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Analysis and classification of Middle Palaeolithic lithic raw materials from Teixoneres cave: Project overview and initial results

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ABSTRACT
In this work, we present a new project that seeks to characterize lithic raw materials and the first results from a macroscopic and microscopic study of the archaeological material from sub-unit IIIb of Teixoneres Cave (NE Iberian Peninsula). During the late Middle Palaeolithic (MIS 3), multidisciplinary research has defined this site underwent short-term occupations by Neanderthals interspersed with visits from carnivores. The project aims to determine the procurement areas of the archaeological lithic materials discovered into the site, exploring the Neanderthals' use of the territory. In the near future, this information will be plotted on a lithological map, along with possible procurement areas, with the aim of developing a graphic and dynamic model that will make it possible to establish routes of displacement to the site, the outcrops, and the Neanderthals' mobility in the territory.

Section: RESEARCH PAPER

Keywords: Neanderthals; Teixoneres Cave; lithic raw materials; macroscopic and microscopic analysis

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1. INTRODUCTION

In this paper we present a project to study the lithic raw materials from Teixoneres Cave (Moià, Barcelona). As this project is currently in the execution phase, we will discuss its objectives, methodology, and the results obtained so far [1].

In Palaeolithic contexts, lithic artefacts represent some of the most important archaeological remains for shedding light on the use and exploitation of territory. The origin of lithic raw materials provides an ideal framework for understanding the territorial movements of prehistoric hunter-gatherers. Following residential or logistical models [2], the goal is to infer patterns of mobility and territoriality through the characterization of the lithic resources [3]. Binford [4] recognized the difficulties in determining the mobility of hunter-gatherer groups based on the archaeological record, considering territory as a living system. Nevertheless, lithic raw materials are among the few elements in the fossil record that allow us to approach the mobility patterns of these societies.

By identifying the catchment areas and the way the material was introduced into the site, we will be able to determine whether the lithic assemblage was collected in proximity of the site (secondary deposits, e.g., riverbed) or in its original formations (primary outcrops). In addition, we will try to provide more data to the knowledge of the evolution of the lithic procurement strategies, which commonly states that since from the Lower Palaeolithic to the Neolithic there was a shift from an eminently local procurement (> 5 km) to a more regional one (15-20 km), and finally to a long distance procurement (> 200 km) [5], [6], [7], [8]. In Teixoneres Cave, the predominant hypothesis for the occupation patterns is that human settlements by small groups of Neanderthals for short periods of time were interspersed with carnivore occupations [9], [10].

The lithic industry is composed mainly of quartz, followed by chert and lower frequencies of quartzite, limestones, sandstones, and hornfels. The quartz nodules were reduced using the tranche de saucisson (recurrent unidirectional reduction) and the discoidal (recurrent centripetal reduction) methods. Hierarchized and unhierarchized technologies are documented in chert and hornfels materials, whereas expeditive methods were common for other rock types [10], [11]. A technological analysis indicates various patterns of transport of the raw materials and differences in the management of the territory. The lithic assemblage is composed of toolkits of the non-predominant raw material complemented by the *in situ* knapping of local quartz. The cave was settled for short stays in the context of high mobility patterns. The Neanderthals arrived at the cave with their toolkits composed mostly of flakes, retouched tools, and some cores in an advanced stage of exploitation [10].

The faunal record shows a high diversity of ungulates such as red deer (*Cervus elaphus*), roe deer (*Capreolus capreolus*), giant deer (*Megaloceros giganteus*), aurochs (*Bos primigenius*), wild goat (*Capra pyrenaica*), chamois (*Rupicapra pyrenaica*), horse (*Equus ferus*), wild ass (*Equus hydruntinus*), wild boar (*Sus scrofa*), woolly rhinoceros (*Coelodontaantiquitatis*) and woolly mammoth (*Mammuthus primigenius*), as well as lagomorphs such as rabbit (*Oryctolagus cuniculus*) and hare (*Lepus sp.*). The presence of carnivores is also common in all the stratigraphic units, including cave bear (*Ursus spelaeus*), hyena (*Crocuta crocuta*), wolf (*Canis lupus*), fox (*Vulpes vulpes*), lynx (*Lynx spelaea*) and badger (*Meles meles*) [12], [13], [14].

Based on the spatial patterning of the archaeological assemblage, a significant dichotomy can be registered. The items associated with carnivore den activities are mainly clustered in the inner parts of the cave, whereas the anthropogenic ones (e.g., lithics and bones with cut marks) are mainly limited to the main entrance [10].

Teixoneres Cave can be interpreted as a diachronic succession of human and carnivore occupations with short seasonal stays occurring mostly during summer and winter [15].

The goal of this project is to determine the outcrops of the lithic raw materials from sub-unit IIIb of Teixoneres Cave, aiming to establish the Neanderthals' mobility patterns and verify the type of settlement (e.g., hunting camps, observation sites, supply camps, etc.). To this end, we will macroscopically and microscopically characterize the lithic assemblage and create a geological/lithological map of the area, which will also be useful for future studies on the procurement of lithic raw materials in the region.

2. 2. GEOLOGICAL SETTING

Teixoneres Cave is in the northeast of the Iberian Peninsula and forms part of the karstic complex of the Toll Caves, in the locality of Moià, Barcelona, within the Moianès Plateau, formed by materials of Palaeogene age (Figure 1). The cave system is

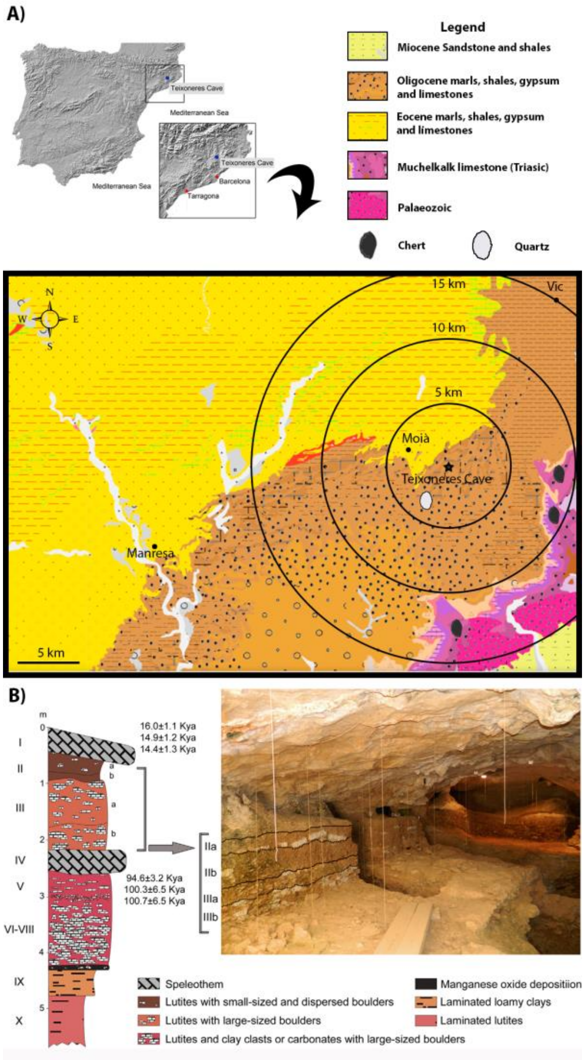

Figure 1. A) Location map and geological map with the main chert and quartz locations, modified from *Institut Cartogràfic i Geològic de Catalunya.* B) stratigraphical section of the deposits of Teixoneres Cave [15].

developed in the limestone of the Collsuspina Formation, which is of Bartonian age (Eocene). The cave is organized into three chambers, which were filled with Pleistocene sediments (200 to 16 ka BP) [10]. Toward the eastern part of the site, the classic geological bibliography cites Triassic materials of the Muschelkalk Formation, in which chert nodules have been found in a primary position [16], [17], [18] and quartz pebbles in the vicinity of Moià [19].

The stratigraphic sequence is formed by eight units divided into several sub-units in an 8m-thick sedimentary sequence [20]. Two main depositional regimes are documented: the lower part (Unit VIII) formed by silts and sands related to endokarst fluvial deposits, and the middle and upper layers (Units II, III, V, VI and VII) formed by debris flows, characterized by lutitic matrix with limestone blocks from the collapse of the walls and roof of the cave. Units I and IV are formed by stalagmitic beds that cover much of the cave surface and represent specific periods with a low or zero rate of sedimentation [21].

3. MATERIALS AND METHODS

3.1. Materials

Our study focuses on chert from sub-unit IIIb of Texioneres Cave, recovered during the field seasons from 2007 to 2021 [22]. The lithic industry comprises 4966 remains, of which 32 % are chert. The rest of the lithologies are quartz (58 %), limestone (3 %), sandstone (1 %), quartzite (1 %), and other rocks (5 %), which include schist, hornfels, and other materials (Figure 2).

We chose to focus on this level because it is where most of the lithic record of Neanderthal activity has been identified, and on chert because it is the raw material that provides most information about mobility patterns, as it is the second most abundant raw material in the record after quartz, and for which there is no evidence of outcrops that could indicate a local procurement (< 5 km).

3.2. Methods

The methodology used to characterize the lithic raw materials from Teixoneres Cave is divided into three main steps: (1) a macroscopic and petrographic study of the lithic materials from the site and the geological samples; (2) geological surveys with the aim of identifying possible source areas and developing a lithological map; and (3) a comparison of the archaeological and geological materials in order to establish the procurement areas of the Neanderthals who occupied the cave.

3.2.1. Macroscopic and microscopic analysis

The main features of the raw materials are described, allowing different lithologies to be distinguished, and different varieties within each lithology. The macroscopic characterization was carried out using a stereoscopic microscope (ZEISS Stemi DV4 8-32x). The characteristics described are colour (*Munsell Color Book*), hardness, translucency, brightness, types of fracture, texture, the presence of sedimentary structures, bioclasts, whether the sample has been subjected to tectonic processes, inclusions, crystal growth, etc. In addition, different alteration processes in the samples, both physical and chemical, are taken into consideration [23].

Petrographic analyses were undertaken with a polarizing microscope (Nikon Eclipse E400 POL 40-400x) to describe the mineral composition in percentage for each of the elements, as well as their shape, sizes, type of contacts, relief, interference colour, inclusions, and allochemical elements. A microscopic study of the samples makes it possible to observe details of the rocks that are not visible to the naked eye (*visu*).

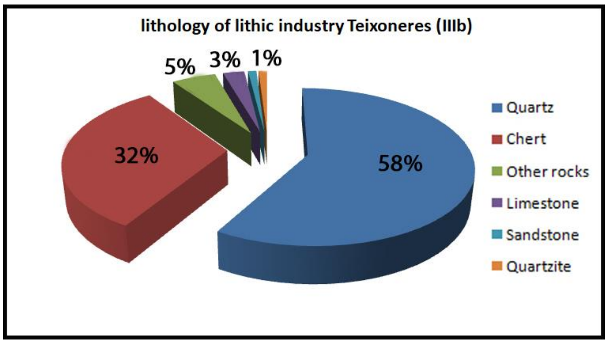

Figure 2. Graph with the percentages of lithic materials of different lithologies in sub-unit IIIb.

3.2.2. Prospecting and development of a lithological map

The geoarchaeological surveys were carried out in 2019 and 2022. The aim of the fieldwork was to locate the potential outcrops that might have served as the stone procurement areas for the lithic artefacts found at the site, as scarce information was available, only through geological maps (Muschelkalk facies) [24] and some preliminary works on chert catchment in the region [18], [25], [26]. Based on our knowledge of the variety of lithologies present in the site and the types of each of them, a study of the possible source areas was carried out, using orthophotographs, geological maps, and bibliographical information. Special attention was paid to the hydrographic basins surrounding the cave and the materials that come from them. This information sheds light on the origin of the pebbles transported by the nearby rivers and creeks.

The location of the outcrops was recorded with a GPS and pinpointed on a map created with QGIS software. These data show the points containing the same materials as those found in the site, the geological units that have these materials, the nearby routes, etc.

3.2.3. Comparison between the geological and archaeological material

The last phase concerns a comparison between the results achieved in the surveys and those obtained through the study of the archaeological artefacts, to infer possible chert procurement routes.

4. RESULTS

The results presented are the initial phase in the study of the lithic raw materials from sub-unit IIIb of Teixoneres Cave [1]. Of the total amount of chert analysed at this stage, 59 % corresponds to limestones of marine origin, 27 % to limestones of lacustrine origin, and 14 % to chert from evaporitic formations (Figure 3a).

A total of 19 different types of cherts were identified on the basis of the lithological origin of the bedrock, the texture, the presence of allochemical elements, sedimentary structures, and inclusions (Figure 3b). The most represented is the TS1 type (Figure 4), comprising 50 % of the total chert in the assemblage, whose geological ascription corresponds to the calcareous Muschelkalk facies (Triassic), specifically Member M1 (lower Muschelkalk). Its main distinctive features are a fine and homogeneous texture, a grey colour, and the presence of laminations (Liesegang rings). Primary cortex predominates, with orange and brown as the main colours. It is macroscopically

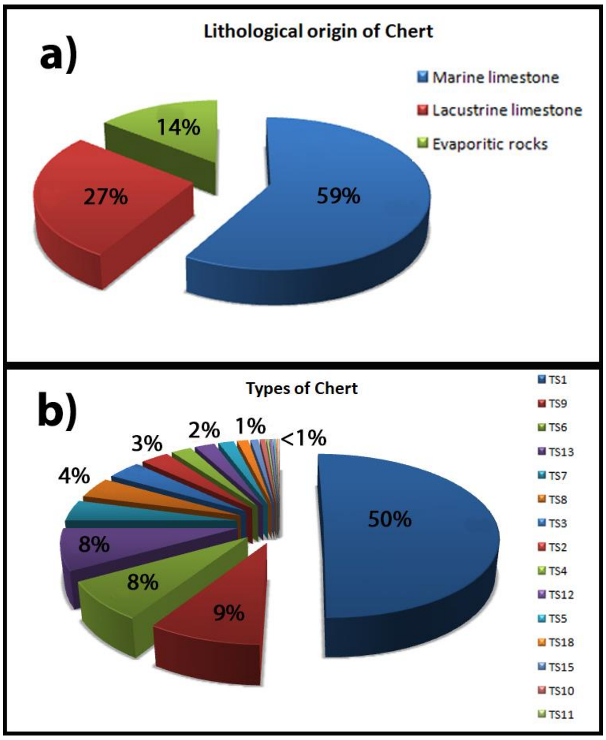

Figure 3. a) Graph showing the different lithological bedrock origins of the chert. b) Graph showing the different types of cherts identified.

characterized by grey colours (*N5 Medium Gray*), opaque and dull, with a fine to very fine texture. Bioclasts are present, visible mainly when the sample is patinated. Under the microscope, it is characterized by a microcrystalline quartz mosaic (2 to 20 µm) replacing the micritic matrix, with percentages of the order of 75 % - 80 %, followed by megaquartz (> 20 µm) filling the porosities with 20 % - 25 %. The second most representative chert type from marine limestones is the **TS8** type (Figure 4). It is characterized by its dark colour and the presence of fractures. When the cortex is preserved, it is mainly a secondary black cortex. The chert is very dark grey in colour (*N3 Dark Gray*), opaque and matte, with a fine texture. It is very homogeneous in appearance, and occasionally bioclasts can be observed when the sample is patinated. It is worth noting that the samples show signs of fractures (tectonic). From a microscopic perspective, it is characterized by microquartz replacing the original matrix with crystal regrowth (45 % - 50 %), which is the dominant component, followed by carbonates in matrix (40 % - 45 %). Additionally, megaquartz can be found filling fractures (5 % - 7 %) with maximum dimensions of 70 µm and disseminated oxides (5 %).

As regards the cherts from lacustrine environments, the following varieties are the most abundant within the archaeological record: TS9 (9 %), TS13 (8 %) and TS3 (4 %) (Figure 4). The **TS9** type is characterized by its bluish-grey colour, semi-translucency, and a high presence of carbonates. It has a secondary cortex with grey and white colours. It is characterized as a blue grey chert (*5B 5/1 Medium Bluish Gray*), semi-translucent and matte, with a fine texture. Small bioclasts are present, visible even when the sample is not patinated, as well as black and red oxides homogeneously spread over the sample. In terms of its microscopic features, it is formed by microquartz replacing the carbonate matrix (70 % - 75 %), followed by carbonates in matrix (15 % - 17 %), megaquartz (8 % - 10 %) reaching sizes of 50 µm, and fibrous quartz (2 %) filling mouldic porosities. The **TS13** type is defined as a silicified limestone, with a medium texture, a high concentration of bioclasts, and secondary cortex with orange and white colours. This chert is identified by its grey to green or brown colours (*5Y 6/1 Light Olive Gray and 10YR 6/2 Pale Yellowish Brown*), and is opaque and matte, with a medium texture. Bioclasts are present, visible even when the sample is not patinated, and there is an abundant presence of carbonates in the form of pseudomorphs generating mouldic porosity, as well as black and red oxides. The petrographic description differentiates microquartz replacing the carbonate matrix and bioclasts (45 % - 50 %), from megaquartz (3 %) and fibrous quartz (1 %) filling the fractures and porosities. Carbonates, as matrix relics and bioclasts (35 % - 40 %), are also abundant. In smaller proportions, scattered oxides are also present (5 %). For, the **TS3** type is characterized by the exclusive presence of ooids and allochemical elements, and the presence of secondary cortex, with grey and white colours. The chert has a blue grey colour with variations towards brown (*5B 5/1 Medium Bluish Gray and 10YR 6/2 Pale Yellowish Brown*), and is opaque and matte, with a fine texture. Ooids are present, visible even when the sample is not patinated. Microscopically, it is characterized by microquartz as the main element replacing the carbonate in the ooids (50 % - 55 %), followed by megaquartz, reaching up to 500 µm in size (20 % - 25 %) and fibrous quartz (5 %) replacing the sparitic cement (20 % - 25 %). The presence of carbonate relicts (20 % - 25 %) should also be noted, as well as oxides around the ooids (1 %).

The final types of cherts are grouped in an evaporitic environment, representing 8 % of the total cherts (Figure 4). The **TS6** type is characterized by the presence of gypsum pseudomorphs, and presents both primary and secondary cortex, of grey and brown colours. It is distinguished by being a light grey chert, with variations towards brown and blue (*N6 Medium Light Gray, 5YR 6/1 Light Brownish Gray and 5PB 7/2 Pale Blue*), and is usually opaque and matte, with a fine texture. Nodular structures and gypsum pseudomorphs are present, visible when the sample is patinated. Some samples have a high concentration of oxides. Microscopically, there is a predominance of microquartz replacing the gypsiferous matrix (65 % - 70 %), followed by fibrous quartz in the gypsum pseudomorphs (15 % - 20 %) and megaquartz filling the porosities (3 %), reaching dimensions of 80 µm. Carbonates are present inside the replaced matrix (5 % - 10 %), and oxides are homogeneously disseminated (1 %).

5. DISCUSSION

The macroscopic and microscopic descriptions of the lithic artifacts from sub-unit IIIb of Teixoneres Cave make it possible to identify certain elements (e.g., the presence of bioclasts, evaporitic relicts, or carbonates) that reveal the nature of the bedrock in which the chert nodules were formed [25], [27], [28]. This information allows the use of different strategies to locate the provenance of the different types of cherts.

It is necessary to understand that geological chert sources are not homogeneous, given that there may be textural or compositional differences within the same geological unit, both laterally and vertically. In case of evaporitic environments this feature is more evident, resulting in different colours, textures, and inclusions. In addition, we must add the post-depositional alterations that the materials have undergone, which may modify the colour and texture of the chert. In some cases, however, these alteration processes reveal bioclasts or other sedimentary

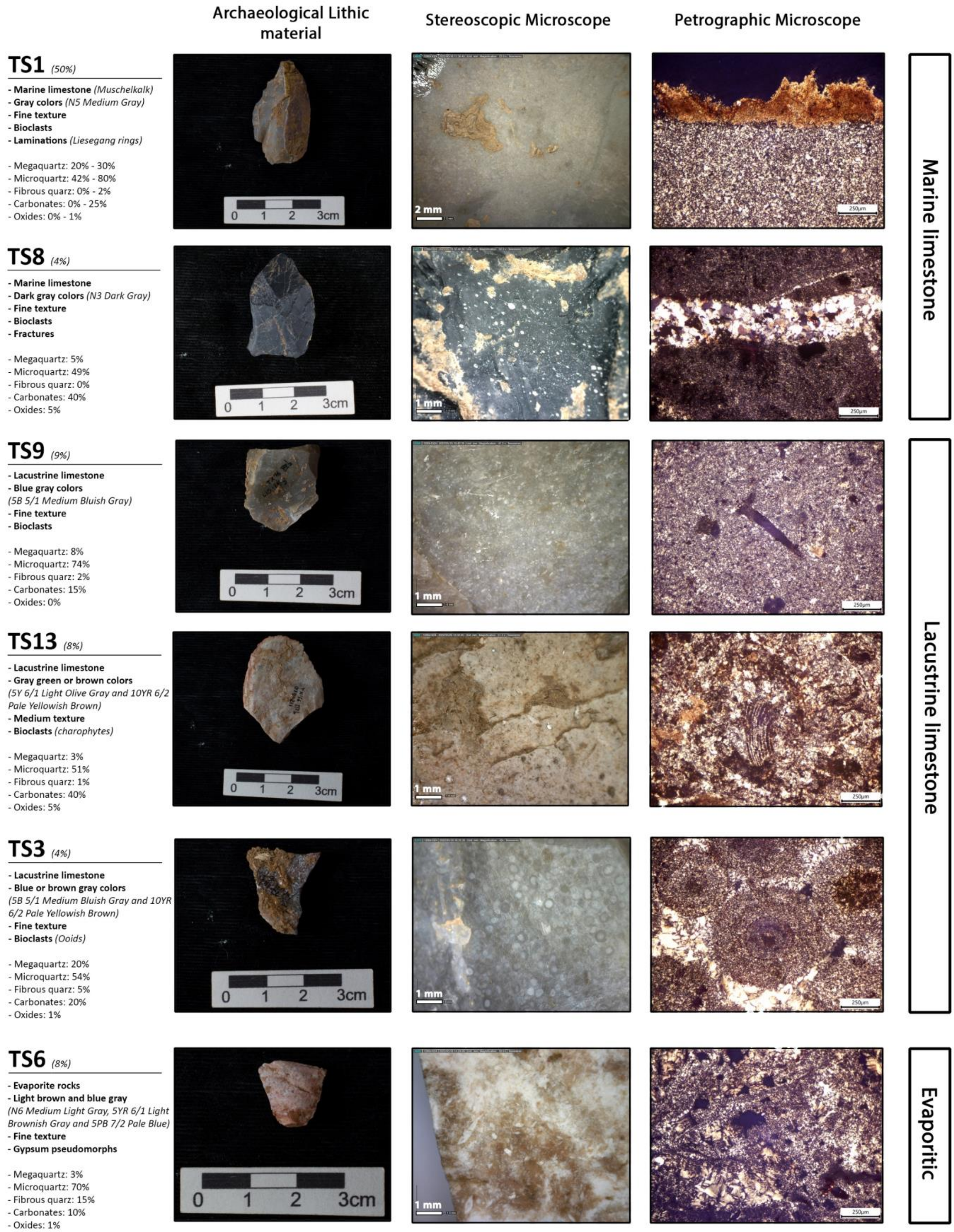

Figure 4. Main types of cherts with their principal features, with their images divided into three columns, and their depositional environment. The first column displays the archaeological lithic artefact. The other columns show details captured using a DinoLite stereomicroscope and a Nikon Eclipse E400 POL 40-400x polarizing microscope, under cross-polarized light.

structures facilitating the correct ascription. An added difficulty is that the silicification process can also present different degrees of intensity, from complete silicification processes to the initial stages of silicification, giving rise to textural and compositional differences within the chert nodules.

Considering this variability and, based on the similarities observed between the archaeological and geological material, we were able to associate the chert most commonly found in the archaeological record with Member M1 of the Muschelkalk facies (TS1), occurring in several outcrops to the southeast and east of Teixoneres Cave within a procurement area of less than 15 km (Figure 5, point Cb, Cb1). This chert would have been collected directly from its primary position, as there are no chert pebbles in the rivers and tributaries near the site, the closest primary outcrops being the ones potentially used for supply. However, in the Upper Palaeolithic of the Balma del Gai site, a few kilometres from Teixoneres Cave, Mangado & Nadal [26] refer to the presence of this chert in secondary deposits associated with pebbles from the riverbed of uncertain origin and scarce material, of which we have not located during our surveys.

As regards the lacustrine cherts, some of the archaeological assemblage could have its origin in the Castelltallat Formation, more than 20 km to the west of the settlement. Nevertheless, a more detailed characterization and a further search for more source areas in the region are still called to determine the origin of the different types of cherts occurring in the various formation environments. Given their total absence in the area, the chert from evaporitic formations could have come from the nearest Eocene evaporitic formations of Sant Genís and/or Valldeperes, about 50 km to the southwest.

These chert types (lacustrine and evaporitic) would not have been collected in secondary deposits near the site, because they are absent in the surrounding rivers and creeks. The chert nodules must come from primary or secondary outcrops located further away from the cave.

6. CONCLUSIONS

Chert is the lithic raw material under analysis in this first phase of this project. The predominant variety in sub-unit IIIb is TS1, with a geological ascription to the Muschelkalk Formation. This constitutes 50 % of the total chert. This variety is characterized by its homogeneous features with grey colours, an opaque texture, a fine-grained structure, and the presence of bioclasts. Its procurement area will have been its primary outcrops less than 15 km to the east of the cave.

The lacustrine and evaporitic types of cherts (whose origin is still to be confirmed) suggest that the Neanderthal groups that occupied Teixoneres Cave had a wide range of mobility and were able to access different types of raw material from various sources.

The classification and ascription of the lithic raw materials based on macroscopic and petrographic analysis are preliminary and will be reviewed and refined as more information is collected through further geoarchaeological surveys, and comparisons are drawn with new geological and archaeological data. This material will provide a more detailed and accurate understanding of the lithic procurement strategies and mobility patterns of the Neanderthals that occupied Teixoneres Cave.

To achieve these goals, it will also be necessary to ascertain how far the cost of supplying these materials in relation to their distance, quality, quantity, and the orography of the territory,

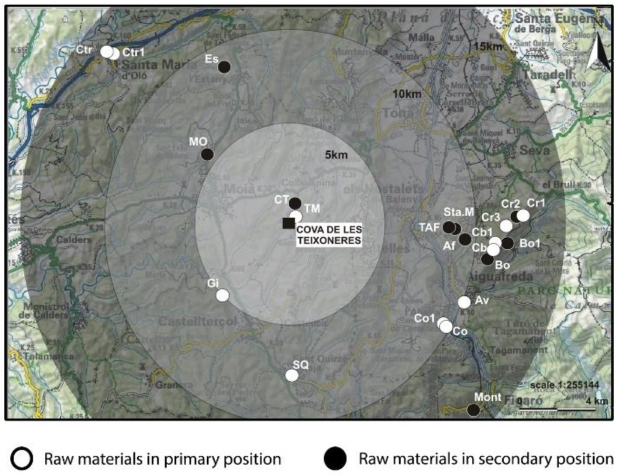

Figure 5. Location within a 15-km radius of the lithic raw material outcrops close to the settlement, found in both a primary and secondary position. ***Av:****Avenço,* ***Af:****Afrau,* ***Bo:****Boix,* ***Bo1:****Boix 1,* ***Bo2:****Boix 2,* ***Cb:*** *Can Brull,* ***Cb1:*** *Can Brull 1,* ***Co:*** *Can Oller,* ***Co1:*** *Can Oller 1,* ***Cr1:*** *Can Rovira 1,* ***Cr2:*** *Can Rovira 2,* ***Cr3:*** *Can Rovira 3,* ***Ctr:*** *Coll de Can Tripeta,* ***Ctr1:*** *Coll de Can Tripeta 1,* ***Es:****L'Estany,* ***Gi:*** *Can Gironès,* ***MO:****Moià,* *Mont: Montmany,* ***SQ:*** *Sant Quirze,* ***Sta. M:*** *Santa Madrona,* ***TAF:*** *Torrent de l'Afrau,* ***TM:*** *Torrent del Mal* [19], [29].

among other factors (using site catchment analysis and gravity models), may have influenced the procurement strategies.

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