ; K : microfossile indéterminé (LPNA) ; L : calcite néoformée dans la porosité et glauconite (LPA). LPNA : Lumière Polarisée Non Analysée. LPA : Lumière Polarisée Analysée.*

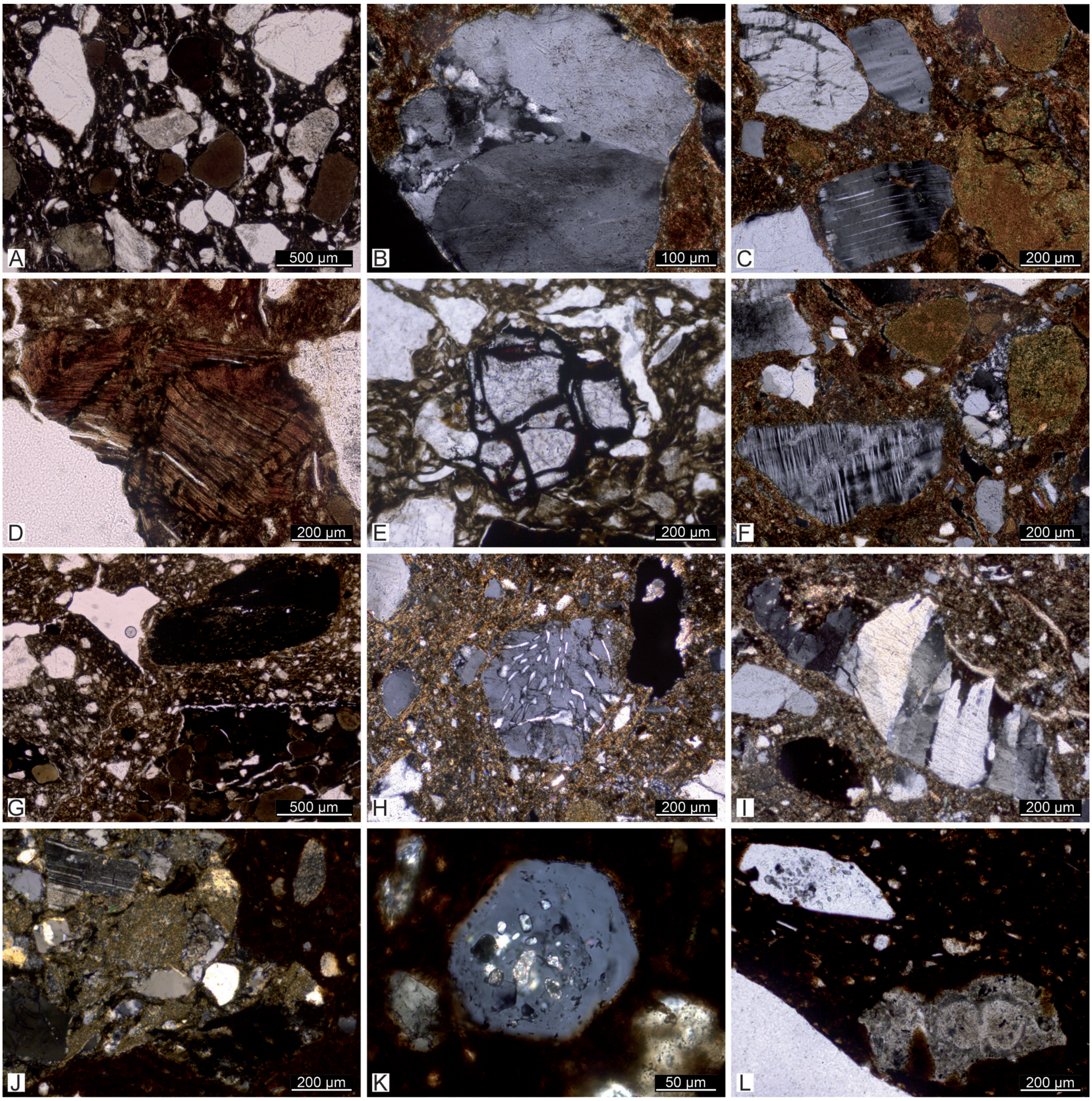



**Fig. 13** – Thin section microphotographs of archaeological pottery pastes from the site of Castellar - Pendimoun. A-F: *Mylonitic meta-granite and glauconite paste*. A: glauconite, quartz and feldspar (PPL); B: polycrystalline quartz recrystallisation and amoeboid boundaries (subgrain bandaries and new grains) (XPL); C: plagioclase twins deformation and undulatory extinction, quartz, feldspar and glauconite (XPL); D: deformed slightly oxidised black mica (PPL); E: garnet and opaque, quartz and feldspar (PPL); F: perthitic microcline with undulatory extinction (XPL). G-I: *Mylonitic meta-granite, glauconite and grog-temper paste*. G: glauconite grog-temper paste, meta-granite grog-temper paste with glauconite second grog-temper generation and pelite (PPL); H: intergrowth of quartz in feldspar, probably graphic texture microstructure (XPL). J-L: *Mylonitic meta-granite, carbonates and Triassic quartz paste*. J: mylonitic meta-granites (fractured feldspars within a fine-grained and highly recrystallized matrix of quartz) (XPL); K: Triassic quartz (XPL); L: Triassic quartz and glauconitic limestone (PPL). PPL: Plane Polarized Light. XPL: Cross Polarized Light.

***Fig. 13** – Microphotographies en lame mince des pâtes de céramiques archéologiques du site de Castellar - Pendimoun. A-F : Pâte à méta-granite mylonitiques et glauconite. A : glauconite, quartz et feldspath (LPNA) ; B : recristallisation polycristalline du quartz et limites amiboïdes (LPA) ; C : plagioclase à macles déformées et extinction ondulante, quartz, feldspath et glauconite (LPA) ; D : mica noir déformé et légèrement oxydé (LPNA) ; E : grenat et opaque, quartz et feldspath (LPNA) ; F : microcline perthitique avec extinction ondulante (LPA). G-I : Pâte à méta-granite mylonitique, glauconite et chamotte. G : pélite, chamotte à pâte à glauconite, chamotte à pâte à méta-granite avec probable chamotte de deuxième génération à glauconite (LPNA) ; H : intercroissance graphique de quartz dans le feldspath (LPA). J-L : Pâte à méta-granite mylonitique, carbonates et quartz du Trias. J : méta-granite mylonitique (feldspaths fracturés dans une matrice de quartz à grain fin et fortement recristallisée) (LPA) ; K : quartz du Trias (LPA) ; L : quartz du Trias et calcaire glauconieux (LPNA). LPNA : Lumière Polarisée Non Analysée. LPA : Lumière Polarisée Analysée.*

evolution (Huggett, 2005). It is preferred to use the term peloids, as it is not possible to determine whether glauconite has a faecal origin, in which case the name to be used would be pellets (Huggett, 2005). Glauconite can also occur in aggregates of several peloids.

Glauconite is variable in colour depending on the state of oxidation and the firing temperatures reached (Basso *et al.*, 2008); generally, colours range from orange to orange-brown, more rarely from green to yellow or from dark red-brown to black (fig. 12G-L).

Lithoclastes related to glauconitic formations are occasional and composed of glauconite peloids in silicate-phosphatic cement with quartz, mica and microfossils. Phosphates are also present in well-rounded forms (fig. 12I).

Quartz is not abundant, mono- and polycrystalline, with a grain size up to fine sand (150µm), generally angular (fig. 12G-J). Other minerals are very few and generally have a grain size less than or equal to very fine sand: anhedral and angular K-feldspar and plagioclase; acicular white mica; lamellar or small packets black mica, which can be partly oxidized and glauconised; zircon (fig. 12J). Some bone fragments, microfossils (fig. 12K), spathic calcite, opaques and plant remains are also present.

Finally, pedofeatures are recognized, such as clays nodules (also with mica, quartz and glauconite) and infilling of neoformed calcite in porosity (fig. 12L).

#### Mylonitic meta-granite and glauconite paste

The non-plastic inclusions have a content of 30-40% and a grain size up to the coarse sand, with rare elements from very coarse sand to fine gravel; these are poorly sorted or unsorted, angular to rounded with low to high sphericity, depending on grain nature (fig. 13A-F).

In this paste, mineral elements found in the two previous pastes are together. In fact, grains mainly consist of glauconite, sialic minerals and mylonitic meta-granite.

Glauconite is common, in the form of peloids and occasionally in aggregates (fig. 13A). Mono- and polycrystalline quartz is frequent, anhedral, with undulatory extinction, intragranular deformation, recrystallisation and amoeboid boundaries (subgrain bandaries and new grains) (fig. 13B). Very rarely it can be rounded and with uniform extinction.

Alkali feldspar/orthoclase is perthitic, may show alterations (sericite). Plagioclase often shows alterations (sericite) and intragranular deformations, especially twins deformation and undulatory extinction (fig. 13C). Microcline can be perthitic, with undulatory extinction (fig. 13F). White mica appears more abundant than black mica, which, however, if altered may be masked by the colour of the matrix (fig. 13D).

Grains of mylonitic meta-granite (quartz ± feldspars ± micas) also present intragranular deformation textures. Occasional granophyre and silicoclastic rocks (sandstone ± glauconite) are found.

In addition, amorphous aggregates, spathic calcite, garnet (fig. 13E), plant bioclasts and a small bone fragment (30µm) are also occasionally present, as well as pedofeatures such as nodules oxides and calcite infilling.

#### Mylonitic meta-granite, glauconite and grog-temper paste

This paste is similar to the previous one both for composition and for texture (fig. 13G-I). However, the presence of grog obtained both from glauconite and from mylonitic meta-granite-glauconite pottery pastes was detected, and second grog generation has also been recognised as a particular technological feature (fig. 13G). Furthermore, in this sample, the occasionally occurrence of pelites was highlighted (fig. 13G).

#### Mylonitic meta-granite, carbonates and Triassic quartz paste

The non-plastic inclusions have a content of about 20% and a grain size up to very fine gravel; these are unsorted, generally angular to sub-rounded with medium-low sphericity (fig. 13J-L).

Mylonitic meta-granites (fractured feldspars within a fine-grained and highly recrystallized matrix of quartz) and glauconitic limestones and sandstones mainly compose lithic inclusions (fig. 13J-L). In addition, grains of Triassic quartz (fig. 13K), glauconite, calcite and probably dolomite, as well as other few minerals, such as feldspars and white mica, were identified.

### *Sourcing raw materials*

The identified pottery pastes were characterized by at least three materials of different origin: (i) an alteration earth, probably alterite of mylonitic meta-granite, as indicated by intracrystalline deformations of non-plastic inclusions under Greenschist facies conditions; (ii) sedimentary deposits of glauconite clays; (iii) clay sediments, carbonates and Triassic formations, probably *terra rossa*.

Considering the local geology, glauconite clays and *terra rossa* can be widely found in the local area (fig. 3E-F). There is no outcrop of meta-granite within a 7km radius around the site. We can therefore also exclude a local sourcing of a natural heterogeneous mylonitic meta-granite and glauconite raw material. Moreover, it is possible to exclude the local Annot sandstone formation, given the absence of rocks such as andesites, ignimbrites, alkaline granites or syenites, alkaline basalts and micaschists from all the thin sections ceramic samples.

Beyond the local area, the geological formation closest to Pendimoun site that could be recognised as a source for mylonitic granitic raw materials is the Argentera-Mercantour massif, more than about 30km away as the crow flies to the north (fig. 2). Furthermore, the sporadic occurrence of granophyres and mafic rocks in pottery pastes may be connected to the presence of aplite and mafic dykes in the Argentera meta-granite (Filippi *et al.*, 2019). Lastly the absence of HP/LT or HT metamorphic imprints in pottery pastes allows us to exclude Savona-Calizzano and Maures-Tanneron massifs respectively.

Considering the closest source to the site, i.e. the Argentera-Mercantour massif, where soil formations suitable for providing clayey materials are evidently contrasted by climatic-environmental conditions, there are nevertheless in situ alterations (arenitization), poorly developed soils and sands (fig. 3G). Indeed, a high tendency for decomposition and argillification (kaolinisation) of mylonitic granites due to the small size of the rock grains and the greater circulation of fluids makes these outcrops suitable for sourcing (Lardeaux *et al.*, this volume).

Moreover, the investigations carried out certainly lead to the exclusion of the local site area as the source of origin of the meta-granitic raw materials, suggesting that they came from the Argentera-Mercantour area (*ibidem*; this paper fig. 3G).

However, considering paste characterized by meta-granitic earth and glauconite, in the Argentera-Mercantour massif, no formations with glauconite clays directly associated with granitic formation are found. The association of glauconite and granitic rocks could find a potential area of origin to the north of the site along the Vesubie and Sospel valleys, where the Cretaceous outcrops, commonly rich in glauconite clays, are closer to the granitic outcrops of the Argentera-Mercantour massif. Nevertheless, the absence in the ceramic pastes of rocks or minerals derived from other formations present in the valley between granite, migmatite and glauconite outcrops, and necessarily included in the alluvial or colluvial deposits hypothetically used as raw materials, excludes these hypotheses.

Similarly, if we look at the formations to the north and north-west of the Argentera-Mercantour massif, where upper Jurassic formations are closer to the migmatites, not only are no banks of glauconite clays detected, but other formations such as cretaceous (limestone), Jurassic (marl) and Triassic (argillites and pelites) are present and imbricated in the geomorphology (Gidon *et al.*, 1977). This geological variability should also be detected in the natural mixing of the secondary formations, potentially used in the pottery manufacture. On the other hand, the greater quantity of migmatite inclusions, compared to those of mylonitic granites, which should characterise the local sediments, is not found in the considered pottery.

In conclusion, glauconite and meta-granite raw materials seem to come from two different and distant areas, not belonging to a circumscribed territory, where a natural mixing of the above-mentioned mineral components could be found. By extension, the identified pottery pastes are not classifiable as belonging to a single and highly variable group, but are quite distinct between them.

On the other hand, the presence of pelites in the pottery paste with grog-temper could indicate a provenance closer to the site, at least for part of the material used, which could be identified with secondary deposits downstream of the meta-granite and glauconite formations (fig. 2).

For the paste characterised by Triassic quartz, the raw materials could be of local origin, coming from red earth formations on Triassic carbonate rocks. The presence of glauconite is not surprising, unlike the occurrence of sporadic fragments of mylonitic meta-granite rocks, as for the other heterogeneous pastes. However, in this case as for the previous one, the unique sample does not allow a detailed and exhaustive evaluation of the raw material origin.

## TERRITORIES AND MOBILITY: PROVENANCE AND TRANSFERS OF RAW MATERIALS AND POTTERY PRODUCTS

### Preliminary remarks

The analysis of *Impressa* pottery in the Liguro-Provençal region from a petro-archaeological point of view, reveals a diversity of choices in paste acquisition and processing (table 2): the use of homogeneous raw materials; the use of heterogeneous raw materials (natural or intentional mixing); and the use of homogeneous or heterogeneous raw materials and grog-temper (intentional mixing).

Those patterns are able to provide various information, especially: on the transfer of both raw materials and finished products; on the local or non-local contexts of production; and on the technical practices, and potentially technical traditions, embedded within paste preparation, *e.g.* the natural or intentional origin of materials mixing.

For the considered site pottery assemblages, seventeen groups of pottery pastes providing exogenous markers have been identified (table 1). Those are, on the one hand, pastes entirely composed of non-local raw materials and, on the other hand, pastes characterised by non-local component(s), *e.g.* grog-temper made itself from exogenous pots. Each site reveals a different variability pattern, with significant differences between paste groups as well as intra-group variability.

In several cases, pastes with similar characteristics, *i.e.* mineral inclusions referring to the variability of a unique geological context of origin, have been recognized among different sites, leading us to classify them in the same family of *terrae*. These can be broadly considered as follows: deformed granites (mylonites and gneiss); undeformed granites; low-pressure ophiolites; andesites; glauconitic clays; mafic rocks.

### Long distance and shared sources: chronological trend

Among the exogenous productions, the place of products acquired over long distances has to be emphasized.

The case of rare pots made from volcanic (potassic affinity) raw materials from Central Tyrrhenian outcrops (Gabriele *et al.*, 2019) is very specific. Their transport over very long distances (*c.* 600km) is of the same order as that of obsidians (Binder, De Stefanis *et al.*, this volume). However, to date, it concerns an *Impressa* facies (*i.e.* Pont-de-Roque-Haute/PRH), which differs from early Arene Candide/Peiro Signado style (Manen et al, this volume) and could even predate it (Binder, Gomart *et al.*, this volume). This "volcanic"

| Sites | Pottery pastes | | |
|---|---|---|---|
| | homogeneous raw materials | heterogeneous raw materials natural mixing | heterogeneous raw materials intentional mixing |
| Finale Ligure-Arene Candide | | | Mylonitic meta-granite and sedimentary inclusions |
| Nice-Caucade | | | Gneiss, meta-granite and sedimentary inclusions (±grog-temper) |
| Castellar-Pendimoun | | | Mylonitic meta-granite and glauconite (±grog-temper) |
| Nice-Caucade | | | Gneiss, meta-granite and glauconite (±grog-temper) |
| Castellar-Pendimoun | | | Mylonitic meta-granite, carbonates and Triassic quartz |
| Nice-Caucade | | | Andesitic and deformed quartz |
| Finale Ligure-Arene Candide | | | Sedimentary rocks with diallage grog-temper |
| Finale Ligure-Arene Candide | | | Acid metamorphic rocks with carbonatic, metamorphic, ophiolitic and volcanic grog-temper |
| Castellar-Pendimoun | | Mylonitic meta-granite | |
| Finale Ligure-Arene Candide | | Serpentinite and amphibole-bearing schist | |
| Finale Ligure-Arene Candide | | Amphiboles-bearing gneiss | |
| Finale Ligure-Arene Candide | | Diallage-bearing gabbro | |
| Nice-Caucade | Granitic | | |
| Nice-Caucade | Granitic and two micas | | |
| Castellar-Pendimoun | Glauconite | | |
| Nice-Caucade | | | |
| Nice-Caucade | Andesitic | | |

**Table 2** – Pottery technological features for the key-sites and pottery pastes.
***Tabl. 2*** – Caractéristiques technologiques des céramiques pour les sites clés et les pâtes à poterie.

| Sites | Pottery pastes groups | Terrae petrographic families | Potential source of raw materials | |
|---|---|---|---|---|
| Finale Ligure-Arene Candide | Mylonitic meta-granite and sedimentary inclusions | Deformed granites | Argentera-Mercantour Massif | Shared sources |
| Nice-Caucade | Gneiss, meta-granite and sedimentary inclusions (±grog-temper) | | | |
| Castellar-Pendimoun | Mylonitic meta-granite | | | |
| Nice-Caucade | Gneiss, meta-granite and glauconite (±grog-temper) | Deformed granites and glauconitic clays | Argentera-Mercantour Massif | |
| Castellar-Pendimoun | Mylonitic meta-granite and glauconite (±grog-temper) | | East-South Provence | |
| Nice-Caucade | Glauconite | Glauconitic clays | East-South Provence | |
| Castellar-Pendimoun | | | | |
| Finale Ligure-Arene Candide | Diallage-bearing gabbro | LP ophiolites | Northern Apennines/Northern Tyrrhenian area | |
| Nice-Caucade | Granitic | Undeformed granites | Maures-Tanneron Massif | Not shared sources |
| | Granitic and two micas | | | |
| Nice-Caucade | Andesitic | Andesites | Provencal andesitic outcrops | |
| | Andesitic and deformed quartz | | | |
| Finale Ligure-Arene Candide | Serpentinite and amphibole-bearing schist | Mafic rocks | Voltri Group | |
| | Amphiboles-bearing gneiss | | Savona-Calizzano Massif | |

**Table 3** – Pottery pastes and related potential raw material sources for the key-sites.
***Tabl. 3*** – Pâtes céramiques et leurs sources potentielles de matières premières pour les sites-clés.

production could be a signature of a very pioneering mobility, and therefore beyond the scope of this paper, which is mainly focussed on inter-regional interactions and the construction of the socio-environmental landscape.

Within the regional area, tree important domains are identified. The Hercynian and Alpine domains in the centre of the Ligurian-Provençal region, which provide metamorphic raw materials (Manen *et al.*, 2006; Convertini, 2010) and the Ophiolitic domain of the Ligurian Appennines (Capelli and Mannoni 1998; Capelli *et al.* 2017). Those were also exploited during the *Impressa* phases but are known to recur in this region during later periods (at least late 6th and 5th millennium BCE, *e.g.* Gabriele, 2014).

During the early *Impressa* phase, the Caucade and Arene Candide (ACN-1A) sites show a great diversity of non-local pottery pastes and raw materials, linked at least to seven geological districts (from west to east): the Maures-Tanneron massif, the coastal andesite outcrops, Cretaceous outcrops of Eastern Provence, the Argentera-Mercantour Massif, the Savona-Calizzano Massif, the Voltri group and the low-pressure ophiolitic formations (fig. 2; table 3).

The Argentera-Mercantour massif is the only outcropping area that is linked to both sites. Overall, the geological districts, linked to the Caucade and Arene Candide sites, draw a network of circulations and contacts over medium and long distances in different directions. For instance, the sites of Caucade and Arene Candide and the Argentera-Mercantour massif are respectively distant of *c.* 50km to the north and *c.* 90km to the north-west.

During the late *Impressa* phases, the assemblages of Pendimoun (PND-1A, PND-1B) and Arene Candide (ACN-1B, ACN-2A) show less diversity. However, one can observe a repeated exploitation of two geological districts, *i.e.* the Argentera-Mercantour and the Savona-Calizzano massifs, already exploited during the previous phase (*supra* fig. 2; table 3).

The punctual data from Pertusello and Pollera sites, where some non-local glauconitic potteries indicates the exploitation of the Cretaceous outcrops of Eastern Provence (fig. 2), can also be attributed to this cultural phase (fig. 14). These glauconitic *terrae*, which feature prominently at Pendimoun (this study), are also observed at Caucade (Manen *et al.*, 2006 and this study) as well as in Sospel – Éole cave, north to Pendimoun (Binder and Maggi, 2001). These clues suggest transfers from the west to the east, towards Liguria. The high quality of glauconitic pastes for pottery making has to be emphasized, justifying their increasing use during the *Impressa* (*supra*), the Cardial phase (Échallier, 1991; Échallier and Courtin, 1994; Gabriele, 2014) and later (Basso *et al.*, 2006). This quality could also explain their subsequent transfers as by-products or pots.

Furthermore, the low-pressure ophiolitic formations of the Eastern Liguria could continue to be exploited, even in this phase: as shown by the presence of diallage grog-temper in some pottery from the Arene Candide cave (Capelli *et al.*, 2017; Gabriele *et al.*, 2020; this study).

A single, badly contextualised, sherd from Grasse – Sans-Peur (Alpes-Maritimes) is made from the same paste (this study); it belongs to a pot decorated in the Tyrrhenian Basi-Pienza-Filiestru style (Binder, Gomart *et al.*, this volume), a style showing connexions with the late aspects of the *Impressa* at Pendimoun (PND-1B, Cassard, 2020), Arene Candide (ACN-1B/2A, Panelli, 2019) and San Sebastiano di Perti (Starnini and Vicino, 1993; Panelli, 2019). Over time, this type of paste will play a key-role in Central Italy, *i.e. Ceramica lineare tosco-laziale*, often in association with volcanic pottery pastes (Martini *et al.*, 1996; Gabriele and Boschian, 2009; Gabriele, 2014; Gabriele and Tozzi 2007).

Considering the different chronocultural phases, the number of geological districts exploited during the first *Impressa* stage seems to decrease in the following stage.

The proportion of exogenous raw materials (including non-local grog-temper and supposed imported pastes) are (table 4): *c.* 26% at Arene Candide 1A and 79% at Caucade; *c.* 4% at Arene Candide 1B, 26% at Pendimoun 1A and 38% at Pendimoun 1B.

If all the supposed locally processed raw materials are excluded, the proportions of exogenous supposed to be imported as pots are (table 4): *c.* 13% at Arene Candide 1A and 9% at Caucade; *c.* 14% at Arene Candide 1B, 42% at Pendimoun 1A and 14% at Pendimoun 1B.

## Transfers of raw materials vs transfers of pots: local *vs* exogenous production

The demonstration of intentional mixing of local and non-local raw materials (excluding grog-temper) is one of the rare evidence of a local pottery production using

| | Early Impressa Phase | | | | Late Impressa Phase | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Arene Candide 1A | | Caucade | | Arene Candide 1B | | Pendimoun 1A | | Pendimoun 1B | | Pendimoun 1 undivided | |
| | MNI | % | MNI | % | MNI | % | MNI | % | MNI | % | MNI | % |
| MNI minimum number of individuals | 46 | 100% | 33 | 100% | 79 | 100% | 19 | 100% | 91 | 100% | 15 | 100% |
| Imported raw materials | 12 | 26% | 26 | 79% | 3 | 4% | 5 | 26% | 35 | 38% | 9 | 60% |
| Imported pots | 6 | 13% | 3 | 9% | 11 | 14% | 8 | 42% | 13 | 14% | 1 | 7% |
| Local raw materials | 28 | 61% | 4 | 12% | 65 | 82% | 6 | 32% | 43 | 47% | 5 | 33% |

**Table 4 –** Quantities of imported and local materials for key-sites and two Impressa phases.
***Tabl. 4 –*** *Quantités de matériaux importés et locaux pour les sites-clés et les deux phases Impressa.*

exogenous raw materials, and of the transfer of raw materials rather than finished products. The example of Pendimoun is quite eloquent since intimate mixing of materials from different origins could be demonstrated.

At this site, *in situ* production using glauconitic *terrae* is demonstrated by the presence of crude paste blocks whose composition is identical to glauconitic pottery pastes, and which can be further interpreted as reserves for pottery manufacturing.

In this respect, the characterization of the pastes resulting from a mixture of local glauconitic *terrae* and exogenous mylonitic *terrae* coming from the Argentera-Mercantour slopes, which cannot be found in the regional geosystem, provides a unique demonstration of intentional mixing of clayey materials since natural mixing in the nearby area seems to be excluded.

Thanks to the precision of the excavations carried out at Pendimoun, this site yielded, in addition to large paste blocks, tenths of small aggregates and residues of glauconitic pastes (*c.* 0.5-1mm) spread within the slicks of remains from the *Impressa* (PND-1A) to the Postcardial/Vhò deposits (PND-3A); but this is not the case for other types of *terrae* residues. There is no demonstration of the transport of crude mylonitic paste on the site. Since "the absence of evidence is not an evidence of absence", this issue remains wide open. Besides, the possibility for producing this kind of pots at intermediate distance of "mylonitic" and "glauconitic" outcrops remains fully open too.

Further on, if one admitted that "mylonitic" pastes or raw materials had been transported at Pendimoun, there would be no reason to exclude that the "mylonitic" pots were also produced locally.

One of the common arguments put forward to assume the transfer of pots is the sporadic presence of exogenous vessels within the ceramic assemblage. Another argument to consider for supporting such a hypothesis is the occurrence in the same "culturally defined landscape" (Arnold, 2017) of local productions that are comparable in typology and composition to the imported ones (Gabriele, 2014 and 2015). This could be the case for instance at the Pertusello and Pollera caves, where non-local pots made from glauconitic pastes show similarities with the local productions of Pendimoun, in the phase 1B (fig. 14). However, this assumption remains to be confirmed thanks to petrographic characterisations at a higher resolution.

The transfer of pottery as finished products is indirectly testified by the re-use of non-local vessels for the production of grog-temper in local productions. At the Arene Candide cave, LP ophiolitic and volcanic grog-temper have been added to local raw materials for the production of several pots (table 1-2; fig. 6). The use of grog-temper derived from pots produced with raw materials from long to very long eastern distances, such as low-pressure ophiolite and potassic volcanic *terrae*, suggests the circulation of finished products rather than raw materials.

## CONCLUSIONS AND PROSPECTS

The technological and provenience study of pottery assemblages from *Impressa* key sites in the Liguro-Provençal region reveals new aspects of pottery production in the context of the dispersal of early farming and raises new questions on the significance of transfers and their related social networks.

As a first main result, one has to note the significant diversity of pottery production during the earliest Neolithic stage in this region, *c.* 5850-5700 BCE, in terms of raw materials used. Moreover, a large part of the pottery final products provides evidence of multidirectional contacts very far from the early farmers' home range, *i.e.* beyond the area devoted to their daily and subsistence activities (Higgs and Vita-Finzi, 1972). In several cases, the distances involved, up to 90km, are higher than those that used to be suggested for seasonal herding activities. The acquisition of exogenous raw-materials or pots has thus to be understood as "indirect" in the perspective of the consumers, *i.e.* as the contribution of part-time specialists, itinerant pedlars, involved in such "trade" (Perlès, 2007). These indirect connexions form branches of the social network, which in some way determines the Cultural Landscape (Arnold, 2017).

During the successive stages, *c.* 5750-5450 BCE, a tightening of the networking, then focussed on a lesser number of geological districts, and the apparent increase

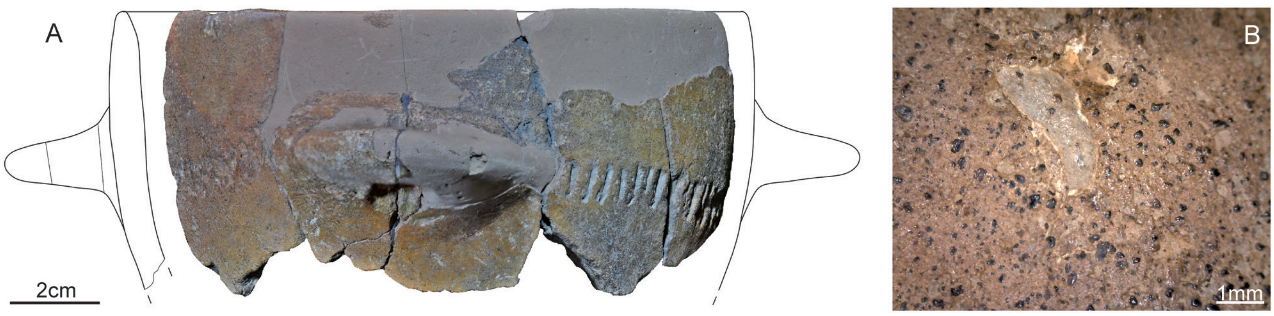



**Fig. 14** – A: Pottery made from non-local glauconitic paste from the Pertusello site (modified from Panelli, 2019); B: photograph of the pottery paste of the same individual as A (taken with Dino-Lite digital microscope).

***Fig. 14*** *– A : individu céramique produit avec une pâte glauconieuse non locale du site de Pertusello (modifié depuis Panelli, 2019); B : photographie de la pâte céramique du même individu que A (prise avec Dino-Lite digital microscope).*

of west-to-east transfers, illustrate a consolidation of intra-regional connexions. The reduced proportion of exogenous materials within the pottery assemblages goes the same way. The latter is in line with a stronger appropriation of the local territory and resources.

Secondly, this study has provided novel information on the use of mountain environments in the early Neolithic period, which was largely underestimated until now. In this instance, the Argentera - Mercantour massif (over 2,000m asl), which is the only outcropping area linked to the three key-sites at different time-periods, is very distant from them and difficult to access, especially during the cold season. This raises the question of the control of a very extended landscape and a deep knowledge of the resource availability, as early as the pioneer Neolithic stage, and/or the possibilities of connexion between earliest farmers and late hunter-gatherers. Indeed, the latter are known for their constant tropism towards high-altitude landscapes (Biagi *et al.*, 1985). This assumption is in line with recent palaeogenomic results demonstrating intense biological links and admixture between early farmers and hunter-gatherers before the Cardial stage, particularly at Pendimoun (Rivollat *et al.*, 2020).

These trends observed overtime for the networking pattern revealed by pottery are very similar to those observed for the chipped-stone industries (Binder, De Stefanis *et al.*, this volume).

A challenging issue arising from the present study concerns the aims of the transfers and the justification of the use of different pastes. The question of choices in pastes preparation determined by their intrinsic properties and, beyond, their suitability for a specific use, is a "*marronnier*" of pottery technological studies (*inter alia* Vitelli, 1993; Binder, 1991a; Binder *et al.*, 1994; Le Mière and Picon, 1994 and 2003). Recent work performed in the frame of the CIMO project indicates that, in the study area, and in the current state of research, first, forming methods are identical, regardless of the raw materials used (Gomart *et al.*, 2017; Gomart, Binder, Gabriele *et al.*, this volume), second, decoration techniques are diverse, but not correlated with raw materials (Panelli, 2019; Cassard, 2020) and third, uses of the pots are diverse, but not correlated with decoration and to raw-materials (Drieu *et al.*, 2021). By the way, the hypothesis that a significant part of the vases was transported because of their specific content, and not for themselves, is not supported by data either.

In other words, there are apparently neither technical, functional nor obvious symbolic reasons that determine the collection of different types of *terrae*. In some way, one can understand the differentiation of groups and families of paste among the pottery assemblages as a feedback of the networks' implementation and complexity, and not a predetermined target of the networking.

Looking at such complex networks, especially in a region offering a high diversity of landscapes, connected by the sea as well as by high altitude passes, the identification of pathways is a very stimulating perspective and a key-target for future research. At present, various obstacles need to be overcome in order to achieve a more accurate and robust view of these phenomena.

For reaching such objective, a great deal of work remains to be done in terms of geomatics and modelling. The main prerequisite is related to the possibility of dealing with ceramic assemblages in a comprehensive way, in terms of sourcing. This perspective, which in a way goes again any sampling strategy, however well-reasoned, is justified because several of our results suggest a possible intra-pottery paste variability. Indeed, the latter is linked to the variability of anthropogenic pastes mixture (this paper) and the variability induced by the implementation of the Spiralled Patchwork Technology (Gomart, Binder, Blanc-Féraud *et al.*, this volume).

In addition to a fundamental parsimonious naturalist approach, non-invasive tomography, *i.e.* µCT, on the one hand (*ibidem*) and non-invasive geochemistry, *i.e*. pXRF on the other hand (Mouralis *et al.*, this volume), seem to be promising for collecting enough proxies and run robust modelling.

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