



Follow that blade! – Petroarchaeological proxies as indicators of human mobility during the Copper age of the SW of the Iberian Peninsula: Vila Nova de São Pedro case study (Portugal)[☆]

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ABSTRACT

Petroarchaeological proxies of blades are a powerful tool for the study of mobility in prehistoric populations to deliver more information on the network relationships of exchange, particularly during the Copper age. However, it is only recently that the first petroarchaeological studies have begun in the SW of the Iberian Peninsula, concerning Recent Prehistory.

A sampling of blades from Vila Nova de São Pedro, one of the main fortified settlements in Portuguese Estremadura, was used for petrographic and geochemical study. Following the same protocol, geological samples of flint and also igneous rocks were analysed. Additionally, a techno-typological approach was combined in order to characterize the blades types in circulation.

This preliminary study traced the diverse and complex dynamics of blade production, which involved the collection of the most readily available Rio Maior flint and the regionally selected Caxarias flint. There were no significant differences in knapping techniques for these two types of flint. The most distant oolitic varieties from Subbetic Cordillera (within 500 km) and the igneous rocks from the Iberian Pyrite Belt (within 250 km), particularly for large blades, were not debated at the site.

Due to the high numbers of those types of materials at the site, Vila Nova de São Pedro most likely played a significant role in the complex mobility networks of large blades, establishing itself as an aggregating site and possibly a distributor of these artefacts to the Southwest of the Iberian Peninsula.

Considering the proximity and the quality of Rio Maior flint sources but also to the amount of raw materials at the site sourced from a long distance, this study shows that mobility is more influenced by cultural motivations than by the availability or quality of raw materials.

1. Introduction and background

This paper presents the first results on raw material sourcing and circulation networks of the chalcolithic blades recovered in Vila Nova de São Pedro settlement, in Portuguese Estremadura.

Our work is developed in the framework of the MOBlades exploratory project: *Provenance of blades' raw material as an indicator of human mobility during the Copper age of the SW of the Iberian Peninsula* (<https://doi.org/10.54499/2023.13251.PEX>). One of the main goals of

this project about long distance mobility and interaction networks is to unravel why communities that consume local/regional flint blades also “import” them from long distances. To achieve this overarching objective, the integration of lithic raw material provenance analysis with the examination of skilled production represents a fundamental approach in order to determine the role of raw material technological constraints and cultural choices in shaping the archaeological record.

This archaeological site will be studied as an intermediate aggregation and diffusion centre, embedded in large-scale circulation networks

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where materials and people from different places would periodically arrive in the sense that was predicated to the enclosure site of Perdígões (Valera et al., 2020).

This study will focus on blades techno-typology combined with the raw material characterization aiming at the recognition of the different technological traditions and the identification of flint types as lithological tracers.

1.1. Human mobility during the Copper age of the SW of the Iberian Peninsula

Mobility is an integral component of society. To be social is, by definition, to be in relation with others and Societies are based on interaction, isolation being the exception. Mobility and contact, in the diversified forms and scales they may assume, are at the core of social organizations, and central to their understanding (Valera et al., 2020).

In recent years, raw material characterization studies along with developments in strontium isotope analyses and DNA studies have provided new evidence for the subject of movement and mobility of people, animals and objects in late prehistoric Europe (Leary and Kador, 2016; Lillios, 2020; Waterman et al., 2014). In Iberia, the existence of long-distance trade of exotic materials is supported by archaeological amber (Murillo-Barroso and Martín-Torres, 2012; Odriozola et al., 2019), ivory (Schuhmacher, 2017; Schuhmacher and Banerjee, 2012), jade, turquoise or variscite (Bradley and Watson, 2020; Pétrequin and Pétrequin, 2016; Ramírez, 2021; Sánchez-Gomez et al., 2026), raw material for polished stone tools (Lillios, 1997; Valcarce et al., 2012), oolitic chert blades (Jordão et al., 2024a; Morgado Rodríguez et al., 2011; Nocete et al., 2005) and flint (Jordão and Pimentel, 2021; Mat-aloto et al., 2017; Rodríguez Rellán et al., 2015; da Silva and Soares, 1987; Valera and Filipe, 2004).

This ‘import package’ where rocks play a nuclear role, reflects the distribution and exchange networks in which the prehistoric sites and intersects with the geological resource’s exploitation territory itself (Delvigne et al., 2021). Our first sourcing study in Vila Nova de São Pedro began with the lithic materials recovered in the recent excavations (Neves et al., 2024) based on a set of cores, flakes, bladelets and a few artefacts to detect the direct supply territory (Jordão et al., 2024b). A detailed appraisal of the raw materials available from domestic to remote sources in each territory is crucial to understand the mobility of these communities (Affolter et al., 2022; Chatzimpaloglou et al., 2020; Moscone et al., 2024). However, despite some techno-typological studies of the Chalcolithic lithic industry that include a raw material provenance component (Furestier, 2005; Moscone et al., 2020) there is a lack of provenance studies on the Late Prehistory from Western Europe, particularly in Portugal.

In a few recently excavated sites of Portuguese Estremadura it has been confirmed that, in general, the blades and particularly the *large ones* (with more than 2 cm width) were not produced in the settlements, due to the absence of blade cores and core preparation flakes (Jordão, 2024; Jordão et al., 2024b; Jordão and Cardoso, 2024; Rocha et al., 2023; Sousa, 2010). The blades but also the bifacial flaked stone artefacts were probably knapped near flint source-areas, as it is documented in Casas de Baixo (Caxarias, Ourém), and distributed from there to the consumption sites (Forenbaher, 2007, 1999, 1998; Jordão and Cardoso, 2024).

The scarcity of knapping workshops in the archaeological record and the absence of petroarchaeological chert provenance studies in Late Neolithic and Chalcolithic sites of Portuguese Estremadura contrasts with the picture available for southern Iberia (e.g. Lozano et al., 2010; Morgado Rodríguez et al., 2009, 2008), and it is difficult to identify the circulation networks of these artefacts in Western Iberia. Nevertheless, as it is observed in Portuguese Estremadura Copper age sites of Zambujal, Fórnea, São Mamede and Leceia, the oolitic chert blades, exceptional due to their raw material and dimension, seem to have their own territory of circulation, independent from the “common” blades,

knapped from local flint and with more reduced dimensions (Jordão, 2023; Jordão et al., 2024a; Jordão and Cardoso, 2024).

The results of the technical studies of blades shows strong differences among Iberian regions. In Southern Spain, the use of pressure and lever pressure with sharp dihedral butts, in Central Portugal, the use of indirect percussion, with thick-faceted butts and in the Ebro Valley, the use of pressure technique knapping, without a sharp dihedral butts, along with indirect percussion, are all well attested (Morgado Rodríguez et al., 2009; Morgado Rodríguez and Pelegrin, 2012; Pelegrin, 2006). Although cultural distinctions may exist, there are no studies that link technology to different raw materials, which would allow for a more complex territorial approach and lead to a better definition of the role of different types of rocks in defining knapping strategies.

1.2. Vila Nova de São Pedro

Vila Nova de São Pedro (VNSP – Azambuja, Portugal) is a fortified Chalcolithic settlement of Portuguese Estremadura and arguably one of the markers in the historiography of European prehistory, classified as a National Monument since November 1971. The settlement itself had two known sets of walls situated around the central redoubt, with robust bastions and various internal structures (Diniz et al., 2022).

Discovered in 1936 and excavated between 1937 and 1967 by A. Paço and E. Jalhay (Diniz et al., 2024), VNSP is situated on a hilltop that lies in the Lower Tagus valley basin in a Miocene-Pontian limestone area, over the valley of the Almoester riverine. It is an outstanding case-study because possesses one of the largest and richest artefact assemblages of Copper Age Western Iberia (Fig. 1). This large collection was recovered during 31 archaeological excavations, and the majority is exposed and kept in the Carmo Archaeological Museum (Lisbon), where there is a room dedicated to this archaeological site.

As part of a new research project – VNSP3000 – 30 years after the last work was conducted at this site (Gonçalves, 1987), excavations were resumed at VNSP in 2017 with the goal of producing new data sets using contemporary excavation techniques and multidisciplinary scientific methodologies, as well as synthesizing data from old excavations (Arnaud et al., 2017; Diniz et al., 2017; Martins et al., 2019; Neves et al., 2024, 2022). The results obtained allowed the identification of preserved archaeological levels, thereby enabling, for the first time, the association of archaeological materials, faunal remains, stone features, structural realities (constructed, reinforced, dismantled, collapsed), and other archaeological contexts. At the same time, the construction of the first chronological framework for this emblematic site of the peninsular Chalcolithic began. The absolute dating obtained for the different areas of intervention frame the Chalcolithic occupation of VNSP between 2800 and 2100 BCE and indicate a brief occupation in the 2nd millennium BCE (Neves et al., 2024).

This settlement played a core role as a production, consumption, and redistribution centre during the third millennium BCE which explains the very large concentration of pottery, flaked/polished stone tools, bone and copper artefacts retrieved at the site. In the Carmo Archaeological Museum, there are finished pieces as well as fragments and work in progress materials which show the workshop nature of the site. At VNSP, artefacts production depended on local (e.g., flint, limestone, clay) and non-local raw materials (e.g., copper, amphibolite).

2. Geological framework: Lusitanian Basin and Lower Tagus Basin

The main sedimentary formations with siliceous rocks that outcrop on the western Iberian margin are post-Palaeozoic (c. 250 Ma) (Fig. 2-A), formed in two basin systems that succeeded each other over time (Fig. 2-B): the oldest – the Lusitanian Basin (LB) –, whose sediments were deposited on the Variscan basement throughout the Mesozoic, forming a predominantly marine carbonate complex, with the occurrence of siliceous levels and nodules. More recently, from the beginning



Fig. 1. Vila Nova de São Pedro (Photo: VNSP3000 project).

of the Cenozoic, the Tagus and Sado Basins (TSB), particularly in the distal and intermediate sector of the Lower Tagus Basin, has undergone diagenesis fed by sedimentary deposits eroded from the Hesperian Massif (Palaeozoic) and the Portuguese Estremadura Limestone Massif (Mesozoic) (Fig. 2- A/B). In Cenozoic lithostratigraphy, flint occurs in carbonate formations of continental/lacustrine environments and in detrital formations, in which we find siliceous elements inherited from previous Mesozoic formations.

In Portuguese Estremadura, the Upper Cretaceous limestones are representative of a large coastal carbonate platform in the Central Sector of the Lusitanian Basin, which extended from Nazaré to Setúbal. On top of these Cenomanian ‘limestones with rudists’, nodular to bedded flint occur in the Bica Formation (Rey et al., 2006), outcropping in the Torres Vedras, Sintra, Rio Maior and Lisboa regions (Jordão and Pimentel, 2021). At its most transgressive Cenomanian stage, this carbonate platform is affected by tectonic movements, on the one hand related to diapiric activity, and on the other hand by the reactivation of fracture lines. These phenomena led to a differentiation into three palaeogeographic domains: in the Coimbra region, an open platform area; an inner sector between Leiria and Ourém and between Leiria and Lisboa, a wide reef complex of rudists. For each sector different siliceous microfacies can be associated: the Northern Sector of the Lusitanian Basin shows a flint formed in shallow, confined and low-salinity waters, receiving fine continental terrigenous inputs during the Late Cenomanian. The Central Sector, around the Torres Vedras area, seems to show that sedimentation occurred in a restricted lagoonal/marine environment, with low energy and shallow water depth. Finally, in the Southern Sector, between Sintra and Lisboa, the bioclastic assemblages became more diverse, with bivalve and gastropod fragments, suggesting sedimentation in a more open, exposed and agitated marginal zone (Jordão and Pimentel, 2025).

After the Late Cretaceous, the Triassic extensional tectonic regime was replaced by compressive phases due to collision between the African and Eurasian plates, leading to the development of sedimentary basins, generally orientated E-W to NE-SW. The Lower Tagus and Sado Basin began to fill in the early Middle Eocene, and throughout the Paleogene, under a subtropical to tropical climate (Pais, 1992). Sandy-conglomeratic sediments were deposited in an endorheic regime with carbonate intercalations, fed by the marginal reliefs of the Hesperian Massif and the uplifted formations of LB.

The Monsanto Alloformation, with a single unit, the Monsanto Sandstones, also called the “Benfica Formation”, is based on a discontinuity over the Upper Cretaceous (Pais et al., 2012). The conglomeratic

levels are particularly rich in veined quartz elements, sometimes with a smaller amount of quartzite and basic rocks, and limestone and flint pebbles from the Mesozoic border, generally highly altered. North of Lisbon, correlated with the “Benfica Complex”, the following stand out in the Alenquer and Carregado region: the Cheganças and Casais Complex, the Abridada detrital complex in the Runa basin, the undifferentiated Paleogene of Runa (Zbyszewski and Torre de Assunção, 1965) and, in the Nazaré-Cós area – the Montes Complex, “reddish conglomerates, sandstones and clays” (Zbyszewski et al., 1974) with remobilized Cenomanian flint.

Throughout the Neogene period, the filling of the Lower Tejo Basin (LTB), in addition to being conditioned by tectonics, also came to depend on eustatic and climatic oscillations. The Miocene record consists of the Almoester Alloformation: Ota Sandstones (Ar Ot), Tomar Clays (essentially on the left margin) and, at the top, Almoester Limestones (Barbosa 1995). This formation contains clasts of remobilized flint, probably from the Bajocian, and from the Monsanto Sandstones, a source of detrital nourishment (Barbosa, 1995; de Carvalho, 1968; Jordão, 2023).

The Pleistocene was characterized by the incision phase of the current river network, resulting from the response of the hydrographic network to a relative drop in sea level, estimated at between 120–140 m below the current level (Vis et al., 2008), and associated with a regional uplift of the continent and climatic modifications with the generation of both marine terraces and fluvial terraces, colluvial and alluvial deposits (Cunha et al., 2005; Martins et al., 2017, 2010). These formations were fed by the upstream lithostratigraphic deposits mentioned previously, with particular emphasis on the Quaternary terraces in the Rio Maior region, with remobilized elements from the Mesocenozoic (Jurassic, Cretaceous, Paleogene and Miocene) and on the Tagus terraces, where silicifications from the Middle Miocene and Paleogene of the Middle Tagus Basin occur (Bustillo, 2010, 1984).

3. Material and methods

Between 2015 and 2023, after bibliographic and cartographic consultation to look for geological formations with some sort of chert content, detailed fieldwork was carried out to find the exact location of the outcrops, framed in petroarchaeological studies at archaeological sites located in the Portuguese Estremadura, corresponding *grosso modo* to the Mesozoic Lusitanian Basin and Lower Tagus Basin (Jordão et al., 2022; Jordão and Cardoso, 2024; Jordão and Pimentel, 2021). From

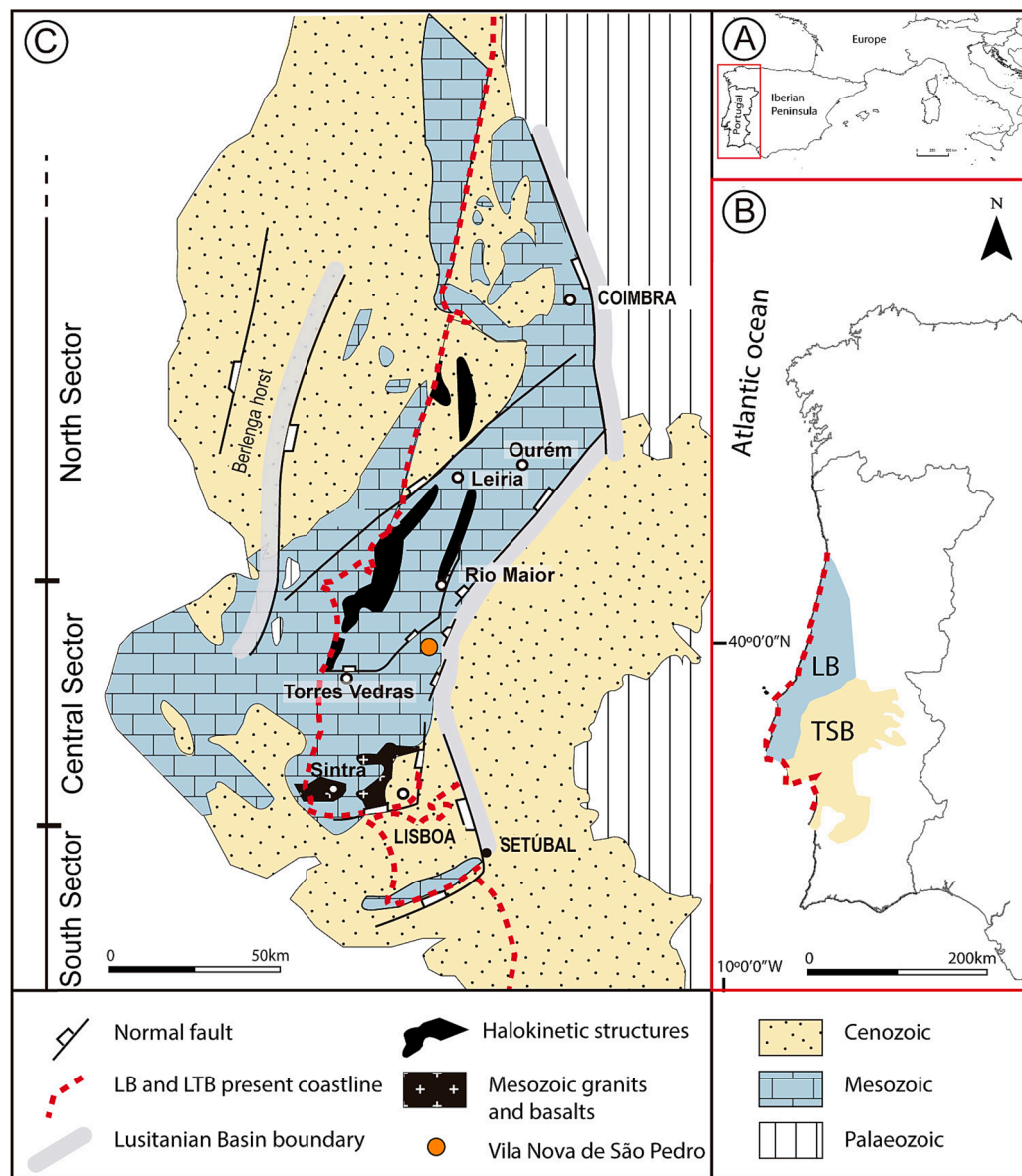


Fig. 2. A: Location of Portugal in Europe; B: Location of main basins referred in the text: LB – Lusitanian Basin and TSB – Tagus and Sado Basins (adapted from Ribeiro et al. 1979); C – Simplified geologic map of the LB, offshore part included (adapted from Azerêdo 1993), with boundaries and faults (adapted from Kullberg 2000) (Jordão 2023).

VNSP, local (5–10 km) and regional (+ 30 km) formations with flint were identified, and both primary and secondary siliceous material were sampled, whenever possible. The 136 geological samples, the central reference for this study, were published (Jordão, 2023; Jordão and Pimentel, 2023; Jordão and Cardoso, 2024). They are currently hosted at the lithothèque of the Centre for Archaeology of School of Arts and Humanities (University of Lisbon). Additionally, a new set of 12 samples were collected (Jordão and Pimentel, 2025) to improve the correlation between geological and archaeological materials: from Santa Quitéria Formation (Pliocene), near Caxarias (Ourém), where the Ne-Chalcolithic flintknapping workshop of Casas de Baixo is located (Zilhão, 1994).

Finally, 2 samples were collected from Milanos Formation (Granada), in Subbetic Zone, and 6 samples from the Iberian Pyrite Belt (IPB). The IPB samples collected in Rio Tinto region include cherts and felsic volcanic rocks with rhyolitic-dacitic chemical composition, and can be compared to equivalent rocks from the Portuguese IPB (Díez Montes et al., 2020). The physical properties of these rock types, with high

contents of SiO_2 , make them highly suitable as raw materials for archaeological tool production.

Concerning the archaeological collection, the dispersion of the assemblages over several museums and research centres hinders the systematic approach to the archaeological materials; thus, at this stage the VNSP3000 project is basically focusing on the artefacts kept at the Carmo Archaeological Museum, which are still in the inventory phase, so the total number is unknown. These finds are devoid of closed contexts and reliable associations or depositions; however, they do feature minimum references that support their ascription to stratigraphic horizons and provides approximate provenances.

A random sample of 423 blades housed in the museum storage was selected. Only unretouched blades or those with marginal retouching were considered. The artefacts made from blade were not included in this study. A combined methodology of analysis of both techno-typology traits and raw materials identification was performed. Techno-typology analysis was based on typological criteria (Inizan et al., 1999) and technological description based on the experimental knapping features

(Pelegrin, 2002, 1988; Tixier, 1976) specially on knapping techniques, crests, blades sections and variety of butt subtypes. To determine raw materials the blades were observed under a stereomicroscope Leica M205 C, with Leica camera and LAS-X software (magnification from x0,64 to x504), and 18 of them were selected to thin section.

Both archaeological and geological polished thin sections were observed and characterized using a Leica DM2700P microscope (magnification from x40 to x100), with Leica camera and LAS-X software. The general methodology for petroarchaeological characterization follows the principles proposed by Paul Fernandes and his team (Fernandes et al., 2024; Fernandes and Raynal, 2006) (Table 1 – Supplementary files). The authors use the broad term “chert” for crystalline siliceous sedimentary rocks, and “flint” specifically for siliceous nodules from Cretaceous limestones, in accordance with the British Geological Society (BGS) following journal’s policy (Hallsworth and Knox, 2020).

The “dark” non-chert blades and the non-sedimentary IPB geological samples were analyzed using a handheld X-ray fluorescence (pXRF) device (Hitachi X-MET8000 Expert Geo) to determine their main geochemical signatures. The handheld XRF analyser incorporates an optimized configuration, featuring a high-performance 50 kV X-ray tube paired with a large-area silicon drift detector (SDD) enhanced by BOOST™ technology. The instrument enables the measurement of a wide range of chemical elements, including light elements and rare earth elements (REEs). However, with an elemental detection range from Mg to U, it cannot detect Na, which may pose limitations when determining the overall chemical composition of igneous rocks. Measurements were carried out using two analytical approaches: Mining Light Elements–Fundamental Parameters and Rare Earth Elements (REE). Data acquisition was performed at two or three distinct points, with reading times of 60 s for the former and 180 s for the latter. Equipment calibrations were conducted using international reference standards that include both light elements and REEs, ensuring analytical accuracy and reproducibility. Although measurements were obtained using the REE method, this study focuses exclusively on the results for major elements, as these provide the necessary basis for the chemical characterization of the rocks.

Major element results were plotted and compared using K₂O vs. SiO₂ diagrams. The A. Ewart (1982) K₂O–SiO₂ diagram, a fundamental tool in igneous petrology, classifies volcanic rocks—such as basalts, andesites, dacites, and rhyolites—according to their potassium oxide and silica contents. Plotting the samples on this diagram allows their chemical compositions (potassium vs. silica) to be evaluated against established compositional fields. The Total Alkali–Silica (TAS) diagram was not applied in this study because sodium (Na) content was not measured by pXRF.

4. Results

4.1. Blades techno-typology

The siliceous blades are one of the most impressive group of artefacts recovered at VNSP. The sample of 423 blades inventoried in this study forms part of that collection which greatly exceeds the quantities of such artefacts recorded in similar settlements in the Portuguese Estremadura. As with related studied sites – Zambujal (Jordão, 2023), Penedo do Lexim (Sousa, 2010) – only a small proportion of the blades (8%) are complete, while a further 10% are nearly complete with a fragmented tip, highlighting those in the mesial and proximal states (Fig. 3).

In the techno-typological characterisation, we selected the width and thickness parameters to detect differences between the raw materials and the degree of standardisation. This is because more than 90% of the set was fragmented, and the proximal fragments containing the butt information were heavily affected by retouching, although this was mostly simple edge retouching.

Most blades have standardised regular edges (60%). Sometimes these are convergent (24%), and less frequently, they are irregular (9%)

Conservation status

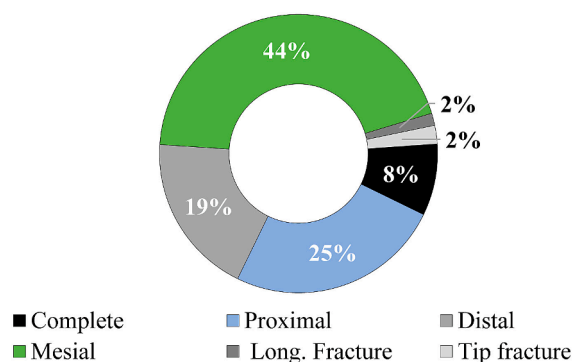


Fig. 3. Conservation status of VNSP blades.

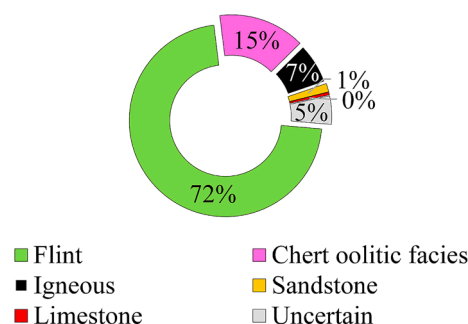


Fig. 4. VNSP blades’s features of the edges (a), the cross section (b) and butt (c).

(Fig. 4a). The blades are in an advanced stage of debitage, as shown by the majority of trapezoidal cross sections (Fig. 4b). A triangular cross-section is also present (36%). Therefore, the number of blades containing cortex is reduced (11%).

In 33% of complete or proximal blades, only where the proximal part is not affected by retouch, it was possible to observe mainly both plain and punctiform butts (38% and 28% respectively), followed by faceted (23%). These butt subtypes indicate the technical features observed in the blades manufactured in Central Portugal – indirect percussion, thick-faceted butts (Morgado Rodríguez et al., 2009; Pelegrin, 2006) or punctual. Faceted butts are most characteristic in blades from the Casas de Baixo workshop (Fig. 4c and Fig. 5, left). Although, dihedral represent a small percentage of butts (7%) (Fig. 4c; Fig. 5, right), suggesting a platform preparation with copper-tipped pressure tools as the author observed previously in Greece during Late Neolithic (early 5th millennium BC) (Perlès, 1984), Pakistan in the Chalcolithic period (late 5th millennium BCE) (Inizan et al., 1994; Inizan and Lechevallier, 1991) and Canaanite flint blade in the Levant (Chabot, 2002; Chabot and Pelegrin, 2012), this new knapping production element, namely, a metallic pressure point (copper) for blades’ debitage, is also characteristic of Southern Spain (Pelegrin and Morgado Rodríguez, 2007).

The maximum widths are distributed between 13.5 mm and 36 mm, but they are concentrated between the 18–22 mm dimensional class, above the needed value for manufacture of lever pressure (Morgado Rodríguez and Pelegrin, 2012). Thicknesses, ranging from 2.7 mm to 14.9 mm, are concentrated between 4 mm and 10 mm. Although wider (and probably longer) products are thicker, there is no proportional increase in width, with a weak R² Pearson correlation of 0.2 (Fig. 6a and Fig. 6b).

VNSP-MAC-88

VNSP-MAC-462



Fig. 5. An example of the most characteristic blade technology is the Caxarias flint (left), which has regular edges, a triangular cross-section and a faceted butt with a clear bulb, obtained by indirect percussion. In contrast, the regular edges, trapezoidal cross-section and dihedral butt with a smooth bulb result from pressure technique (right).

4.2. Blades petrography

The 423 samples from VNSP were macroscopically described and the textural features and micropalaeontological content were defined through stereoscope microscope. Then, 18 thin sections were prepared, and petrographic analyses were performed from blades according to their different features previously observed. Below we describe the main features of the blade's sedimentary raw material at three scales:

- i. six main types of siliceous raw material were identified, mostly cherts. The most significant group contains marine flint from the Lusitanian Basin (72%), from brown to reddish and grey coloured, semi-translucent to opaque, mudstone texture, sometimes with visible bioclasts (Table 1 – Supplementary files).

- ii. in smaller percentage the oolitic variety of chert (15%), very homogeneous in colour – beige to light grey – with rough and opaque surfaces, sometimes exhibiting porosity.
- iii. followed by the igneous fine-grained rocks (7%) and an almost insignificant amount of other sedimentary rocks like sandstone and limestone.
- iv. lastly, a small quantity of rocks with some degree of uncertainty in their classification, notably due to poor visibility of surfaces (burned or coverage with concretions) (4%) (Fig. 7).

The combined observation with stereo and petrographic microscope (thin section) allowed us to confirm and to detail the macroscopic differences between cherts, particularly among Mesozoic flint: a set of samples named Group 1, shows microcrystalline quartz with some marine bioclasts filled with macrocrystalline quartz (e.g., Bivalvia,

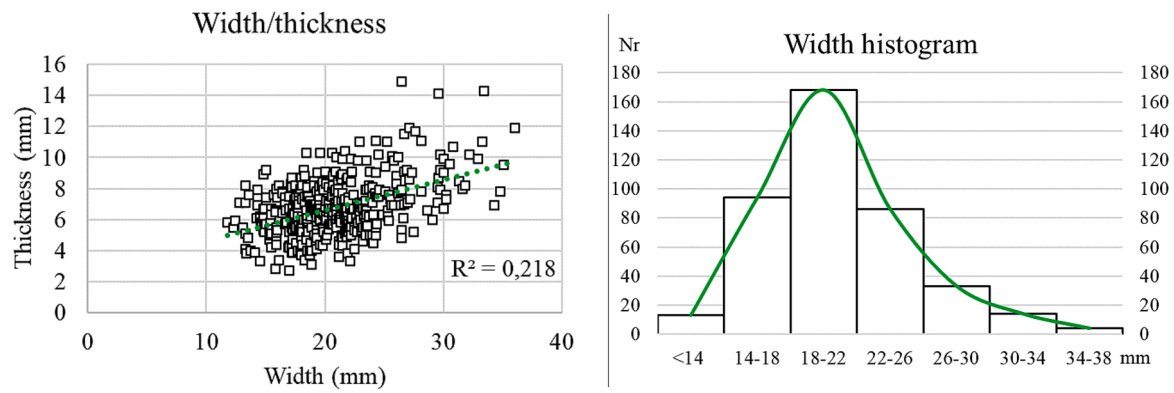


Fig. 6. A: Maximum width /thickness of VNSP's blades with a weak R2 Pearson correlation between both measures (on the right); B: width histogram with the class between 18–22 mm is highlighted.

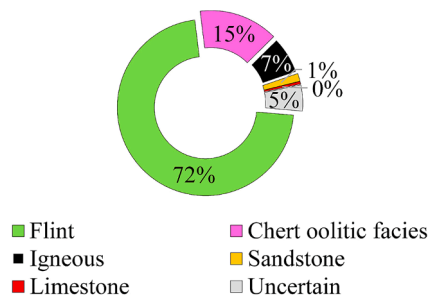


Fig. 7. Flint types from Lusitanian Basin: Oxfordian (J3-LB); Lusitanian Basin Cenomanian (C3-LB); Rio Maior Type Cenomanian flint (RM-2); uncertain Rio Maior Type (RM-1/2); Caxarias flint (Caxarias); Cenomanian Bica Formation and Uncertain type.

Foraminifera), with very altered muscovite (Fig. 9A). Although it is still poorly characterized as RM-2 type (Jordão et al., 2024b), it is probably correlated with Cenomanian shallow marine flint outcropping in secondary deposition at Arenitos de Ota Formation in Rio Maior, close to VNSP (Fig. 9B). This type is one of the main raw materials used in 28% of VNSP's blades (Fig. 8).

The Cenomanian flints from Portuguese Estremadura are texturally and mineralogically very similar. Their *mudstone* microcrystalline textures with very poor palaeontological content cannot be clearly distinguished. In addition, some characteristics have been noted in a few

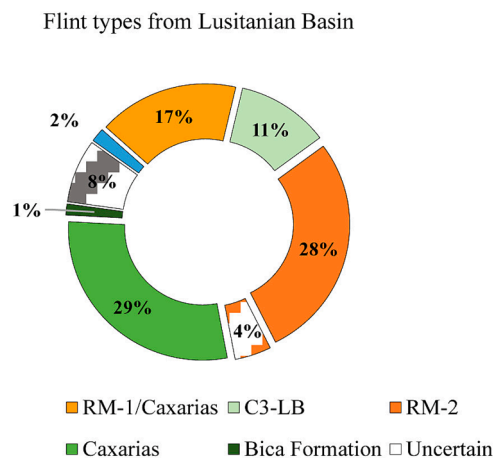


Fig. 8. Main types of siliceous raw material from VNSP's blades: flint (green), chert facies oolitic (purple), fine grained igneous rock (black), sandstone (yellow), limestone (red) and uncertain (grey).

samples (1%, Fig. 5): mostly *wackestone*, with some different bioclasts, as Foraminifera types, which allows us to distinguish another type, the Group 2 with correlation with the Cenomanian flint from Bica Formation (Lisboa) (represented in Fig. 10A, by VNSP-MAC-28 sample and Fig. 10B, by RS-15 sample).

Another type was observed – Group 3 – characterized by greater bioclast diversity typical from shallow marine to lagoon facies. Some samples presented a heterogeneous structure (Fig. 7A), similar to Oxfordian flint from Cabaços Formation (J3-LB, Fig. 8) (Fig. 10B). However, in 17% of the blades the classification assignment between the Oxfordian flint from secondary deposition variety from Rio Maior (RM-1, Jordão, 2023) and the flint from Caxarias – was not conclusive. Both are from secondary deposits and exhibit allochems associated to lagoonal facies (e.g., algae). On the other hand, even genetically different flints outcropping in the same detrital formation may looked very distinct without a microscopic observation.

Another set of blades were distinguished with predominantly opaque to semitranslucent surfaces, iron oxides and micrite aggregates. In thin section, the main *mud-* to *wackestone* textures, containing uncertain fragments of bioclasts, phytoclasts (fragments of vegetal tissues and carbonaceous material) peloids and detrital allochems, as muscovite (Fig. 11A and Fig. 11C). The Group 4 correspond to 29% of the blades set and is associated to marine confined to lagoonal facies, present into the Northern Sector Cenomanian of the Lusitanian Basin, where the Casas de Baixo (Caxarias) flint workshop (Zilhão, 1994) is located. The “Caxarias flint” (Aubry, 2009; Jordão, 2023; Jordão and Pimentel, 2025) is outcropping in a secondary Pliocene formation, approximately 100 km from VNSP (Fig. 11B and Fig. 11D).

Concerning oolitic facies – Group 5 –, its occurrence was observed in approximately 15% of siliceous raw material (Fig. 7). Macroscopically, the VNSP's oolitic blades are very homogeneous in colour – beige to light grey – with rough and opaque surfaces, sometimes exhibiting porosity. In thin section, the structure is micro- to mesocrystalline, related to the original micrite and sparite in the host limestone, partially preserved in both samples VNSP-MAC-92 and VNSP-MAC-96 (Fig. 12 – 5a).

The samples have a grainstone oolitic texture, suggesting a shallow-marine environment, where grains are kept in constant motion (Scholle and Ulmer-Scholle, 2003, p. 228). Although they may be associated to different microfacies:

5a) with a silicified matrix composed of micro- to mesoquartz and some fibrous quartz, and allochems frequently carbonated, containing oolites (up to 0.8 mm), other coated grains, bioclasts (echinoid spines, bivalves, foraminifers) (Fig. 12-5a). This variety could be correlated with oolitic facies from the Milanos Formation (Granada), recently sampled by our team (Fig. 12, Mil_2), where important chert mining and blades workshops, such Los Gallumbares, are located (Morgado Rodríguez et al., 2011) (Fig. 16).

Group 1 - Marine mudstone facies

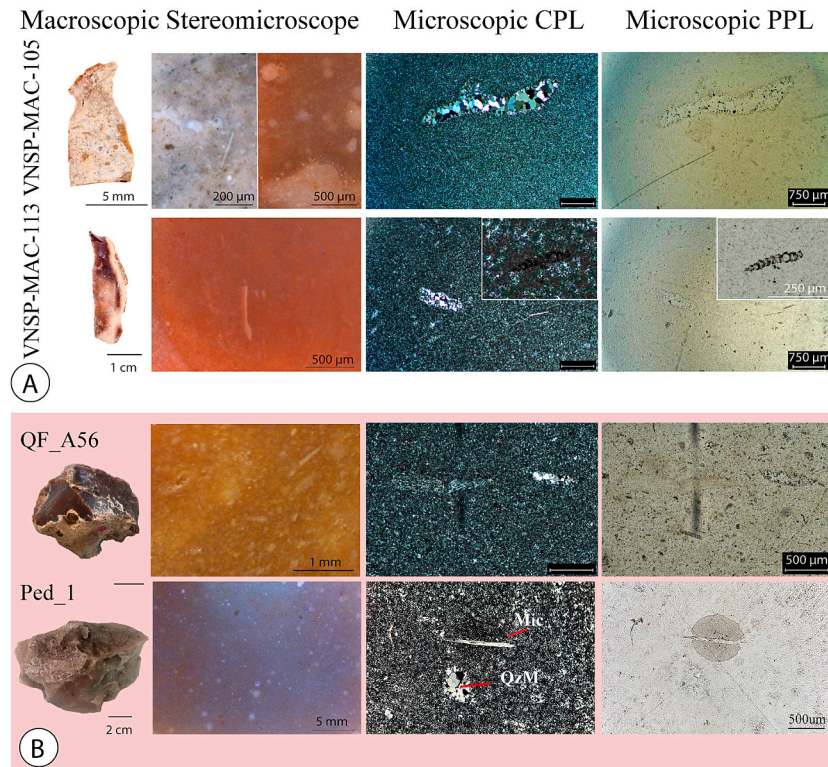


Fig. 9. A: Archaeological samples of shallow marine siliceous microfacies – VNSP-MAC-105 and VNSP-MAC-113 reddish flint, both showing bioclasts; in thin section, with quartz micro- to cryptocrystalline structure, mudstone texture with bivalves' fragments and Foraminifera Textularidae highlighted. B: Samples from Arenitos de Ota Formation (Rio Maior) – QF_A56 and Ped_1, the first one showing bioclasts; in thin section, with quartz micro- to cryptocrystalline structure, mudstone texture with bivalve fragment filled with macrocrystalline quartz (QzM) and muscovite (Mic) (Cross Polarized Light – CPL / Plane Polarized Light – PPL).

5b) almost completely silicified, including the cortical layer of ooids, with a matrix with micro- to mesoquartz and some fibrous quartz. The allochems are mainly homometric oolites (up to 0.2 mm). This high weathered texture shows secondary porosity by dissolution. There is evidence of fissures filled with chalcedony and ferruginous aggregates surrounding oolites (Fig. 12 – 5b). This facies is characteristic of the oolitic chert from the Malaver Formation (Ronda, Malaga), which has several mining sites (Morgado Rodríguez and Lozano, 2011) (Fig. 16).

Some flint artefacts could not be assigned a more exact provenance due to several factors hindering their identification, such as alterations (e.g. fire, white patinas), which result in micro-fissures, colour changes, and porosity. Other factors include the difficulty of identifying discriminant criteria, or the absence of such factors. Therefore, in 12% of the blades the raw material could only be associated to *mudstone* marine flint, frequent in the Lusitanian Basin Cenomanian. In a small fraction of the blades (5%), it was not possible to recognise a texture that could be associated with a formation environment.

4.3. XRF-p analysis

In an attempt to determine the composition of the 7% dark non-sedimentary blades, portable X-ray fluorescence (pXRF) analysis was performed and results were compared with a small group of geological samples.

The dominant elements (Wt% > 10%) for both groups are SiO₂ (46.6–91.6%), Al₂O₃ (0.3–17.2%), CaO (0.2–22.8%), and K₂O (0.0–11.0%). To support sample classification, the results were displayed graphically. Both geological and archaeological samples were plotted on the A. Ewart K₂O vs. SiO₂ graph (Ewart, 1982).

The results of pXRF analysis on the geological samples allowed to

conclude on their volcanic signature, mainly represented within the rhyolitic-dacitic composition fields (Fig. 10). Although samples Geo_2 and Geo_3 are not plotted in the graph, due to their high values of K₂O (8.21%) and SiO₂ (80.44%) respectively, microscope observations confirm rhyolitic affinity. Sample Geo_4 represents a distinct lithology, as it was collected from a quartzite formation.

The results also show that there are clearly rhyolitic-dacitic blades among the collection of the 7% dark non-sedimentary blades (Fig. 13): (VNSP-MAC –) 2, 3, 5, 7, 8, 14, 17, 19, 20, 40, 103, 592.

The figure also shows four archaeological samples plotted in the low-K basalt area but eye and microscope observations are only consistent with a classification as volcanic rocks: (VNSP-MAC –) 9, 12, 33 and 387. This highlights the need for a complete chemical analysis supported by thin-section microscopy.

pXRF is a very convenient analytical technique as it is non-destructive and enables rapid chemical characterization of a wide range of materials. However, the equipment employed demonstrates restricted sensitivity to light elements such as sodium, representing a significant analytical limitation to the accurate determination of the complete chemical composition of rocks.

The preliminary results obtainable for the 'dark' non-chert blades represent only the initial phase of this study. Subsequent research will incorporate a larger set of geological samples and petrographic characterization through thin-section microscopy to contribute to the identification of these blades.

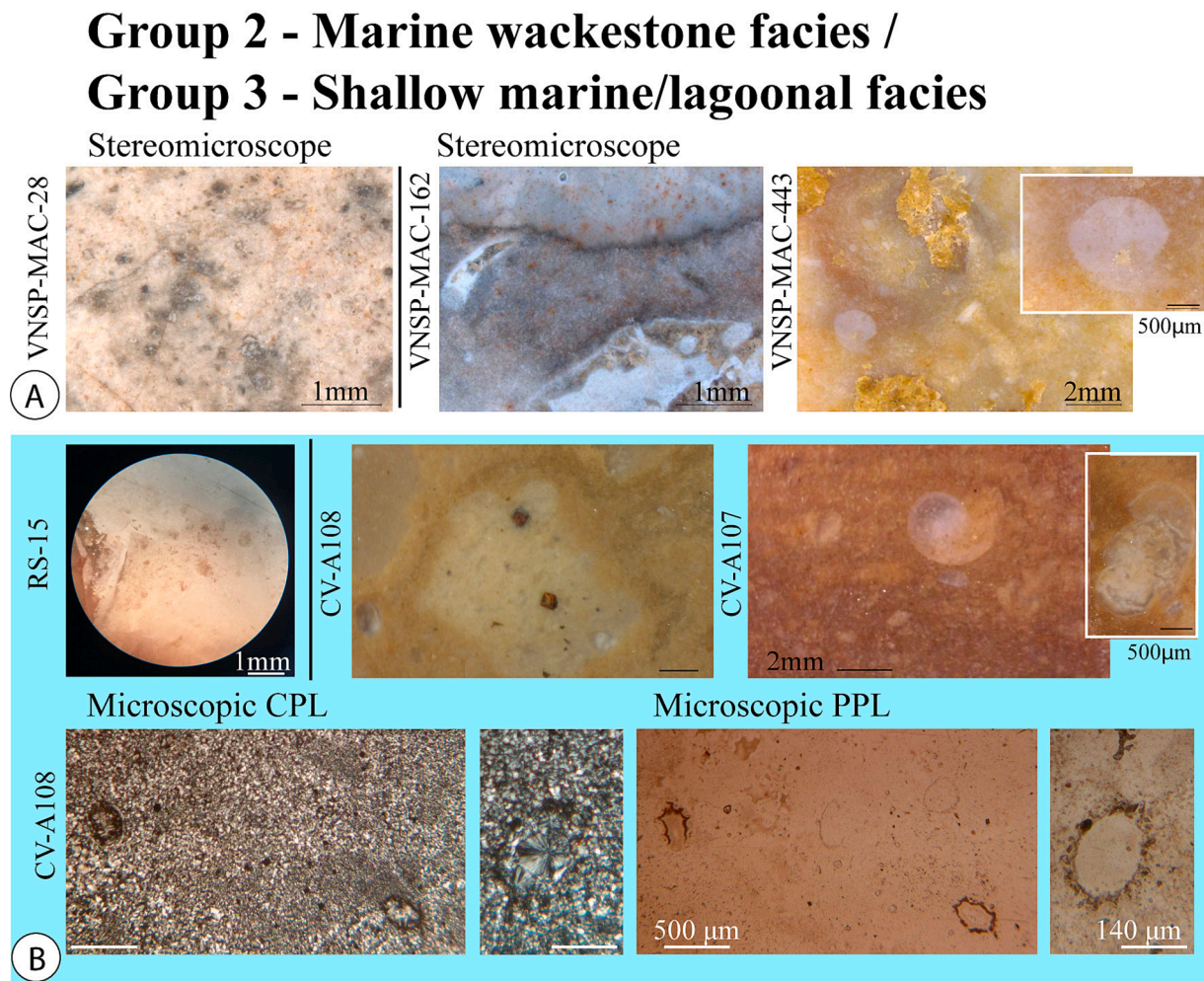


Fig. 10. A: Archaeological sample of marine wackestone siliceous microfacies – VNSP-MAC-28 showing diverse bioclasts included Foraminifera; Archaeological samples of shallow marine / lagoon siliceous microfacies – VNSP MAC-162 and VNSP-MAC-443 with bioclasts with a gastropod highlighted. B: RS-15 – sample from Bica Formation (Cenomanian, Lisboa) showing diverse bioclasts; CV-108 / CV-107 – samples from Cabaços Formation (Oxfordian, Porto de Mós) with similar bioclasts to those identified in the archaeological sample VNSP-MAC-443, with a labelled gastropod; in thin section, with quartz micro- to mesocrystalline structure, *mud-wackestone* texture with charophyte algae highlighted filled with chalcedony (Cross Polarized Light – CPL / Plane Polarized Light – PPL).

5. Discussion

5.1. Provenance of Vila Nova de São Pedro's blades

The combination of petrography, geochemical and techno-typology results of VNSP's blades have allowed us to distinguish six siliceous raw material groups of archaeological microfacies, that can be identified based on particular characteristics.

Flint blades are by far the most common at Portuguese Estremadura Chalcolithic sites (Jordão, 2023; Jordão and Cardoso, 2024), as at VNSP where they reach 70%. Mostly Cenomanian flint, they are texturally and mineralogically very similar, and some samples could not be characterised in detail (12% of C3-LB samples, Fig. 5). The technological features are also very similar among these blades. The width measurements of those flint blades have a wider spectrum than the other main types, between 13,5–30 mm, with two important dimensional classes between 14–22 mm (Fig. 14; Fig. 15 – Other Lusitanian Basin flint). We also noticed that above the 25 mm width these flint blades have an irregular shape.

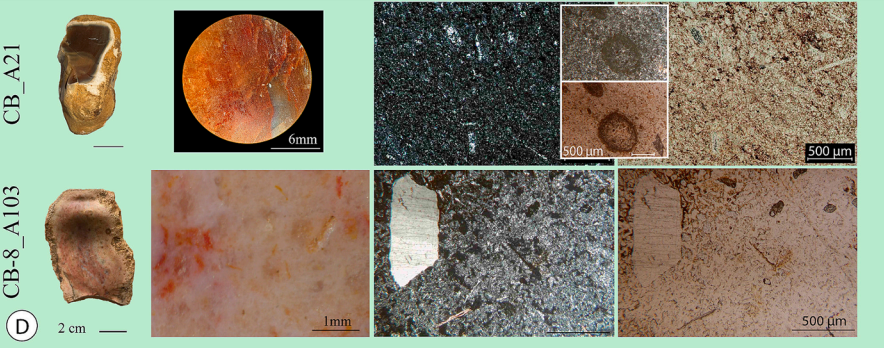
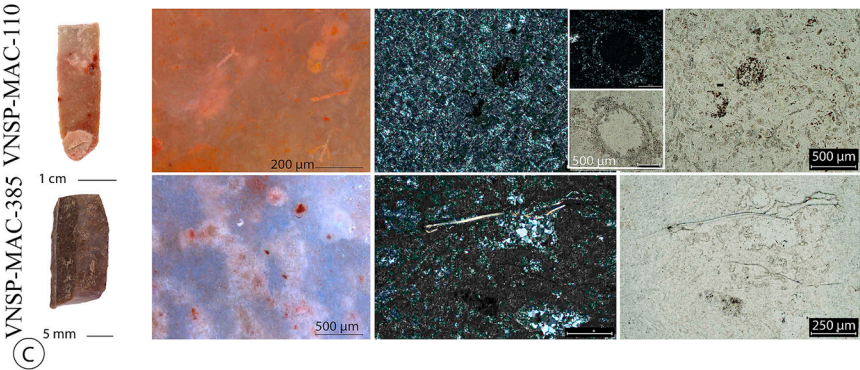
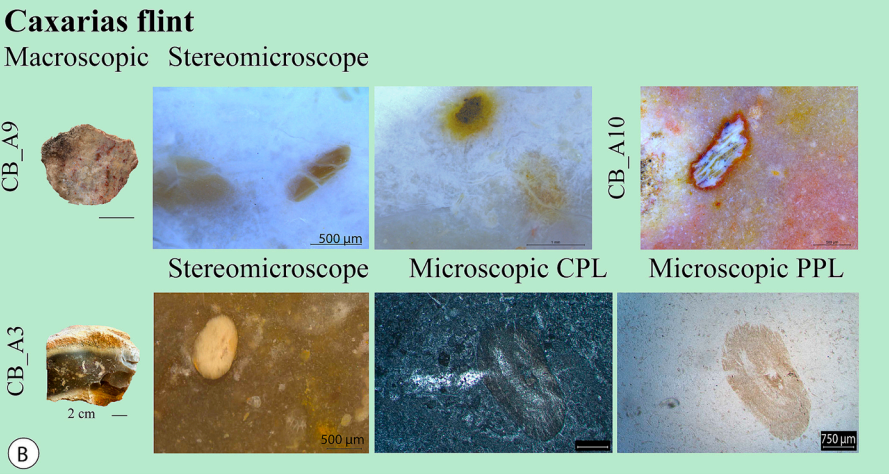
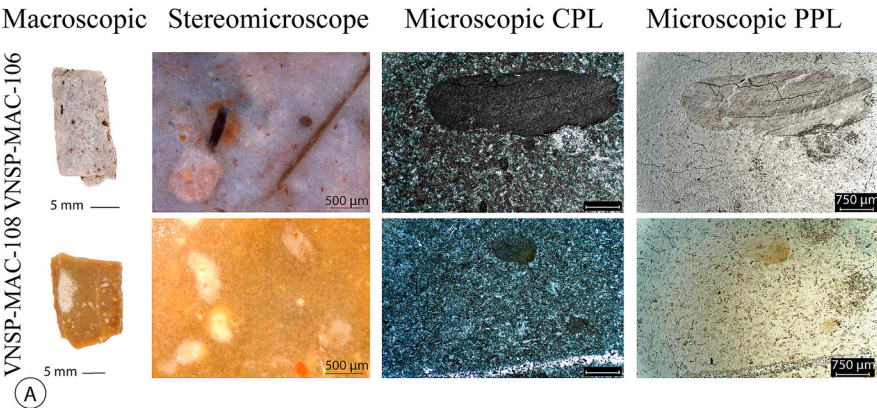
The most significant fraction of LB flint is the Caxarias flint-type, available in the Santa Quitéria Formation in secondary position, next to the Casas de Baixo workshop. The 31% of the elongated products knapped with this rock are more homogeneous in width, ranging from

16 to 20 mm. (Fig. 15). The blades less than 24 mm wide, with faceted or plain butts, produced by indirect percussion are indicative of a technological tradition, which has been associated with Portuguese Estremadura production contexts (Jordão and Pimentel, 2025; Morgado Rodríguez et al., 2009; Morgado Rodríguez and Pelegrin, 2012). The number of blades made from this type of flint may be even higher if we include the 18% of samples which it was not possible to distinguish between Cenomanian marine flint from Rio Maior and Caxarias.

The petrographic analysis enables us to distinguish other LB flint types. Approximately 30% of this flint occurs in secondary position in detrital Miocene and Pleistocene formations up to 15 km away from the site, in the vicinity of Rio Maior. Several production contexts for bifacial flaked stone artefacts have been identified in the Rio Maior region since the Palaeolithic (Bicho, 1992; Forenbaher, 1999, 1998; Shokler, 2002; Zilhão, 1997). However, although there are currently no records of blade workshops in the region, it is likely that they were produced in specialised workshops and then transported to the settlement. One of the specific features of the set lies in the fact that the few cortical or semi-cortical blades were configured from locally sourced Rio Maior flint.

This leads us to believe that perhaps the flint cores were not left behind, but transported to be used in future products and tools. This hypothesis should be cross-referenced in the future with evidence related to the types of support versus types of flint used in the lithic

Group 4 - Marine confined/lagoonal facies



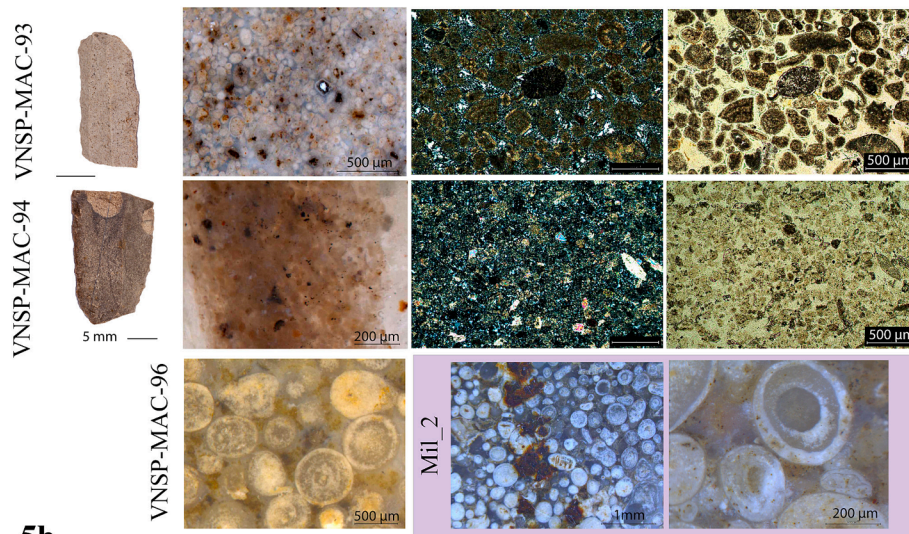
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Fig. 11. A: Archaeological samples of marine confined to lagoonal siliceous microfacies – VNSP-MAC-108 rose and VNSP-MAC-106 reddish flint, the first one showing bioclasts and phytoclasts, in both observed in thin section, with quartz microstructure, *mudstone* texture with fragments of vegetal tissues and carbonaceous material. B: Samples from St. Quitéria Formation (Caxarias) near Casas de Baixo workshop – CB_A9, CB_A10 and CB_A3, all showing phytoclasts fragments as can be observed in thin section as. C: Archaeological samples of marine confined to lagoonal siliceous microfacies – VNSP-MAC-110 reddish and VNSP-MAC-106 reddish grey flint, the first one showing sponge spicules, and charophyte algae in thin section; the other, present muscovite fragments in the matrix. D: Samples from St. Quitéria Formation (Caxarias) near Casas de Baixo workshop – CB_21 reddish and CB-8-A103 rosed flint, with non-carbonated cortex, showing fragments of ferruginous bioclasts; in thin section, mineroclasts of muscovite and calcite can be observed (Cross Polarized Light – CPL / Plane Polarized Light – PPL).

Group 5 - Oolitic chert

Macroscopic Stereomicroscope Microscopic CPL Microscopic PPL

5a



5b

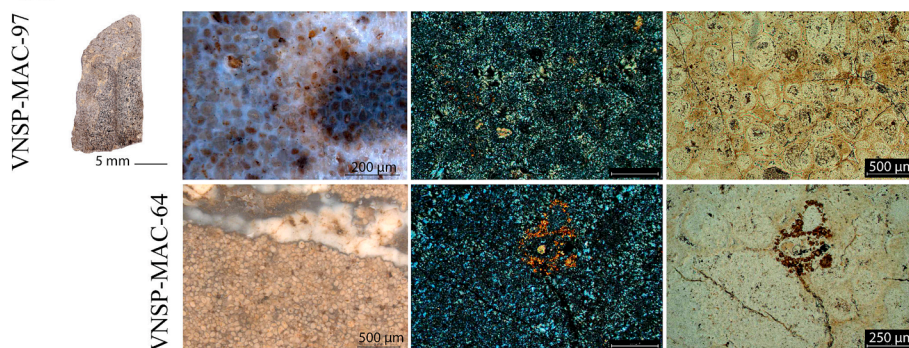


Fig. 12. Group 5a: Archaeological samples of oolitic chert facies Milanos – VNSP-MAC-93 blade with several allochems, such bivalve's and echinoid's fragments and VNSP-MAC-94, partially silicified, with the same texture. The rounded layers of oolites are clearly in VNSP-MAC-96 sample. Samples from Milanos Formation correlated with VNSP's are highlighted in light purple. B: Group 5b: Archaeological samples of oolitic chert facies Malaver – VNSP MAC-97 blade with homometric oolites; in thin section with ferruginous aggregates around oolites; in VNSP-MAC-64 it can be observed fissure filled with chalcedony (Cross Polarized Light – CPL / Plane Polarized Light – PPL).

industries of the Chalcolithic settlements in the region. Despite this, blades from Caxarias stand out from those produced with other types of flint (most of which come from Rio Maior) due to their more standardised characteristics (parallel edges, dimensions, cutting technique), which are systematically present in Chalcolithic sites in Estremadura.

Concerning the oolitic chert blades, they have a similar spectrum with slightly higher values than those of the previous groups, above 16 mm, with the most important dimensional width classes between 18 and 30 mm. The values available for Zambujal are identical: their maximum width and thickness varies between 16–32 mm (Jordão et al., 2024a, p. 6). Studies on blade morphometry concluded that production was not very standardised in the 4th millennium, whereas in the 3rd millennium, production became more normalised (Nocete et al., 2005). Regarding the chronology of Zambujal's oolitic blades, most of them date from the

younger phase, spanning the end of the 3rd millennium to the first half of the 2nd millennium BCE. It seems that there is no association between standardisation and a more recent chronology in Extremadura contexts.

What distinguishes VNSP from other consumption sites in the western Iberian Peninsula is the abundance of extra-regional blades, mostly oolitic chert blades. While these account for approximately 1% of the blades at Zambujal (Jordão et al., 2024a) and Leceia (Jordão and Cardoso, 2024), they constitute 15% of the total at VNSP. The technological characteristics of these super tracer flint blades (Tarrío Vinagre et al., 2016), such as widths greater than 24–26 mm and the sharp butt dihedral preparation technique, suggest an association with the southern part of the Iberian Peninsula (Morgado Rodríguez et al., 2009).

The igneous (7%) blades have identical technological features. Their likely provenance from the Iberian Pyrite Belt (García Sanjuán et al.,

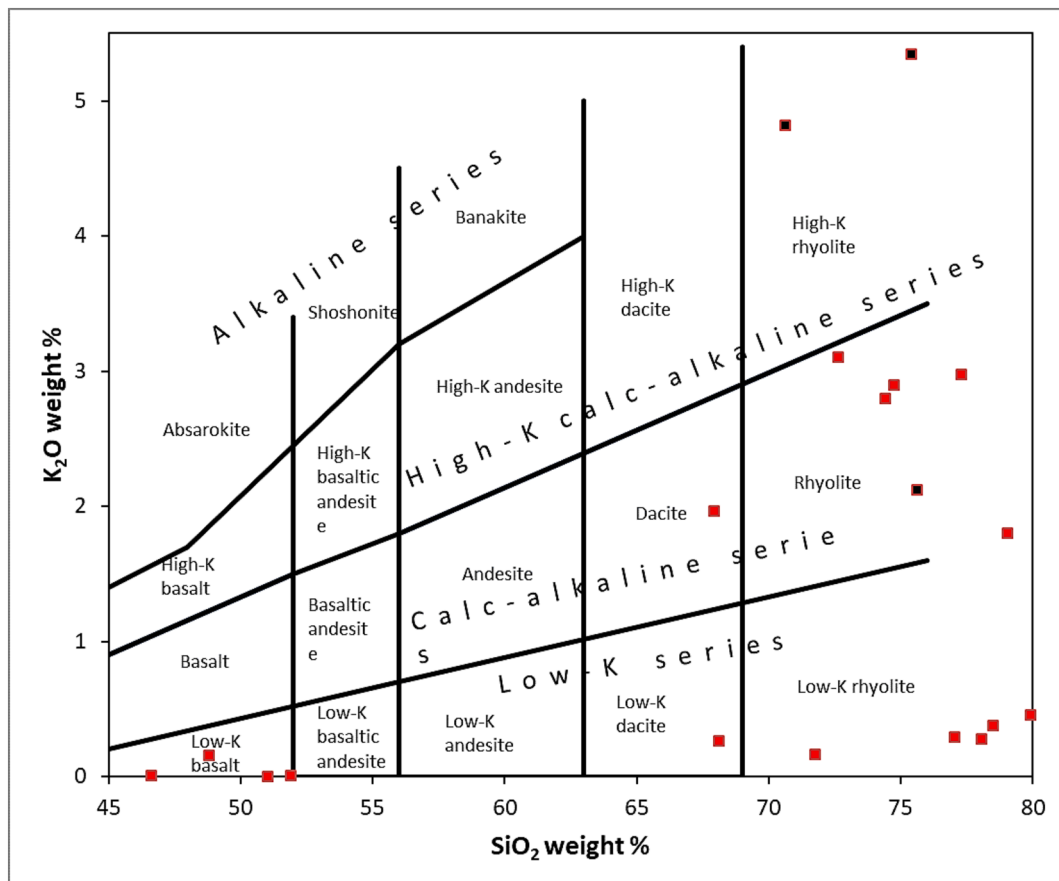


Fig. 13. The A. Ewart K2O vs. SiO₂ graphic – projection of geological samples (black squares) and archaeological samples (red squares) based on their silica (SiO₂) and potassium (K₂O) content. (adapted from Ewart, A., 1982).

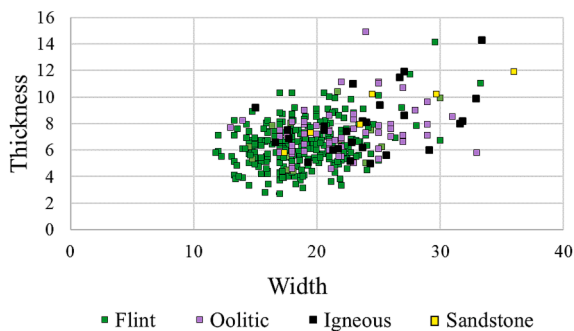


Fig. 14. Thickness and width of VNPS blades by main raw material types: flint (green), oolitic chert (purple), igneous (grey) and sandstone (yellow).

2016; Morgado Rodríguez et al., 2009) where knapping workshops are located (Linares et al., 1998; Vallespi Perez et al., 1988) place these artefacts in the same circulation corridors as the oolitic chert blades. Adding up all the blades from long distance regions, including those made of siliceous sandstone, it is observed that 22% of the sample belongs to the “import package” from the south-west of the Iberian Peninsula.

5.2. Petroarchaeological proxies and human mobility in SW of Iberia

In VNPS's blades flint was the most frequently used raw material. There are two main areas where the flint comes from: Group 1 type from Rio Maior, close to the site, and Group 4 type from Caxarias, about 90 km to the north, both in Cenozoic conglomerates, in secondary position.

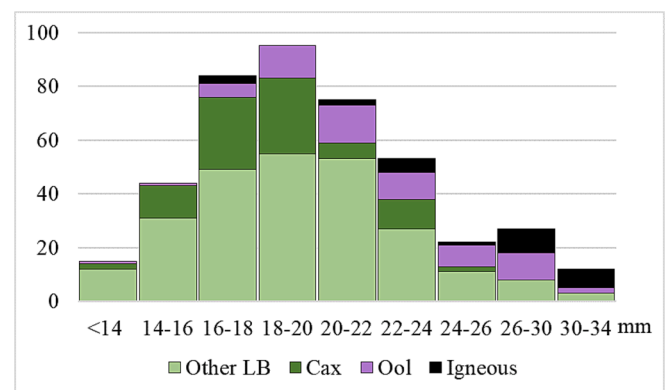


Fig. 15. Width histogram by main raw materials groups: Caxarias flint (dark green); Other Lusitanian Basin flint (light green); oolitic chert (purple); Igneous (black).

Clasts between 5 and 20 cm length of “Caxarias flint” were explored for blades as can be documented at the specialized workshop of Casas de Baixo (Caxarias) (Aubry, 2009; Jordão and Pimentel, 2025). This type of flint, which is associated with blades that are mostly between 18 and 22 mm wide and was produced using an indirect percussion technique, that was systematically recognised at studied Chalcolithic sites in the Estremadura region, such as Zambujal (Jordão, 2023), São Mamede (Jordão, 2024), Leceia (Jordão and Cardoso, 2024), and Outeiro Redondo (Jordão and Cardoso, forthcoming) (Fig. 16). These data confirms that this type of flint is a reliable marker of territorial mobility. Studies we have been conducting as part of the MOBlades project indicate that these

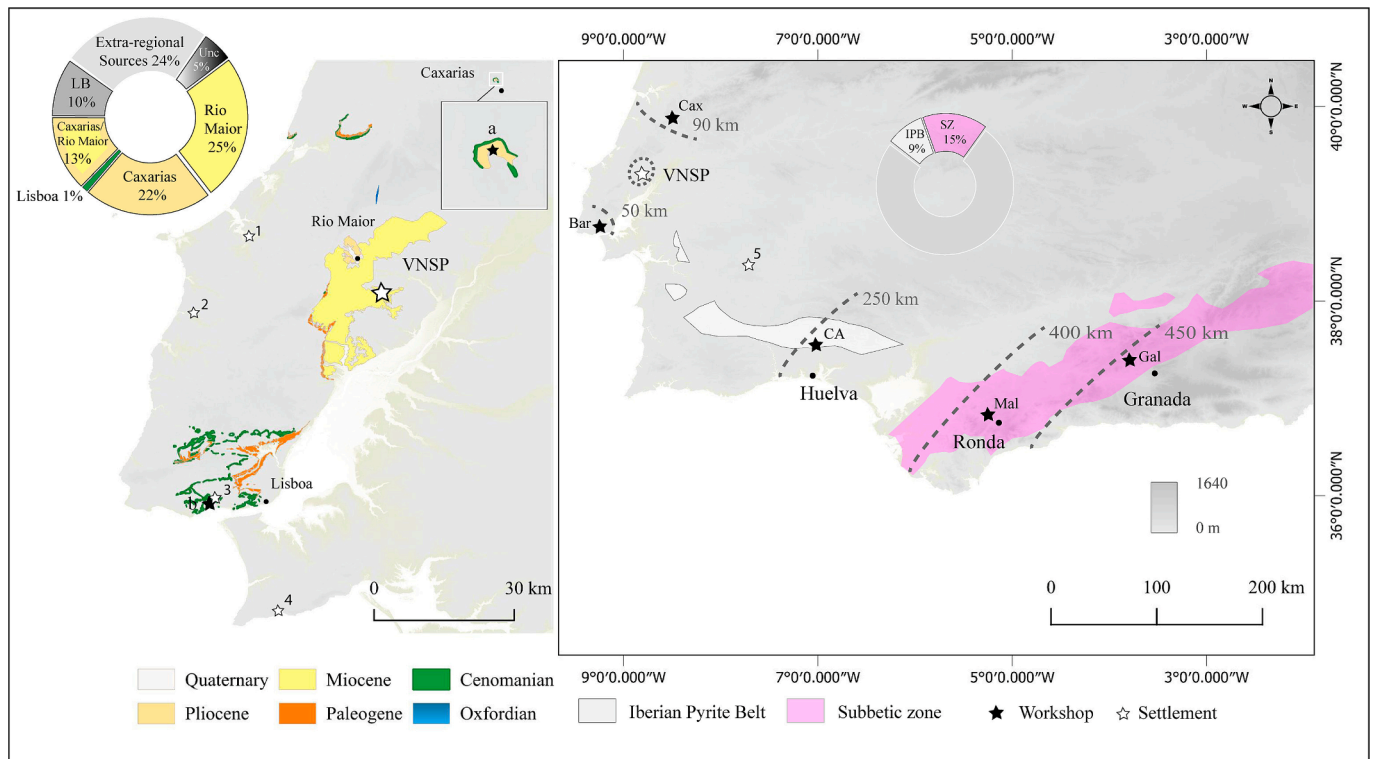


Fig. 16. Local and regional Mesozoic formations as main source-areas of VNSP53's blades raw material, on a simplified geological map (on the left): Group 1 – Rio Maior (32%); Group 4 – Caxarias (29%). Directions of provenance and distance raw material sources of VNSP's blades in the SW Iberia simplified geological map (on the right): local, until 50 km; regional, more than 50 km and extra-regional, more than 200 km. Main settlements referred in this study (white stars): 1 – São Mamede; 2 – Zambujal; 3 – Leceia; 4 – Outeiro Redondo; 5 – Perdigões. Blades' workshops (black stars).

blades are also present in Alentejo and Andalucía (in preparation by the authors), suggesting that it is probably an excellent lithological marker.

The other main type is the Cenomanian marine facies collected in the detrital formations of the Rio Maior source area, from Palaeogene to Pleistocene, close to VNSP (Fig. 16). This flint was explored as raw material for the general tools at the site (Jordão et al., 2024b). Therefore, the fact that VNSP was a consumer of local flint allows us to assign a different value to typologically identical artefacts made from non-local raw materials. It should be noted, however, that it was not possible to clearly distinguish between Caxarias and the Cenomanian flint from Rio Maior (RM-2) in 13% of the blades. Consequently, there may be more Caxarias blades than previously thought, which highlights the importance of the supply from this specialised site (Fig. 16).

With regard to Lisbon flint, this has so far been residual in the VNSP's universe of lithic artefacts. Previously, flint from the Bica Formation, a regional tracer, had been identified in finished tools, such as bifacial flaked stones and arrowheads, indicating integration into regional networks. (Jordão et al., 2024b).

The exceptional character of VNSP focuses on the role it seems to have played in the network of relations between the sites of the westernmost part of the Iberian Peninsula and the flow of materials that would have circulated from what is now Andalucía.

This 'import package' of large blades – oolitic chert beige and igneous 'dark' – did not stem from the necessity to compensate for local shortages of certain raw materials or artefactual typologies. A considerable number of elongated products were indeed obtained from local and regional outcrops in VNSP. Hence, the practices of acquiring and using exogenous blades seem to have had a more cultural and social function than a pragmatic one. Non-economic justifications for the presence of foreign lithic raw materials are common for other European sites. For example, the choice of basalt artefacts related to early agrarian cultures (Neolithic and Bronze Age) in Central Poland (Bartz et al., 2024) – which exploit local flint of good quality – may have been caused

not only by the exceptional physical properties of the material, but also by its unique aesthetic qualities (Werra et al., 2024).

Colour as a means of attributing different meanings to similar objects has been detected in various contexts in recent prehistory, especially in construction elements. The Preseli dolerites and the Stonehenge 'blue-stones' are perhaps the most famous examples (Thomas, 1923), with a wide range of meanings attributed to them (e.g. Bevins et al., 2021). In Perdigões Tomb 4 (Portugal), built with gabbro blocks, a single block of dark grey diorite stands out, creating a chromatic contrast with the beige gabbro, aligned with the north cardinal point (Valera, 2020). In this sense, perhaps black blades and beige blades, which are functionally similar, may have some difference in meaning highlighted by their colour.

In any case, with no answer yet, the issue of widely distributed peninsular blades takes on other dimensions. This is because there is a convergence of characteristics that do not fit into the classic supply of raw materials: a) they are not chosen for the quality of the raw material itself but for their size – they are large (as can be seen from their widths of over 22 mm) – a size provided by the characteristics of the raw material; b) they are not exclusive to certain contexts – they are present in funerary and non-funerary contexts; c) they are widely reused with the edges profusely retouched (especially in oolitic chert). These artefacts, configured using specialised technology and highly functional, were present in small quantities in the settlements, but important enough to be included in votive offerings in funerary contexts. They are present in several necropolises from south-eastern Iberia to Algarve (Nocete et al., 2005), usually better preserved and not retouched.

The systematic presence of these finished and standardised artefacts suggests the existence of a supra-regional circulation (Morgado Rodríguez et al., 2009, 2008; Nocete et al., 2005) up to 500 km – which clearly cannot be interpreted as direct supply. This long-distance mobility involved a complex network of contacts in whose dynamics the large aggregation centres would have played an important role during the

Chalcolithic. The archaeological site of Perdigões (e.g. Lago et al., 1998; Valera et al., 2000) has been interpreted as an important aggregation and redistribution centre (Valera et al. 2020) where goods arrived and underlying networks played as a “ResourceComplex” (Bartelheim & Bueno Ramírez 2017). Located approximately 200 km from VNSP, Perdigões stands out among the Chalcolithic sites of southwestern Portugal due to the diversity and quantity of exogenous artefacts associated with its multiple contexts (Valera, 2017). In VNSP, the significant consumption of blades from long distances indicates a need that goes beyond its own, suggesting an aggregating/redistributing role for the sites in Extremadura.

6. Conclusions

In this study we presented the first preliminary results on raw material sourcing and circulation networks of the chalcolithic blades during the Copper age of the SW of the Iberian Peninsula, based on those recovered in Vila Nova de São Pedro settlement, in Portuguese Extremadura.

The study of the blades' assemblage has combined the characterisation of the raw materials, applied to types of flint and igneous rocks, the debitage techniques and the typological patterns. The reference collection of the University of Lisbon lithothèque, as well as new samples from the Santa Quitéria and the Milanos formations (Ourém and Granada, respectively), were used to correlate the archaeological material with a high degree of probability.

Macroscopic and petrographic characterisation (thin sections) of VNSP's blades has enabled identification of five main chert types, with good correlation with the geological reference: Group 1) marine mudstone facies, associated to Rio Maior-2 type (RM-2), in secondary Cenozoic formations of Rio Maior; Group 2) marine wackestone facies, associated to Bica Formation (Cenomanian), near Lisboa; Group 3) Shallow marine/lagoonal facies, associated to Cabaços Formation (Oxfordian), also available in detrital Cenozoic formations of Rio Maior; Group 4) marine confined to lagoonal facies, correlated with Caxarias flint; Group 5) oolitic facies, correlated with the Milanos Formation (Upper Kimmeridgian-Tithonian), from Granada, and the Malaver Formation (secondary Miocene conglomerates), from Ronda.

Additionally, samples of cherts and felsic volcanic rocks from Iberian Pyrite Belt were also collected for comparison with the fraction of “dark non-sedimentary blades”. The preliminary results of X-ray fluorescence (pXRF) obtained for these show that there are clearly rhyolitic-dacitic rocks, similar to some samples from IPB. However, a few results were not conclusive and this time, the analysed archaeological and geological material cannot clearly be differentiated. Thus, subsequent geochemical studies must incorporate a larger set of geological samples and petrographic characterization through thin-section microscopy in order to determine whether it is possible to address a direct relationship between the archaeological samples and a specific geological unit.

The main conclusions that can be reached through the results of these petroarchaeological approaches are: 1) the continued exploitation of Rio Maior flint, a local raw material, for blades. These would apparently have been extracted near the source area, since we do not have the respective cores; 2) however, there is a clear preference for Caxarias flint blades – a lithological tracer type of flint with regional value – which also occurs systematically in other settlements in Extremadura.; 3) VNSP seems to play a key role within the complex mobility networks of large blades, whether made of chert (from the Subbetic zone) or non-sedimentary “dark rocks” – a super tracer lithological types –, establishing itself as an aggregation site, perhaps a distributor of these artefacts to the Southwest of the Iberian peninsula.

It will be important to compare and complement the results and conclusions of this study with the studies we are conducting on blades from various contexts in Perdigões, a site located in Alentejo, with a different geological framework, which has been interpreted as a large aggregation centre in large-scale interaction networks.

Finally, as a line for future complementary research, we also intend to analyse use-wear traces on the blades from different archaeological contexts, to explore the functionality of these artefacts, the craft activities, broader economic practices and potential sociocultural meanings.

CRediT authorship contribution statement

Patrícia Jordão: Writing – review & editing, Writing – original draft, Validation, Project administration, Methodology, Investigation, Data curation, Conceptualization. **César Neves:** Writing – review & editing, Investigation, Data curation. **Sofia Soares:** Writing – review & editing, Writing – original draft, Methodology. **Antonio Morgado-Rodríguez:** Writing – review & editing, Methodology. **Mariana Diniz:** Writing – review & editing. **José M. Arnaud:** .

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Appendix A. Supplementary data

Supplementary data to this article can be found online at <https://doi.org/10.1016/j.jasrep.2026.105767>.

Data availability

Data will be made available on request.

References

- Affolter, J., Emmenegger, L., Hafner, A., Heitz, C., Hinz, M., Stapfer, R., Wehren, H., 2022. From flint provenance to mobility studies: new raw material determinations from late Neolithic wetland sites at Lake Biel and Lake Constance. *Quat. Int.* 615, 84–95. <https://doi.org/10.1016/j.quaint.2021.05.027>.
- Arnaud, J., Diniz, M., Neves, C., Martins, A., 2017. Vila Nova de São Pedro—de novo, no 3º milénio. Um projecto para o futuro. *Arqueologia & História* 66–67, 7–17.
- Aubry, T., 2009. 200 séculos da história do Vale do Côa: incursões na vida quotidiana dos caçadores-artistas do Paleolítico, IGESPAR, I.P. ed, *Trabalhos de Arqueologia*.
- Barbosa, B., 1995. *Alostratigrafia e Litostratigrafia das Unidades Continentais da Bacia Terciária do Tejo. Universidade de Lisboa, Relações com o eustatismo e a tectónica (Tese de Doutoramento)*.
- Bevins, R.E., Ixer, R.A., Pirrie, D., Power, M.R., Cotterell, T., Tindle, A.G., 2021. Alteration fabrics and mineralogy as provenance indicators; the Stonehenge bluestone dolerites and their enigmatic “spots”. *J. Archaeol. Sci. Rep.* 36, 102826. <https://doi.org/10.1016/j.jasrep.2021.102826>.
- Bicho, N., 1992. *Technological Change in the Final Upper Paleolithic of Rio Mayor. Southern Methodist, Portuguese Extremadura (Doutoramento em Antropologia)*.
- Bradley, R., Watson, A., 2020. Axes from the sky. In: Rodríguez-Rellán, C., Nelson, B.A., Valcarce, R.F. (Eds.), *A Taste for Green, A Global Perspective on Ancient Jade, Turquoise and Variscite Exchange*. Oxbow Books, pp. 141–158. <https://doi.org/10.2307/j.ctv138ws4v.12>.
- Bustillo, M.Á., 2010. Silicification of continental carbonates. In: Alonso-Zarza, A.M., Tanner, L.H. (Eds.), *Carbonates in Continental Settings: Geochemistry, Diagenesis and Applications, Developments in Sedimentology*. Elsevier, Amsterdam, pp. 153–174.
- Bustillo, M.Á., 1984. Sedimentación lacustre-palustre, formación de ópalos y otras silicificaciones en el Mioceno medio al sur de Villaluenga. *Estudios Geológicos* 40, 137–153.

- de Carvalho, A.G., 1968. Contribuição para o conhecimento geológico da Bacia Terciária do Tejo. *Serviços Geológicos de Portugal, Lisboa*.
- Chabot, J., 2002. Tell 'Atij-Tell Gueda. Industrie lithique. Analyse technologique et fonctionnelle, Éditions du Centre interuniversitaire d'études sur les lettres, les arts et les traditions. ed, Série Archéométrie. Québec.
- Chabot, J., Pelegrin, J., 2012. Two examples of pressure blade production with a lever: recent Research from Southern Caucasus (Armenia) and Northern Mesopotamia (Syria, Iraq). In: Desrosiers, P.M. (Ed.), *The Emergence of Pressure Blade Making. From Origins to Modern Experimentation*, Springer, New York, pp. 181–198.
- Chatzimpaloglou, P., French, C., Pedley, M., Stoddart, S., 2020. Connecting chert sources of Sicily with Neolithic chert artefacts of Malta. *J. Archaeol. Sci. Rep.* 29, 102111. <https://doi.org/10.1016/j.jasrep.2019.102111>.
- Cunha, P.P., Antunes Martins, A., Daveau, S., Friend, P.F., 2005. Tectonic control of the Tejo river fluvial incision during the late Cenozoic, in Ródão—central Portugal (Atlantic Iberian border). *Geomorphology* 64, 271–298. <https://doi.org/10.1016/j.geomorph.2004.07.004>.
- Delvigne, V., Lafarge, A., Fernandes, P., Pesesse, D., Angevin, R., Bindon, P., Langlais, M., Piboule, M., Queffelec, A., Tuffery, C., Raynal, J.-P., 2021. Quels territoires en préhistoire ? Une analyse par réseaux de lieux pour penser l'espace au Paléolithique supérieur, in: *En mouvement - on the move - in Bewegung. Mobilités des hommes, des objets et des idées pendant le Paléolithique supérieur européen: mobility of people, objects and ideas during the European upper palaeolithic: Mobilität von Menschen, Objekten und Ideen im europäischen Jungpaläolithikum*, Séances de la Société Préhistorique Française. pp. 27–69.
- Díez Montes, A., Matos, J.X., Dias, R., Carmona, J.J., Albardeiro, L., Oliveira, J.T., Morais, I., Fernandes, P., Inverno, P., Machado, S., Ressureição, R., Pereira, Z., Mendes, M., Solá, R., Salgueiro, R., Matilla, A.S., Valdés, M.C., Gonçalves, P., Santos, S., López, M.T.L., 2020. Memoria técnica del mapa geológico de la zona surportuguesa, escala 1:400.000 = Notícia explicativa da carta geológica da zona sul portuguesa, escala 1: 400.000. Instituto Geológico y Minero de España; LNEG, Laboratorio Nacional de Energia e Geologia, Madrid, Amadora.
- Diniz, M., Arnaud, J.M., Neves, C., Martins, A., 2024. Vila Nova de São Pedro: antes e depois de 2021, in: *Vila Nova de São Pedro e o Calcolítico No Ocidente Peninsular, Estudos & Memórias*. Lisboa, pp. 17–38.
- Diniz, M., Martins, A., Neves, C., Arnaud, J., 2022. Where there is power, there is fear: Muralhas calcólicas, medo, poder e mecanismos de exibição — o caso de Vila Nova de São Pedro (Azambuja, Portugal), in: Sanches, M. de J., Barbosa, M.H., Teixeira, J. de C. (Eds.), *Romper Fronteiras, Atravessar Territórios. Breaking Borders, Crossing Territories*. Porto, pp. 109–140.
- Diniz, M., Martins, A., Neves, C., Arnaud, J.M., 2017. Vila Nova de São Pedro (Azambuja), no 3º milénio, um sítio Calcolítico no Ocidente Peninsular - Contributos para um debate, in: Arnaud, J.M., Martins, A., Associação dos Arqueólogos Portugueses (Eds.), *Arqueologia em Portugal: 2017, Estado da questão*, Guia. Associação dos Arqueólogos Portugueses, Lisboa, pp. 591–604.
- Ewart, A., 1982. The mineralogy and petrology of Tertiary-recent orogenic volcanic rocks: with special reference to the andesitic-basaltic compositional range. In: Thorp, R.S. (Ed.), *Andesites: Orogenic Andesites and Related Rocks*. John Wiley and Sons, New York, pp. 25–95.
- Fernandes, P., Delvigne, V., Piboule, M., Thiry, M., Tufféry, C., Raynal, J.-P., Nouvel, B., Renault, S., 2024. Vade-mecum pour la caractérisation pétroarchéologique des siliques: De l'inventaire sur le terrain à l'analyse naturaliste en laboratoire. *pm* 12, 1–122. <https://doi.org/10.4000/12zm5>.
- Fernandes, P., Raynal, J.-P., 2006. Pétroarchéologie du silex: un retour aux sources. *C.R. Palevol* 5, 829–837.
- Forenbaher, S., 2007. Lithic production at Casas de Baixo and the prismatic blades of the Portuguese Neolithic. In: *IV Congresso De Arqueologia Peninsular. From the Mediterranean Basin to the Portuguese Atlantic Shore, Papers in Honor of Anthony Marks*. Faro, pp. 231–244.
- Forenbaher, S., 1999. Production and exchange of bifacial flaked stone artifacts during the Portuguese Chalcolithic, BAR international series. Archaeopress : Available from Hadrian Books, Oxford, England.
- Forenbaher, S., 1998. Production and exchange during the Portuguese Chalcolithic: the case of bifacial flaked stone industries. *Trab. Prehist.* 55, 55–71. <https://doi.org/10.3989/tp.1998.v55.i2.303>.
- Furestier, R., 2005. Les industries lithiques campaniformes du sud-est de la France. *Université Provence - Aix-Marseille I, Aix-en-Provence*.
- García Sanjuán, L., Lozano Rodríguez, J., Sánchez Liranzo, O., Gibaja Bao, J.F., Aranda Sanchez, V., 2016. La industria lítica del tholos de Montelirio, in: Montelirio. Un Gran Monumento Megalítico de La Edad Del Cobre. Sevilla, pp. 203–244.
- Gonçalves, V.S., 1987. Trabalhos de campo. Distrito de Lisboa – Azambuja: Castelo de Vila Nova de São Pedro: 1985/86, in: *Informação Arqueológica*. Lisboa, pp. 41–43.
- Hallsworth, C.R., Knox, R., 2020. Classification of sediments and sedimentary rocks. (British Geological Survey Research Report, Report No. RR 99–03) (BGS Rock Classification Scheme No. Vol. 3). British Geological Survey, Nottingham.
- Inizan, M.-L., Lechevallier, M., 1991. A techno-economic approach to lithics: some examples of blade pressure debitage in the Indo-Pakistani subcontinent. In: *South Asian Archaeology 1987*. ISMEO, Rome, pp. 43–59.
- Inizan, M.-L., Lechevallier, M., Pelegrin, J., 1994. The use of metal in the lithics of Sheri Khan Tarakai, Pakistan. Evidence provided by the technological approach of pressure debitage, in: *South Asian Archaeology 1993, Annales Academiae Scientiarum Fennicae*. Helsinki, pp. 245–256.
- Inizan, M.-L., Reduron, M., Roche, H., Tixier, J., 1999. Technology and Terminology of Knapped Stone. *Cercle de Recherches et d'Études Pré-historiques*, Nanterre.
- Jordão, P., 2024. O sítio de São Mamede (Bombarral) nas redes de circulação de sílex do 3º milénio a.n.e. na fachada Atlântica da Estremadura, in: Fabião, C., Diniz, M., Carvalho, A.F.D., Silva, F.P., Valera, A.C. (Eds.), *De Gibraltar Aos Pirenéus: Megalitismo, Vida e Morte Na Fachada Atlântica Peninsular: Arqueologia, Património e Turismo*. UNIARQ - Centro de Arqueologia da Universidade de Lisboa. <https://doi.org/10.51427/10400.5/95883>.
- Jordão, P., 2023. A proveniência de sílex e a mobilidade no Calcolítico da Estremadura: Uma abordagem geológica e petroarqueológica. Tese de doutoramento em Geologia, Especialidade de Geodinâmica Externa. Lisboa: Faculdade de Ciências da Universidade de Lisboa. (Doutoramento). Faculdade de Ciências da Universidade de Lisboa, Lisboa.
- Jordão, P., Cardoso, J.L., 2024. Estudo petroarqueológico de proveniência de materiais sílicos de Leceia, Barotas e Monte do Castelo (Oeiras, Portugal). *Estudos Arqueológicos De Oeiras* 33, 181–232.
- Jordão, P., Guedes, A., Pimentel, N., 2022. Raman Micro-Spectroscopy and XRD applied to mineralogical characterization of local and regional Flint source-areas from Chalcolithic settlement of Zambujal. Torres Vedras, Portugal.
- Jordão, P., Pimentel, N., 2025. Geoarchaeological walks through the Cenomanian flint of the Western Iberian Margin. In: *XI Simpósio Sobre a Margem Ibérica Atlântica*. de Outubro. Presented at the XI Simpósio sobre a Margem Ibérica Atlântica, Lisboa, pp. 29–31.
- Jordão, P., Pimentel, N., 2021. Flint sources and mobility at the Chalcolithic (3500–2200 BCE) settlement of Zambujal (Portugal). *Geoarchaeology* 37, 522–543. <https://doi.org/10.1002/gea.21885>.
- Jordão, P., Pimentel, N., Guedes, A., Kunst, M., 2024a. Travelin' stones: the oolitic chert blades from Zambujal Chalcolithic enclosure (Torres Vedras, Portugal). *J. Lithic Studies* 11, 26 p. <https://doi.org/10.2218/jls.7757>.
- Jordão, P., Pimentel, N., Martins, A., Cura, P., Diniz, M., Neves, C., Arnaud, J.M., 2024b. O território de Vila Nova de São Pedro no 3º milénio A.C: Análise de proveniência das matérias-primas líticas a partir de novos dados (2017–2018). *Vila Nova De São Pedro e o Calcolítico No Ocidente Peninsular, Estudos & Memórias* 23, 135–151.
- Lago, M., Duarte, C., Albergaria, J., Almeida, F., de Carvalho, A.F., 1998. Povoado dos Perdigões (Reguengos de Monsaraz): dados preliminares dos trabalhos arqueológicos realizados em 1997. *Rev. Port. Arqueol.* 1, 45–152.
- Leary, J., Kador, T., 2016. Movement and mobility in the Neolithic, in: Leary, J., Kador, T. (Eds.), *Moving on in Neolithic Studies: Understanding Mobile Lives, Neolithic Studies Group Seminar Papers*. Oxbow Books, Oxford; Havertown, PA, p. [s.p.].
- Lillios, K.T., 2020. Mobility and alterity in Iberian late prehistoric archaeology: current research on the neolithic–early bronze age (6000–1500 BCE). *Ann. Rev. Anthropol.* 49, null. <https://doi.org/10.1146/annurev-anthro-010220-042345>.
- Lillios, K.T., 1997. Amphibolite tools of the Portuguese Copper Age (3000–2000 B.C.): a geoarchaeological approach to prehistoric economics and symbolism. *Geoarchaeology* 12, 137–163. [https://doi.org/10.1002/\(SICI\)1520-6548\(199703\)12:2%253C137::AID-GEA3%253E3.0.CO;2-5](https://doi.org/10.1002/(SICI)1520-6548(199703)12:2%253C137::AID-GEA3%253E3.0.CO;2-5).
- Linares, J., Nocete, F., Sáez, R., 1998. Aprovisionamento compartido versus aprovisionamento restringido: los casos de las canteras del III milenio a.n.e. del Andévalo (Huelva). *Rubricatum 2 (Actes 2a. Reunió De Treball Sobre Aprovisionamento De Recursos Líticos à La Prehistòria, Barcelona-Gavà 1997*, 177–184.
- Lozano, J.A., Morgado, A., Puga, E., Martín-Algarra, A., 2010. Explotaciones del sílex tipo «Turón» (Málaga, España): localización y caracterización petrológica y geoquímica. *Geogaceta* 136–166.
- Martins, A., Cunha, P.P., Gomes, A., 2017. Steady state forms and transient fluvial incision on the Tejo and Douro rivers tributaries, a case study in mainland Portugal (Hesperian Massif). Presented at the Late Cenozoic evolution of the Yellor River and its environs. Discussion Meeting. 10-09-2017, Fluvial Archives Group.
- Martins, A., Neves, C., Arnaud, J., Diniz, M., 2019. O povoado Calcolítico de Vila Nova de São Pedro (Azambuja) - Notas sobre as Campanhas de 2017 e 2018. *Arqueologia & História* 69, 133–167.
- Martins, A.A., Cunha, P.P., Rosina, P., Osterbeek, L., Cura, S., Grimaldi, S., Gomes, J., Buylaert, J.-P., Murray, A.S., Matos, J., 2010. Geoarchaeology of Pleistocene open-air sites in the Vila Nova da Barquinha-Santa Cita area (lower Tejo River basin, central Portugal). *Proc. Geologists' Assoc.* 121, 128–140. <https://doi.org/10.1016/j.pgeola.2010.01.005>.
- Mataloto, R., Costeira, C., Nukushina, D., 2017. Local Shop for Local People Resource Management During the 3rd Millennium BCE at São Pedro (Redondo, Portugal). In: Bartelheim, M., Bueno Ramírez, P., Kunst, M. (Eds.), *Key Resources and Socio-Cultural Developments in the Iberian Chalcolithic, RessourcenKulturen*. Eberhard Karls Universität Tübingen, Tübingen Library Publishing, Tübingen, pp. 143–166.
- Morgado Rodríguez, A., Lozano, J.A., 2011. The impact of geological factors on flint mining and large blade production in the Betic Cordillera (Spain) in the 4th–3rd mill. BC, in: Capote, M., Consuegra, S., Díaz-del-Río, P., Terradas, X. (Eds.), *Proceedings of the 2nd International Conference of the UISPP Commission on Flint Mining in Pre- and Protohistoric Times (Madrid, 14-17 October 2009)*, BAR International Series. Archaeopress, Oxford, pp. 183–191.
- Morgado Rodríguez, A., Lozano Rodríguez, J., Pelegrin, J., 2011. Las explotaciones prehistóricas del Sílex de la formación milanos (Granada, España). *MENGA. REVISTA DE PREHISTORIA DE ANDALUCÍA* 1, 111–134.
- Morgado Rodríguez, A., Pelegrin, J., 2012. Origin and Development of Pressure Blade Production in the Southern Iberian Peninsula (6th–3rd Millennia B.C.). In: Desrosiers, P.M. (Ed.), *The Emergence of Pressure Blade Making*. Springer, US, Boston, MA, pp. 219–235. https://doi.org/10.1007/978-1-4614-2003-3_8.
- Morgado Rodríguez, A., Pelegrin, J., Aubry, T., Lozano, J.A., 2009. La producción especializada de grandes láminas del Sur y Oeste de la Península Ibérica. In: Gibaja Bao, J.F. (Ed.), *Les Grans Fules De Sílex: Europa Al Final De La Prehistòria: Actes, Monografies / Museu D'arqueologia De Catalunya Barcelona. Museu d'Arqueologia de Catalunya, Barcelona*, pp. 89–98.
- Morgado Rodríguez, A., Pelegrin, J., Fernández, G., Afonsom, J., 2008. La production de grande lames dans la Péninsule Ibérique (IV-III millénaires). In: Dias-Meirinho, M.-

- H. (Ed.), *Les Industries Lithiques Taillées Des IVe et IIIe Millénaires En Europe Occidentale: Colloque International, Toulouse 7-9 Avril 2005*, BAR International Series. John and Erica Hedges Ltd, Oxford.
- Moscone, D., D'Errico, D., Pellegrini, D., Pellegrini, A., Nobile, E., Lemorini, C., 2024. Arslantepe in the foreground: the economic and social role of the large blades at the end of the 4th millennium BC. *J. Archaeol. Sci. Rep.* 56, 104544. <https://doi.org/10.1016/j.jasrep.2024.104544>.
- Moscone, D., Eramo, G., Caggiani, M.C., Morandi Bonacossi, D., Conati Barbaro, C., 2020. Compositional features of cherts from the Jebel Zawa mines (Dohuk, Kurdistan Region of Iraq) and implications for exploitation strategies during the late Chalcolithic/Early Bronze Age. *J. Archaeol. Sci. Rep.* 29, 102086. <https://doi.org/10.1016/j.jasrep.2019.102086>.
- Murillo-Barroso, M., Martínón-Torres, M., 2012. Amber sources and trade in the prehistory of the Iberian Peninsula. *Eur. J. Archaeol.* 15, 187–216. <https://doi.org/10.1179/1461957112Y.0000000009>.
- Neves, C., Arnaud, J., Diniz, M., Martins, A., 2022. O povoado Calcolítico de Vila Nova de São Pedro (Azambuja) - Notas sobre as Campanhas de 2019. *Arqueologia História* 13 (71–72), 159–184.
- Neves, C., Martins, A., Diniz, M., Arnaud, J.M., 2024. Vila Nova de São Pedro (Azambuja, Portugal): novos dados sobre estruturas, materiais e cronologias, in: Diniz, M., Martins, A., Neves, C., Arnaud, J.M. (Eds.), *Vila Nova de São Pedro e o Calcolítico No Ocidente Peninsular, Estudos & Memórias*. Lisboa, pp. 47–100.
- Nocete, F., Sáez, R., Nieto, J.M., Cruz-Auñón, R., Cabrero, R., Alex, E., Bayona, M.R., 2005. Circulation of silicified oolitic limestone blades in South-Iberia (Spain and Portugal) during the third millennium B.C.: an expression of a core/periphery framework. *J. Anthropol. Archaeol.* 24, 62–81. <https://doi.org/10.1016/j.jaa.2004.10.002>.
- Odriozola, C.P., Sousa, A.C., Mataloto, R., Boaventura, R., Andrade, M., Villalobos García, R., Garrido-Cordero, J.A., Rodríguez, E., Martínez-Blanes, J.M., Avilés, M.A., Daura, J., Sanz, M., Riquelme, J.A., 2019. Amber, beads and social interaction in the late prehistory of the Iberian Peninsula: an update. *Archaeol. Anthropol. Sci.* 11, 567–595. <https://doi.org/10.1007/s12520-017-0549-7>.
- Pais, J., 1992. Contributions to the Eocene palaeontology and stratigraphy of Beira Alta, Portugal. III - Eocene plant remains from Naia and Sobreda (Beira Alta, Portugal). *Ciências da Terra* 91–108.
- Pais, J., Cunha, P.P., Pereira, D., Legoinha, P., Dias, R., Moura, D., Silveira, A.B. da, Kullberg, J.C., González Delgado, J., 2012. The Paleogene and Neogene of Western Iberia (Portugal). *SpringerBriefs in Earth Sciences*. Springer Berlin Heidelberg, Berlin, Heidelberg. <https://doi.org/10.1007/978-3-642-22401-0>.
- Pelegri, J., 2006. Long blade technology in the Old World: an experimental approach and some archaeological results 37.
- Pelegri, J., 2002. Principes de la reconnaissance des méthodes et techniques de taille. *J. Tell Atij tell Gueda, industrie lithique. Analyse technologique et fonctionnelle. Cahiers D'archéologie Du CELAT, Série Archéométrie* 13, 215–224.
- Pelegri, J., 1988. Débitage expérimental par pression : du plus petit au plus grand. In: Tixier, J. (Ed.), *Technologie Pré-Historique, Préhistoire et Technologie Lithique*. CNRS - Centre de recherches archéologiques U.R.A. Valbonne, pp. 37–53.
- Pelegri, J., Morgado Rodríguez, A., 2007. Arqueología experimental en la península ibérica: investigación, didáctica y patrimonio. In: *Arqueología Experimental En La Península Ibérica: Investigación, Didáctica y Patrimonio*. Asociación Española de Arqueología Experimental, Santander, pp. 131–139.
- Perles, C., 1984. Débitage laminaire de l'obsidienne dans le Néolithique de Franchthi (Grèce): technique et place dans l'économie de l'industrie lithique, in: Tixier, J., Inizan, M.-L., Roche, J. (Eds.), *Préhistoire de La Pierre Taillée : Technologie et Expérimentation. Économie de Débitage Laminaire, Préhistoire de La Pierre Taillée*. CREP, Antibes Valbonne, pp. 129–137.
- Pétrequin, P., Pétrequin, A.-M., 2016. The Production and Circulation of Alpine Jade Axe-Heads during the European Neolithic: Ethnoarchaeological Bases of Their Interpretation. In: Biagetti, S., Lugli, F. (Eds.), *The Intangible Elements of Culture in Ethnoarchaeological Research*. Springer International Publishing, Cham, pp. 47–76. https://doi.org/10.1007/978-3-319-23153-2_3.
- Ramírez, P.B., 2021. Carlos Rodríguez-Rellán, Ben Nelson and Ramón Fábregas-Valcarce, eds. *A Taste for Green: A Global Perspective on Ancient Jade, Turquoise, and Variscite Exchange* (Oxford & Philadelphia: Oxbow Books, 2020, 180pp., 82figs figs., ISBN 978-1-78925-275-0). *European Journal of Archaeology* 24, 269–273. <https://doi.org/10.1017/eea.2021.9>.
- Rocha, M., Neto, N., Rebelo, P., Martins, F., Cardoso, J.L., 2023. O Complexo do Neolítico Final e do Calcolítico da Travessa das Dores/Rio Seco (Ajuda – Lisboa): resultados das escavações realizadas no sector do Rio Seco (2017/2018). <https://doi.org/10.5281/ZENODO.10402467>.
- Rodríguez Rellán, C., Morgado Rodríguez, A., Lozano, J.A., 2015. Long distance contacts: North-West Iberia during the 3rd millennium BC. In: Prieto Martínez, M.P., Salanova, L. (Eds.), *The Bell Beaker Transition in Europe: Mobility and Local Evolution during the 3rd Millennium BC*. Oxbow Books, Philadelphia, pp. 127–139.
- Sánchez-Gómez, D., Garrido-Cordero, J.A., Martínez-Blanes, J.M., García, R.V., Benaiges, E.I., Sousa, M., Zambrana Vega, A.C., Borrell, M.D., Barroso Bermejo, F., Bueno Ramírez, R., Odriozola, P., 2026. A forest of green beads: a machine-learning based framework to determine the geological provenance of prehistoric variscite artifacts. *J. Archaeol. Sci.* 185, 106428. <https://doi.org/10.1016/j.jas.2025.106428>.
- Scholle, P.A., Ulmer-Scholle, D.S., 2003. A color guide to the petrography of carbonate rocks: grains, textures, porosity, diagenesis. AAPG memoir, American Association of Petroleum Geologists, Tulsa, Ok.
- Schuhmacher, T., 2017. Ivory exchange networks in the Chalcolithic of the Western Mediterranean. In: Bartelheim, M., Bueno Ramírez, P., Kunst, M. (Eds.), *Key Resources and Socio-Cultural Developments in the Iberian Chalcolithic*. RessourcenKulturen, Tübingen.
- Schuhmacher, T., Banerjee, A., 2012. Procedencia e intercambio de marfil en el Calcolítico de la Península Ibérica. *Rubricatam revista del Museu de Gavà* 289–298.
- Shokler, J., 2002. Approaches to the sourcing of flint in archaeological contexts: results of research from Portuguese Estremadura, in: Hermann, J.J., Herz, N., Newman, R., Association for the Study of Marble and Other Stones Used in Antiquity (Eds.), *Interdisciplinary Studies on Ancient Stone: Proceedings of the Fifth International Conference of the Association for the Study of Marble and Other Stones in Antiquity*, Museum of Fine Arts, Boston, 1998, ASMOSIA. Archetype Publ, London, pp. 176–187.
- da Silva, C.T., Soares, J., 1987. O povoado fortificado calcolítico do Monte da Tumba. I - Escavações arqueológicas de 1982-86 (Resultados Preliminares). *Setúbal Arqueológica* 8, 29–79.
- Sousa, A., 2010. O Penedo do Lexim e a sequência do Neolítico final e do Calcolítico na Península de Lisboa (Tese de Doutoramento). Universidade de Lisboa, Lisboa.
- Tarrío Vinagre, A., Muñoz-Fernández, E., Elorrieta Baigorri, I., Normand, C., Rasines del Río, P., García-Rojas, M., Pérez-Bartolomé, M., 2016. El sílex en la cuenca vasco-cantábrica y el Pirineo occidental materia prima lítica en la Prehistoria. *Cuadernos De Prehistoria y Arqueología De La Universidad De Granada* 26, 191–228.
- Thomas, H.H., 1923. The source of the stones of stonehenge. *Antiq. J.* 3, 239–260. <https://doi.org/10.1017/S0003581500005096>.
- Tixier, J., 1976. L'industrie lithique capsiennne de l'Ain Dokkara, région de Tébéssa. *Fouilles l. Balout. Lybica* 24, 21–54.
- Valcarce, R.F., Lombera Hermida, A., Rodríguez Rellán, C., 2012. Spain and Portugal : long chisels and perforated axes. Their context and distribution, in: Pétrequin, P., Cassen, S., Errera, M., Klassen, L., Sheridan, J.A., Pétrequin, A.-M. (Eds.), *JADE: Grandes Haches Alpines Du Néolithique Européen. Ve et IVe Millénaires Av. J.-C.* Presses Universitaires de Franche-Comté, Besançon, pp. 1108–1135.
- Valera, A.C., 2020. O SEPULCRO 4 DOS PERDIGÕES. UM THOLOS DA SEGUNDA METADE DO 3º MILÉNIO AC, NIA-ERA. ed, *Perdigões Monográfica*. Lisboa.
- Valera, A.C., 2017. The “exogenous” at Perdigões: approaching interaction in the late 4th and 3rd Millennium BC in Southwest Iberia. In: Bartelheim, M., Bueno Ramírez, P., Kunst, M. (Eds.), *Key Resources and Socio-Cultural Developments in the Iberian Chalcolithic*, RessourcenKulturen. Eberhard Karls Universität Tübingen, Tübingen Library Publishing, Tübingen, pp. 201–224.
- Valera, A.C., Filipe, I., 2004. O Povoado do porto Torrão (Ferreira do Alentejo): novos dados e novas problemáticas no contexto do Sudoeste Peninsular. *Era Arqueologia* 6, 28–61.
- Valera, A.C., Lago, M., Duarte, C., Evangelista, L.S., 2000. Ambientes funerários no complexo arqueológico dos Perdigões: uma análise preliminar no contexto das práticas funerárias calcolíticas no Alentejo. *Era Arqueologia* 2, 84–105.
- Valera, A.C., Zalai, I., Maurer, A., Grimes, V., Silva, A.M., Ribeiro, S., Santos, J., Barrocas Dias, C., 2020. Addressing human mobility in Iberian Neolithic and Chalcolithic ditched enclosures: the case of Perdigões (South Portugal). *J. Archaeol. Sci. Rep.* 30, 102264. <https://doi.org/10.1016/j.jasrep.2020.102264>.
- Vallespí Perez, E., Ramos Muñoz, J., Martín Córdoba, E., del Espejo, M., Cantalejo, M., 1988. Talleres líticos andaluces del Calcolítico y Bronce. *Arqueología* 90, 14–24.
- Vis, G.-J., Kasse, C., Vandenberghe, J., 2008. Late Pleistocene and Holocene palaeogeography of the lower Tagus Valley (Portugal): effects of relative sea level, valley morphology and sediment supply. *Quat. Sci. Rev.* 27, 1682–1709. <https://doi.org/10.1016/j.quascirev.2008.07.003>.
- Waterman, A.J., Peate, D.W., Silva, A.M., Thomas, J.T., 2014. In search of homelands: using strontium isotopes to identify biological markers of mobility in late prehistoric Portugal. *J. Archaeol. Sci.* 42, 119–127. <https://doi.org/10.1016/j.jas.2013.11.004>.
- Werra, D.H., Szeliga, M., Pyżewicz, K., Burgert, P., 2024. Value, significance and use of “exotic” materials – in the light of the presence of obsidian on Neolithic sites in Poland. *Spraw. Arch.* 76, 71–97. <https://doi.org/10.23858/SA/76.2024.1.3616>.
- Zbyszewski, G., Manuppella, G., Ferreira, O. da V., 1974. Carta Geológica de Portugal na escala 1/50000. Notícia explicativa da folha 27-A (Vila Nova de Ourém)., *Serviços Geológicos de Portugal*. ed. Lisboa.
- Zbyszewski, G., Torre de Assunção, C., 1965. Carta Geológica de Portugal na escala 1/50000. Notícia explicativa da folha 30-D (Alenquer)., *Serviços Geológicos de Portugal*. ed. Lisboa.
- Zilhão, J., 1997. O Paleolítico Superior da Estremadura Portuguesa. *Edições Colibri*, Lisboa.
- Zilhão, J., 1994. A oficina de talhe neo-calcolítica de Casas de Baixo (Caxarias, Vila Nova de Ourém). *Trabalhos De Arqueologia Da EAM* 2, 35–45.