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# Quartzite selection in fluvial deposits: The N12 level of Roca dels Bous (Middle Palaeolithic, southeastern Pyrenees)

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The exploitation of rocks from secondary deposits is attested widely in the European Middle Palaeolithic. However, few studies have focused on analysing the implications derived from the management of these deposits. The fluvial terraces near the Mousterian site of Roca dels Bous have been sampled to determine their lithological composition and cobble morphology. Comparison with artefacts recovered from level N12 indicate selection patterns in the fluvial deposits of black quartzite, as well as preferential management of blanks with specific morphological and volumetric characteristics. This approach reveals behaviours involved in the acquisition, transport, transformation and discard of stone tools necessary for Neanderthal subsistence, and indicates interest in the study of secondary deposits and local raw materials in Middle Palaeolithic contexts.



## 1. Acquisition of raw materials in secondary deposits

The physical environment and its natural resources embodied in the term "landscape" form an inseparable duality. Various approaches stress the need to characterize the geographic environment of archaeological sites in order to study the organization of subsistence of past hunter-gatherers (among others Higgs, 1972; Binford, 1979; Bailey, 1981; Bailey et al., 2011; Reynolds et al., 2011). In the reconstruction of those landscapes, studies of raw materials reveal connections between rock outcrops and archaeological artefacts recovered from sites (Delage, 2003).

Since the 1950s numerous petrological techniques have been used to identify sources of rocks used in archaeological contexts (Sieveking and Hart, 1986; Luedke, 1992; Malyk-Selivanova et al., 1998; Bressy, 2002; Shackley, 2008; Parish, 2011; Roy et al., 2013). From this perspective, management of lithic resources and their connection with mobility patterns during the Middle Palaeolithic is a central issue (among others Tavoso, 1984; Geneste, 1985; Kuhn, 1995; Roth and Dibble, 1998; Féblot-Augustins, 2009; Meignen et al., 2009; Constance and Wilson, 2011; Delagnes and Rendu, 2011; Turq et al., 2013). Most studies have prioritized the study of rocks in primary position, i.e. those which are found in the place of their formation. Other sources of raw materials are "secondary geological deposits", formed by rocks originating from the dismantling of pre-existing geological formations which are transported from a few metres to hundreds of kilometres. Their lithological composition is very varied as it is often a mix of materials from different provenances, which explains the singularity of this type of raw material source (Shelley, 1993; Turq, 2005; Lindsey et al., 2007; Marsaglia et al., 2010). The formation of secondary deposits is the result of disparate processes, differentiating between slope, alluvial, glacial and coastal deposits (Rapp and Hill, 2006).

Study of secondary deposits from an archaeological perspective is relatively recent. In a pioneering study, Shelley (1993) showed that raw materials selection in these deposits is an identifiable phenomenon, and occurs much more markedly than expected in the Dog Canyon and Llano areas (New Mexico, USA). Most studies are based on Shelley's methodology, although the specific characteristics of each case hinder comparison between studies (García-Antón, 2010). By using classic techniques of sedimentology (Krumbein, 1941; Gill, 1969; Bunte and Abt, 2001), different qualitative and quantitative parameters which affect knapping activities (blank size, roundness, homogeneity of the matrix) can be measured, enabling precise characterization of such outcrops

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(Shelley, 1993; Stout et al., 2005; Turq, 2005; Álvarez-Alonso et al., 2013).

The exploitation of quartzite, a common rock in secondary deposits, has been identified in numerous Lower, Middle and Upper Palaeolithic sites (among others Kuhn, 1991; Moloney et al., 1996; Cura and Grimaldi, 2009; Cologne and Mourre, 2009; Di Modica and Bonjean, 2009; Mester, 2012; Pereira et al., 2012; Álvarez-Alonso et al., 2013). Choice of quartzite results from the interplay of factors such as scarcity of other rocks in the environment, suitability of those materials for specific tasks, or decisions related to cultural traditions (Terradillos-Bernal and Rodríguez-Álvarez, 2014).

This article analyses characteristics of secondary deposits near the Middle Palaeolithic site of Roca dels Bous (Eastern Pre-Pyrenees, NE Iberian Peninsula) (Fig. 1). Samples from the quaternary fluvial terraces of the Segre River near the site were compared with raw materials identified in level N12. Results indicate a selection of rocks and morphologies used for the production of stone tools. Furthermore, a comparison of data on the presence of cortex of different Middle Palaeolithic archaeological assemblages in Roca dels Bous and Cova Gran de Santa Linya (Eastern Pre-Pyrenees, Lleida) is useful in the analysis of resource management strategies.

## 2. Fluvial terraces adjacent to Roca dels Bous

The Segre River, approximately 265 km long, connects an extensive fluvial network of more than 13,000 $km^2$ linking the southern slopes of the Pyrenees with the Ebro Basin (www.chebro.es, 2014). Processes of fluvial incision occurring during the Pleistocene and Holocene generated a system of stepped terraces along its course and its main tributaries (Noguera Pallaresa and Noguera Ribagorçana). These deposits form 2–10 m-thick, polymictic complexes of imbricated gravels and lenticular levels of sands and silts, which are very carbonated in some sections. The materials in these terraces originate from the dismantling of the axial zone of the Pyrenees mountains (granites, quartzites and hornfels), along with Mesozoic and Cenozoic materials eroded from the Pre-Pyrenees (limestones, dolomites, conglomerates, sandstone, etc.). Eight Quaternary terrace levels are located at different heights above the present river bed, reflecting fluvial incision of the Segre: 2–4 m ($Qt_1$), 10 m ($Qt_2$), 20 m ($Qt_3$), 30 m ($Qt_4$), 50 m ($Qt_5$), 70–85 m ($Qt_6$), 110 m ($Qt_7$). Lacking absolute chronometric indicators, they are attributed relatively to the Holocene ($Qt_0$ and $Qt_1$), the Upper Pleistocene ($Qt_2$ and $Qt_3$), the Middle-Lower Pleistocene ($Qt_4$ and $Qt_5$) and Lower Pleistocene ($Qt_6$ and $Qt_7$) (Peña, 1983; ICC, 2014).

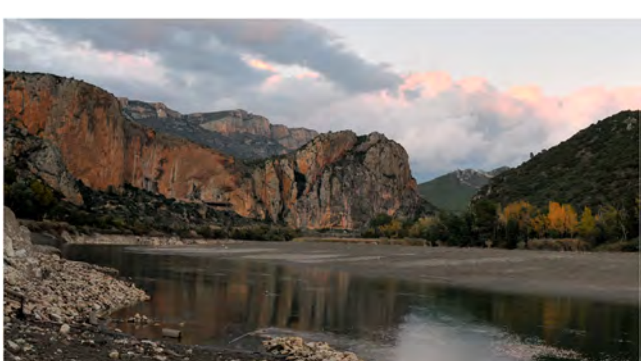

**Fig. 1.** Location of the Roca dels Bous site in relation to the Segre River and the rocky cliff.

Fluvial deposits adjacent to the Roca dels Bous site are located in the final stretch of the middle course of the Segre, at the contact zone between the lower ranges of the Eastern Pre-Pyrenees, and the Ebro Basin (Fig. 2). In this area major Quaternary fluvial sedimentation is associated with the widening of the river channel on its passage through the escarpments of the Pre-Pyrenees. Rocks from these terraces are very common at Roca dels Bous suggesting acquisition of locally available resources (<5 km), a form of resource management which is common in the Middle Palaeolithic (Geneste, 1985; Féblot-Augustins, 1997). To assess the importance of these resources, terraces in a 5 km radius of Roca dels Bous were mapped and sampled to determine the availability and characteristics of blanks, and make a lithological reference collection. The deposits, identified through cartography, orthophotography and available bibliography (Peña, 1983; Peña et al., 2011; ICC, 2014) were later checked against field observations.

## 3. Sampling methodology

Six of the eight terrace levels of the Segre River are located in the study area ($Qt_1$, $Qt_2$, $Qt_3$, $Qt_4$, $Qt_5$ and $Qt_6$). However, as $Qt_5$ is in an isolated area difficult to access, it was not studied (Fig. 2). Ten 1 $m^2$ samples were taken employing a technique of counting surface pebbles using a 10 cm grid sampling frame, and excluding rocks whose *a* −axis was <5 cm (Fig. 3); in this way n ≈ 100 samples were obtained. This method provides reliable results on the lithological composition of the deposits and enables comparison with other studies (Shelley, 1993). Likewise, a 5 $m^2$ sample was taken with a 50 cm grid sampling frame, from which rocks whose *a*-axis was >13 cm were collected to assess differences in a population of larger volumes. Callipers were used to measure the main morphological axes of each sample (length -*a*-, width -*b*-, and thickness -*c*-) (Yuzyk and Winkler, 1991). The following qualitative and semi-qualitative parameters were measured on freshly fractured surfaces: i) rock type; ii) foliation (0 = no foliation, 1 = slight foliation, 2 = pronounced foliation), iii) grain size/crystallinity (VF = very fine, F = fine, M = medium, C = coarse, VC = very coarse, CGL = conglomerate), iv) roundness (using a visual chart) (Krumbein, 1941; Bunte and Abt, 2001), and v) groundmass homogeneity/phenocrysts. Each rock type was macroscopically identified, examples were stored in the reference collection, and samples selected to make thin sections.

Different indices used in sedimentology help characterize morphological features of cobbles and display them in binary and ternary diagrams (Shelley, 1993). Elongation ratio (b/a) and platyness ratio (c/b) indices were calculated which define the following morphologies: disc-shaped, spherical, bladed, and rod-like. The ψ ($((b\cdot c)/a^2)^{1/3}$) index reflects cobble sphericity where 1 is fully spherical and 0 represents flat/elongated morphologies (Krumbein, 1941; Pye and Pye, 1943). Sneed and Folk (1958) established S (c/a) and F (a−b/a−c) indices which are plotted in ternary diagrams and reflect compact, platy, bladed and elongated morphologies. Finally, roundness (which should not be confused with sphericity) allows calculation of the mean roundness (Pm) which measures the degree of wear on cobbles (Bunte and Abt, 2001).

## 4. Description of deposits

Eleven localities were chosen for test pitting based on age and accessibility of deposits. 1011 samples were collected from ten 1 $m^2$ test pits, while 122 samples were recorded from a 5 $m^2$ test pit (Fig. 2). Sedimentary (48%) and metamorphic (38%) rocks dominate while plutonic (11%) and filonian (3%) rocks are less represented (Supplement 1; Fig. 4, left). Classification by rock type shows limestones to be the most abundant (43%) while quartzites are the

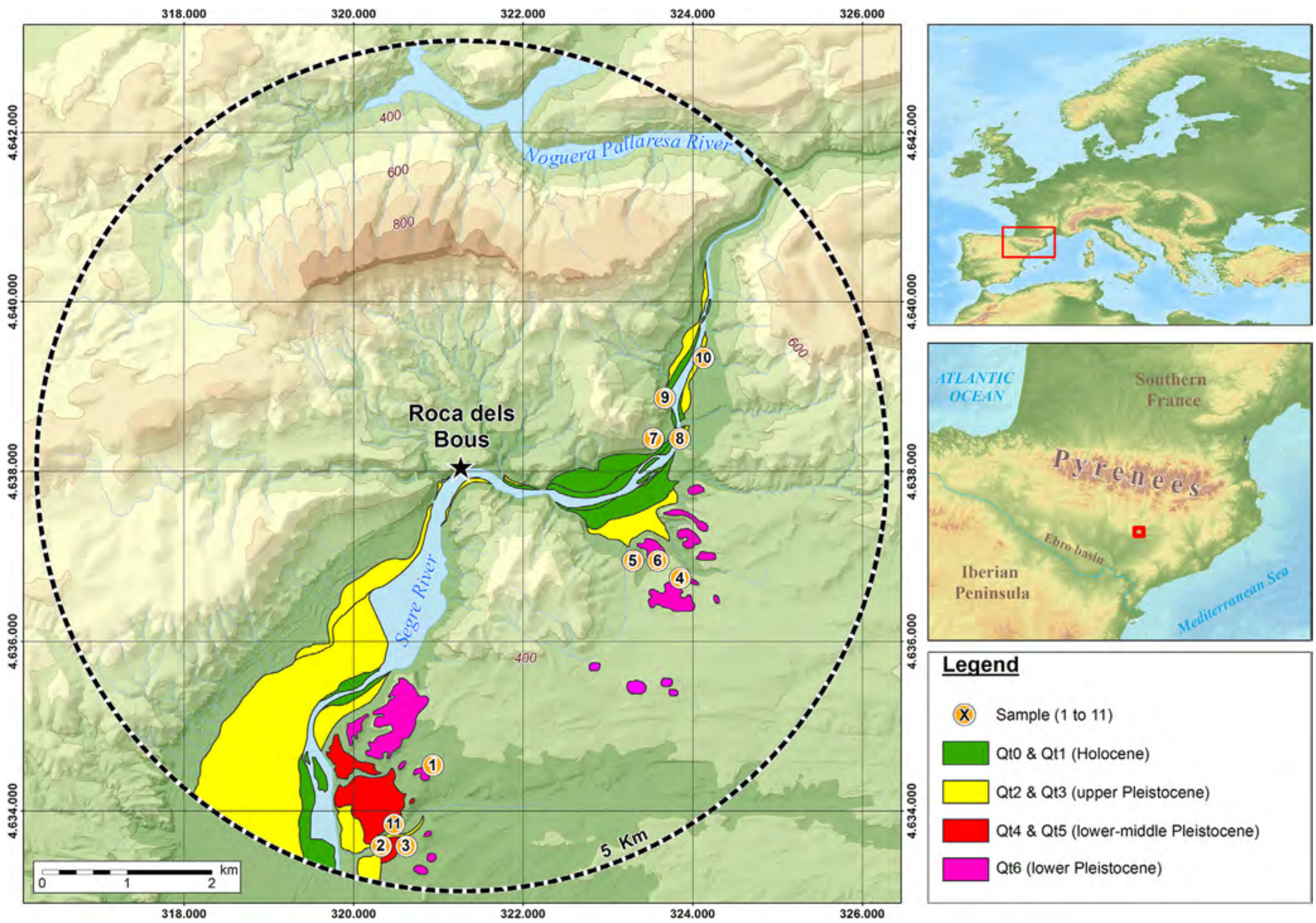


**Fig. 2.** Location of terrace deposits and samples in a 5 km radius of Roca dels Bous.

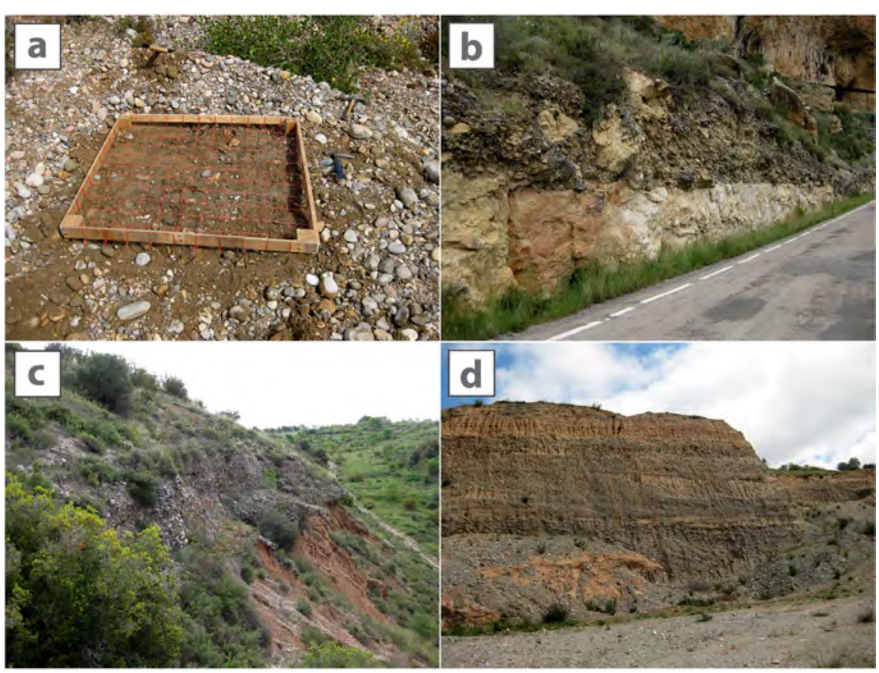


**Fig. 3.** Quaternary fluvial terrace deposits: a) sampling frame for 1 $m^2$ test pits; b) level $Qt_3$ covering Eocene limestones of Cinglera de la Cascalda-Roca dels Bous; c) level $Qt_6$ covering Oligocene strata (near the town of Camarasa); d) level $Qt_6$, gravel deposit (near the town of Camarasa).

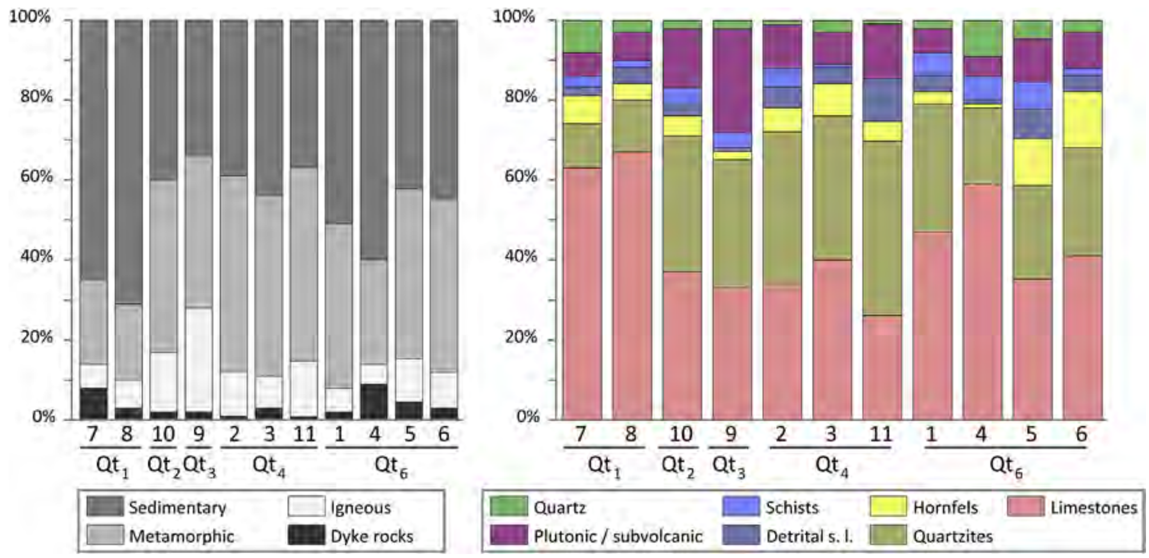


**Fig. 4.** Relative frequencies of rock types according to their origin (left) and lithological classification (right).

second major group (28%). The remainder of the assemblage is formed of hornfels, detrital rocks, schists, quartz, granites and porphyries (Fig. 4, right). All locations are similar although differences visible between test pits are attributed to internal variations of deposits or changes in the drainage area. In samples 4 (Lower Pleistocene), 7 and 8 (Holocene), metamorphic rocks diminish (20%) – especially quartzite (12%) – in favour of a greater proportion of limestones, while in samples 9 and 10 (Upper Pleistocene) limestone diminishes in favour of granite (Supplement 1). The decrease in rocks coming from the axial zone (metamorphic and igneous) may indicate energy loss of the watercourse following specific climatic events such as the last Glacial Maximum, although such inferences cannot be proven from the available data, and therefore we assume that the differences observed in the terrace samples are not significant.

Among the different lithologies, those which come from the dismantling of the Mesozoic and Cenozoic Pyrenean cover are dominant (different types of micritic and esparitic limestones, dolomites, quartz-bearing conglomerates and red sandstone from the base of the Permo-Triassic Buntsandstein facies and Keuper dolerites). Rocks from the axial Pyrenees are mainly represented by Ordovician quartzites, granites from Pyrenean batholiths, and hornfels originating from Pyrenean metamorphic contact aureoles. Other rock types are found in lesser proportions such as schists, porphyries and quartz fragments (Pocoví, 1978; Colombo and Cuevas, 1993; Barnolas et al., 1996; Teixell and Munoz, 2000; Pujalte and Schmitz, 2005; ICC, 2010).

The principal morphological axes of cobbles indicate average sizes on the a-axis from 80 mm to 420 mm. Indices of elongation-ratio and platyness-ratio place the assemblage in a central position although with a slight shift towards disc-shaped forms, reflecting oval and slightly flattened morphologies (Fig. 5), a trend maintained in all test pits and lithologies, apart from hornfels which have more bladed patterns (Supplement 1). All lithologies have roundness values near 0.8, indicating a high degree of transport. Sphericity shows a progression from less spherical forms in hornfels (0.55) towards more spherical patterns in granites and quartz, a phenomenon related to the rheological properties of these rocks. Sedimentary rocks (detrital and limestones) have average sphericity values, while the more isotropic mechanical properties of granites and quartz result in more spherical forms. In contrast, exfoliation planes of metamorphic rocks (hornfels, quartzites and schists) generate flatter/more elongated morphologies (Fig. 6).

The 5 $m^2$ sample showed the lithological composition to be determined by cobble size. Among large cobbles (a-axis >13 cm), an increase is seen in metamorphic rocks (48%), specifically quartzites (43%), as well as in Buntsandstein quartzitic conglomerates (11%) and in granites. These increases are offset by a progressive reduction in the proportion of limestones, which tend to disappear.

This same dynamic is evident in the other test pits. Among larger rocks (≥480 $cm^3$), the number of quartzites (40%), detrital rocks (12%) and plutonic rocks (15%) increases noticeably to the detriment of limestones (29%) which are not present among larger sizes. Inversely, there is an increase in the proportion of limestone and hornfels cobbles with less than 480 $cm^3$ (Fig. 7). This inverted progression is related to the fragility of limestones which break easily creating smaller fragments. In contrast, the toughness of quartzites and Buntsandstein conglomerates is more conducive to fluvial transport in the form of large blocks over longer distances than other less resistant rocks. Finally this lithological progression is also reflected in the morphologies of larger cobbles which are flatter and with sphericity below the average.

## 5. Characterization of quartzite

Quartzite is an important rock in this study due to its abundance in Roca dels Bous. Therefore, it merits a more detailed characterization here than the other rocks recovered, and one which takes into account only the Pleistocene terraces ($Qt_2$, $Qt_3$, $Qt_4$, and $Qt_6$).

Parameters such as grain size, inclusions, colour, foliation and alterations of the matrix were analysed (Tables 1 and 2). Quartzites are defined petrographically as granoblastic aggregrates of allotriomorphic and heterometric quartz crystals, with undulatory extinction and variable preferential orientation depending on whether there is foliation or not, with small concentrations of phyllosilicates scattered between the matrix and allotriomorphic titanite crystals (Fig. 8). The absence of mafic minerals and feldspars indicate a sedimentary origin so they can be classified as paraquartzites (Fettes and Desmons, 2007).

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**Table 1**
Absolute and relative frequencies of quartzite types in 1 m$^2$ Pleistocene samples (n = 244). Quartzite represents 30.1% of the samples.

| Quartzite types | Knappable | Foliated | Altered |
|---|---|---|---|
| Fine grained black quartzites | 18 (2.2%) | 0 | 0 |
| Medium grained black quartzites | 26 (3.2%) | 22 (2.7%) | 2 (0.3%) |
| Medium grained grey quartzites | 53 (6.5%) | 27 (3.3%) | 6 (0.7%) |
| Fine grained grey quartzites | 30 (3.7%) | 6 (0.7%) | 0 |
| Coarse and very coarse grained grey quartzites | 0 | 12 (1.5%) | 0 |
| Medium grained white quartzites | 33 (4.1%) | 3 (0.4%) | 6 (0.7%) |
| **Total** | **244** | | |

**Table 2**
Absolute and relative frequencies of quartzite types with a volume ≥480 cm$^3$ in 1 m$^2$ and 5 m$^2$ samples. Quartzite represents 34.8% of the 1 m$^2$ samples and 44.1% of the 5 m$^2$ samples.

| Quartzite types | 1 m$^2$ samples | | | 5 m$^2$ sample | | |
|---|---|---|---|---|---|---|
| | Knapable | Foliated | Altered | Knapable | Foliated | Altered |
| Fine grained black quartzites | 1 (1.5%) | 0 | 0 | 0 | 0 | 0 |
| Medium grained black quartzites | 5 (7.3%) | 0 | 1 (1.5%) | 3 (2.7%) | 1 (0.9%) | 0 |
| Medium grained grey quartzites | 9 (13.0%) | 0 | 0 | 23 (20.7%) | 1 (0.9%) | 0 |
| Fine grained grey quartzites | 3 (4.4%) | 1 (1.5%) | 0 | 4 (3.6%) | 4 (3.6%) | 0 |
| Coarse and very coarse grained grey qtz. | 0 | 0 | 0 | 0 | 5 (4.5%) | 0 |
| Medium grained white quartzites | 3 (4.4%) | 1 (1.5%) | 0 | 7 (6.3%) | 1 (0.9%) | 0 |
| **Total** | **24** | | | **49** | | |

Different varieties of quartzite have been identified, the most frequent being grey, medium-grained quartzite (6.5%), followed by fine-grained quartzite, fine- and medium-grained black quartzite, and white quartzite with percentage ranges from 2 to 4% (Table 1). Petrographic analysis indicates that these changes in colour are due to tiny quantities of minerals or substances other than quartz (biotite, organic material) (Fig. 8). A significant number were placed in a separate group because they were unsuitable for knapping, either because of foliation or because the matrix is altered. An increase in all varieties of quartzite is observed among larger sizes (≥480 cm$^3$), with grey quartzite forming 13% of the sample while black quartzite ranges between 4 and 7%. A similar increase is seen in the 5 m$^2$ test pit, with the grey quartzite reaching 20.7% and the black quartzite only 2.7% (Table 2).

## 6. Selection of raw materials in level N12 at Roca dels Bous

Roca dels Bous (X = 321.266, Y = 4.638.067, UTM H31 N ETRS89, 275 m a.s.l.) is a rock shelter located at the foot of a 40 m high cliff of Eocene bioclastic limestone partially covered by Oligocene

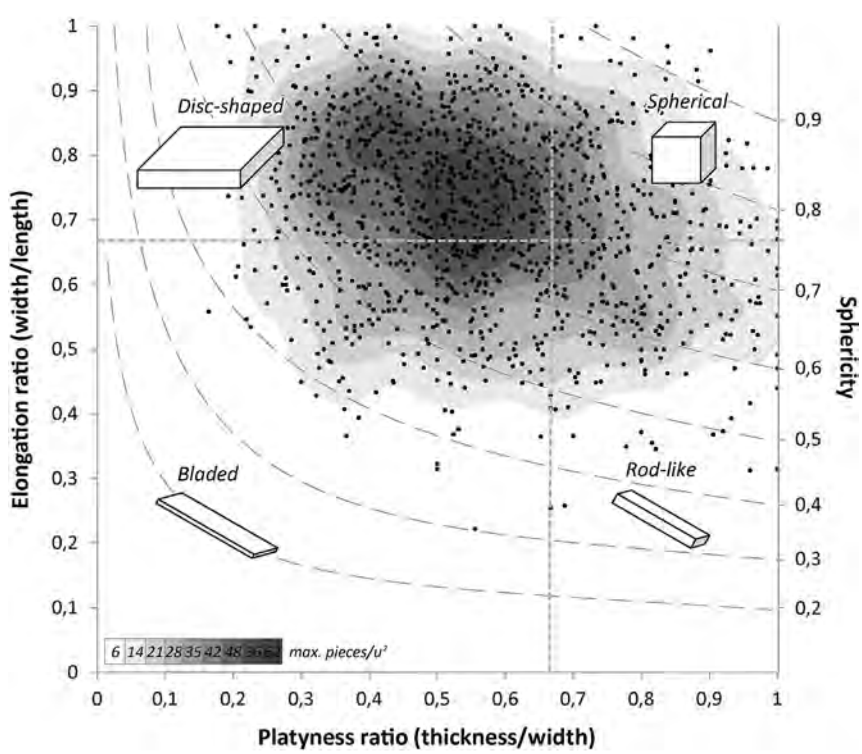


**Fig. 5.** Cobble morphology following Krumbein (1941) classification. The Kernel density diagram was obtained from search radii of 0.1 (classification in 9 density classes using the equal intervals method).

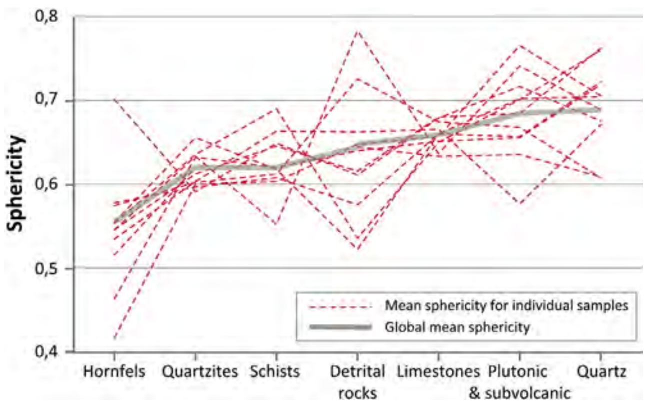


**Fig. 6.** Evolution of average sphericity of different rock types.

conglomeratic breccia (Fig. 1). It is on the right bank of the Segre River in the contact zone between the Eastern Pre-Pyrenees and the Northeast sector of the Ebro Basin (NE Iberian Peninsula) (Teixell and Munoz, 2000) (Fig. 2). The deposit is the result of continuous accumulation of debris during the Pleistocene in two conical bodies attached to the foot of the cornice (Benito-Calvo et al., 2009). Adjacent to the base of the deposit is the $Qt_3$ terrace level, 18 m above the present-day riverbed, marking the altimetric position of the watercourse during the Upper Pleistocene (Fig. 3b).

The archaeological materials form discrete units delimited by sterile levels adapted to the morphology of the deposit, with very homogeneous sedimentation composed of angular limestone clasts and silty matrix. So far five archaeological units, attributed to the Middle Palaeolithic, have been excavated (R3, N10, N12, N14 and S9). In this article we focus on N12, ascribed to MIS 3. centripetal structured knapping systems dominate alongside expedient methods, although centripetal knapping methods *sensu lato* are exclusively on quartzite blanks. The small size of cores indicates intensive exploitation of raw material aimed at the production of small artefacts (Mora et al., 2012; de la Torre et al., 2014).

The lithic assemblage was classified into discrete raw material units (RMU) (Roebroeks, 1988) following the same criteria used for the description of the terrace rocks. Techno-typological analysis was undertaken using the Logical Analytical System (Mora et al., 1994) noting attributes referring to the presence of cortex, patina, rolling and thermal alteration, which were then processed using *ArqueoUAB* software (Mora et al., 2010). Each RMU was macroscopically described, creating a raw material reference collection of archaeological specimens, and thin sections were made in order to complete characterization on a micro scale.

The study has determined the provenance of 97% of the artefacts, corresponding to 10 lithologies attributed to five different geographic/geological sources (Table 3). 85% of the N12 materials are from fluvial deposits; they are primarily quartzites (84%), and in lesser quantities other rocks such as limestone, hornfels, quartz, granite, radiolarite, slate and sandstone (<1%). Given the range of lithologies available in secondary deposits of the immediate environment, one would expect to find a greater variability of rock types on the site. However, results indicate a preference for quartzite. Limestone, quartz, hornfels and other rock types, which were regularly knapped in many Mousterian sites in the NE Iberian Peninsula, are practically invisible in N12 (among others Mora, 1988; Duran and Soler, 2006). The remaining 15% of materials are flint, which has not been identified in the terraces, and comes from primary outcrops in the regional environment located north and south of the site, implying transport distances of >10 km (Roy et al., 2013).

**Table 3**
Geological provenance of rock types identified in the N12 archaeological level.

| Rock type | Raw material provenance | | | | | | | Total |
|---|---|---|---|---|---|---|---|---|
| | Rock shelter | Fluvial deposits | Garumnian chalcedony | Serra Llarga (Oligocene) | Monegros (Miocene) | Indet. | NC | |
| Limestone | 20 (0.10%) | 26 (0.13%) | | | | 2 (0.01%) | | 48 (0.24%) |
| Hornfels | | 172 (0.85%) | | | | | | 171 (0.84%) |
| Quartzite | | 16938 (83.52%) | | | | | | 16939 (83.52%) |
| Quartz | | 54 (0.27%) | | | | | | 54 (0.27%) |
| Dolerite | | | | | | 19 (0.09%) | | 19 (0.09%) |
| Granite | | 2 (0.01%) | | | | | | 2 (0.01%) |
| Radiolarite | | 1 (0.00%) | | | | | | 1 (0.00%) |
| Shale | | 2 (0.01%) | | | | | | 2 (0.01%) |
| Chert/chalcedony | | | 2053 (10.12%) | 466 (2.30%) | 10 (0.05%) | 133 (0.66%) | 306 (1.51%) | 2968 (14.63%) |
| Sandstone | | 4 (0.02%) | | | | | | 4 (0.02%) |
| Other | | | | | | | 73 (0.36%) | 73 (0.36%) |
| **Total** | **20 (0.10%)** | **17199 (84.81%)** | **2053 (10.12%)** | **466 (2.30%)** | **10 (0.05%)** | **154 (0.76%)** | **379 (1.87%)** | **20281** |

Level N12, excavated over a surface of 95 $m^2$, is 20 cm thick and has a central sunken area between two debris cones. Fourteen flat hearths and one fire pit were identified, with diameters between 0.3 and 3 m, located usually against the rockshelter wall and, in some cases superimposed on each other, indicating that in N12 there was a succession of several occupations within a timescale which is difficult to determine precisely (Fig. 9) (Martínez-Moreno et al., 2010). At present, more than 25,000 remains have been catalogued; the lithic assemblage consists of 20,281 artefacts, of which 84% are quartitze and the remaining 15% are flint, a pattern which contrasts with that seen in other levels of the site. Preferential *Levallois* and hierarchical bifacial

Interest in quartzite in N12 led us to undertake a petrographic (macroscopic and thin section) characterization of the different varieties of quartzites in the same way as had been done in the fluvial deposits (Fig. 8). There was a clear dominance of what we call black quartzites (59%) versus grey quartzites (22%) and other minor groups (1%) (Table 4). Such a distribution does not match their presence in the fluvial deposits where black quartzite represents about 3%, while grey quartzite is more abundant (7%). This bias suggests intentional selection of a rock type -black quartzite-which is relatively sparsely represented in the terraces, as opposed to other more common quartzite types (e.g. grey quartzites).

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**Table 4**
Quartzite types identified in the N12 archaeological level. Percentages calculated on the total number of artefacts in N12 (n = 20,281).

| Quartzite types in N12 level | |
|---|---|
| Medium grained black quartzites | 11867 (58.51%) |
| Medium grained grey quartzites | 4388 (21.64%) |
| Fine grained black quartzites | 6 (0.03%) |
| Other quartzite types | 288 (1.42%) |
| Not classified | 389 (1.92%) |
| **Total** | 16938 (83.52%) |

The preponderance of black quartzite is reflected in all lithic categories, both in terms of weight and number of pieces, discarding interpretative distortions generated by fragmentation of the lithic assemblage. As regards weight, black quartzite represents 59% of the assemblage, implying transport to the site of 56 kg of raw material, of which the amount of flake fragments (24 kg) and flakes (19 kg) is striking, while cores and retouched pieces reach 6 kg and 5 kg respectively, indicating provisioning and management of these rocks on the site. As for the number of artefacts, 110 (53%) of the 207 cores in N12 are of black quartzite. Indications of knapping such as

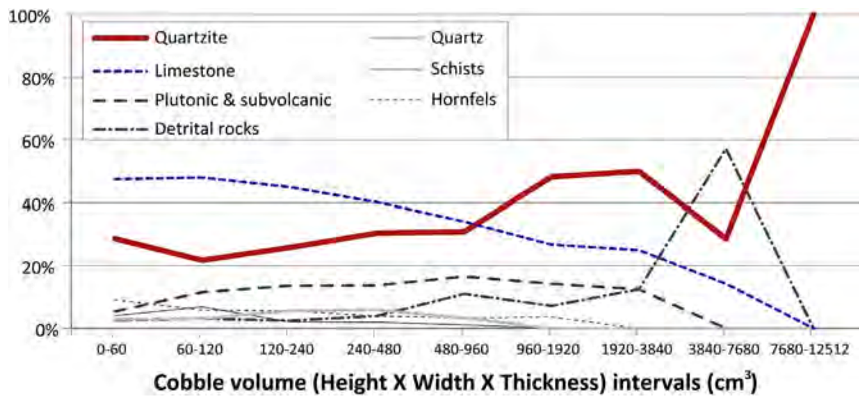


**Fig. 7.** Evolution of relative frequencies of rock types in relation to cobble volume (Height × Width × Thickness).

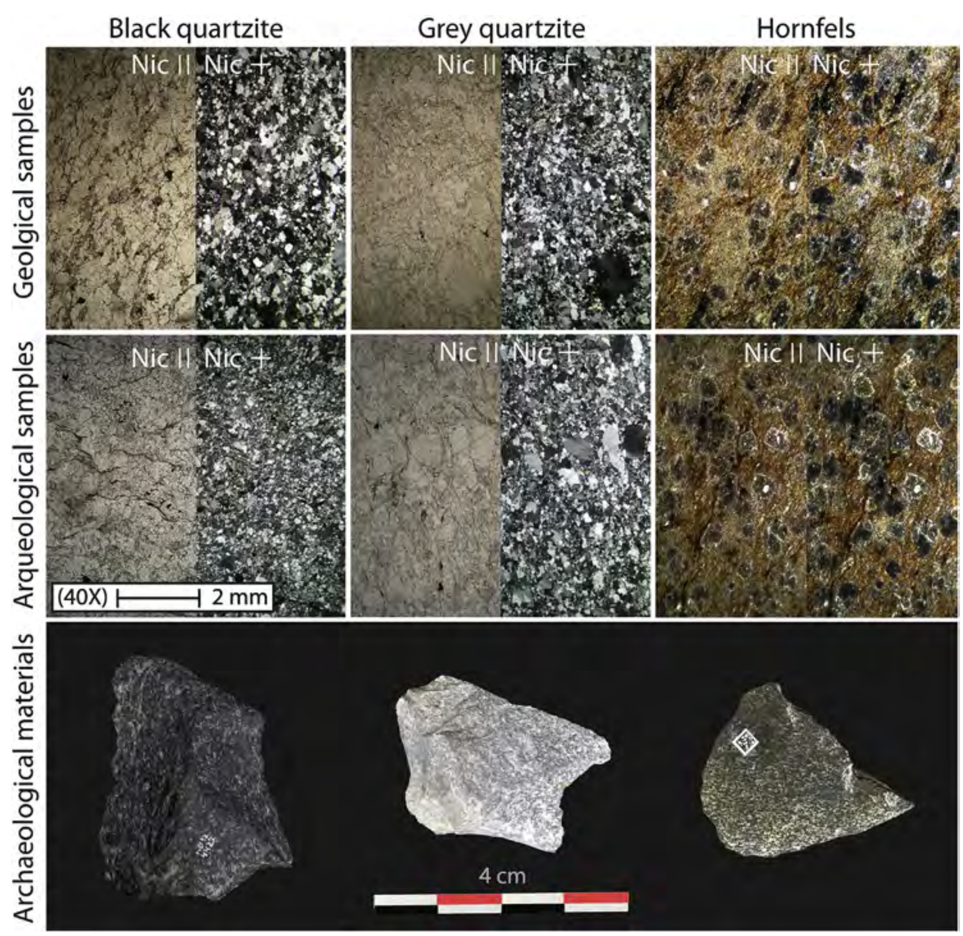


**Fig. 8.** Thin section samples and archaeological examples of two types of quartzite and hornfels: Upper: geological samples; middle: archaeological samples; lower: archaeological material.

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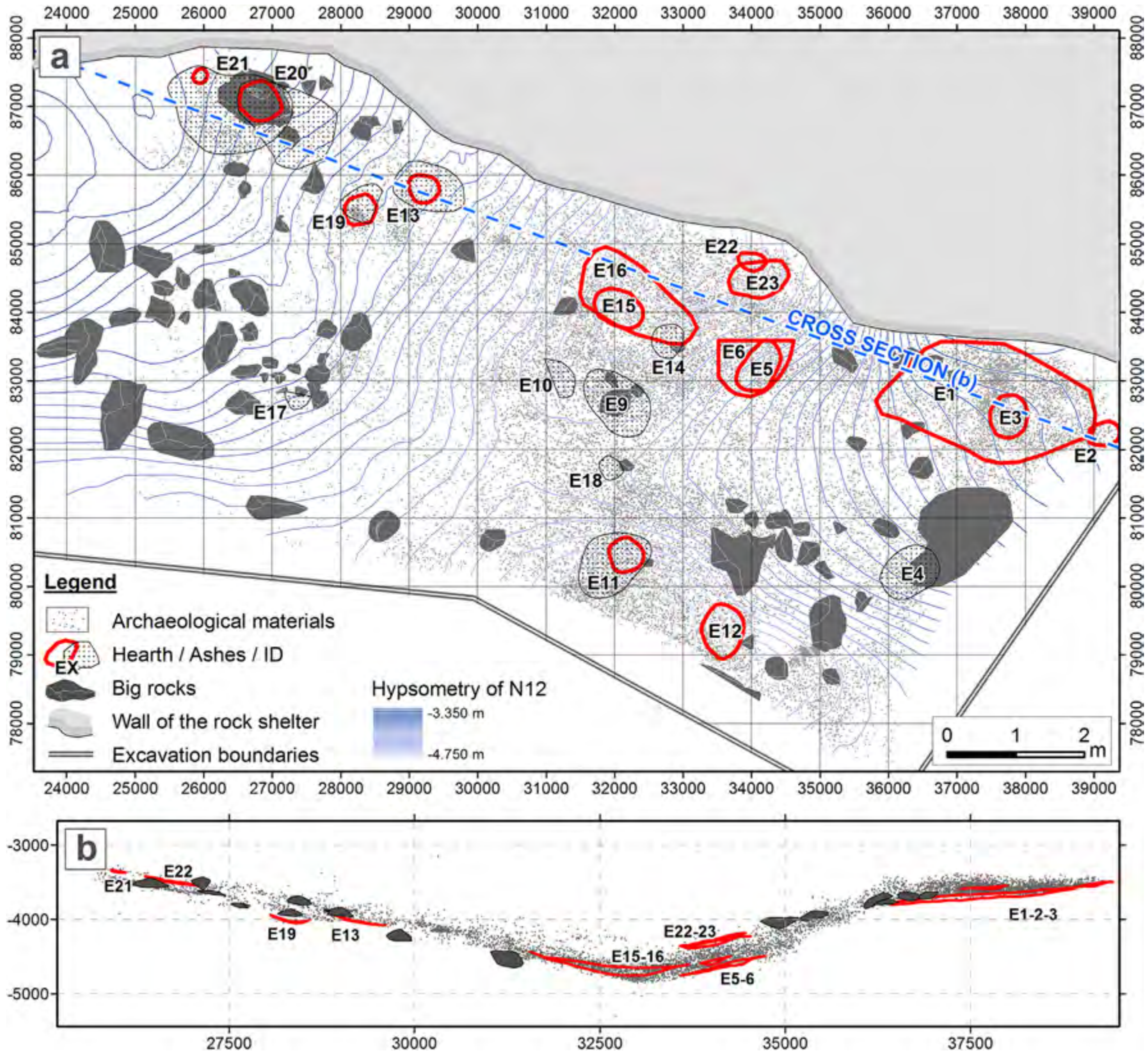


**Fig. 9.** N12 contextual features: a) General topography of the N12 archaeological level; b) Vertical plot of N12 in an oblique cross section.

flake fragments and flakes form 70% and 60% of the assemblage respectively. A change is evident among retouched pieces which show preferential selection of flint from the regional environment for the production of pieces with modified edges (45%) (Martínez-Moreno et al., 2010).

The type of raw material is not the only parameter which may influence cobble election. Other factors such as morphology and size must have been important also. We indicated above that the proportion of quartzite increases when larger volumes only are considered (Fig. 7). Metric analysis indicates a dominance of slightly flattened and oval morphologies with a dominant a-axis and a b-axis slightly larger than the c-axis (Fig. 5). This suggests preferential exploitation – intentional or not – of relatively large (>10 cm) cobbles of such morphologies, which does not necessarily imply selective exploitation given that most cobbles have these morphological characteristics.

It is not easy to assess this perspective through the archaeological material, as the intensity of lithic reduction recorded prevents a rough reconstruction of original volumes and shapes. Although average length of the N12 quartzite artefacts might be an indirect indicator of size, average length of cores (4.6 cm), retouched pieces (3.8 cm), and flakes (2.5 cm) is not necessarily representative of original volumes as their systematic reduction generated numerous small fragments thus decreasing the average. Another indicator could be provided by the presence of artefacts larger than 5 cm in length as in order to get blanks of this size from centripetal methods larger blanks are necessary. As 45.4% of cores and 34.1% of retouched pieces are larger than 5 cm, as opposed to 2% of flakes, this indicator cannot be considered conclusive either. Furthermore, it should be noted that large cobbles are more versatile for the production of artefacts and one blank can generate several preforms, each of which can be modified separately. Likewise, the predominant shape of cobbles in the terraces – flat/oval – have angles which provide natural platforms facilitating knapping. Progress in studies on the reconstruction of cobble shape and volume through refitting (de la Torre et al., 2012) may help address this issue. Despite these problems, a process of double selection can be suggested. On the one hand, cobble acquisition in N12 focuses on black quartzite which is present in the environment but is relatively scarce; at the same time, the focus is also on relatively large (>10 cm), slightly flat/oval cobbles.

## 7. Discussion

The pattern of quartzite selection identified in level N12 at Roca dels Bous generates elements of discussion which go beyond this

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particular case, concerning methodological aspects related to sampling techniques applied and lead to inferences regarding Neanderthal knowledge of the environment and strategies for the acquisition of rocks. Some of these central arguments will be addressed below.

### 7.1. Secondary deposits: methodological remarks

The main advantage of the analytical methodology used for secondary deposits is to have a series of parameters that identify patterns of rock selection. Such an approach is not prevalent in studies of raw materials, usually focused solely on identifying source without examination of other associated behaviours.

Moreover, characterization of local materials has attracted little interest although they are in the majority in most archaeological sites. In contrast, priority has been given to establishing allochthonous materials, considered as long-distance markers, but which form a limited part of the tool assemblage and provide little information related to human behaviour. The current study highlights the importance of studying local materials, especially in the Middle Palaeolithic.

Some points that can be made regarding this methodology concern the choice of 1 $m^2$ areas to narrow sampling zones. Such a choice involves counting cobbles >5 cm, as required by the width of the grid (10 cm). This limitation can be overcome by 5 $m^2$ test pits which provide a good representation of the variability of lithologies and morphologies between 5 and 42 cm. Our 5 $m^2$ pit allowed identification of compositional changes when considering separately smaller cobbles (dominated by limestones) and bigger cobbles (among which quartzites are common). This observation indicates the need to continue sampling deposits with 5 $m^2$ test pits, focusing attention on cobbles >13 cm, to determine whether a similar pattern is repeated in all the Pleistocene terraces.

### 7.2. Management of resources in N12

Patterns in the management of lithic resources identified in Roca dels Bous N12 generate perspectives from which to analyse a key subsistence activity. Knowledge applied and transferred through time is shaped by techno-economic and techno-psychological decisions affecting selection of rocks for the production of artefacts (Boëda, 1991). Such behaviours, although not always highly visible archaeologically, indicate an intimate knowledge by human groups of the landscape and its resources. This view produces several observations with regard to N12.

The parameters documented respond to behaviours linked to a cultural tradition which influences selection of raw materials (Mora, 1988; Kuhn, 1991; Terradillos-Bernal and Rodríguez-Álvarez, 2014). Questions as to whether factors such as knapping aptitude or functional characteristics of tools determine decisions produce ambiguous results. Apparently, the varieties of quartzites are similar in their suitability for knapping, although this point deserves to be tested experimentally. Neither have substantial differences been identified in cobble (secondary deposits), flake and core (archaeological artefacts) size between black and grey quartzites (Fig. 10, Supplement 2). The arguments, then, suggest that preference for black quartzite does not respond to techno-economic factors involved in knapping or tool function.

The above observation needs to be qualified. In the analysed samples, large, black quartzite cobbles form from 3 to 6% of the total. Such a slight increase could indicate an active search for large sizes which are more easily identified. This implies expert knowledge of the type of resource selected, particularly when rocks visually very similar such as hornfels – but not suitable for knapping – are barely represented (<1%) in the N12 lithic assemblage.

Black quartzite is very common in the Mousterian levels of Cova Gran de Santa Linya (personal observations; Mora et al., 2011), 14 km north of Roca dels Bous, so the idea that selection responds to a cultural constraint of Neanderthals in the region cannot be ruled out.

The selection of a particular type of rock from secondary deposits suggests similar mechanisms of selection of other rocks from more distant sources such as flint. In N12, 15% of the tool kit is made on flint originating from 10 to 15 km north and south of the site (Table 3). Flint is preferentially used in the production of retouched tools which are introduced as individual tools (Turq et al., 2013) or as reserves of raw material, as indicted by the presence of 50 flint cores (Martínez-Moreno et al., 2010). We believe that mechanisms of selection used for siliceous rocks were analogous with those identified for quartzite, as their transport from such distances cannot be understood without evidence for the testing and discard of poor quality raw material, which is very common in flint outcrops in this region (Roy et al., 2013). In addition, within the archaeological material, those varieties better suited to knapping are noticeably more abundant than they normally appear in outcrops. It is not easy to justify this inference through materials such as flint, and an approach similar to that undertaken in the fluvial terraces requires a more complex sampling of primary deposits. That is why the methodology presented here is so important. We believe that the selection processes determined in secondary deposits can be extrapolated to materials from primary flint outcrops. Such a view is particularly relevant for the Eastern Pre-Pyrenees as flint is the dominant raw material in some Mousterian levels of Roca dels Bous and dominates the entire Middle and Upper Palaeolithic sequence of Cova Gran.

### 7.3. Procurement strategies

The exploitation of quartzites from fluvial deposits indicates selection of a rock which is not very abundant and preference for relatively large cobbles (>10 cm). Such observations generate technical issues affecting Mousterian lithic assemblages, for example: What types of preforms are used in knapping? Are preforms prepared at outcrop locations? Are whole cobbles transported to consumption sites (Geneste, 1992; Dibble et al., 2005; Moore et al., 2009; Turq et al., 2013)? Such questions relate to whether acquisition is combined with other subsistence activities, is obtained from planned trips, or through exchange; all are scenarios which refer to models of embedded, direct or indirect procurement (Binford, 1979; Gould and Saggers, 1985).

It is not easy to assess these ideas, and different models may coexist in the same site. At N12, 86% (82 kg) of lithic artefacts are on rocks from the immediate environment, which most likely indicates exploitation of locally available resources, a pattern of management that is not out of place in the Middle Palaeolithic (Geneste, 1985; Féblot-Augustins, 1997). Nevertheless, transport of Garumnian chalcedony and flint from the Serra Llarga involves movement within a regional landscape similar to that defined by the Pre-Pyrenean river system. These points suggest that some N12 quartzite lithic artefacts may have come from terraces distant from the site, and brought to the site in the same way as flint, as part of personal gear (Féblot-Augustins, 2009).

Such a premise is not easy to confirm but one could analyse the form in which the material was transported; as pre-formed artefacts (cores or large blanks), or slightly tested cobbles. The presence/absence of cortical pieces would be a relevant attribute, as one might make a rough assumption that scarcity of cortical pieces indicates transport of blanks which are partially cortical and ready to knap. Alternatively, a significant number of fully or partially cortical blanks indicate transport of unmodified cobbles to the site

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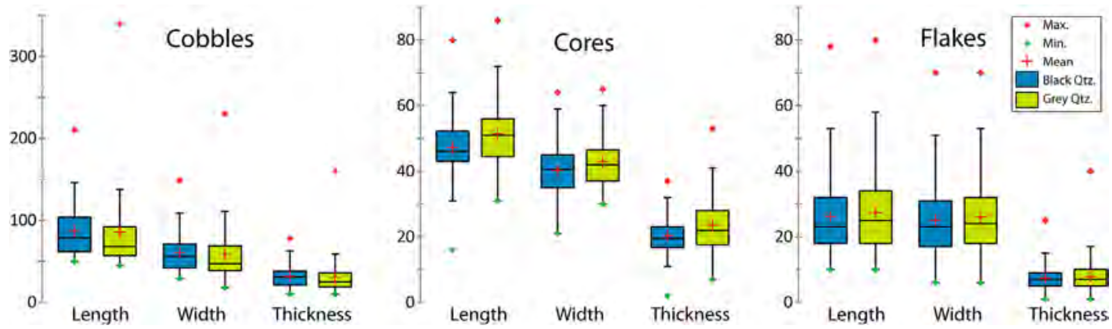


**Fig. 10.** Differences in length, width and thickness measurements between black quartzite and grey quartzite cobbles (terrace samples), flakes and cores (N12 level archaeological materials). See Supplement 2 for details.

where the cortex was removed. These are not rigid indicators and many factors, not always easily identifiable in the archaeological record, condition such inferences (Dibble et al., 2005).

Taking an exploratory approach, we compared the presence of cortex in several levels of the Middle Palaeolithic sites of Roca dels Bous (N10, N12 and N14) and Cova Gran de Santa Linya (S1B, S1B1, S1C, S1D and S1E). Both sites are in the same area and their lithic assemblages were excavated and analysed according to the same parameters. From more than 19,000 quartzite artefacts, groups were separated into fully cortical, partially cortical and non-cortical pieces. Preliminary results indicate two different tendencies: partially cortical pieces fluctuate around 6% of the assemblage in levels N12 and N14 at Roca dels Bous and S1B1, S1C, S1D and S1E at Cova Gran, while percentages reach 17% in Roca dels Bous N10 and Cova Gran S1B. The Pearson adjusted residuals test was used to determine the significance of these results (www.statgraphics.net, 2014). The test results indicate that the tendency in N10 and S1B differs from the other levels in having a greater percentage of partially cortical pieces (statistically significant difference $\chi^2$ (14, 0.05) = 101) (Table 5). Examination of the causes of this pattern merits future analysis as it could indicate changes in the management strategies of lithic raw materials in these sites.

**Table 5**
Cortical, partially cortical and non-cortical pieces in the Middle Palaeolithic levels of Roca dels Bous and Cova Gran sites.

| | Completely cortical | Partially cortical | No cortical | Total |
|---|---|---|---|---|
| Roca dels Bous MP levels: | | | | |
| N10 | 9 (2.28%) | 64 (16.20%) | 322 (81.52%) | 395 |
| N12 | 355 (2.65%) | 1258 (9.40%) | 11776 (87.95%) | 13389 |
| N14 | 63 (2.99%%) | 152 (7.22%) | 1890 (89.79%) | 2105 |
| Cova Gran MP levels: | | | | |
| S1B | 11 (4.49%) | 41 (16.73%) | 193 (78.78%) | 245 |
| S1B1 | 5 (1.45%) | 31 (8.99%) | 309 (89.57%) | 345 |
| S1C | 26 (1.87%) | 89 (6.39%) | 1278 (91.74%) | 1393 |
| S1D | 29 (2.88%) | 57 (5.65%) | 92 (91.47%) | 1008 |
| S1E | 0 (0.00%) | 10 (4.69%) | 203 (95.31%) | 213 |

## 8. Conclusion

Study of the secondary deposits in the area around Roca dels Bous provides important information on human-landscape interaction. The methodology employed in the study of the Segre River terraces indicates patterns of provisioning focused on selection of a particular type of quartzite, black quartzite, which is not very abundant in the environment, as well as a bias in favour of relatively large, oval and slightly flat cobbles. Although reasons for selection are not easy to specify, we suggest that such technical behaviours were part of decisions guided by a deep-seated cultural tradition in the Middle Palaeolithic documented at Roca dels Bous and other sites in this area. This inference deserves further, more detailed study.

Our results indicate that during the Middle Palaeolithic lithic raw materials were subject to strong selection, implying that on the one hand Neanderthals knew exactly where those resources were in the landscape and, on the other used a number of strategies relating to the transport and consumption of rocks suitable for knapping. These observations reveal a complex cognitive environment and a 'know-how' which informs very specialized technical decisions in N12, such as the intense reduction of quartzite cores using structured knapping methods until they are of a size from which it is difficult to get more blanks (Martínez-Moreno et al., 2010; de la Torre et al., 2014).

Other aspects related to management of rocks have been determined in N12. Although management of lithic resources is focused on the local environment, the presence of regional materials such as flint indicates movements in which river courses seem to be important and imply acquisition of quartzite from more distant areas although it is not easy to quantify its frequency.

The mechanisms of selection proposed for black quartzite can be extrapolated to other rocks such as flint and chalcedony, although sampling methods such as those designed for the current study cannot be applied. This idea is of great interest when investigating behaviour patterns of human groups in Roca dels Bous and other sites in the region where flint is dominant.

Finally, we emphasize two elements which we believe should bear more relevance for raw materials studies but which are generally considered to be of limited interest: local resources and secondary deposits. The study of both has proven useful when identifying processes and behaviours which are not easy to detect using traditional approaches to analysis of raw materials in the Middle Palaeolithic.

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## Appendix A. Supplementary data

Supplementary data related to this article can be found at http://dx.doi.org/10.1016/j.quaint.2015.09.010.

## References

Álvarez-Alonso, D., Herrero, M.A., Rojo, J., 2013. La captación de materias primas líticas durante el Paleolítico en el oriente de Asturias, y su caracterización litológica en la cuenca de los ríos Sella y Cares (Asturias, Espa-a). In: Actas de la VIII Reunión de Cuaternario Ibérico. La Rinconada-Sevilla, pp. 296–299.

Bailey, G.N., 1981. Concepts of resource exploitation: continuity and discontinuity in palaeoeconomy. World Archaeology 13, 1–15.

Bailey, G.N., Reynolds, S.C., King, G.C.P., 2011. Landscapes of human evolution: models and methods of tectonic geomorphology and the reconstruction of hominin landscapes. Journal of Human Evolution 60, 257–280.

Barnolas, A., Chiron, J.C., Guérangé, B., 1996. Synthèse géologique et géophysque des Pyrénées. Bureau de recherches géologiques et minières – Instituto Tecnológico y GeoMinero de Espana, Orleans-Madrid.

Benito-Calvo, A., Martínez-Moreno, J., Jordá, J., de la Torre, I., Mora, R., 2009. Sedimentological and archaeological fabrics in Palaeolithic levels of the south-Eastern Pyrenees: Cova Gran and Roca dels Bous Sites (Lleida, Spain). Journal of Archaeological Science 36, 2566–2577.

Binford, L.R., 1979. Organization and formation processes: looking at curated technologies. Journal of Anthropological Research 35, 251–273.

Boëda, E., 1991. Approche de la variabilité des systèmes de production lithique des industries du Paléolithique Inférieur et Moyen: chronique d'une variabilité attendue. Techniques et Culture 17–18, 37–86.

Bressy, C., 2002. Caractérisation et gestion du silex des sites mésolithiques et mésolithiques du nord-ouest de l'arc alpin. Une approche pétrographique et géochimique (Ph.D thesis). Université de Provence.

Bunte, K., Abt, S.R., 2001. Sampling Surface and Subsurface Particle-size Distributions in Wadable Gravel- and Cobble-bed Streams for Analyses in Sediment Transport, Hydraulics and Streambed Monitoring. U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station, Fort Collins, Colorado.

Cologne, D., Mourre, V., 2009. Quartzite et quartzites : aspects pétrographiques, économiques et technologiques des matériaux majoritaires du Paléolithique ancien et moyen du Sud-Ouest de la France. In: Grimaldi, S., Cura, S. (Eds.), Technological Analysis on Quartzite Exploitation, British Archaeological Reports International Series 1998. Hadrian Books, Oxford, pp. 3–12.

Colombo, F., Cuevas, J.L., 1993. Características estratigráficas y sedimentológicas del Garumniense en el sector de Ager (Pre-Pirineo, Lleida). Acta Geológica Hispànica 28, 15–32.

Constance, L.B., Wilson, L., 2011. Resource selection of lithic raw materials in the Middle Palaeolithic in southern France. Journal of Human Evolution 61, 597–608.

Cura, S., Grimaldi, S., 2009. The quartzite exploitation in a Middle Pleistocene open air site: Ribeira da Ponte de Pedra (Central Portugal). In: Grimaldi, S., Cura, S. (Eds.), Technological Analysis on Quartzite Exploitation, British Archaeological Reports International Series 1998. Hadrian Books, Oxford, pp. 49–56.

Delage, C., 2003. Siliceous Rocks and Prehistory: Bibliography on Geo-archaeological Approaches to Chert Sourcing and Prehistoric Exploitation. Archaeopress, Oxford.

Delagnes, A., Rendu, W., 2011. Shifts in Neandertal mobility technology and subsistence strategies in western France. Journal of Archaeological Science 38 (8), 1771–1783.

Di Modica, K., Bonjean, D., 2009. The exploitation of quartzite in layer 5 (Mousterian) of Scandia Cave (Wallonia Belgium): flexibility and dynamics of concepts of debitage in Middle Paleolithic. In: Grimaldi, S., Cura, S. (Eds.), Technological Analysis on Quartzite Exploitation, British Archaeological Reports International Series 1998. Hadrian Books, Oxford, pp. 49–56.

Dibble, H.L., Schurmans, U.A., Radu, P., McLaughlin, M.V., 2005. The measurement and interpretation of cortex in lithic assemblages. American Antiquity 70, 545–560.

Duran, J., Soler, N., 2006. Variabilité des modalités de débitage et des productions lithiques dans les industries mousteriénnes de la grotte de l'Arbreda, secteur alpha (Serinyà, Espagne). Bulletin de la Société Préhistorique Française 103, 241–262.

Fettes, D., Desmons, J., 2007. Metamorphic Rocks: a Classification and Glossary of Terms. In: Recommendations of the International Union of Geological Sciences Subcommission on the Systematics of Metamorphic Rocks. Cambridge University Press, Cambridge.

Féblot-Augustins, J., 2009. Revisiting european Upper Paleolithic raw material transfers. The demise of the cultural ecological paradigm? In: Adams, B., Blades, B. (Eds.), Lithic Materials and Paleolithic Societies. Wiley Blackwell, New York, pp. 25–46.

Féblot-Augustins, J., 1997. La circulation des matières premières au Paléolithique, vol. 75. E.R.A.U.L., Liège, p. 275.

García-Antón, M.D., 2010. Aproximación metodológica a la selección de materias primas paleolíticas centrada en las áreas de aprovisionamiento localizadas en depósitos secundarios. In: Domínguez-Bella, S., Ramos, J., Gutiérrez, J.M., Pérez, M. (Eds.), Minerales y rocas de las sociedades de la Prehistoria. Cádiz, pp. 71–82.

Geneste, J.M., 1985. Analyse lithique d'industries moustériennes du Périgord: Une approche technologique du comportement des groupes humain au Paléolithique moyen (Ph.D. thesis). Bordeaux University.

Geneste, J.M., 1992. L'approvisionnement en matières premières dans les systèmes de production lithique: la dimension spatiale de la technologie. Treballs d'arqueologia 1, 1–36.

Gill, M.A., 1969. Flatness index of non-spherical sedimentary particles. Journal of Geology 77, 120–124.

Gould, R., Saggers, S., 1985. Lithic procurement in Central Australia: a closer look at Binford's idea of embeddedness in archaeology. American Antiquity 50, 117–136.

Higgs, E.S., 1972. Papers in Economic Prehistory. Cambridge University Press, Cambridge.

Institut Cartogràfic de Catalunya, ICC, 2010. Atles Geològic de Catalunya. Institut Cartogràfic de Catalunya, Barcelona.

Institut Cartogràfic de Catalunya, ICC, 2014. Camarasa 328-1-2 (65-26). Mapa Geològic de Catalunya 1:25.000. Institut Cartogràfic de Catalunya, Barcelona.

Krumbein, W.C., 1941. Measurement and geological significance of shape and roundness of sedimentary particles. Journal of Sedimentary Petrology 11, 64–72.

Kuhn, S.L., 1991. "Unpacking" reduction: lithic raw material economy in the Mousterian of West-Central Italy. Journal of Anthropological Archaeology 10, 76–106.

Kuhn, S.L., 1995. Mousterian Lithic Technology: an Ecological Perspective. Pricenton University Press.

Lindsey, D.A., Langer, W.H., Van Gosen, B.S., 2007. Using pebble lithology and roundness to interpret gravel provenance in piedmont fluvial systems of the rocky mountains, USA. Sedimentary Geology 199, 223–232.

Luedke, B.E., 1992. An Archaeologist's Guide to Chert and Flint. Institute of Archaeology, University of California (Archaeological Research Tools 7), UCLA.

Malyk-Selivanova, N., Ashley, G.M., Gal, R., Glascock, M.D., Neff, H., 1998. Geological-Geochemical approach to "sourcing" of prehistoric chert artifacts, northwestern Alaska. Geoarchaeology 13, 673–708.

Marsaglia, K.M., DeVaughn, A.M., James, D.E., Marden, M., 2010. Provenance of fluvial terrace sediments within the Waipaoa sedimentary system and their importance to New Zealand source-to-sink-studies. Marine Geology 270, 84–93.

Martínez-Moreno, J., de la Torre, I., Mora, R., Casanova, J., 2010. Technical variability and change in the pattern of settlement at Roca dels Bous (southeastern Pre-Pyrenees, Spain). In: Conard, N.J., Delages, A. (Eds.), Settlement Dynamics on the Middle Paleolithic and Middle Stone Age, vol. 3. Kerns Verlag, Tubingen, pp. 485–507.

Meignen, L., Delagnes, A., Bourguignon, L., 2009. Patterns of lithic material procurement and transformation during the Middle Paleolithic in Western Europe. In: Adams, B., Blades, B. (Eds.), Lithic Materials and Paleolithic Societies. Wiley Blackwell, New York, pp. 25–46.

Mester, Z., 2012. Exploitation du quartzite à la station du Paléolithique moyen à Érd (Hongrie). Annales d'Université Valahia Targoviste. Section d'Archeologie et d'Histoire 14, 7–18.

Moloney, N., Raposo, L., Santoja, M., 1996. Non-flint Stone Tools. BAR International Series.

Moore, M.W., Sutikna, T., Jatmiko, Morwood, M.J., Brumm, A., 2009. Continuities in stone flaking technology at Liang Bua, Flores, Indonesia. Journal of Human Evolution 57, 503–526.

Mora, R., 1988. El Paleolítico Medio en Catalunya (Ph.D. thesis). Universitat Barcelona.

Mora, R., 1994. El sistema lógico analítico. In: Merino, J.M. (Ed.), Munibe 9 368–381. Donostia.

Mora, R., de la Torre, I., Martínez-Moreno, J., 2010. ArqueoUAB: a systematic archaeographic approach for the analysis of Palaeolithic sites. In: Melero, F.J., Cano, P., Revelles, J. (Eds.), Computer Applications and Quantitative Methods on Archaeology. Granada, CAA, pp. 1–4.

Mora, R., Benito-Calvo, A., Martínez-Moreno, J., González-Marcen, P., de la Torre, I., 2011. Chrono-stratigraphy of the Upper Pleistocene and Holocene archaeological sequence in Cova Gran (south-eastern Pre-Pyrenees, Iberian Peninsula). Journal of Quaternary Science 26, 635–644.

Mora, R., Martínez-Moreno, J., Benito-Calvo, A., Roy, M., Roda, X., Casanova, J., de la Torre, I., 2012. Roca dels Bous y Cova Gran: Historias en torno a dos abrigos musterienses del Prepirineo de Lleida. Mainake 32, 105–130.

Parish, R.M., 2011. The application of visible/near-infrared reflectance (VNIR) spectroscopy to chert: a case study from the Dover Quarry sites, Tennessee. Geoarchaeology 26, 420–439.

Peña, J.L., 1983. La conca de Tremp y sierras prepirenaicas comprendidas entre los ríos Segre y Noguera Ribagorzana. Instituto de Estudios Ilerdenses, Lleida.

Peña, J.L., Turu, I., Michels, V., Calvet, M., 2011. Les terrasses fluvials del Segre i afluents principals: descripció d' afloraments i assaig de correlació. In: Turu, I., Constante (Eds.), XIII Reunión Nacional de Cuaternario: El Cuaternario en Espana y áreas afines, avances en 2011, pp. 51–55.

Pereira, T., Cascalheira, J., Marreiros, J., Almeida, F., Bicho, N., 2012. Variation in quartzites exploitation during the Upper Palaeolithic of Southwest Iberian Peninsula. Trabajos de Prehistoria 69, 232–256.

Pocoví, J.A., 1978. Estudio geológico de las Sierras Marginales Catalanas. Acta Geológica Hispánica 13, 73–79.

Pujalte, V., Schmitz, B., 2005. Revisión de la estratigrafía del Grupo Tremp ("Garumniense", Cuenca de Tremp-Graus, Pirineos meridionales). Geogaceta 38, 79–82.
Pye, W.D., Pye, M.H., 1943. Sphericity determiations of pebbles and sand grains. Journal of Sedimentary Petrology 13, 28–34.
Rapp, G., Hill, C.L., 2006. Geoarchaeology: the Earth-science Approach to Archaeological Interpretation, second ed. Yale University Press, New Haven and London.
Reynolds, S.C., Bailey, G.N., King, G.C.P., 2011. Landscapes and their relation to hominin habitats: case studies from Australopithecus sites in eastern and southern Africa. Journal of Human Evolution 60, 281–298.
Roebroeks, W., 1988. From Find Scatters to Early Hominid Behaviour: a Study of Middle Palaeolithic Riverside Settlements at Maastricht-Belvédère (The Netherlands). Leiden University Press, Leiden.
Roth, B., Dibble, H., 1998. The production and transport of blanks and tools at the french middle paleolithic site of Combe-Capelle Bas. American Antiquity 63, 47–62.
Roy, M., Tarriño, A., Benito-Calvo, A., Mora, R., Martínez-Moreno, J., 2013. Aprovisionamiento de sílex en el Prepirineo oriental durante el Paleolítico superior antiguo: el nivel arqueológico 497C de Cova Gran (Santa Linya, Lleida). Trabajos de Prehistoria 70, 7–27.
Shackley, M.S., 2008. Archeological petrology and the archaeometry of lithic materials. Archaeometry 50, 194–215.
Shelley, P.H., 1993. A geoarchaeological approach to the analysis of secondary lithic deposits. Geoarchaeology 8, 59–72.
Sieveking, G., Hart, M.B., 1986. The scientific study of flint and chert. In: Proceedings of the Fourth International Flint Symposium Held at Brighton Polytechnic. Cambridge University Press, Cambridge.
Sneed, E.D., Folk, R.L., 1958. Pebbles in the lower Colorado River, Texas: a study in particle morphogenesis. Journal of Geology 66, 114–150.
Stout, D., Quade, J., Semaw, S., Rogers, M.J., Levin, N.E., 2005. Raw material selectivity of the earliest stone toolmakers at Gona, Afar, Ethiopia. Journal of Human Evolution 48, 365–380.
Tavoso, A., 1984. Réflexion sur l'économie des matières premières au Moustérien. Bulletin de la Société Préhistorique française 81 (3), 79–82.
Teixell, A., Munoz, J.A., 2000. Evolución tectonosedimentaria del Pirineo meridional durante el Terciario: una síntesis basada en la transversal del río Noguera Ribagorçana. Revista Sociedad Geológica de Espana 13, 251–264.
Terradillos-Bernal, M., Rodríguez-Álvarez, X., 2014. The influence of raw material qualities in the lithic technology of Gran Dolina (Units TD6 and TD10) and Galería (Sierra de Atapuerca, Burgos, Spain): a view from experimental archeology. Comptes Rendus Palevol 13, 527–542.
de la Torre, I., Martínez-Moreno, J., Mora, R., 2012. When the bones are not enough: lithic refits and occupation dynamics in the Middle Palaeolithic level 10 of Roca dels Bous (Camarasa, Spain). In: Seetah, K., Gravina, B. (Eds.), Bones for Tools, Tools for Bones. The Interplay between Objects and Objectives. Institute for Archaeological Research, pp. 9–19.
de la Torre, I., Martínez-Moreno, J., Mora, R., 2014. Change and stasis in the Iberian Middle Paleolithic. Considerations on significance of mousterian technological variability. Current Anthropology 54, S320–S336. Alternative Pathways to Complexity: Evolutionary Trajectories in the Middle Paleolithic and Middle Stone Age.
Turq, A., 2005. Réflexions méthodologiques sur les études de matières premières lithiques. Paléo 17, 111–132.
Turq, A., Roebroeks, W., Bourguignon, L., Faivre, J.P., 2013. The fragmented character of Middle Palaeolithic stone tool technology. Journal of Human Evolution 65, 641–655.
www.chebro.es, 2014. Los ríos Segre y Noguera. Pallaresa. Noguera Rigaborçana. Confederación Hidrográfica del Ebro. Ministerio de Agricultura, Alimentación y Medio Ambiente. (accessed 01.02.15.).
www.statgraphics.net, 2014. (accessed 01.11.14.).
Yuzyk, T.R., Winkler, T., 1991. Procedures for Bed-material Sampling. Lesson Package No. 28. Environment Canada, Water Resources Branch, Sediment Survey Section, Ottawa, Canada.

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