
Raw material sourcing in the Middle Paleolithic site of Gruta da Oliveira (Central Limestone Massif, Estremadura, Portugal)

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Abstract:

The cave site of Gruta da Oliveira is located in the Almonda karst system, at the interface between the Central Limestone Massif of Portuguese Estremadura (CLM) and the adjacent Sedimentary Basin of the River Tagus (TSB). The cave presents a stratification dated to ~37-107 ka containing hearth features, Neanderthal skeletal remains, as well as fauna, microfauna and wood charcoal remains. The lithic assemblages are large and feature a diverse range of raw materials.

Knappable lithic raw materials in primary, sub-primary and secondary position in the CLM and the TSB were systematically surveyed and sampled. The characterization of the geological samples was carried out at both the macro- and the microscopic scales and data were systematized under the petroarcheological and “evolutionary chain of silica” approaches.

The study of the lithic assemblage from layer 14 (dated to the ~61-93 ka 95.4% probability interval by TL) indicates that the Gruta da Oliveira Neanderthals used quartzite, quartz and flint from sources located less than 30 km away in both the CLM and the TSB.

Keywords: Almonda karst system; Gruta da Oliveira; Middle Paleolithic; Neanderthals; petroarcheology; flint

1. Introduction

The Almonda karst system, an extensive network of cavities associated with the spring of the River Almonda, is located in the Meso-Cenozoic Western Border (MCWB) of Iberia, at the boundary between the Central Limestone Massif (CLM) and the Tagus Sedimentary Basin (TSB). Among those of archeological interest, the lowermost passages, 5-15 m above the current spring, contain deposits of Upper Paleolithic and later prehistoric age (Almeida *et al.* 2004; Angelucci & Zilhão 2009; Zilhão 1997) (Figure 1). Higher up in a 70 m escarpment, the labyrinth of passages features several collapsed cave entrances, two of which have been cleared for archeological excavation, ongoing since 1991.



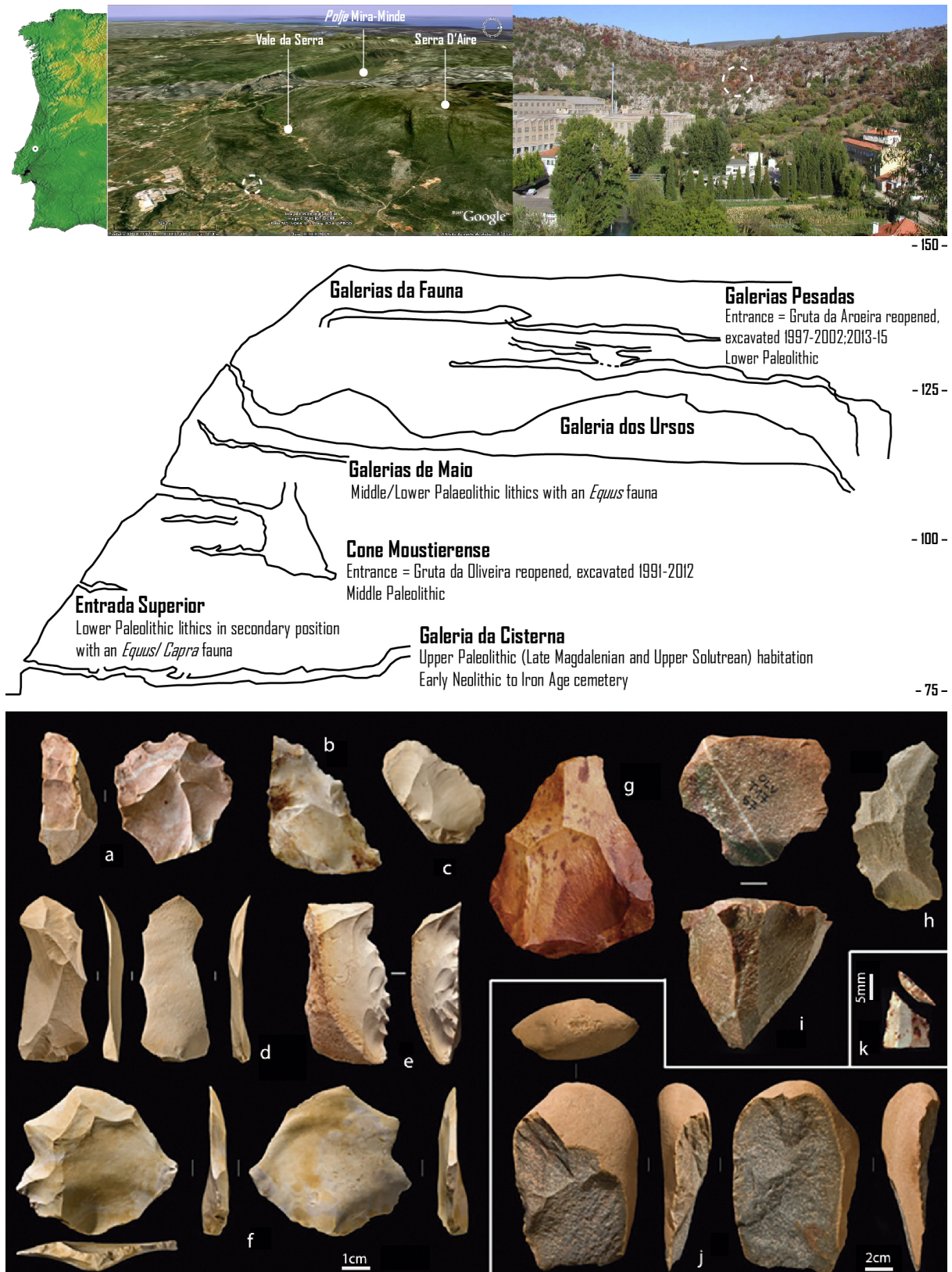


Figure 1. The location of Gruta da Oliveira (top), schematic cross-section of the Almonda escarpment showing the position of the main archeological sites (center), and a selection of stone tools from Gruta da Oliveira (base): a. *Levallois* core, layer 20; b. Denticulate sidescraper, layer 26; c. Sidescraper, layer 26; d. *Levallois* blade, layer 20; e. Denticulate, layer 14; f. *Levallois* flake, layer 19; g. *Levallois* core, layer 13; h. Denticulate, layer 26; i. Pyramidal core, layer 10; j. *hachereau*, layer 20; k. Truncated bladelet, layer 14; a.-f. and k., flint; g.-j., quartzite. (Photos b. to k. by João Zilhão; Photos a., j. and k. by José Paulo Ruas (after Hoffmann *et al.* 2013; Zilhão *et al.* 2013)).

At the top of the escarpment, the Gruta da Aroeira, excavated between 1997 and 2002 and anew since 2013, features an Acheulian breccia dated to >420 ka that yielded an industry with handaxes and other bifacial items (Hoffmann *et al.* 2013; Marks *et al.* 2002). Lower down, the Middle Paleolithic site of Gruta da Oliveira preserved a ~13 m-thick sequence of stratified Mousterian occupations dated by U-series, Thermoluminescence and Radiocarbon to between ~37,000 and ~107,000 years ago (Angelucci & Zilhão 2009; Hoffmann *et al.* 2013; Richter *et al.* 2014). Neanderthal osteological remains were found in several levels of the Oliveira sequence, which also yielded lithic and faunal remains allowing the identification of activity areas (knapping and food processing) organized around fireplaces; the lithic assemblages feature *Levallois* and *Kombewa* reduction methods alongside the production of elongated, Upper Paleolithic-type blanks (Figure 1 - i. and k.) (Marks *et al.* 2001; Zilhão *et al.* 2013).

The main goal of this study was to determine the lithic raw material sources exploited in order to reconstruct the regional Neanderthals' territoriality and subsistence strategies. For this purpose, a reference collection of raw material sources (Figure 2) was compared with a sample of stone tools from layer 14 (dated to the ~61-93 ka 95.4% probability interval by TL), used as a case study.

1.1. Historical background

Interest in lithic raw material sources is documented since the 19th century, but it was not until the 1970's and 1980's that Petroarcheology became established as an autonomous discipline with a well-defined methodological frame (Mangado Llach 2002). Annie Masson (1979; 1981) proposed a methodology for macro- and microscopic analyses of silicifications, while Jean-Michel Geneste (1985) correlated sourcing data with lithic technology for the Mousterian of southwestern France, introducing a spatial dimension in lithic technology studies (Geneste 1991).

In Portugal, mobility and raw material procurement were first addressed in early 1990s, in the context of a study of the Upper Paleolithic of the Rio Maior basin. This preliminary work used macroscopic data and only considered the Upper Cenomanian flints occurring in the siliciclastic formations of the TSB, where archeological sites are located less than 5 km from such flint sources (Marks *et al.* 1991). Recent petroarcheological studies have also included geochemical analyses (Pereira *et al.* 2016; Shokler 2002).

Systematic surveys aiming at the identification of raw material sources were carried out in the Côa Valley in the mid-1990's, in the wake of the discovery of its Paleolithic rock art and coeval settlement sites (Aubry 2005; Aubry *et al.* 2012; Aubry & Mangado Llach 2003a; b; 2006; Aubry *et al.* 2004; Mangado Llach 2002). Despite their absence in the Hercynian Massif region and therefore in the Côa, flint and silcrete are systematically present in the valley's Upper Paleolithic assemblages, and could be sourced to geological formations located more than 150 km to East and Southwest, including the CLM and TSB regions (2003a; b). Using a GIS least-cost algorithm, models of the circulation of these resources and the size of exploitation territories were proposed as proxies for the social networks that knitted together the Upper Paleolithic groups living in the different geographical areas concerned (Aubry *et al.* 2016; Aubry *et al.* 2012).

Subsequent studies in southern Portugal include Veríssimo's (2004; 2005) survey and macroscopic characterization of Jurassic flint in primary and secondary position in the region of Vila do Bispo, Burke's (Bisson *et al.* 2011; Burke *et al.* 2011) survey and geochemical analysis of jasper sources in the context of a study of the Middle Paleolithic in western Alentejo, and Gaspar's (2009; Gaspar *et al.* 2009) research on the igneous and metamorphic rocks used in the Neolithic site of Laginha 8. In the MCWB, Jordão (2010) determined the

origin of local and regional flints used in the Chalcolithic assemblage of São Mamede, while Gameiro (2003; 2012; Gameiro *et al.* 2008) undertook a petrographic characterization of Magdalenian assemblages in the Sicó massif and the Rio Maior basin, as well as in Lapa dos Coelhos, a site in the Almonda karst system. In the latter, preliminary results concerning the Gruta da Oliveira material were reported by Aubry *et al.* (2014) and Matias (2012).

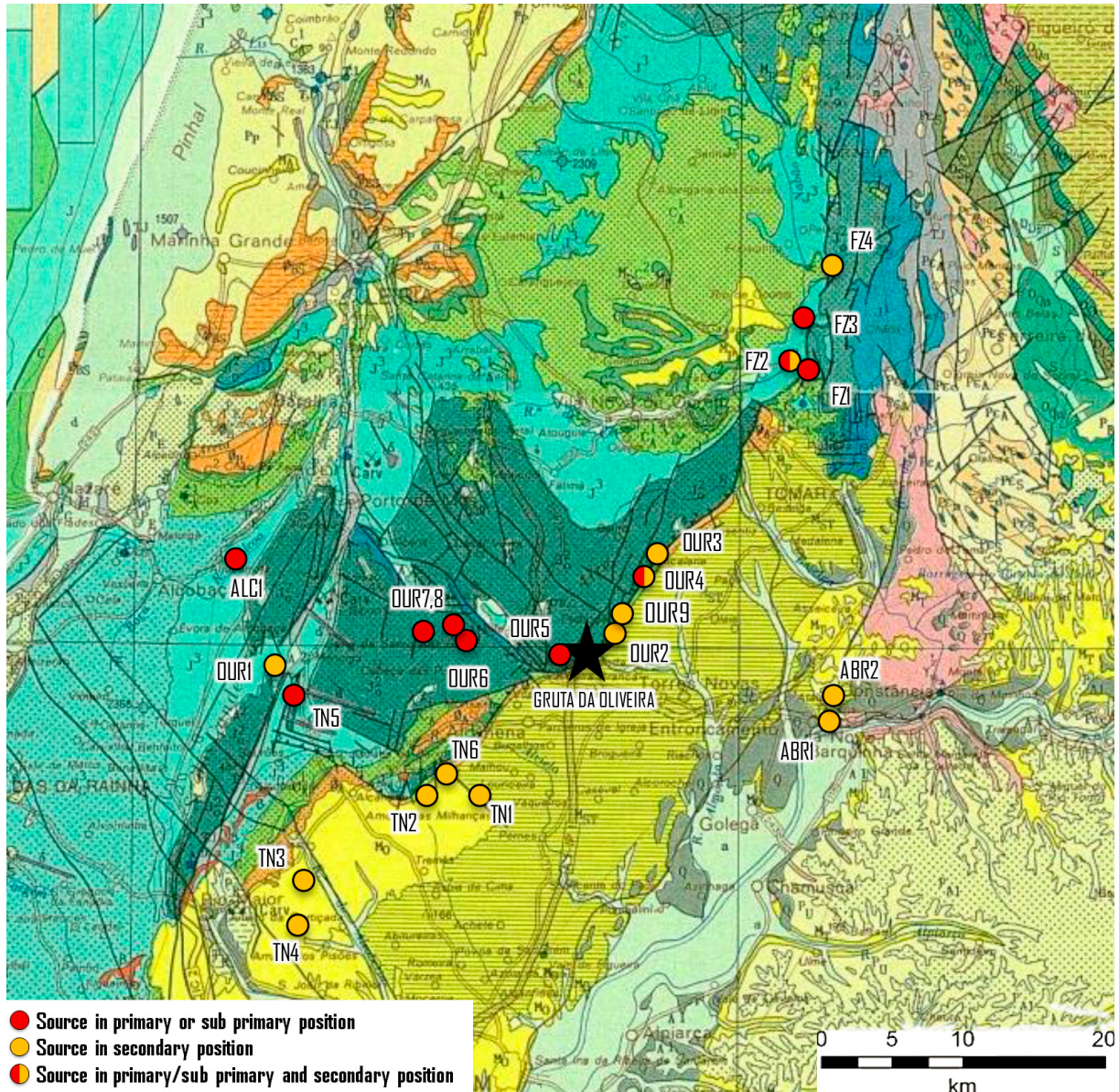


Figure 2. Detail of the Geological Map of Portugal (1:500.000, resized) (Delfim de Carvalho *et al.* 1992), showing the Central Limestone Massif and surrounding area of the Tagus Sedimentary Basin, with location of the geological samples used in this study.

2. Analytical methods and samples

Considering the concept of *chaîne opératoire* in its application to knapping (Leroi-Gourhan 1964), the acquisition of raw materials is logically the first stage of the reduction sequence (Geneste 1991). Thus, the study of the origin and proportions of the different types of raw materials present in an archeological stone tool assemblage should be the first step in its study (Almeida *et al.* 2003; Tixier *et al.* 1980).

Here, available (even though, concerning existent silicifications, their resolution is low), bibliographic and cartographic data were used to define locations in the TSB and CLM to be targeted for survey and sample collection. Samples were analyzed macroscopically using a stereomicroscope (*OLYMPUS SZ61* up to x45 with a coupled photographic camera *OLYMPUS SC20*), and thin sections were observed under the microscope (*CARL ZEISS Axiophot Pol* up to x200 with coupled photographic camera *Sony DXF-S500*).

Flint and other silicifications (*e.g.*, silcrete) were typed according to geological origin, paleoenvironment of formation (Bressy 2003; Séronie-Vivien & Séronie-Vivien 1987) and the “evolutionary chain of silica” concept proposed by Fernandes & Raynal (2006; Fernandes *et al.* 2008), adapted by Aubry *et al.* (2012). Sedimentary rocks, like flint, preserve features resulting from complex physico-chemical and mechanical processes related to their deposition environment, making it possible to classify them according to specific genetic and stratigraphic position, paleogeographic environment and aspects of their post-genetic history relating to the present location of the source (Fernandes & Raynal 2006).

Macroscopical analysis under the binocular stereoscope considered color and its distribution, transparency, grain size, texture (after Dunham 1962), sedimentary structures, skeletal and other bioclastic elements, porosity and non-skeletal elements, surface condition, weathering, cortex type, degree of cortex rounding, and knapping quality. Thin sections observed under the microscope focused on mineralogy and crystallization; the siliceous components, their crystal type and size, as well as their diagenetic and post-diagenetic phases of silicification were described alongside the non-siliceous and detrital components. These data are summarized in Table 1.

The same approach, bar microscopic analysis, which could not be carried out in this initial stage of the Gruta da Oliveira research, was applied to the archeological material. Layer 14 was selected due to its high level of stratigraphic integrity, attested by the presence of a fireplace and associated lithic and bone scatters (Angelucci & Zilhão 2009; Nabais 2011; Zilhão *et al.* 2010; Zilhão *et al.* 2013). The analyzed sample comprises 3071 lithic artifacts (out of the layer’s total of ~7700) retrieved within an area of 6m² (grid units L21, M19, M20, N19, O19, P16 and P19) (Table 2). The Levallois, Kombewa and discoidal methods are represented among both flint and quartzite. The most frequent tools are notches, followed by denticulates, retouched flakes and blades, and sidescrapers.

The flint from the cave presents a significant level of weathering. Desiliconization (Bressy 2003) or flint necrosis (Vignard & Vacher 1964) is present. When broken, flints with this type of weathering show a whitish powder core with no structure or consistency and a hard, external, ~1 mm-thick shell preserving some diagnostic elements (texture, structure fossils, *etc.*) but lacking others (color and translucency). This “necrosis” has been related to the dissolution and neogenesis of silicon in alkaline environments with water circulation, characteristic of cave sites (Masson 1981). Different degrees of weathering are often observed across different areas of the site, within the same stratigraphic unit, and such differences are therefore devoid of chronological meaning (Rottlander 1975).

Despite these weathering problems, the lithic assemblage from layer 14 preserved enough of the structure, texture and other recognizable and distinctive features of the raw materials. Comparison with the geological samples and, hence, identification of the flint sources used, was therefore possible.

Table 1. Silicification types from CLM and TSB. (a) Types are named after geologic map codes followed by a sequential number. (b) 0 (*In situ* outcrops), 1 (sub-primary outcrops), 2 (colluvial occurrence), 3 (recent river deposits), 4 (old alluvial deposits). (c) BRE (brechoidal), LAM (lamination), LCR (liesegang concentric rings), MLR (multiple liesegang rings), PER (peloidal relict). (d) CNG (conglomerate), GRN (grainstone), MUD (mudstone), PAC (packstone), SAN (sandstone), WAC (wackstone). (e) CAL (undetermined chalcedony), CAL-LF (chalcedony length-fast), CAL-LS (chalcedony length-slow), CQ (criptoquartz), mQ-CQ (microquartz-cryptoquartz), DOL (dolomite), MQ (macroquartz), mQ (microquartz), Q (alpha-quartz). (f) BIV (bivalve), CHA-O (Charophyta gyrogonite), CHA-S (Charophyta stem), ESP-M (monoaxone spicule), ESP-T (triaxone spicule), FRAG-IND (Undetermined fragment). FOR (foraminifer), GAS (gastropod), INS (insertae sedis), OST (ostracod). (g) CaCO₃ (calcite), FEN (fenestral porosity), INT (intraclast), MO (organic material), MOL (moldic porosity), MOS (moscovite) OF (iron oxide), OOI (ooid), PEL (pellet), PEO (peloid), Q-TER (terrigenous quartz). (h) CONT (continental), CONT-AL (alluvial), CONT-LAC (lacustrine), MAR (marine). (p) = possible.

Genetic type (a)	Gitologic type(b)	Sample locality	Sedimentary structure (c)	Texture (d)	Mineralogy (e)	Skeletal grain, bioclasts(f)	Porosity and non-skeletal (g)	Formation environment (h)
J2-2a	0	OUR5	LCR, PER	MUD	mQ-CQ(70%), MQ, CAL-LF(10%)	ESP-M, FOR, GAS(p), INS	FEN, MOL, OF, CaCO ₃ ,	MAR
J2-2b	0	OUR6	PER	WAC	mQ-CQ(65%), mQ(5%), CAL-LF(10%)	ESP-M(p), ESP-T, GAS, CHA-S, INS(p)	FEN, PEO, OF, CaCO ₃ , MO(p)	
J2-3	1	OUR7, OUR8	MLR, PER	MUD, WAC	mQ-CQ(75%), mQ(5%), CAL-LF(5%)	ESP-M(p), GAS, OST, FRAG-IND	FEN, MOL, OF, CaCO ₃ , MO(p)	
J3-1	0	FZ1	LCR	MUD	mQ-CQ(90%), MQ(<5%),CAL-LF(<5%)		OF, CaCO ₃	CONT-LAC or MAR
	4	FZ4	LAM	MUD	mQ-CQ(90%), MQ, CAL-LF	CHA-O, CHA-S(p)	OF	
J3-2	0	TN5	LAM, PER	WAC, PAC	mQ-CQ(70%), CAL-LF(5%)	GAS, OST(p), CHA-S(p), FRAG-IND	MOL, OF, CaCO ₃ , DOL	
J3-3	0	FZ2, FZ3	NOTS	NOTS	NOTS	NOTS	NOTS	
	1, 2, 3	FZ2	PER, BRE,	MUD, WAC	mQ-CQ(60-90%), MQ(<10%)	GAS, BIV(p), CHA-O,	FEN, MOL, OF, PEO, INT,	Q-TER, MO(p), CaCO ₃
		FZ3	LAM	PAC, GRN	CAL-LF(<10%)	CHA-S, FRAG-IND		
4	FZ4		WAC	mQ-CQ (85%), MQ, CAL-LF (5%)	FRAG-IND	OF, PEO		
J3-4	0	ALC1	PER, LCR	PAC GRN	mQ-CQ(50%), MQ(5%), CAL-LF(5%)	ESP-T, FOR(p), GAS, FRAG-IND	MOL, OF, PEO, Q-TER, MO, OOI(p), MOS, CaCO ₃	MAR(p)
C2s-6	4	TN1, TN2, TN4	LAM, PER(p)	MUD	mQ-CQ(90%), MQ(5%), CAL	ESP-M, FOR(p), FRAG-BIO	FEN, OF	MAR
IND-1	4	TN3, TN4	BRE, LAM	PAC, GRN	mQ-CQ(40%) MQ(<5%), CAL(10%)		FEN, OF, Q-TER, MOS	CONT
IND-2	1	OUR4	BRE	SAN	Cq(10%)		FEN(p), OF, Q-TER	
	4	OUR3	NOTS	NOTS	NOTS	NOTS	NOTS	
IND-3	4	TN4	PER	MUD	mQ-CQ(85%)	CHA-S, GAS	OF, CaCO ₃	MAR or CONT-LAC(p)

Table 2. Technological categories and raw material types present in the layer 14 sample. For quartz and quartzite, technological categories are given according to field data.

Technological category				Rock		Igneous		Total
	Flint	Quartz	Quartzite	crystal	Limestone	rock	Lydite	
Core	11	46	19					76
Flake	359	576	643		7	8	2	1595
Blade	4	1	1					6
Bladelet	7		1					8
Chip	218	718	361	3				1300
Chunk	3	8	5		2			18
Retouched tool	29	8	9					46
Cobble		9	13					22
Total	631	1366	1052	3	9	8	2	3071

3. Results

Based on their color, mineralogy, sedimentary structure and fossil content, two categories of flint could be identified in the sources located at the boundary between the Bajocian and Bathonian (J2-2, J2-3), and four in sources located in the Oxfordian (J3-1 to J3-4). The structure, texture, mineralogy and constituents of these flints are variable; often, such variation can be observed within a single nodule.

Cretaceous flint (C2s) and silcrete (Ind-1, 2) were found exclusively in siliciclastic deposits of the TSB.

3.1. Middle Jurassic flint (Bajocian)

Two types of Upper Bajocian flint were identified (J2-2, J2-3). They can be easily differentiated by color, sedimentary structure and crystallization. Frequently they have a botryoidal cortex with impregnation of iron oxides. *Liesegang*-type structures, peloidal relicts and a bioclastic content are frequent. In the J2-2 type, the presence of numerous tectonic joints filled and recrystallized with iron oxides and micro-crystalline quartz allows the identification of regional variants. (Figure 3.)

3.2. Upper Jurassic flint (Oxfordian)

Four types of Oxfordian flint (J3-1 to J3-4), representing variation along the East-West axis of the CLM, could be identified. These flints are heterogeneous in structure, texture, mineralogy and constituents, often with such variation being visible in a single nodule. J3-1 and J3-3 (Figures 4 and 5) co-occur in the East, and it was not possible to determine if they were formed together or originate in different strata. J3-2 (Figure 6) and J3-4 (Figure 7) have the same “spotted” macroscopic aspect but distinct constituents; the first shows dolomitization associated with a silicification of the matrix, while the second contains detrital elements and distinctive skeletal remains.

3.3. Late Cretaceous flint (Upper Cenomanian) and Cenozoic silcrete

Cretaceous flint (C2s) and Cenozoic silcrete (ind-1,2) were found exclusively in the TSB, where they occur alongside the quartz, quartzite and lydite cobbles and sands making up the basin’s Lower Miocene siliciclastic deposits. Their secondary position is further supported by a clear rounded cortex with macroscopic impact marks caused by fluvial transport. Often, these Cretaceous flints are translucent and contain geodes with macroquartz crystals growth; they grade in color (from yellow to red and grey) but, mineralogically, are very homogeneous, frequently with rare or almost unnoticeable skeletal remains. Iron oxides concentrations are

also frequent in the siliceous matrix (Figure 8). Cenozoic silcretes have a brecciated structure associated with lamination, frequently contain detrital quartz, and include no skeletal remains (Figure 9). The correspondence of the Late Cenomanian flint to this specific geological stage has been made by comparison with studies made in other localities (*e.g.*, unit H of the Nazaré section (Callapez 1998)).

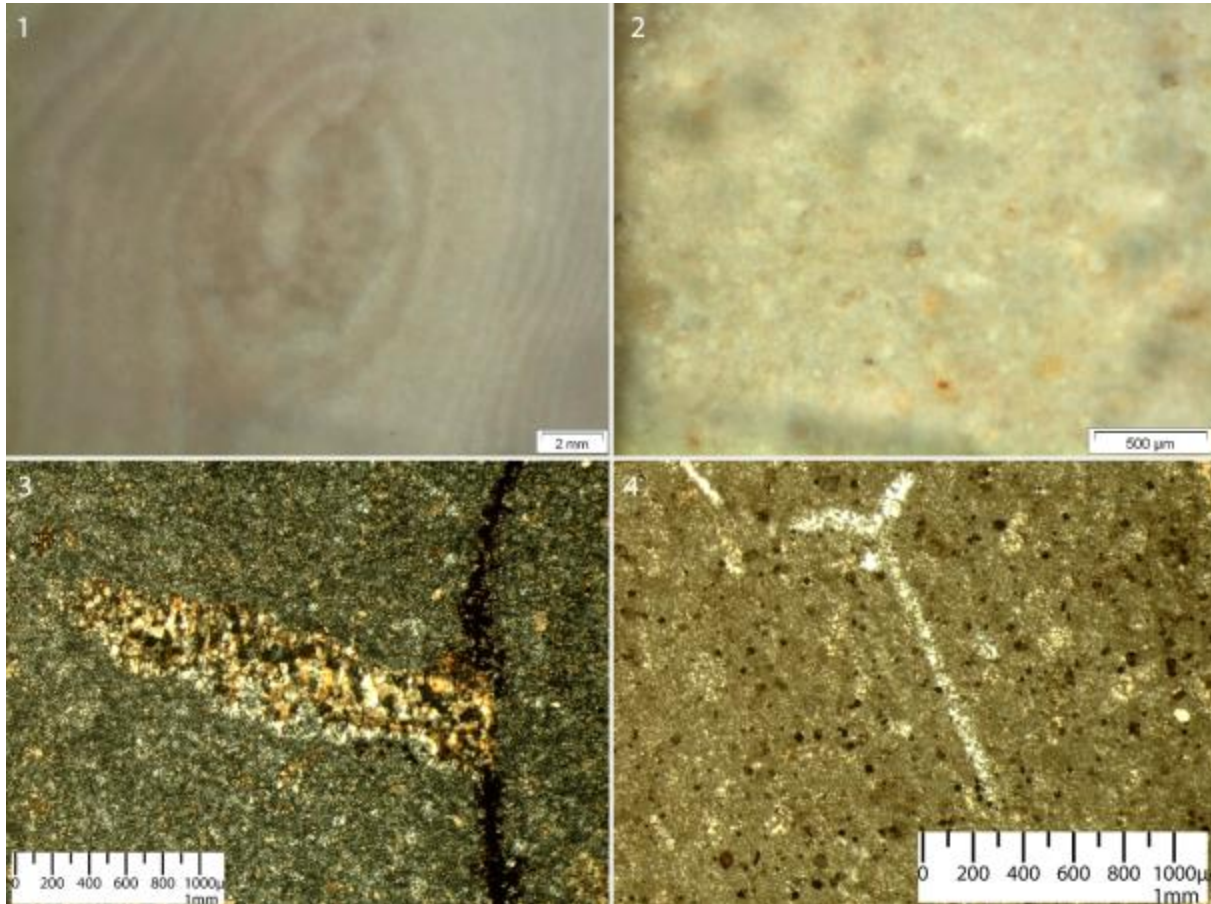


Figure 3. Bajocian flint's macro and microscopic textures and constituents: 1. *Liesegang* concentric rings (scale bar = 2 mm); 2. General texture (scale bar = 500 µm); 3. Diacause cemented by iron oxides and porosity filled by first and second generation micro and macro quartz (scale bar = 1 mm); 4. Triaxonic spicule recrystallized by micro-quartz (scale bar = 1 mm).

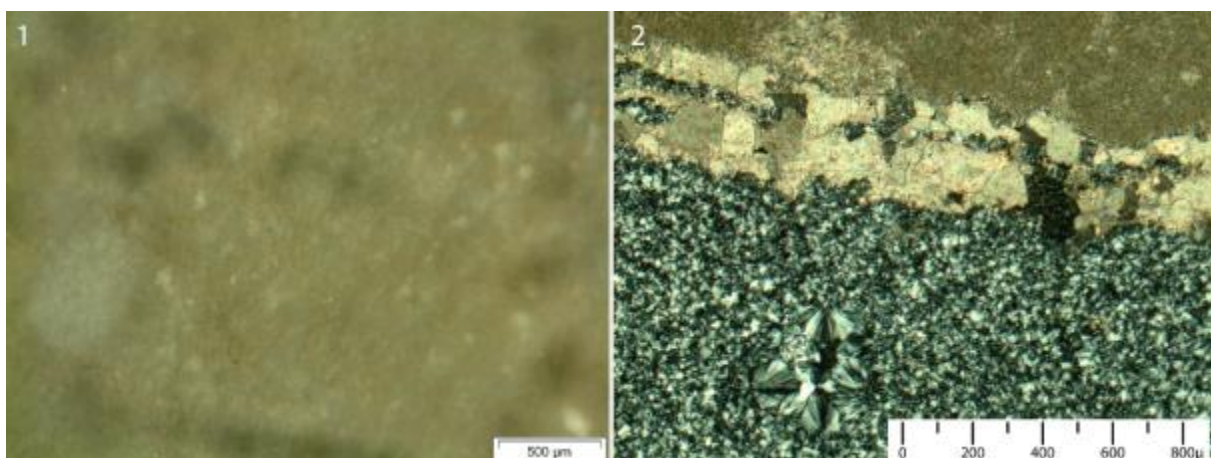


Figure 4. Oxfordian flints' macro and microscopic textures and constituents; Type J3-2: 1. General texture (mudstone) (scale bar = 500 µm); 2. Spar calcite undergoing silicification at the contact between the silica matrix and the limestone (scale bar = 800 µm).

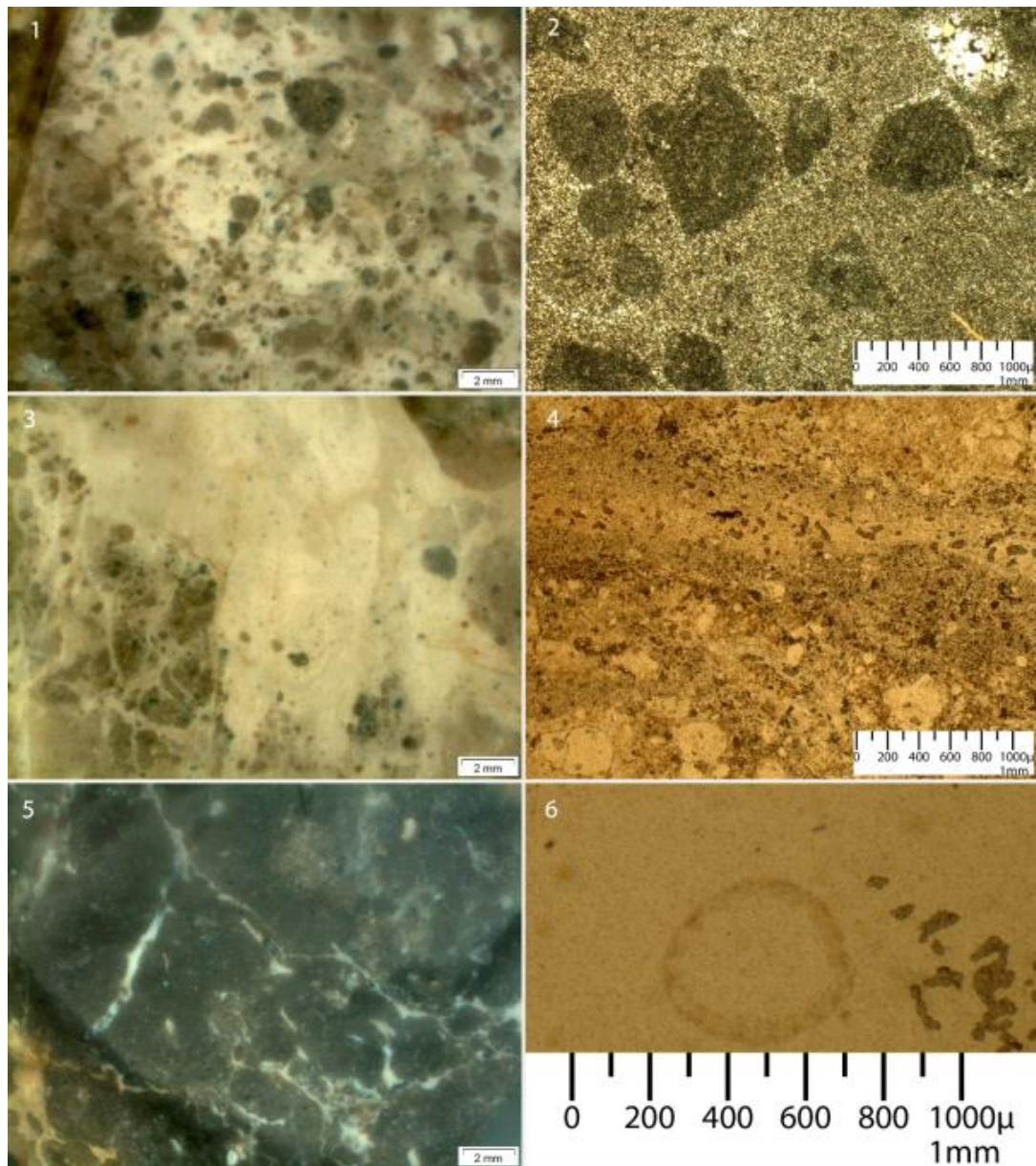


Figure 5. Oxfordian flints' macro and microscopic textures and constituents; Genetic Type J3-3: 1., 3., 5. General heterogenic textures (mudstone to grainstone) (scale bar = 2 mm); 2. Brecciated sedimentary structure (scale bar = 1 mm); 4 Laminated sedimentary structure (scale bar = 1 mm); 5. Charophyta stem (scale bar = 1 mm).

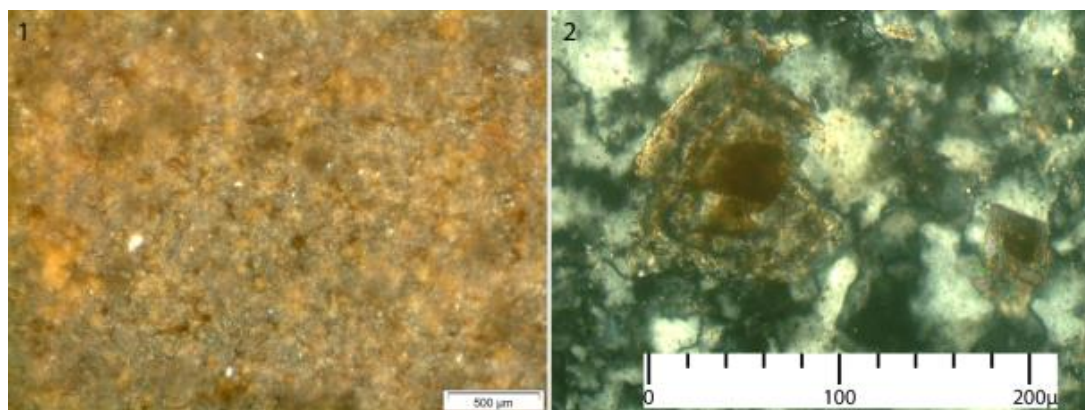


Figure 6. Oxfordian flints' macro and microscopic textures and constituents; Genetic Type J3-2: 1. General texture (scale bar = 500 μm); 2. Dolomite or calcite rhombohedra undergoing silicification (scale bar = 200 μm).

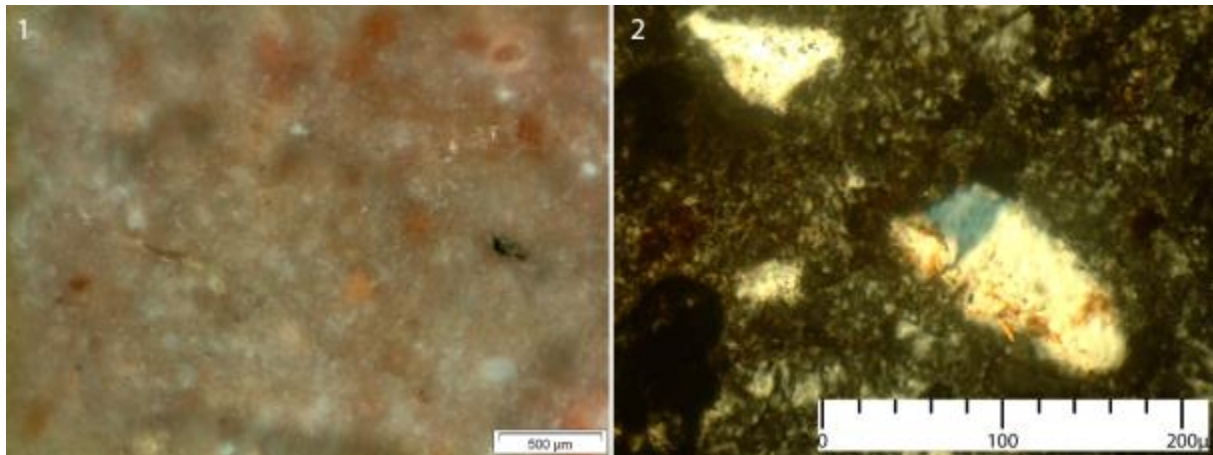


Figure 7. Oxfordian flints' macro and microscopic textures and constituents; Genetic Type J3-2: 1. General texture (scale bar = 500 µm); 2. Detrital quartz embedded in the siliceous matrix (scale bar = 200 µm).

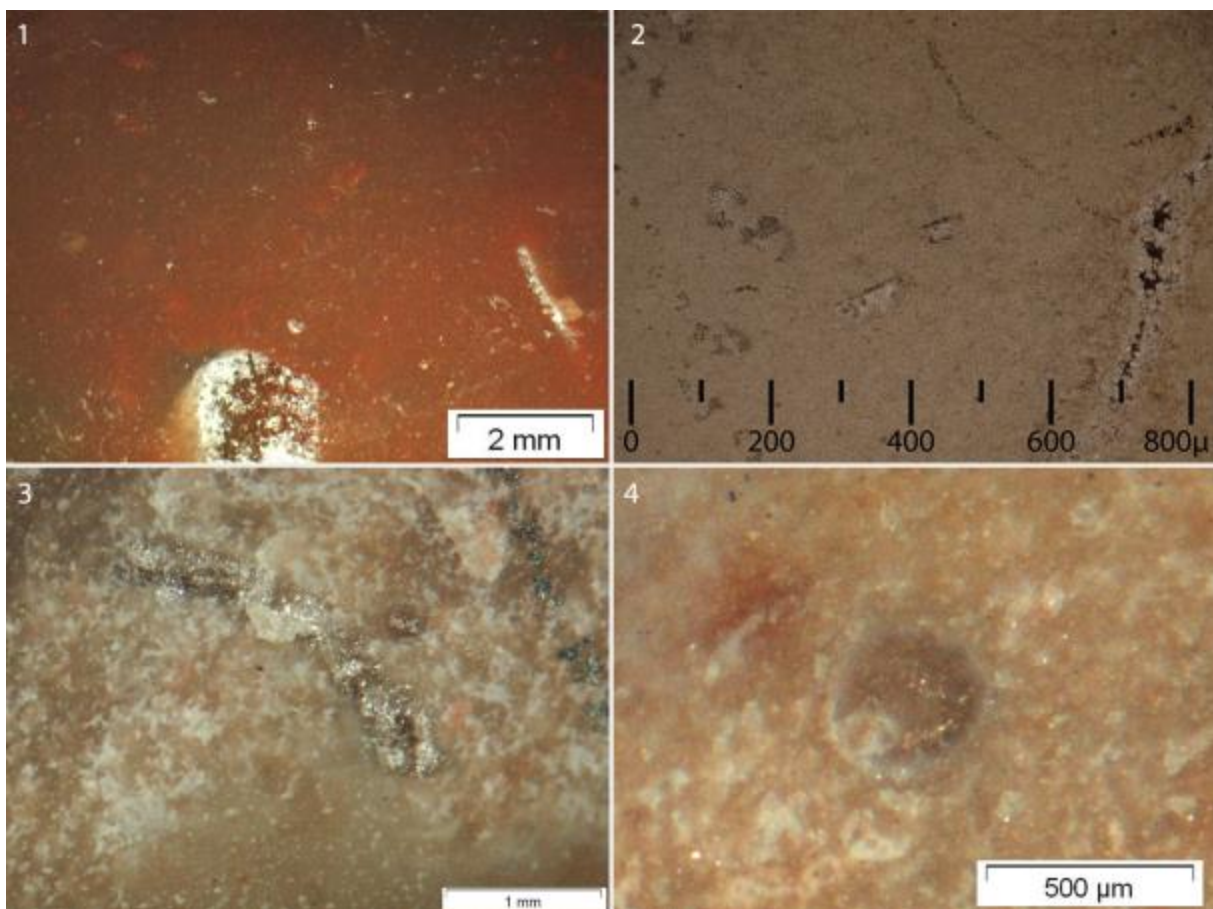


Figure 8. Macro- and microscopic textures and constituents of Cretaceous flints. Note the mudstone texture (1, 2) and bioclastic relicts (3, 4). (Scale bars: 1. 2 mm; 2. 500 µm; 3. 1 mm; 4. 500 µm.)

4. Discussion and conclusions

As the Almonda karst system is located at the boundary between the CLM and the TSB, the raw materials used by the Gruta da Oliveira Neanderthals reflect their natural availability within these two different structural units.

In the CLM, *in situ* and sub-primary Middle and Late Jurassic flint sources are found in geographically restricted outcrops or deposits, while the Miocene plains of the Tagus Basin feature widespread Cenozoic and Quaternary siliciclastic deposits with quartzite, quartz,

lydite, silcrete and Cretaceous flints. The latter are spread over a large area to the SW, S, SE, E and NE, of the cave (although Cretaceous flints and silcrete only occur more than 10 km to SW). Therefore, only the Late and Middle Jurassic flint sources found to NE and W provide spatially precise indications of the Oliveira Neanderthals' mobility.

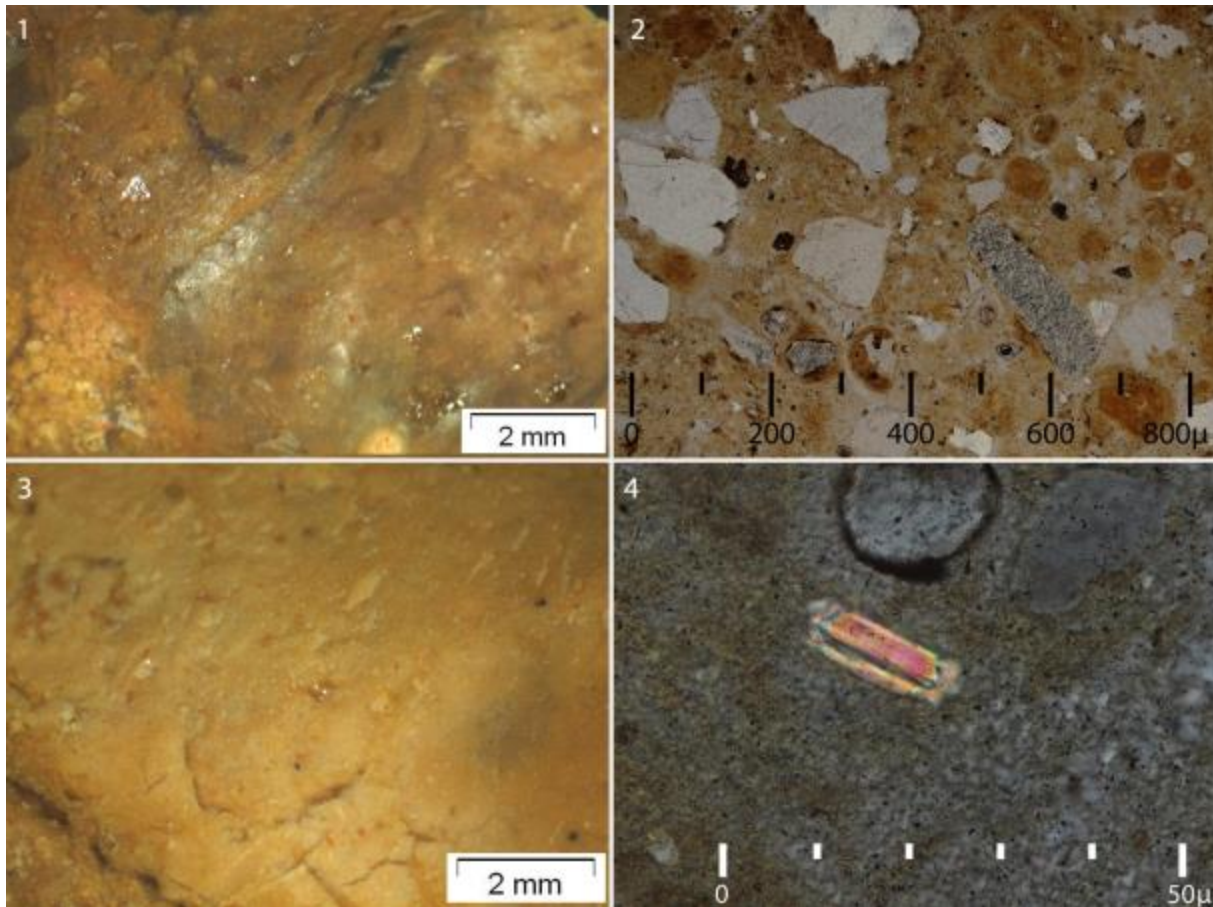


Figure 9. Macro- and microscopic textures and constituents of Cenozoic silcretes. Note the brecciated structure (1-3) and detrital materials (2, 4).

Quartzite, lydite and quartz were collected and introduced in the cave as cobbles, boulders or large flakes, the latter probably produced at or close to the source. These rocks are widely distributed across hundreds of km of the TSB (Figure 10) and are abundantly available in the nearby TSB siliciclastic deposits. However, a fine-grained quartzite was preferentially selected for *Levallois* reduction, due to its homogeneity and excellent knapping qualities. Although it can be occasionally found across the Tagus basin, larger concentrations of this green- or red-colored quartzite were found in versant deposits located less than 5 km NE of the Gruta da Oliveira, implying that this raw material was probably locally collected. Elsewhere in the Almonda karst system, this fine-grained quartzite is rare or found in low proportions. The same applies to the other Paleolithic localities known in the TSB, where it is often altogether absent (as is the case, for example, in the Upper Paleolithic sites of the Rio Maior basin). The available data are not enough for a firm conclusion, but it seems likely that this particular type of fine quartzite can be used as a marker for the regional Middle Paleolithic.

Concerning flint, the Cretaceous type (C2s), the most affected by weathering, represents more than 50% of the Oliveira sample, while Cenozoic silcretes (Ind) are rare (~1%), which can be explained by their geological scarcity in the siliciclastic deposits of the TSB. Both

types of Middle Jurassic flint (J2-2 and J2-3) are present, but only one (J3-3) of the Late Jurassic flint types could be recognized (Figure 11 and 12).

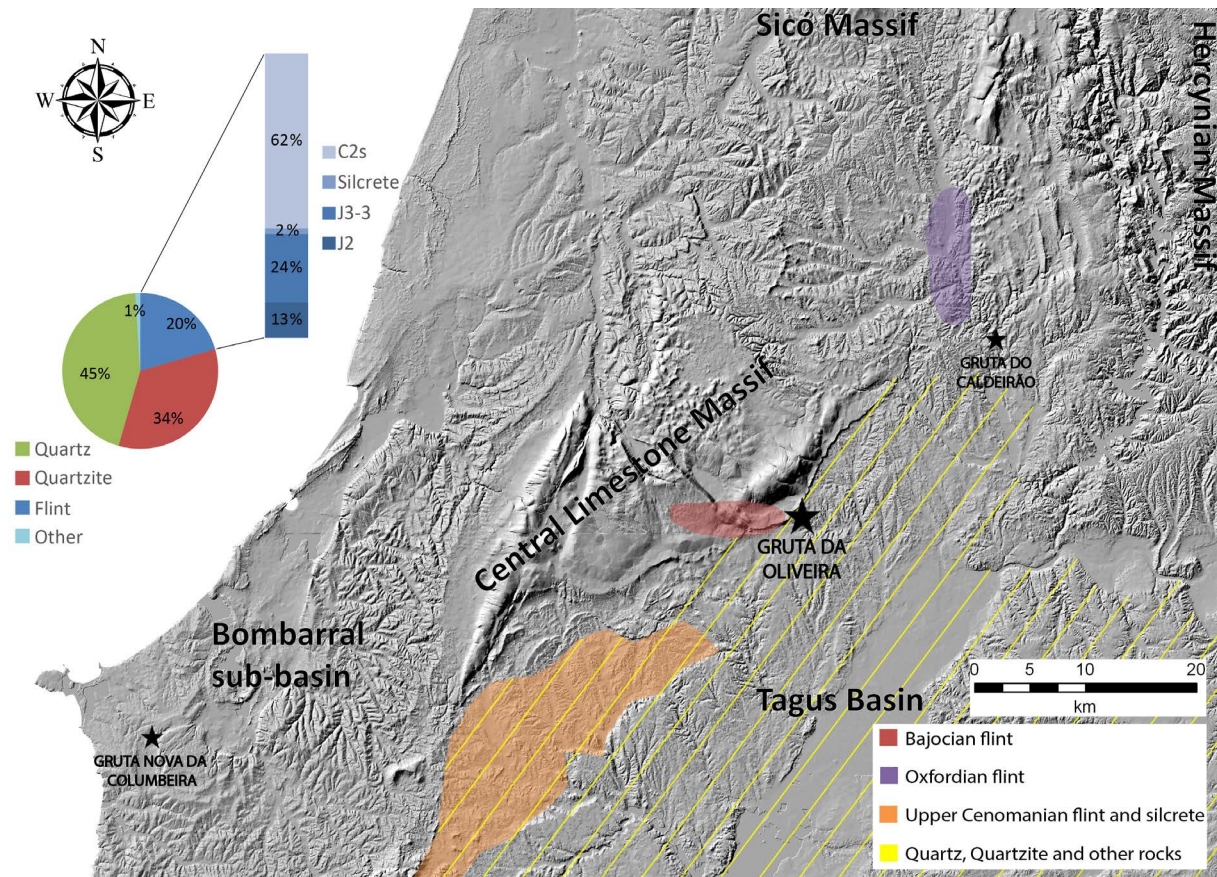


Figure 10. Regional raw material sources, and raw material percentages in layer 14 of Gruta da Oliveira. In the overall pie chart, the “other” category includes limestone, rock crystal, lydite, and igneous rocks.

Using ethnographic data (Binford 1980), the presence in Oliveira of raw materials coming from sources less than 20 km can be interpreted as direct exploitation of the sources. As is the case with the evidence from the species represented among faunal remains (Zilhão *et al.* 2013), the lithic raw material data indicate an exploitation of both the highlands of the CLM and the plains of the TSB and are therefore consistent with procurement having been embedded in daily subsistence activities (Binford 1979).

Sixty-two percent of the Oliveira sample’s flint comes from the TSB, which can be related to the excellent knapping quality of its Cretaceous flint, abundantly represented in all prehistoric sites of the TSB but also found more than 150 km away in the Upper Paleolithic sites of the Côa Valley (Aubry 2005; Aubry *et al.* 2016; Aubry *et al.* 2012; Aubry & Mangado Llach 2003a; b; 2006; Aubry *et al.* 2004; Aubry *et al.* 2014; Mangado Llach 2002). Such a high percentage probably reflects long-term residence in the Tagus plains, with Gruta da Oliveira being used as a temporary camp where the good quality flint, brought from elsewhere, was eventually discarded, and local (<5 km) medium to poor quality Bajocian flint (12%) was used occasionally. Given the location of currently known sources, the significant percentage of Oxfordian flint (24%) could reflect some degree of seasonality within a large territory united by the natural corridor provided by the Nabão river valley, which, during the Upper Paleolithic (Aubry *et al.* 2012; Gameiro *et al.* 2008), linked the inhabitants of the CLM with those of the Sicó Massif to the North. Alternatively, it is also possible that groups primarily based in the CLM alternated use of the Gruta da Oliveira with groups primarily

based in the TSB. The low percentage of cortex found on Oxfordian flint items (~13%; 35-40% in the other types) at least suggests that this raw material was processed differently, namely that it was brought in as pre-configured cores.

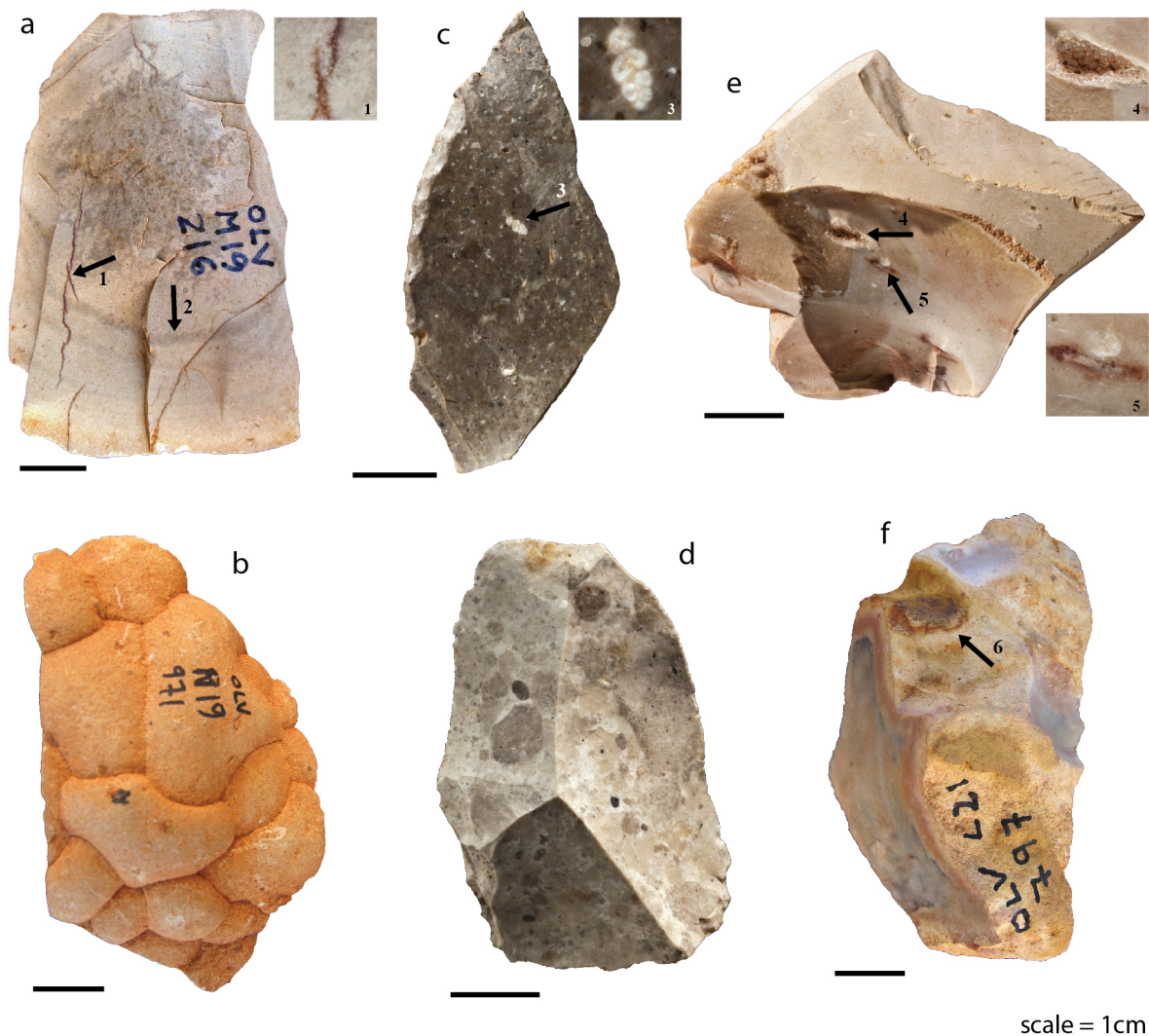


Figure 11. Flint's distinctive features in the archeological sample: a. Bajocian flint. The iron filled diaclasses pointed by arrow 1, and the concentric *liesegang* rings by arrow 2 are typical characteristics of flint type J2-2a (compare with Figure 3); b. botryoidal cortex of J2-3 type (Bajocian); c. and d. heterogenic "spotted like" texture of Oxfordian J3-3 type (compare with Figure 5, with a gastropod relict pointed by arrow 3; e. Upper Cenomanian flint with the siliceous reddish matrix turning rose and arrows pointing to a macroquartz filled geode (arrow 4) and a concentration of iron oxides (arrow 5) (compare with Figure 8); f. typical Upper Cenomanian flint in secondary position with rounded cortex impregnated by iron oxides (arrow 6). (Photos a., b. and f. by João Zilhão, b. to e. by José Paulo Ruas.)

The broader significance of these preliminary results and inferences requires a diachronic study of the lithic assemblages from Gruta da Oliveira and their comparison with other Middle Paleolithic sites, namely Gruta Nova da Columbeira, located 55 km to the SW, Gruta do Caldeirão, 25 km to the NE, close to the Nabão basin's sources of J3-3 flint, and Buraca Escura located in the Sicó Massif, where the Oxfordian flint from the Nabão river is also present (Thierry Aubry, personal communication). Such study and comparisons are the object of ongoing research.

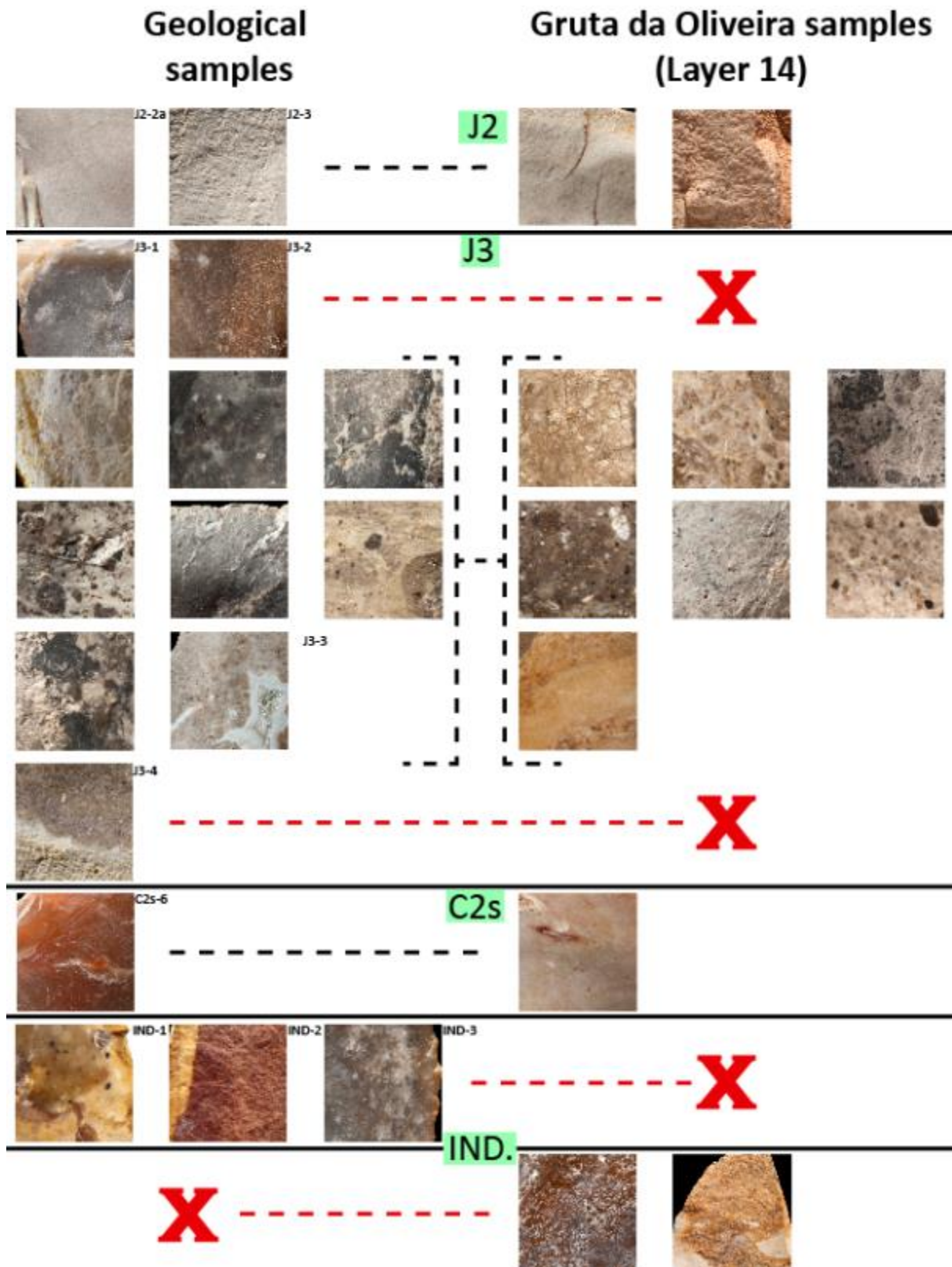


Figure 12. The flint and silcrete types recognized among the geological samples and their representation in layer 14 of Gruta da Oliveira. The cross means not present. Single image scale: 1 cm². (Photos by José Paulo Ruas.)

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