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# When Neanderthals used cave bear (*Ursus spelaeus*) remains: Bone retouchers from unit 5 of Scladina Cave (Belgium)

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ABSTRACT

Evidence of Neanderthals using bear remains as retouchers is rare. In the sedimentary unit 5 of Scladina Cave (Belgium; Weichselian Early Glacial, MIS 5d to 5b), twenty-six bone retouchers have been discovered. Among these, six have been made from cave bear bones (four from a femur and two from two tibiae). The presence of lithic splinters, still embedded in grooves, can be convincingly associated with their function as knapping tools. Particularly interesting are six bone fragments, including four fragments used as retouchers and two unused splinters, which have been refitted together to reconstitute an almost complete cave bear femur diaphysis. These specimens present modifications in the form of cut marks, scraping marks, impact notches and typical fractures of percussions on green (fresh) bone, sometimes overlapping each other, that allow for a complete understanding of the operational sequence in the production of bone retouchers at this site. The identification of a sophisticated operational sequence, where each action succeeds another in the production of a bone tool, is a major argument in favor of predetermination that guided the Neanderthal actions, and is similar to that described for stone tool *chaîne opératoire*.

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## 1. Introduction

Palaeolithic bone retouchers have been known since the second half of the 19th century. Bone retouchers are tools made from bones, antlers or teeth, which bear marks, in the form of pits and scores (according to Mallye et al., 2012), resulting from their intentional and repeated striking (knapping) of lithic raw material. One of the first reference to these finds come from the Palaeolithic context of *Trou Magrite* (Walzin, Belgium), where they have been described as bones "*intentionnellement brisés et portant des traces de coups artificiels et des entailles*" (intentionally broken bones, wearing artificial blow marks and grooves; Dupont, 1871: 39). In 1889, one bone tool coming from the *l'Église* Cave excavations (Dr. Capitan's collection) was called "*retouchoir en os*" (bone retoucher) and illustrated in the catalogue of the International Exhibition of Paris (Société d'Anthropologie de Paris, 1889, Fig. 127: 217). Since then, it has become more common to find and recognise these humanly modified objects among faunal remains from European Palaeolithic sites. Their use has been long debated (Patou-Mathis and Schwab, 2002), sometimes interpreted as hammers or anvils (Henri-Martin, 1910), compressors (Commont, 1916) or push needles (Bourlon, 1916). In some case, their anthropogenic origin has been strongly contested. L.R. Binford (1981), for instance, described the bone modifications as the result of carnivore chewing. Taphonomic studies have highlighted the distinction between gnawing and knapping marks (Giacobini and Patou-Mathis, 2002; Malerba and Giacobini, 2002; Tartar, 2012). Re-analysis of already known collections such as La Ferrassie (France; Castel et al., 2003) or La Quina (France; Verna and d'Errico, 2011) and the results of new experimental works (Chase, 1990; Rigaud, 2007; Mallye et al., 2012; Tartar, 2012; Bello et al., 2013a) have also confirmed the use of this type of unsophisticated tools as retouchers during the Middle and Upper Palaeolithic. This is particularly illustrated by the presence of lithic splinters still embedded in grooves.

The earliest record of a soft hammer used for knapping is dated to the Lower Palaeolithic for the site of Boxgrove (West Sussex,

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England; Roberts and Parfitt, 1999). The record intensifies during the Middle Palaeolithic: e.g., in France: Artenac (Armand and Delagnes, 1998), Biache-Saint-Vaast (Auguste, 1995; Auguste, 2002), Jonzac (Jaubert et al., 2008), La Quina (Henri-Martin, 1906; Chase, 1990; Verna and d'Errico, 2011), Noisetier Cave (Mallye et al., 2012), Saint-Marcel Cave (Daujeard, 2004), Combe-Grenal and Vaufrey caves (Vincent, 1993); in Italy: Fumane Cave (Jéquier et al., 2012); in Czech Republic: Kulna Cave (Vincent, 1993; Auguste, 2002; Neruda et al., 2011); in Croatia: Vindija Cave (Ahern et al., 2004). Their use continues at the very least into the Upper Palaeolithic (Leroy-Prost, 2002; Castel et al., 2003; Tartar, 2012).

During Middle Palaeolithic, bone retouchers were made from bones, teeth and antlers (Patou-Mathis and Schwab, 2002); more often, from herbivores (e.g., Armand and Delagnes, 1998; David, 2002; Patou-Mathis and Schwab, 2002; Valensi, 2002; Neruda et al., 2011; Jéquier et al., 2012; Mallye et al., 2012), and rarely from carnivore (Auguste, 2002; Jéquier et al., 2012) or hominin remains

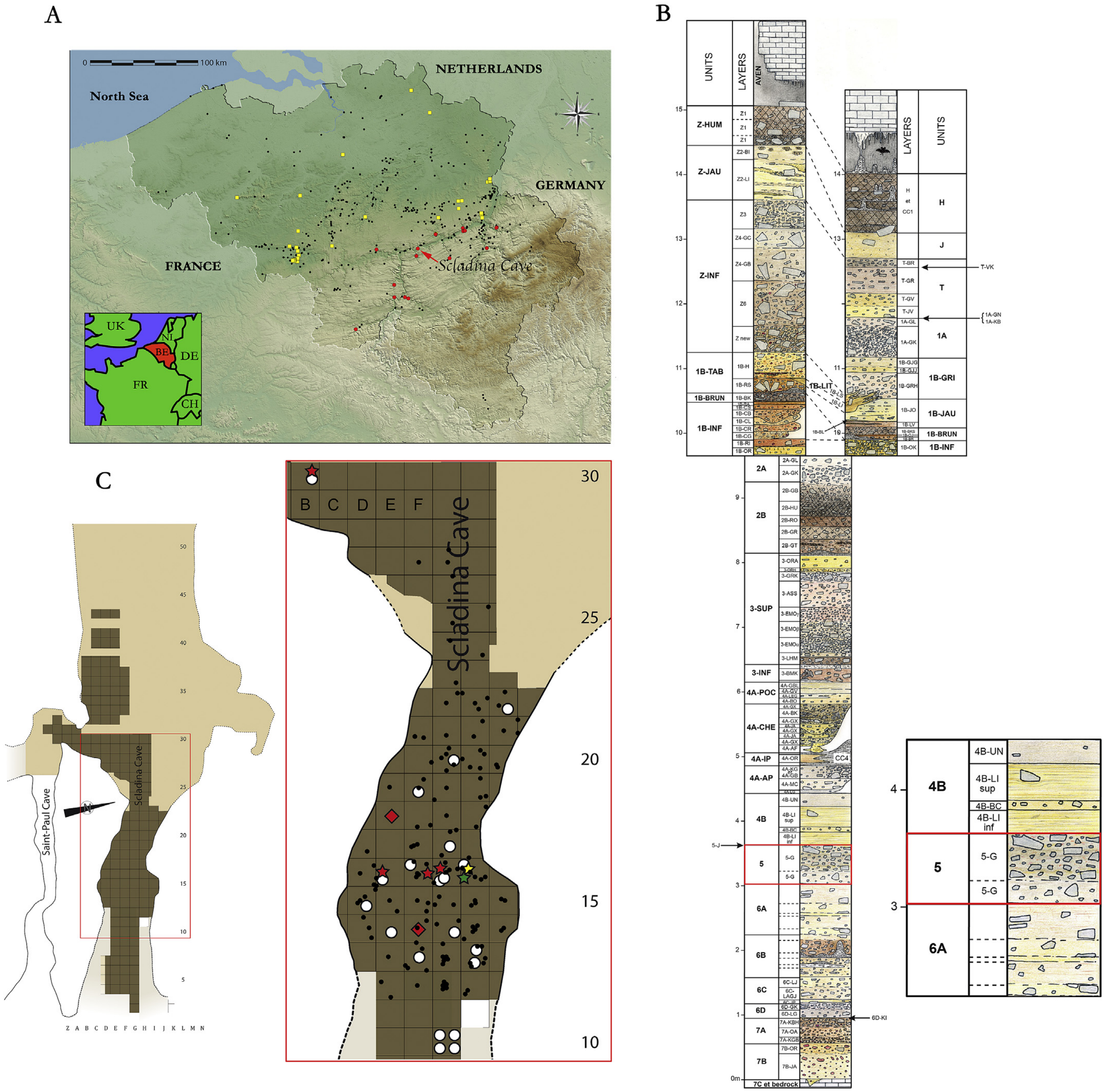

**Fig. 1.** (A) In Belgium, 442 Middle Palaeolithic occurrences are known. The main open area sites are located in yellow while the main caves are located in red (for more details, see Di Modica, 2011). (B) Stratigraphic sequence of Scladina Cave (for more details, see Pirson et al., 2008). (C) Map of the cave: the sedimentary unit 5 excavated area is coloured in dark brown; the stars represent the location of the bear bone retouchers (in red: fragments of the right femur; in yellow: fragment of the right tibia; in green: fragment of the left tibia; also refer to Table 3); the red diamonds represent the two unused bear bone splinters; the white dots represent the location of all other bone retouchers identified in the faunal collection of sedimentary unit 5 (also refer to Table 2); the black dots represent the lithic tools (modified from Otte and Bonjean, 1998, Fig. 16, p. 363). (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

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(Ahern et al., 2004; Mussini, 2011; Verna and d'Errico, 2011). Examples of ursid remains displaying anthropogenic marks are rare, probably because the exploitation of bear carcasses was uncommon during the Middle Palaeolithic (e.g., Stiner, 1994, 2002; Auguste, 1995; Bratlund, 1999; Jéquier et al., 2012). These marks are observed on brown bear (*Ursus arctos*; Auguste, 1995; Cavanhié, 2009–2010) and sometimes on cave bear (*Ursus spelaeus*) remains (Germonpré and Sablin, 2001; Münzel and Conard, 2004). Just a few examples of brown bear bone retouchers used by Neanderthals are known from France and Italy (Auguste, 2002; Valensi and Psathi, 2004; Jéquier et al., 2012).

In a context where the use of cave bear remains as retouchers represents an archaeological exception, the material from Scladina Cave proves to be noteworthy. Recent analysis of the faunal collection from sedimentary unit 5 led to the identification of twenty-six bone retouchers. Approximately a thousand of cave bear bone fragments were found and among these, six have been used as retouchers. This paper describes these unsophisticated bone tools, their spatial distribution in the cave, their breakage patterns, the refitting connections, the presence of associated anthropogenic marks (e.g., cut marks, scraping marks) and the knapping patterns.

## 2. Chronological and archaeological context of the sample

Scladina Cave (Sclayn, Belgium) opens onto the valley of a small tributary ("*Ri de Pontainne*") of the right bank of the Meuse River, 7 m below the interfluve plateau and 30 m above the thalweg. In its current state, the cave appears as a cylindrical karstic cavity that extends more than 39 m into the limestone bedrock (Fig. 1). The height of the gallery is regular, averaging 6 m, and its width varies between 6 and 12 m (Pirson, 2007). Scladina Cave has been under scientific excavation since 1978 and has now become the site of a permanent interdisciplinary research program. Shortly after excavations began, two main Middle Palaeolithic archaeological complexes were identified (Otte et al., 1983). The upper archaeological complex (so-called "1A") is composed of ~4500 lithic artefacts, which were found reworked in different layers, deposited by successive sedimentary processes (mainly debris flow and run-off). Sedimentary unit 1A was deposited during the Weichselian Middle Pleniglacial Period and has been dated to approximately 37,000–40,000 B.P. (MIS 3; Pirson, 2007; Abrams et al., 2010; Bonjean et al., 2013). The lower archaeological complex (so-called "5") lies in sedimentary unit 5. Different sedimentary processes, dominated by solifluction and debris flow, formed this unit, which was deposited during a cold phase of the Weichselian Early Glacial Period (MIS 5d to 5b; Pirson and Di Modica, 2011). These two archaeological complexes have been the subject of detailed research on the lithic artefacts (e.g., Bonjean et al., 2009; Di Modica, 2010a) and the faunal sample (Patou-Mathis, 1998; Bourdillat, 2008; Abrams et al., 2010; Bonjean et al., 2012). This paper focuses on the faunal material from the MIS 5 archaeological assemblage.

## 3. Faunal and lithic assemblages of the sedimentary unit 5

The last complete analysis of the faunal material from sedimentary unit 5 have been published by Patou-Mathis (1998) and is based on 1871 identified specimen (NISP), for a minimum number of individual (MNI) of 93 (Table 1). This study identified a high representation of cave bears (*Ursus spelaeus*; NISP: 1232; MNI: 34), and a lesser representation of wolves (*Canis lupus*; NISP: 160; MNI: 8) and chamois (*Rupicapra rupicapra*, NISP: 138; MNI: 6). Twenty four bones of chamois present anthropogenic modifications (17.4% of their remains). Several pieces of evidence seemed to point towards the use of the cave as a specialized chamois hunting site (Moncel et al., 1998; Patou-Mathis, 1998): the high frequency of modified bones, the completeness of the carcasses, and the presence of cut marks, filleting marks and breakage damage (suggesting skinning, dismembering and breakage of the long bones to extract bone marrow). However, this hypothesis can be questioned by the presence of a few anthropogenic marks on other species (e.g., cave bear, woolly rhinoceros, horse, red deer, fallow deer; Patou-Mathis, 1998) and the huge number of lithic objects.

**Table 1**
Counting of the different species identified in the sedimentary unit 5 (modified from Patou-Mathis, 1998).

| Species | NISP | MNIc |
|---|---|---|
| *Cervus elaphus* | 27 | 4 |
| *Dama dama* | 16 | 2 |
| *Rangifer tarandus* | 11 | 1 |
| *Capreolus capreolus* | 4 | 1 |
| Unspecified cervid | 11 | |
| *Rupicapra rupicapra* | 138 | 6 |
| *Capra ibex* | 7 | 2 |
| *Sus scrofa* | 6 | 2 |
| *Equus (caballus)* | 16 | 2 |
| *Coelodonta antiquitatis* | 31 | 5 |
| *Mammuthus primigenius* | 16 | 3 |
| **Total of herbivores** | 283 | 28 |
| *Ursus spelaeus* | 1232 | 34 |
| *Ursus arctos* | 21 | 3 |
| *Crocuta crocuta spelaea* | 12 | 3 |
| *Canis lupus* | 160 | 8 |
| *Cuon* sp. | 7 | 1 |
| *Vulpes vulpes* | 68 | 5 |
| *Alopex lagopus* | 12 | 2 |
| *Panthera (leo) spealaea* | 16 | 1 |
| *Panthera pardus* | 7 | 2 |
| *Felis silvestris* | 1 | 1 |
| *Meles meles* | 3 | 2 |
| *Martes martes* | 1 | 1 |
| Unspecified carnivores | 35 | |
| **Total of carnivores** | 1575 | 63 |
| Lagomorphs | 13 | 2 |
| **Total** | 1871 | 93 |

Indeed, the sedimentary unit 5 provided ca. 13,500 lithic artefacts. These were made from different raw materials, some collected in the surroundings of the cave (quartz and quartzite pebbles, chert and carboniferous limestone) and some carried from more distant sources (cretaceous flint, tertiary sandstone; minimal distance of 6.5 km as the crow flies, see Di Modica, 2010a). This archaeological collection has been studied many times since the 1980s (e.g., Otte et al., 1983; Bourguignon, 1998; Moncel, 1998; Otte and Bonjean, 1998; Bonjean and Otte, 2004; Di Modica, 2010a). These studies testified a huge variability of the *chaînes opératoires*, which were constraint by the nature of the raw materials (hardness, homogeneity) and their accessibility (local *vs*. more distant sources). The joint presence of Discoïd, Quina and Levallois debitage concepts have been pointed out. Recently, refitting works made on flint and quartzite have highlighted the complexity of the reduction sequences as each concept of debitage can be used separately but can also been successively applied on the same block. It also demonstrates that most of the reduction sequences, especially on flint, cannot be linked to one or multiple classical concepts of Middle Palaeolithic debitage (Di Modica, 2010a, 2010b). Sometimes, the industry has been qualified as "Charentian". The "Charentian" aspect of some Belgian sites has not to be understood as a cultural orientation (like in south-west France) but as an adaptation to regional difficulties on raw material supplying (Otte, 1998; Di Modica, 2010a,b, 2011). Therefore, the "Charentian" qualification should be definitely given up for Middle Palaeolithic sites in Belgium and particularly the Scladina industries. These should be regarded in the north–west Europe Middle Palaeolithic

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context instead of in reference to cultural facies defined in southwest France (Di Modica, 2010a, 2011). Looking at the technology, the spatial distribution and the taphonomy, the unit 5 archaeological sample can be considered as an occupation (*sensu* Depaepe, 2010; see for details Di Modica, 2010a, 2011; Bonjean et al., 2011).

The relatively high number of lithic artefacts should, however, be weighed against the large amount of debris (ca. 11,250; Otte and Bonjean, 1998), partly produced by the high degree of fragmentation of the quartz pebbles. Among the artefacts, 166 (1.3%) have been previously identified as retouched tools (scrapers and denticulated), mainly made on flints (70%; Otte and Bonjean, 1998). A recent overview of this assemblage (Di Modica, analysis still in progress) indicates that this amount of retouched artefacts is probably overestimated and that some of the previously considered as anthropogenic retouch results in fact from natural processes (depositional or post-depositional; see for instance Caspar et al., 2005 on taphonomical incidence on the archaeological material). The undoubted toolkit is characterized by a very limited retouch (marginal) which is mostly limited to regularize a cutting edge. Real scrappers are very limited in number.

## 4. Material and methods

At Scladina cave, 12,596 bone fragments have been unearthed during several excavation campaigns which took place in sedimentary unit 5 between 1982 and 1998. In this faunal assemblage, 26 bone fragments have been recently identified as retouchers. They represent 0.21% of the number of skeletal specimens (NSP).

Except for two of them, found in square B30 (19 m from the porch), these bone tools are located on a surface spreading from square G10 to I22. Their spatial distribution is similar to that of the lithic artefacts (Fig. 1). Fragments of diaphysis of long bones were the most commonly used element (Table 2). Among these bone tools, six were made from cave bear remains (Fig. 2) and are the subject of the present analysis. The complete analysis of the other retouchers is still in progress.

**Table 2**
Anatomical and taxonomic inventory of the totality of bone retouchers identified in the sedimentary unit 5 at Scladina Cave. The ID numbers followed by "star" refit.

| ID retoucher | Location | Species | Anatomic portion |
|---|---|---|---|
| Sc82-348-24 | G10 | Large size mammal | Femur frag. |
| Sc82-348-25 | G10 | Large size mammal | Humerus frag. |
| Sc82-348-27 | G10 | Large size mammal | Rib frag. |
| Sc82-G10-26 | G10 | Large size mammal | Diaphyseal frag. |
| Sc83-D15-17 | D15 | Large size mammal | Humerus frag. |
| Sc83-E14-121 | E14 | Large size mammal | Femur frag. |
| Sc83-F13-25-2 | F13 | Large size mammal | Diaphyseal frag. |
| Sc83-F19-5 | F19 | Large size mammal | Diaphyseal frag. |
| Sc83-G14-128 | G14 | Unspecified | Tibia frag. (?) |
| Sc83-G20-15 | G20 | Large size mammal | Femur frag. |
| Sc84-E16-48* | E16 | *Ursus spelaeus* | Femur frag. |
| Sc84-E16-97 | E16 | Large size mammal | Diaphyseal frag. |
| Sc84-G16-116 | G16 | Large size mammal | Diaphyseal frag. |
| Sc84-G16-67 | G16 | *Equus caballus* | Metacarpal frag. |
| Sc84-G17-26 | G17 | Large size herbivore | Diaphyseal frag. |
| Sc85-F16-10 | F16 | Unspecified | Diaphyseal frag. |
| Sc85-F16-61* | F16 | *Ursus spelaeus* | Femur frag. |
| Sc85-G16-600* | G16 | *Ursus spelaeus* | Femur frag. |
| Sc86-H13-203 | H13 | Large cervid/bovid | Tibia frag. |
| Sc86-H13-289 | H13 | Large size mammal | Femur frag. |
| Sc86-H16-16 | H16 | *Ursus spelaeus* | Tibia frag. |
| Sc86-H16-160 | H16 | *Ursus spelaeus* | Tibia frag. |
| Sc86-H16-185 | H16 | Large size mammal | Diaphyseal frag. |
| Sc86-H22-53 | H22 | Large size herbivore | Diaphyseal frag. |
| Sc98-B30-230 | B30 | Large size mammal | Diaphyseal frag. |
| Sc98-B30-389* | B30 | *Ursus spelaeus* | Femur frag. |

The identification of the retouchers was based on comparisons with experimental material, and an extensive literature on Middle and Upper Palaeolithic knapping tools (e.g., Patou-Mathis and Schwab, 2002; Castel et al., 2003; Verna and d'Errico, 2011; Jéquier et al., 2012; Bello et al., 2013a). We followed the terminology used by Mallye et al. (2012):

- the 'used area' indicates the zone where the knapping-marks are concentrated. A retoucher can present one or more used areas;
- the location of the used area is defined by its proximity to the edges of the fragment (Fig. 3 A). Compared to the location proposed by Mallye et al. (2012, Fig. 1, p. 1133), only two different situations (centred or lateral) were observed on the 6 cave bear bone retouchers;
- the frequency of the traces and their dispersion are also based on that proposed by Mallye et al. (2012, Fig. 1, p. 1133);
- the indentations were recorded as 'pits' when the depressions have a sub-triangular or ovoid form, and 'scores' when the depressions have a more linear form (Mallye et al., 2012, Fig. 2, p. 1134). Their morphology and microscopic details are reminiscent of chop-marks made with a stone tool (Shipman, 1981; Blumenschine and Selvaggio, 1988).

Characterization of cut marks is based on several observations: V-shape, presence of internal microstriations, shoulder effect and hertzian cones (Shipman, 1981; Shipman and Rose, 1983; Andrews and Cook, 1985; Behrensmeyer et al., 1986; White, 1992; Boulestin, 1999; Greenfield, 1999; Bello and Soligo, 2008; Bello et al., 2011). Their frequency and location is also indicative of butchery activity (Bello et al., 2009; Domínguez-Rodrigo et al., 2009).

Measurements (length, width, thickness and weight) of the bone retouchers were taken using digital instruments (electronic calliper and balance). The 'used area' surface is defined as the smallest rectangle surface within which the marks are concentrated. When a retoucher has several used areas, it is reoriented for the analysis of each (according to Mallye et al., 2012). The orientation of scores was recorded on a computer, using calibrated pictures in relation to the main axis of the bone (Fig. 3 B).

All bone fragment surfaces were first analysed under a stereomicroscope (Leica S6D, magnification ranging between 6.3 and 40×). This allowed for a preliminary location of possible cut and scraping marks and for the identification of the grooves and pits associated with a knapping action. To explore the microtopography of the used areas, we employed a Focus Variation microscope (FVM): the Alicona Infinite Focus microscope (AIFM). The use of FVM is a relatively new technique in the analysis of bone taphonomy, but has high potential in this field due to the ability to model the surface topography in three dimensions (3D; Bello and Soligo, 2008; Bello et al., 2009, 2011, 2013a; b; Danzl et al., 2009; Bello, 2011). Volumetric and linear measurements were recorded from the 3D models using MeX software and were calibrated to conform to ISO standards. Typically, images were captured using a 2.5× objective lens (magnification 45.72×) and a vertical and lateral resolution of 10 μm and 3.47 μm respectively; a 5× objective (magnification 91.44×, vertical resolution = 1.74 μm, lateral resolution = 1.49 μm) was used to record smaller features (Fig. 4 B).

Finer details of the modifications of the bone surface were analysed using a LEO1455VP Scanning Electron Microscope (SEM). Images were captured at high lateral resolution (3 nm) with a magnification ranging from 40 to 600×. The SEM was operated in variable pressure mode (chamber pressure ~15 Pa), enabling backscattered electron images to be obtained without the application of a conducting layer on the specimen (Fig. 4 C).

Energy-dispersive X-ray (EDX) spectroscopy was used to confirm the presence of flint fragments embedded in the pits and

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**Fig. 2.** Photos and schematic representations of the 6 retouchers made from cave bear bones: (A) Sc84-E16-48; (B) Sc85-F16-61; (C) Sc85-G16-600; (D) Sc98-B30-389; (E) Sc86-H16-160; (F) Sc86-H16-16.

scores, which can distinguish flint from concretions and adhering sediment and bone splinters on the basis of their chemical composition and fracture characteristics (Bello et al., 2013a). EDX microanalysis was carried out to determine the elemental composition of surface inclusions, using an Oxford Instrument X-Max 80 Silicon Drift Detector and INCA software (Fig. 5 and Fig. 6). The working distance between the specimen and the EDX detector varied between 14 mm and 22 mm. This configuration was used to intercept X-rays from a broad area, which is more suitable for element mapping.

## 5. Results

### 5.1. *The 6 cave bear bone retouchers: deciphering and preservation*

Among 998 bear bone fragments identified in sedimentary unit 5 of Scladina Cave, six present traces (0.6%) that can be associated with their use as tools (Fig. 2). Four fragments have been identified as diaphyseal portions of a right femur (Fig. 7 A: Sc84-E16-48, Sc85-F16-61, Sc85-G16-600, and Sc98-B30-389), one as diaphyseal portion of a left tibia (Fig. 7 B: Sc86-H16-160), and one as a fragment of the distal end of a right tibia (Fig. 7 C: Sc86-H16-16). The high number of bone fragments unearthed made difficult the refitting work; it was however possible to refit six of them, including four retouchers and two unused splinters of bone (Sc84-E18-29 and Sc-F14), to reconstruct an almost complete diaphysis of a right femur (Fig. 8). Although difficult to demonstrate, it is likely that the right femur and the two tibiae belong to the same adult individual.

Five of the six retouchers (femur fragments: Sc85-E16-48, Sc85-F16-61 and Sc85-G16-600; tibiae fragments: Sc86-H16-160 and Sc86-H16-160) and the two unused splinters of bone (femur fragments: Sc84-E18-29 and Sc-F14) were spread across a small area (20 m$^2$; Fig 1). The sixth retoucher (Sc98-B30-389) was discovered 13 m further in the cave. The spatial distribution of these bones seems to be mainly related to natural deposition, which is dominated by solifluction and debris flow (Pirson, 2007; Pirson et al., 2008).

The maximal length of the blanks varies between 5 cm (Sc85-F16-61; Fig. 2 B) and 14 cm (Sc98-B30-389; Fig. 2 D), with an estimated average of about 11 cm (Table 3). In two cases (Sc98-B30-389 and Sc86-H16-160; Fig. 9), several removal scars of the basal edge have reduced the length of the fragments. The refitting made between SC98-B30-389 and SC84-E18-29 (a small unused fragment) suggests a reduction of the support of 2.5 cm. These modifications seem to have been intentional, possibly associated with the reduction of the length (or the thickness) of the fragment in order to make the tool more ergonomic. The size of bear bone retouchers of Scladina is very similar to the blanks length used in other Middle Palaeolithic sites (Armand and Delagnes, 1998; Jéquier et al., 2012; Mallye et al., 2012).

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**Table 3**
Identification number, location, anatomical portion and measurements of the 6 cave bear bones retouchers.

| ID retoucher | Location in the cave | Anatomic portion | N of use area | Weight (in gr) | Length (in cm) | Width (in cm) | Thickness (in cm) |
|---|---|---|---|---|---|---|---|
| Sc84-E16-48 | E16 | Right femur | 1 | 89 | 13 | 3.5 | 1.1 |
| Sc85-F16-61 | F16 | Right femur | 1 | 20.4 | 5.2 | 4.3 | 0.8 |
| Sc85-G16-600 | G16 | Right femur | 1 | 28.3 | 6.8 | 3.6 | 0.8 |
| Sc98-B30-389 | B30 | Right femur | 1 | 57.9 | 13.9 | 2.9 | 1.1 |
| Sc86-H16-16 | H16 | Right tibia | 1 | 186.8 | 12.3 | 8.4 | 1.1 |
| Sc86-H16-160 | H16 | Left tibia | 2 | 33 | 12.7 | 2.4 | 0.6 |
| | | | **Average:** | 69.2 | 10.7 | 4.2 | 0.9 |

Generally, non-anthropogenic marks (e.g., carnivore chewing marks, weathering or root etching) were absent on the six bone tools. Only some trampling marks (Behrensmeyer et al., 1986; Domínguez-Rodrigo et al., 2009) seem to have affected the bone surfaces of 2 fragments (Sc84-E16-48 and Sc98-B30-389). These marks have a syn- or a post-depositional origin, and occurred without erosion of the bone surfaces or the blunt of the edges. Manganese dioxide deposits are present on all the retouchers but they affect more one of the retoucher surfaces (Sc86-H16-16).

### 5.2. *Associated anthropogenic marks*

All cave bear bone retouchers present helical or spiral fracture types (Fig. 2), which are typical of breakage on green (fresh) bone (Chase, 1990; Villa and Mahieu, 1991; Lyman, 1994). These fractures can be associated with hominid or carnivore activities (Binford, 1981; Lyman, 1994). The lack of carnivore tooth marks and the presence of other human induced modifications suggest that hominids were mainly, if not solely, responsible for their presence. The morphology of the impact points (Fig. 8 B–C) and notches, as well as the presence of flake scars on the extremities (Fig. 9), also emphasize the anthropogenic origin of these modifications (Table 4; Villa and Mahieu, 1991; Capaldo and Blumenschine, 1994; Lyman, 1994).

The retouchers present grooves on the cortical surface whose morphology can be interpreted as cut marks (i.e. Sc85-F16-61; Fig. 10 and Table 4). They suggest that Neanderthals had to remove meaty material still present on the bone.

On two retouchers, the use marks overlap clusters of striations parallel to the main axis of the tool (i.e. Sc86-E16-48; Fig. 11). When present, these striations are always located on the used area of the retoucher, crossed by the blows of the knapping work. Their shape suggests Neanderthals probably used an irregular cutting edge tool to clean the bone by scraping its surface. The presence of scrape-marks, related to the removal of tissue from the surface of a bone, more specifically the periosteum, implies that the bone was still partially fresh when modified (Vincent, 1993; Tartar, 2009). These scraping marks also suggest the methodical preparation of the specimen prior to its use, as has been observed for other bone tools and engraved bones (e.g., Auguste, 2002; Verna and d'Errico, 2011; Bello et al., 2013b). Nevertheless, these traces are only present on two fragments (Table 4), suggesting that not all retouchers underwent the same preparatory process.

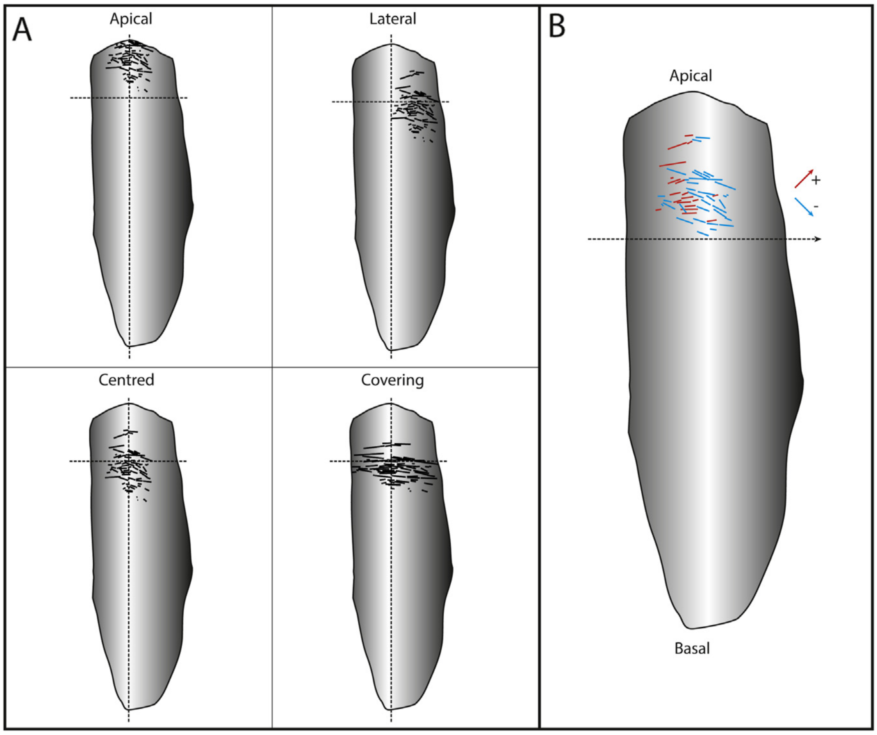

**Fig. 3.** (A) Location of the used area (apical, lateral, centred or covering; for details, refers to Mallye et al., 2012, Fig. 1, p. 1133). (B) Orientation of the scores: the positive angles are represented in red, the negative angles in blue. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

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**Table 4**
Summary of the different anthropogenic marks recorded on the surface of the 6 bear bone retouchers.

| ID retoucher | Impact point | Flake scars on the opposite extremity | Cut marks | Scraping marks |
|---|---|---|---|---|
| Sc84-E16-48 | Present | Absent | Present | Present |
| Sc85-F16-61 | Present | Absent | Present | Present |
| Sc85-G16-600 | Present | Absent | Present | Absent |
| Sc98-B30-389 | Present | Present | Present | Absent |
| Sc86-H16-160 (area 1) | Present | Present | Present | Absent |
| Sc86-H16-160 (area 2) | | Absent | | |
| Sc86-H16-16 | Absent | Present | Present | Absent |
| Total | 5/6 | 2/7 | 6/6 | 2/6 |

### 5.3. Use marks

Five of the six bear bone fragments have a single used area and one (Sc86-H16-160) has two used areas (Fig. 2 E). These seven used areas are all located close to the edge of the fragment, four are centred (Fig. 2 A, B, D and E1) and three are closer to a lateral edge (Fig. 2 C, E2 and F). The sufaces of the used area vary between 0.85 and 5.4 $cm^2$, with an average of 2.77 $cm^2$ (Table 5). The thickness of the fragment, at the point where they were used for knapping, varies from between 0.6 cm and 1 cm, with an average of 0.9 cm (Table 3). Knapping marks are more often found on convex (3 cases) and plano-convex (3 cases) surfaces than on a flat surface (Sc98-B30-389; Table 5).

**Table 5**
Summary of the location, frequency, use intensity and presence/absence of embedded lithic splinters of the used areas on the 6 bear bone retouchers.

| ID retoucher | Convexity | Location of use area | Type of traces | Frequency of the scores | Use intensity | Lithic splinters | Surface of the used area (in cm2) |
|---|---|---|---|---|---|---|---|
| Sc84-E16-48 | Convex | Centred | Scores and pits | Concentrated and superposed | +++++ | Present | 5.37 |
| Sc85-F16-61 | Convex | Centred | Scores and pits | Concentrated and superposed | ++++ | Present | 2.06 |
| Sc85-G16-600 | Plano-convex | Lateral | Scores and pits | Concentrated and superposed | +++ | Present | 3.58 |
| Sc98-B30-389 | Flat | Centred | Scores and pits | Concentrated | ++ | Present | 3.37 |
| Sc86-H16-160 (area 1) | Plano-convex | Centred | Scores and pits | Concentrated | ++ | Absent | 2.34 |
| Sc86-H16-160 (area 2) | Convex | Lateral | Scores and pits | Dispersed | + | Absent | 1.8 |
| Sc86-H16-16 | Plano-convex | Centred | Scores and pits | Dispersed | ++ | Present | 0.85 |
| | | | | | | | Average: 2.77 |

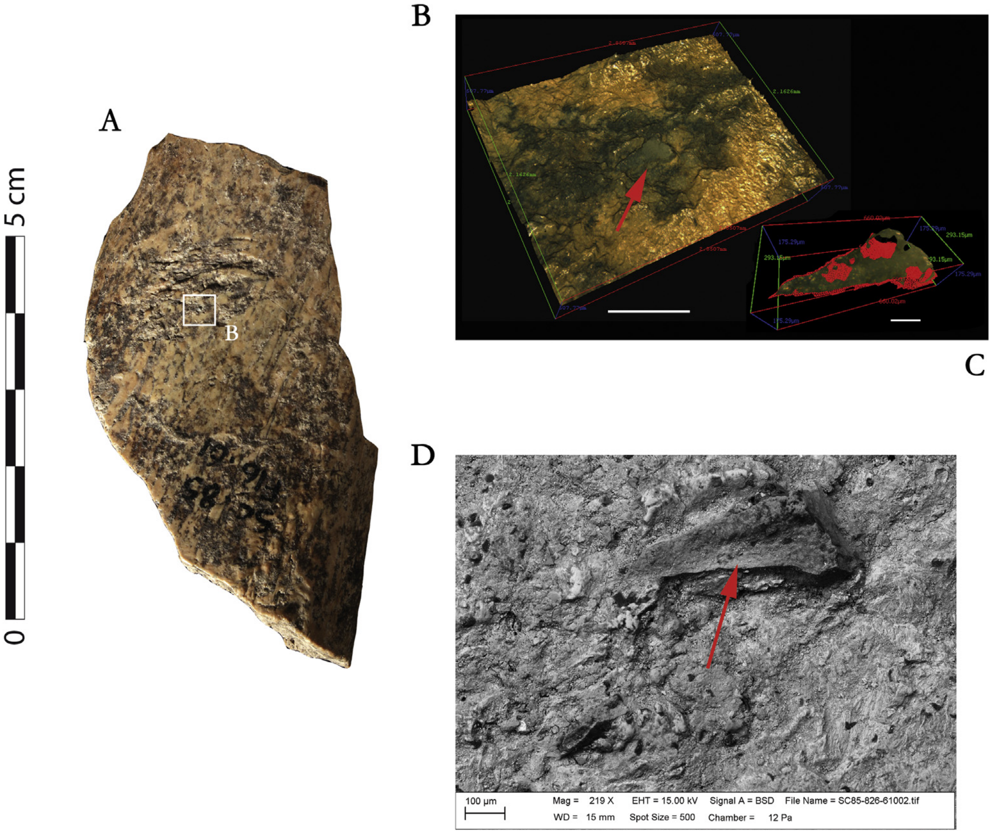

**Fig. 4.** (A) Photo of the bear bone retoucher Sc85-F16-61. (B) Alicona 3D image and (C) 3D detail of the splinter isolated from the bone surface using the Alicona software (scales for $B = 1$ mm; $C = 100$ µm). (D) SEM image of a lithic splinter embedded in a pit of the retoucher.

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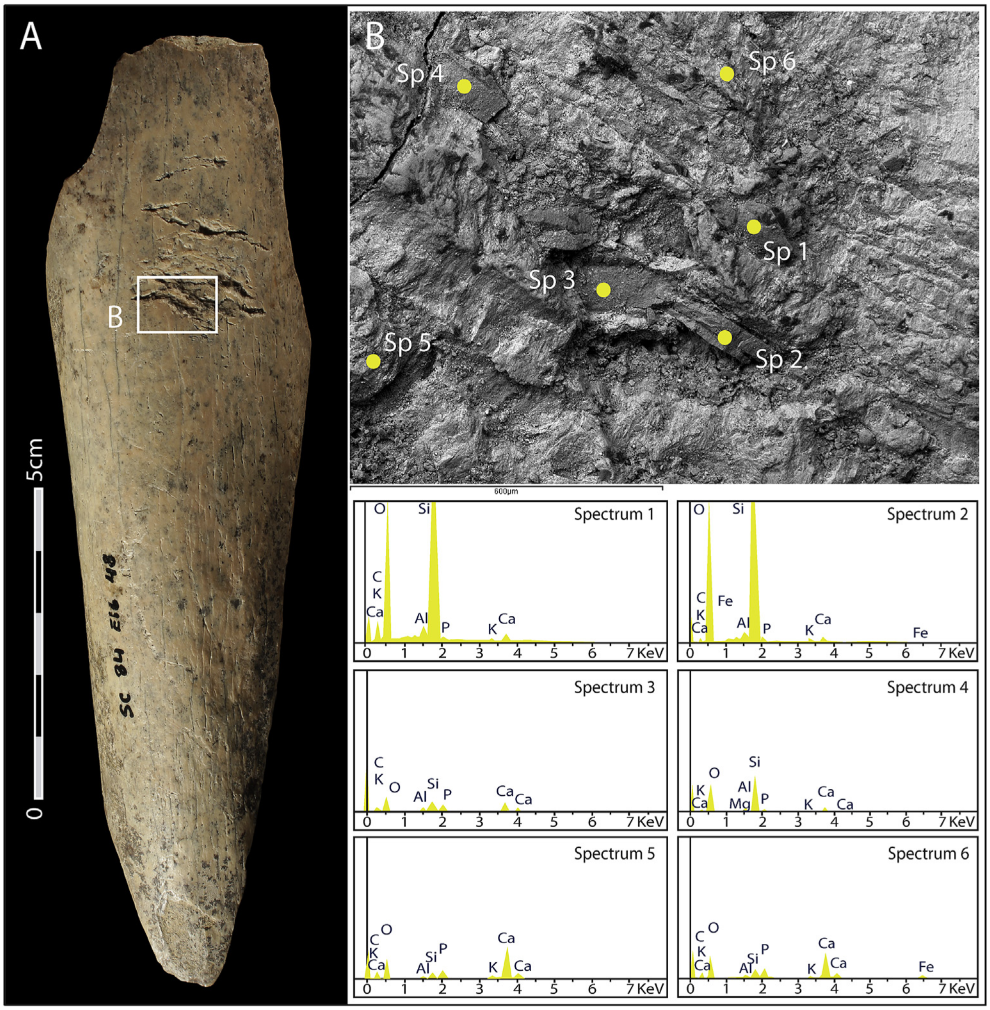

**Fig. 5.** (A) Photo of retoucher Sc84-E16-48. (B) SEM image of the retoucher using backscattered electrons, with points analysed by energy dispersive X-ray spectroscopy (EDX; Sp 1–6). Spectra 1 to 4 show the elemental composition of siliceous inclusions (peaks of O and Si); Spectra 5 and 6 show the elemental composition of bone (peaks of Ca and P). For details refer to text.

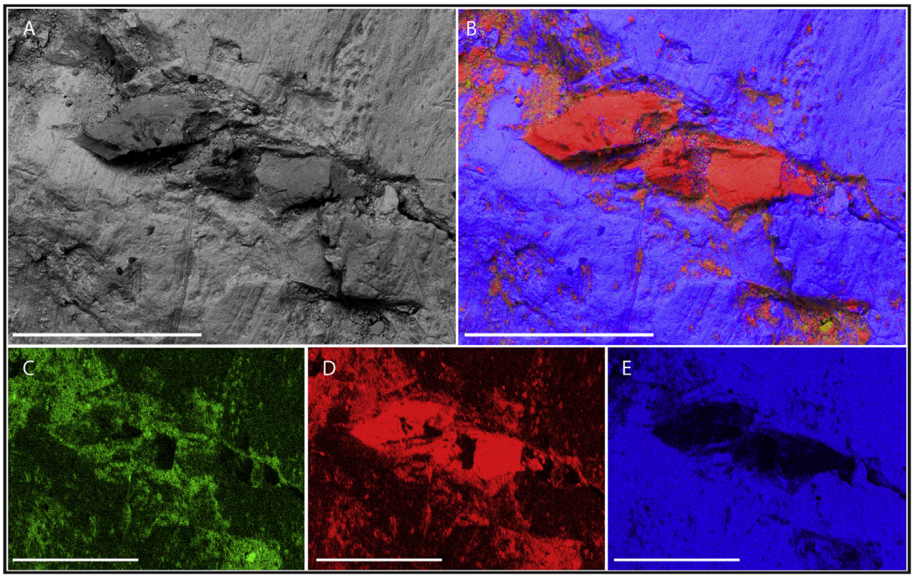

**Fig. 6.** (A) SEM backscattered electron image (BSE) of flint chips embedded in retoucher Sc98-B30-389. (B) BSE image and combined elemental maps shown as false colours: silicon in red, calcium in blue and aluminium in green. (C–E) EDX maps of elemental distribution: aluminium contaminations are distributed in minute particles across the surface (C), silicon (D), and calcium (E). Areas of the embedded flint, which appears darker in the image are due to the uneven topography of the fracture surfaces, which lie below the surface of the bone and are therefore shielded from the X-ray detector. Scales = 100 µm. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

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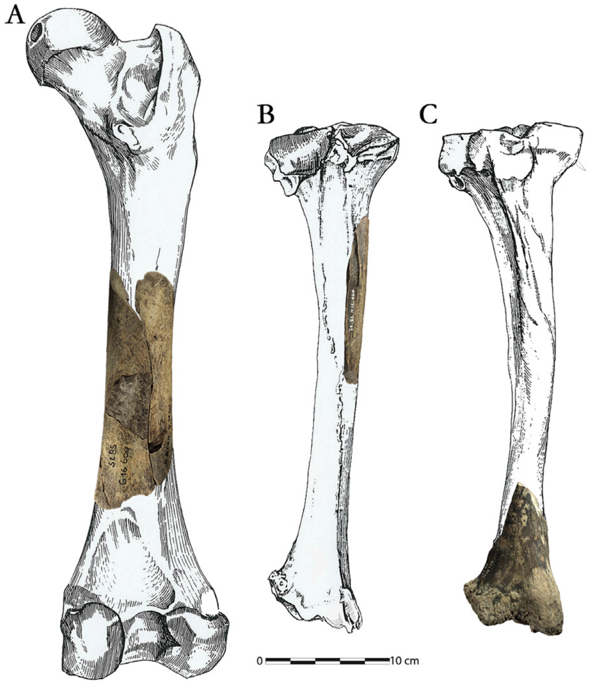

**Fig. 7.** Photos and drawings representing the anatomical position of the bone retouchers: (A) right femur, (B) left tibia, (C) right tibia (modified drawings from Pales and Lambert, 1971).

The seven knapping areas do not show the same frequency of use marks (according to Mallye et al., 2012, Table 5). Three retouchers (Sc84-E16-48, Sc85-F16-61 and Sc85-G16-600) show concentrated and superposed knapping marks (Fig. 2 A, B and C). Among these, Sc84-E16-48 is the most affected: repeated blows could have caused partial flaking and loss of its cortical surface (Fig. 2 A). Three retouchers show concentrated (Sc98-B30-389 and Sc86-H16-160 area 1; Fig. 2 D and E1) or dispersed scores (Sc86-H16-16; Fig. 2 F). In one case the use surface presents dispersed and rare scores, suggesting it was minimally used before its abandonment (Sc86-H16-160 area 2; Fig. 2 E2). Similarly to other Middle Palaeolithic retouchers, the orientation of the indentations is always transverse to the main axis of the blank (Tartar, 2012), without ever being perfectly perpendicular. Relative to an axis perpendicular to the length axis of the blank (Fig. 3 B), the angles range mainly from +12° to +19° and from −15° to −17° (Fig. 12).

The most common types of damage are scores and pits. Both are present on all the bone retouchers (Table 5) even if the elongated scores are the most frequent. These are often associated with micro-cracks and crushing, while internal micro-striations are sometimes observed within and on their flanks (Fig. 13 B), possibly as a result of the sliding of a lithic with irregular edges on the bone (Tartar, 2012). These features are occasionally associated with rounding and polishing of the edges of the use marks. Other traces are more similar to punctiform penetration into the bone matrix and could be considered as pits.

**Fig. 8.** (A) Reconstruction of the diaphysis of a right cave bear femur by the refitting of four retouchers (Sc84-E16-48, Sc85-F16-61, Sc85-G16-600 and Sc98-B30-389) and two unused splinters ScF14, Sc85-E18-29). (B and C) Detailed pictures of two areas showing impact points. (D) Coloured schemed drawing of the four retouchers end two unused fragments.

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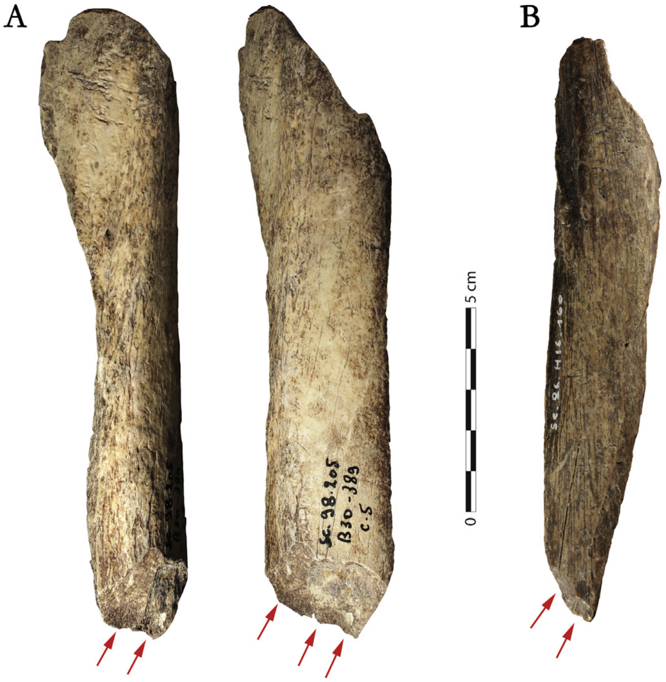

**Fig. 9.** Photos of fragments Sc98-B30-389 (A) and Sc86-H16-160 (B) showing reduction of the length (and the thickness) by removal scars of their basal portion.

Examination under the stereomicroscope of the surface of the retouchers resulted in the identification of several putative lithic chips embedded in five of the retouchers (Table 5). Residual lithics can appear in the form of single isolated fragments often deeply embedded in pits (Fig. 14 A), or in clusters of different sized fragments embedded in one or several sub-parallel scores (Fig. 14 B).

EDX spectra of the embedded lithic chips exhibit silicon peaks, which distinguish them from the surrounding bone (Fig. 5). The large silicon and oxygen peaks in Fig. 5, spectra 1 and 2 (Sp 1 and Sp 2) indicate the presence of silicon dioxide ($SiO_2$), either as a crystalline material such as quartz or a cryptocrystalline material like flint or chert. However, surface contaminants such as mineral precipitation and adhesion of detrital materials may affect the analysis of the underlying substrate. This is seen clearly in Sp 3 and Sp 4, where areas of the flake are partially covered by contaminants, and the silicon and oxygen peaks are very low. Finally, analyses of the surrounding matrix (Sp 5 and Sp 6) showed the presence of calcium and phosphorus peaks typical of bone. Smaller peaks representing carbon, aluminium and iron are probably associated with environmental contamination from soil and handling (sulphur, carbon and potassium). The EDX maps also clearly show that the flakes contain high silicon levels (Fig. 6 D), that the surrounding matrix was calcium-rich (bone; Fig. 6 E) and that the aluminium-bearing contamination was distributed in minute particles across the surface (Fig. 6 C).

## 6. Discussion

The exploitation of bear carcasses (brown and cave bears), recognised by the presence of butchery marks, although recorded, remains a rare event during the Middle Palaeolithic (e.g., Regourdou site, France; Cavanhié, 2009–2010). For this period, with the exception of the site of Biache-Saint-Vaast (Auguste, 1995), there is no evidence of bear hunting. Even rarer is the record of the use of their bones by Neanderthals to produce tools, and only very few sites have yielded brown bear bone retouchers: e.g., Biache-Saint-Vaast (France; Auguste, 2002); Fate Cave (Italy; Valensi and Psathi, 2004) and Fumane Cave (Italy; Jéquier et al., 2012). At Scladina Cave, the evidence of bear exploitation involves only cave bears, even if brown bears are present (Table 1). This observation is supported by the presence of cut-marked cave bear remains, as well as six cave bear bone retouchers.

The presence of characteristic breakage features, which are consistent with humanly induced fractures on green (fresh) bone, cut marks and scraping marks, supports the idea of the recovering of a relatively fresh bear carcass or carcasses (Haglund, 1991; Vincent, 1993; Tartar, 2009). However, the real time between the death of the animal and the exploitation of its carcass is difficult to precise. Recent experiments in active periglacial context showed that bones, after at least 4 years, did not show any weathering marks and that their surfaces were still greasy (Mallye et al., 2009). Moreover, according to Vincent (1993) and Tartar (2009), the lack of scraping marks on most of the used surfaces could indicate that the carcass was, at least, partially decomposed or that the periosteum was not present on the all surface, although the bone was still rich in organic matter.

The presence of butchery marks and the refitting pattern observed among some of the fragments allow for a better understanding of the operational sequence undertaken during the

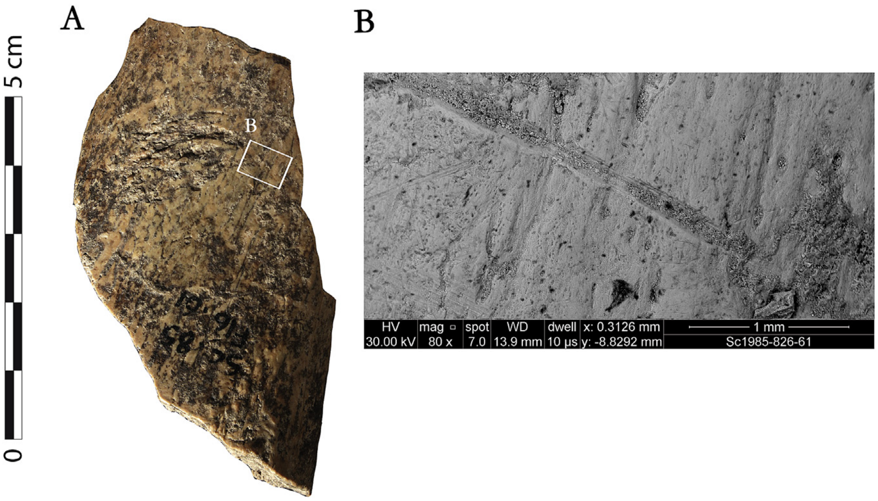

**Fig. 10.** (A) Photo of retoucher Sc85-F16-61 and (B) detailed SEM image of a cut mark incision affecting the cortical surface (Yves Vanbrabant, Geological Survey of Belgium).

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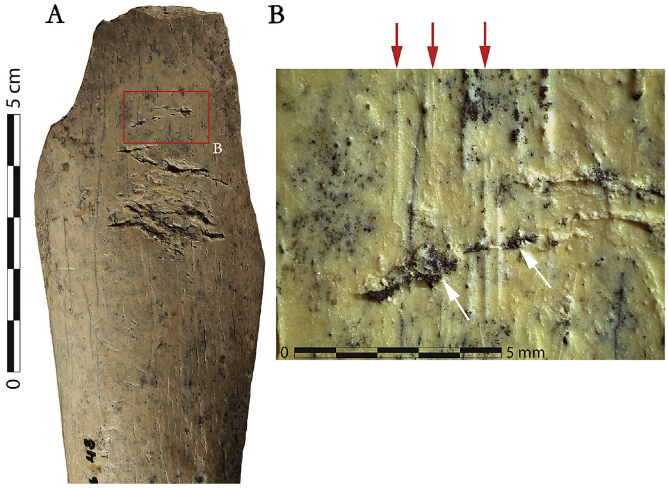

**Fig. 11.** (A) Photo of apical portion of retoucher Sc84-E16-48 and (B) detailed image of scraping marks (red arrows) affecting the cortical surface, overlapped by the knapping marks (white arrows). (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

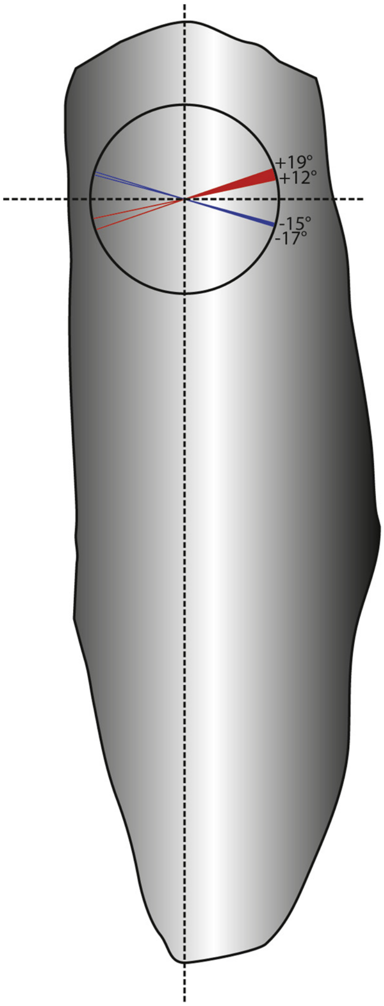

**Fig. 12.** Schematic synthesis of preferential orientations of the scores recorded for the 6 retouchers.

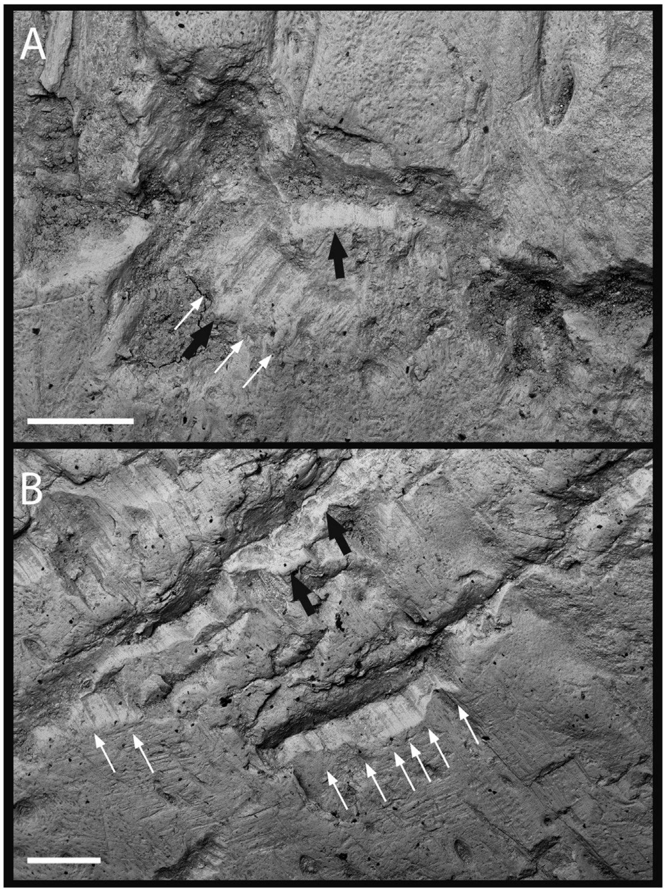

**Fig. 13.** SEM images of Sc98-B30-389 highlighting (A) pits and (B) scores produced during knapping. The white arrows indicate microstrations internal to the indentations, parallel to the direction of the blow, while the black arrows show the rounding and polishing of the edges of the indentations. Scales = 200 μm.

production of these tools. Assuming there was no deliberate hunting of bears at Scladina, it is likely that the first activity undertaken by Neanderthals was the removal of the meaty material still attached to the bones. This operation is revealed by the presence of cut marks on the surface of all bear fragments used as retouchers. In one case, it is possible to identify (Sc85-F16-61) retouching marks overlapping the cut marks. In the case of the six bear bone fragments, which refit together to reconstruct an almost complete diaphysis of right femur, it is possible to observe that the meat removal was followed by its breakage, as demonstrated by the presence of several notches and impact damages (Fig. 8). It is likely that the breakage had occurred before the use of each fragment as a retoucher. If the complete femur was used as a retoucher before its breakage, the knapping areas would sit in the middle of the bone shaft, conversely to its more common location close to the edges of a fragment (Verna and d'Errico, 2011; Jéquier et al., 2012; Mallye et al., 2012). Moreover, the presence of scores on the lateral edge of one of the fragment (Sc85-F16-61), which do not extend to the adjacent refitting segments (Sc84-E16-48 and Sc85-G16-600), seems to confirm that each of these specimens was used after breakage (Fig. 8 B). A second more thorough cleaning of the bone fragments was obtained by a scraping action. Scraping marks have been observed on two fragments (Sc84-E16-48 and Sc85-F16-61) and they are always overlapped by knapping scores and pits. Their location is restricted to the knapping area, suggesting they were probably produced after the breakage of the bones. As for the possible adjustment of the basal extremity, visible on Sc86-H16-

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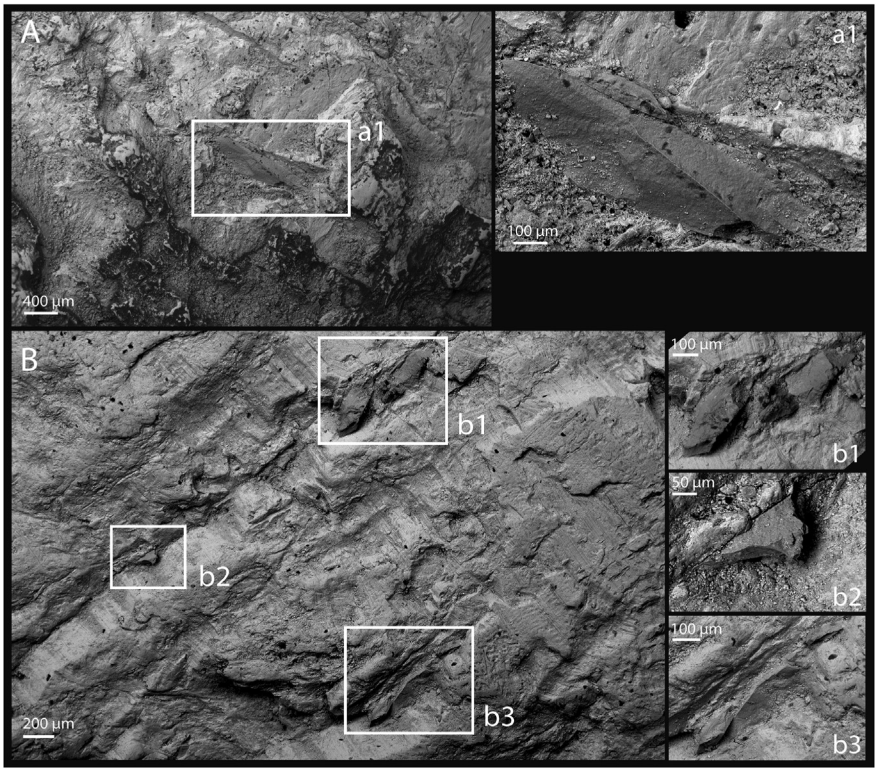

**Fig. 14.** SEM images of Sc98-B30-389 showing residual flints, which appear in the form of (A) single isolated fragment, deeply embedded in a pit, or (B) in clusters of different sized fragments distributed on a larger area and embedded in sub-parallel scores.

160 and Sc98-B30-389, it is more difficult to ascertain the time when the modifications were produced. Nevertheless, Sc98-B30-389 refits with Sc84-E18-29, which does not show any anthropogenic modification of the basal extremity. This evidence may suggest the modelling of the edges took place after the breakage of the bone. However, a post-depositional damage, by trampling cannot be completely excluded (Eren et al., 2010). Once the bear fragments were completely cleaned, broken in reduced segments and possibly shaped to make them more ergonomic, they were used as retouchers to modify the edge of lithic artefacts. Knapping marks in the form of scores and pits overlap any other humanly induced modifications, suggesting they were the last anthropogenic marks impressed on the bone fragments before their abandonment. The presence of embedded flint chips in some of the scores ultimately confirms their use as bone retouchers. The morphology of the embedded flint suggests they are the results of micro-breakage of flint tools. In Scladina cave, all the retouched stone tools are made of flint. More analyses need however to be carried out on these embedded chips to clearly identify the siliceous raw material they are made of (flint, chert, quartz or quartzite). Finally, the preferential orientation of use traces observed for the Scladina bone tools, transverse to the main axis of the fragments, matches the one observed for other Middle Palaeolithic retouchers (Armand and Delagnes, 1998; Verna and d'Errico, 2011; Jéquier et al., 2012; Mallye et al., 2012).

The interpretation of the way retouchers from Scladina were used leans on the results obtained by Tartar (2012). According to this author, the sliding grooves and modification patterns (bony cupules removal) would highlight a use of these bear bone fragments as hammer (percussion operation) in the manufacture of lithic artefacts.

The idea of predetermined actions among Neanderthals, as for the implementation of bone tool blanks, is still debated within the scientific community. While some authors suggest that Neanderthals have recovered previously broken bones (Armand and Delagnes, 1998; Tartar, 2012), others see the result of deliberate choice (Mallye et al., 2012). Analysis of the operational sequence for the production of bear bone retouchers at Scladina cave clearly supports this second hypothesis and reinforces the idea that retouchers are, in some cases, the result of an elaborated conceptual process not dissimilar from the *chaîne opératoire* used in the production of lithic artefacts.

## 7. Conclusions

Evidence of bear remains used as tools by Neanderthals is rare. At Scladina cave, among the twenty-six retouchers obtained from faunal bone remains found within sedimentary unit 5, six were made from cave bear bones. The blank morphology and the anthropogenic marks are comparable to those observed on retouchers found in other Middle Palaeolithic sites. Four bear fragments used as bone retouchers refit together forming an almost complete diaphysis of right femur. The modification pattern of this right femur reveals a sophisticated operational sequence where the complete bone was initially defleshed, broken in fragments, some of them were further cleaned of any residual soft tissue (e.g., periosteum; where the used marks took place), possibly shaped to make it more ergonomic and finally used as retoucher.

Analysis of the Scladina bear bone retouchers reveals a complex *chaîne opératoire* led on faunal remains in order to obtain tools used in the lithic reduction and the stone tools production. This argue in favour of a succession of specific actions to obtain bone tool blanks, approaching their implementation to that usually described for the production of stone artefacts. Together, zooarchaeological and lithic information, unearthed from sedimentary unit 5, highlight a long and complex *chaîne opératoire* performed by Neanderthals. This

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covers activities from the acquisition of lithic and faunal resources, in various natural environments, to their finality and abandonment in Scladina.

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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.2013.10.022.

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