Travelin' stones: The oolitic chert blades from Zambujal Chalcolithic enclosure (Torres Vedras, Portugal)

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Abstract:

The Oolitic chert is an important raw material for large blade production in Betic Cordillera (Spain) during 4th-3rd mill. BCE. These blades are part of a long-distance trade network of artefacts found in Chalcolithic settlements of southwestern Iberia. In Zambujal, the westernmost site with oolitic chert blades, with the source-area distance more than 500km, these utensils are included in the "import package" with remarkable implications for social change and innovation (Lillios 2020). Sourcing oolitic chert blades contributes to understanding mobility in the Chalcolithic of the Iberian Peninsula as part of a complex trade and exploitation network.

In the current study, all the oolitic chert blades recovered in Zambujal are analysed which are recovered from the ancient excavations between 1964 and 1973 by H. Schubart and E. Sangmeister to the recent investigations by M. Kunst (1994-2012).

After first using a techno-typological classification, the raw material characterization focused on the petrographic compositional and textural features (macro-, in hand specimen, meso-, with hand lens, and microscopic, with binocular lens and petrographic microscope). Polished thin-sections were analysed also by Raman Microspectroscopy in order to determine the main crystalline phases present. It was possible to correlate with high probability the archaeological raw material with oolitic chert from the Milanos Formation (Upper Kimmeridgian-Tithonian in Middle Subbetic, Granada) and also from the Malaver Formation (Miocene in Campo de Gibraltar Complex, Malaga), with conglomerates from Lower-Middle Jurassic oolithic chert. The identification of signs of usage, fracturing and reuse are frequently observed in the oolitic chert blades of Zambujal, as in other Portuguese sites. The association of an intensive use of the oolitic chert blades with its scarcity in the archaeological record highlight the importance of blades for domestic activities, as "prestige" functional goods (Teather 2008: 84). In this sense, the oolitic chert blades are material records of an intense mobility of humans and objects in the Chalcolithic. The presence of an expressive set of oolitic chert blades in Zambujal is related to their important role played within the network of transregional relations.

Keywords: petroarchaeology; oolitic chert; Chalcolithic; Portugal; mobility

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1. Introduction and background

The blades and blade-based tools are an important part of the Chalcolithic lithic assemblages over 4th and 3rd millennia BCE in Europe. In southern Iberia the studies developed on laminar products since the late 1980s have documented their technological specialization, their workshops and the raw materials sourcing associated with a perspective of production *versus* consumption by Chalcolithic societies (Ramos Muñoz *et al.* 1986: 97-98; Afonso Marrero 1998: 299-304; Martínez Fernández 1997; Morgado Rodríguez 2002: 833-860; Martínez Fernández *et al.* 1991; Martínez Fernández *et al.* 2006; Linares *et al.* 1998). The large blades from Andalucía are moved long distances supports a hypothesis of increasing circulation and demand of exotic materials and raw materials. The network range of these raw material extends toward NW-W the Guadiana basin, in Extremadura (Cerrillo Cuenca 2009), Algarve (Nocete *et al.* 2005), Alentejo (Boaventura *et al.* 2014; Gomes *et al.* 2012; Mendonça & Carvalho 2016; Nocete *et al.* 2005) and, recently noticed, in Setúbal Peninsula (Cardoso *et al.* 2018).

In Portuguese Estremadura, the oolitic chert is a component of the “exotic package” along with ivory (Schuhmacher 2017; Schuhmacher & Banerjee 2012), both observed in small quantities in burials and settlements. (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 & Knox 2020: 22).) Although not exclusive to the blade group, this raw material is mainly observed in them and - most importantly - appears associated with the large blades. The approach to the blades production, supply and circulation is related to the emergency of complexity and craft specialization.

Two research topics are highlighted: the knapping products standardization (blades and bladelets) and the distinction between production *versus* consumption sites which implies circulation networks (Zilhão 1994; Carvalho 1996: 126-128; Forenbaher 1998; 1999: 11-19; 107-110; 2007; Carvalho 2009). In a few recently excavated sites of Estremadura it is confirmed that in general the blades and particularly the large ones were not produced in the settlements, due to the absence of blade cores and core preparation flakes (Sousa 2010: 610; Cardoso 1994: 97; Jordão 2013). The bifacial flaked stone artefacts and the blades were probably knapped near flint source-areas, as it is documented in Casas de Baixo (Ourém), and widespread from there to the consumption sites (Forenbaher 1998; Forenbaher 1999; Forenbaher 2007).

The scarcity of knapping workshops in the archaeological record in southern Iberia and the absence of petroarchaeological chert provenance studies in Late Neolithic and Chalcolithic sites it difficult to identify the circulation networks of these artefacts. Nevertheless, as it is observed in Zambujal, the oolitic chert blades, seem to have their own territory of circulation, independent of the “common” blades (study in preparation by the authors).

2. Archaeological and petroarchaeological framework

2.1. The Zambujal Chalcolithic enclosure

The Chalcolithic walled settlement of Zambujal is located about 3 km SW of Torres Vedras in the Portuguese Estremadura. It is situated on a hilltop (120 m asl) on the right margin of the Pedrulhos river, a tributary of the Sizandro (Figure 1). The site was established in the beginning of the 3rd millennium BCE and abandoned in the first half of the 2nd millennium BCE; over five construction phases have been identified (Sangmesiter & Schubart 1981: 226-262; Kusnt & Lutz 2008: 36-43; Kunst 2010: 136-142; Kunst 2017: 197-202).

Zambujal has two important stratigraphic moments during the Chalcolithic: an earlier horizon, represented by the cylindrical vessels (Amaro 2012; Kunst 1995c; Kunst 2001), and a Bell Beaker horizon (Kunst 1987; Kunst 1995; Kunst 2001; Kunst 2017), one of the oldest in Europe (Müller & Willigen 2001).

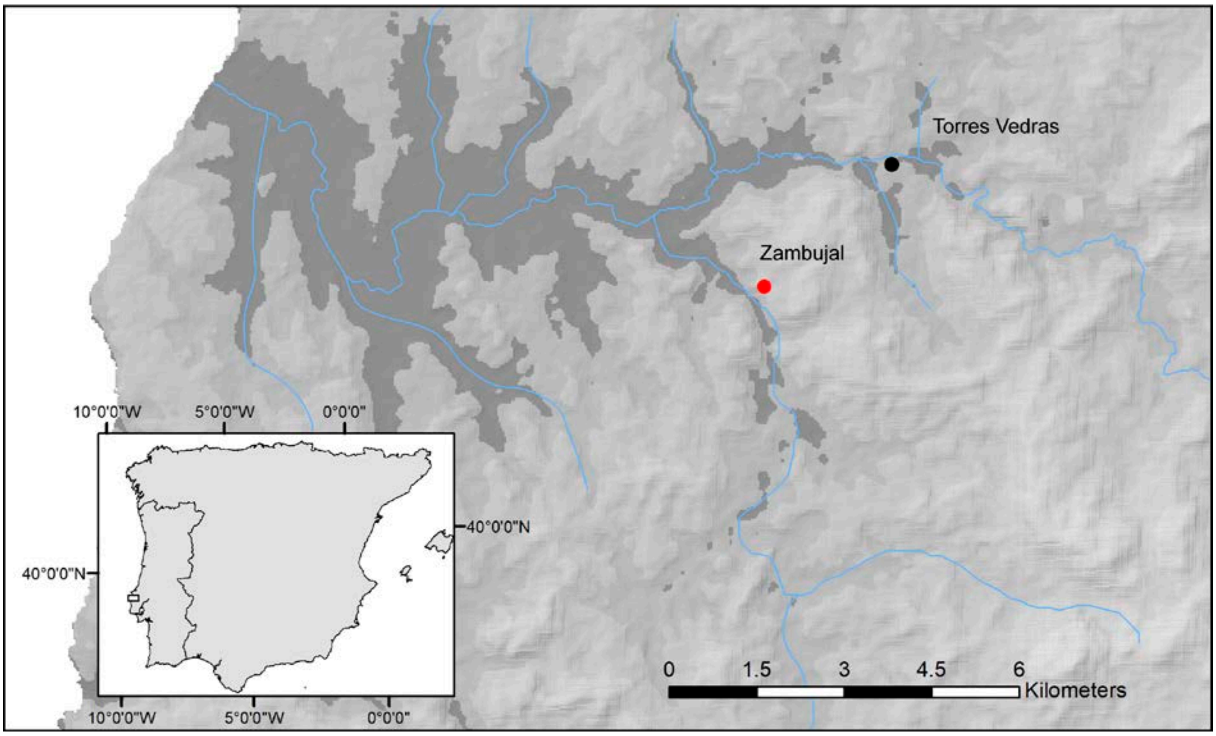

Figure 1. Location of Zambujal settlement in Iberian Peninsula.

Zambujal has been viewed as a “central place” (Kunst 1995a), and archaeological evidence for extra-regional raw materials has been found at the site, including objects not only in finished form but also those worked in situ, such as copper (Sangmeister 1995; Müller et al. 2007; Gauß 2015; Bartelheim et al. 2022; Wang & Ottaway 2022; Schreiner 2022; Hanning & Goldenberg 2022) and amphibolite, the latter made into polished tools (Lillios 1997; Lillios 2020), whose closest source area is the Ossa-Morena Zone in the Alentejo (South-Portugal), circa 150 km from the site. Long-distance raw materials have been recovered at the site as well, such as ivory artefacts, from North Africa (Uerpmann-Uerpmann 2003: 14-15; Schuhmacher & Banerjee 2012) and oolitic chert blades, which raw material does not outcrop in Mesocenozoic formations from Portugal.

Other smaller Chalcolithic sites in the Sizandro´s Basin - Boiaca, Fórnea and Penedo - are in the neighbouring of Zambujal. As at Zambujal, excavations in Fórnea and Penedo and surveys at Boiaca revealed the presence of copper and amphibolite tools (Kunst & Trindade 1991; Spindler & Gallay 1973: 28). The study of the flaked lithic industry suggests, nowadays, after the detailed study of the raw materials by Patrícia Jordão, the presence of exogenous oolitic chert with local flint predominating (Jordão 2023:183-220).

2.2. “Travelling riverside”: The flint supplying territory

In recent petroarchaeological work about chert sources and mobility from Zambujal, the flaked local industry (cores, raw products - flakes and bladelets - and debris) recovered between 1964 and 1979, was analysed (Jordão & Pimentel 2021). It was demonstrated that local Paleogene silcrete (22%) and Cenomanian flint (12%), both available as secondary clasts in nearby Quaternary river terraces (Jordão & Pimentel 2019), were used for knapping at the site. In addition, a regional "supply territory" was detected by the collection of small cobbles from regional formations, in a large (app. 40km) exploration territory, to produce expedient and specialized artefacts (*i.e.*, bladelets) as it is observed in 37% of the assemblage. However, a large portion of stone tools from Zambujal made from Cenomanian flint cannot be assigned to local or regional procurement yet. For this reason, petrographic and geochemical studies of additional samples are being conducted, not only of the raw materials from the Cenomanian outcrops of the Estremadura, but also of artifacts found in workshops. The remaining material from Zambujal - the group of tools that include bifaces and blades - are currently being studied, with thin-sections being prepared for petrographic study. Preliminary technology analysis (in preparation by the authors), based on the *chaîne opératoire* of the tools, allows us to affirm with a certain probability, that they would have been included in the domestic activities of the site.

In contrast, 'specialized' bifaces and blades would have likely been produced far from the settlement, as evidence of large foliate pre-forms or blade cores at Zambujal does not exist. With respect to the latter case, it was possible to verify through macroscopic analysis the existence of different types of siliceous raw material, including oolitic chert.

3. Materials and methods

The 18 oolitic chert artefacts were recovered from Leonel Trindade's, Schubart and Sangmeister's, Michael Kunst's excavations and surface finds, between 1959 and 2004. After the inventory, the material was described following the techno-typological classical categories (Tixier *et al.* 1980: 123; Pelegrin 1988). The material recovered in excavation context has stratigraphic provenance, defined by a sequence of complexes established by E. Sangmeister and H. Schubart (1981: 226-262), which are associated to construction phases (*bauphase* 1-5), with several sub-phases (a-d). The archaeological materials are widespread among phase 1-4, with highest incidence in phase 3-4, which correspond to the younger phase (Table 1).

Chronologically the older phase spans a time period including the first half of the 3rd millennium BCE and the younger phase dates from the middle of the 3rd millennium to the first half of the 2nd millennium BCE (Kunst & Lutz 2008). Although most of the assemblage is composed by knapping products (14 blades and 2 bladelets), one core fragment and one debris were also identified (Table 1, Figure 2, Figure 3).

The three blades for polished thin-section were selected from the surface artefacts, without known stratigraphic provenance. The petrographic macro- and meso- description included their texture and inclusions (allochems) was performed with a Motic SMZ-140 stereomicroscope. Thin-sections were examined and characterized, using a Leitz Laborlux 12 Pol microscope (40x to 100x), focusing on general textures and particular allochems. Both compositional (Folk 1959) and textural (Dunham 1962) carbonate rocks classifications have been visually applied, regardless of its paleoenvironmental interpretation, taking into account that most flint nodules are a product of the silicification of previously carbonate rocks. A full wave-length gypsum plate was also used to identify the presence of chalcedony (negative elongation).

The polished thin-section were analysed by Raman microspectroscopy and several Raman parameters, moganite/α-quartz ratio, integrated intensity (area ratio) (Bustillo *et al.* 2012; Götze *et al.* 1998; Heaney 1995), and full with at half maximum FWHM (α-quartz) calculated. The Raman spectra were obtained in a Raman LabRAM HORIBA Jobin Yvon Spex spectrometer, equipped with a 632.8 nm emission line of a HeNe laser at a power of 20 mW and diffraction gratings of 1800 lines mm-1, interfaced to an Olympus microscope with a 100x objective lens. Extended scans were performed on the spectral range of 100 to 600 or

1200 cm-1. The time of acquisition and the number of accumulations varied in order to obtain an optimized spectrum for each analysed sample.

Table 1. Oolitic artefacts recovered in Zambujal between 1959-2004: inventory number, code number (with the information of stratigraphic complex), typology, collection year, section cut, area, section, complex and construction phase (bauphase, BP). The three blades observed in thin section are in blue filled cells. Abbreviations: ? - unknown

Number	Code	Typology	Year	Section cut	Area	Sub-area	Complex	BP
Z7663	Z-5	Blade	1959	5	Y	-	59005	Surf.
Z7664	Z	Bladelet	?	-	-	-	-	Surf.
Z7665	Z	Blade	?	-	-	-	-	Surf.
Z5661	Z-422-21	Blade	1970	58	U	-	422	Surf.
Z6800	Z-68024-35	Blade notch	1968	41	KM	K	68024	Surf.
Z5660	Z-945-78	Blade	1972	65	Y	YY	945	Surf.
Z5659	Z-1459-90	Blade	1973	71	VX	-	1459	4a-c
Z266	Z-296-9	Blade	1966	23	EG	Tower B	296	4a
Z5543	Z-311	Core	1966	Barbican	EG	Barbican	311	3c(/4a)
Z4344	Z-577-78	Bladelet	1970	33	GH	H	577	3c
Z7185	Z-528-86	Blade	1970	45	AP	A	528	3a/b
Z5653	Z-448-10	Blade	1970	24	EG	-	448	3
Z5971	Z-173-10	Blade	1964	16	AP	P	173	1b/3a
Z267	Z-6845-4	Blade	1968	Tower D	GH	Tower D	68045	1b
Z6202	Z-1444-55	Blade	1973	80	Y	XX	1444	1-4
Z5980	Z-68071-120	Blade	1968	37	EG	-	68071	1-3
Z255	Z-45-354-28-1	Debris	2004	45	AP	A	45354	?
Z8037	Z-45-339-22-1	Blade	2004	45	AP	A	45339	?

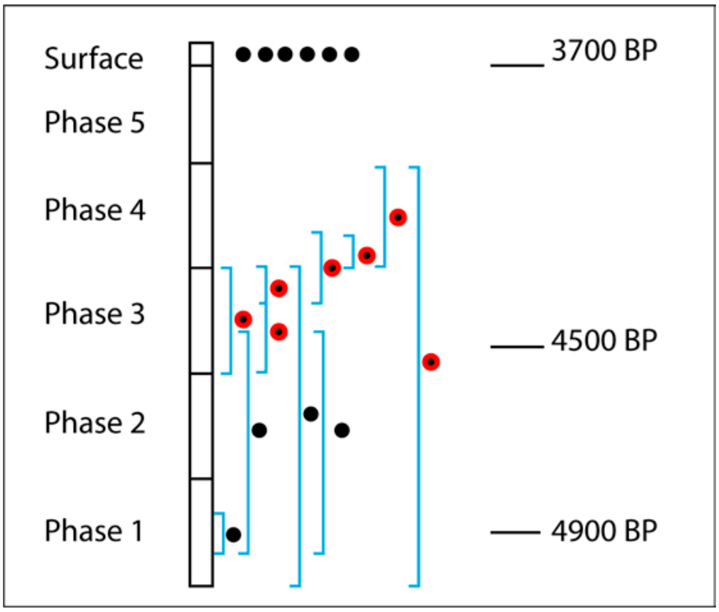

Figure 2 - Distribution of oolitic chert blades collected in Zambujal by occupation phase, highlighting the highest incidence between phases 3 and 4 - end of the 5th millennium BP and the first half of the 4th millennium BP (red circles).

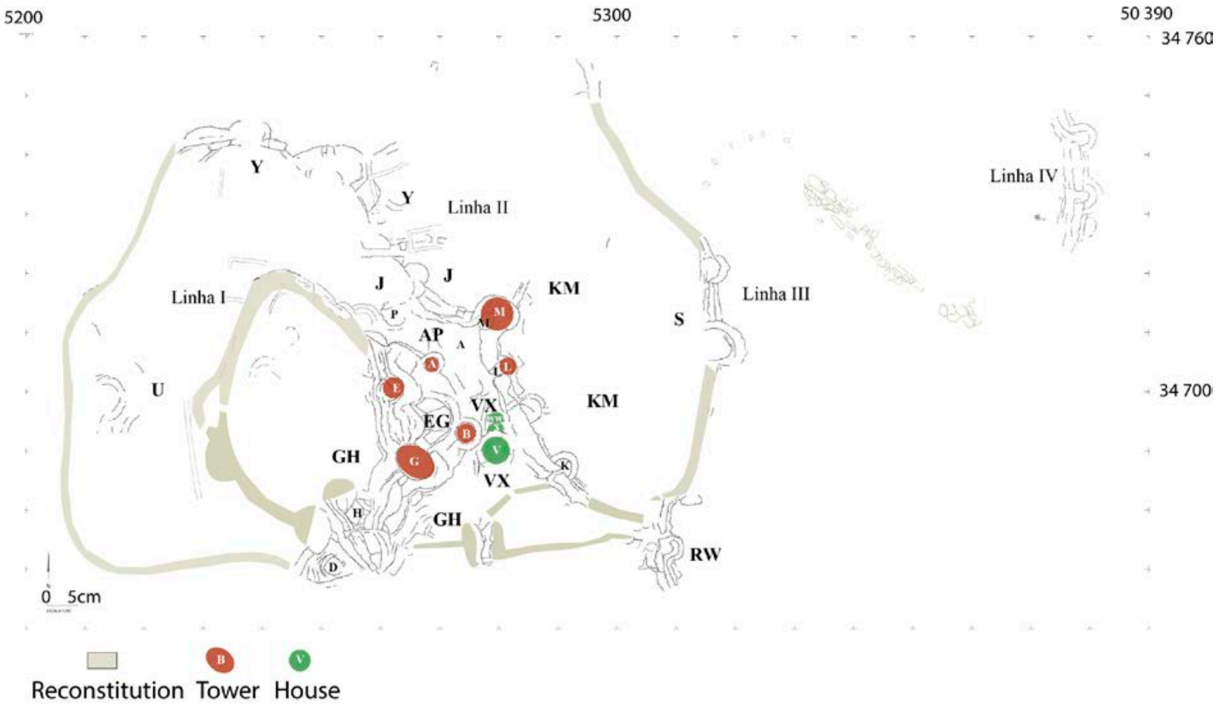

Figure 3. General plan of Zambujal showing the location of the main structures and identification of the four lines of fortifications: Four lines (Linha I, II, III, IV); gray (reconstitution), red (tower), green (house) (Jordão 2022 adapted from G. Casella).

4. The oolitic chert artefacts

The first impression of the artefactual assemblage is the intensive fragmentation and damage of the blades. Only one blade is complete (10.6 mm). The mainly mesial fragments are mostly prismatic with trapezoidal section (11) and three of them have triangular section. They are not very standardized: its maximum width and thickness vary between 32-16 mm and 5-12 mm (the bladelet is 9.7/ by 4.1 mm). These values are hight related to the average of the remaining blades recovered in Zambujal (Figure 4). Besides, there is no distinction between blades from 4th and 3rd millennia BCE contexts recovered in Guadalquivir valley (Nocete *et al.* 2005). All the material are retouched, sometimes in a second stage of use, as the blade reused as notch (Figure 5H). Some micro-use wear traces were observed in blades edges, revealing an intensive use as tools: for example, the presence of thin grooves (Figure 5D**) and lustre (Figure 5E**). The oolitic chert core fragment and the debris also confirm that the blades in Zambujal were reused.

5. Petrographic and mineralogical analysis

Macroscopically, the Zambujal oolitic blades are very homogeneous in colour - beige to light grey - with rough and opaque surfaces, sometimes exhibiting porosity. An exception is a small core with reddish and smooth surface (Figure 6A, A*).

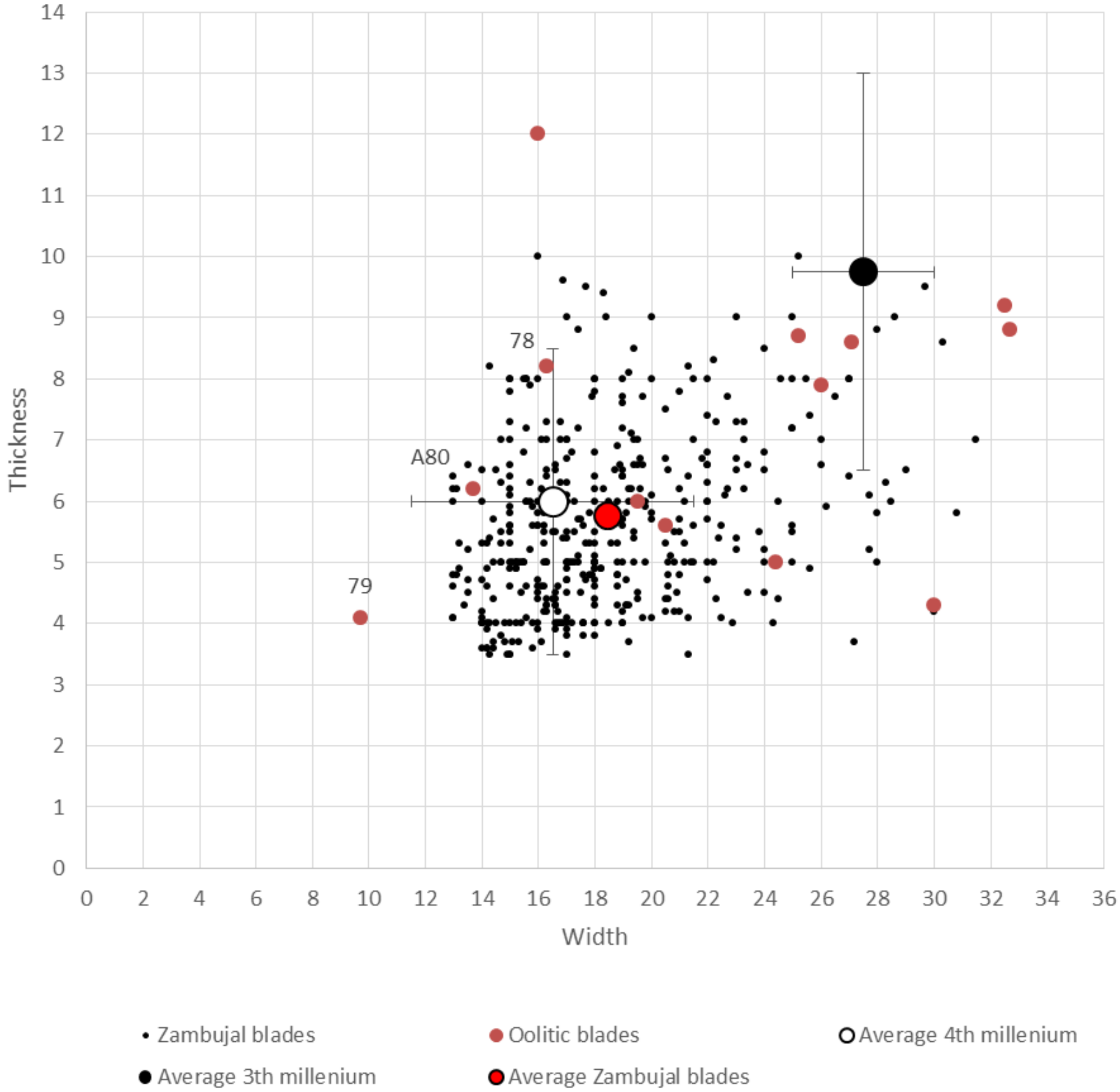

Figure 4. Thickness and width of Zambujal oolitic (orange) and non oolitic (black) blades, average of Zambujal non oolitic blades (red circle), and average with maximum and minimum values of 4th-3rd millennia blades of the Guadalquivir valley (white and black circles) from Nocete 2005.

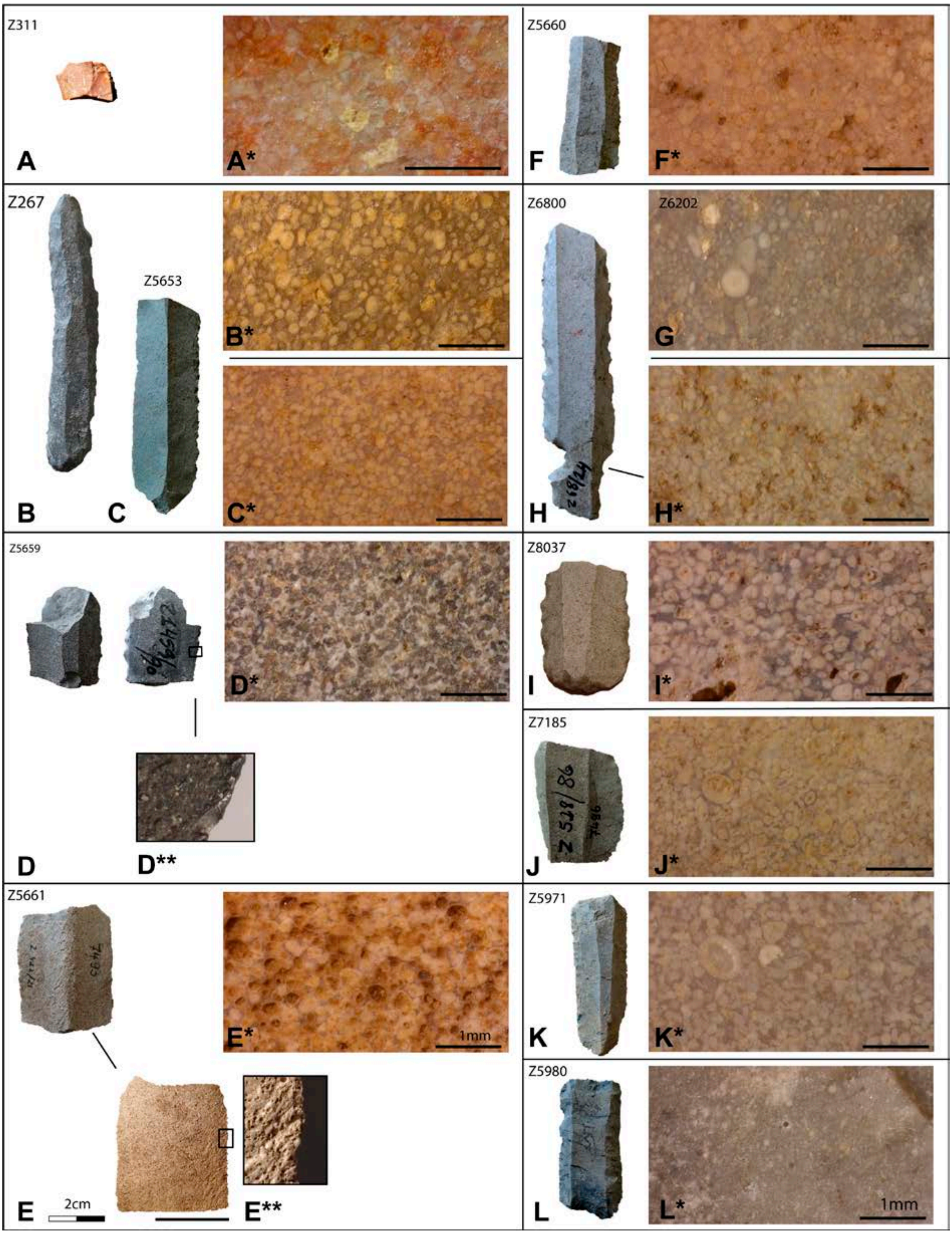

Figure 5. A: Core fragment of ferruginous oolitic chert (A*); blade, trapezoidal section blade fragment (B e F) and triangular section fragment (C), oolitic grainstone (B*, F* e C*); D: blade fragment with luster (D**), oolitic grainstone (D*); E: blade fragment with micro wear (E**), oolitic grainstone with secondary porosity (D*); H: blade fragment with *encoche* (E**), oolitic grainstone (H*); I, J, K: blade fragments, oolitic grainstone with heterometric oolites (G, I*, J* e K*); L: blade fragment, packstone with secondary porosity (L*).

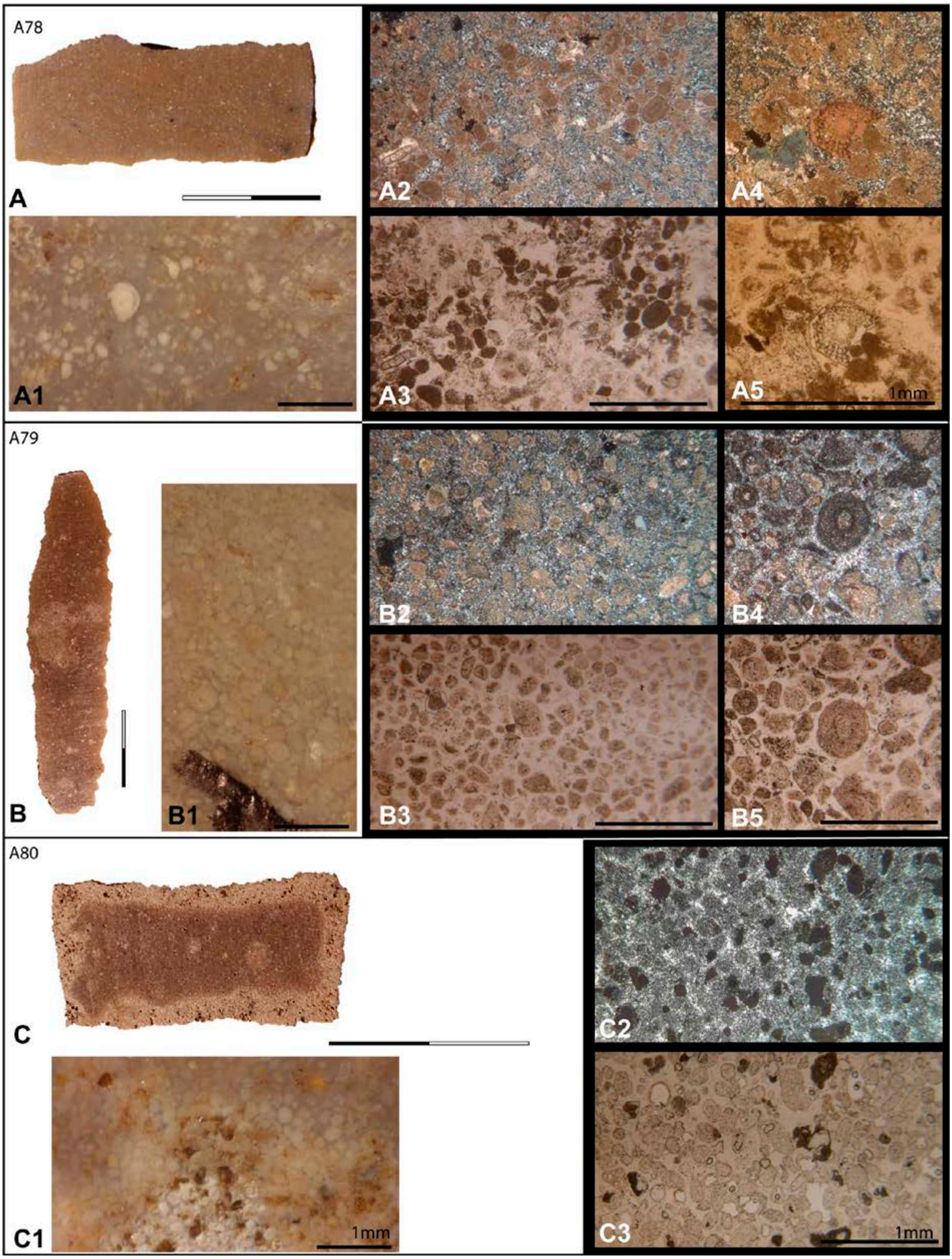

Figure 6. **A**: **Z-11a -** A78 sample, oolitic chert blade, oolitic pack- to grainstone (A1), with partially silicified matrix (A2, nc; A3, np), with several allochems, such bivalve's and echinoid's fragments (A4, CPL; A5, PPL). **B**: A79 sample, oolitic chert blade, with similar texture to A78 (B1; B2 e B4, CPL; B3 e B5, PPL). **C**: **Z-11b -** A80 sample, oolitic chert bladelet, in which it is observed porosity by dissolution (C1), grainstone with silicified matrix (C2, CPL; C3, PPL).

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 A78 and A79. Some fibrous quartz is also observed in the matrix (Figure 6: A2, B2, B4).

All samples have a grainstone oolitic texture. The allochems are mainly ooids, but echinoid fragments (Figure 6: A4, A5), peloids, coated grains, foraminifers and fragments of bivalves are also observed, frequently incompletely silicified (samples A78 and A79). A more silicified and poorly preserved microfacies has been observed in A80 sample, although with similar fabric. In A80 the dissolution of the original ooids and the matrix are observed, also visible in hand specimen. The ooid grains are generally small, around 0.2 mm in diameter, with a nucleus covered by one or more precipitated concentric coatings or a thin cortical coating. These oolitic facies suggest a shallow-marine environment, where grains are kept in constant motion (Scholle & Ulmer-Scholle 2003: 228).

A similar oolitic texture is noted through binocular lens in the remaining blades (Figure 6), and a peloidal with ooids texture was detected in one of them (Figure 6L*).

The analysis by Raman microspectroscopy confirmed that both α-quartz and calcite were the main minerals present. The α-quartz and calcite main vibrational modes, respectively at 465 cm^{-1} and 1089 cm^{-1} in A78 and A79 samples whereas A80 only shows α-quartz (Table 2; Figure 7).

Table 2. Raman data: code sample, peak position (Position), height, full width at half maximum (FWHM α-q) in cm^{-1}, Iintensity (I- α-q), assigned mineral.

Code	**Position**	**Height**	**FWHM (α-q)**	**I (α-q)**	**Mineral**
A78	465.346	161.488	9.5	2208.4	Quartz
	1089.4	208.586	-	1460.48	Calcite
A79	1088.8	254.031	-	1616.12	Calcite
A80	465.363	57.465	8.94	747.4	Quartz

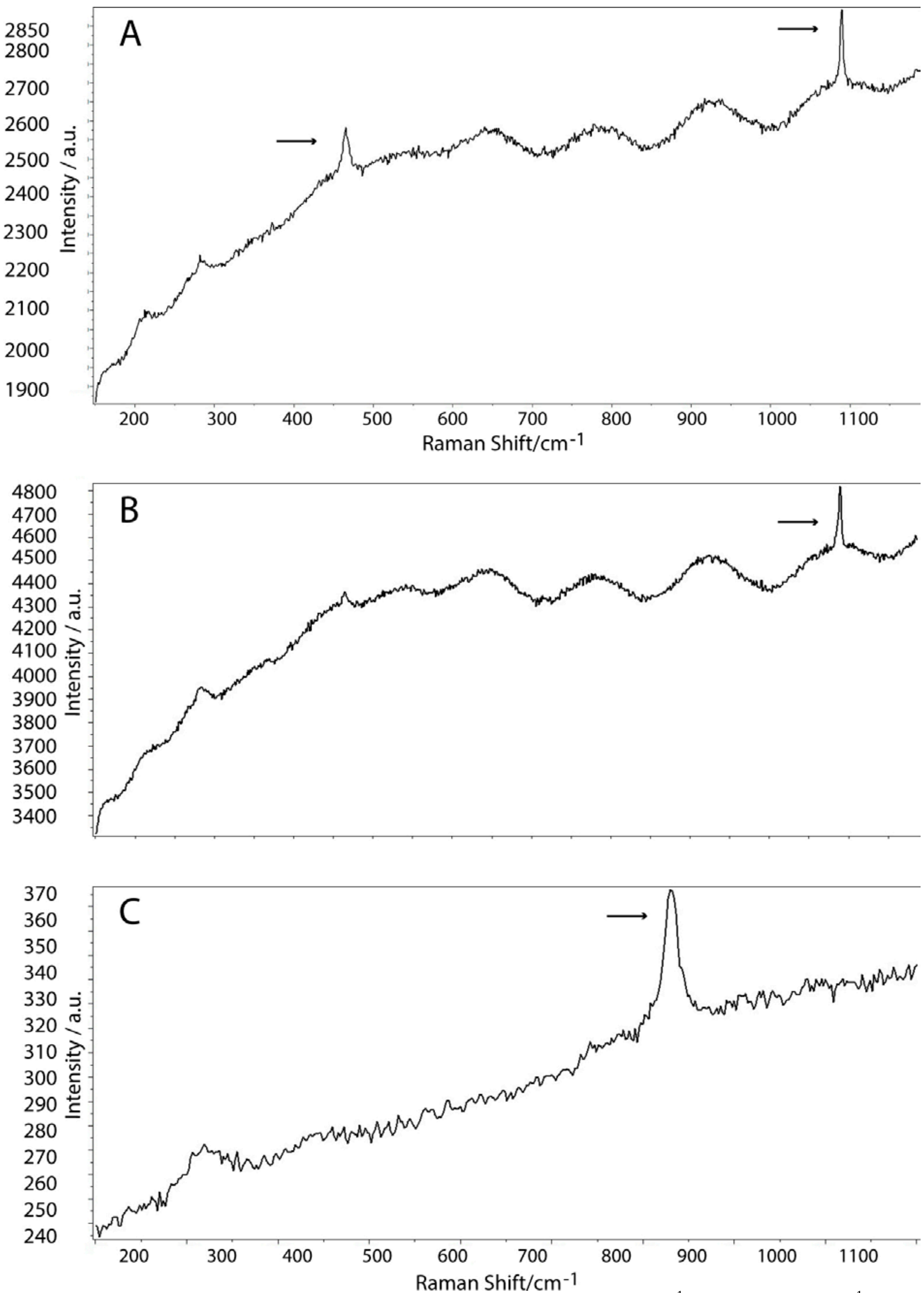

Figure 7. A: Raman spectrum obtained on A78 sample showing the quartz 465 cm^{-1} and calcite 1089 cm^{-1} peaks; B: Raman spectrum obtained on A79 sample showing the calcite 1089 cm^{-1} peak; C: Raman spectrum obtained on A80 sample showing the quartz 465 cm^{-1} peak (peaks are marked with the arrow).

In the Zambujal's oolitic samples two microfacies were observed: **Z-11a)** *Grainstone* oolitic texture, with a silicified matrix composed of micro- to mesoquartz and some fibrous quartz, and allochems frequently carbonated, containing oolites (until 0.25mm), other coated grains, bioclasts (echinoid spines, bivalves, foraminifers). **Z-11b)** *Grainstone* oolitic texture, 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 (until 0.2mm). This hight weathered texture shows secondary porosity by dissolution.

6. Discussion

The grainstone oolitic limestones are well documented in the middle Jurassic geological record of the Lusitanian Basin, in the formations from inner-ramp zones that outcrop in west central Portugal. The micritic limestones of Serra de Aire Formation (Bathonian) have interbedded oolitic levels (Azerêdo 2007); the thick succession of Santo António-Candeeiros Formation (Calovian) has oolitic and bioclastic facies as well (Azerêdo 2007), and also the Andorinha and Sicó Formation (Bathonian) (Azerêdo *et al.* 2003: 22-28; Martins 2007). In the Cesaredas Plateau (Peniche-Lourinhã) the Cabreira limestones (Bajocian) and the Cesareda limestones (Calovian) along with the oolitic bioclastic limestones have been well documented (Ruget-Perrot 1961: 170-179).

In the Algarve Basin (south of Portugal), in the middle Jurassic, the deposits of Malhão Formation interbedded oolitic reef limestones (Manuppella 1988). In the upper Jurassic, oolitic-peloidal packstones to grainstone are recorded in central and south sectors of Lusitanian Basin, such as in the Montejunto Formation, in a thick oolitic-intraclastic succession, and in the marly-limestones of the Alcobaça Formation (Manuppella *et al.* 1999). Also in the Algarve Basin thick successions of oolitic-crinoidal marly-limestones in "Calcários crinóidicos da praia do Tonel" formation occur (Rocha *et al.* 1983). In none of the previously mentioned Jurassic formations with oolitic limestones has the vertical or lateral passage to siliceous facies been observed. There are silicifications in limestones of the same age, mainly forming flint nodules, in non-oolitic facies (*e.g.*, micritic limestones of Chão das Pias Formation, in Lusitanian Basin, or on top of Malhão Formation, in Algarve Basin). The closest formations with these silicifications are located in Betic Cordillera, in the South-Southeast of Iberian Peninsula (Figure 8):

The Milanos Formation (Molina & J.A Vera 1996; Molina & Juan A. Vera 1996), Upper Kimmeridgian-Tithonian, in the Middle Subbetic (in the external zones of the Betic Cordillera), are composed mainly of calcarenitic and calcisiltitic levels, and is composed in the upper part marly limestones with oolitic chert. These cherts were collected in several mining sites in Granada: Los Gallumbares (Loja), Cerro del Reloj (Montefrío), Castijo del Zegrí (Iznalloz), Lomas de los Pedernales (Iznalloz) (Morgado Rodríguez *et al.* 2001)

The Milanos formation chert is of variable colour, with tones ranging from grey-white to grey-blue or even very dark grey. Its texture varies among wake-pack-grainstone oolitic and peloidal textures, with ooids, oncoids, calcareous algae, sponge spicules and other bioclasts (Morgado Rodríguez & Lozano 2011) (Figure 9C and 9D).

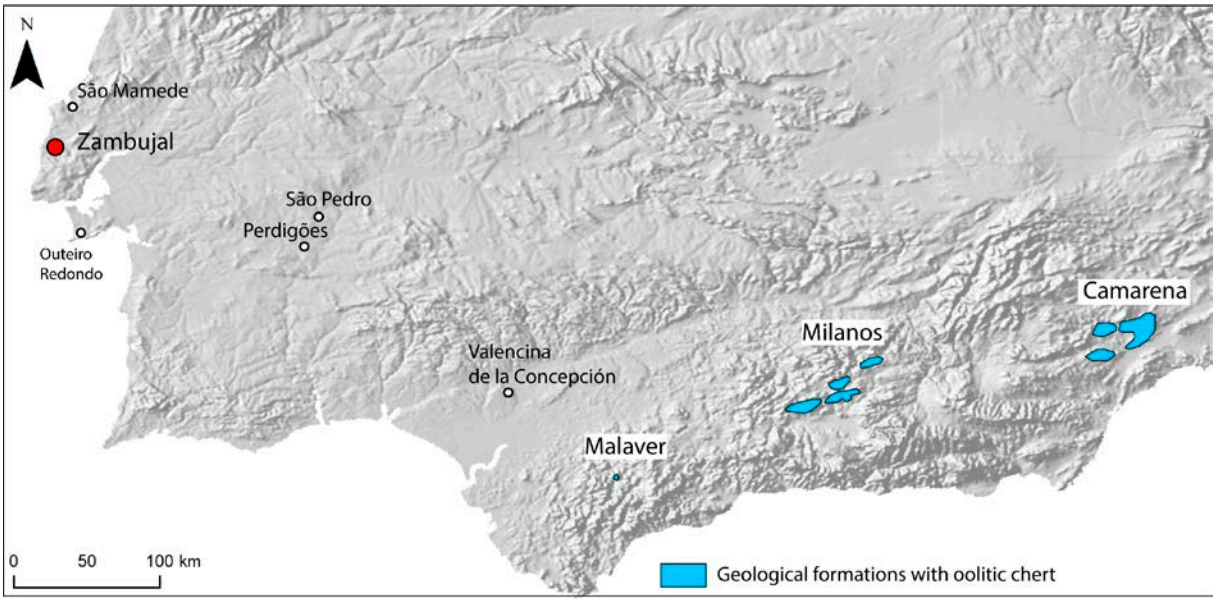

Figure 8 - Location of Zambujal and the other sites referred in the text with the main formations with oolitic cherts in the Iberian Peninsula, in the external zone of the Betic cordillera: Camarena Formation (Middle Jurassic), Milanos (Upper Jurassic) and Malaver (Miocene).

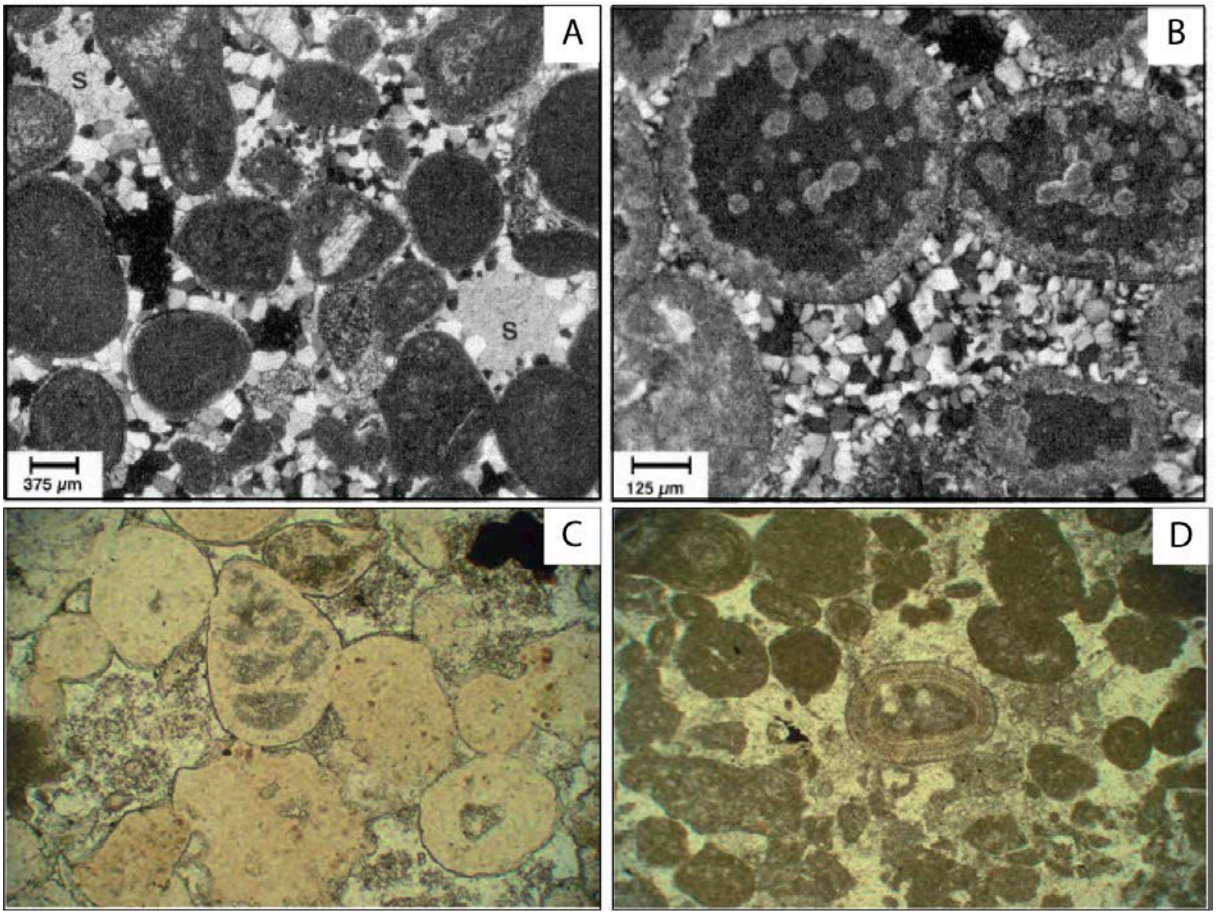

Figure 9. Chert from Camarena Formation: A and B the megaquartz replaces the mosaic cement of the host rock (crossed nicols) (Bustillo 1998); Chert form Milanos formation: C - grainstone texture with oolites, benthic foraminifers and peloids (parallel nicols); D - grainstone texture with oolites (parallel nicols) (Morgado Rodríguez et al. 2011). (Note that C and D lack scale bars in the original publication.)

The Malaver Formation (Bourgois & Chauve 1971), outcropping between Montecorto (Ronda, Málaga) and El Gastor (Cádiz), is a part of the Campo de Gibraltar Complex. Formed during the Lower Miocene, massive conglomerates hundreds of meters thick and megabreccias from the Middle Subbetic (and clays from Campo de Gibraltar Complex) contains a diversity of chert types (Gutiérrez Más 1991: 111-118), generated in Lower-Middle-Upper Jurassic. In cherts from Malaver Formation stylolites filled by quartz have been found. The oolitic facies from Lower-Middle Jurassic of this formation was mainly exploited during the Chalcolithic in order to produced large blades as it is documented at the workshop of Malaver-Lagarín (Cádiz-Malaga) (Martínez Fernández *et al.* 1991).

The Camarena Formation (Molina 1987: 100-136) is the furthermost formation from Zambujal with oolitic chert. The formation is located in the eastern sector of the Subbetic zone, between Murcia and Almeria. Brown and reddish chert layers and nodules occur on top of the formation with no lateral zonation (Rey 1995). The *grainstone* oolitic texture are composed of ooids, onchoids, peloids, but also benthic foraminifers and lamellibranches, showing punctual to tangential contacts in the allochems. In these silicified oolitic limestones, the calcite cement has been replaced partially or totally by megaquartz in a slow process with interference of meteoric water (Bustillo *et al.* 1998; Bustillo *et al.* 1997) (Figure 9A and 9B).

The microfacies observed in Zambujal's oolitic samples - **Z-11a** and **Z-11b** - look more similar to Milanos than to Camarena Formation. In fact, the absence of a mainly matrix filled with megaquartz and ooids with punctual to tangential contact in the most allochems allow us to state the reduced probability of provenance from Camarena Formation. An additional source possibility is from the Malaver Formation (Ronda), a secondary alluvial source of Milanos chert.

The oolitic chert blades from Zambujal probably came from one of the formations exploited in southern Iberia since the Late Neolithic (c. 3700 BCE) until the Beaker culture pottery (between 2400 and 2300 BCE) (Morgado Rodríguez & Lozano 2011).

Recent studies about blades morphometry concluded that in the 4th millennium production is not very standardized, whereas in 3rd millennium the production tendency becomes more normalized (Nocete *et al.* 2005). Regarding the relative chronology of Zambujal's blades in Table 1, most of them belong to the younger phase, dated from the end of the 3rd millennium to the first half of the 2nd millennium BCE. So, apparently, there is no correspondence between normalization and a more recent chronology in Zambujal. Moreover, oolitic artefacts seem to be at the "end of their use life" of their second or third utilization: they are very fragmented and intensively reused, suggesting abandonment after a long time their arrival at the settlement. The lack of complete blades and their intensive reuse makes it difficult to clarify the primary e functionality of these artefacts. An interesting explanation is that the oolitic blades are related to the handling of metallurgical crucibles, recognized throughout the 3rd millennium BCE. In Zambujal there is a copper metallurgy documented from the very beginning of the occupation (Müller *et al.* 2007; Müller *et al.* 2008: 24). However, it is difficult to establish a direct relationship between blades and crucibles with the assemblage.

Nevertheless, the oolitic blades as foreign artefacts manufactured from long distance materials are certainly indicators of paths source networks. Based on geochemical analyses, K. Lillios (1997) showed that the Estremadura's amphibolite possibly came from the Ossa Morena Zone, the same geological source of the early copper of Zambujal (Müller *et al.* 2007), more than 100km away from the settlement. These raw materials may have been exchanged for chert and alluvial gold of the lower Tejo, as J. L. Cardoso suggests (1999), and even for ivory and limestone objects, which are abundant in Estremadura, in return for Alentejos's schist plaques (Schuhmacher 2017).

The oolitic chert blades may have travelled together with amphibolite and copper to Zambujal as part their journey, but probably were included in much larger and organized trade networks of Southern Iberia (García Sanjuán & Murillo-Barroso 2013; Afonso Marrero *et al.* 2011). Their small quantity and functionality documented in settlements are sufficient characteristics to classify oolitic chert blades as pieces of a "foreign package" devoid of prestige status, but important enough to be acquired, perhaps due to the durability of the raw material. These observations of Zambujal's oolitic artefacts are also documented in other Portuguese settlements such as São Pedro, Redondo (Andrade *et al.* 2020), Outeiro Redondo, Sesimbra (Cardoso *et al.* 2018), São Mamede (Jordão in press) e Leceia (Jordão & Cardoso 2024). The apparently non-exceptional status of oolitic artefacts in the lithic assemblages correspond to a hypothesis for poor territorial hierarchization in Portuguese Estremadura where exotic objects were disseminated among the big number of small and medium fortified settlements (Sousa & Gonçalves 2012).

7. Conclusions

The current study presents the preliminary results of techno-typological study and the petrographical and mineralogical analysis of the oolitic artefacts from Zambujal. The *grainstones* oolitic textures recognized are similar to the observed in cherts from Milanos and Malaver formations, distance more than 500km from the site. The absence of megaquartz in the matrix and an occasional punctual to tangential contact of the grains allow us to discard the Camarena Formation as source area for the blade's raw material. In addition, two microfacies were observed, also identified in the Milanos and Malaver Formations: One has a high quantity of calcite, confirmed by Raman microspectroscopy analysis, and varied allochems, with grains and bioclasts while the other contains exclusive α-quartz and homometric allochems, some of them already dissolute.

The pattern in morphometry of oolitic chert blades distinguished between the 4^{th} and 3^{rd} millennia in Iberian Southwest trade - respectively width: thickness between 1-2.3cm:0.3-0.9 and 2.5-3cm:0.65-1.3cm (Nocete *et al.* 2005: p.69) - was not recognized in Zambujal, whose assemblage is more varied in measurements and typologies, suggesting their use for different activities.

The "first" oolitic chert probably arrived to Zambujal in the form of elongated products, mainly blades but also bladelets, then underwent intensive reuse and intentionally segmented for a variety of functions, as it is documented by use wear micro traces.

The wide geographic distribution of oolitic blades from the Guadalquivir Valley and peripheral areas was previously studied showing a supra regional range (Nocete et al. 2005). The exogenous oolitic blades in Zambujal clearly documented that the site was involved in a long-distance network of contacts in whose dynamics the large aggregation centres would have played an important role during the Chalcolithic. The archaeological site of Perdigões has been interpreted as an important aggregation and redistribution centre (Valera et al. 2020) where goods arrived likely in modality of "ResourceComplex" (Bartelheim & Bueno Ramírez 2017).

Despite having an exotic status, the utilitarian nature of the oolitic blades makes unclear their social meaning. On contrary, such ivory objects clearly address individual status or ideological issues (Valera et al. 2015; Schuhmacher 2017).

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Data accessibility statement

The authors confirm that the data supporting the findings of this study are available within the article and its supplementary files.

List of supplementary files

Supplementary file 1
"Jordão et al. - Supplementary file 1.pdf"
Figure 4. Thickness and width of Zambujal oolitic and non oolitic blades, average of Zambujal non oolitic blades, and average with maximum and minimum values of 4th-3th millennia blades of the Guadalquivir valley from Nocete 2005.

Supplementary file 2
"Jordão et al. - Supplementary file 2.pdf"
Figure 5. A: A78 sample with the quartz 465 cm^{-1} and calcite 1089.4 cm^{-1} peaks; B: A79 sample with the calcite 1088.8 cm^{-1} peak; C: A80 sample with the quartz 465.363 cm^{-1} peak.

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Pedras em viagem: as lâminas de sílex oolítico do recinto calcolítico do Zambujal (Torres Vedras, Portugal)"

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Resumo:

O sílex oolítico foi uma matéria-prima importante para a produção de grandes lâminas na região da Cordilheira Bética (Andaluzia, Espanha) a partir do final do 4º e ao longo do 3º milénio a.C. Essas lâminas fazem parte de um conjunto de materiais que circulariam através de redes de comércio de longa distância, como testemunha a sua ocorrência em sítios calcolíticos do Sudoeste da Península Ibérica, que se complexificam no Calcolítico, indiciando importantes mudanças sociais (Lillios 2020). Situado a mais de 500 km de áreas-fonte de sílex oolítico, o Zambujal apresenta-se como o sítio mais ocidental da Península Ibérica onde esta matéria-prima foi observada. Neste sentido, a determinação da proveniência das lâminas de sílex oolítico contribui para a compreensão da mobilidade durante o Calcolítico na Península Ibérica, como parte de uma rede complexa de comércio, exploração e produção especializada.

No presente estudo, foram analisadas todas as lâminas de sílex oolítico recuperadas no Zambujal provenientes das antigas escavações realizadas entre 1964 e 1973 por H. Schubart e E. Sangmeister, até às investigações mais recentes conduzidas por M. Kunst (1994-2012).

Nos primeiros trabalhos de estudo da indústria lítica levados a cabo por M. Uerpmann a matéria-prima foi genericamente caracterizada, tendo sido identificadas, ainda assim, diversas matérias-primas siliciosas, como o sílex, a calcedónia, o quartzo e o quartzito (Uerpmann & Uerpmann 2003). A variedade oolítica, no entanto, só mais tarde foi reconhecida por um dos signatários (P.J.) aquando do estudo de toda a cadeia operatória, que incluiu os recentes materiais recuperados durante as intervenções de M. Kunst.

Após classificação tecno-tipológica do conjunto de lâminas, seguiu-se a descrição da matéria-prima, com particular atenção às características petrográficas de composição mineralógica e textura (fase de ligação e elementos figurados), à escala macroscópica, em amostra de mão, com auxílio de lupa binocular e também à escala microscópica, através de microscópio petrográfico. As lâminas delgadas polidas foram analisadas também através de Espectroscopia Micro-Raman para determinar as principais fases cristalinas presentes.

Foi possível correlacionar, com alta probabilidade, a matéria-prima arqueológica com a matéria-prima geológica, neste caso o sílex oolítico da Formação Milanos (Kimmeridgiano Superior-Titoniano no Subbético Médio, Granada) e também da Formação Malaver (Miocénico no Complexo do Campo de Gibraltar, Málaga), um sílex oolítico gerado no Jurássico Inferior-Médio que ocorre na fracção conglomerática desta última formação.

Observou-se também nas lâminas do Zambujal a presença de sinais de utilização, um comprimento reduzido (por desgaste) e intensa reutilização (por retoque) dos produtos de debitagem de sílex oolítico. Este conjunto de características é frequentemente observado nas lâminas congéneres dos sítios calcolíticos da Estremadura.

A associação entre o uso intensivo e a escassez destas lâminas nos registro arqueológicos sublinha a importância destes artefactos nas atividades domésticas, enquanto utensílios funcionais de "prestígio" (Teather 2008: 84). Ao mesmo tempo, as lâminas de sílex oolítico são testemunho de uma complexa mobilidade de pessoas e, consequentemente, de objetos durante o Calcolítico. O conjunto expressivo de lâminas de sílex oolítico do Zambujal inscreve este sítio e assinala a sua importância na ainda mal conhecida rede de relações transregionais ao longo do 3º milénio a.C.

Palavras-chave: petroarqueologia; sílex oolítico; Calcolítico; Portugal; mobilidade