Journal of Archaeological Method and Theory (2025) 32:36
https://doi.org/10.1007/s10816-025-09702-y

RESEARCH

Bronze Age Frontiers and Pottery Circulation: Political and Economic Relations at the Northern Fringes of El Argar, Southeast Iberia, ca. 2200–1550 BCE

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Accepted: 10 February 2025

Abstract
This paper explores the nature and dynamics of economic and political borders emerging in Later Prehistory between highly centralised and exploitative societies and their much more dispersed and small-scale neighbours. While increasing evidence indicates that Early Bronze Age entities such as El Argar, Únětice or Minoan Crete reached highly complex economic and political forms around 1850–1750 BCE, the processes by which their relations and borders with adjacent, less hierarchical groups were established and maintained still remain poorly understood. To identify such economic and political borders and asymmetric interactions in archaeology, a specific methodological approach was developed which combined extensive field survey, pottery petrography, and spatial modelling of pottery production and circulation areas. Our research focuses on the middle and upper Segura River valley, a largely unexplored borderland between distinct geographic and cultural zones of the Iberian Peninsula. While El Argar expanded over the semi-arid Southeast, adjacent regions—La Mancha and the Spanish Levant—were home to smaller-scale socio-economic entities, known as La Mancha or Las Motillas and the Valencian Bronze Age cultures. At the junction of these three groups, we surveyed 61 settlements across 4800 km^2 and analyzed 1643 pottery sherds, conducting the largest petrographic study of Iberian Bronze Age ceramics. Spatial modeling of the results traced pottery production and circulation, offering insights into economic exchanges, social boundaries and the articulation of borderland spaces. By mapping distinct pottery-making practices, we reveal interactions between El Argar's core regions and its neighbours, demonstrating the potential of ceramic analysis for understanding Bronze Age border dynamics. Comparable studies in other regions are expected to lead to a better understanding of the role of borders in shaping prehistoric societies and inter-group relations.

Keywords Early Bronze Age · El Argar · Political Borders · Pottery Analysis · GIS

Extended author information available on the last page of the article

Published online: 16 March 2025

Introduction

Throughout much of the twentieth century, the European Bronze Age was perceived as following a distinct historical trajectory compared to that of the Near East, Anatolia, or Egypt (Childe, 1930). In recent decades, however, detailed analyses of funerary evidence and, especially, the productive forces developed by certain European societies have called this model into question. The Early Bronze Age (EBA) in Europe, roughly 2200–1550 BCE, has become a focal point for debates surrounding the political structures and socioeconomic organisation of several so-called "hot societies" (Vandkilde, 2014). In a striking and as-yet unexplained synchrony, around 1850–1750 BCE, certain societies—most notably El Argar in southeastern Iberia, the Únětice group in Central Europe, and the palatial society of Minoan Crete—reached unprecedented levels of economic and political centralization, developing social asymmetries unparalleled across most of Europe until the Iron Age (Knappett, 2012; Lull *et al.*, 2011; Meller, 2019). As a result, these societies have thus been classified as early, segmented, proto- or micro-states. While each of these definitions has its nuances, all of these entities shared a set of characteristics which distinguish them from the majority of EBA contexts:

- They managed to establish relatively uniform economic and ideological practices across territories spanning several thousand square kilometres, suggesting some form of centralised political control.
- Idiosyncratic architectural and settlement patterns emerged, featuring monumental buildings covering hundreds of square meters.
- Standardised funerary practices sanctioned substantial investments of wealth into a limited number of graves.
- A complex, supra-domestic economic organisation developed, which relied on the circulation of agricultural products—chiefly cereals—and raw materials, particularly metals.

After several centuries of notable economic development, these societies experienced a sudden economic and political collapse, evidenced by destruction layers, settlement abandonment, abrupt cessation of funerary practices, and interruption of trade networks. Given their shared political, economic, and social traits and common historical trajectory, these societies may be qualified as "disruptive". In an archaeological context, disruptive societies can be defined as highly innovative and dynamic entities that achieved rapid economic and demographic growth over a relatively brief period, followed by a sudden collapse which led to the emergence of markedly different archaeological groups (Peres & Risch, 2023, 15; Moreno Gil *et al.*, 2023, 103). Due to their "spectacularity", EBA disruptive societies have attracted most archaeological attention, often to the detriment of research on the communities neighbouring these groups and the relationships between these entities, which remain poorly understood (Moreno Gil, in press; Moreno Gil *et al.*, 2023).

Within the broader context of the European EBA, the development and consolidation of territorial control strategies is a crucial issue, as the productive forces

fostered by disruptive societies led to exceptional surplus production in certain regions over others (Risch, 2002; Risch *et al.*, 2021; Schoep *et al.*, 2012). This, in turn, necessitated large quantities of raw materials, goods, and workforce, which were likely sourced from territories beyond those directly controlled by disruptive societies. The movement of goods and people was critical to the economic stability of these complex societies, yet it required access to or control over the territories of "others". Research into early state formation and pronounced archaeological distinctions between neighbouring entities inevitably brings into focus the complex issue of borders. Borders, after all, epitomize the assertion of human territoriality.

Borders are fundamental in modern conceptions of the world, limiting the movement and communication of people and the flow of wealth. They are intrinsic to any state, as they establish the bounds within which a state claims sovereignty, including the authority to regulate entry and exit. Consequently, any effort to understand the rise and consolidation of early states must consider how political borders were created and maintained. In prehistoric archaeology, however, borders have received relatively limited attention, despite the fact that one of its key structuring concepts—"archaeological cultures"—presupposes spatial limits between social, economic, or political entities. For over a century, archaeologists have classified settlements, burials, and hoards by assigning them to distinct cultures. However, much less attention has been paid to the specific characteristics of frontier regions, or areas where such classifications become blurry. Borderlands have not typically been studied in their own right but have instead been viewed in relation to "cultural cores". Consequently, the social, political, and economic interactions between neighbouring societies across frontier regions are largely neglected (Van Valkenburgh & Osborne, 2012). This scientific praxis is paradoxical, as archaeology is inherently a spatial discipline, where all materiality is referenced to and in a physical space (Souvatzi, 2012). Indeed, artefacts without context, such as those circulating in the (illegal) antiquities market, are practically meaningless to archaeology.

To approach borders in prehistory,[1] nevertheless, it is essential to disentangle them from the specific "cartographic" structure they adopt in the modern world, that is, the "Westphalian Order". This label describes the political order that emerged after the signature of the Westphalian peace in 1648, in which nation states emerged as clearly demarcated territorial entities separated by line-like borders (Biersteker & Weber, 1996; Biggs, 1999; Agnew, 2009). This "fostered a world view in which discrete, quasi-independent territorial units were seen as the principal building blocks for social and political life" (Murphy, 1996, 82). Such a conceptualization has led to a dehistoricization and decontextualization of the processes of state and border formation, the so-called *territorial trap* (Agnew, 1994, 59), where borders are perceived as fixed entities, creating the illusion that states and their boundaries predate

[1] Borders are a much more prevalent research topics for archaeologists dealing with other time periods. In the case of Roman archaeology, for example, the study of the *limes* has garnered a lot of scholar attention, nonetheless a lot of them rely heavily on textual evidence. Lately, however, borders have also been focused on in Aegean Bronze Age archaeology (Wijngaarden & van Driessen, 2022).

and encompass society, rather than representing the contingent result of historical processes. In reality, borders are constructed and sustained through specific sets of socio-political, economic, and symbolic practices, the so-called bordering practices (Paasi, 1998; Connor, 2021).

In consequence, when approaching borders, it is important to consider that both history and archaeology have provided a plethora of examples of alternative territorial strategies and conceptualizations of state space, from the fiefdom structure of medieval Europe (Murphy, 1996, 84), to the articulation in "vertical archipelagos" of the pre-Hispanic Andes (Murra, 1975), or the territorial fluidity of precolonial African states (MacEachern, 2015). Consequently, in studying a prehistoric borderland, we should be aware of the likelihood that prehistoric bordering practices diverged significantly from those experienced and discussed in present times.

Research Challenge

Recognising this research gap, the present study is part of a broader and ongoing effort to elucidate the relationships between one of these disruptive societies, El Argar, in southeastern Iberia, and its surrounding EBA communities, which notably lack the five socio-economic characteristics outlined above. A defining feature of El Argar is its rapid territorial expansion, from a core area of approximately 5000 km^2 around 2200 cal. BCE to a region covering around 35,000 km^2 by 1750 cal. BCE (Fig. 1). Archaeologically, El Argar is distinguished by highly characteristic funerary practices, with individual or double burials often placed within settlements (Lull & Estévez, 1986). Some of these burials included lavish grave offerings with emblematic objects associated with political power, such as silver diadems, alongside specialised weapons like halberds or swords, exclusively found in male graves (Lull *et al.*, 2017, 2021).

Another central element of El Argar's development is the spread of metallurgy. The frequency of metal artefacts in this society vastly exceeds that of the preceding Copper Age and that of neighbouring EBA groups. Production was highly centralised and sustained at a supra-regional level (Lull *et al.*, 2010; Peres *et al.*, 2024). Most El Argar ores originated from a relatively small area under Argaric control within the Linares-La Carolina mining district in Sierra Morena, situated far from the society's core settlement area. Here alone has the complete metallurgical *chaîne opératoire* been documented (Moreno Onorato & Contreras Cortés, 2010), and excavations of EBA copper mines have been conducted (Arboledas Martínez & Alarcón García, 2018; Arboledas Martínez *et al.*, 2022).

Lastly, the concentration of agricultural produce and the resources needed for its production, along with the presence of specialised workshops in major Argaric settlements located far from regions of high agricultural productivity, indicate a vertically integrated production system. In this system, political centres accumulated and redistributed cereal surpluses (Delgado-Raack & Risch, 2016a, b; Lull & Risch, 1995; Risch, 1995, 2002; Verhagen *et al.*, 1995, 1997).

To the north of El Argar, two distinct cultural groups have been identified in contrasting geographical settings (Fig. 1). In La Meseta, the southern part of the central Iberian plateau, settlements are grouped under the *La Mancha Bronze Age*, also

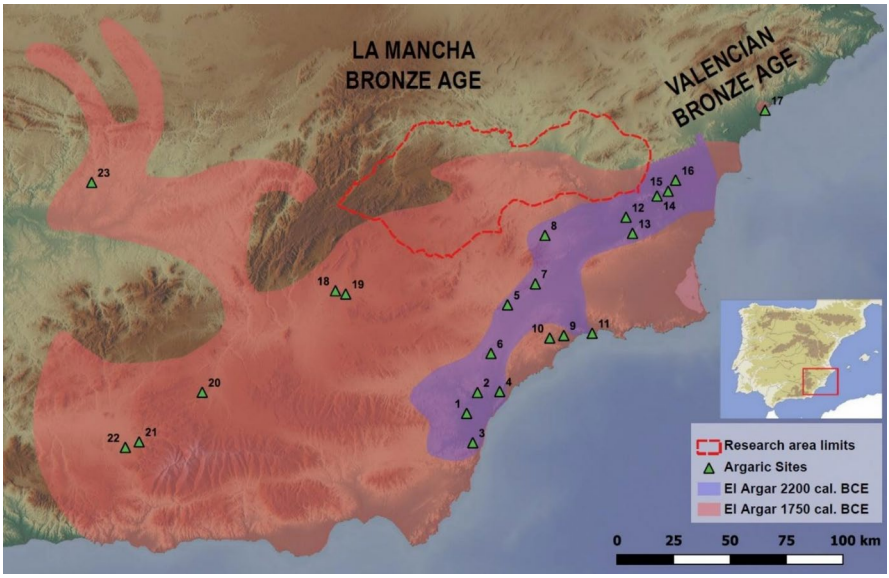

Fig. 1 El Argar core area (purple) and maximum expansion *ca*. 1750 BCE (red), Middle and Upper Segura valley and main Argaric settlements: 1. El Argar, 2. Fuente Álamo, 3. Gatas, 4. El Oficio, 5. La Bastida, 6. Lorca, 7. Tira del Lienzo, 8. La Almoloya, 9. Ifre, 10. Zapata, 11. Punta de los Gavilanes, 12. Monteagudo, 13. Puntarrón Chico, 14. San Antón, 15. Laderas del Castillo, 16. Cabezo Pardo, 17. Illeta dels Banyets, 18. Castellón Alto, 19. Cerro de la Vírgen, 20. Cuesta del Negro, 21. Cerro de la Encina, 22. Cerro de San Cristobal, 23. Peñalosa (maps of El Argar territories are based on Lull *et al.*, 2015**;** Hernández Pérez *et al.*, 2021)

known as the *Las Motillas* culture, characterised by fortified sites or towers situated in the broad plains of present-day Albacete and Ciudad Real (Nájera Colino, 1984; Martínez Navarrete, 1988; Fernández-Miranda *et al*., 1988; Nieto Gallo & Sánchez Meseguer, 1988; Brodsky *et al*. 2013; Sánchez Meseguer & Galán, 2016). In the rugged terrain of the Spanish Levante and the Iberian mountains, marking the eastern limits of the Meseta, numerous small hilltop settlements are attributed to the *Valencian Bronze Age* (Fernández Vega, 1985; Burillo & Picazo, 1997; Jover Maestre, 1999; Jover Maestre & López Padilla 2011; Jover Maestre *et al*., 2018).

While radiocarbon dating confirms the contemporaneity of these three archaeological entities, recent research has highlighted differences in settlement patterns and productive strategies, revealing that the political and economic relationships between El Argar and other EBA groups appear more interconnected and complex than conventionally understood. This complexity becomes evident when studies move beyond highly valued objects—usually of gold, silver and ivory—to focus on materials fundamental to the economic bases of these societies (Moreno Gil *et al.*, 2023; Peres, 2021; Peres & Risch, 2022, 2023). Marked differences in settlement size, scale of production and spatial organisation between El Argar's core areas and other Iberian communities support the existence of distinct political and economic forms of organisation, irrespective of whether they are classified as early states, proto-states, *etc*. Consequently, to examine the relation between El Argar—and

other disruptive EBA societies—and their much less "shiny" neighbours, requires a focus on borderlands and peripheries, traditionally understudied due to the absence of rich burials, large-scale settlements, or significant metal finds.

Alongside systematic excavations and surveys, specific archaeological methods are essential to uncover significant spatial boundaries and contrasts within the material record that reflect past economic, political, and ideological relationships. At this juncture, pottery petrography provides a valuable approach to address the complexities of studying prehistoric borderlands. While archaeological cultures—and consequently their presumed boundaries—have often been defined through typological classifications of pottery and decoration, ceramic raw materials can reveal the connections between specific communities and the natural resources sourced from particular locations. Examining how far clays, rocks, and pottery-making techniques circulated across a territory offers a more reliable means of tracing social mobility, economic interaction, or population circumscription than typological patterns, which could be imitated within pottery production for various reasons.

Another major advantage of this approach is that even small pottery sherds are adequate for characterisation studies of raw materials, whereas more complete vessels are required for typological classification. These sherds are among the most ubiquitous artefacts in EBA archaeology across Europe, and they can be recorded in substantial quantities even in survey projects, where other materials suitable for provenance and technological analysis, such as metal, ivory, or amber, are rarely found. Only macrolithic tools are typically visible on-site surfaces, though they are far less numerous than pottery sherds (Delgado-Raack & Risch, 2016b; Risch, 1995).

This study introduces a novel research methodology to identify and interpret borderlands between economic and political entities,[2] combining petrographic analysis of pottery, archaeological field surveys, and spatial modelling. This research strategy has been specifically developed to improve understanding of social organisation and interaction along the borders of a highly complex and exploitative EBA society such as El Argar and the smaller, more transient and egalitarian communities associated with the *La Mancha* and *Valencian Bronze Ages*. Geographically, these interactions and boundaries are anticipated to have occurred in the Middle and Upper Segura valley, located in the northern part of present-day Murcia and forming a border today with the provinces of Albacete, part of Castilla-La Mancha and Alicante, within the autonomous Community of Valencia (Fig. 1).

This approach enables us to evaluate the extent to which communities associated with different cultural groups interacted and assess the intensity of their relations with El Argar core regions, situated in southern Murcia and northeastern Almería. Finally, by distinguishing pottery production practices and analysing their specific geographic distribution, we gain insights into the articulation and dynamics of a borderland, which had a significant impact on the shaping of the EBA in the Iberian Peninsula.

[2] A similar approach, based on the identification of pottery technical traditions, has been carried out in the Upper Rhône Valley reaching significant results on social interaction and mobility (Derenne *et al*., 2022).

Materials and Methods

Materials

Due to the limited prior research conducted in the Middle and Upper Segura region—an area encompassing approximately 150 km of the 1000-km-long El Argar border (see Figs. 1 and 2)—this study draws on two primary data sources. The first is an extensive archaeological survey conducted as part of a recently completed doctoral project (Moreno Gil, in press). The second is an ongoing research project led by the Autonomous University of Barcelona, which focuses on analysing pottery production at various Argaric sites within the central area. Together with the recent publication of a petrological study on pottery from the site of Cerro Morrón (Garrido García *et al.*, 2023, in press), the work presented here represents the first petrographic study of pottery in this region.

In total, 71 EBA settlements were studied as a part of the archaeological survey of the Middle and Upper Segura, covering an area of 4862.82 km^2. From these, it was possible to gather and study pottery from 61 settlements. The entirety of the archaeological sites were considered as sampling units and the study of pottery was limited to 50 sherds per site. The intention of this procedure was to obtain a significant pottery sample while preserving enough archaeological evidence for future surveys. Only pottery belonging to the Early Bronze Age (*ca*. 2200–1550) was targeted and included in our study. In total, 1643 pottery sherds from the research area were analysed, of which 343 (20.87%) corresponded to diagnostic vessel parts (*i.e.*

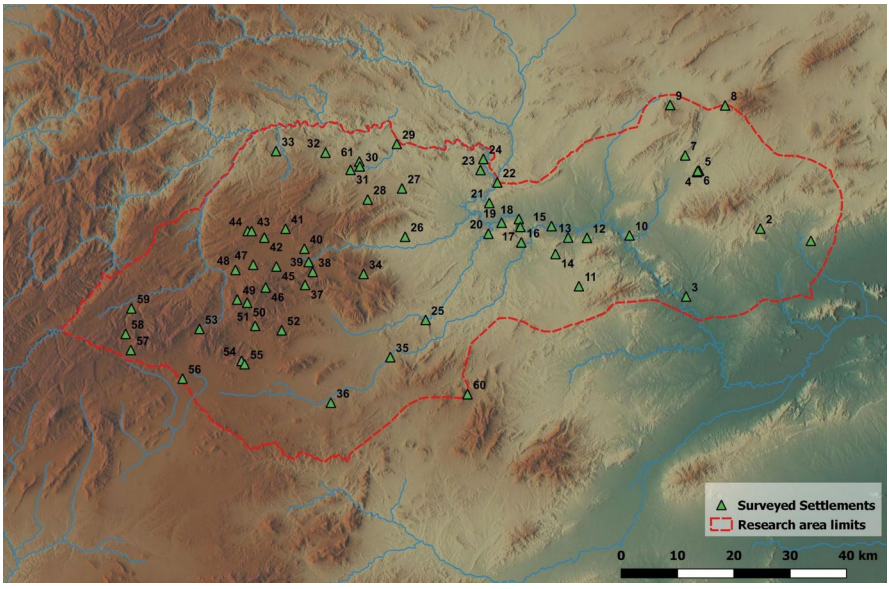

Fig. 2 Map of the research area and all the settlements surveyed (site-numbers can be found in the supplementary material 1)

rim-sherds, carinations, bases, *etc*.). This implies an average of 26.93 sherds and 5.62 diagnostic sherds per settlement.

From a chronological standpoint, it is important to note that due to the unstratified character of the studied pottery, it is not possible to produce a fine-grained chronological reading based on it. To that end, we have to rely on the excavations carried out until now in EBA settlements in the region. These indicate that sites with non-Argaric materials were occupied at least since 2000 cal. BCE. It is also apparent that most of the objects clearly relatable to El Argar can be attributed to the late phases of this group, especially from 1800 cal. BCE onwards. In general, the results of the few published excavations in the Middle and Upper Segura show the coexistence of Argaric and non-Argaric elements in the same stratigraphic levels, which confirms their contemporaneity, particularly between 1800 and 1550 cal. BCE. According to the available chrono-typological criteria and the established absolute chronology of El Argar, La Mancha Bronze Age, and the Valencian Bronze Age excavations where these criteria were established, most of the surveyed and the few excavated settlements seem to have been abandoned during or after the sixteenth century BCE.

Methods

The chosen survey strategy focused on the documentation of settlements rather than other kinds of archaeological sites, as the main goal was to understand the structure of the human occupation of a frontier region. The dimensions of the research area (4862.82 km^2) did not allow for an intensive did not allow for an intensive high-coverage survey, but rather demanded a survey strategy geared towards improving the knowledge on a lot of previously known but very poorly studied and published sites. After a thorough bibliographical and archival review, almost 100 sites were selected to be surveyed. Areas where a lack of previous knowledge was detected were studied more intensively, which led to the discovery of 6 previously unknown EBA settlements. All the sites included in this work correspond to hilltop settlements, with a single exception. This is hardly surprising as this is, by far, the most common settlement type during the EBA in the Iberian southeastern quadrant (Peres & Risch, 2022). Among hilltop settlements we differentiated between flat hilltops or plateau-hills (*cerros amesetados*), artificially terraced conical hills, a combination of the previous two topographies, and micro-sites that were established on top of rocky spurs.

On average, 3 h was spent on the field documenting each settlement, albeit this varied significantly owing to the size and density of archaeological materials. In each of the visited settlements a GPS[3] was used to record the location of any visible archaeological structures and to delimit the perimeter of each settlement based on the density of archaeological materials, topographical features and visible archaeological structures. Non-ceramic archaeological materials, like flaked stone and macro-lithic tools, were documented on the field. The on-site sampling of the

[3] Garmin eTrex e30.

pottery was done following three broad criteria: (1) only handmade pottery with characteristic EBA surface treatments, colour, and texture was selected in order to narrow down our selection to the studied period; (2) pottery was gathered from different sectors within the previously defined site perimeter in order to cover as much of the settlement as possible; (3) whenever possible, the recovery of diagnostic vessel parts (mainly rims) was prioritised.

The petrographic study of the gathered pottery started with the classification of the sherds under stereoscopic microscope (10–60×) based on their identifiable components. In this procedure, the greater the number of individuals analysed and the greater the information content of the groups and taxa of a classification, the better the resulting classification. According to the study of the types and the variety of relationships between them (Sneath & Sokal, 1973), this process of visual classification reveals the brain's ability to detect compositional similarities and differences between complex ceramic patterns. In so doing, it was possible to recognise and differentiate several ceramic groups, based on pattern coincidence of their components and taking into account characteristics such as colour, homogeneity, type of ceramic matrix, texture, the proportion and shape of temper and non-plastic components, and porosity. The presence of carbonates in the pottery matrix was determined by observing under the loupe the reaction of a small quantity of diluted hydrochloric acid on a well cleaned surface of the sherd.

For the next analytical step, a representative sample of the main ceramic groups identified under stereoscopic microscope was selected. Thin-slices with a thickness of 30 µm were produced, so that the optical properties of the minerals could be observed under a petrographic microscope. The identification and description of the main elements identified in the thin-slices was done following the methods of sedimentary petrography detailed by Gómez-Gras (1997) and other authors (Raymond, 2001; Raith *et al*., 2012) and already used in other archaeometric studies of archaeological pottery (Gómez-Gras & Risch, 1999; Risch & Gómez-Gras, 2003; Gómez-Gras *et al*., 2021; Palomar, 2005; Reedy, 2008; Andreu *et al*., 2007; Garrido-García *et al.*, 2021; Garrido García *et al.*, 2023). In doing so, it was possible to identify the rocks and minerals in the pottery and estimate their modal distribution. This analysis also made it possible to determine the way in which the minerals were presented, *i.e.* if they did so individually or as rocks fragments, as well as their lithologies and whether they were part of the matrix or of the coarse size fraction (Delgado-Raack *et al*., 2009). Based on the homogeneity of the lithologies observed, their shape, size, quantity and their relation with the non-plastic fraction and the matrix components, it was possible to identify which elements were a product of intentional mixing by manufacturing processes (*petrofabrics*) or of naturally appearing *petrofacies* with a direct correspondence to a given geological environment (Eramo 2020, 164). These petrologically defined pottery groups constitute the basis of our analysis of pottery production and circulation in the research area.

In a third analytical step, spatial modelling of the identified petrographic groups was performed using GIS software (QGIS). The concrete spatial distribution of each pottery group was represented using the inverse distance weighted (IDW) interpolation tool in QGIS. Unlike heatmaps that rely on point density (*e.g.* Kernel Density),

IDW weighs the sample points using previously specified interpolation values. In our case, the geographical points designating the studied settlements have been weighted using the percentage of a given petrological group found in each of them.

Finally, diagnostic pottery sherds were classified according to their morphology. Given that we are working exclusively with sherds gathered in a surface survey, it has not been possible to develop a typology based on morphometric criteria. Instead, we have sorted the pottery into nine broad shape-groups, based exclusively on morphological criteria (supplementary material 3). Additionally, chrono-typological criteria have been established based on previously published pottery typologies for El Argar (Lull, 1983), La Mancha (Galán, 1994), and the Valencian Bronze Age (Enguix, 1981), as well as more recently published pottery assemblages from well-dated stratigraphic-sequences.

The economic and political dimension of the results of the combined petrographic and spatial analysis can only be reached and evaluated if the geographical and archaeological context of the Middle and Upper Segura is taken into account.

The Middle and Upper Segura: Geographical, Geological and Archaeological Characterization

The research area is structured by the Middle and Upper course of the Segura River, including the meadows of its southern tributaries: the Quípar, Argos and Alhárabe rivers (Fig. 4). The geography of this region, much like the rest of the Iberian Southeast, is quite heterogeneous. Topographically speaking, the research area can be divided into several subregions. The north-western end is characterised by a concatenation of mountain ranges belonging to the Prebaetic and Subbaetic systems,

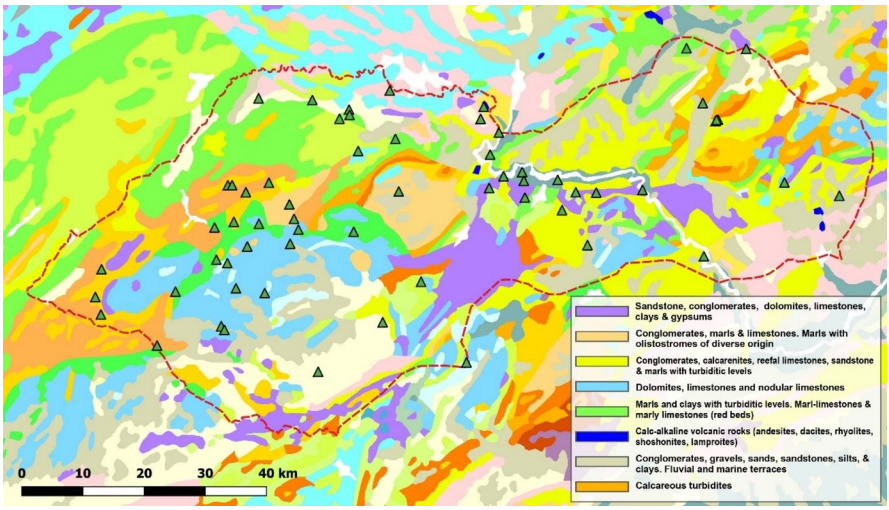

Fig. 3 Geological map of the research (Source: IGME, modified by the author). Full legend available on https://info.igme.es/visor/

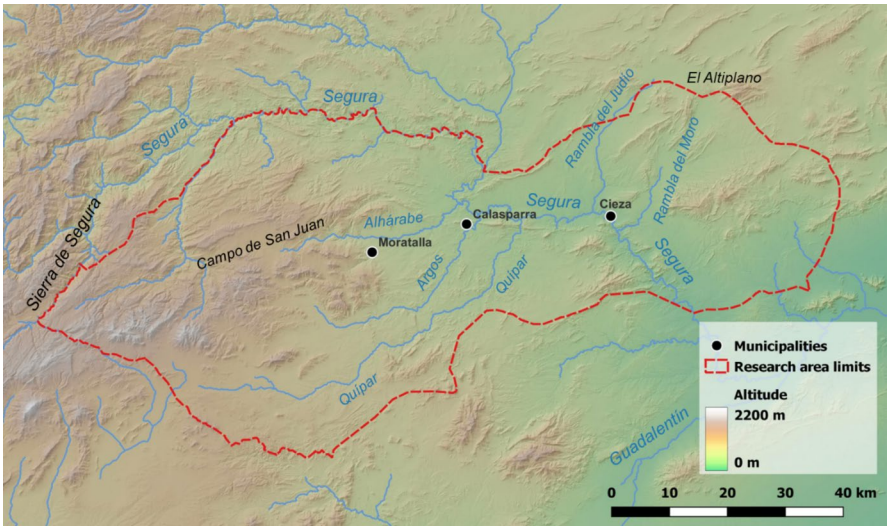

Fig. 4 Physical map of the research area with the present day municipalities and geographical areas mentioned in the text

the most important of them being Sierra de Segura, from which the Segura River originates. Within this rugged landscape, the mountain plateau of Campo de San Juan stands out, as it is one of the few large flatlands within this mountainous area. Further to the east, the landscape gradually loses in altitude, giving way to the middle course of the Segura, characterised by a fertile alluvial valley. This region, nonetheless, is still dissected by minor mountain ranges and includes important chokepoints such as the Ricote Valley. Finally, in the northeastern end of the research area lies El Altipano, an isolated subregion separated from the Segura meadow by two mountain ranges (Sierra de Ascoy and Sierra de La Pila). El Altiplano is linked to the Segura valley exclusively through two natural corridors, Rambla del Moro and Rambla del Judío (Fig. 4).

In geological terms, the study area belongs to the External Zone of the Baetic mountain chain which emerged during the Neogene age and whose most outstanding element is Sierra Nevada in Granada. While the Internal Zone is dominated by a large variety of Paleozoic and older metamorphic rocks, the External belt is basically sedimentary (Arana Castillo *et al*., 2000). Subbaetic and Penibaetic units have been separated based, respectively, on the allochthonous or autochthonous provenance of their materials, formed between the Trias, Jurasic, Cretacic, Eocene, Oligoncene and Lower Miocene. Carbonated rocks, including a notable variety of limestones, dolomite, sandstones, marls and clays, are abundant, while metamorphic and igneous rocks are absent (Fig. 3). Silicified sandstone of Bundsandstein type is characteristic of the Triassic series of the Subbaetic zone. Evaporites, such as gypsum, are also present. Isolated sub-volcanic intrusions and post-orogenic volcanic deposits are present in both areas and provide different meta-basic and magmatic rocks.

Such a clear geological and petrographic distinction between the Internal Baetic mountain ranges of the coastal regions of Southeast Iberia and the Internal formations emerging further north, as well as the different volcanic and sub-volcanic deposits, offers potential criteria to distinguish between petrofacies and petrofabrics, in case rocks were intentionally added. The phyllosilicate clays, including low- to middle-grade metamorphic rock fragments and minerals, such as slate, micaschist and garnet-micaschist, provided the main raw materials of pottery production in the core settlement area of El Argar (Fig. 1) and even became the exclusive sources after c. 1800 cal BCE. Such clays are relatively abundant in certain parts of the coastal mountain ranges of the Internal Baetic range, which runs from Granada in the west to Cabo de Palos in the east, but completely absent in the interior and eastern regions of El Argar or even further north.

In archaeological terms, the Middle and Upper Segura, which still today can be defined as a borderland, has a severe lack of archaeological research dealing with the EBA, with only a handful of archaeological excavations carried out, most of which have only been partially published. Only two systematic archaeological excavations have been undertaken in the region, at the sites of Los Molinicos (Lillo Carpio, 1993) and Cerro de las Víboras (Eiroa García, 1994, 1998, 2010), with neither of their results being fully published. Both were fortified settlements and their size (*ca*. 0.7 and 0.4 ha) suggests that they would have acted as important centres within the research area. In both of them, rich graves following the Argaric ritual were documented, together with non-Argaric common materials, especially pottery. To the aforementioned sites, the recent salvage excavation of the hilltop site of Cerro Morrón carried out by the Universitat Autònoma de Barcelona needs to be added. Despite the small scale of the sondages, it is the most thoroughly published site in the research area (Celdrán Beltrán *et al.*, 2023). Two EBA occupation phases could be documented. The older one, dated *ca*. 2000–1800 cal. BCE, was characterised by the absence of Argaric features and it has been interpreted as a local Bronze Age phase. In the second occupation, *ca*. 1800–1550 cal. BCE, typically Argaric materials as well as rich graves make their appearance, indicating the presence of a very different community coming from the south, as revealed by the large number of grinding tools, copper and silver artefacts, and pottery containing metamorphic rock fragments. Despite that, it is important to note that non-Argaric materials remained a majority until the end of the settlement (Garrido García *et al.*, 2023).

Results

The study of the pottery collected during the archaeological survey of the Middle and Upper Segura valley managed to classify 1388 (84.5%) of the 1643 sherds into 14 specific petrographic groups. The remaining 255 fragments were petrologically highly variable and could not be ascribed to any group. Most of these unclassified ceramics (172 sherds, 67.5%) were manufactured with carbonate clay matrices (marls) containing different natural inclusions, while chamotte appeared occasionally. A comparatively smaller number of pottery with argillaceous or phyllosilicate clay matrices could not be assigned to any of the petrological groups (82 sherds,

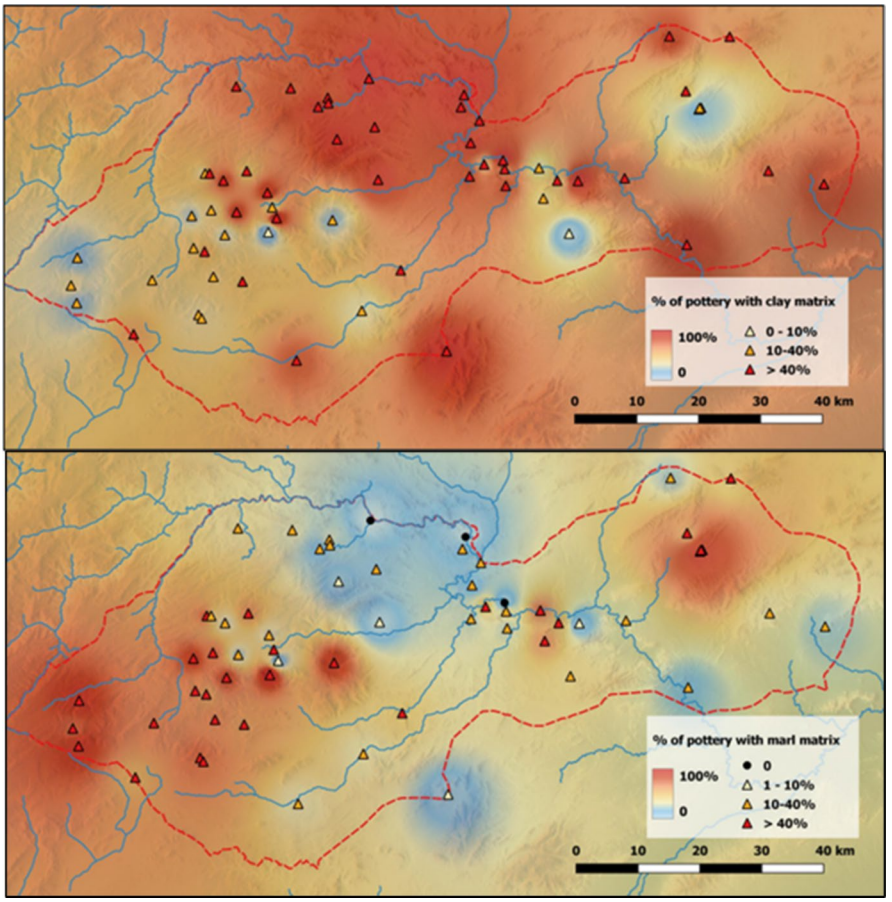

Fig. 5 Heatmap of the distribution of pottery with non-carbonated clayey matrix (top) and carbonated marly matrix (bottom) in the Middle and Upper Segura valley

31%). In other words, while 91% (836 out of 917 sherds) of the non-carbonated clays belong to petrographically distinguishable groups, only 75% (539 out of 723 sherds) of the marls do so,[4] suggesting a greater variability of the pottery manufactures using carbonated raw materials.

Clay Matrices

Before discussing the composition of the 14 identified petrological groups, it is worth looking first into more general aspects, starting with the matrix of the studied pottery. Here, it is crucial to consider the differentiation between carbonated and

[4] $X.^2 = 82.39$ df $= 1$ $p \leq 0.000001$.

non-carbonated pottery, as it has significant implications for the quality of the pottery manufactured, as well as for its provenance.

Our study showed that the analysed sherds were quite evenly split between those with a non-carbonated clay matrix (56.30%) and those with a marly clay matrix (47.30%). Pottery with a non-carbonated matrix was especially abundant in the Upper Segura, the region to the north of Calasparra, and the southern end of the research area. Conversely marls had a significantly higher presence in El Altiplano (northeast) and Campo de San Juan and its surroundings (east) (Fig. 5).

Non-Plastic Components and Temper

Most of the studied pottery sherds contained some sort of mineral, non-plastic components, the most numerous of which were carbonated rocks (calcite, dolomite), mono- and polycrystalline quartz, lutite, hematite, schist, slate, or ophitic rocks. Due to their recurrent appearance, it is also worth mentioning the presence of semi-hydrated clay nodules, fragments of clay aggregates with the same composition as the hydrated matrix. Their appearance is related with the process of clay fragmentation before its hydration (Roux, 2019). During the process of adding water, if the obtained clay is not homogeneous in texture, some not fully hydrated aggregates can appear, which will be included in the matrix and will act as hard non-plastic elements during kneading. For this reason, they normally have low circumgranular porosity and can be easily mistaken for chamotte (Sean Quinn, 2013; Whitbread, 1986).

Intentionally added temper was only detected in six of the identified pottery groups, which represent slightly over half of the sample (841 sherds, 51.19%). Among these, all the petrological groups but one contained chamotte as added temper (472 sherds, 28.73%) (Fig. 6). The vast majority of the chamotte derived from pots made of the same clay as the matrix. The only other petrofacies with added

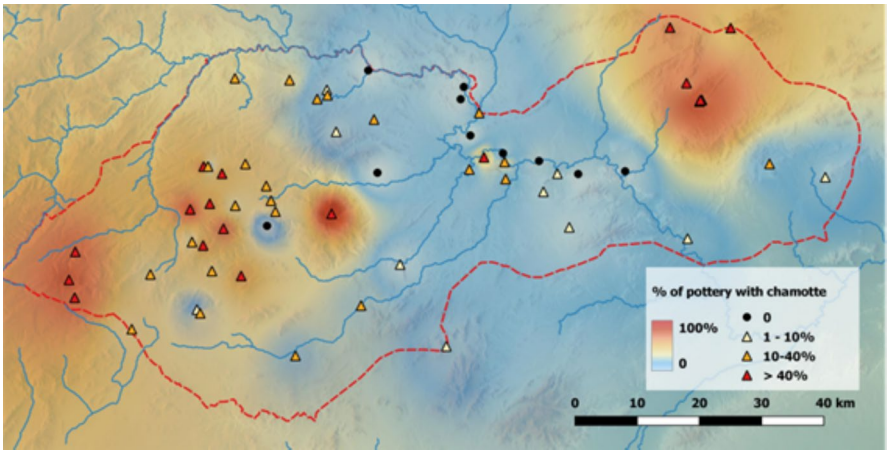

Fig. 6 Heatmap of pottery containing chamotte in the Middle and Upper Segura valley

Table 1 Natural and added components of the different petrological groups identified in the Middle and Upper Segura (for more details on each group see supplementary materials 4). Petrological groups have been coded taking into account the combination of clay, natural non-plastic components and added ones (temper): M: marly clay; A: clay (non-carbonated); PhA: phyllosilicate clay; Cal: carbonate rocks; Qz: quartz; Lut: lutite; Cha: chamotte; Nod: clay nodules; Sch: schist; Gr: garnet; Div: diverse components; Qt: quartzite; Fsp: feldspar; Clc: calcite; Dol: dolomite; Lim: limestone

Petrofacies	N	Matrix	Characteristic non-plastic components	%	Temper	%
C/Clc	369	Argillaceous Clay	Hematite/Qz	<5	Clc/Dol	25–50
M/Lut	57	Marl	Lutite	30–45	–	
M/Qz	67	Marl	Qz, Qt, fine/rounded Fsp	10–50	–	
C/Qz	48	Clay	Czo, Cct, fine/rounded Fsp	10–50	–	
C/Oph	43	Clay	Ophitic rocks	10–50	–	
C/Nod	162	Clay	Micritic Lim	15–40 1–10		
C/Div-Cha	23	Clay	Qz, Fsp Lim, Dol	3–10 3–10	Cha	10–15
M/Div-Cha	71	Marl	Qz, Fsp Lim, Dol, Cal	5–10 5–10	Cha	10–15
M/Qz-Cal-Cha	136	Marl	Lim, Dol, Bioclasts Monocristaline fine/rounded Qz	3–10 2–20	Cha	5–20
M/Cal-Cha	169	Marl	Lim, Dol, Cal	5–10	Cha	10–30
C/Qz-Cal-Cha	22	Clay	Lim, Dol Monocristaline fine/rounded Qz	5–15 1–3	Cha	10–15
M/Nod	43	Clay	Clay fragments	25–30		
PhC/Sch	120	Phylosilicatic clay	Schist	25–50		
PhC/Sch-Gr	1	Phylosilicatic clay	Garnet Schist	35		
C/Sch	57	Clay	low grade metamorphic rocks	10–35		
Unclassified	255	176 Marl 79 Clay	181 frag. with Lim 63 frag. without Lim 11 not identifiable		At least 51 frag present chamotte or Nod (35× in marl, 16× clay)	

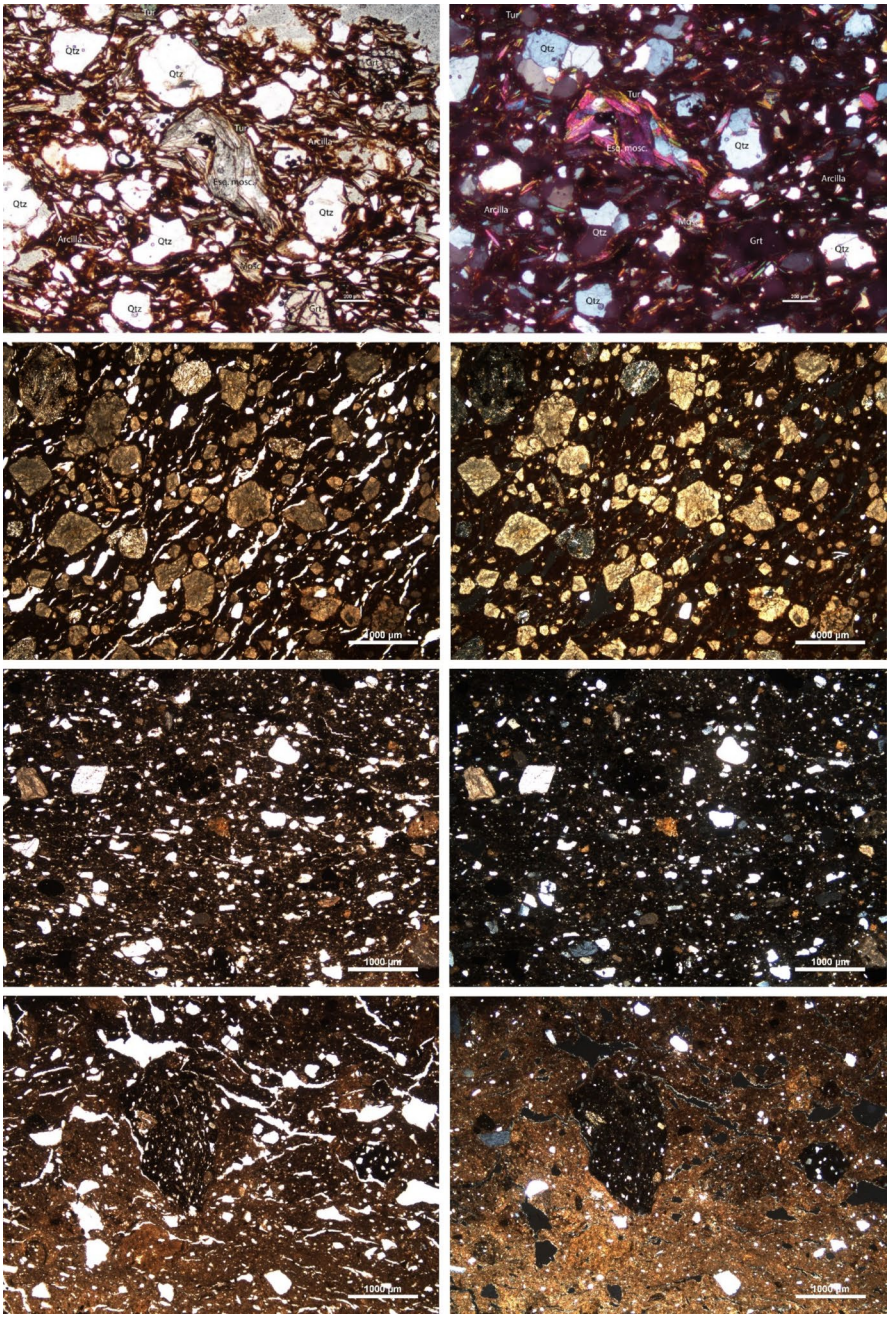

Fig. 7 Petrographic thin sections under parallel (left column) and crossed Nichols (right column) of petrofacies PhC/Sch (first row; source: Garrido García *et al.*, 2021, Fig. 4), C/Clc (second row), M/Div-Cha (third row) and M/Cal-Cha (fourth row)

temper contained relatively homogeneous rhomboid-shaped dolomite grains, crushed before they were mixed with the clay (C/Clc, see Table 1).

The importance of pottery with carbonated components (either the matrix itself or in the non-plastic components), suggests a general productive pattern that prioritised the use of locally available and easily obtainable raw materials. The pottery produced with these raw materials was generally of low quality or resistance, in contrast with containers made of non-carbonated clays and different types of schist (petrofacies PhC/Sch, PhC/Sch-G, C/Sch). These raw materials are derived from metamorphic rocks and are not available in the Middle and Upper Segura valley (see above), but can only be found in the Inner Baetic mountain ranges. They allow the production of much more resistant ceramics (Fig. 7) .

The Petrological Groups of the EBA Pottery of the Middle and Upper Segura

The most relevant petrological groups to understand the social and economic situation in the Middle and Upper Segura will be discussed individually, focusing especially on their spatial distribution as well as productive and technological aspects. The description of the remaining petrological groups can be consulted in the supplementary material.

Argaric Productions: PhC/Sch, PhC/Sch/Gr, C/Sch

Based on previous petrographic analyses of pottery productions from settlements located in the core region of El Argar (Pérez Sirvent *et al*, 1999; Martínez Sánchez *et al.*, 1999; Álvarez, 1999; Seva Román, 2002; Garrido García 2017; Garrido García *et al.*, 2021, 2023), it has been possible to distinguish three typically Argaric *petrofacies*: PhC/Sch, PhC/Sch-Gr and C/Sch. The first two are characterised by a phyllosilicatic clay containing fragments of low and/or middle grade metamorphic rocks (schists) as their main non-plastic elements, with the only difference being the presence of garnets in PhC/Sch-Gr.

This kind of pottery is clearly dominant in all El Argar settlements we have studied in the provinces of Almería and Murcia. Our geoarchaeological surveys confirmed that the metamorphic non-plastic components of these two petrological groups are natural components of the phyllosilicatic clays (petrofacies) developed on different schist deposits of the inner Baetic mountain chain, running in a NE-SW direction along the Mediterranean coast (Garrido García *et al*. in press). Thus, the nearest potential sources of these two petrological groups are located in southern Murcia, around Sierra de la Almenara, at least 50 km south of the Middle and Upper Segura valley (Fig. 8).

The third non-carbonated petrofacies (C/Sch) is found especially in El Argar settlements of eastern Murcia and Alicante. It is differentiated from the other two by the lower grade of metamorphism of its main non-plastic components (slate). The nearest source for this petrological group is probably found in eastern Murcia.

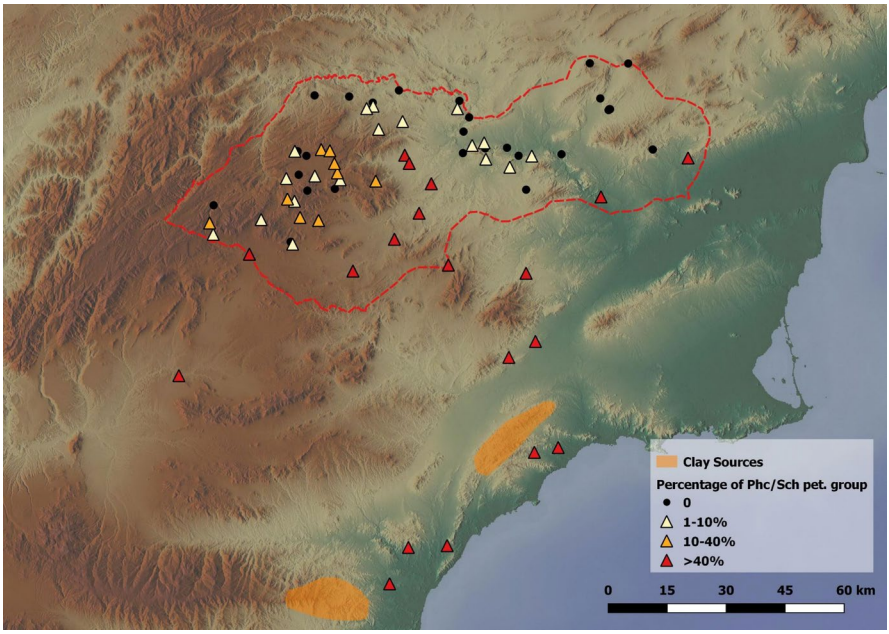

Fig. 8 Presence of PhC/Sch pottery and possible clay origin

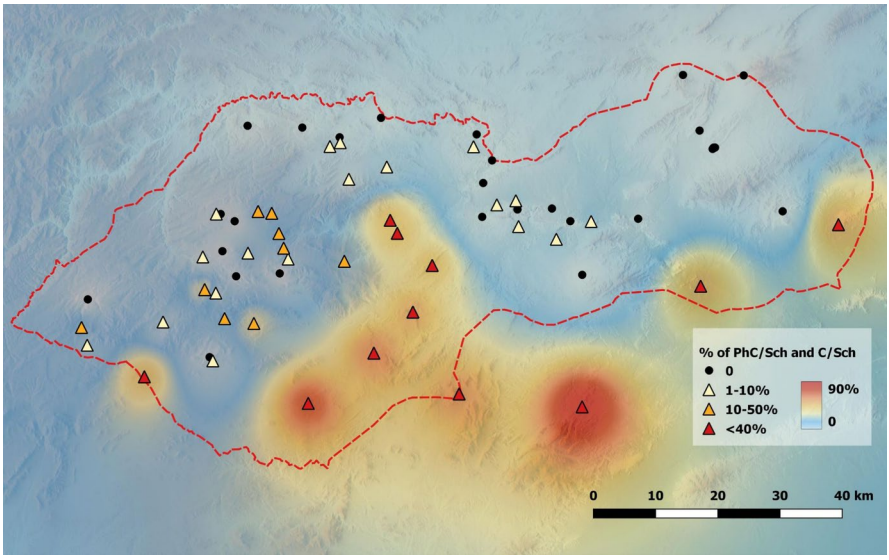

Fig. 9 Geographical distribution of the Argaric petrofacies PhC/Sch and C/Sch

A total of 178 (10.77%) pottery sherds from the Middle and Upper Segura survey could be assigned to one of the three Argaric petrofacies: PhC/Sch was the most numerous with 120 sherds, followed by C/Sch with 57 and a single sherd of PhC/Sch/Gr (Table 1). Argaric productions are present in 34 of the 61 surveyed sites (55.74%). Taken together, they are the second most common pottery type in the Middle and Upper Segura, both in number of sherds and settlements. This is particularly striking given the non-local origin of these clays.

The geographical distribution of these petrofacies is highly revealing (Fig. 9). From a purely qualitative standpoint (*i.e.* presence/absence), the incidence of El Argar productions is quite high. They can be found virtually in any part of the Middle and Upper Segura, with the glaring exception of El Altiplano (northeast of the research area) where not a single sherd belonging to any of these groups has been found. This image becomes more refined when the quantitative importance of these petrological groups in each settlement are considered. Their spatial distribution concentrates in the southern third of the research area. All the settlements where Argaric clays are the most abundant petrological group, *i.e.* represent more than 40% of the studied pottery of a given site, are located in this strip of land, which is the closest for El Argar core region as well as the sources of the raw materials.

North of this southern strip significant differences can be observed between the western and eastern ends of the research area. To the west, in and around Campo de San Juan, Argaric clays are found in approximately two thirds of the surveyed sites, in quantities that never surpass 30% of the recovered pottery. Here, the Argaric petrological groups are never the dominant ones, but normally second or third in order of importance. It is worth noting that the two settlements with the highest concentrations of Argaric pottery are located at the southwestern and the northeastern accesses to the plateau of Campo de San Juan, controlling the access to the Quípar, Argos, and Alhárabe meadows.

To the east, in the Middle Segura area (between Calasparra and Cieza, Fig. 4), Argaric petrofacies were identified in almost half of the surveyed sites (43.5%). Their importance is even more limited than in the Upper Segura, as they never represent more than 10% of the pottery in any given settlement. Apparently, here the "southern strip" of land where El Argar pottery is prevalent was interrupted. This is particularly interesting, considering the relatively high presence of typical Argaric morphotypes in this area, such as chalices or *tulipas* and the abundance of identified intramural graves, another typical trait of the El Argar core area settlements.

A total of 35 diagnostic sherds belonging to the PhC/Sch and C/Sch petrographic groups were documented in ten settlements. All of them can easily be associated with typical Argaric shapes (Fig. 10). Most of them correspond to medium and large storage vessels of types 4 and 5 (Lull, 1983; Siret & Siret, 1890). Some very idiosyncratic Argaric types were also identified, such as a chalice (F7) and inverted rim bowls (F2B), which are extremely uncommon outside El Argar territory. Hence, the typological study of the diagnostic sherds from PhC/Sch and C/Sch confirms the identification of this kind of production

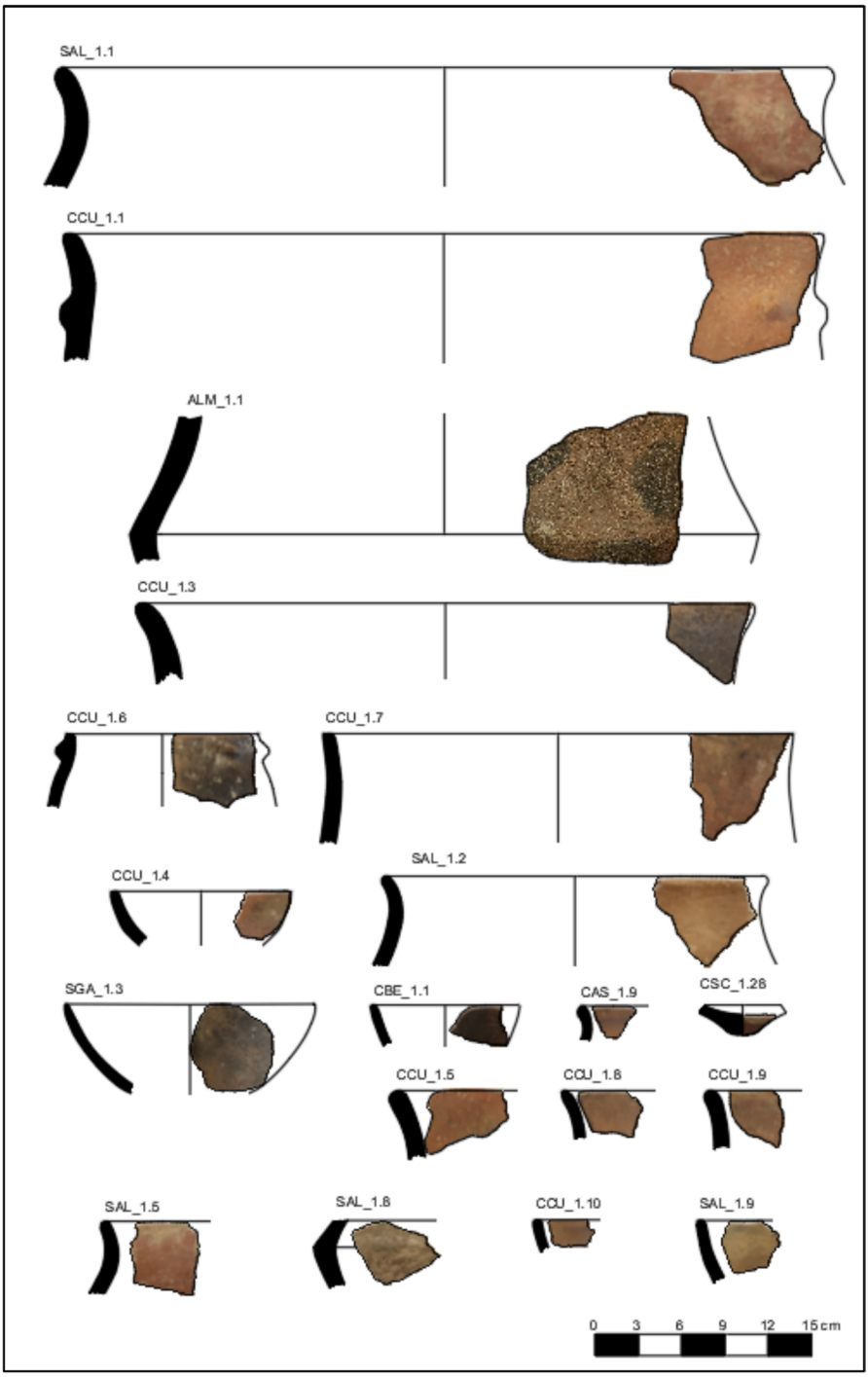

Fig. 10 Diagnostic sherds with petrofacies PhC/Sch and C/Sch

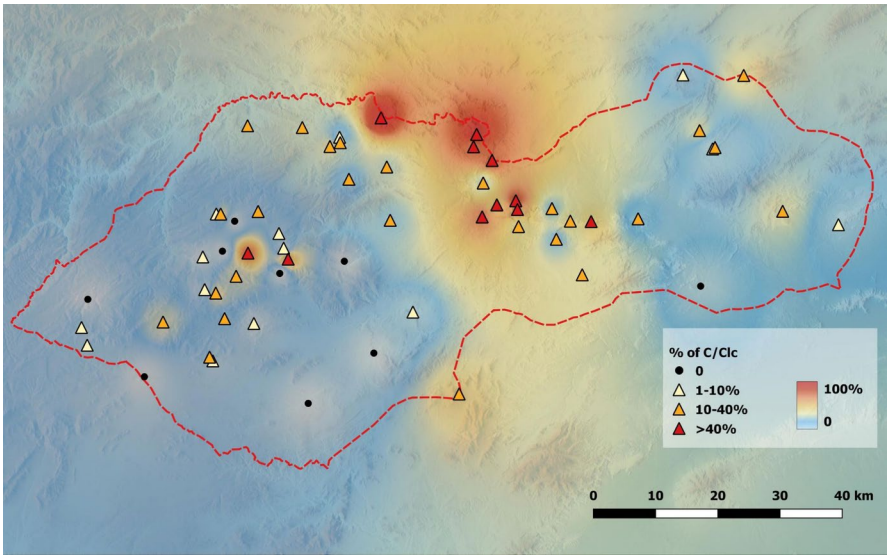

Fig. 11 Geographical distribution of the petrofacies C/Clc

with El Argar, as all the morphotypes identified have clear and abundant parallels in Argaric settlements.

C/Clc

This pottery group can be distinguished by its non-carbonated matrix made up of a reddish clay, with minor non-plastic components such as haematitic nodules (c. 3%) and very fine quartz grains (1–2%). Occasionally, fragments of subvolcanic rocks of ophiolitic texture can be observed dispersed throughout the matrix, reaching percentages of up to 15%. Its main characteristic is the added temper, which takes the form of rhomboidal mono- and polycrystalline calcite or dolomite fragments with a size oscillating between 0.05 and 3 mm. The modal proportion of this temper is high, generally ranging between 25 and 50%. Its angular shape confirms that it is a prepared material added to the clay. Under observation with a magnifying lens, it is possible to document a range of variation in the colour of the calcite or dolomite from grey to white as a consequence of the firing process. Moreover, the observation with optical microscope made it possible to establish that dolomite is sometimes partially replaced by calcite; both minerals appear partially or totally micritized due to the temperature reached during the pottery firing, which suggests that this should have been around 700 °C (Risch & Gómez-Gras, 2003).

The characteristic calcite and/or dolomite temper would have been obtained by the crushing of crystalline limestones and dolomites, rocks that are common in the Mesozoic age geological units (Triassic, Jurassic and Cretaceous) of the Subbaetic

and Prebaetic mountain ranges. Likewise, the fragments of subvolcanic rocks of subophitic texture formed by plagioclase, clinopyroxene, amphibole and epidote, originate from the Upper Triassic in Keuper facies. This geologic unit has diverse outcrops of evaporitic clays with gypsum and carbonates, which frequently include these rocks, known as ophiolites, around the area of the present-day town of Cieza (Sierra del Oro, La Atalaya).

In total, 369 (22.46%) pottery sherds could be assigned to the C/Clc petrological group. This pottery production has been identified in 49 sites, making it the most widespread of the research, both in terms of total number of sherds and geographical reach. It has been documented across all the Middle and Upper Segura, with the exception of the south-western sector, where it is absent in three sites. Coincidentally, all three show a strong preponderance of El Argar petrofacies. However, it is also true that C/Clc has been found occasionally in El Argar settlements.

The heatmap shows a high concentration along the transition area between the upper and middle course of the Segura around the present-day town of Calasparra (Fig. 11). The predominance of C/Clc pottery in this small region is striking, as it represents over 40% of the entire pottery assemblage of most settlements and, in at least two of them, it is the only petrological group documented. Its quantitative dominance as well as the presence of characteristic subvolcanic rocks in many of the sherds, suggests that these raw materials supplied an important local pottery production. However, it cannot be ruled out that ceramics without subvolcanic non-plastic components could have been produced elsewhere as calcite and dolomite can be found in many areas of the Segura valley.

Despite their probable origin in the Middle Segura, the geographical reach of this production is worth noting and includes the area of El Altiplano, where Argaric pottery is completely absent. It is also significant that the quantity of pottery sherds found outside the proposed production area is quite high, reaching between 10 and 40% in most of the sites. This suggests that this pottery, or most likely some product contained in it, was widely exchanged across the entire Middle and Upper Segura.

The idea that C/Clc pottery was included in a large exchange network is further reinforced by the origin of a singular type of object, the so-called *ídolos de Camarillas* (Camarillas idols) in the same region. These idols are naturally appearing mineral nodules, which commonly resemble anthropomorphic figures, originated under very specific conditions, namely in paleo-lacustrine contexts rich in silicates of volcanic origin (Risch, 1995, 141). Camarillas idols have been found in settlements spanning from the Neolithic until Roman times and located hundreds of kilometres apart from each other (Molina Grande & Molina García, 1980, 1990; Ayala Juan & Jordán Montes, 1984; Risch, 1995). The rare combination of factors leading to the formation of these nodules made it possible to clearly pinpoint their origin to a very small area around the present-day Camarillas dam. Coincidentally, one of the identified sources of Camarillas nodules is located in the hillsides of Cerro Salmerón, an ancient volcano in which an EBA settlement was also established. The archaeological site and outcrop are separated only by a few meters and the petrologic analysis of the settlement's pottery showed that almost 70% corresponded to C/Clc, supporting the relation between both materials.

The recovered diagnostic sherds (see supplementary material 4.1) provided further significant information. On the one hand, C/Clc pottery shows some similarities with Argaric shapes, with storage vessels, especially everted rim jars (analogous to El Argar form 4), being the dominant shapes. On the other hand, clear distinctions were also observed. The number of carinated shapes is significantly lower than among El Argar pottery, with a much higher presence of pots with straight or converging rims and platters, both of which are rare in Argaric contexts (SM. 2). The complete lack of any distinctively Argaric types, like chalices or finely burnished carinated vessels, is also remarkable.

C/Oph

This group is characterised by a clay matrix with loose quartz (< 10%) and hematite nodules (< 3%). Components such as caliche nodules (< 5%) were occasionally observed. The distinctive feature of this petrological group is the presence of abundant fragments of subvolcanic rocks such as Keuper ophiolites with pyroxene, amphibole, hornblende, biotite, plagioclase and feldspar or quartzodiorites. The size of the non-plastic components usually ranges from 0.5 to 2 mm, although a subgroup with finer temper (0.1–0.5 mm) has also been identified. The amount of non-plastic components is very high, with most sherds containing around 40%. The lithological and compositional correspondence between the coarse and fine fraction suggests that this petrofabric originated from a red clay deposit generated on a subvolcanic base rock. Such outcrops are found on the left bank of the Segura River south of Cieza. The geographic distribution of this petrofacies immediately to the south and west of present day Cieza reveals that the highest concentration of this pottery type is found precisely in this region (Fig. 12).

With just 41 sherds (2.49%) located in 18 settlements, this petrological group is the best example of a minor production with a very local scope (Fig. 12). Beyond

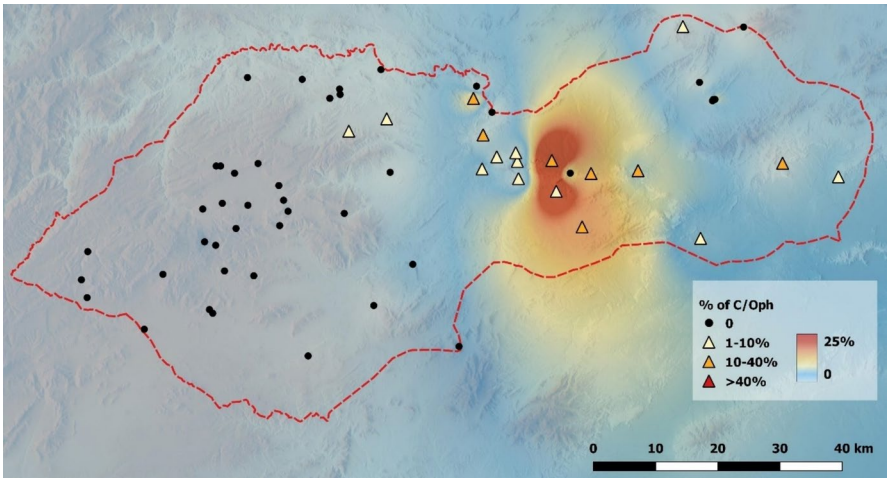

Fig. 12 Geographical distribution of the petrofacies C/Oph

the immediate surroundings of Cieza, the presence of this petrological group is scant, being completely absent from the western half of the research area.

Even within the Cieza area, where this petrological group is most abundant, it does not dominate in any settlement and it never represents more than 30% of the pottery assemblage of any given site. The recovered diagnostic sherds inform about the use of this production. Most of the documented sherds correspond to small or medium sized pots and bowls with a lack of storage vessels (see supplementary material 4.7). As such the C/Oph group can be identified with a local production of small pots for day-to-day activities, such as the preparation and consumption of food, which relied on easily available raw materials located very close to the Cieza settlements.

C/Div-Cha and M/Div-Cha

The next two petrological groups have a very similar petrological composition, with the main difference between them being their matrix. C/Div-Cha is characterised by a reddish clay matrix, very porous and with clay nodules, resulting from a poor kneading, whereas M/Div-Cha features a marly matrix. The modal proportion of non-plastic components of both groups is high (50%) with a high degree of heterogeneity. The most abundant non-plastic elements are semi-hydrated clay nodules (10–15%). In addition, monocrystalline quartz, fine-sized subrounded feldspars, micritised tertiary bioclastic limestones, bioclasts of the same material and oxide nodules have been usually identified. Finally in some sherds, it was possible to observe chamotte (10–15%), both of carbonated and non-carbonated matrices.

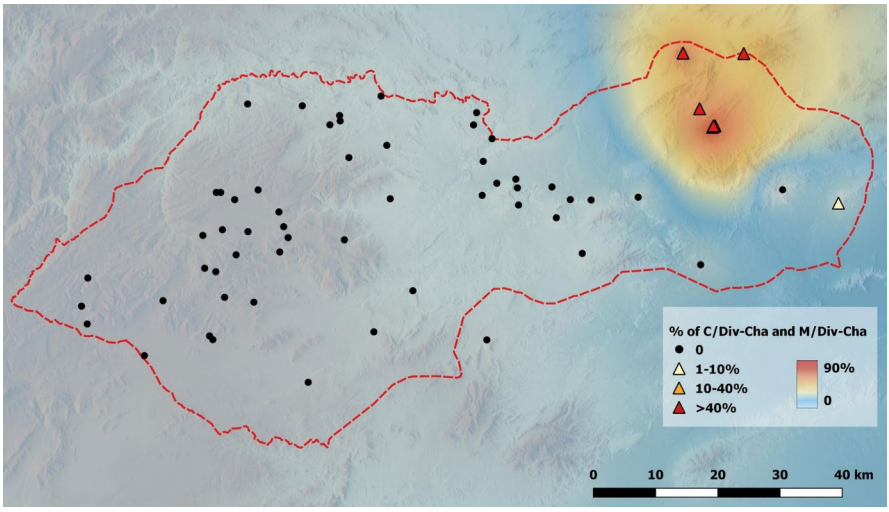

Fig. 13 Geographical distribution of the petrofacies C/Div-Cha and M/Div-Cha

So far, 94 sherds belonging to these petrological groups have been identified in only seven settlements. 71 of these sherds belong to the marly variant, while the remaining 23 have a clay matrix. All of them, with the only exception of a single "stray" sherd, have been located in settlements of El Altiplano region (Fig. 13). If the sherds from the six studied settlements of El Altiplano are combined, both petrological groups account for over 60% of the documented pottery. The geographical specificity and importance they had in the pottery assemblages of El Altiplano sites, sheds little doubt on the local origin and limited circulation of these productions. The only other petrological group found in meaningful numbers in this region is C/Clc (17%). It is also the only group present in all the six surveyed sites from El Altiplano.

The absolute and mutual exclusion between these petrographic groups *and* the Argaric ones is striking, as not a single Argaric sherd has been found in El Altiplano, despite the relative proximity to this region of settlements with abundant Argaric pottery (*e.g.* El Morterico). The diagnostic sherds also show a clear distancing from a typical Argaric repertoire. The few storage containers documented in settlements form El Altiplano are small and their profile is less sinuous than the typical Argaric storage vessels (Siret Form 4). Most documented shapes belong to bowls, platters and straight rim pots, which are indicative of day-to-day activities, such as food preparation and consumption.

M/Qz-Cal-Cha

This petrological group is characterised by a marly matrix including a variety of carbonated rocks (3–10%), to which carbonated chamotte has been added (5–20%) as temper (Garrido García *et al.*, 2023, 87). The chamotte has a micritic texture due

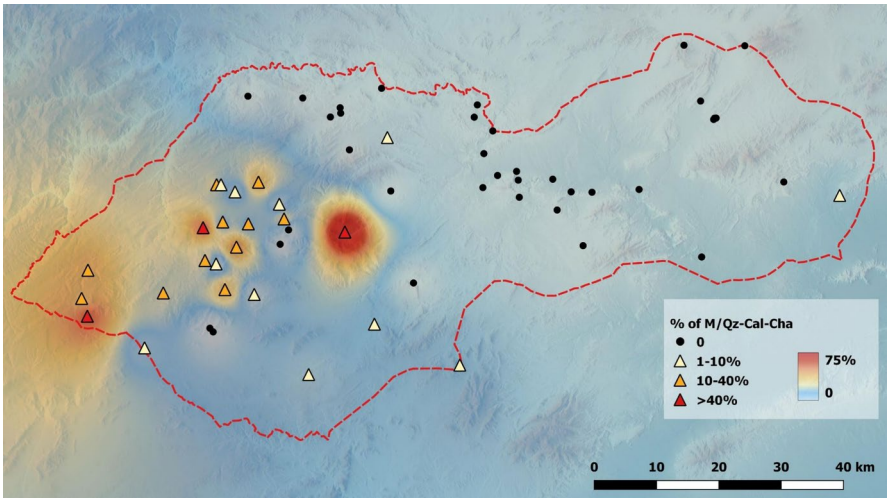

Fig. 14 Spatial distribution of the petrofacies M/Qz-Cal-Cha

to its double firing and an angular or subangular shape. Under microscopic observation, the carbonate fragments could be identified as limestones and dolomites, as well as foraminiferal and gastropod bioclasts. The matrix also contains a variable proportion of monocrystalline quartz and silt-sized feldspar and fine sand (2–20%). The shape of the non-plastic components is rounded, suggesting that the raw material originated from sandy, alluvial or littoral deposits. Occasionally, clay nodules from poor kneading or semi-hydrated clay nodules (up to 20%), with dimensions ranging from 0.5–2 mm and up to 4 mm, have also been observed.

This petrological group is of particular importance, as it was the dominant pottery production identified in the recent excavations of Cerro Morrón and, therefore, one of the few groups with a clear stratigraphic context and C14-dating within the research area. In Cerro Morrón, this *petrofacies* was documented in the two occupation moments of the settlement.[5] In the first phase (*ca*. 2000–1800 cal. BCE) M/Qz-Cal-Cha was the only petrological group documented, whereas it coexisted with Argaric *petrofacies* in the second phase (*ca.* 1800 cal. BCE onwards), albeit still being the most numerous one. This reinforces the idea that non-argaric productions preceded the arrival of El Argar to the research area.

This pottery production has been documented in another 24 settlements of the research area (Fig. 14). All but one are located in its western half and, more specifically, in or around the area of Campo de San Juan, where it is dominant in several settlements, reaching percentages of up to 70%. The limited geographical reach suggests that this petrological group was locally produced and used in Campo de San Juan and neighbouring areas.

Diagnostic sherds belong mostly to hemispheric and conical bowls. Small bowls as well as larger platters and deep bowls are also present. Everted rim jars (analogous to Siret form 4) and carinated vessels are less numerous than in other petrological groups and all of them are medium or small-sized. Finally, a rim-sherd belonging to an inverted rim bowl, which can be classified as type 2B2 of Lull's typology (Lull, 1983, 79–80), a shape clearly associated with El Argar, has also been identified. This serves as a proof that typically Argaric morphotypes were being copied locally. In general, however, the morphotypes belonging to M/Qz-Cal-Cha found across the research area, have close parallels with those documented in the excavations of Cerro Morrón (Micó & Oliart, 2023, 74–79).

Table 2 Production and circulation of the Middle and Upper Segura petrological groups

	Restricted production	Dispersed production
Limited circulation	M/Lut, C/Oph, M/Nod, C/Div-Cha, M/Div-Cha, C/Nod, C/Oz-Cal-Cha, M/Oz-Cal-Cha	M/Qz, M/Cal-Cha, C/Qz
Extensive circulation	C/Clc	PhC/Sch, Phc/Sch-Gr, C/Sch

[5] In the monograph of Cerro Morrón, two petrological groups (PF 3 and PF 4) were differentiated based on their contents of quartz (Garrido García, Gómez-Gras & Risch, 2023, 87); in our study, however, they have all been included in the same group.

Discussion

Pottery Production and Circulation

In order to understand the processes of production and circulation of pottery in the Middle and Upper Segura, each of the identified petrological groups was classified according to their geographically restricted or dispersed production, based on the geological availability of the raw materials and size of the area where each petrological group was dominant. Similarly, their circulation has also been categorised as geographically limited or extensive (Table 2). It should be noted that we understand spatially circumscribed productions not as the result of a single pottery kiln but rather as regionally defined and uninterrupted areas where the manufacture of a given petrological group is dominant.

Within this parameter of production and circulation, more than half of the petrological groups (8) fall into the restricted production-limited circulation category. It is important to note, however, that they only represent 33.9% (557 sherds) of the studied pottery and that only two groups include over 100 sherds. Such a large number of petrological groups with a low number of individuals produced is an expression of the productive variability existing in a geographically limited and geologically rather uniform region. Moreover, the restricted geographical distribution of these petrological groups suggests that many communities of the Middle and Upper Segura produced and used pottery at a local scale, which did not participate in supra-regional exchange networks. Their petrological composition is consistent with a manufacturing process that relied on raw materials found in the immediate vicinity of the settlements. Thus, in the regions where these kinds of productions dominate, a small-scale and mostly self-sufficient economy can be proposed.

Three petrological groups, representing 17.29% of the studied pottery (284 sherds), can be classified as dispersed productions of limited circulation. The groups included here are characterised by being present in at least two geographically differentiated non-contiguous subregions within the research area. This spatial pattern is, most likely, not the result of exchange but rather points at the production of very similar pottery in two geographically distinct zones. This is supported by "geological unspecificity" of this type of pottery, *i.e.* the raw materials used for their production can be easily found across many parts of the Middle and Upper Segura. For example, M/Qz and C/Qz, are characterised by the use of silt-sized rounded and sub-rounded siliceous components (quartzite, mono- and polycrystalline quartz) as non-plastic components, suggesting the use of sand from riverine deposits, whereas M/Cal-Cha is characterised by a marly matrix and the use of carbonated chamotte as temper. The commonness of the raw materials used in these petrological groups imply that they could have been found almost at any point of the research area. Thus, the economic organisation inferred for the areas where these productions dominate is very similar to the previous category, *i.e.* small-scale and self-sufficient economies.

Apart from El Argar pottery, a single petrological group, C/Clc, has been identified as a local production but had an extensive circulation. For this petrological group, the area of production has been identified in a specific region located around the present-day town of Calasparra, where it appears in large numbers (Fig. 11). The geographical reach of C/Clc pottery covers a notable territory, although numbers are lower outside the restricted production area. Given the unspecificity of this pottery in terms of shape, colour, and surface treatment, it seems unlikely that it was used as an exchange good, but rather that it served as the container for something else, which was traded. The fact that the source area of this petrological group overlaps with the outcrops of the so-called *Camarillas idols*, which circulated over hundreds of kilometres since the Copper Age, reinforces the idea that the communities established in the region north of Calasparra engaged in long-range exchange networks with other human groups of the Iberian southeast, both Argaric and non-Argaric.

Finally, only El Argar productions qualify as a dispersed production with an extensive circulation. The fact that these *petrofacies* are not available in the research area but required transport costs of over 50 km clearly sets them apart. The quantity of Argaric pottery and its ubiquity must have required a stable distribution network functioning, at least, from the coastal mountain ranges of southern Murcia until Middle and Upper Segura. Independently, if finished pottery vessels or unworked clay was circulated, the amount of workforce required and logistical complexity of establishing and maintaining such a distribution network of everyday consumables, are a testimony of the development reached by El Argar economy.

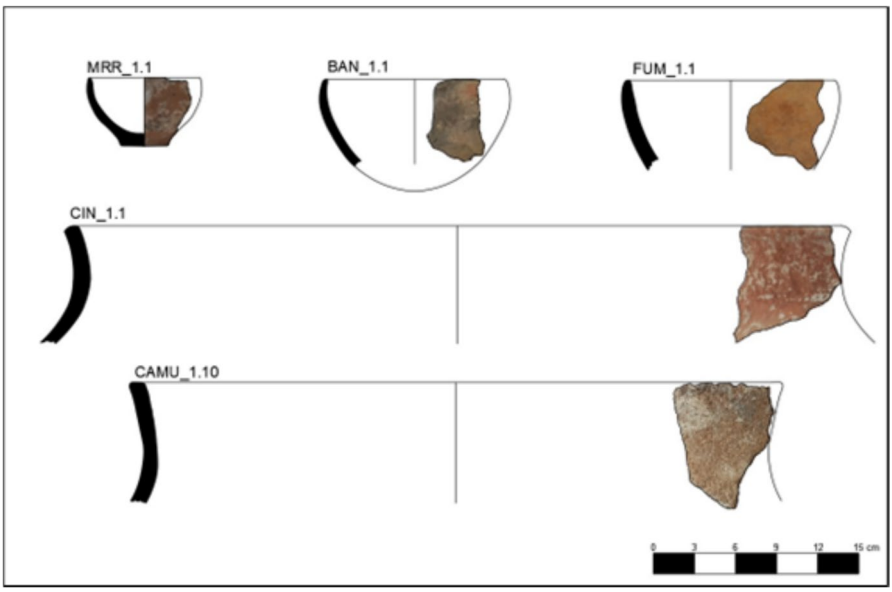

Fig. 15 Example of locally produced Argaric morphotypes

Local Reproduction of Argaric Shapes

As mentioned above, the comparison between the petrological composition and pottery typology revealed that some characteristic El Argar shapes were reproduced in certain local productions of the Middle and Upper Segura, while the opposite could not be confirmed (Fig. 15). Specifically, three Argaric morphotypes were proved to have been locally produced. The most abundant among those are very large storage jars with everted rims and rim diameters that are over 45 cm (Siret Form 4), with estimated capacities that would have exceeded 100 l. Vessels of these dimensions are only found in relevant numbers in the Argaric territory, where they were commonly used to store large quantities of cereals and re-used as grave containers (*pithoi*). Several inverted rim bowls with parabolic outline, akin to types 2B2 and 2B3 in Lull's classification of El Argar pottery have also been recognised (BAN_1.1 & FUM_1.1; Fig. 15). Such vessels are very commonly deposited as Argaric grave goods or, the larger ones, used as funerary containers for child burials (Lull, 1983, 79–80). Finally, a single example of a locally produced chalice was found (MRR_1.1, Fig. 15), which seems to try to imitate one of the most idiosyncratic shapes of El Argar. Such vessels are also commonly found in El Argar burials, but mostly in graves belonging to the upper Argaric classes.

It is worth noting, however, that, despite all the above-mentioned shapes fall within the morphometric criteria established in V. Lull's typology of El Argar pottery, many of them have differences with the canonical Argaric types. For example, one of the large *pithos* has its rim decorated with finger impressions, a feature which is rare in El Argar but quite common among the pottery of La Mancha. In the case of the chalice, it has a straight rim and is smaller than most of its counterparts from El Argar nuclear region, which are larger and tend to have an inverted rim.

All in all, it is clear that Argaric pottery inspired some local productions in the Middle and Upper Segura. This serves as a clear indicator of the influence of El Argar in a geographical border region close to La Mancha. At the same time, it also illustrates how local communities adapted these shapes to their own needs and preferences, by using decoration rarely seen in Argaric pots or making subtle modifications to the shapes. Surprisingly, one of the most easily identifiable and characteristic Argaric shapes, the carinated cups with thin walls and burnished

Table 3 *t* test results (*p* values) showing the relation between the presence of graves/different petrological groups

Petrofacies	PhC/Sch, C/Sch (Argaric)	C/Clc	C/Nod	M/Cal-Cha
Graves	0.0029966	0.57445	0.83581	0.44618

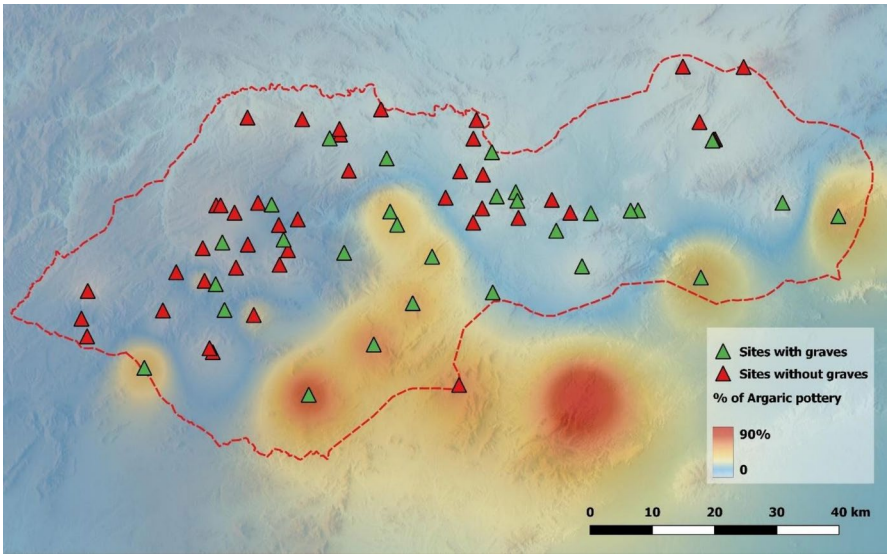

Fig. 16 Map of the geographical distribution of graves and Argaric petrological groups

surfaces (Siret form 5), was rarely reproduced using local, usually carbonated clays.

Petrographic Groups and Social Practices

In order to delve deeper into the economic and political meaning of the different petrographic groups, the funerary record can be used as an additional clue in order to differentiate between Argaric and non-Argaric communities. While intramural burials are a characteristic feature of Argaric settlements, they are much rarer in La Mancha and especially in Valencian sites.

If both features are compared in terms of presence and absence, Argaric clays have been identified in 20 of the 27 surveyed settlements with graves (74.07%), whereas they only appear in 17 of the 37 settlements without graves (45.95%).[6]

A *t* test was used to determine if the quantity of pottery of a given[7] petrological group in a settlement was significantly related with the presence or absence of graves (Table 3). The results revealed that the presence of graves shows a statistically significant relation with the Argaric petrofacies. In other words, settlements with burials tend to have a higher quantity of petrologically Argaric pottery.

The relation between the presence of graves and Argaric pottery can also be clearly seen in its geographical projection (Fig. 16). Most of the settlements

[6] $X.^2$ $p = 0.0244$.

[7] The four larger petrological groups, with over 100 sherds, were tested to warrant representativity.

with burials are located in the southern half of the research area and all settlements where the Argaric petrological groups were dominant had graves (with one exception possibly resulting from limited research). In sum, the correlation between funerary and pottery-making practices strongly supports the idea that certain parts of the Middle and Upper Segura fully adopted the Argaric social, political, and economic system.

More complex situations can be conceived in settlements with intramural burials and typical Argaric grave goods have been reported, but where the Argaric vessels only represent a minor part of the pottery productions. This is the case in the excavated and multiphase settlements of Cerro Morrón and Cerro de la Víboras, both found in the municipality of Moratalla. Both revealed an early settlement phase with no characteristic Argaric materials nor funerary structures (Eiroa García, 1994, 1998, 2010; Celdrán Beltrán *et al.*, 2023). The presence of El Argar is only felt in late settlement moments, when singular El Argar burials appear, some of them including exceptional grave goods, such as long daggers, short swords, and silver ornaments. This development indicates that the "argarisation" of the area around Campo de San Juan took place in a late moment of the EBA, apparently after 1800 cal. BCE, in a social context, where the majority of the community continued to use locally made pottery. The funerary record found in these sites suggests that the introduction of El Argar elements was related to elites rather than to large population groups. So far, a DNA analyses do not allow to conclude if these warrior graves belonged to local elites emulating the funerary customs of the late El Argar dominant class, or individuals of southern origin (Villalba-Mouco *et al.*, 2022).

A third scenario is defined by settlements lacking intramural burials as well as El Argar pottery. Following the described social and chronological development, these sites must have either been abandoned before 1800 cal BCE, when the Argaric elements appeared for the first time in certain areas, or communities resisted the changes arriving from the south. The presence of weapons in the mentioned burials and the abundant evidence of physical violence in relation to the relatively few studied human remains in border regions of El Argar, indicates that the argarisation of interior regions involved elements of violence (Oliart, 2020, 2021).

Conclusions

The extensive archaeological survey and the petrographic analysis of the pottery from all EBA settlements discovered in an area of ca. 4850 km^2, in the Middle and Upper Segura valley allowed us to obtain a complex and highly contrasted image of the pottery production and circulation in a substantial part of the border region between El Argar, the La Mancha Bronze Age, and the Valencian Bronze Age. Fourteen petrographic pottery types could be identified, which account for 85% of the 1643 analysed sherds coming from 61 surveyed sites. Spatial analysis of each of these fourteen groups, combined with their quantitative importance in each settlement and region, made it possible to model the different areas of pottery production and circulation (Fig. 17).

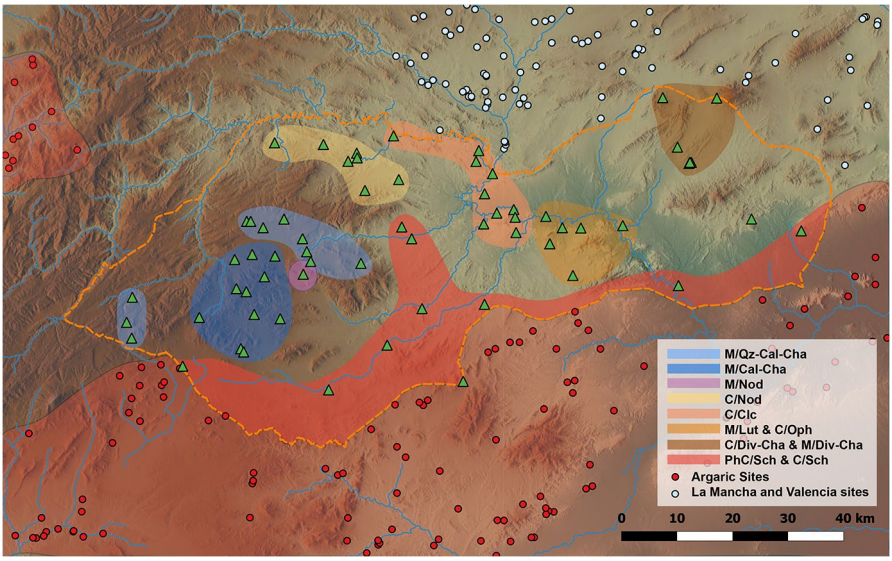

Fig. 17 Geographical distribution of the main petrological groups of the Middle and Upper Segura

The main result which emerges from the spatial modelling of petrographic groups is the sharp contrast, in terms of pottery typology, technology, and spatial patterns, between the vessels made of clays derived from metamorphic rocks and all the other petrographic groups. The first derive from Pleistocene soils developed on certain schist outcrops within the Inner Baetic mountain chain, extending along the Mediterranean coast between present day Granada and southern Murcia (Garrido *et al.*, in press). These clays were exploited and used to manufacture the characteristic pottery found in the main political and economic centres of El Argar, well known for their intramural burials often placed in large storage vessels. The foreign origin of petrographically defined Argaric pottery implies the existence of important pottery manufacture centres near the clay deposits and an inter-regional network of pottery distribution, which made it possible to supply settlements placed over 70 km away from the raw material sources. The logistics and cost in human work required to establish and maintain such a network for a highly demanded product like pottery bears witness to the level of territorial control exercised by El Argar.

The study of the Argaric clay groups recovered during our surveys of the Middle and Upper Segura valley reinforces the idea that El Argar pottery production achieved a high degree of morphometrical and technical standardisation, as suggested by other authors (Velasco Felipe, 2021), but that it also specialised on the use of a sole and comparatively rare clay type (Garrido Garcia *et al.*, 2021, 2023, in press). The close association of clays derived from metamorphic rocks with typical El Argar pottery shapes (Figs. 8, 9) suggests that finished vessels, rather than only the clay, were circulated in El Argar territory. The transport of large containers with capacities up to 300 l over large distances would have required stable routes and means of communication, besides large specialised production centres which

managed to supply dozens of communities with a type of common goods required in everyday tasks, such as cooking, storing or consuming food.

In sum, the abundance of typical El Argar pottery in regions over 50 km away from the clay sources allows us to define productive specialisation in the EBA of Southeast Iberia in terms of the close correlation between (a) shapes, (b) sizes, (c) raw materials, (d) volume of production, and (e) supply distances. In other words, a limited number of types was produced in large quantities, in different, standardised sizes, with a unique clay and circulated to regions where other clay resources were available and used in typologically and technically easily distinguishable pottery productions. El Argar pottery clearly acted as an intrusive element in the Middle and Upper Segura, given that its production centres were placed far to the south, in or close to the coastal mountain ranges. This pottery distribution network was asymmetrical, as equivalent north–south movements are not observed within the analysed region. According to the dated pottery types circulated furthest from the raw material sources, it can be confirmed that the expansion of El Argar reached its maximum territorial expansion after *ca.* 1800 cal. BCE, appearing in regions and settlements where local pottery continued to be produced using markedly different (carbonated) clays or tempers.

A further important observation resulting from the spatial and chronological distribution of the different identified petrographic groups is the concentration of typical Argaric pottery in the settlements occupying the southern fringe of the Middle and Upper Segura (Fig. 17). Further north, only late El Argar types start appearing after 1800 BCE, and they never became the dominant production, underlining again their intrusive character.

Markedly different situations are observed in the northern part of the research area, furthest away from El Argar core region, where pottery production and circulation followed significantly different patterns (Fig. 17). Those areas were characterised by local productions in which the ease of access to clay sources was clearly prioritised over any other concern. It follows that pottery production in these communities would have taken place in a multiplicity of small workshops or at a domestic level, using a variety of clays, tempers, and techniques. These productive differences also had a clear effect on the pottery repertoire. While the most common morphotypes for Argaric petrological groups are large storage vessels, non-Argaric productions are mainly characterised by small and medium size pots, primarily used for food preparation and consumption. This suggests a small-scale production system in which different petrological groups dominated over much smaller areas.

A third pattern emerges from the distribution of pottery made with C/Clc, a petrological group with a notable geographical reach, when compared to the local or domestic productions. These pots originated in a rather small area around the Middle Segura and their wider circulation is likely to be a by-product of the central location of the region where C/Clc was mainly produced (Fig. 17). The abundance of middle-sized containers (Fig. 5 in supplementary Material) suggests that a specific type of product, rather than the pottery itself, was exchanged, maybe in parallel to the well-known *Camarillas idols*, also originating in this region.

The geographical distribution of the petrological groups as well as the other archaeological markers, such as the presence of burials and Argaric morphotypes, enabled a preliminary approach to the socio-political situation of this borderland.

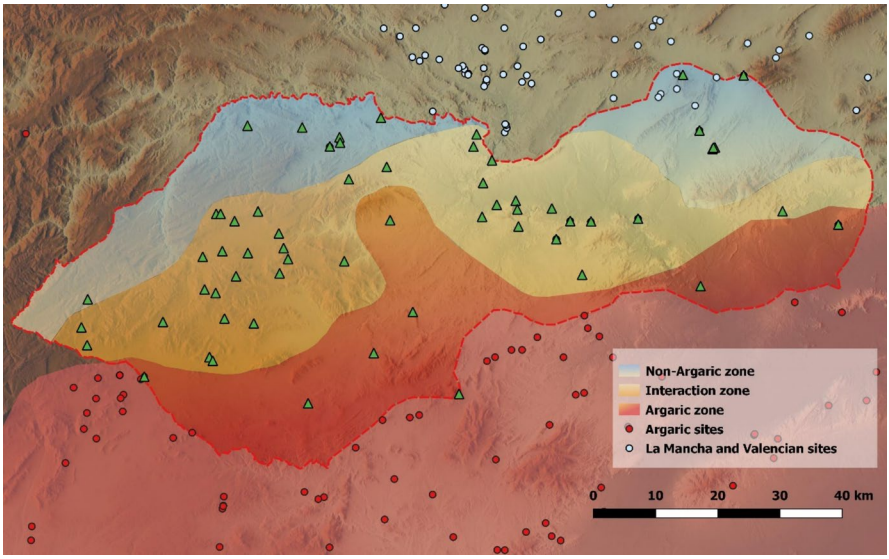

Fig. 18 Socio-political zones in the Middle and Upper Segura

The southern part of the Middle and Upper Segura can be considered as fully integrated in the Argaric world by *ca*. 1800 cal BCE (Fig. 18). This region would have been part of the Argaric exchange networks, completely adopting the pottery-making practices defined by this group and its standardised pottery repertoire. Coincidentally, individual burials beneath the settlements follow the standard El Argar burial rites, indicating also the adoption of a central practice of the Argaric ideology.

The central sector of the Middle and Upper Segura, what we have labelled as "interaction zone" (Fig. 18), should be considered as the borderland *strictu sensu.* Here, a coexistence is documented between settlements with significant quantities ($\leq$30%) of Argaric petrological groups and sites where the Argaric petrofacies are non-existent or just testimonial. It is in this fringe where most of the local imitations of Argaric shapes have been documented (Fig. 15). The funerary practices also underline the influence of El Argar in this area, as the burials beneath the settlements are quite common and have been detected even in those sites where few or no Argaric petrofacies have been identified. Thus, rather than a modern "Westphalian border", this zone seems to have been a place where Argaric and non-Argaric communities coexisted; a segmented space, rather than a continuous territory, where distinct human groups would have occupied territorial niches.

Finally, the northern third of the study area can be clearly considered as non-Argaric. The presence of Argaric petrofacies, albeit attested in some sites, is testimonial, with the overwhelming majority of pottery belonging to a multiplicity of petrological groups of limited geographical reach (Fig. 18). Also, in the realm of funerary practices we can observe a clear shift away from the previous two zones, with much

scarcer funerary evidence, where, a few intra-site individual burials coexist with other types of graves, such as burials outside the settlements or in caves.

The proposed methodological approach also provided valuable insights and nuance of the character of the border itself. The observation that in almost all the studied settlements several petrological groups coexisted is a testimony of the exchange of goods but also of ideas and productive techniques between communities. Argaric materials reached areas that apparently were not controlled by this group, indicating that El Argar pottery was transported and exchanged over large distances, even reaching communities with their own ceramic production. At the same time, the evidence from the *Camarillas Idols* and the C/Clc pottery indicates that certain non-Argaric materials reached Argaric areas. It follows that the Middle and Upper Segura was not a "hard" border, but rather a porous one, which allowed the movements of goods and people. The identification of Argaric shapes belonging to non-Argaric petrological groups is another key indication of the flow of ideas. However, there is a complete lack of non-Argaric morphotypes belonging to an Argaric petrological group. At the same time, some individuals were clearly buried following Argaric burial rites in settlements where local pottery production prevailed. Tombs such as those excavated at Cabezo de las Víboras (Eiroa, 1994) and El Morrón (Celdrán Beltrán *et al.*, 2023) contained El Argar metals and pottery, suggesting that the individuals buried in them probably also come from the south. The presence but not full-adoption of El Argar habits and technologies among communities undertaking local, small-scale pottery production is a clear indication of the economic and ideological impact of El Argar on its neighbours, which were compelled or willing to import their products but not the practices associated with them.

These asymmetrical but intense contacts, however, had a notable exception in the El Altiplano region, in the eastern part of the study region. These communities seem to have resisted any kind of Argaric influence despite their geographical proximity to some settlements of this entity. The complete absence of any Argaric *petrofacies* in this region, as well as the lack of intra-site burials, indicates a strong rejection against influences from the demographically and economically more developed south. Consequently, between El Argar and El Altiplano seems to have risen a "hard border", likely as a consequence of the antagonistic socio-economic systems clashing in this area. In contrast to the situation observed further west, these communities, part of the Valencian Bronze Age sphere of influence, completely opposed the expansion and influence of El Argar.

The present study provides solid evidence of the strong vertebration of the El Argar network in political, economic, and probably also ideological terms, as well as its expansive character between *ca*. 2000–1550 cal. BCE. Moreover, it has been confirmed that the scale of production and circulation of goods of El Argar was substantially larger than in the socio-economic structures of the neighbouring communities. The rise of core-periphery relations would be the most likely outcome of such productive and distributive asymmetries (Moreno Gil *et al.*, 2023; Peres & Risch, 2022, 2023). However, our study also shows that the borders between El Argar and neighbouring communities were far from monolithic and stable. In late El Argar, when political and economic relations

seem to have reached a level of complexity that would have required state or state-like structures, its economic and ideological organisation also reached its maximum expansion. Yet, while some communities managed to establish some type of exchange between core and peripheral regions, other areas seem to have isolated themselves and rejected both forms of influence. Around 1550 BCE, most settlements were abandoned or destroyed and the El Argar structures collapsed in a very short time.

The present results emphasise the heuristic potential of large-scale surveys and pottery analysis in the research of borders between economically and politically asymmetric societies of later Prehistory, away from palaces and temples which have traditionally attracted research and debates around State formation processes.

Supplementary Information The online version contains supplementary material available at https://doi.org/10.1007/s10816-025-09702-y.

Acknowledgements The present study has been supported by the Max Planck Institute for Social Anthropology (Halle Saale, Germany), the Catalan Institution for Research and Advanced Studies (ICREA) of the Generalitat de Catalunya and by the of the Ministry of Science and Innovation of Spain (PID2020-112909 GB-100 & HAR2017-85962-P). The funding for the archaeological survey of the Middle and Upper Segura was provided by the Max Planck Institute for Social Anthropology under the framework of the 4th cohort of the PhD program IMPRS ANARCHIE. The archaeological survey was authorised by the Región de Murcia Autonomous community (permit number EXC 214/2918). We want to thank Jacinto Martinez for his invaluable support during the archaeological survey and Luís Gordón at the Geology department of the Universitat Autònoma de Barcelona for his help with the preparation of ceramic thin-slices.

Author Contributions AMG and RR designed the research; AMG directed the archaeological survey; AMG, BBS and RR inventoried and classified the gathered pottery; RR, CGG and DGG carried out the petrographic analysis; AMG and BBS performed the GIS-modelling of the data, AMG and RR wrote the manuscript with the help of all co-authors.

Funding Open Access Funding provided by Universitat Autonoma de Barcelona.

Data Availability No datasets were generated or analysed during the current study.

Declarations

Competing Interests The authors declare no competing interests.

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