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## HERDS – Animal Husbandry and its Economic Role in the Development of Central Mediterranean Protohistoric Societies

HERDS

LXXVI – S6 – 2026 – Firenze

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## HERDS – Animal Husbandry and its Economic Role in the Development of Central Mediterranean Protohistoric Societies

Edited by
Andrea Cardarelli, Giulia Recchia, Antonio Curci,
Beatrice Demarchi, Claudia Minniti, Marco Pacciarelli

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This volume presents the results of the PRIN 2020 project "*HERDS Animal Husbandry and its Economic Role in the Development of Central Mediterranean Protohistoric Societies*", discussed in advance in a dedicated International Workshop held in Rome, Sapienza University, Dipartimento di Scienze dell'Antichità, on the 20th-21st November 2025.

The volume is organised into three sections. The first is devoted to the results of the HERDS project, the second presents the case studies included within the project, and the third comprises further case studies discussed at the HERDS International Workshop.

Contributions are peer reviewed.

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RU UNIBo: Dipartimento di Storia Culture Civiltà, Alma Mater Studiorum-University of Bologna, coordinated by Antonio Curci.
RU UNINa: Dipartimento di Sudi Umanistici, University of Neapols Federico II, coordinated by Marco Pacciarelli.
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The Herds project logo was created by Lorenzo Cardarelli

Ministero dell'Università e della Ricerca

Dipartimento di Scienze dell'Antichità
Sapienza Università di Roma

# I

# THE RESULTS OF THE HERDS PROJECT

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Andrea Cardarelli [1, 2, 3], Giulia Recchia [1, *], Antonio Curci [4], Beatrice Demarchi [5], Claudia Minniti [1], Marco Pacciarelli [6]

# HERDS. Animal Husbandry and its Economic Role in the Development of Central Mediterranean Protohistoric Societies: An introduction

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The project *Herds. Animal Husbandry and its Economic Role in the Development of Central Mediterranean Protohistoric Societies* was carried out as part of the Italian MUR PRIN programme (*Progetti di Rilevante Interesse Nazionale*; Project no. 2020EP24PP_001). Conducted between May 2022 and May 2025, the research brought together five Italian universities as primary research units: Sapienza – University of Rome, serving as the coordinating institution; Alma Mater Studiorum – University of Bologna; University of Naples Federico II; University of Salento; and University of Turin. Further contributions were provided by the University of Modena and Reggio Emilia, the University of Sassari, and the Department of Earth Sciences at Sapienza University (fig. 1)[1].

The project addressed the chronological span between the 17th and 8th centuries BCE, encompassing the Middle and Late Bronze Age (MBA and LBA) as well as the Early Iron Age (EIA). Throughout this period, the archaeological record documents the consolidation of demographically substantial communities and increasingly stable settlement systems, frequently characterised by large-scale artificial fortifications. These developments are paralleled by the emergence of territorial organisations articulated across multiple spatial scales and marked by varying degrees of structural complexity.

More broadly, this trajectory reflects a progressive intensification of economic practices alongside a marked increase in socio-political complexi-

[1] Andrea Cardarelli was principal investigator from May 2022 to October 2024, and Giulia Recchia from November 2024 to May 2025.

| Site | Region | Site environment | Date | Date Samples |
|---|---|---|---|---|
| Frattesina | Veneto – Po Plain | Low plain | FBA | FBA |
| S. Rosa di Poviglio | Emilia – Po Plain | Low plain | MBA 2-RBA | MBA 3-RBA |
| Baggiovara | Emilia – Po Plain | High plain | MBA 1-2 | MBA 1-2 |
| Gaggio | Emilia – Po Plain | Low plain | MBA 1-2-MBA3 | MBA 1-2 |
| Solarolo | Romagna – Po Plain | Low plain | MBA 2-RBA | MBA 2 |
| San Michele – Monte Valestra | Emilia – Apennine | Mountain – summit | MBA 2-FBA | MBA 2-FBA |
| Pieve di Carpegna | Marche – Apennine | Mountain – small lake | EBA-MBA 1 | MBA 1 |
| Monte Croce Guardia | Marche – Apennine | Mountain – summit | FBA | FBA |
| Moscosi – Cingoli | Marche – Apennine | Mountain valley | MBA3-RBA2 | MBA3-RBA2 |
| Montarice | Marche | Coastal | MBA3-RBA | BM3-RBA |
| Monte Morra | Latium – Apennine | Mountain – summit | RBA-EIA | FBA-EIA |
| Crocetta – Tivoli | Latium | Hill valley | MBA 3 | MBA 3 |
| Campidoglio Giardino Romano – Roma | Latium | Hills – summit | RBA | RBA |
| Villaggio Macine – Lago Albano | Latium | Lake | EBA2-MBA 1-2 | MBA 1-2 |
| Coppa Nevigata | Apulia | Coastal lagoon | EBA 2-EIA | MBA 1-2-RBA |
| Torre Galli | Calabria | Hill plateau | EIA1 | EIA 1 |
| Mursia – Pantelleria | Sicily | Island | EBA 2-MBA 2 | MBA 1-2 |
| Sa Mandra Manna | Sardinia | Hill plateau | MBA 1 | MBA 1 |
| Sa Osa | Sardinia | Coastal lagoon | MBA 1-2-FBA | MBA / FBA |
| Abini | Sardinia | Hill valley | RBA-EIA | FBA |
| Iloi | Sardinia | Hill summit plateau | MBA-EIA | EIA1 |

Tab. 1 – Sites selected for Herds project.
*Contesti selezionati per il progetto Herds.*

ty, with communities exhibiting incipient forms of social stratification. In several regions, particularly between the final phases of the Late Bronze Age and the Early Iron Age, these processes culminated in the appearance of early forms of urbanisation.

Throughout this period, specialised craft production, exchange networks operating over both short and long distances, and interactions involving the circulation of raw materials, finished goods, technologies and ideologies expanded to an unprecedented degree, resulting in intense mobility across Europe and the Mediterranean.These economic and social developments brought about profound changes in primary production strategies, allowing the creation of substantial surpluses that supported significant population growth, alongside a marked increase in craft production and exchange. Within this framework, animal husbandry – and, more broadly, the exploitation of animal resources – played a crucial role.

Zooarchaeological evidence points to increasingly complex and diversified livestock management practices, including patterns of mobility and stabling, the possible selection of specialised varieties, and the consolidation of secondary product exploitation, such as wool, milk and artefacts made from hard animal materials. Faunal remains represent one of the most abundant categories of material recovered from archaeological contexts, and advances in zooarchaeological research over recent decades have greatly improved our understanding of protohistoric economies. More recently, biomolecular approaches – including stable isotope analysis, ZooMS, organic residue analysis, proteomics and ancient DNA – have further expanded the interpretative potential of these data.

Moreover, the analysis of vessel contents has provided new insights into the processing of animal-derived products, as shown by analyses


Fig. 1 – Universty involved in the Herds project.
*Università coninvolte nel progetto Herds.* 1.
Torino; 2. Bologna-Alma Mater; 3. Roma-Sapienza; 4. Napoli – Federico II, 5. Lecce-Unisalento. a) Modena and Reggio Emilia; b) Sapienza-Roma; c) Sassari.


Fig. 2 – Site considered in the Herds project.

*Contesti considerati nel progetto Herds.*

1. Frattesina; 2. S. Rosa Poviglio; 3. Gaggio; 4. Baggiovara; 5. S. Michele Valestra; 6. Solarolo; 7. Pieve di Carpegna; 8. Monte Croce Guardia; 9. Moscosi-Cingoli; 10. Montarice; 11. Monte Morra; 12. Crocetta-Tivoli; 13. Campidoglio Giardino Romano-Roma; 14. Villaggio Macine-Lago Albano; 15. Coppa Nevigata; 16. Sa Mandra Manna; 17. Iloi; 18; Abini; 19.Sa Osa; 20.Torre Galli; 21. Mursia – Pantelleria.

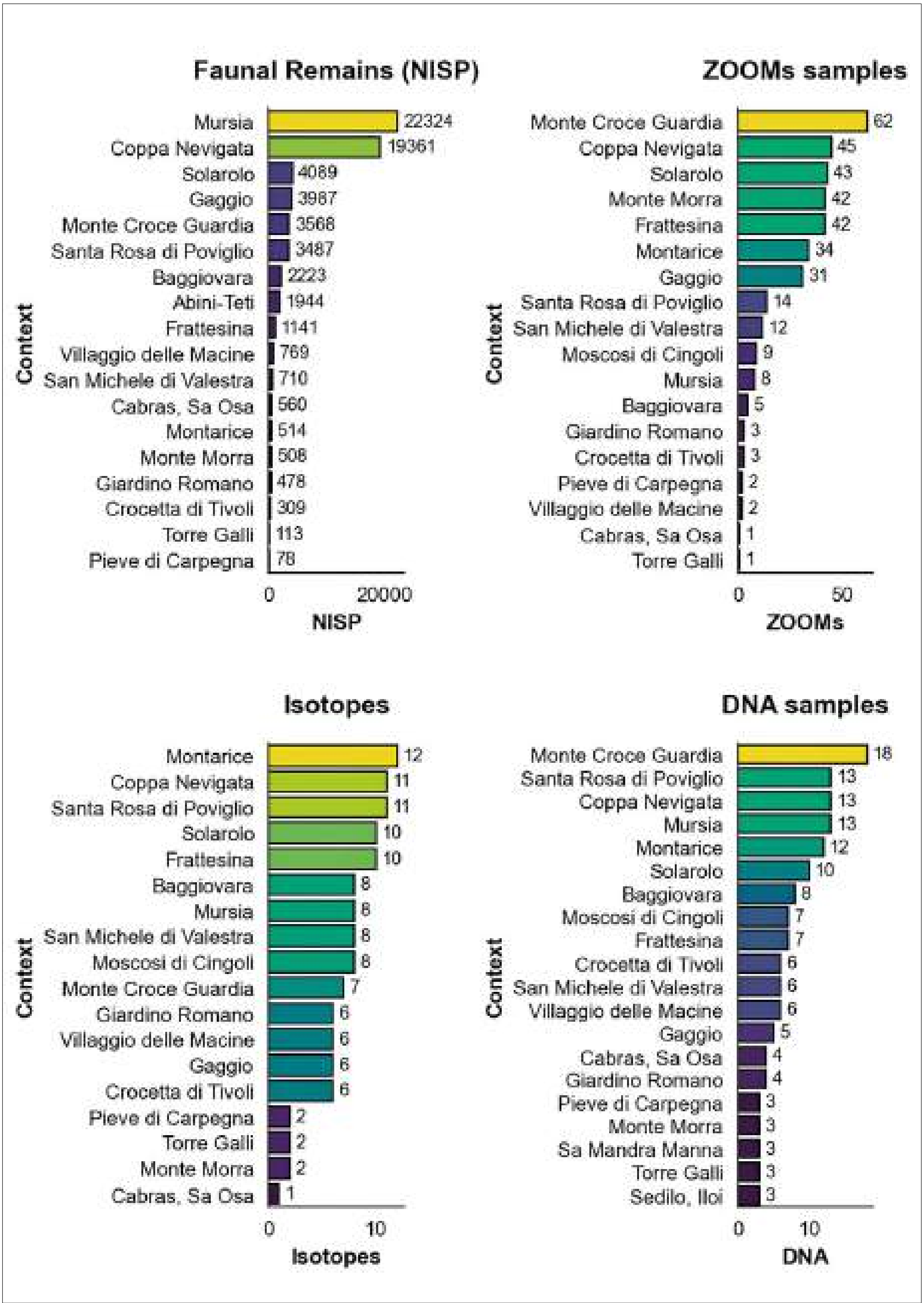


Fig. 3 – Number of samples analyzed.
*Numero di campioni analizzati.*

conducted within the HERDS project on vessel forms for which a role in dairy production had been proposed.

Within this perspective, the HERDS project aimed at integrating established zooarchaeological approaches with more recently developed methods in biomolecular archaeology and ancient DNA analysis, in order to expand the informational potential of faunal assemblages and translate it into a broader historical and archaeological framework. In this respect, the HERDS project also represents a significant innovative contribution within the Italian research landscape, where biomolecular and ancient DNA approaches have so far been only rarely applied to faunal remains, in contrast to their more extensive use in the study of human remains.

The project considered a wide geographical area, including sites distributed across several regions of Italy, with particular focus on the central-eastern Po Plain, central and southern Italy, Sardinia, and the island of Pantelleria. During the course of the research, however, some adjustments proved necessary due to logistical constraints and issues related to sample availability, resulting in a degree of geographical and chronological unevenness. In total, 21 archaeological contexts were sampled. These were investigated through a combination of zooarchaeological, ZooMS, biomolecular and ancient DNA analyses (see table 1; fig. 1). The majority of the contexts (14) are located in north-central Italy, while only two are in southern Italy. Four contexts are situated in Sardinia, and the site of Mursia on the island of Pantelleria was also included. From a chronological perspective, contexts dating to the Middle and Recent Bronze Age are predominant, followed by a smaller number attributable to the Final Bronze Age, while those dating to the Early Iron Age are comparatively few (figs. 2-3).

In November 2025, a workshop was held at the Department of Antiquities, Sapienza University of Rome, at which the preliminary results of the HERDS project were presented. Alongside contributions from the project's research units, the programme also included papers deriving from other zooarchaeological, isotopic and experimental archaeology studies, particularly those aimed at investigating processes related to milk processing.

This volume presents the results of the project through six main contributions addressing: (1) the archaeological framework of Italian protohistory in relation to the HERDS project; (2) the results of zooarchaeological and ZooMS analyses; (3) selected insights derived from strontium, oxygen and carbon isotope analyses; (4) a methodological contribution focusing on ancient DNA from domestic species raised for food production, including issues relating to sample preservation; (5) the results of organic residue analyses carried out on vessels interpreted as milk boilers; and (6) evidence from an excavation conducted in a mountainous Apennine context (Monte Morra), located near extensive upland pastures. These are followed by a series of synthetic contributions dedicated to the archaeological contexts analysed within the HERDS project, prepared by the directors of the respective excavations and research programmes.The volume also includes additional contributions presented at the workshop dedicated to the HERDS project.

The research initiated within this project does not end here: further publications are planned, particularly concerning the isotopic and genetic analyses undertaken as part of HERDS. We are confident that the project has opened up a highly promising line of research.

During the course of the project, we sadly lost our colleague and friend Jacopo De Grossi Mazzorin, who played a pivotal role in the development and consolidation of zooarchaeology in Italy, as well as in shaping the original concept of the HERDS project. We are certain that he would have shared our satisfaction at the completion and success of this work.

HERDS – Animal Husbandry and its Economic Role in the Development of Central Mediterranean Protohistoric Societies – Rivista di Scienze Preistoriche – LXXVI S6 – 2026 – pp. 13-74

RIVISTA DI SCIENZE PREISTORICHE

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# Societies, Mobility, and Trade in the Central Mediterranean between the Middle Bronze Age and the Early Iron Age (ca. 1700-700 BCE): An Archaeological Framework

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Abstract – Societies, Mobility, and Trade in the Central Mediterranean between the Middle Bronze Age and the Early Iron Age (ca. 1700-700 BCE): an archaeological framework. – This paper, conceived within the framework of the HERDS Project, provides a synthetic overview of the major historical processes spanning the period between the beginning of the Middle Bronze Age (MBA) and the Early Iron Age (EIA) (ca. 1700/1650-725 BC). This long time span was characterised by profound transformations and a general increase in economic, social, and political complexity, accompanied by significant demographic growth and an intensification of medium- and long-distance exchange networks with the Aegean, the eastern Mediterranean, and central-northern Europe. These networks involved the circulation of raw materials as well as utilitarian and prestige goods, contributing to increasing mobility and the transmission of knowledge and ideas. These developments were underpinned by the consolidation and expansion of subsistence strategies, in which animal husbandry played a pivotal role. Domestic animals provided not only primary food resources but also secondary products (dairy, wool, and osseous materials), as well as essential support for agricultural labour and transport. Within this framework, zooarchaeological evidence, integrated with biomolecular and ancient DNA analyses conducted as part of the HERDS Project, offers critical insights into key research questions, including herding practices, the mobility of domestic animals – closely linked to human mobility – and the potential presence of distinct haplogroups among caprines, cattle, and suids. This contribution synthesises current knowledge of the archaeological record and the economic and social dynamics in the regions investigated within the HERDS Project, including the Po Plain (with particular reference to Emilia-Romagna), central and southern Italy, Sicily, and Sardinia. From a chronological perspective, particular emphasis is placed on the Bronze Age, as most of the analysed contexts are attributable to this period.

Riassunto – Società, mobilità e reti di scambio nel Mediterraneo centrale tra la media età del bronzo e la prima età del ferro (circa 1700-700 a.C.): un quadro di riferimento archeologico. – Nell'ambito del progetto Herds questo contributo intende fornire un quadro sintetico dei processi storici avvenuti nei secoli compresi fra l'inizio del Bronzo medio e il primo Ferro (circa 1700-1650/725 a.C. Tale periodo fu caratterizzato da profonde trasformazioni e da un generalizzato aumento della complessità economica, sociale e politica. Contestualmente si verificò un elevato incremento demografico e dei traffici a media e lunga distanza con l'Egeo, il Mediterraneo orientale e l'Europa centro-settentrionale, che interessarono materie prime, beni di consumo e di lusso. Questi traffici determinarono anche un notevole aumento della mobilità e conseguentemente anche lo scambio di know-how e di idee. Tale sviluppo fu sostenuto attraverso un consolidamento e un accrescimento dell'economia di sussistenza che interessò fortemente l'allevamento degli animali domestici come fonte diretta di cibo, ma anche dall'utilizzo di prodotti secondari (latticini, lana, materia dura animale) e come fondamentale ausilio al lavoro agricolo e al trasporto. In questa prospettiva il record archeozoologico, le analisi biomolecolari e di genetica antica realizzate con il Progetto HERDS possono offrire importanti indicazioni per rispondere a fondamentali domande storiche, relative alle pratiche di allevamento, alla mobilità degli animali domestici strettamente correlata a quella umana, alla esistenza di possibili differenti aplogruppi di ovicaprini, bovini e suini. In particolare, in questo contributo sono state presentate le principali conoscenze degli aspetti archeologici e delle forme economiche e sociali avvenute nelle aree considerate nel progetto HERDS, comprese fra pianura padana, soprattutto per la parte relativa all'Emilia-Romagna, l'Italia centro-meridionale, la Sicilia e la Sardegna. Dal punto di vista cronologico sono state trattate maggiormente le tematiche relative all'età del bronzo in quanto i contesti considerati nell'ambito del progetto HERDS sono prevalentemente attribuibili a tale periodo.



*Parole chiave:* Italia peninsulare, pianura padana, Sardegna e Sicilia, Età del Bronzo, Prima età del Ferro, Economia, Società, Aspetti culturali.

*Keywords:* Peninsular Italy, Po Plain, Sardinia and Sicily, Bronze Age, Early Iron Age, Economy, Societies, Cultural Aspects.

## INTRODUCTION

This archaeological contribution aims to provide a synthetic overview of the cultural, economic, and socio-political aspects that characterise the long period under study across the territorial contexts involved in the HERDS project (central-eastern Po Plain, Marche, Lazio, Calabria, Apulia, the island of Pantelleria – Sicily, and Sardinia).

The HERDS project focuses on the millennium spanning from the beginning of the Middle Bronze Age to the Early Iron Age ($17^{th}$-$8^{th}$ centuries BC). During this period, Italy and the central Mediterranean underwent far-reaching demographic, socio-economic, and political transformations.

In contexts selected for the HERDS project, faunal remains recovered from archaeological investigations are generally abundant and significant. The application of ZooMS, bio-isotopic, and aDNA analyses has provided additional data to complement established zooarchaeological studies, enabling the acquisition of new and valuable insights into animal husbandry practices. More broadly, it provides significant support for the interpretation of protohistoric societies.

The historical questions addressed by the HERDS project can be summarised in four main aspects:

– Economic patterns of farming: from the adoption of animal penning to the introduction of fodder crops, and the role that transhumance may have played, even over short distances.
– Mobility of domestic animals in relation to the movements of individuals or human communities, such as exchange or cultural interactions (e.g. the introduction of exogenous specimens to strengthen or hybridise flocks and herds; gifts or dowries in marriage exchanges; indicators of movements of human groups of varying size, such as migrants or itinerant merchants).

<table>
<tr><th></th><th>Central-Eastern Po Valley</th><th>Central Italy</th><th>Southwestern Italy</th><th>Southeastern Italy</th><th>Sicily, Southern Calabria, Minor Islands</th><th>Sardinia</th></tr>
<tr><td>Early Bronze Age 2125/00-1650/25</td><td>Late Beaker Polada Cultural aspects of Romagna</td><td>Late Beaker Belverde-Mezzano</td><td>Palma Campania, Early Protoapennine</td><td>Palma Campania, Early Protoapennine, Cavallino</td><td rowspan="2">Castelluccio, Rodì-Tindari, Cessaniti, Capo Graziano</td><td>Bonnannaro</td></tr>
<tr><td>Middle Bronze Age 1-2 (1650/25-1450/1425)</td><td rowspan="3">Terramare</td><td>Grotta Nuova</td><td>Late Protoapennine</td><td>Late Protoapennine, Early Apennine, Punta Le Terrare</td><td rowspan="3">Nuragic</td></tr>
<tr><td>Middle Bronze Age 3 1450/25-1325/00</td><td colspan="2">Apennine</td><td>Late Apennine, Punta Le Terrare</td><td>Thapsos-Milazzese</td></tr>
<tr><td>Recent Bronze Age 1325/00-1150</td><td colspan="3">Subapennine</td><td rowspan="2">Ausonio, Pantalica Nord, Cassibile, Mulino della Badia</td></tr>
<tr><td>Final Bronze Age 1150-950/25</td><td colspan="4">Protovillanovan</td><td rowspan="2">Post-Nuragic</td></tr>
<tr><td>Early Iron Age 950/25-750/25</td><td>Palaeovenetic, Villanovan</td><td>Villanovan, Latial, Picene and others</td><td>Villanovan, Fossakultur</td><td>Iapygian</td><td>Pantalica Sud</td></tr>
</table>

Tab. 1 – Protohistoric Italy and Tyrrhenian Islands. Schematic chronological subdivisions (dates BC) and main cultural aspects.

*Suddivisione cronologica schematica (date a.C.) e principali aspetti culturali della Protostoria italiana e delle isole tirreniche.*

– Development of breeding strategies linked to the intensive exploitation of secondary products (e.g. wool or dairy products).
– Identification of different haplogroups among domestic animals and their distribution across space and time.

These aspects have a potentially significant impact on various historical issues, such as the territorial organization of communities and the ways in which they used the landscape, the social organisation of work activities, the dynamics of contact and exchange, the socio-economic forms associated with livestock farming, for example in relation to the cultivation of agricultural land (plough, and other practices), the exploitation of pastures, the nutrition, and the accumulation of wealth.

As outlined in the introduction to this volume (Cardarelli *et al.* in this volume), the availability of faunal assemblages suitable for analysis has conditioned the selection of case studies, both in terms of their geographical distribution and chronological span. Contexts attributable to Bronze Age are notably better represented than those dating to the Early Iron Age (EIA). This imbalance has resulted in a greater focus on issues related to the Bronze Age rather than those of the Iron Age.

A schematic chronological subdivision (BC) and main cultural aspects are illustrated in tab. 1.

In the text, the following abbreviations are adopted to label the chronological phases: Early Bronze Age (EBA), Early Bronze Age 1 (EBA1), Early Bronze Age 2 (EBA2); Middle Bronze Age (MBA), Middle Bronze Age 1 (MBA1), Middle Bronze Age 2 (MBA2), Middle Bronze Age 3 (MBA3); Recent Bronze Age (RBA), Recent Bronze Age 1 (RBA1), Recent Bronze Age 2 (RBA2); Final Bronze Age (FBA), Final Bronze Age 1 (FBA1), Final Bronze Age 2 (FBA2), Final Bronze Age 3 (FBA3); Late Bronze Age (LBA); Early Iron Age (EIA) (figs. 1-6).


Fig. 1 – Archaeological contexts of the Early Bronze Age (EBA) mentioned in the text.

*Contesti archeologici del Bronzo antico (EBA) citati nel testo.*

1. Cortile San Martino; 2. San Pancrazio; 3. Cattolica via Carpignola; 4. Pieve di Carpegna; 5. Senigallia Strada del Giardino; 6. Ancarano di Sirolo; 7. Castel di Lama – Via Giordano Bruno; 8. Manaccora; 9. Torre Mileto; 10. Villaggio delle Macine; 11. Coppa Nevigata; 12. Monteroduni; 13. Trinitapoli; 14. Posta Rivolta; 15. S. Ferdinando; 16. Giovinazzo; 17. Ariano Irpino; 18. Toppo Daguzzo ipogei; 19. Garagnone; 20. Chiancudda; 21. Porto Perone; 22. Punta di Zambrone; 23. Mursia.


Fig. 2 – Archaeological contexts of the Middle Bronze Age 1-2 (MBA1-2) mentioned in the text.

*Contesti archeologici del Bronzo medio 1-2 citati nel testo.*

1. Oppeano; 2. Olmo di Nogara (necropoli); 3. Castello del Tartaro; 4. Santa Rosa di Poviglio; 5. Cortile San Martino; 6. San Pancrazio; 7. La Braglia – Case del Lago; 8. Redù; 9. Gaggio di Castelfranco; 10. Baggiovara; 11. Montale; 12. Ca' Nova di Albareto; 13. San Michele di Valestra; 14. Solarolo – Via Ordiere; 15. Cattolica via Carpignola; 16. Pieve di Carpegna; 17. Senigallia Strada del Giardino; 18. Ancarano di Sirolo; 19. Giacometti Quarry; 20. Grotta del Mezzogiorno; 21. Castel di Lama – Via Giordano Bruno; 22. Prato di Frabulino; 23. Luni sul Mignone; 24. Manaccora; 25. Campomarino; 26. Torre Mileto; 27. Molinella; 28. Villaggio delle Macine; 29. Coppa Nevigata; 30. Monteroduni; 31. Trinitapoli; 32. Posta Rivolta; 33. S. Ferdinando; 34. Giovinazzo; 35. Ariano Irpino; 36. S. Maria del Buonconsiglio – Bari; 37. Lavello 743; 38. Mola di Bari; 39. Toppo Daguzzo ipogei; 40. Garagnone; 41. Monopoli; 42. Egnazia; 43. Sa Mandra Manna – Tula; 44. Chiancudda; 45. Rissieddi; 46. S. Sabina tumulo; 47. Vivara; 48. Monte Sant'Antonio – Siligo; 49. Scogli di Apani; 50. Punta le Terrare; 51. Scoglio del Tonno; 52. Nuraghe Toscono – Borore; 53. Porto Perone; 54. Torre Castelluccia; 55. Roca; 56. Iloi-Sedilo; 57. Scalo di Furno; 58. Torre dell'Alto; 59. Portorusso; 60. Sa Osa – Cabras; 61. Leuca; 62. Torre Mordillo; 63. Gallo di Briatico; 64. Filicudi; 65. Lipari; 66. Mursia.

Fig. 3 – Archaeological contexts of the Middle Bronze Age 3 (MBA3) mentioned in the text.

*Contesti archeologici del Bronzo medio 3 (MBA 3) citati nel testo.*

1. Olmo di Nogara (necropoli); 2. Franzine (necropoli); 3. Fondo Paviani; 4. Scalvinetto (necropoli); 5. Castello del Tartaro; 6. Santa Rosa di Poviglio; 7. Beneceto; 8. La Braglia – Case del Lago; 9. Redù; 10. Gaggio di Castelfranco; 11. Casinalbo; 12. Anzola; 13. Montale; 14. Ca' Nova di Albareto; 15. San Michele di Valestra; 16. Solarolo – Via Ordiere; 17. Monte della Croce; 18. Riccione; 19. Misano Adriatico; 20. Fano – Foce dell'Arzilla; 21. Colle dei Cappuccini; 22. Montagnolo di Ancona; 23. Massignano; 24. Jesi; 25. Numana; 26. Montarice; 27. Moscosi di Cingoli; 28. Cisterna di Tolentino; 29. Treazzano di Monsampolo; 30. Luni sul Mignone; 31. Crocetta di Tivoli; 32. Manaccora; 33. Campomarino; 34. Torre Mileto; 35. Molinella; 36. Oratino; 37. Coppa Nevigata; 38. Trinitapoli; 39. S. Maria di Ripalta; 40. Canosa; 41. Ariano Irpino; 42. Lavello 743; 43. Toppo Daguzzo ipogei; 44. Monopoli; 45. Egnazia; 46. Sa Mandra Manna – Tula; 47. Chiancudda; 48. Rissieddi; 49. S. Sabina tumulo; 50. Vivara; 51. Monte Sant'Antonio – Siligo; 52. Torre Guaceto necropoli; 53. Scogli di Apani; 54. Punta le Terrare; 55. Scoglio del Tonno; 56. Nuraghe Toscono – Borore; 57. Porto Perone; 58. Torre Castelluccia; 59. Roca; 60. Iloi – Sedilo; 61. Scalo di Furno; 62. Torre dell'Alto; 63. Portorusso; 64. Sa Osa – Cabras; 65. Nuraghe Is Paras – Isili; 66. Broglio di Trebisacce; 67. Leuca; 68. Nuraghe Gasoru – Orroli; 69. Genna Maria – Villanovaforru; 70. Nuraghe Arrubiu – Orroli; 71. Torre Mordillo; 72. Filicudi; 73. Lipari; 74. Thapsos.


Fig. 4 – Archaeological contexts of the Recent Bronze Age (RBA) mentioned in the text.

*Contesti archeologici del Bronzo Recente (RBA) citati nel testo.*

1. Vallese di Oppeano; 2. Olmo di Nogara (necropoli); 3. Franzine (necropoli); 4. Fondo Paviani; 5. Scalvinetto (necropoli); 6. Castello del Tartaro; 7. Campestrin; 8. Santa Rosa di Poviglio; 9. Beneceto; 10. La Braglia – Case del Lago; 11. Redù; 12. Casinalbo; 13. Anzola; 14. Montale; 15. Monte Pilastro; 16. Spilamberto – Cave di Ponte Rio; 17. Vetta di Monte Valestra; 18. San Michele di Valestra; 19. Monte Gebolo; 20. Monte Santa Giulia; 21. Solarolo – Via Ordiere; 22. Monte della Croce; 23. Monte Cimone; 24. Riccione; 25. Misano Adriatico; 26. Fano – Foce dell'Arzilla; 27. Colle dei Cappuccini; 28. Montagnolo di Ancona; 29. Jesi; 30. Numana; 31. Monte Croce Guardia; 32. Montarice; 33. Moscosi di Cingoli; 34. Cisterna di Tolentino; 35. Treazzano di Monsampolo; 36. Luni sul Mignone; 37. Monte Rovello; 38. Monte Morra; 39. Manaccora; 40. Campomarino; 41. Torre Mileto; 42. Campidoglio – Giardino Romano; 43. Molinella; 44. Oratino; 45. Coppa Nevigata; 46. Monteroduni; 47. Trinitapoli; 48. S. Maria di Ripalta; 49. Canosa; 50. Ariano Irpino; 51. Lavello 743; 52. Toppo Daguzzo ipogei; 53. Lacedonia; 54. Monopoli; 55. Egnazia; 56. Sa Mandra Manna – Tula; 57. Sant'Imbenia – Alghero; 58. Chiancudda; 59. Rissieddi; 60. Monte Sant'Antonio – Siligo; 61. Torre Guaceto necropoli; 62. Punta le Terrare; 63. Timmari; 64. Scoglio del Tonno; 65. Surbo; 66. Nuraghe Toscono – Borore; 67. Porto Perone; 68. Torre Castelluccia necropoli; 69. Torre Castelluccia; 70. Roca; 71. Iloi – Sedilo; 72. Scalo di Furno; 73. Abini – Teti; 74. Torre dell'Alto; 75. Sa Osa – Cabras; 76. Nuraghe Is Paras – Isili; 77. Broglio di Trebisacce; 78. Leuca; 79. Nuraghe Gasoru – Orroli; 80. Genna Maria – Villanovaforru; 81. Nuraghe Arrubiu – Orroli; 82. Torre Mordillo; 83. Punta di Zambrone; 84. Lipari; 85. Pantalica.


Fig. 5 – Archaeological contexts of the Final Bronze Age (FBA) mentioned in the text.
*Contesti archeologici del Bronzo finale (FBA) citati nel testo.*

1. Fondo Paviani; 2. Campestrin; 3. Frattesina; 4. Narde (necropoli); 5. Fondo Zanotto (necropoli); 6. Villamarzana; 7. Felsina; 8. Vetta di Monte Valestra; 9. San Michele di Valestra; 10. Pietra di Bismantova (necropoli); 11. Monte della Croce; 12. Colle dei Cappuccini; 13. Massignano; 14. Monte Croce Guardia; 15. Monte Cimino; 16. Luni sul Mignone; 17. Coste del Marano; 18. Monte Rovello; 19. Monte Morra; 20. Manaccora; 21. Campomarino; 22. Torre Mileto; 23. Ardea; 24. Coppa Nevigata; 25. S. Maria di Ripalta; 26. Ariano Irpino; 27. Lavello 743; 28. Toppo Daguzzo ipogei; 29. Monopoli; 30. Egnazia; 31. Sant'Imbenia – Alghero; 32. Monte Sant'Antonio – Siligo; 33. Timmari; 34. Surbo; 35. Nuraghe Toscono – Borore; 36. Porto Perone; 37. Torre Castelluccia necropoli; 38. Torre Castelluccia; 39. Roca; 40. Iloi – Sedilo; 41. Scalo di Furno; 42. Abini – Teti; 43. Torre dell'Alto; 44. Sa Osa – Cabras; 45. Nuraghe Is Paras – Isili; 46. Broglio di Trebisacce; 47. Leuca; 48. Nuraghe Gasoru – Orroli; 49. Genna Maria – Villanovaforru; 50. Nuraghe Arrubiu – Orroli; 51. Torre Mordillo; 52. Lipari; 53. Castellace; 54. Pantalica.


Fig. 6 – Archaeological contexts of Early Iron Age (EIA) mentioned in the text.

*Contesti archeologici del primo Ferro (EIA) citati nel testo.*

1. Fondo Zanotto (necropoli); 2. Villamarzana; 3. Felsina; 4. Colle dei Cappuccini; 5. Matelica; 6. Tarquinia; 7. Manaccora; 8. Campomarino; 9. Torre Mileto; 10. Roma; 11. Coppa Nevigata; 12. S. Maria di Ripalta; 13. Ariano Irpino; 14. Toppo Daguzzo ipogei; 15. Monopoli; 16. Egnazia; 17. Sant'Imbenia – Alghero; 18. Monte Sant'Antonio – Siligo; 19. Pontecagnano; 20. Nuraghe Toscono – Borore; 21. Porto Perone; 22. Torre Castelluccia; 23. Roca; 24. Iloi – Sedilo; 25. Scalo di Furno; 26. Abini – Teti; 27. Nuraghe Is Paras – Isili; 28. Broglio di Trebisacce; 29. Leuca; 30. Nuraghe Gasoru – Orroli; 31. Genna Maria – Villanovaforru; 32. Sant'Anastasia – Sardara; 33. Nuraghe Arrubiu – Orroli; 34. Torre Mordillo; 35. Torre Galli; 36. Pantalica.

## 1. PO PLAIN

### 1.1 Terramare: Territorial and Settlement Organisation from Origins to Crisis

At the beginning of the MBA (ca. 1650-1600 BC), the Terramare culture emerged in the central-eastern Po Plain and developed successfully over the following five centuries, representing one of the most demographically and economically significant societies of European protohistory (Bernabò Brea-Cardarelli-Cremaschi 2018; Cardarelli 2009; Cupitò and Leonardi 2015; Dalla Longa 2019; Vanzetti 2013).

Between the late third and the early second millennium BC, this sector of the Po Plain appears to have been only sparsely occupied. Human impact on the natural landscape – largely characterized by extensive lowland forests – remained limited. During the final phase of the EBA (ca. 1750-1650 BC), territorial occupation began to intensify, possibly in connection with climatic changes linked to the onset of the Löbben climatic phase, characterised by increased humidity. Enhanced fluvial discharge, including that of Apennine-fed streams, together with the widespread presence of resurgence springs, favoured the progressive settlement of the plain by pioneering communities seeking to exploit newly accessible fertile lands for agriculture and pastoral activities.

On the basis of the archaeological record, the principal component appears to have originated from the north, namely from the post-Polada pile-dwelling cultural milieu; however, smaller groups also moved into the region from the south

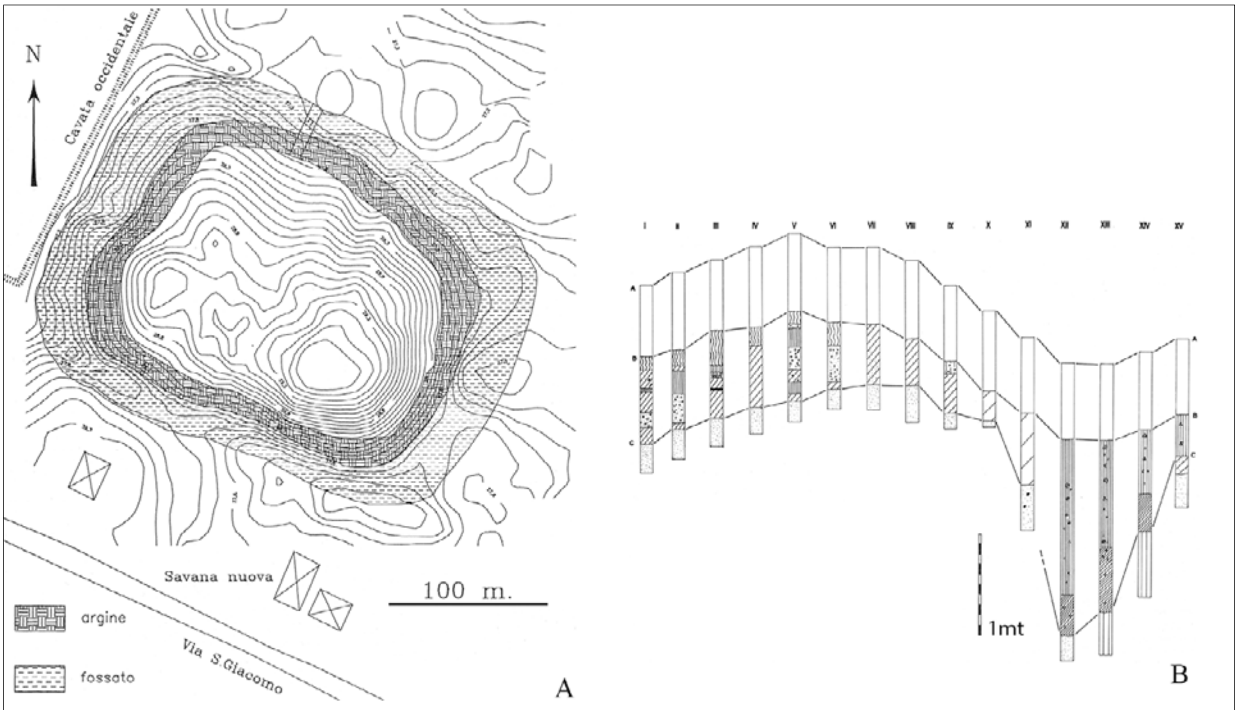


Fig. 7 – The Terramara of Savana di Cibeno (Carpi – Modena). A: This Terramara epitomises terramare settlements in terms of both layout and the presence of a surrounding ditch (light hatching) and an embankment (dark hatching). Despite intensive agricultural exploitation, part of the archaeological deposit – originally up to 4 m thick – has been preserved; B: Section of the ditch and earthen embankment derived from multiple cores obtained using a pedological probe. The ditch is between 25 and 28 m wide, while the embankment is approximately 20 m wide. The surviving height of the embankment is about 2 m. Anthropogenic layers (hatched) reach a maximum thickness of 1.20 m. (Adapted from Cardarelli and Cattani 1994).

*La Terramara di Savana di Cibeno (Carpi – Modena). A: questa Terramara rappresenta un esempio paradigmatico di insediamento terramaricolo in termini di forma, presenza del fossato (retino chiaro) e dell'argine terrapieno (retino scuro). Nonostante il forte sfruttamento agricolo la Terramara ha conservato parte del suo deposito originale che in origine era spesso 4 m. Le curve di livello sono distanziate di 20 cm.; B: sezione del fossato e del terrapieno ricavata da carotaggio con sondino da geopedologico. La larghezza del fossato è compresa fra 25 e 28 m., quella dell'argine terrapieno è di circa 20 m. L'altezza residua del terrapieno è di circa 2 m. Gli strati antropizzati (retinati) raggiungono uno spessore massimo di 1,20 cm. (Rielaborato da Cardarelli e Cattani 1994).*

(the Grotta Nuova cultural aspect – Castellaccio d'Imola *facies*; Pacciarelli 1997; Erbetti 2025) and from the west, particularly from Liguria and southern Piedmont.

The pioneering – or "colonizing" – phase entailed intensive deforestation, as documented at sites such as San Pancrazio, Cortile San Martino, and in the basal layer of the Montale terramara (Bernabò Brea-Cardarelli-Cremaschi 2018; Cardarelli and Labate 2004). The progressive expansion of human settlement led to a profound transformation of the landscape, which assumed a distinctly anthropogenic character.

By the mid-16$^{th}$ century BC, this pioneering process was complete, and the Terramare cultural phenomenon emerged with its defining features, represented by hundreds of settlements that were initially homogeneous in form, size and organisation.

The Terramare phenomenon extended across much of the Emilian plain west of Bologna and the lowland districts of Cremona, Mantua, and Verona, while exerting significant influence on adjacent areas, including the foothills, the Emilian Apennines, and parts of Romagna. The term *Terramare* originally referred to the characteristic settlement mounds and was later broadened to include the material and craft production associated with this cultural phenomenon.

During the MBA1-2 phases, settlements rarely exceeded 2 hectares in extent. They were generally quadrangular in plan, although in some cases they assumed different shapes in adaptation to local geomorphological conditions. From MBA3 onward, certain villages attained much larger dimensions, in some cases approaching 20 hectares (Bernabò Brea-Cardarelli-Cremaschi 2018).

Since the earliest phases, settlements were fortified with earthen ramparts and wide surrounding ditches, which were often fed by nearby watercourses via feeder channels (fig. 7A-B). These structures not only served a defensive purpose but also functioned as reservoirs, supporting irrigation and the development of increasingly sophisticated hydraulic systems during MBA3-RBA phases (Cremaschi and Pizzi 2021; De Guio *et al.* 2015; De Guio 2021). Houses were often constructed on raised wooden platforms, and their ground plan was predominantly rectangular, although ground-founded structures are also attested, including examples with an apsidal layout. The internal organisation of the villages was regular, structured along orthogonal axes; alongside domestic units, there were also ancillary buildings intended for service functions or productive activities.

During the earliest phases attributable to MBA1 and 2, houses generally measured between 50 and 60 square meters, although both smaller and larger dwellings are documented. Demographic estimates – based on reasonably reliable data, particularly from extensive excavations such as that of the Terramara of Gaggio di Castelfranco – suggest a population density of approximately 125 inhabitants per hectare (Balista *et al.* 2008; Scacchetti 2018). In addition to the fortified villages proper, smaller settlements are also attested, suggesting occupation beyond the defended sites and consisting of habitation nuclei of more limited extent.

For the MBA2 phase, hypotheses concerning the region's overall demographic scale have been proposed. Although the number of known settlements is high, the record remains substantially incomplete, as many areas are poorly investigated and in others alluvial deposits have buried Terramare evidence at considerable depth. Consequently, population estimates are based on projections from zones with higher settlement densities, suggesting a total of approximately 100,000-125,000 inhabitants. In the subsequent phases, between MBA3 and the RBA, when the Terramare culture reached its apogee, a process of territorial reorganization became evident, marking the end of the previous relative uniformity (Cattani 2024). Alongside villages of modest size (generally under 2 hectares), a few much larger settlements emerged (e.g., Santa Rosa di Poviglio, Redù, La Braglia-Case del Lago), in some cases exceeding 15 hectares. This indicates a profound transformation in territorial and political organization, likely associated with the emergence of a more hierarchical system (Di Renzoni 2006; Bernabò Brea-Cardarelli-Cremaschi 2018). Some of the larger sites were likely accompanied by smaller settlements, exercising political control over territories of limited extent (a few dozen square kilometers). The number of inhabited sites increased, but more importantly the total area occupied by settlements expanded markedly. This growth likely entailed a significant demographic increase, possibly reaching 200,000-250,000 individuals (fig. 8). In the terminal phase of the RBA (ca. 1200-1150 BC), the Terramare system underwent a severe crisis, marked by widespread settlement contraction (fig. 9). Within a few decades, it collapsed entirely, resulting in the substantial depopulation of the Po Plain (Cardarelli 2009; 2020).

### 1.2 Economy and Exchange Network in Terramare

The remarkable development of the Terramare society was underpinned by a highly productive economy. Palynological evidence indicates that Terramare occupation was initially associated with a significant reduction in forest cover, driven both by the need to clear land for cultivation and pasture and by timber felling for village construction and related wooden infrastructures. This decline in arboreal cover intensified over time, reaching its peak during the later occupational phases (Cremaschi *et al.* 2016; Mercuri *et al.* 2006; 2015). The systematic use of the animal-drawn plough – attested by several wooden examples – and the capacity for water management and redistribution, particularly during the apogee phase, facilitated abundant cereal production, including emmer, wheat, barley, and millet, complemented by some legumes.

From MBA3 onwards, irrigation channels formed an extensive hydraulic network surrounding settlements, as evidenced in the Valli Grandi Veronesi and at the Terramare sites of Santa Rosa di Poviglio and Redù. The organization of the complex hydraulic system documented at the Terramara of Castello del Tartaro may suggest the existence of land parcels designated for specific crops, potentially allocated to distinct productive units (De Guio *et al.* 2015; Cremaschi and Pizzi 2021; Cremaschi and Zerboni in this volume; Cardarelli *et al.* 2003).

Animal husbandry played a central role in Terramare subsistence and the limited presence of wild fauna suggests that hunting contributed minimally to subsistence (De Grossi Mazzorin 2013; Cianfoni *et al.* in this volume). Contextual estimates, notably from the MBA2 phase at Solarolo, via Ordiere, indicate a high availability of animal resources. Caprines (predominantly sheep) – were generally the most abundant, followed by pigs and cattle (Debandi *et al.* in this volume).

Herding practices appear largely sedentary, as supported by isotopic evidence (Sabatini *et al.* 2022; Cavazzuti *et al.* in this volume). Micromorphological analyses of growth deposits associated with structures at Oppeano, dated to the early MBA phase, indicate the presence of byre-houses, suggesting at least partial coexistence of stabling and domestic activities (Nicosia *et al.* 2022; Polisca *et al.* 2025). The presence of stabling facilities beyond the settlement perimeter is particularly significant. At the Terramara of Beneceto, structures erected during the late RBA phase have been interpreted – based on micromorphological soil analyses – as serving distinct functions: some as stables for swine, others as hay storage (Bernabò Brea *et al.* 2022). This evidence may reflect a progressive development of animal husbandry practices over time.

It has been estimated that land use around the villages was distributed as ca. 20-30% to cultivation – mainly in the immediate vicinity of settlements – and 40-60% to pasture, possibly including fallow fields (Cardarelli 2009)[1]. Although assessments of agricultural and pastoral productivity vary, there is broad agreement that during MBA2 output was sufficient to meet subsistence needs.

Subsequent demographic growth, however, required responses to rising demand. The expansion of irrigation networks and further forest clearance may be interpreted as adaptive strategies that continued to secure food supplies, albeit with a reduced surplus potentially vulnerable under adverse conditions.

The strength of the primary economy fostered a marked expansion of craft production. Alongside abundant ceramic manufacture – at times suggestive of semi-specialized activity – antler was widely worked for ornaments, tools, and certain weapons. Most significant, however, was bronze metallurgy, both for its high degree of specialization and the challenges of raw material procurement. The quantity of bronze objects recovered from the Terramare surpasses that of any other MBA or RBA cultural context in Italy, encompassing weapons, ornaments, and numerous tools, including many bronze sickles. The

[1] A different assessment of production estimates is provided by Debandi *et al.* in this volume, with bibliography therein.

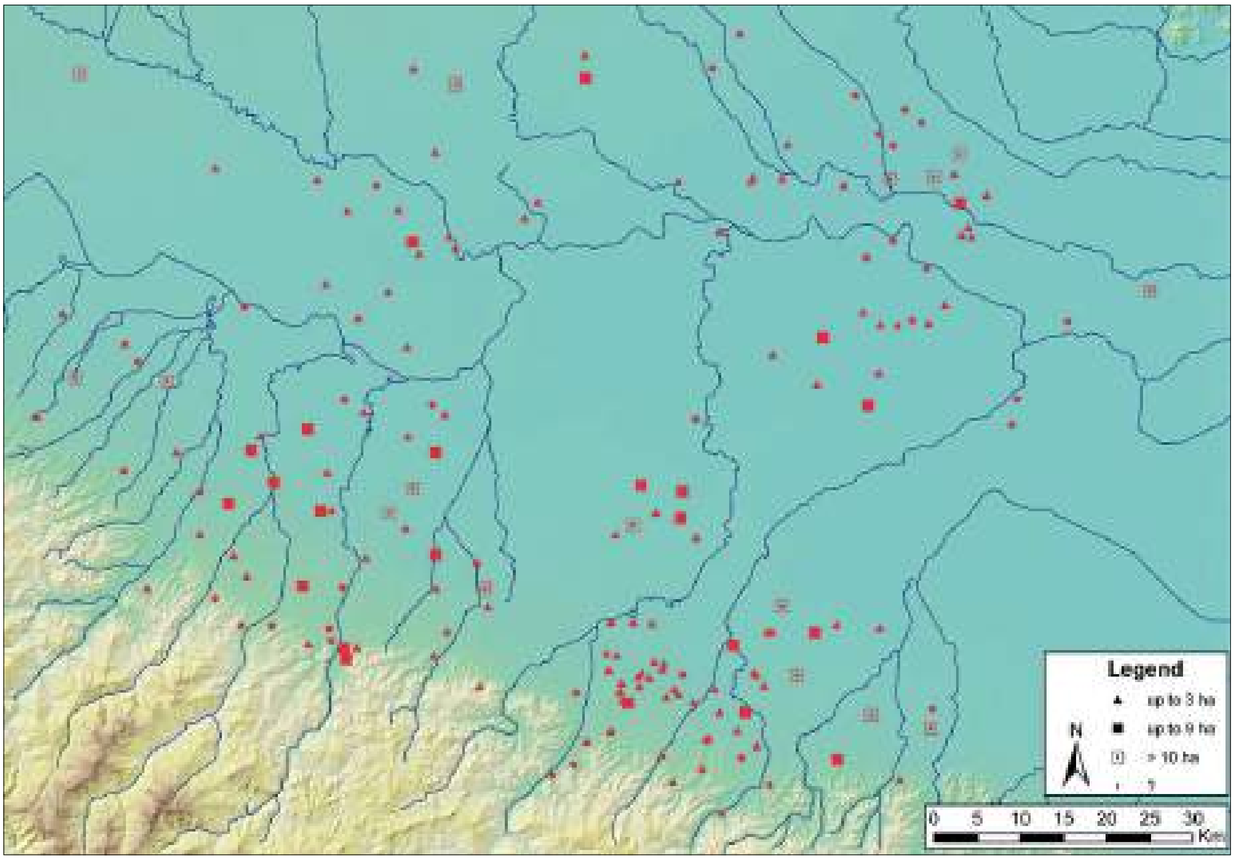


Fig. 8 – The Terramare area during the apogee phase (RBA 1). (Adapted from Cardarelli 2009).
*L'area delle Terramare durante la fase di apogeo (RBA 1). (Rielaborata da Cardarelli 2009).*

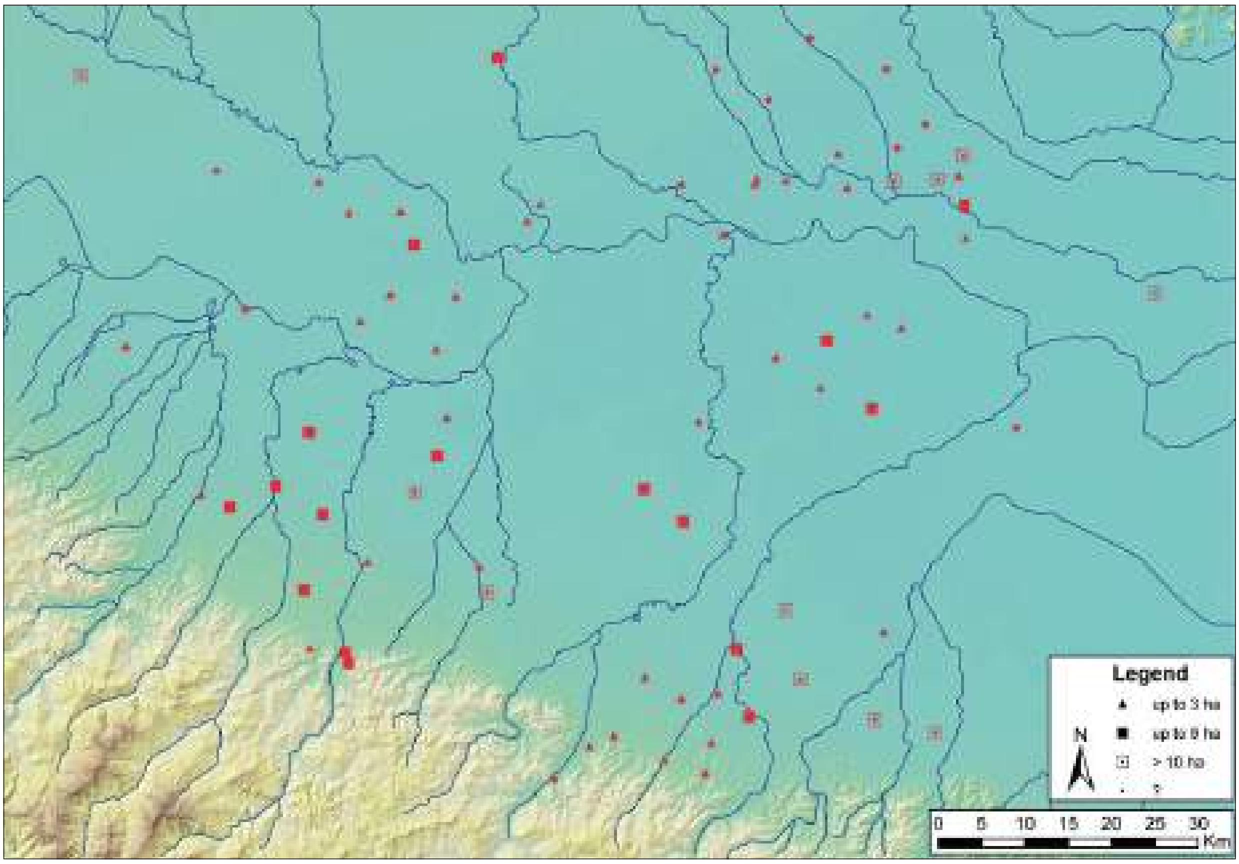


Fig. 9 – The *Terramare* area during the crisis phase (RBA2). (Adapted from Cardarelli 2009).
*L'area delle Terramare al tempo della crisi (RBA2). (Rielaborata da Cardarelli 2009).*

widespread presence in most Terramare sites of evidence for metallurgical activity – documented by pits, metalworking equipment, and casting moulds – demonstrates that the metalworkers were well integrated within village communities. The abundance of utilitarian implements further confirms a social role that extended across the various components of society (fig. 10). The procurement of raw materials – copper and tin – required consistent and regular supply networks. Lead isotope analyses conducted on bronze artefacts from the Terramare are currently ongoing; however, preliminary data suggest that during the early MBA phases copper sources were diversified, though predominantly Alpine in origin. In the subsequent MBA3 and RBA phases, it appears to have derived predominantly from the central – southern Alpine region (Artioli *et al.* 2016; 2020; Bellintani and Silvestri 2021; Severi *et al.* 2022)[2]. Specialized pyrotechnological craft activities are attested in the production of conical buttons in glassy faience during the early MBA phases (Bellintani-Angelini-Venturino 2025), while in RBA phase the manufacture of glass beads – particularly in High Magnesium Brown (HMB) glass – is documented. A glass-working plate discovered at the Terramara of Anzola may indicate production based on an HMB-type recipe, comparable to glass compositions attested in the Eastern Mediterranean (Bellintani and Angelini 2020; Cupitò *et al.* 2018). The presence of Aegean-type faience beads is, moreover, documented by lantern – or spoked wheel-shaped specimens recorded at Santa Rosa di Poviglio and in the necropolis of Franzine, both contexts dating to the RBA. In addition, several fragments from Fondo Paviani have been attributed to High Magnesium Glass (HMG), consistent with compositional recipes characteristic of the Eastern Mediterranean (Bellintani and Gonzato 2017; Bellintani and Angelini 2020; Aspes and Morelato 2025).

The importance of exchange networks within the Terramare system, including long-distance trade, is reflected not only in extensive metallurgical production – dependent on sustained supplies of copper and tin – but also in the widespread occurrence of amber beads. These were probably imported from the Baltic area, through European amber exchange networks, in a semi-finished state and subsequently reworked locally, as indicated by RBA-phase discs decorated with concentric-circle motifs in a characteristic Terramare style, such as those from Santa Rosa di Poviglio and Spilamberto (Cardarelli 2021; Cwalinski 2023).

In Veneto, particularly in the Valli Grandi Veronesi, the presence of ceramic vessels attributable to the RBA, largely of Italo-Mycenaean style, demonstrates openness to Mediterranean trade networks, which may have involved the presence of non-local individuals. The discovery at Fondo Paviani of locally produced Cypriot-Levantine-style ceramics further suggests the involvement of allochthonous actors, during RBA. This interpretation is corroborated by isotopic evidence showing that some of the inhumations in the Scalvinetto necropolis, associated with the nearby Terramara of Fondo Paviani, include a significant proportion of non-local individuals. By contrast, in necropolises south of the Po, particularly at Casinalbo, human mobility detectable through strontium isotopes appears restricted to the local area, within a radius of roughly 50 km (Cavazzuti *et al.* 2019a; 2020). The discrepancy between these two geographic zones may reflect the possibility that the Valli Grandi Veronesi, and specifically the site of Fondo Paviani, have functioned as a polity controlling the distribution of copper sources from Trentino to the numerous villages of the Terramare territory, especially during MBA3 and RBA phases. This economically strategic function may have attracted individuals or groups from more distant regions (Cupitò and Leonardi 2015; 2018; Cupitò-Dalla Longa-Balista 2020; Cardarelli 2021).

The reconstruction of the Terramare exchange economy outlined above lacks an explicit hypothesis regarding the commodities that Terramare communities may have offered in exchange for strategic resources such as metal or amber. As some potentially traded materials do not survive archaeologically, their economic role remains difficult to assess; nevertheless, indirect evidence can be inferred from artefacts associated with

[2] Additional data concerning lead isotope analyses were presented at the workshop *Fare Rame 2* (Trento, 20-22 June 2024) and are forthcoming (Cardarelli A., Angelini I., Artioli G., Cavazzuti C., De Falco M., Lugli F., Mazzucchelli M., Scacchetti F. – Circolazione del metallo tra le Alpi e gli Appennini).

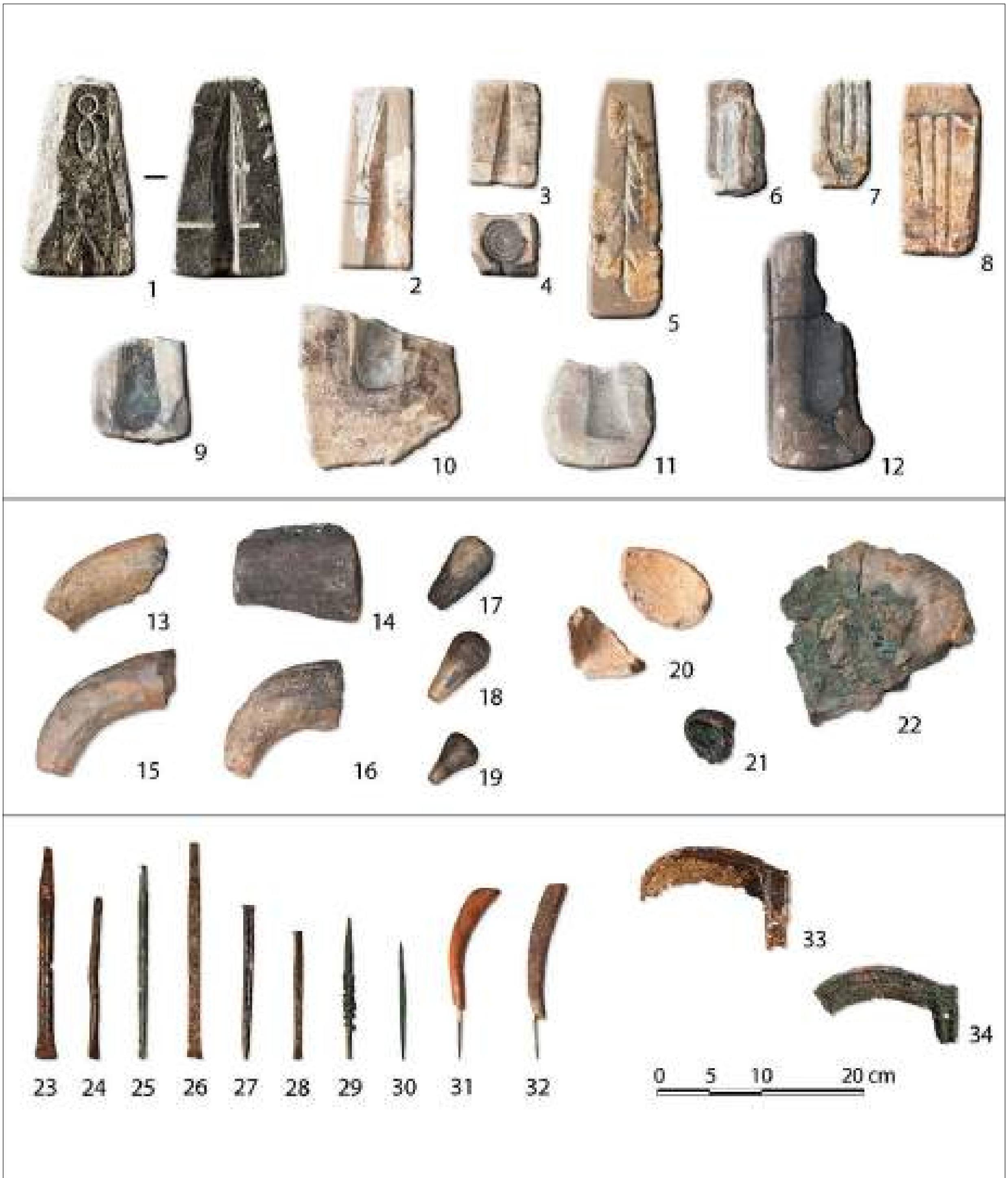


Fig. 10 – Metallurgist's toolkit and bronze working objects. Top: stone casting molds (1-12); in the middle, fragments of bellows nozzles (13-16), tuyères (17-19), and ceramic crucibles (20-22); bottom: bronze working tools – chisels, awls (some with deer-antler handles), and sickles (23-34). Provenances from the Modena Terramare sites: Casinalbo (1, 14); Castiglione di Marano (23, 24); Gaggio – Castelfranco Emilia (20); Gorzano (2, 3, 5, 8, 10, 12, 33); Montale (9, 11, 13, 16-19, 21, 22, 29, 30, 34); Redù (6, 7, 26-28, 32); S. Ambrogio (4, 15, 31); Savana di Cibeno (25). (Courtesy of Museo Civico di Modena; photo G. Pellacani).

*Strumentazione del metallurgo e oggetti in bronzo destinati al lavoro. In alto: forme di fusione in pietra (1-12); nel mezzo frammenti di ugelli di mantici (13-16), tuyères (17-19), crogiuoli (20-22) in ceramica tecnica; in basso oggetti da lavoro in bronzo: – sScalpelli, lesine, punteruoli (alcuni con manico in palco di cervo), falcetti. Provenienze dalle terramare modenesi: Casinalbo (1, 14); Castiglione di Marano (23, 24); Gaggio (20); Gorzano (2, 3, 5, 8, 10, 12, 33); Montale (9, 11, 13, 16-19, 21, 22, 29, 30, 34); Redù (6, 7, 26-28, 32); S. Ambrogio (4, 15, 31); Savana di Cibeno (25). (per gentile concessione del Museo Civico di Modena. Foto di G.Pellacani).*

Fig. 11 – Tongue-hilted sword from the ritual context of the S. Giulia summit (Palagano – Modena), 935 m a.s.l. (top and left); socketed sword intentionally broken from the summit of Monte Cimone (Sestola – Modena), 2,165 m a.s.l. (bottom and right). Both swords can be dated to the RBA phase. Courtesy of Museo Civico di Modena.

*Spada a lingua da presa dal contesto cultuale della vetta di S. Giulia – Palagano (Modena) 935 m slm (a sinistra e in alto); Spada a codolo fratturata intenzionalmente dalla vetta del Mone Cimone – Sestola (Modena) 2165 m. slm (a destra e in basso). Entrambe le spade sono databili al Bronzo recente. Gentile concessione del Museo Civico di Modena.*

production activities. This is particularly evident for spun yarns and textiles, produced using spindle-whorls and loom weights. Recent research, based on the exceptionally large assemblage of spindle-whorls recovered from the Terramara of Montale (4,636 items), indicates that the production of spun yarns, and likely textiles, exceeded subsistence needs and was largely oriented toward exchange (Sabatini 2024; Sabatini and Bergenbrant 2020; Sabatini-Earle-Cardarelli 2018).

Further significant evidence for the important role of exchange in the Terramare economy is provided by the numerous balance weights documented at Terramare sites, corresponding to two distinct weighing systems (Cardarelli *et al.* 2000; Cardarelli-Pacciarelli-Pallante 2004; Ialongo-Hermann-Rahmstorf 2021).

### 1.3 The Society of the Terramare

The social organization of the Terramare has been the subject of extensive specialized study. Renato Peroni considered the Terramare as an archetype of a "tribal system with territorial organization". The village community constituted the core of a complex system no longer based on a single, rigidly vertical kinship structure, while the hegemonic warrior elite acted as guarantors both within and beyond the community (Peroni 2004). More recent research has reconsidered and refined this perspective, while largely maintaining a theoretical framework aligned with Peroni's original positions (Cardarelli 2015; 2020).

Significant insights into social structures have been derived from the study of extensive bi-ritual necropolises and exclusively cremation cemeteries, such as those at Olmo di Nogara, Scalvinetto, and Casinalbo (Salzani 2005; Salzani 2020; Cardarelli 2014; 2023). Despite the constraints imposed by differing funerary practices – which sometimes limited or excluded grave goods – excavations, particularly at Casinalbo, demonstrate that social forms were broadly analogous across communities. A restricted number of hegemonic groups – comprising warriors, high-status women associated with them, and certain infants or adolescents of high social status – represented the society's leading tier. However, evidence from settlements does not support the idea of a strongly hierarchical society, as house sizes and their spatial arrangement show little variation, indicating the absence of marked socio-economic differentiation. The apparent contrast between the greater visibility of social differentiation in necropolises and the relative uniformity of settlements can be explained by the economic system of Terramare society. The construction and maintenance of large-scale infrastructure – necessary for agricultural organization, defence, and communication (including extensive irrigation networks, roads,[3] feeder canals, major fortifications, and rational internal village layouts) – required a substantial collective labour investment.

In more hierarchical societies, such projects were typically directed by central authorities and executed primarily through coerced or servile labour. In contrast, even during the Terramare's peak phase – when some social differentiation is evident, such as larger dwellings or extended family units potentially carrying greater social weight[4] – there is no indication of radical hierarchical reorganization. Communal infrastructure appears instead to have resulted from cooperative participation, facilitated by a high degree of social cohesion that ensured the stability of the village community. Social differentiation was primarily expressed through the rank of prominent individuals, whose authority remained constrained by the need to maintain communal consent, allowing for social distinctions to exist without producing substantial economic inequality.

It was likely this balance between social and economic structures that enabled Terramare communities to prosper successfully for five centuries, maintaining a remarkable degree of political stability (Cardarelli 2015; 2018; 2020)[5].

## 2. THE EMILIAN APENNINE AND THE TERRAMARE: A DIFFERENT AND RESILIENT TRAJECTORY

In recent decades, research in the Emilian Apennines has expanded substantially, bringing to light a significant number of MBA and RBA sites contemporaneous with the Terramare settlements of the Po Plain (Cardarelli 2006; Tirabassi 2006; Putzolu 2016; Putzolu and Cavazzuti 2019; Zanotti *et al.* 2023; Conversi and Bernabò Brea 2024; Cavazzuti *et al.* 2025). As expected, the location, morphology, organization, and scale of Apennine settlements differ markedly from those of the lowland contexts. Sites were frequently selected for their natural defensibility, in some cases reinforced by ditches or defensive enclosures positioned at the most accessible points of the settlement.

A significant distinction can be observed – particularly in the Modenese Apennine belt – between the earlier phases of the MBA and the MBA3-RBA horizon. In these later phases, in addition to the continued preference for defensible locations, summit sites were increasingly

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[3] For example, see the remarkable evidence of the wooden-pile road and land reclamation at Vallese di Oppeano (Gonzato and Nuvolari 2019).

[4] In particular, consider the case of burial cluster K in the Casinalbo necropolis (Cardarelli *et al.* 2014).

[5] Regarding the social and political status of the Terramare, it is interesting to refer to the point of view of Mark Pearce: *Using Heighway's criteria for the identification of a town in medieval Great Britain, it would seem that, although the* Terramare *are clearly not classical* poleis*, they meet many of the criteria used to define a medieval urban form* (Pearce 2020b: 23). Beyond the real applicability of such a comparison to the Italian and European Bronze Age, this parallel effectively conveys the complexity of Terramare society.

selected, affording substantially broader visual and territorial control. This shift in settlement strategy appears closely correlated with contemporary developments in the plain, where the settlement system evolved from a network of small, relatively homogeneous villages into a hierarchical territorial organization structured around larger central sites accompanied by smaller, presumably dependent, settlements (Cardarelli 2006; Cardarelli *et al.* 2018; Barbieri *et al.* 2018; Zanotti *et al.* 2023; Cavazzuti *et al.* 2025).

Apennine settlements do not reach the dimensions documented in the plain, generally extending over only a few hectares. Local geomorphological conditions precluded regular or formally planned layouts, necessitating the construction of terraces in order to optimize available space. Excavations in the Apennine region remain limited both in number and in extent; consequently, detailed reconstructions of internal spatial organization and of domestic or ancillary structures are not yet feasible. Nevertheless, recent investigations at Ca' Nova di Albareto, San Michele di Valestra, Vetta di Monte Valestra, and Monte della Croce have yielded significant new data (Conversi and Bernabò Brea 2024; Cremaschi and Zerboni in this volume; Tirabassi and Donati 2024; Cavazzuti *et al.* 2025).

From a cultural perspective, the western sectors of the Piacenza and Parma Apennines appear, already in the MBA, to be more closely connected to the *facies* of northwestern Italy, whereas the mountains and foothills of Reggio, Modena, and Bologna display a more pronounced adherence to the Terramare cultural sphere, while at the same time also remaining receptive to influences from central Italy.

Several high-altitude contexts dated to the RBA have been interpreted as cult sites or as locations for the ritual deposition of bronze objects. The most comprehensive evidence derives from the summit of Monte Santa Giulia, where the deposition of a sword is associated with a cultic fire installation, documented by a wooden platform upon which offerings – ceramic vessels and foodstuffs – were placed. Archaeological evidence and radiocarbon determinations assign this complex to an advanced phase dating to the RBA. Additional ritual bronze deposits are known from the summits of Monte Gebolo and Monte Pilastro in the Reggio Apennines, consisting predominantly of bronze sickles (Cardarelli 2019). Even more unequivocal is the discovery of an intentionally fragmented sword at the summit of Monte Cimone (2,165 m a.s.l.), which may be interpreted as a deliberate ritual act (fig. 11) likewise attributable to the RBA (Campagnari *et al.* 2017; Cardarelli and Pellacani 2018; Cardarelli and Spaggiari 2009).

In contrast to the Emilian plain – where the end of the RBA largely coincides with the termination of the Terramare phenomenon – the Apennine evidence indicates a continuation of occupation, albeit on a reduced scale, into the FBA, particularly during its initial phases. Notable examples include the well-known necropolis of Campo Pianelli, Pietra di Bismantova (Chilleri *et al.* 2023), Monte Valestra, San Michele di Valestra, Monte della Croce, and other sites in the Modenese and Bolognese Apennines.

The resilience of Apennine communities, compared with the collapse observed in the plain, suggests that the crisis at the end of the RBA had a less severe impact on societies characterized by simpler economic structures and lower demographic pressure, features typical of the mountain environment.

On the basis of current knowledge, the question remains open as to whether these Apennine contexts persisted until the later phases of the FBA and whether they may have contributed to the emergence of the Felsina protourban centre between the tenth and ninth centuries BC. (Vanzini 2023).

## 3. FRATTESINA AND THE MIDDLE POLESINE IN THE FINAL BRONZE AGE: AN INTERNATIONAL "HUB" OF SPECIALISED PRODUCTION AND EXCHANGE

North of the Po, the collapse of the Terramare system was accompanied by limited cases of continuity. Research conducted by the University of Padua at the site of Fondo Paviani, in the Valli Grandi Veronesi – already recognised as a major economic and political centre from MBA 3 onwards – has demonstrated partial continuity into the FBA. Nevertheless, even this site appears to have lost its centrality and was largely abandoned during the middle phase of the FBA (Cupitò-Dalla Longa-Balista 2020).

The causes of this decline likely include, in addition to broader climatic and environmental changes affecting the Po Plain, the loss of the economic function previously fulfilled by the site, which probably operated as the principal terminal of the routes conveying copper and other strategic goods into the Po Valley. The redistribution of these materials to the numerous Terramare settlements had previously conferred upon Fondo Paviani – and upon the Valli Grandi Veronesi as a whole – a position of primacy that, with the systemic crisis around the mid-12th century BC, became unsustainable.

From the advanced phase of the RBA onward, and especially during the FBA, a new area of outstanding economic and political importance emerged in the Middle Polesine, along the course of the ancient Po branch known as the Po di Adria. Although previously frequented, as indicated by archaeological finds, this area does not appear to have held a strategic role prior to the FBA, when it assumed a position of dominant centrality. This development can be attributed to its geographical setting: a water-rich environment close to the Adriatic Sea and located along a navigable fluvial corridor that enabled the reception of raw materials and goods from continental Europe and the Alpine region, and via Adriatic maritime routes from the Eastern Mediterranean. In other words, the collapse of the Terramare system – and of the "market" constituted by the dense network of settlements in the central-eastern Po Plain – shifted economic and political centrality toward an area more favourable to long-distance international exchange. The involvement of Aegean and Eastern Mediterranean agents had already begun during the RBA in the Valli Grandi Veronesi, as demonstrated by numerous fragments of locally produced Mycenaean-style pottery and Cypriot-Levantine vessels from Fondo Paviani, which were likewise probably of local manufacture. When the Terramare system collapsed as a primary political and economic hub, attention shifted eastward to an area better positioned to manage international connections along the axis linking the Alps to the Po Delta and, from there, to southern Italy, the Aegean, and the wider Mediterranean basin (Bettelli *et al.* 2015; Cupitò *et al.* 2015, 2020, 2025; Bettelli and Levi 2020; Cardarelli 2021).

In this context, strontium isotope (Sr) analysis conducted on the cremated remains from a burial in the Narde necropolis, associated with the large settlement of Frattesina at Fratta Polesine, is particularly significant (Cardarelli *et al.* 2015; Cavazzuti *et al.* 2019b). The individual – an adult male interred with a sword, belonging to the earliest phase of the necropolis and clearly representative of an elite group – had arrived at Frattesina during adolescence or early adulthood, very likely from the Valli Grandi Veronesi, specifically from Fondo Paviani. This evidence strengthens the hypothesis that the middle Polesine in the FBA inherited the economic primacy previously held by the Valli Grandi Veronesi, substantially amplifying its potential (Cavazzuti *et al.* 2019a; 2019b; Cavazzuti 2020).

Excavations at Frattesina have brought to light an extraordinary production and exchange centre of international relevance, currently the most significant known in Europe for the final centuries of the second millennium BC (figs. 12-14). Archaeological and archaeometric analyses document exceptional craftsmanship, largely based on imported raw materials. Copper – originating primarily from the mines of eastern Trentino – was worked on-site to produce large quantities of bronze objects, as attested by numerous moulds and five founder's hoards (Bellintani-Cardarelli-Lago 2024). Baltic amber, mainly employed in the manufacture of beads of the Tirinto and Allumiere types, arrived via fluvial routes across Europe and through Alpine passes. Elephant ivory and ostrich eggshells, used in the production of combs and ornaments, were most likely imported by merchants originating from the Eastern Mediterranean (Bietti Sestieri-Bellintani-Giardino 2019; Bellintani and Gonzato 2017; Bellintani and Silvestri 2021; Cardarelli 2021; 2023; Bellintani *et al.* 2021b; Cardarelli 2021; Cwalinski 2023; Jung 2020; Pearce 2020a).

The production of large quantities of glass beads in various colours was made possible by pyrotechnological techniques derived from the Eastern Mediterranean and reproduced locally according to regional compositional recipes, as confirmed by archaeometric analyses. Advanced expertise in glassworking also enabled experimental applications, including ceramic objects coated with a vitreous layer (Bellintani and Angelini 2020).

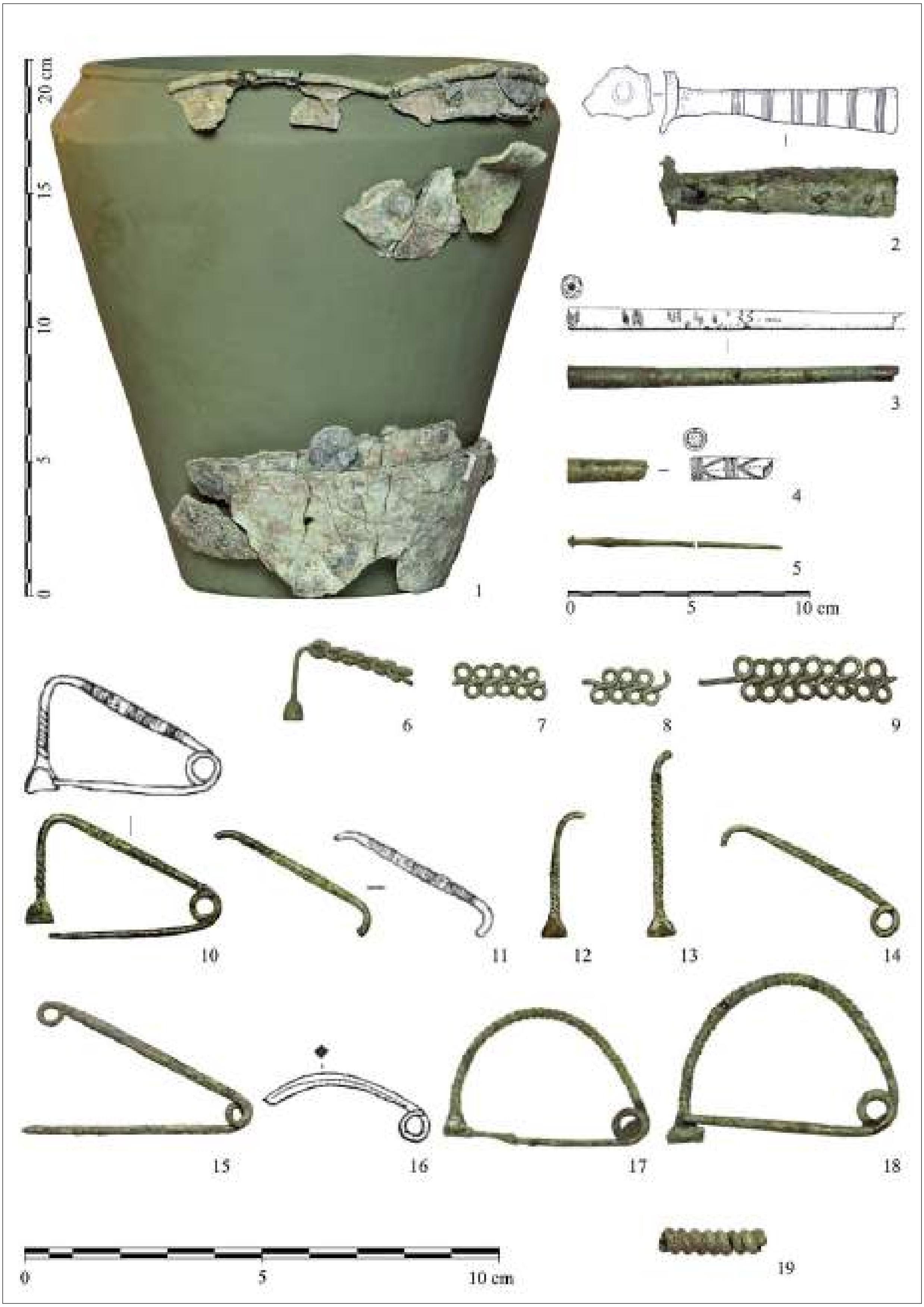

Fig. 12 – The Frattesina prestige goods hoard (Fratta Polesine – Rovigo): the situla containing bronze artefacts, amber, and worked animal hard materials (1), fibulae, pins, and other bronze objects (2-19). (After Bellintani-Cardarelli-Lago 2024).

*Il cosiddetto "tesoretto" di Frattesina (Fratta Polesine – Rovigo): la situla che conteneva i reperti in bronzo, ambra e materia dura animale (1), fibule, spilloni e altri oggetti in bronzo (2-19). (Da Bellintani-Cardarelli-Lago 2024).*


Fig. 13 – The Frattesina prestige goods hoard. (Fratta Polesine – Rovigo): Tiryns and Allumiere types amber beads, necklaces composed of blue glass beads and disc-shaped elements made from ostrich eggshell. (After Bellintani-Cardarelli-Lago 2024).
*Il cosiddetto "tesoretto" di Frattesina (Fratta Polesine – Rovigo): perle in ambra tipo Tirinto e Allumiere, collane in perle in vetro azzurro e in dischetti ottenuti da uova di struzzo. (Da Bellintani-Cardarelli-Lago 2024).*


Fig. 14 – The Frattesina prestige goods hoard. (Fratta Polesine – Rovigo): "Frattesina-type" combs in elephant ivory and so-called "alamari" (toggle fasteners). (After Bellintani-Cardarelli-Lago 2024).

*Il cosiddetto "tesoretto" di Frattesina (Fratta Polesine – Rovigo): pettini tipo Frattesina in avorio di elefante e cosiddetti "alamari". (Da Bellintani-Cardarelli-Lago 2024).*

The large settlement of Frattesina (no less than 25 ha) was densely inhabited[6]. Its two principal necropolises – Le Narde to the north) and Fondo Zanotto to the south – have so far yielded approximately one thousand cremation burials (Salzani 1989; 1986; 1991; Salzani and Colonna 2010; De Min 1982). On this basis, the settlement at its peak may reasonably be estimated to have housed approximately 1,500-2,000 inhabitants. It was not, however, the only significant FBA site in the middle Polesine. Campestrin di Grignano Polesine[7] has yielded evidence of an amber bead production workshop, while the large settlement of Villamarzana[8], located less than four kilometres from Frattesina along the Po di Adria, may have exceeded it in size. Additional settlement evidence in the Polesine confirms the existence of a densely populated, socially articulated, and politically complex polity, which nevertheless ceased to exist at the beginning of the EIA (late 10th – early 9th centuries BC), on the eve of the proto-urban processes that would also affect the Venetian area, as well as Felsina and the middle Tyrrhenian region.

## 4. THE CENTRAL ADRIATIC AREA: THE MARCHE BETWEEN THE MIDDLE BRONZE AGE AND FINAL BRONZE AGE

At the beginning of the MBA, the Marche region preserves a limited yet significant body of evidence. A pile-dwelling settlement at the small lacustrine basin of Pieve di Carpegna, in the Apennine zone, was already occupied during the EBA and abandoned in MBA1 (Baldelli *et al.* 2005; Cardarelli and Pellegrini in this volume). From a cultural perspective, it shows close connections with contemporary sites along the northern Marche coast and in lower Romagna, such as Senigallia and Cattolica (Miari *et al.* 2009; Delpino 2014). More limited links can be identified with contexts in central and southern Marche, including Ancarano – Sirolo, Mezzogiorno Cave in the Frasassi Gorge, Arcevia – Giacometti Quarry, and Castel di Lama – Via Giordano Bruno (Baldelli *et al.* 2005; Cazzella and Moscoloni 1994; Lucentini 2005).

From MBA3 onward and throughout the RBA, the archaeological record increases markedly, reflecting substantial continuity between the Apennine and Subapennine *facies*. Most sites are located between the coast and the inland hills, with a preference for fluvial terraces along valleys descending eastward from the Apennines to the Adriatic. Coastal sites tend to occupy natural landing places (e.g., Montagnolo and Colle dei Cappuccini near Ancona, Numana) or river mouths suitable for mooring, such as Riccione, Misano Adriatico, and Fano – Foce dell'Arzilla (Baldelli *et al.* 2005; Baldelli-Caldarelli-Ercoli 2014; de Neef and Paolini in this volume). The presence of trans-Adriatic materials at Montagnolo and Massignano near Ancona (Conero) indicates that maritime contacts across the Adriatic were already active during the MBA (Baldelli *et al.* 2005; Arena *et al.* 2020).

Several Marche sites dated to the RBA (Treazzano di Monsampolo, Montagnolo di Ancona, Jesi, Moscosi di Cingoli, and Cisterna di Tolentino) have yielded Aegean-type ceramic fragments, mostly Italo-Mycenaean, dating to LH IIIB/C, except for an earlier specimen from Treazzano (LH IIIB), probably imported from the Peloponnese (Jones *et al.* 2014). This evidence suggests that initial contacts with the Aegean world in the 13th century BCE developed

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[6] An interpretation of the spatial extent and internal organisation of the Frattesina site was proposed by Baldo-Balista-Bellintani (2018). Recent excavations (2022-2024) were carried out by Sapienza University of Rome and the Centro Polesano di Studi Storici, Archeologici ed Etnografici of Rovigo, under the coordination of the Soprintendenza ABAP for Verona, Rovigo, and Vicenza, within the framework of the *Prima Europa: La protostoria del Polesine* project funded by the Fondazione Cariparo. Within this framework, magnetometric surveys conducted by Wieke de Neef (University of Bamberg) have significantly enhanced our understanding of the settlement's spatial extent, confirming the presence of artificial channels delimiting the village and internal canals forming an orthogonal layout of blocks. The magnetometric analysis, conducted by Wieke de Neef (Bamberg University), has also demonstrated that the settlement probably extended further than previously assumed, encompassing part of the eastern periphery of the modern centre of Fratta Polesine. Moreover, it was possible to identify numerous dwellings and areas dedicated to production activities within these blocks.

[7] This context dates to the advanced RBA and the earliest FBA (Bellintani *et al.* 2015; Bellintani *et al.* 2021b). Recent excavations within the *Prima Europa* project have also revealed clear evidence of on-site amber working at Frattesina.

[8] The settlement of Villamarzana is a very extensive village (Bianchin Citton 2015). The main occupational phases are attested from the central phase of the FBA to EIA 1 (Salzani and Consonni 2005: Consonni 2008). At Villamarzana, excavations are currently underway, conducted by the University of Padua within the framework of the *Prima Europa: La Protostoria del Polesine* project, coordinated by SABAP Verona, Rovigo, and Vicenza, and supported by the Fondazione Cariparo.

Fig. 15 – The extensive plateau of the naturally fortified and strategically located settlement of Monte Croce Guardia (Arcevia – Ancona, 670 m a.s.l.). The site is estimated to extend over c. 25 ha. Dwellings and ancillary structures were constructed not only in the more gently sloping areas but also on the purposedly terraced slopes. Photo:Andrea Conte.

*Il grande pianoro sommitale dell'insediamento naturalmente difeso e dominante di Monte Croce Guardia (Arcevia – Ancona: 670 m slm.). L'estensione del sito è valutata attorno ai 25 ettari. Le abitazioni e le strutture di servizio erano anche costruite nei pendi su terrazzi, oltreché nelle arre meno acclivi. Foto: Andrea Conte.*

into more systematic e contacts and interactions during the mature and late RBA, possibly involving the presence of Aegean craftsmen or the transmission of technological knowledge through intensified exchange (Jones *et al.* 2014).

The occurrence of Italo-Mycenaean pottery in inland contexts at the foot of the Apennines, even in considerable quantities as at Cisterna di Tolentino, points to substantial mobility along the river valleys of the Esino, Musone, and Potenza, where several RBA sites are attested. These routes were plausibly used for seasonal transhumance between the lowland plains and Apennine pastures, as suggested by isotopic evidence from Montarice (Cavazzuti *et al.* in this volume).

By the end of the RBA, profound changes in settlement patterns become apparent, particularly during the FBA. As in the Terramare region, settlements occupied during the MBA and RBA in the Marche and Romagna were almost entirely abandoned. At the same time, the archaeological *facies* underwent a marked transformation, adopting decorative forms and stylistic elements clearly inspired by late terramare production production (Bettelli-Cardarelli-Damiani 2018). Settlement shifted to mountainous areas, generally characterised by naturally defensible positions offering broad territorial control. These changes likely reflect new defensive and territorial strategies, accompanied by adjustments in economic organisation, particularly in agriculture and livestock management (Bettelli *et al.* 2021).

A clear example is provided by the Arcevia area: several hilltop sites were abandoned at the end of the RBA (Moscoloni-Danesi-Galluzzi 2007; Damiani 2010), while the large summit settlement of Monte Croce Guardia emerged, apparently concentrating the local population into a single centre of approximately 25 hectares (fig. 15). Recent excavations have clarified its internal organisation, revealing rectangular huts up to 130 m², ancillary structures, and a layout probably subdivided into modules of approximately 0.25 hectares each, comprising one or two dwellings (Cardarelli *et al.* 2017; 2023).

With the transition from the FBA to the EIA, mountain settlements were abandoned and habitation returned primarily to coastal zones, hilly belts, and inland contexts located in broad valleys, as exemplified by the settlement and rich necropolises of Matelica.

## 5. SOUTHEASTERN ITALY

### 5.1 Environment, Settlement Pattern and Territorial Organisation in the Bronze Age

#### 5.1.1 *Environment and climatic evidence*

South-eastern Italy is characterised by a highly heterogeneous and environmentally varied landscape. It includes the Subapennine zone and the mountainous promontory of Gargano, the extensive Tavoliere Plain – the second largest plain in Italy after the Po Valley, the wide Murgia Plateau, the narrow Adriatic coastal plains, the Salento uplands and the Messapian plain.

During late prehistory the region was also characterised by a series of coastal and sub-coastal lagoons that played a significant role in Bronze Age settlement choices. Among these were Lake Varano, Lake Lesina, and Lake Battaglia on the northern and eastern coasts of the Gargano, the lagoonal system of Lakes Salso and Salpi immediately south of the promontory, and further south, Alimini Lakes and the lagoons along the Ionian coast of Apulia, including the Taranto lagoon of Mar Piccolo.

Bronze Age settlements in the region therefore occupied and exploited rather diverse ecosystems, characterised by different climatic conditions and environmental resources, developing specific economic strategies.

The history of research, particularly regarding the Bronze Age, has itself been uneven. Investigations have mainly focused on the coastal zones, where numerous settlements have been excavated and continue to be explored. By contrast, the data available for the inland areas remain limited and derive chiefly from surface surveys, many of which have been conducted only in recent years. This situation has also resulted in a bias in the documentation of paleoeconomic and paleoenvironmental data, which thus remain notably scarce for the inland areas.

Paleoenvironmental evidence derived from pollen records obtained through core drillings at Lake Battaglia, Lake Salso, Lake Salpi, and Lake Alimini Piccolo (Caroli and Caldara 2007; Di Rita and Magri 2009; Di Rita *et al.* 2011; Susini *et al.* 2023). A climatic shift towards aridity around 4000 cal. BP is documented. This phenomenon, widely attested in the central Mediterranean south of 43°N, resulted in a marked opening of the vegetation across the region (Di Rita and Magri 2009). From the early centuries of the 2nd millennium BC onwards, a general recovery of arboreal vegetation is observed. However, in the Tavoliere Plain and on the southern slopes of the Gargano the forest did not recover (as indicated by the Lake Salso sequence), and the landscape remained largely open, probably also owing to intensive local human activity within a semi-arid environment (Di Rita *et al.* 2011). Conversely, in the Salento Peninsula (as indicated by the Alimini Piccolo Lake sequence), an expansion of evergreen oaks is detectable, together with other Mediterranean trees and shrubs such as *Olea*, *Pistacia*, and *Phillyrea*. *Olea*, in particular, shows a marked increase from around 1600 BC, reaching a peak around 1100 BC. This trend might have been partly natural but was likely also influenced by human activity, including the exploitation of olive fruits (Di Rita and Magri 2009).

Anthracological evidence from Apulian sites, however, shows an apparently opposite trend, with a reduction in the proportion of *Olea* charcoal during the Late Bronze Age. This pattern has been interpreted as the result of more selective exploitation practices, with wild or progressively domesticated olive trees being increasingly managed for fruit production rather than used as firewood/carpentry. Such hypothesis is further supported by organic residue analyses from Coppa Nevigata revealing the production and use of olive oil since the 18th century BC (Evans and Recchia 2001-2003) and by the abundant olive stones from RBA layers at Monopoli – Piazza Palmieri (Primavera *et al.* 2015).

Climatic conditions, which were temperate and humid during the 18th-17th centuries BC, appear to have shifted towards more arid conditions around the 15th century BC (Primavera *et al.* 2015).

#### 5.1.2 *Cultural aspects*

From the early centuries of the 2nd millennium BC, there is a marked cultural discontinuity in the region with respect to the preceding period, both in the style of material productions, particularly ceramics, and in settlement patterns. Another element that becomes especially evident during the MBA is a cultural differentiation between the northern and southern parts of the region, encompassing not only pottery stiles and ritual and funerary practices but also primary economic strategies. This divide can be approximately located south to the Ofanto River valley.

Across the region, a ceramic style of the Palma Campania type becomes widespread, early 2nd millennium BC although it had already been attested earlier in Campania. In the northern area, it occurs together with early Protoapennine type elements (also documented in Molise, e.g. at Monteroduni, Recchia-De Dominicis-Ruggini 2006), while in the southern area it is associated with those of Cavallino type. By the 17th century BC, the Palma Campania component had largely disappeared. In the north, the Protoapennine style became consolidated, in connections with central and south-western Italy, whereas in the south Cavallino elements persisted alongside a local Protoapennine aspect characterised by distinctive stylistic traits (cf. Egnazia VII, Recchia and Ruggini 2009). From the mid-2nd millennium BC onwards, the Apennine style became established in the northern area, still connected with central and western Italy, while in the south a more autonomous cultural aspect developed, defined as Punta le Terrare, in which geometric incised decorations, often much simpler than the Apennine ones, occur only sporadically (Recchia 2010a).

Within this picture, the Gargano area and the eastern Tavoliere, although belonging first to the Protoapennine and later to the Apennine cultural sphere, are characterised in both phases by the occurrence of ceramic elements typical of trans-Adriatic Dinara-type productions, as well as by metal artefacts of western Balkan type. This evidence points to close contacts between this zone and the eastern Adriatic, which likely involved not only the circulation of models and goods but also the movement of individuals (Arena-Cardarelli-Tunzi 2018; Arena *et al.* 2020; Cazzella and Recchia 2018a, 2020).

With the RBA, the earlier differentiation between the northern and southern areas came to an end, giving way to a more widespread adoption of the Subapennine stylistic tradition. Differences nevertheless emerge between individual sites, even within the same areas, which incorporated, in varying ways, stylistic models circulating in the regions of central and south-western Italy (Cazzella and Recchia 2017).

In all likelihood, a tight connection persisted between the Gargano/eastern Tavoliere Plain area and the opposite Adriatic shore, reflected in the transmission of ceramic and metal models, albeit less clearly visible within the broader metallurgical *koine* (Cazzella and Recchia 2020).

#### 5.1.3 *Settlements and settlement patterns*

At the beginning of the 2nd millennium BC (EBA), the settlement pattern in the region appears to have been characterised by small, short-lived hamlets, generally located inland in ecological niches favourable for subsistence economy. Only a few of these sites have been excavated (i.e. Posta Rivolta and Garagnone in the north, and Cavallino in the south). This settlement pattern persisted throughout the whole of the Bronze Age.

Systematic surveys in inland areas (Irpinia, Celone Valley, Brindisi Murge plateau and north-western Murge plateau, Talamo and Ruggini 2005; Romano and Recchia; Recchia and Ruggini 2009; Recchia *et al.* 2024) have shown that such sites were often organised, probably on a kinship basis, into clusters of small groups of dwellings and associated activity areas located at short distances from one another (fig. 16). Moreover, surveys in mountainous areas of the Apennine have revealed the existence of mid- and high- altitude sites possibly linked to seasonal pastoral activities (Cazzella *et al.* 2020).

From the late 18th-17th centuries BC onwards, however, a new settlement pattern also emerged: that of long-living sites internally organised in a more cohesive manner, often protected by artificial defensive systems or situated in naturally defended locations. Their number increased from the mid-2nd millennium BC. Such settlements are commonly located along the coasts, in areas suitable for landing and maritime interaction (e.g. Campomarino, Torre Mileto, Manaccora, Coppa Nevigata, Mola di Bari, Egnazia, Punta le Terrare, Roca, Portorusso, Leuca, Porto Perone, Scoglio del Tonno), in the sub-coastal hill belt (e.g. Chiancudda, Rissieddi) and sometimes in coastal steep promontories (Torre dell'Alto: Iacono *et al.* 2023), and inland along natural transit routes (e.g. Ariano Irpino), reflecting growing engagement in exchange networks (Bettelli 2022; Cazzella and Recchia 2013a; Iacono 2019; with bibliography therein for the mentioned sites).

Although several fortified settlements are known, because archaeological research in the

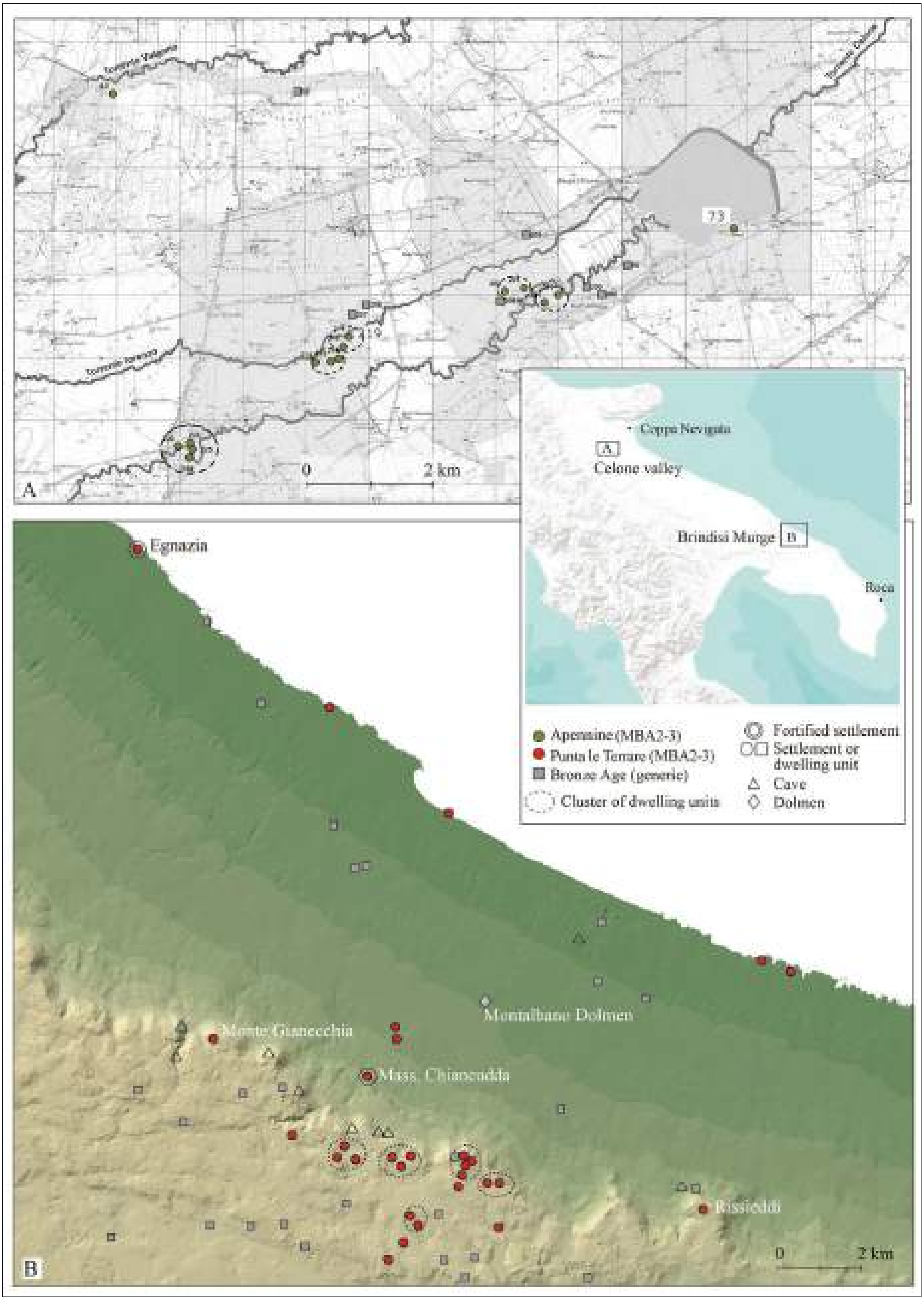


Fig. 16 – Distribution of MBA3 sites in areas investigated by systematic surveys in south-eastern Italy: Celone valley (A) and Brindisi Murge tableland (B); settlement organised in clusters are highlighted. (Adapted from Romano and Recchia 2006; Recchia and Ruggini 2009).

*Distribuzione dei siti relativi al BM3 in alcune delle aree sottoposte a ricognizione sistematica in Italia sud-orientale: Valle del Celone (A) e Murge brindisine (B); i cluster di siti sono evidenziati. (Rielaborato da Romano e Recchia 2006; Recchia e Ruggini 2009).*


Fig. 17 – The fortified settlement of Coppa Nevigata (Foggia) seen from the south-west with the Gargano promontory and the Adriatic Sea in the background (A), and seen from the north-west with the 17th century BC dry-stone wall and main gate flanked by jutting towers in the foreground (B). (Archive of the research at Coppa Nevigata; drone pictures E. Lucci).

*L'insediamento fortificato di Coppa Nevigata (Foggia) visto da sud-ovest con il Gargano e il mare Adriatico sullo sfondo (A) e visto da nord-ovest con le mura del XVII sec. BC e la porta di accesso fiancheggiata da torri in primo piano (B). (Archivio delle ricerche a Coppa Nevigata; riprese da drone E. Lucci).*

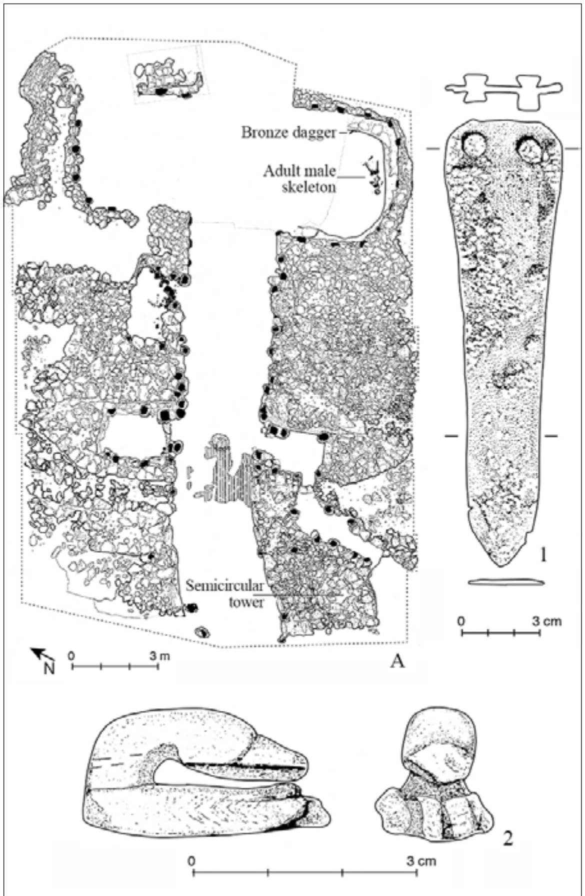


Fig. 18 – Roca (Lecce): plan of the 14th century BC gate, showing the position of the skeleton of a male individual died during the attack on the settlement (A); bronze dagger (1) and ornithomorphic ivory element (2) probably associated with the individual. (Adapted from Scarano 2012; Guglielmino-Pagliara-Rugge 2010).

*Roca (Lecce): planimetria della porta di accesso del XIV sec. a.C. con indicazione della posizione dello scheletro di un individuo deceduto durante l'attacco all'abitato (A); pugnale in bronzo di tipo egeo (1) ed elemento ornitomorfo in avorio (2) rinvenuti in prossimità dell'individuo. (Rielaborato da Scarano 2012; Guglielmino-Pagliara-Rugge 2010).*

region has focused particularly on them, most have been only partially investigated and/or were explored during the early to mid-20th century, often with limited stratigraphic documentation. Moreover, some lie beneath modern coastal cities such as Bari, Monopoli, Brindisi, and Taranto, restricting our understanding of their extent, internal organisation, and defensive systems. Notable exceptions are Coppa Nevigata in the north (fig. 17) and Roca in the south, both of which have been extensively investigated up to recent years.

One of the earliest dry-stone fortification walls is the early Protoapennine circuit at Coppa Nevigata (17th century BC). This already displays complex architectural and poliorcetic features (fig. 17.B), including a gate protected by projecting towers and a series of posterns crossing the wall (Cazzella and Recchia 2013a; Recchia and Cazzella 2019). The fortification at Roca, slightly later (16th century BC), is similarly complex, featuring an imposing gate that became increasingly articulated over time (fig. 18.A), together with a series of posterns in Phase II (Scarano 2012) and an external ditch belonging to the same phase. A large ditch was also added at Coppa Nevigata in the 14th century BC along the newly rebuilt drystone wall, which was equipped with a series of small towers.

Our knowledge of the internal organisation of these settlements remains limited. Available evidence suggests that, during the MBA, several settlements both in the northern and southern areas the region were characterised by communal spaces devoted to functional activities such as food processing (Recchia 2010a) and, at least at Coppa Nevigata, also the storage of crops (Cazzella and Recchia 2013b). Only a small number of dwelling structures are known from this period; these are generally curvilinear or horseshoe-shaped huts, such as those documented at S. Maria del Buon Consiglio (MBA1-2; Radina *et al.* 2002a) and S. Maria di Ripalta (MBA3; Tunzi *et al.* 2002). None of the settlements currently known show evidence of differentiated structures related to emerging groups. Although the construction of complex defensive systems must have required some form of coordination of collective work, this does not necessarily imply the presence of stable elites or economically differentiated groups, alike the situation observed in the Terramare culture (see *supra*).

More substantial data are available from the RBA onwards, pointing to a significantly changed scenario. At Coppa Nevigata, there is clear evidence for a complete reorganisation of the settlement layout, with elongated rectangular dwellings arranged along a common axis, possibly reflecting coordination by a stabilising central authority (Cazzella and Recchia 2023). At Roca, clearer evidence for the organisation of the settlement is available for the FBA, with indications of resource accumulation and control. These include the occurrence of large, cordoned *dolia*, sometimes clustered in a single building (Guglielmino

2014), and a large rectangular structure destroyed by fire, possibly composed of various adjoining spaces. This structure yielded evidence of metal accumulation in two hoards, and furthermore two pairs of decorated gold-sheet discs (Maggiulli 2006).

Long-lived fortified settlements vary in size, but within a relatively narrow range, from approximately 2.5 hectares (e.g. Coppa Nevigata) to 3-5 hectares (e.g. Roca). Although many of these sites remained occupied for extended periods, often until the EIA, and underwent substantial transformations in their architectural layout and internal organisation, their overall extent remained remarkably stable, with successive fortification lines rebuilt along the same alignments.

Based on ethnographic estimates of around 125 inhabitants per hectare, also consistent with that hypothesised for the Terramare (see *supra*), the population of these settlements may be estimated at c. 300 individuals at Coppa Nevigata (Cazzella and Recchia 2013a) and up to 400-600 at the largest sites.

The political role of these long-lived fortified settlements within their wider territorial context, and their relationship with the short-lived hamlets of the "traditional" type, has long been debated. The interpretation sustained here is that fortified sites were functionally specialised in long-distance exchange activities but exerted no political control over the neighbouring villages lying beyond their own subsistence catchment areas. These communities had a clear interest in maintaining their position in favourable locations for maritime and overland interaction; at the same time, they had the need of ensuring the defence of both the goods produced locally for the exchange and acquired through exchange.

The smaller hamlets, in turn, appear to have been primarily oriented towards subsistence activities, developing in time more specialised economic strategies that enabled the accumulation of surpluses and facilitated participation in wider exchange networks, allowing access to valued raw materials and exotic goods.

Other scholars have proposed contrasting models, attributing to these fortified sites a hegemonic role over neighbouring hamlets (Scarano 2012; Guglielmino 2014).

For Coppa Nevigata, the territory required to sustain the community has been estimated by applying a carrying-capacity model that considers the relative incidence of the principal domestic species and the crop types identified at the site. This analysis suggests that an area of approximately 5 km² would have sufficed, including arable land located near the settlement (considering crop rotation and fallow), grazing areas (partly overlapping with fallow land), plots with wild or progressively domesticated olive trees, and limited woodland supporting pig husbandry and occasional hunting (Cazzella-Recchia-Lucci 2021). Even doubling these estimates to accommodate larger populations at some sites or at those with differing economic strategies, the territories required to support such communities would not have exceeded approximately 10-15 km².

A calculation of the labour force required for the construction of the Apennine fortification wall and associated ditch at Coppa Nevigata, based on the demographic estimate of around 300 individuals, suggests that these works could have been completed within a few months by the resident community without external assistance (Cazzella and Recchia 2013a). This implies a substantial degree of self-sufficiency, both in terms of subsistence economy and in the capacity to organise and execute large-scale communal building projects.

As regards the area falling under the political control of individual communities, settlement distribution, particularly in the most intensively investigated parts of the region for the mid-2nd millennium BC, reveals an average distance of approximately 10 km between coastal sites. This would imply a territorial catchment of about 40 square kilometres for each settlement. A similar extent has been proposed for the sphere of control of Coppa Nevigata, defined by natural boundaries and by the absence of other coeval settlements (at least between the 16th and 11th centuries BC).

A different view has been advanced by the scholars leading research at Roca, who favour a model in which small hamlets in the surrounding territory, devoted primarily to subsistence activities, were politically linked to the main settlement and would have taken refuge there in times of danger or conflict (Scarano 2012; Guglielmino 2014).

Recent systematic surveys carried out by F. Iacono (Iacono *et al.* 2024) along a transect extending for approximately 10 km inland from the site of Roca have, in fact, indicated the probable absence of other centres, even small ones, within this area. Rather, a certain amount of material has been documented in the zone immediately surrounding the site that has been interpreted by the author as evidence of activities connected with the settlement, which may have extended beyond the line of the fortifications. Without entering the problem of the settlement's extension, it is worth noticing here that the dearth further traces in the transect appears consistent with the existence of a relatively large catchment area devoid of other communities and sufficient to sustain primary economy and needs of the Roca resident population.

Overall, communities settled both in fortified centres and in inland clusters of hamlets appear to have interacted primarily as peers. Such interactions, however, could have also involved episodes of conflict, ranging from small-scale hostilities to more organised warfare. Coastal settlements were also exposed to the risk of seaborne attacks, as piracy was likely the darker counterpart of participation in maritime exchange networks (Jung and Mehofer 2013).

Significant archaeological evidence of warfare has in fact been documented at both Coppa Nevigata and Roca. At Coppa Nevigata, traces of an organised assault dating to the late 16th century BC include the destruction by fire of an extensive functional area located outside the fortification wall, where numerous scattered flint arrowheads were found (Recchia and Cazzella 2019). At Roca, an attack around 1400 BC resulted in the partial destruction of the defensive circuit, with evidence for casualties involving both local combatants (fig. 18) and individuals apparently seeking refuge in a postern (Scarano 2012; Vincenti *et al.* 2024).

Furthermore, at other settlements, particularly coastal sites such as Punta le Terrare, Scogli di Apani, Portorusso (Radina *et al.* 2002b; Scarano and Guglielmino 2017; Aprile-Notarstefano-Tiberi 2016), extensive traces of fire events dating to the MBA have been recorded, which may also be attributable to episodes of conflict and assault.

## 5.2 Bronze Age Subsistence Economy and Exchange

### 5.2.1 *Subsistence economy*

Subsistence strategies across the region were primarily based on animal husbandry, especially the breeding of caprines (De Grossi *et al.* 2017; Cianfoni *et al.* in this volume), and cereal cultivation. Within this general framework, however, distinct choices made by individual communities can be identified. Although data from inland sites remain limited, hindering comparisons with coastal contexts, some differences in the relative incidence of domestic species between northern and southern sites are apparent. Caprines predominate everywhere, yet their incidence is particularly high in the Tavoliere, where they account for around 60% of the assemblages throughout the Bronze Age (Siracusano 2012). By contrast, pigs are relatively prominent at southern sites, reaching 30-40% of the domestic species at settlements such as Giovinazzo, Monopoli, Egnazia, Chiancudda, and Roca (Minniti 2021: tab. 1). These patterns may partly reflect ecological conditions. Following the drought event around 4000 BP, more extensive oak woodland developed in the southern area in contrast with the persistence of more open landscapes in the north. At the same time, they point to differentiated strategies in animal exploitation and subsistence organisation.

Hunting, particularly of red deer, played a more significant role in this region than in other parts of the Italian peninsula (De Grossi *et al.* 2017). Beyond meat consumption, deer hunting was aimed at obtaining hides and workable hard material. At Coppa Nevigata, the incidence of red deer, and, in the RBA, also of the more elusive roe deer, increases (Minniti 2021). The concentration of deer remains in areas of the settlement associated with prestigious goods (Lucci 2022) further suggests that hunting may have carried a specific social and symbolic significance.

Crop cultivation across the region appears to have been generally oriented towards $C_3$ cereals, particularly barley and wheat (Primavera *et al.* 2015). Stable isotope analyses of human remains from Trinitapoli, Toppo Daguzzo, Roca, indicate a diet largely based on $C_3$ plants, while animal proteins do not seem to constitute a major dietary component (Tafuri-Craig-Canci 2009; Varalli-Moggi Cecchi-Goude 2022; Vincenti *et al.* 2024). Results obtained from MBA2 individuals at Coppa Nevigata align with the consumption of $C_3$ terrestrial diet, with some showing possible marine resources intake (Thompson *et al.* 2025). Although available archaeobotanical data are quantitatively uneven across the region, some different trends can be observed. In the southern area, acorns appear to have been exploited as food supply in the MBA3 – RBA (Monopoli, Scogli di Apani, Scalo di Furno and Roca; Primavera and Fiorentino 2013), possibly in connection with the more extensive oak woodlands surrounding settlements. Whereas, this practice is not attested in the north of the region. A relatively higher incidence of pulses, particularly *Vicia faba*, is also attested in the south (Apani and Roca).

Evidence for $C_4$ plants, notably millet, remains sporadic in the region (Primavera *et al.* 2015). Early occurrences at a few sites in central Apulia (Grotta della Tartaruga and Monopoli) date to MBA3. Millet continues to be rare in the RBA (a single grain at Coppa Nevigata and a few finds from the Taranto area at San Domenico). However, organic residue analyses have identified miliacin in two imported LBA Aegean vessels from Roca (Arena *et al.* 2024).

As noted above, olive oil production is documented at Coppa Nevigata from the 18th century BC, while the harvesting of olive fruits is attested at Monopoli during the RBA. Together with anthracological remains, these data point to the progressive development of olive arboriculture in the region.

### 5.2.2 *Exchange*

Fortified coastal settlements were closely integrated into maritime exchange networks. As mentioned above, sites in northern Apulia, were engaged in tight contacts with the northern and eastern Adriatic, likely involving not only the circulation of goods but also a significant social dimension. From the 16th century BC onwards, Aegean-Mycenaean seafarers began to navigate the lower Adriatic and subsequently the Gulf of Taranto, gradually establishing direct relations with local communities (Bettelli 2002, 2011, 2022; Cazzella and Recchia 2018b; Jones *et al.* 2014). In this framework, settlements in the southern Adriatic and Ionian sectors probably functioned as ports of call. Baltic amber, widely distributed in the region and especially abundant in northern Apulia funerary contexts (Bellintani 2010a; Cwaliński 2023), was among the sought-after materials. It was probably acquired by local communities through Adriatic maritime routes and, after the mid-2nd millennium BC, possibly also via overland connections with the Terramare area. The appearance of Terramare-type elements among local artefacts in the RBA suggests intensified contacts or even some movements of Terramare groups towards the southern Adriatic (Cazzella and Recchia 2017) following the decline of southern Po Plain settlements (see *supra*; Bettelli-Cardarelli-Damiani 2018).

Fleece and dyed fabrics production was also likely oriented towards exchange. At Coppa Nevigata, the manufacture of purple dye is documented from the late EBA and reached its peak during the MBA2-3 (Minniti 2012; Minniti and Recchia 2018).

As the region lacks local metal sources, communities relied on exchange to obtain them. Isotopic analyses indicate the use of copper from the Trentino region from at least the 14th century BC (Jung-Mehofer-Pernicka 2011), although further sources cannot yet be excluded. Local metalworking (Cazzella-Recchia-Tunzi 2017 with bibliography therein) is documented from the early phases of the Bronze Age, notably at inland sites (e.g. a casting mould from Garagnone and a crucible from San Ferdinando). Evidence is available for MBA2-3 at sub-coastal settlements such as Santa Maria di Ripalta and Chiancudda and increases further from the RBA onwards (e.g. casting moulds from the Manaccora cave, Coppa Nevigata – fig. 19.5, Roca, and Scoglio del Tonno). A similar trend is observable in the distribution of metal artefacts, which become far more common in settlement contexts from the RBA, whereas in earlier periods they are mainly documented in funerary assemblages.

In addition to types commonly attested in central and southern Italy (fig. 19.1-3), sites on the Gargano promontory and in the eastern Tavoliere have yielded metal artefacts of trans-Adriatic type (fig. 20; Manaccora-type swords, repoussé-decorated studs, so-called “spectacle” ornaments, small knives with curved blades; Cazzella and Recchia 2020) which are otherwise absent from the Italian peninsula. Conversely, Aegean-type metal objects occur in the southern area from the MBA onwards (e.g. Santa Sabina tumulus, Roca, Scoglio del Tonno), as well as in the Surbo hoard, dating to the transition between the RBA and FBA (Bietti Sestieri 2010).

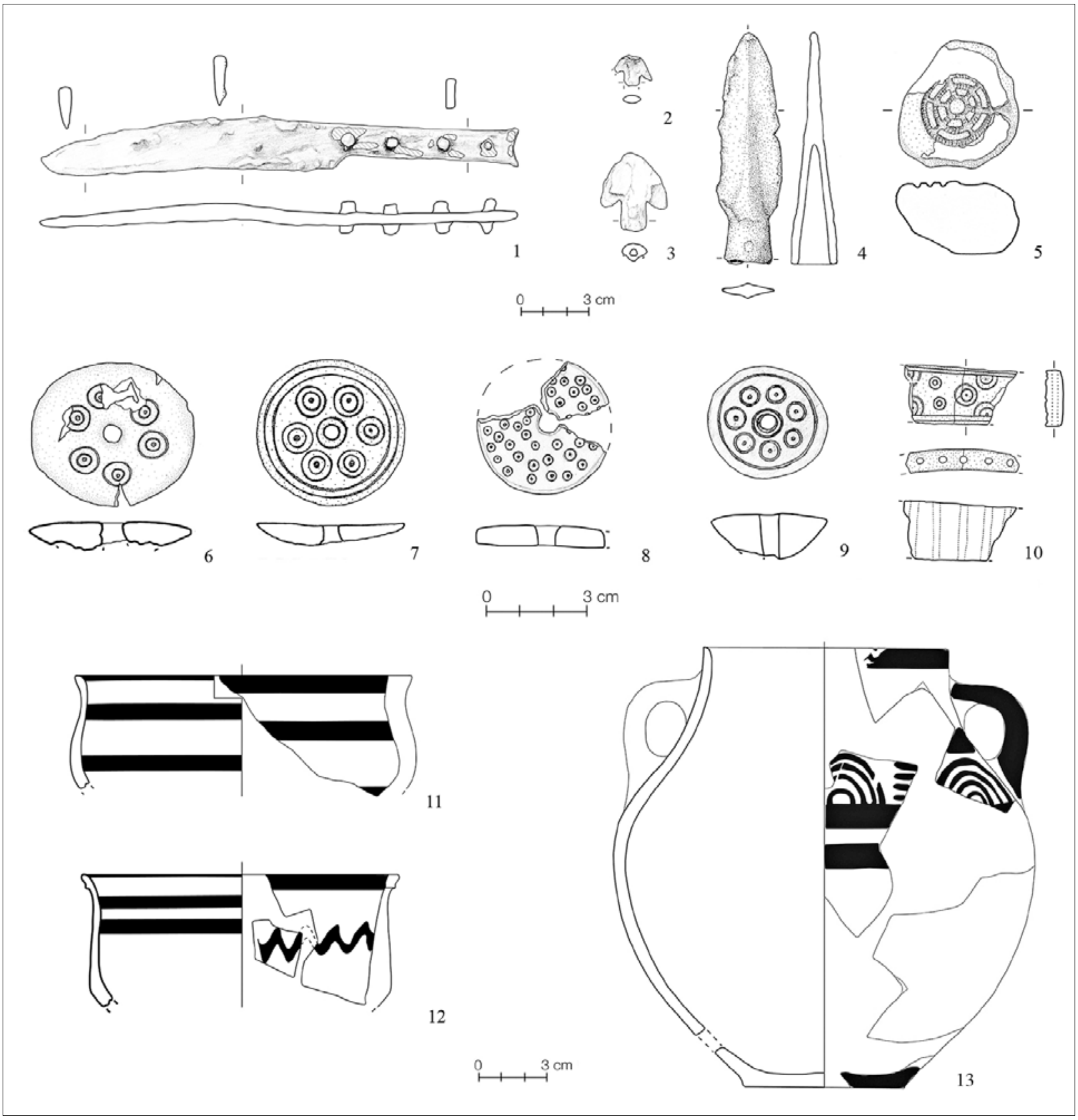


Fig. 19 – Coppa Nevigata (Foggia), artefacts made of bronze (1-4), arenaria (5), hard animal material (6-10), and painted fine wheel-thrown pottery (11-13) from the RBA layers: 1. Scoglio del Tonno-type knife; 2-3. arrowheads; 4. Pila del Brancòn-type spearhead; 5. stone mould; 6-9. Dyce-eye decorated pierced discs; 10. Dyce-eye decorated necklace spacer; 11-13. Aegean-Mycenaean type pottery. (Archive of the research at Coppa Nevigata).

*Coppa Nevigata (Foggia), manufatti in bronzo (1-4), arenaria (5), materia dura animale (6-10), ceramica tornita e dipinta (11-13) dai livelli del BR: 1. coltello tipo Scoglio del Tonno; 2-3. punte di freccia; 4. punta di lancia/giavellotto tipo Pila del Brancòn; 5. forma di fusione; 6-9. rondelle decorate ad occhi di dado; 10. distanziatore di collana decorato ad occhi di dado; 11-13. ceramica di tipo egeo-miceneo. (Archivio delle ricerche a Coppa Nevigata).*

The working of hard animal materials, attested at all centres, appears to have acquired particular importance during MBA2-3 in some settlements of the southern area, such as Punta Le Terrare, where a comb-needle or pin with globular decoration occurs (fig. 21.1), showing close parallels in the Mycenaean sphere; similar objects also comes from MBA 2 levels at Grotta Manaccora (fig. 21.2; Recchia 2010b) and from MBA3 levels at Oratino (Copat 2022: 11, fig. 11.2).

Finely worked ivory artefacts are attested at Roca (hippopotamus ivory, MBA3 – fig. 18.2,

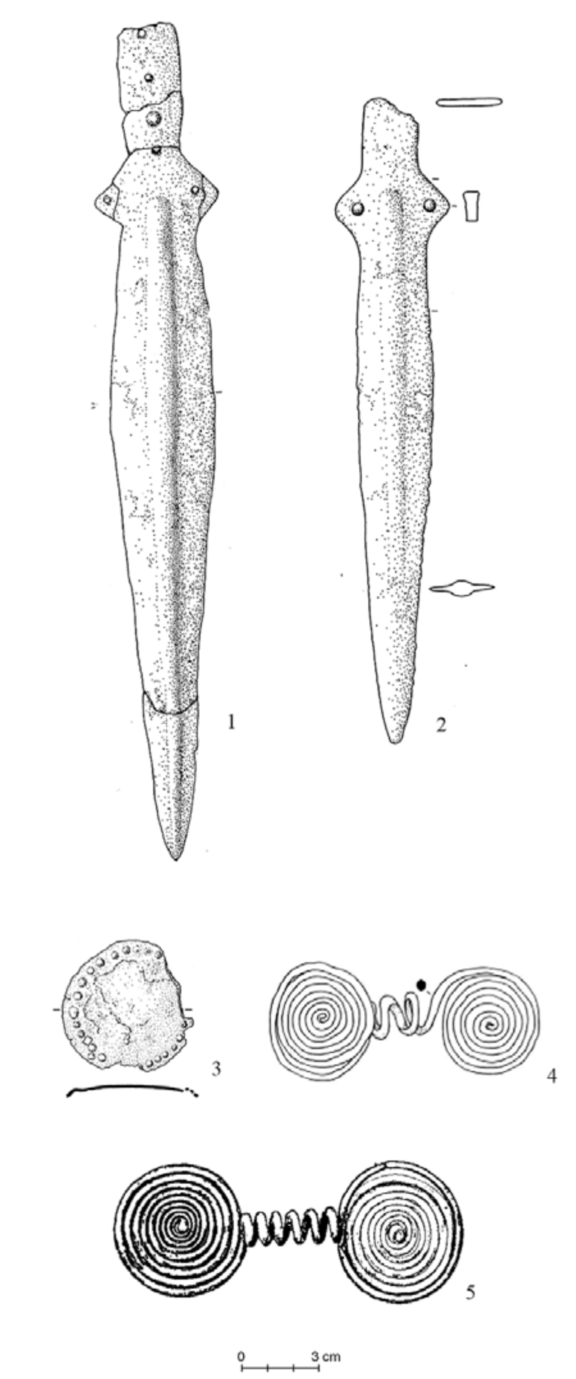


Fig. 20 – Eastern Adriatic-type bronze artefacts from northern Apulia (Foggia province): Manaccora-type swords from Manaccora (1-2), repoussé-decorated stud from Coppa Nevigata (3), so-called spectacle ornaments from Trinitapoli-Bronze hypogeum (4) and Manaccora (5). (Adapted from Bianco Peroni 1970; Cazzella and Recchia 2018; Tunzi Sisto 1999; Recchia 1993).

*Elementi in bronzo di tipo trans-adriatico dalla Puglia settentrionale (provincia di Foggia): spade tipo Manaccora da Manaccora (1-2), borchia decorata a repoussé da Coppa Nevigata (3), monili ad occhiali da Trinitapoli – Ipogeo dei Bronzi (4) e Manaccora (5). (Rielaborati da Bianco Peroni 1970; Cazzella e Recchia 2018; Tunzi Sisto 1999; Recchia 1993).*

and FBA levels; Guglielmino-Pagliara-Rugge 2010) and in the Ivory Hypogeum of Trinitapoli (elephant ivory; Tunzi and Devoto 2005). A decorated necklace spacer from RBA levels at Coppa Nevigata (fig. 19.10; Cazzella and Recchia 2021) may also be made of ivory. While the raw material must be considered among the imports associated with Mycenaean exchange networks, it remains more difficult to establish whether manufacture was local or external; however, the discovery at Roca of ivory blanks, both of hippopotamus and elephant, in RBA levels (Guglielmino-Pagliara-Rugge 2010) suggests the development of local production, at least from that period onwards. In any case, the working of bone and antler also expanded markedly from the RBA, when decorated elements with close parallels in the Terramare cultural sphere are frequently attested (fig. 19.6-9).

One of the principal indicators of the active involvement of local communities in Mycenaean exchange networks is the occurrence of imported Aegean-Mycenaean pottery at several sites from the 16th century BC onwards (Jones *et al.* 2014; Jung *et al.* 2021). In the earliest phase of contacts, imported ceramics are attested from the southern area as far as the Gargano promontory; from the 15th century BC, however, they are found predominantly in centres of the southern area. Even among these sites, significant differences in the quantity of imports can be observed (Jones *et al.* 2014; Bettelli 2021), suggesting that only certain centres functioned as direct ports of call, among which Roca and Scoglio del Tonno, while others acquired exotic goods through regional exchange networks.

Other imported goods conveyed by Aegean-Mycenaean seafarers distributed across the region include vitreous materials (Bellintani 2010b, with bibliography therein), both in the form of raw material and, probably, finished objects, such as beads of Aegean type (seed-shaped LMLK – fig. 21.3, and lantern-shaped beads).

Bitumen was probably another commodity traded across the Adriatic. Archaeometric analyses have demonstrated the presence of bitumen of Albanian provenance at some Apulian sites (Faraco *et al.* 2016). A shaped bitumen lump (not yet analysed for provenance) comes from one of the wall's posterns at Roca, illustrating how this material was stored and likely exchanged (Guglielmino 2012).

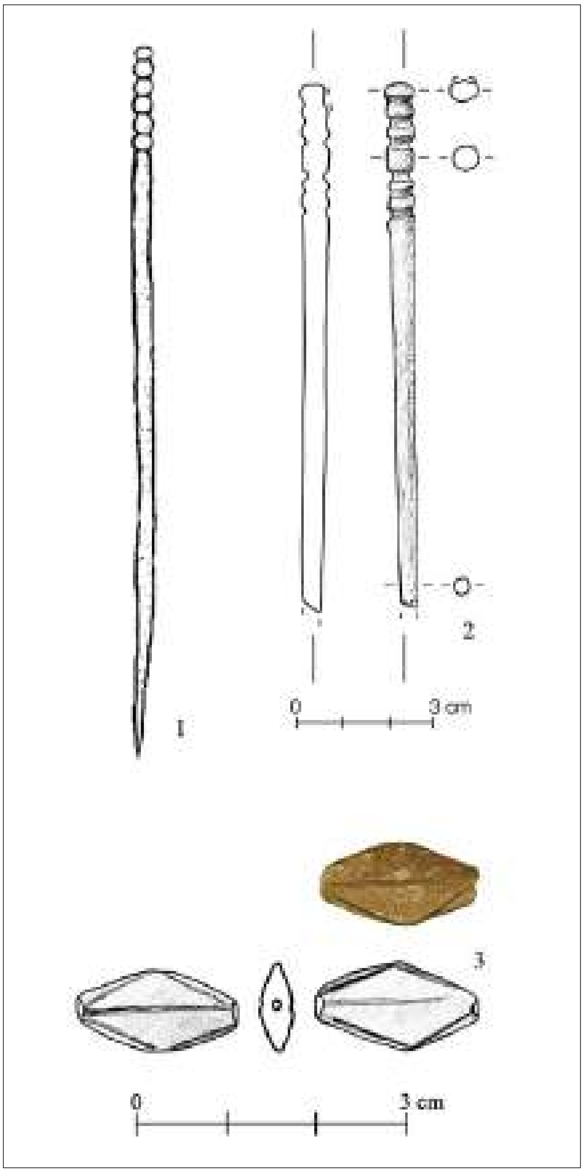


Fig. 21 – Aegean-Mycenaean type artefacts from south-eastern Italy: bone pins/ combe-needles with globular decoration from Punta le Terrare – Brindisi (1) and Manaccora – Foggia (2); seed-shaped LMLK glassy beads from Masseria Chiancudda – Brindisi (3). (1 not to scale; drawings G. Recchia).

*Elementi di tipo egeo-miceneo dall'Italia sud-orientale: spilloni/ aghi crinali in osso decorate a globetti da Punta le Terrare – Brindisi (1) e Manaccora – Foggia (2); vago decorato a seme in glassy faiance da Masseria Chiancudda – Brindisi (3). (1 non in scala; disegni G. Recchia).*

From the late MBA3, the local production of fine painted wheel-thrown pottery imitating Aegean-Mycenaean types developed in the southern part of the region (Jones *et al.* 2014), alongside wheel-thrown fine wares reproducing indigenous stylistic models. These productions expanded significantly during the RBA, reaching sites that were probably never directly reached by Aegean seafarers.

Maritime exchange networks continued to flourish during the later RBA and FBA, with the probable arrival in the Adriatic of Cypriot-Levantine seafarers, who appear to have reached northern ports directly and to have interacted with major productive centres such as Frattesina (see *supra*). A parallel phenomenon, from the RBA onwards, is the spread of Italian-type elements in the Aegean, including pottery, which appear to result from different factors, possibly including the movement of individuals towards that region (Bettelli 2009).

### 5.3 Social Organisation in the Bronze Age

Current evidence from settlement organisation during the MBA does not support the existence of stable socio-economic distinctions. From the 15th century BC onwards, however, funerary practices in the region begin to reflect increasing social competition and the emergence of differentiated kin groups.

Funerary traditions vary across the region (Cazzella-Recchia-Tunzi 2017 with bibliography therein). In the northern area they chiefly consist of collective inhumations in artificial hypogea and caves. In all cases, former cultic hypogea (Trinitapoli, Toppo Daguzzo, Lavello 743) or cave recesses previously used for ritual activities (Manaccora) were converted into burial spaces, suggesting a spatial and ideological link with ancestral ritual places and possibly with claims of kinship. The deceased are often accompanied by valuable grave goods, including exotic materials such as Baltic amber, glassy beads, and metal weapons and ornaments. Hypogea tend to occur in clusters or, as at Manaccora, collective inhumations are distributed in multiple cave recesses, possibly indicating burial areas used by specific kin groups (Recchia 1999; Cipolloni Sampò and Canci 2024). Isotopic analyses at Trinitapoli (Ivory hypogeum) have also revealed the presence of non-local individuals (Arena *et al.* 2020 with bibliography therein). At the Coppa Nevigata settlement, formal inhumations of male individuals occur in 15th century BC levels, alongside scattered human remains. Isotopic analyses suggest they were local; yet, as expected in a site actively engaged in long-range exchange activities, the ancestry of analysed individuals is varied, including continental and peninsular Italian Bronze Age affinities and potential Balkan affinities (Thomson *et al.* 2025). Although associated grave goods in the formal inhumations are modest, their distinct burial context may point to specific social characters.

In the southern area, funerary practices include dolmens with multiple burials, often heavily disturbed, and tumuli (*specchie*) with single inhumations in cist graves (Bietti Sestieri and Scardozzi 2010).

The large Santa Sabina tumulus, which shows connections with the western Balkans and western Greece, stands out for the presence, in its earliest burial (tomb 12), of LHIIIA Aegean-Mycenaean pottery and an Aegean-type knife (fig. 22; Onnis 2011), items otherwise unattested in funerary contexts in the region.

Overall, the evidence points to increasing social competition and the emergence of differentiated kin groups, and possibly prominent individuals, although these had not yet developed into stable elites.

From the later MBA 3, cremation cemeteries, already widespread in central and northern Italy, begin to appear in the region (e.g. early urns at Torre Guaceto, Scarano *et al.* 2023, and possibly Canosa) and increase in the RBA (e.g. Lacedonia, Molinella, Torre Castelluccia, Timmari), without ever becoming widespread. Some hypogea in the northern area remained in use into the RBA1 (Trinitapoli) and even the FBA (Lavello 743), although grave goods in these later phases appear to no longer include bronze weaponry. Together with the general tendency of cremation rites to include limited grave goods, this suggests that funerary practices in the RBA did not strongly emphasise social inequality.

By contrast, settlement evidence points to significant socio-political transformations during this period. Specialised craft production increased, not only in fortified centres but also in smaller "traditional" villages. Intensifying social competition likely contributed to the emergence of more stable elite groups, who may have exercised control over secondary and tertiary production and influenced the spatial organisation of settlements, which increasingly adopted more regularised layouts. The local production of Aegean-Mycenaean-type pottery (fig. 19.11-13), widely distributed even in areas not directly reached by Aegean seafarers, further suggests the presence of specialised artisans supported by elite groups expressing their status through the consumption of such materials.


Fig. 22 – Aegean-Mycenaean type grave goods from Santa Sabina tumulus tomb 12 (Brindisi): LHIIIA painted wheel-thrown jug (1), *alabastron* (2), cup (3) and bronze knife (4). (Adapted from Radina and Recchia 2010; Onnis 2011; Recchia 2010b).

*Elementi di corredo di tipo egeo-miceneo della tomba 12 del tumulo di Santa Sabina (Brindisi): brocca (1),* ala*bastron* *(2), tazza (3) in ceramica tornita e dipinta del TEIIIA e coltello in bronzo (4). (Rielaborati da Radina e Recchia 2010; Onnis 2011; Recchia 2010b).*

## 6. WESTERN ITALY

### 6.1 Settlement Patterns and Cultural Aspects of the Bronze Age

In western Italy – corresponding to Tuscany, Latium, Campania and Calabria regions – between the end of the EBA and the MBA ($18^{th}$-$14^{th}$ centuries BC), intense occupation of the territory developed, with numerous settlements on plateaus or hilltops. The naturally defended areas – sometimes equipped with artificial fortifications – of these settlements usually covered a few hectares, but in some cases they could reach or exceed ten hectares. A well-known example is the plateau of the Torre Mordillo settlement in Ionian Calabria, which covers approximately 13 hectares (Trucco and Vagnetti 2001).

Larger, defended settlements, which often lasted several centuries, coexisted with smaller, mostly short-lived and undefended settlements within integrated territorial systems and resource exploitation patterns. These included pastures intended for livestock farming, often located in the widespread hilly and mountainous areas of the peninsula. Seasonal, mostly short-range livestock mobility is likely, as demonstrated by isotopic analyses of bone samples from domestic animals of the Punta di Zambrone settlement (Calabria), dated to the EBA and RBA (Pike *et al.* 2021).

The smaller settlements served the purpose of exploiting local resources and probably managing livestock. One such settlement is the MBA3 site at Crocette di Tivoli, examined as part of the HERDS project.

Between the late EBA and MBA1-2 ($18^{th}$-$15^{th}$ centuries BC), various archaeological *facies* developed (Pacciarelli 2001, 19-32), including the Belverde-Mezzano (EBA2) and subsequently the Grotta Nuova (MBA1-2) *facies* in the central Tyrrhenian area, and the Proto-Apennine *facies* in much of southern Italy. In MBA3 ($14^{th}$ century BC), the peninsular regions became culturally integrated into the Apennine *facies*, which spread also beyond the Tyrrhenian Sea, as far as Corsica (Lorenzi 2001). Southern Calabria, however, appears culturally connected to Sicily and the Aeolian Islands through the Thapsos-Milazzese *facies*.

In the RBA and FBA, many settlements continued to develop on naturally defended plateaus and hills. The population was often concentrated in these larger centers, where more complex economic activities developed, likely managed by increasingly stable elites. In sites such as Broglio di Trebisacce in Ionian Calabria, and in some other contexts, specialized livestock management aimed at wool and milk production seems to have emerged (Minniti 2021, with references therein).

During the RBA, the Subapennine *facies* – whose origins can be traced back to the interactions between the Po Valley and central Italy – spread widely toward the southwest, reaching southern Calabria, the Aeolian Islands, and the area of the present-day province of Messina in northeastern Sicily (Capriglione 2024).

During the FBA, many of the main settlements continued to be occupied, and the material culture transformed first into the so-called Proto-Villanovan *facies* and subsequently – especially in the late phase of the FBA – into differentiated regional aspects, which in some cases prefigure the cultures of the EIA.

Southern Etruria is the region for which the clearest and most documented model of development is available from a territorial perspective. During the FBA, this territory was populated by a large number of villages mostly on naturally defended plateaus and hills, typically extending between 2-3 and 10-13 hectares (di Gennaro 1986; Barbaro 2010). One of the best-known examples is the settlement of Luni sul Mignone, which occupied a plateau of about five hectares surrounded by steep rocky slopes (fig. 23). In the best-explored areas of Southern Etruria, distances between FBA sites vary between 5 and 8 kilometers, suggesting a territorial radius predominantly between 2,5 and 4 kilometers, corresponding to territories of a few dozen square kilometers (Pacciarelli 2001: 104).

The widespread occupation of the territory by villages like those described presupposes the existence of associative forms centred on larger settlements or on cult places, such as that found on the summit of Monte Cimino at 1053 meters a.s.l. (Cardarelli and Trucco 2014; Cardarelli 2018).

This multicentric – and probably federal – organization in southern Etruria dissolved in conjunction with the profound geopolitical restructuring that, in the late FBA3, led, on the one hand, to the abandonment of most of the villages, and on the other, to the formation of proto-urban centers (Pacciarelli 2001).

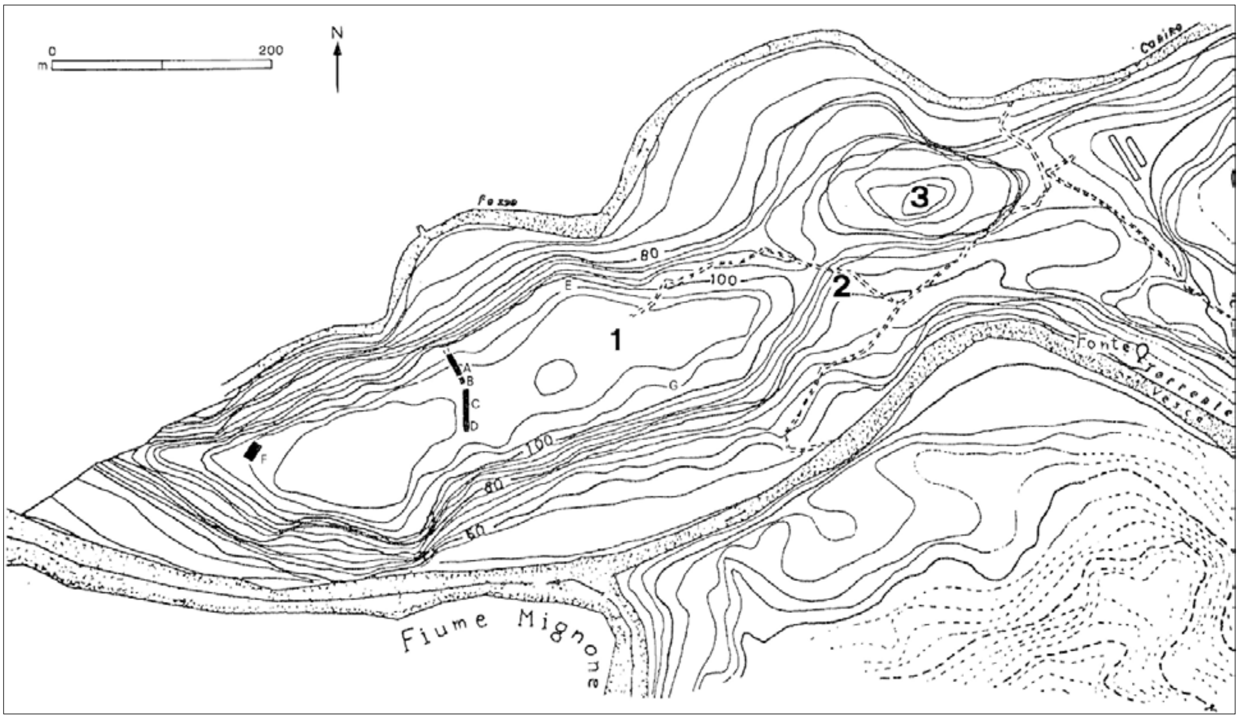


Fig. 23 – Luni sul Mignone (Blera), location of the main Bronze Age structures and finds. 1: Pian di Luni (A: northern house, B: central house, C. southern house, D: FBA hut; E: FBA huts, F: FBA large semi-subterranean building: G: Bronze Age chamber tomb); 2: Tre Erici; 3: Monte Fornicchio (After di Gennaro 1986; Pacciarelli 2001: fig. 55).

*Luni sul Mignone (Blera), ubicazione delle principali strutture e reperti dell'età del bronzo. 1: Pian di Luni (A: casa settentrionale, B: casa centrale, C: casa meridionale, D: capanna del Bronzo Finale; E: capanne del Bronzo Finale, F: grande edificio semi-sotterraneo del Bronzo Finale; G: tomba a camera dell'età del bronzo); 2: Tre Erici; 3: Monte Fornicchio (Da di Gennaro 1986; Pacciarelli 2001: fig. 55).*

### 6.2 Circulation of Goods and Technologies in the Bronze Age

Since MBA important settlements in well-defended positions along the coasts and on islands became key hubs for maritime exchange, which began to connect some areas of the Tyrrhenian Sea and the Aegean. Significant evidence of direct contact with the Greco-Aegean world is represented by the presence of abundant Mycenaean pottery dated to Late Helladic I-II and IIIA, partly from the Peloponnese, found in naturally defended island settlements such as Vivara in the Gulf of Naples and Lipari and Filicudi in the Aeolian Islands (Bettelli 2002; Jung 2006; Jones *et al.* 2014).

Imports from the Aegean also included other prestigious goods, such as faience beads; noteworthy, as will be discussed, is the presence of a large rock crystal bead, a silver bracelet, and a Minoan carnelian cushion seal in the MBA1-2 tomb of Gallo di Briatico in Calabria (Pacciarelli 2001: 185-188).

The availability of copper was guaranteed by extensive exchange networks, through which the metal, largely mined in the Alpine regions especially during the RBA, circulated on a large scale. The origin of tin, however, remains uncertain.

In the RBA (and sometimes at the end of MBA 3), Italo-Mycenaean pottery spread in Ionian Calabria (Jones *et al.* 2014). It consisted of refined clay pottery, worked on a wheel, decorated with painted motifs, and fired in special kilns (at high temperatures and a controlled atmosphere). It was very similar, and sometimes almost identical, to that produced in the Aegean, but made in Italy. Italo-Mycenaean vases were mostly used as fine tableware – along with the local *impasto* ware and the so-called gray ware, also of Aegean influence but locally made – in convivial gatherings that must have fulfilled important functions of social integration (Castagna 2004).

Of a different nature, but no less important, is another category of Aegean-type ceramics produced in Italy from the 13th century onwards, with continuity at least until the 10th century BC:

the so-called *dolii a cordoni o fasce*, large Aegean-style pithoi made of semi-purified, wheel-finished ceramic, fired in high-temperature kilns (Schiappelli 2006). These pithoi held several hundred liters and were stored in small storehouses, such as the one containing five specimens found in the settlement of Broglio di Trebisacce in Ionian Calabria (Trucco 1994: 100-102, fig. 53). Their function is clearly linked, as in the Aegean, to the preservation of large quantities of agricultural products, likely including olive oil, perhaps also produced with the help of new cultivation methods of Aegean origin.

### 6.3 Weaponry, funerary Practices, and Evidence of Social Differentation in the Bronze Age

In MBA1-2 there is few evidence of weapons, but there are burials attributable to high-status individuals. In southern Etruria, several rock-cut tombs with a quadrangular chamber and a dromos entrance have been discovered, likely reserved for an elite group. Although all were at least partially violated by illegal excavators, they have sometimes yielded valuable artifacts, as in the case of the Prato di Frabulino tomb, which contained silver spirals and numerous faience necklace elements (Casi *et al.* 1995). The 16th century BC tomb of Gallo di Briatico in Calabria (fig. 24) – likely intended for a child, given the small size of the burial container, a small pithos – yielded valuable objects of Aegean origin (Pacciarelli 2001: 185-188), including a Minoan carnelian cushion seal, a rock crystal bead similar to those used as pinheads in the Circle B Omicron shaft tomb at Mycenae, and a silver bracelet whose metal, according to an analysis conducted in collaboration with Reinhard Jung and Enrst Pernicka, originates from the northern Aegean (Jung *et al.* 2021). The plausible attribution of the tomb to a child is a clear indication of early hereditary differentiations.

In MBA3, swords were mostly short, while in RBA, long slashing swords prevailed (Pacciarelli 2006) and penetrated toward the southwest, coinciding with the spread of the Subapennine *facies* into this area, also through the migration of human groups (Pacciarelli 2018). Judging by the numerous weapon fragments found in the Lipari RBA hoard, warriors of this period also used spears with a bronze head.

In the RBA and FBA, the funerary rite of cremation was quite diffused and linked, especially in the early stages, to a leveling ideology. This ideology likely served to strengthen community cohesion, weakened by the emergence of dominant groups.

In the Tyrrhenian area and the Aeolian Islands is worth noting the presence of rich FBA1-2 burials, belonging to a social elite composed of warriors with complex weaponry and women with precious ornaments. The male component of these societies is documented primarily by a rare example of an inhumation cemetery discovered at Castellace, in southern Tyrrhenian Calabria (Pacciarelli 1999b). The grave goods from this site include a medium-length sword, a very short sword and/or a knife, and sometimes a spearhead (fig. 25A). One of these elite warrior burials yielded a bronze greave, likely imported from the Mycenaean area, as indicated by comparisons and isotopic analyses (Jung *et al.* 2021).

Even more significant is the presence of high-status female burials with highly valuable ornaments of distant provenance. Pairs of gold spiral bracelets of Central and Eastern Europe type were found at Castellace (fig. 25B), while the high-status woman from Tomb 31 at Lipari-Piazza Monfalcone (also dated to the FBA1-2) was accompanied by rich grave goods that included, in addition to gold and bronze ornaments and tools, necklaces made with Tyrins and Allumiere types amber beads or with hundreds of glass beads, produced in Frattesina (Bernabò Brea and Cavalier 1959; Peroni 1989; Matarese 2024). A similar amber necklace comes from a cremation tomb of the same period found at Ardea in Latium (Delpino 1987).

These findings suggest that a social elite, in which high-status women played a significant role, emerged in several village communities of the central Mediterranean between the late 12th and 11th centuries BC.

In southern Etruria (now northern Lazio), another piece of evidence attributable to this phenomenon comes from the Coste del Marano hoard (Tolfa, RM), also datable to the FBA1-2 (Peroni 1961). This complex of prestigious bronze objects is an intentional collection of intact artifacts, following a precise compositional logic. The core of the complex revolves around a triple series of objects: three cups in embossed bronze sheet (two

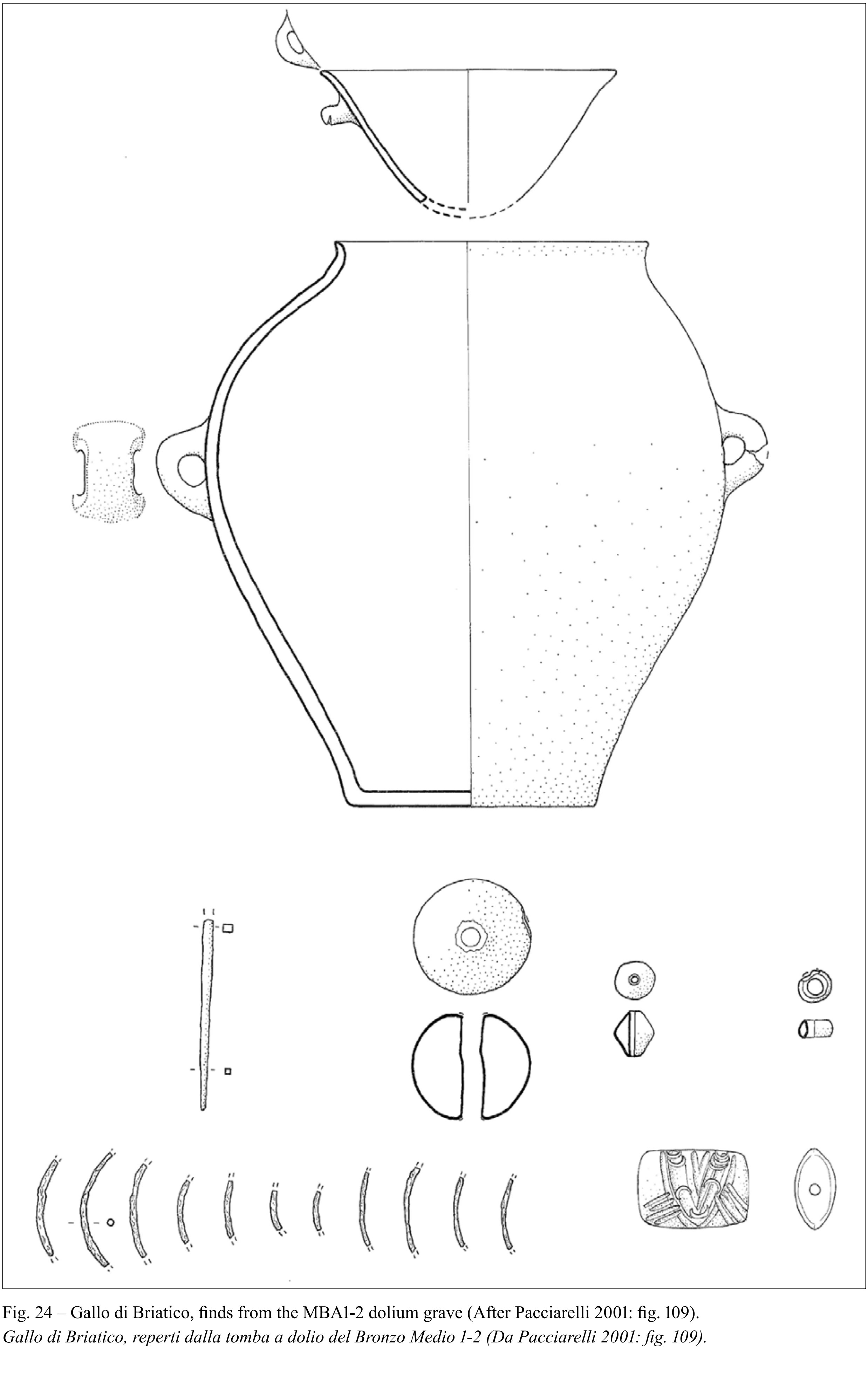

Fig. 24 – Gallo di Briatico, finds from the MBA1-2 dolium grave (After Pacciarelli 2001: fig. 109).
*Gallo di Briatico, reperti dalla tomba a dolio del Bronzo Medio 1-2 (Da Pacciarelli 2001: fig. 109).*

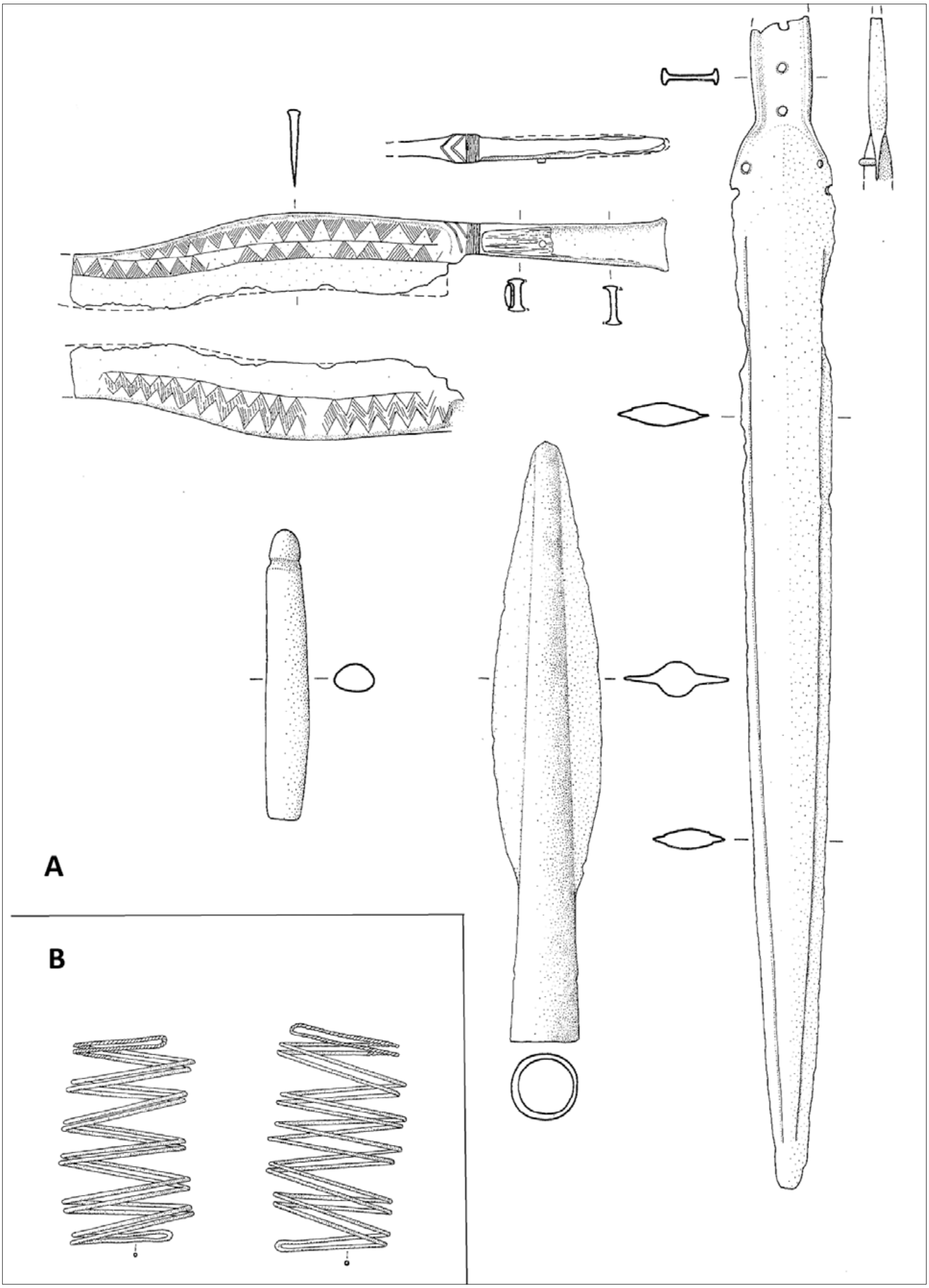


Fig. 25 – Castellace (Oppido Mamertina), FBA 1-2 cemetery. A: tomb found in 1927: knife, sword, spearhead, whetstone; B: tomb 1 found in 1929: golden bracelets (After Pacciarelli 2001: fig. 111).

*Castellace (Oppido Mamertina), sepolcreto del Bronzo Finale 1-2. A: tomba rinvenuta nel 1927: coltello, spada, punta di lancia, cote; B: tomba 1 rinvenuta nel 1929: braccialetti d'oro (Da Pacciarelli 2001: fig. 111).*

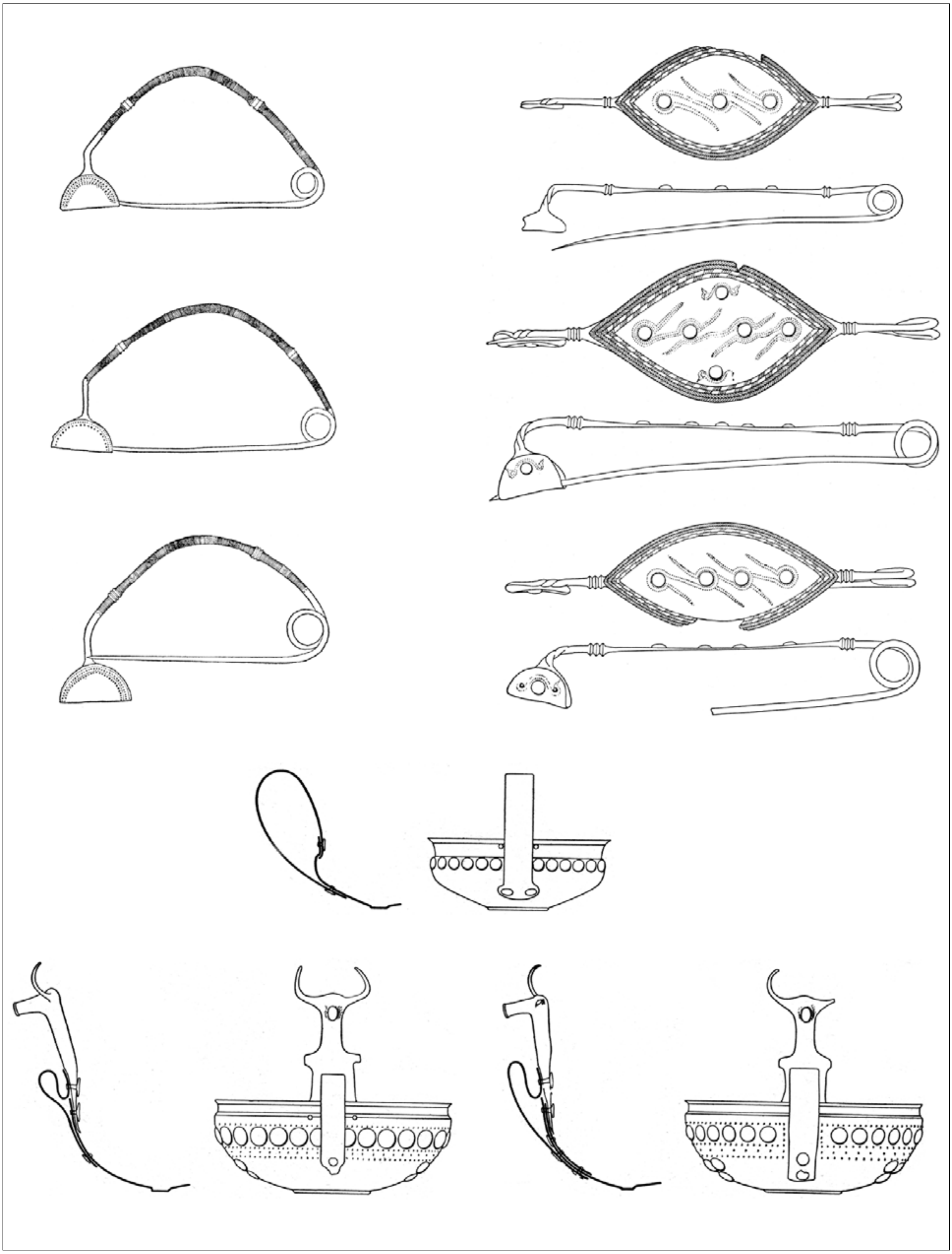

Fig. 26 – Coste del Marano (Tolfa), FBA 1-2 hoard: triple sets of bronze cups (two of which with a handle featuring a bull's head), and of bronze large leaf-shaped violin bow fibulae and of large bronze bow fibulae with nodules (After Pacciarelli 2016: fig. 2; drawings after Peroni 1961).

*Coste del Marano (Tolfa), ripostiglio del Bronzo Finale 1-2: triplice serie di tazze in bronzo (due delle quali con manico desinente a protome taurina), e di grandi fibule in bronzo dei tipi ad arco di violino foliato e ad arco semplice con noduli (Da Pacciarelli 2016: fig. 2; disegni da Peroni 1961).*

of which have bull's-head handles), three large foliated violin-bow fibulae, and three other large bow fibulae with nodules (fig. 26). The presence of numerous feminine ornaments and some tools likely used for wool processing makes it plausible that the complex belonged to the female sphere. The Coste del Marano treasure could therefore be interpreted an elaborate collection of high-status goods belonging to a woman (or three women?) of very high rank, who held important social and ceremonial roles, as indicated by the bronze cups and large "parade" fibulae (Pacciarelli 2016).

Regarding the differentiated structures in the late RBA and FBA settlements, southern Etruria has yielded two large rectangular rock-cut structures at the sites of Monte Rovello and Luni sul Mignone (Biancofiore and Toti 1973; Hellström 1975). The Luni structure has been reconstructed by Swedish scholars as a huge hut that served as the chief's residence, with a large cellar-like room underneath (Hellström 1975, pl. 14).

### 6.4 Early Iron Age

As mentioned, the most radical change occurred in southern Etruria during the late FBA3: almost all Bronze Age villages (except in the area between Lake Bolsena and the Tiber) were abandoned, while six very large settlements began to form mostly on plateaus extending between 85 and 180 hectares, 20 to 40 kms apart (Pacciarelli 2001). This profound and rapid transformation corresponds to the beginning of the local version of the process that Vere Gordon Childe (1950) aptly called the 'Urban Revolution'. Indeed, the gradual emergence of an urban civilization began in the large EIA settlements of Etruria, known as proto-urban centers (fig. 27). Some of these elements – including, of course, writing – were acquired over time by groups originating from the eastern Mediterranean, but the entire process was firmly rooted locally in the large settlements founded in the late 10th century BC.

From the beginning of the EIA – and sometimes as early as FBA3 – regional cultural areas are recognized, in some cases linked to the emergence of ethno-political-linguistic communities of the early historical period. This is the case of the Latins, whose identity is recognizable even from the initial phase of the Latium Vetus culture, that is, from the end of the FBA (Bietti Sestieri and De Santis 2007). A connection with the Etruscans is hypothesized for the Villanovan culture of EIA (Pallottino 1984: 69; Bartoloni 1989).

In some important necropolises, such as that of Torre Galli (Calabria), a widespread male warrior identity is recognizable from the beginning of the EIA, characterized by the possession of spears and sometimes also short swords (Pacciarelli 1999a). Larger settlements emerged during this period, capable of controlling vast territories. The phenomenon is documented in Calabria, albeit on a smaller scale – for example, in the case of the fortified settlement of Torre Galli (Pacciarelli 2017; Pacciarelli-Iaia-Matarese 2017), whose faunistic remains were examined as part of the HERDS project – but is particularly evident in Etruria, Latium Vetus, and Campania, where proto-urban centers reached extensions ranging from 40 to 180 hectares.

In some areas emerged political-territorial units composed of multiple associated centers, sometimes with smaller fortified settlements dedicated to the control of marginal and mountainous territories, as in the case of the site of Monte Morra, near Rome, excavated as part of the HERDS project (Fiorillo *et al.*, in this volume).

## 7. SICILIAN AREA

In Sicily and the smaller islands, between the end of the EBA and MBA1-2, settlements spread on defensible heights of several hectares, often along the coast. Some of these specialized in exploiting island environments, as in the case of Pantelleria, examined in the HERDS project, and became involved in maritime trade, as is evident in the cases of Lipari and Filicudi.

In Sicily, MBA3 reveals extraordinary connections with the Greco-Aegean area. In this period, the settlement located on the Magnisi peninsula in the Gulf of Augusta, in the place called *Thapsos* by the Greeks, received large quantities of Mycenaean vases, discovered in the local necropolis, and adopted architectural forms of oriental origin. An initial traditional settlement with huts delimited by a circular wall was succeeded by a layout with rectilinear cobbled streets and houses consisting of rectangular rooms arranged around a paved courtyard (Crispino 2024). The arrival of this new urbanistic culture in Thapsos can be

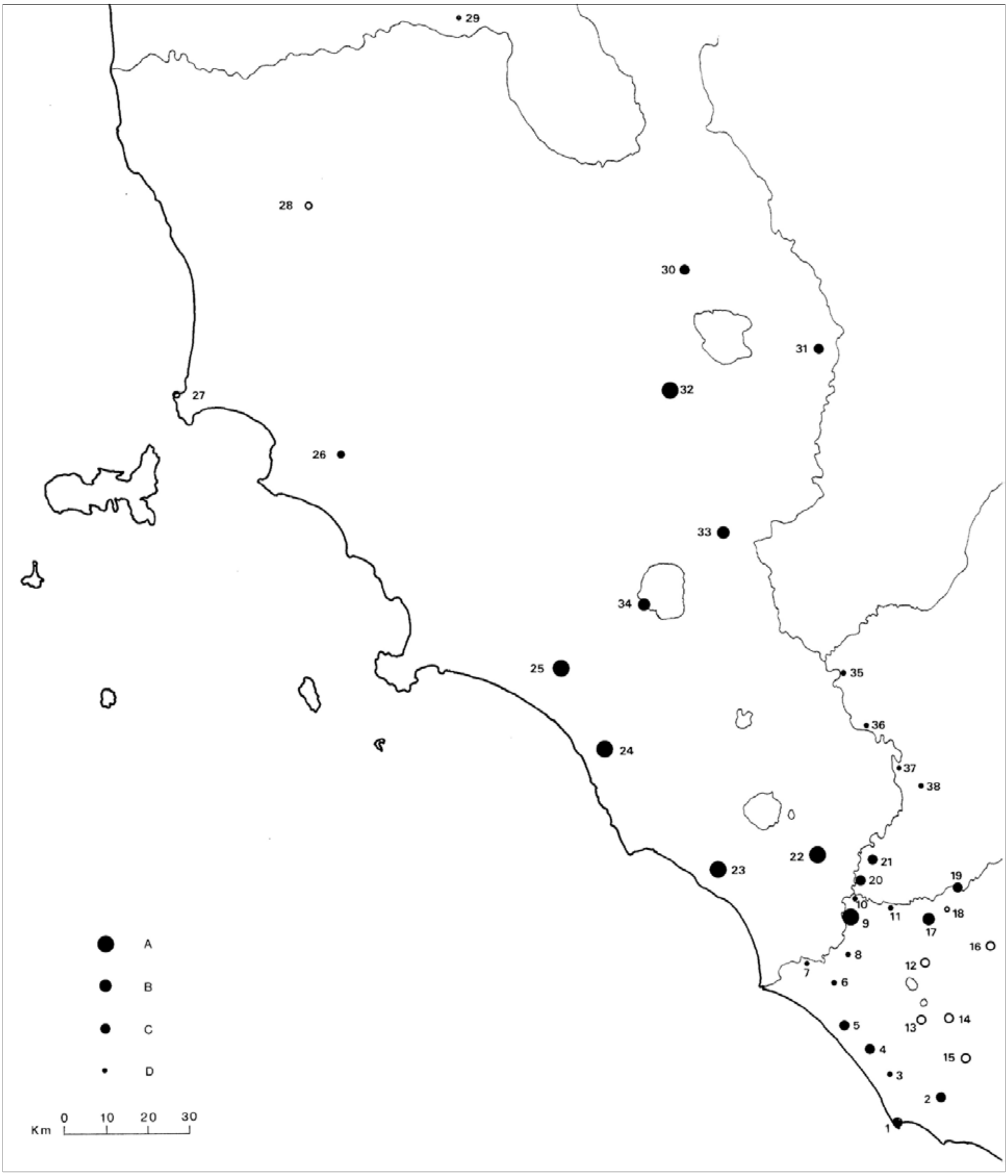


Fig. 27 – Middle Tyrrhenian region, main EIA settlements.

*Regione medio tirrenica, principali insediamenti del Primo Ferro.*

A: 100-200 ha; B: 50-100 ha; C: 20-50 ha; D: 1-15 ha. 1: Anzio; 2: Satricum; 3: L'Altare; 4: Ardea; 5: Lavinium; 6: Decima; 7: Ficana; 8: Acqua Acetosa Laurentina; 9: Rome; 10: Antemnae; 11: La Rustica; 12: Tusculum; 13: Lanuvium; 14: Velletri; 15: Caprifico; 16: Palestrina; 17: Gabii; 18: Corcolle; 19: Tivoli; 20: Fidenae; 21: Crustumerium; 22: Veii; 23: Caere; 24: Tarquinii; 25: Vulci; 26: Vetulonia; 27: Populonia; 28: Volterra; 29: Fiesole; 30: Cortona; 31: Perugia; 32: Chiusi; 33: Orvieto; 34: Bisenzio; 35: Ocriculum; 36: Poggio Sommavilla; 37: Campo del Pozzo; 38: Cures (After Pacciarelli 2001: fig. 70).

considered the extreme westward expansion of complex civilizations of the eastern Mediterranean type.

The RBA saw the spread into northeastern Sicily and Lipari of the Subapennine archaeological *facies*, as said before likely brought by new human groups. This period also coincides with the abandonment of many settlements that had flourished during the Thapsos-Milazzese *facies* of MBA3, and the establishment of the center of Pantalica on a large plateau with exceptional natural defenses in the Syracusan hinterland (Bernabò Brea 1990).

The FBA is characterized in Sicily by the emergence of clearly differentiated archaeological *facies*, such as that of Pantalica-Cassibile on the one hand and that of Mulino della Badia on the other, likely linked, as in Italy, to the emergence of distinct ethno-political identities (Albanese Procelli 2003).

## 8. SARDINIA: THE NURAGIC CIVILIZATION

### 8.1 Origins, Development and Consolidation – Territorial and Settlement Organisation

The Bronze Age of Sardinia corresponds to the emergence, consolidation and long-term transformation of the Nuragic cultural cycle, a phenomenon that profoundly shaped the island's social and territorial organisation between the early second millennium and the beginning of the first millennium BC. Rather than representing a static architectural tradition defined solely by the construction of stone towers, Nuragic civilisation developed as a dynamic and cumulative process that progressively restructured settlement patterns, resource management and social interaction across the island. The thousands of stone towers known as nuraghi remain the most visible and emblematic expression of this period; however, an exclusive focus on monumentality obscures the broader territorial and socio-economic dynamics that underpinned their construction and use.

The *nuraghe* was not an isolated architectural statement, nor a self-contained defensive unit, but a component within a territorially articulated settlement system composed of villages, agricultural lands, pastures and craft areas (Depalmas 2018).

From its earliest phases, the Nuragic phenomenon was embedded within inhabited landscapes structured by environmental affordances and communal strategies of resource control. Over several centuries, Sardinia witnessed a cumulative process of architectural innovation, demographic growth, environmental transformation and socio-economic differentiation that cannot be reduced to static monumentalism. Instead, it reveals a historically layered formation grounded in environmental adaptation, negotiated territoriality and internally organised community structures.

During the early MBA, settlement patterns consisted primarily of dispersed clusters of rectangular, elliptical and circular domestic structures distributed across ecologically favourable zones. These early villages were frequently situated in proximity to arable land, pasture and water sources, often on basaltic uplands particularly suitable for mixed agro-pastoral economies. In several documented cases, such settlements either preceded or developed in close association with corridor-type nuraghi. The site of Sa Mandra Manna provides a particularly instructive example: here a semicircular megalithic wall encloses an area that was not naturally defended, incorporating within its perimeter a corridor-type monument (Basoli and Doro 2012). Excavation data from comparable contexts demonstrate architectural continuity between prehistoric domestic units and the earliest stone towers, attesting that the emergence of monumentality was rooted in established local building traditions rather than resulting from intrusive or externally imposed forms.

The corridor nuraghe, characterised by elongated internal passages, relatively modest elevation and complex internal circulation, appears as an initial stage in a longer process of architectural elaboration. Its construction required coordinated labour, technical competence and collective planning, implying the existence of social mechanisms capable of mobilising communal effort on a significant scale. Yet these monuments were embedded within lived-in landscapes and should not be interpreted primarily as fortifications. Their spatial positioning and association with villages suggest that they functioned as focal points within defined territorial units, articulating communal identity and serving as reference markers in inter-community relations.

Funerary monuments formed an integral part of this territorial articulation. The so-called Giants' Tombs were not only burial places, but also highly visible landmarks embedded within the landscape, often positioned along routes or at the margins of plateaus. Their monumentality and prolonged use reinforced the relationship between communities and their ancestors, contributing to the symbolic appropriation and legitimisation of territory through descent and collective memory (Depalmas 2020).

The subsequent transition from corridor nuraghi to tholos-type towers, employing corbelled vaulting and achieving greater verticality, occurred at the beginning of the late MBA and marks a significant architectural refinement. This development was not abrupt but cumulative, building upon earlier technical experimentation. In later phases, multi-tower complexes incorporating bastions and enclosed courtyards further elaborated this tradition. The trajectory from single-tower monuments to architecturally complex compounds reflect increasing structural ambition and technical sophistication; however, it does not necessarily signal the emergence of centralised political authority. Rather, it indicates the capacity of territorially based communities to invest collective labour in increasingly elaborate architectural forms.

The distribution of nuraghi, both simple and complex, corresponds closely with geomorphology and resource availability. Basaltic plateaus rich in pasture and arable land, together with zones offering accessible building stone and reliable water sources, display particularly high densities of monuments. Regional survey data confirm that certain micro-regions exhibit concentrated clusters of nuraghi and associated villages, implying demographic growth during the MBA and RBA. Such patterns indicate that settlement organisation was structured according to environmental logic and territorial management strategies, forming a spatial mosaic of autonomous yet culturally interconnected communities (Depalmas and Melis 2010).

Beginning in the late MBA and intensifying during the RBA, larger villages developed around single-towered and later complex tholos nuraghi, enabling more permanent and internally articulated settlement forms. Domestic architecture reveals a gradual centripetal tendency: circular dwelling units aggregated into increasingly cohesive compounds, a process that culminated during the LBA and EIA in courtyard-centred architectural complexes. Within these compounds, rooms were arranged radially around a central open space that likely functioned as a shared working area, locus of social interaction and setting for food-processing activities. Surrounding rooms accommodated habitation, storage and craft tasks, indicating the integration of productive and domestic functions within architecturally unified frameworks.

By the FBA, although complex nuraghi reached the height of their architectural elaboration, the construction of new towers ended. New constructive efforts shifted progressively toward the expansion and internal reorganisation of villages. Courtyard compounds became widespread, and the number of rooms per residential unit increased. This reorientation suggests a redistribution of labour from monumental construction toward productive infrastructure and domestic articulation. In this phase, the village, rather than the tower, constituted the primary socio-economic unit within the territorial system (Depalmas 2023).

Parallel to domestic and settlement reorganisation, sacred architecture achieved full development during the Iron Age. Megaron temples, circular ritual structures and sacred wells and springs structured ritual landscapes integrated within settlement territories. Around these temples, small groups of huts were constructed. These may have functioned seasonally during communal gatherings and festivals, although the possibility of more permanent occupation cannot be excluded. Larger cult complexes – sometimes interpreted as federal sanctuaries – likely operated as centres of political-religious coordination, facilitating interaction between multiple territorial groups while reinforcing shared cultural frameworks.

Across this longue durée trajectory, the Nuragic territorial system reveals a cumulative process of adaptive transformation. From dispersed early settlements and corridor monuments to aggregated courtyard villages and elaborate sanctuary complexes, the civilisation reached its apogee not through rigid centralisation, but through the capacity of territorially organised communities to negotiate identity, manage resources and articulate space in increasingly complex ways.

### 8.2 Economy and Social Organisation – Agro-Pastoral Strategies and Heterarchical Structures

The economic foundations of Nuragic civilisation were rooted in a diversified agro-pastoral system that evolved progressively from the MBA through the EIA. Although the archaeological visibility of different sectors varies according to preservation conditions and excavation strategies, the combined evidence of zooarchaeology, archaeobotany, material culture and settlement context allows the reconstruction of a complex and regionally differentiated economic framework. Subsistence was not static; rather, it underwent gradual intensification, diversification and increasing structural articulation over time.

Throughout much of the Bronze Age, animal husbandry constituted the core of subsistence. Faunal assemblages consistently indicate that sheep and goats dominated domestic herds, frequently accounting for close to 60% of identified remains. These were followed by pigs and cattle in varying proportions depending on region and chronological phase. Age-at-death profiles reveal that most caprines and pigs were slaughtered at relatively young stages, suggesting a primary orientation toward meat consumption. In contrast, cattle display broader age ranges, indicating their use not only for meat but also for traction, milk production and other secondary products. The exploitation of secondary products – milk, wool, skins and draught power – points to a diversified management strategy that integrated pastoral and agricultural systems.

Hunting formed a consistent complement to domestic production. Deer hunting, in particular, contributed a significant proportion of wild protein, while smaller game such as *Prolagus* was regularly exploited (Fonzo 2003). The relative importance of hunting varied between sites and phases, reflecting local ecological conditions and socio-economic strategies. In some inland contexts, wild fauna represents a substantial component of the faunal assemblage, suggesting that hunting retained economic and possibly symbolic importance even within increasingly structured agro-pastoral systems.

The site of Arrubiu (Orroli) provides particularly instructive evidence for diachronic change in herd composition. In the FBA levels, there is a marked increase in pig husbandry accompanied by a significant reduction in cattle and deer, while sheep and goats maintained stable proportions. During the transition from the FBA to the EIA, cattle numbers rose again, together with an increase in wild species including deer, *Prolagus* and birds. The greater representation of adult ovicaprines in later phases suggests that these animals were increasingly valued for secondary products – wool, skins and milk – rather than being exploited exclusively for meat (Fonzo 2003). These shifts reflect adaptive management strategies responsive to changing economic priorities and environmental conditions.

Further insights are provided by the faunal assemblage from the nuraghe of Toscono di Borore. Here, muflon constituted approximately 50% of the combined domestic and hunted fauna, an unusually high proportion that may reflect specific local ecological conditions or targeted exploitation strategies. Cattle accounted for 19% and pigs for 17%, while deer and roe deer together represented approximately 25% of the total remains (Webster 1996). The prominence of wild and semi-wild species in this context highlights the variability of economic strategies across the island.

EIA assemblages from Genna Maria and Sant'Anastasia further confirm regional diversity. In these contexts, sheep and goats again predominate numerically, followed by pigs, cattle and deer. However, when considering meat yield, cattle – and subsequently pigs and large wild ungulates – appear to have represented economically valuable resources despite their lower numerical representation. The relatively low proportion of old animals in these assemblages indicates that most livestock were slaughtered young, yet the survival of adult specimens confirms continued exploitation for traction, dairying and hide production. The significant presence of wild fauna at these sites demonstrates that hunting remained an important complement to pastoralism.

Marine resources also contributed to the economic system. Shellfish remains and occasional fish bones attest to the exploitation of coastal environments. At Sant'Imbenia (Alghero), marine fauna constitutes a substantial proportion of the assemblage, reflecting the strategic integration of maritime resources into local subsistence. Smaller quantities of marine remains have also been identified at inland settlements such as Sant'Antonio (Siligo) and Is Paras (Isili) (Wilkens 2003). The relatively low frequency of such finds in certain contexts may partly reflect earlier recovery methodologies rather than limited exploitation.

Agriculture formed the second fundamental pillar of the Nuragic economy. Although archaeobotanical evidence is often less abundant than faunal remains, available data attest to the cultivation of hulled barley, emmer wheat and durum wheat, together with legumes such as broad beans, and fruits including figs and grapes. The gathering of wild olives and other wild fruits complemented cultivated production. Botanical remains from contemporary sites demonstrate that agriculture was well integrated into settlement systems.

The archaeological complex of Sa Osa provides particularly illuminating evidence of diversified agricultural and subsistence strategies. Dated to the MBA (excluding its earliest phase), RBA and FBA, Sa Osa has yielded abundant archaeobotanical and faunal remains associated with perishable structures, pits and wells (fig. 28, A.1-3). Evidence includes cereal agriculture, systematic grape exploitation (fig. 28, A.4), pig and cattle husbandry, deer hunting, fishing and wetland resource use. The integration of terrestrial and aquatic resources at this site demonstrates adaptive strategies tailored to specific ecological niches. Importantly, the absence of a nuraghe at Sa Osa underscores that socio-economic complexity did not depend exclusively on stone monumentality. Productive intensification and diversified subsistence strategies were sufficient to sustain stable and resilient communities outside major monumental contexts (Usai *et al.* 2012; Depalmas *et al.* 2021b).

From the late MBA onward, economic complexity progressively increased. Larger villages developed around single-towered and later complex tholos nuraghi, enabling more permanent and internally structured settlement forms. Agricultural production intensified, and archaeobotanical remains indicate a diversified crop system centred on barley and emmer wheat, complemented by durum wheat, legumes, figs and grapes. The systematic presence of vine remains suggests organised cultivation and long-term investment in perennial crops.

The increasing presence of large storage vessels (*dolia*) during the RBA and FBA indicates systematic surplus accumulation beyond immediate household needs. Functional analyses of ceramic assemblages reveal differentiation between cooking vessels, large storage containers and forms associated with liquid consumption. Substantial storage capacity implies stockpiling of cereals and liquids, suggesting mechanisms of surplus management and redistribution.

Cooking vessels adapted for boiling and roasting indicate standardised culinary practices, while the coexistence of vessels suitable for communal consumption suggests that collective feasting may have been embedded within both social and ritual life (Depalmas *et al.* 2021).

Funerary evidence provides an important complementary perspective on these socio-economic dynamics. During the MBA and RBA, the predominance of collective burials within Giants' Tombs suggests that social identity was primarily constructed at the level of kin-based groups rather than individual status. The relative scarcity of differentiated grave goods and the communal nature of funerary rituals indicate that, although economic complexity was increasing, social distinctions were not explicitly materialised in mortuary practices. In this sense, Nuragic society appears to have maintained a strongly cohesive structure in which group affiliation prevailed over individual representation (Depalmas 2020).

Pottery production itself diversified regionally. Distinct ceramic *facies* – such as comb-decorated wares in the north and Antigori types in the south – point to differentiated cultural and possibly economic spheres within the island. At the same time, evidence of Mycenaean influence in southern Sardinia indicates participation in wider Mediterranean exchange networks. Maritime contacts extended toward the eastern Mediterranean, including Cyprus, Crete and Sicily. Sardinia's central geographical position and mineral wealth made it a strategic node in East-West maritime routes.

Metallurgy played a central role within this economic system. The intensive production of tools, weapons and ritual bronzes reflects technological sophistication and craft specialisation even though substantial evidence of metal artifacts only appears from the end of the Bronze Age and the EIA. Representations of ox-drawn ploughs in EIA bronze figurines confirm the use of animal traction in agriculture, increasing productive capacity. The presence of metallurgical workshops in both settlement and sanctuary contexts indicates structured production and possibly controlled distribution. Control over land, livestock, metallurgical production and long-distance connections likely underpinned evolving forms of socio-economic differentiation during the Iron Age.

In its entirety, the Nuragic economic system evolved from predominantly agro-pastoral foundations toward increasing diversification, surplus accumulation and integration into Mediterranean exchange circuits. This transformation unfolded gradually and unevenly across regions, reflecting local ecological conditions, demographic pressures and expanding interregional connections.

### 8.3 Architecture, Production and Ritual Landscapes – Monumetality and Socio-Economic Reorganisation

The social organisation of Nuragic civilisation must be interpreted within the broader framework of its territorial and economic structures. Although architectural elaboration, surplus accumulation and metallurgical specialisation intensified over time, the available archaeological evidence does not indicate the emergence of a centralised apparatus during the Bronze Age. Instead, Nuragic society appears to have operated through territorially grounded and on family-based communities' systems in which authority was distributed, negotiated and situational.

Settlement patterns provide the first key indicator. The close correspondence between nuraghi distribution and environmental resources suggests that communities were organised around discrete territorial basins rather than subordinated to a supra-regional political centre. High densities of monuments and villages in certain micro-regions point to demographic growth and intensification of land use, but they do not reveal evidence for hierarchical administrative control. The absence of palatial residences clearly segregated elite quarters or radically differentiated domestic architecture reinforces the interpretation of a system structured through locally organised family groups.

Domestic architecture offers further insight into social organisation. From MBA2-3 onward, the aggregation of circular dwelling units into more cohesive compounds indicates a progressive articulation of household structure. By the LBA and EIA, courtyard-centred complexes became widespread. In these architectural arrangements, multiple rooms were organised around a central open space used for productive tasks, food preparation, storage and social interaction. The integration of habitation and production within unified compounds suggests the co-residence of extended kin groups and the development of internally coordinated household economies.

In later phases, particularly during the EIA, additional rooms were appended to existing compounds, sometimes modifying earlier spatial symmetry. This architectural expansion may reflect segmentation within extended families, demographic pressure, or diversification of economic activities requiring specialised spaces. The differentiation of rooms within domestic units indicates increasing internal complexity at the household level. However, such complexity does not necessarily correspond to rigid class stratification; rather, it points to evolving forms of social organisation responsive to demographic and economic change.

Earlier funerary monuments also played a central role within the ritual sphere. In the MBA and RBA, Giants' Tombs functioned not only as burial places but as focal points for communal ceremonies, including offerings, feasting and ritual gatherings conducted in the exedra spaces. These practices emphasised collective identity and the veneration of ancestors. In the FBA and EIA, however, a progressive shift can be observed: ritual activities increasingly concentrated in purpose-built sanctuaries, while funerary structures lost part of their central ceremonial role. This transition reflects a broader reorganisation of ritual landscapes and the differentiation of religious functions within Nuragic society (Depalmas 2020).

Ritual contexts embedded within settlements illuminate further dimensions of social structure. Sites such as Abini – which falls within the category of sanctuaries defined as "federal" – have yielded concentrations of weaponry, bronze figurines and faunal remains that are consistent with communal feasting events (Fig. 28, B). The association between surplus consumption and symbolic deposition suggests that ritual performance functioned as a mechanism for reinforcing social

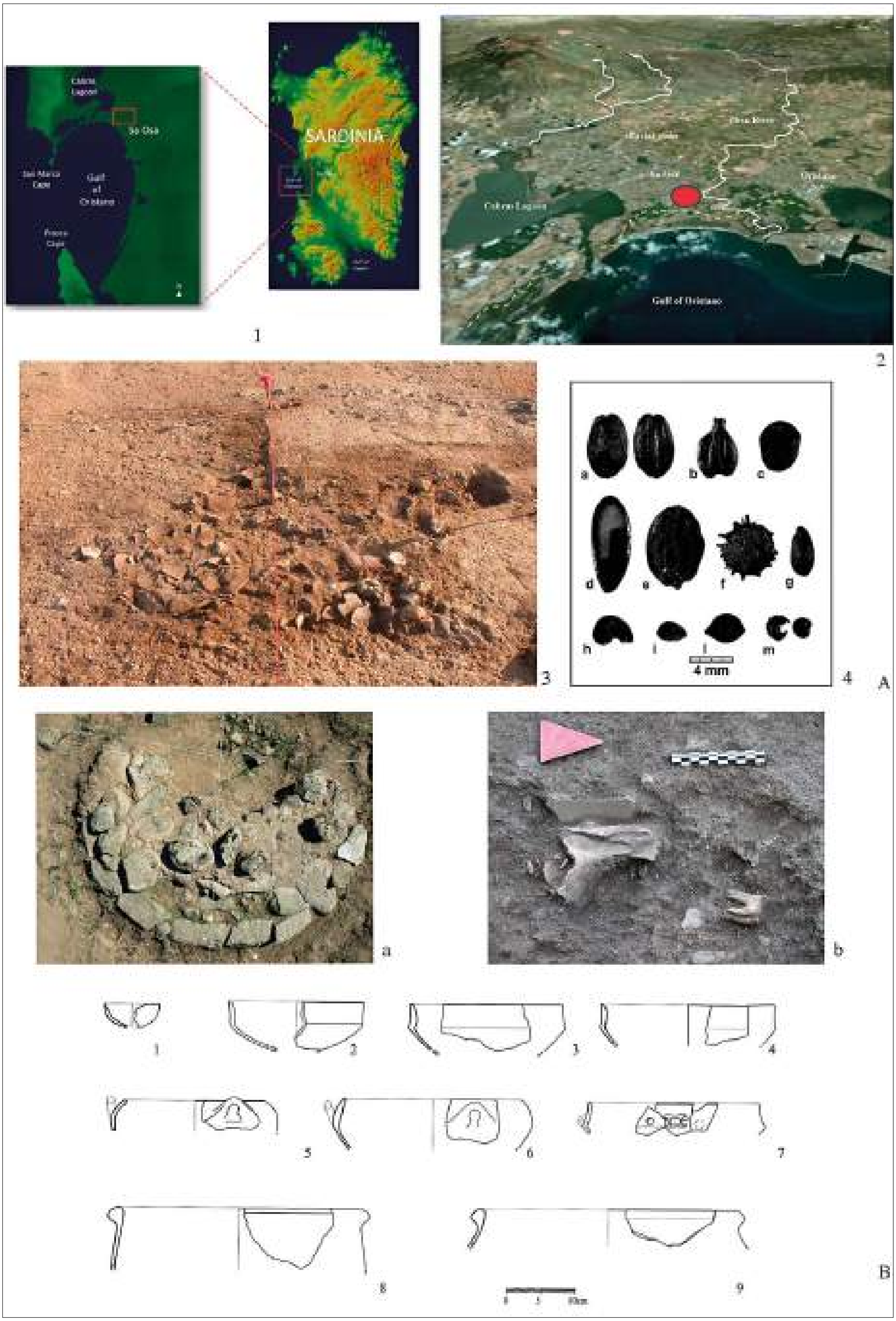
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Fig. 28 – A. Sa Osa – Cabras: location of the area in the central-west coast Sardinia (1); schematic geomorphological map of the Tirso coastal plain (2); surface of Structure Alpha (northern sector) prior to archaeological excavation (3); seeds and fruits from layer N (4): a) *Triticum aestivum/durum*, b) *Pistacia lentiscus*, c) *Juniperus oxycedrus* s.l., d) *Olea europaea*, e) *Prunus spinosa*, f) *Cucumis melo*, g) *Myrtus communis*, h) *Medicago* cf. *arabica*, i) *Medicago* cf. *littoralis*, j) *Vitis vinifera*, k) *Quercus* sp., l) *Malva* sp. (capsule and seed), m) *Rubus* sp., n) *Linum* cf. *usitatissimum*, o) *Morus* sp., p) *Fumaria* sp., q) *Ranunculus* cf. *trilobus*, r) *Rumex* sp., s) *Silene* sp., t) *Ficus carica*. B. Abini – Teti: Remains of the tholos structure of the Abini sacred spring (a); faunal remains from Structure 4 in front of the temenos (b); pottery from Structure 4: bowl (1), carinated bowls (2-4.,7),. bowls with curve inwards rim (5-6), jars with thick rim (8-10) (A 1-2: Adapted from Melis *et al*. 2017; A4: Sabato *et al.* 2015; B: drawings C. Bulla; elaborated by A. Gallo).

*A. Sa Osa – Cabras: localizzazione dell'area nella costa centro-occidentale della Sardegna (1); carta geomorfologica schematica della pianura costiera del Tirso (2); superficie della Struttura Alfa (settore nord) prima dello scavo archeologico (3); semi e frutti dal livello N (4): a) Triticum aestivum/durum, b) Pistacia lentiscus, c) Juniperus oxycedrus s.l., d) Olea europaea, e) Prunus spinosa, f) Cucumis melo, g) Myrtus communis, h) Medicago cf. arabica, i) Medicago cf. littoralis, j) Vitis vinifera, k) Quercus sp., l) Malva sp. (capsula e seme), m) Rubus sp., n) Linum cf. usitatissimum, o) Morus sp., p) Fumaria sp., q) Ranunculus cf. trilobus, r) Rumex sp., s) Silene sp., t) Ficus carica. B. Abini – Teti: Resti della struttura a tholos della sorgente sacra di Abini (a); resti faunistici recuperati durante lo scavo della Struttura 4 di fronte al temenos (b); Struttura 4: 1. Ciotola; 2-4,7. Ciotola carenata; 5-6. Ciotola a bordo ricurvo verso l'interno; 8-10. Olla con bordo spesso (A 1-2 riadattato da Melis et al. 2017; A 4 da Sabato et al. 2015; B: disegni di C. Bulla; elaborazione di A. Gallo).*

cohesion and negotiating authority. Collective gatherings around sanctuaries likely facilitated interaction among multiple territorial groups, strengthening broader cultural networks while preserving local autonomy.

Large cult complexes, i.e. "federal" sanctuaries, may be interpreted as nodal points within this networked system. These centres appear to have combined ritual authority with economic functions, including the management of storerooms and offerings and, in some cases, control over metallurgical production as indicated by workshop evidence. Rather than representing centralised state institutions, such complexes likely operated as arenas for inter-community coordination, where authority was expressed through ritual knowledge, symbolic capital and the capacity to mobilise resources.

The intensification of metallurgy during the Iron Age also had social implications. The production of tools, weapons and figurative bronzes required specialised skills and technical knowledge. Bronze figurines depicting warriors, animals and agricultural scenes suggest symbolic representations of status, identity and productive activity. Control over metallurgical expertise, surplus resources and exchange networks may have facilitated the emergence of socially differentiated groups, even if these distinctions did not crystallise into rigid hierarchical structures.

Zooarchaeological evidence further reflects the embedded nature of social organisation within economic practice. Flexible herd management strategies, the exploitation of secondary products and the continued integration of hunting into subsistence patterns indicate decision-making processes operating at household and community levels. Variability between sites suggests that economic choices were locally negotiated rather than imposed through centralised authority.

Overall, Nuragic society appears to have been structured through heterarchical relations: authority was distributed across multiple spheres – economic, ritual and territorial – and exercised through negotiation rather than through fixed institutional frameworks. Monumentality, economic intensification and ritual elaboration did not necessarily culminate in state formation but instead supported a dynamic and adaptive social landscape. Social cohesion was maintained through shared ritual practices, territorial identity and the coordinated management of resources within interconnected yet autonomous communities.

### 8.4 Economic Intensification and Landscape Transformation – From the MBA to the EIA

The trajectory of Nuragic civilisation from the MBA through the EIA is best understood as a process of cumulative transformation rather than abrupt disruption. Architectural innovation, economic intensification, environmental modification and social reorganisation unfolded gradually, interacting over several centuries to produce a dynamic and adaptive system. The apparent shifts visible in the archaeological record – whether in monumentality, settlement form, subsistence strategy or ritual practice – reflect structural reconfiguration rather than decline.

From the late MBA onward, demographic growth and economic complexity stimulated progressive changes in land use and landscape management. Pollen analyses from sites such as Arrubiu and Gasoru document expanding cereal cultivation and increasing use of fire for land clearance (López-López Sáez-Macías 2005). Forested areas were gradually reduced and converted into pasture and arable land, indicating sustained agro-pastoral expansion. The resulting landscapes became increasingly open, characterised by diminished oak woodland and the spread of Mediterranean scrub vegetation. These transformations reflect not only agricultural intensification but also deliberate environmental management practices embedded within community strategies of production.

Archaeobotanical evidence confirms the consolidation of a diversified agricultural system centred on barley and emmer wheat, complemented by durum wheat, legumes, figs and grapes. The systematic presence of vine remains suggests organised cultivation and long-term investment in perennial crops, implying stability and forward planning in land management (Ucchesu *et al.* 2015). Increasing storage capacity, as evidenced by the widespread presence of silos, large *dolia* and substantial storage jars, further indicates surplus production and structured accumulation. Such developments reflect the integration of agricultural intensification with mechanisms of storage, redistribution and possibly inter-community exchange.

Climatic conditions also formed part of this evolving context. Studies indicate that the beginning of the Iron Age, corresponding to the Early Sub-Atlantic phase (1000-600 BC), was relatively arid. Such conditions would have required adaptive responses in agricultural and pastoral management. The discovery of preserved oak acorns in a large EIA vessel at Genna Maria (Villanovaforru, Marmilla region) demonstrates continued exploitation of woodland resources within increasingly open environments, suggesting that communities balanced agricultural expansion with selective woodland use.

Environmental and economic developments were paralleled by significant architectural shifts. As already noted, the change occurred in FBA should be interpreted as a deliberate reallocation of labour and resources focused on village enlargement, the reorganisation of domestic space, and the strengthening of productive infrastructure.

Metallurgical activity expanded significantly during the Iron Age, contributing to broader socio-economic transformation. Workshops identified within village contexts, in which there appears to be a strong cultural component, such as Iloi demonstrate specialised production embedded within settlement space. The repair of storage vessels and the continued manufacture of tools, weapons and ritual bronzes indicate sustained technological competence and ongoing emphasis on surplus management (Depalmas 2024).

Sacred architecture achieved full development during this period. Megaron temples, circular ritual buildings and sacred wells structured ritual landscapes that were integrated into settlement territories. Around these sanctuaries, clusters of huts were constructed, possibly functioning during seasonal gatherings or communal festivals. The scale and organisation of certain cult complexes suggest their role as centres of coordination linking multiple territorial groups. Within these settings, the management of wealth in the form of offerings and stored goods likely intersected with ritual authority and metallurgical control.

Across the longue durée, therefore, Nuragic civilisation demonstrates adaptive resilience grounded in flexibility and negotiated transformation. Intensified agriculture, demographic growth, environmental modification, expanded metallurgy and evolving ritual landscapes did not produce abrupt rupture but cumulative reconfiguration. The cessation of new nuraghe construction marks not the end of a system but its reorientation toward new socio-economic priorities.

These transformations are also clearly reflected in funerary practices. From the FBA onward, alongside the continued reuse of earlier collective tombs, new burial forms emerged, including corridor tombs without exedra and individual pit or cist graves. The increasing presence of grave goods – often including weapons, ornaments and prestige items – suggests a growing emphasis on individual identity and status. While this shift has often been interpreted as evidence for emerging social stratification, it should be understood as part of a broader process of socio-economic differentiation that did not result in rigid hierarchical structures, but rather in more articulated and variable forms of social organisation (Depalmas 2020).

The MBA and EIA in Sardinia thus reveals a civilisation capable of balancing monumentality with productive intensification, environmental management with territorial organisation, and ritual authority with distributed social structures. Change was gradual yet profound, rooted in the capacity of interconnected communities to respond to ecological constraints, demographic pressures and expanding Mediterranean interactions while maintaining coherent cultural identity.

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Author Contributions

Andrea Cardarelli authored paragraphs 1-4; Giulia Recchia authored paragraph 5; Marco Pacciarelli authored paragraphs 6-7; Anna Depalmas authored paragraph 8. Lorenzo Cardarelli and Melissa Vilmercati contributed to multiple aspects of the research, as well as to the preparation of the text and figures.

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Matteo Cianfoni [1], Emanuele Grotto Maffiotti [2], Elena Maini [3], Fabio Fiori [4], Carmen Dominguez-Castillo [5], Ana R. Hortal [5], Bruno Martinez-Haya [5], Marlisa Mazzola [2], Alberto Cosimo Potenza [6], Miriam Punzurudu [7], Eleonora Serrone [4], Francesca Alhaique [8], Eugenio Cerilli [†], Beatriz Pino Uría [8], Antonio Tagliacozzo [8], Aurora Calderone [9], Angelica Fiorillo [9, 11], Letizia Silvestri [9, 12, 10], Simone Satriano [9], Jacopo De Grossi Mazzorin [†], Andrea Cardarelli [13], Anna Depalmas [7], Marco Pacciarelli [14], Giulia Recchia [13], Marco Zedda [7], Antonio Curci [4], Beatrice Demarchi [2], Claudia Minniti [13, *]

# Herding Strategies and Economic Roles in Italy between the Middle Bronze and the Early Iron Ages: New Insights from Zooarchaeology and ZooMS Analysis

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ABSTRACT – HERDING STRATEGIES AND ECONOMIC ROLES IN ITALY BETWEEN THE MIDDLE BRONZE AND THE EARLY IRON AGES: NEW INSIGHTS FROM ZOOARCHAEOLOGY AND ZOOMS ANALYSIS. – This paper presents the results of zooarchaeological analyses conducted within the HERDS project, which investigates socio-economic dynamics in Italy between the Middle Bronze Age and the Early Iron Age. A selection of key sites was examined to provide a broad comparative framework for understanding regional husbandry strategies. The study integrates quantitative analyses of the main domestic taxa (cattle, caprines, and pigs) and their relationship with wild fauna, kill-off patterns reflecting herd management and economic exploitation, and morphometric and biometric data. These approaches are complemented by ZooMS analyses, applied to refine taxonomic attribution in morphologically ambiguous sheep/goat remains and to identify fragmentary or otherwise unidentifiable remains. The results reveal diversified yet stable animal economies, closely adapted to local environmental conditions and regional contexts, and rooted in long-established management strategies rather than major structural transformations. Observed differences primarily reflect ecological and regional variability, highlighting the flexibility and resilience of prehistoric subsistence systems in Italy throughout the second and early first millennia BC. ZooMS outcomes are fully consistent with morphologically derived sheep/goat ratios, while significantly improving taxonomic resolution and reinforcing the overall robustness of the zooarchaeological interpretations.

RIASSUNTO – STRATEGIE DI ALLEVAMENTO E RUOLO ECONOMICO IN ITALIA TRA LA MEDIA ETÀ DEL BRONZO E L'INIZIO DELL'ETÀ DEL FERRO: NUOVE PROSPETTIVE DALLE ANALISI ARCHEOZOOLOGICHE E ZOOMS. – Il contributo presenta i risultati delle analisi archeozoologiche condotte nell'ambito del progetto HERDS, dedicato allo studio delle dinamiche socio-economiche in Italia tra il Bronzo Medio e la Prima Età del Ferro. È stata esaminata una selezione di siti chiave, al fine di costruire un ampio quadro comparativo per l'interpretazione delle strategie di allevamento su scala regionale. Lo studio integra analisi quantitative dei principali taxa domestici (bovini, ovicaprini e suini) e del loro rapporto con la fauna selvatica, profili di abbattimento indicativi delle modalità di gestione delle mandrie e dello sfruttamento economico, nonché dati morfometrici e biometrici. Questi approcci sono affiancati da analisi ZooMS, applicate sia per affinare l'attribuzione tassonomica dei resti di pecora/capra morfologicamente ambigui, sia per identificare resti frammentari o altrimenti non determinabili.
I risultati evidenziano economie animali diversificate ma stabili, strettamente adattate alle condizioni ambientali locali e ai contesti regionali, e fondate su strategie di gestione di lunga durata piuttosto che su trasformazioni strutturali rilevanti. Le differenze osservate riflettono principalmente la variabilità ecologica e regionale, mettendo in luce la flessibilità e la resilienza dei sistemi di sussistenza preistorici in Italia nel corso del II e dei primi secoli del I millennio a.C. Gli esiti delle analisi ZooMS risultano pienamente coerenti con i rapporti pecora/capra derivati dall'analisi morfologica, migliorando significativamente la risoluzione tassonomica e rafforzando la solidità complessiva delle interpretazioni archeozoologiche.

*Parole chiave:* Italia, età del Bronzo-Primo Ferro, Archeozoologia, ZooMS, Strategie di Allevamento.

*Keywords:* Italy, Bronze-Early Iron Ages, Zooarchaeology, ZooMS, Herding Strategies.

Supplementay data:

https://www.openprehistory.org/wp-content/uploads/2026/05/Cianfoni-SD-1.pdf



## 1. INTRODUCTION

This paper presents the results of zooarchaeological analyses carried out within the HERDS project, which investigates socio-economic dynamics and changes in protohistoric Italy, using the role of domestic animals (Cardarelli *et al.* in this volume) as a proxy. Within the project, archaeological sites spanning from the Middle Bronze Age to the Early Iron Age were selected based on their geographical setting, environmental context, cultural background, and chronological framework with the aim of covering a broad portion of the Italian territory and of providing an overall view of husbandry strategies adopted by prehistoric communities (tab. 1).

The choice of sites was affected by previous archaeological and archaeozoological research, carried out by the scholars involved in the project, and by the settlement dynamics of ancient communities. This led to a rather unbalanced geographical and chronological representation. From a geographical perspective, sites located in lowland areas are predominant, especially those belonging to the terramara settlements of the Emilia and Romagna regions. Chronologically, Middle Bronze Age sites are the most numerous, while those from the Early Bronze and the Early Iron Ages are less well represented.

Chronology is considered here only at the phase level, Early Bronze Age, Middle Bronze Age, Recent Bronze Age, Final Bronze Age, and Early Iron Age, since not all sites could be assigned to well-defined sub-phases (e.g. Middle Bronze Age 1, Middle Bronze Age 2 or Middle Bronze Age 3) and some of them are characterised by broader chronological spans[1].

The faunal assemblages were examined and compared using quantitative analyses of the main domestic taxa (cattle, caprines, and pigs) and their relationship with wild fauna, domestic kill-off patterns – that reflect herd management and economic exploitation – together with morphometric and biometric data. These approaches were complemented by ZooMS analyses, applied to refine taxonomic attribution in morphologically ambiguous sheep/goat remains and to identify fragmentary or otherwise unidentifiable specimens. Despite traditional morphological identification being the primary approach used to study faunal assemblages, its reliability can be limited by fragmentation, poor preservation, and the intrinsic similarity of skeletal elements among closely related taxa. This is particularly true for caprines (*Ovis* and *Capra*), which display limited distinctive morphological characters (Boessneck-Müller-Teichert 1964; Payne 1985; Halstead-Collins-Isaakidou 2002; Zeder and Lapham 2010) and overlapping biometric traits. Zooarchaeology by Mass Spectrometry (ZooMS), or peptide mass fingerprinting of collagen type I, has emerged as a valuable biomolecular method to support taxonomic identification in such contexts. By targeting taxon-specific collagen peptides, ZooMS enables the identification of zooarchaeological remains with minimal sampling, offering a rapid and cost-effective complement to morphological analysis and facilitating large-scale screening of faunal assemblages (Buckley *et al.* 2010; Buckley 2018; Korzow Richter *et al.* 2022).

Despite its growing application, ZooMS is subject to a number of methodological and interpretative challenges that must be carefully considered. Phylogenetic proximity between closely related taxa can result in shared collagen peptides, limiting taxonomic resolution and, in some cases, restricting identifications to high taxonomic groupings. These constraints are compounded by gaps in reference databases, which may prevent confident attribution when comparative spectra are unavailable (Korzow Richter *et al.* 2022). In addition, the success of ZooMS depends on the preservation of collagen, which can vary substantially within and between assemblages (Simpson *et al.* 2016), leading to incomplete peptide fingerprints or indeterminate results.

## 2. METHODS

### 2.1 Taxonomic data and domestic groups

Taxonomic composition was analysed using NISP (Number of Identified Specimens) as a measure of relative abundance (Grayson 1984). Because the assemblages differ greatly in size, and small samples are particularly sensitive to random variation, uncertainty around domestic proportions was estimated using bootstrap resampling. For each assemblage, 2,000 bootstrap samples were generated by resampling domestic NISP with replacement. For each taxonomic group, 95% confidence intervals were calculated from the bootstrap distributions. The width of the confidence intervals was used as an indicator of compositional stability and statistical reliability. Assemblages with narrow confidence intervals were interpreted as showing robust and stable domestic compositions, whereas wide intervals indicate high statistical uncertainty and require cautious interpretation. To explore similarities and differences in husbandry strategies across sites, a matrix of relative abundances of the three domestic groups (cattle, caprines, pigs) was constructed.

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[1] The supplementary materials include the chronological framework, preserving the original phase and sub-phase attributions as defined by the researchers responsible for the study of each site.

[2] Zooarchaeological data from the site of Moscosi were not included in all the analyses discussed in this study due to the absence, in the original report (Wilkens 2022), of information on mortality and biometric parameters.

| ID | Site | Chronology | Reference |
|---|---|---|---|
| 1 | Gaggio | MBA 1/2 | Minniti-Cianfoni-Potenza in study |
| 2 | Frattesina | FBA | De Grossi Mazzorin 2019 |
| 3 | Solarolo – Via Ordiere | MBA 2 | Maini-Curci 2013; Debandi-Maini 2021 |
| 4 | S. Michele di Valestra | MBA-LBA | Maini in study |
| 5 | Baggiovara | MBA 1/2 | De Grossi Mazzorin-Epifani 2013 |
| 6 | S. Rosa di Poviglio | MBA 3 – RBA | Maini in study |
| 7 | Pieve di Carpegna | EBA2-MBA1/2 | Maini in study |
| 8 | Monte Croce-Guardia | FBA | Cianfoni 2023 |
| 9 | Moscosi[2] | MBA 3 - RBA 2 | Wilkens 2002 |
| 10 | Montarice | MBA 3-RBA 1 | Maini in study |
| 11 | Monte Morra | FBA-IA 1 | Minniti-Cianfoni in Fiorillo *et al.* this volume |
| 12 | La Crocetta di Tivoli | MBA 3 | Silvestri in study |
| 13 | Roma Campidoglio | RBA | Minniti 2012 |
| 14 | Le Macine | MBA 1/2 | Tagliacozzo 2002; 2006; Tagliacozzo *et al.* 2012 |
| 15 | Coppa Nevigata | EBA2-RBA | Siracusano 2012 |
| 16 | Torre Galli | IA | Minniti in study |
| 17 | Mursia | MBA | Fiori in study |
| 18 | Abini-Teti | FBA | Zedda in study |
| 19 | Sa Osa | MBA-IA | Zedda in study |

Tab. 1 – List of the sites included in the study, with associated chronological attribution and main bibliographic references. Chronological phases follow the periodisation adopted in this work.
*Elenco dei siti inclusi nello studio, con indicazione della cronologia di riferimento e delle relative principali fonti bibliografiche. Le fasi cronologiche seguono la periodizzazione adottata in questo lavoro.*

Hierarchical clustering using average linkage was applied to the resulting matrix to identify groups of assemblages characterised by similar domestic compositions.

### 2.2 Mortality profiles

Age-at-death data were compiled from published dental wear and epiphyseal fusion data. Because different researchers involved in the project used different ageing and quantification methods, direct comparison of detailed age classes was not possible. To maximise comparability, age estimates were grouped into three broad categories: juvenile (animals slaughtered within the first year of life), sub-adult (animals slaughtered between approximately one and three years), and adult/elderly (animals slaughtered after three years of age). These categories were applied consistently to cattle, caprines, and pigs. Mortality profiles were analysed descriptively and compared across sites and chronological phases. This coarse classification inevitably reduces resolution, particularly for caprines, as it does not account for differences in the exploitation of males and females or between the different age groups among the juveniles, between sheep and goats. However, it allows the integration of heterogeneous datasets within a common analytical framework.

### 2.3 Biometric analysis

Osteometric variation was investigated using the Log Size Index (LSI) method, a widely applied zooarchaeological approach for comparing body size across archaeological populations (Simpson-Roe-Lewontin 1960; Meadow 1999; Albarella 2002; Wolfhagen 2020). The LSI technique allows measurements from different skeletal elements and anatomical districts to be expressed on a common scale by normalising them against a standard specimen, thereby increasing sample size and improving the robustness of sta-

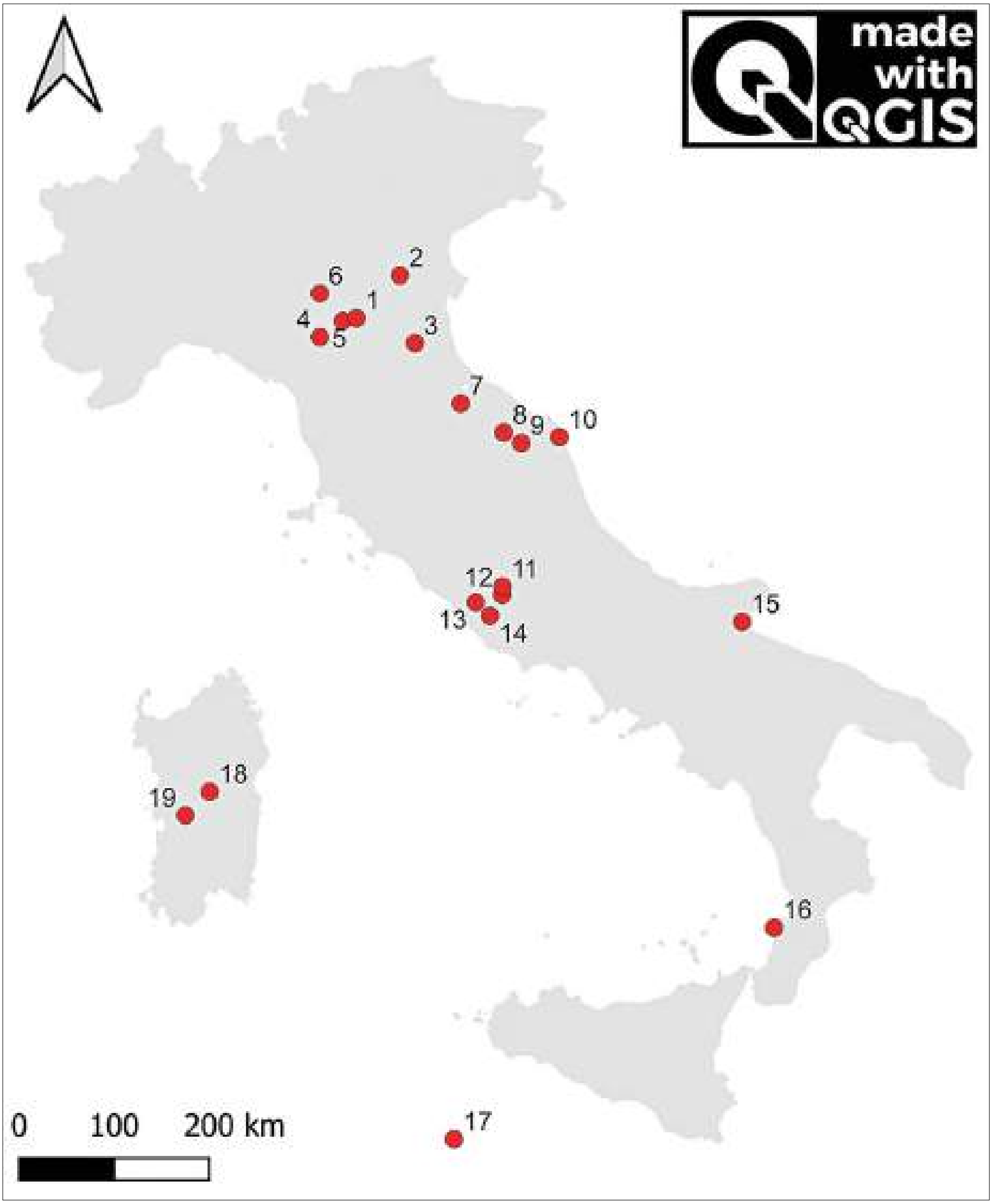


Fig. 1 – Geographic distribution of the analysed sites in this study. The identification numbers (IDs) shown on the map refer to Tab. 1 in the text.

*Distribuzione geografica dei siti analizzati in questo studio. I numeri identificativi (ID) indicati sulla mappa fanno riferimento alla Tab. 1 nel testo.*

tistical comparisons. LSI values were calculated according to the standard logarithmic formula:

$$LSI = log10\,x - log10\,x_{ref} = log10\left(\frac{x}{x_{ref}}\right)$$

where x is the observed measurement and $x_{ref}$ is the corresponding reference value derived from a standard individual. Only post-cranial elements that do not show substantial post-fusion growth of the articular epiphyses were included in the analysis, to minimise the effect of age-related size variation (Davis 2000; Popkin *et al*. 2012). Measurements from elements more affected by post-fusion growth (e.g. scapula and proximal radii or proximal metapodials with unfused distal ends) were excluded. Only fused or fusing specimens were considered. For each skeletal element, one measurement was selected to represent length and one to represent breadth, following the priority order established by Pozo *et al*. (2023) and implemented through the Zoolog R package. This procedure ensures that only one measurement per specimen is included in the statistical analysis, reducing variable interdependency and thus complying with the assumption of independence required by statistical tests. (Trentacoste *et al*. 2018; Pozo *et al.* 2023). Length and breadth measurements were analysed separately, as proxies for animal height and width respectively.

Because LSI distributions were non-normal, differences in size between sites and chronological phases were considered and tested using the non-parametric Kruskal-Wallis test. When significant differences were detected, pairwise comparisons were explored using Dunn's post-hoc test with Benjamini–Hochberg correction. To assess the magnitude of statistically significant differences, effect size was calculated as $\eta^2$ (eta squared), following the approach proposed by Tomczak and Tomczak (2014). Effect size values were interpreted using Cohen's f index (Cohen 1992), allowing the distinction between small, medium, and large effects. Because the archaeological assemblages differ greatly in the number of available osteometric observations, a preliminary exploratory assessment of data structure was performed to evaluate the statistical reliability of individual site samples. For each site, descriptive statistics were calculated, including mean, standard deviation, standard error, skewness and kurtosis. In addition, normality tests were applied to assess departures from normal distributions. This preliminary analysis showed that sites characterised by small sample sizes systematically displayed unstable descriptive parameters, strong

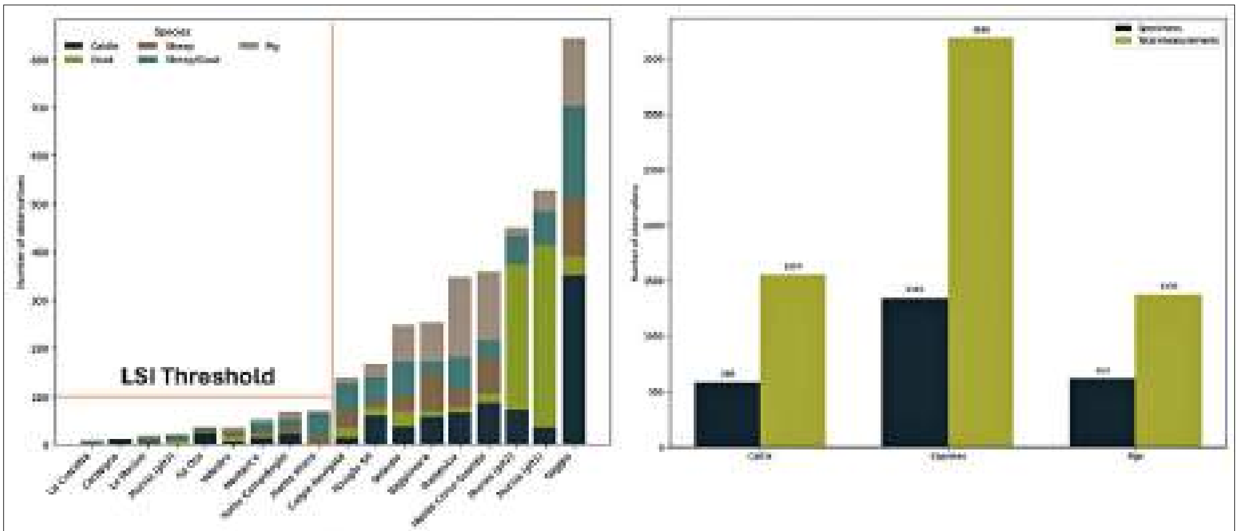


Fig. 2 – Structure of the sample used for the LSI analysis. Left: number of LSI observations per site, grouped by species (cattle, goats, sheep, indeterminate caprines, and pigs). The horizontal line indicates the minimum sample size threshold (LSI threshold) adopted for including sites in the comparative biometric analyses. Right: total number of specimens and osteometric measurements for each main category (cattle, caprines, and pigs) included in the dataset.

*Struttura del campione utilizzato per l'analisi LSI. A sinistra: numero di osservazioni LSI per sito, suddivise per specie (bovini, capre, pecore, ovicaprini e suini). La linea orizzontale indica la soglia minima di numerosità (LSI threshold) adottata per includere i siti nelle analisi biometriche comparative. A destra: numero totale di campioni (specimens) e di misure osteometriche (total measurements) per ciascuna categoria principale (bovini, ovicaprini e suini) inclusi nel dataset.*

departures from normality and highly irregular distributions, indicating a high sensitivity to random variation and outlier effects. Conversely, larger samples showed more stable statistical properties and more reliable estimates of central tendency and dispersion. Based on these results, a minimum threshold of 100 osteometric observations per site was adopted for inclusion in the LSI analysis (fig. 2). Sites below this threshold were excluded, as their data were considered statistically unreliable for meaningful logarithmic size comparisons. This filtering step was applied to minimise noise and avoid over-interpretation of patterns driven by small and highly variable samples.

The distinction between morphologically similar taxa (pig/wild boar, sheep/goat) was explored through bivariate analyses of osteological measurements (von den Driesch 1976; Davis 1992; Payne and Bull 1988) on selected diagnostic skeletal elements. Post-cranial elements were selected according to the availability of the largest number of measurable specimens for each metric pair. While dental measurements are generally considered a more reliable proxy for assessing population structure, teeth were excluded from the present analysis due to limited representation in several contexts.

In pigs and wild boar, metric variability was assessed using both the coefficient of variation (V) and a non-parametric coefficient of variation (NPV), following the approach proposed by Albarella and Payne (2005). V and NPV values, together with descriptive statistics (number of observations, minimum, maximum, mean, and standard deviation), are provided in the Supplementary Information (S6). Low coefficients of variation (typically around 4-6%) were interpreted as compatible with a single population, whereas higher values were considered indicative of potential heterogeneity, possibly reflecting the presence of multiple size groups within the assemblage.

In the case of caprines, particular emphasis was placed on the analysis of the astragalus using the Astragalar Dimension Index (ADI), a method developed by Davis (2017) to discriminate sheep and goats on an osteometric basis across different geographical areas (see Harding *et al.* 2023). The indices are calculated from ratios between distal breadth, lateral depth and greatest length (Bd/Dl and Dl/GLl, after von den Driesch 1976) and are based on the principle that sheep astragali are relatively more elongated along the proximo-distal axis, whereas goat astragali tend to be proportionally less elongated and more compact (Davis 2017). All the analyses presented in this work were performed in R (R core Team 2026). All biometric measurements (tabs. 3-4 SD), the standard reference values used for LSI calculations (tab. 1 SD), the results of the comparative tests (tab. 5 SD), and the NISP values (tab. 2 SD) are provided in the Supplementary Data.

### 2.4 ZooMS analysis

A total of 172 bone samples were analysed using ZooMS. Sampling and collagen extraction followed established protocols (Buckley *et al.* 2009; Welker *et al.*, 2015), with minor modifications. Using pliers, approximately 40-60 mg of bone chips were sampled from each specimen and demineralised in 500 µL of 0.6 M HCl for 48 h at 4 °C. During the sampling process, compact bone was preferred – as it is the portion most likely to preserve collagenous material – avoiding diagnostic areas (i.e. epiphysis), where present, to avoid potential interference with future morphological analyses. After demineralisation, the supernatant was removed and the samples were rinsed twice with 200 µL HPLC-grade water and twice with 200 µL of 50 mM ammonium bicarbonate (AmBic). The liquid fraction was discarded after each rinse, and the final AmBic wash was adjusted to pH >7.5. Subsequently, 200 µL of 50 mM AmBic was added and the acid-insoluble collagen fraction was denatured at 65 °C for 1 h, followed by enzymatic digestion with 2 µL of 0.5 µg/µL trypsin solution at 37 °C overnight. Digestion was terminated by the addition of 10% trifluoroacetic acid (TFA) until pH <2 was reached. Peptide digests were purified using C18 resin tips, dried, and stored at −18 °*C*. MALDI-TOF-MS analyses were performed in an Ultraflextreme equipment (Bruker-Daltonics) at the BIO-MS laboratory of Universidad Pablo de Olavide (Seville, Spain). The digested collagen samples were reconstituted in 0.1% TFA and mixed with a-cyano-hydroxycinnamic acid as matrix. Finally, a 0.8 µL aliquot of the sample-matrix mixture was spotted onto the sample plate and the solvent was allowed to evaporate. MALDI-TOF peptide fingerprint spectra were obtained in positive ion reflectron mode, averaging 3000 laser shots (355 nm Nd:YAG laser). The mass spectrometer was calibrated with standard compounds in the mass range m/z 500-3500 Da.

Resulting spectra were processed in mMass v5.5.0 (Niedermeyer and Strohalm, 2012) applying baseline correction (precision: 100; relative offset: 100), peak picking (S/N ratio: 3.5), and removing common contaminants' peaks (e.g., keratin peptides). No collagenous peaks were detected in procedural blanks, excluding the possibility of interference in the analysis. Once processed, replicates for each sample were averaged and taxonomic identification was attempted by comparing identified peaks against published peptide markers (BioArCh 2024). Markers were considered valid with a tolerance of ±0.6Da, and taxonomic groups with incompatible geographical range were excluded. Discrimination between sheep (*Ovis aries*) and goat (*Capra hircus*) was primarily based on diagnostic collagen type I α2-chain peptide markers. In particular, the presence of the peptide at m/z 3033.4 (α2 757-789) was used as a diagnostic marker for *Ovis aries*, whereas *Capra hircus* is characterised by the corresponding peptide at m/z 3093.4. All ZooMS data, including raw MALDI-TOF spectra and R script to reproduce fig. 10 can be found on Zenodo at https://doi.org/10.5281/zenodo.18668443.

## 3. RESULTS

### 3.1 DOMESTIC COMPOSITION AND COMPOSITIONAL STABILITY

Fig. 3 shows the relative proportions of the main domestic species and of the principal wild mammals exploited for food at each site, together with the total size of the faunal samples considered. For cervids, antler fragments were excluded from the counts, as they may derive from naturally shed antlers and not necessarily from hunted animals. In most assemblages, domestic species clearly dominate the faunal spectra although the relative frequencies of cattle, pigs, and caprines vary substantially between sites. One notable exception is the site of Le Macine, where the proportion of wild taxa – mainly red deer – is particularly high. At Coppa Nevigata, the contribution of wild fauna increases from the Middle to the Recent Bronze Age, indicating a higher exploitation of wild resources in later phases. In contrast, wild taxa are entirely absent at Mursia, in all its occupational phases, and at the upland site of Monte Morra. Due to the uneven chronological representation of the dataset, however, no clear temporal trend can be identified. Taken together, these results confirm patterns already documented in previous zooarchaeological studies from both southern and northern Italy: domestic species consistently dominate the faunal assemblages, while higher proportions of wild taxa are restricted to specific, locally defined contexts rather than reflecting broader regional or chronological shifts.

Bootstrap confidence intervals (fig. 4 right) further highlight marked differences in statistical reliability between assemblages. Large samples, such as Mursia, Coppa Nevigata, and Frattesina, show narrow confidence intervals, indicating stable and robust domestic compositions. In contrast, smaller assemblages, including Pieve di Carpegna, Torre Galli, and Sa Osa, display wide confidence intervals and high uncertainty. This demonstrates that not all assemblages can be compared with the same degree of confidence, and that domestic proportions derived from small samples must be interpreted cautiously.

The heatmap of relative abundances reveals clear differences in domestic composition across the dataset (fig. 4 left). Two broad patterns can be identified. The first group is characterised by a strong dominance of caprines, suggesting husbandry strategies focused primarily on sheep and goats. The second group includes more balanced assemblages, with cattle, caprines, and pigs occurring in comparable proportions, although with substantial internal variability. Within this second group, several sub-patterns emerge. Baggiovara, Le Macine, and Frattesina show a stronger emphasis on pig husbandry, while Sa Osa, Pieve di Carpegna, and Torre Galli stand out for their high proportions of cattle. Other sites, such as Poviglio, Gaggio, and Monte Croce-Guardia, display more balanced compositions, with caprines being frequent but not dominant. Despite the uneven geographical distribution of the dataset, a broad territorial trend is observable: southern Italian sites tend

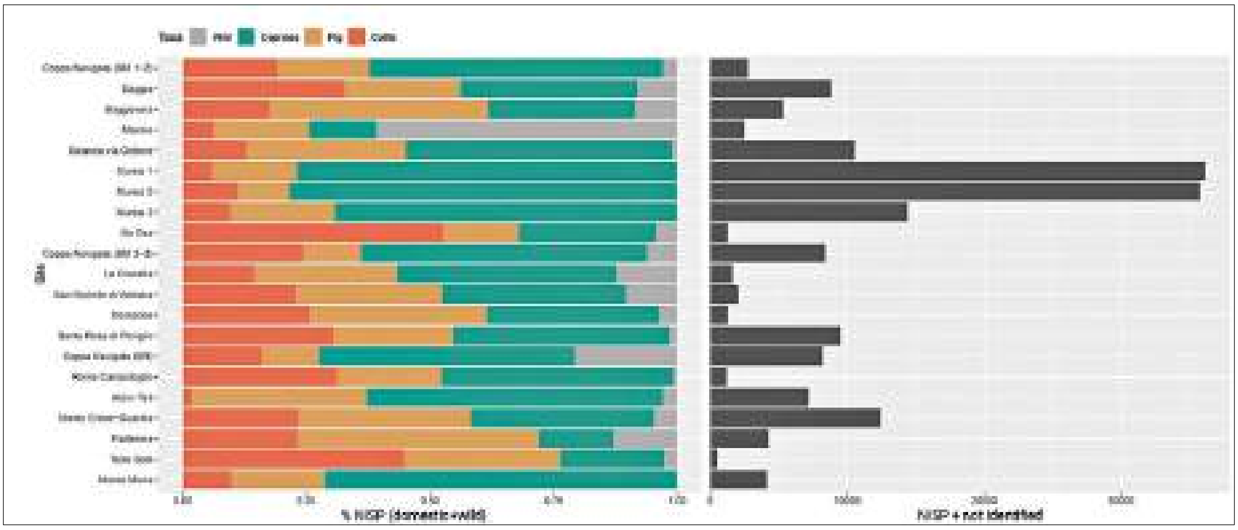


Fig. 3 – Faunal composition of the analysed sites. Left: relative frequencies (% NISP) of the main taxonomic groups (cattle, caprines, pigs, and wild fauna) for each site, calculated on the total number of identified remains (domestic + wild). Right: overall sample size per site, expressed as total NISP including unidentified remains.

*Composizione faunistica dei siti analizzati. A sinistra: frequenze relative (% NISP) dei principali gruppi tassonomici (bovini, ovicaprini, suini e fauna selvatica) per ciascun sito, calcolate sul totale dei resti identificati (domestici + selvatici). A destra: numerosità complessiva del campione per sito, espressa come NISP totale comprensivo dei resti non identificati.*

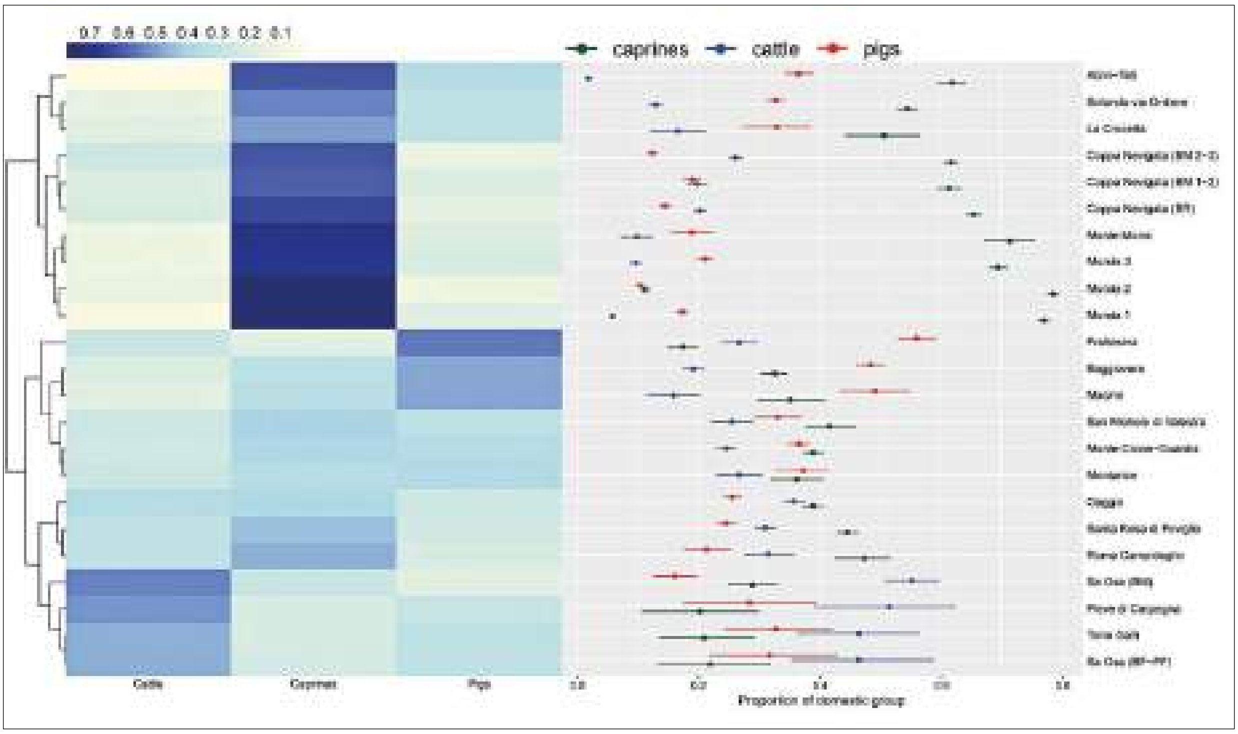


Fig. 4 – Comparison between relative frequencies and uncertainty in the proportions of the main domestic groups. Left: heatmap of relative frequencies (normalised NISP) of cattle, caprines, and pigs across the analysed sites, with hierarchical clustering of sites based on faunal composition. Right: estimated proportions of the three domestic groups for each site, with 95% confidence intervals obtained through bootstrap resampling (2,000 replicates) of NISP counts. The width of the confidence intervals is used as an indicator of compositional stability and statistical reliability.

*Confronto tra frequenze relative e incertezza nelle proporzioni dei principali gruppi domestici. A sinistra: heatmap delle frequenze relative (NISP normalizzato) di bovini, ovicaprini e suini nei siti analizzati, con clustering gerarchico dei siti sulla base della composizione faunistica. A destra: stima delle proporzioni dei tre gruppi domestici per ciascun sito, con intervalli di confidenza al 95% ottenuti tramite bootstrap resampling (2.000 repliche) sui conteggi NISP. L'ampiezza degli intervalli di confidenza è utilizzata come indicatore della stabilità composizionale e dell'affidabilità statistica dei campioni.*

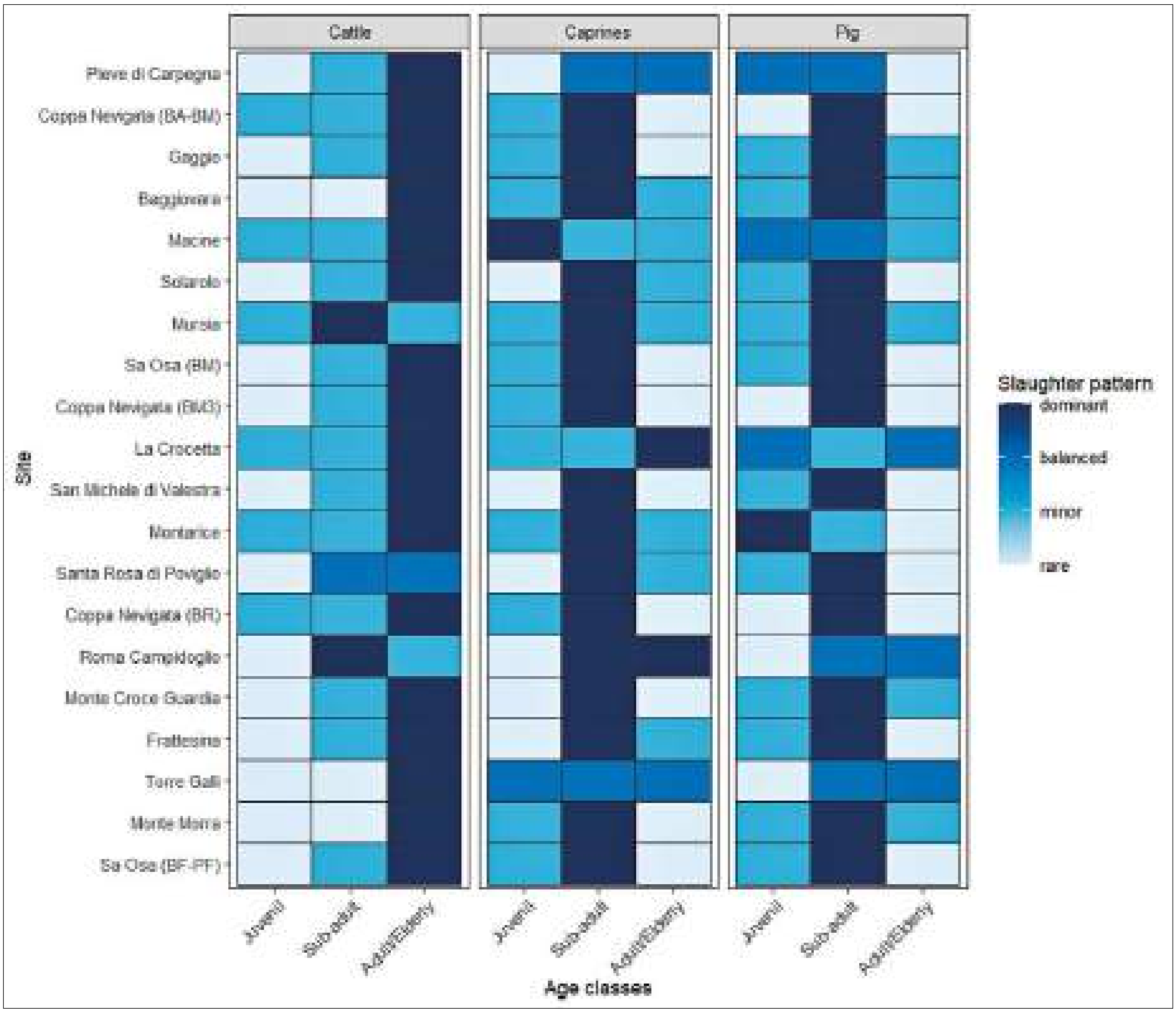


Fig. 5 – Slaughter profiles of the main domestic species. Left: cattle; centre: caprines; right: pigs. Heatmaps show the relative frequency of age classes (juvenile, subadult, adult/elderly) for each site, coded into four qualitative categories (rare, minor, balanced, dominant).

*Profili di abbattimento delle principali specie domestiche. A sinistra: bovini; al centro: ovicaprini; a destra: suini. Le heatmap mostrano la frequenza relativa delle classi d'età (giovanili, subadulti, adulti/anziani) per ciascun sito, codificate in quattro categorie qualitative (raro, minoritario, bilanciato, dominante).*

to show caprines-based husbandry economies, whereas central and northern Italian contexts are more often characterised by mixed, cattle or pig-oriented strategies.

### 3.2 Mortality patterns

Kill-off patterns show limited variation across the chronological sequence (fig. 5). Cattle were predominantly slaughtered at mature ages, consistent with their primary use as working animals and secondary exploitation for meat. Caprines display greater variability. In most sites, sub-adult individuals are prevalent, suggesting meat-oriented management strategies, while the presence of adult and elderly animals indicates flock maintenance and possibly wool production. The site of Le Macine stands out for a higher proportion of juvenile caprines, pointing to an intensified exploitation of very young individuals for milk and tender meat production. Pigs show a similar pattern, with slaughter concentrated in the juvenile and sub-adult stages and very few adult individuals. This pattern is consistent with a primarily meat-oriented exploitation strategy. Overall, mortality data suggest a broad continuity in husbandry practices across the dataset, with no clear chronological or regional shifts.

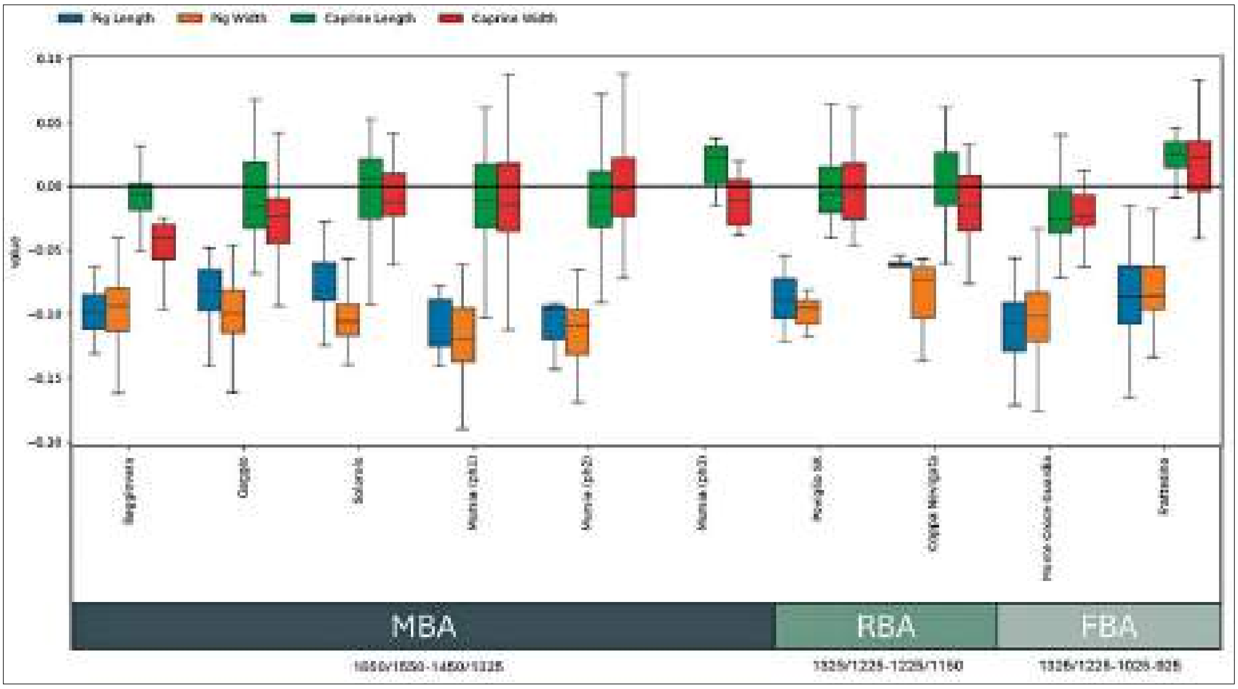


Fig. 6 – Distribution of taxon-specific LSI values (length and width) for pigs and caprines, grouped by site and chronological phase (MBA, RBA, FBA). LSI values were calculated independently for each taxon using their respective reference specimens; the zero value therefore reflects taxon-specific standards. Boxplots illustrate intra-site variability relative to each taxon's internal scaling.

*Distribuzione dei valori LSI specifici per taxon (lunghezza e larghezza) di suini e ovicaprini, raggruppati per sito e fase cronologica (MBA, RBA, FBA). I valori LSI sono stati calcolati indipendentemente per ciascun taxon utilizzando i rispettivi standard di riferimento; il valore zero riflette pertanto standard specifici per taxon. I boxplot illustrano la variabilità intra-sito rispetto alla scala interna di ciascun taxon.*

| **Taxa** | **Variable** | **chi-squared** | **df** | *p-value* | **η2** | **f** | **magnitudo** |
|---|---|---|---|---|---|---|---|
| Sheep/Goats | Width | 59.146 | 9 | 1.96E-06 | 0.0786 | 0.3042702 | moderate |
| Sheep/Goats | Length | 34.758 | 9 | 6.57E-02 | 0.0569 | 0.2528318 | small |
| Pig | Width | 27.733 | 10 | 0.001991 | 0.0568 | 0.252774 | small |
| Pig | Length | 29.629 | 6 | 4.62E-02 | 0.115 | 0.3825575 | moderate |
| Cattle | Width | 18.985 | 13 | 0.1236 | | | |
| Cattle | Length | 11.603 | 10 | 0.3125 | | | |

Tab. 2 – Results of Kruskal-Wallis tests comparing LSI distributions for length and width across sites within the main domestic taxa (caprines, pigs, and cattle). The table reports the Kruskal-Wallis $\chi^2$ statistic, degrees of freedom (df), p-value, effect size ($\eta^2$), corresponding f value, and magnitude of the effect. Effect sizes ($\eta^2$ and f) are provided only for statistically significant results.

*Risultati dei test di Kruskal-Wallis che confrontano le distribuzioni dei valori LSI per lunghezza e larghezza tra i diversi siti all'interno dei principali taxa domestici (ovicaprini, suini e bovini). La tabella riporta la statistica di test di Kruskal-Wallis ($\chi^2$), i gradi di libertà (df), il valore di p, la dimensione dell'effetto ($\eta^2$), il corrispondente valore f e la relativa magnitudo. Le dimensioni dell'effetto ($\eta^2$ e f) sono riportate solo per i test statisticamente significativi.*

### 3.3 Log Size Index results

The Kruskal-Wallis test revealed statistically significant differences in LSI values between sites for both pigs and caprines (tab. 2). No statistically significant differences were detected for cattle, which were therefore excluded from further size analyses. Effect size estimates indicate a moderate magnitude of variation for the caprine robustness index and for the pig height index, identifying these parameters as those showing the greatest variability across the dataset. Comparisons of height and robustness indices for pigs and caprines across sites show marked differences in sample size between Middle Bronze Age contexts and those of the Recent and Final Bronze Age, resulting in an uneven chronological distribution of observations (fig. 6). As a consequence, no clear trend of size variation across chronological phases can be identified. In all these taxa, variation in width appears to operate primarily at a local scale. The Middle Bronze Age sites of Baggiovara and Gaggio display lower robustness values, whereas most Recent and Final Bronze Age assemblages tend to show higher ones. Frattesina stands out consistently, exhibiting the highest values across all indices. However, small-sized pigs and caprines are also recorded at the Final Bronze Age site of Monte Croce–Guardia, indicating that size variation does not follow a simple unidirectional temporal pattern.

### 3.4 Biometric assessment of closely related taxa: pigs and wild boar

Since pigs and caprines are the domestic taxa that showed the highest degree of size variability in the LSI analysis, a more detailed biometric investigation was conducted to explore the relationships between morphologically close species within these two groups. We focused on the distinction between domestic pigs and wild boar, and between sheep and goats.

### 3.5 Pigs and wild boar

Taxonomic attribution followed the original morphological determinations provided by the respective analysts. Specimens falling between the main distributions of domestic pigs (*Sus domesticus*) and wild boar (*Sus scrofa*) were classified as *Sus* sp., based on their intermediate position in the bivariate plots. For these specimens, the original taxonomic identifications were retained in the raw dataset (tabs. 3-4 SD); V and NPV were calculated both excluding these ambiguous specimens and alternatively treating them as wild boar and as domestic pigs (tab. 6 SD).

Bivariate plots of selected suid skeletal elements (fig. 7) show a clear size separation between remains attributed to domestic pigs and those attributed to wild boar. In all graphs, pigs consistently occupy the lower portion of the distributions, while wild boar display the highest values. In each plot, at least one specimen shows intermediate dimensions, each time originating from different sites.

The presence of two distinct populations is supported by high NPV values and non-parametric distributions when pig and wild boar measurements are treated as belonging to a single group. When the two groups are analysed separately, taking into account the researchers' original identifications and excluding intermediate specimens with ambiguous values (*Sus* sp.), the V values of both groups are consistent with those expected for single populations. Wild boar show lower variability, likely due to the small number of observations, whereas domestic pigs display a relatively high V value for the proximal breadth of the radius (Bp), probably reflecting the inclusion of younger individuals (see also the greater dispersion in the lower left quadrant of the scatterplot). When ambiguous specimens are treated as domestic pigs, the coefficient of variation does not change substantially (mean increase of 0.5%). In contrast, when these specimens are merged with the wild boar dataset, the increase is slightly higher (mean increase of 1.5%). The higher increase in the coefficient of variation observed in the wild boar sample after inclusion of ambiguous specimens is likely influenced by the small sample size of this group. With low number of observations, V is highly sensitive to the addition of single observations, and therefore changes should be interpreted cautiously.

Metric variation within an animal population can be considered as a result of the interaction of three main components: age-related variation, sexual dimorphism, and residual individual variation (Payne and Bull 1988). Sexual dimorphism constitutes a significant component of metric variability in suids, being males noticeably larger than females. The effect is generally limited in dental measurements, particularly molar widths, whereas it is more evident in post-cranial elements and especially in forelimb bones (Payne and Bull 1988; Albarella *et al.* 2009). Sexual dimorphism may increase the coefficient of variation and generate apparently bimodal distributions even in samples deriving from a single population (Payne and Bull 1988). In archaeological contexts, where sex determination is rarely possible on osteometric grounds, the relative proportion of males and females can substantially influence data dis-

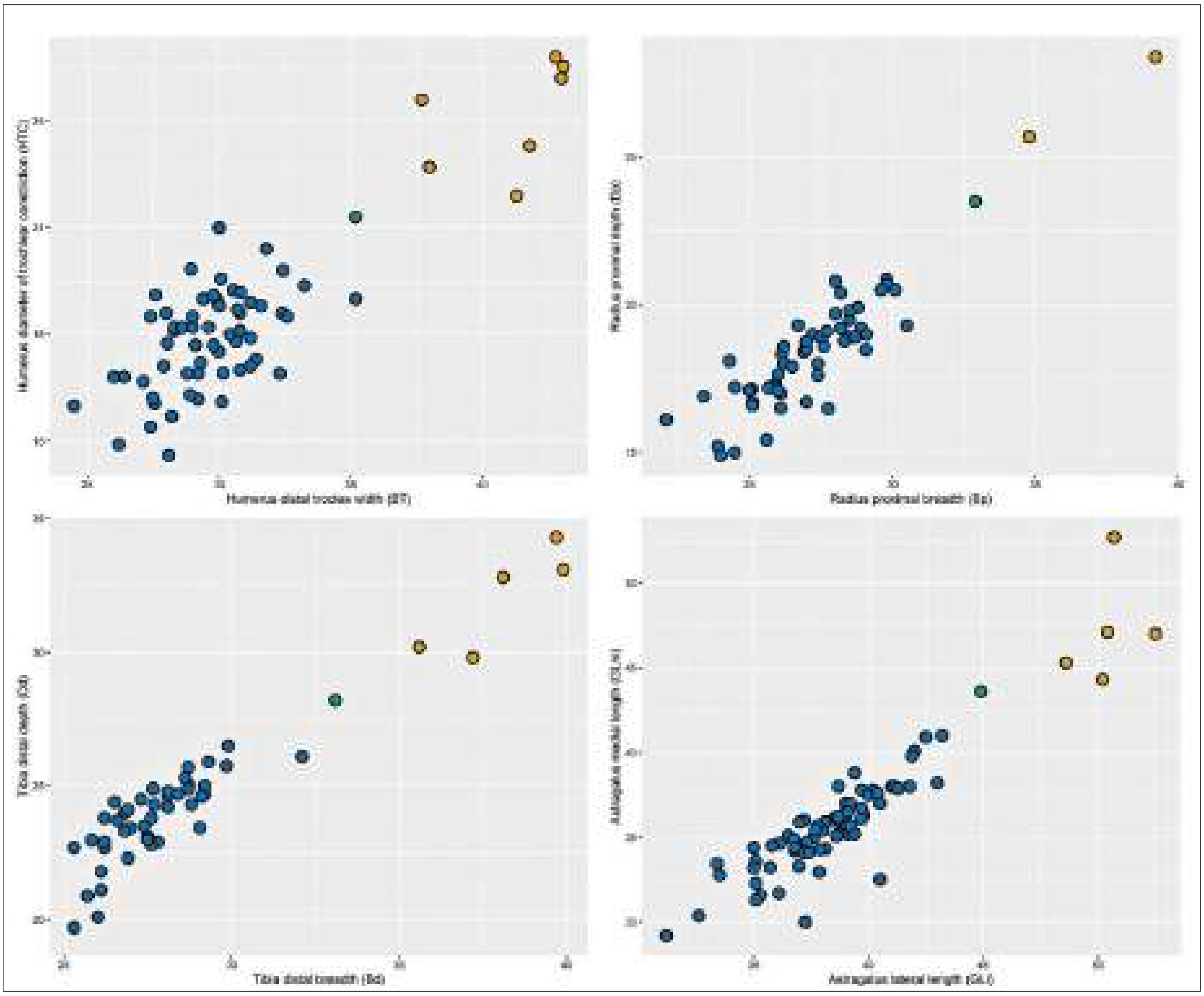


Fig. 7 – Bivariate biometric comparisons between *Sus domesticus*, *Sus scrofa*, and *Sus* sp. based on post-cranial measurements (humerus, radius, tibia, and astragalus).

*Confronti biometrici bivariati tra* Sus domesticus*,* Sus scrofa *e* Sus *sp. basati su misure postcraniali (omero, radio, tibia e astragalo).*

persion and the overall structure of the observed metric distribution. It therefore represents a parameter that must be explicitly considered when interpreting biometric patterns (see discussion).

### 3.6 Sheep and goats

The composition of the herds at each site was initially reconstructed based on morphological identifications performed on diagnostic skeletal elements (Boessneck-Müller-Teichert 1964; Zeder and Lapham 2010). It should be noted that these determinations derive from zooarchaeological analyses carried out by different researchers, with varying levels of experience; consequently, a certain degree of inconsistency in taxonomic attribution cannot be excluded. Unpublished data from the goats of Mursia provide a particularly informative reference sample, as this taxon is generally underrepresented in most Protohistoric Italian sites, where sheep are usually far more frequent (Minniti 2012; Wilkens 2012; Bertolini *et al.* 2021; Cianfoni-De Grossi Mazzorin-Minniti 2024). For most skeletal elements (fig. 8)[3] sheep and goats show a certain degree of over-

[3] The anatomical elements included in the bivariate plots were selected primarily on the basis of data availability. Priority was given to elements widely used in the literature for sheepgoat distinction and represented by the largest number of measurable specimens in the dataset. This approach was intended to maximise statistical robustness while remaining within the set of skeletal elements traditionally regarded as taxonomically informative.

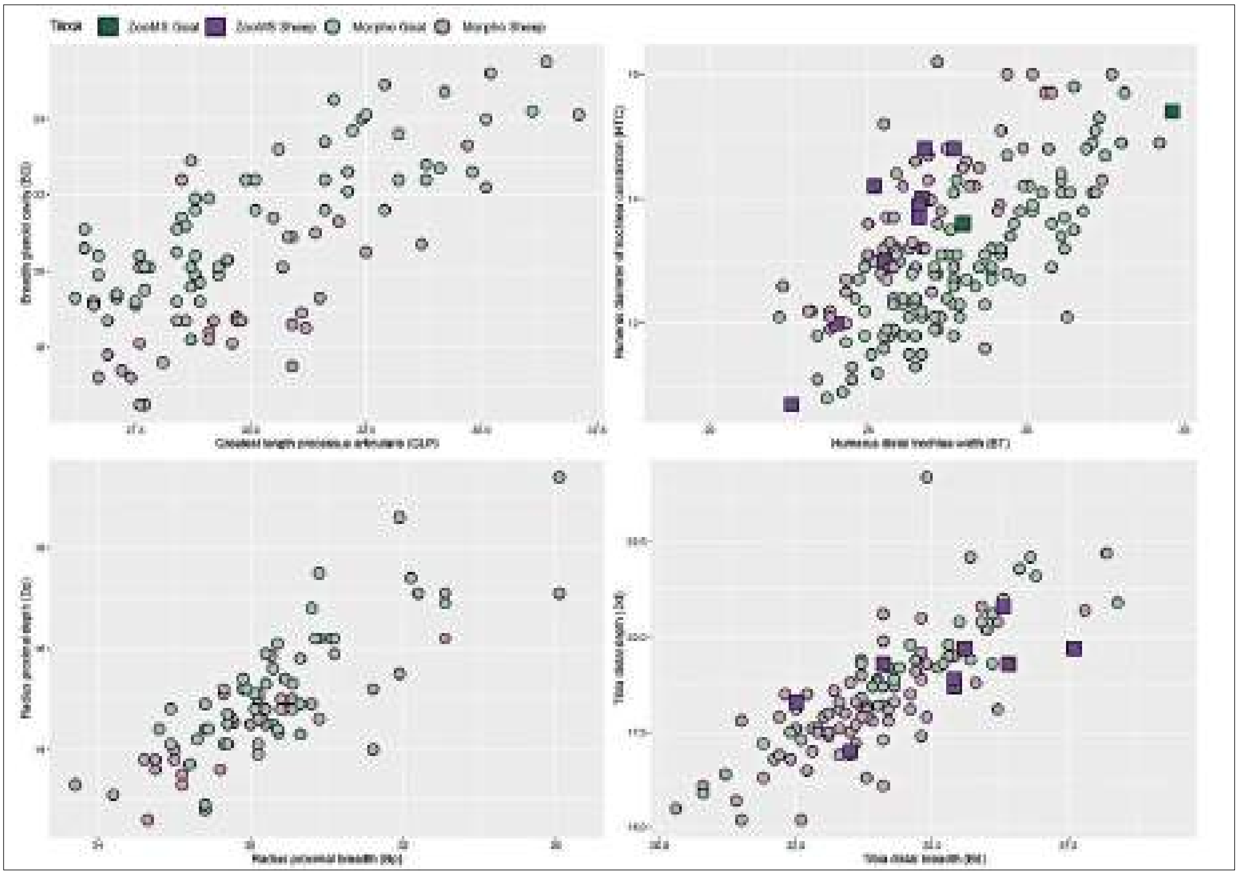


Fig. 8 – Bivariate biometric comparisons between *Ovis aries* and *Capra hircus* based on post-cranial measurements (scapula, humerus, radius, and tibia).
*Confronti biometrici bivariati tra* Ovis aries *e* Capra hircus *basati su misure post-craniali (scapola, omero, radio e tibia).*

lap in their metric distributions, although a clearer separation can be observed in some elements, particularly the scapula. The reliability of the morphological identifications is further supported by the elements analysed through ZooMS (larger squares within the graph, see fig. 9 and fig. 8). However, in both goats and sheep, several outliers are present that fall well outside the hypothetical range of overlap that is formed between the two species. The analysis of astragalus ADI provides a more robust framework for species discrimination, as biometric indices were preferred over standard linear measurements because they capture shape-related differences between sheep and goats and are less affected by size and age-related variability, thus providing a more robust and objective basis for taxonomic discrimination (Davis 2017; Salvagno and Albarella 2017; Salvagno 2020; Aniceti-Rizzetto-Giacalone 2026).

In the peninsular sites considered in this analysis, the ADI provides a clear visualisation of the separation between the two species (fig. 9, left). Although limited in number, ZooMS results contribute to defining the distribution areas of sheep and goats, even though a certain degree of overlap between the two species is expected. The data presented in this study are too scarce to define the actual morphometric distribution of astragali during the Bronze Age, especially for goats; however, if the boundaries of the sheep distribution area are assumed to be representative, what is particularly striking is the presence of extreme sheep outliers in the bottom right corner of the graph (see also the distribution of other Bronze Age sites in Cianfoni-De Grossi Mazzorin-Minniti 2024: fig. 8). For Mursia (fig. 8, right), no astragalus was selected for ZooMS analysis; however, in numerical terms the sample is considerably larger. Unlike the peninsular contexts, sheep are less numerous, yet their distribution appears consistent with that observed at the other sites. The distribution of goats is much broader, with a high number of outliers falling within the hypothetical sheep distribu-

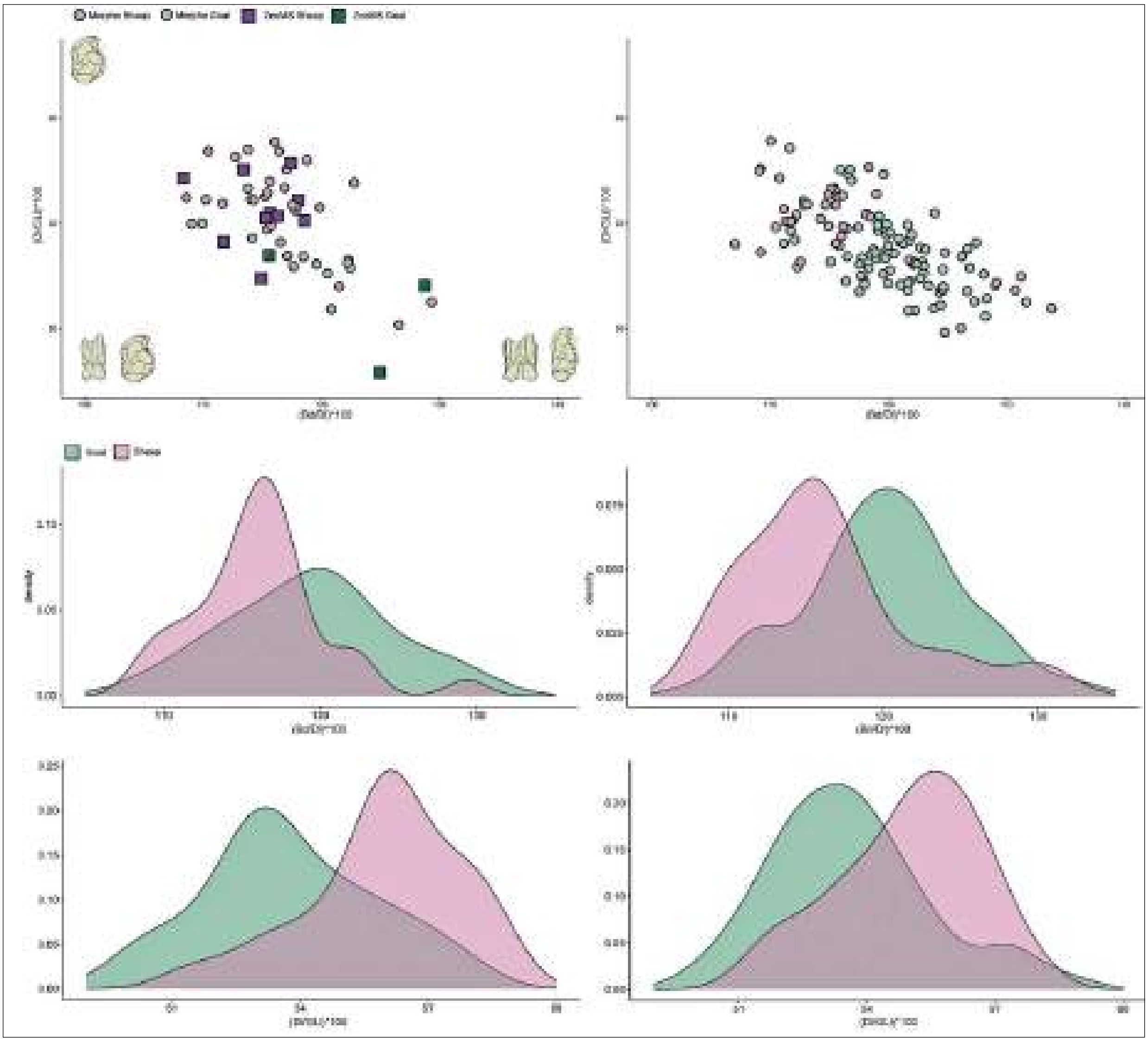

Fig. 9 – Comparison between morphological and biomolecular (ZooMS) identifications in distinguishing sheep (Ovis aries) and goats (Capra hircus), based exclusively on astragalus measurements. Left column: data from all analysed sites, excluding the site of Mursia. Right column: data from the site of Mursia only. Top: bivariate scatterplots of astragalus biometric indices (Bd/Dl × 100 vs Dl/GL × 100), showing morphological identifications and ZooMS-based reassignments. Bottom: density curves of the main astragalus indices (Bd/Dl × 100 and Dl/GL × 100). At the margins of the graph relating to the Bronze Age sites (upper left), schematic sketches deliberately exaggerate the morphological differences of the astragali (courtesy of Simon J.M. Davis).

*Confronto tra identificazioni morfologiche e biomolecolari (ZooMS) nella distinzione tra pecora (Ovis aries) e capra (Capra hircus), basato esclusivamente su misure dell'astragalo. Colonna sinistra: dati provenienti da tutti i siti analizzati, con esclusione del sito di Mursia. Colonna destra: dati relativi esclusivamente al sito di Mursia. In alto: scatterplot bivariati degli indici biometrici dell'astragalo (Bd/Dl × 100 vs Dl/GL × 100), con indicazione delle determinazioni morfologiche e delle riassegnazioni tramite ZooMS. In basso: curve di densità dei principali indici dell'astragalo (Bd/Dl × 100 e Dl/GL × 100). Alle estremità del grafico relativo ai siti dell'età del Bronzo (in alto a sinistra), gli schizzi schematici enfatizzano in modo accentuato le differenze morfologiche degli astragali (cortesia di Simon J.M. Davis).*

tion area. Nevertheless, most goats cluster in the lower right corner of the plot, an area whose attribution is supported by ZooMS data and by morphological identifications from the peninsular sites.

### 3.7 ZooMS results

The Sankey diagram (fig. 10) compares morphological identifications of caprine remains with ZooMS-based taxonomic determinations. Specimens morphologically attributed to *Ovis aries* largely remained consistent after ZooMS analysis, with the majority confirmed as sheep. In contrast, samples classified morphologically as *Capra hircus* show a greater degree of redistribution, with several specimens identified as sheep by ZooMS. Notably, the largest group of morphologically indeterminate caprines (*Ovis/Capra*) was resolved by ZooMS, predominantly to *Ovis aries* and to a lesser extent *Capra hircus*, substantially reducing taxonomic ambiguity. Only a limited number of specimens remained indeterminate after ZooMS analysis, and a small fraction were assigned to other taxa. Overall, the ZooMS results refine taxonomic attribution within the assemblage, particularly by resolving morphologically ambiguous caprine remains, while broadly supporting existing morphological identifications where these were more secure.

## 4. DISCUSSION

Despite the uneven and partly fragmentary coverage of the archaeological record, the results of this study allow the outline of a coherent framework of animal husbandry strategies in Italy across the Bronze Age, highlighting both strong chronological continuities and marked regional variability. Although Early Iron Age sites were included in the analysis, their limited representation does not allow a reliable reconstruction of husbandry practices for this late phase.

The clear predominance of domestic species in all assemblages emerges as the clearest pattern. Wild fauna appears to have played only a marginal role in most contexts, confirming a long-established trend documented in Bronze Age zooarchaeological assemblages across Italy (Minniti

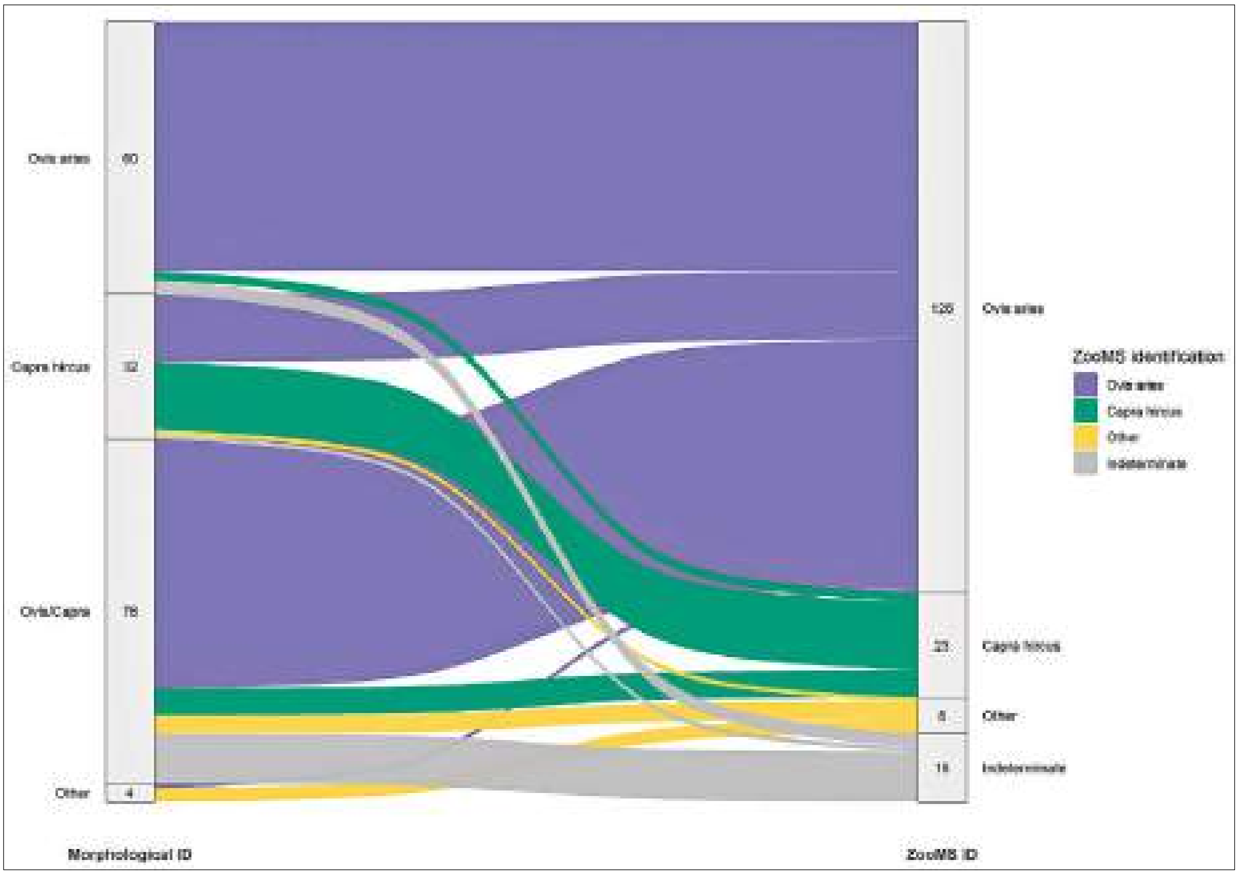


Fig. 10 – Comparison between morphological and ZooMS-based taxonomic identifications of caprine remains. The Sankey diagram illustrates the flow of specimens from initial morphological attribution to ZooMS results, highlighting the resolution of morphologically ambiguous (Ovis/Capra) specimens and overall taxonomic distribution.

*Confronto tra le identificazioni tassonomiche basate sulla morfologia e quelle ottenute tramite ZooMS sui resti di ovicaprini. Il diagramma di Sankey illustra il flusso dei campioni dall'attribuzione morfologica iniziale ai risultati ZooMS, evidenziando la risoluzione dei casi morfologicamente ambigui (Ovis/Capra) e la distribuzione tassonomica complessiva.*

2012; Wilkens 2012; Bertolini *et al.* 2021; Cianfoni-De Grossi Mazzorin-Minniti 2024; Minniti-Cianfoni-Maini *in press*). The few exceptions include most notably, Le Macine, where red deer remains are unusually abundant. The assemblage suggests that red deer hunting constituted a fundamental economic resource, while animal husbandry played a complementary role at this site. This economic model appears to have been strongly conditioned by the woodland environment surrounding the settlement (Tagliacozzo 2002, 2006; Tagliacozzo-Pino Urìa-Angle 2012).

Comparable situations are known from other Italian sites not included in this dataset such Amolara (Bertolini-Zanini-Thun Hohenstein 2015), Campestrin (Bertolini and Thun Hohenstein 2016), Monte Castellaccio (De Grossi Mazzorin 1996), Vejano (Minniti 2012: 24-25), and Ancona-Colle dei Cappuccini (Wilkens 1990), where wild taxa locally exceed 15% of the assemblage. Overall, the exploitation of wild resources appears to be opportunistic and context-specific, rather than reflecting broader regional or chronological shifts (Minniti-Cianfoni-Maini *in press*).

The analysis of domestic (cattle-pig-sheep/goat) frequencies reveals a mosaic of regionally differentiated herding economies. The predominance of goats at Mursia can be plausibly interpreted considering the specific environmental conditions of Pantelleria, characterised by a highly fragmented, rocky and resource-limited landscape, particularly suited to goat husbandry. As browsers with high ecological flexibility, goats are better adapted than sheep to exploit marginal environments, steep slopes and shrub-dominated vegetation, making them the most resilient livestock species in insular and environmentally constrained settings.

A similar ecological rationale may also explain the high frequencies of sheep and goats (with sheep-dominated flocks) observed at several sites located in mountainous or hilly contexts, such as Monte Morra, La Crocetta and Abini-Teti, which are favourable to caprine management and well suited to vertical mobility and seasonal transhumance.

Conversely, at Coppa Nevigata, where sheep largely outnumber goats, the presence of an open and flat lowland environment would have favoured ovine husbandry, in line with the grazing-oriented ecology of sheep. The data from Coppa Nevigata are consistent with those from other Bronze Age settlements located on the Adriatic coast of southern Italy (Minniti 2021).

In central Adriatic and north-central Italian sites, the situation appears more heterogeneous, with mixed assemblages that most likely reflect local environmental conditions and site-specific economic choices rather than the adoption of supra-regional cultural models. A distinct pattern instead emerges in those assemblages where pigs are predominant, notably at Le Macine, Baggiovara and Frattesina. In the case of Montarice, a relatively balanced distribution of pigs, caprines, and cattle is supported by the presence of all ecological zones, from the Adriatic coast to the Apennine uplands in Marche region (Cavazzuti *et al*. in this volume), while at the Baggiovara site the authors have suggested that the proximity of woodland environments at the foothills of the Modenese Apennines may have favoured pig husbandry (De Grossi Mazzorin-Epifani 2013). Conversely, this pattern does not seem to recur systematically in other *Terramare* contexts such as Gaggio, Tabina di Magreta, Crocetta di Sant'Agata Bolognese, and Montale, suggesting that additional factors must have contributed to the peculiar structure of this assemblage.

Frattesina represents a true outlier, characterised by a strong emphasis on pig husbandry, a pattern otherwise documented only in a limited number of earlier sites such as Canàr (Riedel 1998) and Lucone di Polpenazze (Bona 2018). In this case, the high proportion of pigs, although potentially facilitated by the presence of extensive woodland in the Po plain, may also be linked to more strictly functional factors. The exceptional nature of the site and its role as a central place within long-distance exchange networks connecting the northern Adriatic Sea to the Near East (Cardarelli 2018; Bietti Sestieri *et al.* 2019) make it plausible that a large and fluctuating population was present at certain times. Under such conditions, the need to rapidly satisfy an increased demand for food may have favoured pig husbandry. While mortality data of caprines already suggest a tendency towards protein-oriented exploitation strategies (Cianfoni-De Grossi Mazzorin-Minniti 2024), only pigs, by virtue of their intrinsic biological and management characteristics, could have provided an efficient and rapid source of animal protein at the scale required by such a context.

Although it emerges as a distinct cluster within the matrix, an economic model entirely based on cattle exploitation, such as that suggested for the assemblages of Torre Galli, Sa Osa and Pieve di Carpegna, is highly unlikely. This interpretation is supported by the high level of statistical uncertainty indicated by the wide confidence intervals associated with these samples. Most likely, the predominance of cattle remains in these assemblages reflects taphonomic or recovery biases rather than a specialised husbandry strategy.

Overall, mortality profiles seem to support the idea of long-term stability in husbandry practices. However, as already noted, the analysis presented in this contribution should be regarded primarily as a necessary generalisation aimed at enabling comparisons between datasets that derive from different analytical protocols and are therefore not directly comparable. This study clearly shows that, despite the considerable inferential potential of mortality patterns for reconstructing animal management strategies, this line of evidence has not yet been fully exploited in Italian zooarchaeological research (see Helmer-Gourichon-Vila 2007; Wright *et al.* 2014). In this perspective, it is essential that future studies converge towards a shared methodological framework, also through a re-analysis with renewed methodologies of previously published assemblages.

In this paper, this methodological framework is applied for the first time to Italian archaeological contexts as a tool to assess the internal reliability and statistical robustness of zooarchaeological samples prior to their comparative interpretation. In this sense, the method provides a critical corrective, allowing the identification of assemblages whose structure is not sufficiently robust to support high-level economic inferences.

Biometric data provide an additional line of evidence. Animal size varies significantly between sites, especially for pigs and caprines, while cattle show no statistically meaningful differences. The lack of chronological structure in size variation may indicate that these differences are not driven by long-term evolutionary or demographic trends, but rather by local husbandry practices, environmental constraints and possibly selective breeding strategies. Frattesina consistently stands out for larger and more robust animals, suggesting particularly favourable ecological conditions and/or more intensive management. In contrast, Baggiovara, Gaggio and Monte Croce Guardia are characterised by smaller individuals, possibly pointing to different ecological settings or lower investment in herd improvement. The coexistence of small-sized animals even in Final Bronze Age contexts further confirms that size increase does not reflect a chronological trend.

The biometric analysis of pigs and wild boar confirms a clear metric separation between the two taxa during the Bronze Age, a pattern already documented in previous studies (Albarella *et al.* 2006; Tecce 2020). However, our dataset includes sporadic specimens with intermediate values falling between the two distributions. Pigs and wild boar played a quantitatively different role in the diet of protohistoric communities, and their distinct modes of exploitation are likely mirrored in the biometric distributions observed in the zooarchaeological record. In Bronze Age contexts, hunting occupied a secondary position within the economic system and, for this reason, appears to have been selective rather than systematic, targeting specific individuals rather than representing an intensive exploitation of wild resources. This could explain the small frequency of wild boar remains that is reflected in a lesser availability of measurements and the absence of a clear bimodal representation within the wild population created by the presence of males and females (different in size). Furthermore, among domestic pigs, a broad representation of age classes is expected – including juveniles, subadults, adults, mature individuals, males, females, and likely castrated pigs – while wild boars were presumably hunted predominantly as adults. Therefore, it cannot be completely ruled out that some intermediate values, falling between the two distributions, may actually represent young and/or subadult wild boars or adult female wild boars. This uncertainty is compounded by the fact that the coefficient of variation is derived from the mean and standard deviation, parameters that have inherent limitations when applied to small samples or datasets containing outliers.

Although the presence of hybrid individuals cannot be excluded on biometric grounds alone, any such cases would likely be isolated. Ethnographic and zooarchaeological evidence suggests that in management systems involving recurrent breeding with wild males, continuous gene flow tends to prevent the formation of morphometrically intermediate populations, instead maintaining a predominantly wild-type size structure (Rowley Conwy-Albarella-Dobney 2012). By contrast, the clearly separated bimodal size distributions observed in the present assemblage indicate the coexistence of two biologically distinct populations with limited or no interbreeding.

The data therefore support the hypothesis that, during the Bronze Age, domestic pig populations were managed in a system that maintained separation from wild boar. It is highly probable that pigs were kept within or in close proximity to settlements under direct community control, with limited or no opportunity for interaction with their wild counterparts. At the same time, pig management practices likely encompassed a spectrum of strategies that may have varied between sites.

ZooMS analysis was employed to refine the taxonomic distinction between sheep and goats, a well-known challenge in zooarchaeology due to morphological overlap between the two species. The results, although based on a limited sample size, indicate a systematic tendency toward the over-representation of goats in the original morphological identifications, with nearly half of the analysed specimens subsequently reassigned to sheep.

This pattern is consistent with recent experimental studies demonstrating genuine interspecific morphological overlap, particularly in certain skeletal elements such as the astragalus (Sipilä *et al*. 2023). Misclassification is therefore not solely attributable to observer error but may also reflect intrinsic morphological convergence between the two taxa.

The observed reassignment pattern suggests that some morphological traits traditionally considered diagnostic for goats may be overemphasised in ambiguous cases. In assemblages where both taxa are expected to co-occur, analysts may be more inclined to interpret intermediate morphologies as goats, especially in the absence of clear population-level comparative frameworks.

Despite these limitations, morphological identification remains the primary and most practical method in zooarchaeological research and ZooMS provides a powerful complementary tool for testing problematic identifications. The integration of biomolecular and morphological approaches therefore represents an optimum strategy for testing problematic identifications and for assessing the degree of observer-related uncertainty.

Overall, the work conducted on some faunal samples from Italian sites demonstrates the importance of biometric analyses and the systematic publication of osteological specimen measurements. This strategy would not only significantly improve the analytical potential of biometric approaches (see Albarella 2002) but would also provide an effective screening framework for targeted biomolecular analyses. Furthermore, biometric data are useful control tools for verifying uncertain taxonomic identifications, as well as a robust analytical tool for detecting specific and/or anomalous patterns within metric distributions. These cases should then be prioritised for further investigation, in order to validate taxonomic attributions through ZooMS – here in the specific case of sheep/goat – and to explore additional lines of evidence, including ancient DNA and stable isotope analyses.

## 5. CONCLUSION

This study provides an integrated framework for investigating husbandry strategies and animal exploitation in Italy between the Middle Bronze Age and the Early Iron Age, combining quantitative zooarchaeology, mortality profiles, biometric analyses and ZooMS. The results highlight diversified yet stable animal economies, primarily shaped by local environmental conditions and site-specific functional roles rather than by supra-regional cultural models.

Domestic species consistently dominate the faunal assemblages, while wild resources play a marginal and context-dependent role. Variability in the relative importance of caprines, cattle and pigs reflect ecological constraints and economic specialisation. Goat-based herding strategies appear closely linked to marginal or insular environments, whereas pig-oriented economies emerge only in a limited number of functionally distinctive contexts.

Mortality and biometric data indicate a general continuity in husbandry practices, with no evidence for long-term directional trends in kill-off patterns or animal size.

Methodologically, this study demonstrates the importance of assessing the statistical reliability of zooarchaeological samples prior to comparative interpretation. Future research should therefore prioritise quality-controlled datasets and the systematic integration of biometric and biomolecular methods to strengthen reconstructions of animal economies in ancient Italy.

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## AUTHOR CONTRIBUTIONS

*Zooarchaeological analysis*

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HERDS – Animal Husbandry and its Economic Role in the Development of Central Mediterranean Protohistoric Societies – Rivista di Scienze Preistoriche – LXXVI S6 – 2026 – pp. 97-132

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# Animal Management Strategies in Bronze Age Italy. Integrating Isotopes, Zooms, Bioarchaeology and Land Use Modelling

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Abstract – Animal management strategies in Bronze Age Italy. Integrating isotopes, ZooMS, bioarchaeology and land use modelling. – The reconstruction of animal management practices is crucial for understanding prehistoric societies, their subsistence economies, and their relationships with the environment. Recent advances in biomolecular and biogeochemical research have provided key methodological tools for addressing these questions, which are particularly relevant for the study of emerging complex societies, such as those of 2nd millennium BCE Italy. In this study, we apply an integrated research protocol combining zooarchaeology, ZooMS, and strontium, oxygen, and carbon isotope analyses to investigate husbandry practices at three key Italian Bronze Age sites – Solarolo-via Ordiere, Montarice, and Coppa Nevigata – each located within distinct ecosystems. Our results indicate that Bronze Age communities developed diversified management strategies adapted to local ecological conditions, aimed at maximising primary production. Marked differences emerge between lowland systems (the Po and Tavoliere plains), characterised by residential management of domestic herbivores, and the hilly areas of Central Italy (Marche region), where transhumance were likely employed to prevent overgrazing and consequent soil erosion in the immediate hinterland of settlements. Furthermore, isotopic evidence indicates the integration of cultivated $C_4$ plants (likely broomcorn millet) into animal diets, and documents mobility of livestock individuals at both local and long-distance scales.

RIASSUNTO – STRATEGIE DI GESTIONE ANIMALE NELL'ETÀ DEL BRONZO ITALIANA. UN'INTEGRAZIONE TRA DATI ISOTOPICI, ZOOMS, BIOARCHEOLOGIA E MODELLAZIONE DI SFRUTTAMENTO DEL TERRITORIO. – La ricostruzione delle pratiche di gestione degli animali è fondamentale per la ricostruzione delle società preistoriche, le loro economie di sussistenza e i loro rapporti con l'ambiente. I recenti progressi nella ricerca biomolecolare e biogeochimica hanno fornito nuovi strumenti metodologici per affrontare queste questioni, particolarmente rilevanti per lo studio delle società complesse, come quelle dell'Italia del II millennio a.C.

In questo studio applichiamo un protocollo di ricerca integrato che combina dati archeozoologici, ZooMS e isotopici dello stronzio, dell'ossigeno e del carbonio per indagare le pratiche di allevamento in tre importanti siti italiani dell'età del Bronzo – Solarolo-via Ordiere, Montarice e Coppa Nevigata – ciascuno situato in ecosistemi distinti. I risultati indicano che tali comunità svilupparono strategie di gestione diversificate, adattate alle condizioni ecologiche locali, con l'obiettivo di massimizzare la produzione primaria. Emergono differenze marcate tra i sistemi di pianura (la pianura Padana e il Tavoliere), caratterizzati da una gestione stanziale degli erbivori domestici, e le aree collinari dell'Italia centrale (area medio-adriatica), dove si ricorreva probabilmente alla transumanza per prevenire il pascolamento intensivo e la conseguente erosione del suolo nell'immediato hinterland degli insediamenti.

Inoltre, le evidenze isotopiche indicano l'integrazione di piante coltivate a metabolismo $C_4$ (probabilmente il miglio) nella dieta degli animali e documentano la mobilità dei capi di bestiame sia su scala locale, sia su lunga distanza.

*Parole chiave:* Età del bronzo, strategie di gestione animale, analisi isotopiche.

*Keywords:* Bronze Age, Animal Management Strategies, Isotope Analysis.



## INTRODUCTION

The analysis of husbandry practices represents a fundamental step in the reconstruction of the primary economy, land use, and cultural adaptations of ancient communities to their ecosystems. Zooarchaeological methods provide a wide range of data for this purpose, including the relative frequencies of domestic and wild taxa, the proportions of major food-producing species (caprines, cattle, and pigs), sex ratios, age-at-death profiles, as well as estimates of body mass.

In recent decades, advances in biomolecular archaeology have substantially expanded the interpretive potential of zooarchaeological assemblages. While ancient DNA (aDNA) and ZooMS (Zooarchaeology by Mass Spectrometry) primarily address genetic relationships and taxonomic identification, isotope analyses contribute complementary information by investigating animal diet, mobility, and seasonality. These methods offer a means to investigate how herds were managed across landscapes and seasons, how animals were integrated into agricultural systems and how pastoral practices responded to environmental changes and socio-economical demands.

Given the importance of integrating these methods in the most standardised, replicable and efficient way, here we present a general overview of the isotopic methods and protocols that can be applied to faunal assemblages, and illustrate the potential of this approach applied to three key Italian Bronze Age contexts: Solarolo-via Ordiere (Ravenna province, Northern Italy), Montarice (Ancona province, Middle Adriatic coast), and Coppa Nevigata (Foggia province, Tavoliere plain)[1]. The sites were selected based on several criteria: (1) the availability of extensive archaeological documentation; (2) the substantial presence of domestic faunal remains; (3) a well-defined and consistent chronological framework spanning the Middle to Recent Bronze Age (MBA-RBA); and (4) their distribution across distinct climatic and ecological settings, enabling a more robust comparative analysis. The new results are then discussed in relation to available environmental data and land-use models, with the aim of contextualising animal management strategies within the territories and ecological niches occupied by these settlements.

## 1. THE IMPORTANCE OF ANIMAL HUSBANDRY IN THE CONTEXT OF BRONZE AGE ITALY

The 2nd millennium BCE witnessed a marked increase in the number of sites across Europe and the Mediterranean. This phenomenon is also clearly observable in the various regions of Italy (Cardarelli *et al.* in this volume). In parallel, assuming that an increased density of archaeological evidence reflects a phase of population pressure (Drennan *et al.* 2015), kernel density estimation (KDE) and summed probability distributions (SPDs) of calibrated radiocarbon dates from the Italian territory indicate dramatic expansions during the Early Bronze Age (2200-1700 BCE) and a phase of consolidation during the Middle Bronze Age (1700-1350 BCE) (Palmisano *et al.* 2021; Parkinson *et al.* 2021).

This pattern is partly attributable to the low visibility of settlements in the preceding 3rd millennium, which were often occupied for relatively short periods and left ephemeral archaeological traces, at least in the alluvial plain zones. However, the proliferation of evidence (i.e., sites) in the earliest phases of the Bronze Age (2200 BCE onwards) also reflects a generalized stabilization of settlements, organization of production and demographic expansion (Peroni 1996). From the Middle Bronze Age, communities began to develop a more effective relationship with their environment, stabilizing the productive potential of both agriculture and animal husbandry and creating a more conspicuous food surplus. This sustained production was supported by several strategies, such as crop rotation, renovation of soil fertility through periods of fallow, ploughing, manuring and drainage/irrigation systems (Cremaschi 2009a, 2009b; Mercuri-Sadori-Uzquiano Ollero 2011; Cattani 2021). This is particularly visible and well-documented in the framework of the Terramare system in the Po plain (Cardarelli 2010 and references therein).

Population can increase substantially in a given region when mortality decreases and/or natality rates rise. In general, increased food availability reduces the risk of malnutrition and, consequently, lowers infant mortality rates, while also enhancing female fertility and overall birth rates (Chamberlain 2007). A systematic evaluation of palaeopathological markers from 868 burials ranging from the EBA and advanced MBA in the Po Plain showed a drastic decrease in markers of metabolic disease and nutritional stress at the transition to the MBA, coinciding with the emergence of the Terramare cycle (Capecci *et al.* 2024: 122-123). This trend has been interpreted as the result of improved living conditions and nutritional patterns during the Terramare period, likely linked to a substantial increase in food production and availability. As noted above, this increased food availability derived from the application of more effective agro-pastoral practices, improved food storage and preservation methods, and greater investment in animal-derived products, all of which contributed to a more secure, balanced, and protein-rich diet.

Beyond demographic expansion, the Bronze Age witnessed an unprecedented development of exchange networks, both in terms of the intensity and diversity of exchanged goods and the geographical extent of maritime and terrestrial connections. Livestock presumably constituted a significant component of exchange and gift econ-

[1] The analyses presented in this study constitute part of a broader dataset generated within the framework of the HERDS project, which includes a larger number of Bronze and Iron Age sites distributed across different regions of Italy (Cardarelli *et al.* in this volume). The results discussed here should therefore be considered preliminary. A comprehensive analysis and a broader discussion of animal management strategies during the Bronze Age will be presented in future publications.

omies. For example, a recent study on pigs documented the introduction of an italic mtDNA haplogroup into palatial and post-palatial contexts in the Peloponnese, suggesting preferential connectivity between Central Mediterranean and Aegean societies (Meiri *et al.* 2019).

With regard to mobility, last years' isotopic research has focused predominantly on human individuals, while animals have largely been treated as proxies for establishing the local isotopic baselines. In contrast, fewer studies have specifically investigated patterns of livestock management, which appear of great relevance for the understanding of past societies.

Transhumance, in particular, occupies a central position in theoretical debates concerning the formation of the *Civiltà Appenninica*, since the work of Salvatore Maria Puglisi (Puglisi 1959). According to the scholar, the widespread evidence of implements used in the processing of animal-derived products indicates that pastoralism and transhumance were structural components of communities settled along both the eastern and western sides of the Apennine mountain chain. In his view, the seasonal movement of sheep and goat herds towards Apennine upland pastures represented the principal mechanism of interaction and cultural transmission, facilitating the development of a peninsular koine. However, this and similar hypotheses centred on animal mobility still require empirical cross-validation (see also Carrer-Migliavacca 2019). Here we argue that isotope analysis can provide a substantial contribution toward this objective.

## 2. THE USE OF ISOTOPE DATA TO INTERPRET ANIMAL MANAGEMENT STRATEGIES AND ECOLOGY

Isotope analysis has become a central tool for investigating animal management strategies and ecological interactions in archaeological contexts. Four isotopic systems are most commonly employed for this purpose: carbon ($\delta^{13}C$), nitrogen ($\delta^{15}N$), oxygen ($\delta^{18}O$), and strontium ($^{87}Sr/^{86}Sr$). Together, these isotopic ratios reflect the composition of the animal diets and drinking water, as well as the characteristics of the soils and underlying geolithology in which food resources grew.

More specifically, $\delta^{13}C$ and $\delta^{15}N$ values are primarily influenced by dietary inputs (e.g. the consumption of $C_3$ and/or $C_4$ plants and the level of protein intake), while also being modulated by broader ecological parameters, such as soil exposure, precipitation rates, and soil organic matter content. $^{87}Sr/^{86}Sr$ and $\delta^{18}O$ values are largely controlled by local geolithology and water composition and temperature, respectively, therefore providing insights into animal provenance and potential mobility across seasons or different life stages.

The type and interpretative value of isotopic data depend on sampling and analytical protocols. Analyses of $\delta^{13}C$ and $\delta^{15}N$ generally require preservation of organic components, most commonly collagen, which can be extracted from either bone or dentine. In contrast, $^{87}Sr/^{86}Sr$, $\delta^{13}C$ and $\delta^{18}O$ are preferentially measured on tooth enamel.

For both tooth enamel and dentine, sampling may be conducted either in bulk or using sequential methods, as described in detail below. Tooth enamel, in particular, represents an optimal substrate for isotopic analysis, as it undergoes minimal (or none) remodelling during the individual's lifetime and is relatively resistant to chemical diagenesis in post-depositional environments. Sequential sampling involves the extraction of a series of samples starting from the earliest formed ('older') portions of enamel and progressing along the tooth growth axis[2]. This approach allows isotopic variation to be tracked throughout the developmental stage of the tooth, reflecting changes in diet, water intake, or mobility across the seasons.

### 2.1 STRONTIUM

Strontium is one of the most widely used tracers of mobility and provenance in archaeological and palaeoecological research, with applications to investigate movements of humans and animals, exchange networks and animal trade (e.g. Lee-Thorp 2008; Montgomery 2010). In nature Sr has four isotopes ($^{84}Sr$, $^{86}Sr$, $^{87}Sr$, $^{88}Sr$), of which $^{87}Sr$

[2] For example, the third molar (M3) crowns of sheep/goat forms at 9-12 months of age and is completed around 18-22 months of the individual's life. In cattle, M3 crown formation begins 6-9 months after birth and is completed around 18-24 months of the individual's life (Barone 2001).

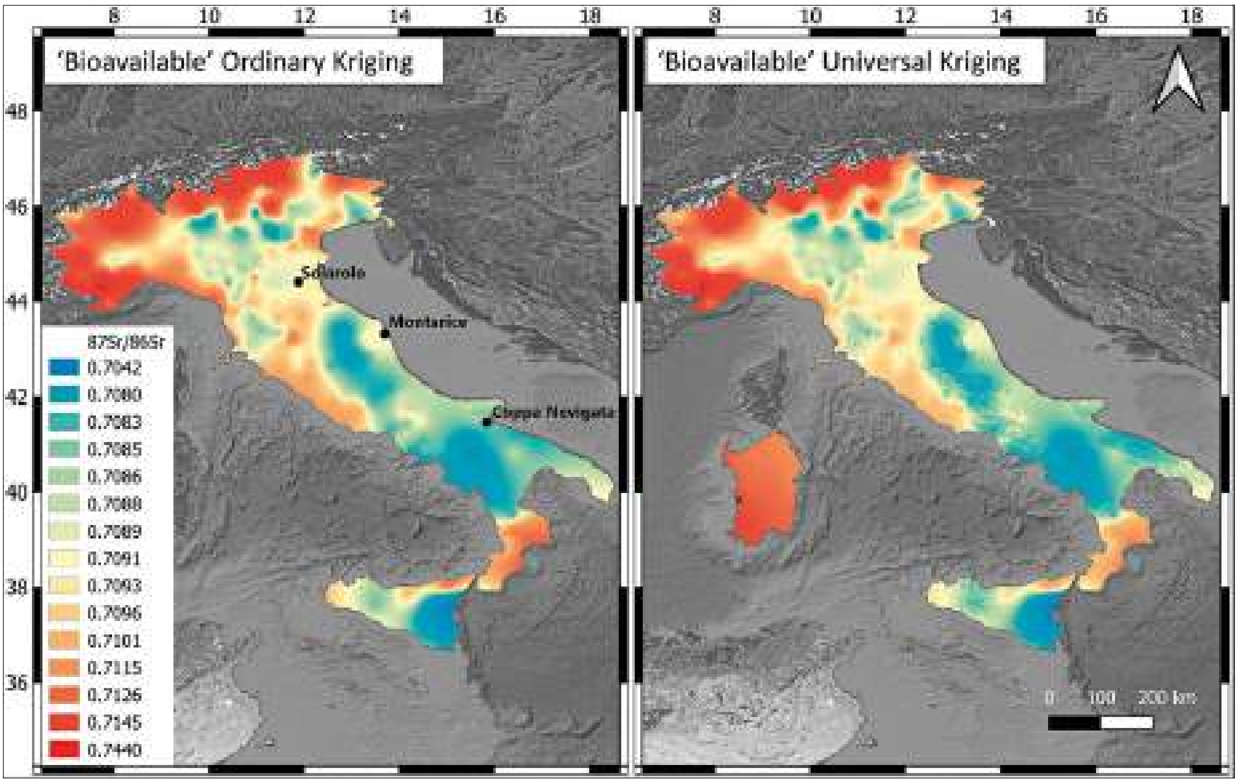


Fig. 1. $^{87}Sr/^{86}Sr$ isoscape of Italy, using different geostatistical models (Ordinary and Universal Kriging; after Lugli *et al.* 2022).

*$^{87}Sr/^{86}Sr$ isoscape del territorio italiano, ottenuto con i due metodi geostatistici (Ordinary and Universal Kriging; Lugli et al. 2022).*

is radiogenic, produced by the beta-decay of $^{87}Rb$. Because of this, the $^{87}Sr/^{86}Sr$ ratio varies across the landscape mainly as a function of bedrock type, initial Rb/Sr ratio and geological age. Older, Rb-rich rocks tend over time to yield higher (more radiogenic) $^{87}Sr/^{86}Sr$ ratios.

Strontium enters the ecosystem through weathering of bedrock, moving from rocks to soils and waters and subsequently into plants and animals as 'bioavailable' strontium (Evans *et al.* 2010). Notably, the $^{87}Sr/^{86}Sr$ signal is transferred from bedrock to soil/water, plants and tissues with negligible isotopic fractionation. In mammals, Sr substitutes for Ca in mineralized tissues, recording the isotopic composition of local food and water consumed during tissue formation. Tooth enamel is particularly important because it forms at different lifetimes without subsequent remodelling and is more resistant than bone to alteration in post depositional settings.

An important step in Sr based mobility studies is establishing the local bioavailable Sr baseline (the '*isoscape*'). Bedrock values can differ from the Sr that enters the food chain, which might reflect a mixture of sources including weathered bedrock, groundwater, atmospheric inputs and rainfall (Price *et al.* 2002; Bentley 2006). For this reason, local baselines are built using modern plants and waters and archaeological fauna/microfauna with limited home ranges. Once established, these baselines allow the $^{87}Sr/^{86}Sr$ values of animal enamel to be evaluated: values consistent with the baseline suggest local life, while differences may indicate non-local origin or seasonal movements (i.e. transhumance).

The reliability of such interpretations depends strongly on the spatial resolution and quality of the isoscape. Recent work has substantially expanded the Sr dataset for the Italian territory, enabling the construction of a national isoscape based on 1,831 measurements derived from plants, modern and archaeological animals, snails, soils, and waters (fig. 1) (Lugli *et al.* 2022). Nevertheless, the assessment of the 'local signatures' can be challenging, as each type of environmental source is characterized by its benefits and limitations (Holt *et al.* 2021; Spies *et al.* 2025). Therefore, besides the comparison of animal *vs* environment Sr signatures, it is important to evaluate the internal distribution of faunal data, to identify internal variability and potential outliers, indicative of mobility.

Since 2022, additional studies have further enriched the Italian strontium isoscape, although gaps remain. Northern, Central, and Southeastern Italy are well covered, whereas the Middle Adriatic coast, Sicily, and Sardinia require further refinement. Nowadays, isoscapes are built with increasingly sophisticated geostatistical and machine learning approaches and are widely used to predict $^{87}Sr/^{86}Sr$ across regions to strengthen provenance assignments and mobility interpretations (Gigante *et al.* 2023; Holt *et al.* 2025; Lugli *et al.* 2022; Scaggion *et al.* 2025).

### 2.2 Oxygen

Oxygen occurs in a wide range of solid, liquid and gaseous compounds and has three naturally occurring stable isotopes: $^{16}O$ (99.76%), $^{17}O$ (0.0384%) and $^{18}O$ (0.205%). Because $^{16}O$ and $^{18}O$ are by far the most abundant isotopes, oxygen isotope studies most commonly focus on the $^{18}O/^{16}O$ ratios expressed as $\delta^{18}O$.

In geochemistry and bioarcheology, $\delta^{18}O$ is especially valuable because it links environmental water to animal tissues through well understood fractionation processes, making it useful for reconstructing climate and past environments, investigating drinking behaviour, and aspects of provenance and mobility (Pederzani-Britton, 2019).

Oxygen isotope compositions are typically reported using delta (δ) notation in per mill (‰). In delta notation, a sample isotope ratio is expressed relative to an international standard. For oxygen this is commonly VSMOW (Vienna Standard Mean Ocean Water) but could also be VPDB (Vienna Pee Dee Belemnite).

The general formula is:

– $\delta^{18}O$ (‰) = [(Rsample / Rstandard) − 1] × 1000

where R is the $^{18}O/^{16}O$ ratio.

Because different laboratories may use different reporting scales (SMOW vs VPDB for carbonates), it is important to always state the reference standard used when presenting $\delta^{18}O$ values.

In mammals, oxygen-isotope analysis is commonly performed on bioapatite, the mineral component of skeletal tissues such as tooth enamel and bone. Bioapatite contains oxygen in two ionic forms both suitable for isotopic measurements: phosphate ($PO_4^{3-}$) and carbonate ($CO_3^{2-}$) groups present within the apatite structure. Although phosphate is more abundant and more resistant to alteration, carbonate-based measurements are now widely used because they have shown to be equally accurate and precise, while being easier, faster and more cost-effective in analytical practice (Iacumin *et al.* 1996). Both phosphate and carbonate in bioapatite form in isotopic equilibrium with body water, but they undergo different fractionation pathways, which can introduce species-specific offsets (Iacumin *et al.* 1996). Oxygen isotope carbonate ($\delta^{18}Oc$) data (in SMOW ‰) can be converted in phosphate ($\delta^{18}Op$) values using the equation from Iacumin *et al.* (1996), i.e. $\delta^{18}Op = \delta^{18}Oc * 0.98-8.5$.

Mammalian body water oxygen derives primarily from drinking water but also from oxygen bound in organic food compounds and atmospheric $O_2$ inhaled during respiration (Lutz-Kolodny-Horowitz 1984). The $\delta^{18}O$ of these inputs varies geographically because meteoric water is shaped by multiple environmental parameters, including precipitation regime, humidity, continentality, altitude and latitude, which all depend on temperature differences (D'Angela and Longinelli 1990). In Italy, annual average precipitation $\delta^{18}O$ values are significantly negative in Alpine and upper Apennine areas and progressively increase towards the coasts and southern regions (fig. 2). For this reason, $\delta^{18}O$ is expected to vary significantly among the three selected sites.

In continental temperate climates, $\delta^{18}O$ typically shows a marked seasonal cycle: lower values in winter and higher values in summer in the Northern hemisphere (Pederzani-Britton 2019). If tooth enamel is sampled sequentially along the growth axis, these seasonal cycles can be preserved, enabling seasonal reconstructions relevant to ecology and herding strategies, detecting shifts in water sources or elevation movements. Ingested water isotope values ($\delta^{18}Ow$) can be calculated starting from $\delta^{18}Op$ using taxon-specific equations, e.g. for goats $\delta^{18}Ow = (\delta^{18}Op-24.1)/0.88$ (Huertas *et al.* 1995). Water values can be converted to air

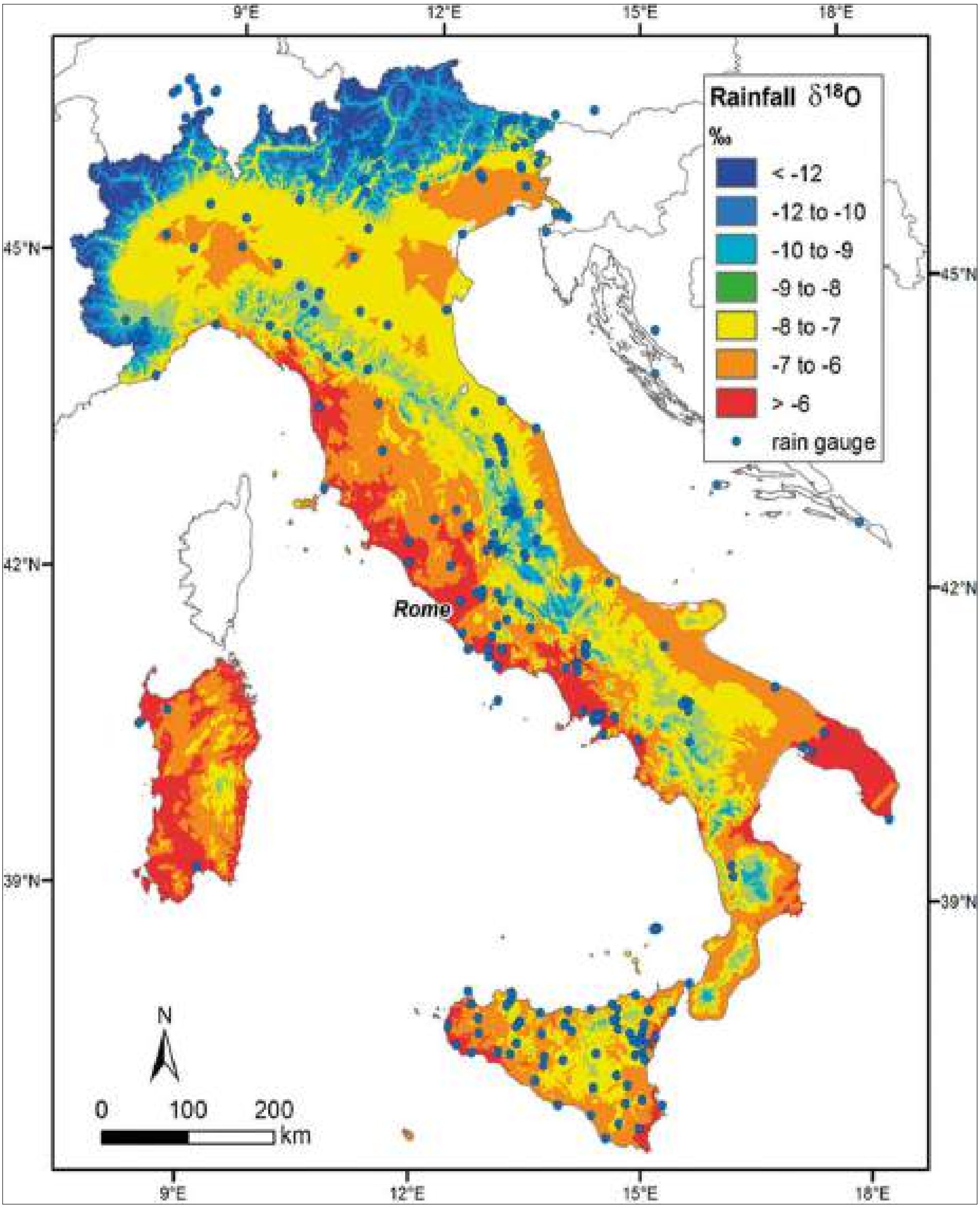


Fig. 2. Map of spatial distribution of average $\delta^{18}O$ (‰) of precipitation in Italy (data collected between 1971 and 2012; after Giustini *et al.* 2016).

*Mappa di distribuzione dei valori medi di* $\delta^{18}O$ *(‰) delle precipitazioni in Italia (dati tra il 1971 e il 2012; da Giustini et* al. *2016).*

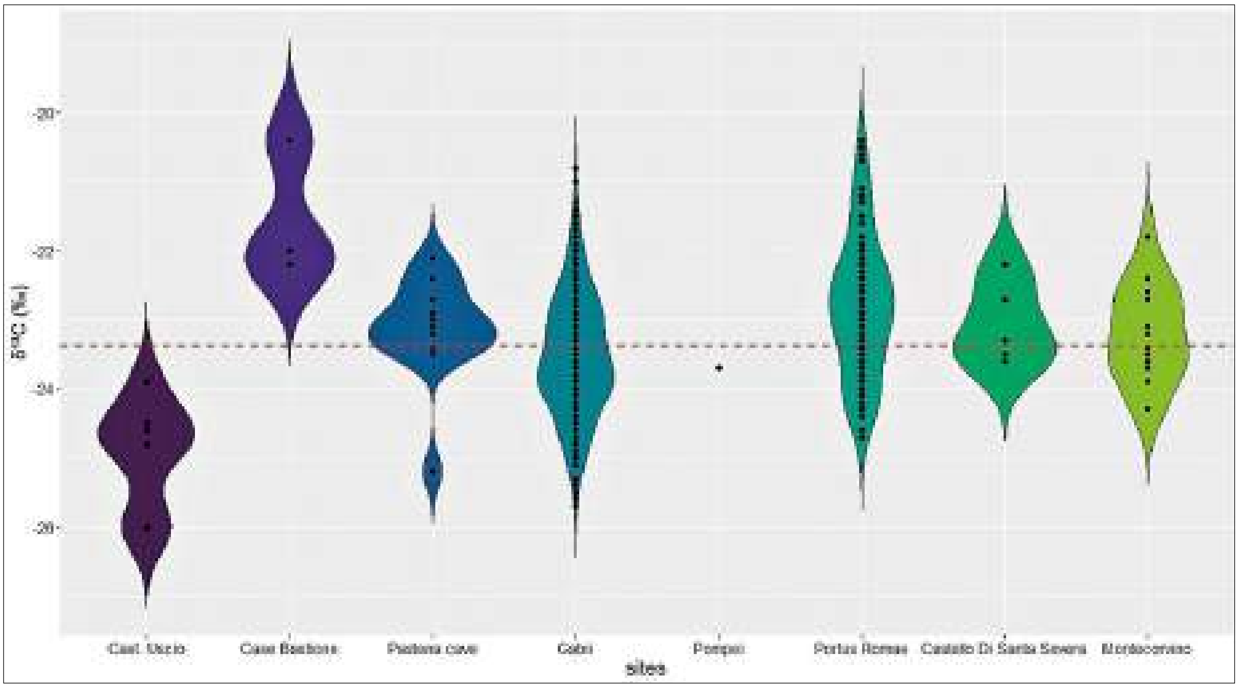


Fig. 3. $\delta^{13}C$ distributions of $C_3$-plant-grains (*Triticum* and *Hordeum* sp.) from various Italian sites (general dataset extracted from Depaermentier *et al.* 2025, and references therein).

*Distribuzione dei valori di $\delta^{13}C$ ottenuti da semi di piante $C_3$ (*Triticum *and* Hordeum *sp.) da vari siti archeologici italiani (dataset general estratto da Depaermentier et al. 2025 con bibliografia).*

temperature ($T_{air}$) using specific equations, e.g. $T_{air} = (\delta^{18}Ow+13.74)/0.53$ (equation for Europe, see Pryor *et al.* 2014).

In mobility and management studies, sequential enamel sampling is particularly informative: with incremental samples, seasonal patterns of $\delta^{18}O$ values can be observed and used to define interpretations of seasonal transhumance in livestock (see e.g. Balasse *et al.* 2002). $\delta^{18}O$ is also integrated into multi-isotope frameworks with strontium and carbon and used for the development of oxygen isoscapes to determine the expected spatial/environmental $\delta^{18}O$ variation.

## 2.3 Carbon

Carbon is a key element in the Earth biosphere and atmosphere, central to organic molecules and photosynthetic processes. It has two stable isotopes: $^{12}C$ (98.93%) and $^{13}C$ (1.07%) and a radioactive cosmogenic isotope, $^{14}C$, widely used in geochronology. Because of their different weight, carbon isotopes fractionate during chemical and biological processes, producing systematic $\delta^{13}C$ differences across environments, plants and animal tissues. $\delta^{13}C$ is widely used in archaeological research for dietary and paleoenvironmental reconstructions.

Carbon isotopes are expressed as $\delta^{13}C$ in per mill (‰) using the delta notation reported relative to the VPDB (Vienna Pee Dee Belemnite) standard.

The general formula is:

– $\delta^{13}C$ (‰) = [(Rsample / Rstandard) − 1] × 1000

where R is the $^{13}C/^{12}C$ ratio.

A major reason $\delta^{13}C$ is so powerful in archaeological and ecological studies is that the $\delta^{13}C$ values of plants vary in Europe in a predictable way with photosynthetic pathways (O'Leary 1981). $C_3$ plants (Calvin cycle pathway) typically vary between -27 and -21‰ and are commonly distributed in temperate zones (Depaermentier *et al.* 2025). $C_4$ plants (Hatch-Slack pathway) typically vary from -14 to -10‰ and are more common in warmer (tropical/subtropical) settings. Because these ranges are distinct between $C_3$ and $C_4$ plants, $\delta^{13}C$ values can often distinguish grazing in $C_4$ grassland from browsing in $C_3$ woodlands and it can track feeding strategies of livestock (Still *et al.* 2003; Cerling *et al.* 2015).

Even in regions dominated by $C_3$ vegetation $\delta^{13}C$ values can still provide environmental infor-

| Site | *Ovis aries* | *Capra hircus* | *Bos taurus* | *Sus domesticus* | Total N |
|---|---|---|---|---|---|
| Solarolo, via Ordiere (c. 1550-1450 BCE) | 5 | | 2 | 3 | 10 |
| Montarice (c. 1450-1250 BCE) | 6 | 2 | 2 | 2 | 12 |
| Coppa Nevigata (c. 1650-1550 BCE) | 1 | | | | 1 |
| Coppa Nevigata (c. 1450-1350 BCE) | | | 1 | 1 | 2 |
| Coppa Nevigata (c. 1250-1150 BCE) | 3 | 2 | 1 | 2 | 8 |
| Total N | 15 | 4 | 6 | 8 | 33 |

Tab. 1. Tooth sample distribution for isotope analysis. Coppa Nevigata specimens are subdivided among the different chronological phases.
*Distribuzione dei campioni dentali per l'analisi isotopica. I reperti di Coppa Nevigata sono suddivisi tra le diverse fasi cronologiche.*

mation. One widely discussed mechanism is the so-called "canopy effect", which causes plants to be more depleted in $^{13}C$ due to factors such as reduced light intensity and re-assimilation of $^{13}C$ depleted $CO_2$ (Van der Merwe-Medina 1991).

Carbon isotopes are measured on bone or dentine collagen (organic component) and the carbonate group ($CO_3^{2-}$) in bioapatite of bones and teeth (mineral component). Isotopic fractionation occurs in both tissues. Relative to the average diet, collagen $\delta^{13}C$ is typically about +5‰ more positive, while apatite carbonate is about +9 to +14‰ more positive, with fractionation varying with factors such as body mass (Lee-Thorp 2008). These tissues do not record identical dietary information. Collagen and apatite carbonate reflect different macronutrients pools. Collagen tends to reflect primarily the protein portion of the diet while apatite carbonate tends to reflect the energy component (carbohydrates and lipids and, only secondarily, protein). Because the relative importance of protein vs energy differs among herbivores, carnivores and omnivores, the relationship between collagen and apatite carbonate $\delta^{13}C$ can vary with trophic ecology (DeSantis *et al.* 2022)[3].

In animal management studies, $\delta^{13}C$ is particularly informative when combined with oxygen (and often strontium) and when applied at higher spatial resolution. $\delta^{13}C$ in enamel can identify seasonal foddering (e.g. switching between $C_3$ pasture and $C_4$ crop products). Intra-tooth sequential sampling can also capture diet changes and when interpreted together with $\delta^{18}O$ help evaluate seasonal mobility and land use. As with oxygen, the mineralization of enamel can introduce a damping effect of the original input signals, therefore inverse models might be necessary to reconstruct precisely the timing and amplitude of dietary changes.

A recent Europe-wide synthesis of $\delta^{13}C$ values measured on archaeobotanical macroremains of $C_3$ and $C_4$ plants has reported mean values of approximately −23‰ and −10‰, respectively (Depaermentier *et al.* 2025). In Italy, analyses of *Triticum* and *Hordeum* grains ($C_3$) from a range of ecological and chronological contexts (from the Copper Age to the sixteenth century CE) revealed values ranging between −26.0‰ and −20.4‰, with a mean of −23.4‰ (fig. 3). Established equations used to compare $\delta^{13}C$ values between a $C_3$ plant-based diet and the carbonate fraction of tooth enamel account for a systematic enrichment of approximately +13/14‰ (depending on the animal species) in tooth enamel bioapatite relative to the ingested plant material (Cerling-Harris 1999; Lee-Thorp-Van der Merwe 1991). In other words, a domestic animal consuming exclusively $C_3$ plants in the Italian geographic context should display enamel $\delta^{13}C$ values of approximately −10.4‰ to −9.4‰, depending on the species. Higher values usually indicate the inclusion of $C_4$ plants in the diet. Estimates of the proportion of $C_4$ plants in the diet follow linear mixing model equations with two end-members.

[3] Moreover, due to collagen turnover in bone, $\delta^{13}C$ values measured in bone collagen reflect an average of the bone remodelling time window of an individual's life. In contrast, $\delta^{13}C$ values measured in dental enamel apatite – which does not undergo remodeling during the individual's lifetime – represent a more restricted time frame, corresponding to the period of tooth formation.

## 3. MATERIALS

In this study, we focus on the animal management strategies employed by Middle and Recent Bronze Age communities, analysing three case studies from present-day Italy, each situated in distinct ecological niches (tab. 1). Samples were collected from well-dated archaeological layers.

The teeth from Solarolo-via Ordiere come from MBA2 layers of the settlement (c. 1550-1450 BCE). The teeth selected from Montarice belong to the MBA3-RBA1 phase (c. 1450-1250 BCE). The teeth from Coppa Nevigata are attributed to different chronological phases of the site (Protoapennine: c. 1650-1550 BCE; Apennine: c.1450-1350 BCE; Subapennine: 1250-1150 BCE).

Selected materials were first subjected to zooarchaeological analysis in order to identify pig, cattle and caprine specimens. The 18 caprine specimens were subsequently analysed using ZooMS to distinguish *Ovis* from *Capra*. Site and context descriptions are provided in the following sections. The sampling strategy was designed to assess the extent to which ecological factors influenced husbandry practices in different environments, exploring potential relationships with other aspects of land use and food production, particularly agriculture. Overall, we generated 90 $^{87}Sr/^{86}Sr$, 322 $\delta^{18}O$, and 322 $\delta^{13}C$ new data.

## 4. METHODS

### 4.1 Zooarchaeology by Mass Spectrometry (ZooMS)

ZooMS analyses were performed to determine the taxonomic assignment of 18 caprine hemimandibles by targeting diagnostic collagen peptide markers distinguishing *Capra* and *Ovis* (Buckley *et al.* 2010).

Sampling and collagen extraction followed established protocols (Buckley *et al.* 2009; Welker *et al.* 2015), with minor modifications. Approximately 40-60 mg bone chips were taken from each specimen and demineralised in 500μL 0.6M HCl for 48h at 4°C. Following demineralisation, the supernatant was removed and samples were rinsed twice in 200μL HPLC-grade water and twice in 200μL 50mM ammonium bicarbonate (AmBic), discarding the liquid fraction after each rinse and ensuring that the final AmBic aliquot reached a pH>7.5. After adding 200μL 50mM AmBic, the acid insoluble fraction of collagen was denatured at 65°C for 1h and digested in 2μL of 0.5μg/μL trypsin solution incubated at 37°C overnight. Enzymatic digestion was stopped by adding 10% trifluoroacetic acid (TFA, aqueous solution) until pH<2 was reached. Peptide digests were then purified using $C_{18}$ tips, dried and stored at -18°C.

MALDI-TOF-MS analyses were performed using an Ultraflextreme instrument (Bruker-Daltonics) at the BIO-MS laboratory of Universidad Pablo de Olavide (Seville, Spain). The digested collagen samples were reconstituted in 0.1% TFA and mixed with a-cyano-hydroxycinnamic acid as matrix. Finally, a 0.8 mL aliquot of the sample-matrix mixture was spotted onto the sample plate, and the solvent was allowed to evaporate. MALDI-TOF peptide fingerprint spectra were obtained in positive ion reflectron mode, averaging 3000 laser shots (355 nm Nd:YAG laser). The mass spectrometer was calibrated with standard compounds in the mass range m/z 500-3500 Da.

Resulting spectra were processed in mMass v5.5.0 (Niedermeyer-Strohalm 2012) applying baseline correction (precision: 100; relative offset: 100), peak picking (S/N ratio: 3.5), and removing common contaminants' peaks (e.g., keratin peptides). No collagen peaks were detected in procedural blanks, excluding the possibility of interference in the analysis. Once processed, replicates for each sample were averaged and taxonomic identification was conducted by comparing identified peaks against published peptide markers (BioArCh, v2024). Markers were considered valid with a tolerance of ±0.6Da.

### 4.2 Sampling for isotope analysis

Lower third molars (M3) were selected for analysis, as these teeth have a generally uniform growth rate within the same species (they form approximately between the first and the second year of life, see note 1). Pigs were sampled in bulk (minimum 7 mg of enamel), while herbivores (sheep, goats and cattle) were subjected to sequential sampling (minimum 1.12 mg of enamel powder).

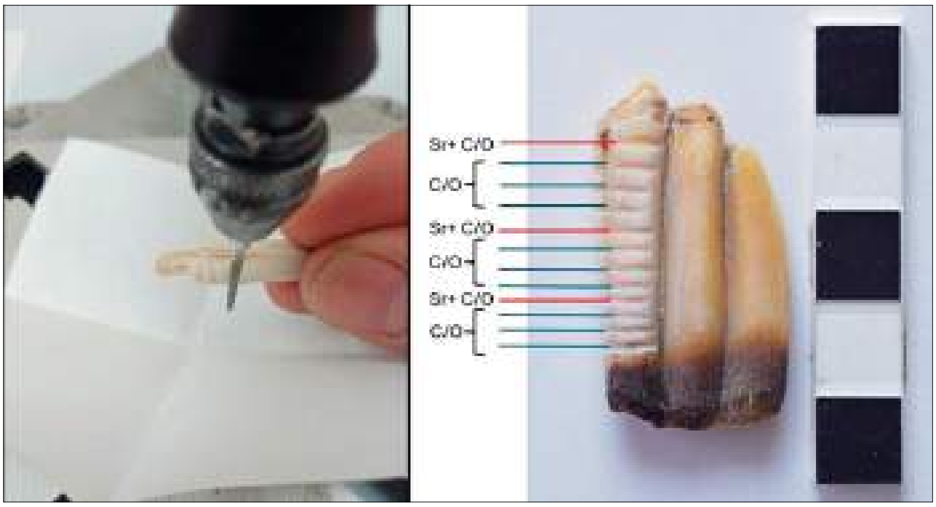


Fig. 4. Left: collection of enamel powder using sequential parallel plane sampling. Right: diagram of the sequential sampling strategy. The blue lines represent samples for C and O isotope analysis, while the red lines represent samples for Sr, C and O analysis.

*A sinistra: operazioni di campionamento di polvere di smalto dentario con campionamento piano-parallelo. A destra: schema della strategia di campionamento sequenziale. Le linee blu rappresentano i campioni prelevati per le analisi di C e O, mentre le linee rosse per il campionamento per l'analisi di Sr, C, e O.*

Sequential sampling – now well established for multi-isotopic work on herbivore teeth (Balasse 2002; Tornero *et al.* 2018; Chazin-Gordon-Knudson. 2019; Isaakidou *et al.* 2019; Messana *et al.* 2023; Trentacoste *et al.* 2020, 2023) – allows for extremely high temporal resolution of isotopic variations. If we consider the M3 to be formed between the first and the second year after birth, it is possible to detect variations that have occurred over approximately one year of the animal's life, at a nearly monthly rate. Sequential sampling is particularly well-suited to selenodont teeth, typical of bovids, which exhibit a crescent-shaped crown composed of multiple columns and a considerable crown height when unworn. For bunodont teeth (such as those of pigs), one enamel subsample was taken for $^{87}Sr/^{86}Sr$ analysis and a separate subsample for $\delta^{18}O$ and $\delta^{13}C$ analyses. Consequently, isotopic values obtained from bulk pig teeth represent averages over the period of tooth formation rather than discrete signals, as captured by sequential sampling.

A column-mounted drill was used to sample the sequence of herbivore enamel (fig. 4). Parallel sampling was conducted along the tooth column, starting from the apex of the dental crown and progressing toward the enamel-root junction. Following surface cleaning, twelve parallel samples were taken for carbon and oxygen, and three for strontium, from each tooth. The first strontium (Sr) enamel sample was taken at the same layer as the first carbon (C) and oxygen (O) sample, the second at the layer of the fifth C and O sample, and the third at the layer of the ninth C and O sample[4].

To minimize contamination, the work surface, drill tip, tooth surface and the operator's hands were cleaned and sterilized with denatured ethanol after the collection of each sample. Enamel powder was obtained by abrading the tooth surface with diamond tips of various thicknesses and collected in *Eppendorf* tubes for subsequent preparation, including chemical separation of strontium. Each sample taken was weighed using a high-precision balance. In addition, the distance between the sample and the enamel-root junction of each tooth was measured using a caliper, allowing precise spatial positioning of the sample along the tooth crown and enabling accurate representation of the isotopic variations during interpretation and graphical representation.

[4] The larger number of carbon and oxygen samples relative to strontium is justified by the higher analytical costs associated with Sr isotope analysis. This strategy is routinely adopted in isotopic studies (e.g., Chazin 2019; Trentacoste *et al.* 2020, 2023).

### 4.3 Analytical procedures

Oxygen and carbon isotope ratios were measured on 270 samples of carbonate moiety of tooth enamel at the Centro Interdipartimentale Grandi Strumenti (CIGS) of the University of Modena and Reggio Emilia (UNIMORE) according to Armaroli *et al.* (2025). Sample powders (~3 mg) were reacted for 2 h at 50 °C with +100% phosphoric acid. Isotope ratios were determined on liberated $CO_2$ by continuous flow IRMS (Elementar precisION) coupled to an equilibration system (Elementar isoFLOW). Repeated analyses of NBS18 and NBS19 reference materials showed a precision (1SD) of ±0.1‰ for $\delta^{13}C$ and ± 0.2‰ for $\delta^{18}O$. C-O values are expressed in ‰ against VPDB. Oxygen and carbon isotope ratios were measured on a second set of 52 samples at the Dept of Earth Sciences of Sapienza – University of Rome, using an automatic gas preparation and introduction system (ThemoFisher Gas Bench II), on line with a ThemoFisher DeltaV IRMS.

The $^{87}Sr/^{86}Sr$ isotope ratio was determined *via* solution MC-ICPMS. Specifically, enamel samples (~ 2 mg) were digested with suprapur nitric acid and processed through extraction chromatography columns filled with Eichron Sr-resin at the MeGic lab of the Department of Chemical and Geological Sciences of UNIMORE. Sr solutions were measured at the Neptune MC-ICPMS housed at the CIGS, following the analytical procedure described in Argentino *et al.* (2021).

Data were statistically processed using the "R" (Version 4.0.5) software and subsequently interpreted, including through comparison with the isoscape currently available for Italy and built by Lugli *et al.* (2022) with regard to the $^{87}Sr/^{86}Sr$ isotopic values.

## 5. CASE STUDY 1: SOLAROLO-VIA ORDIERE (RAVENNA)

Recent research carried out at the archaeological site of Solarolo-via Ordiere (RA) has significantly expanded our knowledge of Bronze Age settlements in northern Italy, offering new opportunities for comparison with regions traditionally included within the Terramare cultural area. Extending settlement analysis to the Romagna area allowed the reconstruction of productive practices (animal husbandry and agriculture) and cultural interactions among Bronze Age village communities (Carra *et al.* 2023; Maini-Curci 2013; Debandi-Maini 2021).

The settlement of Solarolo-via Ordiere is organized into several residential areas separated by watercourses or depressed zones, distributed over a total surface of approximately 7 ha. Based on surface finds and investigations carried out through trenches, coring, and excavation areas, the site was occupied from the Middle Bronze Age (advanced MBA1 phase) to the end of the Recent Bronze Age (advanced RBA2 phase), with rare elements attributable to the Final Bronze Age (Cattani 2009).

The village developed along the banks of an ancient palaeochannel of the Santerno River, approximately 25 m wide and 11 m deep, showing clear evidence of artificial regularization of the inner side. Excavation campaigns mainly focused on Sector 1, corresponding to a 10×50 m transect crossing the southern residential area of the settlement from south to north. This area, covering approximately 8,000 m², is located on the right bank of the river. Estimates of population size and simulations of agricultural and pastoral production were calculated exclusively on the basis of this intensively investigated area, identified as a residential zone. Other investigated sectors could correspond to different use destinations, like enclosures for animals or complementary infrastructures.

Excavation of Sector 1 revealed, starting from the riverbank, a 15 m-wide strip extending northwards that appears to be devoid of residential structures, bordered by large tree stumps and a palisade beyond which evidence of huts distributed over several phases emerges (Cattani *et al.* 2018). The earliest phase consists of raised structures supported by vertical posts, while a later phase includes a structure with a floor made of redeposited silt. Both structures belong to the MBA2 phase, approximately dated between the mid-16th and mid-15th centuries BCE. In the northern part of Sector 1, excavation uncovered a thicker and better-preserved stratigraphic sequence extending the chronology to the advanced Middle Bronze Age and the initial phase of the Recent Bronze Age, corresponding to the period from the mid-15th to the end of the 13th century BCE (Cattani *et al.* 2019).

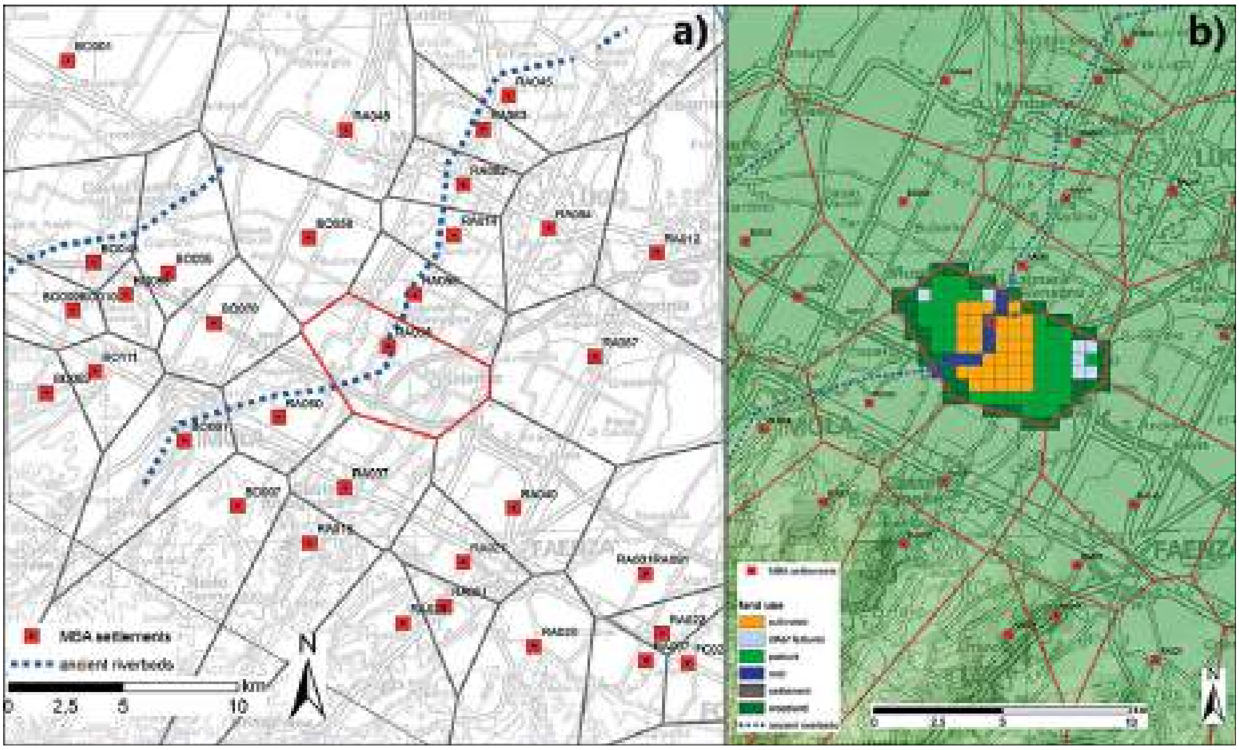


Fig. 5. a) Thiessen polygon model, applied to the MBA settlement pattern in the hinterland of Solarolo (RA038); b) simulation of land-use (30% cultivated areas; 30% pasture; 30% woodland: 10% other uses) for the territory controlled by Solarolo.
*a) Modello con poligoni di Thiessen, applicato al territorio dell'hinterland di Solarolo (RA038); b) simulazione di utilizzi del suolo (30% aree coltivate; 30% pascoli; 30% aree boschive; 10% altri usi) per il territorio controllato dal sito di Solarolo.*

### 5.1 Analysis of the territory associated with the Solarolo settlement

The availability of resources – derived from crop cultivation, gathering of other plant species, animal husbandry, and secondarily from wild resources – was assessed through an analysis of the territory and landscape characteristics surrounding the Solarolo settlement (Carra-Cattani-Debandi 2021).

The first necessary step in this analysis is the identification of the area hypothetically exploited by the village community. In the case of Solarolo, located in the middle plain and lacking significant topographical constraints, the territory pertaining to the settlement can be delineated using Thiessen polygons (fig. 5a). The only uncontrollable bias is the possible presence of other settlements not yet identified, which would reduce the territory attributable to the village. Based on current research, the area calculated using this method amounts to approximately 3,200 ha (32 km²). Even assuming a smaller extent, the land available for subsistence appears more than sufficient (Debandi 2021).

An alternative approach involves estimating population size based on the settlement core area of 0.8 ha, corresponding to approximately 150 individuals, and calculating the amount of land required to sustain them using parameters of agricultural productivity and protein acquisition from animals or other products. Simulations applied to Middle Bronze Age settlements in the plains generally use a territorial subdivision into four land-use categories with similar proportions: approximately 30% arable land, 30% pasture, and 30% woodland (both coppiced and high forest), plus an additional 10% allocated to other uses (rivers, settlement areas, cemeteries) (fig. 5b) (Debandi 2021). This approach also indicates a wide potential availability of productive land (see Debandi *et al.* in this volume).

### 5.2 Archaeobotanical investigations

Archaeobotanical data confirm that by the Bronze Age, cereal cultivation had become well established and that cereals, once processed into food products, likely constituted approximately 70% of individual dietary intake (Carra-Cattani-Debandi 2012).

The abundant multicropping cereal production at Solarolo included traditional winter-sown cultivars (*Triticum monoccocum*, *T. diccocum*, *T. aestivum*, *T. timopheevii*, *Hordeum*), with particular emphasis on high-yield species (in terms of grain size and weight) or those offering greater resistance and storability due to robust glumes (*Triticum spelta*) (Carra 2009; Carra 2012; Carra *et al.* 2023). Spring-sown small-grain cereals such as millet (*Panicum miliaceum*) and foxtail millet (*Setaria italica*) were also introduced, reaching a proportion of 22% for millet in MBA layers. This high diversity reflects deliberate planning aimed at ensuring productivity. Millet cultivation could alternate with more soil-demanding cereals or replace failed crops under specific conditions (Kirleis-Filipović-Dal Corso 2022), given its short growing cycle, summer maturation, and high resistance to drought and high temperatures.

The high proportion of millet identified in the Solarolo assemblage confirms a multicropping strategy focused on agricultural productivity and aimed at guaranteeing a substantial subsistence base and significant anthropogenic impact on the landscape.

Pollen analyses of samples taken from layers predating settlement establishment already document human presence, with open areas designated to agricultural activities (cereal and hemp cultivation) and animal husbandry (meadows/pastures), reaching 60% of the spectrum. 40% of the pollen spectrum indicates the proportion of arboreal landscape, characterized by coniferous and deciduous broadleaf forests, particularly oak woodland. A natural watercourse flowed through the area where the settlement would later develop, bordered by hygrophilous vegetation and associated with wetlands of varying degrees of stagnation. Spontaneous anthropogenic indicators (7.0%), including ruderal and nitrophilous plants, are well represented both qualitatively and quantitatively. Cultivated plants show moderate values (3.7%), represented mainly by cereals (3.3%) – notably barley/*Hordeum* (2.6%) and oat-wheat/*Avena-Triticum* (0.7%) – alongside a low percentage of hemp/*Cannabis sativa* (0.4%) (Pancaldi 2016).

With the village's beginning, a marked intensification of anthropogenic pressure across the area is evident, confirmed by a decline in forest cover due to woodland clearance for residential structures and the expansion of cereal fields (barley, oat-wheat, spelt). Wetland plant taxa show an overall decrease; however, there is a notable increase in herbaceous species and the introduction of new taxa, possibly linked to the network of channels and ditches separating the different settlement zones. Meadow and pasture areas intended for livestock breeding further expanded.

### 5.3 Zooarchaeological investigations

Zooarchaeological analyses at the site of Solarolo-via Ordiere provide clear evidence of a highly structured and specialized animal economy during the Middle Bronze Age 2 (MBA2), a period spanning approximately one century. The faunal assemblage, comprising over 6,800 remains, is overwhelmingly dominated by domesticates (98%), indicating a fully developed agro-pastoral system. Preliminary investigations (Maini-Curci 2013) and more recent studies (Debandi-Maini 2021) identified a clear hierarchy among the exploited taxa. In a subsample of 2,249 identified specimens, aprines – mainly sheep and to a lesser extent goats – emerged. as the most abundant group (NISP 1,176; MNI 95), followed by pigs (NISP 651; MNI 67) and cattle (NISP 284; MNI 29). Wild species-including red deer (*Cervus elaphus*), roe deer (*Capreolus capreolus*), hare (*Lepus europaeus*), and wild boar (*Sus scrofa*)-are only sporadically represented and account for less than 2% of the total assemblage.

Within the flocks, a selective trend appears to favour animals with higher fibre (wool) productivity rather than body mass; similarly, the clear size separation between domestic pigs and wild boars reflects a high degree of human control over breeding and herd management.

Mortality profiles reveal distinct, species-specific exploitation strategies. Caprines were managed with a 'triple vocation' (meat, milk, and wool), and the 5:1 sheep-to-goat ratio-confirmed by both morphological observations and ZooMS analysis-points to an emphasis on high-quality meat and wool production. Pigs were raised exclusively for meat and fat, with rapid turnover: 50% of individuals were slaughtered within their first year, reflecting a strategy focused on intensive protein yield and efficient resource conversion. Cattle, despite their modest size, played a crucial role as draught animals; they were generally kept alive until 3-4 or even 6 years of age, before being slaughtered to maximize meat returns at low maintenance costs.

Quantitative estimates of livestock herds at Solarolo during the Middle Bronze Age indicate substantial numbers. Zooarchaeological results from sampled areas, combined with projections of the minimum number of animals present annually at the Via Ordiere settlement – based on the minimum number of individuals slaughtered (MNI) – suggest herds consisting of approximately 125 cattle, 208 caprines, and 133 pigs. These values correspond to the average derived from the two reference areas used for the zooarchaeological sample (Debandi-Maini 2021).

Faunal data from Solarolo suggests solid planning and organization of production. The effects of abundant food availability likely promoted the demographic growth characteristic of the Middle Bronze Age expansion phase. These results provide a robust baseline for integrating isotopic and biomolecular analyses aimed at refining mobility, diet, and herd management strategies.

## 6. CASE STUDY 2: MONTARICE (PORTO RECANATI-MACERATA)

During the Middle Bronze Age 3 and Recent Bronze Age (14th -13th BCE) the middle Adriatic region was characterized by a relatively dense settlement pattern, with sites widely distributed along the coastal zone, particularly in locations offering favourable natural landing places or in proximity to river estuaries, which would have provided suitable conditions for coastal access and anchorage*:* Riccione, Fano at the mouth of the Arzilla River, Ancona-Montagnolo, Ancona-Colle dei Cappuccini, Numana, Civitanova Bambozzi (Baldelli *et al.* 2005). The topographic setting of the Montarice site, which dates to the same period and lies approximately 1 km from the coast, close to the mouth of the Potenza River, clearly falls within this settlement pattern (De Neef-Paolini in this volume; De Neef-Paolini 2025; Paolini 2023). The excavations at Montarice were conducted in the 1970s by Delia Lollini. Recently, the site has been the subject of archaeological and geophysical surveys conducted by the University of Ghent (for further information, see De Neef, Paolini in this volume).

More generally, during Middle Bronze 3 and the Recent Bronze Age (Apennine and Subapennine *facies* – 14th and 13th centuries BCE), the Marche territory experienced a substantial and widespread occupation encompassing all ecological zones, from the Adriatic coast to the Apennine uplands. As evidenced by the location of many settlements, the river valleys crossing the region must have played a key role as communication routes. These corridors likely facilitated the movement of people and goods, as indicated by the presence of Aegean-type ceramics even in inland contexts: Cisterna di Tolentino, Fonte Marcosa at Moscosi di Cingoli, Jesi, Ancona Montagnolo, Treazzano di Monsampolo (Jones *et al.* 2014). The same routes may also have supported the seasonal movement of flocks and herds toward summer and winter pastures.

### 6.1 Zooarchaeological investigations

Zooarchaeological analysis at Montarice was carried out on a total of 1,383 faunal remains dated to the final stages of the Middle Bronze Age and the early phases of the Recent Bronze Age. Of these, 614 specimens (44.4%) were taxonomically identified to at least the genus level, while 769 (55.6%) remain undetermined (Maini, ongoing study). The assemblage is clearly dominated by domestic animals, which account for 83.2% of the identified sample (NISP = 511), suggesting a well-established agro-pastoral system. Wild taxa are only marginally represented, with 18 remains (2.9%), including cervids, wild boar, and hare, confirming the strong prevalence of domestic exploitation.

The principal domestic species at the site -pigs, caprines, and cattle- display a relatively balanced distribution, pointing to a diversified subsistence strategy with no clear dominance of one taxon over the others. These three groups account for the vast majority of the domestic assemblage, with pigs representing 37.2% of the identified remains (NISP = 185), caprines 36.0% (NISP = 179), and cattle 26.8% (NISP = 133). An additional 24 dog remains (*Canis familiaris*) and 8 equid remains-likely horses-bring the total number of identified domestic animal remains to 529.

Within the caprine group, although most specimens remain indeterminate at the species level, sheep appear to predominate over goats, with an estimated ratio of approximately 3:1, a trend also confirmed by ZooMS analyses.

Age-at-death data indicate a relatively balanced slaughtering pattern for all major domestic taxa, with a notable representation of adult individuals among pigs, caprines, and cattle (Maini, ongoing study). Young and sub-adult specimens are also present, particularly among pigs, likely reflecting the aim of obtaining higher-quality meat. Conversely, the predominance of mature animals-especially among cattle and caprines-may suggest a reliance on secondary products such as wool and labour, alongside meat exploitation. Milk was likely obtained from all three domestic species (sheep, goats, and cattle), although none appears to have been exploited exclusively for dairy production.

## 7. CASE STUDY 3. COPPA NEVIGATA (FOGGIA)

The Bronze Age fortified settlement of Coppa Nevigata, located south of the Gargano Promontory, is one of the most extensively explored Bronze Age sites in Italy. Located on the shore of the former coastal lagoon of Lago Salso, which connected it to the Adriatic Sea while offering protection from seaborne attacks, the site was continuously occupied for approximately one millennium (18th-8th centuries BCE; Cazzella-Recchia 2012; Recchia in this volume). Characterised by substantial defensive lines, repeatedly modified and rebuilt over time, the settlement was actively engaged, and likely specialised, in long-range maritime exchange networks, particularly with the eastern and northern Adriatic (Cazzella-Recchia 2018a; 2018b). The settlement retained the same location throughout its occupation, and the area enclosed by the fortifications, approximately 2.5 ha, remained relatively stable in extent. The surrounding territory was well suited to cereal cultivation and animal husbandry, while the lagoon environment provided additional resources. The settlement lay close to the mouth of the River Candelaro, which flowed into the lagoon, and benefitted from a nearby brackish spring.

### 7.1 Territorial control

Based on the size of the Bronze Age settlement enclosed by the fortifications (c. 2.5 ha) and ethnographic estimates of approximately 125 inhabitants per hectare, a population of around 300 individuals has been proposed for the Coppa Nevigata community.

Considering the relative incidence of domestic species and the crop types identified at the site, and applying a carrying-capacity model, the territory required to sustain the community's subsistence economy has been estimated at approximately 5 km². This area would have included arable fields located closer to the settlement, pastures, and a limited proportion of woodland, mainly oak, supporting pig husbandry and possibly some hunting activities (Cazzella-Recchia-Lucci 2021).

Estimates of herd and flock size in this model were not based directly on the NMI of faunal remains recovered for each phase, but on the assumption that a nuclear family slaughtered one pig per year. The total number of living animals, including those kept alive to ensure reproduction, was then extrapolated according to the relative proportions of species (1 pig = 3 cattle = 7 caprines).

In this picture the community was self-sufficient. The area under its political control has been hypothesised at approximately 40 km², defined by natural boundaries (the River Candelaro to the south and the Gargano promontory to the north) and by the absence of other coeval stable settlements (at least between the 16th and 11th centuries BCE) within this territory.

### 7.2 Environmental data and agricultural practices

A series of core drillings carried out in the vicinity of the site, from its margins into the lagoon, have provided stratigraphic data and pollen diagrams for the reconstruction of the environment and its transformations in relation to both climatic variation and anthropogenic impact, although the respective influence of these two factors is not always easily to disentangle. Additional data have emerged from new cores taken from the Lago di Salpi lagoon, once forming a single water body with the Lago Salso (Susini *et al.* 2023). For the Bronze Age (between 3600 and 3090 cal. yr BP), the Salso lagoon has been identified as a brackish environment characterised by Hydrobiidae spp. and Cerastoderma sp., with salinity values ranging between 25‰ and 18‰. In the later phase, a reduction in salinity (to c. 6‰) indicates a shift towards a salt-marsh environment (Caldara-Simone 2012).

Pollen diagrams (Di Rita *et al.* 2011), particularly from core C3, located 0.8 km from the site within the lagoon, indicate that from the Neolithic onwards the coastal Tavoliere was characterised by relatively open shrubland. Core C5, situated closer to the site, covers the phase 3500-3230 cal. yr BP: the pollen record points to a markedly open and deforested landscape, a condition that persisted thereafter. Pollen from cultivated, ruderal, and pastoral plants is abundant, indicating strong anthropogenic impact, plausibly linked to the proximity of the settlement. As the authors observe, "*differently from other Mediterranean sites where arboreal vegetation recovered after the drought of 4000 cal. BP, in the Tavoliere Plain the landscape remained substantially open, probably because of intense local human activity in a semi-arid area*".

During excavation, particular attention has consistently been paid to the collection of archaeobotanical data: each excavated layer is sampled at a rate varying between 5% and 100%, depending on the context. This strategy provides a broad and detailed record for both the different phases of occupation and various contexts within each phase.

The evidence derived from anthracological remains at the site is influenced by the selective practices adopted by the community of Coppa Nevigata in procuring timber. Wood was probably chiefly obtained from forests on the nearby slopes of the Gargano promontory, as well as from riparian environments near the site (Fiorentino-D'Oronzo 2012; Primavera *et al.* 2015). For the 16$^{th}$ century BCE, the dominant arboreal taxa derive from mesophilous woodland environments, such as *Fagus* and deciduous oaks, indicating temperate-humid conditions. Species characteristic of Mediterranean maquis display a locally xerophilous tendency. Riparian taxa such as *Populus/Salix* are also attested, along with *Vitis*, probably in its wild form[5]. Data from core C5 indicate the presence of nearby Mediterranean maquis and taxa reflecting increased anthropogenic impact, such as Prunoideae. From a climatic perspective, a more pronounced xerophilous tendency appears to emerge. In the Subapennine period (13$^{th}$-12$^{th}$ centuries BCE), a decrease in xerophilous taxa and an increase in mixed mesophilous woodland, particularly *Ostrya carpinifolia* would suggest warmer and more humid conditions. However, as noted above, this picture may partly reflect selective strategies in timber procurement. An increase in pine remains points to the probable presence of coastal pinewoods.

The subsistence economy appears to have been strongly based on the cultivation of $C_3$ cereals, particularly wheat and barley (Fiorentino-D'Oronzo 2012), with a shift from the Late Apennine period onwards towards the cultivation of *Triticum dicoccum*, which is better adapted to warmer and drier climatic conditions.

The earliest sporadic evidence for $C_4$ plants in the region, most notably broomcorn millet, dates to the phase 1500-1300 BCE coming from limited remains at few sites in central Apulia (Grotta della Tartaruga and Monopoli Piazza Palmieri; Primavera *et al.* 2015). Millet continues to be scarcely represented during the Late Bronze Age: at Coppa Nevigata, only a single seed has been identified, while a few finds come from the Taranto area (Taranto San Domenico).

Stable isotope analyses on human remains from Trinitapoli, in the southern coastal Tavoliere, indicate a diet primarily based on $C_3$ plants, confirming either the absence or the deliberate avoidance of millet, while animal proteins do not appear to constitute a major dietary component (Arena *et al.* 2020; Varalli-Moggi Cecchi-Goude 2022). Organic residue analyses, however, have demonstrated the occurrence of miliacin in two imported Late Bronze Age Aegean vessels from Roca (Arena *et al.* 2024).

### 7.3 Zooarchaeological data and breeding practices

Explorations at the site have so far yielded over 45,000 taxonomically identified animal remains, in addition to more than 400,000 aquatic mollusc remains. This dataset provides a statistically robust basis for reconstructing the Bronze Age subsistence economy at Coppa Nevigata, from the early Protoapennine to the Late Subapennine periods (18$^{th}$-12$^{th}$ centuries BCE; Minniti 2012; Siracusano 2012).

Throughout all phases, primary economy was centred on the husbandry of caprines, cattle, and

[5] For the Apennine period (15$^{th}$-14$^{th}$ centuries BC), results from on-site sampling were previously unavailable and are only now being published within the framework of the PRIN PNRR Shores project.

| Site | HERDS ID | PALTO Number | Taxonomic ID |
|---|---|---|---|
| Coppa Nevigata | COP_180 | 3046 | *Ovis aries* |
| Coppa Nevigata | COP_183 | 3048 | *Capra hircus* |
| Coppa Nevigata | COP_185 | 3049 | *Ovis aries* |
| Coppa Nevigata | COP_186 | 3050 | *Ovis aries* |
| Coppa Nevigata | COP_189 | 3051 | *Ovis aries* |
| Coppa Nevigata | COP_202 | 3054 | *Capra hircus* |
| Montarice | MNT_26 | 3007 | *Ovis aries* |
| Montarice | MNT_27 | 3008 | *Ovis aries* |
| Montarice | MNT_28 | 3009 | *Ovis aries* |
| Montarice | MNT_30 | 3010 | *Ovis aries* |
| Montarice | MNT_31 | 3011 | *Ovis aries* |
| Montarice | MNT_32 | 3012 | *Ovis aries* |
| Montarice | MNT_35 | 3013 | *Capra hircus* |
| Montarice | MNT_36 | 3014 | *Capra hircus* |
| Solarolo | ORD_18 | 3003 | *Ovis aries* |
| Solarolo | ORD_25 | 3004 | *Ovis aries* |
| Solarolo | ORD_37 | 3005 | *Ovis aries* |
| Solarolo | ORD_178 | 3006 | *Ovis aries* |

Tab. 2: ZooMS identification results for the subset of archaeological teeth analysed in this study. The table reports the site of provenance, HERDS ID and unique lab number (PALTO), and the final taxonomic identification.

*Risultati dell'identificazione mediante ZooMS per il sottoinsieme di denti archeologici analizzati in questo studio. La tabella riporta il sito di provenienza, l'ID HERDS e il numero di laboratorio univoco (PALTO), nonché l'identificazione tassonomica finale.*

pigs. Caprines – mixed sheep and goat herds, with a predominance of sheep – consistently dominate the assemblage, accounting for 48 to 66% of the remains. Cattle range between 20% and 30%, while pigs never exceed 20%.

Caprines were raised for both meat and secondary products, particularly fleece. Caprine milk exploitation, probably increasing in the Late Subapennine, is documented by small percentages of lambs and kids slaughtered within the first six months of life and, more indirectly, by females culled between two and four years of age. Cattle were kept both for ploughing and for direct meat consumption; the notable evidence of calves slaughtered within the first year of life (4 to 20%) likely indicates cow's milk exploitation. Pigs were mainly slaughtered between the first and third years of life, reflecting an optimal meat-oriented strategy, although a significant consumption of piglets – with more tender and higher-quality meat – is also documented.

Wild resources, deriving from hunting (red deer, roe deer, wild boar), fishing, and tortoise gathering, played a secondary but significant role, with an incidence of 5 to 30%. The large quantity of highly fragmented murex shells from the marine environment strongly indicates purple dye production at the site, particularly from the Protoapennine to the Late Apennine periods (Minniti-Recchia 2018).

## 8. RESULTS

### 8.1 ZooMS

ZooMS analysis was carried out on a subset of hemimandibles previously identified zooarchaeologically as *Ovis* vel *Capra* on a morphological basis. Peptide mass fingerprinting enabled species-level attribution of these specimens, allowing assignment to either *Ovis aries* or *Capra hir-*

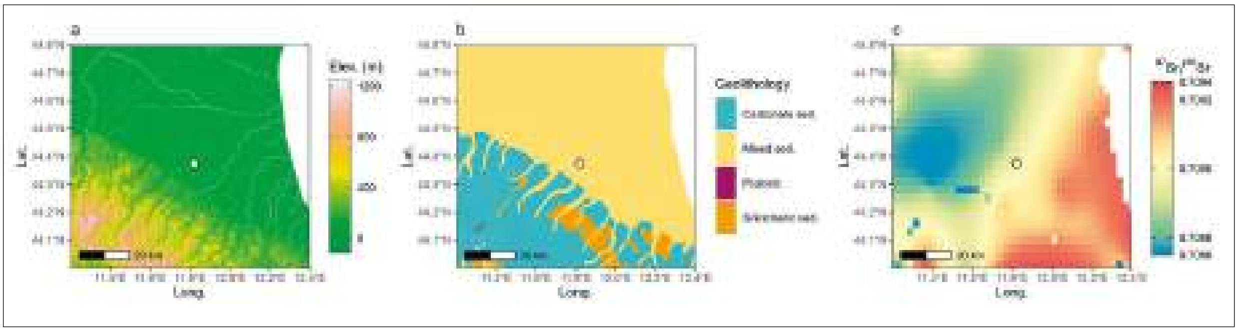

Fig. 6. a) DEM, b) geolithological map, and c) isoscape of bioavailable $^{87}Sr/^{86}Sr$ of Solarolo's territory.
*a) DEM, b) mappa geolitologica e c) isoscape del $^{87}Sr/^{86}Sr$ biodisponibile per il territorio di Solarolo.*

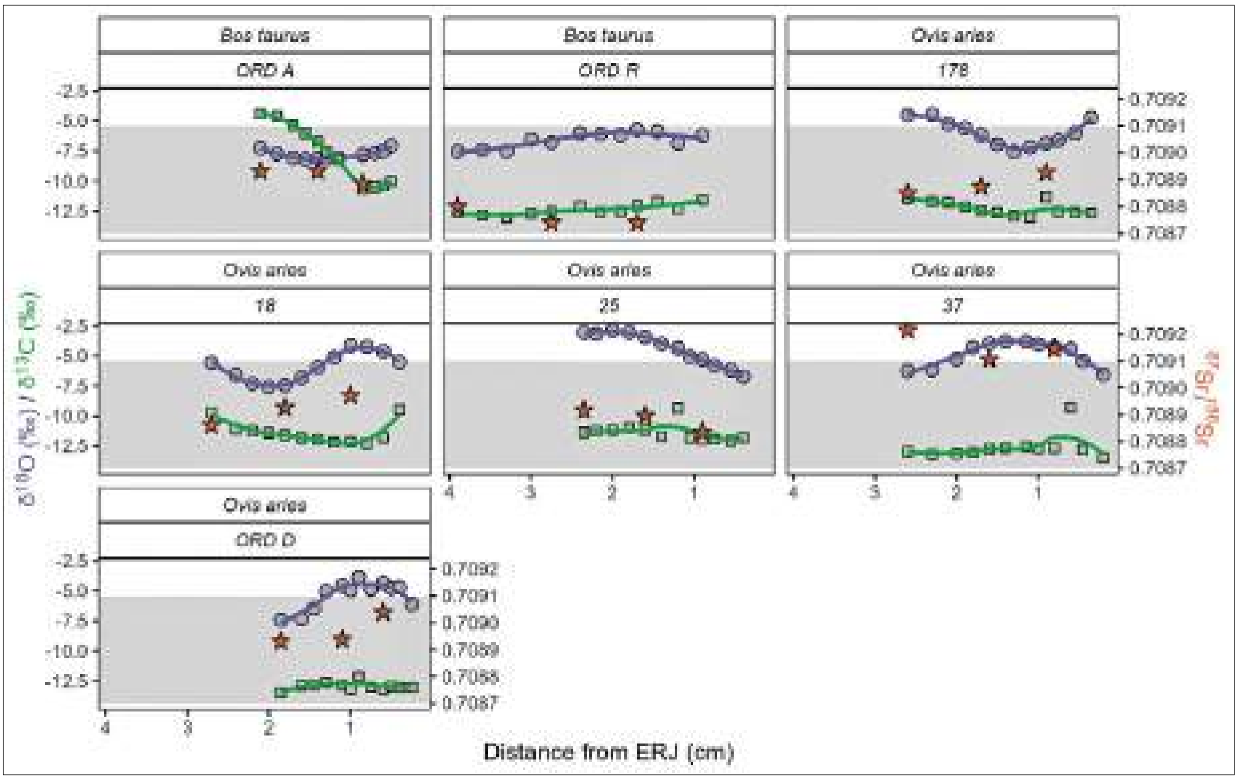


Fig. 7. Intra-tooth $^{87}Sr/^{86}Sr$, $\delta^{18}O$, $\delta^{13}C$ isotope profiles of herbivores at Solarolo.
*Profilo isotopico intra-dente di $^{87}Sr/^{86}Sr$, $\delta^{18}O$, $\delta^{13}C$ degli erbivori di Solarolo.*

*cus* across the analysed assemblage from Coppa Nevigata, Montarice, and Solarolo (tab. 2).

## 8.2 Isotope analysis and data interpretation

### 8.2.1 *Solarolo, via Ordiere*

ZooMS analyses identified all caprine specimens from Solarolo as sheep.

Four of the five sheep display $^{87}Sr/^{86}Sr$ values compatible with the local environmental baseline (~0.7087-0.7091) (fig. 6). In addition, their $\delta^{18}O$ profiles reflect the sinusoidal fluctuations typical of local annual variation at latitudes characterized by marked seasonal contrasts between warm and cold period (fig. 7). $\delta^{18}O$ values range between −2.9‰ and −9.6‰, an interval broadly consistent, though slightly lower, with present-day precipitation in Romagna. The limited intra tooth variation observed across all $^{87}Sr/^{86}Sr$ triplets suggests non-mobile management practices. One individual, ORD_37, differs from this pattern, exhibiting a slightly more radiogenic strontium isotopic composition. Comparable values are well

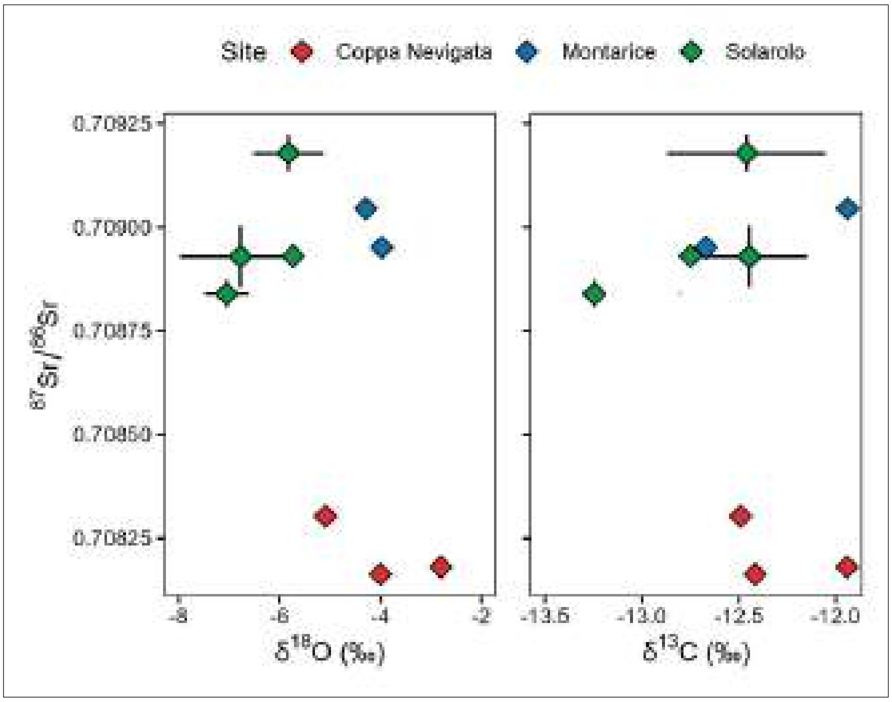


Fig. 8. $^{87}Sr/^{86}Sr$, $\delta^{18}O$, $\delta^{13}C$ values among pigs of all sites. Error bars represent the standard deviation of intra-tooth replicates.

*Valori di $^{87}Sr/^{86}Sr$, $\delta^{18}O$, $\delta^{13}C$ fra i vari suini di tutti i siti analizzati. Le barre di errore rappresentano la deviazione standard di campioni replicati.*

represented along the Adriatic coastal areas of Romagna, approximately 30 km east of Solarolo; for this reason, this individual is interpreted as non-local, likely originating from the coastal hinterland, although provenance from another area with similar geolithology cannot be excluded.

The two cattle analyzed also show local or slightly less radiogenic Sr isotope signatures, although their $\delta^{18}O$ profiles appear flatter than those of sheep, plausibly reflecting differences in drinking behaviour or water sourcing. Nevertheless, the limited variation in $^{87}Sr/^{86}Sr$ values indicates that these bovines were raised locally.

Of the three pigs, two are clearly compatible with the local $^{87}Sr/^{86}Sr$ baseline, suggesting that they were raised on site (fig. 8). By contrast, ORD_B displays a non-local Sr isotope signature and therefore was probably imported. Notably, its $^{87}Sr/^{86}Sr$ value is similar to that of sheep ORD_37, potentially indicating a comparable provenance. This pattern may reflect regular exchanges of animals between communities settled in central and western Romagna. Alternatively, acts of abduction could also occur with relative frequency.

Carbon isotope values provide particularly informative insights into feeding strategies. Cattle ORD_A shows a substantial increase in carbon isotope values (ranging from −8.2‰ to −4.4‰) during the autumn-winter period, whereas in spring-summer $\delta^{13}C$ values drop to between −10.0‰ and −10.7‰. This pattern suggests that during the colder season the animal's diet was supplemented with a variable proportion of $C_4$ plants, estimated-using a linear mixing model-at between 9% and 37% of the consumed plant material. The timing of the $C_4$ plant ingestion would imply a storage of fodder for the cold season.

Similarly, sheep ORD_18, ORD_25, and ORD_37 are characterized by significant $\delta^{13}C$ peaks of up to −9.3‰, all concentrated in the autumn, whereas their regular values range between −11‰ and −13.5‰. These patterns suggest the possible integration of $C_4$ plants into the diet of most sheep at the end of the warm season. However, linear mixing model estimates suggest that the proportion of $C_4$ plants does not exceed 1% of total plant intake.

This isotopic evidence – clearer in cattle ORD_A and more limited in the three sheep – can be explained either by the ingestion of spontaneous $C_4$ plants (less likely for cattle, given the substantial estimated proportion) or by the integration of

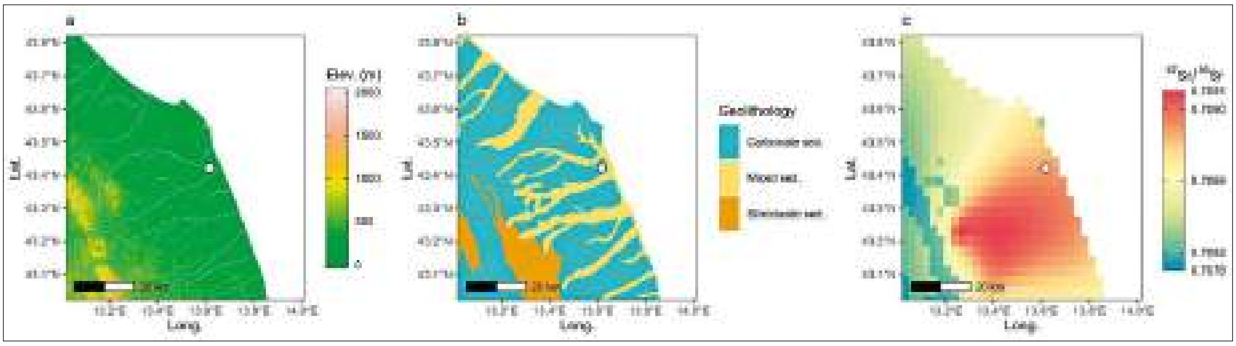


Fig. 9. a) DEM, b) geolithological map, and c) isoscape of bioavailable $^{87}Sr/^{86}Sr$ of Montarice's territory.
*a) DEM, b) mappa geolitologica e c) isoscape del $^{87}Sr/^{86}Sr$ biodisponibile per il territorio di Montarice.*

cultivated $C_4$ plants, most plausibly millet. *Panicum miliaceum*, in fact, is particularly abundant in MBA 2 layers at Solarolo, accounting for up to 22% of the cultivated taxa (see above). Moreover, $\delta^{13}C$ peaks are concentrated in the autumn, which coincides with the harvest season of this cereal. As noted above, millet is characterized by a short growing cycle, summer maturation, and high resistance to drought and elevated temperatures (Kirleis *et al.* 2022). The isotopic and archaeobotanical evidence suggests that the use of millet as animal fodder was a planned and practiced strategy, if not systematic, then at least relatively regular, perhaps applied in years characterized by scarce spring and summer rainfall.

In conclusion, the isotopic data delineate a framework fully consistent with the archaeological and archaeobotanical evidence. The territory surrounding the village was sufficiently wide and open to provide adequate fodder for herbivores, which explains the non-mobile management of animals. The long-term occupation of the settlement (c. 300-350 years) appears sustainable only if agricultural practices were organized in a manner that avoided conditions leading to soil overexploitation. This was likely achieved through crop rotation – suggested by the wide spectrum of cultivated cereals – and fallow periods, during which cereal cultivation was replaced by grazing. Overall, the evidence points to an integrated organization of agriculture and residential animal management.

### 8.2.2 *Montarice*

The picture emerging from isotope analysis appears quite different for Montarice. First, ZooMS analysis indicates that two of eight *Ovis* vel *Capra* specimens are goats, while the remaining individuals are sheep. Goat MONT_36 appears to be local and non-mobile, as its $^{87}Sr/^{86}Sr$ profile is flat and consistent with the local signatures (0.7088-0.7092)[6] (fig. 9), and $\delta^{18}O$ shows typical seasonal variation (fig. 10). In contrast, goat MONT_35 shows variable $^{87}Sr/^{86}Sr$ values and a flat $\delta^{18}O$ curve, which concurrently suggests that the animal was transhumant, being moved elsewhere during the warmer seasons, perhaps to mountainous areas of the Marche region.

Sheep exhibit even greater variability in mobility patterns. MONT_26, MONT_27, MONT_30, and MONT_32 show $^{87}Sr/^{86}Sr$ triplets in which at least one value falls outside the expected local range. In particular, MONT_26 appears to have grazed elsewhere during the warm season, while MONT_30 and MONT_32 likely did so during colder seasons[7]. For these animals, we can infer seasonal mobility (transhumance) from or towards various places, although data might also indicate the use of different pastures in the hinterland of Montarice at different times of the year. Conversely, $^{87}Sr/^{86}Sr$ triplets of sheep MONT_28 and MONT_31 show low variability and are compatible with local baselines, which suggests a resident management strategy for these domestic herbivores.

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[6] Despite the limited availability of $^{87}Sr/^{86}Sr$ baselines for the Marche region, this range is strongly supported by the interval published by Esposito *et al.* (0.7087-0.7092) for the area of Fermo, approximately 30 km south of Montarice (Esposito *et al.* 2023). This interval also clearly reflects the high degree of geolithological and biogeochemical homogeneity across the Marche region.

[7] We will not discuss MONT_27 $\delta^{18}O$ values, since they show an atypical, random intra-tooth variation likely derived from analytical issues.

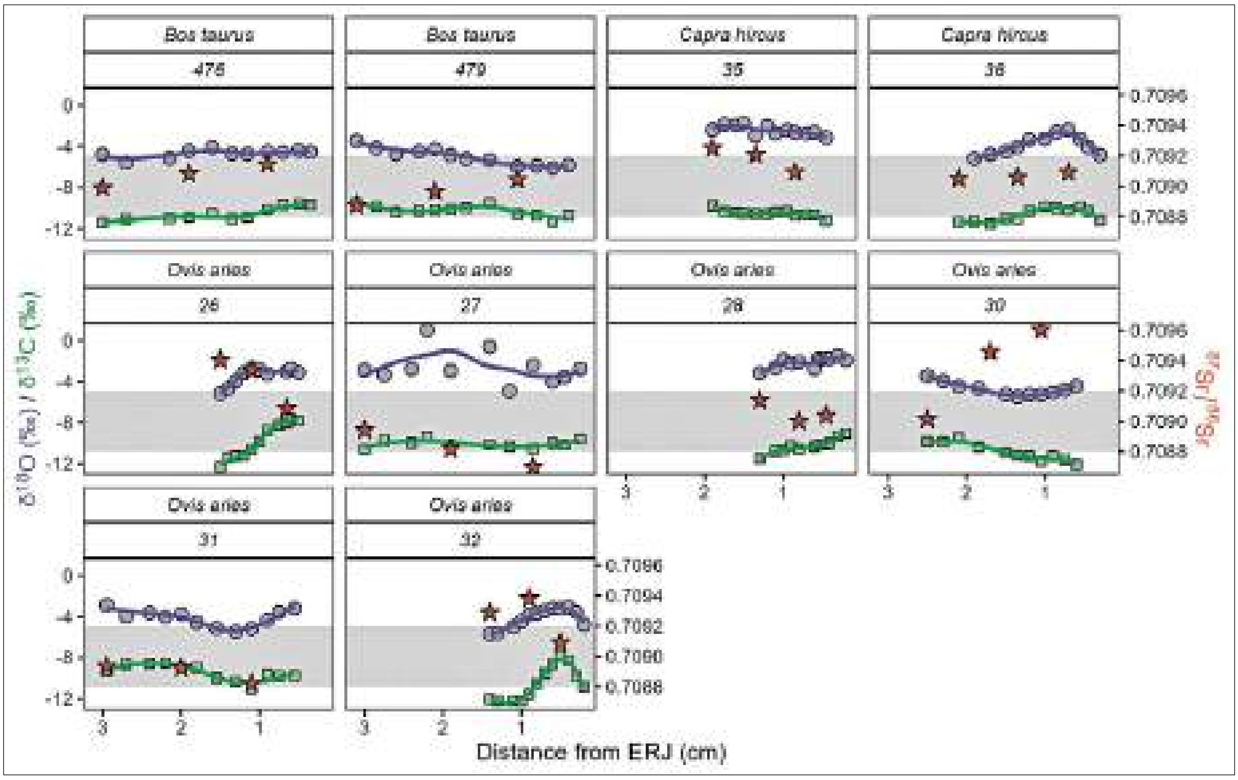


Fig. 10. Intra-tooth $^{87}Sr/^{86}Sr$, $\delta^{18}O$, $\delta^{13}C$ profiles of herbivores from Montarice.
*Profilo isotopico intra-dente di $^{87}Sr/^{86}Sr$, $\delta^{18}O$, $\delta^{13}C$ degli erbivori di Montarice.*

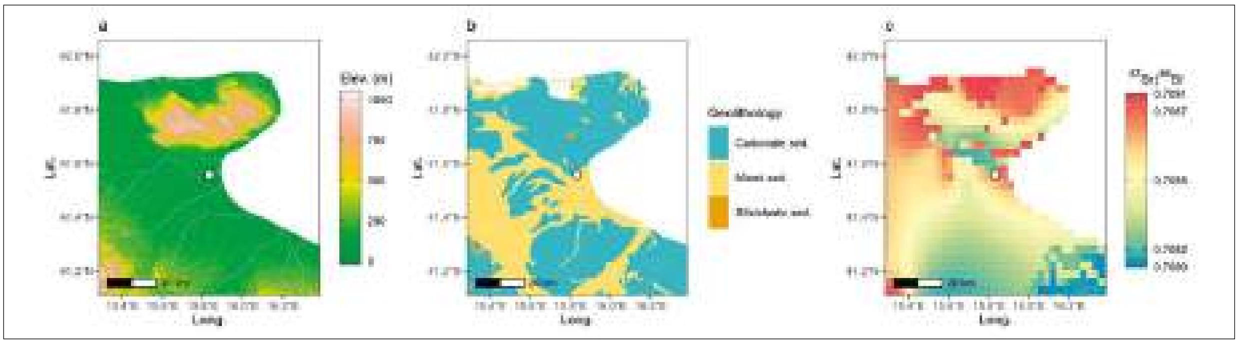


Fig. 11. a) DEM, b) geolithological map, and c) isoscape of bioavailable $^{87}Sr/^{86}Sr$ of Coppa Nevigata's territory.
*a) DEM, b) mappa geolitologica e c) isoscape del $^{87}Sr/^{86}Sr$ biodisponibile per il territorio di Coppa Nevigata.*

Regarding $\delta^{13}C$, MONT_26, MONT_28, MONT_31, and MONT_32 show some high values, which are compatible with the integration of $C_4$ plants into the diet. Linear mixing models estimate $C_4$ plant contributions of 13%, 2%, 7%, and 12%, respectively. Although the absence of archaeobotanical data from Montarice limits direct comparison with crop types, the strikingly high $\delta^{13}C$ values, reaching up to −7.6‰, suggest intentional feeding with $C_4$ plants, presumably millet. Moreover, the fact that all four individuals display $\delta^{13}C$ enrichment during the late summer-autumn seasons reinforces the hypothesis of artificial feeding in specific times of the year.

The two cattle from Montarice, MONT_476 and MONT_479, show $^{87}Sr/^{86}Sr$ values fully compatible with the local signature, low variability in $\delta^{18}O$ values, and low $\delta^{13}C$ values, consistent with a $C_3$-plant-based diet. For these individuals, we can argue for a residential management strategy.

Similarly, the two pigs, MONT_480 and MONT_481 seem indigenous and show no evidence of $C_4$-plant intake (fig. 7).

Overall, animal management practices in Montarice are characterized by a high rate of seasonal mobility among caprines. This is likely linked to the high soil erodibility in the Marche region (Grimm *et al.* 2002; van der Knijff-Jones-Montanarella 1999; Zema-Bombino-Zimbone 2023), an issue that will be discussed in greater detail below.

Considering the strong negative impact of large herds on the fragile calcareous vertisols of the Apennine region (cfr. Torresani *et al.* 2019; Arroyo-Pueyo-Barrantes 2024), this strategy could be justified by the need to maintain the productive potential of land in the immediate vicinity of the site for agricultural purposes, while moving animals towards the broader hinterland (short-distance transhumance) or even to more remote regions (long-distance transhumance).

The combination of residential and mobile strategies for Montarice sheep and goats could be explained by the presence of large mobile herds alongside small groups or single animals that were kept within individual households for subsistence purposes.

8.2.3 *Coppa Nevigata*

ZooMS analysis on the caprines from Coppa Nevigata confirmed the presence of two goats and four sheep, previously identified through morphological analysis. Previous studies established that commonly sheep outnumber goats throughout the Bronze Age sites in peninsular and Northern Italy (Cianfoni-De Grossi Mazzorin-Minniti 2024; Minniti 2021). All analysed sheep (COP_180, COP_185, COP_186, COP_189) show limited $^{87}Sr/^{86}Sr$ variability (0.7081-0.7083), fully compatible with the environmental range of the Tavoliere plain and the Gargano area (0.7080-0.7085)[8] (fig. 11), as well as with recently published human from the settlement itself (0.7081-0.7085; Thompson *et al.* 2025). $\delta^{18}O$ profiles range between 0 and −4.5‰, which clearly reflects the low variation in atmospheric temperatures typical of Mediterranean coastal areas. Both isotopic proxies suggest a non-mobile (local) management of these animals (fig. 12).

The two goats exhibit contrasting isotopic patterns. COP_183 shows Sr and O isotope values comparable to those of the sheep. In contrast, COP_202 is characterized by a highly radiogenic $^{87}Sr/^{86}Sr$ triplet (0.7109, 0.7108, 0.7113) and a $\delta^{18}O$ range from −4.4‰ to −8.2‰. These latter are considerably lower than those of all other analysed specimens from Coppa Nevigata and are typical of much colder regions (e.g. the Alpine areas)[9]. We can therefore interpret COP_202 as a goat, imported to Coppa Nevigata likely from the Alpine region during the Subapenninic phase. Between 1 and 2 years of age, when it was still in the place of origin, the animal used to move towards a more radiogenic area during the warm seasons, plausibly for some forms of transhumance.

The two cattle (COP_223 and COP_225) show limited $^{87}Sr/^{86}Sr$ variability and full compatibility with the environmental range of the Tavoliere and Gargano areas. This suggests a local management strategy for bovines. Bulk analyses of pig specimens (COP_194, COP_198, COP_203) similarly indicate that these animals were likely local or, alternatively, raised within the hinterland of Coppa Nevigata (fig. 7).

Carbon isotope data indicate a predominant $C_3$-plant-based diet for all animals, as also documented by archaeobotanical record (see above). Nevertheless, some individuals (*Bos* COP_225, *Capra* COP_183, *Ovis* COP_185 and COP_189) display relatively enriched $\delta^{13}C$ values, up to −9‰. This may reflect occasional ingestion of $C_4$ plants or of plant species typical of coastal/lagoon environments, characterized by enriched $\delta^{13}C$ values.

[8] Compared to the Italian territory, fewer $^{87}Sr/^{86}Sr$ data are currently available from the trans-Adriatic regions (e.g. Dudás-Burbank 2023; Gregorčič *et al.* 2021). Nevertheless, the geolithological similarities between the two shores suggest broadly comparable strontium isotope signatures. Consequently, it cannot be excluded that some of the animals identified as 'local' at Coppa Nevigata may in fact have originated from Istria, Dalmatia, or the southern Balkans. However, the high degree of $^{87}Sr/^{86}Sr$ and $\delta^{18}O$ homogeneity among specimens strengthen the local hypothesis.

[9] The Alpine provenance hypothesis is also corroborated by the high $^{87}Sr/^{86}Sr$ values identified in the area of Trento and Valsugana (Ladegaard-Pedersen *et al.* 2022). Other potential origins, such as the trans-Adriatic regions of the Karst, Dalmatia and the Balkans – proposed on the basis of archaeological evidence indicating contacts with southeastern Italy (Arena 2020; Cazzella-Recchia 2020) – can be excluded. These regions are characterized by significantly lower $^{87}Sr/^{86}Sr$ and higher $\delta^{18}O$ (e.g. Gregorčič *et al.* 2021; Dudás-Burbank 2023; Thompson *et al.* 2025), than those observed in the present dataset.

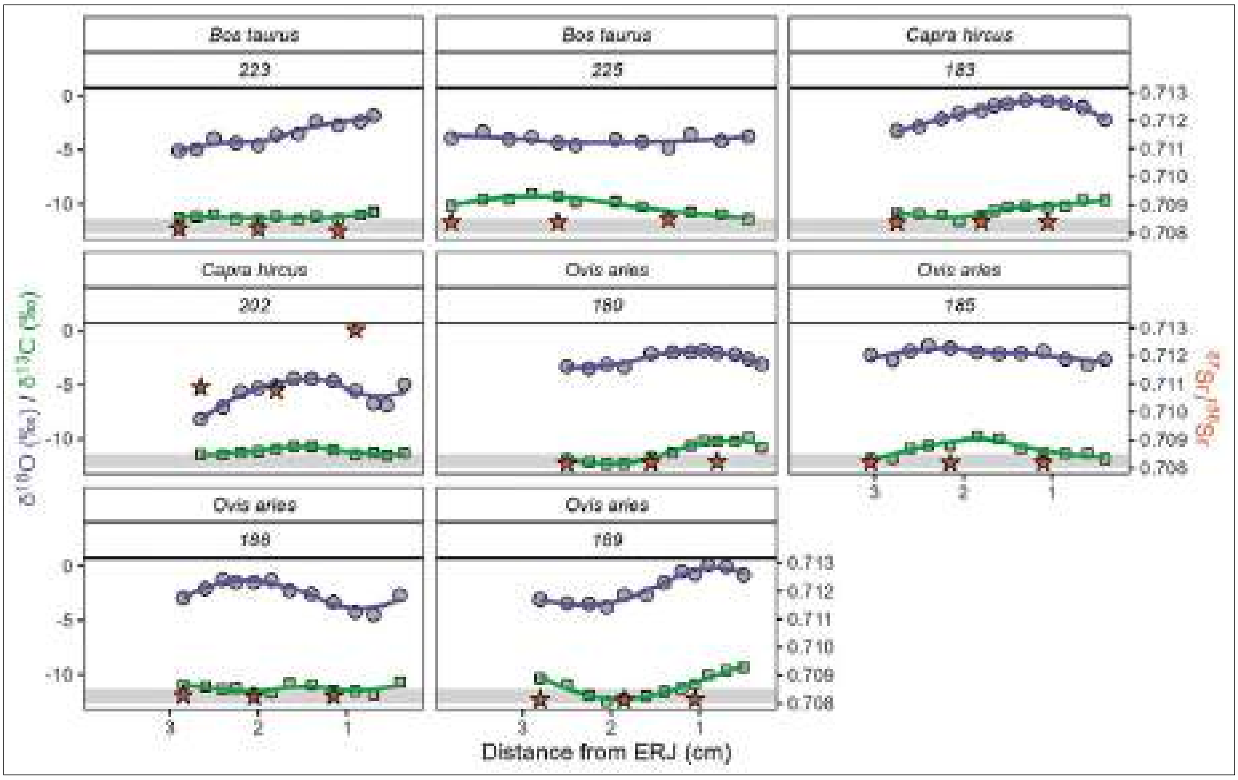


Fig. 12. Intra-tooth $^{87}Sr/^{86}Sr$, $\delta^{18}O$, $\delta^{13}C$ profiles of herbivores from Coppa Nevigata.
*Profilo isotopico intra-dente di $^{87}Sr/^{86}Sr$, $\delta^{18}O$, $\delta^{13}C$ degli erbivori di Coppa Nevigata.*

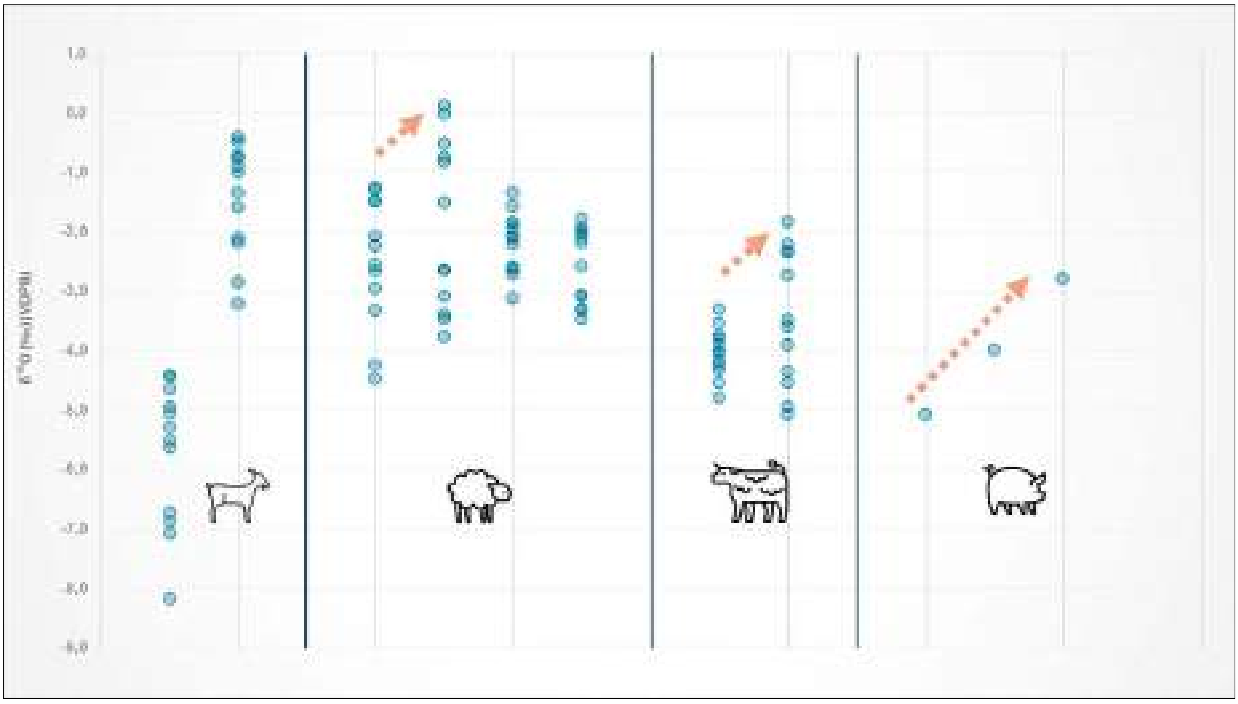

Fig. 13. $\delta^{18}O$ values for each animal analysed from Coppa Nevigata. Red arrows indicate increasing values at the onset of the Subapenninic phase (Recent Bronze Age; 1350-1150 BCE).
*Valori di $\delta^{18}O$ per tutti gli animali analizzati da Coppa Nevigata. Le frecce rosse indicano i valori crescenti alla transizione alla fase Siubappenninica (Bronzo recente; 1350-1150 a.C.).*

One of the most interesting aspects, which certainly requires further investigation, is the chronological trend observed in $\delta^{18}O$ values. Although the small sample size from Coppa Nevigata precludes broad generalization, there is an overall tendency towards an increase in $\delta^{18}O$ values over time, particularly at the transition to the Subapenninic phases. This pattern is observable among obligate (cattle and pigs) and non/semi-obligate drinkers (sheep; goats are exclusively from the Subapennine phase) and may reflect a possible increase in atmospheric temperatures, leading to higher $\delta^{18}O$ values in groundwaters consumed by the animals, both directly and indirectly through ingested vegetation (fig. 13).

## 9. DISCUSSION

The results of this study reveal a clearly differentiated pattern of animal management between the Po and Tavoliere plains – represented here by Solarolo and Coppa Nevigata – and the hilly regions of the Middle Adriatic region, represented by Montarice (fig. 14). At Solarolo and Coppa Nevigata, herbivores were kept in the immediate vicinity of the settlements. The exploitation of nearby pastures was likely integrated into an agricultural system based on crop rotation and fallow, with natural manuring as a primary strategy for maintaining soil fertility. As demonstrated by the modelling of territorial exploitation and archaeobotanical data at Solarolo and Coppa Nevigata, the area under the sites' control was sufficiently extended and open to supply all the fodder required for herbivorous livestock. Using rough estimates, an adult cow and an adult sheep require approximately 2 ha and 0.5 ha of grazeland per year, respectively, in temperate climates (Putfarken *et al.* 2008). Based on the estimated MNI of domestic animals coexisting at Solarolo-125 cattle, 208 caprines, and 133 pigs (see above)-the minimum grazeland required is roughly 350 ha. This area is well within the estimated 3,200 ha controlled by the Solarolo settlement. Pollen data indicate that approximately 60% of this territory consisted of open land (cropfields + pastures). Assuming that 30% of this open land was exploited as grazeland (under a rotation/fallow system), about 960 ha would have been available for this purpose, nearly three times the area required to sustain the estimated domestic herbivore population, based on zooarchaeological and stratigraphic data. In addition to major villages such as Solarolo, territorial management could be supported by smaller settlements, which have left fewer and less visible traces in the archaeological record. It can therefore be hypothesized that surplus land was also exploited by 'invisible' settlements or even small farmsteads.

Residential management among Bronze Age communities of the plain areas is also supported by recent studies, which ascertained the presence of structures specifically used as stables within the settlements, starting from the initial phase of the MBA in the Po-Adige plain, such as at Oppeano and La Muraiola (Nicosia *et al.* 2025; Polisca *et al.* 2025).

Within this predominantly residential management system, limited introduction of external livestock is also attested (one sheep and one pig at Solarolo, one goat at Coppa Nevigata). Accordingly, our revision of published strontium isotope data from a large set of caprines from the Terramara of Montale (Sabatini *et al.* 2022) suggests that at least 2 of the 33 analysed specimens (6%) may have been imported at least from the hinterland. Animal exchange was therefore relatively frequent within the hinterland and could be useful to maintain adequate levels of genetic diversity and herd health, although different, less practical reasons (e.g. gifts, dowries, etc.) must be considered[10]. Another possible explanation, which does not exclude the first, is that part of the non-local livestock may have resulted from acts of forced acquisition, such as theft and predatory raids.

The goat found at Coppa Nevigata, however, indicates that some animals could be imported from distant regions, in this case likely from the Alpine area. This evidence well matches a framework of intense terrestrial and maritime exchange between the coastal regions of the Adriatic, and more in general of the Mediterranean that involved primarily finished artefacts and raw materials (Cazzella-Recchia 2020). The supply of metal and Baltic amber from the regions of

[10] Our protocol did not involve sex determination through genetic analysis. Ideally, it would be important to establish which imported animals were males or females. For example, specific males with certain characteristics (e.g. body mass) could be selected for interbreeding.

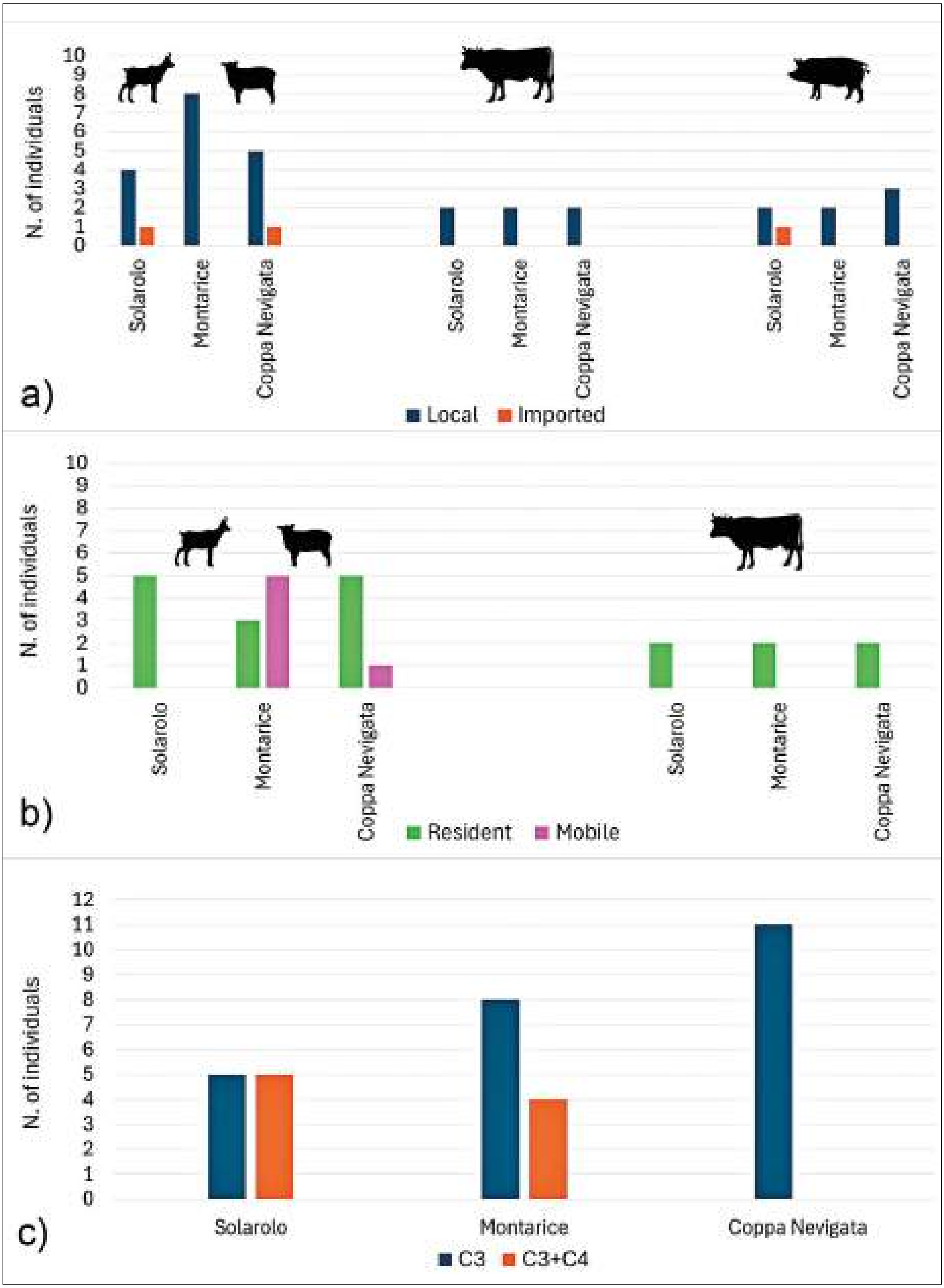


Fig. 14. Data interpretation. a) number of local and imported animals per site; b) number of resident and mobile animals per site; c) number of animals characterized by $C_3$-plant based diet and by the integration with $C_4$ plants.

*Interpretazione dei dati. a) numero di animali locali e importati per sito; b) numero di animali allevati localmente o mobili stagionalmente per sito; c) numero di animali caratterizzati da dieta a base di piante $C_3$ o con integrazione di $C_4$.*

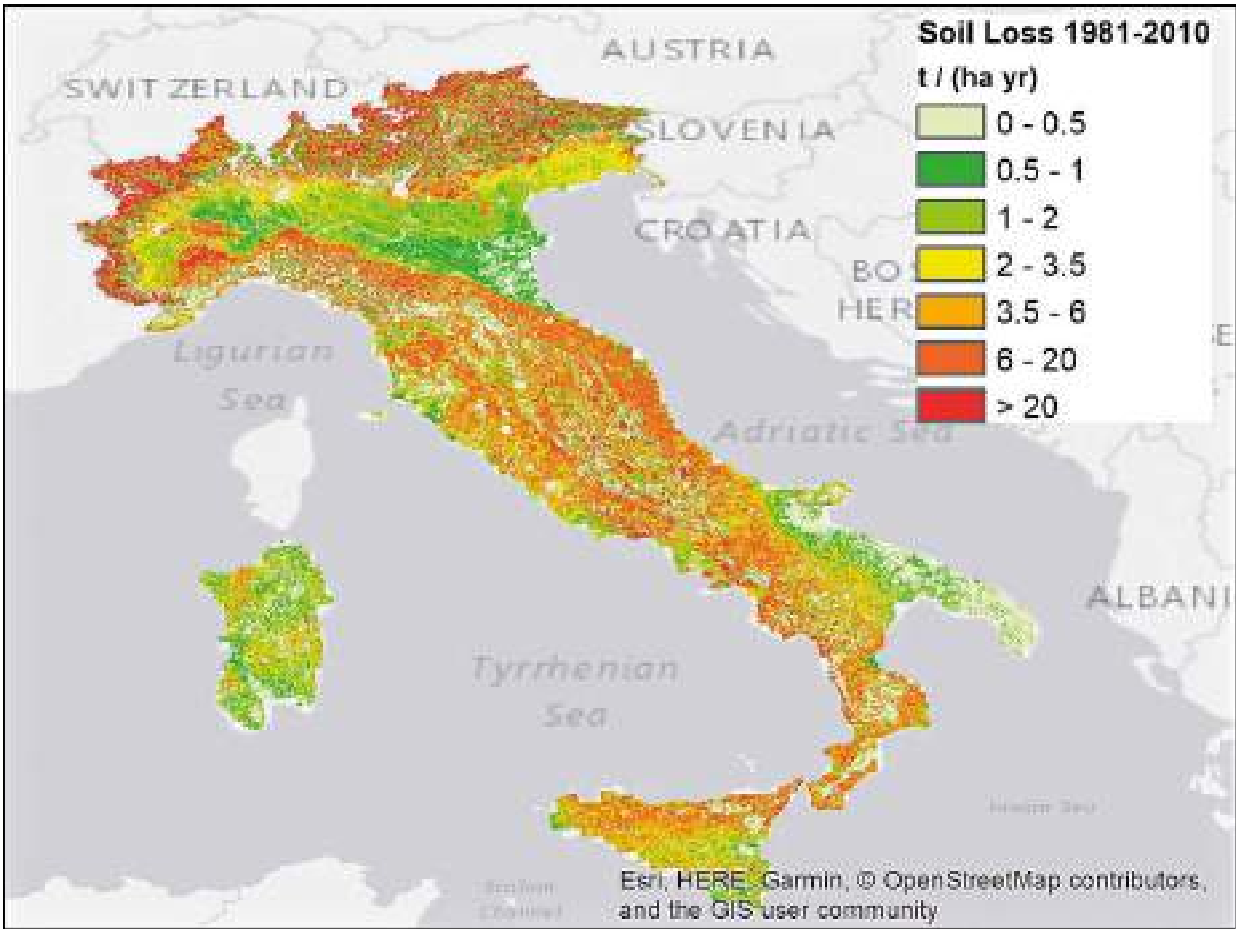


Fig. 15. Map of soil loss in Italy (after https://climate.copernicus.eu/soil-erosion-italy).
*Mappa di perdita di suolo in Italia (da https://climate.copernicus.eu/soil-erosion-italy)*

Northern Italy, in particular, is well-documented in the sites of Northern Apulia at least from an advanced phase of the MBA (Jung-Mehofer-Pernicka 2011; Jung and Mehofer 2013; Bellintani 2014; Cwaliński 2023).

Alternatively, livestock may have been used to provision ship crews during maritime journeys. The substantial volume and frequency of exchanges support the existence of an intensive maritime network, which would have required advanced seafaring technologies, most notably sewn-plank boats, as exemplified by the Zambratija shipwreck, dated to the 13th-11th centuries BCE (Koncani Uhač-Boetto-Uhač 2017).

At Montarice, caprine management followed a more variable strategy. The majority of the animals were grazed on distant pastures, although the specific locations cannot unambiguously be identified, preventing a clear distinction between short- and long-distance transhumance. Nevertheless, evidence for residential management is also attested at the site. This combination of practices suggests a mixed system, which may be interpreted in several ways. Given that the Montarice assemblage spans a broad chronological range (MBA3 to RBA1), a diachronic shift in herd management at the transition to the RBA cannot be ruled out. However, we propose that the most plausible explanation is the coexistence of different ownership and functional regimes: part of the livestock – probably that primarily devoted to wool production – may have belonged to large, transhumant herds, whether of common or private ownership remains to be determined; another portion was likely owned by individual households and oriented toward subsistence needs.

The significant investment in transhumant pastoralism among Bronze Age communities of the Middle Adriatic region was likely a response to the nature of soils along the Apennine ridge. Pedological studies indicate considerable variation in soil erodibility across the Italian territory, largely due to steep slope gradients and fine calcareous sediments, which are particularly susceptible to rainfall-induced erosion. Erodibility maps show limited soil loss in the Po Plain and the Tavoliere (<1 ton ha$^{-1}$ yr$^{-1}$), whereas mountain areas of the Alps and Apennines experience much higher rates (>20 tons ha$^{-1}$ yr$^{-1}$) (fig. 15). For the purposes of this study, the hilly areas of the Marche region exhibit high vulnerability (>6 tons ha$^{-1}$ yr$^{-1}$) (Grimm *et al.* 2002; van der Knijff *et al.* 1999; Borrelli *et al.* 2016).

Zoogenic erosion further exacerbates soil loss in vulnerable pedozones, particularly under conditions of large herds and overgrazing (Torresani *et al.* 2019; Arroyo *et al.* 2024). Animal trampling causes soil compaction, which reduces water infiltration (Kumbasli *et al.* 2010), and detachment of soil particles during hoof lifting. Overgrazing also leads to a loss of vegetation cover and biodiversity (Ibáñez-Martínez-Schnabel 2007; Oztas-Koc-Comakli 2003; Thornes 2007; Zucca-Canu-Previtali 2010). These ecological constraints, plausibly complemented by increased demographic pressure, food demand, investment in wool production and therefore in large sheep herds, likely acted as push factors, encouraging the exploitation of more distant pastures and the adoption of a more extensive pastoral strategy.

Such dynamics may have been one of the principal factors driving the systematic occupation of mountain areas – closer to high-altitude pastures and along major communication routes – observable. from at least MBA3 throughout the Apennines (Cardarelli 2006; Cavazzuti-Putzolu 2015; Putzolu-Cavazzuti 2019). Supporting evidence comes from a recent study in the Tuscan-Emilian Apennines, which documents that soils above 1,550 m were subjected to extensive deforestation by fire and pedogenetic processes during the Recent Bronze Age, likely linked to the use of highlands as grazing pastures (Vittori Antisari *et al.* 2018). Although derived from a different sector of the Apennines, these data are consistent with the broader patterns inferred here.

Beyond ecological push factors, the seasonal displacement of herds likely entailed a wide range of socio-cultural implications. First, passage through territories controlled by different communities would have required a more profound geographical knowledge, as well as forms of negotiation through alliances and agreements, potentially strengthened by exogamic practices (e.g. Cavazzuti *et al.* 2019) and a certain degree of economic interdependence. Second, communication networks had to be maintained in order to secure and facilitate movement, implying a substantial investment of labour in the maintenance of paths and a dense occupation of upland areas. Further research is needed to assess the extent of mobile pastoralism in central and southern Italy; however, these preliminary results clearly highlight the complexity of the phenomenon.

Another noteworthy aspect is the occasional incorporation of $C_4$ plants into the animal diet, occurring predominantly during autumn. Approximately half of the herbivores from Solarolo and one third of those from Montarice exhibit $\delta^{13}C$ enrichment consistent with episodic consumption of $C_4$ plants. The sporadic nature of this signal may reflect responses to specific environmental conditions, such as particularly dry summers that reduced the availability of fresh pasture and necessitated the use of supplementary fodder for herbivores. On the contrary, Coppa Nevigata does not show this kind of evidence, as confirmed by archaeobotanical data.

Although spontaneous plants, such as cockspur grass (*Echinochloa crus-galli*) might be included in the $C_4$-plant proportion (cfr. Nicosia *et al.* 2025), multiple independent lines of evidence, including archaeobotanical and biomolecular data, seems to indicate broomcorn millet (*Panicum miliaceum*), as the major contributor. Millet is known to have been cultivated by Middle Bronze Age communities in northern Italy, as documented in MBA2 layers at Solarolo (c. 1550-1450 BCE) (Carra 2009, 2012, Carra *et al.* 2023) and Muraiola di Povegliano (Polisca *et al.* 2025), as well as in MBA3 contexts (1450-1400 BCE) at the Lavagnone lake-dwelling site (Filipović *et al.* 2020) and at the votive pool of Noceto (Rottoli-Castiglioni 2009). Isotopic analyses of both collagen and enamel apatite further indicate that human and animal diets in the Po Plain included variable proportions of $C_4$ plants from at least the Middle Bronze Age onward (Tafuri *et al.* 2018; Cavazzuti *et al.* 2019; Varalli-Moggi-Cecchi-Goude 2022), and in Recent Bronze Age at Punta Zambrone (Rumolo *et al.* 2020). With specific regard to animals, $C_4$ plant consumption has previously been identified in several bovine and swine specimens from multiple sites, including

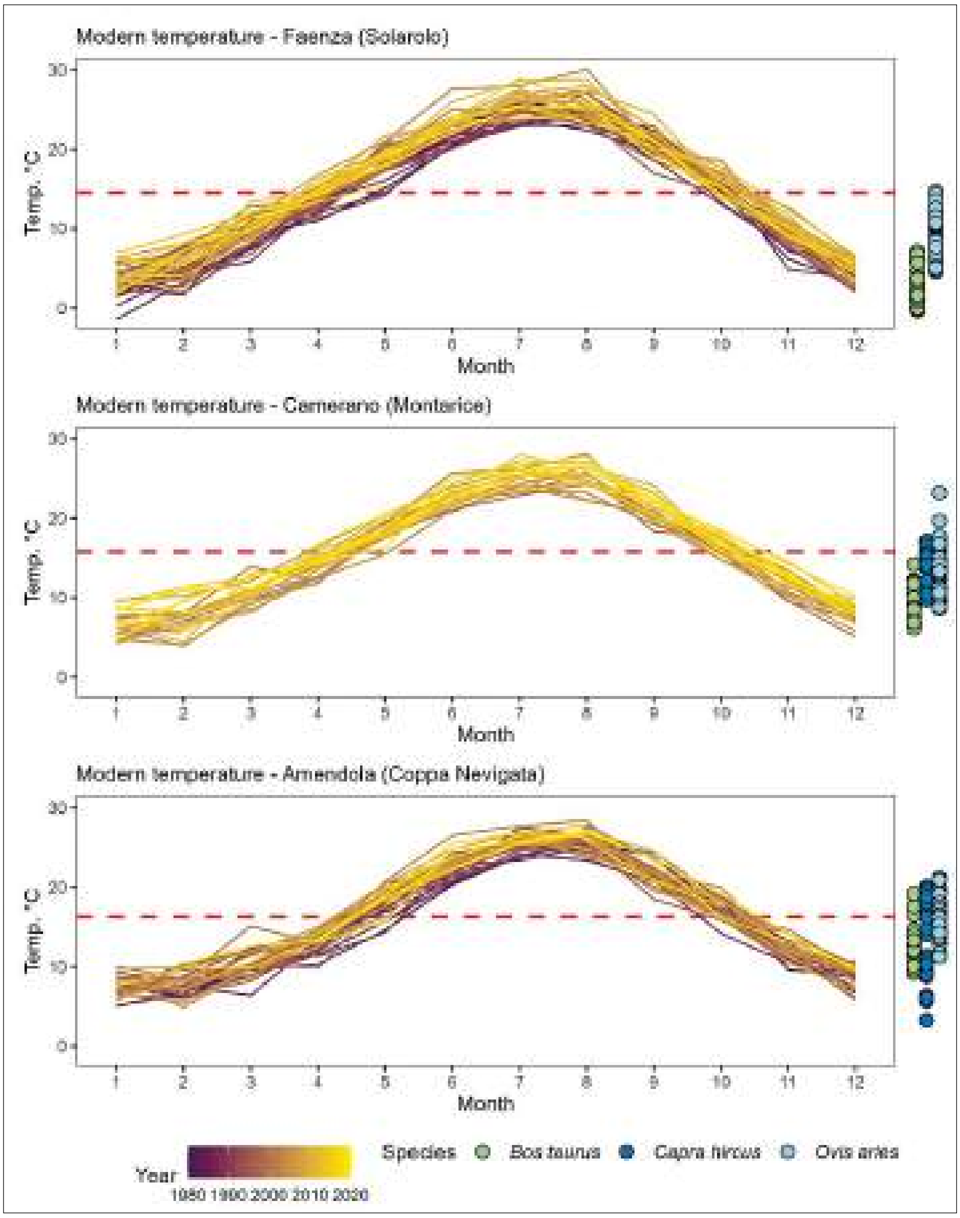


Fig. 16. Atmospheric temperature records from 1980 to 2020 (https://scia.isprambiente.it/) for representative sites in the vicinity of the study areas. Horizontal dashed red lines represent the average annual temperature at each site. Filled circles are temperature estimates based on the $\delta^{18}O$ values of herbivores' enamel. These data consist of direct measurements, not modelled to account for enamel damping, and therefore do not capture the full amplitude of the water isotope signature.

*Temperature atmosferiche misurate tra il 1980 e il 2010 (https://scia.isprambiente.it/) in siti prossimi alle zone campione di questo studio. Le linee tratteggiate orizzontali rappresentano la temperatura media al suolo da ogni sito. I cerchi colorati rappresentano le temperature stimate sulla base dei valori di $\delta^{18}O$ sullo smalto degli animali analizzati. Questi dati consistono in misurazioni dirette, non modellate per tenere conto dell'effetto di attenuazione dello smalto, e pertanto non catturano l'intera ampiezza del segnale isotopico dell'acqua.*

Mereto, Olmo di Nogara, and Fondo Paviani (Tafuri *et al.* 2018; Cavazzuti *et al.* 2019).

Another interesting aspect derives from the analysis of $\delta^{18}O$ variations among the three different sites. The higher values recorded among local animals in Coppa Nevigata, compared to Montarice and Solarolo reflect the climatic differences between south, central and northern Italy that clearly depend on latitude and distance from the coast (cfr. Giustini-Brilli-Patera 2016).

Higher $\delta^{18}O$ values recorded among local animals in Coppa Nevigata reflect the warmer and more stable climatic conditions of southern Italy, whereas lower values at Montarice and Solarolo correspond to cooler and more continental settings.

Air temperature estimates derived from $\delta^{18}O$ values of herbivore enamel are broadly consistent with modern mean annual temperatures at each site, suggesting comparable climatic conditions (fig. 16). Solarolo, however, represents a notable exception, with reconstructed average temperature lower than present-day values. This discrepancy may reflect local ecological factors affecting the isotopic signal (e.g. consumption of $^{18}O$-depleted drinking water), or alternatively, cooler conditions at the time of enamel formation (MBA2), which could be connected to the 3.6 ka event, suggested by the advance of the Tyrolean Alps glaciers (beginning of the Loebben oscillation) (Moran *et al.* 2017).

An interesting diachronic trend in our results is provided by $\delta^{18}O$ from Coppa Nevigata, where we detected an increase of values among sheep, cattle, and pigs at the transition to the *Subapennine* phase, which may reflect a possible increase in atmospheric and ground temperatures around 3.2 ka BP (see for example Molloy 2022 and references therein). This trend, also supported by archaeobotanical data, certainly requires additional isotopic confirmation.

Future studies applying multi-isotopic protocols to larger, well dated faunal assemblages will be essential for validating and refining regional climatic reconstructions in specific areas and for disentangling environmental from management driven isotopic signals.

## 10. CONCLUSIONS

This study represents a first attempt to reconstruct animal management strategies across different Bronze Age contexts in present-day Italy using an integrated multi-isotopic and zooarchaeological approach. Our results highlight a range of diversified practices, largely shaped by local ecological conditions, particularly pedological characteristics.

In the Po and Tavoliere plains, isotopic evidence points to an integrated system combining residential husbandry and agriculture, oriented toward intensive land use and maximization of food production in the immediate vicinity of settlements, complemented by a relatively frequent import of livestock, either from the hinterland or from distant regions.

In contrast, in the Marche region, communities appear to have adopted a mixed strategy of residential management and transhumance for different kinds of herds (e.g. for subsistence or for wool production), likely in response to the high susceptibility of local soils to erosion in the surrounding hinterland.

We also identified the occasional use of $C_4$ plants (broomcorn millet) as fodder for domestic animals at Solarolo and Montarice, further indicating a close interdependence between agro-pastoral practices.

Although the sample size remains too limited to support broader generalizations, this study establishes, in our view, a robust methodological framework for investigating animal management, mobility and land use strategies in prehistoric contexts. Future research applying similar integrated approaches to larger datasets will test and refine the patterns we observed here and place them within a broader comparative perspective of the socio-economic organization of Bronze Age communities.

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### Data availability

All ZooMS data are available on Zenodo: https://doi.org/10.5281/zenodo.18554110

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HERDS – Animal Husbandry and its Economic Role in the Development of Central Mediterranean Protohistoric Societies – Rivista di Scienze Preistoriche – LXXVI S6 – 2026 – pp. 133-153

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# Benchmarking Biomolecular Preservation and Ancient DNA Recovery from Bronze Age Italian Livestock Remains: Preliminary Results from the HERDS Project

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Abstract – Benchmarking ancient DNA recovery from Bronze Age Italian livestock remains: Preliminary results from the HERDS project. – Ancient DNA (aDNA) preservation in archaeological remains is strongly influenced by environmental and taphonomic factors, with warm and humid climates posing a major challenge for biomolecular analyses. While these issues are well documented for human remains, systematic assessments of aDNA preservation in domestic animals across heterogeneous climatic contexts remain limited.
Here, we present a methodological evaluation of aDNA preservation in Bronze Age livestock remains (sheep, goat, cattle, and pig) from multiple archaeological sites

distributed across the Italian peninsula, within the framework of the HERDS project. Leveraging a geographically broad dataset, we explore patterns of DNA degradation along latitudinal and environmental gradients. We assess DNA preservation according to skeletal element, comparing different bone districts to identify those yielding higher endogenous DNA content, from a nuclear and a mitochondrial perspective. Preservation is further evaluated at the site level, and compared to ZooMS (zooarchaeology by mass spectrometry) results, providing an overview of Bronze Age Italian archaeological contexts that are more favorable to the survival of biomolecules. We also report sequencing coverage, success rates of molecular sex determination at the site level, and mitochondrial DNA haplogroup assignments. The preliminary results reveal substantial variability in DNA preservation across skeletal elements and sites. However, no clear latitudinal trend was revealed by neither DNA nor ZooMS results, highlighting the importance of context-specific sampling and laboratory strategies. The petrous portion yields a higher recovery of endogenous DNA compared to teeth; however, this difference is statistically significant only for nuclear DNA, whereas mitochondrial DNA shows a non-significant increase.
This study provides a practical methodological framework and reference dataset for future aDNA investigations of domestic animals in environmentally challenging regions, such as the Italian peninsula. In particular, targeted mitochondrial DNA capture and deep sequencing of samples with higher endogenous DNA content will enable high-resolution genetic analyses, offering deeper insight into the diversity and evolutionary history of ancient Italian livestock. As a foundational phase of the HERDS project, the results outlined here pave the way for future palaeogenetic reconstructions of Bronze Age animal husbandry in the Italian peninsula.

RIASSUNTO – LA CONSERVAZIONE DEL DNA ANTICO IN RESTI DI BESTIAME DELL'ETÀ DEL BRONZO IN ITALIA: RISULTATI PRELIMINARI DAL PROGETTO HERDS. – La conservazione del DNA antico nei resti archeologici è fortemente influenzata da fattori ambientali e tafonomici, con i climi caldi e umidi che rappresentano una sfida significativa per le analisi biomolecolari. Sebbene tali problematiche siano ben documentate per i resti umani, le valutazioni sistematiche della conservazione del DNA antico negli animali domestici in contesti climatici eterogenei restano limitate. In questo studio presentiamo una valutazione della conservazione del DNA in resti di bestiame (pecore, capre, bovini e suini) dell'Età del Bronzo provenienti da diversi siti archeologici distribuiti lungo la penisola italiana, nell'ambito del progetto HERDS. Sfruttando un dataset geograficamente ampio, sono stati indagati i pattern di degradazione del DNA lungo gradienti latitudinali e ambientali. La conservazione del DNA è stata valutata in base all'elemento scheletrico campionato, confrontando diversi distretti ossei per identificare quelli con maggiore contenuto di DNA endogeno, sia dal punto di vista nucleare sia mitocondriale. La conservazione del DNA e del collagene (ZooMS – zooarchaeology by mass spectrometry) è stata inoltre analizzata a livello di sito, fornendo una panoramica dei contesti archeologici italiani dell'Età del Bronzo più favorevoli alla sopravvivenza del DNA. Sono stati ricavati i dati sulla copertura di sequenziamento, le percentuali di successo nella determinazione molecolare del sesso e l'assegnazione degli aplogruppi mitocondriali.
I risultati preliminari di DNA e ZooMS evidenziano una notevole variabilità nella conservazione del DNA tra elementi scheletrici e siti, ma non mostrano un chiaro trend latitudinale, sottolineando l'importanza di strategie di campionamento e di laboratorio specifiche per ciascun contesto. Per quanto riguarda la tipologia di campioni, la rocca petrosa consente un recupero maggiore di DNA endogeno rispetto al dente; tuttavia, tale differenza risulta statisticamente significativa solo per il DNA nucleare, mentre per il DNA mitocondriale si osserva un incremento non significativo.
Questo studio fornisce un quadro metodologico pratico e un dataset di riferimento per future indagini archeogenomiche sugli animali domestici in contesti ambientali complessi o avversi, come la penisola italiana. In particolare, l'applicazione di protocolli di arricchimento del DNA mitocondriale e del sequenziamento ad alto coverage sui campioni con maggiore contenuto di DNA endogeno consentiranno analisi genetiche ad alta risoluzione, offrendo nuove prospettive sulla diversità e sulla storia evolutiva del bestiame italiano nel passato. Questo contributo preliminare e di carattere metodologico, apre la strada successive indagini paleogenomiche previste dal progetto HERDS, volte a ricostruire le dinamiche di allevamento dell'Età del Bronzo nella penisola italiana.



*Parole chiave:* DNA antico, degradazione, bestiame, Età del Bronzo.

*Keywords:* ancient DNA, Degradation, Livestock, Bronze Age.

## 1. INTRODUCTION

The transition from foraging to sedentary agricultural lifestyles represents one of the most intense shifts in human history, fundamentally reshaping the evolution, ecology, and demography of both humans and the various species they engaged with and ultimately managed (Mac Hugh-Larson-Orlando 2017; Frantz *et al.* 2020; Koupadi *et al.* 2020). Central to this transition was the domestication of livestock, which acted as the primary engine for pastoral economies, influencing human mobility, social stratification, and the management of ancient landscapes (Cardarelli 2015; Cavazzuti *et al.* 2019; Frantz *et al.* 2020). While traditional zooarchaeological research has successfully documented these processes through morphological changes, age-at-death profiles, and material culture, the record remains inherently fragmentary (Larson and Fuller 2014; Vigne 2015). Moreover, any critical traits selected during the early stages of domestication, such as specific colouration, docility, fertility, and physiological adaptations, are effectively osteologically invisible (Frantz *et al.* 2020). Consequently, the field of paleogenomics has become an indispensable tool, offering a high-resolution approach through which to reconstruct the genomic history of livestock, the patterns of migration, and to clarify the complex nature of human-animal interactions (McHugo-Dover-MacHugh 2019; Frantz *et al.* 2020; Cilli 2024).

In the central Mediterranean, specifically within the Italian peninsula, the period between the 18th and 8th century BC witnessed profound demographic and socio-economic shifts (Cardarelli 2018; Cavazzuti *et al.* 2019; Cazzella, Recchia 2021; Cardarelli *et al.* in this volume). Structural transformations and incipient urbanization necessitated a major revision of the subsistence strategies established during the Neolithic, and were characterized by a marked trend toward specialized husbandry aimed at obtaining secondary products such as milk and wool. This expansion of pastoralism led to the establishment of large flocks managed through vertical mobility and transhumance (Cavazzuti *et al.* 2019; Cardarelli *et al.* in this volume). However, the zooarchaeological records in these contexts often faces diagnostic limitations, as species determination remains challenging in fragmented assemblages. In these studies, biomolecular techniques such as ZooMS and stable isotope analysis provide essential data on taxonomic identification, mobility, and diet (Cavazzuti *et al.* 2019; Cavazzuti *et al.* in this volume; Cianfoni *et al.* in this volume). Crucially, paleogenomics offers a uniquely high-resolution picture of population dynamics and ancestry, which are essential for understanding past economic choices and husbandry strategies.

Despite the potential of ancient DNA (aDNA) to improve our understanding of these Bronze Age trajectories, its feasibility is strictly governed by the taphonomic and environmental history of archaeological remains. Upon death, the cessation of cellular repair mechanisms leaves the genome vulnerable to a series of complex diagenetic processes, including DNA fragmentation, blocking lesions and miscoding lesions, most notably the hydrolytic deamination of cytosine to uracil (Dabney *et al.* 2013). Similarly, the protein content of bone (mainly represented by collagen) decreases rapidly due to hydrolytic breakage of peptide bonds, releasing free amino acids (Demarchi 2020). The kinetics of these degradation processes are significantly accelerated in the Mediterranean basin, where warm and humid climates challenge the long-term survival of genetic material (Smith *et al.* 2003; Allentoft *et al.* 2012; Kistler *et al.* 2017). While it was once assumed that biomolecular survival was primarily a function of time and average temperature, it is now established that local micro-environments, characterized by stable temperatures, neutral pH, and low humidity, are the decisive factors in preservation (Geigl and Grange 2018; Cilli 2024).

In light of rapid improvements in sequencing technologies and laboratory protocols, the ability to address complex biological questions through ancient DNA has expanded significantly, but identifying the right samples for analysis is becoming increasingly important. A major advancement has been the identification of specific skeletal elements that maximize endogenous DNA yield. The petrous portion of the temporal bone has emerged as the best reservoir of ancient DNA, due to its extreme density and minimal remodeling, it often yields 4 to 16 times more DNA than teeth and up to 183 times more than other bone districts (Gamba *et al.* 2014). However, in contexts where the petrous bone is unavailable, researchers must rely on alternative sources such as dental remains (cementum and dentine) or cortical bone, though these elements are often more prone to environmental contamination and accelerated degradation.

Within the framework of the HERDS project, this study presents a systematic evaluation of aDNA preservation in 143 livestock remains, including sheep, goats, cattle, and pigs, retrieved from 21 Bronze Age archaeological sites across the Italian peninsula. We augment this by pairing ZooMS data obtained on 182 *Ovis* vel *Capra* samples from the same project and sites.

Leveraging Italy's diverse latitudinal and environmental gradients, we aim to benchmark aDNA recovery to identify optimal sampling strategies for livestock in Mediterranean climates. By integrating evidence on DNA preservation, sequencing coverage, molecular sex determination success, and mitochondrial haplogroup assignment, this study establishes a comprehensive reference dataset to support future investigations into the genomic history of domestic animals from environmentally challenging contexts.

These results represent the preliminary outcomes of the HERDS project, providing a useful methodological framework for subsequent laboratory procedures and downstream bioinformatic analyses. This approach will ultimately facilitate the reconstruction of livestock mobility patterns and animal husbandry strategies throughout the Italian Bronze Age.

## 2. MATERIALS AND METHODS

### 2.1 Samples

A total of 143 specimens from 21 archaeological sites (Cardarelli *et al.* in this volume) were selected for archaeogenetic analysis. Samples were chosen to ensure their suitability for multiple biomolecular analyses in addition to ancient DNA, including isotopic and ZooMS analyses. Samples were obtained from domestic species, including sheep (*Ovis aries*), goats (*Capra hircus*), cattle (*Bos taurus*), and pigs (*Sus domesticus*). Sampling targeted skeletal elements known to provide optimal DNA preservation (Gamba *et al.* 2014; Parker *et al.* 2020). The petrous portion of the temporal bone was preferentially selected when present; otherwise, teeth were sampled, including both isolated specimens and teeth retained within mandibles or maxillae. In the absence of these elements, alternative skeletal elements, such as metacarpal or long bones, were sampled. ZooMS analyses were conducted on 182 samples, as reported in Cianfoni *et al.*, and Cavazzuti *et al.*, in this volume.

### 2.2 Ancient DNA analysis

The genetic analyses were performed at the ancient DNA facilities of the Department of Cultural Heritage (University of Bologna) following the standard criteria for ancient DNA processing (Cilli 2024). Prior to sampling, bone fragments were cleaned with a brush soaked in 4% sodium hypochlorite, rinsed in 80% ethanol, and later UV-C irradiated for 20 min. Due to the very fragile nature of the remains, a small fragment was obtained from each sample using a dental drill fitted with a diamond cutting disc. Approximately 100 mg of material was collected and subsequently grounded into a fine powder using a mortar and pestle. DNA isolation was conducted in a separate room, following extraction protocols described in (Utzeri *et al.* 2023), modified from (Dabney *et al.* 2013). Briefly, the samples were digested for 15 h at 37°C in a solution composed of 0.45 M EDTA (pH 8), 0.25mg/mL of proteinase K and water. PB binding buffer (Qiagen, Hilden, Germany) was added to the supernatants and transferred into silica columns (High Pure Viral Nucleic Acid Large Volume Kit, Roche, Basel, Switzerland). Two washing steps with PE buffer (Qiagen) were performed before eluting the DNA in 50 µL of EB buffer (Qiagen). Blank controls were processed along with the samples during every phase of the analysis. The presence of genetic material was confirmed by measuring the raw extracts on Qubit fluorometer (Thermo Fisher Scientific). Afterwards, single-stranded genomic libraries were built according to (Kapp-Green-Shapiro 2021), without enzymatic damage repair steps. A qPCR quantification was performed prior to indexing to identify the cycle threshold. Then the single-stranded libraries were indexed and quantified on Agilent 2100 Bioanalyzer or TapeStation (Agilent). Then,

| Species | Whole genome | Mitochondrial genome |
|---|---|---|
| *Ovis aries* | GCF_000298735.2_Oar_v4.0_genomic.fna | NC_001941.1 |
| *Capra hircus* | GCF_001704415.2_ARS1.2_genomic.fna | NC_005044.2 |
| *Bos taurus* | GCF_002263795.2_ARS-UCD1.3_genomic.fna | NC_006853.1 |
| *Sus domesticus* | GCF_000003025.6_Sscrofa11.1_genomic.fna | NC_012095.1 |

Tab. 1 – References for whole genome and mitochondrial genome analyses.
*Genomi di riferimento per le analisi genomiche e mitocondriali.*

the libraries were pooled in equimolar amounts with other samples and screened for endogenous DNA on Novaseq X 2×150 bp lane.

### 2.3 Bioinformatic analysis

The EAGER v2.5.1 pipeline (Fellows Yates *et al.* 2021) was used for downstream bioinformatic analysis. Illumina adapters were removed from the sequences using AdapterRemoval v.2.2.0 (Schubert-Lindgreen-Orlando 2016). Sequences were evaluated with FastQC (Andrews 2010) and mapped to the reference genome (reference genomes used for each species are listed in tab. 1) using bwa tool (Li and Durbin 2009), disabling the seed option and setting a mapping quality threshold >30. After mapping, duplicates were removed using MarkDuplicates tool from GATK (DePristo *et al.* 2011) and postprocessed with SAMtools (Li *et al.* 2009). General statistics were obtained through MultiQC (Ewels *et al.* 2016). mapDamage (Ginolhac *et al.* 2011) was used for calculating and observing the frequency ratio of deamination patterns along the 5′ ends of the resultant sequences. The values for the mean mitochondrial genome coverage per sample were obtained with Qualimap (Okonechnikov-Conesa García Alcalde 2016), demonstrating the mean per-base coverage values across the reference mitogenome. Mapped mitochondrial genomes were utilized to statistically determine species classification (*Ovis aries* or *Capra hircus*) with the MTaxi tool (Atağ *et al.* 2023). Sex determination analyses were conducted using an adapted version of the script published by Mittnik and colleagues (2016).

### 2.4 Haplogroup identification

Consensus FASTA sequences were generated from the aligned BAM files using SAMtools with a minimum mapping quality of 30, minimum depth of 3, and a consensus threshold of 75%, in accordance with established parameters for aDNA analysis (Bergstrom *et al.* 2022). To avoid ambiguous haplogroup assessment, only reconstructed FASTA sequences with less than 20% of missing data were used in subsequent analysis. Selected mitochondrial genome sequences were aligned with publicly available mitogenome reference sequences for *Ovis aries*, *Capra hircus*, *Bos taurus*, and *Sus domesticus* using MAFFT (version 7) (Katoh and Standley 2013) under default settings. Alignments were inspected and manually edited in BioEdit (version 7.0) (Hall-Biosciences-Carlsbad 2011). The finalized alignment was processed in DnaSP 6 (Rozas *et al.* 2017) to generate haplotype and network files, which were visualized using PopArt (version 1.7) (Leigh-Bryant-Nakagawa 2015). Haplogroups were determined by comparison with published mitochondrial sequences included in the dataset.

### 2.5 Statistical analysis and data visualization

Endogenous mitochondrial and whole genome content utilized for sample comparison was retrieved from EAGER pipeline files. Analyses were conducted using R version 4.5.1 (R Core Team 2026) with the packages dplyr (version 1.2.1) (Wickham *et al.* 2023), ggplot2 (version 3.4.3) (Wickham 2016), tidyr (version 1.3.2) (Wickham and Henry 2023), readxl (version 1.5.3) (Wickham and Bryan 2023), and rstatix (version 0.7.2) (Kassambara 2023). Group differences were evaluated using the Mann-Whitney U test.

## 3. Results

### 3.1 Success of aDNA retrieval and analysis across various archaeological sites within the HERDS project

The paleogenomic pipeline implemented in this study was subdivided into three stages. The first stage, processing, comprised samples

| Site | Sample ID | Processed reads | Mapped reads | mtDNA coverage | Taxon identified | Haplogroup identified |
|---|---|---|---|---|---|---|
| Frattesina | 505 | 22302022 | 4336 | 12.2 | *Bos taurus* | T |
| Frattesina | 506 | 13614716 | 533 | 1.7 | *Bos taurus* | – |
| Frattesina | 507 | 15306800 | 1959 | 6.3 | *Bos taurus* | – |
| Frattesina | 509 | 12504799 | 1480 | 4.7 | *Ovis aries* | B |
| Frattesina | 510 | 19119972 | 3845 | 12 | *Ovis aries* | B |
| Frattesina | 511 | 28199574 | 3010 | 9.3 | *Ovis aries* | B |
| Poviglio Santa Rosa | 51 | 18626368 | 735 | 2.2 | *Ovis aries* | – |
| Poviglio Santa Rosa | 60 | 14228426 | 1171 | 3.5 | *Ovis aries* | – |
| Poviglio Santa Rosa | 64 | 12280083 | 63 | 0.2 | *Ovis aries* | – |
| Poviglio Santa Rosa | 305 | 13560062 | 656 | 2 | *Sus domesticus* | – |
| Solarolo | 18 | 20093793 | 514 | 1.5 | *Ovis aries* | – |
| Solarolo | 25 | 7323373 | 69 | 0.2 | *Ovis aries* | – |
| Solarolo | 178 | 16083593 | 437 | 1.5 | *Ovis aries* | – |
| Solarolo | 235 | 19295216 | 693 | 2.3 | *Bos taurus* | – |
| Solarolo | 514 | 23032362 | 399 | 1.4 | *Sus domesticus* | – |
| San Michele di Valestra | 61 | 11843123 | 1650 | 5.3 | *Ovis aries* | B |
| San Michele di Valestra | 63 | 10439606 | 613 | 1.8 | *Ovis aries* | – |
| San Michele di Valestra | 70 | 11485287 | 345 | 1 | *Ovis aries* | – |
| Carpegna | 448 | 19342273 | 75 | 0.4 | *Capra hircus* | – |
| Montarice | 31 | 13388589 | 115 | 0.4 | *Ovis aries* | – |
| Montarice | 32 | 34392855 | 4929 | 15.3 | *Ovis aries* | B |
| Montarice | 26R | 21894373 | 834 | 2.3 | *Ovis aries* | – |
| Montarice | 32R | 24202275 | 351 | 1.1 | *Ovis aries* | – |
| Montarice | 36 | 25187163 | 146 | 0.4 | *Capra hircus* | – |
| Montarice | 478 | 19506141 | 5671 | 19.2 | *Bos taurus* | T |
| Montarice | 481 | 16535028 | 3142 | 10.2 | *Sus domesticus* | A |
| Moscosi di Cingoli | 239 | 18749382 | 1843 | 6.1 | *Bos taurus* | T |
| Moscosi di Cingoli | 241 | 13069409 | 447 | 1.5 | *Bos taurus* | – |
| La Crocetta | 495 | 15057406 | 568 | 1.9 | *Ovis aries* | – |
| La Crocetta | 498 | 11705802 | 116 | 0,4 | *Sus domesticus* | – |
| Giardino Romano | 353 | 9310751 | 53 | 0.2 | *Sus domesticus* | – |
| Monte Morra | 503 | 21876401 | 294 | 0.9 | *Capra hircus* | – |
| Coppa Nevigata | 181 | 6142159 | 453 | 1.8 | *Ovis aries* | – |
| Coppa Nevigata | 182 | 10629787 | 360 | 1.3 | *Bos taurus* | – |
| Coppa Nevigata | 186 | 8613517 | 48 | 0.2 | *Ovis aries* | – |
| Coppa Nevigata | 189 | 9022720 | 279 | 0.9 | *Ovis aries* | – |
| Coppa Nevigata | 193 | 7582198 | 8451 | 27.9 | *Capra hircus* | A |
| Coppa Nevigata | 205 | 15549842 | 85 | 0.3 | *Bos taurus* | – |
| Coppa Nevigata | 209 | 11170437 | 423 | 1.5 | *Sus domesticus* | – |
| Cabras, Sa Osa | 281 | 21222207 | 906 | 3 | *Ovis aries* | – |
| Cabras, Sa Osa | 296 | 19082264 | 64 | 0.2 | *Ovis aries* | – |
| Mursia | 108 | 14223278 | 88 | 0.3 | *Capra hircus* | – |

Tab. 2 – Summary of the samples sequenced through the low-coverage screening. For each sample, the total number of reads obtained, the number of reads successfully mapped to the reference mitogenome, the resulting mitochondrial DNA (mtDNA) mean coverage, the identified taxon, and the assigned mitochondrial haplogroup are reported.

*Riepilogo dei campioni sottoposti a sequenziamento di screening a bassa copertura. Per ciascun campione si riportano il numero totale di reads, le reads mappate sul mitogenoma di riferimento, la copertura del mtDNA, il taxon di appartenenza e l'aplogruppo mitocondriale.*

that were selected and submitted for DNA extraction. The second stage, screening, included samples that yielded libraries passing quality and quantitative controls and were subsequently subjected to endogenous DNA screening. The final stage, taxonomic identification, comprised samples that were successfully assigned to a species using the EAGER pipeline and the MTaxi tool by mapping reads from the screening to the reference mitochondrial genome. Of the 147 samples processed, 66 yielded libraries that were screened for endogenous DNA content, and 42 samples were taxonomically identified at the species level through molecular analysis (tab. 2). Patterns of post-mortem degradation were consistent across all samples, enabling the authentication of the ancient origin of the recovered biomolecules. Moreover, blank and negative controls support the absence of contamination possibly introduced during the laboratory analyses. Fig. 1 shows the distribution of samples passing through stages of the pipeline across different archaeological sites.

Among all sites, Frattesina (Veneto) showed the highest success rate, with 6 out of 7 samples successfully reaching taxonomic identification. Montarice (Marche) and Coppa Nevigata (Puglia) also performed well, with 7 out of 12 and 7 out of 13 samples, respectively, passing through all stages of the pipeline, demonstrating the highest amount of completely analysed samples per site. Solarolo (Emilia-Romagna), San Michele di Valestra (Emilia-Romagna), and Cabras, Sa Osa (Sardinia) each yielded 50% of samples reaching stage 3. In contrast, Baggiovara (Emilia-Romagna), Gaggio (Emilia-Romagna), Montecroce Guardia (Marche), Villaggio delle Macine (Lazio), Sa Mandra Manna (Sardinia), Sedilo, Iloi (Sardinia), and Torre Galli (Calabria) did not yield any samples that progressed to the final stage.

Overall, the success rate of sample processing was universally distributed among multiple regions of Italy, reflecting a range of climatic and environmental conditions that may influence ancient DNA preservation. A general north-south trend was observed: Frattesina, the most successful site, is located in northern Italy, whereas sites with no samples reaching the final stage were predominantly in southern regions (Sardinia and Calabria). Nevertheless, breaking the above-mentioned pattern, Coppa Nevigata, located in southern Italy, showed a comparatively high proportion of successfully processed samples, while some northern Italian sites (Emilia-Romagna), characterized by mixed climatic conditions, exhibited a lower processing success rate.

The final species distribution from taxon identification is demonstrated in fig. 2.

For specimens yielding sufficient mitochondrial genome coverage, the reconstructed mitogenomes were obtained. This enabled the assignment of mitochondrial haplogroups, providing further insight into specimen's genetic ancestry. Haplogroup assignment was successful for five *O. aries* samples from Frattesina (3 samples), San Michele di Valestra (1 sample) and Montarice (1 sample). All sheep specimens were identified with haplogroup B. In addition, one *C. hircus* sample from Coppa Nevigata was assigned to haplogroup A and one *S. domesticus* sample from Montarice was assigned to haplogroup A. Regarding *B. taurus* species, 3 samples were assigned with haplogroup T from archaeological sites: Frattesina, Montarice and Moscosi di Cingoli (Marche) (tab. 2).

After species assignment and haplogroup identification, the EAGER pipeline was rerun to align reads to the nuclear reference genome (tab. 1), enabling sex determination analysis. Genetic sexing is based on the ratio of reads mapped to the X chromosome relative to the autosomes and therefore requires sufficient nuclear genome coverage, which was not achieved for some samples. Therefore, only 35 of the 42 taxonomically identified samples were sexed. The resulting distribution of samples with sex identified across sites is shown in fig. 3.

Across most sites, samples that yielded sufficient data for taxonomic identification also allowed successful sex determination. The biggest gap was observed in the Montarice site, with only 4 samples sexed out of 7. One-sample step discordancies were observed in San Michele di Valestra, Moscosi di Cingoli, La Crocetta and Coppa Nevigata sites.

Moreover, no clear regional pattern in sexing success rates was detected. The resulting species and sex distribution across archaeological sites is shown in fig. 4.

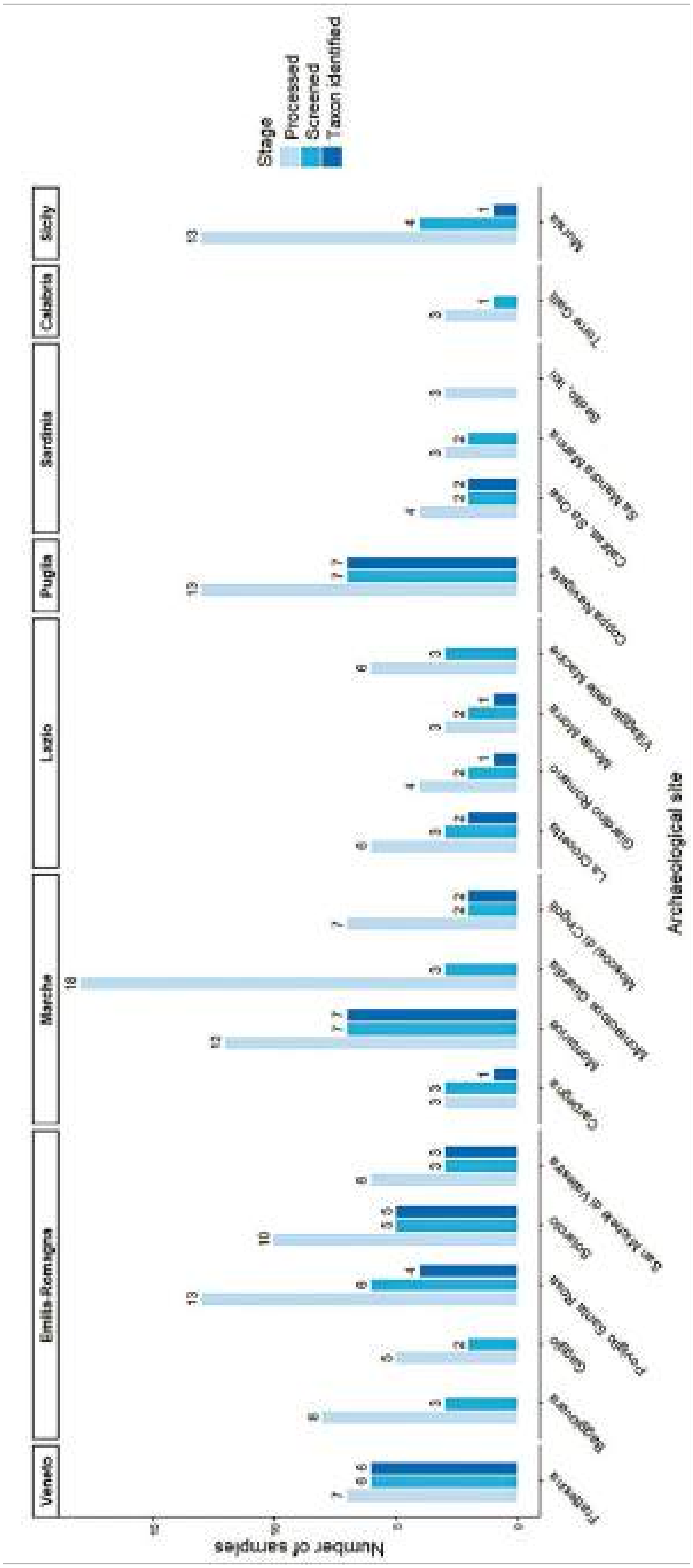


Fig. 1 – Samples analysed per archaeological site.
*Campioni analizzati per i vari siti archeologici.*

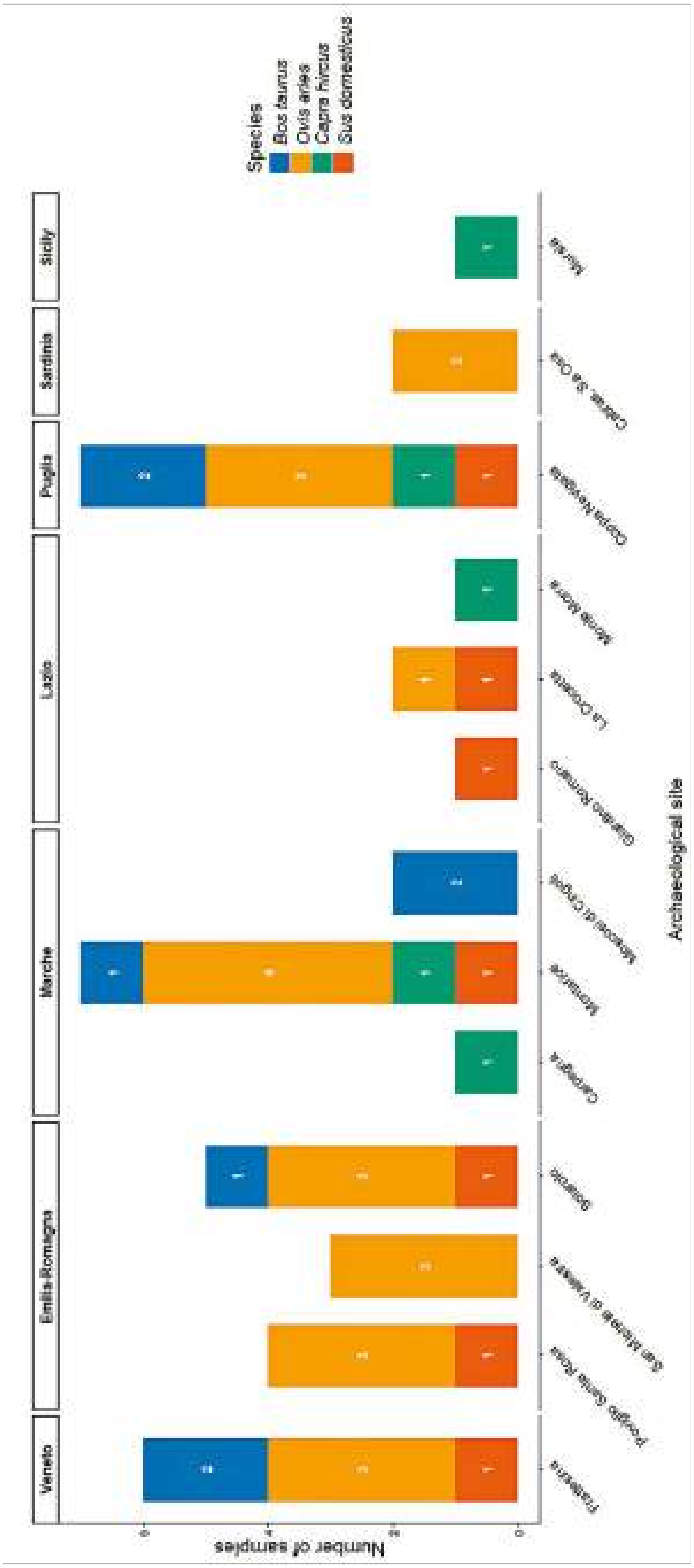


Fig. 2 – Species distribution among archaeological sites.
*Distribuzione delle specie tra i siti archeologici.*

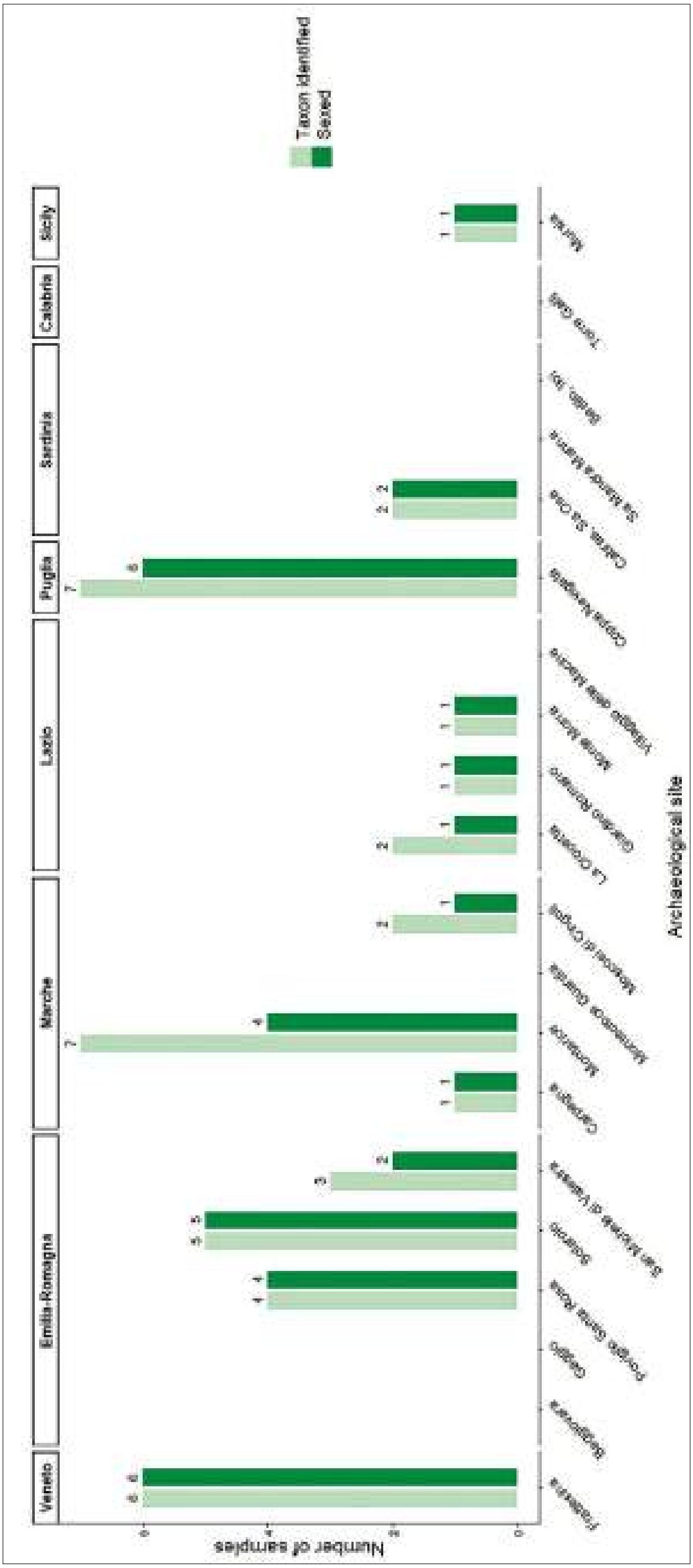


Fig. 3 – Taxon and sex identification distribution across archaeological sites.
*Distribuzione delle identificazioni tassonomiche e del sesso nei siti archeologici.*

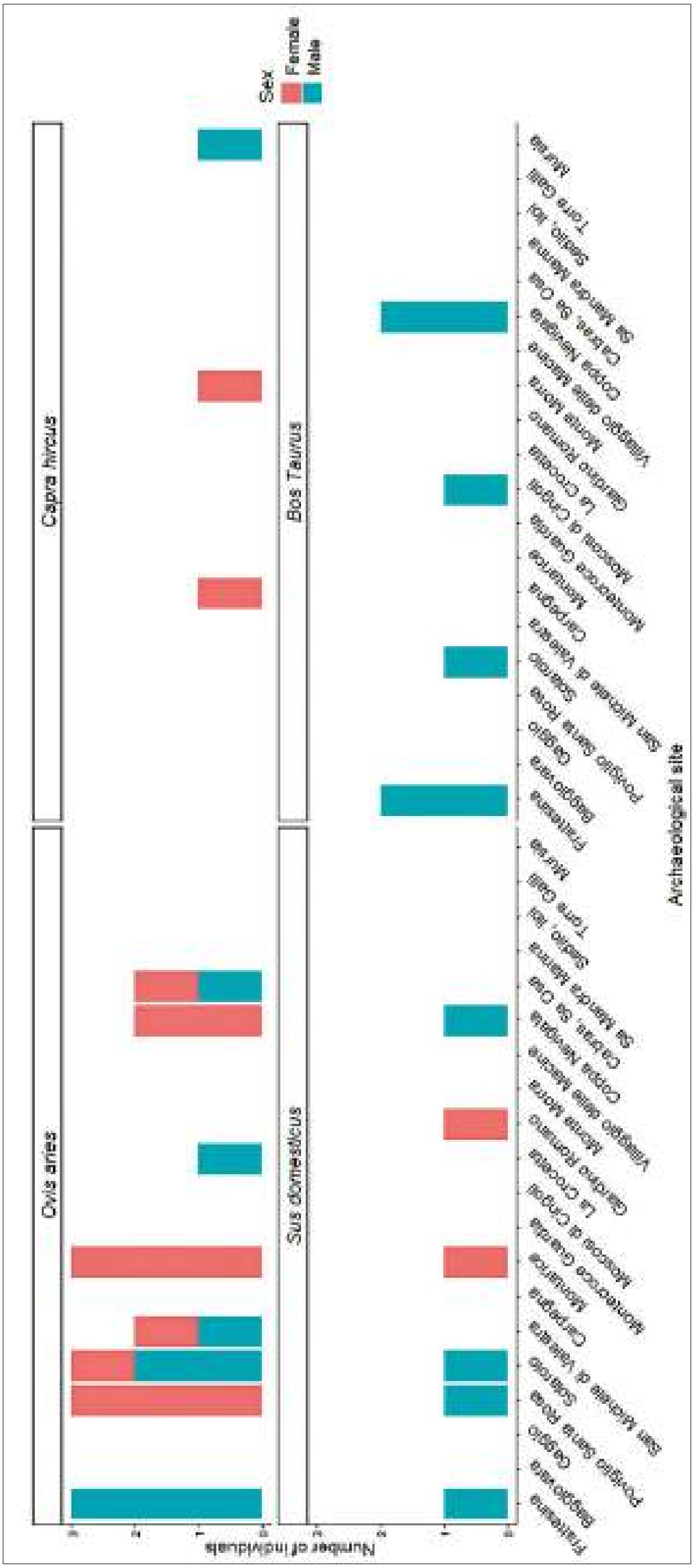


Fig. 4 – Number of individuals identified by sex, distributed across the different archaeological sites.
*Numero di individui identificati per sesso, distribuiti nei diversi siti archeologici.*

### 3.2 Comparison of endogenous DNA content between various archaeological sites, skeletal elements, and chronological periods featured in the HERDS project

EAGER pipeline allowed us to estimate the endogenous mitochondrial and nuclear DNA content per sample. This data was used to create a comparative analysis of sample endogenous DNA content, first grouped by anatomical element (fig. 5).

Mean values of endogenous mitochondrial DNA and nuclear DNA were higher in petrous bone samples. Notably, the difference between sample groups was more pronounced for nuclear than for mitochondrial DNA content. Statistical significance was assessed using the non-parametric Mann-Whitney U test to account for non-normal distributions and the disparity in sample sizes (36 teeth and 6 petrous bones analysed). While endogenous mtDNA yields showed only a non-significant trend toward higher recovery in petrous bones ($p = 0.075$), endogenous nuclear DNA percentages were significantly higher in petrous samples compared to teeth ($p = 0.0012$), with a very large effect size (Cohen's $d = 1.98$).

The next objective of the study was to observe differences in endogenous DNA content between samples dated from various chronological periods (fig. 6).

Within the chronological comparison framework, there were no clear trends or patterns of DNA preservation observed. The mean values for endogenous nuclear and mitochondrial DNA, as well as their ratio, varied between chronological groups but also strongly varied within the groups. Therefore, probably the age of the samples was not the main factor driving the difference in DNA content within the samples recovered.

Finally, we compared the endogenous DNA content in samples from different archaeological sites (fig. 7). Keeping in mind that endogenous mitochondrial and nuclear DNA can be estimated only in samples that were assigned with taxon, which was not achievable for samples from all sites within the study, the final dataset for endogenous DNA content comparison includes 13 sites out of 21.

Frattesina has the highest median value of endogenous mtDNA content compared to other

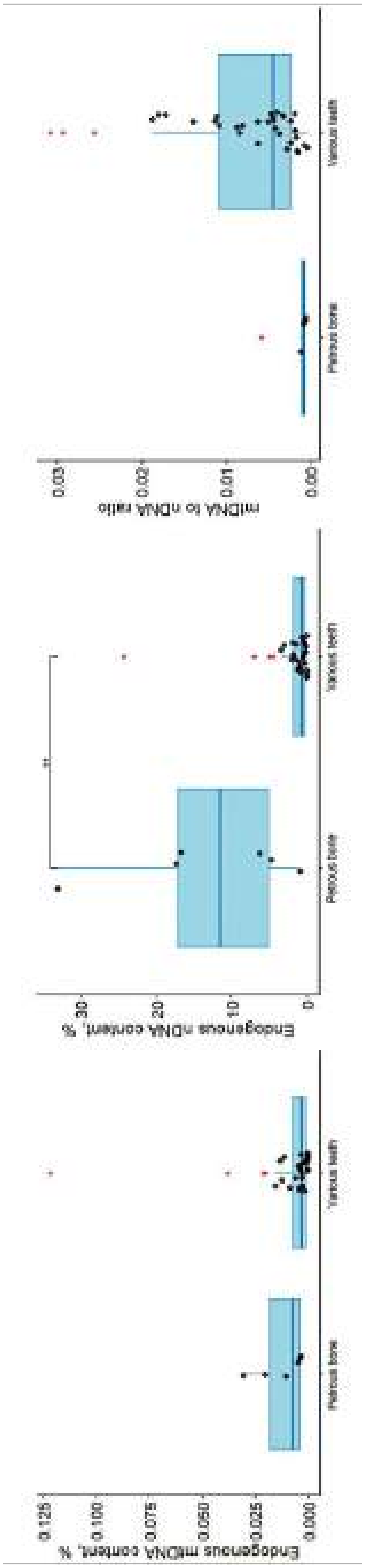


Fig. 5 – Comparison of endogenous DNA content between various anatomical elements. Samples that fall more than 1.5 times the IQR (Interquartile range) from the box plot's upper or lower quartile are coloured in red. Statistical significance is indicated by ** ($p < 0.01$).

*Confronto del contenuto di DNA endogeno tra diversi elementi anatomici. I campioni che si collocano oltre 1,5 volte l'intervallo interquartile (IQR) rispetto al quartile superiore o inferiore del box plot sono evidenziati in rosso. La significatività statistica è indicata con ** ($p < 0{,}01$).*

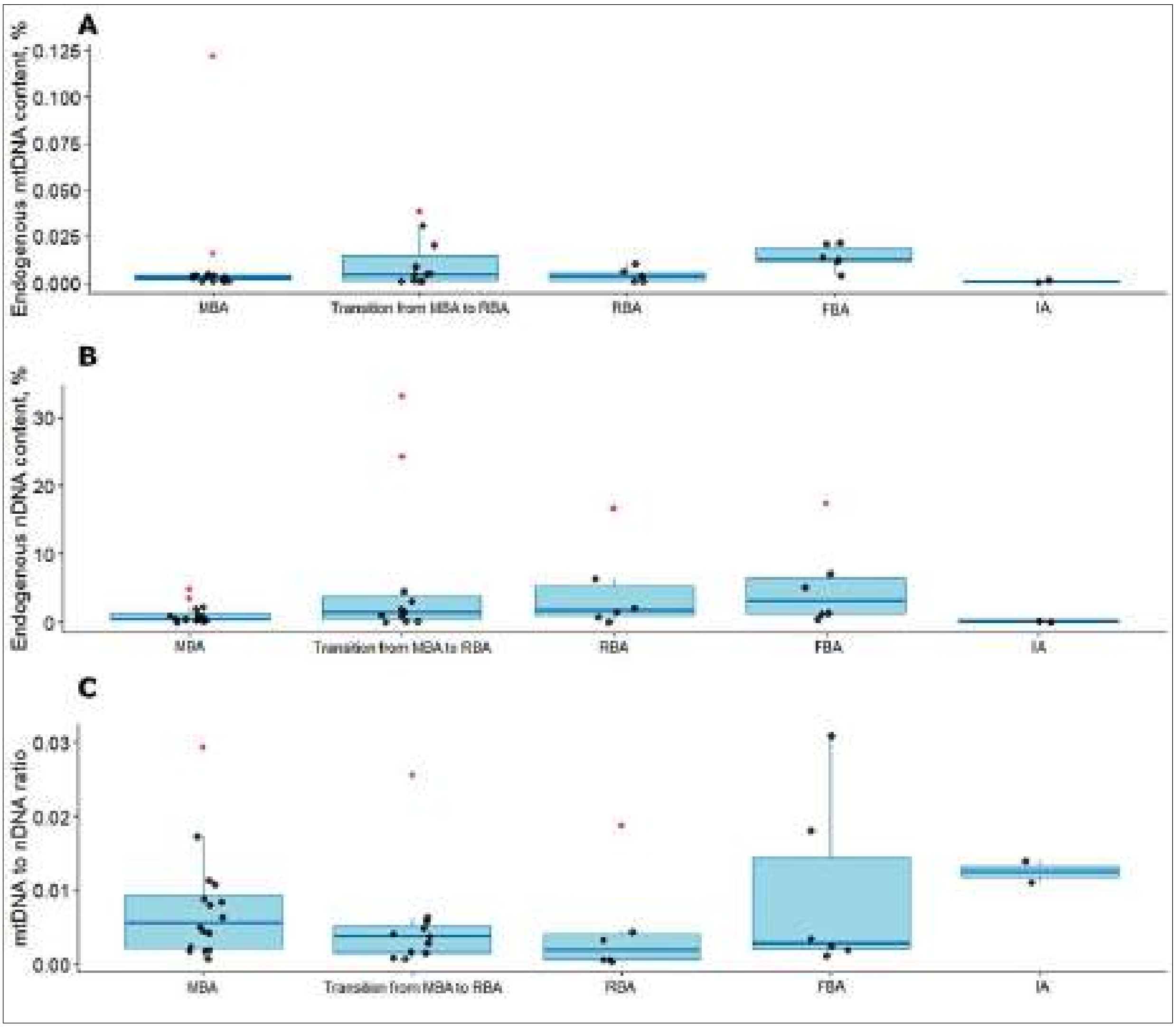


Fig. 6 – Comparison of endogenous DNA content across various chronological periods (MBA = Middle Bronze Age; RBA = Recent Bronze Age; FBA = Final Bronze Age; IA = Iron Age). Samples falling more than 1.5 times the IQR (interquartile range) above the upper quartile or below the lower quartile are highlighted in red.

*Confronto del contenuto di DNA endogeno tra diversi periodi cronologici (MBA = Bronzo Medio; RBA = Bronzo Recente; FBA = Bronzo Finale; IA = Età del Ferro). I campioni con valori superiori a 1,5 volte l'IQR (intervallo interquartile) rispetto al quartile superiore o inferiori rispetto al quartile inferiore del box plot sono evidenziati in rosso.*

samples, whereas Montarice demonstrates the greatest variability, as indicated by the widest interquartile range of the values within the site. In terms of nuclear DNA content, Moscosi di Cingoli demonstrates the highest median value of endogenous nuclear DNA content.

Although needless to mention that the difference in DNA preservation between sites can be attributed not only to different climatic conditions but also to different anatomical elements samples within regions. Figure 8 demonstrates the distribution of anatomical element samples at different archaeological sites.

Guided by this information, we can deduce that high endogenous nuclear DNA content demonstrated by Moscosi di Cingoli is explained by the fact that only the petrous bone was sampled on this site, which is dramatically different from teeth in terms of nuclear DNA content. However, Frattesina and Montarice sites seemingly demonstrated optimal conditions for nuclear DNA preservation, since both sites have a high mean value of endogenous nuclear DNA content but are represented mostly by teeth samples.

ZooMS screening performance across archaeological sites was evaluated, for each site,

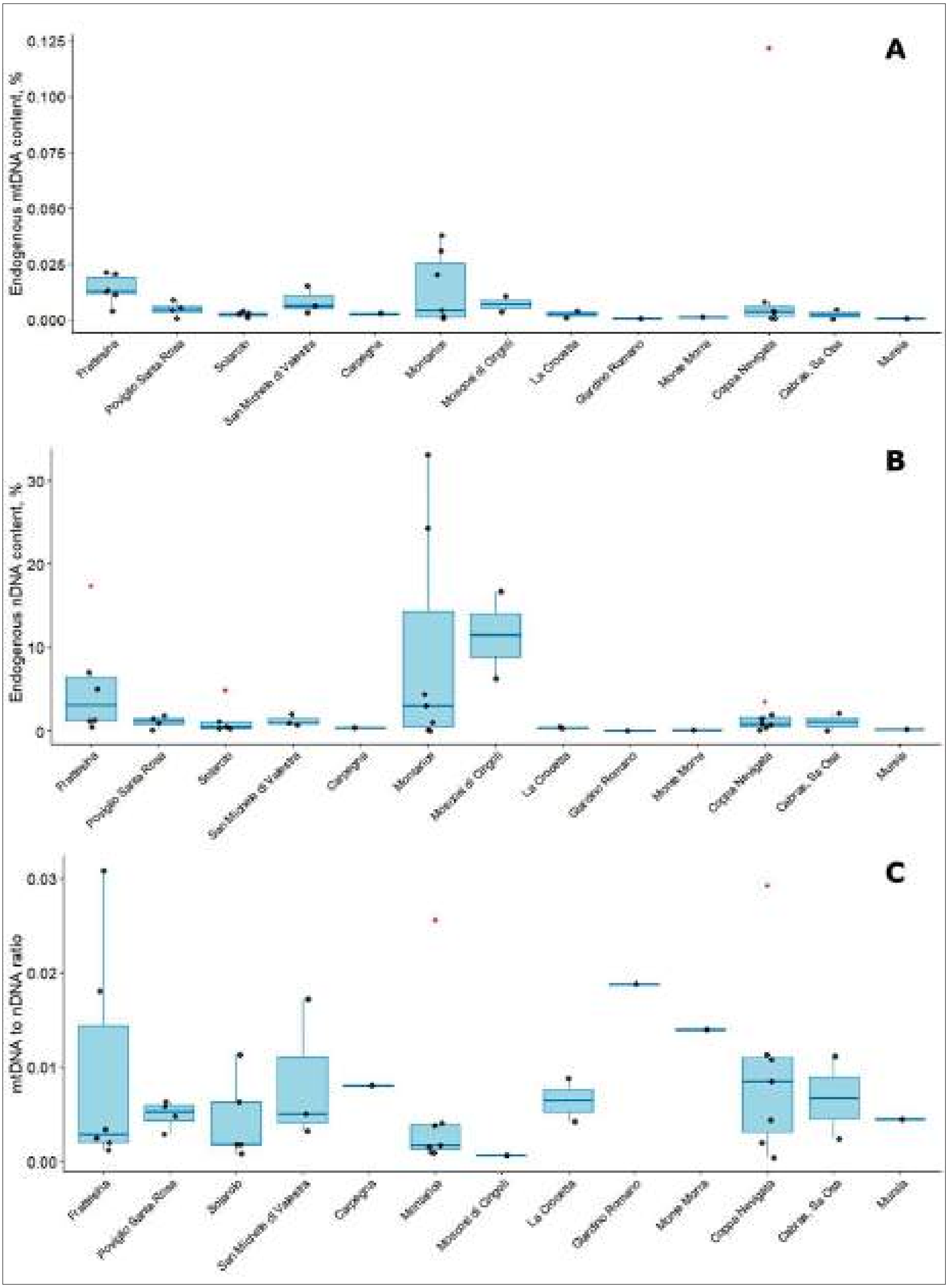


Fig. 7 – Comparison of endogenous DNA content between various archaeological sites. Samples that fall more than 1.5 times the IQR (Interquartile range) from the box plot's upper or lower quartile are coloured in red.

*Confronto del contenuto di DNA endogeno tra i diversi siti archeologici. I campioni con valori superiori a 1,5 volte l'IQR rispetto al quartile superiore o inferiore del box plot sono evidenziati in rosso.*

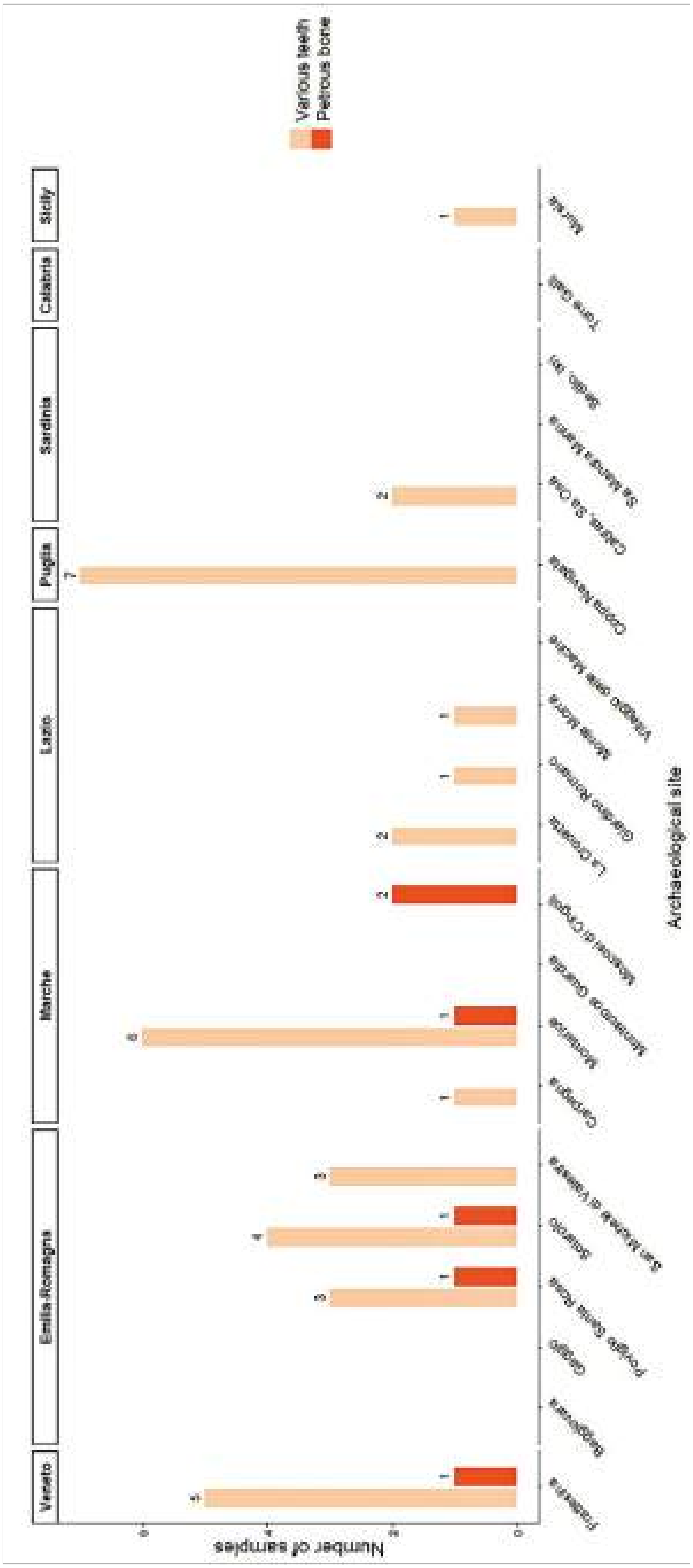


Fig. 8 – Distribution of different anatomical elements sampled among archaeological sites.
*Distribuzione dei diversi elementi anatomici campionati tra i siti archeologici.*

and the distribution of ZooMS marker counts is taken as a simple proxy for collagen preservation (fig. 9). Across sites, ZooMS marker counts are generally high, with most specimens clustering around roughly 6-11 markers, indicating that collagen peptide signals were recovered for the majority of samples. A small number of specimens show very low marker counts, and these are mostly associated with indeterminate assignments and/or "Not improved" outcomes. Overall, collagen recovery was very good across the dataset, with site-to-site differences in both marker-count distributions and the degree to which ZooMS confirmed or altered prior identifications.

## 4. DISCUSSION AND CONCLUSIONS

These preliminary results generated by the HERDS project underscore the complex interplay between environmental factors and the survival of ancient DNA in Mediterranean livestock remains. While the Italian peninsula presents significant taphonomic challenges due to its varied and often warm climate, our analysis reveals that high-quality genomic data can be recovered from Bronze Age contexts by tailoring sampling and laboratory protocols to specific site conditions.

A primary observation of this study is the absence of a predictable latitudinal gradient in DNA preservation. Although Frattesina in northern Italy exhibited the highest overall success rate, this did not translate into a linear degradation pattern as one moves south. Moreover, Frattesina is the only site in northern Italy included in the study, which may introduce bias when compared with the multiple sites located in central and southern regions of Italy. The relatively high success at Coppa Nevigata, a southern site, compared to several central Italian locations, suggests that local micro-environments and immediate burial conditions are far more influential than broad geographic trends and southern Mediterranean sites can be useful for paleogenomic studies. This supports the growing consensus that local depositional environments, characterized by thermal stability, soil pH, and hydrological conditions, are far more influential than absolute latitude or even chronological age (Hofreiter *et al.* 2015; Cilli 2024). ZooMS results are consistent with this interpretation. Across the same north-south transect, ZooMS marker counts are generally moderate to high at most sites, including Coppa Nevigata, with only a small number of low-marker outliers that tend to correspond to indeterminate or "not improved" identifications (fig. 9). Rather than showing a clear latitudinal decline, the ZooMS distributions vary primarily at the site level, reinforcing the view that biomolecular preservation patterns are controlled more by local conditions than by latitude alone.

Regarding skeletal elements, our data reinforces the petrous portion of the temporal bone as the most reliable reservoir for endogenous DNA, particularly nuclear DNA (Pinhasi *et al.* 2015). The statistical disparity in nuclear DNA yield between petrous samples and teeth was statistically significant ($p=0.0012$), showing a substantial effect size. This reflects the unique density of the otic capsule and its minimal in vivo remodeling, which provides a superior physical barrier against environmental degradation and microbial infiltration (Pinhasi *et al.* 2015; Geigl and Grange 2018). However, the performance of teeth in specific contexts is noteworthy; for example, at Frattesina and Montarice, teeth yielded high endogenous content, indicating that dental remains are a highly viable alternative in some environmental conditions. Conversely, the high nuclear DNA mean observed at Moscosi di Cingoli is likely due to the type of samples collected, which were exclusively from petrous bones.

These results also suggest that the chronological age of the specimens was not a decisive factor in molecular degradation. The wide variability in DNA content within specific time periods suggests that the initial post-mortem interval and subsequent taphonomic history of the site likely dictate preservation more than the time elapsed since deposition.

Regarding the effects of DNA preservation on potential population genomic studies of samples from the HERDS project, haplogroup assignment was successful for a small proportion of samples after the shallow sequencing screening. All five *O. aries* samples for which haplogroup assignment was successful were assigned to haplogroup B, which is retrieved in modern and ancient European sheep samples (Sandoval-Castellanos *et al.* 2024). One *C. hircus* sample from

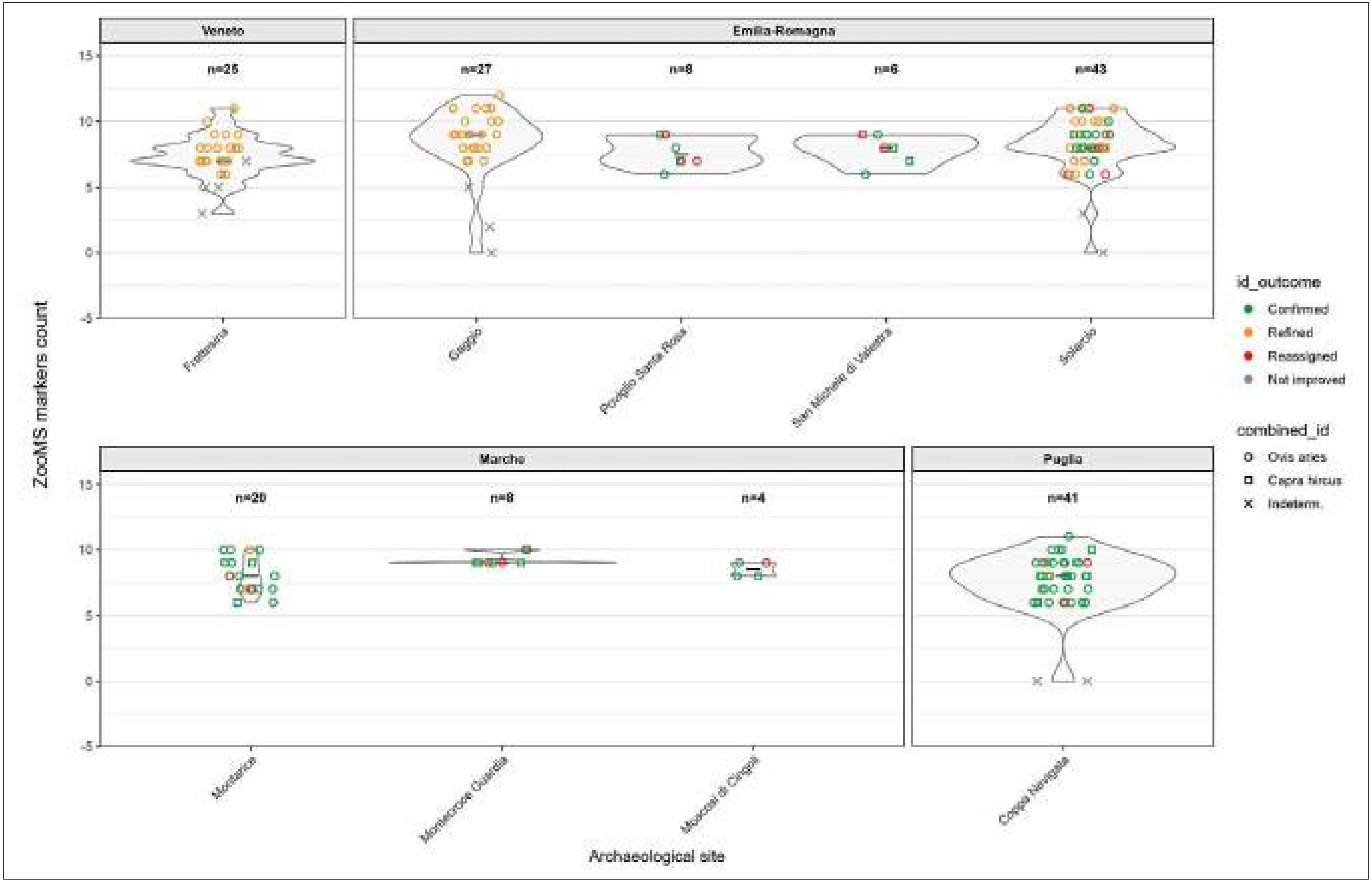


Fig. 9 – summarizes ZooMS screening performance across archaeological sites in four regions (Veneto, Emilia-Romagna, Marche, Puglia).
*La Fig. 9 riassume le performance dello screening ZooMS nei siti archeologici di quattro regioni (Veneto, Emilia-Romagna, Marche, Puglia).*

Coppa Nevigata was assigned to haplogroup A, widespread across modern and ancient European goat populations (Colli *et al.* 2015; Daly *et al.* 2018). The pig sample from Montarice was assigned to haplogroup A, which was present in Europe since prehistory (Lega *et al.* 2017). Among *Bos taurus* samples, all individuals were assigned to mitochondrial haplogroup T, which is dominant in European cattle populations (Achilli *et al.* 2008). A few instances of successful haplogroup determinations reflect limited mitochondrial coverage obtained for the dataset. Future analyses incorporating deep sequencing and targeted mitochondrial genome enrichment would significantly improve haplogroup assignment success and thus aim for more detailed studies of specimens' origin and dispersal (More *et al.* 2025).

This investigation provides a comprehensive methodological baseline for the study of domestic animal genomes in the challenging climatic landscape of the Italian Bronze Age. By evaluating 143 specimens across 21 sites, we have demonstrated that while the petrous bone remains the gold standard for nuclear DNA recovery, teeth can serve as effective proxies in favorable taphonomic contexts.

The findings emphasize that context-specific sampling strategies are essential, highlighting the importance of site-level preservation. In this perspective, the HERDS project delivers both a solid reference dataset and a refined paleogenomic workflow, providing a reliable framework for future studies aimed at reconstructing the complex trajectories of livestock and human-animal interactions across the Mediterranean. The present contribution represents an initial and preparatory step within the broader framework of the HERDS project. The methodological aspects discussed here provide the baseline for subsequent work, which will focus on population genetic analyses to investigate livestock dynamics during the Bronze Age in Italy.

## AUTHOR CONTRIBUTIONS

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Mazzini A.: [Methodology; Investigation]
Prantoni E.: [Methodology; Investigation; Formal analysis; Data curation]
Maini E.: [Resources; Investigation; Data curation]
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Mazzola M.: [Methodology; Investigation; Data curation]
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Luiselli D.: [Conceptualization; Supervision]
Demarchi B.: [Conceptualization; Funding acquisition; Project administration; Project research unit manager; Methodology; Supervision; Writing – review & editing]
Curci A.: [Conceptualization; Funding acquisition; Project administration; Project research unit manager; Supervision; Resources; Investigation]
Cardarelli A.: [Conceptualization; Funding acquisition; Project administration; Project research unit manager; Supervision; Resources]
Cilli E.: [Conceptualization; Supervision; Methodology; Formal analysis; Investigation; Writing – original draft; Writing – review & editing]

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# Milk-boilers of the Italian Bronze Age: from Archaeological Hypotheses to Analytical Evidence

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Abstract – Milk-boilers of the Italian Bronze Age: from archaeological hypotheses to analytical evidence. – This contribution presents new data and observations on protohistoric ceramic vessels characterized by an internal ledge, interpreted as milk-boilers, and on the multi-perforated lids, possibly intended for collecting boiling milk spills. These two ceramic forms are largely attested during the Bronze Age in central and southern Italy, but they also occur, within more limited chronological phases, in northern Italy, Sardinia, Sicily, and Corsica; in addition, a few artefacts can be dated to the Early Iron Age. Despite their long-standing interpretation as milk-processing vessels based on morphology, no direct chemical evidence has so far been available for Italian milk-boilers, and just two lids have previously been subjected to organic residue analysis. A PhD project of the University of Naples Federico II carried out the complete cataloguing and classification of milk-boilers and multi-perforated lids, and collected about forty samples for organic residue analyses. The analyses were funded by the PRIN HERDS project and carried out at the Laboratory of Analytical and Isotopic Mass Spectrometry of the University of Salento. A combined analytical approach based on High Temperature Gas Chromatography-Mass Spectrometry (HTGC-MS) and Gas Chromatography-Combustion-Isotope Ratio Mass Spectrometry (GC-C-IRMS) was adopted to identify lipids absorbed by the ceramic fabric and to investigate artefacts' function. Lipid profiles and compound-specific stable carbon isotope ratios allowed the distinction between ruminant dairy fats, adipose fats, and mixed residues, offering direct insights into the nature of the substances processed or contained in these ceramic artefacts. All analysed samples indicate residues from ruminant fats and none of the samples showed values that indicate the presence of subcutaneous fat from non-ruminants such as pigs. In several cases isotopic signatures consistent with ruminant dairy products were present, confirming that part of this ceramic assemblage was involved in milk and dairy processing. Other samples show evidence of mixed lipid input, suggesting complex processing practices or occasional reuse. Lastly, some samples were restored so contaminations are present. Overall, this study demonstrates how the integration of chemical analyses and ceramic typology can significantly refine our understanding of food processing technologies and dairy exploitation strategies in Bronze Age Italy.

Riassunto – Bollitoi da latte dell'età del Bronzo italiana: dalle ipotesi archeologiche alle evidenze analitiche. – Il presente contributo propone nuovi dati e osservazioni sui contenitori ceramici protostorici caratterizzati da un listello interno, interpretati come bollitoi per il latte, e sui coperchi multiforati, probabilmente destinati a recuperare il latte durante l'ebollizione. Queste due forme ceramiche sono principalmente attestate durante l'età del Bronzo nell'Italia centromeridionale, ma compaiono, in fasi cronologiche più limitate, anche nell'Italia settentrionale, in Sardegna, Sicilia e Corsica; inoltre, alcuni esemplari sono databili alla prima età del Ferro.
Nonostante la loro consolidata interpretazione come contenitori per la lavorazione del latte, basata su caratteristiche morfologiche, finora non erano disponibili evidenze chimiche dirette per i bollitoi italiani, e solo due coperchi erano stati precedentemente sottoposti ad analisi dei residui organici.
Con un progetto di dottorato dell'Università degli Studi di Napoli Federico II sono state svolte la catalogazione e la classificazione completa dei bollitoi e dei coperchi multiforati, e sono stati raccolti circa quaranta campioni per le analisi dei residui organici. Le analisi, finanziate dal progetto PRIN HERDS, sono state eseguite dal Laboratorio di Spettrometria di Massa Analitica e Isotopica dell'Università del Salento. È stato adottato un approccio analitico integrato basato su gascromatografia ad alta temperatura accoppiata a spettrometria di massa (HTGC-MS) e gascromatografia-combustione-spettrometria di massa isotopica (GC-C-IRMS), al fine di identificare i lipidi assorbiti dalla ceramica e indagare la funzione dei manufatti. I profili lipidici e i rapporti isotopici del carbonio specifici dei composti hanno consentito di distinguere tra grassi lattiero-caseari di ruminanti, grassi adiposi, e residui misti, fornendo indicazioni dirette sulla natura delle sostanze lavorate o contenute in questi manufatti ceramici. Tutti i campioni analizzati presentano residui di grassi di ruminanti e nessuno mostra valori compatibili con la presenza di grasso sottocutaneo di animali non ruminanti, come i suini. In diversi casi sono state individuate firme isotopiche compatibili con prodotti lattiero-caseari di ruminanti, confermando per una parte dei contenitori campionati l'impiego nella lavorazione del latte e dei suoi derivati. Altri campioni mostrano evidenze di apporti lipidici misti, testimoniando lavorazioni complesse o riusi occasionali. Infine, alcuni campioni presentano contaminazioni causate dai restauri. Nel complesso, questo studio dimostra come l'integrazione tra analisi chimiche e tipologia ceramica possa notevolmente migliorare la comprensione delle tecnologie per la trasformazione degli alimenti e delle strategie di sfruttamento dei prodotti lattiero-caseari nell'Italia dell'età del Bronzo.



*Parole chiave:* Bollitoi da latte, Residui organici, Gascromatografia, Analisi isotopiche, Età del Bronzo, Ceramica, Mediterraneo Centrale.

*Keywords:* Milk-boilers, Organic residues, Gas Chromatography, Isotopic Analysis, Bronze Age, Pottery, Central Mediterranean.

## 1. INTRODUCTION

This contribution presents new data and observations on protohistoric ceramic vessels characterized by an internal ledge, which have traditionally been interpreted as boilers, and on the multi-perforated lids, supposed to have been used to collect boiling milk spills (Puglisi 1959).

These two ceramic categories are well attested during the Bronze Age in central and southern Italy, but they also occur, with a lower frequency and within more limited chronological span, in northern Italy, Sardinia, Sicily, and Corsica; in addition, a few artefacts can be dated to the Early Iron Age.

R. Avella, through a PhD project of the University of Naples Federico II, carried out the complete cataloguing and classification of published milk-boilers and related lids, together with unpublished artefacts, and selected samples for chemical residue analysis (Avella 2021-2022). About forty samples were collected from four archaeological sites: San Giovenale, Coppa Nevigata, Scoglio del Tonno, Scalo di Furno. Sampling at Coppa Nevigata was conducted in collaboration with G. Recchia, director of the excavation. The analyses were funded by the PRIN *HERDS* project and carried out at the Laboratory of Analytical and Isotopic Mass Spectrometry of the University of Salento, directed by G.E. De Benedetto.

## 2. ARCHAEOLOGICAL RESEARCH HISTORY

### 2.1 The "Secondary Products Revolution" interpretative model

The research is set within the broader context of studies on the spread of milk consumption in prehistoric and protohistoric Europe, which have been largely influenced by the model of the "Secondary Products Revolution" introduced by Andrew Sherratt. According to Sherratt, after a long phase of agricultural development, by the mid-to-late fourth millennium BC in the Near East and in Europe several major technological innovations emerged, namely animal traction, sheep shearing for wool production, and cattle milking for the use and processing of milk (Sherratt 1981, 1983, 1997). These innovations, in Sherratt's view, led to an intensification of both agriculture and animal husbandry, and to an increase in economic and social complexity. Their spread occurred roughly simultaneously across regions, as they represented a variety of adaptive responses to population growth following the advent of agriculture. The consumption of milk and other innovations made it both possible and advantageous to maintain larger herds and flocks, composed not only of animals intended for slaughter but also of those suitable for traction, shearing, or milking. According to this model, the development of pastoralism also enabled the exploitation of areas less suitable for cultivation, ultimately leading to the emergence of nomadism in arid regions and transhumance in mountainous zones. Sherratt defined milking as the *precondition* that made possible the effective development of all the other innovations included in the Secondary Products Revolution package (Sherratt 1981, 1983, 1997).

A different picture emerged however in the last decades. Zooarchaeological evidence and residue analyses show that milk exploitation was already practiced in the Near East and in Europe during the earlier Neolithic period, although the evidence remains uneven (Evershed *et al.* 2022; Roffet-Salque *et al.* 2018; Vigne and Helmer 2007). Helmer and Vigne demonstrated that the exploitation of livestock for milk production took place in the Near East as early as the 9th millennium BC, and they suggested that the use of milk may have been among the motivations that led to the domestication of cattle and caprines in this region (Vigne and Helmer 2007: 33-36). Chemical analyses of vessel residues have shown that milk processing was carried out from the 7th millennium BC in north-western Anatolia (Evershed *et al.* 2008) and from the 6th millennium BC in several European regions including Kuyavia (Poland) (Salque *et al.* 2013), south-central Italy (Salque *et al.* 2012; Debono Spiteri *et al.* 2016), southern France, and the Iberian Peninsula (Debono Spiteri *et al.* 2016). Proteomic analyses of dental calculus have revealed milk and/or dairy products consumption among the populations of the northern Caucasus steppes during the 5th and 4th millennia BC (Scott *et al.* 2022), and in Britain during the 4th millennium BC (Charlton *et al.* 2019). Conversely, genomic studies on ancient DNA and models tracing the spread of the lactase persistence gene indicate that the frequency of this allele increased much later, in the last three millennia (Burger *et al.* 2020).

In summary, the evidence for milk and/or dairy products consumption varies across chronological phases and geographical areas, and a homogeneous picture through time and space is still lacking. Nevertheless, recent studies have made it clear that since the Early Neolithic lactose-intolerant populations were already raising livestock for milk production. From the seventh millennium BC in Anatolia and the sixth millennium BC in Europe, milk was being processed in ceramic containers, probably with the aim of producing low-lactose or lactose-free dairy products.

### 2.2 The emergence of the milk-boiler interpretation

Italian protohistoric studies developed a specific functional interpretation that linked particular ceramic forms to milk processing. As Marco Pacciarelli observed (Pacciarelli 2016: 172-173), in 1948 Giorgio Buchner noticed that two sherds from the Bronze Age site of Vivara in the Gulf of Naples were similar to ceramic forms published by Carucci and Patroni from Grotta Pertosa, and he identified them as lids used for the recovery of boiling milk spills (Buchner and Rittmann 1948: 37-38). However, this important insight resonated within the scholarly community only when it was systematically formulated by Salvatore Maria Puglisi in *La Civiltà Appenninica: origine delle comunità pastorali in Italia* (Puglisi 1959).

As is well known, in this landmark work, Puglisi interpreted the vessels with an internal ledge as milk-boilers, and presented a reconstruction of how these vessels functioned in association with their lids (fig. 1). Puglisi writes: "[…] The concern with obtaining a controlled temperature cannot but be related to the well-known practice of milk processing and the production of dairy products among pastoral communities […].", and he underlines "the need for milk-boilers with recovery devices, which represent a guarantee for the preservation of the precious liquid." (Puglisi 1959: 40-41).

Puglisi argued that the central and southern groups of the Bronze Age Apennine culture of the Italian peninsula were characterized by different forms of milk-boilers. According to his proposal, *a bugia* milk-boiler lids were typical of the southern group; because of their morphology, these lids could have been used also in association with vessels lacking an internal ledge. On the other hand, the multi-perforated, truncated-conical or funnel-shaped lids were typical of the central group and were used together with milk-boilers with an internal ledge.

In 2020, the results of GC-MS and GC-C-IRMS analyses carried out by one of the authors of this paper (GEDB) were published (Pennetta *et al.* 2020). The analyses were conducted on six ceramic fragments recovered during the 2013 excavation at the antecave of the Pertosa-Auletta Caves, in Southern Italy. A milk-boiler lid of the disk-shaped or baking tray-shaped type was analysed in order to verify whether it had been used for milk processing; the analysis confirmed the presence of dairy lipids. The results provided an initial encouraging confirmation of the hypothesis that milk-boiler lids were specialised ceramic forms intended for milk processing.

## 3. CHRONOLOGY AND TYPOLOGY OF MILK-BOILERS AND THEIR LIDS

This section provides a very synthetic overview of the main chronological and typological patterns of milk-boilers (fig. 3) and their lids (fig. 2), based on a broader and more detailed chrono-typological study (Avella 2021-2022) that will be the subject of a separate contribution (Avella *in press*).

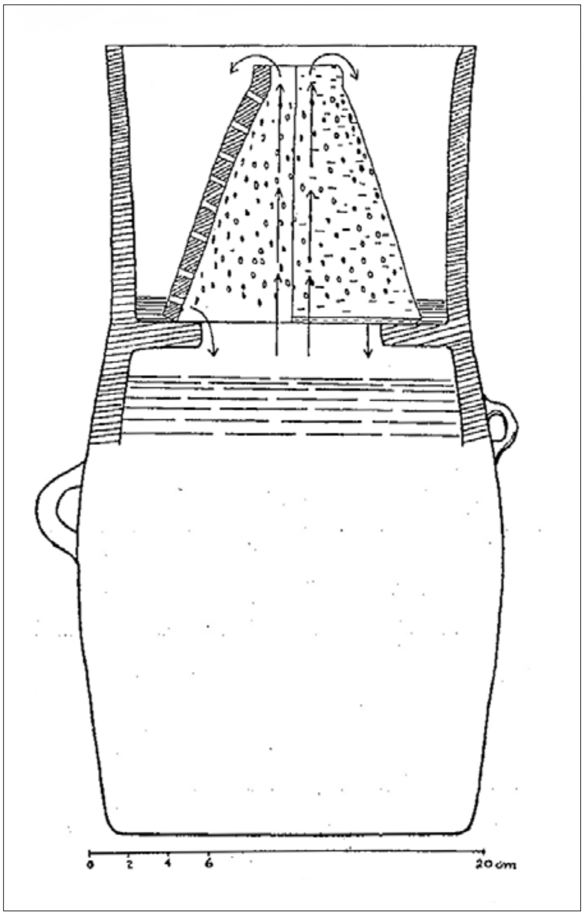


Fig. 1 – Reconstruction of milk-boiler and lid in use during milk processing (after Puglisi 1959: 35, fig. 8).
*Ricostruzione del funzionamento di bollitoio da latte e del coperchio durante la lavorazione del latte (da Puglisi 1959: 35, fig. 8).*

Before addressing Bronze Age milk-boilers and lids, it is important to note that a few rare multi-perforated truncated-conical lids are attested in Italy as early as the Late Neolithic, for example in the Diana *facies* layers of the Cave of San Michele Arcangelo at Saracena (Natali *et al.* 2021, fig. 14.8-9). Multi-perforated truncated-conical lids are known from Spatarella (Martinelli 2001, pl. II.6), an Aeolian site of the early 4$^{th}$ millennium BC, and from Layer III of Grotta Sant'Angelo III (Tinè 1964, fig. 8.17 and p. 35), a Copper Age context of Ionian Calabria. The earliest known milk-boiler with internal ledge comes from the Middle Eneolithic site of Le Cerquete-Fianello at Maccarese (Fiumicino, Rome) (Marconi 2020: 75, fig. 3.5.17.12); this site also yielded a funnel-shaped milk-boiler lid without small holes (Marconi 2020: 75, fig. 3.5.17.7). Nevertheless, the limited number of milk-boilers

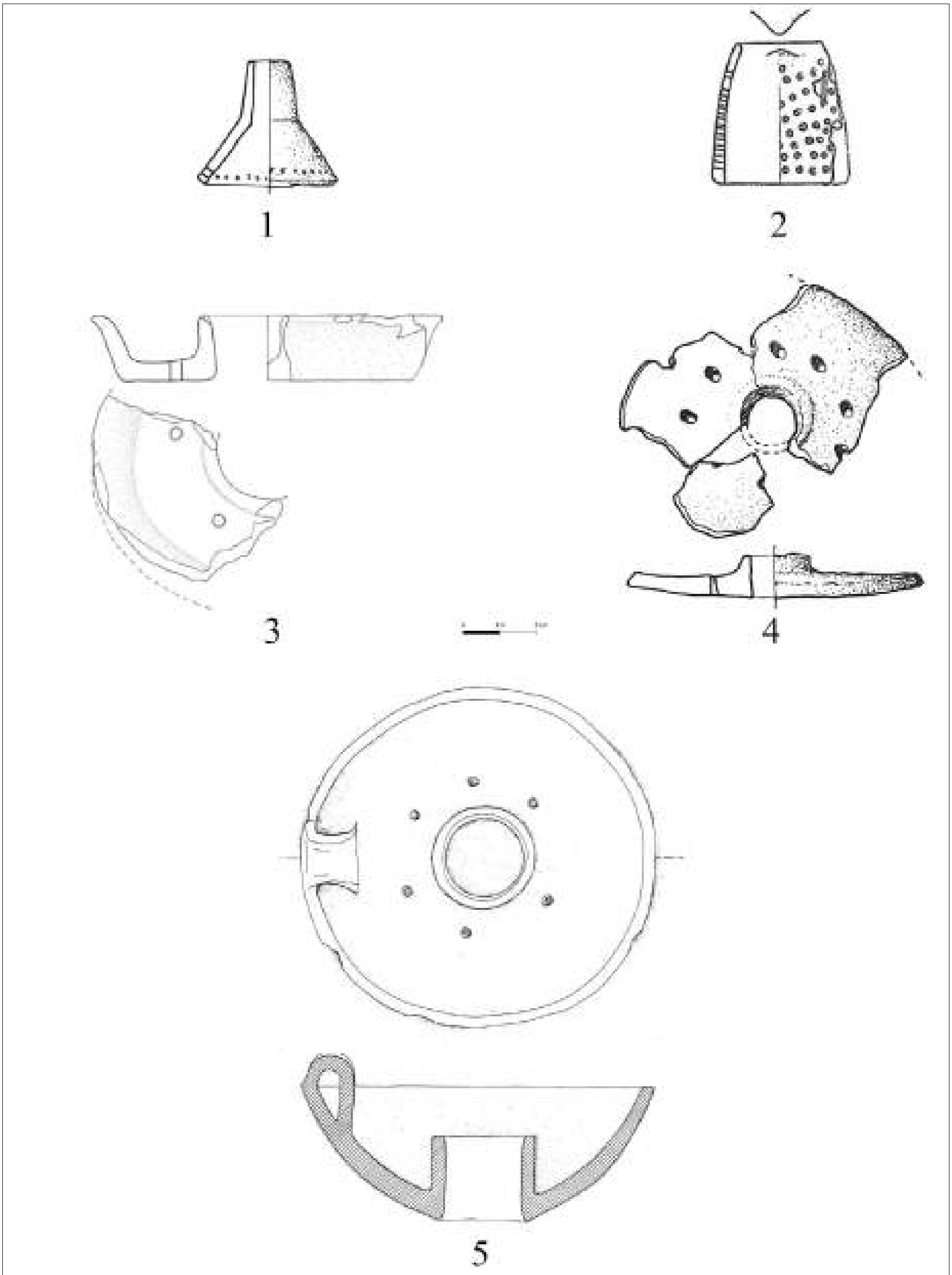


Fig. 2 – Representative drawings of the principal milk-boiler lid types. Scale 1:4. 1: Belverde (Puglisi 1959, fig. 7.1); 2: Lipari Acropolis (Basile 2018, fig. 14.7); 3: La Starza (Di Lorenzo and Talamo 2023, tav. 12.195); 4: Spigolizzi (Ingravallo and Piccinno 1985, tav. 36.6); 5: Grotta della Tartaruga di Lama Giotta (Coppola and Radina 1985, tav. LXXVII).

*Disegni esemplificativi dei principali tipi di coperchi di bollitoio. Scala 1:4. 1: Belverde (Puglisi 1959, fig. 7.1); 2: Acropoli di Lipari (Basile 2018, fig. 14.7); 3: La Starza (Di Lorenzo e Talamo 2023, tav. 12.195); 4: Spigolizzi (Ingravallo e Piccinno 1985, tav. 36.6); 5: Grotta della Tartaruga di Lama Giotta (Coppola e Radina 1985, tav. LXXVII).*

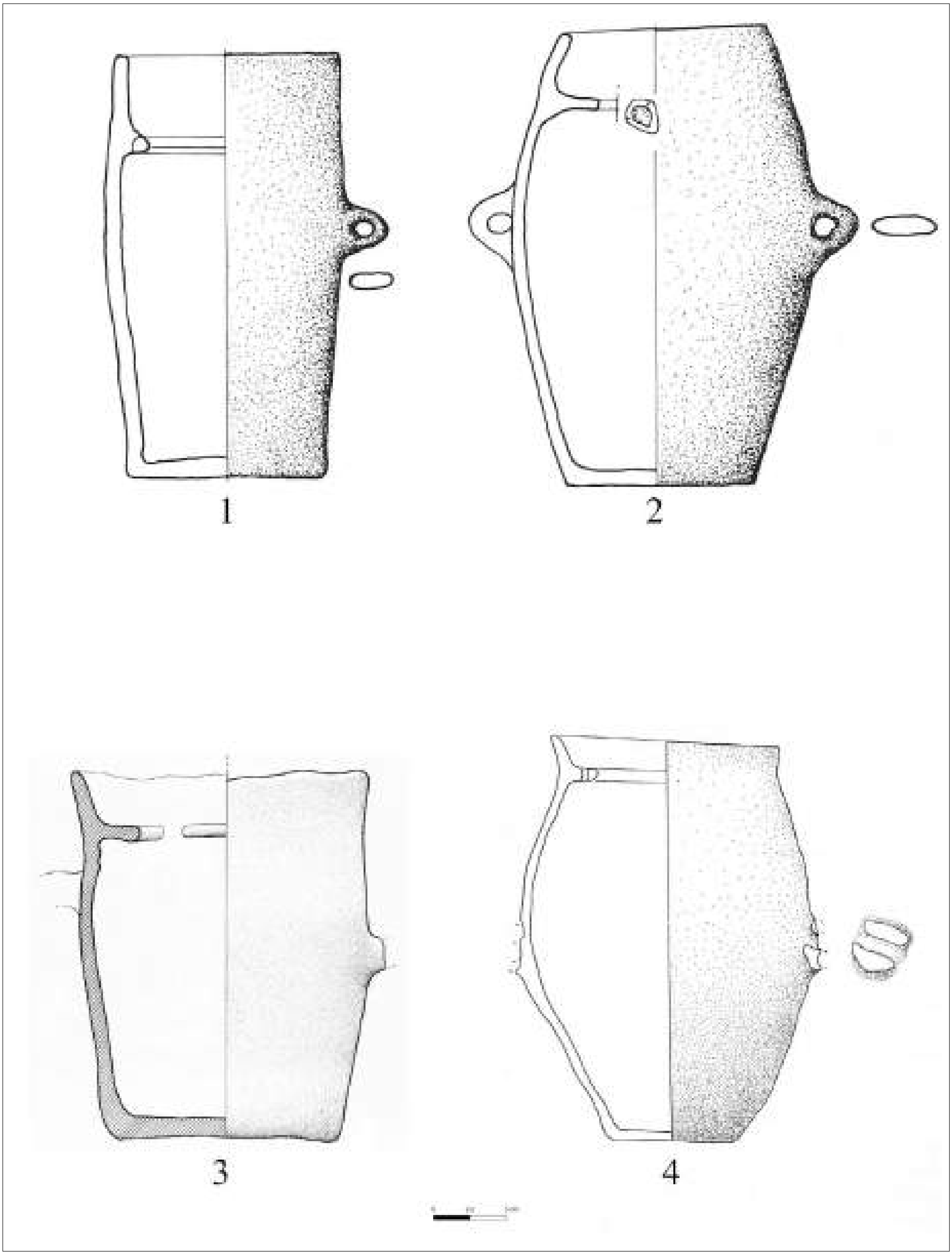


Fig. 3 – Representative drawings of the principal milk-boiler types. Scale 1:4. 1: Mezzano Lake (Franco 1993, tav. 5.15); 2: Mezzano Lake (Petitti and Mitchell 1993, tav. 8.4); 3: Fossa 5 (Andreotti and Ciampoltrini 1997, fig. 86.41); 4: Madonna del Petto (Muntoni 2002, fig. 2).

*Disegni esemplificativi dei principali tipi di bollitoi da latte. Scala 1:4. 1: Lago di Mezzano (Franco 1993, tav. 5.15); 2: Lago di Mezzano (Petitti e Mitchell 1993, tav. 8.4); 3: Fossa 5 (Andreotti e Ciampoltrini 1997, fig. 86.41); 4: Madonna del Petto (Muntoni 2002, fig. 2).*

and lids attested for the prehistoric phases made it impossible to extend the chrono-typological study to Neolithic and Eneolithic specimens.

Funnel-shaped multi-perforated lids (fig. 2.1) are attested in the pile-dwelling settlement of Molina di Ledro in the Trento province (Rageth 1974, figs. 87-88) (EBA-MBA 1-2)[1]; however, vessels with an internal ledge are not known to occur there. No clear milk-boilers nor multi-perforated lids are however known from other pile-dwelling settlements in the Alpine area and in the Terramare culture of Northern Italy.

Funnel-shaped lids with one line of small holes are attested during the late EBA and MBA (likely 1-2) in Etruria, where milk-boilers with internal ledge are also present, mostly of cylindroid shape (fig. 3.1), though ovoid examples are also attested (fig. 3.2).

Disk-shaped (fig. 2.4), baking tray-shaped (fig. 2.3) and *a bugia* (fig. 2.5) milk-boiler lids were widespread during EBA-MBA 1-2 of Campania. These three forms probably were developed within the EBA Palma Campania archaeological *facies*, and continued to be used in central and southern Italy until the end of the MBA. At the same time, during the MBA some multi-perforated funnel-shaped and truncated-conical (fig. 2.2) milk-boiler lids appeared in central-southern Italy. It is important to note that these two morphological categories of lids must have been associated to different milk-boilers, according to their quite different diameter, much larger in the disk-shaped, baking tray-shaped and *a bugia* types. Ovoid vessels with an internal ledge and an everted rim are attested in southern Italy between the EBA and the MBA; they were probably used in association with disk-shaped and baking tray-shaped milk-boiler lids.

During the RBA, vessels with an internal ledge interpreted as milk-boilers spread throughout the area of the Subapennine archaeological *facies* and are therefore attested from Veneto to Lipari (figs. 3.3-4). Milk-boiler lids are quite rare in RBA sites, but one sherd of multi-perforated truncated-conical lid from Oratino in Molise (Copat 2022, fig. 65.5) attests the use of this type, that becomes widespread during the FBA, and possibly persisted until the EIA.

## 4. ZOOARCHEOLOGICAL RESEARCH HISTORY

### 4.1 AGE AT DEATH AND HERD MANAGEMENT GOALS

Before considering the analysis of organic residues, a brief overview of milk production is also appropriate from a zooarchaeological perspective. Identifying the age at death of animals recovered from archaeological contexts is of fundamental importance, as it allows us to reconstruct herd management strategies of ancient communities.

A faunal assemblage dominated by the remains of adult female cattle and caprines, together with those of calves, lambs, and kids slaughtered within six months of age, may indicate an economy oriented toward milk and dairy production. In such systems, young animals were slaughtered early to divert maternal milk for human consumption. Conversely, if livestock were mainly used for ploughing and traction, we would expect a higher frequency of adult or elderly cattle remains, slaughtered only at the end of their working life. An economy focused primarily on meat production would instead yield assemblages composed largely of subadult animals, slaughtered when they had reached maturity and maximum body weight, since maintaining them beyond the age that would not have been economically advantageous. Finally, a system specialized in wool production would have kept rams alive until old age in order to obtain several fleeces before butchery.

The main analytical methods used to estimate age at death are the study of epiphyseal fusion in long bones (Silver 1969; Bullock and Rackham 1982) and the assessment of tooth eruption and wear stages (Payne 1973). Among these, dental analysis provides a more detailed picture, especially regarding mortality in juvenile classes, which represents the main indicator of milk exploitation. Both methods, however, present some limitations, related to the difficulty of distinguishing sex groups on osteological material and, in the case of caprines, of reliably assigning remains to sheep or goat due to the high morphological

[1] EBA: Early Bronze Age (2100-1650 B.C.); MBA: Middle Bronze Age 1-2 (1650-1400 B.C.); MBA 3: Middle Bronze Age 3 (1400-1300 B.C.); RBA: Recent Bronze Age (1300-1160/30 B.C.); FBA: Final Bronze Age (1160/30-950/30 B.C.); EIA: Early Iron Age (950/30-750/30 B.C.).

similarity of their skeletons and the frequent fragmentary state of the archaeological specimens (Cianfoni *et al.* in this volume).

The overall picture of milk exploitation in Italian protohistoric communities therefore remains incomplete – partly because of these intrinsic limits, and partly because such analyses have not always been systematically applied and are often carried out using different quantitative approaches (Number of identified Specimens or Minimum Number of individuals). Moreover, not all chronological phases of the Bronze Age are equally represented in zooarchaeological studies, and the varying size of faunal samples affects the reliability of quantitative evaluations (De Grossi Mazzorin and Guidi 2015; Curci *et al.* 2021).

### 4.2 Zooarchaeological evidence for milk exploitation in Bronze Age Italy

In southern Italy, relevant zooarchaeological studies focus on sites along the Adriatic coast of Apulia. Most have yielded small to medium-sized faunal assemblages, with the exception of the multi-layered site of Coppa Nevigata, which provided an exceptionally rich collection of animal remains (Minniti 2021 with reference therein; Cavazzuti *et al.* in this volume).

The data show that caprines, dominant in all periods, were mainly raised for meat production, as the majority of individuals were slaughtered at a juvenile or subadult stage. No significant chronological variations are observed.

The cattle kill-off pattern indicates a predominant use of these animals as labour-force throughout all phases, although they were kept alive longer during the MBA 3 and RBA 1. The high proportion of calves slaughtered before 12 months of age in the MBA 2B and in some layers of the RBA 1 has been interpreted as evidence of cow's milk consumption (Siracusano 2012).

In Calabria, one of the main settlements on the coastal area of Sibari is Broglio di Trebisacce, which has yielded large faunal assemblages (Minniti 2021 with reference therein).

Sheep and goats, largely dominant over other domestic species, were probably raised for a variety of purposes. However, comparison of slaughter profiles across different periods shows that, starting from the MBA 3, herd management became increasingly specialized in the exploitation of secondary products, such as wool and milk, as suggested by the growing presence of both neonatal and senile individuals.

Cattle, on the other hand, were mostly slaughtered at an adult stage, reflecting their primary use as draught animals and maybe in case of females for milk. During the RBA, their proportion increases compared to earlier phases, indicating a greater economic relevance.

In central Italy, the frequencies of the main domestic species reveal a predominance of cattle during the EBA and MBA 1-2, followed by a rise in caprines from the MBA 3 onwards (Minniti 2012, 2021).

Already in the MBA, cattle appear to have been primarily used as draught and traction animals, and in the case of females, possibly also for milk production, as suggested by slaughtering at adult or senile age. However, their role as a source of meat seems to increase in sites dated to the FBA.

Mortality profiles for caprines suggest that, up to the RBA, herd management was mainly oriented toward meat production, with a secondary role for wool. Milk production appears to gain greater importance only in certain contexts. The presence of some very young caprines have been documented during MBA 1-2 at Le Macine on the shore of the Albano Lake (Cianfoni *et al.* in this volume).

## 5. SITES AND SAMPLES

As mentioned above, approximately forty samples were collected from four archaeological sites located across the central and southern Italian peninsula, from north-west to south-east: San Giovenale, Coppa Nevigata, Scoglio del Tonno, and Scalo di Furno. The following section summarises the excavation history and research context of each site. The complete catalogue of the analysed samples is provided in tab. 1[2].

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[2] Six *a bugia* lids were analysed out of the 22 specimens currently known and securely attributable to this type. Three funnel-shaped lids were analysed; for one of these, two different samples were collected and analysed from different points (ST8 and ST10), resulting in a total of four analysed samples. Twenty specimens of this type are currently known and securely attributable to this type. Six truncated-conical lids were analysed out of the 38 specimens securely attributable to this

The site of San Giovenale (Blera) is a naturally defended settlement of Southern Etruria extending over 3 hectares, which had a remarkable development especially during the RBA and the FBA. The site was accurately investigated by the Swedish Institute at Rome during the 1950s and 1960s. The samples come from two oval huts dating to the FBA in area E (Pohl 1977) and from area B (Olinder and Pohl 1981), particularly from trenches M-N and H (Berggren and Berggren 1981).

The fortified settlement of Coppa Nevigata (Manfredonia), located south of the Gargano Promontory in northern Apulia along the shore of an ancient lagoon, has been the focus of archaeological research for more than a century – from the early 20th century to the present – making it one of the most extensively investigated sites in Italy. A long-lived Bronze Age settlement, actively involved in maritime exchange, developed here from the later stages of the EBA (18th century BC), and remained continuously inhabited until the EIA (8th century BC) (Cazzella-Moscoloni-Recchia 2012: Recchia-Cazzella-Lucci 2025). One of the defining features of the settlement is its complex system of artificial defensive lines protecting its landward side (Cazzella and Recchia 2013).

In addition to substantial stretches of the fortification wall, excavations have brought to light significant portions of the settlement belonging to the Early, Middle and Recent Bronze Age phases. Activity areas – typically characterised by concentrations of multiple firing structures – have been identified both within the settlement and immediately outside the perimeter of the defensive wall (Cazzella and Recchia 2014).

A considerable number of ceramic elements potentially associated with the processing of milk and dairy products have been found (approximately 80 examples from the 1970-2016 excavations). These items frequently occur within the activity areas.

For the present project, fifteen such items were sampled, of which thirteen (reported in tab. 1) yielded reliable results. The samples were selected to represent the three different typologies of possible milk-processing equipment and their relative frequency by period (fig. 4): boiler lids (8; fig. 5.1) and vessels with an internal ledge (2; fig. 5.3). In addition to them, strainer vessels (5; fig. 5.2), were also sampled, in order to test whether these could have been related to milk processing as well. Vessels with an internal ledge appear to come into use at the site during a very late stage of the MBA and increase in frequency during the RBA, coinciding with a decline in the use of boiler lids, which in turn are now generally lacking the small holes around the central one. Strainer vessels, by contrast, are ubiquitous throughout the sequence. A boiler lid featuring a large central perforation, but lacking the smaller surrounding holes, was previously analysed by means of GC-MS (Evans and Recchia 2001-2003)[3].

The settlement of Scoglio del Tonno (Taranto) stood on a promontory that marked the western edge of the coastal lagoon of the Mar Piccolo at Taranto. Between 1899 and 1900, Quintino Quagliati excavated the site within a few months, shortly before the promontory was destroyed (Quagliati 1900). The stratigraphic provenance of the samples is unknown, therefore their dating can be broadly placed between the MBA and the EIA (Matricardi 2021-2022).

Scalo di Furno (Porto Cesareo) is a coastal site of Ionian Apulia excavated by Felice Gino Lo Porto between 1968 and 1977 (Lo Porto 1990). The artefacts, studied by Elena Matricardi as part of her master's thesis at the University of Naples Federico II, span a chronological range from the MBA to the EIA (Matricardi 2017-2018). The samples come from a group of significant finds probably selected by Lo Porto himself; unfortunately, data on their original context has been lost, and therefore it is not possible to date them precisely.

type among those currently known. Thirteen vessels with an internal ledge were analysed, yielding a total of 14 samples (samples ST3 and ST9 were taken from different points of the same specimen), out of 94 known specimens securely attributable to a specific type. In vessels used for cooking, lipids tend to impregnate mainly the areas closest to the rim of the vessel (Evershed 2008). For this reason, samples from vessels with an internal ledge were collected immediately below the ledge. Milk-boiler lids and strainers samples were collected from the area closest to the recovery holes, on the assumption that this was the area most likely to become impregnated with lipids. In the case of funnel-shaped lids without holes, samples were collected near the base and/or the rim.

[3] The results revealed traces consistent with the fermentation of cereals, possibly associated with beer production. This evidence may suggest that this ceramic category was also employed in the preparation of fermented beverages, at least during the Late Bronze Age.

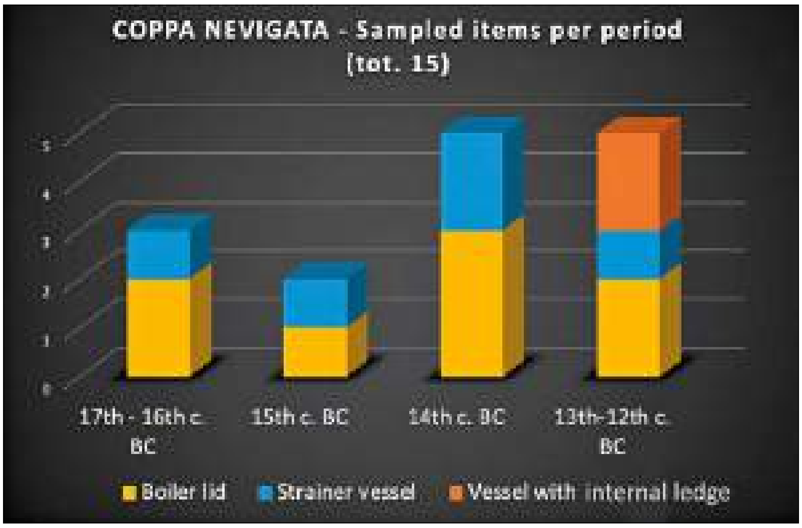


Fig. 4 – Distribution of the analysed ceramic artifacts from Coppa Nevigata by chronological phase.

*Distribuzione per fase cronologica dei manufatti ceramici analizzati da Coppa Nevigata.*

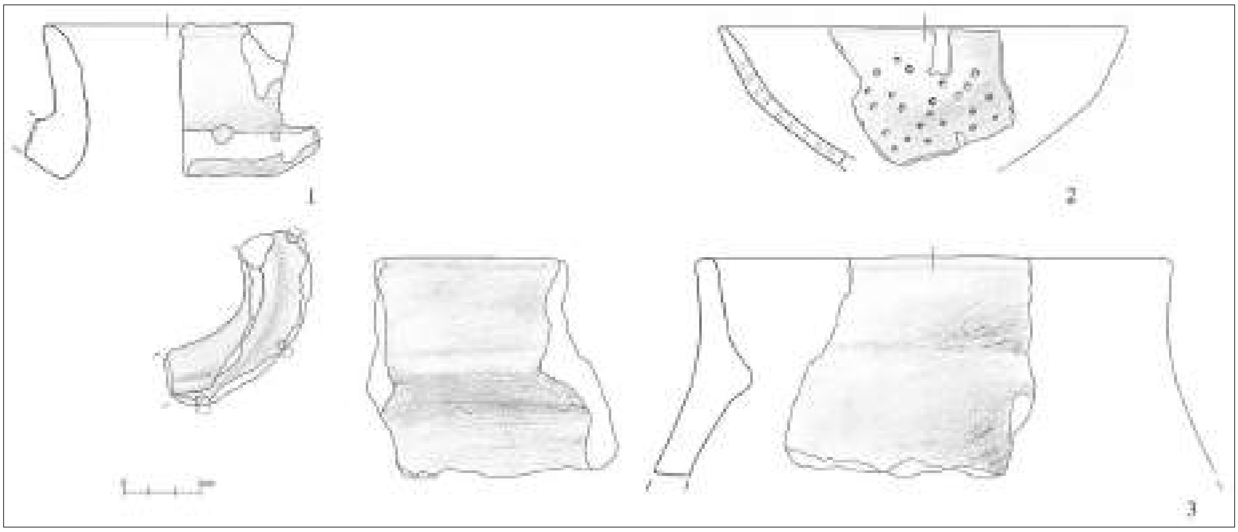


Fig. 5 – Coppa Nevigata sampled milk-related pottery shapes. 1: boiler lid from the 14th c. BC layers (sample CN3); 2: strainer vessel from the 14th c. BC layers (sample CN6); 3: vessel with internal ledge from the 13th-12th c. BC layers (sample CN12); 1-2 drawings M. Forcina; 3 drawing V. Grisci; archive of the Coppa Nevigata research.

*Forme ceramiche connesse alla lavorazione del latte campionate a Coppa Nevigata. 1: coperchio di bollitoio dagli strati del XIV sec. a.C. (campione CN3); 2: colatoio dagli strati del XIV sec. a.C. (campione CN6); 3: vaso a listello interno dagli strati del XIII–XII sec. a.C. (campione CN12); disegni 1-2 di M. Forcina; disegno 3 di V. Grisci; archivio della ricerca di Coppa Nevigata.*

## 6. CHEMICAL ANALYSES

### 6.1 Analytical methods

The samples of Bronze Age milk-boilers and their lids were analysed at the Laboratory of Analytical and Isotopic Mass Spectrometry of the University of Salento using the common methods of organic residue analysis. High Temperature Gas Chromatography-Mass Spectrometry (HTGC-MS) and Gas Chromatography-Combustion-Isotope Ratio Mass Spectrometry (GC-C-IRMS) were employed to identify lipids absorbed by the ceramic matrix and to infer the use and function of the artefacts. For HTGC-MS analyses, lipids were solvent extracted from the ceramic matrix after the addition of 10 μL of internal standard (1000 mg/L n-tetratriacontane in isooctane, IS) with DCM:MeOH (2:1 v/v, 3×3 mL) alternating ultrasonic bath and vortex agitation for 25 minutes. The extracts were separated by centrifugation (4000 rpm, 15 minutes), collected and dried in a centrifugal evaporator at room temperature. The residue was reconstituted in 1 mL DCM:MeOH; 2:1 before analyses. An aliquot was added of 10 μL of a 0.1 mg/mL norleucine solution as derivatization internal standard, dried, and then derivatized with N, O-bis(trimethylsilyl)-trifluoroacetamide (BSTFA) at 70°C for 1 h. 1 μL was injected in splitless mode for HTGC-MS analysis.

Palmitic and stearic acids were methylated for GC-C-IRMS analyses using methanol acidified with sulfuric acid (Correa-Ascentio and Evershed 2014). In brief, the TLE residue was dried and, after addition of 1 mL of methanol, the samples were sonicated for 10 min. Subsequently, 100 μL of $H_2SO_4$ was added and the samples were heated at 70°C for at least 2 h. The samples were then centrifuged for 5 min. The supernatant was extracted with hexane (3×2 mL) and the extracts were collected and dried under a gentle stream of nitrogen, then re-dissolved in 70 μL of hexane and analysed for the determination of $\delta^{13}C$ isotopic ratio of methyl-stearate and methyl stearate by GC-C-IRMS. The $\delta^{13}C$ values were calculated relative to Vienna Peedee Belemnite (V-PDB) and were corrected for methylation by comparing them with the known isotope values of standard $C_{16:0}$ and $C_{18:0}$ fatty acids treated with the same method.

### 6.2 Results and interpretation

Pottery samples yielded different abundances of lipid from 5 μg/g to over 1600 μg/g and all the TLE are above the contamination limit.

A chromatogram of the total lipid extract from potsherd CN1 is shown in fig. 6a, illustrating the main compounds detected in the sample. As can be seen, the lipid profile is dominated by the C16:0 and C18:0 fatty acids. The C18:1 fatty acid is a minor component of the lipid profile, which is consistent with the tendency for fatty acids containing double bonds to degrade during burial/vessel use. A greater quantity of trans C18:1 compared to the cis C18:1 is found as often in the residues of ruminant fats. Other fatty acids detected in almost all the samples are C8:0 to C14:0 and most importantly branched C15:0 and C17:0: the latter are typical biomarkers of bacterial population from the rumen and characteristic of animal fats thus confirming the ruminant origin of the lipid extracted from the vessel.

The presence of short chain fatty acids suggests dairy products were actually processed/contained in the vessel but due to their compositional alteration during burial to a distribution more resembling adipose fats, cannot be used as single diagnostic criteria for milk or milk processing. The presence of cholesterol and derivatives confirmed the animal origin of the total lipid extract.

There are also small amounts of monoacylglycerols (MAG) both sn-2 and sn-1,3 but no diacylglycerols (DAGs) and triacylglycerols (TAGs) were detected in any sample, typical of very degraded fats. Typical biomarkers of marine fish/resources, such as 3,7,11,15-tetramethylhexacosanoic acid (phytanic acid) and 4,8,12- trimethyltridecanoic acid (4,8,12-TMDT), were absent.

*Pinaceae* resin as well as pitch biomarkers were identified in many of the TLEs (as in CN8, fig. 6b), often detected in archaeological Bronze Age pottery and widely used in the past for a variety of purposes, e.g. as adhesives, for waterproofing, for lighting, and for the preparation of unguents and perfumes. On considering the vessel typology waterproofing is mostly plausible.

These vessels were not used for the processing of plant products during their life-use, as only CN14 (fig. 6c) preserves traces of sitosterol and stigmastanol, sterols of vegetable origin, that along with the presence of azelaic and suberic acids, suggest vegetable oils were also contained/processed. Interestingly, this sample also contains bile acids such as lithocholic, deoxycholics: so, the question of a possible rennet use for milk processing, respect to a faecal contamination, cannot be ruled out.

The GC-C-IRMS is a technique developed at the end of the 1970s and applied since the 1990s in the field of archaeology, to determine $\Delta^{13}C$ values of individual components of lipid extracts from potsherds. This method offers considerable opportunities to extract and identify representative isotopic ratios that are unequivocally linked to their animal source, for example making it possible to distinguish adipose from dairy lipids and to assess the specific origin of certain fats.

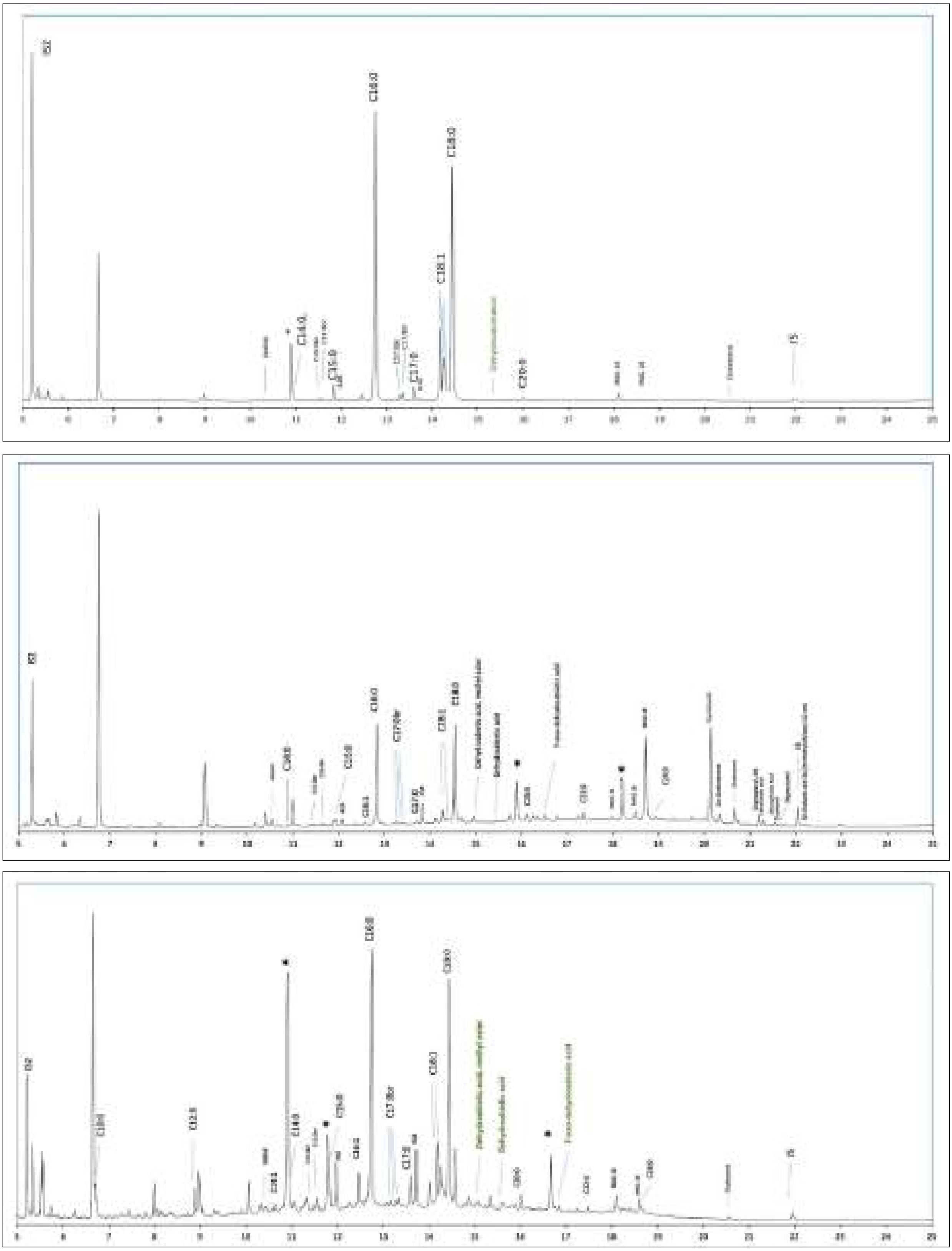

Fig. 6 – Partial gas chromatograms of total lipid extracts from selected pottery samples from Coppa Nevigata: a) CN1; b) CN8; c) CN14. Abbreviations: N:x, fatty acids with N carbon atoms and x double bonds; br, branched; MAG, monoacylglycerols; Ax, fatty alcohols with x carbon atoms; *, contaminations; IS, tetratriacontane; and IS2, norleucine (internal standards).

*Gascromatogrammi parziali degli estratti lipidici totali di campioni ceramici selezionati da Coppa Nevigata: a) CN1; b) CN8; c) CN14. Abbreviazioni: N:x, acidi grassi con N atomi di carbonio e x doppi legami; br, ramificato; MAG, monoacilglicerolI; Ax, alcoli grassi con x atomi di carbonio; *, contaminazioni; IS, tetratriacontano; IS2, norleucina (standard interni).*

Fig. 7 shows the compound specific isotope results, in particular the $\Delta^{13}C$ values of palmitic acid C16:0 ranging from – 30.4‰ to – 24.3‰ *versus* $\Delta^{13}C$ values (corresponding to $\delta^{13}C18{:}0$-$\delta^{13}C16{:}0$). This graph is quite useful in the differentiation of animal fats, since $\Delta^{13}C$ values of the C18:0 fatty acid in milk are always depleted compared to the C18:0 fatty acid in ruminant adipose fats by on average 2.3‰ (Evershed *et al.*, 2022). About half of the extracts overlaps to ruminant dairy fats, confirming the archaeological hypothesis linked to the functional typology, i.e. the presence of milk/dairy residues.

On considering that some authors (Spangenberg-Jacomet-Schibler 2006) reported $\Delta^{13}C$ values for sheep cheese and goat milk and cheese in the window from -2.5 to -3.3, also the samples next to the -3.3 separation line, for instance SF6, SG4 and SG11, could have been used to store/process ovicaprid dairy products (fig. 7). In this respect, archeozoological evidences confirm this possibility. All the other samples have isotopic patterns suggesting ruminant adipose fats or, more likely, mixtures of dairy and non-ruminant or vegetable fats, occurred either synchronously or during use/re-use. It is important to observe that none of the vessels was used to process exclusively non ruminant or vegetable products.

Different samples among those showing higher $\Delta^{13}C$ values have lower lipid amounts. This evidence could be explained with a less frequent use and/or an extensive washing/treatment of the samples: the latter hypothesis is suggested by the presence of contaminants such as phthalates, whose peaks in some samples are as intense as those belonging to C16:0 and C18:0 fatty acids

A word on Scoglio del Tonno samples: all have chemical biomarkers compatible with the dairy processing but none of them has $\Delta^{13}C$ below the -3.3‰ line. The possible explanation is that during the restoration alkidic resins have been used along with acrylic ones thus confounding the isotopic signal of the archaeological record.

## 7. CONCLUSIONS

In conclusion, the research presented here has provided a new and more complete archaeological framework for the distribution and articulation of the ceramic forms interpreted as milk-boilers and their lids, integrating it into the existing zooarchaeological data and obtaining analytical data concerning their actual use. In particular, a set of concluding observations can be drawn from the relevant results of the isotopic analyses (fig. 7; tab. 1).

Thirteen samples have a $\Delta^{13}C$ value lower than -3.3‰, meaning that they contain residues that can be directly linked to milk processing. These are samples CN1, CN3, CN6, CN8, CN10 and CN13 from Coppa Nevigata; SF2 and SF5 from Scalo di Furno; and SG5, SG6, SG8, SG9 and SG10 from San Giovenale. These samples were taken from three *a bugia* milk-boiler lids and three strainers from Coppa Nevigata, from four truncated-conical multi-perforated lids from San Giovenale, and from three vessels with internal ledge, one from San Giovenale and two from Scalo di Furno. As a result, main ceramic classes included in the sampling produced at least three results clearly associated with milk processing. This confirms both the functional association hypothesized by Puglisi between the vessels with internal ledge and the related lids, and that the particular characteristics of these shapes were really linked to milk processing. The data from the three strainers from Coppa Nevigata are new and noteworthy, given that this vessel type is often interpreted as being related to milk processing, but until now there was a lack of data on its actual use.

Twenty-four samples fall between -3.3‰ and 0‰. Within these 24 samples five have $\Delta^{13}C$ values very close to -3.3‰ (ST3, ST8, SF6, SG4 and SG11) and considering literature data (Spangenberg-Jacomet-Schibler 2006) and zooarchaeological evidences, it is plausible that these too contained ovicaprid – but not cow – dairy residues.

The remaining nineteen samples, clearly positioned between -3.3‰ and 0‰, may reflect the presence of adipose fats from ruminants, or a mixture of milk residues together with other lipids. As previously noted, none of the samples showed values above 0‰ – which would indicate subcutaneous fat from non-ruminants such as pigs – so all analysed samples indicate residues from ruminant fats. Two interpretations are possible for these nineteen samples: as already mentioned, the vessels may have been used either for forms of milk processing that involved the presence of additional fats (either from non-ruminant animals or from plants), or for preparing other foods as well.

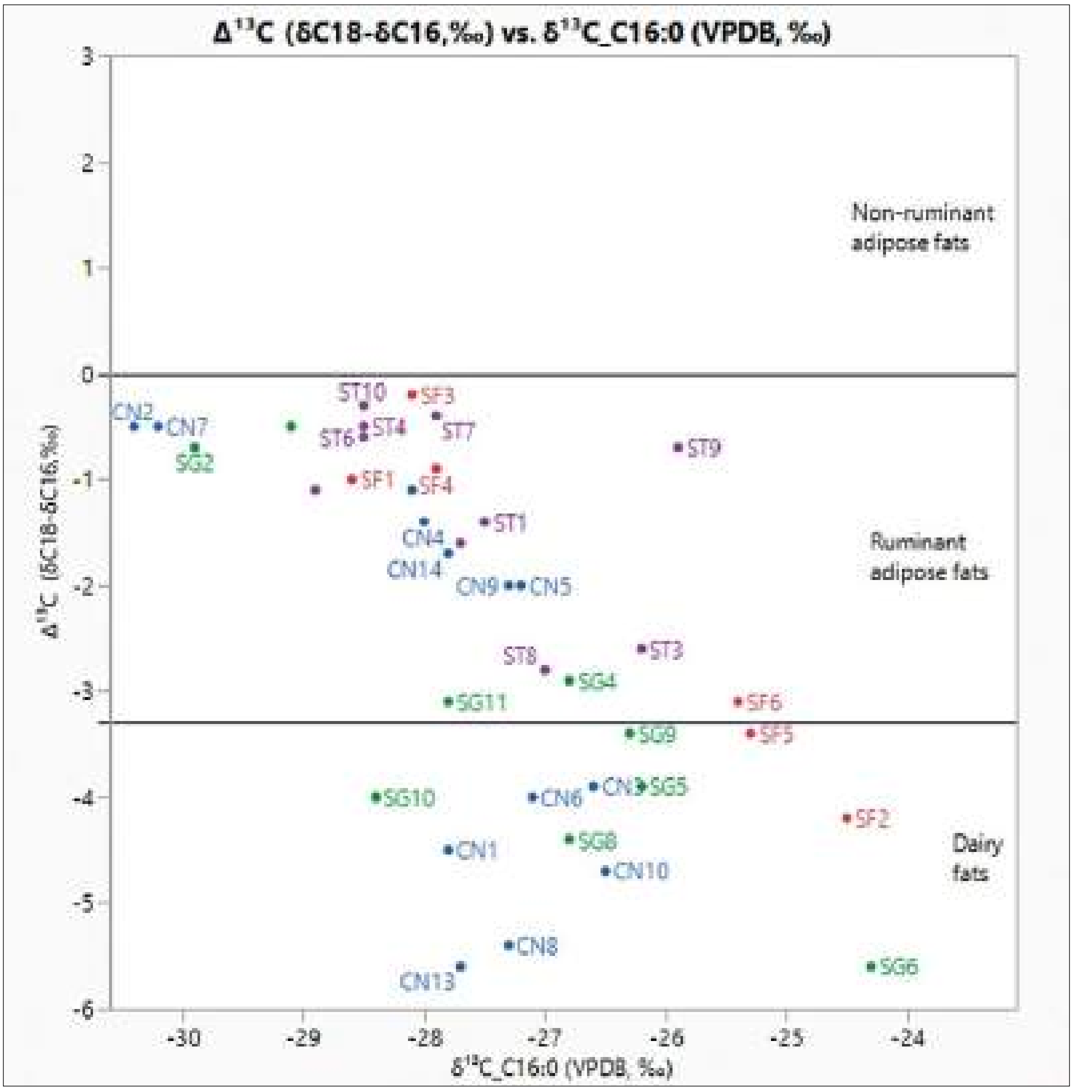


Fig. 7 – Plots of the $\delta^{13}C$ values for archaeological organic residues in all the analysed pottery samples. Pottery was from Coppa Nevigata, CNx; Scoglio del Tonno, STx; San Giovenale, SGx; and Scalo di Furno, SFx. The $\delta^{13}C$ values (i.e., $\delta^{13}C_{18:0}$- $\delta^{13}C_{16:0}$) for the ruminant dairy fats are more depleted than the ruminant adipose fats. All $\delta^{13}C$ values are relative to Vienna Peedee Belemnite (VPDB) international standard.

*Grafici dei valori di $\delta^{13}C$ dei residui organici archeologici in tutti i campioni ceramici analizzati. Le ceramiche provengono da Coppa Nevigata, CNx; Scoglio del Tonno, STx; San Giovenale, SGx; e Scalo di Furno, SFx. I valori di $\delta^{13}C$ (ossia $\delta^{13}C_{18:0}$- $\delta^{13}C_{16:0}$) dei grassi lattiero-caseari dei ruminanti risultano più impoveriti rispetto ai grassi adiposi dei ruminanti. Tutti i valori di $\delta^{13}C$ sono riferiti allo standard internazionale Vienna Peedee Belemnite (VPDB).*

The production of specialised containers of course does not exclude occasional alternative uses. These milk-boilers may have been used for different purposes during periods of the year when milk processing did not take place, or they may have been occasionally used for other kinds of preparation.

None of the samples from Scoglio del Tonno have $\Delta^{13}C$ values below -3.3‰. As mentioned earlier, however, it is likely that alkyd resins, in addition to acrylic ones, were used during restoration, affecting the isotopic signal. This could also explain the results from the funnel-shaped lids and the vessels with an inward-thickened rim, since most of the former and all of the latter come from Scoglio del Tonno. Therefore, it is not possible to exclude that also the vessels with an inward-thickened rim were used as milk-boilers.

Increasing the number of analysed specimens will certainly help clarify which primary processing activity these specialised forms were intended for, and which uses were occasional or dictated

| Sample | Site | Vessel class | Type | References |
|---|---|---|---|---|
| CN1 | Coppa Nevigata [D4L/1] | multi-perforated lid | A bugia | Unpublished |
| CN2 | Coppa Nevigata [F2G/2Izeta] | multi-perforated lid | A bugia | Unpublished |
| CN3 | Coppa Nevigata [F2A/2Ia] | multi-perforated lid | A bugia | Fig. 4.1 |
| CN4 | Coppa Nevigata [G3H/4If] | possible multi-perforated lid | Not included in the typology | Unpublished |
| CN5 | Coppa Nevigata [E2Q/3IIIgamma] | Strainer | | Unpublished |
| CN6 | Coppa Nevigata [F2B/7I] | Strainer | | Fig. 4.2 |
| CN7 | Coppa Nevigata [G1OY/6Ib] | multi-perforated lid | A bugia | Unpublished |
| CN8 | Coppa Nevigata [D4G/1IIIA] | Strainer | | Unpublished |
| CN9 | Coppa Nevigata [E3F/6Igamma] | possible multi-perforated lid | A bugia | Unpublished |
| CN10 | Coppa Nevigata [G3D/20] | multi-perforated lid | A bugia | Unpublished |
| CN12 | Coppa Nevigata [H3F/5II] | vessel with an internal ledge | | Fig. 4.3 |
| CN13 | Coppa Nevigata [D4C/2Id] | Possible strainer | | Unpublished |
| CN14 | Coppa Nevigata [G3D/6] | vessel with an internal ledge | | Unpublished |
| SG1 | San Giovenale [saggio H] | vessel with an internal ledge | | Berggren and Berggren 1981, pl. 12.11 |
| SG2 | San Giovenale [saggio M/N, strato 3] | vessel with an internal ledge | | Berggren and Berggren 1981, pl. 23.21 |
| SG4 | San Giovenale [Area B] | multi-perforated lid | truncated-conical | Olinder and Pohl 1981, pl. 9.229 |
| SG5 | San Giovenale [saggio M/N, strato 2] | multi-perforated lid | truncated-conical | Berggren and Berggren 1981, pl. 27.84 |
| SG6 | San Giovenale [saggio M/N, strato 1] | multi-perforated lid | truncated-conical | Berggren and Berggren 1981, pl. 29.114 |
| SG8 | San Giovenale [AOHI / strato IV ] | vessel with an internal ledge | | Pohl 1977, pl.19.210 |
| SG9 | San Giovenale [AOHI / strato IV] | multi-perforated lid | truncated-conical | Pohl 1977, pl.19.207 |
| SG10 | San Giovenale [AOHII / strato II] | multi-perforated lid | truncated-conical | Pohl 1977, pl.19.56 |
| SG11 | San Giovenale [OHI / strato IV e IV B] | multi-perforated lid | truncated-conical | Unpublished |
| SF1 | Scalo di Furno | vessel with an internal ledge | | Matricardi 2017-2018 |
| SF2 | Scalo di Furno | vessel with an internal ledge | | Matricardi 2017-2018 |
| SF3 | Scalo di Furno | vessel with an internal ledge | | Matricardi 2017-2018 |
| SF4 | Scalo di Furno | multi-perforated lid | Funnel-shaped | Matricardi 2017-2018 |
| SF5 | Scalo di Furno | vessel with an internal ledge | | Matricardi 2017-2018 |
| SF6 | Scalo di Furno | vessel with an internal ledge | | Matricardi 2017-2018 |
| ST1 | Scoglio del Tonno | vessel with an internal ledge | | Matricardi 2021-2022 |
| ST2 | Scoglio del Tonno | vessel with an inward-thickened rim | | Matricardi 2021-2022 |
| ST3 | Scoglio del Tonno | vessel with an internal ledge | | Matricardi 2021-2022 |
| ST4 | Scoglio del Tonno | vessel with an internal ledge | | Matricardi 2021-2022 |
| ST5 | Scoglio del Tonno | vessel with an inward-thickened rim | | Matricardi 2021-2022 |
| ST6 | Scoglio del Tonno | vessel with an internal ledge | | Matricardi 2021-2022 |
| ST7 | Scoglio del Tonno | vessel with an internal ledge | Funnel-shaped | Matricardi 2021-2022 |
| ST8 | Scoglio del Tonno | multi-perforated lid | Funnel-shaped | Matricardi 2021-2022 |
| ST9 | Scoglio del Tonno | vessel with an internal ledge | | Matricardi 2021-2022 |
| ST10 | Scoglio del Tonno | multi-perforated lid | Funnel-shaped | Matricardi 2021-2022 |

Tab. 1 – List of samples collected for organic residue analysis.
*Elenco dei campioni raccolti per le analisi dei residui organici.*

by everyday needs. At this point, the importance of sampling vessels that have certainly not undergone restoration is clear, given the results from the Scoglio del Tonno samples.

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## Author Contributions

A. Cardarelli and M. Pacciarelli co-authored the Introduction.
R. Avella wrote the sections on archaeological research history and on the chronology and typology of milk-boilers and their lids.
C. Minniti wrote the section on zooarchaeological research history.
R. Avella and G. Recchia co-authored the section on sites and samples.
G.E. De Benedetto wrote the section on chemical analyses.
All authors contributed to the Conclusions.

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# Human Occupation of Apennine Grazing Landscapes: Archaeological and Environmental Indicators, and the Excavation at Monte Morra (Latium)

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Abstract – Human occupation of Apennine grazing landscapes: archaeological and environmental indicators, and the excavation at Monte Morra (Latium). – A key aspect of protohistoric strategies concerning the management of cattle and sheep/goat flocks relates to mobility practices connected to the exploitation of vast yet seasonally available grazing resources. Among the principal resources of this type are mountain pastures suitable for summer use. The first part of this paper briefly summarizes the main theories and available evidence for the Apennine region, drawing on palynological data (Di Lorenzo, Russo Ermolli), faunal analyses (Minniti, Cianfoni) and evidence from Bronze Age and Early Iron Age settlements (Cardarelli, Filippi, Pacciarelli). The second part presents the main results of the archaeological excavation carried out in 2023 as part of the PRIN *HERDS* project, which investigated the Final Bronze Age and Early Iron Age settlement located on the summit of Monte Morra (1,036 m a.s.l.) (Fiorillo, Miranda). Monte Morra, a relief in the Lucretili Mountains (Latium), occupies a strategically significant position for territorial control, particularly over the nearby mountain pastures, including the *Pratone di Monte Gennaro*.

Riassunto – L'occupazione umana nei paesaggi montani appenninici vocati al pascolo: indicatori da carotaggi pollinici e resti faunistici, e lo scavo archeologico di Monte Morra (Lazio). – Un aspetto rilevante delle strategie protostoriche legate alla gestione delle mandrie bovine e delle greggi ovicaprine è rappresentato dalle pratiche di mobilità connesse allo sfruttamento di pascoli ampi ma disponibili solo stagionalmente, tra cui i pascoli montani idonei all'utilizzo

*Parole chiave:* Monti Lucretili, età del bronzo, prima età del ferro, insediamenti di sommità, pascoli montani, analisi archeozoologiche, indicatori pollinici di pascolo.

*Keywords:* Lucretili Mountains, Bronze Age, Early Iron Age, Hilltop Settlements, Mountain Pastures, Zooarchaeological Analysis, Pastoral Pollen Indicators

estivo. La prima parte di questo contributo offrirà una breve sintesi delle principali teorie e dei dati disponibili su questo tema per l'area appenninica, sulla base delle analisi palinologiche (Di Lorenzo, Russo Ermolli), dei reperti faunistici (Minniti, Cianfoni) nonché delle testimonianze insediative dell'età del Bronzo e della prima età del Ferro (Cardarelli, Filippi, Pacciarelli). La seconda parte presenterà i principali risultati dello scavo archeologico condotto nell'ambito del progetto PRIN *HERDS* nel 2023, che ha consentito di indagare l'insediamento del Bronzo finale e della prima età del Ferro situato sulla sommità di Monte Morra, a 1,036 m s.l.m. (Fiorillo, Miranda), un rilievo dei Monti Lucretili (Lazio) di grande rilevanza per il controllo del territorio e, in particolare, dei vicini pascoli montani, tra cui il Pratone di Monte Gennaro.



## 1. EVIDENCE AND HYPOTHESES CONCERNING USE OF MOUNTAIN PASTURES AND PROTOHISTORIC SETTLEMENTS IN THE APENNINE AREA

A highly significant aspect of livestock management strategies in protohistoric and ancient times concerns patterns of mobility aimed at exploiting seasonally available grazing resources. Among the principal resources of this kind were the vast mountain pastures of the Apennines, suited to late spring and summer use and exploited from very early periods through practices of both short- and long-distance mobility.

The central importance of long-distance transhumance for the Bronze Age of peninsular Italy was theorized in the 1959 work by Salvatore Maria Puglisi, *La civiltà appenninica. Origine delle comunità pastorali in Italia* (Puglisi 1959).

According to the Puglisi's theory, Bronze Age societies in peninsular Italy – particularly those of the so-called Apennine Culture – were highly specialized in pastoralism, to the extent that they organized themselves into mobile groups that moved in late spring and summer from low-altitude residential areas on the Adriatic and Tyrrhenian sides towards the mountain pastures of the Apennines. In Puglisi's view, the encounter of these groups during the warm months along the Apennine chain facilitated the development of shared cultural traits. These traits are recognizable, for example, in certain decorative features of pottery and in the use of specific ceramic forms functionally related to milk processing.

Puglisi, however, believed that a progressive integration of pastoral and agricultural economies occurred through intermingling with communities of the Po Valley Terramare area, where an agricultural economy was already widely established. This economic "hybridization" led to the development of the Sub-Apennine *facies* (which, in Puglisi's interpretation, has cultural significance and does not correspond to a distinct chronological period). According to Östenberg, however, an agricultural component had already been present in the Apennine culture since its origins (Östenberg 1967).

Seasonal livestock mobility undoubtedly represents an efficient mode of exploiting the mountain ecosystems of peninsular Italy. Long-distance transhumance was widespread at least from the Roman period onward, and also earlier (Gabba 1990), and it continued to be practiced on a large scale until recent times. However, the hypothesis that this practice dates back to the Bronze Age has not yet been conclusively demonstrated. In the case of the Early and Recent Bronze Age settlement of Punta di Zambrone (Calabria), isotopic analyses of animal bones allowed to reconstruct a pattern of short-range "vertical" livestock mobility. Some of the animals slaughtered at the settlement, located on the coast, were shown to have originated from the overlying Poro plateau, situated at approximately 600 m a.s.l. and reachable via movements of only a few kms (Pike *et al.* 2021). Important new data on livestock mobility have also been obtained within the framework of the *HERDS* project (Cavazzuti *et al.* in this volume).

Human presence dating to the protohistoric period in Apennine mountainous areas compatible with summer occupation is, however, well established, as demonstrated by collections of

Bronze Age pottery from high altitudes sites. Among the finds recovered at the greatest elevations are Middle Bronze Age 3 ceramics from the site of Rocca Calascio in Abruzzo, located at approximately 1,400 m a.s.l. (Mattiocco 1986).

During the second half of the twentieth century, protohistoric human presence in the Apennines was also associated with more structured hilltop settlements, usually characterised by one or more ramparts around a summit, with a defensive and/or terracing function. These summit sites, quite common in mountain areas, are frequently dated to the Final Bronze Age and sometimes to the Early Iron Age, though some of them may also date back to Middle Bronze Age 3.

One of the most significant cases is that of Monte Ingino near Gubbio (nearly 900 m a.s.l.), which has been the subject of archaeological excavations by the University of Cambridge. These investigations brought to light evidence of intensive occupation of the summit between Middle Bronze Age 3 and the Final Bronze Age. The study of the abundant faunal remains revealed the early slaughter of pigs and caprines, leading to the hypothesis that the site may have functioned as a seasonal meeting point for transhumant pastoral groups, with convivial and probably ceremonial roles (Malone and Stoddart 1994: 126; Bruni 2014). Together with nearby Monte Ansciano, Monte Ingino certainly had an actual function as a cult place in the Final Bronze Age, as demonstrated by the exceptional quantity of bronzes discovered, particularly pins.

The interpretation of mountain summit sites as ceremonial centres has been reaffirmed in other significant cases, notably Monte Cavo (ancient *Mons Albanus*) in *Latium Vetus* (Pacciarelli 2009), for wich a substantial body of mytho-historical traditions exists, and Monte Cimino in southern Etruria (Barbaro *et al.* 2011; Cardarelli and Trucco 2014; Cardarelli 2018). At the latter site, which reaches an elevation of 1,053 m a.s.l., excavations conducted by Sapienza University and directed by one of the present authors (AC) brought to light a large fortified Bronze Age hilltop settlement with a small acropolis delimited by a massive stone enclosure. Within this space, traces of periodic ritual practices dating to Final Bronze Age 3 (late eleventh and early tenth centuries BCE) were identified, including large fires and the deposition of combustion residues together with selected ceramics. The proposed interpretation is that of a sacred place of federal significance, where populations gathered to celebrate ceremonies intended to affirm a shared political identity (Cardarelli 2018).

For this category of protohistoric hilltop settlements, probably often occupied year-round, one may envisage complex functions encompassing ceremonial, political-territorial and also residential roles. In some instances, residential functions may have been performed by settlements located at a lower elevation, as in the cases of Gubbio in relation to Monte Ingino-Monte Ansciano (Bettelli *et al. in press*), and of San Marino-Poggio Castellano in relation to Monte Titano-Seconda Torre (Bottazzi and Bigi 2008).

This type of settlement is undoubtedly widespread and deserving of in-depth investigation. A recent study based on the systematic examination of LiDAR mapping has demonstrated that summit settlements equipped with ramparts are fairly common in the Umbro-Marchigian Apennines, although the chronology of the numerous sites identified remains largely un-defined (Conte *in press*).

A relationship between certain mountain summit sites and the economic exploitation of upland areas was hypothesized in 1982 for a group of protohistoric settlements in the Lucretili Mountains (Latium) (Angle *et al.* 1982). Some of the settlements considered at that time, however, appear to have been typical defensively positioned hilltop centres not clearly specialised in the exploitation of mountain pastures, because of their relatively modest elevation and their limited proximity to the true mountain environment (see Filippi and Pacciarelli 1991 for Monte Calvo and Monte San Martino). A more meaningful integration within the mountain ecosystem seemed instead plausible for the settlement of Monte Morra, which was selected within the framework of the *HERDS* project for archaeological excavation – as discussed later in this contribution (see Section 4) – specifically aimed at clarifying its nature and collecting cultural and faunal remains (Section 5) useful for defining the activities carried out there.

Monte Morra is a peak in the Lucretili Mountains (Latium), whose summit reaches 1,036 m a.s.l. and was the site of a Final Bronze Age and

Early Iron Age settlement. The site lies within a mountain landscape characterized by woodlands and also extensive clearings, including areas not excessively steep and particularly well suited to grazing, such as the terrace to the southwest and Prato Favale on its northern slopes (both mostly situated between 800 and 850 m a.s.l.), and above all, approximately 2.5 km to the north, the Pratone and the nearby Campitello, which together extend over an almost flat surface of roughly one hundred ha at an altitude slightly above 1,000 m a.s.l.

The potential significance of the Monte Morra site is multifaceted. On the one hand, as noted, it lies in proximity to an extensive mountain habitat also suitable for grazing. On the other, the site possesses considerable strategic value. From the summit, it is possible to command a wide view over a substantial sector of northern *Latium Vetus* and lower Sabina, extending as far as the Tiber, Rome, and the sea. At the same time, the mountain is clearly visible from this entire area. The strategic role of the site also derives from its location along a critical boundary between the lowlands that hosted the proto-Latin territorial system and the Apennine chain.

## 2. GRAZING ACTIVITIES DETECTED IN POLLEN RECORDS

Since the Neolithic, grazing has constituted one of the principal anthropogenic activities influencing natural vegetation. Its impact can be detected in fossil pollen records, although grazing-induced changes are often subtle and difficult to distinguish from other forms of land use. Consequently, the reconstruction of past grazing practices requires a multidisciplinary approach, combining pollen analysis with archaeological evidence.

Building on the work of Mazier and colleagues in the Pyrenean Mountains (Mazier *et al.* 2006, 2009), a group of herbaceous taxa termed Local Pastoral Pollen Indicators (LPPI) was identified. The simultaneous occurrence of these taxa in pollen assemblages has been demonstrated to provide reliable evidence for the local presence of pasturelands. In particular, pollen of Asteroideae, Cichorieae (*sensu* Florenzano *et al.* 2015), *Cirsium*-type, *Galium*-type, Ranunculaceae, *Stellaria*-type and *Potentilla*-type has been shown to strongly correlate with grazing activity at a local scale.

In addition to LPPI, the co-occurrence of coprophilous fungal spores (CFS) in pollen slides has been established as a robust indicator of pastoral activity, given that these spores are uniquely adapted to herbivore dung (Bell 2005; LópezSáez and López-Merino 2007; Florenzano 2019). Numerous studies on CFS concur that the most reliable indicators of grazing pressure are *Sporormiella* and *Sordaria* types, followed by Sordariaceous ascospores and other spores such as *Podospora*, *Delitschia*, *Cercophora* and Coniochaetaceae (LópezSáez and López-Merino 2007; Mazier *et al.* 2009; Cugny-Mazier-Galop 2010; Ejarque-Miras-Riera 2011).

A further pastoral indicator can be *Trifolium* of the Fabaceae family (Behre 1981), whose elevated pollen values may reflect either the accumulation of livestock dung or the proximity of stored fodder (Dietre-Gauthier-Gillet 2012). In this regard, Miras *et al.* (2018) identified *Trifolium*-group pollen adhering to a macro-lithic tool from a Neolithic/Bronze Age site in Spain, tentatively interpreted as evidence of milled animal fodder. Furthermore, high *Trifolium* pollen values have been recorded at several archaeological sites in southern Italy (Basilicata) dated to the Hellenistic, Roman and Medieval periods (Mercuri *et al.* 2010; Florenzano 2019). Collectively, these data demonstrate that *Trifolium* likely formed part of the (cultivated) fodder supplied to domestic livestock and was grown in the vicinity of settlements.

More recently, a study conducted at the medieval site of Kastrì in Greece revealed substantial quantities of *Salvia*, *Mentha* and *Thymus* (Lamiaceae family) pollen occurring in association with grazing indicators (Comegna *et al.* 2024). Such anomalously high values of Lamiaceae pollen suggest the deliberate harvesting of these aromatic plants by shepherds in the vicinity of the site, plausibly for use as fodder supplements for flocks, in line with the archaeological interpretation of the investigated medieval structure as a shelter for shepherds. Both *Trifolium* and Lamiaceae may therefore be included among the LPPI.

Where the co-occurrence of LPPI and CFS supports the hypothesis of pastureland surrounding the investigated site, the simultaneous detection of peaks of microcharcoals may be interpreted as evidence of slash-and-burn practices. Widely employed since the Neolithic, such techniques were used to clear land and to fertilize soils through the deposition of nutrient-rich ash (Cremaschi and Nicosia 2012).

For the pre-protohistoric period, grazing activities have been identified through pollen analysis at numerous Italian sites, attesting to the long-term occurrence of pastoral practices. At Crotte Basse mire (2,365 m a.s.l., Valle d'Aosta), for instance, pollen analysis has recorded a continuous Holocene landscape history of the subalpine-alpine highlands on the southern flank of Mt. Fallère. The data indicate sustained forest disruption at high elevations and the establishment of alpine pastures around 5,600 cal BP, associated with organised land use from the Copper Age onwards (Pini *et al.* 2017). A further example from northern Italy derives from Bergamo (360-380 m a.s.l., Lombardia) where pollen records from cores and trenches document intensive pastoral activities during the Bronze and Iron Ages. Evidence includes herd stalling near watering ponds, woodland grazing, haymaking, and episodes of overgrazing peaking between the eleventh and eighth century BCE. The hilltop setting facilitated strategic seasonal exploitation of pastures extending from the plains to higher Alpine zones (Pini *et al.* 2021).

At the beginning of the Bronze Age, intensive human activity is recorded in central Italy around the shores of Lake Mezzano (456 m a.s.l., Latium), where settlement was established following a pronounced hydrological crisis that caused a substantial lowering of the lake level. Communities deeply shaped the landscape through cereal cultivation, livestock grazing and combustion activities associated with domestic hearths and craft practices, thereby accelerating forest clearance (Sadori 2018).

In the upper Sarno Plain (30 m a.s.l., Campania), pollen data indicate a significant increase in grazing indicators during the the Early Bronze Age (4100-3800 cal yr BP; 2150-1850 cal yr BCE), reflecting more intensive exploitation of the landscape surrounding the Fossa San Vito lake compared with earlier periods (Russo Ermolli *et al.* 2024). Additional evidence from southern Italy derives from Calabria. On the Tropea Promontory (555 m a.s.l.), pollen data from a peat sequence demonstrate that between c. 3000 and 1000 yr cal BCE the area was primarily devoted to agriculture and grazing, the latter constituting the primary activity around the marsh. The record indicates stable livestock presence during the Eneolithic (ca. 4950-4300 yr cal BP; 3000-2350 yr cal BCE) and seasonal transhumance in the Early-Middle Bronze Age (ca. 4020-3250 cal yr BP; 2070-1300 cal yr BCE; Di Lorenzo *et al.* 2021). On the Ionian side of northern Calabria, palynological evidence from Fontana Manca (~1,000 m a.s.l.) documents Bronze Age mobile pastoralism around 1700 BCE (Sevink *et al.* 2019). In higher upland contexts, such as at Lago Forano (~1,500 m a.s.l.), pastoral activity appears a few centuries later than at Fontana Manca, showing the gradual spread of upland grazing practices within the region (Sevink *et al.* 2019). In the framework of the *HERDS* project, a core was drilled at Piani d'Ischia (1,200 m a.s.l., Mt Terminio, Campania), providing robust evidence of pastoral activities (transhumance) through the detection of LPPI and CSF (unpublished data). However, since the $^{14}C$ dating of the core sediments yielded an age interval between 850 and 1850 cal. BP, these data cannot contribute to the discussion on the pre-protohistoric development of pastoral activities.

## 3. ZOOARCHAEOLOGICAL EVIDENCE FROM UP-AND MIDLAND SITES IN THE APENNINES

Zooarchaeological studies from upland sites in the Apennines are relatively scarce. Some contexts are represented by high-altitude caves, which may have fulfilled a range of functions, including continuous or seasonal occupation, as well as ritual activities. Their interpretation is complicated by research history, post-depositional disturbances, and various form of damage affecting the deposits – such as collapses, modern pastoral reuse or occupation during the World Wars, and illicit excavations. These factors hinder not only the functional interpretation of the sites but, in some cases, also the definition of their chronological framework. Most caves display long sequences of use extending both before and after the Bronze Age, yet they have generally yielded relatively small faunal assemblages.

Excavations conducted in the 1960s at Grotta San Angelo, situated approximately at 1,000 m a.s.l. on the southern slope of the Montagna dei Fiori (province of Chieti), produced limited faunal remains from Layers 1-2 and 3-4, dating to the Middle and Late Bronze Age (Di Fraia and Grifoni Cremonesi 1996; Wilkens 1996). These assemblages primarily consist of domestic species, with caprines prevailing in the earlier phases and a more balanced representation of domestic species in the later phases. Micromorphological analyses suggest intensive use of the cave by shepherds and their flocks (Iaconis and Boschian 2007).

Grotta a Male, located near Assergi (~940 m a.s.l., province of L'Aquila) and excavated during the same period (Pannuti 1969; Merlino 2005), yielded mixed faunal assemblages spanning from the Middle Bronze Age to the Early Iron Age (Minniti 2012), again predominantly domestic species. In Layer 4, dated to Middle Bronze Age 3 and regarded as the most chronologically secure deposit, caprines account for 91% of the remains. This distribution strongly suggest that the cave functioned as a seasonal site associated with transhumant movements towards high-altitude pastures.

Grotta di Beatrice Cenci, located at 1,039 m a.s.l. in the mountainous area of Petrella Liri (province of L'Aquila), similarly yielded a predominantly domestic faunal assemblage, with caprines as the most represented category. The stratigraphic deposit is dated to the Middle Bronze Age, and a diversified use of the cave has been proposed, including ritual activities. Mortality data indicate that sheep were exploited for both primary and secondary products, such as meat, wool and milk, with a significant proportion of lambs slaughtered within their first year of life (Agostini-De Grossi Mazzorin-D'Ercole 1991-92; Cosentino-D'Ercole-Mieli 2001).

Open high-altitude sites include Monte Ingino and Monte Ansciano, both situated at approximately 890 m a.s.l., and c. 900 m apart, overlooking the Eugubino basin (province of Perugia). Monte Ingino is dated from Middle Bronze Age 3 to the Final Bronze Age, whereas Monte Ansciano spans the late Middle Bronze Age to the Early Iron Age (Malone and Stoddard 1994). At both sites, domestic species dominate, particularly caprines (McVicar *et al.* 1994: 95-101). Mortality data point to husbandry strategies primarily oriented towards meat production; however, the early slaughter of pigs and caprines indicates that these sites may have functioned as seasonal meeting points for local and Adriatic communities engaged in transhumant mobility, and possibly as venues for specific ceremonial practices (Malone and Stoddard 1994: 126; Bruni 2014).

Mid-altitude sites in central Italy, located well below 1,000 m a.s.l. and dated to the Recent and Final Bronze Ages, such as Vejano (Cosentino and De Grossi Mazzorin 2000), Elceto (Caloi and Palombo 1996), Torrionaccio (Cassano and Manfredini 1978; Placidi 1978), and Monte Sant'Elia (di Gennaro and Trucco pers. com.), have yielded small faunal assemblages consistently indicative of economies centred on caprine husbandry (Minniti 2012: 102-106). Collectively, these assemblages highlight a broader pattern in Bronze Age subsistence, in which sheep and goats were central to both meat production and exploitation of secondary resource. They further suggest that high- and mid-altitude sites fulfilled complementary roles within systems of seasonal herding, food provisioning, and, potentially, ritual activities.

An atypical case is represented by the faunal assemblage from Levels 7-6 of Monte Rovello (Allumiere) (Toti 1987; Caloi and Palombo 1987), likewise dated to the Recent Bronze Age. Although domestic species predominate, cattle constitute the most represented species, followed by caprines and pigs. Mortality data indicate the presence of adult and mature individuals across all categories. Among caprines, no individuals younger than one year were identified, whereas adults are well represented, including individuals exceeding four years of age. Pigs were generally slaughtered between their second and third years, although some older individuals are attested. Cattle, as commonly observed, were kept alive beyond four years of age. This assemblage diverges from the caprine-dominated pattern characteristic of other mid-altitude sites and may reflect a distinct livestock management strategy or a different cultural framework.

## 4. FIRST DATA ON THE ARCHAEOLOGICAL EXCAVATION CONDUCTED ON THE SUMMIT OF MONTE MORRA

### 4.1 Geographical framework

Monte Morra is located within the municipality of San Polo dei Cavalieri (Rome). This limestone relief forms part of the Lucretili Mountains, the southern offshoot of the Sabini Mountains. The highest peaks are Monte Pellecchia (1,369 m a.s.l.) and Monte Gennaro (1,271 m a.s.l.), the latter situated slightly to the north of Monte Morra (fig. 1)[1].

As anticipated in Section 1, the site displays a marked strategic character: it is defined by steep slopes that enhance its defensive potential. From the summit, which reaches 1,036 m a.s.l., it is possible to perform a visual control on a broad territory: to the southwest part of *Latium Vetus* and the lower Sabina, to the northeast the inner peaks of the Lucretili Mountains and the ridges of the Abruzzo Apennines. To the north lie the extensive mountain pastures of Prato Favale, Campitello and Pratone di Monte Gennaro, the latter located approximately 2,5 km in straight-line distance from Monte Morra.

### 4.2 Previous research on Monte Morra

The summit of Monte Morra was first investigated in the second half of the 1970s through field surveys by the Soprintendenza Archeologica del Lazio (Angle 1979, 2007; Angle and Guidi 1995). These investigations documented the remains of three dry-stone enclosure walls constructed from flakes and large blocks of local limestone, whose preserved height in some sections exceeded – at the time of the surveys – 1 m above the walking surface (Angle 2007).

The enclosure walls were detected along the eastern, southern, and western slopes, where the gentler morphology suggests the presence of artificial terracing. No defensive structures were recorded on the northern side, which is naturally protected by an exceptionally steep escarpment. Numerous ceramic finds were collected in proximity to the three enclosures (fig. 2).

Among the diagnostic material, a fragment of a carinated cup with rim marked by an internal angular ridge (fig. 2A, no. 1) may be attributed to Recent Bronze Age 2 (Damiani 2010: 239-245, type 39). A fragment decorated with light angular grooves (fig. 2A, no. 2) can be assigned to the Final Bronze Age (FBA) and finds parallels at the settlement of Luni sul Mignone (Pacciarelli 2001: 39, fig. 20C, n. 1). Several collar-necked cups with pronounced rounded shoulder decorated with vertical ridges or grooves (fig. 2B, no. 3-5) belong to the advanced phase of the Early Iron Age (EIA2), which, in the chronological framework for *Latium Vetus*, corresponds to Phase III (Bettelli 1997).

Particularly noteworthy is the presence of fragments of cooking stands and of a multi-perforated lid of a milk-boiler (fig. 2C), elements pointing to domestic activities and milk processing (Avella 2023).

Taken together, the character of the assemblage and the environmental setting of the site have been interpreted as evidence for a settlement associated with the exploitation of summer mountain pastures (Angle-Gianni-Guidi 1982; Guidi-Nomi-Truffi 2023).

### 4.3 The 2023 excavation campaign

On the basis of published data and within the framework of the PRIN *HERDS* project, Monte Morra was selected as a case study of a high-altitude settlement, at least partially associated with pastoral activities and the exploitation of summer mountain pastures.

Preliminary investigations began in 2022, when targeted surveys carried out by one of the authors (P.M.), with the support of local collaborators[2], identified scatters of pottery fragments associated with dark, organic-rich soil exposures on the summit.

[1] Monte Morra falls within a protected area established in 1989 with the creation of the Regional Park of the Lucretili Mountains. For a history of the establishment of the Park Authority and for a geo-morphological, hydrographic, archaeological, and historical-cultural overview, as well as for information on the flora and fauna of the area under consideration, the starting point is the guide edited by G. De Angelis; the fifth edition (De Angelis 1995) has been taken into account here. For a recent overview of prehistoric and protohistoric finds in the Lucretili Mountains area: Guidi-Nomi-Truffi 2023.

[2] We extend our sincere thanks to Dino and Franco Gubinelli, who provided important support to the excavation activities.

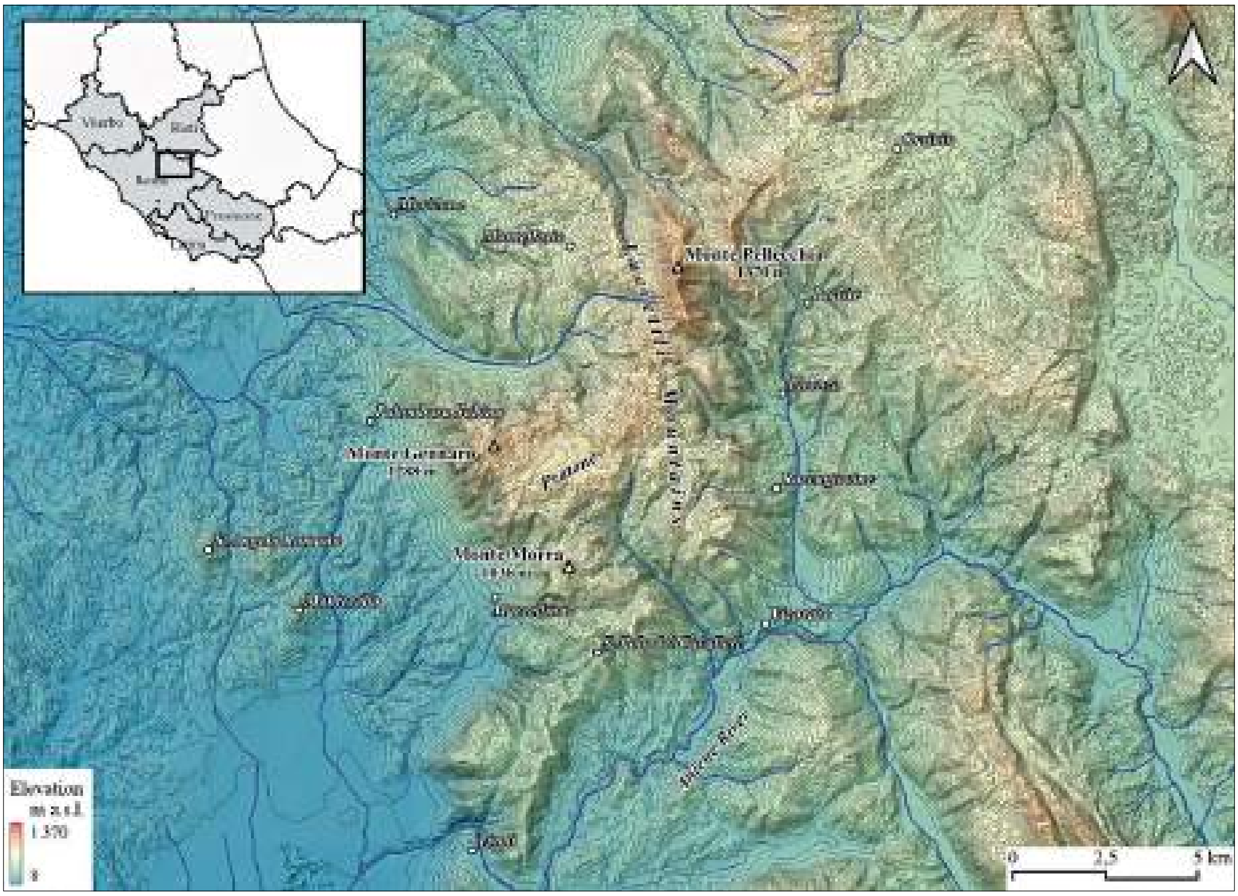


Fig. 1 – Geographical setting of the Lucretili Mountains.
*Inquadramento geografico dei Monti Lucretili.*

Following these results, the Department of Humanities of the University of Naples Federico II obtained a ministerial excavation permit[3], and fieldwork was undertaken in July 2023[4] (for preliminary notice see Miranda *et al.* 2025; Fiorillo *et al. in press*).

Three excavation areas were opened on the summit of Monte Morra (fig. 3). Trench 3, located almost at the center of the summit, investigated a rectangular cavity cut into the limestone bedrock. The fill of the cavity consisted of soil mixed with small and medium-sized stones. No diagnostic material was found, and the function of the structure, as well as its chronology remains uncertain. More substantial evidence for occupation spanning the FBA to the EIA derives from the excavations in trenches 1 and 2.

#### 4.3.1 *Trench 1*

Measuring 4×3,5 m, Trench 1 was opened along the northern edge of the summit, above a very steep slope. The excavation targeted this area with the aim of identifying possible terracing levels, slope stabilization features, or dwelling remains, also considering that erosion is generally more moderate along hilltop margins, increasing the likelihood of preserved archaeological deposits.

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[3] The excavation permit (n. 0020458-P), issued by the Ministry of Culture, was obtained thanks to the collaboration of the SABAP for the Metropolitan Area of Rome and the Province of Rieti; we take this opportunity to thank Dr. Diana Raiano and Dr. Maria Teresa Moroni. We thank the Municipality of San Polo dei Cavalieri (RM), in the person of the Mayor, Dr. Simone Mozzetta, and the Councillor for Culture, Dr. Oreste Lori. We also thank the Regional Park Authority of the Lucretili Mountains, particularly Vincenzo Lattanzi, for issuing the authorization required to carry out excavation activities within the protected area.

[4] Scientific direction: Marco Pacciarelli (Director), Andrea Cardarelli (Co-Director), and Giorgio Filippi (Co-Director). The following participated in the 2023 excavation campaign: Rosaria Avella, Chiara Buonincontro, Camilla Cittadini, Maria Rita Fazio, Lorenzo Fiorillo, Fabiana Grilli, Fabio Mattera, Pasquale Miranda and Valeria Ruocco.

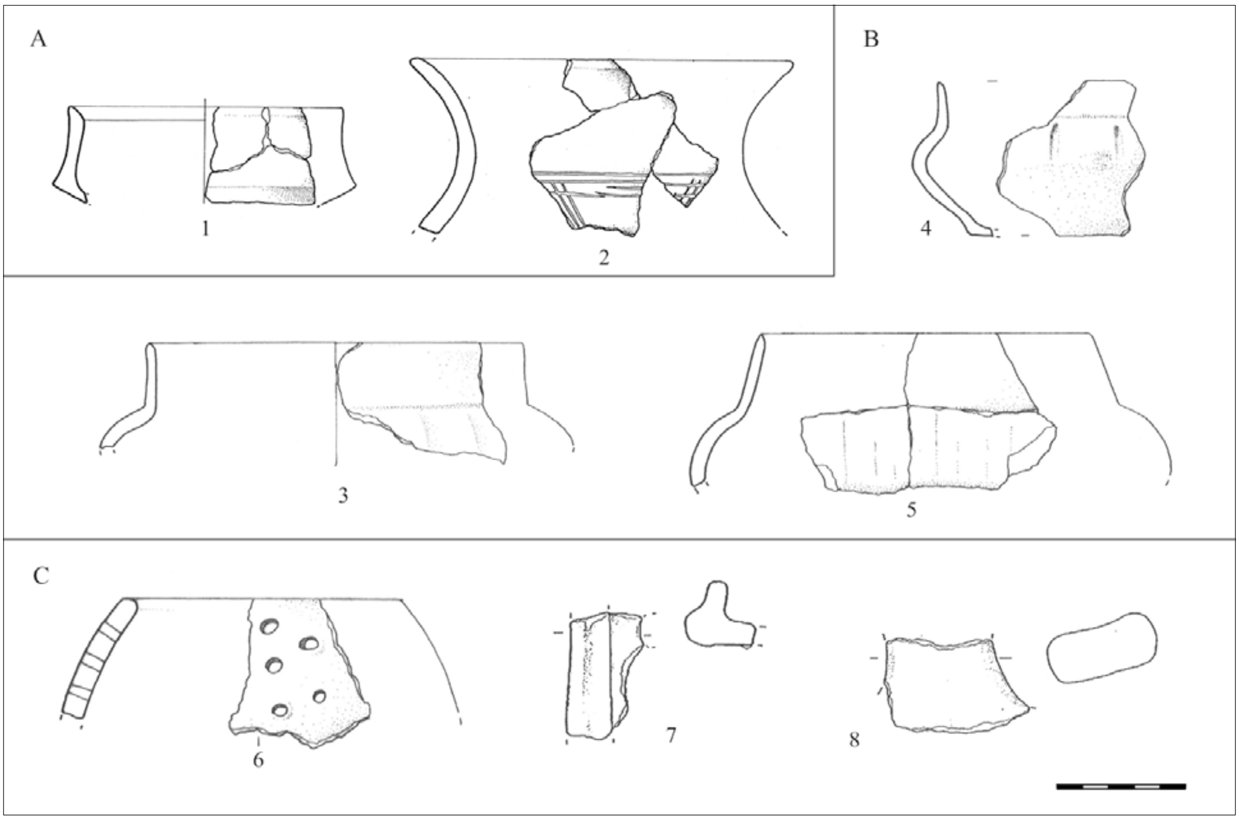


Fig. 2 – Ceramic fragments found during the surveys in the 1970s (A: after Angle 1979; B-C: after Angle 2007).
*Frammenti ceramici rinvenuti durante le ricognizioni degli anni 1970 (A: da Angle 1979; B-C: da Angle 2007).*

Beneath the humus layer, the central portion of the trench revealed Stratigraphic Unit (SU) 21, corresponding to the limestone bedrock. Surrounding it was a layer (SU 6) with a dark colour and a sandy-silty matrix, rich in stones ranging from centimetric to decimetric dimensions (fig. 4A). SU 6 contained several concentrations of pottery fragments and was also sampled for pollen analysis. Once SU 6 was removed, the bedrock SU 21 was fully exposed, displaying a highly irregular surface (fig. 4C). Artificial cuts were identified in the bedrock, some of which may represent postholes (fig. 4B). Only the fills of a few of these cuts contained protohistoric pottery fragments, none of which were diagnostic.

Based on the stratigraphic sequence described above, SU 6 can be interpreted as a levelling deposit composed of soil and stones, laid down to compensate for the irregularities of the limestone bedrock and to create a regular surface. It is possible that above this landfill there were once layers of settlement in place, removed over time by erosion.

SU 6 yielded numerous ceramic finds, currently under study. A significant chronological indicator is a small amphora with a flaring rim and short truncated-conical neck (fig. 6, no. 1), comparable to an example from Tomb 124 of the Osteria dell'Osa cemetery, dated to Latial Subphase IIA2 (Bietti Sestieri 1992: 573, fig. 3a.36, n. 4). This find allows the levelling deposit and the consequent regularization of the Monte Morra summit to be dated after Latial phase IIA, in connection with the construction of the fortification, which will be discussed as dating to Phase IIB. SU 6 also contained residual FBA fragments attributable to a previous occupation phase. Among these, a carinated bowl (fig. 6, no. 2) is comparable to a specimen from Narce dated to FBA 1-2 (Pacciarelli 2001: fig. 19A, no. 2). A fragment of a closed form decorated with comb incision combined with a row of impressed dots and a cord-impressed line (fig. 6, no. 4) does not currently find a precise parallel. The combination of these decorations is well attested in FBA 3 (e.g., Montecelio: Mari and Sperandio 1984: fig. 10, no. 15), but it is also widespread in the initial EIA (e.g.,

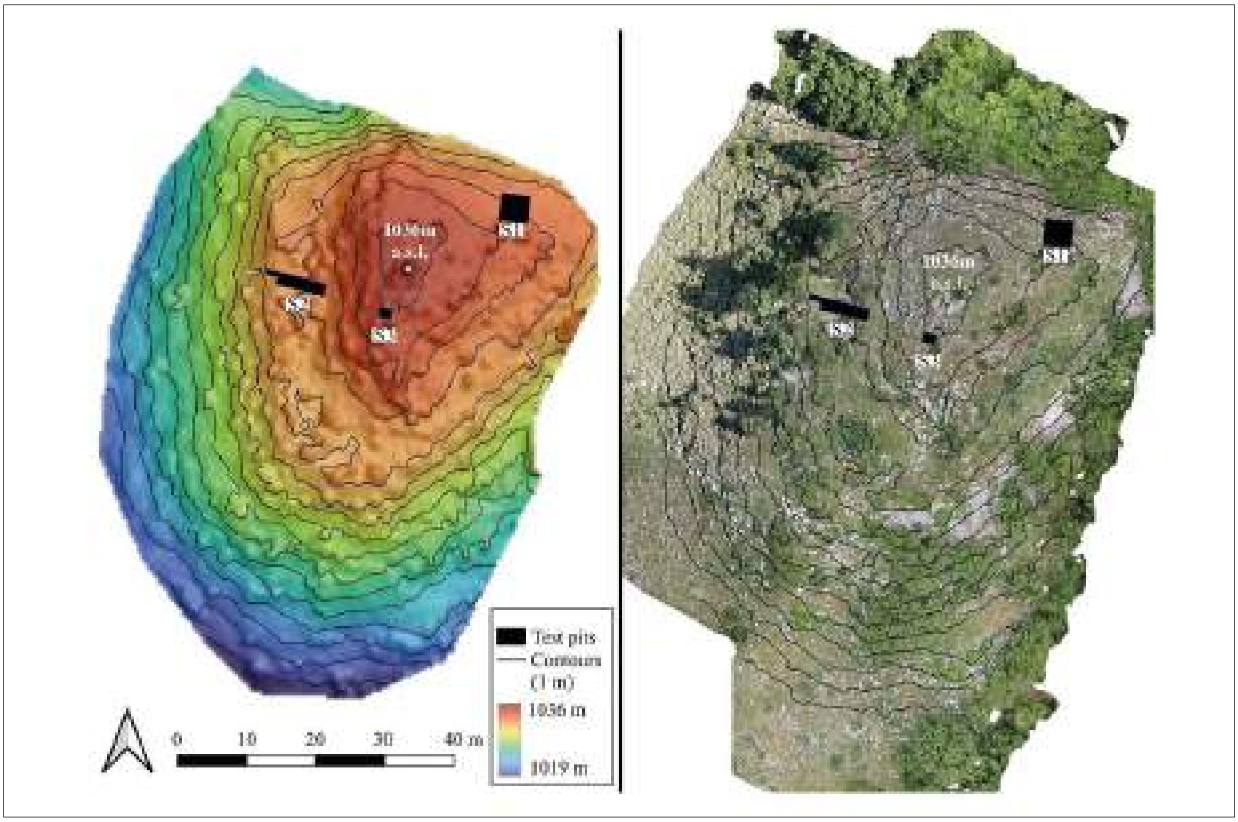


Fig. 3 – Digital elevation model of the summit of Monte Morra and location of the excavation areas.
*Modello digitale di elevazione della sommità di Monte Morra e posizionamento delle aree di scavo.*

in southern Etruria). Similarly, a comb-decorated fragment with angular motif surmounted by horizontal incisions (fig. 6, no. 3) may be assigned either to FBA3 (Barbaro 2010: 92, fig. 72; Bietti Sestieri and De Santis 2003: fig. 20, no. 5) or to the initial phase of the EIA (Bietti Sestieri 1992: tomb 157, fig. 3a.9, no. 1). A cylindrical-ovoid olla with flaring rim and plastic cordon decorated with fingertip impressions (fig. 6, no. 5) belongs to long-lasting types attested along the Tyrrhenian coast in settlement and production contexts between the FBA and the EIA (Aranguren *et al.* 2014, with bibliography).

Finally, near the western limit of the trench, three tools associated with spinning and weaving were recovered: a spindle whorl, a spool, and a loom weight (fig. 6, nos. 6-8).

4.3.2 *Trench 2*

Trench 2 was opened on the western side of the summit (fig. 3), where the terrain is more regular and flattened, a feature suggestive of an artificial terrace. In this area, a dark soil layer crops out, rich in stones and protohistoric ceramic fragments. Along the western edge of this flat surface, just before the beginning of the slope, a slight mound suggested the presence of a buried structure. Based on these observations and previous surveys, a trench measuring 7 m in length and 1,5 m in width was opened (fig. 5A) to verify the presence of a fortification wall or terracing structure.

Corresponding to the mound on the western margin, a dry-stone structure composed of stones of various sizes mixed with protohistoric pottery (SU 7) was immediately exposed. Upslope, in the central and eastern portions of the trench, beneath thin colluvial layers (SU 2, 4), a series of cuts were identified within the geological bedrock (SU 5). Some of these – particularly those running parallel and aligned with the structure (SU -12, -14, -37; fig. 5A) – may be interpreted as postholes.

The uppermost level (SU 7) of the stone structure contained a large limestone block in primary position, beneath which a dense concentration of pottery fragments was recovered, largely attributable to the collar-necked cup illustrated in fig. 7,

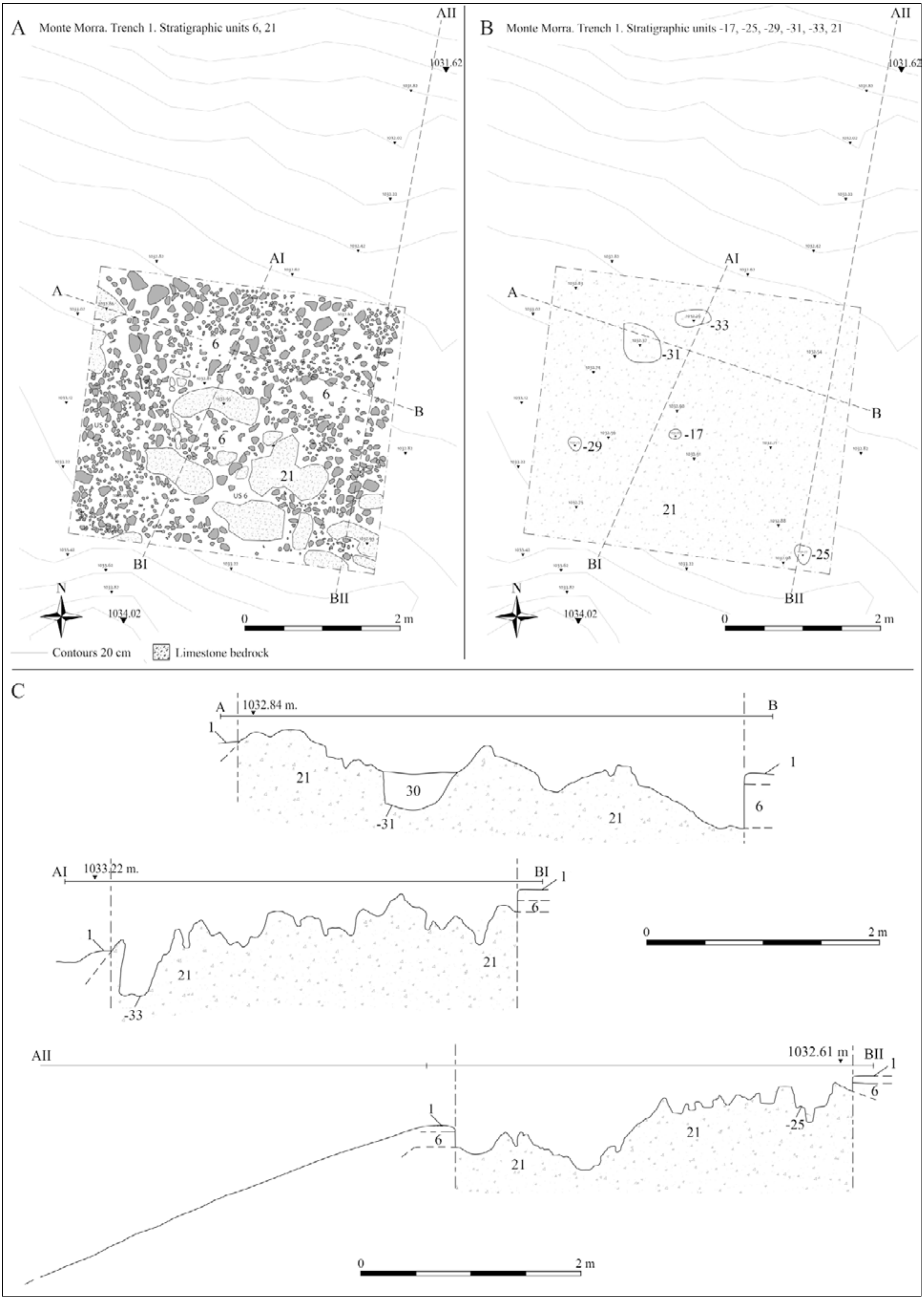


Fig. 4 – 2023 excavation campaign. Trench 1. A-B. Plans. C. Sections.
*Campagna di scavo 2023. Saggio 1. A-B. Planimetrie. C Sezioni.*

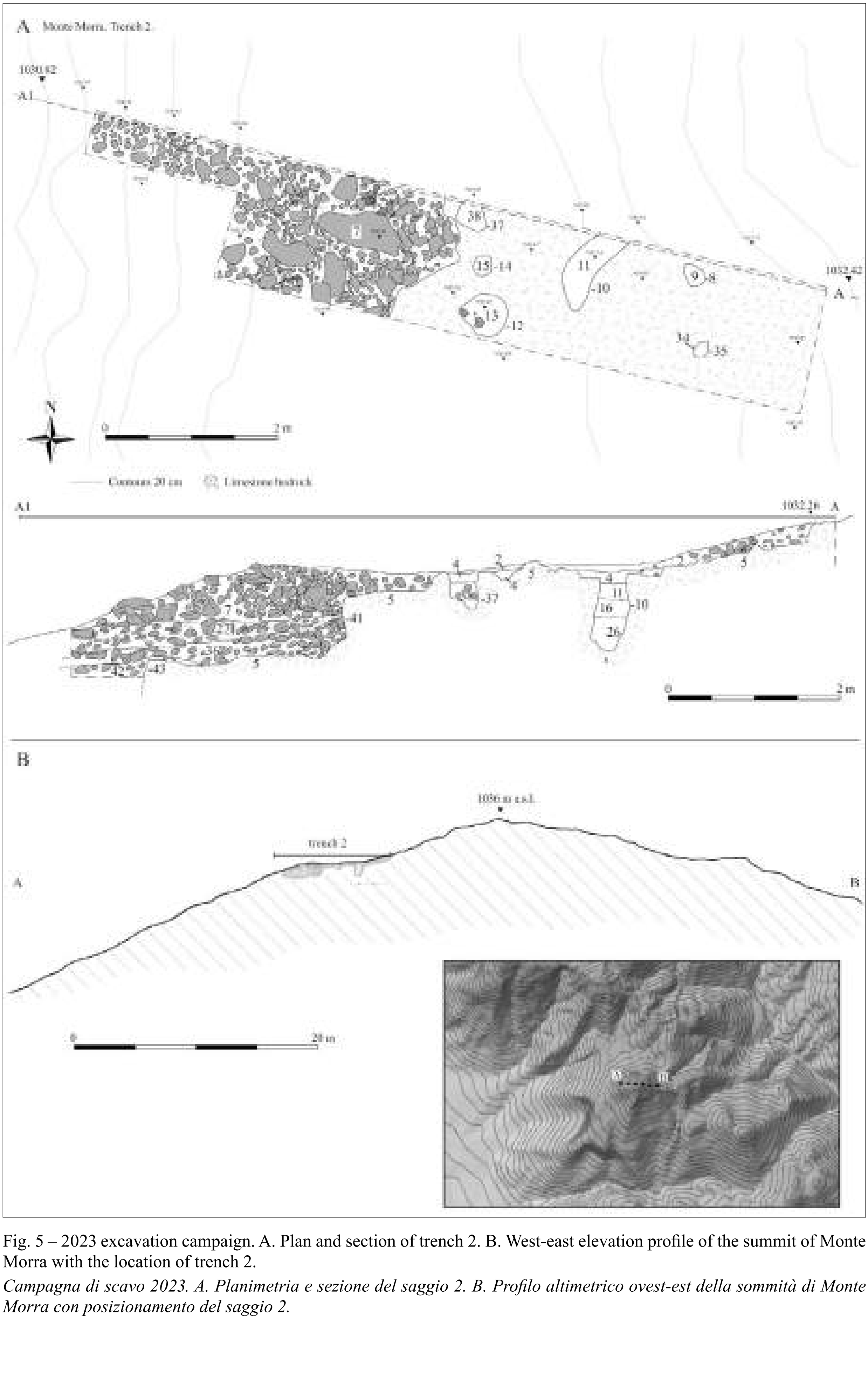


Fig. 5 – 2023 excavation campaign. A. Plan and section of trench 2. B. West-east elevation profile of the summit of Monte Morra with the location of trench 2.

*Campagna di scavo 2023. A. Planimetria e sezione del saggio 2. B. Profilo altimetrico ovest-est della sommità di Monte Morra con posizionamento del saggio 2.*

no. 1. The intentional fragmentation may indicate a ceremonial foundation act.

Below SU 7, a second level (SU 27) was identified, composed of smaller stones and very dark soil rich in charcoal, pottery, and mostly burnt animal bones. A third level (SU 36) formed the base of the structure, also containing small stones mixed with pottery and animal bones. The entire structure, composed of these stratigraphic units, was set within a large, regular cut in the limestone bedrock, interpreted as a foundation trench (SU -41). The structure likely continued further west, as suggested by a lower foundation cut, partially exposed and also filled with stones (SU -43; fig. 5A). SU 7, 27 and 36 were sampled for pollen analysis.

The evidence supports the interpretation of a dry-stone fortification wall, preserved only in its basal portion. The lower two levels (SU 36, 27), characterized by a higher proportion of soil and fewer small stones, likely represent the bedding for an above-ground structure composed at least in part of tightly packed stones and large blocks, traces of which are preserved in SU 7.

Regarding the dating of the structure, a precise chronological reference is provided by the collar-necked cup (fig. 7, no. 1) found beneath the large block in SU 7. This type is frequently attested in Latial funerary assemblages (Gjerstad 1956: 186, fig. 163, 1, Esquiline, Tomb LI; Zevi *et al.* 1975: 387, fig. 24, 13, Castel di Decima, Tomb 122) attributed to Subphase IIB2 of the Latium Vetus sequence (Bettelli 1997: pl. 71, no. 4). This evidence allows the foundation of the fortification wall to be placed in the late EIA 1. An EIA date is also attributable to a dolium fragment with thickened rim, flattened lip, and globular body profile (fig. 7, no. 4), comparable to a specimen from Fidene (di Gennaro *et al.* 2009: 155, fig. 9, no. 5).

Residual materials from earlier FBA occupation phases were also recovered within the fortification levels. This is the case of the bowl fragment with markedly concave profile and expanded carination (fig. 7, no. 2), comparable to an example used as an urn lid in a FBA 1-2 cremation discovered at Campo del Fico near Ardea (Pacciarelli 2001: 213, with bibliography).

### 4.4 Preliminary interpretation

The stratigraphic excavation conducted on the summit of Monte Morra has confirmed the presence of a protohistoric hilltop settlement. An initial use could date back to the RBA, but it is attested only by the cup fragment.recovered during the surveys of the 1970s (see above). The earliest stable occupation dates to the FBA, although it is currently attested only by residual materials recovered within the EIA levels. During the FBA phase, the settlement does not appear to have been equipped with artificial defensive structures, and its primary function was most likely that of a mountain site exploited by lowland communities such as the one established at Monte Celio (Mari and Sperandio 1984) for the use of summer highland pastures, including the Pratone di Monte Gennaro (fig. 1).

With the transition to the EIA, a profound reorganization of the settlement is evident. In addition to its pastoral function, its role now appears strongly linked to territorial control and the defence of Monte Morra's strategic position. The irregular summit was reshaped and protected by a dry-stone enclosure wall (trench 2, SU 7, 27, 36).

The 2023 excavation campaign partially investigated the uppermost enclosure, whose construction was preceded by the artificial leveling of a wide perimeter band, clearly visible in the elevation profile (fig. 5B). This intervention further isolated the summit, giving it its present triangular spur shape (fig. 3), with the apex oriented southward and a total surface area of c. 1,200 m². Along the outer edge of this artificial terrace, the fortification wall was constructed, extending along the west, south, and east sides for a total length of approximately 120 m. On the northern side the summit is naturally defended by a steep escarpment. As for the other two lower enclosure walls observed during the surveys of the 1970s (see above), it has not been possible to verify their presence again, probably due to progressive deterioration that has caused their gradual erosion along the slopes of the mountain.

The construction of the summit wall likely involved not only levelling the limestone bedrock but also the removal of substantial portions of earlier stratigraphy. Evidence for this includes residual FBA materials, as well as large concentrations of charcoal, animal bones, and fragments of domestic pottery and cooking stands (fig. 7, no. 3) mixed with the stones and perhaps originating from pre-existing huts, traces of which may survive in the postholes identified in Trench 1.

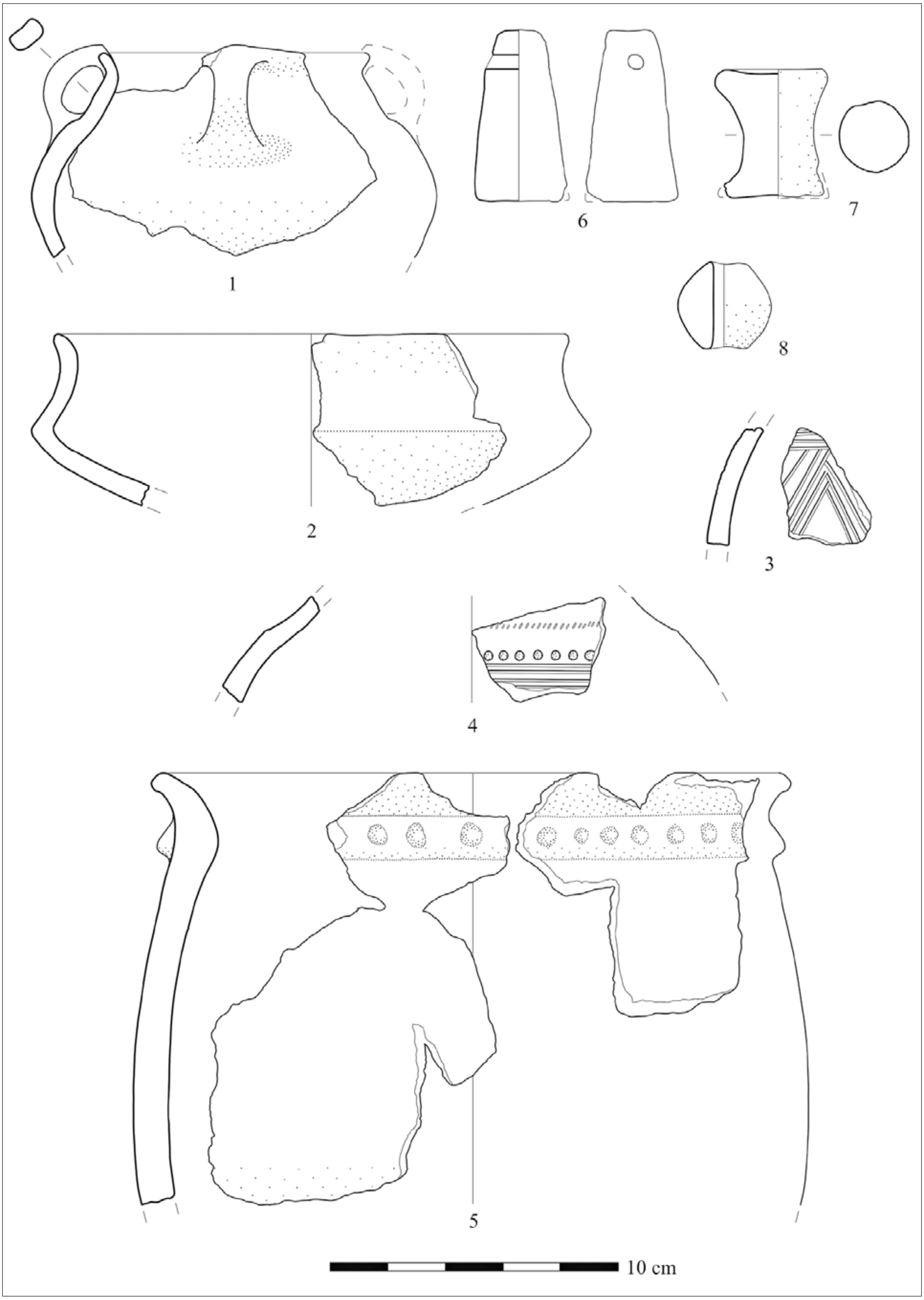


Fig. 6 – 2023 excavation campaign. Trench 1. Ceramic finds from SU 6.
*Campagna di scavo 2023. Saggio 1. Reperti ceramici dall'US 6.*

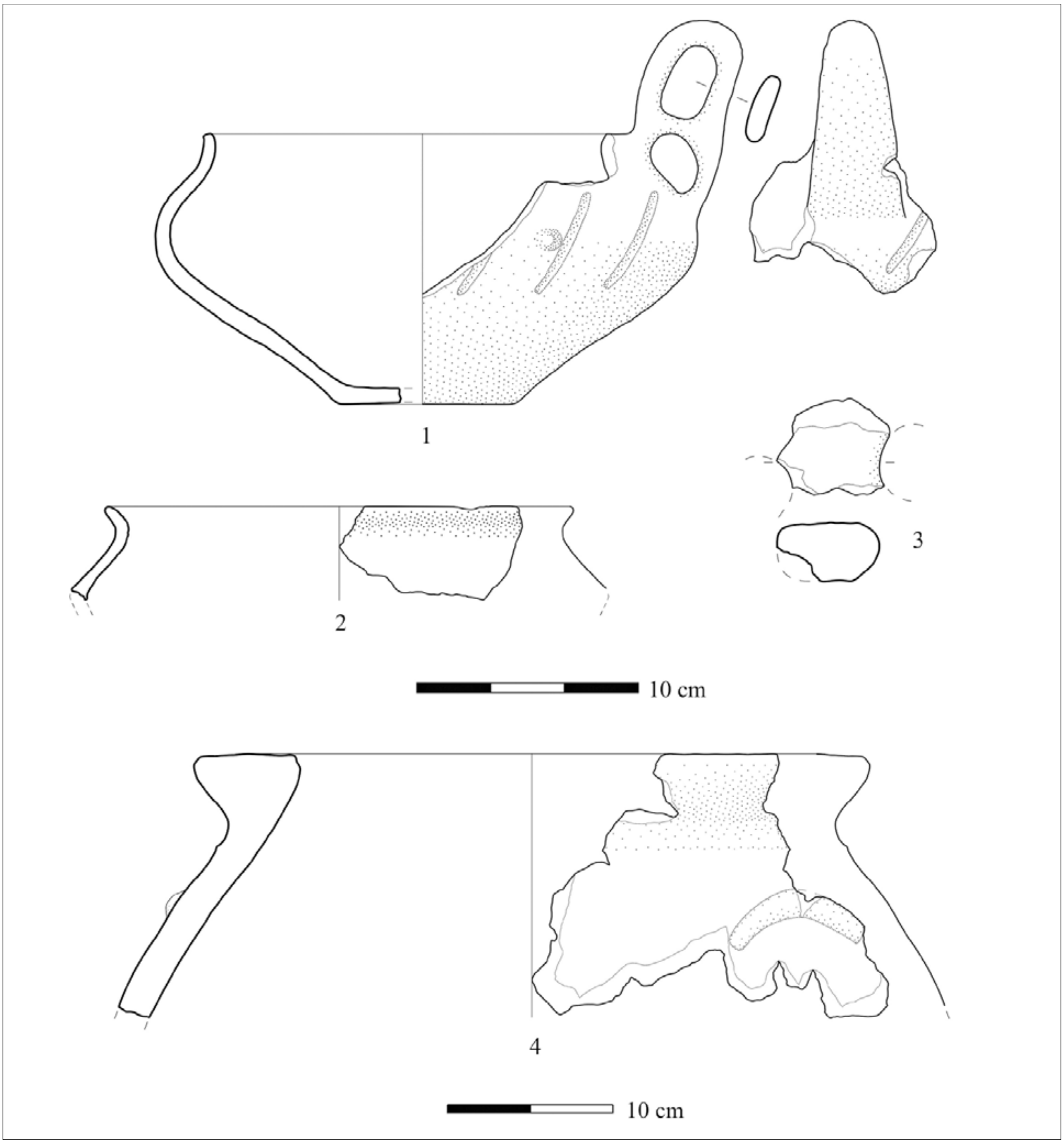


Fig. 7 – 2023 excavation campaign. Trench 2. Ceramic finds from SU 7.
*Campagna di scavo 2023. Saggio 2. Reperti ceramici dall'US 7.*

It may be hypothesized that the fortification system consisted of a series of stepped foundation levels cut into the limestone bedrock, each filled with bedding layers of small- and medium-sized dry-stones. Moreover, the defensive system likely included structures in perishable materials leaning against the stone walls, as suggested by the alignment of postholes identified immediately in front of the foundation trench (fig. 5A).

A similar stepped fortification system has been documented on the summit of Monte Cimino (1,053 m a.s.l.), the highest relief in southern Etruria, associated with a site of marked cultic-ceremonial character frequented during the FBA (see Section 1).

As anticipated, the reorganization of the Monte Morra settlement in a defensive and strategic capacity can be placed at the beginning of the EIA, between Phases IIA and IIB of the Latium

Vetus sequence. The settlement appears to have persisted into a more advanced stage of the Early Iron Age, during Phase III of Latium Vetus, as suggested by materials recovered in the surface surveys of the 1970s.

## 5. FIRST DATA ON THE FAUNAL REMAINS FOUND IN THE MONTE MORRA EXCAVATION

The faunal remains from the Monte Morra site derive from both the infilling layers of Trench 1 (SU 6) and the domestic refuse layers uncovered in Trench 2, associated with slope terracing and the construction of the settlement's fortification wall (SU 7, 27, 36). The assemblage comprises over 4.600 specimens, of which only 509 (approximately 15%) could be identified to the taxonomic level (tab. 1) All identified remains belong to the primary domestic species exploited for food: cattle, sheep/goats, and pigs. Caprines are predominant, accounting for 71% of the assemblage, while pigs and cattle are less represented, with 19% and 10%, respectively. Within the caprine category, sheep clearly outnumber goats. The distribution of anatomical elements includes both axial and appendicular skeletons across all species; however, the high degree of fragmentation is evident from the large proportion of isolated teeth.

Mortality profiles for caprines suggest that animals were primarily slaughtered between one and four years of age for meat consumption, representing 45-71% of the assemblage depending on the criteria used (epiphyseal fusion of long bones or mandibular tooth eruption and wear stages). Secondary slaughtering occurred after four years, primarily for the exploitation of secondary products such as wool (accounting for 29-55% of the remains, depending on the two methods). The focus on wool production is further supported by the presence of spinning and weaving artifacts (Miranda *et al.* 2025: fig. 6, nos. 6-8). Cattle remains are mostly attributable to adult individuals, with the exception of a pair of upper deciduous teeth and a first phalanx with an unfused epiphysis, indicating an individual slaughtered before 18 months of age. Pig remains predominantly belong to animals slaughtered between one and three years, reflecting an optimal strategy for meat exploitation.

## 6. CONCLUSIVE REMARKS

Domesticated livestock farming became widespread in Italy as early as the sixth millennium BCE, since the beginning of the Neolithic. There is no doubt, however, that these practices increased considerably in both importance and complexity between the second and early first millennium BCE, in connection with broader processes of socioeconomic development, which in some regions culminated in the start of urbanization.

A crucial advancement of these practices was the exploitation of the vast mountain pastures of the Apennine chain, particularly during the warmer months, accessible through short- or long-distance seasonal mobility.

The summer use of high-altitude areas may have been implemented through either small temporary camps or more structured occupation and control, marked by the establishment of hilltop settlements, often equipped with fortifications.

The first type of use remains poorly documented, but it could correspond to small clusters of ceramic fragments, mostly dating to MBA 3, which, as mentioned, have been recovered from open sites well above 1,000 meters a.s.l. Another possible form of seasonal occupation is the use of caves and shelters at relatively high altitudes.

Hilltop sites appear in MBA 3 but are particularly well attested between the FBA and the EIA. As mentioned, many settlements of this type – although often of uncertain chronology – have been identified in the Umbria-Marche Apennines through LiDAR analysis.

Research on these mountain settlements is underdeveloped, and further investigation is needed to understand their role in the development of new livestock farming practices between the late second and early first millennium BCE.

Even more than in other contexts, the study of mountain habitats requires an integrated, multidisciplinary approach. Pollen analysis has proven crucial for reconstructing plant landscapes and detecting pastoral practices, even in high-altitude areas. For example, palynological studies on a sediment core from Lago Forano in Calabria documented, primarily through the presence of coprophilous fungal spores, the existence of grazing livestock in the second millennium BCE, at elevations up to 1,500 meters a.s.l.

| | NISP |
|---|---|
| Cattle – *Bos taurus* L. | 51 |
| Sheep/Goat – *Ovis* vel *Capra* | 241 |
| Sheep – *Ovis aries* L. | 112 |
| Goat – *Capra hircus* L. | 9 |
| Pig – *Sus domesticus* Erx. | 96 |
| Total identified | 509 |
| ribs | 150 |
| vertebrae | 51 |
| non identified | 3390 |

Tab. 1 – Number of Identified animal Specimens (NISP) per species from Monte Morra.
*Numero di resti animali identificati per specie da Monte Morra.*

However, such cores must be collected from specific depositional contexts, such as lakes and ponds, favourable to pollen preservation, and even then, they do not always yield the expected results. As previously mentioned (Section 2), the core sampling conducted as part of the PRIN *HERDS* project at Piani d'Ischia, on a mountain plateau in the Campanian Apennines, allowed the identification of clear indicators of grazing but did not reach sediments corresponding to the protohistoric period. Such analyses can also be performed on samples from archaeological layers, although pollen in these contexts is often subject to degradation, resulting in partial preservation or total absence. Indeed, all samples collected in the Monte Morra excavation trenches proved barren.

Important data on animal husbandry practices and their products can also be obtained from faunal remains, particularly from the study of slaughter strategies in relation to species, age, and sex, as well as from archaeological artefacts, which provide precise chronological references and can document activities such as milk processing.

To this end, as part of the *HERDS* project, an archaeological excavation was conducted at one of the most significant mountaintop settlements, Monte Morra (1,036 meters a.s.l.) in the Lucretili Mountains (Latium).

Although only a single excavation campaign was undertaken, the results were substantial. The site provides clear evidence of long-term occupation, from at least the FBA (and possibly as early as the late RBA) up to the late EIA, corresponding roughly to the twelfth-eighth centuries BCE. The abundant ceramic assemblages include domestic vessels such as large containers and cooking stands, and spinning and weaving tools, typical of a settlement context.

Faunal remains indicate a marked prevalence of caprines, animals particularly suited to mountain pastures and seasonal mobility. Some individuals, as noted, were likely exploited for secondary products, such as wool. Selected faunal samples from Monte Morra have been analysed within the *HERDS* project and have produced interesting results, presented in other contributions to this volume.

As it is often the case, the excavation revealed a more complex situation than anticipated, suggesting a change in the nature of the site during its later stages. The earliest occupation, primarily dated between the FBA and the beginning of the EIA, is poorly documented, consisting only of residual pottery, and does not appear to have featured fortification structures on the summit.

With the transition to the Latial Phase IIB, datable to the mid-to-late ninth century BCE, a fortification project was undertaken. This involved terracing works, including the removal of bedrock (which altered the original profile of the summit), followed by filling and levelling to create a regular surface, and the subsequent construction of a dry-stone wall around the summit.

It is possible that strategic considerations influenced the choice of the site from the onset, but the extensive fortification work clearly reflects a notable increase in the strategic importance of Monte Morra from the advanced phase of EIA 1. This does not imply a corresponding decrease in the exploitation of mountain pastures; rather it suggests that pastoral activity became integrated within more complex political and territorial frameworks during the EIA.

## Author Contributions

A. Cardarelli, G. Filippi and M. Pacciarelli co-authored the section on evidence and hypotheses concerning use of mountain pastures and protohistoric settlements in the Apennine area.
H. Di Lorenzo and E. Russo Ermolli co-authored the section on grazing activities detected in pollen records.
C. Minniti and M. Cianfoni co-authored the sections on zooarchaeological evidence from up- and midland

sites in the Apennines and on the faunal remains found in the Monte Morra excavation.
L. Fiorillo and P. Miranda co-authored the section on the archaeological excavation conducted on the summit of Monte Morra.
All authors contributed to the conclusive remarks.

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HERDS – Animal Husbandry and its Economic Role in the Development of Central Mediterranean Protohistoric Societies – Rivista di Scienze Preistoriche – LXXVI S6 – 2026 – pp. 193-200

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# The HERDS Project: Conclusions

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This paper presents a synthesis of the first results obtained to date within the HERDS project; additional discussion of results, based on the extensive analytical dataset generated through the project's funding, will be published in forthcoming papers.

Faunal remains from archaeological contexts – particularly those dating to protohistory – are generally abundant and therefore well suited to quantitative analytical approaches. Together with archaeobotanical evidence, they constitute key proxies for primary economic practices that underpinned the subsistence of village communities, while simultaneously forming the basis for the development of specialised craft production (e.g. regarding antler and bone, textiles etc.) as well as exchange networks.

Developments in archaeological research in the last two decades, considered by Kristiansen so momentous as to constitute the "third scientific revolution in archaeology" (Kristiansen 2014), are characterised by the increasing application of biomolecular and geochemical analyses such as stable isotope analysis, ancient DNA (aDNA), and palaeoproteomics (including Zooarchaeology by Mass Spectrometry – ZooMS). These have significantly expanded the range of information retrievable from the archaeological record related to human and animal bones. In Italy, however, the application of these methodologies to faunal assemblages has so far remained limited[1], in contrast to their widespread use in the study of human

[1] A very recent contribution in this regard has been devoted to the faunal assemblages from two Middle Bronze Age contexts at Oppeano and Muraiola, in the province of Verona (Manfrin *et al.* 2026).

skeletal remains. The HERDS project therefore aims at integrating established zooarchaeological methods with these biomolecular and geochemical techniques, applying them to the archaeological framework spanning the Middle Bronze Age to the Early Iron Age in Italy (18$^{th}$/17$^{th}$ to 8$^{th}$ centuries BC). The study focuses primarily on mainland contexts (from the central-eastern Po Valley to Calabria and Apulia), supplemented by selected insular sites in Sardinia and Pantelleria. The species analysed are the most common domesticates during protohistory: sheep, goats, cattle and pigs, which constituted the principal resources for meat production and secondary products (milk and wool), as well as, in the case of cattle, for traction and transport.

The archaeological record for this period is particularly rich and informative, documenting a marked intensification of economic activities, investment in settlement systems and landscape organisation, as well as the expansion of specialised craft production and medium- to long-distance exchange. These processes are embedded within a broader framework characterised by significant demographic growth and increasing social and political complexity. Given the close relationship between humans and economically exploited animals, the expansion of datasets derived from analyses applied to these species has the potential to provide critical insights into protohistoric societies.

During the course of the research, some modifications to the original project design proved necessary, primarily due to difficulties in accessing faunal remains from certain contexts. This has resulted in some imbalance in the geographical, cultural and chronological coverage of the dataset. As outlined in the introduction to this volume, sites from the Po Valley and central Italy are more strongly represented than those from southern Italy and the islands; chronologically, Bronze Age contexts predominate over those of the Early Iron Age.

As noted above, the HERDS project embraced a very large territory, a high number of contexts, and an extended chronological span, from the beginning of the Middle Bronze Age to the Early Iron Age. Consequently, the number of samples available for each individual context is limited and often uneven – the results should therefore be regarded as indicative of broad trends rather than of fine-grained and local patterns.

Despite these constraints, the HERDS project yielded significant methodological insights as well as a number of important historical conclusions. Notable methodological advances in integrating zooarchaeological research with biomolecular archaeology, including ZooMS, isotopic analysis, aDNA, and organic residue analysis, in protohistoric Italy, are discussed in the individual contributions to this volume (Cianfoni *et al.*; Cavazzuti *et al.*; Makarova *et al.*; Avella *et al.*; Fiorillo *et al.*). With regard to the interpretative aspects and the historical questions that the HERDS project was expected to address (Cardarelli *et al.* in this volume), several significant results were obtained, which may be summarised under four main headings:

– Economic patterns in farming: from the adoption of animal penning to the introduction of fodder crops, and the potential role of transhumance, even over short distances (e.g. between the coast and the Apennines).
– Mobility of domestic animals in relation to the movement of individuals or human groups, including exchange and cultural interaction (e.g. the introduction of exogenous specimens to strengthen or hybridise flocks and herds; gifts or dowries in marriage exchanges; indicators of movements of human groups of varying scale, such as migrants or itinerant traders; outcomes of warfare and raiding).
– Development of breeding strategies linked to the intensified exploitation of secondary products (especially wool and dairy production).
– Identification of different haplogroups among domestic animals and their distribution across space and time.

Regarding the first point, the zooarchaeological study (Cianfoni *et al.*, in this volume) considered not only the faunal remains from the contexts analysed within the HERDS project, but also previously published data from Italian protohistoric sites, thereby significantly broadening the available evidence. During the Bronze Age, wild fauna appears to have played a largely marginal role in most contexts, confirming a well-established pattern widely documented in zooarchaeological assemblages of this period. A relatively large population such as that of the Bronze Age must have relied on subsistence strategies that were more stable and predictable than hunting, with particular emphasis on the husbandry of caprines, cattle, and pigs. Within this framework, caprines represent the dominant taxon, with sheep generally prevailing over goats, except in specific cases characterised by ecological conditions more favourable to the latter, such as at the settlement of Mursia on the island of Pantelleria. Cattle are less well represented in quantitative terms; nevertheless, as is well known, their contribution in terms of meat yield was substantial due to their body size. Moreover, cattle husbandry played a key economic role, as these animals were essential for traction, particularly for ploughing and transport.

Pigs appear to have held considerable importance in the economic strategies of Italian protohistoric communities, and in some contexts their husbandry is particularly emphasised. The Final Bronze Age site of Frattesina represents a notable case, characterised by a marked focus on pig rearing, likely linked to the exceptional nature of the settlement as a major craft and production centre, as well as a strategic hub within long-distance exchange networks connecting Europe and the eastern Mediterranean. In a context marked by a substantial population heavily engaged in craft activities, and possibly including individuals originating from distant regions, the need to meet a high and rapid demand for food would have been pressing – one to which pig husbandry could respond with particular efficiency.

Biometric analyses of pigs and wild boar demonstrate a clear separation between the two taxa during the Bronze Age, indicating the coexistence of two biologically distinct populations with very limited or no reproductive interaction. These data support the hypothesis that domestic pig populations were managed in ways that maintained their separation from wild boar. It is therefore highly likely that pigs were often raised within settlements or in their immediate surroundings, under the direct control of human communities, with little or no interaction with wild suid populations.

Particularly significant in this regard is the evidence from the terramara site of Beneceto (Parma), where a substantial group of rectangular structures arranged side by side in row, dating to the Recent Bronze Age and measuring between 60 and 75 $m^2$, has been identified approximately 180 m east of the settlement. In the absence of archaeological indicators attributable to domestic occupation, the authors have proposed, on the basis of micromorphological and geochemical analyses, a functional interpretation whereby some of these structures served as hay storage facilities and others as animal shelters, probably for pigs (Bernabò Brea *et al.* 2023).

The practice of stalling was likely more widespread in protohistoric Italy than is currently documented. In the Po Plain, alongside the case of Beneceto, the site of Oppeano is also particularly informative. Here, a series of early Middle Bronze Age structures, arranged side by side in alignment, have been interpreted as byre-houses, that is, buildings designed to accommodate animals (in this case primarily caprines), within which humans and livestock are likely to have cohabited, if not permanently, at least on a recurrent basis (Nicosia *et a.l* 2022; Polisca *et al.* 2025). Large dwellings (longhouses) incorporating spaces designated for animal housing are, moreover, well documented in northern Europe[2].

With regard to the management of herds, both in relation to stabling practices and more generally to modes of husbandry, significant insights derive from isotopic analyses conducted within the framework of the HERDS project (Cavazzuti *et al.* in this volume). The data pertain to three sites distributed across Italy: in the Po Plain (Solarolo – Via Ordiere), on the Adriatic coast of the Marche region (Montarice – Porto Recanati), and on northern coast of Apulia (Coppa Nevigata – Manfredonia).

At Solarolo and Coppa Nevigata, both located in lowland areas with extensive pastures surrounding the settlements, the isotopic evidence largely indicates sedentary husbandry practices. By contrast, at Montarice, situated within a hilly landscape, the data for herbivores, particularly caprines, suggest a system that involved seasonal mobility for a substantial portion of the flocks. It is therefore likely that a form of transhumance was practiced, potentially over short- to medium-range distances, given the proximity of the Apennine foothills[3].

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[2] In the case of Oppeano 4D, the size of the structures cannot be clearly defined, as only one of the short sides and portions of the long sides are known. Nevertheless, their extent exceeded 20 $m^2$ and was probably no less than 30-40 $m^2$.

[3] Short-range mobility in areas exhibiting significant altitudinal differences over relatively limited territories is, for example, attested during the Bronze Age at the coastal settlement of Punta Zambrone, located on the Tropea promontory (Pike 2021).

Both herding strategies – sedentary management and transhumant pastoralism – also entailed significant social and political dimensions. In the Po Plain, and particularly within the terramare cultural sphere, the predominant use of pastures in close proximity to settlements would have required stable inter-community agreements among neighbouring villages, aimed at preventing persistent conflict. The practice of transhumance, in turn, presupposed negotiated access to transit routes, ensuring their safe passage and protection from ambushes and raiding – activities that, as is well known, were widespread forms of warfare during protohistory.

A further aspect emerging from isotopic analyses is the possible seasonal integration of livestock diets with C4 plants, most likely millet. The use of this crop, attested in particular at the sites of Solarolo and Montarice, does not appear to be documented at Coppa Nevigata, thus confirming the limited role of millet in southern Italy during the Bronze Age. More broadly, the use of supplementary fodder alongside grazing points to specialised strategies of animal husbandry in relation to the local environmental resources and agricultural strategies underscoring the central role of pastoral activities within the subsistence economies of Bronze Age societies.

Regarding the second point, strontium isotope analyses have also revealed the presence of non-local individuals in contexts such as Solarolo and Coppa Nevigata, which are otherwise characterized by predominantly sedentary herding practices (Cavazzuti *et al.* in this volume). Specifically, a sheep and a pig at Solarolo, and a goat at Coppa Nevigata, have been identified as non-local, the latter displaying an isotopic signature indicative of a provenance from a very distant area, possibly the Alps. Supporting the hypothesis that the presence of non-local individuals was not an isolated phenomenon, possible cases have also been identified in the Terramare of Montale and Baggiovara. At least one of the caprines from Montale, may have originated outside the local area, a possibility that could extend to a second individual; both belong to the early or middle phases of the Recent Bronze Age. In the nearby Terramara of Baggiovara, dated to the early phases of the Middle Bronze Age, a caprine exhibits an isotopic signature significantly different from other samples, likewise suggesting a potential non-local origin (Sabatini *et al.* 2021).

Until recently, faunal assemblages were not considered a significant indicator of mobility; nevertheless, the presence of a few non-local individuals within herds largely composed of autochthonous animals must be interpreted in the context of human practices. Isotopic data applied to skeletal remains indeed confirm substantial human mobility during the Bronze Age, particularly in contexts of notable economic and socio-political importance, such as the necropolis of Scalvinetto, associated with the Terramara of Fondo Paviani (Cavazzuti *et al.* 2019; Cavazzuti, 2020).

Extensive archaeological evidence demonstrates the significance of medium- and long-distance trade during the Bronze Age. This period is well known for substantial and widespread mobility, primarily evidenced through trade networks linking the palatial and post-palatial societies of the Aegean with developed societies of the Eastern Mediterranean, as well as with Italy and Europe, for the procurement of raw materials and goods. The intensity of these contacts and the importance of Italy within this highly dynamic network of exchange is highlighted by the occurrence of large quantities of imported Aegean pottery from the Middle Bronze Age onwards at several Italian sites, as well as the local production of Italo-Mycenaean vessels from the late 14th century BCE onwards (Jones *et al*. 2014). Major centres actively involved in international exchange developed along the coasts and inland (Bettelli 2002; Cazzella and Recchia 2018; Jung 2021; Peroni 2004), among which Coppa Nevigata. During the subsequent phase of the Final Bronze Age, the site of Frattesina emerged in the Po River delta as an international centre of fundamental importance for specialised production and for exchange networks linking Europe, Southern Italy, Aegean and the Eastern Mediterranean (Bietti Sestieri, Bellintani and Giardino 2019; Cardarelli 2021).

The identification, through aDNA analysis, of a pig belonging to an Italic haplogroup at Tiryns in a Late IIIC context (late 12th-11th centuries BC) demonstrates that long-distance mobility could also involve domesticated animals (Meiri *et al.* 2019), as has been hypothesized for a goat that may have reached Coppa Nevigata from the Alps (Cavazzuti *et al.* in this volume).

While activities related to economic trade, matrimonial exchanges, population transfers, or gift-giving intended to consolidate alliances and foster goodwill appear to be probable motivations for the movement of livestock, it cannot be excluded that some of these transfers aimed to introduce new external individuals in order to increase the genetic variability of herds or flocks. The acquisition of non-local animals may also have been driven by raiding activities, which were certainly practiced during protohistory.

As for the third point, the use of secondary products derived from animal husbandry during prehistory is well attested. Depictions of ploughing scenes are known in Italy as early as the Copper Age, while the earliest wooden plough comes from the pile-dwelling settlement of Lavagnone and is dated to an early phase of the Early Bronze Age. The use of this implement was likely widespread; however, being made of wood, preservation of these items is limited.

Within the periods and regions considered by the HERDS project, ploughs are well documented in the terramare context. Evidence includes the remains recovered from the votive basin of the Terramara of Noceto (Parma), datable to the second half of the 15th century BCE, as well as various objects interpreted as small ploughs or plough components from other terramara sites (Bernabò Brea and Cremaschi 2009; Cremaschi *et al.* 2021; Forni 1997; Cardarelli 2004).

Another production likely highly developed was that of wool. Direct evidence of textiles is rare, as these materials are highly perishable. Most textile and thread remains in Italy come from pile-dwelling contexts, where particular environmental conditions allowed for their partial preservation (Bazzanella and Mayr 2009). Within the chronological and geographic scope of the HERDS project, fragments of wool textiles are attested, for example, at the Terramara of Castione dei Marchesi (Parma), but more frequently such activities are documented indirectly through spindle whorls and loom weights. It is plausible that specialised production of threads and textiles existed during the Bronze Age. This hypothesis is supported by the exceptionally high number of spindle whorls recovered from the Terramara of Montale (4,636 specimens), predominantly datable to the Middle Bronze Age 2-3, as well as by evidence potentially related to the production of purple-dyed textiles or threads at Coppa Nevigata (Minniti and Recchia 2018; Sabatini-Earle-Cardarelli 2018). As has been recently suggested, the wool-based economy may have played a significant role and represented one of the commodities intended for exchange (Sabatini 2020; 2024).

A particularly important aspect of the exploitation of secondary products concerns dairy production, which may have represented a strategic resource within subsistence economies. It is currently thought that in Europe milk was processed in ceramic containers as early as the Early Neolithic, likely with the aim of producing lactose-reduced or lactose-free dairy products.

For the period and region considered by the HERDS project, a specific study was conducted on specific ceramic vessels and their associated lids, long thought to be connected with dairy production (Puglisi 1959). The results of this study (Avella *et al.* in this volume) demonstrated, through organic residue analysis, the extensive use of these so-called *milk boilers* as tools for dairy processing, probably at least in part involving sheep or goat milk.

Finally, regarding point four, one of the most ambitious aims of the HERDS project was the genetic identification and characterisation of domestic species (caprines, cattle, and pigs) in terms of mitochondrial haplogroups, assessing their temporal and spatial distribution (Makarova *et al.* in this volume). Biometric differences previously identified (Cianfoni *et al.* in this volume) suggested a variability that could also be explored genetically.

However, the research was considerably constrained by preservation issues, particularly regarding the condition required for the extraction of ancient DNA (aDNA) from many of the samples.

Following a low-coverage sequencing screening, mitochondrial coverage within the dataset is currently limited, and haplogroup assignment was possible for only a small proportion of the samples analysed.

The five Ovis aries samples from Frattesina, San Michele di Valestra and Montarice were assigned to haplogroup B, known from both modern and ancient European sheep. One Capra hircus sample from Coppa Nevigata was assigned to haplogroup A, widely distributed among modern and ancient European goat populations. The pig sample from Montarice was assigned to haplogroup A, present in Europe since prehistory. Among the Bos taurus, three specimens from Frattesina, Montarice and Moscosi di Cingoli were assigned to haplogroup T, dominant within European cattle populations (Makarova *et al,* in this volume).

Future analyses incorporating deep sequencing and targeted enrichment of the mitochondrial genome are expected to significantly increase the number of haplogroup assignments, enabling more detailed interpretations of the genetic variability of domestic species in Italy during prehistory. These developments are currently underway and constitute a continuation of the HERDS project.

Several concluding remarks may be offered as a provisional assessment of the research carried out within the HERDS project. For the first time in Italy, collaboration between multiple research units has enabled the application of an integrated set of multidisciplinary analyses to faunal remains of the principal domestic species exploited during protohistory. Taken together, these approaches have significantly expanded our understanding of primary production, exchange, and mobility in Bronze and Early Iron Age societies. From this perspective, the archaeozoological record – often represented by substantial assemblages in protohistoric contexts – has demonstrated considerable interpretative potential, in line with the objectives of the HERDS project.

The decision to frame the research across a broad chronological span and an extensive geographical area has, however, introduced certain constraints. These relate in particular to the number of samples analysed for each context and, with regard to ancient DNA analyses, to issues of preservation. At the same time, this approach has made it possible to generate datasets that collectively outline both shared trends in herding strategies and variability in livestock management practices. Such differences may be related to the orographic diversity of the Italian peninsula and to the range of socio-economic configurations associated with different chronological and cultural contexts. The HERDS project therefore represents a significant advance in our understanding of the historical processes that shaped protohistoric societies in Italy.

From a methodological perspective, the project has enabled the application of innovative approaches and the assessment of their interpretative potential, providing important guidance for future multidisciplinary research on faunal remains. It is likely that such studies will be further stimulated by the results achieved within the framework of the HERDS project.

Overall, the results obtained confirm the success of the project, which represents a substantial collaborative and multidisciplinary effort involving a large number of researchers, including many early-career scholars.

This research, however, does not conclude with the present publication. Additional data are currently under analysis and will form the basis of forthcoming contributions.

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# II

# CASE STUDIES INCLUDED IN THE HERDS PROJECT

HERDS – Animal Husbandry and its Economic Role in the Development of Central Mediterranean Protohistoric Societies – Rivista di Scienze Preistoriche – LXXVI S6 – 2026 – pp. 203-204

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# The Archaeological Contexts of the Herds Project

A brief description has been prepared of the contexts from which the samples used in the HERDS project derive. Exceptions are the contexts of Monte Croce Guardia (Arcevia, AN), Moscosi di Cingoli – Piano di Fonte Marcosa (Macerata), and Villaggio delle Macine – Lake Albano (Rome), for which a basic bibliography is provided.

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# Frattesina (Fratta Polesine, Rovigo). A Centre of Specialised Craft Production and International Exchange near the Po River Delta

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The settlement of Frattesina, near Fratta Polesine (Rovigo), was located on the southern bank of an ancient branch of the River Po, known as the Po di Adria, approximately 30-40 km from the Adriatic coast. The considerable width of the fluvial channel suggests that the site could have been accessed by boats coming from the Adriatic Sea via the Po delta system.

The site was discovered in 1967 by members of the *Centro Polesano di Studi Storici, Archeologici ed Etnografici* (CPSSAE), following agricultural land levelling works (Bellintani-Peretto-Peretto 1968). From the earliest surface collections and trial excavations, the exceptional nature of the site became apparent. It dates to the final phase of the Bronze Age and is characterised by a remarkably high concentration of specialised craft production. Subsequent investigations conducted under the direction of Anna Maria Bietti Sestieri between 1974 and 1989 confirmed the importance of the site, which has been interpreted as an international centre of production and exchange, chronologically spanning the later phase of the Recent Bronze Age and the beginning of the Early Iron Age, with its main phase of settlement expansion and productive activity during the Final Bronze Age (Bietti Sestieri-Bellintani-Giardino 2019).

From the late 1970s onwards, two cemeteries located in the immediate vicinity of the settlement were identified. To the north, beyond the ancient branch of the Po di Adria, lies the Narde necropolis. Excavations have revealed two burial clusters (Narde I and Narde II), and approximately 900 graves are now known, almost all dating to the Final Bronze Age, with a small number possibly attributable to the very early phase of the Early Iron Age (Salzani 1989; 1990/91; Salzani and Colonna 2010; Cardarelli *et al.* 2015; Cavazzuti *et al.* 2019). The second cemetery was identified to the south of the settlement, at Fondo Zanotto, and has yielded around 150 burials dating between the Final Bronze Age – predominantly its later phase – and the Early Iron Age (De Min1984; 1986; Bovio 2023-24).

More recent survey and stratigraphic investigations within the settlement area (Baldo-Balista-Bellintani 2018) have identified evidence for the internal organisation of the site, which appears to have been structured by a network of canals oriented roughly west-east and south-north. On this basis, the settlement has been estimated to have covered an area of approximately 20 hectares. These canals were in use until phase 2 of the settlement (corresponding to a middle stage of the Final Bronze Age), after which they were progressively abandoned. The latest evidence for occupation may date to the very beginning of the Early Iron Age.

Since 2022, a new research programme has been underway within the project *Prima Europa. The Pro-*

Fig. 1 – Frattesina: excavation area at the end of the 2023 field season. In the upper part of the image, the floor surface of Structure 2 can be seen, interpreted as a probable dwelling (c. 80 m²).

*Frattesina: l'area di scavo alla fine della campagna 2023. In alto si può notare in chiaro la pavimentazione della struttura 2 attribuita ad una probabile abitazione (circa 80 m²).*

Fig. 2 – Frattesina: discovery of a small hoard during the 2022 excavation season.

*Frattesina: il rinvenimento del piccolo ripostiglio durante la campagna di scavo 2022.*

*tohistory of the Polesine*, made possible by funding from the Fondazione Cassa di Risparmio di Padova e Rovigo (CARIPARO) and coordinated by the *Soprintendenza ABAP* of Verona, Rovigo and Vicenza. The investigations have produced a substantial body of new data. In particular, geomagnetic prospection surveys have been carried out by Prof. Wieke de Neef of the University of Bamberg. These investigations have confirmed and refined previous hypotheses (Baldo-Balista-Bellintani 2018), significantly enhancing our understanding of the organisation of the settlement.

Overall, the site is estimated to have extended over at least 25 hectares, as geophysical anomalies appear to continue beneath the eastern outskirts of the modern village of Fratta Polesine. To the north, the settlement was bounded by the course of the Po di Adria, while to the south several canals are visible both in aerial imagery and geophysical data. One of these, the canal closest to the settlement area, was investigated through excavation, revealing a substantial artificial ditch and an associated embankment that delimited and flanked the settlement on this side.

Internally, the settlement appears to have been traversed by a network of canals arranged in a broadly orthogonal pattern, oriented west-east and south-north. Within the blocks defined by this network, numerous traces of dwellings and production facilities are visible, organised according to a relatively regular layout. In some areas, the settlement extended directly to the riverbank. Two extensive areas between the main settlement core and the river are devoid of residential and productive structures and may have been used for animal penning or for cultivation requiring greater control and management.

Excavations carried out between 2022 and 2024 have revealed several structures attributable to the phase following the infilling of the canals and therefore datable to a mature or late stage of Final Bronze Age 2, corresponding in absolute chronology to the 11th century BC. Two large rectangular structures, most likely interpretable as dwellings, have been identified. The larger covers an area of approximately 80 m², while the smaller measures just over 40 m². At present, it cannot be determined with certainty whether the two structures are contemporary or exhibit a slight chronological difference.

Between these two structures, an exceptionally well-preserved furnace was uncovered, most probably attributable to primary glass production. Immediately north of the larger structure, evidence of amber working was also identified, and nearby a series of quadrangular beaten-floor surfaces, plausibly interpreted as working areas or productive yards, were documented.

From the uppermost levels come two further significant finds: a small hoard of bronze objects, consisting of fragmented artefacts and portions of ingots – the only such deposit so far identified in stratified context – and a ritual burial of a neonatal equid.

The underlying strata, pertaining to earlier phases and at least partially contemporary with the functioning of the canal system, have not yet been investigated. However, a trench was opened through the fill deposits of one of the west-east oriented canals in order to establish the stratigraphic sequence and to collect samples for micromorphological and archaeobotanical analyses, conducted by the Geodap team directed by Prof. Cristiano Nicosia of the Department of Geosciences, University of Padua.

The subsistence economy was based on a rich and diversified agriculture, centred primarily on barley and emmer wheat, supplemented by millet and several pulses, including broad bean and lentils (Delle Donne, Costantini 2019). Animal husbandry played a fundamental role. The overwhelmingly dominant species were pigs, followed by cattle and caprovines. Horse and donkey are also attested among the domesticates. Hunting was practised with a certain frequency and focused mainly on deer and wild boar, as well as roe deer and fauna typical of riverine and wetland environments, such as beaver, otter and waterfowl. Fishing was of particular importance, as evidenced by the recovery of fish hooks, some of considerable size, and was directed mainly at tench, pike and sturgeon (De Grossi Mazzorin 2019; Cianfoni *et al.*, this volume).

At the current state of research, Frattesina represents the most important known production and exchange centre in the central Mediterranean during the Late Bronze Age. Its strategic location near the Po delta was ideally suited to mediating exchanges between the central Alpine region, the Adriatic and Ionian coasts, the Aegean and the eastern Mediterranean. The raw materials reaching Frattesina were further employed in a flourishing and highly diversified craft production. Metallurgical activity certainly involved the arrival of ingots in the form of plano-convex and pick-shaped ingots, obtained predominantly from copper of Trentino origin (Artioli *et al.* 2016; 2020; Villa and Giardino 2019).

Metallurgical activity was of major importance and was certainly not limited to local consumption, as demonstrated by the numerous casting moulds (Le Freve-Lehöreff 1992), the five smithing hoards recovered from the settlement, consisting of hundreds of bronze objects intended for remelting (Bellintani-Cardarelli-Lago 2024), as well as the large quantity of finished artefacts recovered through excavation and surface survey.

Another imported "exotic" product was Baltic amber, which reached the Polesine area in the form of semi-processed blocks through a dense exchange network extending from northern Europe to the Po valley. There, it was refined and most likely re-exported. Significant evidence for amber working is also known from Campestrin, a few kilometres east of Frattesina, along the same branch of the Po di Adria. This context is dated to the transition between the Late Bronze Age and the beginning of the Final Bronze Age, but evidence for amber working – particularly for beads of Tiryns and Allumiere types (Angelini 2019a; Bellintani *et al.* 2021; Cwaliński 2023) – is now also documented at Frattesina, especially during the central phase of the Final Bronze Age.

From the eastern Mediterranean further raw materials were also imported, including elephant ivory, used for the production of personal items (such as combs) and weaving implements (Bettelli and Damiani 2005; Borgna 2003), as well as ostrich eggshells, mainly employed in the manufacture of necklace elements (Angelini 2019b). The specialised working of hard animal materials is further evidenced by numerous artefacts made from red deer antler, in this case of local origin.

Technologies were also transmitted from the eastern Mediterranean and subsequently reworked at Frattesina. Alongside locally produced Aegean-type pottery (Jones *et al.* 2014), the site has yielded evidence of a highly developed glass production industry. Thousands of coloured glass beads have been recovered, often bicoloured, together with "experimental" products such as ceramic fragments decorated with applied blue glass and white glass droplets. The recipe used for the production of these beads, manufactured in exceptionally large quantities, was local and likely derived from the adaptation of technological traditions originating in the eastern Mediterranean (Henderson 2019; Bellintani and Angelini 2020).

A substantial proportion of these luxury productions is represented in the celebrated "hoard" of Frattesina, consisting of a Kurd-type situla containing fibulae, pins and other bronze objects, Tiryns- and Allumiere-type amber beads, glass beads and perforated ostrich eggshell discs used in necklaces, as well as combs and so-called "alamari" or weaving implements in elephant ivory (Bellintani-Cardarelli-Lago 2024).

The territory of the middle Polesine, within which Frattesina is located, had been occupied in earlier centuries; however, it is only from the end of the Recent Bronze Age and especially during the Final Bronze Age that this area assumed a pivotal role, developing into a highly structured economic and political system. This growth appears to have followed the collapse of the Terramare system, which during the Middle and Recent Bronze Age (1650-1150 BC) had dominated the central Po plain.

In particular, from the $14^{th}$ century BC onwards, the polity of the Valli Grandi Veronesi emerged to the west of the Polesine, within which the site of Fondo Paviani appears to have played a leading role. For a long period, this region was able to intercept flows of raw materials and goods (metals, amber, textiles, and others), which were then redistributed to the numerous villages of the Terramare area or exported from them. With the collapse of the Terramare system at the end of the Recent Bronze Age (Cardarelli 2009), this extensive and widespread "market" disappeared, leading also to the decline of the Valli Grandi Veronesi polity (Cupitò and Leonardi 2015).

Within this historical framework, particularly significant is the evidence provided by strontium isotope analyses conducted on the Narde I necropolis, specifically on an individual buried with a sword, dating to an early phase of the cemetery and attributable to the site's elite (grave 168). This individual appears to have spent his childhood in an area compatible with the isotopic baseline of the Fondo Paviani site (Cavazzuti *et al.* 2019).

In the Polesine region, other Final Bronze Age contexts are also known, in particular the large centre of Villamarzana, which together with Frattesina played a key role in this area as part of an advanced economic, social and political system, characterised by substantial population density, economic prosperity, openness to international exchange networks, and highly specialised craft production (Cupitò-Dalla Longa-Balista 2020; Cardarelli 2021).

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# The Terramara Santa Rosa di Poviglio: Main Archaeological Features and Environmental Context

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## 1. Premise

The excavations at the Terramara Santa Rosa (Fodico di Poviglio – RE) began in 1984 as part of an emergency archaeology operation, which was soon transformed into a long-term project.
From the outset, the project aimed to explore the site extensively, with particular focus on structural remains, to assess how closely the model defined in nineteenth-century studies (Chierici 1871) corresponded to the actual organization of the settlement. More than forty years of excavation have revealed both confirmations and significant departures from that model, particularly regarding its critical elements: settlement shape, buildings, ditches, and embankments.

## 2. The shape of the site

The observation of aerial photography (Cremaschi 2004) and more recently the interpretation of geophysical data (Mele *et al.* 2013) indicate that the terramara has a complex shape that cannot be reduced to a simple model (fig. 1). It consists of two settlements: the *Villaggio Piccolo* (VP, in Italian Small Village), quadrangular in shape with a crescent-shaped extension on the eastern side, and the *Villaggio Grande* (VG, in Italian Large Village), trapezoidal in plan. Aerial photographs of the ploughed area highlight, around the VP and along the southern margin of the VG, the traces of the perimeter embankments, visible as light-colored features against the darker soil of the field.

## 3. Buildings

The VP, covering approximately 1 hectare, represents the earliest part of the settlement, dating to the Middle Bronze Age (MBA2) (Bernabò Brea and Cremaschi 2004). It was enclosed by a wooden palisade and, within it, thousands of postholes have been uncovered, testifying to buildings raised on wooden platforms that were rebuilt several times. These alternate with rectangular baked-earth floors laid directly on the ground and with storage pits intended for the preservation of food supplies (Bernabò Brea and Cremaschi 2004). The stratigraphy of the VP was heavily damaged by nineteenth-century topsoil quarrying, and evidence of later occupation phases up to the Recent Bronze Age (RBA) has been found only inside the ditch surrounding the settlement.
The VG, extending over 5 hectares, represents the expansion of the site beginning in the final phase of MBA3 (fig. 2). The identified domestic structures, all built on platforms, are rectangular and appear larger and better defined than those of the VP. Within their perimeter there is a regular distribution of characteristic "ash mounds" (Bernabò Brea and Cremaschi 1997; Bernabò Brea-Cremaschi-Pizzi 2003), deposited by gravity on dry ground. Their physical-chemical and microscopic characteristics exclude the presence of standing water beneath the platforms, contrary to what nineteenth-century scholars had suggested (Bernabò Brea and Cremaschi 2004). The buildings are organized into sectors separated by roads running alongside them and separating them from the palisade


Fig. 1 – Terramara di Santa Rosa. Geophysical survey superimposed on a satellite image; the grayscale represents electrical resistivity, highlighting the morphology of the settlement (1 – VP; 2 – VG). Note the traces of the ditches, which are particularly evident between the two villages and to the east of VG.

*Terramara di Santa Rosa. Il rilievo geofisico sovrapposto all'immagine satellitare; i toni di grigio indicano la resistività elettrica che mette in luce la forma dell'abitato (1 – VP; 2 – VG). Si osservano le tracce dei fossati particolarmente evidenti tra i due villaggi e ad est del VG.*

surrounding the village (Cremaschi and Pizzi 2021); these roads exited the settlement through structured gateways (fig. 2).
In this phase, which dates to RBA1 (Bernabò Brea and Cremaschi 1997a), the Terramara had the structure and organization of a pile-dwelling settlement, but unlike true pile dwellings it was built on dry ground (Bernabò Brea and Cremaschi 1997b). In an advanced phase of RBA2, the remains of the platform houses were sealed by extensive earthen deposits upon which the structures of the final occupation phase were built. These consist of elongated concentrations of fragments of fired daub bearing the impressions of the elements they originally covered, arranged orthogonally. Such evidence probably indicates buildings constructed on beams laid directly on the ground, thus representing a markedly different building technique from the earlier one (Bianchi 2004).

## 4. Ditches

Both villages were surrounded by ditches. The ditch of the VP, explored in the stretch between the two villages, is the deeper one, reaching four meters below the topographic surface. Its infilling, deposited over the entire lifespan of the site (MBA2-RBA2), consists at the base of laminated silts interbedded with diatom layers, indicating the persistence of relatively deep water; toward the top, in RBA2, clays prevail, testifying to a marshy environment. These sediments allowed excellent pollen preservation, and their study has provided an important contribution to reconstructing the site's environmental context (Cremaschi *et al.* 2016).
The situation along the margin of the VG is markedly different (Cremaschi, Pizzi eds. 2021). A ditch, active from RBA1 onward, received a canal, which represents the archaeological evidence of the so-called "canale incile" (canal connecting to a natural river channel) theorized by nineteenth-century palaeoethnologists (Pigorini 1889). The canal was probably connected to a palaeochannel perhaps more than 1 km away, from which it derived its water. It measured 4 m in width and 2 m in depth, had a V-shaped section with stepped, terraced sides to ensure stability, and narrowed at its confluence with the ditch, where it had a flat bottom forming a regulating device to better control water flow.
Water supply to the ditch did not rely solely on the canal but also on large wells distributed along the village margin. Drawing from sandy aquifers in the substratum at depths of more than three meters, these functioned as artesian wells, bringing groundwater to the surface (Cremaschi and Pizzi 2006). Through a network of small channels, this water was conveyed not into the village, as might be expected, but into the ditch. It was therefore essential that the ditch be constantly supplied, not only for defensive purposes but also to make water available, for example, for watering livestock, which could descend into the ditch from its gently sloping outer bank.
The situation changed radically in RBA2, together with the reorganization of the entire settlement and the construction of the VP embankment. The ditch and the feeder canal were both affected by a major flood event that filled them with sediment. The canal was abandoned, and only the ditch was restored, but it no longer carried flowing water. Water was instead obtained by digging numerous wells into the ditch bottom to reach an aquifer located five meters below the ancient topographic surface, more than two meters lower than that tapped by the marginal wells. Thus, in the time interval between the excavation of the marginal wells and those in the ditch bottom (RBA1-RBA2), a significant lowering of the water table is documented. This represents the local manifestation of the aridity episode which, based on chronological overlap, may have contributed to the crisis of the terramara system (Cremaschi *et al.* 2006).

## 5. Embankments

Contrary to what was assumed in the nineteenth-century model, the embankments did not belong to the original architectural plan but were constructed during the final phase of the site. Although contemporary, the embankments of the two villages differ markedly (fig. 3). That of the VG is limited to part of the perimeter and, despite its considerable width, has a thickness of only a few decimeters; it was never put into use and was probably an unfinished work. By contrast, the embankment of the VP surrounds its entire perimeter and has a thickness of about one meter. Its width is around twenty meters, but along the eastern margin it widens to form a large crescent-shaped platform. The embankments involve substantial volumes: a conservative estimate attributes 3,650 $m^3$ to that of the VG, 8,100 $m^3$ to that of the VP, and at least 3,000 $m^3$ to the platform. Their construction therefore required a considerable investment of labour and time to provide at least part of the site with massive defensive structures. It is significant that they were built only in RBA2, toward the end of the terramara's history, when, presumably due to declining resources, competition among neighbouring villages may have increased (Cremaschi and Pizzi 2021). On the other hand, the difference between the two villages (the well-defended VP and the poorly defended VG) could also be interpreted as the beginning of differentiation within the community inhabiting the site, and thus as an evolution toward more complex social models.

## 6. Environment and fauna

From the onset of investigation, the excavation adopted a multidisciplinary approach: archaeological

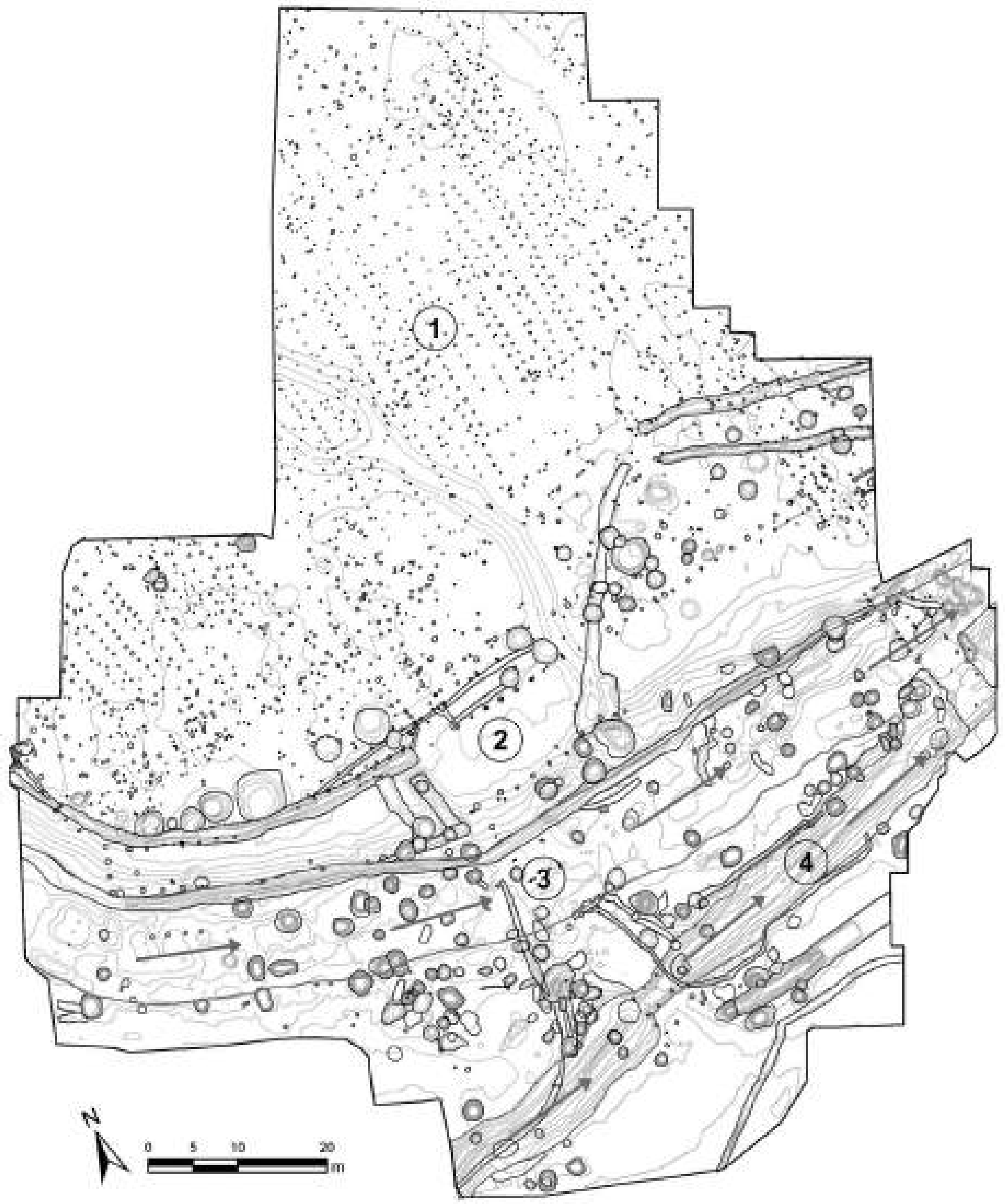


Fig. 2 – Terramara di Santa Rosa. Excavation area at the edge of VG. (1) Building area: postholes defining rectangular structures and the roadways delineating them. (2) Enclosure area: postholes of the enclosure surrounding the village, gate-related structures, and the roads passing through them. The well openings and their connecting channels are also shown. (3) Ditch with associated channels and wells excavated within it. (4) Intake channel (canale incile), wells, and associated channels. Arrows indicate the direction of drainage; contour lines at the excavation base are shown at 10 cm intervals.

*Terramara di Santa Rosa. L'area dello scavo al margine del VG. 1) Area degli edifici: sono rappresentate le buche di palo, che definiscono edifici rettangolari, e le strade che li delimitano. 2) Area della recinzione: sono rappresentate le buche di palo della recinzione che delimita il villaggio, le strutture relative alle porte ed alle strade che le attraversano; sono inoltre rappresentati gli imbocchi dei pozzi e le canalette che li collegano. 3) Fossato e canalette ad esso connesse e pozzi scavati al suo interno. 4) Canale incile, pozzi e canalette connessi. Le frecce indicano la direzione del drenaggio; sono indicate le curve di livello della base dello scavo con equidistanza 10 cm.*

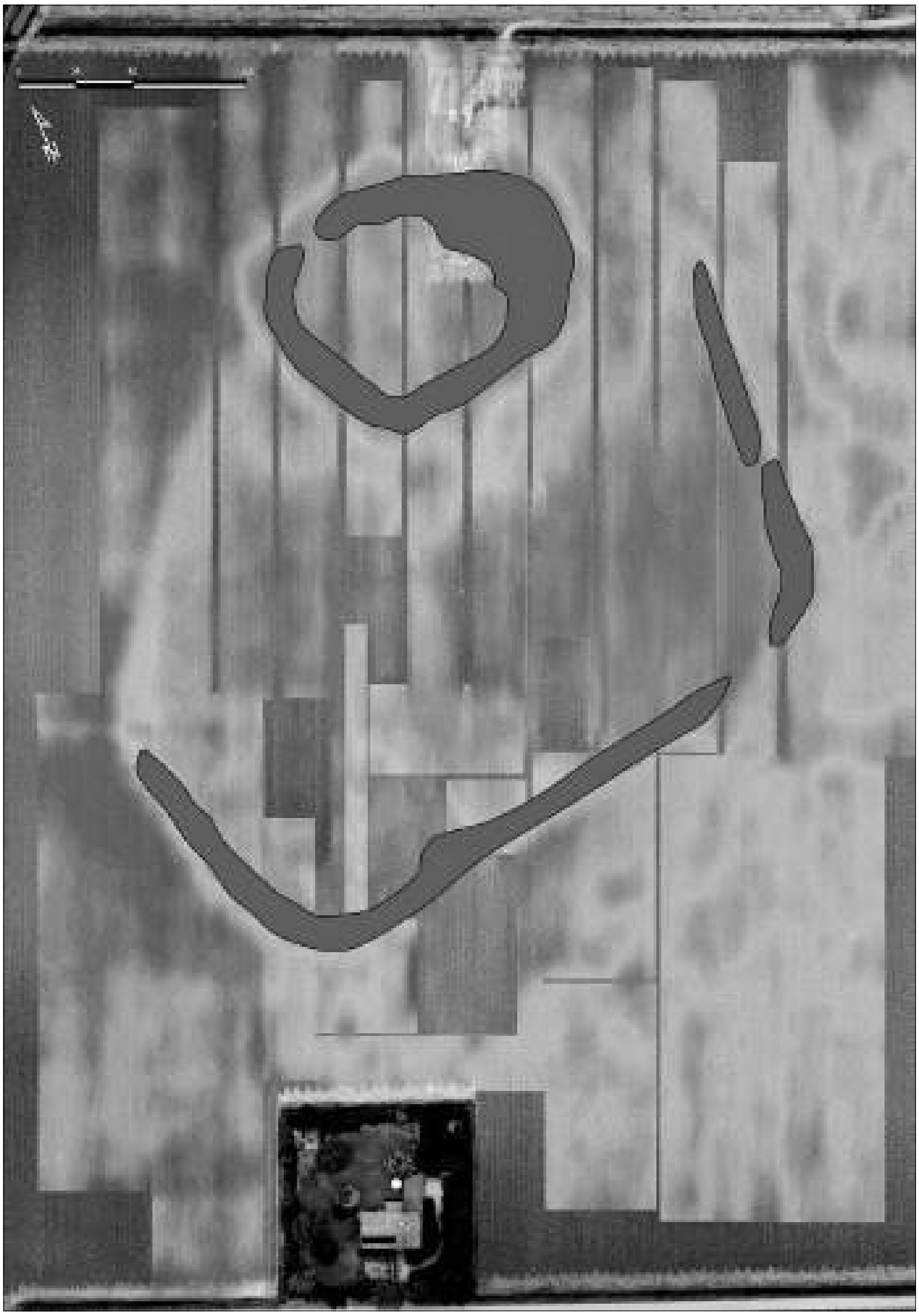

Fig. 3 – Terramara di Santa Rosa. Planimetric map of the embankments superimposed on the geophysical survey of the Terramara.

*Terramara di Santa Rosa. Planimetria dei terrapieni sovrapposta al rilievo geofisico della Terramara.*

investigation and the study of material culture were accompanied by natural science research, especially archaeobotany and zooarchaeology, thus reconnecting with the method inaugurated by nineteenth-century palaeoethnologists. These studies have led to a substantial advancement in knowledge concerning both the environment surrounding the Terramara Santa Rosa and the ways in which human communities exploited it. Moreover, the extent and level of detail with which research has been conducted at the Santa Rosa site have, for the first time, made it possible to fully understand the relationship between the terramara villages, the surrounding environment, and the exploitation of natural resources.

Pollen spectra (Ravazzi *et al.* 2004; Cremaschi *et al.* 2016), derived mainly from ditch sediments, indicate that the area surrounding the terramara was heavily deforested from the outset and that the remaining woodland was managed, including through coppicing practices. The cleared areas were subject to intensive cultivation, especially of cereals, but fruit trees and probably grapevine were also cultivated (Mercuri *et al.* 2021). Cultivated soils were periodically converted to pasture in rotation with crops to restore nutrients. Uncultivated areas expanded toward the end of the period, within a broader context of increasing aridity that saw the reduction of wet environments and the adoption of less demanding cereal varieties.

The importance of herding is also highlighted by the high incidence of sheep and goats in the faunal assemblages, already in the basal layers of the VP (Riedel 2004) and also in the later phases of the VG and the adjacent ditch (Maini 2021), with a tendency to increase in the most recent phases, likely in response to increasingly arid conditions. In addition to pastoralism, cattle and pig husbandry (used both as labour force and food resources) remained important throughout the life of the settlement, while wild fauna, although present, played a marginal role.

The faunal assemblages currently under study within the framework of the Herds Project significantly enrich the previously known sample, as they derive from a recently explored area (2013-2026) located along the margin of the VP and the adjacent VG and spanning the entire chronological sequence of the terramara.

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HERDS – Animal Husbandry and its Economic Role in the Development of Central Mediterranean Protohistoric Societies – Rivista di Scienze Preistoriche – LXXVI S6 – 2026 – pp. 217-221

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# The Protohistoric Settlement at San Michele di Valestra (Carpineti, Reggio Emilia): New Research 2017-2023

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## 1. Premise

The site of San Michele di Valestra (coordinates 44°27'08" N – 10°33'49" E) lies just east of the ridge of Monte Valestra (between 790 and 795 m a.s.l.), in a naturally defended, strongly elevated position. It was the subject of systematic investigations carried out by the Scientific Committee of the Italian Alpine Club (CAI) of Modena between 1965 and 1972 (Bertolani 1967; Bellodi *et al.* 1971, 1979). Based on the archaeological materials recovered at that time (Bronzoni 1967), the site was occupied from the Middle Bronze Age (MBA) through to the Final Bronze Age (FBA), and possibly beyond (Tirabassi 1979), with no apparent interruption in settlement. Located only a few dozen kilometers south of the Terramare area, it witnessed their collapse (Bernabò Brea *et al.* 1997) without being directly involved. It therefore represents a potentially significant case study for investigating the reasons why Bronze Age communities settled in the Apennines, unlike those of the Po Plain, were able to overcome the crisis (Cremaschi 1997).

## 2. The new excavation

Within the framework of the new research, two large trenches were opened along the margin of the area previously explored by the CAI of Modena, in the central part of the settlement (fig. 1), which lies on a structural terrace bounded upslope and downslope by essentially vertical rock scarps.

The base of the investigated archaeological deposit rests on a step (natural or artificial?) in the bedrock and is organized into two levels separated by a height difference of approximately three meters.

The lower level, overlooking the scarp that bounds the settlement to the south, was reached in the trench excavated during the 2018-2023 campaigns (fig. 2) and consists of debris and marls of the substratum. Resting upon this, is an accumulation of large, deliberately arranged stones forming a probable retaining structure at the edge of the settlement (SU 222). Adjacent to this structure are layers very rich in ash (SU 219) strongly cemented at their base, which appear to have been dispersed by trampling and contain ground-based features: small hearths and a large grinding stone. Together, they testify to activities carried out in proximity to a substantial combustion area that remained active for a long time. These layers are cut by postholes distributed across several levels, indicating superimposed phases of structure construction.

The upper level was reached at the base of the trench opened in 2017. The debris at its base forms a thin and extensive layer of medium-sized slabs (SU 41), very similar to one another and laid flat, among which three larger slabs stand out and may have had a structural function (e.g., as supports for wooden uprights). The overlying layers show continuity and similar characteristics in both trenches and consist of strongly anthropogenic deposits rich in charcoal, ash, and archaeological materials, partly reworked by colluvial processes, particularly evident in 2017 trench. Intercalated within these levels, at least three superimposed phases of post-setting were identified (SSUU 111-114 in trench

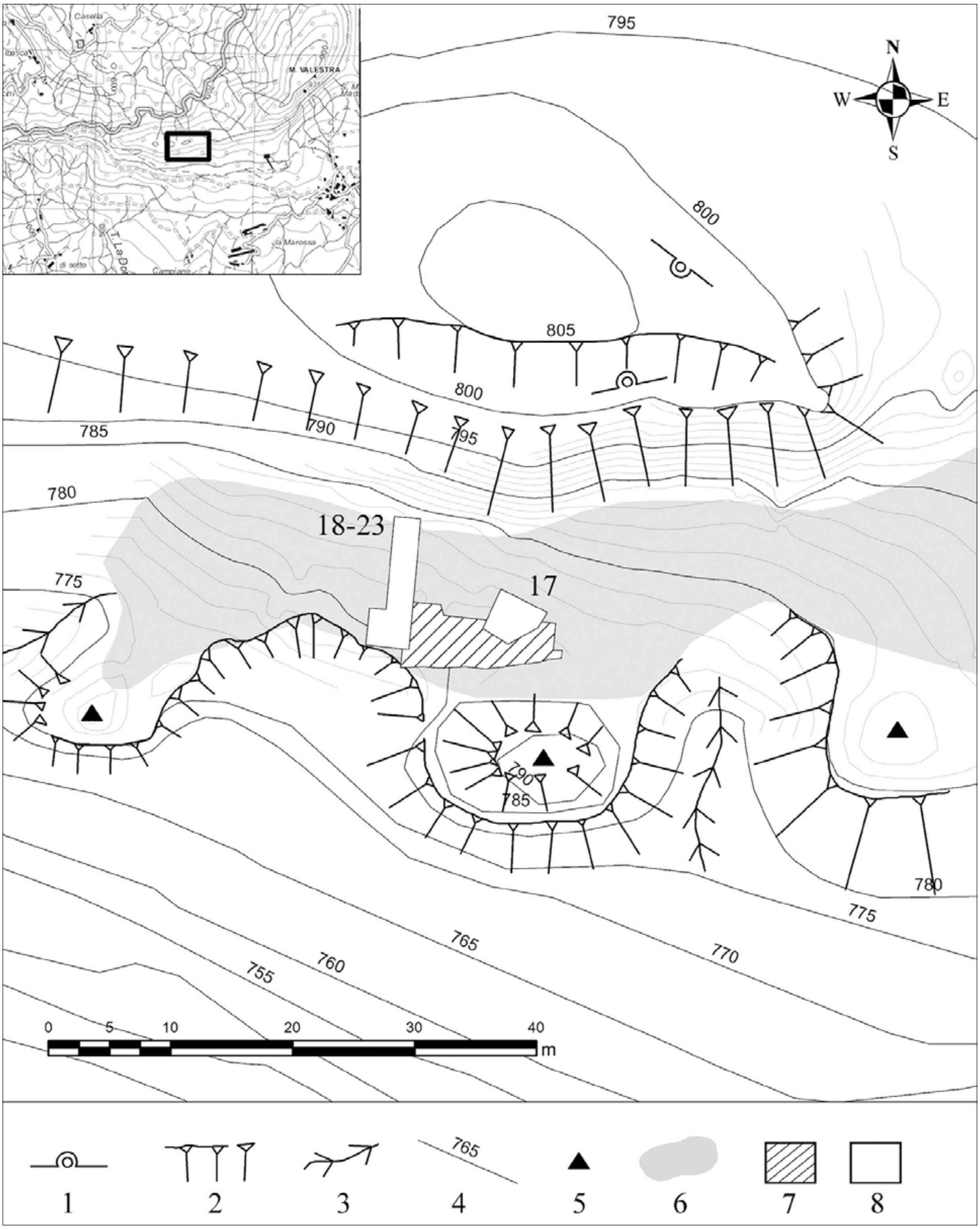


Fig. 1 – Site plan and topographic map of the excavation area. (1) San Michele Cave; (2) escarpments/steep slopes; (3) linear erosion furrows; (4) contour lines (m a.s.l.); (5) rock outcrops delimiting the site margin; (6) site area; (7) excavation conducted by the Scientific Committee of CAI Modena; (8) recent excavations: 17 (2017 trench), 18-23 (trenches excavated between 2018 and 2023).

*Planimetria e carta topografica dell'area di scavo. (1) Grotta di San Michele; (2) scarpate/pendii ripidi; (3) solchi lineari di erosione; (4) curve di livello (m s.l.m.); (5) affioramenti rocciosi che delimitano il margine del sito; (6) area del sito; (7) scavo condotto dal Comitato Scientifico del CAI Modena; (8) scavi recenti: 17 (trincea 2017), 18-23 (trincee scavate tra il 2018 e il 2023).*

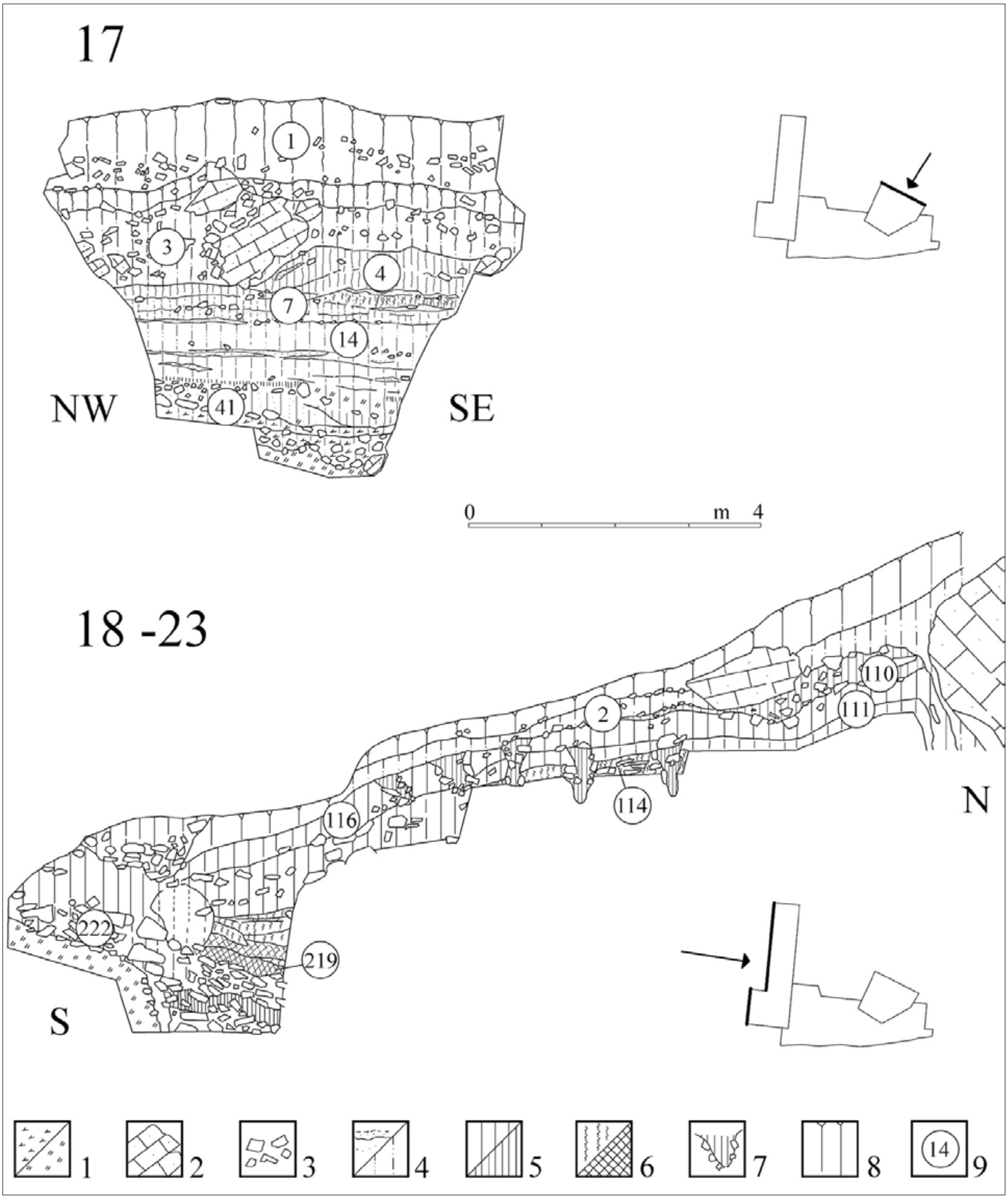


Fig. 2 – Schematic stratigraphic sections of the 2017 and 2018-2023 trenches. (1) Marls and marly substratum deposits; (2) collapsed boulders; (3) stones; (4) sandy deposits; (5) silty loam and organic silty loam; (6) ash-rich deposits and heavily cemented ash-rich deposits; (7) stone-wedged postholes; (8) topsoil; (9) main stratigraphic units (SU).

*Sezioni stratigrafiche schematiche delle trincee 2017 e 2018-2023. (1) Marne e depositi marnosi del substrato; (2) massi di crollo; (3) pietre; (4) depositi sabbiosi; (5) limo argilloso e limo argilloso organico; (6) depositi ricchi in ceneri e depositi ricchi in ceneri fortemente cementati; (7) buche di palo rincalzate con pietre; (8) suolo superficiale; (9) principali unità stratigrafiche (US).*

Fig. 3 – Photograph of trench 2018-2023. Detail of postholes wedged with sandstone slabs (SU 111).
*La trincea 2018-2023. Dettaglio delle buche di palo rincalzate con lastre di arenaria (US 111).*

2018-2023 and SU14 in trench 17/1). Unlike the earlier posts, these were not driven directly into the ground but set into pits and supported by wedges of large stone slabs. The posts are aligned perpendicular to the scarp delimiting the site, although, due to the limited extent of the excavated area, it has not been possible to establish the ground plan of the associated building. The overlying units (UUSS 4 and 111 in trenches 2017 and 2018-2023, respectively) show clear evidence of pedogenesis (humification of organic matter and leaching of carbonates), indicating prolonged geomorphological stability of the area.

At their top lies a major landslide caused by the collapse of the slope above the site, documented by the large boulders brought to light in both excavation areas (SU 3 in trench 2017 and SU 2 in trench 2018-2023). These were subsequently buried by slope deposits upon which the soil associated with the present-day topographic surface developed.

Recent radiocarbon dating on collagen indicates that the site was occupied, at a minimum, between (SU 219) 3258 ± 20 uncal BP (1535-1500 cal BC, 1 sigma) and (SU 7) 2870 ± 20 uncal BP (1056-1007 cal BC, 1 sigma). The archaeological material, currently under study by Angela Mutti, especially the ceramics, allows for a more detailed chronotypological framework.

From the upper slope deposits derive some fragments of combed pottery attributable to the Early Middle Ages, as well as Roman materials reported in the earlier CAI excavations, while there are no dating elements for the underlying landslide. The archaeological material recovered in the pedogenized deposits below the landslide (SSUU 4-14, trench 2017 and SU 110, trench 2018-2023), dates to the FBA. The underlying units (UUSS 20-40 in trench 2017 and UUSS 114-116 in trench 2018-2023) all contain materials from the Recent Bronze Age (RBA), including advanced phases, while the deepest part of this trench (UUSS 174-226) yielded earlier contexts ranging from MBA3 to the full MBA2. It should also be noted that in this part of the excavation, within the basal marly debris, a fragment of scale-decorated pottery was found, documenting occupation of the area during the Copper Age.

Geoarchaeological, archaeometric, and archaeological investigations are currently ongoing, together with archaeobotanical and archaeozoological analyses, including faunal samples studied by Elena Maini within the framework of the Herds project. While awaiting the completion of these studies and the full publication of the new excavations, some interpretative lines are already emerging concerning the relationship between environmental changes and human occupation.

## 3. Preliminary considerations

Occupation appears to have continued without interruption from MBA2 to FBA and, based on archaeological materials recovered during the Modena investigations, may have extended into the Protovillanovan period. There is, however, a marked difference in sedimentation mechanisms between the lower part of the sequence (MBA2-RBA materials), where colluvial processes dominate, and the upper part (FBA materials), where pedogenetic processes prevail. The former suggests a dynamic environment with open areas poorly protected by vegetation in the immediate vicinity of the site, whereas the latter seems to reflect a more dispersed settlement, or rather a situation of geomorphological stability and woodland regrowth.

This difference may be due to anthropogenic impact, more significant during the MBA – RBA and less intense during the subsequent FBA, but it may also have palaeoclimatic implications, indicating a cooler and wetter environment during the MBA – RBA, corresponding to the full Subboreal period (following the Loebben glacial advance), and subsequently a more temperate environment during the late Subboreal (Magny 1993, 2004). If the chronological framework proposed here is confirmed, the age of the landslide (post-Protovillanovian, pre-Roman) would coincide with the acceleration of landslide phenomena in the northern Apennines (Bertolini and Tellini 2001; Bertolini 2007) and fall within the Subatlantic period, which in this area is marked by a cold and humid climatic oscillation.

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# The Terramara of Baggiovara (Modena)

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The Terramara of Baggiovara, with an estimated extent of approximately 1 hectare, is located in the municipality of Modena, about 6 km south-west of the modern city centre. The site lies within a landscape characterised by a high density of terramare settlements, alongside smaller sites. Most of these consist of relatively small villages, generally ranging between 1 and 2 hectares in size. Many were abandoned during the Middle Bronze Age 2 (c. 1550-1450 BC), when the territory of the upper Modenese plain underwent a reorganisation marked by a more rational settlement pattern (Cardarelli 2009).

Excavations at the Terramara of Baggiovara, known since the 1990s, were initially undertaken as part of a rescue intervention prompted by the construction of an access road and cycle path leading to the Baggiovara Civil Hospital. Following a series of trial trenches in 2005, the first systematic excavations were carried out in 2009 by the cooperative AR/S Archeosistemi, under the direction of Giuliana Steffè and with the scientific collaboration of Andrea Cardarelli[1]. Further excavation campaigns were conducted in 2011 and 2013 by the Civic Archaeological and Ethnological Museum of Modena, in collaboration with the Department of Antiquities of Sapienza University of Rome[2].

The structural evidence recovered is currently under study. It includes refuse deposits and a substantial number of postholes, which cannot yet be confidently assigned to structures of defined form and size. The eastern edge of the settlement was marked by a ditch approximately 20 m wide, probably excavated by reusing a pre-existing watercourse. This feature, almost entirely infilled by post-abandonment deposits, was subsequently reused during the Roman period. A bank may have been present between the ditch and the inhabited area, although the evidence for this remains uncertain.

The archaeological assemblage is dominated by ceramic material and has been the subject of two undergraduate dissertations (Erbetti 2016/2017; 2020/2021). Lithic artefacts were also recovered, including small flint arrowheads – generally with concave bases – and sickle elements, bronze ornaments (fig.1) and antler tools (Epifani 2013) are also attested, some of which show evidence of manufacture (fig 2). One specimen bears cut marks produced by a toothed implement, possibly indicating the use of a tool comparable in function to a saw, although such implements are otherwise mainly documented in later phases of the Bronze Age (Ruggiero 2013).

From a chronological perspective, the data confirm earlier interpretations (Cardarelli 2013). Three principal phases of occupation have been identified: the earliest dates to an advanced stage of the Middle Bronze Age 1,

[1] Giuliana Steffè: Archaeological Superintendency of Emilia-Romagna; Andrea Cardarelli: Civic Archaeological and Ethnological Museum of Modena and the University of Modena and Reggio Emilia.

[2] The excavations were conducted under an official excavation concession, with scientific direction by Andrea Cardarelli and fieldwork coordinated by Andrea Di Renzoni, Cristiano Iaia, Gianluca Pellacani and Cristiana Zanasi.


Fig. 1 – Terramara of Baggiovara, 2011 excavation. Double-spiral pendant.

*Terramara di Baggiovara, scavo 2011. Pendaglio a doppia spirale.*

Fig. 2 – Terramara of Baggiovara, 2011 excavation. Small plough or dibble fashioned from the tine of a red deer antler.

*Terramara di Baggiovara, scavo 2011. Piccolo aratro o zappetta in palco di cervo.*

while the subsequent phases belong to the initial stages of the Middle Bronze Age 2. This framework is supported by radiocarbon determinations: for Phase 1, calibrated dates range between 1668-1532 BC (68.3% probability) and 1736-1506 BC (95.4% probability), while for Phases 2 and 3, dates fall within the ranges 1616-1516 BC (68.3% probability) and 1730-1457 BC (95.4% probability)[3]. Overall, the ceramic assemblage from Baggiovara is of considerable importance for reconstructing the chronological sequence of the early terramare and for understanding settlement dynamics in the Po Plain at the onset of the Middle Bronze Age (Erbetti 2024).

Palynological analyses indicate that the settlement was located within a moderately wooded environment, consistent with current knowledge of the terramare region during the Middle Bronze Age. Cultivation was primarily based on cereals, and arable fields may have been situated at some distance from the site. Pastoral activities are also well attested (Montecchi *et al.* 2012; Mercuri *et al.* 2015).

The study of faunal remains (De Grossi Mazzorin and Epifani 2013) indicates a substantial continuity in the composition of domestic species across all phases. Pigs are the most represented taxon (c. 45%), followed by caprines and cattle (c. 29% and 26%, respectively). The proportion of wild fauna is relatively high compared to what is usually observed in terramare contexts. Red deer, in particular, is well represented, accounting for approximately 25% of the total faunal assemblage, while wild boar, roe deer, bear and otter are less frequently attested.

[3] Phase 1: LTL 5165A: 3328±45 BP; Phase 2: LTL 5166A: 3299 BP; Phase 3: LTL 5167A: 3300 BP.

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# The Terramara of Gaggio (Castelfranco Emilia – Modena)

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Excavations at the terramara of Gaggio (Castelfranco Emilia, Modena) were conducted between 2001 and 2004 in advance of the construction of the high-speed railway line. The site lies in the low plain east of Modena, along the Panaro River valley, whose course during the Middle and Recent Bronze Age ran close to the settlement. The area was densely occupied by terramare; the nearest and best known is Redù, located 3 km north of Gaggio.

A preliminary report was published in 2008 (Balista *et al.* 2008). The settlement was occupied from the advanced phase of Middle Bronze Age (MBA) 1 (1650/1550 BCE) to the end of MBA 3 (c. 1325 BCE). Radiocarbon dates place the earliest occupation between 1733-1614 BCE (68.2% probability) and 1744-1506 BCE (95.4% probability).

Excavations covered approximately 6100 m², of which c. 2500 m² corresponds to the internal area of the settlement.

Four main stratigraphic phases were identified. Following a pre-settlement phase, Phase 1 (MBA 1-2) is sealed by a substantial fire layer. Phase 2 (MBA 2-early MBA 3) ends with a similar event, separating it from Phase 3 (MBA 3). Phase 4 marks the final occupation and abandonment of the site.

The settlement was enclosed by a ditch and a bank; in the earliest phase, this bank appears to have been constructed using timber caissons, comparable to those documented in nineteenth-century excavations at Castione dei Marchesi (Parma).

The extent of the excavations provides detailed evidence for both domestic and productive structures. In contrast to the canonical terramare model – rectangular houses raised on wooden platforms – the buildings at Gaggio (Phases 1-2) were constructed directly on the ground. They have a quadrangular plan with a rear apse and are generally oriented NE-SW, except for Hut 2 (W-E).

In Phase 1, the structures appear broadly contemporaneous, with the exception of Hut 2, which may be earlier, as suggested by its divergent orientation. Detailed analysis (Scacchetti 2017) distinguishes between dwellings (fig. 1: 4, 5, 9), probable ancillary structures (fig. 1: 6, 8), and productive installations associated with pyrotechnological activities (fig. 1: 3, 7). Functional differentiation is clear: dwellings are larger (85-96 m²; internal area 38-48 m²), while non-residential structures are smaller (50-52 m²; internal area 18-25 m²). Productive structures measure c. 35-40 m² and feature unusually large hearths, distinct from those in domestic contexts.

In Phase 2, four huts were fully exposed and a fifth partially excavated. Buildings retain a rectangular plan with a rear apse and an entrance on the short front side (fig. 2). Their size ranges between 70 and 80 m². The layout is notably regular, with a NW-SE orientation.

Data for Phase 3 are less clear; however, it is likely that a shift in domestic architecture occurred during this period. Buildings may have adopted the canonical terramare form, with rectangular plans raised on wooden platforms. To date, only one structure of this type has been identified, measuring close to 100 m², consistent with other contexts dated between the late Middle Bronze Age 3 and the Recent Bronze Age.

Phase 4 follows a series of alluvial events. By this stage, the settlement appears to have been in decline

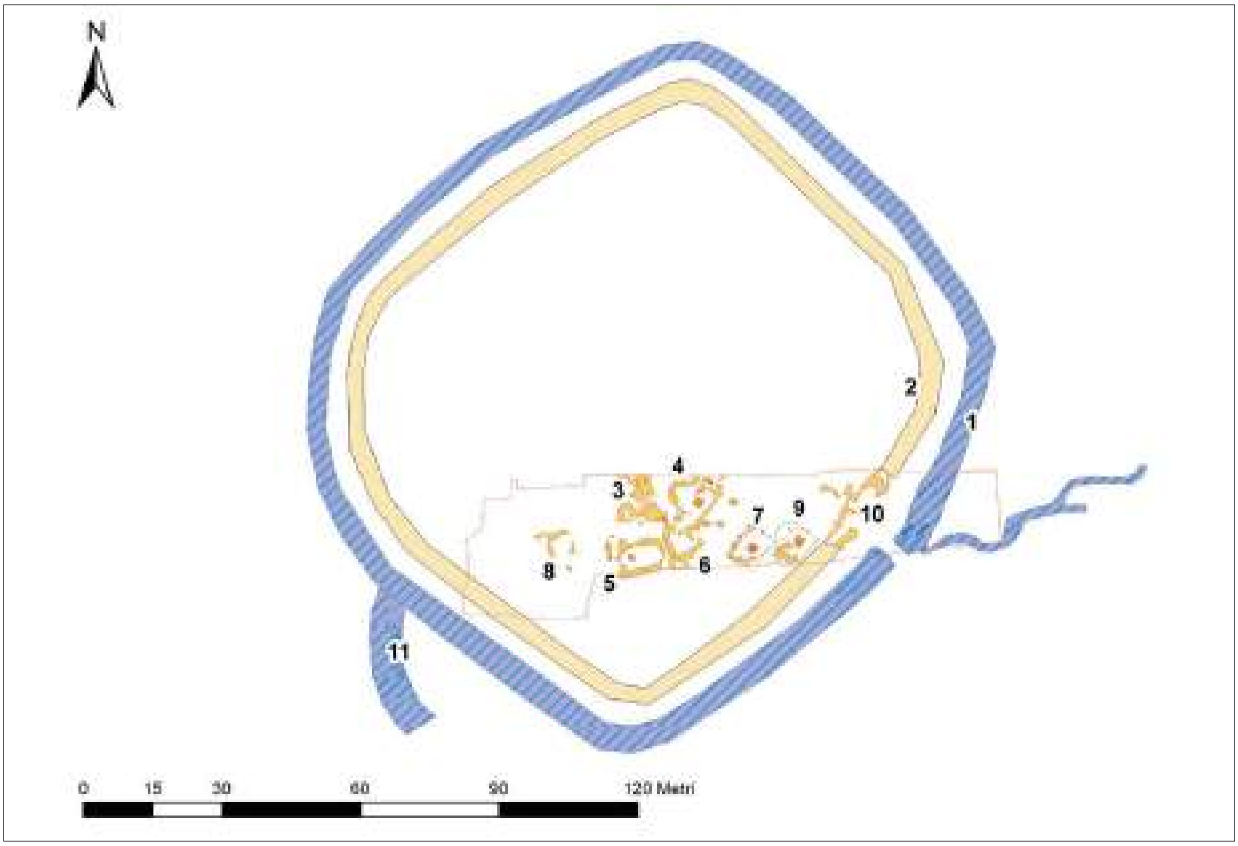


Fig. 1 – Phase 1 of the terramara of Gaggio (Castelfranco Emilia): 1. ditch; 2. rampart; 10. traces of "timber caissons" associated with the rampart and entrance; 4, 5, 9 dwellings; 6 and 8 ancillary structures; 3 and 7 productive structures and workshop areas.

*La fase 1 della Terramara di Gaggio di Castelfranco Emilia. 1. fossato, 2. terrapieno, 10. tracce di gabbioni lignei dell'argine e porta, 4, 5, 9 abitazioni, 6-8 strutture di servizio, 3 e 7 strutture e aree produttive.*

Fig. 2 – Terramara of Gaggio. Rectangular-absidal hut from phase 2.

*Terramara di Gaggio. Capanna rettangolare absidata della fase II.*

and approaching abandonment. At the same time, the terramara of Redù expanded significantly, reaching an overall extent of 14 ha. It is possible that, as part of a broader reorganisation of the terramare landscape, the settlement at Gaggio was abandoned and its inhabitants relocated to Redù, although it remains unclear whether this process was voluntary or enforced.

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# Solarolo (RA), Via Ordiere. Bronze Age Settlement

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The archaeological site of Via Ordiere at Solarolo (RA) represents one of the most significant Bronze Age settlements in the eastern sector of Emilia-Romagna. Identified in 1979 through surface surveys, it has been the subject of a systematic excavation project since 2006, revealing a complex settlement composed of distinct inhabited zones distributed over a total estimated area of approximately 7 hectares (fig. 1). On the basis of ceramic material collected during surface surveys and excavations, the settlement can be dated between The site's chronology spans a broad timeframe, from the final phase of the Middle Bronze Age 1 (MBA1) to the advanced phase of the Recent Bronze Age (RBA2) (Cattani *et al.* 2018; Cattani *et al.* 2019; Cavazzuti *et al.* 2025).

The area examined in this contribution corresponds to Sector 1, a settlement nucleus of slightly less than 1 hectare (ca. 8,000 m²), investigated stratigraphically from 2006 to the present. It is located along the bank of a large watercourse that bordered it on the southern and western sides. Materials recovered from ploughsoil indicate that the settlement nucleus had a long occupation span between the beginning of MBA2 and RBA2; however, the preserved archaeological deposit, approximately 40-50 cm thick, is limited to the earliest phases and does not extend beyond the transition to MBA3 (1550-1450 BC), thus covering roughly 100 years of occupation.

The settlement developed along an ancient course of the Santerno River, a natural meandering channel approximately 25 metres wide and over 10 metres deep, documented through trenches and manual boreholes. This feature represents the remnant of an ancient fluvial ridge known as the *Paleodosso di Bagnara*, characterised by a soil likely formed up to the Bronze Age (Marabini 2007).

The best-preserved archaeological deposit is located in Sector 1, corresponding to the southern settlement developed along a partially artificially regularised riverbank. Between the riverbed and the proper residential area, a buffer strip of about 15 metres was identified, devoid of domestic structures and likely used as horticultural space or for secondary activities, characterised by tabular accumulations rich in ceramic fragments and organic remains. The inner boundary of this strip is marked by two large tree stumps and rows of postholes aligned parallel to the river's course (Cattani 2009).

The stratigraphic sequence in Sector 1 documents the evolution of construction techniques. The earliest occupation phase (from the mid-16$^{th}$ century BC) is characterised by rectangular huts built on raised wooden platforms supported by vertical posts driven directly into a palaeosoil. The ground plans display regular rows of posts (often four alternating with three). Subsequently, within MBA2, after a fire episode, additional huts were constructed with ground-level floors made of clayey silt deposits. Inside these structures, clay hearth plates and ash layers were identified, documenting continuous domestic activities (Peinetti-Debandi-Cattani 2023).

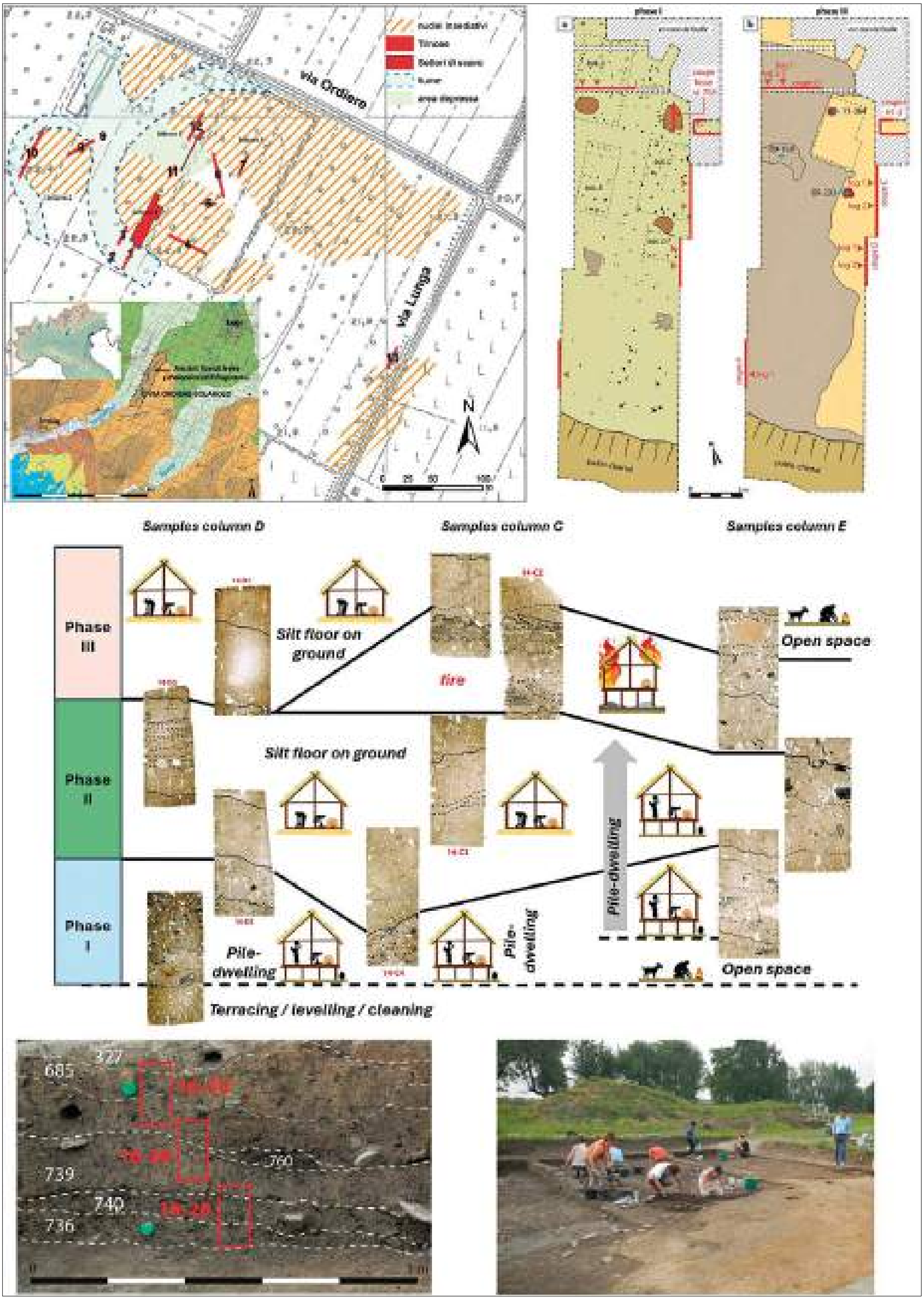


Fig. 1 – Localization and internal features of the Solarolo settlement, Via Ordiere. Plans of Sector 1, first and third phases. Sequence of the three construction phases according to the micromorphological analysis of the stratigraphy (modified from Peinetti 2021). View of the stratigraphy with samples taken for micromorphological analysis. View of the ongoing excavation.

*Localizzazione e caratteri interni dell'abitato di Solarolo, via Ordiere. Planimetrie del settore 1, prima e terza fase. Sequenza delle tre fasi costruttive secondo l'analisi micromorfologica della stratificazione (modificato da Peinetti 2021). Vista della stratigrafia con campionamenti per analisi micromorfologiche. Vista dello scavo in corso.*

An intermediate phase shows the contemporaneous presence of both architectural models, while the latest episode appears linked to an extensive deposit of sterile silty material, likely corresponding to the levelling of a silty-sandy ridge along the eastern margin of the sector. Both structural phases are dated between the end of MBA1 (mid-16th century BC) and the advanced MBA2 (mid-15th century BC), indicating a complex sequence of construction and rebuilding within a relatively limited time span. Two radiocarbon dates obtained from charred seeds (LTL5044A 1630-1430 BC; LTL5045A 1750-1520 BC, 95.4% probability) confirm the chronological attribution of the deposit (Cattani and Miari 2018).

The stratigraphic excavation revealed structures and activity evidence related to the earliest occupation phase, including raised huts and refuse layers rich in organic material above the sterile clay substrate, recalling the pile-dwellings known from other Emilian settlements. The stratigraphic sequence on the eastern side concludes, immediately below the ploughsoil, with a series of productive structures, probably small kilns associated with ceramic firing.

An expansion of the excavation toward the northern side of Sector 1 revealed thicker stratigraphy, with basal layers extending to depths exceeding 1.5 metres. The upper levels contained clayey silt layers and materials datable to MBA3 and RBA1, previously identified only in ploughsoil.

The ceramic production from Sector 1 dating to MBA2 is distinguished by remarkable cultural hybridity, combining in similar proportions diagnostic elements of the Grotta Nuova facies and the Terramare facies. Ribbon handles with rolled ends, sinuous-profile bowls, and various handle types typical of central Italy occur in the same Middle Bronze Age stratigraphic units as truncated horn handles and bowls with grooved decorations characteristic of settlements in the central Po Plain. This mixture suggests that the Solarolo community functioned as a process of formation and integration of regional identities, producing original stylistic syntheses (Cattani *et al*. 2018; Cattani 2019).

Investigations in Sectors 2, 3, and 4 identified ceramics contemporary with those from Sector 1, demonstrating the broad extension of the inhabited area, although some sectors may have been devoted to complementary rather than strictly residential activities. In Sector 3, explored in recent campaigns, a more homogeneous stratigraphy was identified, associated with alignments of large post-holes and a small sunken feature interpreted as an enclosure along the edge of a depressed area.

Late Bronze Age phases are represented by limited stratigraphic remnants adjacent to Sector 1, preserved due to the presence of an ancient trackway that prevented deep ploughing. These remains document productive activities, including a metallurgical area identified in 2017. It consists of a slightly sunken oval structure containing a central casting pit, carbonised floor layers, and numerous metallurgical waste products such as bronze droplets and scraps (Cattani *et al.* 2019).

Metallurgical production is further confirmed by the discovery in Sector 1 of a mould for casting a javelin head from Middle Bronze Age layers. It is noteworthy that until MBA2 specialised tools such as sickles and arrowheads were still produced in flint, and only in subsequent phases they were replaced by metal versions. The presence of numerous amber beads and a gold hair ornament is also significant.

The subsistence economy was based on an agro-pastoral system organised around multi-crop agriculture and livestock husbandry, in quantitative order caprines, cattle, and pigs (Maini and Curci 2009). Archaeobotanical analyses indicate a predominance of wheat (67%), a substantial presence of millet (22%), and other cultivated plants including barley, oats, legumes, and flax (Carra *et al.* 2023). Animal husbandry was dominated by sheep and goats (over 50% of faunal remains), followed by pigs (29%) and cattle (12%); remains of dogs and horses are also attested, while wild fauna is extremely scarce, indicating limited reliance on hunting.

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# The Pile-Dwelling Settlement at Pieve di Carpegna (Carpegna, Pesaro-Urbino)

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The lacustrine pile-dwelling site of Pieve di Carpegna is situated within a small basin (c. 1.5-2 ha), now entirely peat-filled and buried. It was occupied between the Early Bronze Age and the beginning of the Middle Bronze Age. The site was identified during earthworks associated with the construction of basins for a hydraulic system serving a horticultural enterprise established over the area (fig. 1). The results of these initial discoveries were presented at the 38th Scientific Meeting of the Istituto Italiano di Preistoria e Protostoria dedicated to the Marche region (Baldelli *et al.* 2005)[1]. Following this discovery, Dr Gabriele Baldelli (Soprintendenza Archeologia delle Marche) initiated a stratigraphic excavation to assess the preservation and extent of the archaeological deposits. This represented the first systematic excavation in the territory of Carpegna. The research, directed by Baldelli in collaboration with Andrea Cardarelli (University of Modena and Reggio Emilia), was conducted in July 2005, with scientific support from Claudio Balista and Sara Tiziana Levi.

Prior to excavation, a detailed micro-topographic survey was carried out with 0.2 m contour intervals[2]. This survey suggests that the basin originally had an elongated NW – SE orientation, exceeding 200 m in length and with a maximum width of approximately 80 m. The excavation area is located near the centre of the basin, which appears to have been very shallow, probably not exceeding 4 m in depth.

The excavated levels correspond to the final phase of occupation, datable to the beginning of the Middle Bronze Age. Nevertheless, a stratigraphic section including underlying layers was documented, characterized by the presence of in-situ wooden piles (fig. 2). Two radiocarbon dates are available for this terminal phase, indicating that the settlement came to an end in the second half of the 17th century BC, consistent with an attribution to Middle Bronze Age 1[3]. The underlying deposits can therefore

[1] The comprehensive publication of the 2005 excavation is currently in preparation.

[2] The micro-topographic survey was conducted by Gianluca Pellacani.

[3] Two radiocarbon determinations are available: US 337, Phase 1 (seed), 27 July 2005, CEDAD code: LTL5174A: 3420 ± 45 BP, corresponding to 1879-1623 BC (95.4% probability)

be attributed to the Early Bronze Age, in agreement with the dating of certain finds recovered at the time of the site's discovery (Baldelli *et al.* 2005).
The ceramic assemblage has been studied by Luca Pellegrini (Pellegrini 2010) and is currently in the process of publication. The assemblage includes several handles with axe-shaped elevations, typically attributed to an early Middle Bronze Age 1 horizon (fig. 3) and finds the closest parallels in the contexts of Cattolica, Senigallia and Ancarano di Sirolo, dated between the Late Early Bronze Age and Middle Bronze Age 1 (Miari 2009; Delpino 2014; Baldelli 2005). A few sporadic finds of uncertain provenance from the site may be attributable to the Recent Bronze Age, possibly indicating a later reoccupation of the area, in a location different from that investigated during the excavation.
The faunal assemblage from the site is highly fragmented. A total of 147 bone fragments were recovered, more than half of which could not be identified to species level. A total of 82 remains were identified to species. Among domestic animals, cattle were predominant – a pattern also supported by the undetermined portion of the assemblage, over 60% of which could be attributed to large-sized animals. Pigs and caprines follow in frequency. The 38 remains confidently attributed to cattle represent at least four individuals, including three adults – one of which is female – and one subadult. The 21 pig remains belong to at least three individuals, including one adult male and two piglets slaughtered before the age of four months. Fifteen caprine remains belong to at least two individuals: an adult female goat culled at around three years of age, confirmed by genetic analysis (Makarova *et al.*, this volume), and a subadult aged between one and 1.5 years. Among wild species, only wild boar is attested. Given the small sample size, the data are of limited statistical value for any meaningful reconstruction of the site economy.
Analyses of seeds and fruits were carried out on the site (Provesi 2017/2018). Fifteen samples, taken during excavations in 2003 and 2005 from ten different stratigraphic units, were sieved, representing a total of approximately 280 litres of soil. Approximately 4,600 seeds and fruits

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and 1860-1646 BC (68.2% probability). US 338, CEDAD code: LTL5175A: 3392 ± 45 BP, corresponding to 1874-1545 BC (95.4% probability) and 1743-1631 BC (68.2% probability


Fig. 1 – Pieve di Carpegna. Excavation 2003. Jar with a slight developed axe-shape handle: EBA 2
*Pieve di Carpegna. Olla con ansa ad ascia poco sviluppata dai saggi di scavo 2003: EBA 2.*

Fig. 2 – Pieve di Carpegna. Excavation 2005. The archaeological deposit with wooden piles.
*Pieve di Carpegna. Scavi 2005 il deposito archeologico con le palificazioni.*

Fig. 3 – Pieve di Carpegna. 2005 excavations. Funnel-shaped vessel: MBA 1.

*Pieve di Carpegna. Scavi 2005. Vaso ad imbuto: MBA 1.*

were recovered, well-preserved, mostly waterlogged (89%) and some charred (11%). Most of the finds (65%-43 taxa) belong to spontaneous plants, including weeds, wetland and woodland species, indicative of open forest, meadow, and highly anthropogenic environments (e.g., numerous nitrophilous species). Other finds (35%-18 taxa) come from plants with known or potential use, especially for food. Some were cultivated, including cereals (predominantly barley, followed by naked wheat and emmer), broad beans, and possibly grape. Wild fruits were also harvested, including Cornelian cherries, elderberries, blackberries, strawberries, plums, acorns, and hackberries. A small number of flax seeds were recovered, probably representing a textile resource rather than food. Overall, the assemblage shows the same food plant taxa that characterize Bronze Age sites in nearby Emilia-Romagna, for which numerous archaeobotanical analyses exist (Bosi *et al.* 2024; Carra 2013).

The Pieve di Carpegna pile-dwelling site presents several aspects of considerable interest. Its location highlights the attraction of wetland environments – even small ones – within the Apennine area for communities of the Early Bronze Age and the earliest phase of the Middle Bronze Age (the site is situated at 620 m a.s.l.). This provides further evidence for the tendency to establish settlements, often of long duration, in wetland or lacustrine settings – a pattern well attested in northern and central-Tyrrhenian Italy, as well as in the internal areas of the central Apennines, from the Early Bronze Age onwards. The presence of occupations in lacustrine contexts within the Marche Apennines represents a new occurrence. Notable connections with contemporary settlements in Romagna and northern Marche may indicate a specific archaeological facies, which has not yet been fully defined.

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# Montarice (Porto Recanati, MC): Discovery and First Excavations by Delia Lollini in the 1970s

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Montarice is a low plateau (ca. 54 m a.s.l.) situated on the outskirts of the present-day town of Porto Recanati (MC, Marche), at a distance of ca. 1 kilometer of the current Adriatic coastline (fig. 1). It has relatively steep slopes to the north and south and a gentler descend towards the east. Its western connection to the adjacent Colle Burchio is cut by the Autostrada A14, the construction of which undoubtedly obliterated relevant archaeological evidence. The hill overlooks the coastal zone of river Potenza which presently runs directly along its southern slopes. During the Bronze Age the river was located at a distance of ca. 3 km in the southern part of the coastal delta. From the 4th millennium BCE onwards, heavy river aggradation transformed the Atlantic-type coastal cliffs into a broader coastal strip with a beach ridge. The final formation of the beach ridge took place during the MBA and RBA occupation of Montarice, allowing an easy passage along the coast.

Archaeological remains on the low hilltop plateau of Montarice were already known and investigated in the 1970s. Archaeological artefacts on the hill were first reported by two residents of Porto Recanati, who informed Delia Lollini of the Soprintendenza Archeologica delle Marche. Lollini conducted a preliminary inspection on 21 December 1973. In her report, she noted lithic artefacts, Roman potsherds, and protohistoric pottery with characteristic "Apennine"-style decorations along the southern side of the plateau. At that time, urgent concern arose over a recently dug trench in the northwest corner of the plateau for planned construction work. In its exposed sections, Lollini observed a dark layer about 80 cm thick containing prehistoric pottery, extending to at least 150 cm below the surface. Pottery was abundant both in the trench and in the spoil heaps along the plateau's edge. She also recorded an Upper Palaeolithic pointed scraper on the surface in this area. Alarmed by the threat to the archaeological deposits, she requested a test excavation to assess the need for protective measures. Permission for excavation was granted in 1977, following additional funding from the Ministry. Lollini conducted a single campaign in October 1977, which confirmed the site's scientific importance and ultimately led to its protection. In her excavation diary, she explained her decision to focus on the northern slope rather than the area of the 1973 construction trench. By 1977, the northern embankment had been cleared of vegetation and cut back – likely to expand arable land – exposing a sloping section roughly 70-80 m long. Within this section, dark archaeological layers containing eroding ceramics, including Apennine-style decorated impasto pottery, were visible. Cleaning and documenting this exposed section appeared the most efficient means to confirm Bronze Age occupation across a larger area, rather than opening new trenches on the plateau (fig.

Fig. 1 – The archaeological area of Montarice seen from the south, photographed from a small aircraft. The motorway separates Montarice (right) from the ridge of Colle Burchio (left). River Potenza is visible at the base of the hill, the town of Porto Recanati in the right. In the far distance is the Conero limestone massif, looking out over the Adriatic Sea (photograph Frank Vermeulen).

*L'area archeologica di Montarice vista da sud, fotografata da un piccolo aeromobile. L'autostrada separa Montarice (a destra) dal crinale di Colle Burchio (a sinistra). Il fiume Potenza è visibile alla base della collina, mentre sulla destra si riconosce l'abitato di Porto Recanati. In lontananza si distingue il massiccio calcareo del Conero, affacciato sul Mare Adriatico (fotografia di Frank Vermeulen).*

2). Lollini selected the zone where the dark layers appeared thickest. A strip approximately 18 m long in the northwest part of the slope was excavated by cutting back the escarpment in spits of 15-20 cm, reaching a total depth of about 2 m below the slope break (fig. 3, left). Finds were collected per spit in 2×2 m grid units, labelled A-I from west to east. A total of 82 crates of artefacts were recovered, now stored at the Museo Archeologico Nazionale delle Marche (Ancona). These materials span all phases of occupation, from the Palaeolithic to the Middle Ages. Most finds consist of pottery fragments, along with lithic artefacts, metal and plaster pieces, and faunal remains. Among diagnostic artefacts, 92% (approximately 2,800 fragments) date to the Bronze Age – mainly to the final phase of the Middle Bronze Age (MBA3; late 15th–late 14th century BCE) and, to a lesser degree, the Recent Bronze Age (RBA; c. late 14th–mid 12th century BCE). This chronology aligns with the results of the 2002 and 2019 surface artefact surveys of the plateau and its slopes conducted by teams of Ghent University (Belgium)[1]. The upper six spits (I–VI) yielded mixed materials from various periods. Most sherds are protohistoric handmade impasto, but there are also imported Attic pottery and painted Italo-Geometric wares, as well as lithic artefacts. These layers are therefore interpreted as secondary deposits, likely containing material displaced from the plateau top. Finds from spits VII–X, however, date exclusively to the Bronze Age[2]. The abundance of bone and delicate seashells suggests that these lower layers represent well-preserved occupation deposits. Faunal remains from these exclusively Bronze Age layers are included in. At the base of the escarpment, about 2 m below the hilltop, several pits up to 35 cm in diameter were identified (fig. 3, right). These were distinguishable by their greyish fill, contrasting with the brown surrounding layer. The pits contained small ceramic fragments – some with typical Apennine-style geometric decoration (MBA3) – and faunal remains. Their possible alignment as postholes for structures remains to be verified. Evidence for

[1] De Neef and Paolini 2025; Vermeulen and De Neef *in press*.

[2] The MBA3 pottery of Montarice from both the Lollini excavations and the Ghent University surveys was analyzed by Elisa Paolini in her PhD on pottery shapes and decoration motives in Apennine-style pottery throughout the Italian peninsula: Paolini 2023.


Fig. 2 – The approximate locations of Lollini's trench (1977, grey) and survey units (1979, orange with areas labelled). The exposed slope visible in 1977 is indicated with a dashed white line.

*Le posizioni approssimative della trincea di Lollini (1977, in grigio) e delle unità di ricognizione (1979, in arancione, con aree etichettate). Il pendio esposto visibile nel 1977 è indicato con una linea bianca tratteggiata.*

Fig. 3 – The 1977 excavation on the north slope of Montarice. Left: the excavation of the escarpment in progress. Right: the lowest level of the trench; visible are postholes and a lowered basin. Photo reproduced under permission of the Soprintendenza Archeologia, Belli Arti e Paessaggio Marche Sud.

*Lo scavo del 1977 sul versante nord di Montarice. A sinistra: lo scavo della scarpata in corso. A destra: il livello più basso della trincea; sono visibili buche di palo e una fossa ribassata. Foto riprodotta su autorizzazione della Soprintendenza Archeologia, Belle Arti e Paesaggio delle Marche Sud.*

buildings is plausible, as fragments of hut loam with twig impressions were also recovered from the lowest levels. Because of the narrowness of the excavated strip, structural reconstruction is not possible; however, future magnetometry may reveal house plans. Two years later, in August 1979, Lollini inspected an area directly downslope from the 1977 excavation after ploughing had exposed new material. A sketch of her collection zones – labeled A, B, and C – shows concentrations of artefacts between 6 and 20 m from the slope edge (fig. 2). Area C, the largest and closest to the autostrada, produced two crates of finds, while Areas A and B yielded one crate each. Area A, located furthest east, bordered a hedge marked in Lollini's sketch. Although the hedge no longer exists, it likely corresponds to the central field boundary on the north slope, providing a general indication of the findspot. Two additional crates contained artefacts and ecofacts from the wider surroundings. In total, six crates represent all phases of occupation at Montarice. Lollini described the assemblage as comprising "handles, rims, bases, and animal bones; some fragments with incisions and others with dark or red paint." Non-diagnostic sherds were apparently excluded. A re-examination of the 1979 materials confirms the presence of both decorated MBA3 wares and painted fine wares from later phases, consistent with the 1977 finds. No further excavations have taken place at Montarice since Lollini's work. Following her 1973 request, the hilltop received protected archaeological status. The Potenza Valley Survey project of Ghent University (Belgium) applied several non- and minimally invasive methods to study the site from 2000 onwards, including aerial photography (between 2000-2004), artefact surveys at a relatively low resolution (2002), geophysical prospection and coring (2013), and high-resolution artefact surveys (2019)[3]. However, the Lollini excavation and surface collections were never fully analyzed or published until now. In 2022, the 82 excavation crates and six surface collection crates became available for study at the Museo Archeologico Nazionale delle Marche in Ancona. The current studies of these materials, undertaken as a spin-off of the Potenza Valley Survey, will culminate in a dedicated publication[4].

[3] Percossi-Pignocchi-Vermeulen 2006; Verhoeven *et al.* 2017; Vermeulen *et al.* 2017; De Neef and Paolini 2025.

[4] De Neef and Paolini in prep.

Lollini's original notes, drawings, and photographs – archived at the Soprintendenza in Ancona – have been crucial in retracing her work and reconstructing the provenance of the finds.

The archaeozoological analysis carried out by Elena Maini, partly incorporated into the HERDS project, forms part of the ongoing study of these important legacy data (see Cavazzuti *et al.* in this volume). The faunal remains analyzed for the HERDS project derive from the lowest levels of the Lollini excavation (VII–X), which, on the basis of the associated material culture, can be attributed exclusively to the Middle Bronze Age 3 and the Recent Bronze Age (Apennine and Sub-Apennine *facies*). Remains attributable to the Recent Bronze Age – mainly referring to an early stage of the phase – are relatively scarce in the lowest levels (X and IX), whereas they appear to increase quantitatively starting from level VIII.

*For bibliographical references relating to the archaeological site of Montarice, please see the reference below.*

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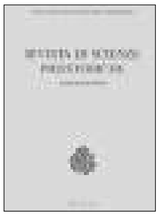

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# La Crocetta (Tivoli): a Late Middle Bronze Age settlement along the Aniene River

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The protohistoric site of La Crocetta takes its name from the homonymous locality situated southeast of the historic center of Tivoli, in an area bounded by the route of the Via Tiburtina Valeria and the course of the Aniene River. The archaeological deposit was identified during preliminary works for the construction of private residential buildings along Strada Caroli and was investigated between June 2010 and February 2011[1]. The deposit is preserved in a secondary depositional position, attributable to a localized natural slope-movement event.

From a topographic perspective, the site lies at approximately 239 m above sea level, near the edge of a fluvial terrace extending along the right bank of the Aniene River, approximately 70 m from the active river channel (fig. 1). The terrace is bordered by the river on three sides (N–E–S), while to the west it connects with a modest hill (ca. 267 m above sea level), beyond which rise the higher elevations of Colle Vescovo (ca. 445 m above sea level).

The site is located upstream of the Tivoli "narrows," within a geomorphologically favorable sector for river crossing and for controlling a natural mobility corridor aligned with the valley axis. This route, later formalized by the Via Tiburtina Valeria, constituted a major connection between the central Apennines and the Tiber plain, whose strategic significance was likely already established during the Bronze Age.

Although the original excavation documentation is currently unavailable, the analysis of several photographically recorded sections, on which the boundaries of the stratigraphic units are indicated, allows its main characteristics to be defined. The observed configuration, characterized by inclined yet laterally continuous archaeological units, suggests a coherent displacement of the stratigraphic sequence. This pattern is consistent with low-energy gravitational processes typical of marginal fluvial terrace contexts and indicates limited secondary redeposition.

This interpretation is further supported by the good state of preservation of the archaeological materials,

[1] The investigations were directed by Dr Micaela Angle of the Soprintendenza per i Beni Archeologici del Lazio, whom we gratefully acknowledge for granting access to the materials and for supervising their study in her role as co-supervisor of Dr E. Paolini's Master's thesis.

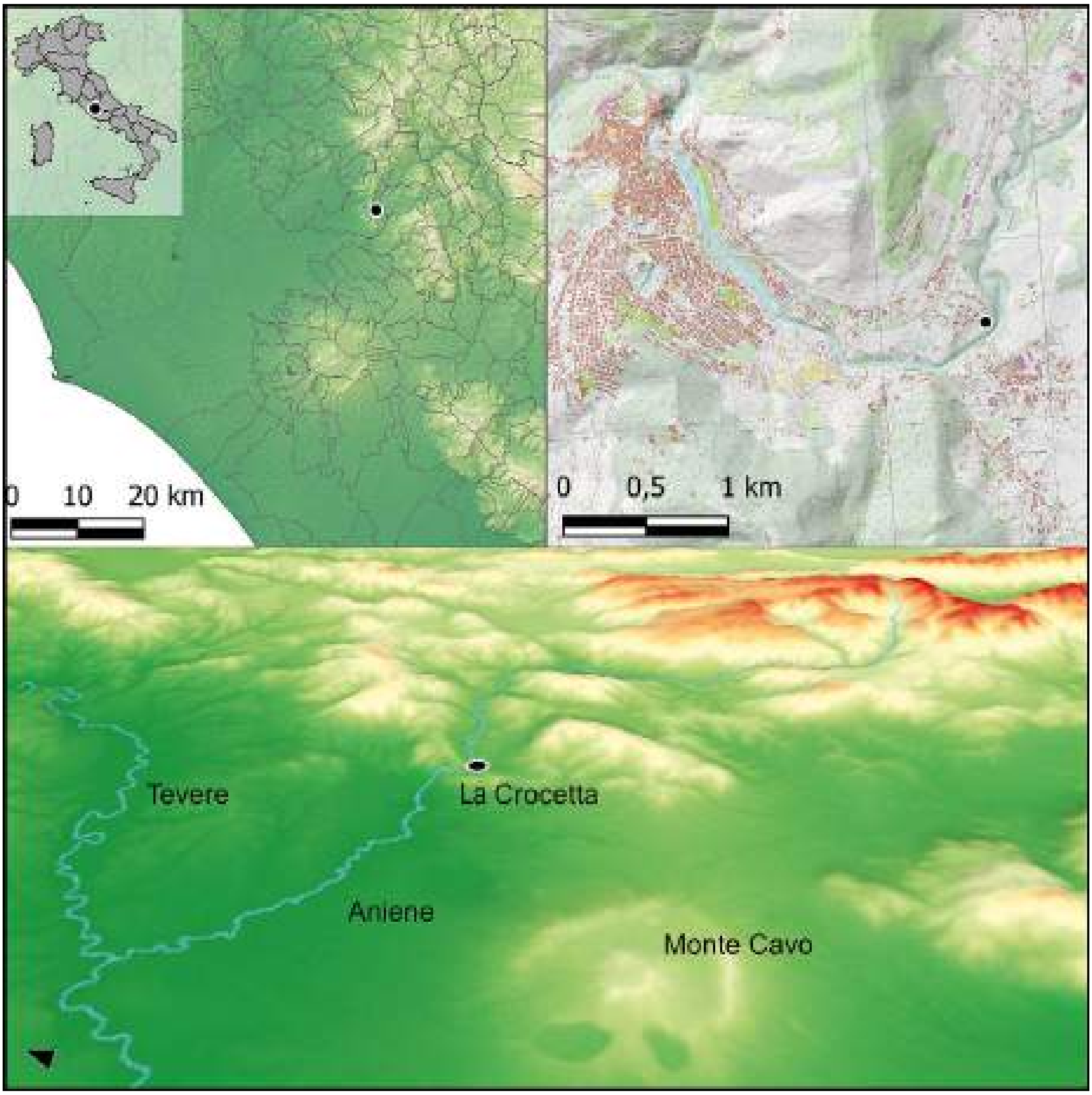


Fig. 1 – Site location. Top left: regional framework showing the position of the site. Top right: location of the site on the CTR (Carta Tecnica Regionale) 1:5,000 map. Bottom: Digital Elevation Model (DEM) illustrating the geomorphological context in which the site is situated, viewed from the southwest.

*Ubicazione del sito. In alto a sinistra: inquadramento regionale con indicazione della posizione del sito. In alto a destra: localizzazione del sito sulla CTR (Carta Tecnica Regionale) 1:5.000. In basso: modello digitale del terreno (DEM) che illustra il contesto geomorfologico entro cui si colloca il sito, con vista da sud-ovest.*

including both ceramic and faunal assemblages (Silvestri *et al.*, in prep.). The integrity of the finds suggests short-distance displacement and implies that the original location of the settlement did not differ substantially from the currently identified site.

The archaeological deposit yielded a substantial and varied assemblage, comprising approximately 3,500 impasto pottery sherds, lithic tools, and around 1,700 faunal remains, indicative of a structured settlement context.

The study of the ceramic assemblage, conducted by E. Paolini as part of a Master's thesis (Paolini 2015-2016), was based on a significant corpus of diagnostic material (approximately 1,500 specimens). A representative selection of the principal vessel classes was established, and 630 sherds were documented through technical drawings.

The ceramic repertoire includes tableware as well as storage and cooking vessels, forming a functionally comprehensive assemblage associated with activities of food preparation, cooking, storage, and consumption. Numerous tableware vessels display incised, impressed, or excised decoration attributable to the Apennine *facies*. White paste inlay within decorative motifs is also frequently attested.

Of particular relevance to the reconstruction of economic activities is the recovery of five spindle whorls (three with flattened globular bodies, one discoidal, and one plano-convex discoidal), four fragments of ceramic strainers, and a possible vessel with an internal ledge. This evidence points to craft activities associated with caprine husbandry and the exploitation of secondary products, especially wool and milk, the latter likely intended for dairy processing.

Typological analysis and comparison with reference assemblages allow the material to be dated to the entire span of Middle Bronze Age 3 (c. 1400-1300 BC), with possible antecedents in Middle Bronze Age 2B. No materials attributable to later phases have been identified (Paolini 2023).

The ceramic production and decorative style documented at La Crocetta are fully consistent with the Apennine *facies*, while exhibiting closer affinities with the cultural expressions of the Middle Tyrrhenian region. This interpretative framework gains particular significance in light of the site's position along the Aniene valley, a natural corridor facilitating mobility and interaction between the Tyrrhenian slope and inland territories. Although connections with the Abruzzo region are archaeologically attested, they appear limited and selective. Overall, the evidence suggests preferential integration within exchange and interaction networks oriented toward the Middle Tyrrhenian sphere.

Taxonomic identification was possible for 24% of the recovered faunal remains[2]. Of these, more than three quarters belong to domestic species, particularly caprines, which were predominantly slaughtered at adult age. This pattern suggests herd management strategies aimed not only at meat production but also at the exploitation of secondary products. Pigs are also well represented and display a slaughter profile consistent with a primarily alimentary function. Cattle follow in frequency and were likewise mainly slaughtered as adults. Red deer and dog are attested in smaller numbers. Among wild taxa, a bear incisor and numerous carapace fragments attributable to turtles were recovered, a pattern consistent with the site's proximity to a fluvial environment. Approximately one third of the analyzed remains exhibit taphonomic modifications, predominantly of anthropogenic origin, including cut marks, butchery traces, and burning. Biostratinomic and diagenetic alterations are also frequent. Of particular interest is the complete absence of femora. Overall, the faunal evidence indicates a settlement area characterized by activities related to animal husbandry, agricultural resource management, and food consumption, in agreement with the ceramic data.

Isotopic analyses conducted within the framework of the HERDS project will contribute to a more detailed understanding of herding practices and the exploitation of secondary products, while also providing further interpretative insight into the nature and organization of the settlement.

[2] The study of the faunal assemblage forms the subject of the Master's thesis in Archaeozoology of Dr Simone Satriano at the University of Rome "Tor Vergata," supervised by Prof. Letizia Silvestri and Prof. Mario F. Rolfo, with the collaboration of Dr Angelica Fiorillo and Dr Aurora Calderone. Preliminary results were presented at the 11th National AIAZ Conference (Trento 2024) and are currently in preparation for publication (Silvestri *et al.* in prep.).

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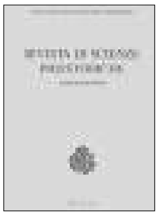

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Valentina Copat [(1)]

# The Giardino Romano on the Capitoline Hill: Evidence from the Late Bronze Age (Excavations 1999-2000)

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The *Giardino Romano* area, situated on the north-eastern slope of the *Capitolium* facing the rise of the *Arx*, underwent preliminary investigations between 1998 and 2000 on the occasion of the realization of the Exedra of Marcus Aurelius[1]. These investigations brought to light an uninterrupted stratigraphic sequence extending from the Bronze Age through to the Republican period.

Particularly noteworthy are also the remains associated with the interventions carried out during the nineteenth and twentieth centuries: first the construction of the exhibition hall known as *Sala Ottagona*, and, later, the realization of the Garden promoted by Rodolfo Lanciani at the beginning of the last century, which significantly shaped the exhibition history of the Capitoline Museums and of the Capitoline Hill[2].

The archaeological deposit was especially preserved in the northern portion of the area, although these latter interventions partially compromised its integrity, entirely removing it in several portions. Moreover, the eastern edge of the podium of the Temple of Jupiter Capitolinus lies to the south-west, with its foundation trench reaching the tuff bedrock.

Regarding the Bronze Age, in situ levels relating to the occupation of the area are documented from the Late Bronze Age, while earlier residual fragments attest to the use of the hill at least from the Middle Bronze Age (Baroni 2001; Lugli and Rosa 2001). In particular, for the Subapennine phase, a recent re-examination of the earliest occupation levels has allowed for the reconstruction of a more articulated sequence than was achievable at the time of the preliminary publications (Baroni *et al.* 2024).

The earliest documented activity on the Hill, as is well known, concerns the modification of the north-eastern slope, through a significant terracing operation carried out by cutting into the hillside, followed by the levelling of the upper area and subsequently by the redeposition of the excavated material to fill the lower cut. This process must have taken place through successive accumulations, which were organized and levelled in order to expand the available surface and to create a more suitable configuration for the establishment of a settlement, probably also contributing to strengthening the defensive character of the Hill (Baroni *et al.* 2024: 258-263, figs. 4-6).

Such a demanding undertaking clearly reflects the strong interest in occupying this specific location. However, it is not an isolated case in the framework of Late Prehistory in central and southern Italy, although close parallels are not particularly numerous. Similar works are in fact often difficult to identify in the field, while, in the Capitoline case, this recognition was made possible thanks to the accuracy of the excava-

[1] The investigations were carried out under the direction of the Capitoline Museums (dott.ssa A. Mura Sommella) and, from 1999 onward, with the emergence of evidence from the Bronze and Iron Ages, in collaboration with the University of Rome – Sapienza (prof. A. Cazzella).

[2] The first results were published shortly after the completion of the excavations in the Bullettino della Commissione Archeologica Comunale (2001 – which provides the bibliography for phases following the Late Bronze Age). The Capitoline Superintendency is currently re-examining the documentation to produce a comprehensive reconstruction of the different occupation phases and to publish the associated materials.


Fig. 1 – Occupation levels of the elliptical area. In the representation of later cuts, the absence of hatching indicates that the deposit was only partially affected down to the level shown, while the presence of hatching indicates that the corresponding levels were completely removed. Heights are relative to a reference point at 45.5 m a.s.l. (graphic processing – Valentina Copat).

*Livelli di frequentazione dell'area ellissoidale. Nell'indicazione dei tagli di epoca successiva, l'assenza di campitura indica che il deposito è stato intaccato fino al piano rappresentato; la presenza della campitura indica che i relativi livelli risultano invece completamente asportati. Le quote sono relative a un punto base posto a m 45,5 s.l.m. (elaborazione grafica – Valentina Copat).*

tion and the multidisciplinary character of the research (Baroni *et al.* 2024: 275-278).

Immediately above the fill deposit, an initial occupation surface was identified, characterized by pebble surfaces, charcoal-rich soils, concentrations of pottery, burnt areas and well defined hearth features. These elements suggest outdoor preparation activities, probably related to food processing (Baroni *et al.* 2024: 263-264, figs. 5, 7).

Following this initial phase, the area was further rearranged. An additional substantial dumping of clayey soils created an elliptical structure with raised edges, partly formed through the slight excavation of the underlying layers (fig. 1). Within this area, a functional space – presumably open – was established, whose use can be placed in an advanced phase of the Late Bronze Age. This feature no longer preserved its original extent, as it was disturbed to the northwest by several negative features dating to the Iron Age, Orientalizing and Archaic periods, by the westernmost of two large quadrangular cuts belonging to the Republican period, as well as by more recent interventions.

The use of the elliptical area appears to have been associated with food processing, likely on multiple occasions. The occupation surface is in fact characterized by the presence of several hearth points, such as simple burnt areas and cooking plates, which are distributed both within the structure (or along its edges) and in the surrounding area. Varying in shape and size, these pyrotechnological structures suggest that a range of activities was carried out and with fire likely used in different ways.

Many materials derive from these occupation levels. Given the exceptional nature of the context, they were considered worth recording individually during excavation. The collection, which comprises over 4,000 numbered items categorized by material type, allows for the analysis of their distribution and associations, and more generally provides insight into the use of space and the functional purpose of the structure, following the approach adopted in other studies[3].

The study of ceramics is still ongoing and addresses not only stylistic aspects of production but also their functional analysis and spatial distribution (Copat *in press*). The same approach is applied to the study of other artifacts and bioarchaeological remains, within an integrated framework. Preliminary data from faunal remains[4], for example, have already shown that the activities carried out may have been oriented more toward the processing of animal resources rather than their consumption in situ (Minniti 2012).

Integrating data from all other material classes, including carpological and anthracological remains, will thus facilitate an overall functional interpretation, accounting for potential differences both synchronically and diachronically.

After this space fell out of use, still within the Subapennine phase, the area was covered by a series of clayey layers devoid of recognizable features, likely reflecting a period of less intensive use of this part of the hill, which was probably peripheral to the main settlement. It is likely that the settlement did not extend beyond the Capitolium (Cazzella 2001), consistent with other contemporary contexts in both size[5] and choice of a naturally defensible location, strategically positioned along a natural communication route that would have facilitated integration into short- and long-distance exchange networks. The presence of Italo-Mycenaean pottery precisely in these latest Late Bronze Age occupation levels (Bettelli 2016; Jones 2016) further suggests that the settlement was actively involved in this network.

[3] In this regard, reference can be made to a broader research project on several contexts of the Bronze Age in central and southern Italy (Bietti Sestieri *et al.* 2002) and, more recently, to analogous work carried out for the site of the Rocca di Oratino (Copat 2022: pp. 291-349).

[4] Among these are included the samples selected for the Herds project, focus of this volume.

[5] As already discussed, other size estimates appear to be excessive for the phases in question (Baroni *et al.* 2024: 256-257, note 18, with the corresponding bibliography).

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# Coppa Nevigata (Foggia)

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Coppa Nevigata is one of the most important fortified Bronze Age settlements in south-central Italy currently known, and one of the sites that has been most extensively investigated (fig. 1). First excavations were carried out at the beginning of the 20th century by Q. Quagliati and then A. Mosso; investigations at the site were resumed by S.M. Puglisi between 1955 and 1975, with the first extensive excavations conducted between 1972 and 1975. Since 1983, systematic extensive explorations have been carried out through annual campaigns over an area that now extends to approximately 3,500 m² (Cazzella-Moscoloni-Recchia 2012, with bibliography therein).[1]

The settlement was located just south of the Gargano Promontory on the margins of an ancient lagoon (Lago Salso), now reclaimed. The lagoon connected it to the Adriatic Sea, yet providing protection from seaborne attacks. Prior to the Bronze Age, the area hosted a ditched Neolithic village and was subsequently frequented during the Early Eneolithic (Cassano and Manfredini 1987). The Bronze Age settlement developed from at least the 18th century BC and was continuously occupied until the Early Iron Age (8th century BC).

Research at the site has always been characterised by interdisciplinary collaborations, providing a wide range of bioarchaeological, archaeometric, geomorphological, and biomolecular data (Cazzella-Moscoloni-Recchia 2012, with bibliography therein; Jones *et al.* 2014; Thompson *et al.* 2025), including the results obtained through the PRIN 2020 HERDS project. Moreover, an extensive series of $^{14}C$ dates provides a robust chronological framework for the various phases of occupation.

## 1. The fortification lines

One of the most distinctive features of the settlement is the complex system of fortifications protecting it on the inland side. Starting from the early 17th century BC, these fortifications were built and then repeatedly modified and rebuilt throughout the various phases of occupation (Cazzella and Recchia 2012, 2013a). The overall extent of the settlement enclosed by the defensive lines is estimated at around 2.5 hectares and appears to have not changed much in size throughout the Bronze Age.

The earliest fortification line, dating to the 17th century BC (Protoapennine – Middle Bronze Age 1), already displays a notably complex layout, possibly inspired by external models (Cazzella and Recchia 2013b). It consisted of massive dry-stone walls (fig. 1.1), with an average thickness of approximately 5.5 m and a currently preserved height in some sections of about 2 m, but which is estimated to have originally reached circa 5 m along the whole of the walls. The circuit was interrupted by a series of posterns, two of which are

[1] Excavations at Coppa Nevigata are carried out under concession by the MiC (Italian Ministry of Culture) to the Department of Antiquity, Sapienza University of Rome; the local responsible functionary is Dr. Donatella Pian. Scientific director of research: Alberto Cazzella (1983-2020), Giulia Recchia (2021- present). Research at Coppa Nevigata is sustained by Sapienza University through funds obtained in the framework of 'Grandi Scavi' research projects. The research also benefits from the MIUR and European Union funds with the PRIN research project 'HERDS' and PRIN PNRR 2022 research project 'SHORES'.

preserved up to their stone-slab roofing, and by at least one main gate, 3.5 m wide, thus allowing the passage of carts (fig. 1.2). This gate was flanked by jutting towers with semicircular external fronts, inside which chambers were created that opened directly onto the access road.

During the 16th century BC (Late Protoapennine – Middle Bronze Age 2A), the settlement expanded beyond the defensive wall. However, there is no evidence to determine whether an additional outer wall was constructed at this stage, since the excavation of the later ditch may have obliterated any such remains. To the end of the 16th century BC a major fire event, likely deriving from a significant attack by one or more antagonistic communities, affected the entire area outside the original fortifications (Recchia 2010; Recchia-Cazzella 2019).

A new defensive line, almost adjacent and running parallel to the earlier one, was constructed in the 15th century BC (Early Apennine – Middle Bronze Age 2B). This is characterised by an unusual technique: rather than forming a continuous circuit, it was divided into separate segments, spaced at intervals of between 5 and 7 m (fig. 1.3); moreover, on the preserved lower portion, the outer perimeter was made of dry-stone, but the filling consisted in yellow crushed limestone mixed with soil.

In the 14th century BC (Late Apennine – Middle Bronze Age 3), the fortifications were completely rebuilt (fig. 1.4), partially overlapping the layout of the earlier 17th-century BC circuit. The former gate between the towers was blocked and a new entrance opened further to the east (fig. 1.5). The number of posterns was also considerably reduced and, within the same phase, eventually closed altogether. Several external turrets were added along the walls, and at a short distance from the wall a large defensive ditch (12 m in width and 4 m in depth) was excavated (fig. 1.6).

From the 13th century BC onwards (Early Subapennine – Recent Bronze Age 1), the defensive line, as well as the settlement, underwent significant restructuring. The ditch remained into use, yet the former wall was partially dismantled. It is likely, however, that the settlement was now protected by a defence that has left little archaeological trace, such as a palisade erected atop the residual portions of the earlier dry-stone walls (Cazzella and Recchia 2015: fig. 5).

During the final phase of occupation in the 8th century BC (Early Iron Age), the defensive system was radically transformed once again. The ditch was replaced by a lowered clearing around the settlement, within which a dense series of upright stones was installed (fig. 1.6). This technique, known as *chevaux-de-Frise*, possibly associated with the wider use of horses in warfare, is known elsewhere in Europe but is first documented in Italy at Coppa Nevigata. Closer comparisons are in the Istrian *Castellieri* (i.e. Vrčin, Monkodonja, Gradac Turan, Veliki Brijun) where this technique was in use since the Late Bronze Age, if not earlier (Mihovilić-Hänsel-Teržan 2013; Cupitò *et al.* 2018, Recchia and Cazzella 2019).

## 2. Internal organisation of the settlement

Regarding the internal organisation of the settlement, evidence relating to the earliest phases remains limited. An apsidal hut destroyed by fire, unearthed by Puglisi, currently represents the sole evidence for the 18th century BC (Early Protoapennine), prior to the construction of the fortification wall (Cazzella and Recchia 2012, fig. 4). For the first fortified settlement (17th century BC), the main known feature is a sub-rectangular structure, probably domestic, with an associated clay vaulted oven, located in the north-western area close to the inner face of the defensive wall (fig. 1.7).

As mentioned above, during the 16th century BC (Late Protoapennine), the settlement expanded partially beyond the defensive circuit. This external area was devoted to activities connected with the storage and processing of foodstuffs, likely carried out on a collective basis. Functional installations of various types were identified, including a cereal storage silo, various clay hearts and firing structures for cereal roasting, and at least two roofed structures intended for storage and processing (fig. 1.8). It was precisely this area that was destroyed by the extensive fire event, probably of military origin, at the end of the Protoapennine.

Evidence for the settlement in the Early Apennine (late 16th-late 15th centuries BC) is limited to a cobbled space partially overlying the residual remains of the earlier Protoapennine fortifications, now partly dismantled, in the north-western area. Very significant evidence, however, is that of funerary practices within the settlement, including both formal burials and the deposition of human remains, particularly along the lines of fortification (Recchia 2012; Thompson *et al.* 2025). While no coeval settlements in southern-central Italy have yielded comparable evidence, close parallels can be identified with the *Castellieri* of Istria and the Friulian plain, highlighting cultural connections and shared ideological practices with the northern Adriatic (Recchia and Cazzella 2021, with bibliography therein).

During the Late Apennine (late 15th-14th centuries BC), along with the radical transformation of the defensive system, the overall layout of the settlement was reorganised. Among the most notable features is the creation of a large open cobbled area near the new entrance in the north-eastern sector (fig. 1.9). This space, intentionally kept free of built structures, was probably intended for collective social activities, possibly including intra- and inter-community exchange (Cazzella and Recchia 2015).

From the Early Subapennine (13th century BC – Recent Bronze Age 1) onwards, the settlement underwent


Fig. 1 – Coppa Nevigata, the explored area 1983-2025 (photomosaic of drone pictures). 1: the 17th c. BC dry-stone wall with posterns; 2: the 17th c. BC gate flanked by towers, then blocked in the 14th c. BC; 3: segments of the 15th c. BC wall; 4: the 14th c. BC dry-stone wall; 5: the 14th c. BC gate; 6: the 14th c. BC ditch converted into a clearing with chevaux the Frise in the 8th c. BC; 7: 17th c. BC dwelling structure with associate vaulted oven; 8: burnt 16th c. BC area with structures outside the 17th c. BC wall; 9: wide open area near the north-east entrance (14th-13th c. BC); 10: artificially raised mound and small path (13th c. BC); 11: two-room building on the slope of the artificially raised mound (12th c. BC); 12: cluster of cylindrical storage pits (late 12th c. BC); 13: series of elongated rectangular burnt structures aligned along the same axis (late 13th-12th c. BC). (Archive of the Coppa Nevigata research; drone pictures E. Lucci).

*Coppa Nevigata, l'area esplorata tra il 1983 e il 2025 (foto-mosaico di riprese da drone). 1: le mura con postierle del XVII sec. a.C.; 2: la porta del XVII sec. a.C. fiancheggiata da torri e poi tamponata nel XIV sec. a.C.; 3: i segmenti delle fortificazioni del XV sec. a.C.; 4: le mura del XIV sec. a.C.; 5: la porta del XIV sec. a.C.; 6: il fossato del XIV sec. a.C. poi convertito in una spianata con cavalli di Frisia nell'VIII sec. a.C.; 7: la probabile capanna del XVII sec. a.C. con associato forno 'da pane'; 8: area incendiata del XVI sec. a.C. con strutture funzionali al di fuori delle prime mura di fortificazione; 9: ampia area aperta presso l'entrata nord-orientale (XIV-XIII sec. a.C.); 10: dosso artificiale e stradina (XIII sec. a.C.); 11: struttura bicellulare sul fianco del dosso artificiale (XII sec. a.C.); 12: nucleo di fosse circolari di stoccaggio (tardo XII sec. a.C.); 13: serie di strutture rettangolari allineate secondo il medesimo asse (tardo XIII- XII sec. a.C) (Archivio ricerche a Coppa Nevigata, riprese da drone E. Lucci).*

profound spatial and socio-political transformation. An artificially raised mound, made of crushed yellow limestone mixed with soil, was constructed near the entrance gate (fig. 1.10), and a system of paths was laid out, along which buildings and open spaces were progressively organised.

The levels attributable to the Late Subapennine (late 13th-12th century BC) are those most extensively investigated. In this period, elements indicative of the presence of an elite become more clearly visible. These include: the construction of buildings on the artificial mound near the gate (fig. 1.11), associated with an area characterised by a concentration of prestige goods (such as Italo-Mycenaean pottery, metal artefacts, and a rock crystal bead); the spatial definition of areas devoted to craft production (Lucci 2022); the clustering of storage facilities (fig. 1.12) and of installations for the preparation and collective consumption of food, presumably imbued with symbolic value and coordinated by a central authority. Metallurgical activity also intensified in this period, for which clearer evidence of on-site production within the settlement is available (Cazzella and Recchia 2021).

Recent excavations in the eastern area of the site have revealed at least five phases of restructuring, characterised by alternating domestic buildings, artificially accumulated silt deposits, and functional installations (mostly structured clay hearths and ovens). Of particular interest is the layout of the earliest identified phase (V), comprising a series of elongated rectangular structures neatly arranged along a north-west/south-east axis (fig. 1.13), resulting from deliberate planning, possibly controlled by the elite (Cazzella and Recchia 2023).

Due to erosion and modern ploughing, deposits relating to the Final Bronze Age and Early Iron Age (11th-8th centuries BC) are largely unpreserved, except for fills from some pits and from the lower clearing/ditch outside the former dry-stone walls. Nevertheless, the settlement appears to have continued to flourish, as indicated by the remodelling of the defensive line and the abundant Proto-Geometric and Geometric pottery recovered from these fills and from surface layers. The site was eventually abandoned in the 8th century BC, most likely because of the progressive silting up of the lagoon (Caldara and Simone 2012), which rendered it no longer navigable.

## 3. Exchange networks

From the earliest phases of occupation, the Bronze Age settlement of Coppa Nevigata appears to have a marked orientation towards maritime exchange. Early contacts with the pre-Mycenaean Aegean are suggested by the introduction of purple-dye production as early as the 18th century BC (Minniti and Recchia 2018), currently the earliest evidence in Italy, as well as by the production of olive oil from the same period.

Throughout its life, the settlement seems to have maintained continuous and direct contacts with the trans-Adriatic regions, plausibly extending as far as the Istrian area. These relationships are attested by stylistic similarities in ceramic and metallurgical productions (Cazzella and Recchia 2018), alongside affinities in ideological and symbolic practices, such as the abovementioned placement of burials along the lines of fortification (Recchia and Cazzella 2021). They may also include the transmission of poliorcetic techniques, such as that of the so-called *chevaux-de-Frise*.

Maritime and overland contacts with the Po Valley and northern Italy are illustrated by technological and stylistic affinities, particularly in the manufacture of antler/bone artefacts, which display clear parallels with the Terramare cultural sphere, especially during the Recent Bronze Age. Further indication is provided by the influx of raw materials, including amber and possibly copper originating from the south-eastern Alpine region.

Direct contacts with Mycenaean seafarers are less evident. It is therefore possible that the resident community acquired exotic goods originating from the Mycenaean Aegean through exchange networks involving intermediary sites along the central-southern Apulian coast. Aegean-Mycenaean pottery remains numerically scarce until the advanced phase of the Recent Bronze Age, when local production of fine painted wheel-thrown ceramics imitating Mycenaean wares flourished (Vagnetti-Bettelli-Recchia 2012; Jones *et al.* 2014: 139-142). It is during this period, coinciding with the crisis of the Mycenaean world, that a new route appears to have been established between the eastern Aegean and the Adriatic, extending as far as the northern Adriatic. Within this changing political and economic scenario, Coppa Nevigata may have assumed a different role within the network of international exchange (Cazzella and Recchia 2021).

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# Torre Galli (Drapia, VV): from 1922-23 Paolo Orsi's Investigations to 2012-13 Researches in the Early Iron Age Settlement

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The flanks of the Tropea promontory – the major western prominence of Southern Calabria – rise with a series of terraces from the coast inland, culminating in the vast summit plateau of the Poro highplain, an undulating landscape with altitudes ranging from 500 to 700 meters a.s.l., whose very fertile soils originated from fine ashes ejected by the Aeolian volcanoes (Vingiani *et al*. 2014).

The highplain juts out toward the Tyrrhenian Sea with a trapezoid-shaped plateau – 18 hectares in size and just over 600 meters a.s.l. – on which the protohistoric settlement of Torre Galli was located (fig. 1). This plateau joins the highplain on the eastern side with a gentle slope, while on the other three sides it slopes sharply toward the valley with high and steep slopes. The site is located approximately 2.5 kilometers east of the village of Carìa (municipality of Drapia, province of Vibo Valentia).

In 1922 and 1923, Paolo Orsi directed two excavation campaigns in the plain east of the settlement (fig. 2A), which brought to light one of the most important protohistoric necropolises in Italy, published shortly thereafter in *Monumenti Antichi dei Lincei* (Orsi 1926). 280 burials, dating to the initial phase of the Early Iron Age (late 10th and part of 9th century BC), were the subject of a critical re-edition in 1999 (Pacciarelli 1999). Another 54-55 tombs pertained to the final phase of the indigenous community's development, dating to the sixth century BC (Cardosa 2017).

Beginning in the 1970s, new data were acquired on the topography of the settlement and necropolis. In the area marked B on the map (fig. 2), remains of residential structures dating from the late Iron Age to the Archaic Age were excavated in 1989-90. Throughout the central and western area of the plateau, were found surface fragments mostly attributable to these final phases of the site's life, but also artifacts from various prehistoric periods. Early Iron Age fragments were found in an area of approximately 2 hectares (sector corresponding to fig. 2 D) located on the eastern edge of the plateau. At point C of the map (fig. 2; see also fig. 3), an excavation was carried out in 1997, revealing a stretch of cobbled road, slightly recessed into virgin soil; in the fill was found pottery datable to the end of Phase 1 or the beginning of Phase 2 of the Early Iron Age (Pacciarelli 2001, fig. 65).

The main necropolis, excavated by Orsi, extends across the plain located immediately east of the settlement (fig. 2A), while other smaller burial grounds are located near small hills on the slopes facing NW (Pett'a'Rina and Cava Vigne: see Pacciarelli 2001, fig. 64, points E and F).

The study of the significant remains from the necropolis has demonstrated the existence at Torre Galli of an Early Iron Age community that was quite prosperous and organized on the socio-economic and political-military levels, capable of very early involvement in the nascent network of Mediterranean relations at the beginning of the first millennium BC (Pacciarelli 1999 and 2001). Evidence of this is provided by early imports from the Cypriot-Levantine area (Pacciarelli and Lo Schiavo 2017) as well as the pioneering role that Torre Galli assumed in

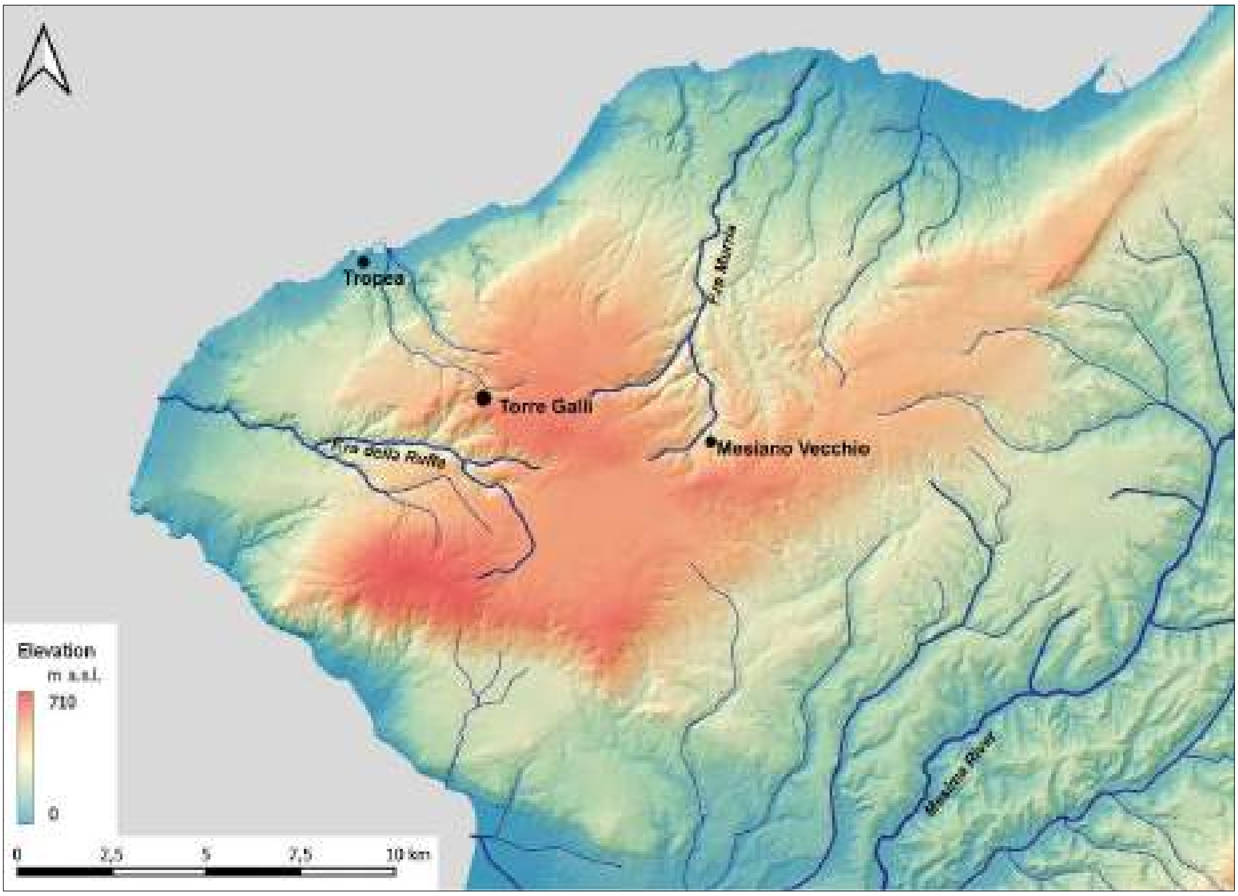


Fig. 1 – Poro Promontory: Torre Galli and other Early Iron Age settlements (elaborated by Lorenzo Fiorillo).
*Promontorio del Poro: Torre Galli e gli altri insediamenti della prima età del ferro (elaborazione di Lorenzo Fiorillo).*

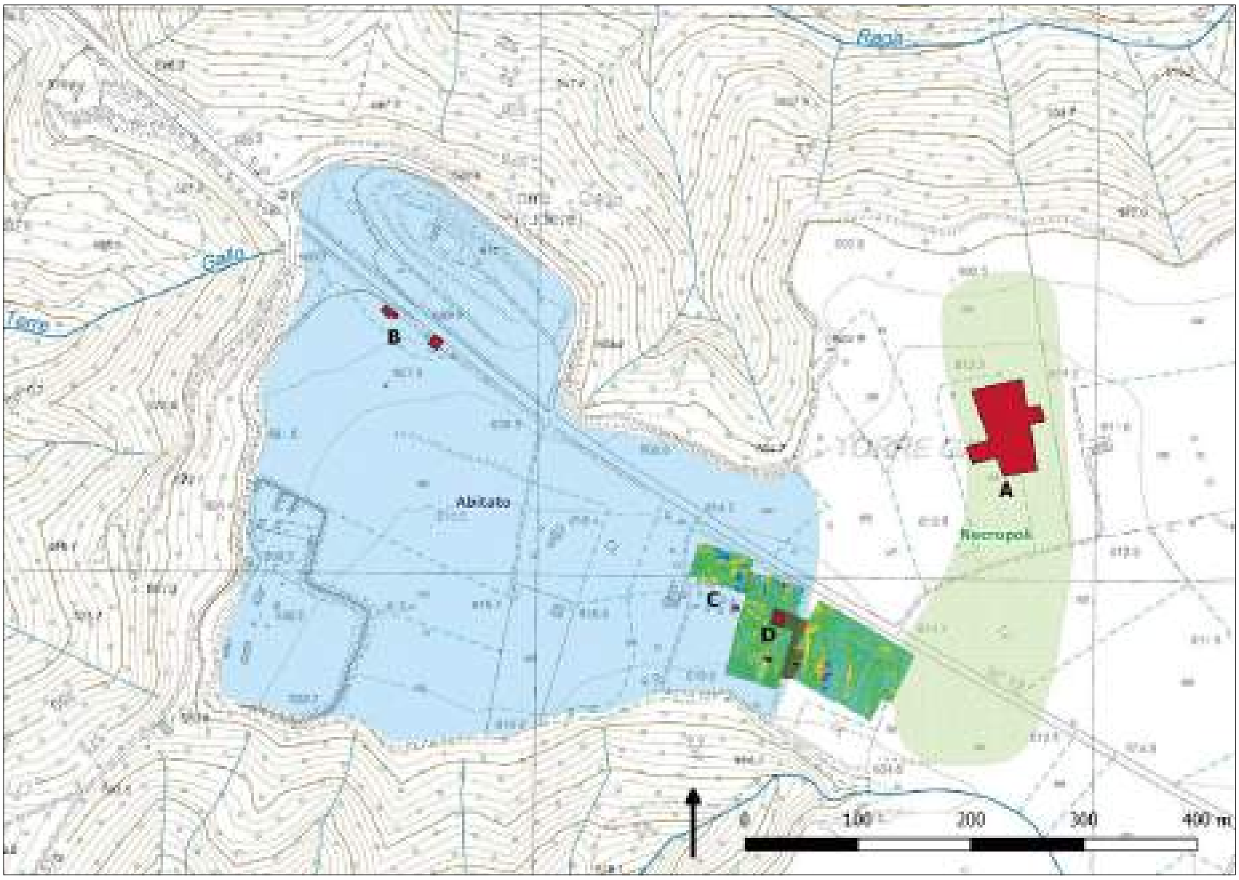


Fig. 2. – Topography of Torre Galli, highlighting the area of the plateau occupied by the settlement and the area of the main necropolis, with the location of the excavations in the necropolis of 1922-23 (A) and those in the settlement of 1987-90 (B), 1997 (C), and 2012-13 (D). Pacciarelli *et al.* 2017, fig. 5a and tav. XIa (elaborated by Lorenzo Fiorillo).
*Topografia di Torre Galli: in evidenza l'area del pianoro occupato dall'insediamento e l'area della necropoli principale, con posizionamento degli scavi nella necropoli del 1922-23 (A) e di quelli nell'insediamento del 1987-90 (B), del 1997 (C), del 2012-13 (D). Pacciarelli et al. 2017, fig. 5a e tav. f.t. XIa (elaborazione di Lorenzo Fiorillo).*

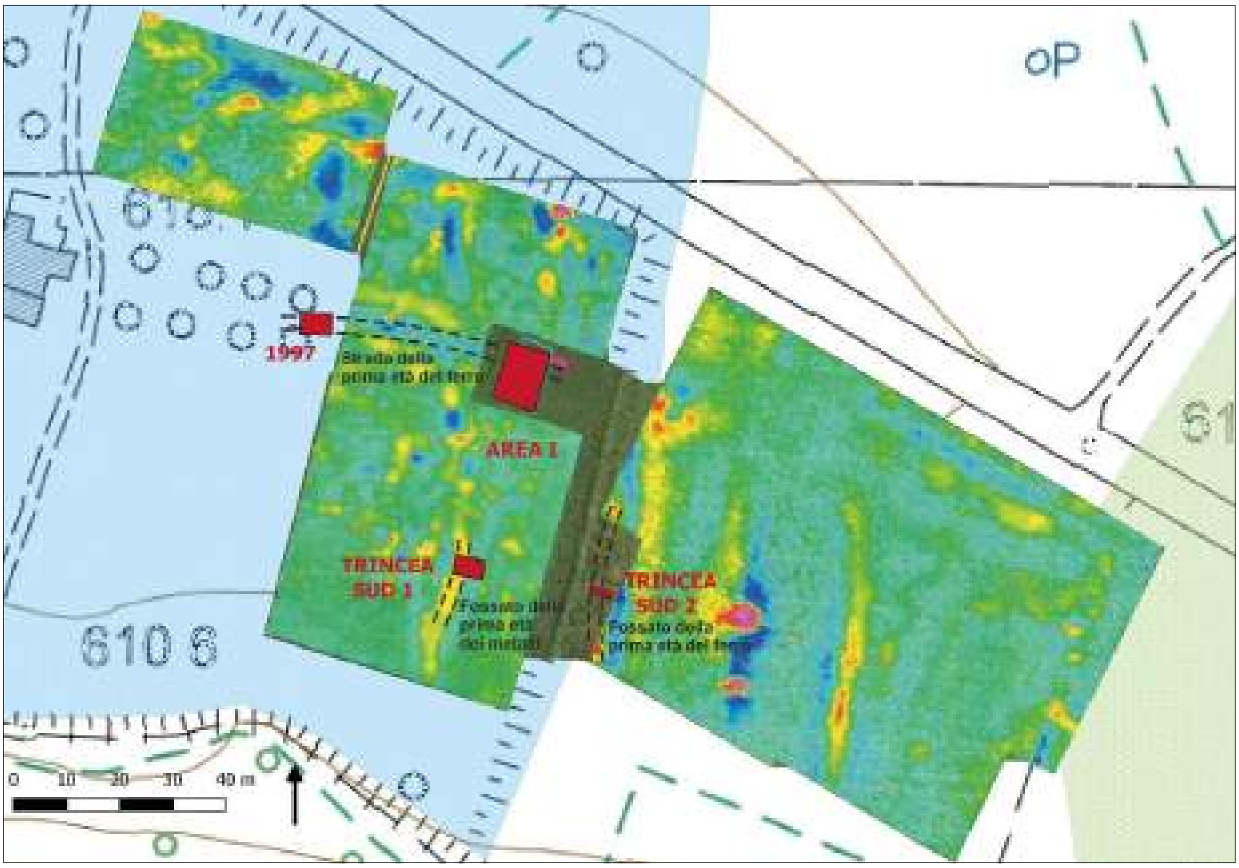


Fig. 3 – Torre Galli, map of the geophysical anomalies detected in 2012 and location of the 1997 and 2012-13 excavations, with reconstruction of part of the Early Metal Age defensive ditch and the Early Iron Age road and defensive ditch. Pacciarelli *et al*. 2017, fig. 8b and plate XII, 1 (elaborated by Lorenzo Fiorillo).

*Torre Galli, mappa delle anomalie geofisiche rilevate nel 2012 e posizionamento degli scavi del 1997 e del 2012-13, con ricostruzione di parte del fossato difensivo della prima età dei metalli e della strada e del fossato difensivo della prima età del ferro. Pacciarelli et al. 2017, fig. 8b e tav. f.t. XII, 1 (elaborazione di Lorenzo Fiorillo).*

the technological field as the first hub for the systematic reception of ironworking in the central Mediterranean (Pacciarelli and Quondam 2020; Pare 2025). Evidence of medium-range maritime exchange is provided by the large piece of Sicilian amber from tomb 206 (Guerreschi 1999) and the Nuragic-type artefact discovered in the necropolis (Lo Schiavo Pacciarelli 2017).

A new cycle of geophysical surveys and archaeological excavations in the necropolis, still underway, was started by the University of Naples Federico II in 2023 (Quondam *et al*. in press).

As surface and geophysical surveys have shown, the necropolis covers approximately 4.5 hectares (fig. 2), which, when compared to the density documented in the Orsi excavation, would yield a total of at least two thousand tombs.

The settlement which developed on the nearby 18-hectare plateau, considering its location, size and high level of development, must have controlled and exploited a vast surrounding territory, which included the fertile soils of the adjacent highplain – at least up to the vicinity of the minor coeval site of Mesiano, likely part, as Tropea, of Torre Galli polity – as well as the underlying terraces sloping down towards the sea, and in particular towards the coastal center of Tropea (fig. 1). Early active involvement in maritime activities was greatly facilitated by the position of Torre Galli, affording a commanding view of the entire lower Tyrrhenian Sea.

As part of the PRIN 2009 project "*Centri fortificati, sistemi di insediamento e processi ambientali nella Calabria tirrenica tra secondo e primo millennio a.C. Un'indagine interdisciplinare*" (Principal Investigator Marco Pacciarelli), the settlement of Torre Galli was the subject of two research campaigns between 2012 and 2013 (Pacciarelli *et al*. 2017).

Along the naturally less defended eastern edge of the settlement, a combination of geophysical surveys and exploratory trenches identified structures of various periods (fig. 3). The trench designated Sud 2 revealed part of an Early Iron Age defensive ditch, dug into the granite rock (fig. 3; Pacciarelli *et al.* 2017, fig. 8a). Abundant archaeological material and faunal remains were found within it. The lower part of the fill consisted of mostly silty or sandy layers, while the upper part contained

Fig. 4 – Torre Galli settlement: image of the 2012-13 excavation (photo by Cristiano Iaia).
*Abitato di Torre Galli: immagine dello scavo del 2012-13 (foto di Cristiano Iaia).*

abundant stone (and a certain amount of charred wood), likely resulting from the collapse of a fortification. This suggests that the Early Iron Age settlement of Torre Galli, along the eastern open side, approximately 250 m wide, was equipped with a defensive structure.

In the main excavation area, a complex series of structures excavated into the geological subsoil – a clayey paleosoil that developed on the local granite bedrock – was investigated. The main structure consisted of a sunken road bordered on at least one side by a stone wall reinforced internally by wooden posts (fig. 4). This road, paved with small stones, was aligned with the route – also sunken – identified in 1997 (fig. 3). The excavation uncovered faunal remains and abundant Early Iron Age pottery, attributable, like that of the 1997 excavation, to the end of Phase 1 or the beginning of Phase 2 of the Early Iron Age (Matarese 2017), in terms of absolute chronology to late ninth or early eighth century BC.

In the 2012-13 excavation area, significant traces of a conflagration were identified that appear to mark a moment of traumatic interruption in the life of the settlement – probably due to a war event – which essentially coincides with the beginning of a marked rarefaction of presences in the necropolis starting from the beginning of phase 2B of the Early Iron Age, that is, from the central decades of the 8th century BC, up until the 7th century BC. Data from excavations in the settlement carried out in 1989-90 and from recoveries in the necropolises, as well as from the 2012-13 excavations, however, allow us to at least partially fill this gap, testifying to the fact that the crisis certainly greatly weakened the community for some generations but did not completely interrupt its continuity (Pacciarelli 2017).

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# Mursia. Pantelleria (TP). Bronze Age Settlement and Cemetery

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Investigated repeatedly from the first research conducted by Paolo Orsi in 1895 to the excavations led by Carlo Tozzi in the late 1960s, the settlement of Mursia and the associated monumental cemetery of “I Sesi” represent one of the most significant contexts for understanding the complex social and economic dynamics of the Bronze Age in the central Mediterranean. The settlement, covering approximately 1 hectare, together with its massive fortification wall and large tumulus tombs, testifies to a complex society integrated into the trade and exchange networks that intensified at the beginning of the second millennium BC (Cattani 2016; Cattani *et al*. 2019; Cattani-Marazzi-Tusa 2020). The archaeological complex is dated between 1800 and 1450 BC, a chronology confirmed by the majority of radiocarbon dates and by the ceramic assemblage, which does not yet display features typical of the Sicilian Middle Bronze Age (Ustica, Milazzese facies, Thapsos).

Research resumed in 2001 through an interdisciplinary project directed by the late Sebastiano Tusa, involving scholars and specialists from the University of Bologna and the University Suor Orsola Benincasa of Naples, in collaboration with the Soprintendenza per i Beni Culturali e Ambientali di Trapani and the Archaeological Park of Selinunte, Cave di Cusa and Pantelleria. These investigations brought to light several sectors of the settlement and examined some of the monumental tombs.

The settlement of Mursia is located along the north-western coast of the island of Pantelleria, occupying the flat summit of a volcanic rocky spur approximately 30 m above sea level. The choice of location was dictated by fundamental strategic factors: the natural protection provided by steep sea cliffs and the proximity to two inlets, Cala di Mursia to the north and Cala dell’Alca to the south, which functioned as sheltered landings protected from prevailing winds. Additional key resources included the {*bovire* – coastal springs of brackish but potable water essential for human and animal sustenance (Cattani 2015: 4) – and the extensive surrounding slopes suitable for cultivation and grazing.

The settlement extends over approximately 1 hectare, largely overlooking the cliff edge, and is protected on the inland side by the “Muro Alto,” a monumental drystone fortification approximately 210 m long, 6-8 m wide at the base, and originally over 10 m high (fig. 1). The structure features an external scarped profile and at least three presumed semicircular bastions positioned strategically. Its defensive character clearly prevented access from the non-naturally isolated side; however, its dimensions exceed what would be strictly necessary based on contemporary military requirements. It is therefore likely that the fortification also fulfilled additional roles, such as defining the physical and symbolic boundaries of the settlement, distinguishing those living within from outsiders, and representing the power and strength of the community that built it. For those approaching by sea, the view must have been striking, conveying an impression of wealth, prosperity, and prestige. The wall may also have functioned as a unifying element for community members organised into family groups or tribal segments, assuming a symbolic value linked to collective identity and egalitarian ideological management. This same prosperity is reflected in the abundance of resources gathered within the settlement, which may have constituted exchange goods in Mediterranean trade.

## 1. Settlement dynamics and domestic architecture

The development of the Mursia settlement is documented through a continuous stratigraphic sequence spanning approximately three centuries, between the 18th and the mid-15th century BC, corresponding to the advanced phases of the Early Bronze Age and the beginning of the Middle Bronze Age. Settlement dynamics show no clear interruption; for analytical purposes, three main architectural macro-phases can be distinguished, interspersed with numerous episodes of restructuring that were not always simultaneous (Debandi and Magrì 2023: 204).

The initial phase reflects an organic and planned building project, particularly evident in Sector B, where residential units are arranged in parallel rows oriented north – south. The huts have elongated oval plans (average surface 20-30 m²) and are semi-subterranean, with floors recessed below ground level (Cattani 2015: 8; Ardesia *et al.* 2006: 298). In Sector D, some structures display asymmetrical ends with ogival apses evocative of boat hulls. Walls were built using a single course of dry-laid lava stones, sometimes coated with reddish clay plaster (Debandi *et al.* 2021: 214). A distinctive technological feature is the presence of small holes in clay floors, interpreted as devices to accelerate the drying of damp sediment or facilitate drainage (Cattani 2015: 9). Each unit appears as an autonomous residential nucleus, likely housing families of approximately 8-10 individuals.

Soon after the initial phase, non-simultaneous transformation activities affected selected structures, involving room amalgamations and functional changes. Some huts were temporarily abandoned and later reused without architectural modification, while others underwent radical restructuring. In cases such as complex B13-B14, original huts were subdivided into multiple rooms or combined to create interconnected spaces (Debandi and Magrì 2023: 205).

The final occupation phase marks a significant urban transformation, with the adoption of a new building model (Cattani 2015, p. 12). Huts became substantially larger, with horseshoe-shaped plans (e.g., B10, 48 m²) and thick double-faced walls; floors were generally level with the exterior ground surface. A clearer separation emerged between residential areas and spaces dedicated to productive activities. “kitchen huts” (e.g., B5, B7 and cluster E1-E3 in Sector E) were identified as small rooms almost entirely occupied by food-processing installations: raised clay hearth plates, firedogs, grinding stones, and abundant pottery (Debandi-Magrì-Peinetti 2021: 215). In the seaward sector, a limited number of agglutinated quadrangular-plan buildings were constructed, recalling proto-urban organisational processes documented at Ustica and Thapsos.

The abandonment of the settlement around 1450 BC is marked by a series of fires documented in Sectors B and E, which sealed domestic assemblages and tools in primary position beneath collapsed roofing debris (Debandi and Magrì 2023: 206). However, these fires alone do not explain the reasons for the site’s final abandonment, as it was never reoccupied. Stratigraphic evidence indicates episodes of burning in all phases, and the latest occupation evidence has been partially lost due to modern stone clearance and pedogenetic processes affecting preservation.

The uninterrupted sequence reflects a society structured around independent family nuclei that gradually evolved into more complex communities capable of managing collective activities while fully integrated into central Mediterranean exchange networks. Most imported prestige objects belong to the advanced phases.

External contacts are confirmed by numerous allochthonous materials (Marazzi 2016; Cattani-Marazzi-Tusa 2020). Some ceramic fragments show parallels in the Nile Delta and along eastern Mediterranean coasts, in some cases confirmed by archaeometric analyses demonstrating non-local clay compositions. Other fragments with deep incised decoration are comparable to Malta’s Tarxien Cemetery phase and other central Mediterranean productions (Magrì 2024). Additional materials – including glass beads, vitreous materials, faience (Barchiesi and Cattani 2024), and approximately ten ivory objects (bracelets and worked raw material) – attest to exchange networks involving prestige materials from the eastern Mediterranean to the Iberian Peninsula.

Community prestige was further expressed through the construction of monumental tombs featuring original funerary practices and architectural models without clear parallels in the Mediterranean. Distributed around the village in several groups, these tumuli likely served as collective burial places for the same tribal segments composing the Mursia community. The circular or oval tumuli, measuring 5-20 m in diameter and 3-6 m in height, constituted highly visible ritual landmarks, either from the settlement or from approaching vessels, reinforcing the inhabitants’ prestige. Built in dry stone, the monuments consist of multiple corridors (3-12) leading to burial chambers.


Fig. 1 – Aerial view of the settlement from south and from west. View of eastern side of the fortification wall. Excavation of E1 structure. Imported finds (rock crystal bead, blue glass bead, white glass bead, ivory bracelet). Stone mould for axe casting.

*Vista aerea dell'insediamento da sud e da ovest. Vista del lato orientale del muro di fortificazione. Scavo della struttura E1. Reperti di importazione (perla in cristallo di rocca, perla in vetro blu, perla in vetro bianco, bracciale in avorio). Matrice in pietra per la fusione di asce.*

The subsistence economy of Mursia was based on an integrated system of agriculture and pastoralism, with marginal contributions from hunting, fishing, and shellfish gathering (Cattani and Tusa 2012: 815).
Zooarchaeological data confirm that husbandry focused on the four principal domestic species: sheep and goats, cattle, and pigs. Osteological remains recovered from occupation layers – often in the form of micro-fragments, fish bones, and shell fragments – indicate that meat and fish consumption took place directly within domestic spaces, near hearths.
Archaeobotanical analyses of charred macro-remains reveal a diet based on cultivated cereals and a wide variety of edible wild plants (Iacono 2019-2020: 74). The most frequently attested species include barley (*Hordeum vulgare* L.), emmer wheat (*Triticum turgidum* ssp. *dicoccon*), and, to a lesser extent, oats (*Avena* sp.). Anthropogenic weeds are also present, particularly goosefoot (*Chenopodium album* group) and purslane (*Portulaca oleracea*), which were likely used to supplement flour or consumed as vegetables. Seeds of wild apple (*Malus sylvestris*), fig (*Ficus carica*), and mastic (*Pistacia lentiscus*) are also documented. Recent excavation campaigns have yielded large quantities of charred pea and grass pea seeds, currently under study.

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HERDS – Animal Husbandry and its Economic Role in the Development of Central Mediterranean Protohistoric Societies – Rivista di Scienze Preistoriche – LXXVI S6 – 2026 – pp. 259-264

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# The Archaeological Complex of Sa Mandra Manna (Tula, Sardinia)

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The archaeological area of Sa Mandra Manna, in the territory of Tula (Northern Sardinia), occupies a modest trachytic plateau in a dominant position overlooking the Riu Mannu Coghinas plain. The complex comprises a settlement enclosed by a wall, a protonuraghe, and a Tomb of the Giants located approximately 100 m to the NNE of the fortified area and still partially buried. While the Nuragic structures are clearly defined, the chronological attribution of the enceinte remains uncertain in the current state of research and continues to be debated. This uncertainty is further compounded by the presence within the area of evidence attributable to earlier phases, including a dolmen and a domus de janas, attesting to prehistoric occupation of the site. An additional element of analysis is provided by the dense pattern of linear engravings and cup-marks incised on certain blocks of the entrance corridor of the enceinte, contributing to the complexity of the monument's overall interpretation.

The site of Sa Mandra Manna was first reported by Antonio Taramelli in the Carta Archeologica della Sardegna, noting a domus de janas and a nuraghe of which only a "small trace" remained (Taramelli 1939). More than fifty years later, Paola Basoli, at the international conference Sardinian Stratigraphy and Mediterranean Chronology (Tufts University, 1995), identified and described the megalithic wall, comparing it with the complexes of Monte Baranta (Olmedo) and Monte Ossoni (Castelsardo), attributed to the Monte Claro culture (Basoli 1998). The enceinte was subsequently mentioned by Alberto Moravetti in his study of Sardinian megalithic fortifications published in the volume on Monte Baranta (Moravetti 2002).

Between 2005 and 2006 Basoli conducted a first excavation campaign, bringing to light the protonuraghe, the engravings on the walls of the NNW corridor of the enceinte, and, beneath the Nuragic masonry, the remains of an earlier hut (Space A). An initial synthesis of the results was presented in 2009 at the conference La preistoria e la protostoria della Sardegna, where two construction phases were distinguished: the earlier enceinte and the later protonuraghe (Basoli and Doro 2012). In the same context, comparisons were proposed between the Tula engravings and the rock carvings of Othierie (Irgoli), of uncertain chronology (Massetti *et al.* 2011).

In 2011 the complex underwent conservation and consolidation works; test trenches in the affected areas refined the occupational phases during the Bronze Age and clarified the wall stratigraphy. Preliminary results were presented in 2012 at the Salone del Restauro in Ferrara (Basoli *et al.* 2012). Structural analysis and the study of the materials from Area A were developed in two theses (Doro 2013; 2014) and subsequently synthesized (Doro 2016; 2017a; 2017b).

Recent contributions have further examined the interpretation of the engravings in the northern corridor (Carrera *et al.* 2021; Basoli 2021). Ongoing research conducted by A. Depalmas and L. Doro includes the systematic study of materials and radiocarbon dating to refine the chronological framework of the principal constructional and occupational phases (Doro and Depalmas 2025), as well as experimental archaeological analyses of basketry impressions documented on several cooking pans recovered during the excavations (Doro *et al.* in press).

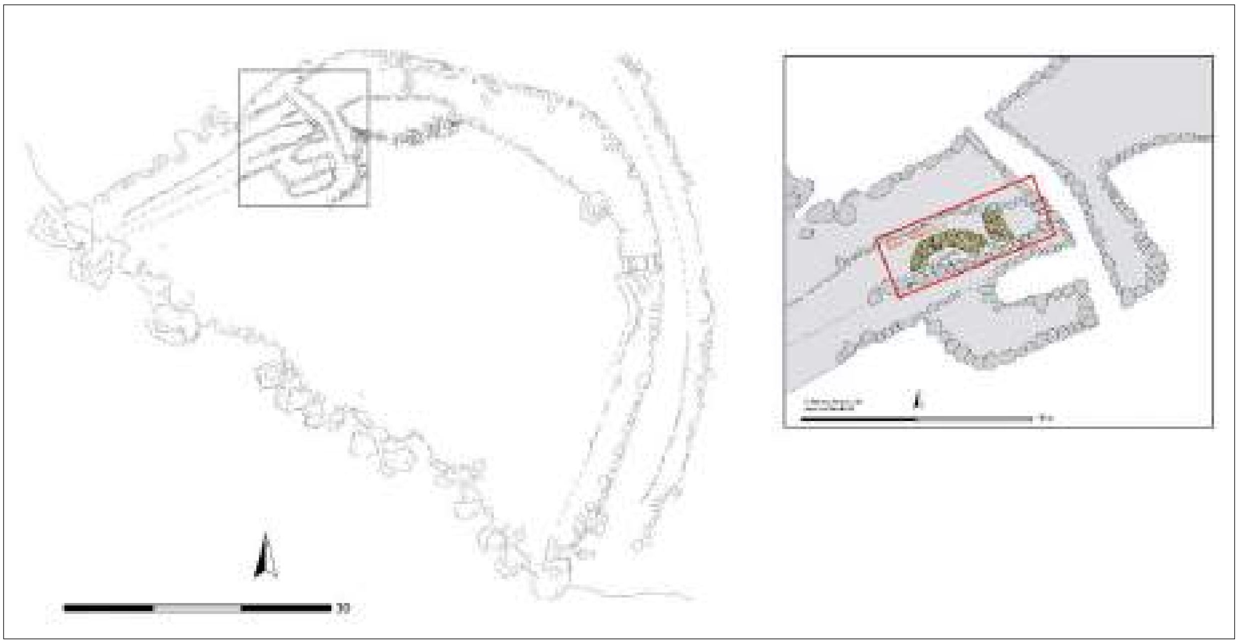

Fig. 1 – Sa Mandra Manna. General plan and detailed plan of Space A.
*Sa Mandra Manna. Planimetria generale e particolare dell’ambiente A.*

Fig. 2 – Sa Mandra Manna. Northern sector of the wall.
*Sa Mandra Manna. Tratto settentrionale della muraglia.*

Fig. 3 – Sa Mandra Manna. Eastern entrance.
*Sa Mandra Manna. Ingresso orientale.*

Fig. 4 – Sa Mandra Manna. Northern entrance.
*Sa Mandra Manna. Ingresso settentrionale.*

Fig. 5 – Sa Mandra Manna. Decorated blocks in the Northern entrance.

*Sa Mandra Manna. Massi incisi nell'ingresso settentrionale.*

The enceinte delimits a semicircular area of approximately 2,200 m², naturally defended by the edge of the plateau (fig. 1). It extends for about 120 m, with a maximum preserved height of 3 m and a width varying between 2.40 and 8.00 m. (fig. 2). It features two corridor entrances, oriented E (fig. 3) and NNW (fig. 4), as well as a third opening, now collapsed, which provided access from the cliff. The northern entrance (length 4.50 m) preserves linear engravings on the corridor blocks, of uncertain chronological and functional attribution (fig. 5).

During the Middle Bronze Age, significant restructuring is attested in the area of the northern entrance, including enlargement of the enceinte and its access corridor, upon which the subsequent protonuraghe was constructed. The new building belongs to the group of corridor-type protonuraghi widely documented in Sardinia and attributed to the Middle Bronze Age. The external plan is sub-rectangular (width c. 10 m; length 4.80 m on the W side and 3.57 m on the E side). Internally, the layout is defined by a longitudinal corridor running through the entire structure (fig. 6), from which a large lateral niche opens (fig. 7).

Archaeological excavations in the area between the enceinte and the protonuraghe identified, beneath the restructuring levels, the remains of an earlier building (fig. 1) interpreted as a hut (Space A). The structure is attested by a curvilinear double-faced wall with an internal fill of earth and stones; up to three courses are preserved to a maximum height of approximately 0.70 m. The building is directly founded on bedrock. Internally, a rammed-earth floor overlying a carefully laid stone pavement was documented.

Associated stratigraphic levels yielded ceramic materials attributable to the Sa Turricula facies (Early Middle Bronze Age) and fragments of clay bearing impressions of wattle, interpreted as remains of the timber superstructure. Outside the hut, in the area between the building and the enceinte, archaeological deposits containing ceramics and faunal remains attributable to the same cultural horizon were identified. Levels associated with the earliest hut phase were also recognized beneath the occupation surface of the protonuraghe niche and in foundation deposits under its masonry.

Excavation of the corridor revealed, in the upper levels, a thick layer of sterile soil with abundant collapse stones, associated with traces of sporadic historical-period activity. The underlying layers yielded a substantial assemblage of ceramic vessels – predominantly cooking pans and large storage jars – attributable to the Middle Bronze Age; their association with legume remains suggests domestic use of the structure. The widespread presence of charcoal and numerous fragments of fired clay debris within the corridor likely indicates a destructive event and supports the hypothesis of a sudden interruption of occupation of the nuraghe during the Middle Bronze Age.

Within the niche chamber, a hearth was uncovered, with faunal remains and ceramics likewise attributable to the Middle Bronze Age cultural horizon.

The current interpretative hypothesis, pending further confirmation, considers the enceinte as a structure predating the Nuragic phases, subsequently reused and transformed during the early Nuragic period.

Archaeological excavation and structural analysis of the monuments have defined a complex sequence of occupation and restructuring phases attributable to the early stages of the Nuragic sequence. However, the precise moment of construction of the enceinte remains undefined and requires further stratigraphic investigation. Regardless of its exact attribution, it is evident that the enceinte – whether erected or reused during the initial Nuragic phase – together with the hut documented to date, attests the existence of a settlement provided with a defensive system. Upon this initial nucleus, during the Middle Bronze Age, the protonuraghe was constructed, marking the beginning of a process of monumentalization associated with the full development of Nuragic architecture.

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Fig. 6 – Sa Mandra Manna. Corridor of the protonuraghe.
*Sa Mandra Manna. Corridoio del protonuraghe.*

Fig. 7 – Sa Mandra Manna. Corridor of the protonuraghe with lateral niche.
*Sa Mandra Manna. Corridoio del protonuraghe con nicchia laterale.*

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# Iloi (Sedilo, Oristano): the Nuragic Complex and Recent Archaeological Investigations

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The archaeological site of Iloi lies approximately 2.5 km south-west of the modern village of Sedilo (Oristano province), on the edge of a basaltic plateau overlooking the middle valley of the Tirso river, today partly occupied by the waters of Lake Omodeo. The location commands extensive views over the surrounding plains and the natural routes connecting the inland districts of central Sardinia with the coastal regions.

The archaeological complex comprises both a settlement and a funerary sector. The settlement is centred on a complex nuraghe of mixed type surrounded by an extensive village, while the funerary landscape includes at least two Giants' tombs built with isodomic masonry arranged in regular courses. In the surrounding area a large rock-cut necropolis of *domus de janas*, known as Ispiluncas, further attests to the long-term significance of the site within the Nuragic settlement system of the Tirso valley.

Excavations carried out between 2000 and 2004 revealed several domestic structures surrounding the nuraghe and provided the first insight into the organization of the settlement. The village appears to have covered an area of approximately 2 ha, partly enclosed by an outer defensive wall that may originally have been provided with towers. Thirteen structures have so far been investigated, most of them located in the north-western sector of the settlement, while structures 2 and 5 lie respectively in the south-western and south-eastern areas (fig. 1, 1).

Structures 6-9 and 12-13 appear to form an architectural compound organized around a central open space interpreted as a courtyard (structure 13) (fig. 1, 2). Within this cluster circular and elliptical buildings are connected by short rectilinear wall segments and small transitional spaces with quadrangular or elliptical plans. The huts brought to light are predominantly circular, with diameters ranging between c. 4 and 6.5 m. Their walls consist of dry-stone double-faced masonry with a thickness varying from 0.80 to 1.30 m. In several cases the wall bases are preserved to a considerable height, reaching approximately 1.70 m in structure 3 and 1.85 m in structure 8.

Entrances are generally oriented towards the east and occasionally display later modifications, such as the addition of steps, probably introduced during subsequent phases of use. Internal features frequently include niches cut into the wall thickness or small cupboards built against the inner face of the wall. In structure 2 a large niche was partly created by adapting the natural bedrock. Hearths have also been documented, either arranged against the wall opposite the entrance, as in structure 3, or in less formal configurations, as in structure 8.

Floor levels often correspond to the natural basaltic bedrock, sometimes regularized by clay surfaces or supplemented with stone pavements or cobbled floors, occasionally arranged in successive phases. Some huts contain central architectural features of particular interest. In huts 9 and 3 a trachyte column base and a circular basalt base were discovered respectively. In structure 3 the presence of a fragment of a limestone basin together with decorated sherds belonging to jugs and amphorae suggests that the building may have been used for ritual practices, possibly associated with lustral ceremonies.

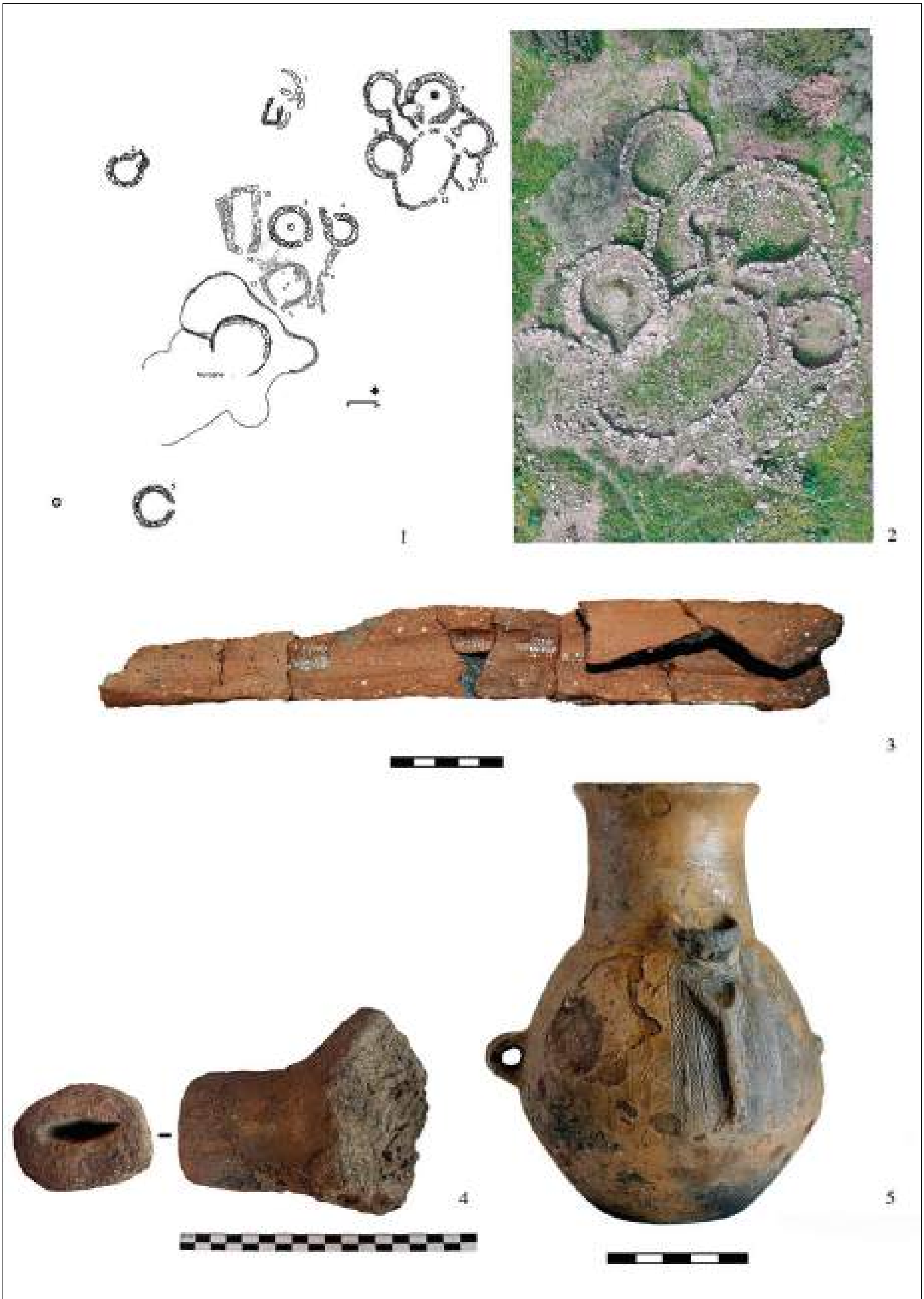

Fig. 1 – Iloi, Sedilo: plan of the Nuragic complex (1); detail of the north-eastern block (2); tuyere (3) and crucible (4) from Structure 3; piriform vessel from cultic Room 7 (5).

*Iloi, Sedilo: pianta del complesso nuragico (1); dettaglio dell'isolato nord-orientale (2); ugello (3) e crogiolo (4) dalla Struttura 3; vaso piriforme dall'ambiente cultuale 7 (5).*

A clear cultic interpretation has been proposed for the nearby structure 7, where a large hearth approximately 1.50 m in diameter was uncovered. The hearth was delimited by six carefully shaped stones bearing eight cup-marks and surrounded by a fragmentary stone pavement resting on a clay layer. The structure yielded numerous finds, including a stone basin and approximately 220 ceramic vessels. Among these, a richly decorated piriform vessel was recovered intact, intentionally deposited within the clay layer, probably as part of a foundation or refoundation ritual (fig. 1, 5).
Adjacent to structure 7 lies an elongated space (7a) paved with basalt and trachyte slabs. Its overall layout recalls that of Nuragic sacred wells or spring sanctuaries and it may therefore represent a structure connected with ritual activities.
Metal artefacts from the settlement are relatively scarce. Nevertheless, outside structure 3 a clay crucible with a hemispherical bowl and a solid quadrangular-section handle was recovered, while fragments of a slightly flared cylindrical clay element interpreted as a tuyère were found inside the same building, suggesting metallurgical activities within the settlement (fig. 1, 3-4).
The stratigraphic sequence documented in structure 3 indicates that the settlement was established during the Middle Bronze Age, with continued occupation throughout the Late Bronze Age and a phase of intensified activity during the Early Iron Age extending into the Orientalizing period. Radiocarbon determinations obtained from samples collected in structure 7 fall between 1189 and 813 BC.
In recent years the site has been the focus of renewed investigation within the Iloi Archaeological Project, directed by Anna Depalmas. Excavations resumed in 2018 and have concentrated primarily on the area north of the nuraghe, where additional portions of the settlement have been investigated. The campaigns conducted in June and July 2024, carried out under ministerial concession with the support of the Municipality of Sedilo and in collaboration with the Soprintendenza Archeologia, Belle Arti e Paesaggio for the metropolitan city of Cagliari and the provinces of Oristano and South Sardinia, involved students and postgraduate researchers from the University of Sassari and other institutions.
These investigations focused in particular on structure 17 and its immediate surroundings. Excavation exposed the preparation layers underlying the floor surface and clarified the building sequence, including the levelling of the natural bedrock and the installation of successive pavement layers and perimeter walls. In the passage between the structure and the outer face of the nuraghe a substantial collapse deposit containing worked stones and numerous ceramic fragments dating to the Early Iron Age was identified.
Further excavation was carried out immediately east of structure 17, where structures 22 and 28 and an open space (area 29) are located. Structure 22 displays a rectangular plan with an apsidal short side and walls built of carefully worked blocks arranged in relatively regular courses. The removal of collapse deposits revealed the entrance and a possible niche. Among the finds recovered were fragments belonging to a Phoenician jug dated to the 8th century BC, providing an important chronological marker for the latest phases of occupation of the settlement.
Overall, the investigations at Iloi are progressively refining our understanding of the spatial organization and development of the Nuragic village between the Middle Bronze Age and the Early Iron Age, highlighting the coexistence of domestic spaces, craft activities and buildings with probable ritual functions.

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# Abini (Teti, Nuoro): the Sanctuary Complex and Associated Settlement

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The archaeological site of Abini is located within the territory of Teti (Nuoro province), within a valley at approximately 250 m a.s.l. among the mid-altitude uplands of the surrounding mountainous landscape. The site occupies a flat terrace near the Taloro river, in a naturally sheltered position within the valley.

The complex was first identified in 1865, when inhabitants of Teti unearthed a considerable number of bronze artefacts. Giovanni Spano reported the discovery in 1866, describing the site as a prehistoric temple characterized by offerings and votive deposits. Part of the material recovered during these early finds was purchased by Cav. Timon and subsequently transferred to the Museum of Cagliari.

In 1878 a further clandestine discovery of bronzes attracted the attention of Filippo Vivanet, then Commissioner for Antiquities in Sardinia, who visited the site, acquired several artefacts and donated them to the Museum of Cagliari. Vivanet interpreted the context as a sanctuary and suggested that the other visible structures represented the remains of small nuraghi intended to accommodate priests and pilgrims.

Ettore Pais also discussed Abini as a sacred place in 1884, referring to excavations conducted in 1882 by the engineer Leone Gouin, who had purchased part of the land in order to continue investigations. The excavation was later reported by Filippo Nissardi for the Ministry of Public Instruction. In addition to the finds recovered during his excavation, Gouin acquired part of the bronzes from earlier discoveries and added them to his private collection, which was later transferred by his heirs to the Museum of Cagliari.

For several decades the site suffered from clandestine digging and destructive agricultural activities. Antonio Taramelli first visited the area in 1909, but systematic excavation was undertaken only in 1929, when he carried out investigations and published the available data together with a reconstruction of the site layout.

Taramelli was the first to focus attention on the architectural remains of what he also interpreted as a sanctuary. He identified the enclosure with a perimeter bench as a gathering place for worshippers assembled around a monumental spring, which he considered the central element of the cult.

After these investigations the site remained exposed for many years to clandestine excavations encouraged by the reputation of Abini as a rich source of bronze artefacts. This reputation is well founded, as the figurative bronzes from Abini represent approximately 23% of all known examples from Sardinia.

Archaeological research resumed only in 1981 and again between 2000 and 2002 under the direction of Maria Ausilia Fadda on behalf of the Soprintendenza Archeologica for the provinces of Sassari and Nuoro. These investigations included the examination of Taramelli's spoil heaps and the excavation of several architectural remains. Between 2013 and 2018 the University of Sassari carried out new campaigns aimed at further investigating both the sanctuary and the associated settlement.

The complex can be classified as a Nuragic village-sanctuary, since it includes both domestic structures and architectural features typical of cult places, such as a sacred spring, a cult enclosure (*temenos*)

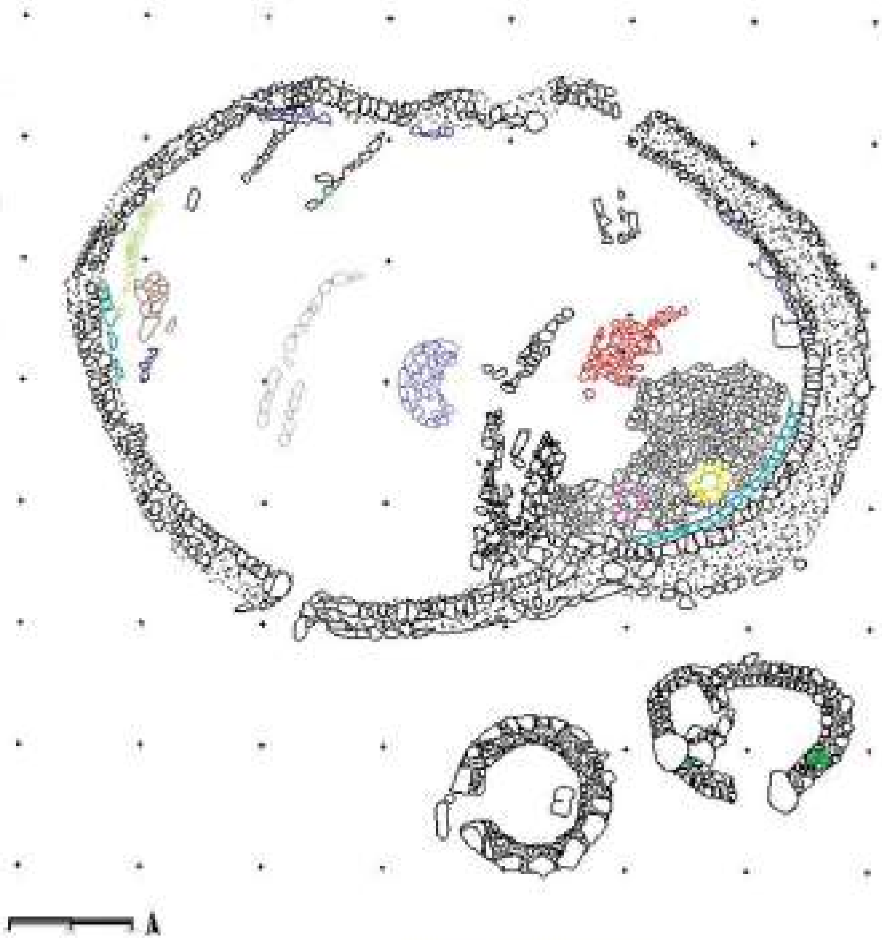

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Fig. 1 – Abini, Teti: plan of the *temenos* and adjacent Structures 2-4 (1); interior of Structure 4 showing a high concentration of pottery and bones (2) (Ripam Laboratory Archive).

*Abini, Teti: planimetria del* temenos *e delle strutture contigue 2-4 (1); interno della struttura 4 con la significativa concentrazione di materiali ceramici e resti faunistici (2) (Archivio Laboratorio Ripam).*

and a perimeter bench facing the principal monument (fig. 1,1).

Within a wooded area the remains of numerous buildings are still visible. Most of these structures have circular or elliptical plans and are built with dry-stone walls of granite blocks arranged in regular courses. In several cases the walls are preserved to a considerable height and contain niches and small cupboards. The settlement extends for approximately 3.5 ha south of the sacred enclosure and reaches the vicinity of the Taloro river.

The sanctuary consists of a cult area enclosed within a large elliptical wall approximately 35 m in length, built with roughly worked granite blocks and accessed through a simple entrance opening.

The principal monument, originally located at the centre of the *temenos*, is now almost entirely destroyed as a result of both clandestine excavations and natural processes of collapse and erosion. Only the cavity used for water collection and a basal course of granite blocks remain visible. On the basis of the lithic elements recovered in the area it is possible to suggest that the monument was constructed using granite blocks together with grey basalt and pink rhyolite.

A granite wall divides the enclosure into two sectors. In the eastern sector a continuous stone bench runs along the inner perimeter, while a substantial portion of the original stone pavement of the sanctuary is still preserved. Two circular pits are also present and may have collected water flowing from the sacred spring.

The western sector is today delimited by a modern wall that roughly follows the ancient alignment, which is no longer visible because it is buried beneath colluvial deposits from the hillside above. Excavations conducted in 2013 in this portion of the enclosure demonstrated that the two discontinuous rows of stones arranged north-south do not represent benches but rather retaining structures for soil accumulation belonging to a later phase, subsequent to the original use of the open space.

South of the enclosure extends the settlement area, composed of both isolated circular huts and clusters of buildings organized into small architectural units consisting of two or three rooms opening onto a central courtyard. The buildings are defined by low dry-stone walls constructed with double-faced masonry. The total number of structures remains uncertain due to the dense vegetation covering the area and the fact that several buildings are completely buried, as demonstrated by recent investigations.

Among the structures brought to light during the campaigns of 2014-2015 are structure 4, an oval building located immediately south of the enclosure, and the adjacent structure 3, a small circular room affected by clandestine excavations (fig. 1,1). The latter contained deposits of dark and greyish soil rich in charcoal and burnt or calcined faunal remains.

Structure 4 also yielded a very dark, carbon-rich deposit containing abundant archaeological material, especially pottery (fig. 1,2). The presence of overturned vessels broken in situ suggests a destruction layer probably caused by the collapse of containers from a shelf or platform, possibly following a sudden event such as a fire, as indicated by the carbonized soil layer. The north-eastern sector of the structure was characterized by the concentration of six triangular-bladed daggers, most of them found close to the inner face of the wall.

Structure 4 appears to represent a service building connected with the sanctuary complex, both because of its proximity to the *temenos* and the sacred spring and because of the characteristics of the archaeological deposit discovered inside it. The pottery assemblage and the faunal remains – especially pig bones – suggest that the building was used for the storage of foodstuffs, probably intended for consumption during communal rituals taking place within and around the sacred enclosure.

Absolute dating and the associated finds from structure 4 indicate an initial phase during the early Final Bronze Age. On the basis of the materials recovered from Taramelli's spoil heaps, it has been proposed that the earliest phases of activity at the sanctuary site date back to the Late Bronze Age (c. 1300-1150 BC), while the period of greatest development extended from the Final Bronze Age (1150-950 BC) to the Early Iron Age (950-750 BC).

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HERDS – Animal Husbandry and its Economic Role in the Development of Central Mediterranean Protohistoric Societies – Rivista di Scienze Preistoriche – LXXVI S6 – 2026 – pp. 272-276

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# Sa Osa (Cabras, OR): a Late Bronze Age Settlement in the Tirso Plain

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The archaeological site of Sa Osa, located in the territory of Cabras (province of Oristano), lies within the coastal plain of the River Tirso, in the northern sector of the Gulf of Oristano (fig. 1, A.1). The landscape is characterised by lagoons, wetlands and coastal dune systems that form a complex and resource-rich environmental setting. The site occupies two geomorphologically distinct areas: part of it lies on an alluvial terrace of the Tirso River situated approximately 5-6 m above sea level, while another portion extends across the more recent alluvial plain formed during the Holocene through the interaction of fluvial processes and coastal dynamics active in the region (Depalmas and Melis 2010; Melis *et al*. 2017) (fig. 1, A.2). From a geomorphological perspective, the Tirso plain constitutes the northern sector of the Campidano graben, a Plio-Quaternary structural depression oriented NW – SE and filled with marine, lagoonal and continental deposits. During the Holocene the shoreline and lagoonal environments of the Gulf of Oristano underwent substantial transformations as a result of the interplay between sea-level fluctuations and the fluvial activity of the Tirso and its tributaries (Di Rita and Melis 2013). Stratigraphic and sedimentological studies indicate that during protohistoric times the coastal plain experienced a progressive increase in fluvial sedimentation, probably facilitated by anthropogenic pressure in the inland portions of the river basin (Melis *et al.* 2017). Within the broader context of protohistoric settlement in the Sinis peninsula and central-western Sardinia, the Tirso plain represents an area of particular importance. Archaeological evidence demonstrates an intense and long-lasting human presence over the last four millennia, with a significant expansion of settlement activity during the Bronze Age and the Iron Age (Depalmas and Melis 2010). Prior to systematic excavation, Sa Osa was known in archaeological literature under the toponyms S'Arrieddu or Serra Siddu, based on sporadic surface finds consisting mainly of ceramic fragments attributed to the Middle Bronze Age, together with later materials dated to the Final Bronze Age and Early Iron Age. The true extent and nature of the site only became clear following preventive archaeological investigations conducted between 2008 and 2009, in connection with the construction of the new road linking Oristano and Cabras. Excavations carried out in the area affected by the construction of a road roundabout, under the direction of the Archaeological Superintendency for the provinces of Cagliari and Oristano and in collaboration with the University of Sassari, revealed an extensive settlement complex dating between the Middle, Recent and Final Bronze Age (Usai *et al*. 2012; Depalmas *et al*. 2021). Further archaeological investigations conducted between 2015 and 2016 identified and explored additional features belonging to the same settlement system (Depalmas *et al*. 2021). The settlement of Sa Osa displays distinctive characteristics when compared with many other Nuragic sites in Sardinia. Unlike numerous contemporary contexts, no monumental stone structures or nuraghe towers – normally central elements in Bronze Age settlement organisation on the island – have been identified. The inhabited structures were most likely built using perishable materials, such as timber, brushwood and clay, which explains the absence of preserved architectural remains. Consequently, the archaeologi-

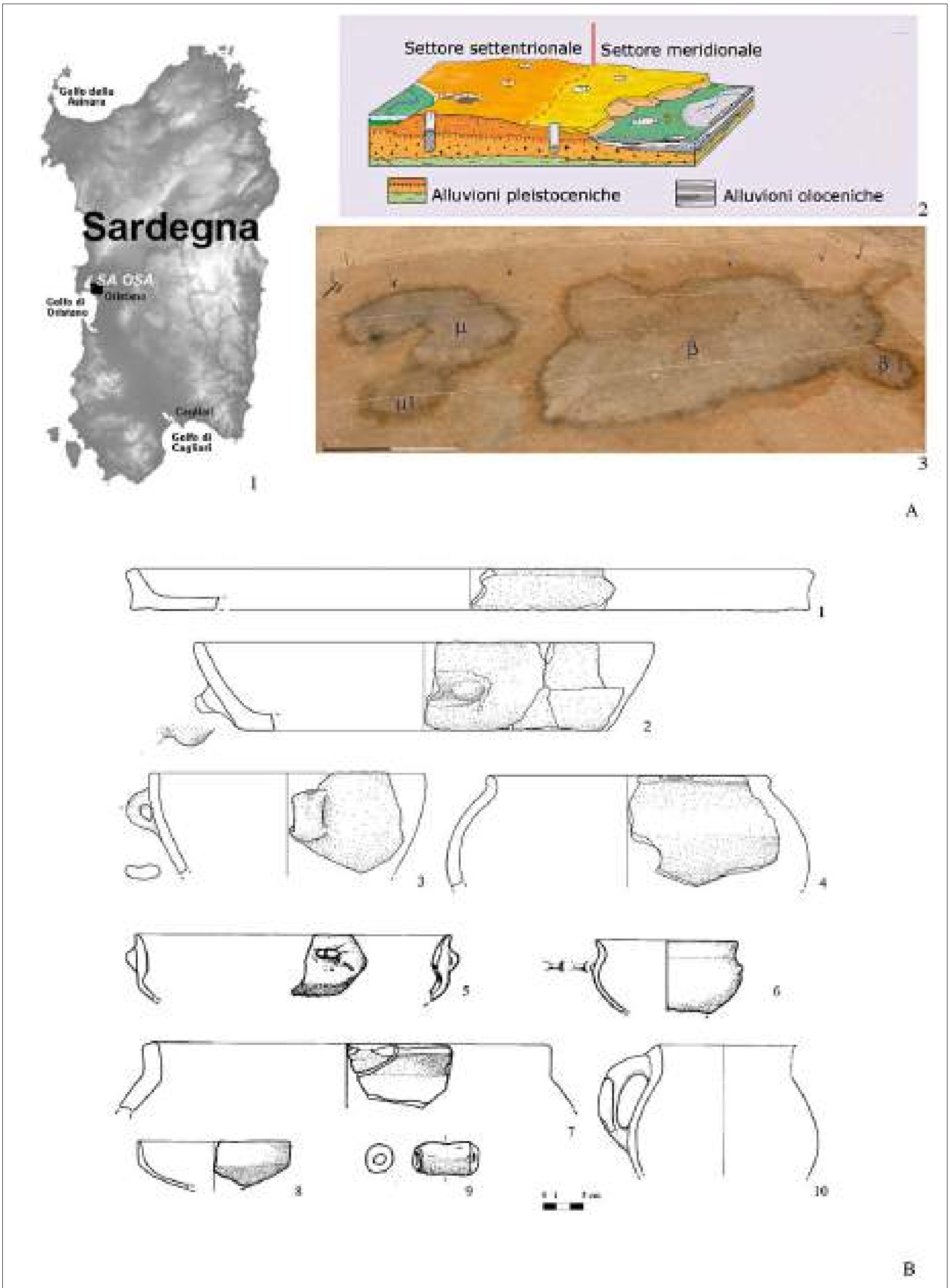


Fig. 1 – Sa Osa, Cabras: A. 1. Location of the area; 2. Block diagram of the morpho-stratigraphic context (prepared by R.T. Melis); 3. Detail of selected structures in the northern sector prior to excavation (quadrant O16-18) (image by L. Soro and S. Vidili). B. Structure α: 1-2. cooking pans; 3. bowl; 4. globular-bodied jar (after Depalmas and Vidili 2011). Shift β1: 5. carinated bowl; 6. cup; 7. olla; 8. bowl; 9. fishing net weight; 10. jug (after Vidili 2013-14).

*Sa Osa, Cabras: A. 1. Localizzazione dell'area; 2. Diagramma a blocchi del contesto morfo-stratigrafico (elaborato da R.T. Melis); 3. Dettaglio di alcune strutture nel settore settentrionale, prima dello scavo (quadrante O16-18) (immagine di L. Soro e S. Vidili). B. Struttura α: 1-2. tegami; 3. scodella; 4. olla a corpo globulare (da Depalmas e Vidili 2011). Pozzo β1: 5. ciotola carenata. 6. tazza; 7. olla; 8. scodella passante a tazza; 9. peso per rete da pesca; 10. boccale (da Vidili 2013-14).*

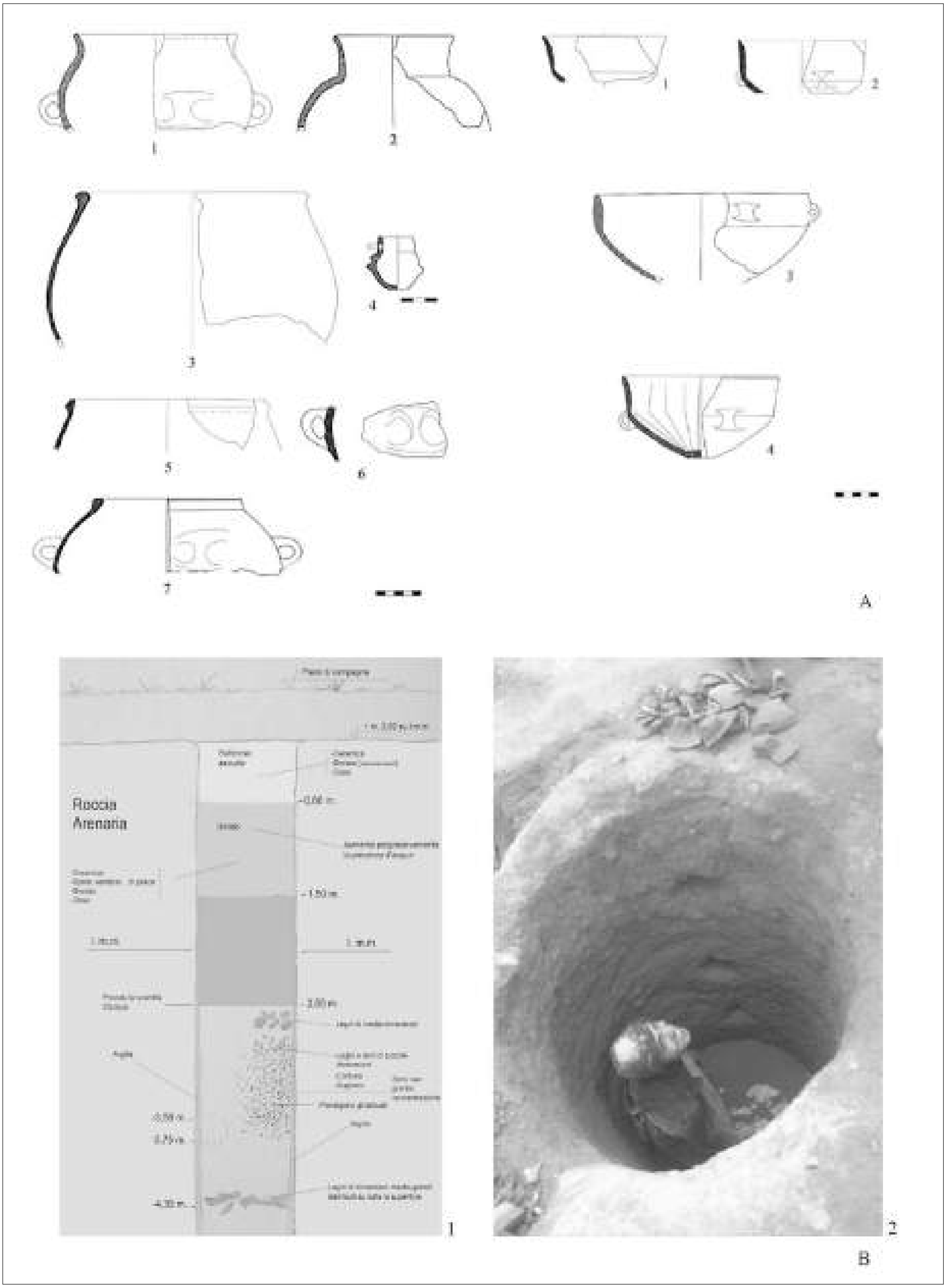


Fig. 2 – Sa Osa, Cabras: Shift N. A. Ceramic finds (after Serreli 2011); B. Section (1) and the structure under excavation (2) (after Sanna 2011).

*Sa Osa, Cabras: Pozzo N. A. Reperti ceramici (da Serreli 2011); B. Sezione (1) e la struttura in corso di scavo (2) (da Sanna 2011).*

cal record is dominated by negative features, namely cavities excavated into the alluvial deposits and subsequently filled with archaeological sediments (fig. 1, A.3). These include pits of various shapes and sizes, silos, storage pits, wells and areas associated with domestic and productive activities (Usai *et al*. 2012). The excavated area is now divided into two principal sectors by the Torre Grande – Madonna del Rimedio provincial road. The northern sector, located on the higher alluvial terrace, represents the elevated portion of the site, whereas the southern sector lies within the lower alluvial plain. Covering approximately 3000 m², the northern sector yielded the highest concentration of archaeological features (fig. 1, B). Numerous pits of varying dimensions and morphologies were identified here, often intersecting one another and reflecting different phases of occupation and activity within the settlement (Usai *et al*. 2012). Among the most notable features are several large pits with elliptical or lobed plans, interpreted as the floor areas of spaces used for domestic or productive purposes. In some cases, fragments of clay daub bearing impressions of branches and reeds were recovered, providing evidence for superstructures constructed using perishable building techniques, most likely wattle-and-daub walls (Usai *et al*. 2012). Other features include deeper and narrower cavities with circular openings and occasionally equipped with cut footholds facilitating access. These structures have been interpreted as wells or storage silos, probably used either for water procurement or for the storage of agricultural produce and other food resources (fig. 2, B.1-2). The fills of these features yielded a particularly rich archaeological assemblage (fig. 2A), including ceramics, lithic artefacts and numerous organic remains such as seeds, grape pips, faunal remains and occasional complete animal depositions. This material provides valuable evidence for reconstructing the subsistence strategies of the community that inhabited the site. Archaeobotanical analyses indicate the presence of a range of cultivated and gathered plant species, including domesticated grapevine, cereals and other food plants. The recovery of numerous carbonised grape pips represents one of the most significant outcomes of the excavation and has contributed to ongoing discussions regarding the origins and early development of viticulture in the western Mediterranean (Sabato *et al.* 2015; Ucchesu *et al.* 2015a, 2015b; Usai *et al.* 2016). Zooarchaeological evidence indicates that the inhabitants practised pig and cattle husbandry, complemented by the exploitation of wild fauna, particularly through deer hunting. The presence of fish remains and related indicators also points to riverine and coastal fishing activities, a pattern fully consistent with the site's proximity to the Tirso River and the lagoon environments of the Gulf of Oristano (Depalmas *et al*. 2021). Alongside subsistence practices, the archaeological record also reveals evidence of specialised craft production, including ceramic manufacture and the working of animal hard materials. From a chronological perspective, stratigraphic analysis combined with available radiocarbon determinations indicates that occupation at Sa Osa extended from the Middle Bronze Age through to the Final Bronze Age. The earliest features appear to belong to the central phases of the Bronze Age, while several deeper pits and vertical structures have been attributed to later stages in the life of the settlement (Depalmas *et al*. 2021). Within the broader settlement pattern of the Sinis peninsula and central-western Sardinia, Sa Osa therefore represents a particularly significant example. In contrast to the large, monumental complexes characterised by nuraghi and stone-built villages, the site illustrates a form of rural settlement closely integrated with the exploitation of the environmental resources of the fluvial plain and lagoon systems. In this respect, Sa Osa provides important insight into the economic strategies and patterns of territorial organisation in Bronze Age Sardinia, demonstrating that alongside the well-known monumental centres there existed productive and agricultural settlements embedded within the environmental framework of the coastal plain.

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# III

# CASE STUDIES PRESENTED IN THE HERDS WORKSHOP

Rome, Sapienza University

20th-21th November 2025

HERDS – Animal Husbandry and its Economic Role in the Development of Central Mediterranean Protohistoric Societies – Rivista di Scienze Preistoriche – LXXVI S6 – 2026 – pp. 279-293

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# Subsistence Economy and Animal Management in the Bronze Age Lagoon Site of Ca' Baredi-Canale Anfora near Aquileia

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Abstract – Subsistence economy and animal management in the Bronze Age lagoon site of Ca' Baredi-Canale Anfora near Aquileia. – This paper presents the results of an integrated archaeological and bioarchaeological investigation at the Bronze Age site of Ca' Baredi/Canale Anfora (eastern Friuli plain, northern Adriatic), aimed at exploring animal husbandry practices, subsistence strategies, and patterns of mobility within a lagoonal environment. The site, strategically located near the mouth of a river flowing into the lagoon at the interface between the Alpine piedmont and the Adriatic coast, developed between Middle Bronze Age 2 and the early Late (Recent) Bronze Age (ca. 1550-1200 BCE).

The analytical results of stable isotope investigation (strontium, oxygen, and carbon) conducted on domestic and wild faunal remains, are here integrated with other multidimensional data aimed at environmental reconstruction. Results indicate a diversified and dynamic subsistence economy structured around mixed farming and herding, intensive exploitation of aquatic resources, and early and sustained cultivation of millet ($C_4$). Isotopic evidence reveals moderate variability in livestock management strategies and identifies cases of long-distance animal mobility.

These data suggest that Ca' Baredi functioned not only as a subsistence-oriented lagoonal settlement but also as a node within multidirectional exchange networks connecting sub-Alpine, inland, and maritime regions. Variability in faunal exploitation, the integration of $C_4$ crops in animal diet, and isotopic signatures of mobility point to adaptive and flexible economic strategies embedded within broader systems of connectivity. The results contribute to ongoing discussions on animal management, environmental adaptation, and the role of lagoonal landscapes in fostering mobility and interaction in Bronze Age northern Italy.

RIASSUNTO – SUSSISTENZA E GESTIONE DELL'ECONOMIA ANIMALE NEL SITO LAGUNARE DELL'ETÀ DEL BRONZO DI CA' BAREDI-CANALE ANFORA PRESSO AQUILEIA. – Il contributo presenta i risultati di una ricerca archeologica e bioarcheologica integrata, incentrata sul sito dell'età del Bronzo di Ca' Baredi/Canale Anfora, nella pianura friulana orientale, ed è finalizzato all'indagine delle pratiche di gestione dell'economia animale in ambiente lagunare. Il sito, collocato in posizione strategica presso una foce fluviale al margine della laguna di Grado e all'interfaccia tra percorsi pedemontani e costa adriatica, fu attivo dal BM 2 al BR 1 (ca 1550-1200 a.C.). I risultati delle analisi isotopiche (stronzio, ossigeno, carbonio) su fauna domestica e selvatica sono qui integrati con altri dati multidimensionali mirati alla ricostruzione dell'ambiente antico. Ne emerge un'economia di sussistenza dinamica e diversificata, strutturata intorno a pratiche miste agro-pastorali, tra le quali si segnala la precoce coltivazione del miglio, e allo sfruttamento intensivo delle risorse acquatiche. Le evidenze isotopiche suggeriscono inoltre una certa variabilità nella gestione animale e permettono di identificare dei casi di importazione di animali da lunghe distanze.
Sulla base dei dati raccolti, Ca' Baredi sembra aver funzionato non soltanto come un abitato di laguna orientato alla sussistenza, ma come un nodo di reti multidirezionali di scambio che connettevano le regioni interne ed alpine alla costa e al mare. La variabilità delle strategie di sussistenza, l'integrazione delle piante $C_4$ nella dieta animale e i segnali isotopici di mobilità sono indizio di un'economia adattiva e flessibile, integrata in un tessuto altamente connettivo.
I risultati intendono contribuire più in generale alla discussione corrente sull'economia animale, la sostenibilità ambientale e il ruolo dei paesaggi lagunari nella promozione di mobilità e interazione durante l'età del Bronzo.

*Parole chiave:* Età del bronzo, gestione animale, analisi isotopiche.

*Keywords:* Bronze Age, Animal Management, Isotope analysis.



## 1. INTRODUCTION

The presentation of the results of the HERDS project by Sapienza University of Rome provides a valuable opportunity to contribute further evidence to the broader framework of animal husbandry in north-central and peninsular Italy. In particular, it allows us to introduce into the discussion a small but significant dataset from the northern Adriatic region, specifically the eastern coastal plain of Friuli facing the Grado Lagoon. These data – potentially suitable for comparative analysis – derive from a research project coordinated by the University of Udine and focused on the investigation of resources and environment in the Adriatic coastal lagoons through an integrated, multidisciplinary approach (Borgna *et al. in press*).

After a brief overview of the environmental context, including the main evidence for subsistence strategies, this paper presents the results of faunal isotope analyses (strontium, oxygen, and carbon) carried out on a sample of animal remains from both domestic and wild species documented in the bioarchaeological record of the Bronze Age site of Ca' Baredi/Canale Anfora. The study focuses on animal husbandry practices – particularly the balance between sedentary livestock farming and mobile pastoralism – the proportion of non-local animals, and patterns in animal diet and foddering strategies.

Although still limited in scope within the *Caput Adriae* region, these data, when integrated with traditional archaeozoological analyses, contribute to shedding light on patterns of variability and mobility in the management of animal resources. In this respect, they align with the broader outcomes of the project, which highlight the central role of lagoonal environments in fostering connectivity, mobility, and diversification in resource exploitation (Caliò *et al.* 2022; Felici 2023; Bivolaru, Cottica, Morhange 2025).

## 2. THE SITE OF CA' BAREDI

The site of Ca' Baredi – referred to in the scholarly literature as Canale Anfora, after the channel excavated immediately south of the settlement in the 2nd century AD following the foundation of Roman Aquileia – is located 3.5 km west of modern Aquileia, within the municipality of Terzo di Aquileia.

Discovered in the 1980s and initially investigated through a small-scale sounding conducted by the Soprintendenza of Friuli Venezia Giulia, the site has been the focus of renewed multidisciplinary research led by the University of Udine since 2013 (Borgna *et al.* 2018; Borgna, Corazza 2022a; Borgna *et al.* 2022).

During the Bronze Age, Ca' Baredi – today situated within the reclaimed agricultural landscape of the Aquileia territory – formed part of an extensive waterscape that included the marshy lowlands bordering the lagoon and a river flowing into it. The settlement was established near the mouth of the river, a secondary or spring-fed watercourse that, around 4000-3500 BP, had replaced a former Alpine river or an ancient branch of the Torre River (fig. 1). The site occupied a strategic, elevated, and well-drained position atop the fluvial ridge rising 4-6 m above the surrounding plain and enclosed within a pronounced river meander. From this bend, a pair of overbank channels created a small lagoonal delta, facilitating access to both the lagoon and the open sea (Fontana *et al.* 2017; Fontana 2024). Based on the dimensions of the riverbed – approximately 30 m wide and 5-6 m deep – the river was likely navigable.

In addition to geomorphological investigations, bioarchaeological research has substantially contributed to environmental reconstruction. Both faunal and botanical remains attest to the marked biodiversity of the lagoonal ecosystem.

The fluvial ridge consisted of soft, workable soils suitable for cultivation, while the surrounding landscape supported a diverse woodland dominated by floodplain mixed oak forest associated with hygrophilous and riparian species (Borgna *et al. in press*).

The faunal assemblage is correspondingly broad and diverse, including species from woodland, marshland, and aquatic environments, the latter represented by marine molluscs and fish (Petrucci 2020; Borgna *et al.* 2022; Borgna *et al. in press*).

Pollen analysis, integrated with stratigraphic and geomorphological data, allows the reconstruction of a complex environmental setting evolving from the central phases of the – Middle Bronze Age onward. Vegetation cover and species composition indicate a dynamic and non-linear trajectory, characterized by alternating phases: a gradual decline in forest cover accompanied by the expansion of open areas and pastures, followed by renewed woodland regeneration.

At present, it remains difficult to determine whether these fluctuations were primarily driven by anthropogenic factors – such as intensified construction and agricultural activities – or by environmental and climatic changes. A reduction in streamflow toward the end of the settlement's occupation represents one of the few discernible indicators of environmental change. Together with lagoonal regression, possible silting of the river mouth, and progressive waterlogging of the surrounding plain, these processes may have contributed to the abandonment of the site around 1200 BCE (Borgna *et al.* 2022; Borgna *et al. in press*).

Excavations within an elongated area parallel to the right riverbank have revealed numerous fire intsallations, including various types of hearths and ovens. These installations were located either outdoors or protected within light enclosures or rooms built of perishable materials which are best interpreted as annexes forming part of a communal service area devoted to the processing of subsistence resources and food preparation (Borgna *et al.* 2019; Borgna *et al.* 2022; Borgna *et al.* forthcoming).

The most recent field investigations (July 2025) have yielded new data refining the chronological framework of the settlement, which developed through six building phases spanning Middle Bronze Age 2 to the early stage of the Late Bronze Age or Recent Bronze Age 1. Two radiocarbon dates obtained from a burnt wooden floor place the foundation of the settlement between the mid- and late 16$^{th}$ century BCE (ca. 1550-1500 BCE) (Borgna *et al. in press*).

From both archaeological and bioarchaeological perspectives, the community appears to have practiced a complex, mixed agro-pastoral economy that may have included elements of intensification and even specialization. Some discontinuities, even if faint, both in the stratigraphical record and in the evidence of subsistence strategies, prompt to recognize two broad macro-phases: an earlier phase (MBA 2-3) and a later phase spanning the final Middle Bronze Age to the early Recent Bronze Age (MBA 3-RBA 1).

From the foundation onward, cereals played a central role in subsistence. A wide range of crops is documented, including barley, einkorn and em-

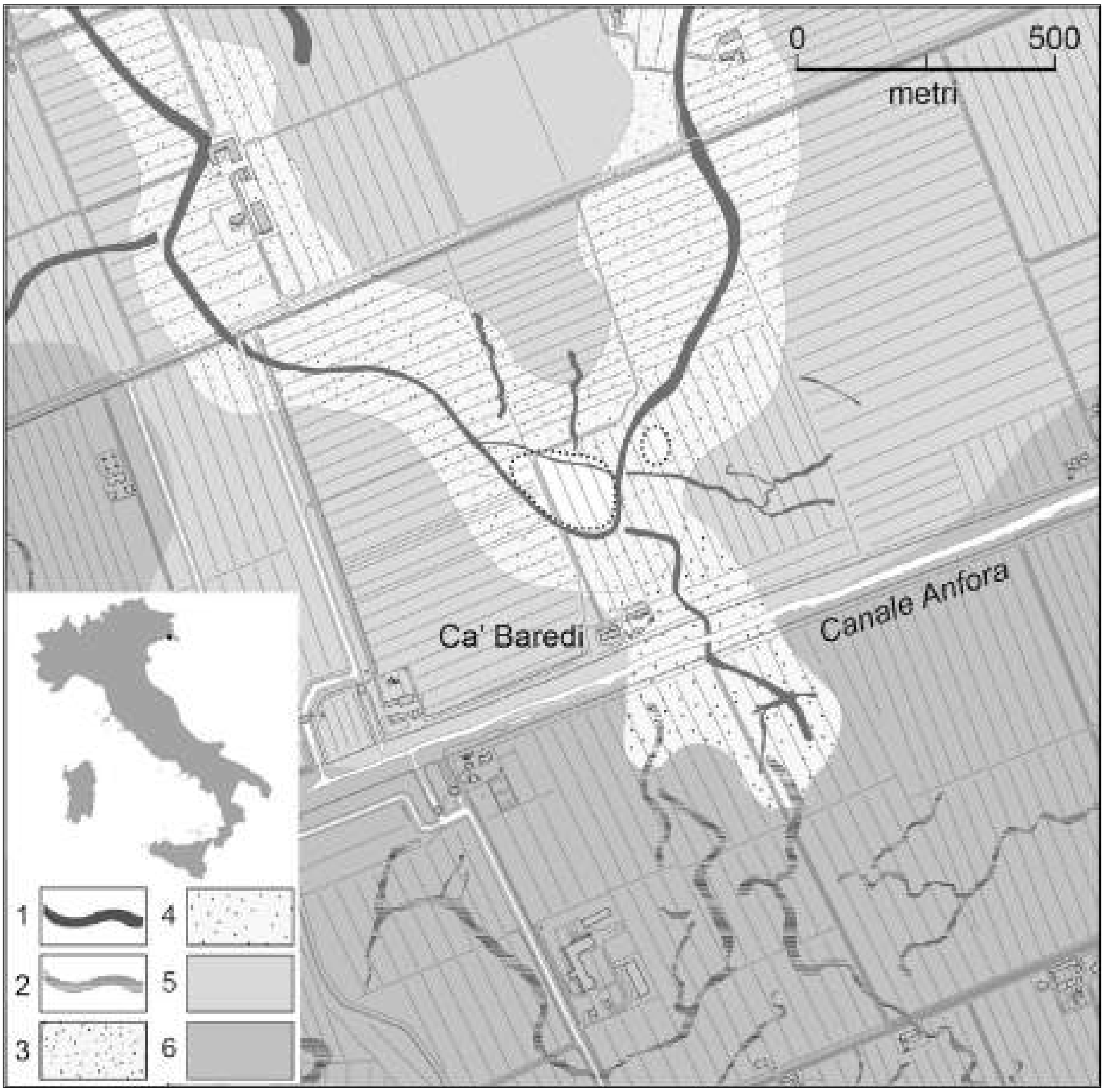


Fig. 1 – Ca' Baredi: geomorphological map of the site (after A. Fontana and G. Vinci in BORGNA *et al.* 2018). The main archaeological areas are within dotted line. Legend: 1) fluvial paleochannel; 2) lagoonal paleochannel; 3) natural levee (fluvial ridge); 4) Holocene crevasse splay; 5) Holocene alluvial plain; 6) Lagoon deposits.

*Ca' Baredi: carta geomorfologica del sito (elaborazione A. Fontana, G. Vinci in* BORGNA *et al. 2018). Le principali zone archeologiche sono comprese nelle linee puntinate. Legenda: 1) paleoalveo fluviale; 2) antico canale lagunare; 3) dosso fluviale; 4) ventaglio di rotta olocenico; 5) piana alluvionale olocenica; 6) depositi lagunari.*

mer (*Triticum monococcum* and *T. dicoccum*), free-threshing wheat (*T. aestivum/durum*), oats, rye, and millet, alongside pulses such as fava bean, vetch, and lentil. Fruit-bearing trees – including plum, service tree, and cherry (*Prunus domestica*, *Sorbus domestica*, *Prunus cerasus*, *Prunus avium*) – are also attested and appear to increase slightly over time.

The faunal assemblage shows a decrease in wild species exploitation during the later phase (changing from 10% to 2-3% of the total amount), while domestic taxa are consistently represented in both periods. Cattle predominate in the earlier phase (35% to be compared with 30% swine and 26% sheep/goat), whereas pig frequencies increase in the later one.

Evidence for meat consumption remains however problematic. Organic residue analyses have indeed detected animal fats in ceramic vessels but suggest the processing of dairy products rather than unequivocal evidence of meat preparation[1].

In contrast, fish consumption is well documented. Micromorphological analyses of early occupation surfaces have identified micro-remains such as gill bones and scales,[2] while residue analyses confirm the cooking and processing of fish in ceramic containers.

The same analytical approaches have provided clear evidence for the widespread use of millet in human nutrition, combined at times to traces of wine or other products of grape fermentation such as vinegar, which, according to the most updated evidence, were obtained since the earliest phase of the settlement or MBA 2.

Animal fat residues (notably caprylic and capric acids) and miliacin have also been identified in sediments from the earliest occupation layers, suggesting on-site processing of dairy products and cereals. Additional evidence – including remains of hulled wheats and spikelet forks discarded in a nearby shallow ditch dating to the early macro-phase – points to the initial stages of crop processing, further supported by the presence of grinding stones.

The high density of faunal remains, together with substantial quantities of hay derived from wild grasses and legumes found in the shallow ditch, suggests that livestock were kept in proximity to the service area and integrated within the domestic space, at least in the early macro-phase.

Afterwards, in the later macro-phase, the decrease in faunal remains and their highly fragmented, fire-affected condition might indicate the recycling of bones as fuel, as has been proposed in a previous study (Borgna *et al.* 2022). It is also possible that the spatial reorganization may have resulted in livestock being managed at a greater distance from the settlement, consistent with a more extensive land-use system involving expanded pastures during the final MBA.

Interpretation must, however, consider possible depositional and sampling biases. The large assemblage of faunal remains from the earlier phase derives primarily from the shallow ditch, which was filled and sealed at the end of the period; in the later phase, waste disposal practices may have shifted to areas not yet excavated.

Despite such potential distortions, archaeological and bioarchaeological data converge in indicating a degree of discontinuity between the two macro-phases, less in the range of exploited resources than in the organization of subsistence practices.

The earlier phase is characterized by predominantly domestic-scale activities, including weaving, slaughtering, carcass disposal, fishing – attested also by a couple of net weights – and the processing of aquatic resources. The area appears to have functioned as a shared space for primary subsistence activities, including the allocation, transformation, and possibly distribution of food resources, which could have been further processed and consumed elsewhere.

In the later phase, the multiplication and enlargement of fire installations may reflect intensified communal labour. Furthermore, from the late Middle Bronze Age onward, clear evidence of consumption is associated with several hearths (Pecci *et al.* 2020; Borgna *et al.* 2022). Grape fermentation products – likely wine when found in association with fine drinking vessels – appear to have played a symbolic role in fostering social interaction during communal gatherings which favoured exchange between the community and external visitors along the river bank (Borgna *et al.* 2019; Borgna *et al.* 2022).

The site's location near the river mouth and the coast underscores indeed its probable function as a landing place. This role may have been particularly significant within the broader system of metal supply and bronze circulation in northern Italy (Pearce *et al.* 2019; Artioli *et al.* 2020; Bellintani *et al.* 2021 with refs).

Of particular interest in this perspective is the evidence for an artisanal quarter or cluster of large hearths established on the opposite riverbank, at the periphery of the village, during the most recent phases (MBA 3-RBA), where traces

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[1] In the framework of the *Shores* project a number of e Organic Residue Analysis have been carried out on 10 ceramic samples in the laboratory of the University of Salento at Lecce under the coordination of Giuseppe Egidio De Benedetto. Results are currently being processed and will be presented in a paper in preparation; they will integrate a first cluster of data obtained within a previous project (Pecci *et al.* 2020; Borgna *et al.* 2022).

[2] The analysis has been carried out by Michele Bassetti (Trento).

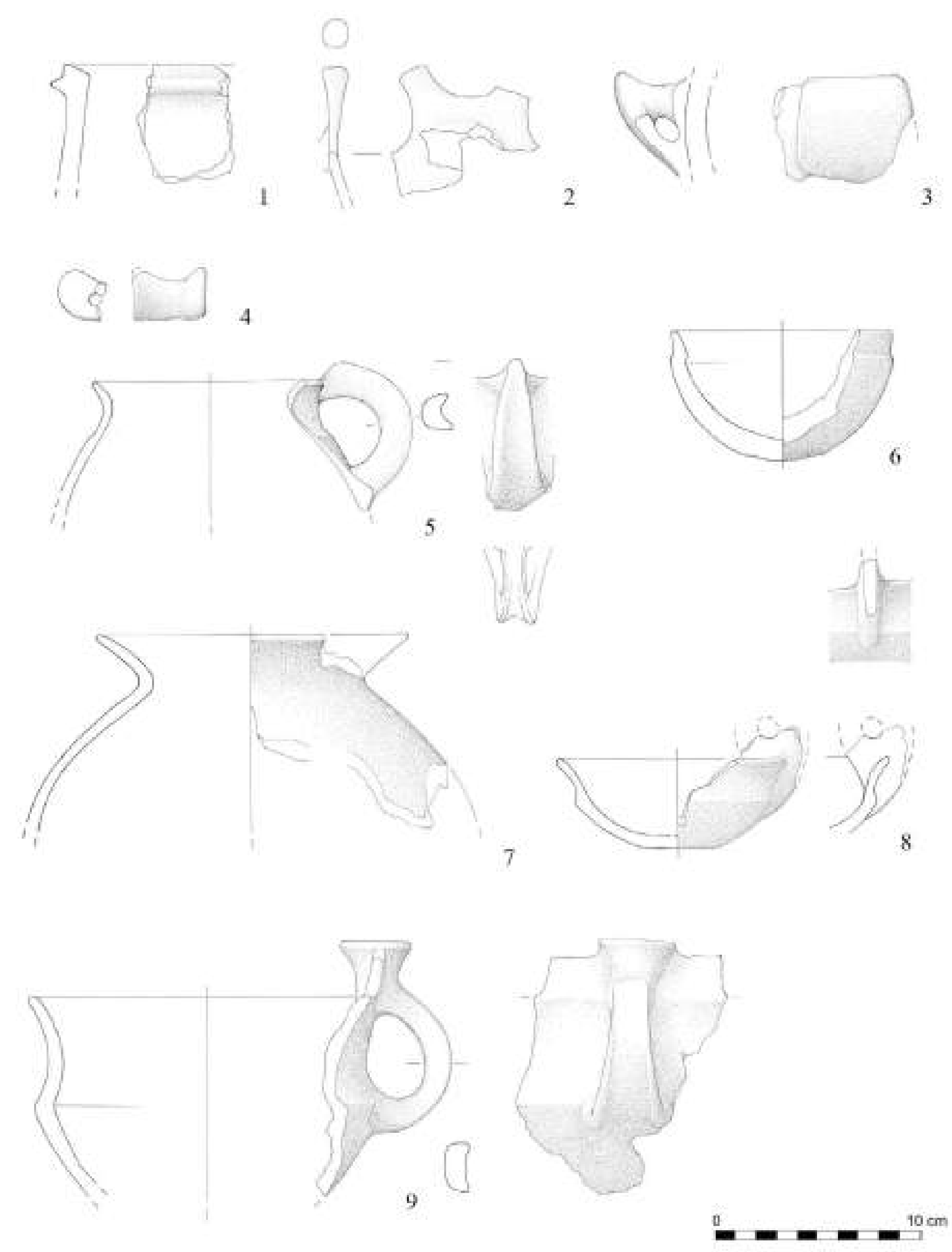


Fig. 2 – Ca' Baredi: selected ceramics dating to the Middle Bronze Age, with parallels in the Alpine and Terramare cultural areas (1-4) and in the *castellieri* of the Karst and Istria regions (5-7); dating to the Recent Bronze Age, with distinctive Subapennine features (8-9) (drawing by Giuliano Merlatti).

*Ca' Baredi: alcuni materiali ceramici del Bronzo Medio con confronti in area alpina e terramaricola (1-4), e nei castellieri del Carso e dell'Istria (5-7), e del Bronzo Recente con elementi peculiari del Subappenninico (8-9) (disegni di Giuliano Merlatti).*

of metalworking have been identified in association with the hearths. This interpretation is reinforced by the numerous stray bronze finds recovered at Ca' Baredi and in the wider Aquileia region (Borgna 2018; Borgna, Corazza *in press*), suggesting that the area functioned as a key node within a network of bronze production and exchange largely supplied by ores from the southern Alps (Canovaro *et al.* 2019).

The site's prominent role in long-term interaction networks is further supported by ceramic evidence, which reveals shifting cultural connections through time (Borgna, Corazza 2020; Borgna, Corazza 2022a). In the earliest phase (MBA 2), influences from sub-Alpine and western regions – particularly pile-dwelling and early Terramare contexts – are evident (fig. 2). These were later combined with strong elements from the Castellieri cultural facies of the Karst and Istria. In addition, from MBA 3 onward, the site appears connected with both transalpine western Slovenia, and the Adriatic coastal regions including peninsular Italy through extensive maritime contacts (cf Arena *et al.* 2018; Arena *et al.* 2020; Borgna, Simeoni 2020). As a results of this increasing maritime connectivity, during the Recent Bronze Age Subapennine cultural components from western Adriatic were incorporated into the local ceramic production.

## 3. MATERIALS

Isotope analyses were carried out on tooth enamel samples from two cattle, six caprine[3], three pigs, and two red deer. Specimens were carefully selected from undisturbed, well-dated archaeological layers assigned to two main identified macro-phases, namely MBA 2-3 (c. 1550-1400 BCE) and MBA 3-RBA 1 (c. 1400-1200 BCE) (tab. 1). This strategy enabled the determination of diachronic changes in livestock mobility and diet and allowed the integration of isotopic data with other lines of evidence, including archaeological, archaeobotanical, and biomolecular data from the same sequence.

Overall, 29 samples were analysed for $^{87}Sr/^{86}Sr$, and 96 for $\delta^{18}O$ and $\delta^{13}C$.

## 4. METHODS

Lower third molars (M3) were selected for analysis[4]. Pigs and red deer were sampled in bulk (minimum 22 mg of enamel), while herbivores (sheep, goats and cattle) were subjected to sequential sampling (minimum 1.51 mg of enamel powder).

Sequential sampling was carried out for domestic herbivores (selenodont teeth), to verify potential seasonal mobility by comparing the three isotopic systems ($^{87}Sr/^{86}Sr$, $\delta^{18}O$ and $\delta^{13}C$). A column-mounted drill was used to perform parallel sampling along the tooth column, starting from the apex of the dental crown and progressing toward the enamel-root junction. Following surface cleaning, twelve parallel samples were taken for carbon and oxygen, and three for strontium, from each tooth. The first strontium (Sr) enamel sample was taken at the same layer as the first carbon (C) and oxygen (O) sample, the second at the layer of the fifth C and O sample, and the third at the layer of the ninth C and O sample.

Oxygen and carbon isotope ratios were measured on 96 samples of carbonate moiety of tooth enamel at the Centro Interdipartimentale Grandi Strumenti (CIGS) of the University of Modena and Reggio Emilia (UNIMORE) according to Armaroli *et al.* (2025). Sample powders (~3 mg) were reacted for 2 h at 50 °C with +100% phosphoric acid. Isotope ratios were determined on liberated CO2 by continuous flow IRMS (Elementar precisION) coupled to an equilibration system (Elementar isoFLOW). Repeated analyses of NBS18 and NBS19 reference materials showed a precision (1SD) of ±0.1‰ for $\delta^{13}C$ and ± 0.2‰ for $\delta^{18}O$. C-O data are expressed in ‰ against VPDB.

The $^{87}Sr/^{86}Sr$ isotope ratio was determined *via* solution MC-ICPMS. Specifically, enamel samples were digested with suprapur nitric acid and processed through column chemistry with Eichrom Sr-resin at the MeGic lab of the Depart-

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[3] *Ovis* vel *Capra* specimens were not subjected to ZooMS analysis and are therefore referred to here as generic caprine. None of the samples were analysed genetically; consequently, no data are available regarding the sex of the individuals.

[4] For detailed information of sampling strategies and analytical procedures, see Cavazzuti *et al.* in this volume.

| | **Early Phase (MBA 2-3; c. 1550-1400 BCE)** | **Late Phase (MBA 3-RBA 1; c. 1400-1200 BCE)** |
|---|---|---|
| *Bos taurus* | 1 | 1 |
| *Ovis vel Capra* | 5 | 1 |
| *Sus domesticus* | 2 | 1 |
| *Cervus elaphus* | 2 | |
| *Total N.* | 10 | 3 |

Tab. 1. Selected specimens for isotope analysis from the two macro-phases of Ca' Baredi.
*Campioni selezionati per le analisi isotopiche dalle due macro-fasi di Ca' Baredi.*

ment of Chemical and Geological Sciences of UNIMORE. Sr solutions were measured at the Neptune MC-ICPMS housed at the CIGS, following the analytical procedure described in Argentino *et al.* (2021).

Data were statistically processed using the "R" (Version 4.0.5) software and subsequently interpreted, including through comparison with the isoscape currently available for Italy and built by Lugli *et al.* (2022), integrated with data recently published (Capuzzo *et al.* 2025) with regard to the $^{87}Sr/^{86}Sr$ isotopic values in Northeastern Italy.

## 5. ISOTOPE ANALYSIS: RESULTS

The two deer from Ca' Baredi yielded $^{87}Sr/^{86}Sr$ values of 0.7086 and 0.7090, respectively. Together with previously published environmental data within a 50 km radius, these values allow us to define a local isotopic range between 0.7082 and 0.7093 (figs. 3 and 4). This range is further supported by recent studies on food traceability in the Slovenian Karst area, characterized by Cretaceous carbonates and an $^{87}Sr/^{86}Sr$ interval between 0.7085 and 0.7093 (Gregorčič *et al.* 2021).

The three pigs display $^{87}Sr/^{86}Sr$ values ranging from 0.7083 to 0.7088 and $\delta^{18}O$ values between -3.9‰ and -5.3‰, all consistent with the local environmental baseline (fig. 5). Interestingly, specimens no. 4 and no. 7 from the Early Phase show low $\delta^{13}C$ values (-11.2‰ and -11.5‰, respectively), compatible with a fully C3 plant – based diet. In contrast, specimen no. 11 from the Late Phase exhibits a higher $\delta^{13}C$ value (-5.4‰), indicating a significant consumption of $C_4$ plants. Application of a linear mixing model suggests that $C_4$ plants accounted for up to 28% of total plant consumption. This evidence indicates the introduction of $C_4$ plants as supplementary fodder for pigs at least from MBA 3 onward.

Both bovids (nos. 1bis and 12) exhibit a typical $C_3$ plant – based diet (fig. 6). However, while specimen no. 12 from the Late Phase presents an $^{87}Sr/^{86}Sr$ triplet consistent with residential management at Ca' Baredi, specimen no. 1bis from the Early Phase appears clearly non-local. Its strontium isotope composition is markedly radiogenic, a pattern that is relatively rare in Italy but documented in the Trentino region, for example in the Adige Valley near Trento and in Valsugana (Ladegaard-Pedersen *et al.* 2022). A provenance from a colder region such as Trentino is further supported by the depleted $\delta^{18}O$ values (-9.7‰ to -7‰), which are substantially lower than those measured in the other animals analysed in this study. Notably, *Bos* no. 1bis was mobile during the formation of its third molar, i.e., between 6-9 months after birth and 18-24 months of age. The isotopic triplet indicates movement from a more radiogenic to a less radiogenic area during late spring, plausibly as a result of vertical transhumance, a practice widely attested in Alpine regions until modern times.

Regarding caprine, specimens nos. 2, 5, 13, and 15, all from the Early Phase, appear local and non-mobile based on their $^{87}Sr/^{86}Sr$ triplets and $\delta^{18}O$ sequences. All individuals consumed $C_3$ plants exclusively, with the exception of specimen no. 13, which shows enriched $\delta^{13}C$ values during autumn, suggesting seasonal integration of $C_4$ plants. Another caprine, specimen no. 14, exhibits two out of three $^{87}Sr/^{86}Sr$ values incompatible with the local bioavailable strontium range. The internal variability of the triplet suggests movement toward a more radiogenic area during spring/summer, consistent with transhumant mobility. Moreover, its $\delta^{18}O$ sequence (-3.7‰ to -0.5‰) is typical of warmer climates, such as Mediterranean regions.

Caprine no. 9, the only individual from the Late Phase, presents ambiguous data, which suggest different interpretations. Its $^{87}Sr/^{86}Sr$ triplet includes at least two values close to the upper limit of the local range. However, its $\delta^{18}O$ sequence (-4.6‰ to -1‰) may indicate either provenance from a region warmer than the *Caput Adriae* or

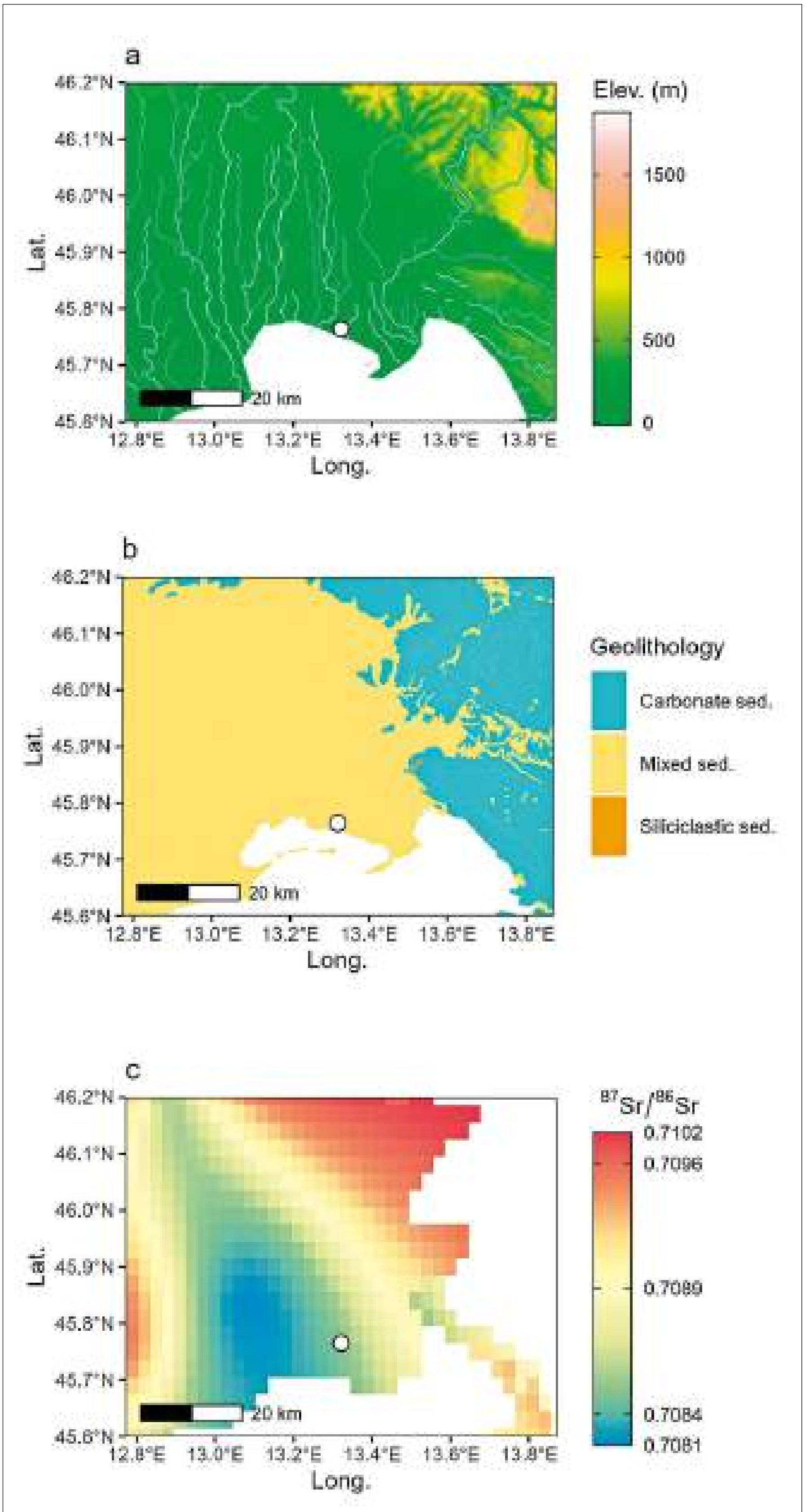


Fig. 3 – a) DEM, b) geolithological map, and c) isoscape of bioavailable $^{87}Sr/^{86}Sr$ of Ca' Baredi territory.

*a) DEM, b) mappa geolitologica e c) isoscape di $^{87}Sr/^{86}Sr$ biodisponibile nel territorio di Ca' Baredi.*

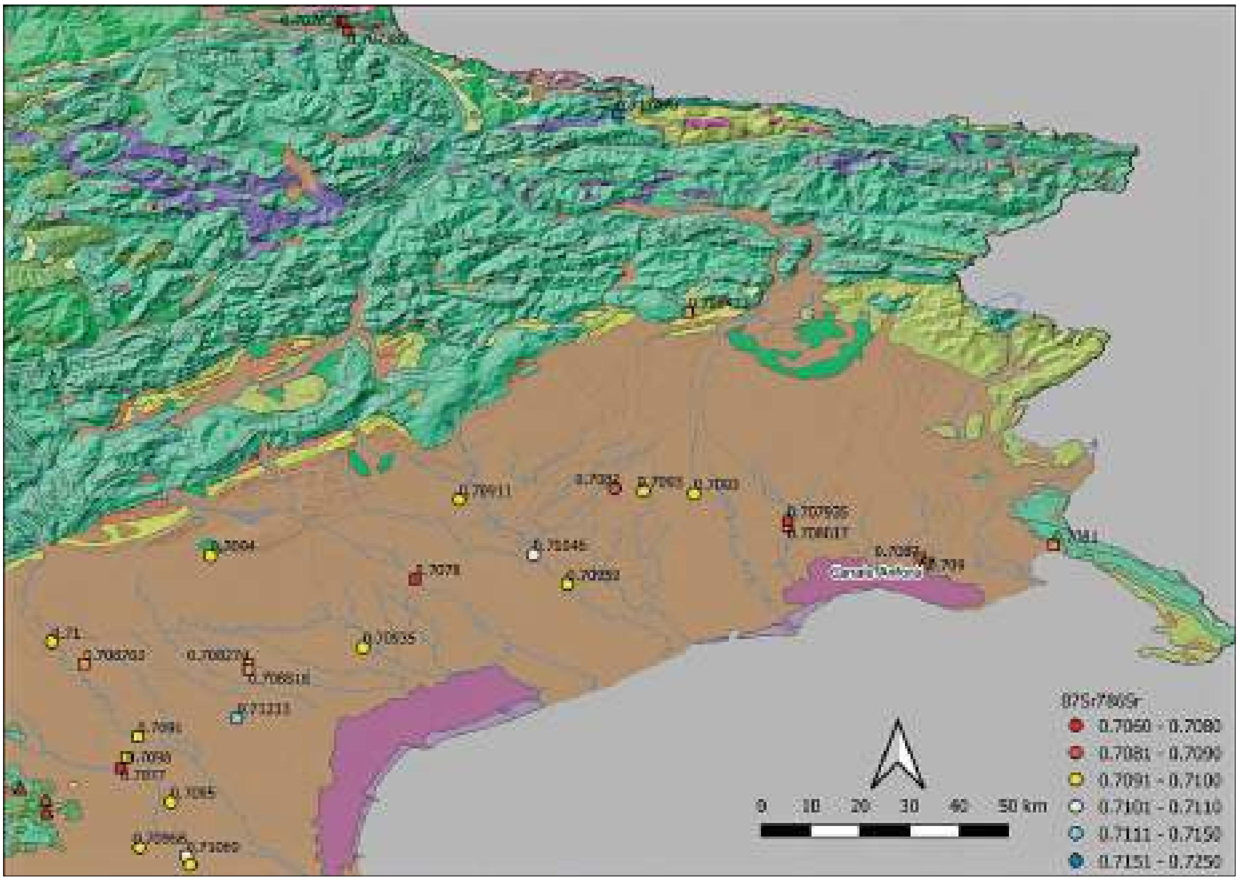


Fig. 4 – Geolithological map and bioavailable $^{87}Sr/^{86}Sr$ baselines in Northeastern Italy.
*Mappa Geolitologica con e baselines di $^{87}Sr/^{86}Sr$ biodisponibile in Italia nord-orientale.*

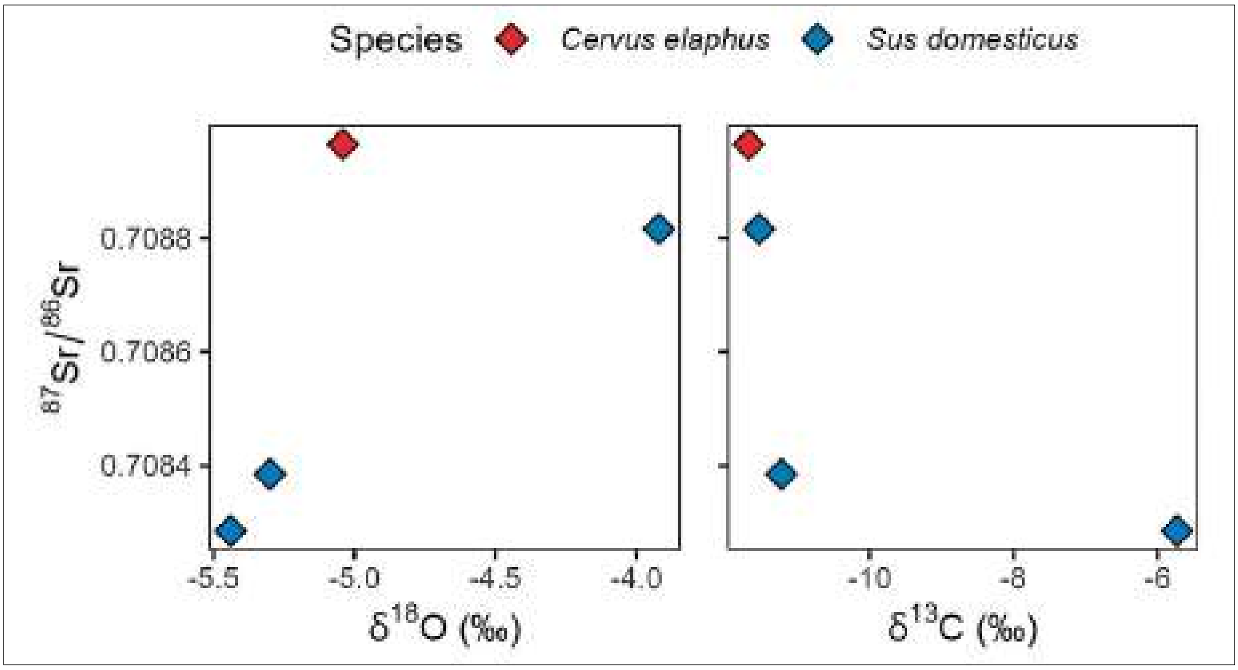


Fig. 5 – $^{87}Sr/^{86}Sr$, $\delta^{18}O$, $\delta^{13}C$ values among pigs and deer from Ca' Baredi. The enriched $\delta^{13}C$ value belong to specimen n. 11, dated to the Late Phase of the settlement. All other samples belong to the Early Phase.
*Valori di $^{87}Sr/^{86}Sr$, $\delta^{18}O$, $\delta^{13}C$ ottenuti su suini e cervi da Ca' Baredi. Il valore alto di $\delta^{13}C$ è riconducibile al campione n. 11, maiale di fase tarda. Tutti gli altri campioni sono databili alla fase antica dell'abitato.*

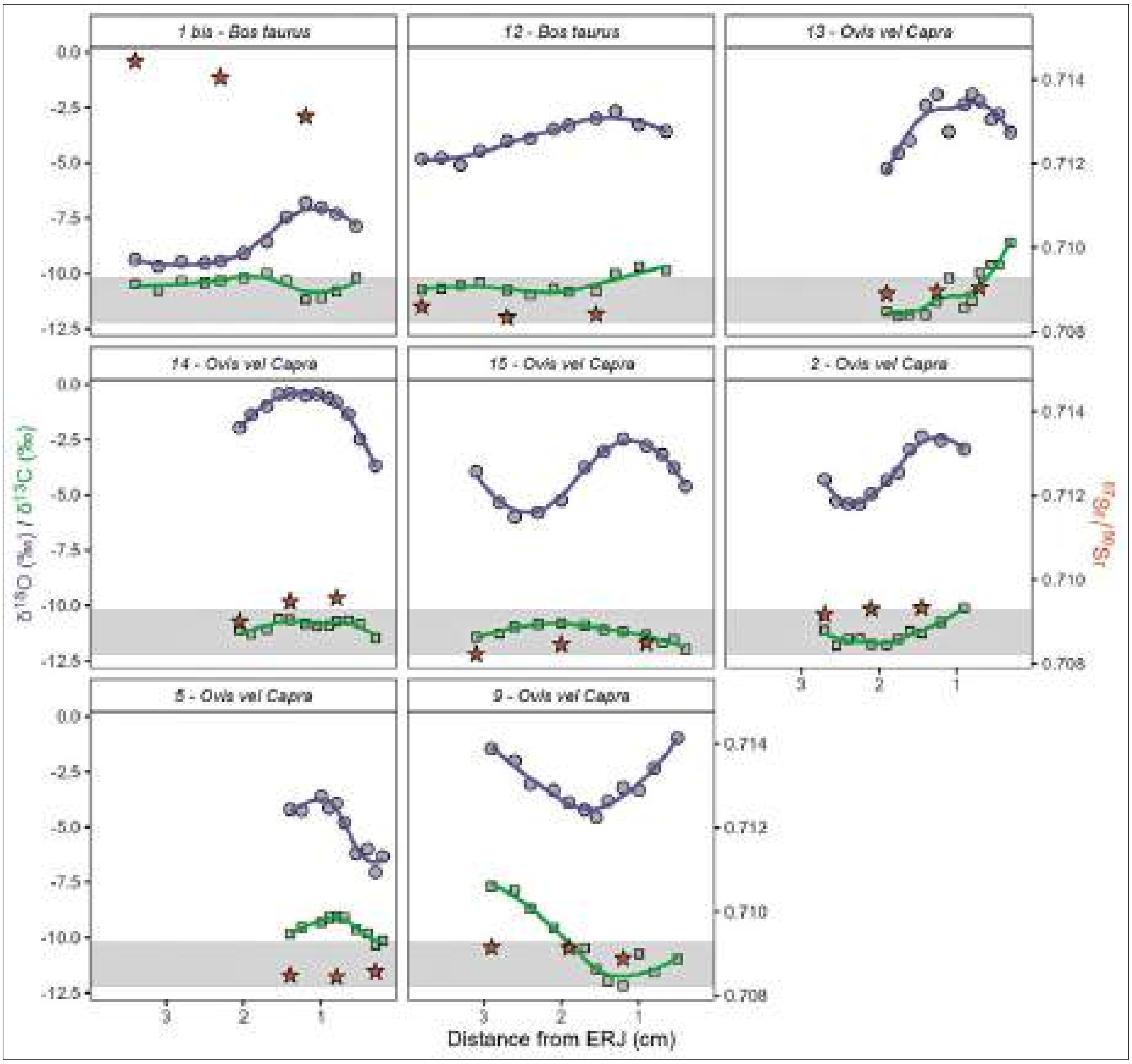


Fig. 6 – Intra-tooth $^{87}Sr/^{86}Sr$, $\delta^{18}O$, $\delta^{13}C$ isotope profiles of herbivores at Ca' Baredi.
*Profili isotopici di* $^{87}Sr/^{86}Sr$, $\delta^{18}O$, $\delta^{13}C$ *ottenuti con campionamento sequenziale dei denti di erbivori da Ca' Baredi.*

a climatic shift toward warmer conditions at the onset of the RBA (see also evidence from Coppa Nevgata; Cavazzuti *et al.* in this volume). The latter hypothesis would require a larger sample size of non-obligate drinkers for the RBA phase. This individual also shows enriched $\delta^{13}C$ values (up to -7.7‰) at the beginning of the cold season, indicating autumnal integration of $C_4$ plants, similar to specimen no. 13.

Overall, the data suggest that: (a) livestock importation was relatively frequent, plausibly originating from both Alpine areas (via terrestrial routes) and Mediterranean regions (via maritime routes); (b) local animals were raised in the hinterland of Ca' Baredi and show no clear evidence of vertical or horizontal transhumance; (c) bovids and caprine imported from Alpine valleys or Mediterranean regions were seasonally mobile during their second year of life prior to arrival at Ca' Baredi; and (d) the integration of $C_4$ plants into animal diets was occasional but systematically practiced during autumn, at least from MBA 3 onward.

## 6. CONCLUDING REMARKS

Biographical information obtained from individual animals – potentially and indirectly related to livestock management strategies – indicates a moderate degree of variability. Within this framework, the evidence for long-distance mobility identified in two individuals is particularly noteworthy.

In order to contextualize these data, it is important to underline once more that variability and diversification in animal resource exploitation are also reflected in the results of traditional zooarchaeological analyses, integrated with the other scientific approaches aimed at recovering macro-remains from sediments and organic residues from ceramic vessels. Overall, the assemblage reveals a broad spectrum of wild taxa and a marked emphasis on certain species – particularly marine molluscs and fish – whose prominence appears exceptional when compared to the more typical faunal exploitation patterns documented at Bronze Age settlements.

At Ca' Baredi/Canale Anfora, fish and marine resources seem to have supported an intensive subsistence strategy, which may also help explain the initial occupation of this coastal lagoon environment. In later historical periods, highly specialized fishing techniques developed in comparable wetland contexts and also in the Grado lagoon (Marzano 2023; Felici 2023).

Crop diversification provides a parallel line of evidence. The cultivation and processing of millet alongside a wide range of major cereals have been demonstrated – through both pollen and organic residue analyses – to date back to the foundation of the settlement in Middle Bronze Age 2. Additional isotope data, indicating the occasional incorporation of $C_4$ plants into animal diets from the Middle Bronze Age onward, may be interpreted within the broader economic strategies adopted by the community.

Among the $C_4$ plants potentially included in animal foddering regimes, wild species such as *Echinochloa crus-galli* (cf. Nicosia *et al.* 2025) – well attested in the north-eastern Italian plains – should be considered, alongside domesticated crops, particularly *Panicum miliaceum*. The isotopic signal of $C_4$ intake detected in swine no. 11, a non-grazing animal, is most plausibly attributable to the consumption of millet rather than wild grasses.

More broadly, the evidence for millet at Ca' Baredi finds parallels in other northern Italian contexts, including Solarolo and Muraiola di Povegliano, where archaeobotanical data indicate that *Panicum miliaceum* may have constituted up to 20% of total cereal assemblages already in MBA 2 (Carra 2009, 2012; Carra *et al.* 2023; Polisca *et al.* 2025). Furthermore, isotopic analyses conducted on human and animal collagen from several Bronze Age sites in northern Italy show elevated $\delta^{13}C$ values, demonstrating the consumption of $C_4$ crops from the advanced Middle Bronze Age through the Recent Bronze Age (Tafuri *et al.* 2018; Cavazzuti *et al.* 2019; Varalli *et al.* 2022).

With regard to animal mobility, the evidence from Ca' Baredi can plausibly be interpreted in light of the site's geographical position, located at the southern end of the Isonzo River basin and at the crossroads of major maritime and inland communication routes. In this sector of north-eastern Italy – where the distance between the Alpine piedmont and the Adriatic coast is markedly compressed – the area has long functioned as a privileged corridor for communication and cultural transmission between the mountains and the sea. It is therefore not coincidental that the earliest material culture from the site indicates significant connections with the Polada cultural sphere.

In this respect, it is worth recalling that in the wider hinterland of Ca' Baredi – within the Isonzo basin and particularly in the Collio region around Gorizia, including the peatlands of Mossa and Capriva, as well as in the Tagliamento morainic amphitheatre at Qualso – evidence from earlier, unsystematic investigations has been tentatively interpreted as indicating pile-dwelling structures. At Preval, near Capriva del Friuli, several substantial wooden posts (8-9 m in length and approximately 40-50 cm in diameter) were reportedly recovered during peat extraction in the early twentieth century (Borgna, Corazza 2022b). Although this evidence remains uncertain, it may point to a connective route linking the Adriatic coast with the pile-dwelling environments of the sub-Alpine hinterland.

Within this geographical framework, it cannot be excluded that the bovine no. 1 may have travelled along the piedmont corridor and through the Isonzo basin – possibly employed as a draught animal pulling a cart. Isotopic evidence suggests that its early life was spent in a region characterized by a colder climate and a radiogenic geological substrate. The sample derives from the uppermost fill of the shallow ditch, which was definitively closed and levelled during MBA 3; accordingly, both the arrival and death of the animal can be placed within a period when contacts with the south-eastern Alpine region were particularly active, especially in relation to metal procurement.

In the later phases – certainly by the Late Bronze Age – Ca' Baredi was integrated into a well-established network linking coastal and sub-coastal sites. Some of these were located in lagoonal environments, such as Bonifica Muzzana and Marano, while others lay further inland, including Pramarine di Sesto al Reghena. These settlements appear to have been involved in intensive metallurgical activities sustained by flows of raw metal and technological knowledge across the Friulian plain (Borgna 2018). At the same time, coastal sites likely functioned as outer nodes within broader settlement systems aligned along river courses. These waterways connected the coast to the principal east-west axis along the spring belt that separates the upper from the lower Friuli plain, thereby facilitating the circulation of resources and goods to and from the inland territories occupied by hillfort communities or *castellieri*.

The sheep/goat no. 9, attributed to the later macro-phase and possibly accustomed to seasonal mobility or originating from pastures beyond the immediate catchment area of Ca' Baredi, may represent evidence for functional relationships between communities settled in the lower wet plain and those inhabiting the drier upper plain and hilly areas, where most hillforts were established around Udine (Borgna *et al.* 2025). Within this same network, the Karst plateau immediately east of Ca' Baredi likely played a significant role, especially in light of the strong cultural influence exerted by the hillforts of the Karst and Istria on the material culture of the site. These hillfort communities, lacking direct access to the sea, may have relied on landing places along the eastern low-lying coasts of the Friuli plain.

Maritime mobility dynamics are even more clearly reflected in the case of sheep/goat no. 14, whose isotopic signature indicates upbringing in a Mediterranean or southern environment characterized by warmer climatic conditions. The sample, recovered from the same depositional context as bovine no. 1bis, further underscores the participation of Ca' Baredi in multidirectional, long-distance exchange networks from at least the advanced Middle Bronze Age onward.

In this perspective, an additional social and possibly ceremonial dimension of exchange may be envisaged. As suggested by the evidence of the Italian swine transported to Tiryns in roughly the same period (Maeiri *et al.* 2019), animals may have travelled on board not only to support subsistence needs but also as elements of intercommunity exchange, potentially functioning as gifts or offerings during encounters structured around commensality and communal consumption (see also Cavazzuti *et al.* in this volume). Such practices may plausibly be associated with the outdoor area with hearths along the river at Ca' Baredi, where collective food preparation and consumption appear to have played a role in fostering social interaction and connectivity.

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# The Animals' Contribution to the Economy of Alpine Bronze Age Societies

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Abstract – The animals' contribution to the economy of Alpine Bronze Age societies. – This paper reconstructs, through a long-term diachronic perspective, the economic significance of animals in Bronze Age Alpine societies of Trentino – South Tyrol, currently the best-documented sector of the southern Alpine arc thanks to a sustained archaeozoological research tradition. Early pioneering analyses in the late nineteenth and early twentieth centuries were followed by systematic work from the 1970s onward, notably driven by Alfredo Riedel and the group of younger scholars who formed an informal "school" around him. The region's high site density, continuous coverage across the whole second millennium BC, and strategic location at the junction of major riverine and overland corridors linking the Po-Mediterranean and Danubian worlds make it a paradigmatic case for exploring how animal economies evolved alongside settlement stabilisation, demographic growth, and the functional integration of lowlands, pre-Alpine zones and high-altitude pastures, within wider exchange networks. Regionally, hunting and wild-fauna use are consistently minor and structurally subordinate to herding. Dogs and horses are rare and not primarily linked to consumption, pointing to specialised functional and social roles. Pig husbandry is highly variable and, in some contexts, increases between the Final Bronze Age and the Early Iron Age, consistent with settlement concentration and demographic growth. Cattle remain the main productive cornerstone, yet management strategies shift from meat-oriented profiles in the Early Bronze Age to stronger investment in secondary products, especially milk, during the Middle Bronze Age, in parallel with sheep strategies oriented toward dairying and, secondarily, wool. Overall, the archaeozoological record documents increasing economic complexity and rationalisation, potentially generating dairy surpluses embedded in inter-Alpine and Po-plain circulation networks, in which high-altitude pastoralism played a key integrative role.

Riassunto – Il contributo degli animali all'economia delle società alpine dell'Età del Bronzo. – l contributo ricostruisce, in prospettiva diacronica, il ruolo economico degli animali nelle società dell'Età del Bronzo dell'area trentino-altoatesina, oggi il settore meglio documentato dell'arco alpino meridionale grazie alla continuità degli studi archeozoologici avviati già tra Otto e Novecento e ripresi sistematicamente dagli anni Settanta, con particolare impulso dato da Alfredo Riedel e dalla "scuola" formatasi attorno a lui. La densità di siti, la copertura dell'intero II millennio a.C. e la posizione dell'area all'incrocio di grandi corridoi fluviali e terrestri (tra mondo padano-mediterraneo e danubiano) consentono di interpretare le economie animali entro processi di lunga durata: stabilizzazione insediativa, crescita demografica, integrazione funzionale tra fondovalle, Prealpi e pascoli d'alta quota, controllo di vie di scambio e formazione di sistemi insediativi a quote diversificate. I dati regionali indicano una netta marginalizzazione della caccia dal Bronzo antico in avanti, con contributi dei selvatici generalmente inferiori al 10% (cervo e cinghiale prevalenti) e scarso ricorso a risorse avifaunistiche e ittiche, coerentemente con la trasformazione degli habitat forestali e con la crescente prevedibilità dei prodotti provvisti dall'economia agro-pastorale. Cane e cavallo sono rari e generalmente non legati al consumo: il primo rimanda a funzioni di sorveglianza e governo delle greggi, il secondo (attestato con certezza dal Bronzo medio) appare soprattutto connesso a valenze sociali e di prestigio. Il maiale mostra invece forte variabilità e, in alcuni contesti, un incremento tra Bronzo finale e prima Età del Ferro, dato interpretabile come risposta adattiva alla concentrazione insediativa e all'aumento demografico. I bovini restano il perno produttivo (carne, latte, forza lavoro), ma nel Bronzo medio cambiano modalità di gestione verso i prodotti secondari, soprattutto latte, con mandrie strutturate attorno a vacche adulte; parallelamente, tra i piccoli ruminanti prevalgono le pecore, con strategie orientate al latte e, in misura collaterale, alla lana. Nel complesso emerge un'economia sempre più complessa e razionale, potenzialmente capace di surplus lattiero-caseari e inserita in reti di circolazione interalpina e padana, in cui il pastoralismo d'alta quota – affermatosi tra Bronzo antico avanzato e Bronzo medio e favorito anche da finestre climatiche più miti – contribuisce alla gestione integrata dello spazio produttivo alpino.

*Parole chiave:* Archeozoologia; Età del Bronzo alpina; Economia agro-pastorale; Prodotti secondari; Pastoralismo d'alta quota.

*Keywords:* Archaeozoology; Alpine Bronze Age; Agro-pastoral Economy; Secondary Products; High-Altitude Pastoralism.



## 1. HISTORY OF RESEARCH

The reconstruction of the contribution made by animals to the economies of Alpine Bronze Age societies is, at the present state of research, in fact possible above all in the northeastern quadrant of the southern Alpine arc and, specifically, in the territories of the present-day Trentino – Alto Adige region, where particular conditions favourable to the development of research in this field have allowed, at least since the 1970s, the study and publication of numerous faunal assemblages. The fact that these are not all datable to the Bronze Age does not constitute a limitation; on the contrary, it offers the valuable opportunity – elsewhere not very frequent – to follow over time the evolution of the relationship established with animals by the Alpine societies settled in this geographical quadrant.

Alfredo Riedel (Trieste, 1925-2014), still today the principal contributor to the Alpine archaeology of northern Italy, correctly intuited the historical significance of this relationship, to which he constantly paid attention and which he illustrated in two extensive syntheses (Riedel 1986, 1994). It is scarcely necessary to observe that the valorisation of a diachronic point of view is always promising on the heuristic plane, but it is much more so – and for reasons that also pertain to an evolutionary approach – in those territories, such as the pre-Alpine and Alpine area, where human settlement never underwent interruptions of appreciable duration, being founded upon assumptions of homeostatic equilibrium between the needs of the established communities and the carrying capacities of their respective environments. Although from the 1970s onward the development of the archaeological discipline could proceed with continuity, it is nevertheless necessary to note that, beginning already in the last quarter of the nineteenth century and then again in the 1930s, scientific investigations had been conducted, for example, on the faunal remains from two important sites in southern Trentino. We refer here to the study of animal bones that Paolo Orsi entrusted to Giovanni Canestrini in 1882 (a degree thesis in Natural Sciences by Giuseppe Noldin) (Richard 1931; Dalla Longa-Marconi-Tecchiati 2022), and to the fine publication of the animal bone remains from Ettore Ghislanzoni's 1929 excavations at the pile-dwelling of Molina di Ledro, brought to press by Camillo Richard in 1931 (Tecchiati 2025a:19-20.). One may regret that these early experiments in the study of faunal remains of archaeological provenance did not have a sequel until the resumption of studies by Riedel; but we know that this was, in general, the twentieth-century fate of research in the archaeozoological field in our country – a situation to which, despite common opinion, there likely contributed, more than the philosophical climate of the time, the subordination of Prehistory to Classical and particularly Roman Archaeology, dear to the propagandistic interests of the Fascist regime (bioarchaeological studies first arose and developed within Palethnology), two world wars with the decimation of numerous young scholars, and organisational problems of various kinds.

Alfredo Riedel, who for decades had in fact worked alone – occasionally relying on the authority of scholars somewhat older than himself (e.g., Angelo Pasa, 1911-1966, Museum of Natural History of Verona), or younger but highly established (Benedetto Sala, University of Ferrara) – conceived, in the last twenty years of his professional activity (1990-2010), the idea of being flanked by young scholars (Gabriella Petrucci, Francesco Boschin, Stefano Marconi, Jasmine Rizzi) active in Trentino – Alto Adige (Bressanone, Rovereto) and in Friuli – Venezia Giulia (Trieste), who would constitute his "school," despite the fact that Riedel never taught at the university. These are also the years that saw him found, together with others, first the Informal Group of Italian Archaeozoologists (GIZA), and later the Italian Association of Archaeozoology (AIAZ) (Tecchiati and Sala 2006).

## 2. ARCHAEOLOGICAL SITES, THEIR CHRONOLOGY AND FUNCTION

The density of sites characterising the territories of the present-day provinces of Bolzano (South Tyrol) and Trento (Trentino), together with the chronological coverage spanning the entire Bronze Age, confers upon the area considered in this contribution a paradigmatic quality, pending the integration – through new research – of the territories of the western Alpine arc (Piedmont, Lombardy) and, respectively, of the eastern arc (Veneto, Venezia Giulia) into a broader-scale framework. For Veneto, only the faunal remains from Castel de Pedena (Rinaldi and Tecchiati 2015), dated between the Early Bronze Age and the Early Iron Age, may be mentioned. For Lombardy, the hilltop site of Rocca di Chiuso, overlooking the Lecco branch of Lake Como, has yielded for the Final Bronze Age and the Early Iron Age only a very modest number of remains (Boscato *et al.* 2019); however, excavations are presently ongoing (Dir. Alice Sbriglio), and a more substantial assemblage awaits examination by the local Soprintendenza. For Venezia Giulia, it is appropriate to cite the extensive analytical work conducted by Riedel during the 1960s and 1980s; yet the faunal assemblages derive mostly from contexts whose stratigraphic reliability is generally difficult to evaluate, particularly in the case of caves, which were rarely excavated according to strict criteria and were frequented over long periods for purposes often very different from one another. Nonetheless, a recent study by Gabriella Petrucci on the Bronze Age fauna from the Castelliere degli Elleri in the Triestine Karst (Muggia) must be acknowledged (Petrucci 2017).

The location of Trentino – Alto Adige (fig. 1) at the intersection of two important fluvial routes (1: Adige – Isarco – Inn – Danube; 2: Adige – Isarco – Rienza – Drava – Danube) exemplifies in an exemplary manner the cultural characterisation of this area, positioned between the Po plain and Mediterranean world and the Danubian world.

Its broader significance also depends on the close functional relationship between Alps and Prealps, and between the Plain and the Alpine and pre-Alpine areas (a network evident, for example, in transhumant pastoralism and in the circulation of metals). The sites whose faunal assemblages have been studied in the territory described are relatively numerous, distributed – as noted – across the entire Bronze Age, and are for the most part functionally characterisable as settlements. The list presented in tab. 1 may be considered exhaustive. Only sites of clearly cultic or funerary character have been excluded here, as their faunal remains must be interpreted as products of selection for ritual purposes and would not have contributed useful data for a strictly economic discussion. The morphological-functional type of the hilltop settlement predominates, though open-air villages and occupations in caves and rock shelters are also documented.

A possible line of research, which for reasons of opportunity cannot be developed here, concerns a potential specialisation of the economy of hilltop settlements relative to other settlement types.


Fig. 1: The Alpine area corresponding to the present-day provinces of Trento and Bolzano lies at the intersection of two continental-scale hydrographic axes. Graphic elaboration by the Author.

*L'area alpina corrispondente alle attuali province di Trento e Bolzano si trova all'intersezione di due assi idrografici di scala continentale. Elaborazione grafica dell'Autore.*

In this respect, it already seems possible to propose that the economy of these hilltop sites – always grounded in solid agricultural bases – depended at least in part on the need to control terrestrial and fluvial routes and to take an active role in intersocietal exchanges. If in recent prehistory the occupation of territory by individual communities seems to have privileged ecotones according to a recurring pattern,as in the case of the Early and Middle Neolithic settlement of Villandro in the Isarco Valley (Nisbet 2006/2007), beginning in the Bronze Age (fig. 2) true settlement systems – whether vertebrate or invertebrate – emerged; their formation was influenced by the phenomenon of settlement stabilisation and demographic increase where these are documented or reasonably inferred (Mottes-Nicolis-Tecchiati 1999; Tecchiati 2025b). These systems seem instead to encompass environments situated at different altitudes, enabling an integrated exploitation of environmental resources (Tecchiati 2010; Battisti 2010). Forms of adaptation to environment and altitude appear to prevail over cultural traditions, though widely shared attitudes characterising homogeneous *facies* must nonetheless have played a role, perhaps largely adapted to the specific strategies of individual productive units embedded within coherent territorial systems of land use and resource management. This is likely the case for two similar animal economies observed at Sotciastel (Salvagno and Tecchiati 2011; Tecchiati 2020) and at Albanbühel (Riedel and Rizzi-Zorzi 1998, 2002), fortified hilltop settlements situated in quite different ecological settings.

The settlements of Nössing, Naturno – Schnalserhof (Riedel and Tecchiati 2000), and Siusi – Via Valzura in South Tyrol (Tecchiati and Pizzini 2025), and the Castelcorno Caves (Fontana-Marconi-Tecchiati 2009; Battisti and Tecchiati 2022), the Castelliere dei Pizzini of Villa Lagarina (Mar-

| | Locality | Municipality | Type | Chronology | Bibliography |
|---|---|---|---|---|---|
| 1 | Albanbühel | Bressanone – S. Andrea | Hill-top settlement | LEBA, MBA, LBA and FBA | Riedel and Rizzi 2002 |
| 2 | Bäckenwiesl | Tires | Open air settlement | FBA | Tecchiati-Cavalieri-Di Braida 2013 |
| 3 | Carera | Fiavè | Pile-dwelling | LEBA, MBA, ELBA | Gamble and Clark 1987 |
| 4 | Castellano | Bressanone | Open air settlement | FBA | Tecchiati and Neri 2010 |
| 5 | Dosso Alto | Rovereto, Borgo Sacco | Hill-top settlement | EBA, MBA, LBA, FBA | Tomasini-Marconi 2024 |
| 6 | Fingerhof | Aica di Fie | Open air settlement | EBA | Riedel 1986 |
| 7 | Gafriller | Barbiano | Open air settlement | LBA, FBA, EIA | Cavalieri-Marconi-Tecchiati 2010 |
| 8 | Ganglegg | Sluderno | Hill-top settlement | MBA, LBA, FBA | Schmitzberger 2007 |
| 9 | Grotte di Castel corno | Isera, Lenzima | Cave | (L)EBA | Tecchiati-Fontana-Marconi 2012; Battisti and Tecchiati 2022 |
| 10 | Il Colombo | Mori | Rock shelter | LCA, EBA | Bonardi *et al.* 2000 |
| 11 | Huber | Bressanone, Elvas | Open air settlement | MBA | Tecchiati and Farina in press |
| 12 | Kaltenhauser | Bressanone, Elvas | Pit, settlement | FBA | Boschin and Tecchiati 2019; Boschin 2018 |
| 13 | Kofler Moos | Laion | Open air settlement | FBA/EIA | De March-Rinaldi-Tecchiati 2015 |
| 14 | Kreutzwiese | Bressanone, Elvas | Open air settlement | FBA | Tecchiati-Girardi-Boschin 2012 |
| 15 | Laimburg | Vadena | Abitato all'aperto | FBA | Riedel 2001 |
| 16 | Molina | Ledro | Pile-dwelling | EBA, MBA | Riedel 1976 |
| 17 | Monte Mezzana | Terlago | Hill-top settlement | LCA, BA | Riedel 1979 |
| 18 | Nössing | Varna | Hill-top settlement | BA | Riedel and Tecchiati 1999 |
| 19 | Pizzini | Villa Lagarina, Castellano | Hill-top settlement | BA | Battisti and Marconi 2003 |
| 20 | Via Valzura | Castelrotto, Siusi | Hill-top settlement | LEBA, EMBA | Tecchiati and Pizzini 2025 |
| 21 | Riparo del Santuario | Lasino | Rock shelter | LCA, EBA | Riedel and Tecchiati 1992, 1995 |
| 22 | Riparo Gaban | Trento, Martignano | Rock shelter | EBA, MBA | Zanetti *et al.* 2024 |
| 23 | Schnalserhof | Naturno | Open air settlement | EBA | Riedel and Tecchiati 2000 |
| 24 | Siechenhaus | Appiano Sulla strada del Vino | Open air settlement | FBA | Riedel 1985 |
| 25 | Sonnenburg | San lorenzo di Sebato | Hill-top settlement | LCA, EBA, MBA, LBA | Riedel 1984 |
| 26 | Sotciastel | San Leonardo-Badia | Hill-top settlement | LEBA, MBA, ELBA | Salvagno and Tecchiati 2011 |
| 27 | Wasserbühel | Laion | Hill-top settlement | MBA, LBA | Tecchiati-Fontana-Marconi 2010 |

Tab. 1: List of Bronze Age sites in Trentino – Alto Adige for which archaeozoological investigations are available. Legend of the Chronologies: BA: Bronze Age; CA: Copper Age; IA: Iron Age; E: Early; F: Final; L: Late; M: Middle.

*Elenco dei siti dell'età del Bronzo del Trentino-Alto Adige, di cui sono disponibili indagini archeozoologiche. Legenda delle cronologie: BA: età del Bronzo; CA: età del Rame; IA: età del Ferro; E: antica/iniziale; F: finale; L: recente/tarda; M: media.*

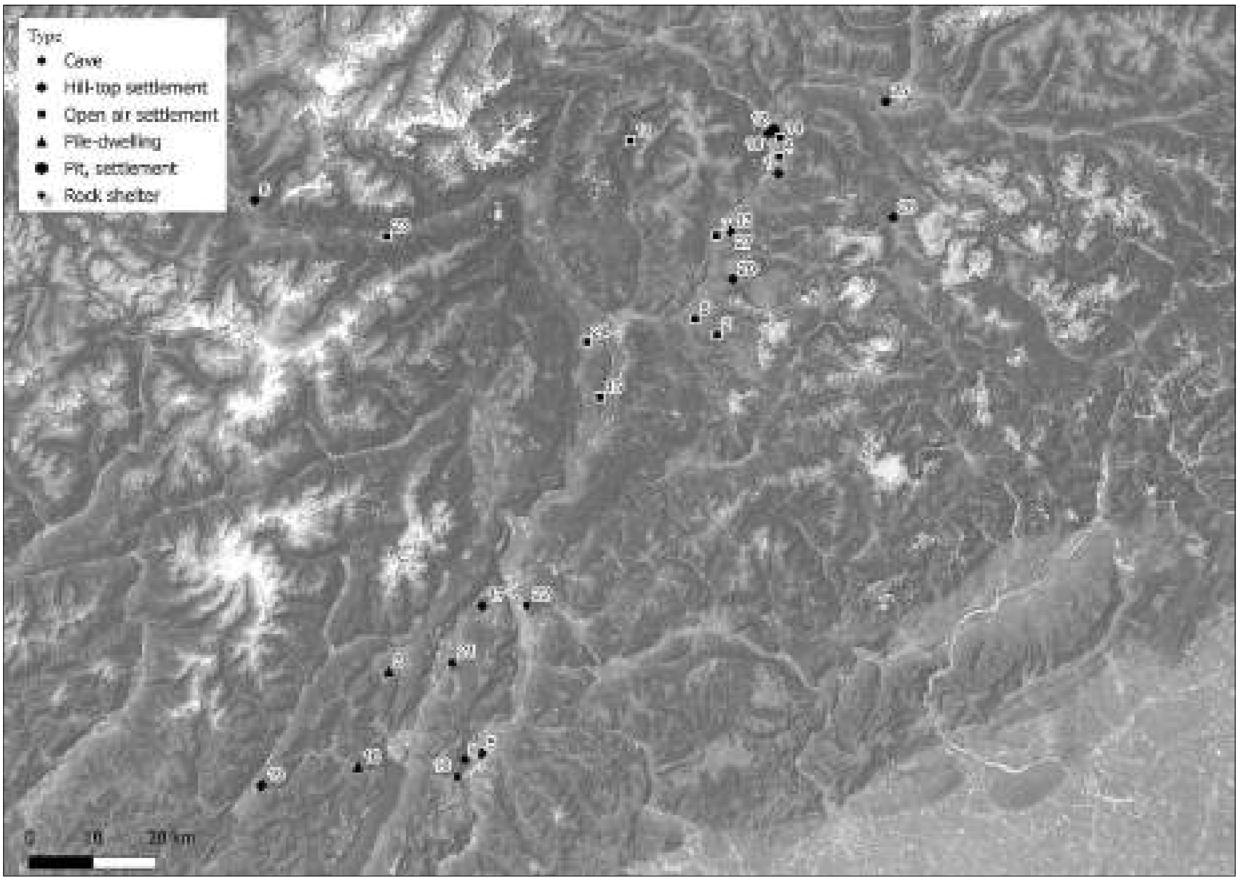


Fig. 2: Distribuzione GIS dei siti elencati in Tab. 1. Elaborazione dati e grafica di Fiorenza Gulino.
*GIS distribution of the sites listed in Tab. 1. Data processing and graphics by Fiorenza Gulino.*

coni and Battisti 2003), and Dosso Alto of Borgo Sacco near Rovereto in Trentino (Tomasini and Marconi 2024), all date to the Early Bronze Age. Several multistratified sites contain faunal remains datable to different moments of the Early Bronze Age and the subsequent Middle Bronze Age, such as Sonnenburg, Albanbühel, and Sotciastel in South Tyrol, and the Riparo del Santuario of Lasino (Riedel and Tecchiati 1992, 1995) and the pile-dwelling of Molina di Ledro in Trentino (Riedel 1976). The Middle Bronze Age is represented by the settlements of Laion – Wasserbühel (Tecchiati-Fontana-Marconi 2010) and Elvas – Proprietà Huber (Farina and Tecchiati in press). The Fiavé pile-dwelling (Gamble and Clark 1987) is dated to the Middle Bronze Age and the initial phases of the Recent Bronze Age, while the fortified settlement of Ganglegg at Sluderno (Steiner 2007; Schmitzberger 2007) in South Tyrol covers the entire period between the Middle and the Final Bronze Age. Finally, Laion – Kofler Moos, Vadena (Riedel 2001), and San Paolo di Appiano (Riedel 1985) near Bolzano are dated to different moments within the Final Bronze Age and the beginning of the Iron Age.

## 3. CHARACTERISATION OF THE ARCHAEOLOGICAL *FACIES* IN THE BRONZE AGE

The geographical area addressed in this contribution displays cultural peculiarities determined by its geographical position and its environmental preconditions. In particular, its location immediately south of the Alpine watershed and, as noted, at the intersection of communication routes whose importance exceeds the regional scale, must always be kept in consideration.

The intermediate position between the cultural outcomes of the Po Plain and the southern peri-Alpine region, on the one hand, and those observable north of the Alpine watershed, on the other, appears to have generated forms of cultural contamination recognisable in the material culture. These may be understood within the framework of exchange relationships at various levels and of the local re-elaboration of external influences. This is particularly evident in the Early Bronze Age, when proximity to the geographical area of the Polada culture – which extended, with its own distinctive traits, across all of Trentino and was perceptible in South Tyrol especially in the ceramic repertoire and in participation in the phenomenon of the so-called "enigmatic objects" (Tecchiati 2011) – did not exclude the reception of cultural elements belonging to the Straubing culture and, subsequently, to the Arbon – Bleiche 3 horizon.

Thus, already in the final centuries of the third millennium BC, a local *facies* essentially Polada-like seems to take shape in Trentino – based on elements derived from the Bell Beaker tradition and on formative aspects of the Polada culture – while in South Tyrol it may have progressively assumed the characteristics of the so-called *Inneralpine Bronzezeitkultur* (Tecchiati 1998), documented primarily in Switzerland. This *facies* would be characterised by Bell Beaker-derived shapes (globular-bodied jugs) and by large and medium-sized ceramic forms of coarse manufacture, such as jars and dolia of truncated-conical or convex profile, distinguished by smooth or impressed cordons and sometimes furnished with rows of holes along the rim.

South Tyrol's connections with the flint procurement areas (Val di Non, Monte Baldo, the Venetian Pre-Alps), which remained fairly strong until the Copper Age, seem to weaken significantly, as suggested by the quantitative collapse of this raw material from the earliest phases of the Bronze Age onwards, and by the almost exclusive presence of finished tools (arrowheads, sickle elements), with little or no evidence of local knapping. This loosening of connections could also be explained by greater proximity to metal sources. The overall rarity of metal artefacts in South Tyrolean sites of this period may be interpreted in light of repeated recasting of finished objects. Casting moulds are, in fact, documented.

In the Middle Bronze Age, the South Tyrolean ceramic repertoire shows an evident loss of the rich incised and impressed decoration that characterises the medium and small black-burnished forms of Trentino, as an effect of adherence to the pile-dwelling / terramare *facies.* Nevertheless, several characteristic forms are present, such as handled cups with handles rising above the rim (particularly the truncated-horn types typical of the earliest Middle Bronze Age).

In the initial phases of the Recent Bronze Age, the earlier ceramic tradition seems to persist in South Tyrol, with some aspects perhaps attributable to the Trentino Recent Bronze Age (Fiavé – Dos Gustinaci *facies*) and to the Po plain; whereas with the developed Recent Bronze Age, one observes the emergence of the Luco – Meluno *facies*, accompanied by a marked expansion of mining and metallurgical activities. The ceramic repertoire of this *facies* displays traits of notable technical skill, while the shapes and decorations of the typical handled jugs and pitchers show autonomy and originality, though still exhibiting some continuity with the ceramic outcomes of the late Middle Bronze Age and the earliest Recent Bronze Age. This is a moment – also attested elsewhere – of formation of a *facies* which, in continuous and direct evolution, would maintain homogeneous features at least throughout the Hallstatt period.

With regard to the economy, no significant elements appear, at least for the moment, to characterise the *facies* as such, whereas clear forms of adaptation to the environmental preconditions of the individual regions are evident. On a strictly archaeozoological level, the most relevant phenomena are represented by: a) the almost sudden collapse, beginning in the Early Bronze Age, of the contribution of hunting – and perhaps of aleatory economic activities more generally – to subsistence; b) the gradual transition from forms of animal husbandry based exclusively on the exploitation of meat to others in which a more pronounced interest in secondary products (primarily milk, and possibly wool) may be detected; c) the introduction of the horse, perhaps as early as the late Early Bronze Age, but certainly by the Middle Bronze Age; d) the activation, in advanced stages of the Early Bronze Age, of high-altitude pastoral activities and the formation of settlement systems shaped according to a model of integrated distribution of sites at different elevations, including within internal Alpine areas and not only along the principal valley corridors (the Adige, Isarco, and Rienza basins and their tributaries).

## 4. THE CONTRIBUTION OF WILD ANIMALS

The data available at the regional level outline a scenario in which hunting and the exploitation of wild animals play, throughout the entire Bronze Age, a quantitatively modest and structurally subordinate role in comparison with animal husbandry. Red deer and wild boar predominate among the represented taxa; the percentages of wild animal remains are generally below 10%, there is limited reliance on avifaunal and ichthyic resources, and a marked variability from site to site is evident, linked to the history and specific function of individual settlements, to deposit-formation processes, and to the statistical reliability of the faunal assemblages. This configuration – already observed in contrast to the wide fluctuations documented for the Copper Age of northern Italy (Tecchiati-Castiglioni-Rottoli 2013) – may plausibly be situated within the broader phenomenon of settlement stabilisation and the parallel transformation of forest habitats, with direct impacts on the availability and accessibility of prey.

More specifically, the percentages recorded for several key contexts in the south-eastern Alpine region confirm the low systematic incidence of wild taxa: at Fiavé (Middle Bronze Age), wild fauna accounts for approximately 2%; at Siusi (late Early Bronze Age – transition to MB1), around 3.9%; at Sotciastel (Middle Bronze Age), 0.7%; and at Appiano – Giardineria Gamberoni (Siechenhaus; Recent – Final Bronze Age) (Bonardi *et al.* 2000), about 2.5%. In all these cases, hunting appears to function as an opportunistic supplement to an economy increasingly oriented towards "secondary products" (milk and, to a lesser extent, wool), in accordance with long-term trends already noted for the Alpine and Po regions during the transition from the Early to the Middle Bronze Age. A datum that runs counter to this trend is observed at Colombo di Mori (Early Bronze Age), where the proportion of wild species reaches 14%, a value exceptionally high for the chronological phase and geographical area in question. This is probably the result of a recovery bias linked to the excavation methods and to the history of the excavations carried out by Orsi in the 1880s, suggesting caution in interpreting the figure as representative of an actual relative importance of hunting. On the contrary, it highlights the need to make explicit – case by case – the taphonomic and diachronic "filters" that intervene between economic behaviours and the archaeozoological series observed.

Overall, the regional profile suggests that from the Early Bronze Age onwards, hunting loses relative importance not only as a protein source but also as a domain of environmental resource management. In a context in which productive activities (agriculture and animal husbandry) become increasingly central – with the rise of zootechnical specialisation and the predictability of the primary and secondary products derived from livestock – aleatory activities diminish in marginal utility. The limited presence of birds and fish, and more generally of aquatic resources, appears consistent both with settlement choices (often located on slopes or alluvial fans, yet with economies centred on the agricultural hinterland) and with the cost – benefit balance of economic activities that are less profitable – at least over the long term – than agriculture. The taxonomic pattern – domination by red deer and wild boar – accords with the progressive opening of forest cover (clearance, burning, and pastoral activities around villages). Within this framework, the relative constancy of modest percentages of wild fauna may be read as an index of hunting practices of marginal economic utility, serving both episodic provisioning and symbolic or identity-related needs. The percentage variability observable across different sites – from the minimum recorded at Sotciastel to the anomalous high figure at Colombo di Mori – points to local ecological gradients, differing depositional histories, and a non-negligible methodological component related to recovery techniques.

From an interpretative standpoint, the data underscore three aspects: a) subsistence in the Bronze Age of the Trentino – South Tyrolean area is structurally agro-pastoral, with hunting relegated to an accessory role; b) the transformation of environments and the emergence of systems of integrated management of natural and soil resources – evident in the appearance of organised settlement systems – contribute to the substantial marginalisation of aleatory activities; c) intra-regional differences appear explicable primarily in terms of historical-taphonomic and ecological factors at the local scale, rather than as indicators of a plurality of distinct economic models. Illuminating, in this regard, is the differing relative weight of wild taxa in the Neolithic economies of northern Italy, where high percentages may be attributed to the occupation of previously untouched land and to reliance on "traditional" activities during the establishment of agricultural infrastructures (Zanetti-Fontana-Tecchiati 2020).

Further refinement requires assemblages comparable in quantity, context, and methods of study, as well as the systematic integration of archaeobotanical and isotopic indicators, to assess with greater precision the actual contribution of wild fauna to the food budget and to subsistence strategies.

## 5. THE ROLE OF THE DOG AND THE HORSE

Within the framework of the economy and the symbolic sphere of the Bronze Age in the Trentino – South Tyrolean area, the dog and the horse occupy a peculiar position, significantly different from that of the primary domestic animals such as cattle, sheep and goats, and pigs. The archaeozoological data available indicate, for both species, a marked scarcity of skeletal remains – an aspect suggesting that their use was not ordinarily connected with food consumption and instead points to specific functions, both utilitarian and symbolic in nature.

The dog is attested in a discontinuous and quantitatively limited manner in Bronze Age contexts of the region. The rarity of the remains confirms the absence of a systematic exploitation for alimentary purposes and highlights a differentiated relationship between dogs and human communities. From a morphological perspective, the individuals documented generally exhibit small or medium size. The site of Sotciastel (Middle Bronze Age) is particularly significant: analyses have made it possible to distinguish at least two size categories, interpretable as indicating a functional specialisation of the dog, probably connected with the surveillance of settlements and the management of herds. A similar pattern emerges from the pile-dwelling settlement of Ledro, where size variability suggests differentiated uses within structured agro-pastoral economies. The horse presents a situation partly comparable to that of the dog. Attestations of *Equus caballus* are rather rare and initially concentrated in only a few contexts. Over the course of the Bronze Age – that is, from the early Middle Bronze Age to the Final Bronze Age – these attestations tend to involve an increasing number of sites, yet the horse consistently appears with only a few remains. The earliest evidence supported by reliable radiocarbon dating comes from the site of Bressanone – Elvas (Prop. Huber) (Farina and Tecchiati in press), with dates ranging between the fifteenth and the thirteenth century BC, although a placement in the fifteenth century BC appears more probable on the basis of ceramic data (Farina and Tecchiati, in press). Additional finds, chronologically uncertain but perhaps attributable to the Early Bronze Age, come from Sonnenburg near San Lorenzo di Sebato, eastern South Tyrol) (Riedel 1984).

In any case, the scarcity of remains and the rarity or absence of butchery marks or signs of systematic exploitation indicate that the horse was neither employed as a food resource nor as a work animal. This suggests instead a social significance of the species – symbolic or related to prestige.

## 6. THE PIG BETWEEN CULTURAL CHOICES, ENVIRONMENTAL ADAPTATION, AND HUMAN DEMOGRAPHY

Within the framework of Bronze Age economies in the central-eastern Alpine area, and in particular in Trentino – Alto Adige, the pig stands out for its high quantitative variability and for a distribution that is also conditioned by altitudinal factors, although strong percentage oscillations may be observed in contemporaneous sites situated in comparable environmental contexts. Such oscillations may partly reflect the limited reliability of some of the faunal assemblages studied, or may instead indicate economic choices made in contexts where environmental preconditions left wide margins of discretion, possibly as an effect of culturally driven traditions.

In Trentino, the percentages of pig remains fluctuate significantly across different contexts. The pile-dwellings of Ledro and Fiavé, both located in an endo-Alpine environment at around 600 m a.s.l., show relatively low values (approximately 8% and 6.5% respectively), whereas the Riparo del Santuario (Riedel and Tecchiati 1992, 1995), situated at the same altitude, yields a percentage almost twice as high (around 14%). Even more striking is the situation at the Pizzini of Castellano, situated at roughly 700 m a.s.l., where pig remains exceed 30% of the total fauna, in contrast with low-altitude sites such as Colombo di Mori or Dosso Alto di Borgo Sacco (around 200 m a.s.l.), which display intermediate values, around 18-22%. This distribution demonstrates that altitude, at least in Trentino, does not constitute a primary explanatory factor, and that the variability is better interpreted in light of local paleoenvironmental and microclimatic conditions and, above all, of specific socio-economic configurations.

The situation differs in South Tyrol, where a clear altitudinal gradient in the reduction of pig percentages may be observed as an effect of the diminishing availability of forested environments suitable for pig husbandry, providing a clearer picture of environmental adaptation in geographically harsher settings (Amato and Tecchiati 2016).

From a biological standpoint and in terms of its likely management, the domestic pig appears clearly distinct from the wild boar, with scarce evidence of hybridisation – perhaps as an effect of a growing distance, not only spatial but also ecological, between the areas occupied by wild populations and those designated for domestic pig grazing. Withers heights generally within 75 cm indicate domestic populations of small to medium size.

A significant evolution in the role of the pig is observable between the end of the Bronze Age and the Early Iron Age, as documented at the site of Appiano – Siechenhaus. Here, cattle, small ruminants, and pigs represent respectively 54.4%, 22.5%, and 23.3% of the faunal remains. Although cattle maintain a dominant position, the pig reaches values close to those of sheep and goats, indicating a rebalancing of husbandry strategies. This configuration cannot be explained solely on the basis of environmental potential – which would have permitted the predominant rearing of any domestic species – but instead seems to reflect new economic needs linked to demographic growth and to processes of settlement selection and concentration.

In this context, the pig assumes a strategic function: an animal with a rapid reproductive cycle, relatively undemanding in terms of grazing space, and closely tied to the environment immediately surrounding the settlement, it is particularly well suited to sustaining numerically expanding communities. The increase in pig presence thus appears as a sensitive indicator of changes in socio-economic structures, accompanying phenomena of settlement selection and reorganisation, as suggested by the comparison between Appiano – Siechenhaus – which ceased to exist by the very beginning of the Iron Age – and the continued occupation of nearby Vadena throughout the first millennium BC and beyond.

## 7. CATTLE AND SHEEPS: FROM PROVIDERS OF MEAT TO A PILLAR OF AN ECONOMY BASED ON THE EXPLOITATION OF DAIRY PRODUCTS

The available data suggest configurations that vary through time and space, with exploitation profiles oscillating between a predominantly meat-oriented management and models more distinctly centred on secondary products (milk, dairy derivatives, and labour power).

At Nössing (Early Bronze Age) (Riedel and Tecchiati 1999), the ratio between adults and juveniles cattle shows a relative balance, with adults at 57% and juveniles at 43%, indicating a management strategy that does not rely exclusively on early slaughtering, yet at the same time does not systematically prolong the animals' lives into advanced age. The age-class distribution indeed shows a concentration in young adults, a pattern that points to a still predominant interest in meat and only a modest interest in milk.

Between the end of the Early Bronze Age and the beginning of the Middle Bronze Age, the picture becomes more articulated and diversified. At Siusi – Via Valzura, the demographic curve of cattle is clearly skewed toward adults (71.8% adults / 28.2% juveniles), with a predominance of adult cows: this suggests a pronounced interest in milk production and its derivatives, paralleling similar data recorded for sheep.

Sotciastel (Middle Bronze Age) follows a trajectory comparable to that of Siusi – Via Valzura: here too a predominance of adult cows and sheep emerges, indicating a clearly recognisable orientation toward milk, signalling a subsistence economy whose primary objectives appear to lie in maintaining a continuous yield of secondary products (milk and dairy goods) and in preserving the numerical stability of the herd. This tendency – connected with the organisation of pasture spaces and with the seasonal scheduling of activities

– accords with structured agro-pastoral models in which the labour power and draught capacity of castrated males raised into old age accompany, perhaps in a somewhat subordinate yet not marginal position, the management of cows beyond juvenile age.

A comparison between the Nössing data on the one hand and those from Siusi – Via Valzura and Sotciastel on the other allows for several economic and territorial considerations. Nössing suggests a strategy in which meat production retains significant relevance; Siusi – Via Valzura and Sotciastel, conversely, display configurations more distinctly oriented toward milk exploitation, with herds structured around adult cows and sheeps. The coexistence of different models in geographically proximate areas and overlapping chronological spans points – beyond paleoenvironmental and microclimatic factors – to the weight of cultural choices and settlement strategies (density, continuity of occupation, access to forage resources), as well as to the need to calibrate slaughter calendars in relation to expected yields (meat versus milk) and to the interannual stability of herd size. From the perspective of territorial organisation, milk-oriented profiles presuppose forms of close control over pastures and long-cycle management practices, involving seasonal movements and investment in the rearing of adult females; meat-oriented profiles, though still requiring adequate infrastructure and foddering, seem instead more closely tied to the availability of pastures around the settlement and allow for greater flexibility in slaughter scheduling. It is plausible that, at the regional scale, the two models coexisted, adapting to demographic conjunctures and to secondary uses of cattle (traction, manuring), and that the transition from the Early to the Middle Bronze Age favoured, in some contexts, a greater capitalisation of females in order to stabilise milk supply throughout the year.

Thus, different cattle-management strategies can be discerned: at Nössing a still predominantly meat-oriented approach is evident (with most adults being young adults); at Siusi – Via Valzura and Sotciastel, an interest in milk centred on adult cows emerges, accompanied by indications of sheep specialisation (wool) and, more broadly, by a functional integration of the various resources obtainable from different domestic animals.

## 8. SUMMARY OVERVIEW AND CONCLUSIONS

In the second millennium BC, the productive economy of the Alpine Bronze Age appears characterised by increasing complexity. From a predominant interest in meat – and, at a much greater distance, in milk – still typical of the Early Bronze Age, one moves in the Middle Bronze Age toward a more distinct interest in secondary products (milk and wool). This growing complexity may be linked to the phenomenon of settlement stabilisation, to the adoption of new forms of agricultural exploitation that were more stably permanent and sedentary – entailing crop rotations, fallow cycles, and field manuring – to demographic growth, and to the emergence of territorially based social structures (Tecchiati *et al.* 2020). Functional adaptations of settlements to ecologically diversified environmental contexts, including altitudinal variation, imply a logic of integrated resource management that, in certain geographic sectors, would lead to the formation of *Siedlungskammern* and fully fledged settlement systems exhibiting various degrees of functional hierarchy, depending also on the chronological phase. These systems appear to gravitate around the hydrographic corridors and their control (the basins of Brunico – San Lorenzo, Bressanone, Bolzano, Trento, and the Rovereto area).

From a zootechnical perspective, cattle retain clear centrality as providers of meat, milk, and labour power, even in those cases in which they are, as at Sotciastel, subordinate to sheep flocks. Middle Bronze Age cattle herds favour adult cows (Siusi – Via Valzura; Sotciastel), thus surpassing – at least to some extent – the exploitation model still widespread in the Early Bronze Age, which prioritised meat production (Nössing). It is worth noting that this shift entails a zootechnical and zootechnological advancement, and the diffusion within communities of knowledge concerning the organisation of daily labour (milking and milk processing, herding, watering, etc.) and of seasonal – annual management scales (management of parturition cycles, summer pasturing, forage storage, etc.).

Among small domestic ruminants, sheep are essential: at Sotciastel (Middle Bronze Age), their mortality profiles mirror those of cattle and show notable similarities with the situation at Siusi –

Via Valzura, where adult females predominate among caprines. The proportion of rams, slightly below 30%, may be interpreted as primary evidence for an interest in wool that is not central to the site's economy but rather collateral to a milk-oriented exploitation. The general correspondence between sex and age ratios observable in cattle and sheep is an indication of increasing rationalisation in animal management among Alpine communities of the second millennium BC. Juvenile slaughtering – or slaughter of animals in age classes not rigidly standardised – for both cattle and small domestic ruminants must have ensured the principal supply of meat, since hunting, as noted, was an occasional activity and pigs were generally scarce, irregularly available and raised, especially at higher elevations and in South Tyrol.

One might ask whether the difficulty of pig husbandry, combined with specific economic choices oriented toward exploiting secondary products in the case of cattle and sheep, may have resulted in a semi-permanent deficit of animal proteins in the diet of Alpine groups, perhaps motivating exchanges even of food (sausages, dried or smoked meat, etc.) with communities characterised by different economic orientations. Although this is difficult or impossible to prove, and despite my belief in the substantial self-sufficiency – above all alimentary – of the communities considered in this contribution, the proposed model appears coherent, on the one hand, with an Alpine production of milk that would easily have exceeded the needs of local groups, and on the other, with the emergence of very embryonic forms of market behaviour underlying, in my view, the "secondary products revolution," at least in those geographic areas where it resulted in surpluses that necessarily required "commercialisation".

Where a surplus arises, in fact, a circulation network of goods of all kinds – including foodstuffs – must exist, whose movement compensates for what individual communities do not produce for themselves. This observation necessarily implies a link among the endo-Alpine communities, potentially belonging to the same *Siedlungskammer* or the same settlement system, thus underscoring the aforementioned "integrated" character of the Alpine productive space, from valley floors to high-altitude pastures. Yet, at a deeper level of reflection, such a link must probably be extended to relationships between endo-Alpine societies and those of the Po plain and, respectively, the northern Alpine regions. This is a topic for which mobility studies seem best suited to provide answers – or at least stimuli for continued research.

Returning to the relationship among communities belonging to the same settlement system, the issue of high-altitude pastoralism – apparently emerging during the Early Bronze Age and at the beginning of the Middle Bronze Age – presupposes conscious forms of environmental management and stable, efficient political relations among communities. Indeed, up to historical times, the crossing of territories belonging to different *polities*, as well as the allocation of pastures and the respect of their boundaries, posed critical issues of this kind. The predominance of adult females among the sheep at Sotciastel is consistent with summer milking cycles in high-altitude pastures, not necessarily very far from the settlement in absolute elevation (Sotciastel lies at 1400 m a.s.l.) (Tecchiati 2025b) and fits within the broader intensification of high-altitude pasture use in the second half of the second millennium BC.

The pattern observed in Val Senales (Putzer-Festi-Oeggl 2016) confirms that regular and systematic use of high-altitude environments does not precede the Middle Bronze Age. Since no evidence of continuity emerges thereafter – at least in the area investigated in Val Lagaun, a side valley of Val Senales – it is likely that these occupations did not always have a systematic or prolonged character across successive archaeological periods and phases. Nevertheless, the chronological distribution of *Höhenfunde* (Tecchiati 2007; Catena and Tecchiati 2022), as well as of cult sites (Haupt 2009) and copper-ore-reduction areas (Niederwanger and Tecchiati 2000), intuitively linked to the use of high elevations also for pastoral purposes, seems to compensate, at the local scale, for the lack of pastoral continuity between the Middle and the Final Bronze Age.

The intensification of the use of internal Alpine areas and high altitudes coincides with a warm phase (ca. 1500-950 BC), which provided a climatic window favourable to high-altitude pastoralism, especially for summer lactation cycles and vertical movements, within a broader pattern of medium glacial retreat followed by the well-known Late Holocene neoglaciation. These conditions increased the interannual stability of dairy yields and mitigated risk for communities settled in internal and higher-altitude areas – communities more exposed than others to climatic variability.

In the period between the late Bronze Age and the Early Iron Age, demographic growth and the phenomenon of settlement selection and concentration – especially evident in the Final Bronze Age – may have required increased productive flexibility, including long-term occupation of geographic sectors near major waterways and favourable to pig husbandry, as demonstrated by the significant pig percentages observed, for example, at the emporic settlement of Vadena.

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HERDS – Animal Husbandry and its Economic Role in the Development of Central Mediterranean Protohistoric Societies – Rivista di Scienze Preistoriche – LXXVI S6 – 2026 – pp. 311-329

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# Experimental Archaeology and Simulation of Animal Resources and Derived Products in the Bronze Age

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Abstract – Experimental archaeology and simulation of animal resources and derived products in the Bronze Age. – The abundant archaeological documentation relating to Bronze Age settlements in Northern Italy enables us to frame research aimed at reconstructing resource management practices and addressing specific aspects of food productivity. For the purposes of this contribution, two lines of research were pursued. The first considers analyses carried out on animal husbandry and on all factors that may have interacted with this aspect of village economy, including data derived from archaeobotanical research closely related to animal feeding. The second addresses the methodological approaches applied to the research, focusing primarily on experimental archaeology and the use of simulations in resource management studies.
For the assessment of animal resources, documentation from the excavation of the Bronze Age settlement of Solarolo (RA) was analyzed. The archaeological remains at the site relate to a well-defined chronological phase corresponding to the central phase of the Middle Bronze Age (BM2). The excavation included the complete recovery of faunal remains and systematic sampling aimed at the application of statistical analyses. With regard to applications of experimental archaeology, after several years devoted to reconstructing agricultural practices in order to calculate cereal productivity, the research was conducted to reconstruct patterns of consumption of animal products, including meat cooking and milk pasteurization. The experimental work is particularly aimed at achieving a better understanding of the use of specific vessel types, such as strainers and pots with an internal ledge. Simulations allowed the estimation of the number of live animals by projecting the Minimum Number of Individuals (MNI) calculated from the faunal remains of cattle, sheep/goats, and pigs identified in two excavation areas at Solarolo, as well as to assess the sustainability of the territory by calculating – on the basis of available land – the quantities of fodder required to support the domestic herds. The results obtained from the simulations provide a basis for discussing the actual scale of livestock holdings managed by a Bronze Age village community.

Riassunto – Archeologia sperimentale e simulazione delle risorse animali e dei prodotti derivati nell'età del Bronzo. – L'abbondante documentazione

archeologica relativa ai contesti di abitato dell'età del Bronzo in Italia settentrionale ci permette di impostare la ricerca per ricostruire le pratiche di gestione delle risorse e di affrontare aspetti specifici della produttività alimentare. In occasione di questo contributo sono state seguite due linee di ricerca: la prima prende in considerazione le analisi effettuate sull'allevamento animale e su tutto ciò che poteva interagire con questo aspetto dell'economia di villaggio, inclusi i dati ricavati dalla ricerca archeobotanica in stretta relazione con l'alimentazione animale; la seconda affronta gli aspetti metodologici applicati alla ricerca che convergono soprattutto sull'archeologia sperimentale e sull'applicazione di simulazioni alla gestione delle risorse. Per la valutazione della risorsa animale è stata analizzata la documentazione dello scavo dell'abitato dell'età del Bronzo di Solarolo (RA), dove i resti archeologici sono relativi ad una fase circoscritta nel tempo corrispondente alla fase centrale della Media età del Bronzo (BM2) e dove è stato effettuato il recupero integrale dei resti faunistici e un campionamento sistematico volto all'applicazione di analisi statistiche.
In merito alle applicazioni dell'archeologia sperimentale dopo vari anni dedicati alla ricostruzione delle pratiche agricole destinate a calcolare la produttività dei cereali, sono state condotte ricerche dedicate a ricostruire le pratiche di consumo dei prodotti animali, tra cui la cottura delle carni e la pastorizzazione del latte. La sperimentazione è in particolare dedicata ad una migliore comprensione dell'utilizzo di particolari recipienti come colini e vasi a listello interno. Le simulazioni hanno permesso di ipotizzare il numero di animali vivi ottenuto dalla proiezione del NMI dei resti faunistici di bovini, caprovini e maiali individuati in due aree dello scavo di Solarolo oppure di valutare la sostenibilità del territorio calcolando in base alla superficie disponibile le quantità di nutrimento necessario al numero di domestici. I risultati ottenuti dalle simulazioni offrono lo spunto per la discussione sulla reale consistenza del patrimonio animale gestita da una comunità di villaggio dell'età del Bronzo.



*Parole chiave:* Età del Bronzo; archeozoologia, alimentazione; capacità del territorio; Solarolo.

*Keywords:* Bronze Age; Archaeozoology, Nutrition; Carrying Capacity; Solarolo.

## 1. PREFACE

This work represents a case study for the presentation of rarely applied approaches in a framework that includes archaeological data, experimental archaeology, and simulation hypotheses for the evaluation of animal resources and derived products in the Bronze Age. The aim is to test an analytical methodology to estimate the exploitation of resources, with particular reference to livestock farming.

In order to assess the role of animal resources in the economic management of Bronze Age settlements in northern Italy, the study of faunal remains is the starting point for a multidisciplinary approach that examines resource use, diet, economy, spatial organisation, ritual and social identity (Reitz and Wing 2008: 1).

The identification of remains recovered during archaeological excavations is usually proposed with a preliminary distinction between the percentages of domesticated species bred in a dominant relationship with wild fauna, which reduced to a minimum percentage in the Bronze Age. This initial data emphasises the role of animal resource management as the result of precise planning among Bronze Age communities. Archaeozoological remains (NR / NISP) are then counted by quantity, percentage distribution of domestic species and identification of the minimum number of individuals (MNI). In addition to the various issues concerning the methods used to identify and calculate the number of remains (Morin *et al.* 2017a, b), it should be noted that the result obtained represents in any case a small percentage of the original composition of the domestic fauna present related to the settlement (Domínguez-Rodrigo 2012). Finally, the question, rarely addressed (Lee Lyman 2019; Cazzella-Recchia-Lucci 2021), of the presumed number of animals raised at any given time in the life of the village (Actual number of individuals: ANI) remains unsolved. This information is extremely useful and necessary to calculate the food products (meat, milk and dairy products) or handicrafts (fabrics, leather, tools) available to the community and to obtain a reference for assessing the demography of a village.

Another approach aimed at investigating animal husbandry and related to the number of animals present within the territory associated with each village, is the analysis of carrying capacity, to be applied in assessing fodder requirements, watering needs, and the sustainability of livestock support (Šálková *et al*. 2022). The quantification of pasture land within the territory pertaining to each village can be calculated in relation to land allocated to other activities (agriculture in cultivated areas and gathering in woodland) or to natural features (rivers, wetlands) and anthropogenic elements (settlement areas, production zones, and cemeteries), by identifying applicable percentages (fig. 1) through equating and standardize land-use categories in order to proceed in further spatial analyses (Burigana 2023; Cattani 2015; Cazzella-Recchia-Lucci 2021; Debandi 2021; Sotgia 2024).

## 2. THE SOLAROLO CASE STUDY

To propose a discussion on the possible applications of these investigations, the excavation record of the Middle Bronze Age settlement in Via Ordiere at Solarolo[1] (RA) (Cattani *et al*. 2018; Cattani and Peinetti 2023), was selected, as it presents several suitable characteristics:

- The short duration of the stratigraphic sequence investigated, limited to the central phase of Middle Bronze Age (MBA2), which allows for detailed analysis of the archaeological data divided into relatively well-defined chronological phases (approx. 25 years) (fig. 2);
- The stratigraphic excavation and documentation methodology applied continuously from 2006 to the present, with particular attention to microstratigraphy and micromorphological analyses, including detailed recording and description of contexts;
- The careful recovery of all archaeological remains through systematic sieving and sampling of the entire archaeological deposit using 5 mm mesh, which ensured the preservation of most indicators, particularly small faunal remains, with organized cataloguing by stratigraphic unit and by 1×1 m grid square;
- The collection from each stratigraphic unit (SU) and from each grid square of a sediment sample of approximately 5-8 litres, intended for flotation or wet sieving, to recover archaeobotanical remains and to verify the presence of micro-remains embedded in the archaeological deposit (fig. 3).
- The attention devoted to the recovery of archaeological data makes it possible to apply specific analyses focused on resource management in the Bronze Age. Regarding livestock management, several key research questions were formulated for interpretative purposes:
- What feeding regime was adopted for domestic animals, and which resources (fodder, agricultural by-products, pasture, pollarding) were used for their maintenance?
- What was the management capacity of a Bronze Age village in terms of the number of animals that could be sustained, according to palaeoenvironmental characters and estimates of the territory?
- What were the productive potentials in terms of milk, wool, and other dairy products?
- How many people could be supported on the basis of available animal resources, and what quantity of products (meat, milk, and dairy products) could realistically be supplied per capita?

These questions serve a dual purpose: to assess the validity of applying new methods and evaluation protocols for faunal remains in relation to the analysis of subsistence strategies based on agricultural production and animal resources, and to estimate demographic presence on the basis of available food resources (per capita caloric intake), as well as to identify forms of social organization grounded in the control of subsistence goods or surplus production.

To address these questions, in addition to evaluating the archaeological data, an experimental archaeology protocol and a simulation framework were applied to test the hypotheses formulated on the basis of the results. A significant role has been assigned to experimental archaeology applications, seen as a necessary step in producing scientific results to be used in estimates. In this regard, agricultural productivity and cereal yields allow us to proceed further in the analysis of resources supported by the results of a scientific process that is measurable, repeatable and open

[1] Hereafter only Solarolo.

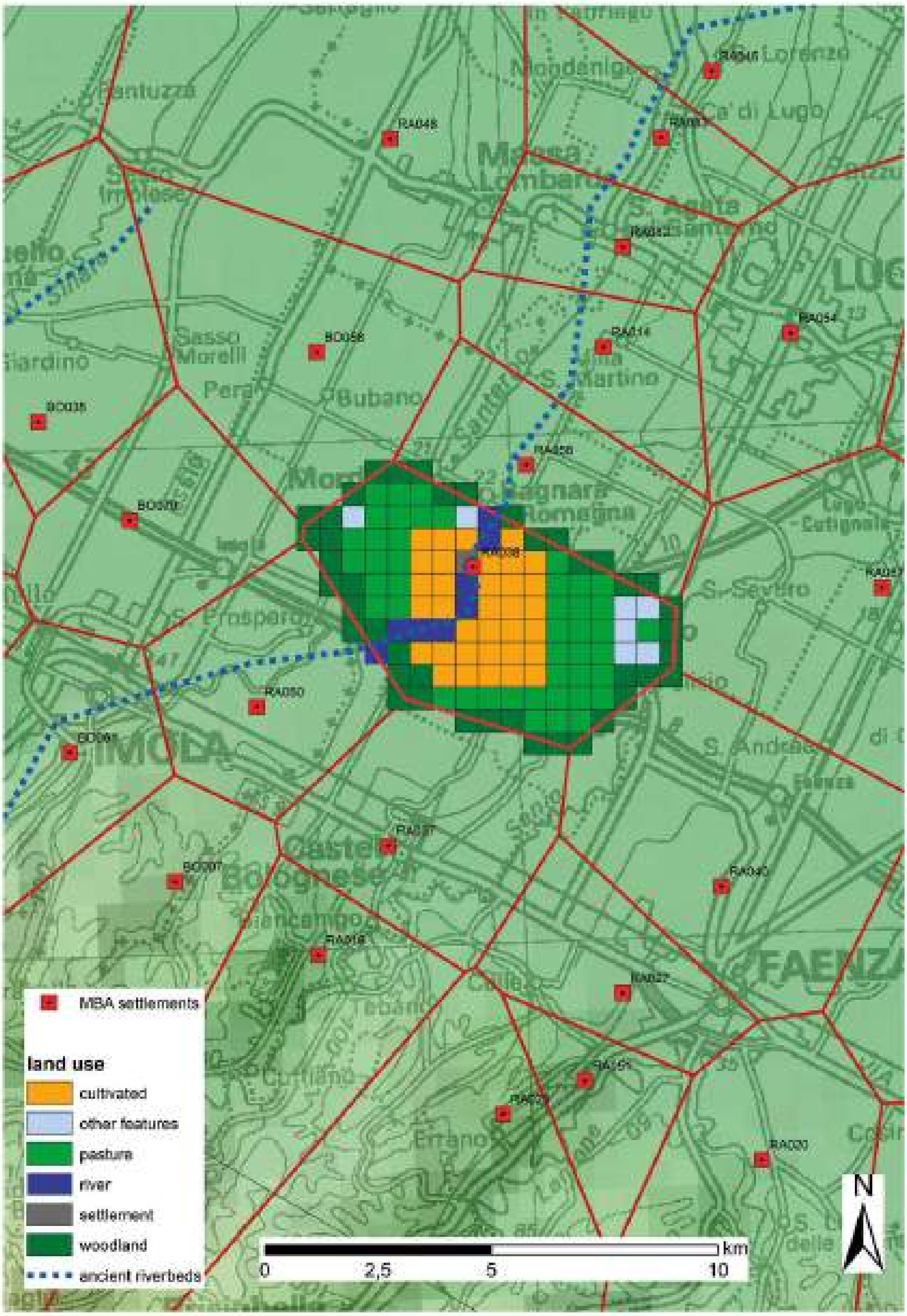


Fig. 1 – Ideal allocation of land use within the territory of Solarolo Bronze Age settlement identified with Thiessen polygons analysis.

*Ipotesi di distribuzione delle destinazioni d'uso all'interno del territorio relativo all'abitato dell'età del Bronzo di Solarolo identificato dall'analisi dei poligoni di Thiessen.*

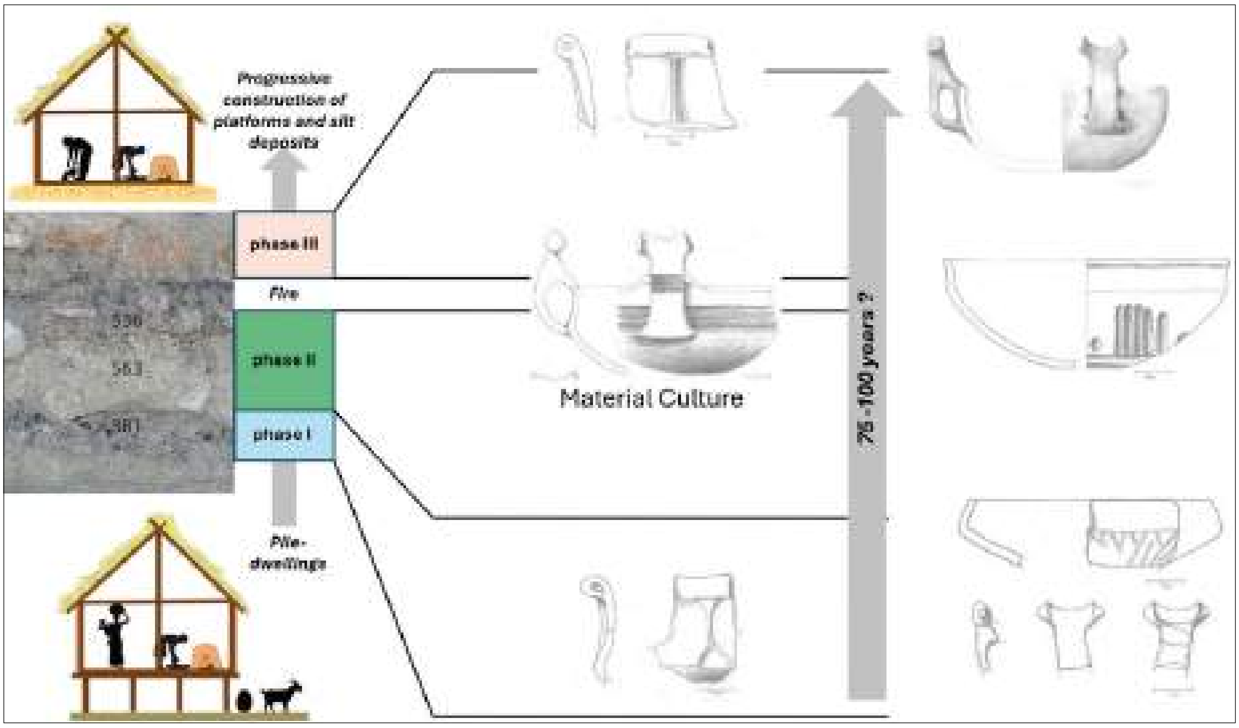


Fig. 2 – Solarolo, Via Ordiere. Building phases and association with material culture (after Cattani, Peinetti 2023).
*Solarolo, Solarolo, Via Ordiere. Sequenza delle fasi costruttive e associazione con la cultura materiale (modificato da Cattani, Peinetti 2023).*

to discussion. This approach is part of a long-term research and experimentation process started with the opening of the Solarolo excavation and marked by several key stages corresponding to publications from 2008 to the present (Cattani 2008; Cattani and Marchesini 2010; Carra-Cattani-Debandi 2012; Debandi 2021; Carra-Cattani-Debandi 2021; Cattani-Debandi-Sotgia 2021; Cattani *et al*., forthcoming). Many of these studies primarily focused on agricultural productivity, whereas livestock management has not yet been subject to equally extensive experimental application, apart from research on textile production (Cattani-Debandi-Zannoni 2023). The present work aims to assign greater emphasis on the evaluation of animal resources through simulation of herd management applied to the case of the Solarolo settlement and its surrounding territory.

## 3. EXPERIMENTAL ARCHAEOLOGY APPLIED TO RESOURCE MANAGEMENT

Experimental archaeology is a research approach aimed at understanding past human behaviour through the systematic analysis and reproduction of ancient technological processes. Rather than focusing solely on the replication of artefacts, it seeks to investigate the entire operational sequence – from raw material procurement to production, use, reuse, and symbolic meaning – through controlled and scientifically documented experimentation (Giannichedda and Mannoni 2003).

From a methodological perspective, experimental archaeology occupies a dual role within academia. First, as a form of applied archaeology, it represents a fundamental training tool that encourages students and researchers to translate theoretical knowledge into practice by actively engaging with past technologies (Hurcombe 2004). Second, it functions as a problem-solving discipline, supporting archaeological interpretation during fieldwork through the testing of hypotheses derived from excavation data and material evidence.

Experimental archaeology is inherently grounded in interdisciplinary collaboration (Cattani 2016; Comis 2022; Lemorini 2025). Archaeologists, technological specialists, ethnoarchaeologists, and archaeometrists contribute complementary expertise that no single individual can

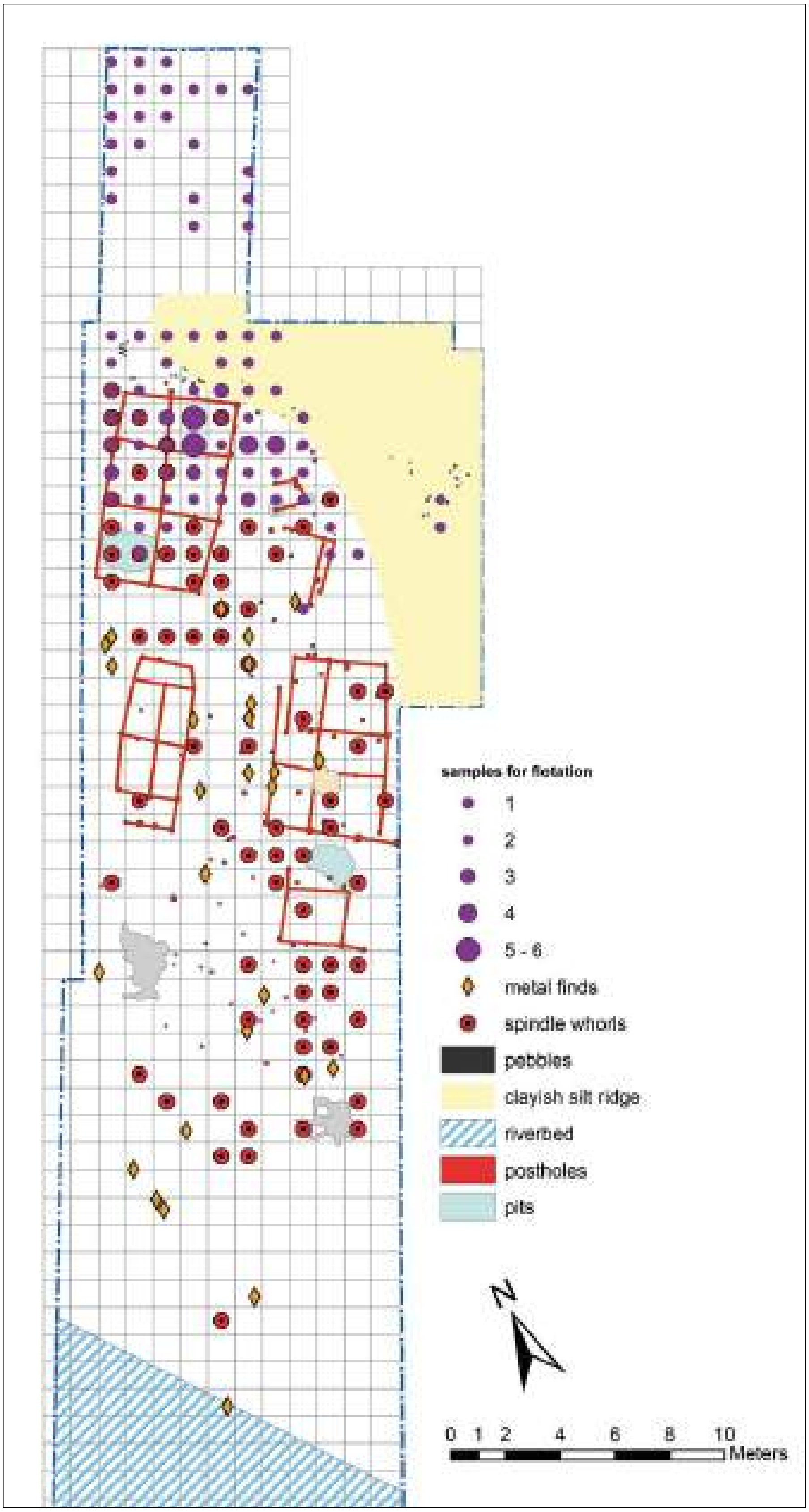


Fig. 3 – Solarolo, Via Ordiere. Example of sampling records and detailed recording of archaeological finds.

*Solarolo, Via Ordiere. Esempio di registrazione dei campionamenti e del rilevamento dettagliato degli indicatori archeologici.*

fully master independently. Practitioners in this field often act as mediators among these disciplines, facilitating dialogue and streamlining interpretative reasoning through the integration of practical experience and scientific analysis.

The discipline is based on the assumption that ancient craft practices relied on empirical knowledge and repeated trial rather than on rigid rules uniformly applied. The contemporary challenge lies in translating such processes into repeatable, structured, documented, and shareable procedures, without resorting to modern shortcuts or uncritical artisanal reproduction. Experiments therefore aim to replicate ancient technologies using historically attested materials, tools, and techniques, grounded in archaeological evidence, archaeometric data, and ethnographic comparisons. This is an ongoing, often provisional process subject to revision, reflecting the open and iterative nature of archaeological research.

Although detailed results of the archaeobotanical research are presented elsewhere, some aspects are worth summarising for understanding Bronze Age management potential. The data indicate an agricultural system primarily based on cereal cultivation, integrated by gathering or preferential attention to complementary plant species. Among these, the significant presence of millet may be closely related also to animal husbandry (Carra *et al.* 2023).

The experimental approach was mainly directed toward evaluating cereal productivity and availability, given its central role in the Bronze Age diet. Starting from the archaeobotanical remains recovered at Solarolo and defining optimal experimental conditions – including uncultivated land without artificial fertilisation, the use of historical, non-genetically modified seeds comparable to those documented for the Bronze Age – a four-year experimental cultivation programme was undertaken. Different sowing methods were tested and yields assessed[2] (fig. 4).

Among the most significant outcomes is the reassessment of agricultural productivity in the Po Plain. Together with a critical review of historical sources and data, the findings suggest yields higher than traditionally assumed: between 1:10 and 1:20, with an estimated production of approximately 10-12 hundred kilograms per hectare (Carra-Cattani-Debandi 2021).

## 4. FROM AGRICULTURAL YIELDS TO DEMOGRAPHIC MODELS

Building on experimental data, the 2021 study extended the analysis to demographic reconstruction. By integrating agricultural productivity, territorial catchment models, and estimated caloric requirements, new demographic estimates for Bronze Age settlements were proposed. Assuming that approximately 30% of a settlement's territory was devoted to cultivation and that cereals provided 70-75% of daily caloric intake, simulations suggest that for a settlement covering 1 hectare (inhabited surface, excluding defensive or perimeter structures) the territory could sustain an average population of around 150-200 individuals under conservative yield conditions[3].

Under more favourable scenarios, larger territories (up to 3,000 hectares) could theoretically support populations exceeding 1,000 individuals. These estimates contrast sharply with earlier models proposing much smaller communities and limited agricultural surplus (Cardarelli 2009). The study emphasises that such demographic growth would have been possible only through long-term planning, seed management, and social cooperation, rather than through intensive or profit-oriented agriculture, typical of Roman Age (Forni 2002).

The results support the interpretation of Bronze Age societies in northern Italy as relatively prosperous, resilient, and capable of sustaining dense populations for several centuries. Agricultural surpluses ensured not only food security, but also demographic expansion, territorial colonisation, and complex social organisation. Conversely, the subsequent collapse of these systems may be linked to disruptions in this delicate equilibrium, caused by several factors, like climatic instability, environmental stress, or failures in resource management and social conflicts.

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[2] For the results and discussion regarding cereal productivity in the Bronze Age, refer to previous publications, including the relevant bibliography (Carra-Cattani-Debandi 2012).

[3] Previous studies suggest slightly lower estimates, corresponding to an average of 125-130 individuals per hectare of inhabited area (Cardarelli 2010: 459; Cardarelli 2014: 841; Cardarelli 2018: 361).

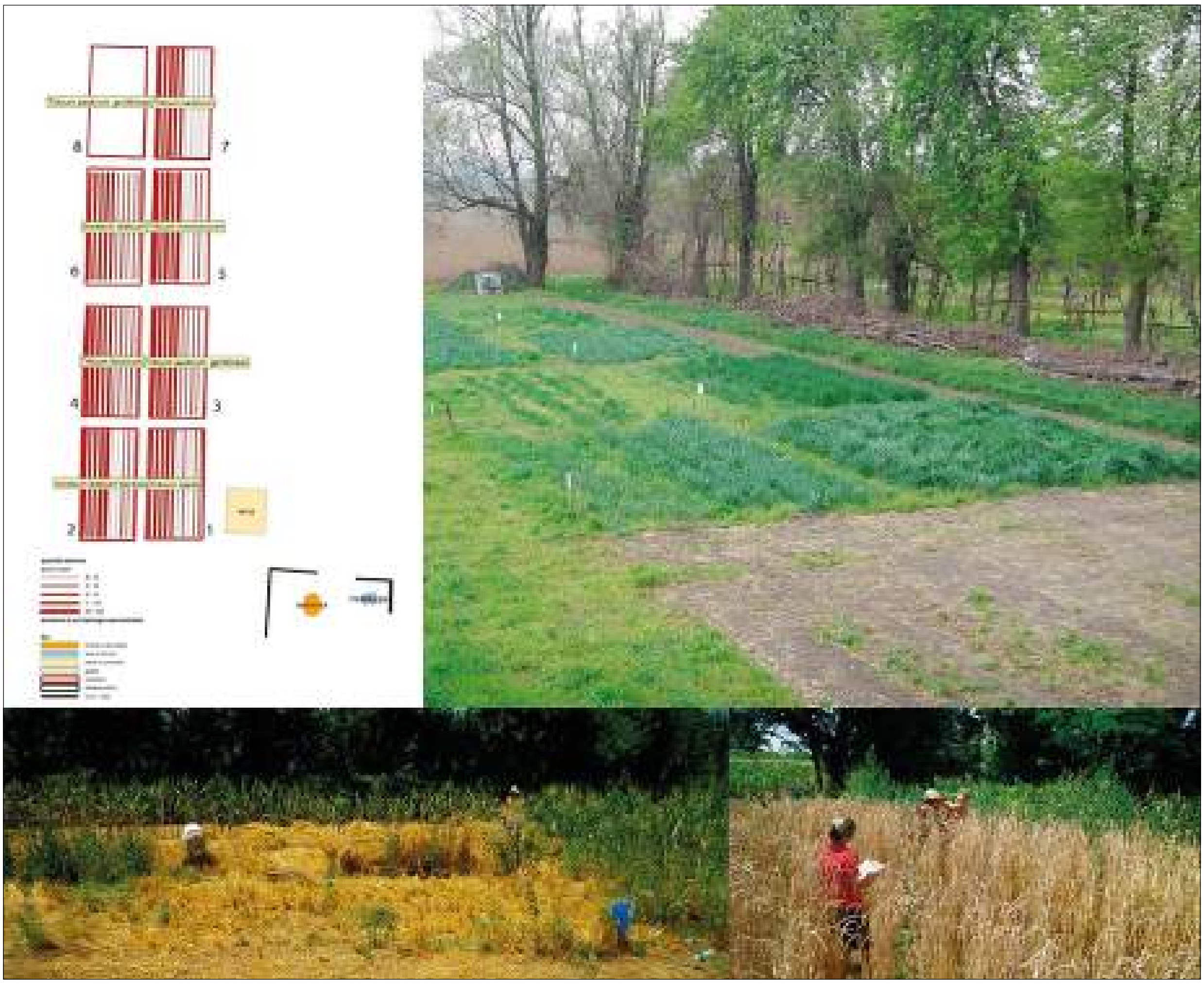

Fig. 4 – Solarolo, Via Ordiere. Experimental cultivations within the Experimental Laboratory program at Bologna University.

*Solarolo, Via Ordiere. Coltivazioni sperimentali, parte del programma del Laboratorio di Archeologia sperimentale dell'Università di Bologna.*

## 5. ANIMAL RESOURCE MANAGEMENT

The composition of faunal remains identified during research at Solarolo (Maini 2012; Debandi and Maini 2021) shows a clear predominance of domestic species: ovicaprines (over 50% of osteological remains), pigs (almost 30%), and cattle (approximately 12%).

The systematic recovery of faunal remains through complete sieving of the archaeological deposit made it possible to use Minimum Number of Individuals (MNI) data for quantitative simulation of animal populations (Debandi and Maini 2021). The methodological premise is based on stratigraphic continuity and the homogeneity and repetitiveness of ceramic production, which allow attribution of the faunal assemblage to the MBA2 phase, corresponding to a chronological span of approximately 100 years, confirmed by radiocarbon dating. Detailed stratigraphic and micromorphological documentation further allowed subdivision into four sub-phases of approximately 25 years each (Cattani and Peinetti 2023).

Zooarchaeological analysis followed the "diagnostic zones" approach (Dobney and Rielly 1988; Serjeantson 1991, Davis 1992; Albarella and Davis 1994), adapted to a specific recording protocol including only species-diagnostic remains with metric or age-related value, in order to reduce margins of error. Faunal composition was assessed for each stratigraphic unit (SU) by selecting two sample areas within the village: a residential inner area and a peripheral area between the settlement and the riverbank, characterised by different depositional processes and presumably distinct activities (horticulture, animal movement or management). Data were subsequently aggregated by sub-phase.

Faunal remains were quantified using MNI and divided into age classes (Barone 1976, Grant 1982, and Bull and Payne 1982). Aggregation by SU, sub-phase, and area produced a conservative but representative estimate of slaughtered animals.

From MNI and age distribution, a hypothetical herd structure was reconstructed across four age classes (juvenile, sub-adult, fully mature adult, elderly). Survival curve interpolation allowed evaluation of exploitation strategies, economic aims (meat, milk, wool, traction), and long-term sustainability.

## 6. SIMULATION OF ANIMAL POPULATION

By relating MNI data to animal life expectancy (never exceeding 10 years), scaling to the proportion of excavated area, and projecting to the entire settlement nucleus (ca. 8,000 m$^2$), it was possible to estimate the number of animals simultaneously present in the village (Debandi and Maini 2021: 102).

The final estimate derives from averaging zooarchaeological analyses from different site areas (residential and peripheral sub-phases). Importantly, no direct proportional relationship between MNI and live population was applied. Instead, a demographic model accounting for internal herd structure was developed. MNI represents only slaughtered individuals, not the total herd.

Assuming that the slaughter profile reflects a stable management system, the number of slaughtered individuals in each age class implies a larger breeding population, including reproductive animals and individuals destined for secondary production (milk, wool, traction). By comparing MNI age classes with theoretical proportions in a stable herd, minimum herd sizes were calculated.

The estimated annual average for the settlement – approximately 125-126 cattle, 208 caprines, and 133 pigs – represents the theoretical live population necessary to sustain the observed slaughter pattern (Debandi and Maini 2021: 110). These figures derive from species-specific coefficients based on reproductive biology, mortality, and management strategies, rather than a fixed MNI multiplier. For example, slaughtering a 3-4-year-old bovine requires years of herd maintenance, whereas a young caprine may be slaughtered within months; thus, sustaining equivalent slaughter rates requires a proportionally larger live cattle population (fig. 5).

These estimates may appear conservative (given the MNI basis) yet high compared with traditional Bronze Age economic models, making it necessary to compare results with territorial sustainability inferences.

## 7. TERRITORIAL SUSTAINABILITY AND LIVESTOCK REQUIREMENTS

To address the question, “How many animals could a Bronze Age village manage?”, animal dietary requirements (water and fodder), spatial availability, and resource distribution within the hypothetical Solarolo territory were evaluated (tab. 1).

For territorial reconstruction, parameters previously applied to other areas (Cattani and Marchesini 2010; Debandi 2021) were adopted: 30% arable land, 30% pasture, 30% woodland, 10% other The percentage breakdown is derived from an estimate of deforested land, which in the BM accounts for 70% (Cremaschi 1992, Mercuri *et al.* 2006), assuming a similar 30% split of the territory between cultivated land and pasture. The rest is obtained by the assessment of various physical and anthropogenic features of the territory (rivers, settlements, necropolises, etc.). Cattle requirements were calculated considering (tab. 2):

- Daily grass consumption of approximately 50-70 kg during grazing months, and 10-15 kg of hay in winter;
- Pasture productivity of approximately 30-40 q annually in favourable seasons;
- A realistic minimum requirement of at least 2 hectares per head of cattle;
- Daily water consumption of at least 40 litres per animal.

Seasonal variability required consideration of stabling structures and winter fodder storage. Greater attention was therefore devoted to identifying archaeobotanical evidence of fodder plants

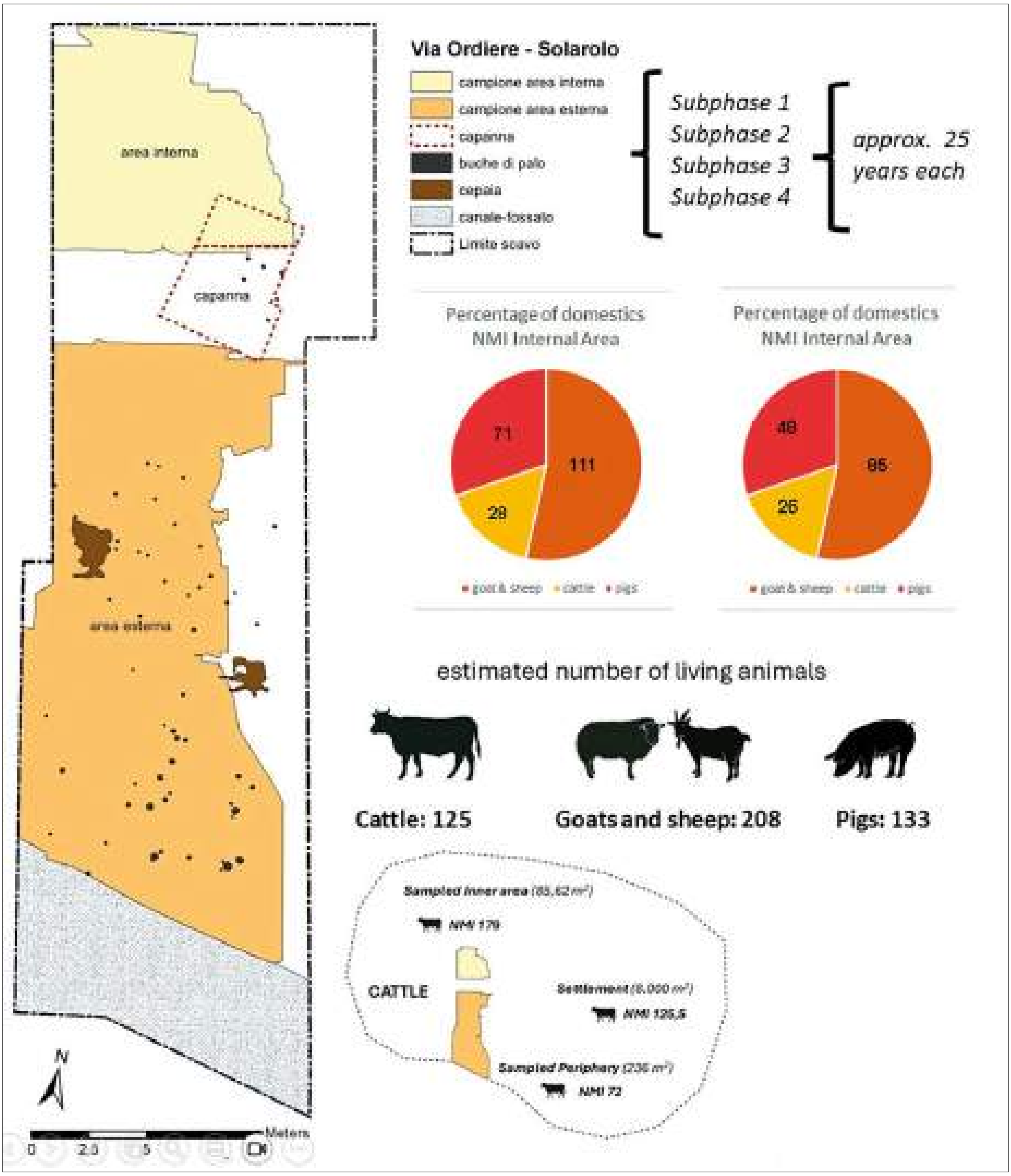


Fig. 5 – Solarolo, Via Ordiere. Selected excavated area for the calculation of MNI and estimation of actual number of domestic animals (after Debandi, Maini 2021).

*Solarolo, Via Ordiere. Aree dello scavo selezionate per l'identificazione delle percentuali del Numero Minimo di Individui degli animali allevati e proiezione del numero di animali vivi. (modificato da Debandi, Maini 2021).*

and to peripheral structures potentially linked to animal management (Debandi 2021: 256). Recent excavations in Sector 3 at Solarolo revealed stratigraphy and structural remains distinct from residential areas, preliminarily interpreted as enclosures or activity areas related to livestock management (Peinetti 2021).

Research is ongoing regarding potential animal mobility and exchange networks (Herds project, cfr Cavazzuti *et al*. in this volume), as well as seasonal resource management. Winter conditions during the Loebben phase, likely characterised by colder climates and frequent snowfall even in lowland areas, would have required careful fodder planning and stabling strategies.

Special attention is given to millet during MBA2, a crucial phase of settlement expansion. Its high frequency in the archaeobotanical record suggests deliberate cultivation; while likely used as animal fodder, its abundance within domestic contexts indicates it may also have contributed significantly to human diet.

Finally, sheep and goat husbandry must be considered in relation to textile production. Analysis of spindle whorls, loom weights, and reels from the settlement provides evidence for wool-based textile activities.

## 8. SPINDLE WHORLS, ANIMAL HUSBANDRY, AND WOOL PRODUCTION IN BRONZE AGE COMMUNITIES

In Bronze Age archaeological contexts, spindle whorls constitute one of the most reliable indirect indicators of textile production, particularly of yarn obtained from animal fibres such as wool. Although organic materials are rarely preserved, the systematic study of spindle whorls allows archaeologists to reconstruct not only spinning techniques, but also the scale of wool exploitation and its close relationship with animal husbandry (Sabatini 2020).

The Bronze Age settlement of Solarolo provides a clear case study for this relationship. Zooarchaeological evidence documents the presence of domestic animals, especially sheep, within the settlement. Sheep were multifunctional animals, providing meat, milk, and crucially wool. From the Middle Bronze Age onward, changes in sheep management across Europe indicate a growing emphasis on secondary products, particularly wool, which became increasingly important for textile production.

At Solarolo, the recovery of more than 300 spindle whorls in well-defined stratigraphic contexts points to an intensive and long-lasting spinning activity (Cattani-Debandi-Zannoni 2023). Morphometric analysis shows that most spindle whorls are small and lightweight, with low moment of inertia values. Experimental archaeology demonstrates that such tools are especially suitable for spinning fine, short, and elastic fibres, characteristics typical of sheep's wool rather than of long and resistant plant fibres. This technological choice strongly supports the hypothesis that wool derived from local sheep herds was the primary raw material for yarn production.

The number of spindle whorls and their concentration within domestic spaces suggest a continuous household-based activity rather than occasional or specialised production. Although spindle whorls cannot be directly equated with the number of spinners, their quantity reflects the intensity and duration of spinning over time. This implies the availability of a substantial and regular supply of raw wool.

Estimating the number of animals involved requires caution, but reasonable approximations can be proposed. Ethnographic and historical data indicate that a Bronze Age sheep could produce on average between 1 and 2 kilograms

| Site | Area ($m^2$) | ha | cultivation 30% | grazing 30% | woodland 30% | others 10% |
|---|---|---|---|---|---|---|
| Solarolo | 3.2803.516 | 3.280,35 | 984,11 | 984,11 | 984,11 | 328,04 |

Tab. 1 – Surface area of Solarolo territory classified into four land-use categories: crops, pasture, woodland and other.
*Estensione del territorio dell'abitato di Solarolo classificato in quattro categorie: coltivo, pascolo, bosco e altro.*

| grazing (30%) | ha for cattle breeding 20% | ha for sheep and goat breeding 10% | N° of cattle | N° of sheep and goats calculated at 10 ha | N° of sheep and goats calculated as 1/5 of cattle | Forage productivity (q) 40 per ha | Forage for consumption for 6 months of 0.3 q per day |
|---|---|---|---|---|---|---|---|
| 984,11 | 656 | 328 | 656 | 3280 | 1640 | 39364 | 702 |

Tab. 2 – Calculation of the max. number of cattle and goats in the territory with 30% dedicated to grazing.
*Stima del numero massimo di bovini e caprovini nell'areale dedicato al pascolo corrispondente al 30% del totale.*

of raw wool per year, depending on breed, age, and management practices. After cleaning and processing, usable wool would be reduced by approximately 30-50%. If even a modest household flock of 20-30 sheep is assumed, annual production could range between 20 and 60 kilograms of raw wool, yielding roughly 10-30 kilograms of spinnable fibre.

Such quantities would be sufficient to sustain continuous spinning activities and to produce significant amounts of yarn over the year. Experimental reconstructions show that spinning fine wool yarn is time-consuming, often requiring several hours to produce a small quantity of thread. The large number of spindle whorls at Solarolo therefore implies not only the presence of animals, but also a well-organised system of herd management, fibre processing, and labour allocation within the community (Cattani-Debandi-Zannoni 2023: 18).

Moreover, the production of fine wool yarn suggests aims beyond basic subsistence. Fine textiles may have served as clothing, furnishings, or prestige goods, and possibly as items for

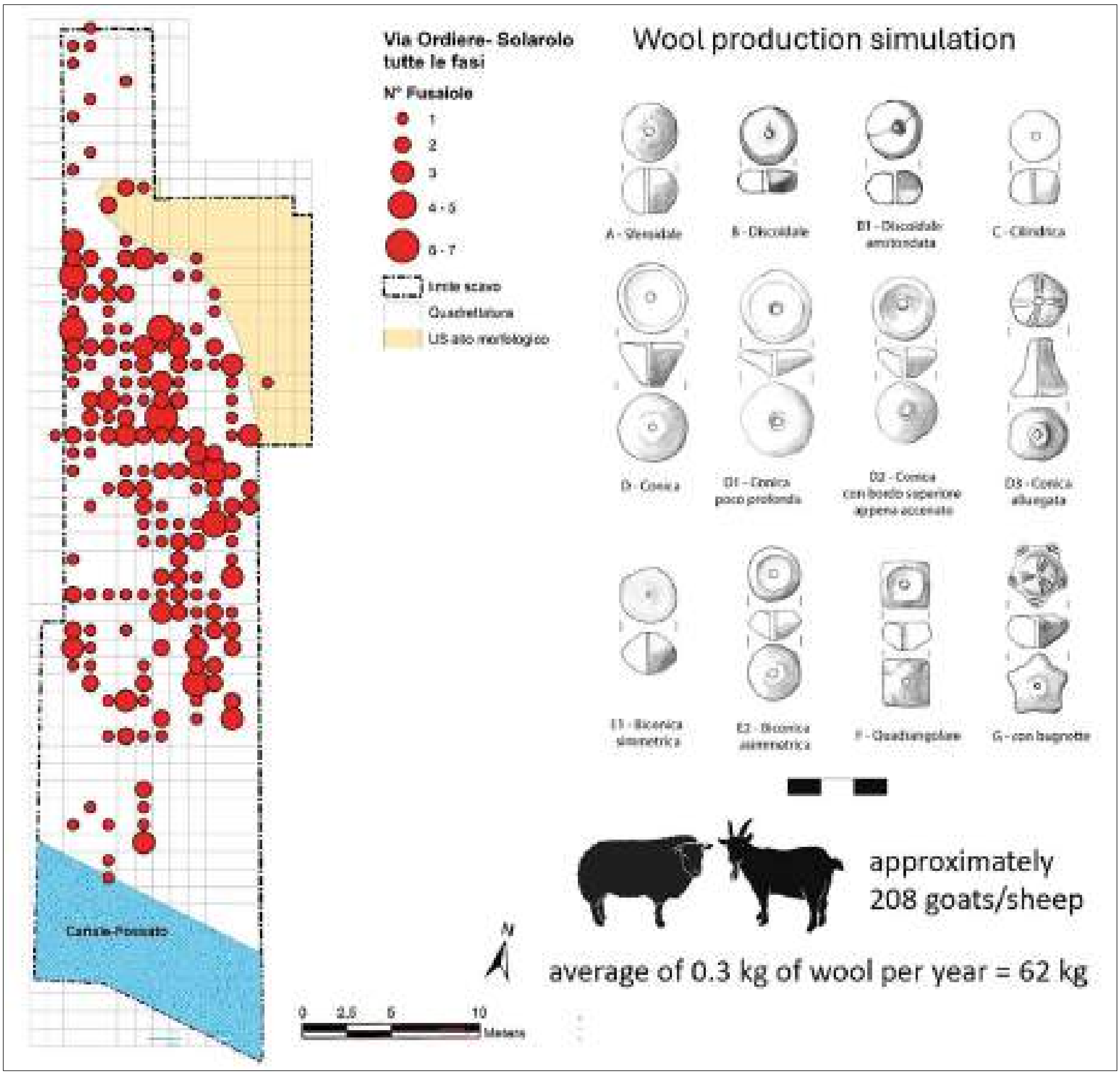


Fig. 6 – Solarolo, Via Ordiere. Spindle whorl distribution and types for the estimation of wool production (after Cattani, Debandi, Zannoni 2023).

*A – Solarolo, Via Ordiere. Distribuzione e tipologie dei fusi per la stima della produzione di lana (after Cattani, Debandi, Zannoni 2023).*

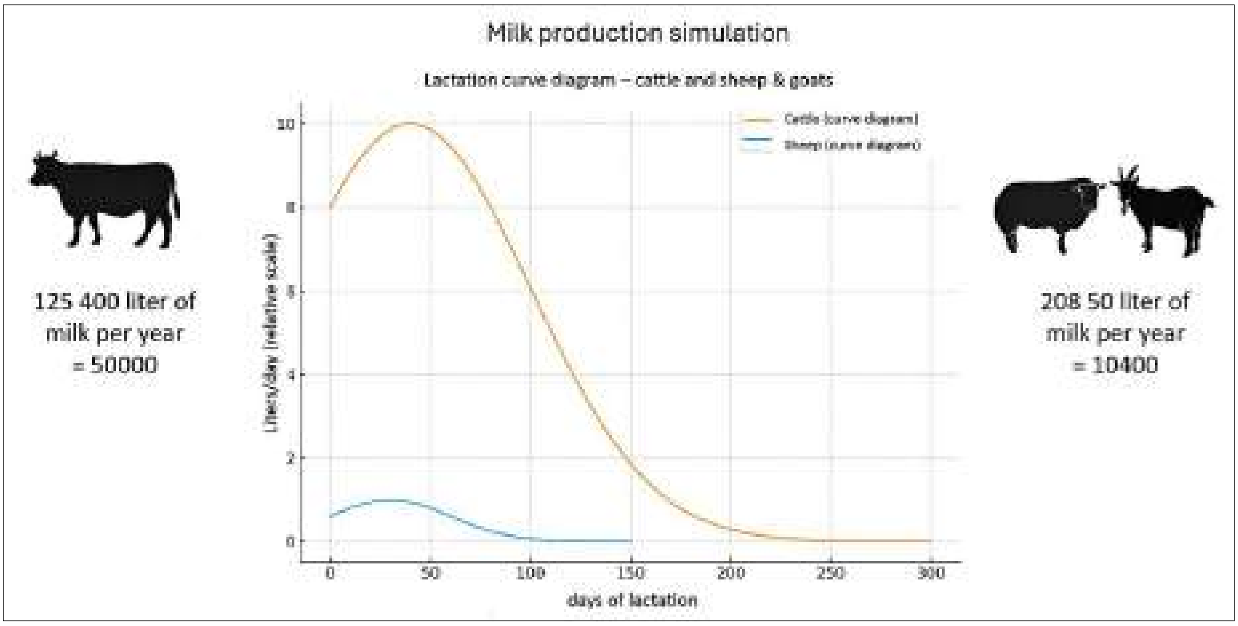


Fig. 7 – Seasonality and estimation of milk production.
*Stagionalità e stima della produzione del latte.*

exchange with other communities. In this perspective, wool production represents a key link between animal husbandry, domestic labour, and broader economic and social strategies during the Bronze Age.

In conclusion, the association between spindle whorls, sheep husbandry, and wool production at Solarolo highlights a tightly integrated economic system. The archaeological evidence indicates that wool was a deliberately managed resource, produced in quantities sufficient to support sustained textile manufacture and to play a significant role in the economic life of Bronze Age communities.

From the estimated number of sheep and goats in the flock, assuming an average wool yield of 0.3 kg per animal, an annual production of approximately 62 kg of wool can be calculated. At this stage, the simulation of textile production cannot proceed further due to insufficient data; however, this will constitute one of the next experimental steps, aimed at estimating the potential quantity of textiles produced.

Nevertheless, the scale of textile production was likely significant, as suggested by the number of spindle whorls recovered. When projected over a 25-year period (one generation), the data suggest the presence of more than 1,000 spindle whorls across the entire settlement. This figure should be considered conservative, as it does not account for possible wooden spindle whorls, which would not have been preserved archaeologically (fig. 6).

## 9. MEAT YIELD AND OTHER ANIMAL PRODUCTS

Returning to the zooarchaeological analysis, an estimate was made of the potential meat yield from the livestock raised. Given the high number of slaughtered animals derived from the MNI, a substantial availability of meat can be inferred, possibly including processes of preservation or exchange, which are not currently supported by direct archaeological evidence. By calculating the hypothetical individual protein requirement (calculated at approximately 55 g of protein per day)[4] and comparing it with the availability provided by animal husbandry, it is possible to suggest the sustainability of at least 324 inhabitants within a settlement of approximately 1 hectare.

[4] For an average-sized adult man, the minimum protein requirement is estimated to an average of approximately 63 g of protein per day, while for women, to approximately 54 g (source: National Research Council, Recommended Dietary Allowances).

This result broadly corresponds with the estimated carrying capacity based on cereal production, calculated at 307 inhabitants (Debandi and Maini 2021: 117).

The simulation of milk yield required the identification of parameters appropriate to the Bronze Age, a challenging task due to the numerous variables involved in the exploitation of this resource. Regardless of the specific values adopted for the period, the estimated milk production appears exceptionally high (fig. 7). The deliberate choice by the Solarolo community to maintain substantial flocks of sheep and goats, along with a significant number of cattle, necessarily raises questions regarding how milk was consumed or preserved. This consideration prompted the decision to experimentally investigate milk preservation and processing practices.

## 10. EXPERIMENTAL ARCHAEOLOGY OF THE MILK PRODUCTION CYCLE AND ITS DERIVATIVES CON EXPERIMENTAL ARCHAEOLOGY OF THE MILK CYCLE AND DAIRY PRODUCTS

Within a broader effort to understand food preparation and consumption practices, an experimental project was undertaken to analyse and test the presumed functions of ceramic vessels, in comparison with organic residue analyses using available techniques (gas chromatography and mass spectrometry, GC/MS). The ultimate aim is to create a reference dataset containing indicators corresponding to different food products.

Selected vessels were replicated using clays comparable to those identified at the Solarolo site and were employed in the preparation of various foodstuffs. Samples were subsequently taken for gas chromatographic analysis.

Milk was also included in the experimental programme through two parallel approaches. First, certain vessel types were tested to assess the plausibility of their presumed functions, such as internally flanged vessels and so-called “boilers” with perforated cones. Second, cheese production was replicated using different types of rennet (animal and vegetal) in order to investigate coagulation processes, with particular attention to plant species documented in the archaeobotanical record.

These experiments are based on several underlying assumptions:

- Zooarchaeological data indicate a numerically significant livestock population, suggesting not only meat production but also abundant milk production, likely generating surplus.
- Increased attention to milk consumption – particularly through more digestible processed dairy products – may contribute to understanding the prevalence of lactase persistence within Bronze Age populations.
- The presence of specific ceramic artefacts, such as boiling vessels interpreted as milk boilers, perforated vessels (strainers) possibly used in ricotta or cheese production, and wooden implements such as multi-pronged radial churners potentially associated with butter production.

These artefacts were replicated and tested to evaluate their functional suitability (fig. 8).

Preliminary results from residue analyses conducted on material from the Solarolo excavation confirm the presence of ruminant fats, as well as porcine adipose fats, in some cases occurring together. One sample also revealed the presence of succinic and malic acids, indicating the fermentation of beverages; however, the absence of tartaric acid suggests that these were not wine-based fermentations.

## 11. SIMULATION OF RESOURCE MANAGEMENT IN THE BRONZE AGE

Archaeological simulation of settlement systems is a process of integration between material data, bio-ecological parameters, and mathematical formalisation aimed at reconstructing the socio-ecological sustainability conditions of a settlement system. It operates through deterministic models (carrying capacity), spatial models (catchment/GIS), energetic models, and dynamic models (Agent-Based Modeling). Its value is not predictive but heuristic and comparative: it enables the exploration of the quantitative plausibility of the observed settlement configurations[5].

[5] These models apply formulas that often do not take into account numerous variables (the configuration of the ancient


Fig. 8 – A – Interpretation of the internal strip vase with the perforated vase above, from the Montagna di Cetona site (Puglisi 1959: fig. 8); B – Experimental archaeology at Solarolo with boiling activities for milk pasteurization.

*A – Interpretazione dei vasi a listello e dei colini nell'abitato di Cetona (Puglisi 1959: fig. 8); B – Archeologia sperimentale condotta a Solarolo dedicata alla bollitura del latte per la pastorizzazione.*

The territorial simulation proposed in Debandi's study represents a methodological attempt to move beyond qualitative interpretations of Bronze Age subsistence and to quantitatively assess the relationship between resources, population, and landscape management (Debandi 2021: 218-223). Rather than aiming to produce definitive demographic figures, the simulation is conceived as a heuristic tool to identify variables, constraints, and thresholds that governed the sustainability of Bronze Age economic systems and the necessary changes over time.

The simulation is based on the concept of carrying capacity, defined as the ability of a given territory to support a population through the production of food resources. This approach starts from the productive potential of the landscape rather than from settlement size alone, integrating agricultural and pastoral outputs with spatial organization and land-use strategies.

A key assumption of the model is that Bronze Age communities operated within a clearly structured territorial framework. Each settlement controlled a defined exploitation area, articulated into zones with different functions: cultivated fields, pastures, woodland, water resources, and settlement space. This territorial partition was dynamic rather than fixed, allowing seasonal shifts in land use, crop rotation, and alternation between cultivation and fallow.

landscape, symbolic or ritual constraints, and the presence of minor settlement attractors) but are nevertheless considered highly useful for the hypothetical assessment of resource exploitation.

The simulation integrates several parameters derived from archaeological, archaeobotanical, and experimental data. For agriculture, these include cereal productivity estimates, based on conservative yield values compatible with Bronze Age technologies, and the proportion of cultivated land relative to the total territory. Cereals are assumed to provide the majority of caloric intake (approximately 70-75%), making their productivity the primary driver of demographic sustainability.

Animal husbandry is incorporated as a complementary system. Livestock contributes not only to dietary protein but also to agricultural productivity through manure fertilization and traction. The simulation accounts for pasture availability, fodder requirements, and the spatial relationship between grazing areas and cultivated fields. This integration reflects the strong interdependence between agriculture and animal management emphasized throughout the study.

The model also considers storage and accumulation. The presence of granaries, pits, and large containers is interpreted as evidence for planned surplus management (Darmangeat 2020). In the simulation, surplus acts as a buffer that mitigates annual variability in production, allowing communities to withstand poor harvests without immediate demographic collapse. However, the model highlights that surplus accumulation also requires increased labour investment and careful coordination.

Two chronological scenarios are explored: the Middle Bronze Age and the Recent Bronze Age. In the Middle Bronze Age simulation, territories appear capable of sustaining moderate population growth while maintaining ecological balance. In contrast, simulations for the Recent Bronze Age show a marked intensification of land use, with expanded cultivated areas and reduced woodland. While this intensification supports higher population densities, it also reduces system resilience.

The territorial simulation thus reveals a critical tension inherent in Bronze Age economies. Increased productivity and surplus generation enable demographic expansion and social complexity, but they simultaneously narrow the margin for environmental and social error. Small disruptions, as climatic instability, soil degradation, or social conflict, can rapidly compromise the system.

Importantly, the simulation underscores that Bronze Age resource management was not opportunistic but highly planned. Decisions regarding land allocation, crop selection, herd management, and storage reflect a collective knowledge of environmental limits and economic priorities. At the same time, the model demonstrates that the long-term sustainability of these systems depended on continuous adaptation.

## 12. FOOD SURPLUS AND SOCIAL DYNAMICS: THE CASE STUDY OF SOLAROLO

The Bronze Age settlement of Solarolo (RA), offers a particularly clear case study for understanding how food surplus was produced, managed, and embedded within broader social and economic systems. Archaeological, archaeobotanical, and zooarchaeological evidence indicates that Solarolo was not merely a subsistence-based community, but one capable of generating and sustaining surplus over time, in line with the evidence of processes of expansion and settlement saturation within the territory.

Agricultural production at Solarolo was strongly oriented toward cereal cultivation, which constituted the nutritional backbone of the community. Archaeobotanical remains attest the cultivation of several cereal species, including hulled wheats and barley, but also with a significant proportion of millet, reflecting a diversified strategy aimed at reducing risk of famine and stabilizing yields. Experimental archaeology conducted in comparable environmental conditions suggests that cereal productivity was sufficient not only to meet daily caloric requirements but also to allow the accumulation of reserves. This is further supported by the presence of storage features, such as granaries and large containers, which indicate planned conservation of agricultural produce beyond immediate consumption, especially for the provision necessary for sowing in two or more subsequent years, counteracting any periods of famine.

Animal husbandry at Solarolo played a complementary and reinforcing role in surplus generation. Zooarchaeological data document the presence of cattle, sheep/goats, and pigs, managed according to strategies that balanced meat consumption with the exploitation of secondary products. Livestock contributed to surplus not only through meat and dairy production, but also indirectly through manure used to maintain soil fertility and traction animals employed in agricultural labour. This integrated agropastoral system enhanced overall productivity and resilience, allowing the community to intensify food production without exhausting local resources in the short term.

The existence of a food surplus at Solarolo had significant social implications. Firstly, it supported demographic stability and growth, as suggested by the long duration of the settlement and the density of domestic structures. Secondly, surplus enabled the organization of labour beyond immediate subsistence needs. Activities such as textile production, and large-scale works for the exploitation of land (drainage systems and grazing management) required time and energy that could only be sustained if basic food needs were securely met. In this sense, surplus food acted as a prerequisite for craft specialization and economic diversification.

Surplus also played a central role in social organization and power relations. Control over production, storage, and redistribution of food resources likely contributed to the emergence of internal hierarchies. While Solarolo does not show clear evidence of rigid social stratification, the coordinated management of agricultural and animal resources inevitably in mutual agreement with the neighbouring communities, implies decision-making structures capable of regulating access to surplus. Food may also have been used in communal practices such as collective meals or feasting, reinforcing social cohesion and shared identity.

In conclusion, the territorial simulation provides a structured framework for understanding how Bronze Age communities balanced population growth, surplus production, and landscape exploitation. Rather than offering fixed answers, it identifies the mechanisms through which economic strategies could succeed, or fail, over time, highlighting the fragile equilibrium at the core of Bronze Age territorial organization.

The Solarolo case highlights the ambivalent nature of surplus-based systems. While surplus underpinned prosperity and stability, it also increased dependence on intensive land use and careful resource management. It is widely known that the broader regional patterns observed at the end of the Bronze Age indicate that surplus-oriented systems became vulnerable when environmental stress or social tensions disrupted this balance (Cardarelli 2010, 2018).

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# INDICE

## II. CASE STUDIES INCLUDED IN THE HERDS PROJECT

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per conto dell'Istituto Italiano di Preistoria e Protostoria