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How to cite

IGRISHTA, Kaltrina, CARLONI, Délia, BESSE, Marie. Petrographic study of Middle and Final Bronze Age (1625–800 BC) pottery from Eremita Cave (Borgosesia, Vercelli, Italy): inferences on pottery production and exploitation of natural resources. In: Water Supply and Water Management in the Metal Ages. Dirk Brandherm and Thomas Zimmermann (Ed.). Ankara, Turkey. United Kingdom : Archaeopress, 2024. p. 123–127. (Proceedings from the UISPP Metal Ages colloquium)

This publication URL: https://archive-ouverte.unige.ch/unige:182196

Water Supply and Water Management in the Metal Ages

Edited by

Dirk Brandherm and Thomas Zimmermann

UNION INTERNATIONALE DES SCIENCES
PRÉHISTORIQUES ET PROTOHISTORIQUES

Water Supply and Water Management in the Metal Ages

Proceedings from the UISPP Metal Ages colloquium, 13–16 October 2022, Ankara (Türkiye)

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ARCHAEOPRESS ARCHAEOLOGY

ARCHAEOPRESS PUBLISHING LTD
13-14 Market Square
Bicester
Oxfordshire OX26 6AD
United Kingdom

www.archaeopress.com

ISBN 978-1-80327-905-3
ISBN 978-1-80327-906-0 (e-Pdf)

Cover: Aerial view of the motilla of Azuer (Daimiel, Ciudad Real) in 2013 – Luis Benítez de Lugo Enrich and Miguel Mejías Moreno

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Petrographic study of Middle and Final Bronze Age (1625–800 BC) pottery from Eremita Cave (Borgosesia, Vercelli, Italy): inferences on pottery production and exploitation of natural resources

Kaltrina Igrishta, Delia Carloni and Marie Besse

Located on the western slope of Mount Fenera, the Eremita Cave overlooks the Alpine Sesia Valley in Piedmont region (Italy). Ten years of excavation (2012–2021) revealed that the cave was frequented for burial purposes during the Middle and Final Bronze Age (1600–800 BC) and yielded a ceramic assemblage composed of 2982 sherds. The petrographic study regarded 28 samples, selected by taking into account pottery typology, relative chronology, surface and core colours as well as macroscopic features of pastes. The analysis aimed at investigating paste composition and exploitation of natural resources. Pottery from Eremita Cave displays the characteristics of five fabrics, mainly discriminated by aplastic inclusions (quartz, granite-granodiorite, pyroxenite, volcanic rocks). These findings allowed to draw inferences on the Middle and Final Bronze Age pottery production in the Lower Sesia Valley and on the exploitation of local natural resources by human groups.

Keywords: Eremita Cave, Bronze Age, pottery raw materials, archaeometry

Située sur le versant ouest du Mont Fenera, la Grotte de l’Eremita surplombe la vallée alpine de Sesia dans la région du Piémont (Italie). Dix années de fouilles (2012–2021) ont révélé que la grotte était fréquentée à des fins funéraires au cours de l’âge du Bronze moyen et final (1600–800 av. J.-C.) et ont livré un assemblage de céramiques composé de 2982 tessons. L’étude pétrographique a porté sur 28 échantillons, sélectionnés en tenant compte de la typologie des poteries, de la chronologie relative, des couleurs de surface et de l’intérieur ainsi que des caractéristiques macroscopiques des pâtes. L’analyse visait à étudier la composition de la pâte et l’exploitation des ressources naturelles. Les poteries de la Grotte de l’Eremita présentent les caractéristiques de cinq pâtes, caractérisées principalement par des inclusions aplastiques (quartz, granite-granodiorite, pyroxénite, roches volcaniques). Ces résultats ont permis de tirer des conclusions sur la production de poteries de l’âge du Bronze moyen et final dans la basse vallée de Sesia et sur l’exploitation des ressources naturelles locales par les groupes humains.

Mots-clés : Grotte de l’Eremita, âge du Bronze, matières premières de poterie, archéométrie

Fenera Dağı’nın batı yamacında yer alan Eremita Mağarası, Piedmont bölgesindeki (İtalya) Alp Sesia Vadisi’ne bakmaktadır. On yıl süren kazı çalışmaları (2012-2021), mağaranın Orta ve Son Tunç Çağı’nda (MÖ 1600-800) ölü gömme amacıyla kullanıldığını ve 2982 parçadan oluşan bir seramik topluluğu ortaya çıkardığını göstermiştir. Petrografik çalışmada, seramik tipolojisi, göreceli kronoloji, yüzey ve çekirdek renklerinin yanı sıra hamurların makroskopik özellikleri de dikkate alınarak seçilen 28 örnek değerlendirilmiştir. Analiz, hamur bileşimini ve doğal kaynakların kullanımını araştırmayı amaçlamıştır. Eremita Mağarası’ndan elde edilen çanak çömlekler, esas olarak aplastik içeriklerle (kuvars, granit-granodiyorit, piroksenit, volkanik kayaçlar) ayırt edilen beş dokunun özelliklerini sergilemektedir. Bu bulgular, Aşağı Sesia Vadisi’ndeki Orta ve Son Tunç Çağı çanak çömlek üretimine ve yerel doğal kaynakların insan grupları tarafından kullanımına dair çıkarımlar yapılmasına olanak sağlamıştır.

Anahtar Kelimeler: Eremita Mağarası, Tunç Çağı, çanak çömlek hammaddeleri, arkeometri

Introduction

This paper presents the results of the petrographic study conducted on the pottery found at Eremita Cave, located in Northern Italy, Piedmont region, in the territory of the municipality of Borgosesia. Eremita Cave constitutes an important archaeological context for the analysis of social and ideological development in the Middle and Final Bronze Age in the southern Alpine region of Central Europe.

This work focuses on how people/potters produced ceramic containers in general and how they procured and used raw materials in particular, contributing to the research on the wider social, cultural and environmental contexts of Bronze Age societies. Raw materials selection and use provide valuable information on various aspects of ancient lifeways and cultural identities (Albero 2014; Arnold 1985; 2018; Orton *et al.* 1993; Rice 1987; Roux 2019; Shennan 2013). As Shepard (1965) notes, the importance of the potter’s knowledge of materials is obvious. The choice of materials sets the boundaries within which the potter must work, and the status of the craft must be judged within these boundaries. In addition, the potter’s choice of materials and the way he/she uses them, as well as

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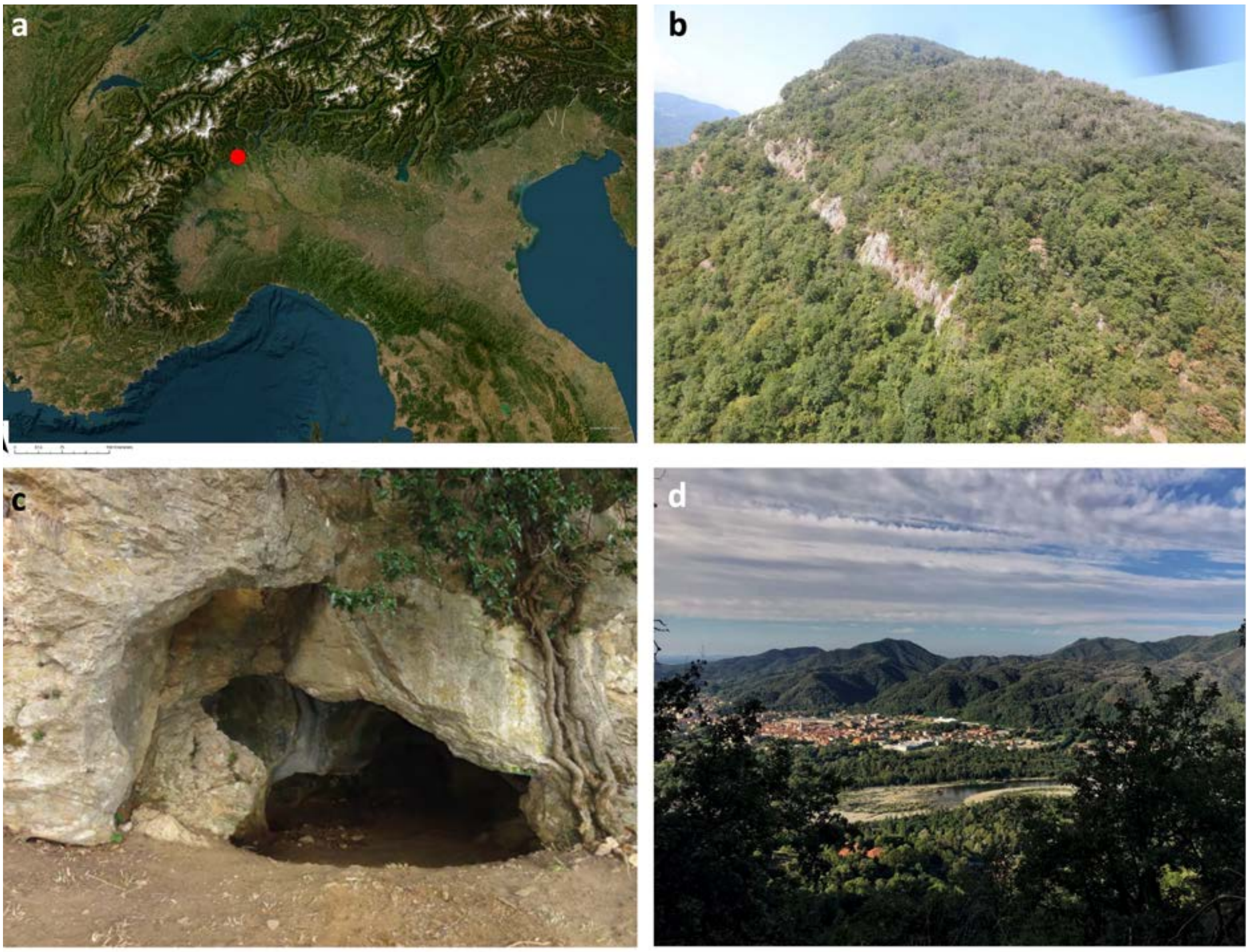


Fig. 1 – The Eremita Cave archaeological context: Location in the north of Italy with respect to Alps (a). – The western flank of Mount Fenera where the cave opens (b). – The cavity entrance before the excavation (c). – View from the Eremita Cave to the Lower Sesia Valley (d). – (a: satellite photo adapted from and courtesy of Google Earth; b-c: after Derenne 2016: figs. 1, 2; fig. d: photo by Bastien Gallay).

the form and style of decoration, are trademarks – our often powerful means of locating centres of production (e.g., Arnold 2018). The study of each of these areas provides valuable information on different but related aspects of human behaviour (Stoltman and Mainfort 2002).

The analysis of the pottery found at the Eremita Cave is carried out using petrography, a technique that consists in the systematic examination of ceramic pastes and allows to classify vessels' remains based on their compositions and the effects of the manufacturing processes (Degryse and Braekmans 2016; Quinn 2013; 2022; Whitbread 2001). The characteristics of the clay matrix (e.g., homogeneity/heterogeneity, colours, optical behaviour, b-fabrics), of the voids (shape, size and orientation), and of the inclusions (e.g., type, roundness/angularity, sphericity degree, and particle-size distribution) indicate how the raw material has been collected and the *chaîne opératoire* followed to make the pot (Arnold 1985; Balfet 1981; Creswell 1976; 1983; 1996; Dietler and Herbich 1994; Gallay 1992; Gosselain 1992; Latour and Lemonnier 1994; Lemonnier 1983; 1992; 1993; Leroi-Gourhan 1964; Longacre 1991; Quinn 2013; 2022; Roux 2017; 2019; Sigaut 1994).

Archaeological background

Eremita Cave

The Eremita Cave (Fig. 1a) known as "*Grotta dell'Eremita*", or as it is found in local traditions "*Tana dell'Armittu*" (Besse and Viola 2013a) opens on the western flank of Mount Fenera (Fig. 1b) and extends for 30m^2 (Fig. 1c). Its entrance overlooks the Alpine Sesia Valley in Piedmont region (Italy). Located at an altitude of 598m a.s.l., it can be reached by following the so-called 'Strada dei Buoi' path and the one leading to the ancient church of San Quirico (Fig. 1d) (Derenne 2016). Like most of the other caves in the massif, it is formed in the 'San Salvatore' dolomitic sheet (Bini and Zuccoli 2005) and represents a single open compartment inside the dolomitic layers.

Mount Fenera

Mount Fenera (899m) is an isolated massif located on the southern margin of the Sesia River, on its left bank. It straddles the Piedmont provinces of Novara and Vercelli, which, from a geographical point of view, are made up of three main areas: the Alpine reliefs, the Italian Pre-Alps and finally the alluvial plains (Besse and Viola 2013a). The winding course of the Sesia River crosses these three geographical areas. The river originates from the Monte Rosa Glacier, it runs along the low hills of Gattinara and Romagnano Sesia and finally reaches the plain, where it flows into the Po River at Casale Monferrato (Besse and Viola 2013a).

The Mount Fenera massif accounts for about seventy caves, many of which contain traces of human occupation, dating from the Middle Palaeolithic to the Late Middle Ages (Gambari 2005). The massif could thus have been a place of passage for the prehistoric populations during their transalpine travels. This consideration is not surprising, considering its location, at the entrance of several valleys leading to numerous hills giving access to the Upper Rhône Valley, and its specific geological characteristics (Besse and Viola 2013b).

Neolithic materials were discovered on the terrace of Fenera San Giulio (414m a.s.l.) and in the cave of Riparo del Belvedere (662m a.s.l.). Chalcolithic materials were found in the caves of Uomo libero (620m a.s.l.), Ciotarun (635m a.s.l.) and Ciota Ciara (675m a.s.l.) – the latter better known for its Middle Palaeolithic remains – as well as on the Montrigone hill. The terrace of Castello di Robbiallo (354m a.s.l.) shows evidence of Chalcolithic and Early Bronze Age occupation, while the Tana della Volpe Cave (661m a.s.l.) contains only Early Bronze Age materials. Finally, in the Laghetto Cave (701m a.s.l.), Early and Middle Bronze Age remains were uncovered (Besse and Viola 2013a).

History of research

The presence of an archaeological deposit in the cave was first detected in the 1980s by the *Gruppo archeo-speleologico di Borgosesia (GASB)* (Besse and Viola 2013b), which opened test trenches. Later, in 2012, a test trench was excavated by the *Laboratoire d'archéologie préhistorique et anthropologique* of the University of Geneva headed by one of us (M. B.), who uncovered, besides ceramic and bone remains, a metal pin and spiral beads (Fig. 2), leading to further excavations from 2013 in the northern part of the cave. The digging operations undertaken in the cave combined two essential approaches: stratigraphic and planimetric. During the numerous excavation campaigns carried out between 2013 and 2021, structures and a number of 2982 pottery sherds, fauna, human cremation remains, bronze objects and flint were discovered. All the findings were assigned to a specific stratigraphic unit (US). The Eremita Cave was excavated up to the depth of 120cm in 2013 and to the depth of 198.4cm in 2021. Acquired data highlight that the cave was frequented for burial purposes during the Middle (1625–1325 BC) and Final Bronze Age (1250–800 BC) (Besse and Viola 2013a; Besse *et al.* 2014; Derenne *et al.* 2020; Rubat-Borel *et al.* 2022). The chronology of human use was determined according to obtained radiocarbon dates (16 samples analysed by the Swiss Federal Institute of Technology of Zürich, Fig. 3) and pottery typology (Derenne *et al.* 2020).

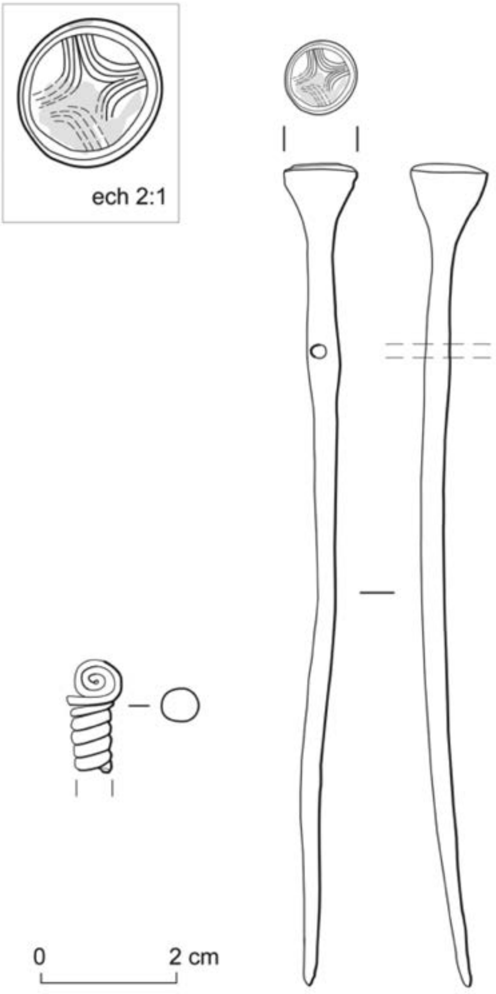


Fig. 2 – Bronze spiral pin and ornament from Eremita Cave. – (after Besse *et al.* 2014: fig. 6).

Geological setting

The complexity of Piedmont region's geology mainly results from the Paleogene to Neogene Alpine orogenesis, originated by the collision of the European and Palaeo-Adriatic continental margins (Handy *et al.* 2010; Piana *et al.* 2020; Schmid *et al.* 1996, 2004). The study area of the present work is occupied by the Palaeo-Adriatic

Sample code	Sample number	Dating BP	2 sigma (prob. 95.4%)	Material
BE15-F5-prCH4	ETH-64659	2794 ± 27 BP	1013–850 cal BC	charcoal
BE14-E4-prCH14	ETH-64658	3323 ± 28 BP	1684–1527 cal BC	charcoal
BE13-E2-prCH6	ETH-64656	3334 ± 28 BP	1689–1530 cal BC	charcoal
BE14-E4-prCH10	ETH-64657	3404 ± 28 BP	1767–1627 cal BC	charcoal
BE15-F5-prCH2	ETH-104336	2688 ± 22 BP	895–806 cal BC	charcoal
BE16-F3-prCH5	ETH-104337	3159 ± 22 BP	1497–1403 cal BC	charcoal
BE18-F3-prCH105	ETH-104338	3294 ± 25 BP	1626–1507 cal BC	charcoal
BE18-F3-prCH106	ETH-104339	3318 ± 24 BP	1664–1527 cal BC	charcoal
BE18-G5-prCH111	ETH-104340	3475 ± 22 BP	1882–1701 cal BC	charcoal
BE18-F4-prCH118	ETH-104341	3207 ± 24 BP	1520–1427 cal BC	charcoal
BE18-F5-prCH131	ETH-104342	3318 ± 22 BP	1660–1528 cal BC	charcoal
BE18-F5-prCH136	ETH-104343	3363 ± 25 BP	1741–1566 cal BC	charcoal
BE18-G3-prCH137	ETH-104344	3275 ± 25 BP	1616–1501 cal BC	charcoal

Fig. 3 – Radiocarbon dates obtained for the various layers of Eremita Cave. – (Calibration with OxCal 4.4.4 [Bronk Ramsey 2021], based on the IntCal20 calibration curve [Reimer *et al.* 2020]).

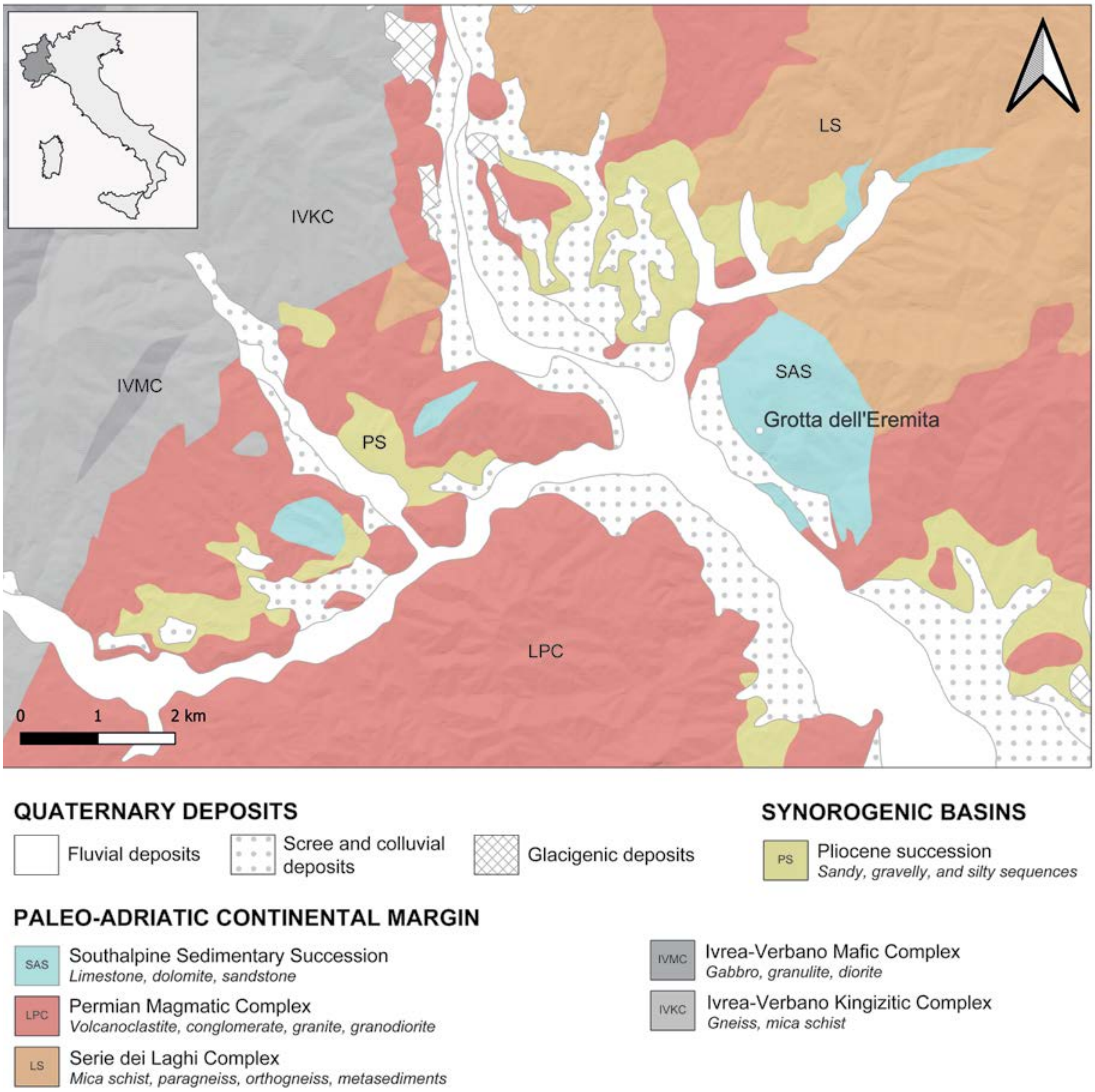


Fig. 4 – Geotectonic map of the Lower Sesia Valley with location of the Eremita Cave. – (Data source: GeoPiemonte https://www.geoportale.piemonte.it/cms/; design: Delia Carloni).

margin, and specifically, by the Southalpine Domain geologic unit. This unit consists of Variscan and pre-Variscan metamorphic rocks of granulite-amphibolite facies, derived from sedimentary, felsic and mafic igneous protoliths (Ivrea-Verbano Complexes, Serie dei Laghi Complex), intruded by granitoids and gabbros of Permian age (Permian Magmatic Complex, sub-unit 'Graniti dei Laghi Complex') and covered by both volcanic and volcaniclastic deposits (Permian Magmatic Complex, sub-unit 'Porfidi Quartziferi Complex') and Triassic-Jurassic sediments (Southalpine sedimentary succession) (Piana *et al.* 2017; 2020). Figure 4 shows the outcropping areas of these various rock bodies in the Lower Sesia Valley. Mount Fenera, where the Eremita Cave opens, is part of the Southalpine sedimentary succession and has the double peculiarity of being the only massif composed of dolomites and limestones in this part of the valley and of being located near two tectonic lines, the Cremosina line and the Colma line (Fantoni *et al.* 2005a; 2005b). This explains the development of important karstic phenomena within it (Derenne 2016). Most of the caves in the Mount Fenera massif were formed in the Miocene (Bini and Zuccoli 2005), before undergoing modifications and enlargements during the climatic changes of the Pliocene-Pleistocene transition (Berruto 2011). The geological sequence of the Mount Fenera is placed on the Serie dei Laghi Complex and the Permian Magmatic Complex and consists of multiple successions of sandstone, carbonate rocks, and breccias (Fantoni *et al.* 2005b). Finally, the Quaternary cover of the study area is composed of glacigenic, scree and colluvial deposits, which are eroded and reworked by the Sesia River, thus contributing to the fluvial deposits formed on the banks of its winding course. Glacigenic deposits include a great variety of lithoclasts derived from various complexes of the Palaeo-Adriatic margin (Piana *et al.* 2017; 2020).

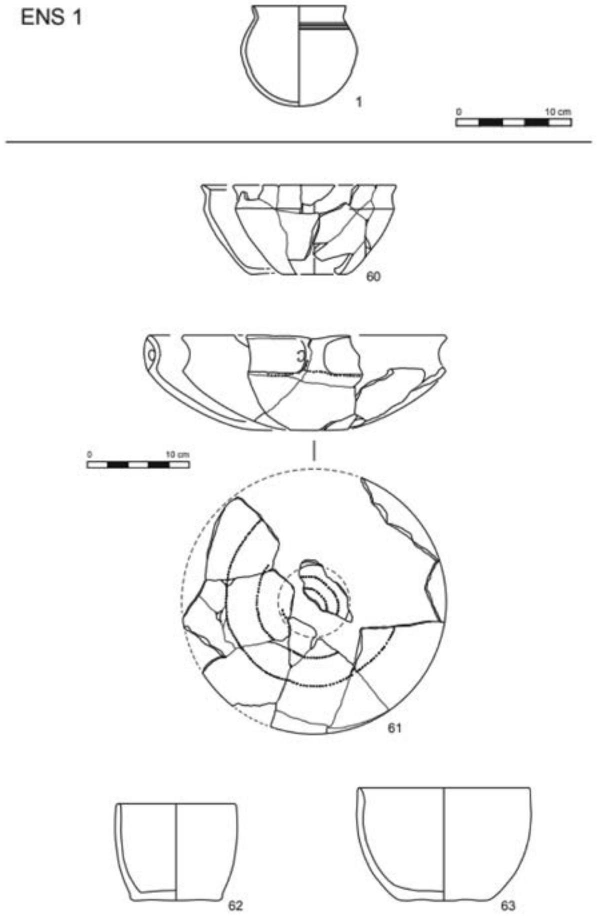


Fig. 5 – Important shapes from Eremita Cave: small globular vessel with flared rim dating to the Final Bronze Age (no. 1), segmented profile bowls (nos 60, 61) and simple profile vessels (nos 62, 63) dating to the Middle Bronze Age – (after Derenne 2016: appendix 1: 1; appendix 7: 60–63).

Materials and methods

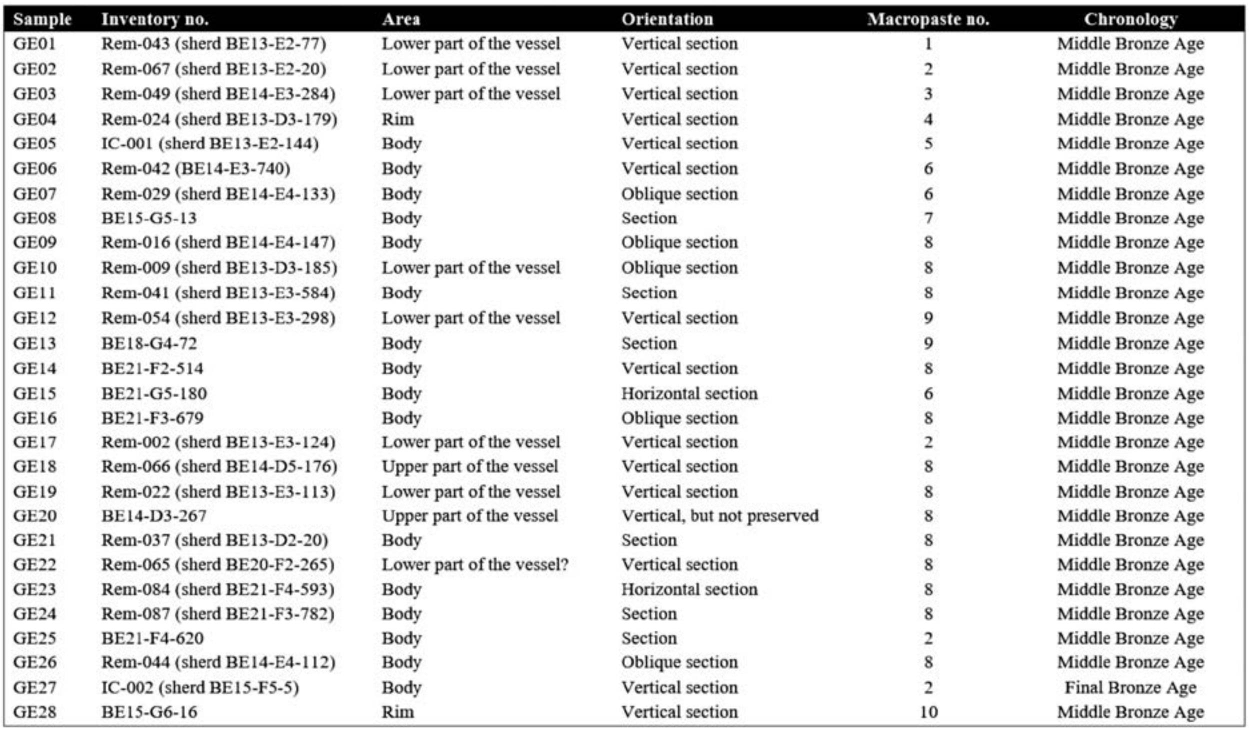
Materials

The archaeological finds from the Eremita Cave are under the care of the *Museo di Archeologia e Paleontologia Carlo Conti* in Borgosesia, Vercelli, Italy. The ceramic assemblage from the Eremita Cave comprises materials from the Middle and Final Bronze Age (1625–800 BC) and accounts for 2982 pottery sherds. Five reconstructed vessels are of particular importance (Fig. 5). The diagnostic sherds (rim, base, handle, carination, decoration) constitute 13% of the corpus, compared to the non-diagnostic pottery sherds, whose percentage is 87%, in the proportion of 297 diagnostic sherds versus 1997 body fragments. A number of 701 sherds are not counted as a single sherd because they refit with other diagnostic or non-diagnostic sherds. Out of the 297 diagnostic sherds, 159 are rim fragments, 36 are bases, 21 are vertical or lug-shaped handles, 16 are carinated sherds, 54 are sherds with decoration (cordon, fingerprint, incised dots, etc.), 3 profile sherds and 8 pieces that could belong either to bases or carinated body fragments.

The petrographic study regarded 28 samples, selected by taking into account pottery typology, relative chronology, surface and core colours as well as macroscopic features of pastes. The set of 28 sampled pottery sherds included 27 samples dating to the Middle Bronze Age (1625–1325 BC) and 1 to the Final Bronze Age (1250–800 BC) (Fig. 6).

Methods

The petrographic description and classification of the fabrics were carried out by polarized-light microscopy (OM). The analysis was performed at the University



Sample	Inventory no.	Area	Orientation	Macropaste no.	Chronology
GE01	Rem-043 (sherd BE13-E2-77)	Lower part of the vessel	Vertical section	1	Middle Bronze Age
GE02	Rem-067 (sherd BE13-E2-20)	Lower part of the vessel	Vertical section	2	Middle Bronze Age
GE03	Rem-049 (sherd BE14-E3-284)	Lower part of the vessel	Vertical section	3	Middle Bronze Age
GE04	Rem-024 (sherd BE13-D3-179)	Rim	Vertical section	4	Middle Bronze Age
GE05	IC-001 (sherd BE13-E2-144)	Body	Vertical section	5	Middle Bronze Age
GE06	Rem-042 (BE14-E3-740)	Body	Vertical section	6	Middle Bronze Age
GE07	Rem-029 (sherd BE14-E4-133)	Body	Oblique section	6	Middle Bronze Age
GE08	BE15-G5-13	Body	Section	7	Middle Bronze Age
GE09	Rem-016 (sherd BE14-E4-147)	Body	Oblique section	8	Middle Bronze Age
GE10	Rem-009 (sherd BE13-D3-185)	Lower part of the vessel	Oblique section	8	Middle Bronze Age
GE11	Rem-041 (sherd BE13-E3-584)	Body	Section	8	Middle Bronze Age
GE12	Rem-054 (sherd BE13-E3-298)	Lower part of the vessel	Vertical section	9	Middle Bronze Age
GE13	BE18-G4-72	Body	Section	9	Middle Bronze Age
GE14	BE21-F2-514	Body	Vertical section	8	Middle Bronze Age
GE15	BE21-G5-180	Body	Horizontal section	6	Middle Bronze Age
GE16	BE21-F3-679	Body	Oblique section	8	Middle Bronze Age
GE17	Rem-002 (sherd BE13-E3-124)	Lower part of the vessel	Vertical section	2	Middle Bronze Age
GE18	Rem-066 (sherd BE14-D5-176)	Upper part of the vessel	Vertical section	8	Middle Bronze Age
GE19	Rem-022 (sherd BE13-E3-113)	Lower part of the vessel	Vertical section	8	Middle Bronze Age
GE20	BE14-D3-267	Upper part of the vessel	Vertical, but not preserved	8	Middle Bronze Age
GE21	Rem-037 (sherd BE13-D2-20)	Body	Section	8	Middle Bronze Age
GE22	Rem-065 (sherd BE20-F2-265)	Lower part of the vessel?	Vertical section	8	Middle Bronze Age
GE23	Rem-084 (sherd BE21-F4-593)	Body	Horizontal section	8	Middle Bronze Age
GE24	Rem-087 (sherd BE21-F3-782)	Body	Section	8	Middle Bronze Age
GE25	BE21-F4-620	Body	Section	2	Middle Bronze Age
GE26	Rem-044 (sherd BE14-E4-112)	Body	Oblique section	8	Middle Bronze Age
GE27	IC-002 (sherd BE15-F5-5)	Body	Vertical section	2	Final Bronze Age
GE28	BE15-G6-16	Rim	Vertical section	10	Middle Bronze Age

Fig. 6 – List of ceramic samples selected for the petrographic study.

Fabric groups	Sample	Chronology	Dominant inclusions 50–90%	Frequent–Common 15–50%	Few–Rare 0.5–15%	Clast %	Matrix %	Voids %	GSD
Fabric I	2 samples: GE02, GE07	Middle Bronze Age	quartz	granite, biotite	muscovite, plagioclase, quartzite	20	75–77	3–5	BI
Fabric II	1 sample: GE08	Middle Bronze Age		granite with biotite, quartzite, quartz	plagioclase, pyroxenite, muscovite	20	70	10	BI
Fabric III	12 samples: GE04, GE05, GE10–GE14, GE17, GE19, GE25, GE26, GE28	Middle Bronze Age		granite biotite and granodiorite with biotite or hornblende, plagioclase, biotite	muscovite, quartz, hornblende, quartzite, gneiss with quartz and feldspar, sandstone, mica schist, volcanic rock, mudstone	10–34	65–87	1–5	U, BI, TRI, P
Fabric IV	10 samples: GE09, GE15, GE16, GE18, GE20, GE21, GE22, GE23, GE24, GE27	Middle and Final Bronze Age	granite with biotite, granodiorite with biotite or hornblende	biotite, quartz, muscovite	plagioclase, microcline, hornblende, volcanic rock, mudstone	15–40	57–82	1–5	U, BI, TRI, P
Fabric V	3 samples: GE01, GE03, GE06	Middle Bronze Age	granite	quartz	quartzite, biotite, muscovite, plagioclase, microcline, metapelite, orthopyroxene, pyroxenite	26–35	63–68	2–7	U, BI

Fig. 7 – Summary of the fabric characteristics.

of Geneva, using a Leica Leitz DM-RXP polarized-light microscope. The main petrographic characteristics of the ceramic paste (matrix, voids, inclusions) were reported according to the guidelines by Quinn (2013; 2022). The classification of fabrics in this study is mainly based on the type and morphometry of aplastic inclusions, which revealed to have a high discriminatory potential in the classification of prehistoric pottery pastes and to play a considerable role in fabric classification (Brunelli *et al.* 2013; Cannavò and Levi 2018; Day *et al.* 2011; Montana 2020; Salanova *et al.* 2016). Focusing on the characteristics of clasts further revealed to be particularly beneficial in Alpine contexts, where outcropping geological units consist of complex lithological assemblages and sequences, and where Quaternary sediments are dominated by chaotic morphometry and modal distribution (Carloni *et al.* 2022, 2023; Convertini 1997; Di Pierro and Martineau 2002; Maggetti 2009; Nungässer and Maggetti 1992; Stapfer *et al.* 2019).

Results

Polarized-light microscopy allowed to estimate the percentage of matrix, inclusions and voids and to define five ceramic fabrics. Figure 7 shows some criteria adopted in order to distinguish five pottery fabrics among the 28 samples.

Fabric I: Quartz

This fabric (Fig. 8a) describes two samples of Middle Bronze Age chronology. Its groundmass is homogeneous or heterogeneous and optically active with a reddish-brown colour. B-fabric features occur in only one sample and consist of coupled striated and elongated domains (GE02). The shape of the voids is channel-like and size varies from micro to macro with a random orientation. The dominant presence of quartz characterizes Fabric I. Quartz particles are silt- or sand-sized and randomly oriented; their shape is equant with sub-rounded and sub-angular edges. In addition to quartz, this fabric is characterized by sand-sized inclusions of biotite and granite with rounded to sub-angular edges. Furthermore, few-rare muscovite, plagioclase and quartzite inclusions are also documented. Their shape is equant or elongate, while the edges are rounded to angular. The grain-size distribution for Fabric I is bimodal.

Fabric II: Granite, quartzite and pyroxenite

This fabric (Fig. 8b) features only one sample dating to the Middle Bronze Age. The groundmass is homogeneous and optically active with a reddish-brown colour. It has channel-like voids varying in size from 1 to 10mm, and randomly oriented vughs

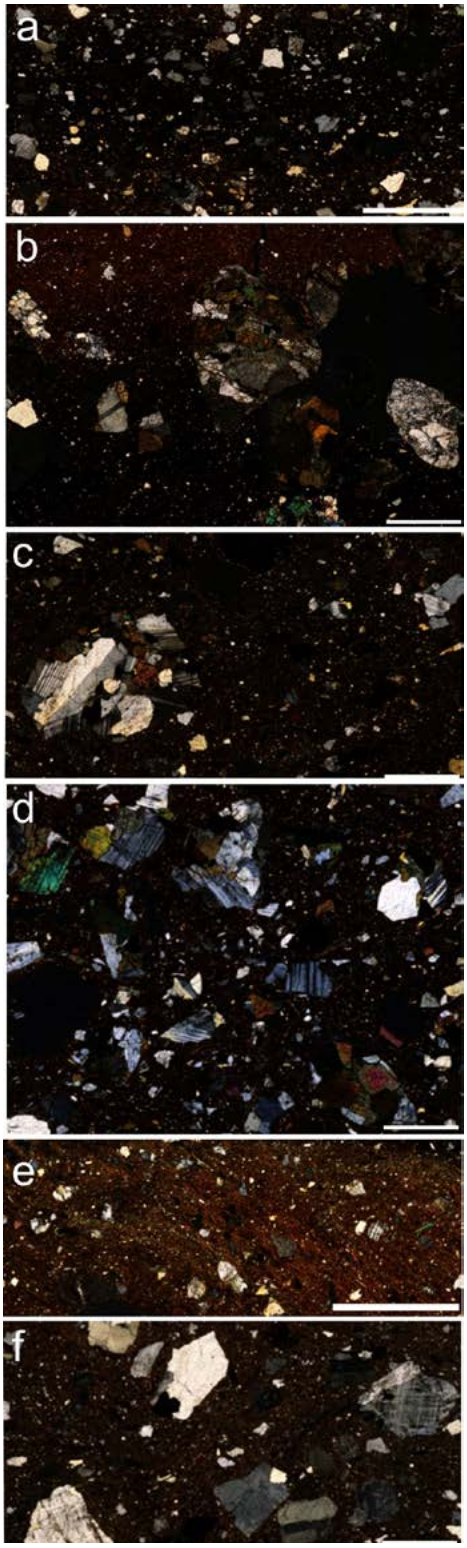


Fig. 8 – Microphotograph showing the characteristics of: Fabric I; GE02, Middle Bronze Age, cross-polarized light (a). – Fabric II; GE08, Middle Bronze Age, cross-polarized light (b). – Fabric III; GE13, Middle Bronze Age, cross-polarized light (c). – Fabric IV; GE16, Middle Bronze Age, cross-polarized light (d). – Fabric IV; GE27, Final Bronze Age, cross-polarized light (e). – Fabric V; GE06, Middle Bronze Age, cross-polarized light (f). – The length of the white bar is 2mm.

are also documented. With reference to inclusions, this fabric is characterized by randomly oriented silt to sand particles and an equant and elongate shape of inclusions of granite with biotite, quartzite, and quartz with sub-rounded to sub-angular edges. Fabric II also contains poorly sorted inclusions of plagioclase, muscovite and pyroxenite in equant or elongate shape with sub-rounded, sub-angular and angular edges. The particle size distribution is bimodal.

Fabric III: Granite and granodiorite

This fabric (Fig. 8c) is represented by 12 Middle Bronze Age samples. The ceramic groundmass is homogeneous or heterogeneous, brownish-coloured and optically active. B-fabric features are rare and consist of coupled striated and elongate domains (GE10). Voids are channel-like in shape, they range in size from 0.04 to 1.4mm and are randomly, subparallel or parallel oriented. The occurrence of intrusive rocks characterizes this fabric, mainly granule to sand-sized inclusions of granite-granodiorite with biotite or hornblende. Randomly oriented, their shape is equant or elongate, while the edges are mostly sub-rounded, sub-angular and rounded. Plagioclase, quartz, quartz schist, muscovite, biotite, volcanic rock, and hornblende are common in this group. They have equant and elongate shape with sub-angular, sub-rounded, angular and rounded edges. Fabric III also contains poorly sorted inclusions of gneiss with quartz and feldspar, sandstone, mudstone, polycrystalline quartz and micaschist with sub-rounded, sub-angular, rounded and angular edges, in equant or elongate shape. The grain-size distribution is unimodal, bimodal, trimodal or polymodal.

Fabric IV: Granite and granodiorite, quartz, muscovite, plagioclase

This fabric (Figs 8d and 8e) was observed in ten samples of Middle Bronze Age and Final Bronze Age chronology. The matrix is either homogeneous or heterogeneous; it has a blackish-brown, optically active matrix. A heterogeneous matrix was recorded in two specimens of this fabric (GE18, GE20). Different clay domains, possible evidence of mixing, were noted in sample GE27. The voids comprise randomly oriented, sub-parallel and parallel channels and vesicles, ranging in size from 0.05 to 1.4mm. The dominant presence of granite and granodiorite with biotite or hornblende, quartz, muscovite and plagioclase characterizes this fabric. The particles are randomly oriented, equant or elongate, with sub-angular, sub-rounded and angular edges. The poorly sorted inclusions include microcline, mudstone and lava particles with equant or elongate shapes and sub-angular to rounded edges. The grain-size distribution of ceramic paste of Fabric IV is unimodal, bimodal, trimodal or polymodal.

Fabric V: Granite

The fabric (Fig. 8f) is documented in three Middle Bronze Age samples. Their homogeneous matrix shows optical activity and is brown, yellow and black in colour. The voids are channel- and vough-shaped, randomly or sub-parallel oriented and vary in size from 0.05 to 1mm. Fabric V is characterized by the presence of granite. Granite particle shapes are equant and elongate with sub-rounded and sub-angular edges. Quartz and quartzite inclusions are common in this group, and are equant and elongate with sub-angular and sub-rounded edges. Finally, inclusions of biotite, muscovite, plagioclase, microcline, metapelite, orthopyroxene and pyroxenite complete the lithological assemblage of Fabric V. These inclusions are equant and elongate in shape, and characterized by sub-angular, sub-rounded, angular and rounded edges. A unimodal and bimodal grain-size distribution is a feature of the ceramics of this group.

Discussion

Exploitation of natural resources

Raw material procurement by Middle and Final Bronze Age people using Eremita Cave for burial purposes may be inferred based on petrographic data acquired as part of the present study. The first type of data to examine in this sense is matrix homogeneity/heterogeneity. Quinn (2013) explains that in most thin sections there are variations in regard to composition, colour and texture of ceramic matrix. This may reflect the homogeneous raw materials (Fig. 9b) or the presence of natural heterogeneity in the raw materials that have not been sufficiently homogenized during clay processing and working. Natural variations in composition are generally common in residual clay deposits formed *in situ*, which may have been bioturbated by the activity of plants and animals living in the upper layers of the soil and regolith (Quinn 2022; Roux 2019). Heterogeneity in the composition of the clay matrix can also be introduced during the ceramic manufacturing process, when two or more different clay raw materials have been intentionally mixed or blended (Arnold 1971; 1972; Quinn 2013; Rice *et al.* 1981; Roux and Courty 1998; Roux 2019; Schiffer and Skibo 1987; Schultz 1971). Whether this heterogeneity is natural or anthropogenic is important to distinguish, both for the provenance and for the reconstruction of the manufacturing technology.

Out of 28 analysed samples, ten present a heterogeneous matrix, regardless of the kinds of aplastic inclusions and the fabric (Figs 9a, 9c and 9d). In the case of the pottery from Eremita Cave, evidence does not allow us to state if the heterogeneity features are of natural or anthropogenic origin. This could be further investigated in the future through an analysis of local sediments. Therefore, inferences about the type of raw materials used in pottery manufacturing can be only drawn based on another kind of data collected in the study: the characteristics of rock and mineral inclusions and the type of resources available in the region.

Roundness and angularity are grain shape parameters from sedimentology that describe the sharpness of the clast angles (Whitbread 1989). The degree of angularity/roundness of sediments or sedimentary rocks is normally related to the distance the clastic material has been transported from its source (Boggs 2009; Pomerol *et al.* 2015). Sedimentary clay deposits that may contain quartz, feldspar and mica clasts tend to be rounded by water transport, whereas sedimentary clay deposits that may contain quartz, feldspar and mica clasts left by glacial action have angular edges (Quinn 2013).

Fabric I is composed of rounded to angular particles, equant and elongate in shape, and showing a bimodal grain-size distribution. The morphometry of the aplastic inclusions in Fabric I corresponds to the compositional features of fluvial sediments in mountainous contexts (e.g., Carton *et al.* 2009; Fredi and Palmieri 2017) and highlights the possible exploitation of clay originated from the Sesia River's activity.

Fabric II is equally recognized by rounded to angular inclusions with predominant equant sphericity, but some of the inclusions display elongate sphericity. The grain-size distribution of Fabric II is bimodal. Presence of pyroxenite, which does not outcrop in the area of the Lower Sesia Valley point out the use of local glacigenic deposits, formed during Quaternary glaciations (Ivy-Ochs 2015) and being featured by a great variety of lithoclasts from the several complexes of the palaeo-Adriatic margin (Piana *et al.* 2017).

Fabric III shows a lithological assemblage that largely corresponds to the Permian Magmatic Complex and the Serie dei Laghi Complex (granite, granodiorite, volcanic rock, metasediments) and does not present lithotypes from other nappes of the Palaeo-Adriatic unit. Morphometry of aplastic inclusions is mixed: rounded to angular edges, equant and elongate sphericity, and unimodal/bimodal/trimodal/polymodal grain-size distribution. All these characteristics suggest the use of residual clays procured from soils developed on outcrops of the Permian Magmatic Complex and the Serie dei Laghi Complex, which form slopes located at both sides of the Sesia River's winding course (Fig. 4).

Fabric IV presents a very similar lithological assemblage to the ones of Fabric III but lacks the metasediments from the Serie dei Laghi Complex. The morphometry of aplastic inclusions is also similar to the one of Fabric III, being composed of rounded to angular equant and elongate particles, and unimodal to polymodal grain-size distribution (Figs 10b and 10d). Like Fabric III, Fabric IV possibly correlates with a residual clay developed on a granitic bedrock from the Permian Magmatic Complex. However, in this case the area where the raw material was collected saw little or no sedimentological contribution by the Serie dei Laghi Complex (Piana *et al.* 2017).

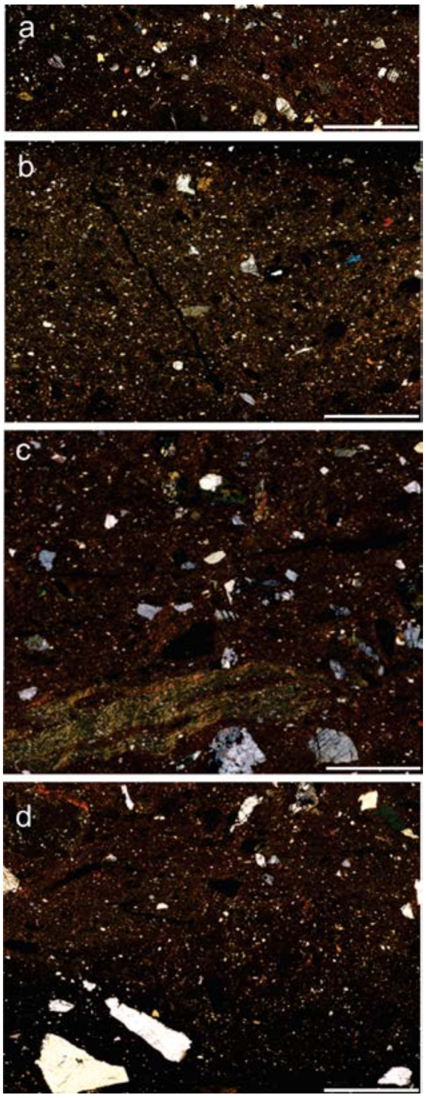


Fig. 9 – Microphotographs under cross-polarized light: Heterogeneous matrix-mixed clay GE27 (a). – Homogeneous matrix GE25 (b). – Heterogeneous matrix GE10 (c). – Heterogeneous matrix GE12 (d). – The length of the white bar is 2mm.

Fabric V hosts inclusions of various origins: granite from the Permian Magmatic Complex, metasediments from the Serie dei Laghi Complex, and pyroxene-based rocks from other nappes of the Palaeo-Adriatic margin, possibly from the Sesia-Lanzo Zone (Piana *et*

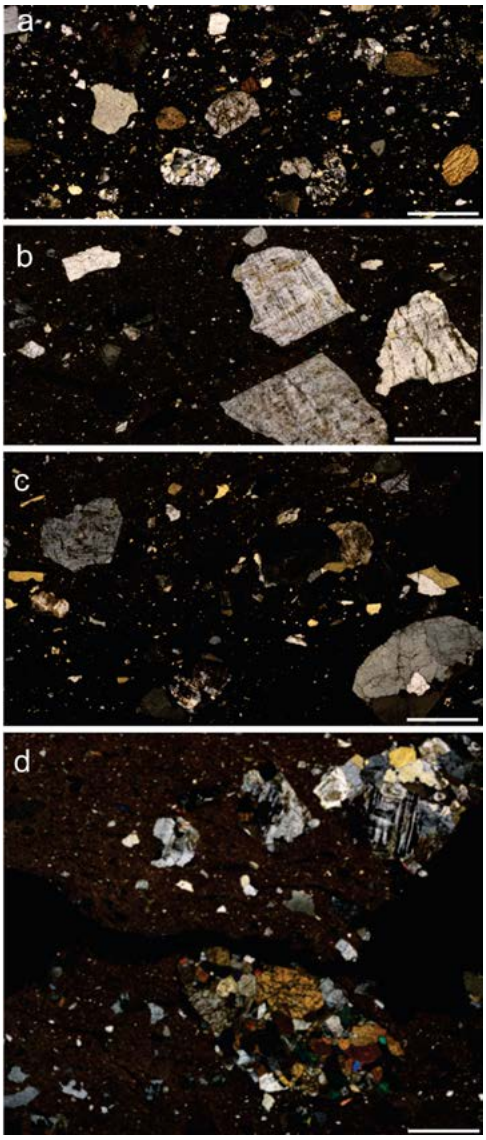


Fig. 10 – Types of grain size distribution documented in 28 samples: GE01; unimodal grain size distribution (a). – GE06; bimodal grain size distribution (b). – GE15; trimodal grain size distribution (c). – GE22; polymodal grain size distribution (d). – Cross-polarized light. The length of the white bar is 2mm.

al. 2017; 2020). The morphometry of aplastic inclusions is indicative of a chaotic pattern of transport (Figs 10a and 10c) (Brodzikowski and Van Loon 1991; Pomerol *et al.* 2015). The lithological assemblage and the shape and size characteristics point out that the clay may have been procured from glacigenic deposits or, most probably, their reworking by the Sesia River.

Inferences about the pottery chaîne opératoire

The petrographic analysis of the pottery from Eremita Cave enabled the acquisition of important information on the ceramic *chaîne opératoire*. With regard to the first step, the acquisition of the raw materials, three main sources are plausible: the fluvial deposits bordering the Sesia River's winding course, the local glacigenic deposits flanking the valley, and the alteration horizons of granitic/volcanic bedrocks from the Permian Magmatic Complex developed on local hills (Fig. 4). Identified raw materials thus reflect the local environment, but the reasons behind this variety of exploited resources remains heretofore unknown.

Regarding the second step of the *chaîne opératoire*, it is possible to assume that the raw materials were likely not modified or manipulated. Notwithstanding the presence of angular particles, generally indicative of rock crushing (Levi 2010; Quinn 2022; Roux 2019; Whitbread 1989), it is more likely that they featured the original clay-rich deposits in the first place. This because of the sedimentological processes related with the mountainous environment (e.g., Brodzikowski and Van Loon 1991; Carton *et al.* 2009; Fredi and Palmieri 2017; Pomerol *et al.* 2015) and the fact that particles with angular edges occur along with others showing rounded, sub-rounded, and sub-angular edges that would have been damaged if crushing or powdering of clay had been carried out (e.g., Albero 2014, and references therein).

As far as shaping techniques are concerned, it is possible to draw some – non-conclusive – inferences based on void characteristics (Quinn 2013; 2022; Roux 2019). Large transversal voids in samples GE12, GE17, GE25, GE26, and GE28 represent gaps between adjacent pieces or 'crumbs' of clay, if not coils or patches, that have not completely closed during the forming process and may be indicative of the employ of the coil technique. Furthermore, elongate voids in ceramics from Eremita Cave are occasionally parallel oriented (Fig. 11b), which may be indicative of the paste having been subjected to compressive and/or shear stresses due to the application of physical force by hand or with a tool that forced the voids to align. Therefore, techniques such as beating/paddling may also have been applied. Other voids, randomly oriented and vughular in shape are most likely related with the drying process, due to the shrinkage of clay as it loses absorbed water, as well as with the firing process (Orton *et al.* 1993; Orton and Hughes 2013; Quinn 2013; Rice 1987; Roux 2019; Stoltman 1991; Stoltman and Mainfort 2002; Stoltman 2015; Whitbread 1995).

With regard to the firing process, the optically active matrices of all 28 samples indicate that the firing temperature was surely <800–850°C (Albero 2014; Quinn 2013; 2015; Velde and Druc 1998). The process of sintering of the matrix may have started but was not completed, as the groundmass preserves its

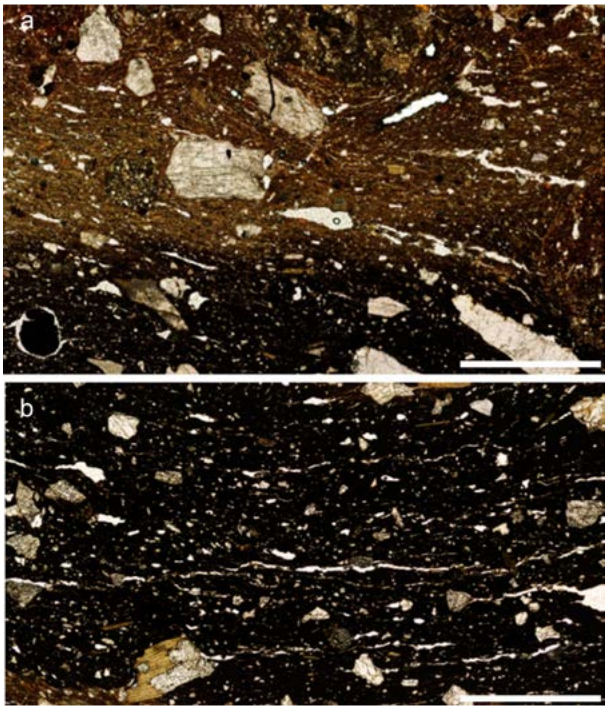


Fig. 11 – Microphotographs showing void orientation: Random orientated voids of GE12 (a). – Parallel oriented voids of GE04 (b). – Plane polarized light. The length of the white bar is 2mm.

birefringence and clay minerals are not fused together or melted. In addition, no mineralogical change generally occurring at 800°C and discussed in the literature (Gliozzo 2020, and references therein) was detected. Finally, void characteristics also support a firing temperature surely <800–850°C, as vescicles are very rare and there were no blisters (Tite *et al.* 2001).

Concerning the firing atmosphere, the brown, orange and red colours that were observed in 15 ceramic thin sections from Eremita Cave (GE06, GE08, GE09, GE10, GE12, GE13, GE14, GE18. GE20, GE21, GE22, GE23, GE25, GE26, GE27) are indicative of mostly oxidizing conditions (D'Anna *et al.* 2011; Echallier 1984; Picon 1973; Rice 1987). These conditions determine if the iron is oxidized to ferric minerals such as haematite (Fe_2O_3), a process that takes place above *c.* 600°C (Quinn 2013). However, the darker colours of the remaining 13 samples (GE01, GE02, GE03, GE04, GE05, GE07, GE11, GE15, GE16, GE17, GE19, GE24, GE28) show predominant reducing firing conditions (D'Anna *et al.* 2011; Echallier 1984; Picon 1973; Rice 1987), in which iron exists as dark ferrous minerals such as magnetite (Fe_3O_4) (Quinn 2013). Dark grey or black cores in oxidized ceramics having reddish or brownish surface colours are documented in five thin sections from Eremita Cave (GE08, GE21, GE22, GE25, GE27) and may be interpreted as resulting from short firing times, when oxygen has not penetrated the mass sufficiently to remove carbon (organic matter) (Quinn 2013). A similar effect can be achieved in ceramics fired under reducing conditions which are then allowed to cool in air, although there may be a sharper delineation between the margin and the core (Quinn 2022; Rice 1987; Roux 2019). This is the case for five thin sections from Eremita Cave (GE02, GE04, GE05, GE11, GE17).

Finally, as regards the place of production, it is possible to state that the pottery was not manufactured in the vicinity of the cave for multiple reasons: i) the cave's interior and outside spaces are not sufficiently spacious, and there is no water flow at a close enough distance to serve the manufacturing process; ii) there is no evidence of pottery production in the cave, nor outside; iii) documented raw materials were procured downhill Mount Fenera and are not likely to have been brought uphill. Hence, the pottery, linked to the burial site of Eremita Cave, was brought into the cave from one or multiple – heretofore unknown – settlement or production sites, possibly located in the Lower Sesia Valley.

Conclusions

The petrographic study of Middle and Final Bronze Age pottery from Eremita Cave allowed to answer questions concerning the pottery production and exploitation of natural resources by the communities living in the Lower Sesia Valley during the second half of the 2nd millennium BC and the beginning of the 1st millennium BC. Analysed ceramic containers cluster into five fabrics that all revealed to result from the exploitation of raw materials located in the vicinity of Mount Fenera, downhill from where the studied cave opens. The different types of paste testify to the use of different sources: fluvial, glacigenic, and *in situ* alteration deposits. Regarding the different steps of the ceramic *chaîne opératoire*, it was possible to draw the following conclusions:

- The acquisition of the raw materials involved procurement from different sources: the fluvial deposits bordering the Sesia River's winding course, the local glacigenic deposits flanking the valley, and the alteration horizons of granitic/volcanic bedrocks from the Permian Magmatic Complex developed on local hills. The reasons behind this variety of exploited resources remains unknown.
- Raw materials were likely not modified or manipulated, as the variety of lithic inclusions and of their morphometric characteristics are most probably related to local geology rather than to any activity by the potters.
- Evidence related to the shaping operations suggest junction of 'crumbs'/coils/patches of clay and, possibly, beating/paddling.

- The firing temperature did not definitively reach 800°C, as the process of sintering of the matrix may have started but was not completed. The firing atmosphere was mostly oxidizing or reducing, depending on the analysed samples. Dark grey or black cores documented in few samples may be indicative of a short firing time.

To conclude, the pottery was not likely produced in the vicinity of the cave and was brought there from one or multiple – heretofore unknown – settlement or production sites, possibly located in the Lower Sesia Valley.

Bibliography

Albero, D. 2014. *Materiality, Techniques and Society in Pottery Production: The Technological Study of Archaeological Ceramics through Paste Analysis. Production.* Warsaw, De Gruyter Open.

Arnold, D. E. 1971. Ethnomineralogy of Ticul, Yucatan potters: etics and emics. *American Antiquity* 36(1): 20–40.

Arnold, D. E. 1972. Mineralogical analyses of ceramic materials from Quinua, Department of Ayacucho, Peru. *Archaeometry* 14(1): 93–102.

Arnold, D. E. 1985. *Ceramic Theory and Cultural Process.* Cambridge, Cambridge University Press.

Arnold, D. E. 2018. *Maya Potters' Indigenous Knowledge: Cognition, Engagement, and Practice.* Boulder, University Press of Colorado.

Balfet, H. 1981. Production and distribution of pottery in the Maghreb. In H. Howards and E. L. Morris (eds), *Production and Distribution: A Ceramic Viewpoint*: 257–269. Oxford, British Archaeological Reports.

Berruto, G. 2011. *Comportamento economico dei neandertaliani della grotta della Ciota Ciara (Borgosesia, VC): analisi della provenienza delle materie prime. Unpublished PhD thesis, Universita degli Studi di Ferrara.*

Besse, M. and Viola, S. 2013a. Gli scavi dell'Università di Ginevra alla Grotta dell'Eremita sul Monte Fenera a Borgosesia. *De Valle Sicida, Periodico annuale della Società Valsesiana di Cultura (Borgosesia)* 23: 7–20.

Besse, M. and Viola, S. 2013b. Borgosesia, Monte Fenera, Grotta dell'Eremita. Primi sondaggi in una grotta archeologicamente inedita. *Quaderni della Soprintendenza archeologica del Piemonte* 28, 297–299.

Besse, M. Viola, S., Cattin, F. and Von Tobel, C. 2014. La grotte de l'Eremita au Monte Fenera (Vercelli, Italie): Nouvelles découvertes du Bronze moyen. In J. Bullinger, P. Crotti and C. Huguenin (eds), *De l'âge du Fer à l'âge du verre. Mélanges offerts à Gilbert Kaenel, dit « Auguste », à l'occasion de son 65e anniversaire:* 291–296. Cahiers d'archéologie romande 151. Lausanne, Musée cantonal d'archéologie et d'histoire.

Bini, A. and Zuccoli, L. 2005. Evoluzione del carsismo nelle Alpi. In R. Fantoni, R. Cerri and E. Dellarole (eds), *D'acqua e di pietra. Il Monte Fenera e le sue collezioni museali:* 143–152. Magneta, Associazione Culturale Zeisciu Centro Studi.

Boggs, J. S. 2009. *Petrology of Sedimentary Rocks (2nd ed.).* Cambridge, Cambridge University Press.

Brodzikowski, K. and Van Loon, A. J. 1991. *Glacigenic Sediments.* Amsterdam, Elsevier.

Bronk Ramsey, C. 2021. OxCal 4.4.4 [on-line]. https://c14.arch.ox.ac.uk/oxcal.html (accessed 3 February 2023).

Brunelli, D., Levi, S. T., Fragnoli, P., Renzulli, A., Santi, P., Paganelli, E. and Martinelli, M. C. 2013. Bronze Age pottery from the Aeolian Islands: definition of temper compositional reference units by an integrated mineralogical and microchemical approach. *Applied Physics A* 113(4): 855–863.

Cannavò, V. and Levi, S. T. 2018. *Atlas of Ceramic Fabrics 1: Italy: North-East, Adriatic, Ionian. Bronze Age: Impasto.* Oxford: Archaeopress.

Carloni, D., Šegvić, B., Sartori, M., Zanoni, G. and Besse, M. 2022. Who was buried at the Petit-Chasseur site? The contribution of archaeometric analyses of Final Neolithic and Bell Beaker domestic pottery to the understanding of the megalith-erecting society of the Upper Rhône Valley (Switzerland, 3300–2200 BC). *Open Archaeology* 8: 1064–1111.

Carloni, D., Šegvić, B., Sartori, M., Zanoni, G. and Besse, M. 2023. Who venerated the ancestors at the Petit-Chasseur site? Examining Early Bronze Age cultic activities around megalithic monuments through the archaeometric analyses of ceramic findings (Upper Rhône Valley, Switzerland, 2200–1600 BC). *Archaeological and Anthropological Sciences* 15, 62.

Carton, A., Bondesan, A., Fontana, A., Meneghel, M., Miola, A., Mozzi, P., Primon, S. and Surian, N. 2009. Geomorphological evolution and sediment transfer in the Piave River system (northeastern Italy) since the Last Glacial Maximum. *Géomorphologie : Relief, Processus, Environnement* 15: 155–174.

Convertini, F. 1997. Origine des ressources argileuses. In B. Othenin-Girard (ed.), *Le Campaniforme d'Alle, Noir Bois (Jura, Suisse)*: 70–84. Porrentruy, Office du patrimoine historique.

Creswell, R. 1976. Techniques et culture, les bases d'un programme de travail. *Techniques et Culture* 1: 7–59.

Creswell, R. 1983. Transferts de techniques et chaînes opératoires. *Techniques et Culture* 2: 143–164.

Creswell, R. 1996. *Prométhée ou Pandore? Propos de technologie culturelle.* Paris, Kimé.

D'Anna, A., Desbat, A., Garcia, D., Schmitt, A. and Verhaeghe, F. 2011. *La céramique. La poterie du néolithique aux temps modernes.* Paris, Errance.

Day, P. M., Quinn, P. S., Rutter, J. B. and Kilikoglou, V. 2011. A world of goods: transport jars and commodity exchange at the Late Bronze Age harbor of Kommos, Crete. *Hesperia* 80(4): 511–558.

Degryse, P. and Braekmans, D. 2016. Petrography: optical microscopy. In A. Hunt (ed.), *The Oxford Handbook of Archaeological Ceramic Analysis*: 233–265. Oxford, Oxford University Press.

Derenne, E. 2016. Les niveaux de l'âge du Bronze de la Grotte de l'Eremita sur le Monte Fenera (Vercelli, Italie) Fouilles 2012–2015. Unpublished Master Thesis, Université de Genève.

Derenne, E., Viola, S. and Besse, M. 2020. I livelli dell'Età del Bronzo della grotta dell'Eremita in Piemonte (Vercellli, italia): Primi dati cronologici e culturali. *IpoTESI di Preistoria* 13: 9–14.

Di Pierro, S. and Martineau, R. 2002. Pottery tempering with Mont Blanc granite across the Jura belt during Swiss and French Final Neolithic. In *33rd International Symposium on Archaeometry, Amsterdam, 22th–26th April 2002.* Abstract book: 75–76.

Dietler, M. and Herbich, I. 1994. Ceramics and ethnic identity. Ethnoarchaeological observations on the distribution of pottery styles and the relationship between the social contexts of production and consumption. In J. Courtin and D. Binder (eds), *Terre cuite et société. La céramique, document technique, économique, culturel*: 459–472. XIVe Rencontres Internationales d'Archéologie et d'Histoire d'Antibes. Juan-les-Pins: APDCA.

Echallier, J.-C. 1984. *Eléments de technologie céramique et d'analyse des terres cuites archéologiques.* Documents d'archéologie méridionale. Numéro spécial, série méthodes et techniques 3. Lambesc, Association pour la Diffusion de l'Archéologie Méridionale.

Fantoni, R., Cerri, R. and Dellarole, E. (eds) 2005a. *D'acqua e di pietra. Il monte fenera e le sue collezioni museali.* Magneta, Associazione Culturale Zeisciu Centro Studi.

Fantoni, R., Decarlis, A., and Fantoni, E. 2005b. Geologia del Montefenera. In R. Fantoni, R. Cerri, and E. Dellarole (eds), *D'acqua e di pietra. Il Monte Fenera e le sue collezioni museali*: 89–91. Magneta, Associazione Culturale Zeisciu Centro Studi.

Fredi, P. and Palmieri, E. L. 2017. Morphological Regions of Italy. In M. Soldati and M. Marchetti (eds), *Landscapes and Landforms of Italy.* Cham, Springer International Publishing.

Gallay, A. 1992. A propos de la céramique actuelle du delta intérieur du Niger (Mali) : approche ethnoarchéologique et règles transculturelles. In A. Gallay, F. Audouze and V. Roux (eds), *Ethnoarchéologie: Justification, Problèmes, Limites*: 67–90. Juan-les-Pins, APDCA.

Gambari, F. M. 2005. Archeologia al Monte Fenera. In R. Fantoni, R. Cerri and E. Dellarole (eds), *D'acqua e di pietra. Il Monte Fenera e le sue collezioni museali:* 230–233. Magenta: Associazione Culturale Zeisciu Centro Studi.

Gliozzo, E. 2020. Ceramic technology: how to reconstruct the firing process. *Archaeological and Anthropological Sciences* 12: 260.

Gosselain, O. P. 1992. Technology and style: potters and pottery among Bafia of Cameroon. *Man* 27(3): 559–586.

Handy, M. R., Schmid, S., Bousquet, R., Kissling, E. and Bernoulli, D. 2010. Reconciling plate-tectonic reconstructions of Alpine Tethys with the geological–geophysical record of spreading and subduction in the Alps. *Earth-Science Reviews* 102: 121–158.

Ivy-Ochs, S. 2015. Glacier variations in the European Alps at the end of the last glaciation. *Cuadernos de Investigación Geográfica* 41: 295–315.

Latour, B. and Lemonier, P. 1994. *De la préhistoire aux missiles balistiques: L'intelligence sociale des techniques.* Paris, La Découverte.

Lemonnier, P. 1983. L'Étude des systèmes techniques: une urgence en technologie culturelle. *Techniques et culture* 1: 11–34.

Lemonnier, P. 1992. *Elements for an anthropology of technology*. Museum of Anthropology, University of Michigan.

Lemonnier, P. 1993. *Technological choices: Transformation in material cultures since the Neolithic*. Routledge.

Leroi-Gourhan, A. 1964. *Le geste et la parole. Technique et langage* 1. Paris, Albin Michel.

Levi, S. T. 2010. *Dal coccio al vasaio. Manifattura, tecnologia e classificazione della ceramica.* Bologna, Zanichelli.

Longacre, W. A. 1991. *Ceramic Ethnoarchaeology*. Tuscon, University of Arizona Press.

Maggetti, M. 2009. Neolithic pottery from Switzerland: raw materials and manufacturing processes. In A. Shortland, I. C. Freestone and T. Rehren (eds), *From Mine to Microscope. Advances in the Study of Ancient Technology* 29–42. Oxford, Oxbow Books.

Montana, G. 2020. Ceramic raw materials: How to recognize them and locate the supply basins—mineralogy, petrography. *Archaeological and Anthropological Sciences* 12(8): 175.

Nungässer, W. and Maggetti, M. 1992. Analyse der Scherbensubstanz mit Mikroskop und Röntgenlicht. *Jahrbuch des Historischen Vereins für das Fürstentum Liechtenstein* 91: 85–165.

Orton, C. and Hughes, M. 2013. *Pottery in Archaeology* (2nd ed.). Cambridge, Cambridge University Press.

Orton, C., Tyers, P. and Vince, A. 1993. *Pottery in Archaeology.* Cambridge, Cambridge University Press.

Piana, F., Fioraso, G., Irace, A., Mosca, P., d'Atri, A., Barale, L., Falletti, P., Monegato, G., Morelli, M., Tallone, S. and Vigna, G. B. 2017. Geology of Piemonte region (NW Italy, Alps–Apennines interference zone). *Journal of Maps* 13: 395–405.

Piana, F., Barale, L., Compagnoni, R., d'Atri, A., Fioraso, G., Irace, A., Mosca, P., Tallone, S., Morelli, M. and Vigna, B. 2020. *Geological Map of Piemonte 1:250 000* *scale* (2nd ed.). Torino, Istituto di Geoscienze e Georisorse Arpa Piemonte.

Picon, M. 1973. *Introduction à l'étude technique des céramiques sigillées de Lezoux*. Dijon, Centre de recherches sur les techniques gréco-romaines.

Pomerol, C., Lagabrielle, Y., Martin, E., Rafélis Saint Sauveur, M. and Renard, M. 2015. *Éléments de géologie (15e éd., rév.).* Paris, Dunod.

Quinn, P. S. 2013. *Ceramic Petrography: The Interpretation of Archaeological Pottery and Related Artefacts in Thin Section*. Oxford, Archaeopress.

Quinn, P. S. 2022. *Thin Section Petrography, Geochemistry and Scanning Electron Microscopy of Archaeological Ceramics*. Oxford, Archaeopress.

Reimer, P. J., Austin, W., Bard, E., Bayliss, A., Blackwell, P. G., Bronk Ramsey, C., Butzin, M., Cheng H., Edwards, R. L., Friedrich, M., Grootes, P. M., Guilderson, T. P., Hajdas, I., Heaton, T. J., Hogg, A. G., Hughen, K. A., Kromer, B., Manning, S. W., Muscheler, R., Palmer, J. G., Pearson, C., Van der Plicht, J., Reimer, R. W., Richards, D. A., Scott, M., Southon, J. R., Turney, C., Wacker, L., Adolphi, F., Büntgen, U., Capano, M., Fahrni, S. M., Fogtmann-Schulz, A., Friedrich, R., Köhler, P., Kudsk, S., Miyake, F., Olsen, J., Reinig, F., Sakamoto, M., Sookdeo, A. and Talamo, S. 2020. The IntCal20 Northern Hemisphere radiocarbon age calibration curve (0–55 cal kBP). *Radiocarbon* 62(4): 725–757.

Rice, P. M. 1987. *Pottery Analysis: A Sourcebook.* Chicago, University of Chicago Press.

Rice, P. M., Adams, W. Y., Ball, J. W., Davis, W. M., Earle, T., Fry, R. E., Hodder, I., Joesink-Mandeville, L. R. V., Kolb, C. C., Nishimura, M., Kojo, Y., Dorado, M. R., Stark, B. L. and Van Der Leeuw, S. E. 1981. Evolution of specialized pottery production: A trial model. *Current Anthropology* 22(3): 219–240.

Roux, V. 2017. Ceramic manufacture: the *chaîne opératoire* approach. In A. Hunt (ed.), *The Oxford Handbook of Archaeological Ceramic Analysis*: 101–113. Oxford, Oxford University Press.

Roux, V. 2019. *Ceramics and Society: A Technological Approach to Archaeological Assemblages.* Cham, Springer International Publishing.

Roux, V. and Courty, M.-A. 1998. Identification of wheel-fashioning methods: technological analysis of 4th–3rdmillennium BC oriental ceramics. *Journal of Archaeological Science* 25(8): 747–763.

Rubat Borel, F., Martinelli, N., Köninger, J. and Menotti, F. 2022. Un contributo per la cronologia assoluta del Bronzo Medio: L'abitato perilacustre di Viverone Vi1-Emissario e l'Italia nordoccidentale. *Rivista di Scienze Preistoriche* 72: 441–457.

Salanova, L., Prieto Martínez, M. P., Clop García, X., Convertini, F., Lantes Suárez, O. and Martínez Cortizas, A. 2016. What are large-scale archaeometric programmes for? Bell Beaker pottery and societies from the third millennium BC in Western Europe. *Archaeometry* 58(5): 722–735.

Schiffer, M. B. and Skibo, J. M. 1987. Theory and experiment in the study of technological change. *Current Anthropology* 28(5): 595–622.

Schmid, S. M., Fügenschuh, B., Kissling, E. and Schuster, R. 2004. Tectonic map and overall architecture of the Alpine orogen. *Eclogae Geolicae Helvetiae* 97: 93–117.

Schmid, S. M., Pfiffner, O. A., Froitzheim, N., Schönborn, G. and Kissling, E. 1996. Geophysical-geological transect and tectonic evolution of the Swiss-Italian Alps. *Tectonics* 15: 1036–1064.

Schultz, L. G. 1971. Mixed-layer Kaolinite—Montmorillonite from the Yucatan Peninsula, Mexico. *Clays and Clay Minerals* 19(3): 137–150.

Shennan, S. 2013. Lineages of cultural transmission. In R. Ellen, S. J. Lycett and S. E. Johns (eds), *Understanding Cultural Transmission in Anthropology: A Critical Synthesis*: 346–360. New York, Berghahn Books.

Shepard, A. O. 1965. *Ceramics for the Archaeologist.* Washington, DC, Carnegie Institution of Washington.

Sigaut, F. 1994. Technology. In *Companion Encyclopedia of Anthropology. Humanity, Culture and Social Life*: 420–459. London, Routledge.

Stapfer, R., Heitz, C., Hinz, M. and Hafner, A. 2019. Interdisciplinary examinations carried out on heterogeneous coarse ceramics from Neolithic lakeside settlements in the Northern Alpine foreland (3900–3500 BCE): analysis strategy and preliminary results from a test series using pXRF. *Journal of Archaeological Science: Reports* 25: 217–238.

Stoltman, J. B. 1991. Ceramic petrography as a technique for documenting cultural interaction: an example from the Upper Mississippi Valley. *American Antiquity* 56(1): 103–120.

Stoltman, J. B. 2015. *Ceramic Petrography and Hopewell Interaction*. Tuscaloosa, The University of Alabama Press.

Stoltman, J. B. and Mainfort, R. C. 2002. Minerals and elements: using petrography to reconsider the findings of neutron activation in the compositional analysis of ceramics from Pinson Mounds, Tennessee. *Midcontinental Journal of Archaeology* 27(1): 1–33.

Tite, M. S., Kilikoglou, V. and Vekinis, G. 2001. Strength, toughness and thermal shock resistance of ancient ceramics, and their influence on technological choice. *Archaeometry* 43(3): 301–324.

Velde, B. and Druc, I. C. 1998. *Archaeological Ceramic Materials: Origin and Utilization.* Berlin, Springer.

Whitbread, I. K. 1989. A proposal for the systematic description of thin sections towards the study of ancient ceramic technology. In Y. Maniatis (ed.), *Archaeometry: Proceedings of the 25th International Symposium*: 127–138. Amsterdam, Elsevier.

Whitbread, I. K. 1995. *Greek Transport Amphorae: A Petrological and Archaeological Study*. London, British School at Athens.

Whitbread, I. K. 2001. Ceramic petrology, clay geochemistry and ceramic production – from technology to the mind of the potter. In D. R. Brothwell and A. M. Pollard (eds), *Handbook of Archaeological Sciences*: 449–458. Chichester, John Wiley.

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Water Supply and Water Management in the Metal Ages gathers papers originally presented at the Metal Ages 2022 colloquium, hosted by the Archaeology Department of Bilkent University, Ankara and bringing together the UISPP's Scientific Commissions 'Metal Ages in Europe and the Mediterranean' and 'Archaeometry of Prehistoric and Protohistoric Inorganic Artefacts, Materials and their Technologies' for their respective annual meetings.

Five of the papers included here focus specifically on water supply and water management. Others cover copper metallurgy, pottery studies and fighting techniques, and overall they range chronologically from the Chalcolithic to the Late Iron Age, and geographically from Iran to Iberia. A significant number of papers cover topics focusing on artefact archaeometry, due to the participation in the Ankara colloquium of many colleagues from the UISPP's Archaeometry commission.

The publication of these proceedings in their present format was made possible thanks to generous financial support by Valentín de Torres Solanot and E2IN2.

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