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# Archaeopetrological approximation to the lithic procurement of the neolithic axes and adzes from Can Sadurní's cave (Begues, NE Iberian Peninsula)

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## Abstract:

Can Sadurní's cave, located in Begues (NE Iberian Peninsula), in the Baix Llobregat region, is an archaeological site with a wide stratigraphic sequence covering from the Epipaleolithic hunter-gatherers societies at the beginning of the Holocene to Roman times. During the excavations of the last years a large number of different raw materials used for the manufacture of axes have been recovered.

The present study is focused on the Neolithic sequence. 31 axes and adzes have been characterised petrographically with the aid of a binocular microscope and transmission microscope. A great variety of rocks constitute the raw materials of these stone tools, ranging from contact and regional metamorphic rocks to plutonic and porphyric igneous rocks. The formers are the most abundant (up to 78%) and include hornfels, spotted phyllites, marbles, quartzites, slates and phyllites. The igneous rocks consist of granodiorite, porphyry and aplites. Such a great assemblage of rocks matches in a geological context representative of a plutonic intrusion and its metamorphic contact aureole. Following that scenario we suggest that the most likely source area for all these materials occur at the Collserola hills, at 27 km far to the east from the cave, at the other side of the Llobregat River, where an Hercynian granodiorite and related igneous rocks intruding Ordovician metasedimentary materials are presented.

**Keywords:** axe; Neolithic; archaeopetrology; Can Sadurní's cave; lithic procurement

## 1. Introduction

The site of Can Sadurni covers a complete stratigraphy of the Holocene, consisting on 27 archaeological layers (Núñez *et al.* 2013). The aim of this study is to characterize the nature



of the rocks used to manufacture the neolithic axes and adzes recovered in Can Sadurní's cave to define a first geological and geographical approach to its provenance. These results will help us to understand the potential degree of knowledge of the regional raw materials.

### 1.1. Geological setting

Can Sadurní's cave is located in the Garraf massif, 2 km northeast of the village of Begues (Barcelona, Spain). The site is situated in the north face of a hill parallel to the Begues rill at 421 m A.S.L., and it is considered a strategic natural interlock in the massif (Blasco *et al.* 1981).

The Garraf massif forms part of the Littoral Range within the Catalan Coastal Ranges, which extends over 250 km along the north-eastern coast of the Iberian Peninsula. The massif is a structure composed mainly of Jurassic and Cretaceous limestones and dolostones that lay unconformably the Triassic and Palaeozoic materials (Daura *et al.* 2014) (Figure 1). The cave occurs in the intensively karstified carbonate materials and it is part of the Begues polje (Montoriol 1964).

### 1.2. Archaeological background

In 1978 took place the first excavation of the site; until now, up to 37 archaeological campaigns have been carried out (Figure 2). The excavated surface is about 51 m<sup>2</sup>, in which 5 strata and 31 different layers have been identified. The oldest occupation of the site has been dated by <sup>14</sup>C-AMS on 10540±60 BP. The sample -on bone- corresponds to the Ancient Epipalaeolithic layer "Microlaminar" (Forkea 1973).

The cave shows a long chronocultural sequence, characterized by several occupations from the Ancient Epipalaeolithic: "Microlaminar" facies and "Ancient geometric facies" as they were defined by Forkea (1973), Mesolithic ("Notches & Denticulates" facies), Ancient Cardial Neolithic, ancient Epicardial Neolithic, Postcardial Neolithic, ancient Neolithic - Chalcolithic, ancient and early Bronze Age and Iberian to Roman age (Edo *et al.* 2012).

## 3. Methods and materials

### 3.1. Arqueopetrological method: laboratory analysis and fieldwork

The characterization of the rocks is based on petrographical description at naked eye, with hand lenses and binocular magnifier. Only for two indistinguishable samples thin sections have been done for the study under transmission microscope. The state of conservation of the lithic assemblage is relatively good, and no chemical or mechanical post-depositional alterations are evident.

The petrographical study includes the identification of rock mineral assemblages and the diagnostic textures, in order to discriminate among igneous, sedimentary and metamorphic rocks. The macroscopic description follows the classical method based on the identification of the colour of the rocks, the percentage and kinds of minerals, the shape and the form of minerals, as well as, their orientation in the sample.



Figure 1. Location of Can Sadurn's cave and geological cross-section from Litoral range, in the Garraf massif (Gámez *et al.* 2011; ICGC 2016; NASA 2016).





Figure 2. An ordinary working day at the cave in 2014.

Taking into account the different types of rocks available as raw materials, we used the geological maps -concerning this area- of the Geological Survey of Catalonia (Roca Adrover & Miranda Canals 2010) at 1:25.000 and 1:10.000 scale; and the geological map -sheet number 420- of the Spanish Geological Services (IGME 2000) at 1:50.000 scale, in order to define several potential areas to survey and to sample. As a result, the fieldwork had been done in the Palaeozoic materials of the Garraf massif, and in other nearby areas, as Collserola range, in order to identify the most potential source-areas. The fieldwork in Collserola has shown several igneous and metamorphic rocks outcrops that have supplied different samples, which have been used to compare with the archaeological materials. These outcrops are located at the west of the town of *Torrelles de Llobregat*, where phyllites and quartzites are widespread represented and towards the south and the west of the hilltop of *Sant Pere Màrtir*, where Palaeozoic mottled hornfelses and porphyries are present. Besides, metamorphic and igneous pebbles were observed in the Quaternary terraces placed at *Can Cortés* and *Can Biosca* creeks.

### 3.2. Macrolithic tools

We analysed for this study a total number of 31 specimens (Figure 3). Twenty six of them show the presence of traces of manufacture, use, or both manufacture and use. The rest of specimens (five) have not been included in any functional group due to their small size, the lack of anthropogenic traces or its poor preservation (Figure 4).

The macrolithic tools of Can Sadurní appear highly fragmented and its degree of preservation is variable. Only six pieces (23%) are unbroken. A half of the items (13: 50%)



only preserves a third part of the original tool, and the rest of pieces (27%) only two-thirds of the original item.



Figure 3. Neolithic adze (sample 08CS-KL12-EGr8-Spf-1) made from porphyry from 10b layer. The scale bar is 5 cm wide with 1 cm intervals.

The complete artefacts usually have broken or unutilized active surfaces so, along with fragmented items, they represents basically the waste of the production, typical of waste deposits or discards.

Taking into account the macroscopic and microscopic observation -at a range of magnification between 10x and 60x - of the preserved areas of the macrolithic tools, we have defined their typological classification considering its morphometric analysis based on the categories defined by Semenov (1981), Ricq of Bouard (1996), Bosch (1984) and Fíguls (2012).

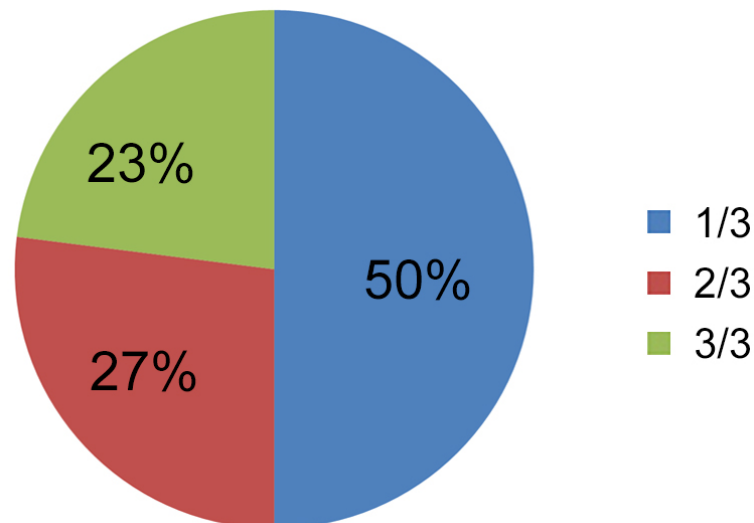


Figure 4. Degree of preservation of the macrolithic tools.

### 3.2.1. Cutting edge tools

A total number of ten cutting edge tools have been identified. Considering their profiles and setting, regarding its foot holder, they have been divided between five axes and five adzes. Moreover, we have five fragmented artefacts with the same morphology but without any active surface, so it has not been possible to define their tool category. We have also a flake potentially related with this kind of tools, and three cutting edge tools reused as hammers. All these tools, representing in fact the more abundant category of macrolithic tools (72%) have been manufactured on metamorphic rocks, most hornfels and phyllites.

The scarcity of complete artefacts does not allow us to define morphometric or typological parameters, however their metric characteristics agree within the established parameters by authors in previous studies. These tools have suffered numerous modifications because of its manufacture and its use (Table 1).

Generally, the traces of manufacture involve uniformly pecking providing rough surfaces, which are necessary for foot holder. In some cases (n=7), this pecking is combined with larger and aleatory removals allowing a greater anchorage or with a previous work of sleeking. The bevelled cutting edges of these artefacts have been intensively and carefully polished.

The use-wear traces observed in these artefacts correspond generally to very long stretch marks, commonly parallel. The direction of these stretch marks in relation to the edge allows us to determine the relative position of the handle and so, its typological category. Usually use-wear marks over the edge correspond to varying size fractures, according to the original worked material: small removals, which rarely exceed 5mm, resulting from soft materials, such as wood, and bigger removals due to the impact with harder materials, such as stones.

### 3.2.2. Other tools

The remaining specimens (n=7) show a high degree of fragmentation, that excludes their categorization as artefacts and do not allow us to precise properly any functional interpretation; six of them show use-wear traces and the other one could be a flake resulting from a percussive action. Small fronts of percussion in three of these artefacts and abrasion traces in the other three have been observed.

Table 1. Use-wear traces and cutting edge percussor use from axes and adzes (based on Semenov, 1981; created by M. Ache). Abbreviations: OBL - oblique; PERP - perpendicular.

	Label	Type	Preserved part	Production traces			Edge morphology			Use wear traces			
				extractions	picket	sharp polishing	Edge symmetry	Frontal symmetry	Longitudinal section	Stretch marks	pits	fractures	
Layer 9	02CS-E7-Ie-9-53	axe percussor or adze	Top and middle part		X	X						X	X
	03CS-E7-If-9-46	axe	Top and middle part	X		X	no	no	centred	OBL		X	
	05CS-F11-IF-9-6	axe percussor or adze	Complete		X	X						X	X
	06CS-F11-Ie-9-37	undefined axe or adze	Fragment		X	X							
Layer 9b	07CS-D8-Ig-9b-28	undefined axe or adze	Fragment			X							
	07CS-E6-Ig-9b-61	adze	Top and middle part	X	X	X	yes	yes	displaced	PERP		X	
	06CS-D10-Ig-9b-5	axe	Complete		X		no	no	centred	OBL		X	
Layer 10	08CS-F6-Ig-10-23	axe (possibly)	Top part	X		X	no	no	centred	OBL		X	
	08CS-L5-nq-10-28	undefined axe or adze	Fragment	X		X							
Layer 10b	09CS-E10-Ig-10b-73	axe	Complete	X	X	X			centred	OBL			X
	08CS-KL12-EGr8-Spf-1	adze	Complete	X	X	X	yes	yes	displaced	PERP		X	
	09CS-E11-Ig-10b-10	adze(possibly)	Top and middle part		X	X	yes	yes	centred	PERP		X	X
Layer 11	03CS-G6-If-11-32	undefined axe or adze	Middle part		X	X							
	12CS-E6-lic-11-83	axe percussor or adze	Complete		X	X						X	X
	12CS-E6-Ile-11-30	undefined axe or adze	Middle and bottom part		X	X							
	96CS-I4-IIb-11-181	axe	Right side		X	X			centred	OBL		X	
	CS-H10-IIc-11-36	adze	Complete	X			yes	yes	displaced	PERP		X	
Layer 11b	06CS-F10-1F-11b-3	adze	Fragment		X				displaced	PERP (possibly)		X	

## 4. Results

### 4.1. Petrographic description

The 31 axes and adzes studied in Can Sadurni's cave derive from a great diversity of rocks. A first approximation at naked eye allows us to subdivide into two groups of rocks, based on their colour. The darker ones represent the more abundant (75%) and coincide with pelitic metamorphic rocks and porphyries, whereas the lighters represent plutonic rocks and a reduced number of metamorphic rocks.

Dark samples were mostly represented by contact metamorphic rocks (49%), followed by foliated rocks (16%), porphyry rocks (10%) and one unidentified sample (Table 2) (Figure 5).

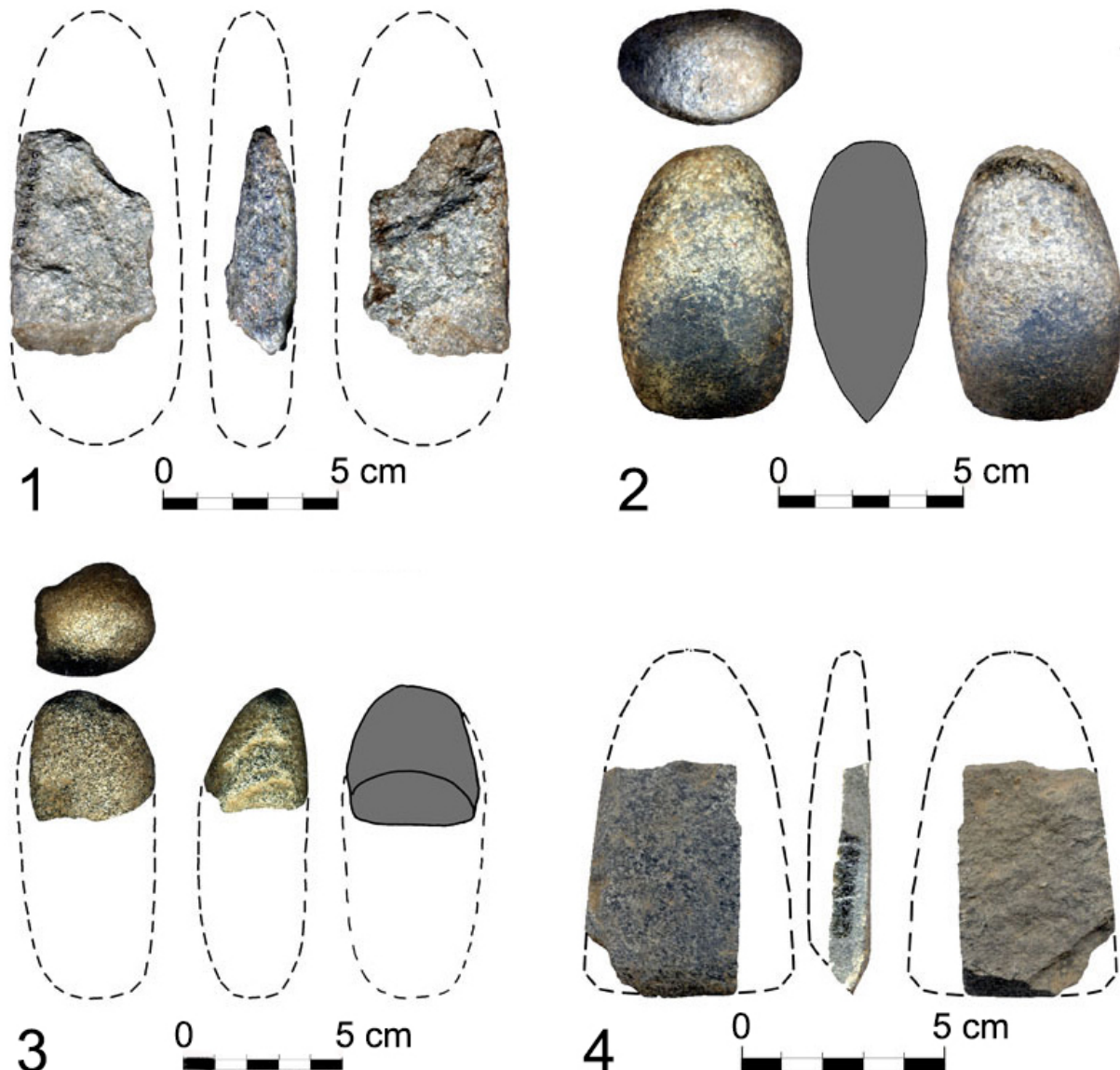


Figure 5. 1: sample 06CS-H11-If-9b-56 made from quartzite. 2: sample 06CS-D10-Ig-9b-5 made from mottled hornfels. 3: sample 10CS-D8-Ih-10b-11 made from transition phyllite-schist. 4: sample 06CS-F10-If-9b-3 made from slate. The scale bar is 5 cm wide with 1 cm intervals.

Contact metamorphic rocks include mottled and unmottled hornfels and mottled phyllites (Figure 6.), whereas foliated rocks consist of slates and phyllites representative of regional metamorphism.



Table 2. List of rocks used as raw materials for axes industry. Abbreviations: C - colour; d - dark samples; l - light samples.

Nature of rocks		Type of rocks	C	%	Total
Metamorphic	Contact metamorphism	Mottled, unmottled hornfels, or both	d	39	25
		Mottled phyllite	d	10	
	Regional metamorphism	Phyllite	d	10	
		Slate	d	6	
	Contact, regional metamorphism, or both	Quartzite	l	10	
		Marble	l	3	
Unknown		d	3		
Igneous	Plutonic	Granodiorite	l	3	6
		Aplite-pegmatite	l	3	
	Hypabissal	Porphyry	d	10	
		Unknown	l	3	

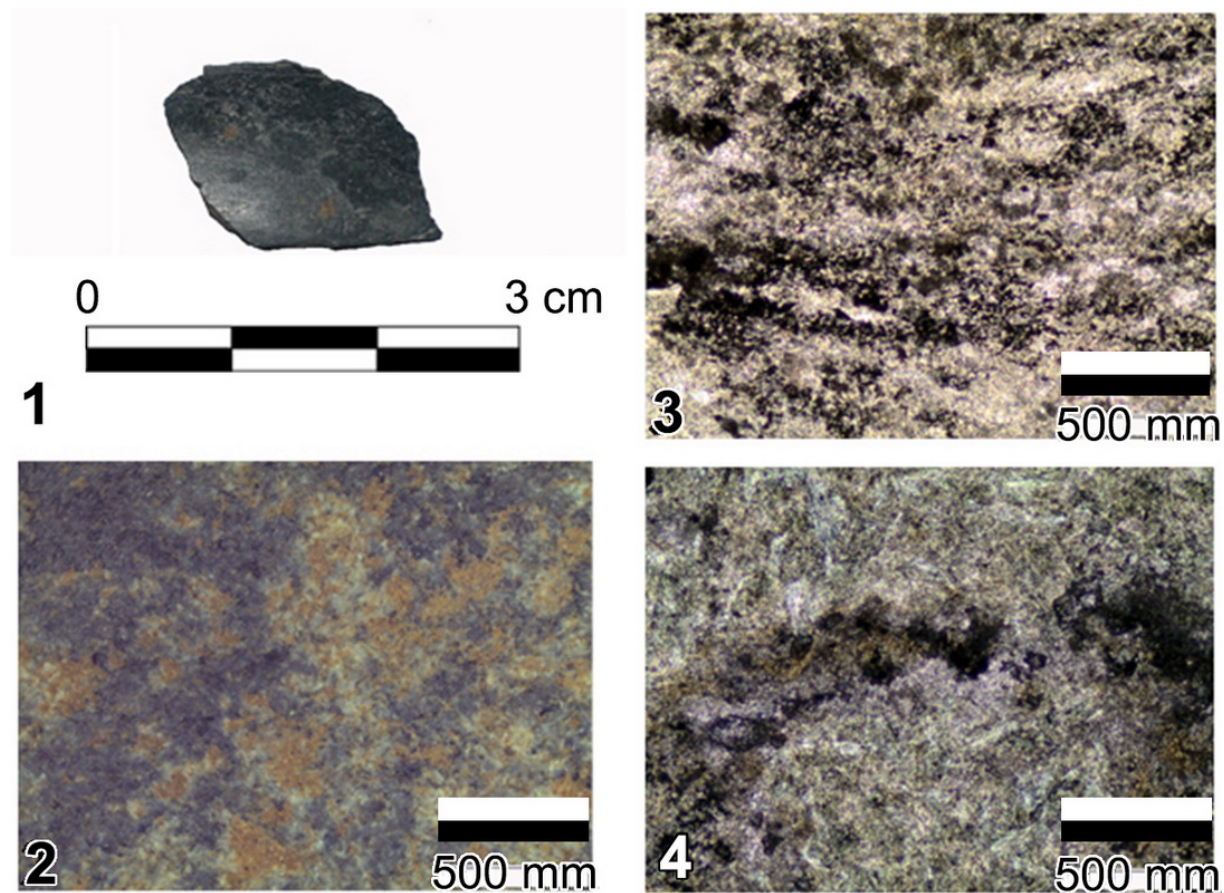


Figure 6. Dark axe (fragment) sample 96CS-I4-IIb-11-181. Mottled phyllite. 1) Hand sample The scale bar is 3 cm wide with 1 cm intervals; 2) Spotted texture (binocular magnifier: scale 500 mm); 3) Fine-grained granoblastic matrix (optical microscope: scale 500 mm) and 4) Cordierite porphyroblast replaced by chlorite and muscovite surrounded by a fine-grained matrix (optical microscope: scale 500 mm)..

Light samples comprise granodiorites, aplite-pegmatites, one unidentified sample and, as metamorphic rocks, quartzites and marbles (Figure 7).

Micropetrographic observations allow more detailed characterization of the texture and the mineral assemblage of each singular rock.



Figure 7. Light axe (fragment) sample 02CS- H6-IId-11b-107. Granodiorite. 1) Hand sample. The scale bar is 4 cm wide with 1 cm intervals.; 2) Granular texture (binocular magnifier: scale 200mm).

Hornfels are isotropic in appearance with small porphyroblasts (ranged in 1 to 2 mm in size) included in a fine-grained matrix. Porphyroblasts are mainly cordierites (see Figure 6) which form rounded to oblate crystals of black to purple colour; however in some samples decussated prismatic white crystals of quiazstolite may be also present. Matrix usually is retrogressed to sericite and consists of decussate muscovite and biotite, granoblastic quartz and accessory minerals such as titanite and iron oxides. Spotted phyllites share the same mineral assemblage though foliation is the outstanding character, along with the aphanitic and shiny appearance. Some rocks can be considered strictly the transition between hornfelses and spotted phyllites as they present both foliated and decussated textures. Slates and phyllites are aphanitic with greyish dark colours and show a pervasive foliation formed by phyllosilicates. Marbles are white colour rocks with granoblastic texture, composed of calcite crystals of 2 mm in size. Quartzites are finer grained, harder and consist mainly of quartz.

Porphyry has an inequigranular texture made of idiomorphic phenocrysts of quartz embedded in an aphanitic dark matrix. Phenocrysts are 2 mm in size and are scarce (up to 5% in volume) but stand up by its white colour. Granodiorite is a coarse-grained rock with an equigranular texture formed by crystals of quartz and feldspars of 2 mm in size, and minor amounts of biotite and muscovite. Aplite is recognized by the homogeneous mosaic of small grains (up to 1 mm in diameter) consisting uniquely of quartz and feldspar.

The overall assemblage of rocks recognised in Can Sadurní's cave is distinctive of a geological context where extensive thermal aureole develops around plutonic intrusion and its related dyke swarm. In particular, the contact aureole is superimposed on low-grade regional metamorphism as the presence of spotted phyllites indicates. In fact, the occurrence of both

hornfels and spotted phyllites suggest the existence of two zones representing different metamorphic grades (the internal and the external aureole) related to the metamorphic gradient between the intruding magma and the surrounding country rock (Figure 8).

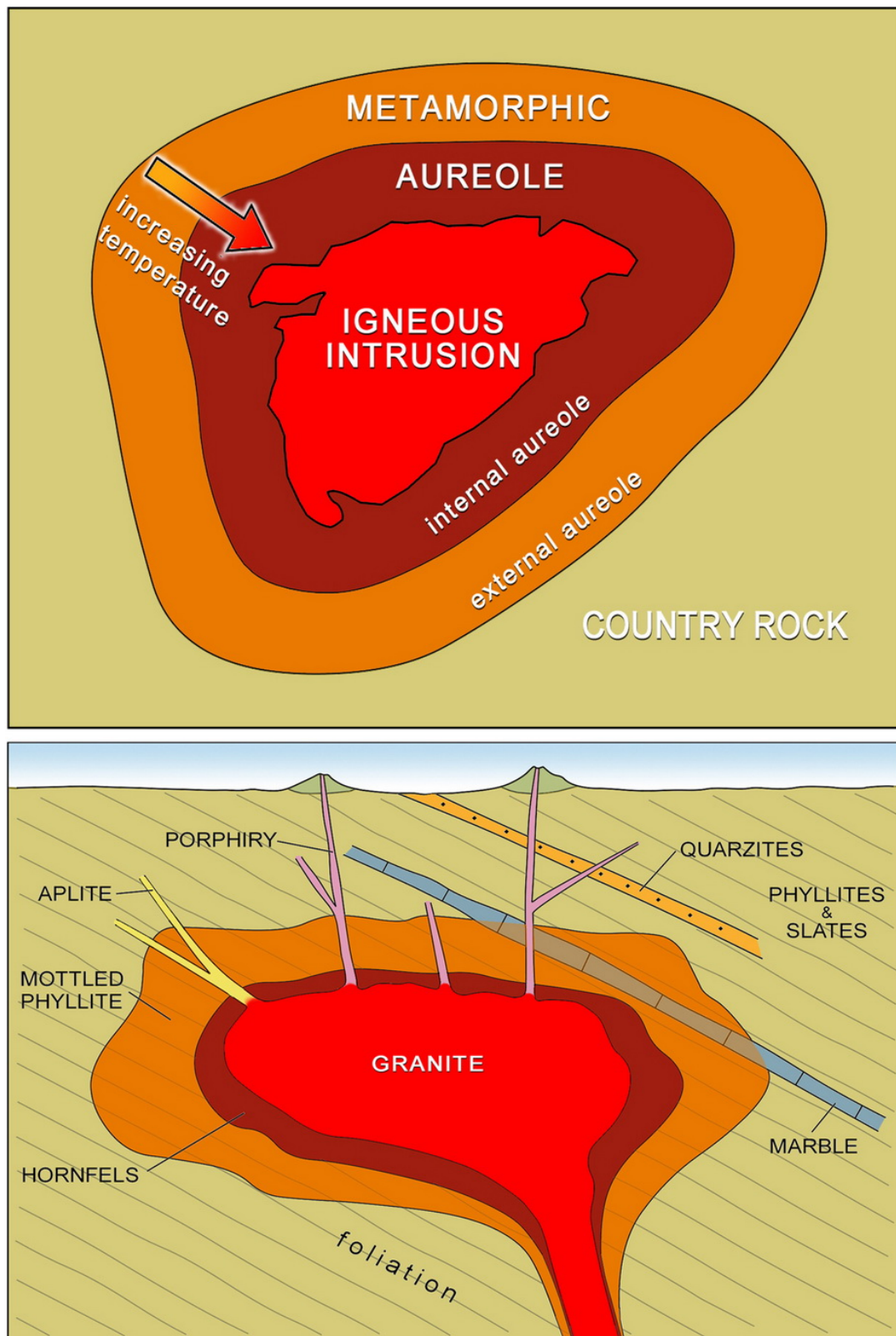


Figure 8. Schematic illustration of an igneous intrusion and its contact metamorphic aureole distinguished from the country rock. A) Plan view of metamorphic zones' distribution inside the aureole. B) Cross-section view and localization of major rocks.



## 4.2. Fieldwork

A fieldwork has been done in order to know the most possible source area for the supplying lithic materials similar to the archaeological samples. Two sectors have been taken into account: the sector at the vicinity of the cave in Begues, and the sector located at the other side of the Llobregat River, the Collserola range.

Sant Sadurni's cave is located in the Cretaceous limestones and very close to the Jurassic dolostones and Triassic carbonate materials. None of these rocks coincide with our samples. Further to the east, the Buntsandstein conglomerates contain a great variety of clasts, though the majority are made of quartz. Even more to the east, at the locality of Torrelles del Llobregat, metamorphic Palaeozoic rocks, such as phyllites and quartzites, occupy a large extension, though locally they are covered by alluvial deposits (*e.g.*, La Clota and Torrelletes creeks) consisting of silts, sands and gravels. The gravels present very little clasts (range between 2-5 cm) of mottled hornfelses, unmottled hornfelses, phyllites and mottled phyllites.

In the Collserola range at the surroundings of the Barcelona granodiorite outcrop contact metamorphic rocks four outcrops have been studied: in the n. 1 (Finestrelles), at the west of Sant Pere Màrtir hilltop, mottled and unmottled hornfelses occur. Further to the south, a porphyry dyke (outcrop n. 2) and phyllites and mottled hornfelses (outcrop n. 3) have been found. And, finally, at Can Cortés and Can Biosca creeks (outcrop n.4), local Quaternary terraces formed by sands and gravels with metamorphic and igneous pebbles up to 6 cm length are present (Figure 9).

## 5. Discussion and conclusions

### 5.1. Discussion

The analysis of the archaeological record of the Neolithic axes of Can Sadurní cave show that the overall rock assemblage fits perfectly in a geological context typical of regional metamorphic environment, accompanied by igneous intrusions and the surrounding metamorphic aureoles. However, considering the outcrop materials of the Garraf massif is difficult to consider this region as the supply area. The Garraf massif is composed mainly of limestones and dolostones of Jurassic and Cretaceous age and uniquely to the east, parallel to the Llobregat River, Triassic materials and the Palaeozoic basement are present. The Palaeozoic basement is represented by Ordovician - Cambro-Ordovician and Silurian rocks affected by Hercynian low-grade regional metamorphism. Therefore a monotonous sequence of quartzites and phyllites predominates in this area, with no signals of contact metamorphism and granitic intrusions. However the pebbles of the Quaternary terraces in the vicinity of Can Sadurni cave contain igneous or contact metamorphic rocks of small dimensions. At the other side of Llobregat River, just at northwest of Barcelona city, the Collserola range exhibits the overall rock assemblage. In this area, a fairly complete Palaeozoic stratigraphic sequence (from Cambro-Ordovician to Carboniferous) crops out, although the oldest rocks occupy the most of the part. The whole sequence has been affected by polyphase deformation accompanied by a regional low-grade metamorphism during the Hercynian orogeny. Late-Hercynian granodiorite and a swarm of pegmatites, aplites and porphyry dykes intrude the Palaeozoic sequence resulting in a contact aureole of up to a 1 km width (Gil Ibarra & Julivert 1988; Alías *et al.* 2008; Vila & Pin 2015).

Most of the rocks are slates, phyllites, quartzites, marbles and metabasites formed during regional metamorphism, but spotted hornfelses and phyllites are also present within the contact aureole, at the vicinity of the Barcelona granodiorite. Aureoles adjacent to felsic intrusions (*e.g.*, granodiorites) are usually restricted to relatively shallow depths and range from about 0.5 to 2.5 km in width.

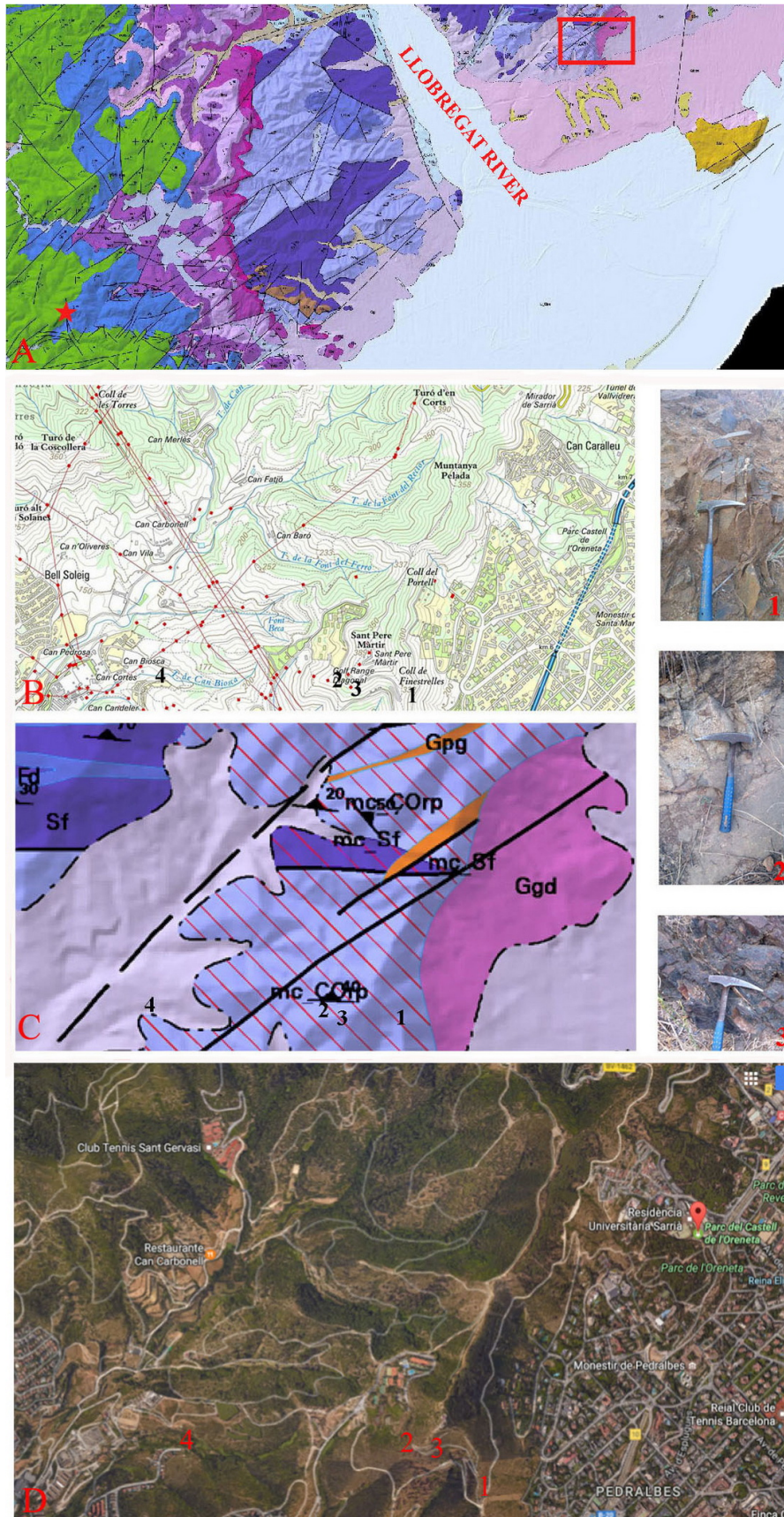


Figure 9. A: General map of Collserola range (1:25.000). Star: Can Sadurn's cave. B: Road map (1:10.000). C: Geologic map (1:10.000). D: Google Earth view. Geological points and images from geological surveys'. n.1: Finestrelles; 2: Sant Pere Màrtir hilltop; 3: Sant Pere Màrtir hilltop; 4: Can Biosca creek. Sources: ICGC (2016), Google Maps (2016).



The raw materials described in this study coincide completely with those occurring at the Collserola range (Figure 10), and more specifically with those related to the igneous intrusion and the surrounding rocks close to the Sant Pere Màrtir hilltop. Even two different kinds of hornfelses can be equivalent to those derived from the metamorphism of Cambro-Ordovician pelites (gray dark colour with porphyroblasts of cordierite) and the metamorphism of Silurian graphitic-rich pelites (black colour with porphyroblasts of andalusite). Uniquely, the metabasites have not been found as a raw material, probably because they are distant from the supply area.

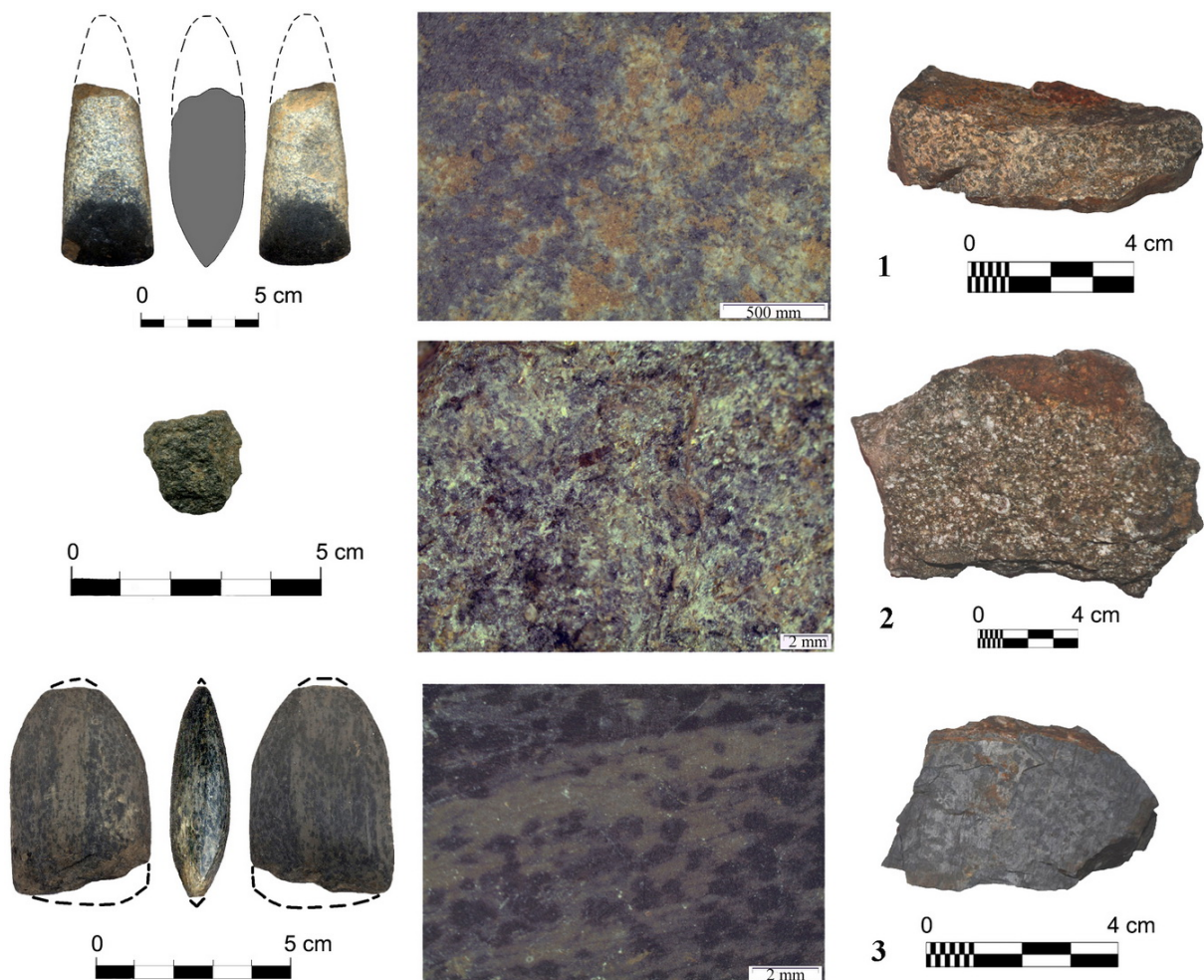


Figure 10. Archaeopetrological comparison between texture and mineralogy from the axes and the geological samples collected at different outcrops. From top to bottom: Axe made of mottled hornfels (sample 07CS-E6-Ig-9b-61) and its geological correspondance sample (binocular magnifier: scale 500 mm), fragment of axe made of porphyry (sample 11CS-D9-Ih-10b-221) and its geological correspondance sample (binocular magnifier: scale 2 mm) and axe made of mottled phyllite (sample 09CS-E10-Ig-10b-73) and its correspondance sample (binocular magnifier: scale 2 mm). The scale bar is 4 or 5 cm wide with 1 cm intervals.

Regarding the geological map of the Collserola range close to Llobregat River, such a diversity of rocks is exposed in an area of about 8 km<sup>2</sup> (see Figure 9). We consider that the most plausible hypothesis is that the inhabitants of the cave found all the materials concentrated in a single outcrop as an alluvial deposit (see other authors like Fíguls 2012). The first explorations done at Can Cortés and Can Biosca creeks close to Sant Pere Màrtir hilltop have shown that metamorphic and igneous pebbles are very small to explain the supplied material, so more explorations in others creeks should have to be realized. We have



to keep in mind the great human impact of the whole area that, probably, will hinder our future research strategy.

## 5.2. Conclusions

Macroscopic and microscopical study of a total of 31 Neolithic axes from the site of Can Sadurní, let us to discriminate two different groups, the light axes and the dark axes, corresponding to igneous and metamorphic rocks respectively.

The great spectra of metamorphic and igneous rocks let us to conclude that all the rocks fit perfectly in a geological context of a metamorphic aureole developed around an igneous intrusion (Figure 11).

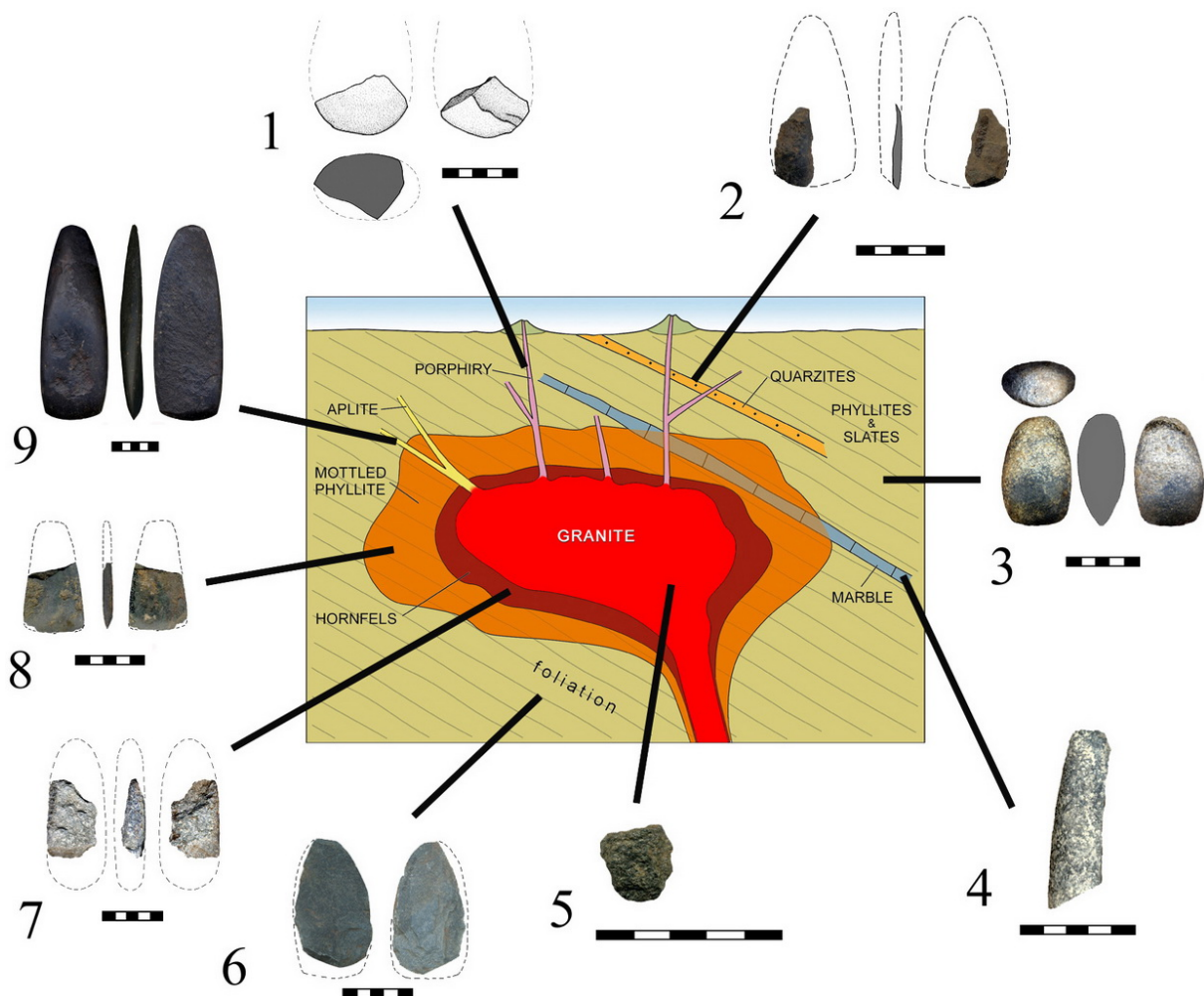


Figure 11. Localization of raw materials in relation to the schematic distribution of contact metamorphic rocks and plutonic intrusion. 1: sample 03CS-I9-IIId-11-29. 2: sample 06CS-H11-If-9b-56. 3: sample 06CS-D10-Ig-9b-5. 4: sample CS-G-32. 5: sample 11CS-D9-Ih-10b-221. 6: sample 03CS-I8-IIIC-18-51. 7: sample 06CS-H11-If-9b-56. 8: sample 08CS-LB12-Spf-252. 9: sample 08CS-KL12-EGr8-Spf-1. The scale bars are 5 cm wide with 1 cm intervals.

This geological context can be found at a distance of 27 km as the crow flies, from Can Sadurní's cave, crossing the Llobregat River, at Collserola range, particularly at Sant Pere Màrtir hilltop.

So, we can suggest Collserola range as the closer and most likely area of original provenance of the raw materials used to manufacture the axes and adzes at Can Sadurní, but we also suggest that raw material procurement have been collected probably in secondary

outcrops, like the Llobregat River terraces, that nowadays kept yet unknown due to the high disturbance of that area, near the city of Barcelona. This would mean a well-known mobility pattern by the inhabitants of the cave, reaching medium distances to collect raw materials from the terraces as secondary outcrops, were raw material could be found easily and probably in a good shape and size.

From a Neolithic mobility pattern studies point of view, similar works concerning this subject of the macrolithic tools procurement in the north-eastern Iberia in general or in this area - near the Llobregat River mouth - have been done by different authors (Álvarez 1993; Risch 1995; Risch & Martínez Fernández 2008; Fíguls *et al.* 2012); assuming that the exact determination of the original procurement area of the Neolithic axes is unfeasible from a strictly petrographic perspective, a few of them discard the Collserola range and that area of the Llobregat River as a provenance zone of raw materials for polished stone tools during the Neolithic; basically considering, on one hand, the inexistence of prehistoric quarries, and on the other hand, taking into account morphological criteria of the original lithic supports. In fact, it is well known that there is a long tradition of discoveries of prehistoric macrolithic tools along the Segre River, with many workshops detected (Maluquer de Motes 1979; Risch 1995; Risch & Martínez Fernández 2008). Nevertheless, other authors (Fíguls *et al.* 2012) positively suggested that this zone of Collserola range might have also to be considered as a potential area of supply.

Nowadays, many areas of the Collserola range are intensively disturbed, which could hamper the location of prehistoric quarries or workshops, nevertheless an integral research of polished stone tools workshops along the Llobregat River in that area and specifically on their terraces, has not been done.

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