

Investigating raw materials and clay recipes for Bronze Age ceramic production on the Eastern Adriatic coast: multi-analytical approach

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Introduction

The selection of raw materials in ancient pottery is shaped by local geology, technological and cultural factors, making their characterization essential for understanding ancient production techniques. Despite its significance, this topic remains underexplored in Croatia, particularly concerning prehistoric pottery from the eastern Adriatic coast. This research addresses that gap by focusing on Bronze Age ceramics (2400–1000 BC) from 14 archaeological sites (155 samples) distributed along the eastern Adriatic coast and its hinterland. To trace the origins of the pottery materials, raw clay collected near prehistoric sites was also analysed for comparative purposes. This study employs a multi-analytical research approach to address issues related to ceramic production, aiming to enhance understanding of interaction, trade, and exchange, with pottery as a key mediator of cultural and social dynamics in the prehistoric eastern Adriatic coast (Kudelić et al. 2023).

Methods

- Optical microscopy (OM) is used to determine the characteristic of the raw materials (clay and tempers) and pottery production techniques.
- Portable X-ray fluorescence (p-XRF) and geochemical analyses (ICP-ES and ICP-MS) are applied on ceramics and raw clay to investigate the origin of raw materials in ancient pottery production.
- Scanning electron microscopy with energy dispersive X-ray spectroscopy (SEM-EDS) is used to analyse geochemical variations in grog-tempered pottery.
- Clay raw material sampling was conducted near the archaeological sites of Old Rakalj and Šiljar in Istria, as well as Biranj and Znojilo in central Dalmatia.

Results

The study results reveal a preference for clay with a high proportion of naturally occurring inclusions (sandy clay), across all case studies. This clay, common along the Eastern Adriatic coast, mainly consists of crystalloclasts such as quartz, mica, and feldspar, offering moderate plasticity and low levels of swelling minerals like smectite, making it ideal for pottery. In contrast, inclusion-poor clays, with higher concentrations of swelling clay minerals and greater plasticity, were used less frequently, mostly during the EBA. A third type of clay identified, enriched with clay coatings (pellet-rich clay), is typical of terra rossa soils, the dominant soil type in Istria (Durn et al. 2023). Rarely, non-local practices were noted, such as the presence of foraminiferal tests in three ceramic samples from Istria, indicating the use of marls that outcrop approximately 20 km north of the settlement (Čosović et al. 2004).

Research aims

- to identify characteristics of paste recipes, including the type and proportion of non-plastic tempers deliberately added to the clay,
- to identify the origin of the raw materials used in pottery production,
- provide insights into the production techniques and firing conditions of the ceramics.

Materials

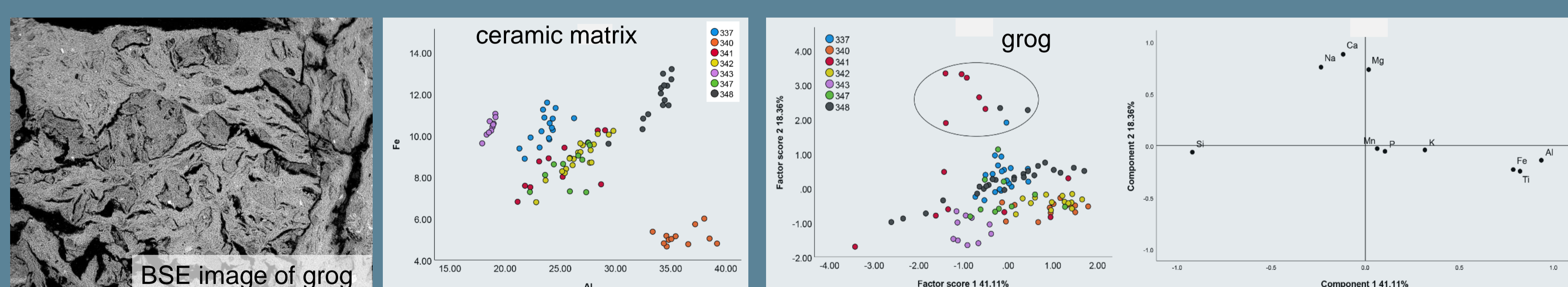
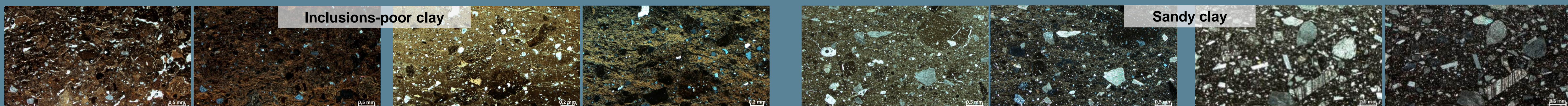
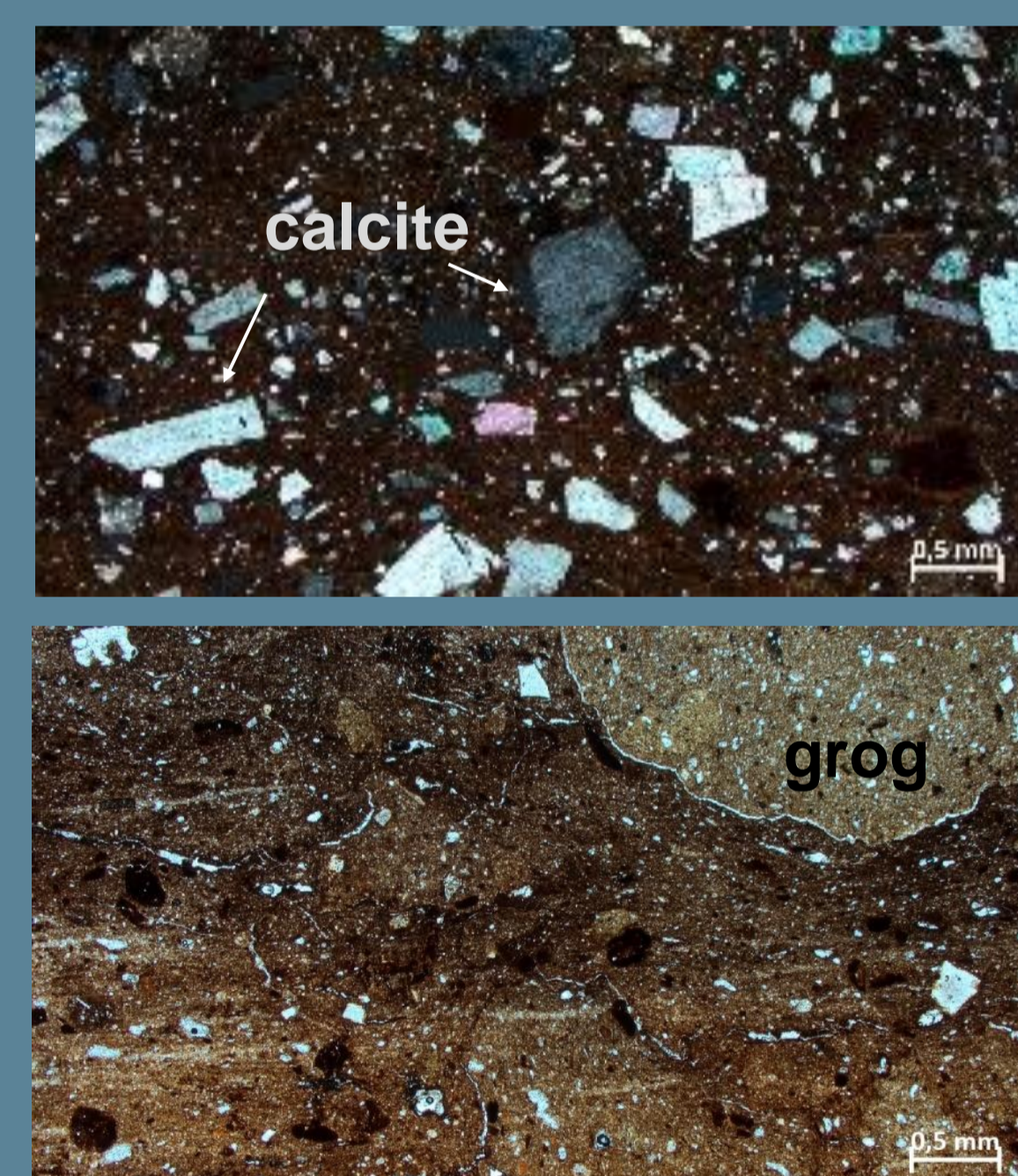
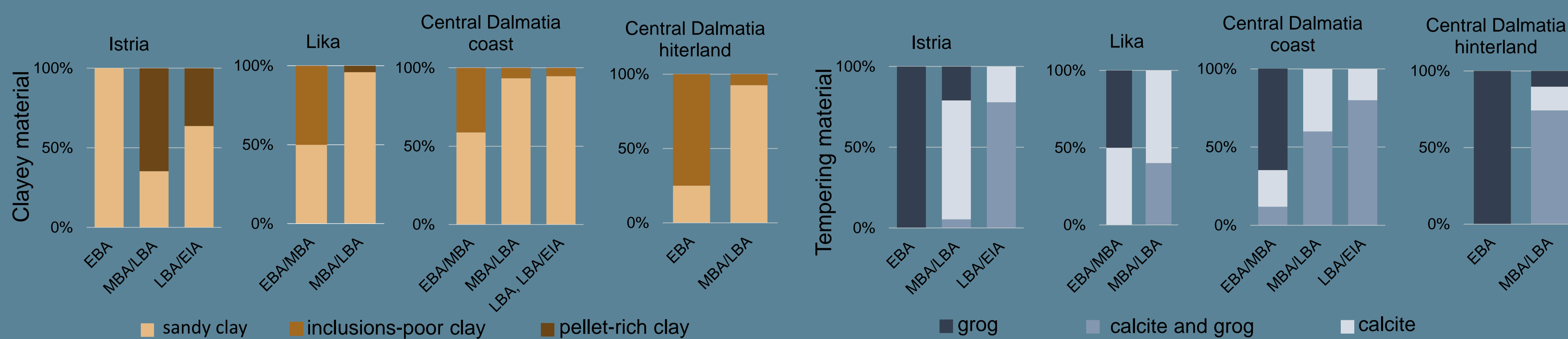
Case study regions	Archaeological sites	Number of samples
Istria	1 Old Rakalj, Šiljar	30
Lika	2 Lower Cerovac cave	27
Central Dalmatia coast	3 Trogir, Bristivica Šupljak, Vinišće Oriovišćak, Marina Drid, Sutilla, Plano-Kraljeva ograda, Biranj	51
Central Dalmatia hinterland	4 Dugiš-Otok near Sinj, Gala-Gacko, Otišić Vlaka, Znojilo	47



All analysed ceramics were tempered with non-plastic inclusions such as calcite, occasionally limestone, and grog. These tempering materials were incorporated in different recipes, and research has demonstrated that certain recipes are distinctive to specific phases of the Bronze Age (see the graph below).

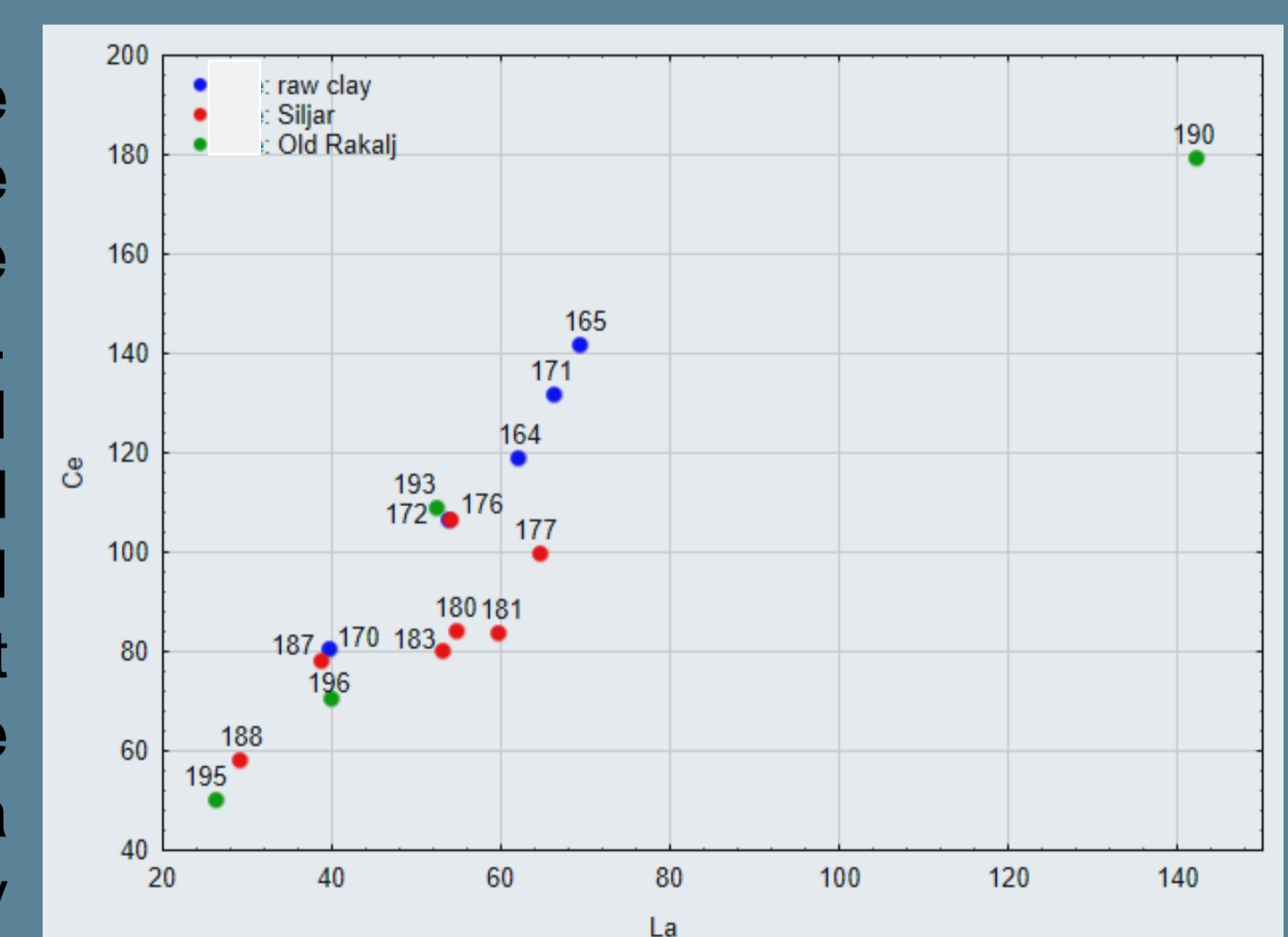
Given the medium to high optical activity observed in the ceramic matrix and the presence of calcite, which decomposes at temperatures between 700°C and 800°C, it is inferred that the firing temperatures for most ceramics did not exceed 800°C (Cultrone et al. 2001). This suggests a relatively low firing temperature characteristic of the technological practices in these regions during the Bronze Age.

Types of clay and tempers in ceramics from Eastern Adriatic coast (EBA – Early Bronze Age, MBA: Middle Bronze Age; LBA: Late Bronze Age; EIA: Early Iron Age)



Geochemical analysis of the ceramic matrix from the Biranj site, conducted using SEM-EDS, reveals the presence of at least two distinct clayey raw materials among the analyzed ceramics. Principal component analysis (PCA) conducted on grog and ceramic matrix measurements reveals notable variation in the grog grains strongly suggesting that the pottery likely contains **grog** from **different origins** compared to the base clay.

Certain geochemical ratios of trace and rare earth elements (REEs) are employed to investigate the provenance of clayey raw materials. The strong correlation in elemental ratios, such as La/Ce, Sm/Nd, and Ti/Al, between ceramic samples and terra rossa deposits in Istria (Durn et al. 2023), indicates that Bronze Age potters extensively utilized terra rossa soils as a raw material for pottery production.



Conclusion

This research represents the first comprehensive study of prehistoric pottery raw materials along the eastern Adriatic coast. The findings indicate that Bronze Age potters primarily utilized locally sourced clay from areas close to the production sites, a practice that prevails across all case studies. However, several ceramic vessels from Istria were likely acquired from a broader region, approximately 20 km from the sites, suggesting the presence of exchange networks among Bronze Age communities throughout the wider Istrian peninsula.

Potters utilized two main types of temper: naturally occurring calcite and anthropogenic grog. Grog, made from recycled ceramic fragments, was predominant in the Early Bronze Age. During the Middle Bronze Age, and occasionally in the Late Bronze Age, potters used both tempering materials; however, the use of grog was abandoned toward the end of the Late Bronze Age, with calcite becoming the dominant temper, marking a significant shift in pottery practices. This transition aligns with broader social changes during the onset of the Iron Age along the eastern Adriatic coast. This research suggests that these changes in calcite usage occurred earliest in the hinterland of Dalmatia and later in the northern Adriatic region, particularly the Istria peninsula.

Literature: Cultrone, G., Rodríguez Navarro, C., Sebastián, E., Cazalla, O., De La Torre, M.J. 2001. Carbonate and silicate phase reactions during ceramic firing. *European Journal of Mineralogy* 13, 621–634; Čosović V., Drobne, K., Moro, A. 2004. Paleoenvironmental model for Eocene foraminiferal limestones of the Adriatic carbonate platform (Istrian Peninsula). *Facies*, 50, 61–75; Durn, G., Perković, I., Razum, I., Ottner, F., Škapin, S., Faivre, S., Beloša, L., Vlahović, I., Rubinić, V. 2023. A tropical soil (Lixisol) identified in the northernmost part of the Mediterranean (Istria, Croatia). *Catena*, 228, 107144; Kudelić, A. Neral, N., Paraman, L. 2023. Archaeometry of Bronze Age Ceramics from the Area of Trogir. *Vjesnik arheološkog muzeja u Zagrebu* vol. 56/2, 99-129.