Chapter 7

TAPHONOMY OF THE JUVENILE NEANDERTAL REMAINS FROM SEDIMENTARY COMPLEX 4A, SCLADINA CAVE

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1. Introduction

When hominid remains are discovered, such as the Neandertal specimen Scladina I-4A, many different questions arise. These include: What was the cause of death? How did the deceased individual, or parts of their body or skeleton, enter the site? What happened to the fossils between their deposition and the archaeological excavation that unearthed them?

All these questions, and numerous related others, are on the topic of 'taphonomy' (Efremov, 1940), i.e. the study of the processes an organism is subject to between its death and its discovery (Grupe, 2007), including effects induced by the passage of an individual from a living community to a fossil one (Denys, 2002). Numerous applications of this discipline for palaeontology and palaeoanthropology have been developed for over half a century (see, for instance, among thousands of contributions: Dart, 1957; Behrensmeyer, 1978; Behrensmeyer & Hill, 1980; Shipman, 1981; Brain, 1981; Binford, 1981; Behrensmeyer & Kidwell, 1985; Blumenschine, 1986; Villa & Mahieu, 1991; White, 1992; Boulestin, 1999; Martin, 1999; Behrensmeyer et al., 2000; Lyman, 2001; Pickering et al., 2007; Krovitz & Shipman, 2007).

However, as far as European Pleistocene hominid remains are concerned, only a limited number of them have been the subjects of taphonomic studies. Some works focus on cut marks (e.g. Le Mort, 1988; 1989). Others are about cannibalism, for instance at Krapina (Patou-Mathis, 1997; Frayer et al., 2006; Ullrich, 2006), or Moula-Guercy (Defleur et al., 1999). Others try to apply various aspects of taphonomy to studied bones, for example at Atapuerca–Sima de los Huesos (Andrews & Fernández-Jalvo, 1997), Le Moustier 1 (Ullrich, 2005), Rochers-de-Villeneuve (Beauval et al., 2005), and Oliveira Cave (Trinkaus et al., 2007).

At Scladina, the 19 fossils (3 bone fragments and 16 isolated teeth) from Sedimentary Complex 4A that belong to the 8-year-old juvenile Neandertal exhibit a particular set of various characteristics. Among these attributes is a planimetric dispersal within an elliptical area of around 13 m long by 6 m wide, a stratigraphic dispersal within different layers/units of Sedimentary Complex 4A, colour differences between bones and between isolated teeth, the presence of manganese coatings on some bones, the fact that most fossils were scattered in the axial part of the cave while some others were discovered nearly against the south wall, and the relative completeness of the mandible when the two parts are refitted juxtaposed against the relative incompleteness of the maxilla.

This wide variety of information (detailed and analysed below) immediately indicates a complex depositional history. Therefore, this chapter tries to decipher, at least in part, these events. To do this, the following approaches were taken into consideration:

- the examination of the fossils for evidence of different surface modifications and, when applicable, their description;
- the analysis of the spatial and stratigraphic distribution of the isolated teeth and fragments of bones;
- the comparison of these observations to those from the analysis of faunal remains;
- the integration of all these approaches in order to build a model of successive chronological phases in relation to death (necrology), pre-burial processes (biostratinomy), burial processes, post-depositional processes (diagenesis), and archaeological or palaeontological excavation.

2. Material and methods

2.1. Stratigraphic context of the Neandertal fossils from Scladina Cave

Although the main stratigraphic units of Scladina were identified during the initial excavation (e.g. Deblaere & Gullentops, 1986; Gullentops & Deblaere, 1992; Haesaerts, 1992), the real stratigraphic complexity of the site was observed and recorded during the research for a PhD in geology (Pirson, 2007). This revision identified 30 sedimentary units comprised of more than 120 layers. Also, numerous sedimentary processes were recognised, including run-off, debris flow, torrential flow, and decantation. Post-depositional phenomena, such as bioturbation, the precipitation of manganese, and cryoturbation were also recorded. All of these processes have an impact on the preservation of both hominid and faunal remains.

The stratigraphic revision of former Layer 4A, which yielded the hominid remains, demonstrated that 4A is clearly much more sedimentologically complicated than previously considered (Pirson et al., 2005, 2008; Pirson, 2007; see Chapter 5). Therefore, former Layer 4A was renamed Sedimentary Complex 4A, and is now comprised of approximately 20 layers situated around Speleothem CC4. They are organized into 4 units (Figure 1):

- underlying Speleothem CC4, Unit 4A-AP contains layers 4A-LG, 4A-MC, 4A-GB, and 4A-KG;
- Speleothem CC4 and the layers interstratified with CC4 are grouped into Unit 4A-IP. Locally, CC4 is divided into 2-3 distinct generations that are separated by lenses of sediment. The layers interstratified with CC4, with which they are contemporary, are layers 4A-OR, 4A-SGR, and 4A-YS;
- a unit composed of several discontinuous lithofacies and corresponding with the filling of an important gully is called Unit 4A-CHE. This gully cross-cuts the layers of units 4A-AP and 4A-IP, as well as Speleothem CC4. These lithofacies contain many limestone fragments, as well as calcite fragments eroded from Stalagmitic Floor CC4;
- layers that were deposited after the gully, overlying both units 4A-IP and 4A-CHE, constitute Unit 4A-POC, which is divided into 4 layers: 4A-BO, 4A-LEG, 4A-GV, and 4A-GBL.

According to what is currently understood from a chronostratigraphic perspective, the entire Sedimentary Complex 4A appears to have been deposited during the Weichselian Early Glacial (for details, see Chapters 4 & 5).

Following the stratigraphic revision, the increased number of identified layers caused the excavations at Scladina to become much more precise. The stratigraphic contexts of bones and artefacts are therefore now better understood (for excavation methodology see Bonjean et al., 2009; see Chapter 2).

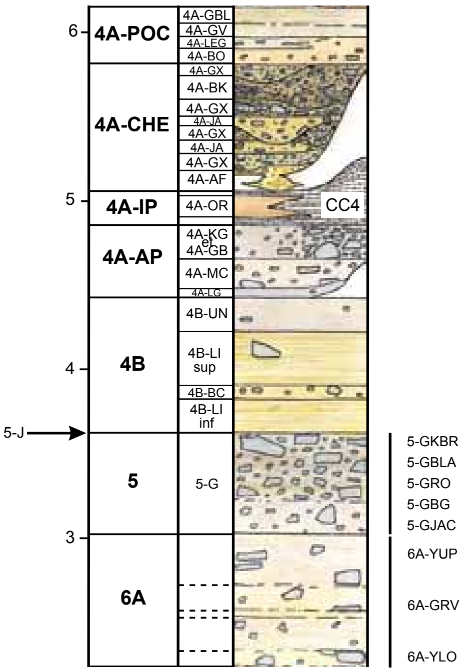


Figure 1: Stratigraphic log of units 6A to 4A-POC that contained the faunal remains used in this study (from Pirson, 2007).

2.2. Taphonomy of the Neandertal child

The Scladina Neandertal fossils have been examined under a hand lens and, in some cases, a stereomicroscope in order to check for the presence or absence of numerous classic taphonomic criteria. These observations are related to surface colour, coloration at breakage sites, surface condition/lustre (polished, glossy, porous, etc.), weathering traces, adhered matrix, types of fracturing, degree of fragmentation, abrasion of fracture edges, peeling, trampling, burning, precipitation of manganese and iron hydroxides, tool-induced marks, carnivore and rodent tooth marks, (micro) mammal gnawing, insect action, pathological markers, excavation damage, preparation damage, and sampling damage (Potter & Rossman, 1979; Binford, 1981; Hill, 1982; Ortner & Putschar, 1985; Behrensmeyer et al., 1986; Noe-Nygaard, 1989; White & Toth, 1989; Haglund, 1992, 1997; White, 1992: 129; Andrews & Fernández Jalvo, 1997; López-González et al., 2006).

When possible, the features were then classified according to the different chronological phases of the taphonomic process that they were related to:

1. antemortem trauma, which precedes the study area of taphonomy *sensu stricto*, is by definition characterized by the survival of the victim. Therefore, these traces show clear signs of healing as well as associated breaks consistent with fresh or 'green' bone fractures;
2. perimortem trauma, i.e. damage to bone that occurs just before, during, or shortly after death, which exhibits no evidence of healing; the associated breaks are similar to antemortem fractures, as both occur on fresh or 'green' bones (Wakely, 1997; Craig et al., 2005; Knüsel, 2005). Perimortem traces can, theoretically, be divided into three types: (a) trauma occurring shortly before death but not a direct cause of death (e.g. "perimortem injury that occurred before death," see Walker, 2001: 577); (b) trauma responsible for the death, i.e., lethal perimortem damage (fractures indicating violence, arrowhead wounds, carnivore predation activity, etc.; see Craig et al., 2005; Knüsel, 2005); (c) anthropogenic traces occurring shortly after death (e.g., "perimortem injury that occurred after death" as defined by Walker, 2001: 577) or scavenger damage which can sometimes be distinguished from perimortem damage occurring just before death by other clues, such as the location and symmetry of the marks, which do not allow assumption that these marks could have been inflicted on a living person/animal. However, in many cases, it is impossible to distinguish between these three types of traces, as the persistence of collagen allows bone to respond to trauma in a similarly elastic manner in the three types (Walker, 2001; Rogers, 2004; Craig et al., 2005);
3. postmortem damage exhibits no signs of healing and is mainly due to site formation processes, occurring more or less long after death. Postmortem damage consists of "stage 2, dry bone breakage" and "stage 3, post-fossilization breakage" of Krovitz & Shipman (2007). Such damage is inferred from numerous taphonomic markers;
4. recovery and post-recovery damage induced by archaeological activity, either from excavation (e.g., metal tool damage), preparation (White & Toth, 1989; White, 1992: 129), sampling (DNA, biogeochemistery, dating), or museum curation.

2.3. Taphonomy of the faunal remains

Since 2005, the archaeologists at Scladina have undertaken a systematic examination of the main taphonomic signatures of the faunal remains from the cave. Six main attributes were used including: the general colour of the fossils, the number of fractures, the degree of abrasion of fractured edges, the condition and lustre of the cortical surface (original, polished, cracked), and the precipitation of both metallic oxides (mainly iron and manganese) and carbonates (Delaunois, 2010; Delaunois et al., 2012).

This analysis showed that the majority of the faunal remains from the same sedimentary layer exhibited a similar state of preservation. Between the objects from different layers, a logical variation of the intensity of taphonomic properties was observed. When combined, the various physical attributes observed on the bones of each layer provide a unique taphonomic signature that can be used as a dynamic tool in the field during excavation, as well as in the laboratory, to evaluate the integrity of a group of objects. The results of the use of this tool may have large implications on the understanding of the contemporaneity of faunal remains and their attribution to a specific type of environment (Delaunois et al., 2012).

The results of the taphonomic analysis described above show the potential for the use of this method when analysing the Neandertal child, especially because the 2 hemimandibles have different taphonomic signatures (e.g. colour, surface cracking). Verification of whether or not the variation of the taphonomic characteristics was unique to the Neandertal child or if they were also exhibited on faunal remains from the same sedimentary complex was important.

Secondary to this, the results of this study will also have stratigraphic, and therefore chronological, implications. Because the Neandertal remains were excavated before the stratigraphic revision (started in 2003; Pirson, 2007), the objects were attributed to the entirety of the 4A stratigraphic complex (Bonjean et al., 1997; Pirson et al., 2005). Later, with the help of the new stratigraphic framework, some of the objects were reattributed to more precise contexts, including the gully, Unit 4A-CHE (at least 1 hemimandible), or to Unit 4A-POC (post-gully; see Chapter 5). The affirmation of this reattribution by a method other than stratigraphic observation was relevant. To do this, the taphonomic properties examined on faunal remains were compared to the ones on the Neandertal remains in order to observe if commonalities exist. This comparison determined whether or not the hominid and faunal remains were altered in the same way, which is possibly linked to similar biostratinomic and diagenetic processes, and thus their deposition in the same sedimentary environment. Therefore, the layers that provided most of the animal remains that are taphonomically similar to the child could become potential candidates to have contained the Neandertal remains before they were reworked into the gully (Unit 4A-CHE).

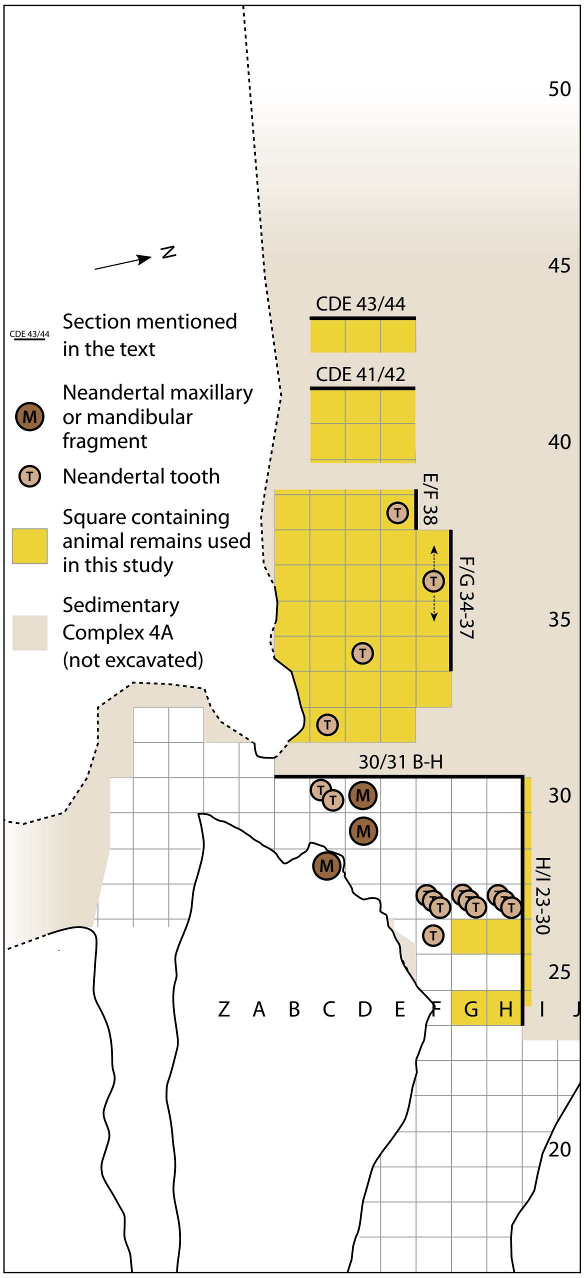


Figure 2: Spatial distribution of the hominid and animal remains compared in the study.

The fauna that constituted the comparative material used in the analysis came mainly from recent excavations (2003–2010) that respected microstratigraphy. Only 1 cave bear (*Ursus spelaeus*) phalanx that was exhumed in 1996 was added to this collection, due to the pertinence of its taphonomic criteria when compared to those of the child. The collection is composed of 597 bones that belong to various mammalian species, but mainly to cave bear. The chosen anatomic segments were variable, and therefore represented objects with different densities. These segments include cranial elements, sterna, vertebrae, and both upper and lower limb bones.

The 597 bones are from 4 different zones within the cave (Figure 2), which are all situated on the periphery of the area that yielded the hominid remains. One of them is a zone between metres 24 and 30 adjacent to the concentration of the 10 isolated teeth of the child. The 3 other zones are deeper in the cave, from metres 32 to 43, and surround the area where the other 4 isolated teeth were exhumed.

The faunal remains originate from 16 different layers within 7 sedimentary units:

- 6A (6A-YLO, 6A-GRV, 6A-YUP)[1];
- 5 (5-GJAC, 5-GBG, 5-GRO, 5-GBLA, 5-GKBR)[1];
- 4B (4B-LI, 4B-UN);
- 4A-AP (4A-KG);
- 4A-IP (4A-OR);
- 4A-CHE;
- 4A-POC (4A-BO, 4A-LEG, 4A-GBL).

In addition to this, a complimentary study was undertaken due to the fact that most of the Neandertal fossils from Scladina are isolated teeth. Therefore, a comparison of the Neandertal teeth to

[1] In this paper, these lithologies will be considered as layers. The stratigraphic study of this part of the sequence, still in progress, will have to confirm if those lithologies are real layers or rather lateral variations of facies.

the isolated incisors of cave bear from the same sedimentary units was appropriate. However, the excavations after the stratigraphic revision have yielded only 52 *Ursus spelaeus* teeth. To increase the sample size, 248 other cave bear incisors were selected from 32 m^2 of former Layer 4A. These 248 objects were all reattributed to their original sedimentary units (4A-AP, 4A-CHE, 4A-POC), which was made possible thanks to several observations recorded during excavation of this specific area. Stalagmitic Floor CC4 was excavated when in situ on a surface of 6 m^2 (F, G, and H from metres 28 to 29). The altitudes of the teeth were recorded which facilitated clarification of whether they were excavated from below the stalagmitic floor (Unit 4A-AP) or from above it (Unit 4A-POC). Unit 4A-CHE was also localized in squares G30 and H30 through stratigraphic observation of the adjacent profiles 30/31 and H/I.

3. Results

3.1. Taphonomy of the Scladina Neandertal fossils

The three osseous fragments of the Scladina Juvenile, including the Scla 4A-1 and Scla 4A-9 hemimandibles, and the small part of the right maxilla (Scla 4A-2), as well as the child's isolated teeth are all fossilized to some degree (the extent of fossilization is presently under investigation; Figure 3).

3.1.1. Left hemimandible Scla 4A-9

Scla 4A-9 (Figure 4) consists of the very anterior part of the right body, the symphysis, and the essentially complete left body, but the ramus is not present. It weighs 31.69 g.

Figure 3: The 19 juvenile Neandertal fossils (scale 1:1):
4A-1, right hemimandible;
4A-2, right maxillary fragment;
4A-3, permanent maxillary right second molar (M^2);
4A-4, permanent maxillary right first molar (M^1);
4A-5, deciduous maxillary right second molar (dm^2);
4A-6, mandibular right first premolar (P_3);
4A-7, deciduous maxillary right first molar (dm^1);
4A-8, permanent maxillary right third molar (M^3);
4A-9, left hemimandible;
4A-11, permanent maxillary right central incisor (I^1);
4A-12, permanent mandibular right canine (C_1);
4A-13, deciduous mandibular right second molar (dm_2);
4A-14, permanent maxillary right lateral incisor (I^2);
4A-15, permanent mandibular right central incisor (I_1);
4A-16, permanent maxillary right canine (C');
4A-17, permanent maxillary left lateral incisor (I^2);
4A-18, permanent maxillary left canine (C');
4A-19, permanent mandibular left lateral incisor (I_2);
4A-20, permanent mandibular right lateral incisor (I_2).

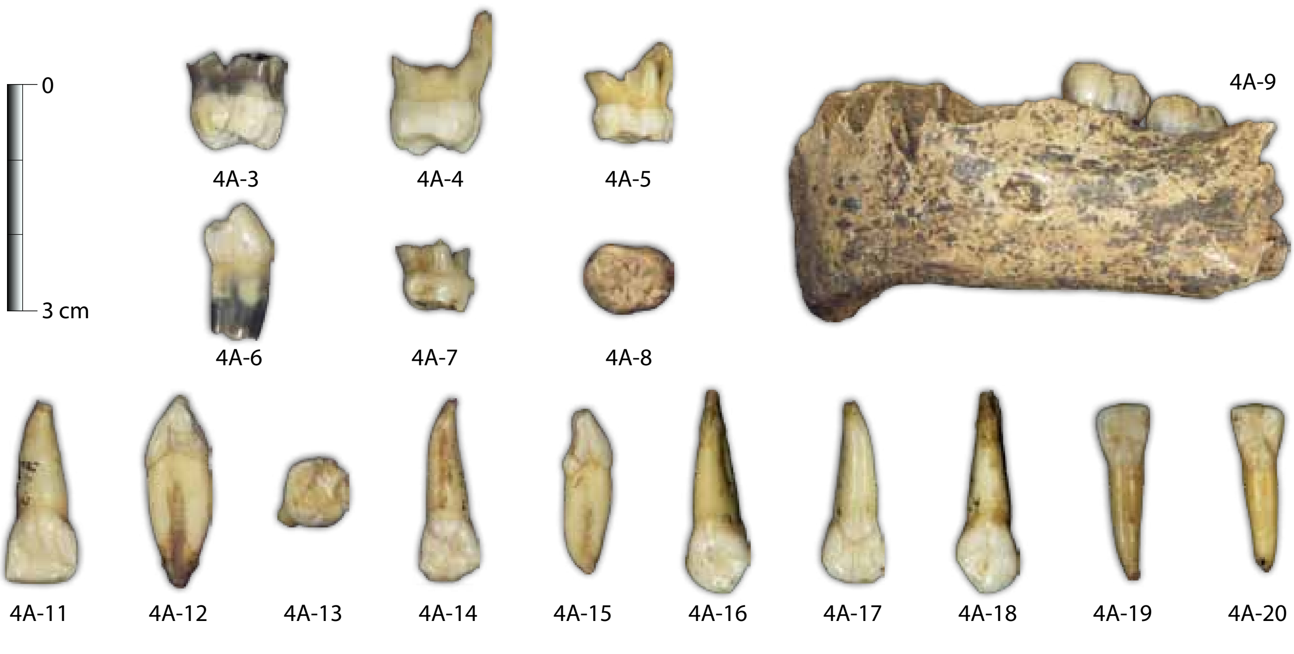


Figure 4: The left hemimandible Scla 4A-9, labiobuccal (above) and lingual (below) surfaces (scale 1:1).

The main colour of the fossil is orange (dull yellow orange, 10 YR 7/4 and light yellow orange, 10 YR 8/3 and 8/4). Its surface is slightly polished.

Numerous thin cracks (Figure 5), visible to the naked eye, are present and correspond to stage 1 of Behrensmeyer (1978); no flaking is associated with them. The fractures are nearly parallel to the inferior margin of the body and present on both faces, although mainly the lingual one. There are also some subvertical cracks.

Small stains of manganese are present (generally no more than a few millimetres in diameter, but sometimes connected) on both the lingual and buccal faces of the fossil (Figure 6). The area covered by manganese is at stage 2 of López-González et al. (2006), which is to say between 10% and 50%. The colour of the coating is intense dark dun (intensity 2) on the buccal surface and in the posterior lingual part of the hemimandible, but darker (intensity 2 to 3) in the mesial lingual area. In most cases, manganese covers the fractures. Some stains of manganese are also present inside the fracture that separated the mandible in two, as well as inside the dental alveoli. Manganese is never precipitated in dendritic form on the Neandertal fossils. All the manganese is clearly superimposed over previously existing features on the bone's surfaces, such as the fractures.

The anterior break of this fossil, which can be refitted almost perfectly with the anterior break of the right hemimandible (Scla 4A-1), is transversal

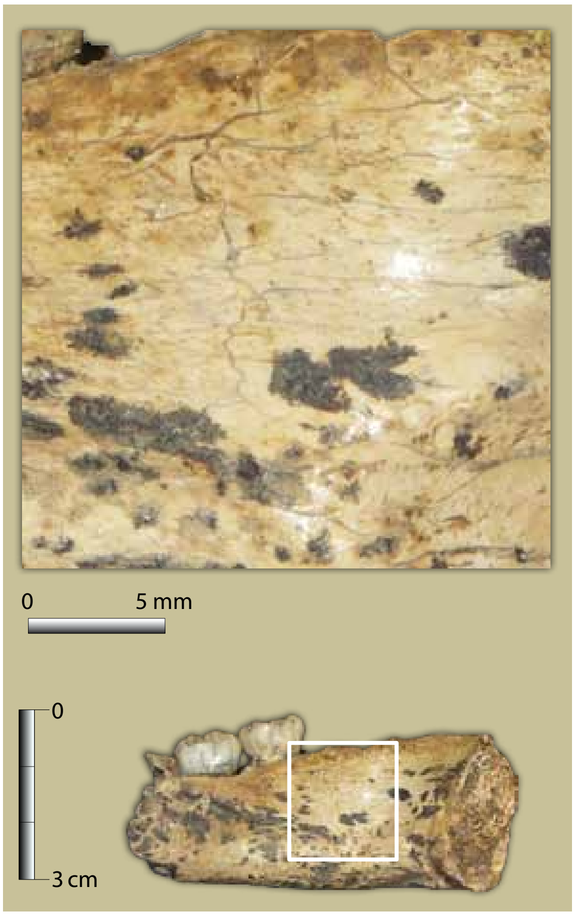


Figure 5: Cracks on Scla 4A-9.

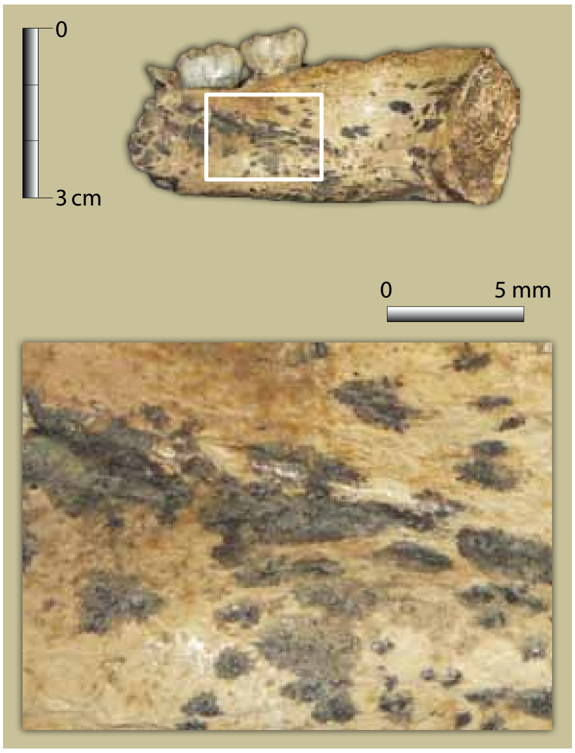


Figure 6: The manganese deposits on Scla 4A-9.

and nearly vertical in the superior half of the body, curving distally in its inferior part. The edges of the break are sharp on the buccal surface. On the lingual surface, adjacent to the anterior fracture, a small area of 'peeling' was observed (Figure 7), which is a pattern related to fractures that have occurred in fresh, fibrous osseous material (White, 1992: 140–143). Some small manganese stains are present on the peeled surfaces.

The facial portion of the canine dental alveolus is largely missing. The anterior wall of the dental alveoli of the four incisors and the buccal face of the P_4 are also eroded.

The posterior break is affected by some recent small fractures, which were the result of the excavation of the object.

Some other excavation damage was detected on the lingual surface, below the second molar and third molar crypts: metal scraper marks made by the excavator who unearthed the fossil (Figure 8). Contrary to the thin cracks discussed earlier, these marks were made after manganese had already precipitated onto the object. Several other thin marks are present on the fossil, for instance a curved one on the facial surface which is inferiorly concave, under M_1 and under the dental alveolus of P_4.

Neither rodent nor carnivore marks, such as scoring and furrowing from gnawing/chewing, pits, or punctures are observed on 4A-9. Also, no cut marks are present.

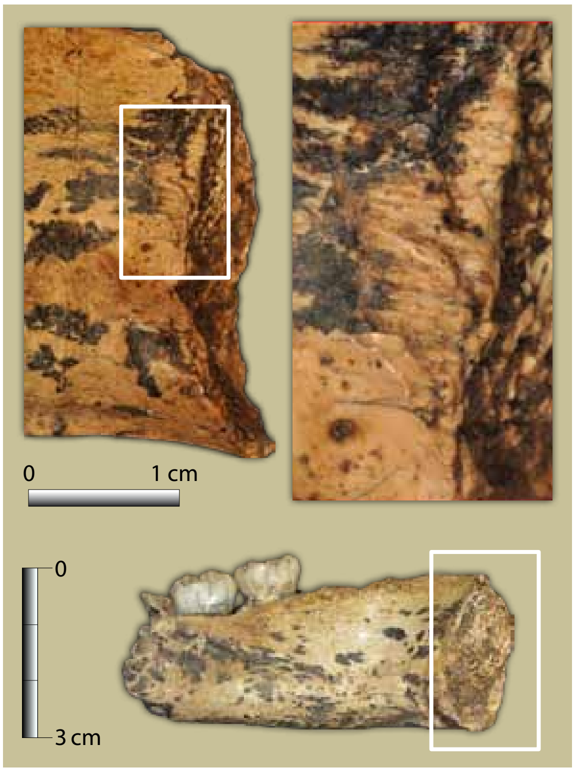
No real curatorial damage has occurred, and no moulding or casting methods have been used, no sampling for DNA or isotopic analysis has been done. In fact, a replica of this left hemimandible was made with a medical scanner and stereolithography. It was then replicated using classical moulding methods to produce further copies.

3.1.2. Right hemimandible Scla 4A-1

The Scla 4A-1 (Figure 9) hemimandible consists of the right body and ramus. The bone is highly lustrous, likely due to fossilization. However, that characteristic may be slightly accentuated by the presence of wax residue from when both Scla 4A-1 and Scla 4A-2 were moulded.

The general colour of the fossil is greyish-green. The two main components are light grey (2.5 Y 8/2) and pale yellow (2.5 Y 8/3) with traces of grey (7.5 Y 6/1 and 5/1) and pale green. Cracks, mainly parallel to the body, are present but not as visible as on Scla 4A-9 (Figure 10); they are at the very beginning of Behrensmeyer (1978)

Figure 7: The peeling adjacent to the anterior fracture of Scla 4A-9.



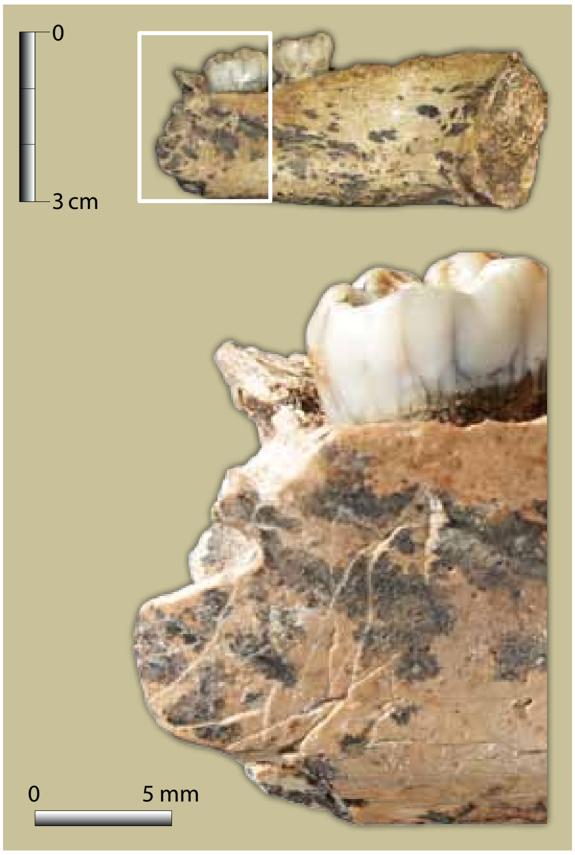


Figure 8: Excavation damage on Scla 4A-9.

Figure 9: The right hemimandible Scla 4A-1, buccal (left) and lingual (right) surfaces (scale 1:1).

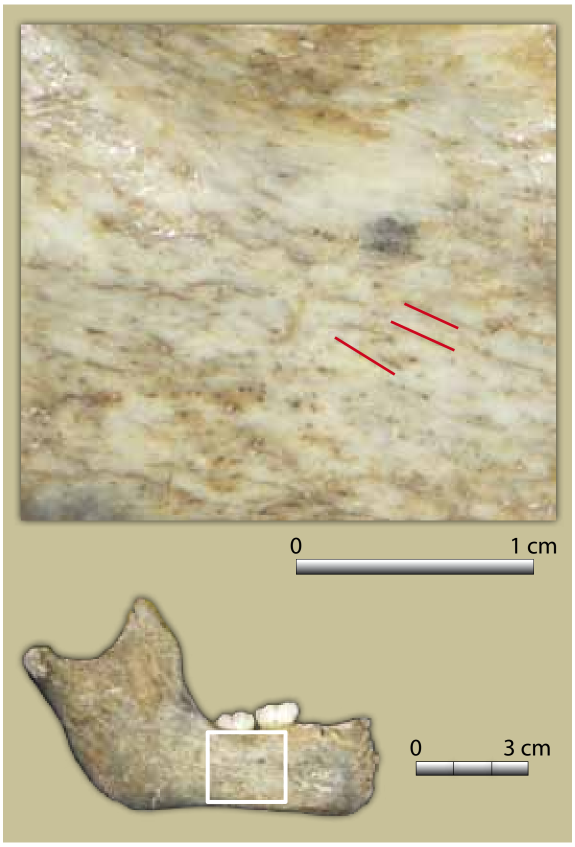


Figure 10: Thin horizontal cracks on Scla 4A-1, represented by thin red lines.

stage 1. The external wall of the M_1 dental alveolus exhibits a wider subvertical crack.

A few subtle manganese stains are present. Neither rodent nor carnivore marks, such as scores, furrows, pits, or punctures are observed on Scla 4A-1.

The anterior break corresponds to that of Scla 4A-9: vertical in its upper part, then distally oblique (Figure 11).

The gonion is eroded (Figure 12). On the bone's buccal surface a network of surface cracks is present in a star-shaped form (Figure 13). No trace

Figure 11: Fig 11. Side-by-side comparison of the anterior break that separates Scla 4A-1 and 4A-9.

of applied pressure is visible. The cracks appear to be the possible result of cortex rupturing that originated from inside the bone. This rupture could have been produced by an expansion of the bone from freezing (gélifraction, Guadelli & Ozouf, 1994). The condyle is damaged; its lingual part is eroded and its buccal one is missing at least 4 mm of osseous material. The posterior border is also heavily worn.

A straight, thin groove that at first glance is very similar to an anthropogenic cut mark, is present on the lingual surface of Scla 4A-1 (Figure 14). However, the position is unusual for cut marks and it is the only similar trace observed on the three bones of the juvenile, so this mark was probably caused by some sedimentary process.

The facial surfaces of some dental alveoli, mainly of P_3, are heavily abraded.

A small splinter from the upper part of the anterior border of the right ramus was detached during the excavation process and later refitted (Figure 15).

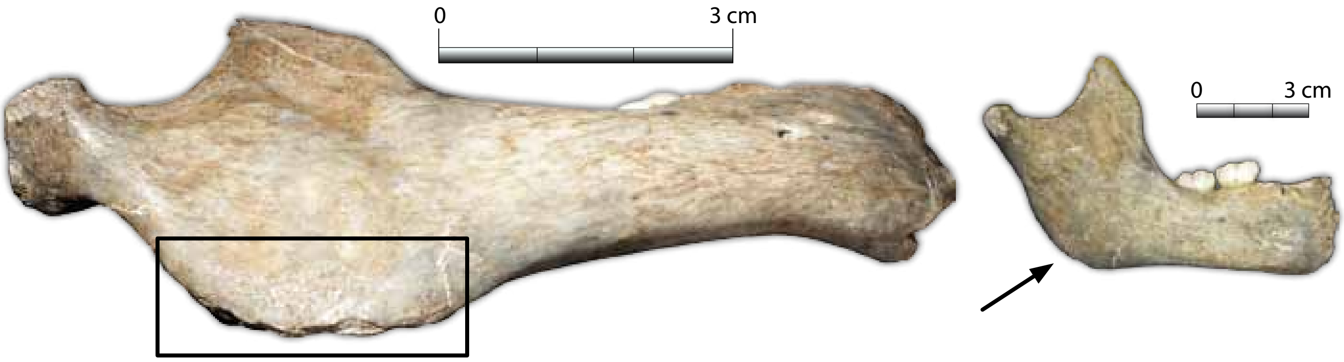


Figure 12: The eroded gonion of Scla 4A-1.

Figure 13: The star-shaped fracture of Scla 4A-1.

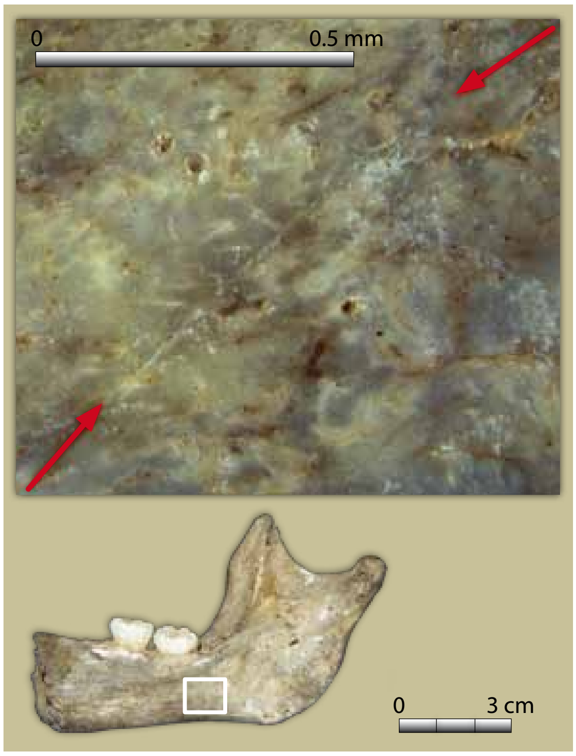


Figure 14: The straight thin groove that was likely caused by sedimentary processes (between the red arrows).

Figure 15: The splinter broken off from Scla 4A-1 during excavation.

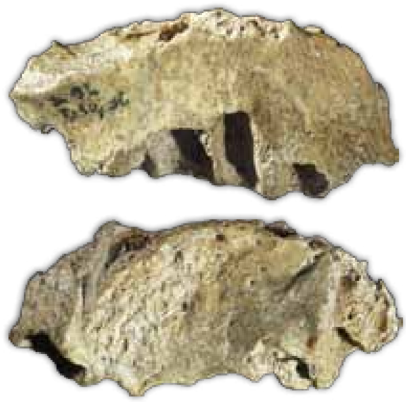


Figure 16: The maxilla Scla 4A-2, labiobuccal (above) and lingual (below) surfaces (scale 1:1).

Contrary to Scla 4A-9, a mould was prepared in order to obtain casts of this fossil and some tiny traces of white silicone are still present on it.

3.1.3. Maxilla Scla 4A-2

This fossil (Figure 16) is a part of the right maxilla, comprised of just the partial alveolar processes, from the complete I^1 crypt to the middle of the M^1 crypt. The maxilla is broken mesially, distally, and superiorly. On the bone's inferior component, the mesial breakage extends along part of the inter-maxillary suture for a few millimetres in front of the incisive canal and then curves distally on the superior part. The distal fracture is vertical but irregular and located in the middle of the socket of the first molar. The floor of the nasal cavity constitutes the superior part of the fossil medially, and the floor of the maxillary sinus laterally.

Currently, the superior margin of the fossil is somewhat crenulated, especially above the canine alveolus (Figure 17).

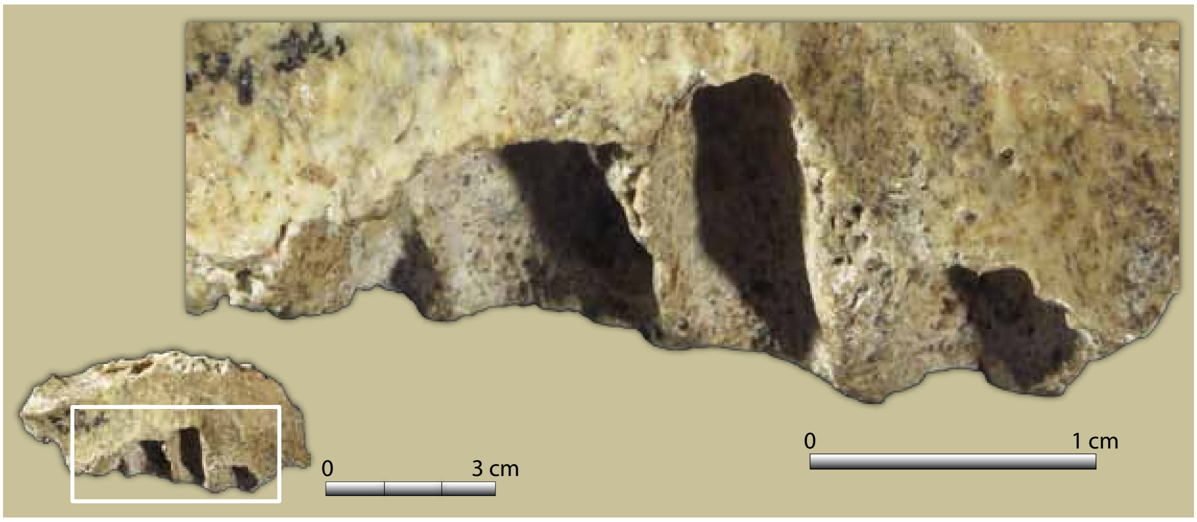


Figure 17: The crenulated margin of Scla 4A-2, especially above the canine dental alveolus.

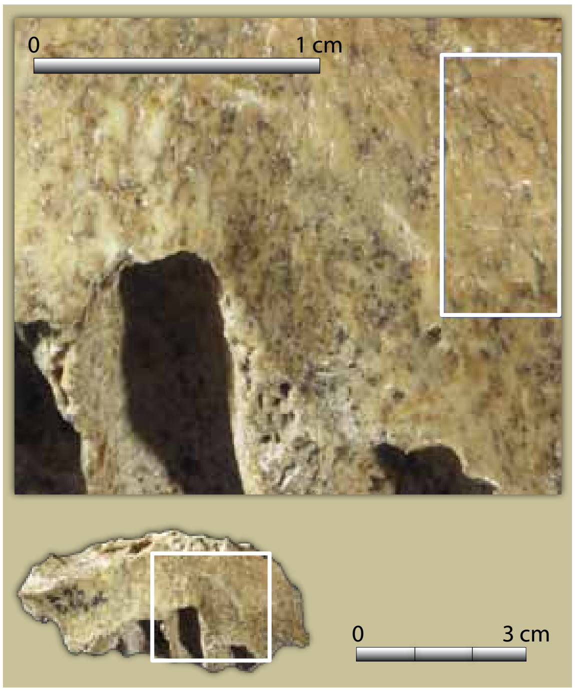


Figure 18: The thin cracks of Scla 4A-2.

The general colour of Scla 4A-2 is greyish-green, relatively similar to that of the right hemimandible Scla 4A-1. The main colours are pale yellow (2.5 Y 8/3 and 8/4) with traces of greyish yellow (2.5 Y 7/2) on the lingual surface and bright yellowish brown (10 YR 7/6) on the buccal surface.

Some thin cracks are present but not as visible as those on Scla 4A-9. There are also some rare manganese stains that are as subtle as the ones on Scla 4A-1 (Figure 18).

The facial walls of the alveoli of both incisors and the anterior part of dm^2 and M^1 are heavily worn; those of the C' and the P^4 are also significantly altered.

As for Scla 4A-1, a mould was prepared in order to cast the fossil and some tiny traces of white silicone are still present.

3.1.4. Isolated teeth

All of the teeth (see Figure 3) from the mandible and the maxilla that were found scattered throughout the sediment were disarticulated postmortem. The alveoli of the permanent teeth are still open and not resorbed at all. Such a situation is expected as the juvenile died at only 8 years of age (see Chapters 8 & 16). Only antemortem trauma could have made the child lose a permanent tooth and have a resorbed alveolus, which was not the case for this individual.

Most of the teeth are nearly complete and very well preserved. The roots of the deciduous teeth have started to resorb. The roots of the permanent maxillary right second molar (Scla 4A-3) are not fully developed. The apexes of some incisors are not completely closed (Scla 4A-16). Only two incisors (Scla 4A-20 & Scla 4A-11) have broken roots, which occurred after they were lost postmortem.

The 16 isolated teeth of the Neandertal child are exceptionally well preserved with little alteration. 15 of the teeth exhibit crowns with light grey enamel (2.5 Y 8/1 and 8/2) comparable to the original colour of in vivo teeth. Their roots exhibit a white-yellow colour (yellow 2.5 Y 8/6, pale yellow 5 Y 8/3 and 8/4, light grey 7.5 Y 7/2) with the exception of 2 not fully developed roots that exhibit a darker, greyish colour (black 10 YR 2/1 and brownish grey 10 YR 4/1). On Scla 4A-3 the dark colour covers the entire root while on Scla 4A-6 only the apical part of the root is covered (Figure 3).

The 16th isolated tooth, the crown of the permanent maxillary right third molar (Scla 4A-8), exhibits a dull yellow orange tint (10 YR 6/4), probably due to the fact that it was not yet erupted and still inside the hemimandible (Scla 4A-9) at the time of death. Because of its unique colour in comparison to the other 15, Scla 4A-8 was excluded from this study. The crown of the permanent mandibular right third molar is still included in the right hemimandible Scla 4A-1. This crown is visible within the alveolus and has the same colour as Scla 4A-8.

Four other in situ erupted teeth were within the alveoli of the 2 hemimandibles at the time of discovery. The original colour of the enamel of the M_1 and M_2 of hemimandible Scla 4A-1 is very similar to the 15 isolated teeth that were previously described. However, the colour of the permanent mandibular left first and second molars, still in situ in the hemimandible Scla 4A-9, is completely different. Their crowns exhibit dull yellow orange enamel (10 YR 7/4) and are full of microcracks, in which a blue-black substance has precipitated (possibly manganese). If a definite sedimentary context gives the bones and teeth within it a homogeneous taphonomic signature (as proposed in the introduction), Scla 4A-9 was not present within the same sediment as Scla 4A-1 during its diagenesis.

3.2. Planimetry and stratigraphy of the juvenile Neandertal

The remains of the Scladina Neandertal child were spread throughout different layers of Sedimentary Complex 4A over quite a large horizontal area. The understanding of the stratigraphic (see Chapter 3) and planimetric context of the isolated teeth and fragments of mandible and maxilla is therefore very important in deciphering their unique taphonomic histories.

3.2.1. Stratigraphy

Current stratigraphic information indicates that the Neandertal remains came from layers that were deposited after the Stalagmitic Floor CC4 (units 4A-CHE and 4A-POC). The remains were at least in secondary position, either brought from outside the cave or reworked by the erosion of one or more sedimentary layers that were already present within the cave. Unit 4A-CHE has reworked sediment from at least 12 different layers from sedimentary units 6A, 5, 4B, and Complex 4A.

3.2.2. Spatial distribution

Currently, the excavated area of the Complex 4A is approximately 6 m wide by 40 m long (see Figure 2). No Neandertal remains have been discovered on the terrace or within the first 15 metres of the cave (i.e. before and including metre 25). The fossils were found beyond this area, from metre 26 to 38. The child's remains were distributed within the second half of the cave, along a narrow band included within a rectangle that is 6 m wide by 13 m long and subparallel to the cave's axis. That region dips gently towards the back of the cave, and seems to correspond to the course of the 4A-CHE gully. Inside the band, the fossils were organized in 3 groups:

- first, 10 teeth were concentrated on a small surface of 4 m² (F26, F27, G27, and H27), and are spread perpendicular to the long axis of the cave;
- second, the 2 mandibular fragments, the fragment of maxilla, and 2 isolated teeth were grouped in a rectangle that is 2.5 m × 2 m and in contact with the left wall of the cave (C28, C30, D29, and D30);
- third, 4 isolated teeth were found further in the cave, spread in 3 squares (C32, D34, E38), and in a zone from F35 to F37.

3.3. Comparative taphonomic study: the rest of the faunal remains

Six physical taphonomic criteria were selected for the study of the 597 faunal remains: colour, number of fractures, abrasion of fracture edges, bone surface state, the precipitation of manganese, and the precipitation of carbonate. The analysis of those attributes is synthesized in Table 1, where the Neandertal remains are indicated by a black triangle.

3.3.1. Colour

The analysis of bones has continuously indicated a distinctive dominant colour of objects from the same sedimentary layer, which is sometimes accompanied by variations of intensity. The objective of this study was to observe and record faunal remains from units 6A, 5, 4B, 4A-AP, 4A-IP, 4A-CHE, and 4A-POC that exhibit the typical colour of the Neandertal hemimandibles and maxilla. Therefore, all of the other colours not relevant to the Neandertal child, yet observed on the faunal remains, are not differentiated in Table 1 and are presented as 'other colour'.

The colours represented on the Neandertal fossils are extremely rare amongst the studied faunal remains. Only 16 bones (2.8%) could be used as comparisons for this study.

The greyish-green colour of the hemimandible Scla 4A-1 and the maxilla Scla 4A-2 (Figure 19) is totally absent in the material from units 6A and 5. Layer 4B-UN has yielded 2 bones that exhibit similar colouration: 1 metatarsal (Figure 19-a) and 1 cranial fragment (Figure 19-g). The most frequent similarities have been recorded in Complex 4A with 5 remains that have colours very similar to those of the Neandertal fossils: 1 pisiform from Layer 4A-KG (Figure 19-c); 1 fragment of a radius (Figure 19-h), 1 diaphyseal fragment (Figure 19-b), and 1 rib fragment (Figure 19-e) from Unit 4A-CHE; and 1 diaphyseal fragment from Layer 4A-GBL (Figure 19-i).

The orange colour, exhibited on hemimandible Scla 4A-9, is absent from the remains of Unit 6A. Higher in the stratigraphic sequence, the colour is present on 10 remains (Figure 20). They are distributed in layers 5-GRO (pisiform,

		Neandertal Fossils			Stratigraphical distribution of the studied faunal remains																
		4A 1	4A 2	4A 9	Layers cross-cut by the gully												Gully	Layers above the gully		
		Former Layer 4A			6A-			5-					4B-		4A-		4A-	4A-		
					YLO	GRV	YUP	GJAC	GBG	GRO	GBLA	GKBR	LI	UN	KG	OR	CHE	BO	LEG	GBL
	Number of fossils	1	1	1	11	29	39	15	9	7	30	19	9	39	91	11	213	33	7	35
Taphonomic criteria: Colour	greyish-green	▲	▲		0%	0%	0%	0%	0%	0%	0%	0%	0%	5%	1%	0%	1.5%	0%	0%	3%
	orange			▲	0%	0%	0%	0%	0%	14%	3%	0%	0%	0%	3%	9%	1%	3%	0%	
	other				100%	100%	100%	100%	100%	86%	97%	100%	100%	95%	96%	91%	97.5%	97%	100%	97%
Fractures	none				36%	10%	36%	27%	22%	29%	33%	21%	56%	29%	42%	27%	38%	9%	0%	11%
	1	▲			10%	38%	20%	7%	67%	43%	10%	11%	22%	16%	12%	0%	18%	21%	86%	17%
	2			▲	27%	45%	36%	13%	11%	14%	40%	26%	22%	37%	14%	18%	13%	9%	14%	31%
	>2		▲		27%	7%	8%	53%	0%	14%	17%	42%	0%	18%	32%	55%	31%	61%	0%	41%
Abrasion	none				18%	10%	5%	0%	0%	0%	0%	0%	11%	0%	13%	0%	8%	0%	0%	0%
	low	▲	▲	▲	64%	21%	51%	7%	22%	29%	13%	37%	33%	47.5%	66%	45%	48%	27%	14%	40%
	medium				9%	31%	36%	53%	78%	57%	57%	63%	56%	34%	19%	45%	33%	64%	43%	57%
	high				9%	38%	8%	40%	0%	14%	30%	0%	0%	18.5%	2%	10%	11%	9%	43%	3%
Lustre	high	▲	▲		0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0.9%	0%	0%	2.8%
	matte			▲	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	99.1%	100%	100%	97.2%
Manganese	none/very few spots	▲	▲		0%	7%	0%	0%	0%	0%	0%	0%	0%	13%	1%	0%	26%	3%	71%	17%
	regular spots			▲	0%	3%	10%	0%	0%	0%	0%	5%	15%	5%	84%	27%	29%	64%	29%	34%
	large spots				100%	76%	85%	100%	100%	86%	97%	95%	48%	71%	13%	73%	38%	12%	0%	23%
	total cover				0%	14%	5%	0%	0%	14%	3%	0%	37%	11%	2%	0%	7%	21%	0%	26%
Calcite	none	▲	▲	▲	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	99%	91%	95.3%	100%	57%	100%
	present				0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	1%	9%	4.7%	0%	43%	0%

Table 1: Table of the taphonomic results. Six taphonomic criteria have been taken into account. The Neandertal fossils are marked by a black triangle. Important criteria are highlighted in grey.

Figure 19: The greyish-green colour of the right hemimandible Scla 4A-1 (f) and the maxilla Scla 4A-2 (d) among 7 faunal remains (scale 1:1).

	Taxon	Segment	Inventory Nº	Figure
4A-GBL	?	Splinter	Sc 2006-341-1	**19-i**
4A-CHE	Unidentified Herbivore	Rib fragment	Sc 2007-668-2	**19-e**
4A-CHE	?	Diaphysis fragment	Sc 2007-122-3	**19-b**
4A-CHE	*Rupicapra rupicapra*	Proximal radius fragment	Sc 2004-678-1	**19-h**
4A-KG	*Ursus spelaeus*	Pisiform	Sc 2006-416-2	**19-c**
4B-UN	*Ursus spelaeus*	Juvenile cranium fragment	Sc 2006-477-3	**19-g**
4B-UN	*Ursus spelaeus*	3rd metatarsal	Sc 2004-185-1	**19-a**

	Taxon	Segment	Inventory Nº	Figure
4A-GBL	?	Splinter	Sc 2006-341-1	**20-k**
4A-BO	*Ursus spelaeus*	Patella	Sc 2006-497-3	**20-i**
4A-CHE	*Ursus spelaeus*	2nd phalanx	Sc 1996-26-12	**20-d**
4A-CHE	?	Hemimandible fragment	Sc 2006-510-1	**20-a**
4A-OR	*Dama dama*	2nd phalanx	Sc 2006-330-1	**20-f**
4A-KG	*Ursus spelaeus*	Ulnar fragment	Sc 2006-370-8	**20-b**
4A-KG	?	Rib fragment	Sc 2006-506-4	**20-j**
4A-KG	*Ursus spelaeus*	Thoracic vertebra	Sc 2006-511-1	**20-c**
5-GBLA	*Ursus spelaeus*	Cranium fragment	Sc 2008-409-23	**20-g**
5-GRO	*Ursus spelaeus*	Pisiform	Sc 2008-156-1	**20-h**

Figure 20: The orange colour of the hemimandible Scla 4A-9 (e) among 10 faunal remains (scale 1:1).

Figure 20-h), 5-GBLA (cranial fragment, Figure 20-g), 4A-KG (thoracic vertebra, Figure 20-c ; rib fragment, Figure 20-j ; ulnar fragment, Figure 20-b), 4A-OR (phalanx, Figure 20-f), 4A-CHE (hemimandible fragment, Figure 20-a ; phalanx, Figure 20-d), 4A-BO (patella, Figure 20-i), and 4A-GBL (diaphyseal fragment, Figure 20-k). However, of these bones, 4 are more similar than the rest. These bones are from layers 4A-KG (thoracic vertebra, Figure 20-c), 4A-OR (phalanx, Figure 20-f), and 4A-CHE (hemimandible fragment, Figure 20-a ; phalanx, Figure 20-d). One of the last two bones listed from 4A-CHE (above) is a 2nd phalanx of *Ursus spelaeus* (Sc 1996-26-12 ; Figure 20-d) that has a nearly identical colour to the Neandertal hemimandible Scla 4A-9 and was found approximately 20 cm from Scla 4A-9. The phalanx was exhumed in 1996 before the stratigraphic revision; but by observing numerous pictures, it has been clearly attributed to 4A-CHE.

The rarity of comparable objects has negative implications on the viability of a statistical approach to this study. Regardless, nearly perfect matches based on colour have been made between the Neandertal fossils and faunal remains which permitted the determination that the hominid fossils are most similar to objects from Sedimentary Complex 4A.

Among the 597 osseous remains, only one diaphyseal fragment (Sc 2006-341-1) from Layer 4A-GBL exhibits the two different colours discussed previously on the same object. The cortical surface is light orange in colour (Figure 21), which is similar to hemimandible Scla 4A-9. A band on the middle part of the cortex is greyish-green in colour and highly lustrous, which is very similar to hemimandible Scla 4A-1. This greyish-green area appears to be superimposed over the orange, which is possibly due to the object being subjected to multiple sedimentary environments. The specific mechanism(s) that would cause a single object to exhibit two different colours and lustres inside Unit 4A-POC are currently unknown and could be the subject of a future analysis.

3.3.2. Number of fractures

The depositional mode of sediment has unavoidable impacts on the preservation state of material within it. Therefore, Layer 4B-LI, constituted by alternating lithofacies of silt and clay caused by decantation (low energy) contains the highest

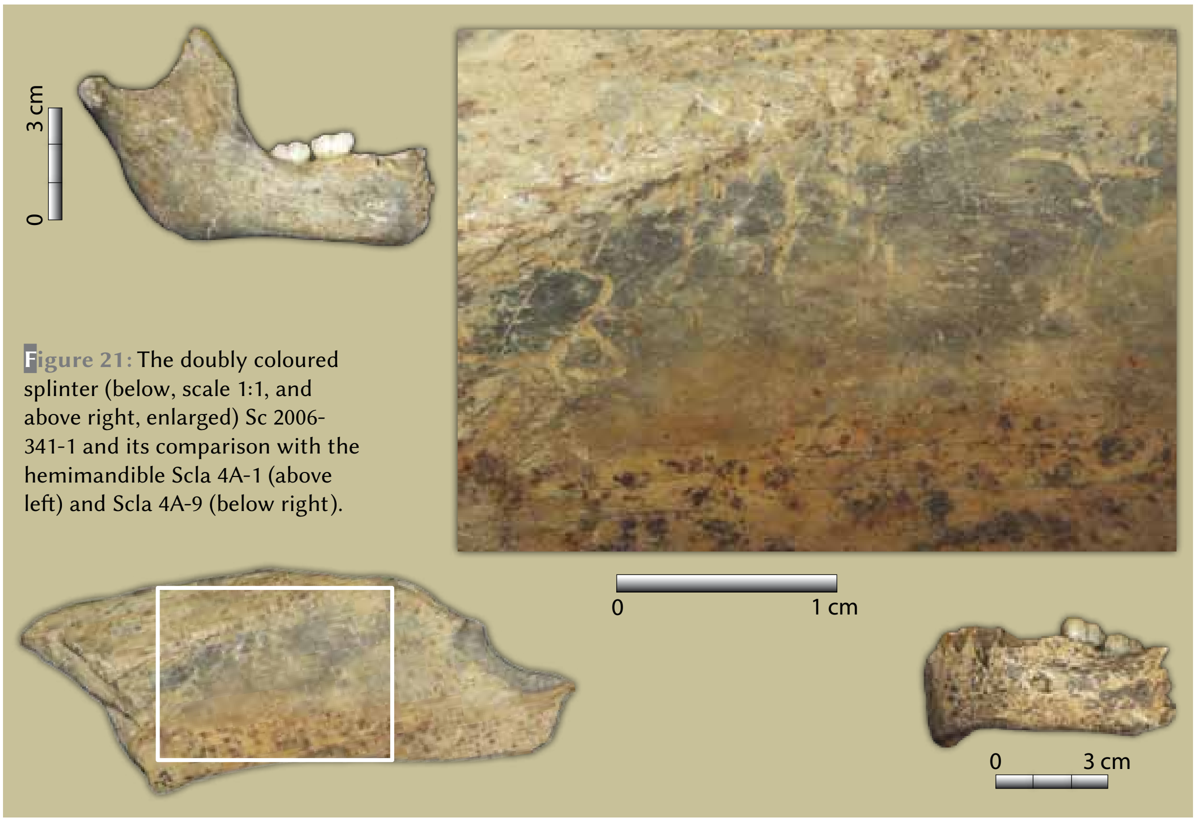


Figure 21: The doubly coloured splinter (below, scale 1:1, and above right, enlarged) Sc 2006-341-1 and its comparison with the hemimandible Scla 4A-1 (above left) and Scla 4A-9 (below right).

frequency of intact bones (56%). The stratigraphic distribution of the objects according to the number of fractures per bone demonstrates an increased amount of alteration as they were reworked upwards through the sedimentary sequence from Layer 4A-KG to Unit 4A-CHE. For example, the number of completely intact bones differs between the two layers: 42% intact bones in 4A-KG, compared to 38% in 4A-CHE. This observation is accompanied by only 12% of the bones from 4A-KG exhibiting 1 fracture, compared to 18% in 4A-CHE.

The number of fractures per object varies between the 3 osseous fragments of the Neandertal child: Scla 4A-1 has 1 fracture, Scla 4A-9 has 2 fractures, and Scla 4A-2 has at least 3 fractures. Therefore, their dispersion in the 3 categories allows them to be attributed to any of the studied layers since they are comparable to every object which renders this method as not useful for this study.

3.3.3. Abrasion of fracture edges

The low degree of edge abrasion ('low' category; Table 1) that categorizes the 3 osseous fragments of the Neandertal child is a characteristic that is also present on a large number of faunal remains, constituting the major tendency for 5 faunal assemblages: 6A-YLO, 6A-YUP, 4B-UN, 4A-KG, and 4A-CHE. The remains from the other studied layers show a globally higher degree of abrasion and, therefore, are not comparable to the Neandertal child.

3.3.4. The state of the cortex

Climatic agents affect bones that are shallowly buried or in direct contact with the atmosphere. This effect is also known as "weathering" (Behrensmeyer, 1978). The process begins by longitudinal followed by transversal cracking, the intensity of which varies based on the bone density, the age of the individual, the fragmentation of the bone before the weathering began, the degree of fossilization, etc. (Guadelli & Ozouf, 1994; Guadelli, 2008; Mallye et al., 2009). In some extreme cases, lengthy exposure of bones to these processes can lead to the formation of long rectangular prism-shaped fragments (state 4) that can eventually lead to the complete fragmentation of the object. Furthermore, during a prolonged exposure to the sun the bone cortex can become white to greyish-white (Figure 22).

Some of these attributes were observed in the material studied; however, they were only minimally visible on the Neandertal remains. Among the hominid bones, only the left hemimandible Scla 4A-9 has cortex cracking comparable to weathering stage 1 (Behrensmeyer, 1978), which includes longitudinal cracking parallel to the fibrous bone structure, accompanied by thin transversal cracking. Scla 4A-1 and Scla 4A-2 exhibit very light superficial cracking that is between stages 0 and 1 of Behrensmeyer (1978). Nearly all the faunal remains of Scladina are also between these two stages of weathering. This attribute is not useful for this study and is not included in Table 1.

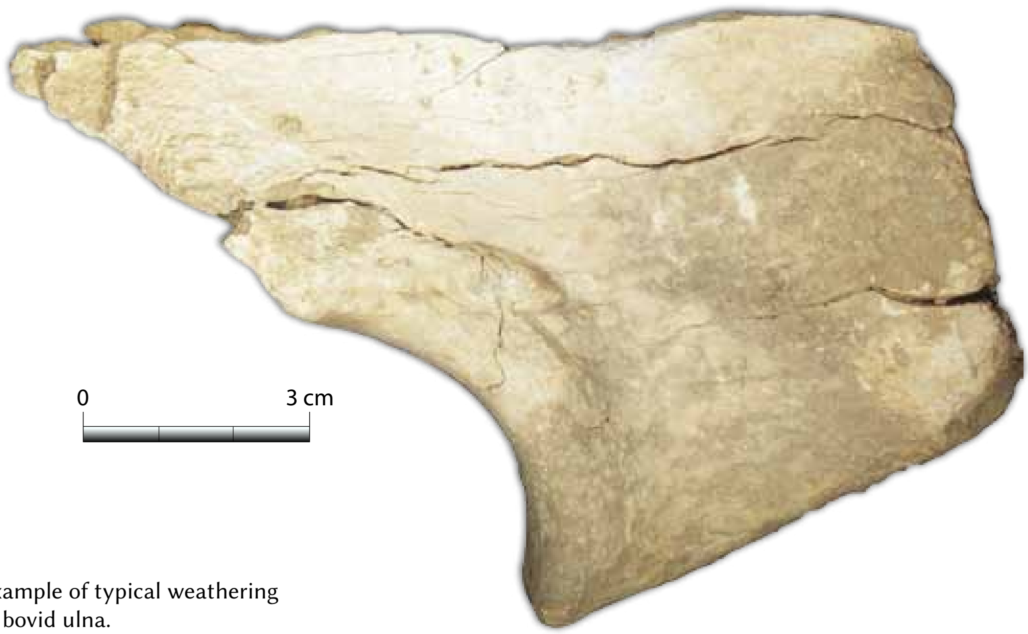


Figure 22: An example of typical weathering marks on a large bovid ulna.

Furthermore, the fossils Scla 4A-1 and Scla 4A-2 both have very highly lustrous surfaces. This is a very rare trait for bones used in this study and is only visible on 3 bones (0.5%). This characteristic can be the result of chemical processes as well as physical processes, such as run-off. A highly lustrous surface is often accompanied with slightly dulled fractured edges (Lenoble, 2005: 106) and this characteristic is also exhibited on these 2 Neandertal remains. Unfortunately, these 2 fossils were traditionally cast which possibly artificially changed the lustre of the objects.

3.3.5. Manganese deposits

The origin of the manganese in the sediment must be assessed carefully and may possibly result from the percolation of rainwater through the limestone; from the deterioration of organic material in the sediment; and from bacterial or fungal activity, the intensity of which is dependant on the hygrothermic conditions as well as pH (Marín Arroyo et al., 2008). The precipitation of manganese on objects must be used with care in the determination of the homogeneity of the collection. In some layers, large spots of manganese covering the faunal material from sedimentary units 6A, 5, and 4B constitute a viable taphonomic characteristic of the bones from those units. However, the Neandertal remains do not exhibit this trait.

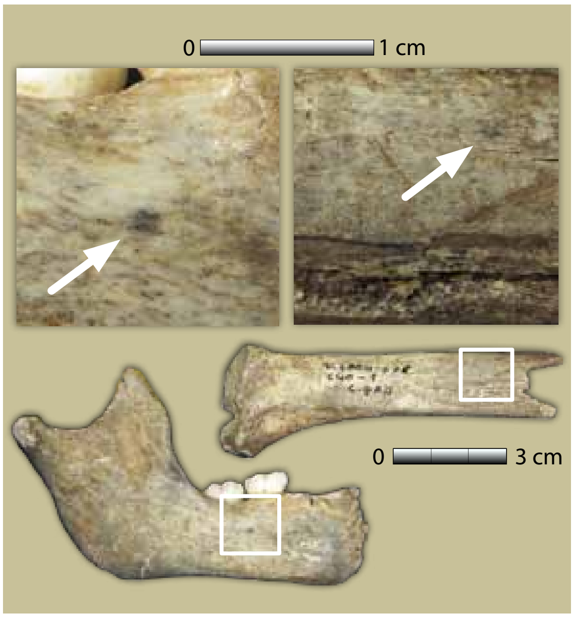


Figure 23: The tiny light grey spots on Scla 4A-1 (left) compared with the *Ursus spelaeus* proximal radius fragment Sc 2004-678-1 (right).

On the contrary, in Layer 4A-KG, manganese variably affects bones. This variable effect is directly linked with the unit's relationship to Speleothem CC4. Often, the remains directly beneath CC4 do not have any trace of manganese while those not protected by the speleothem are affected by manganese. The 91 bones and fragments from 4A-KG of this study do not show any manganese (1%) or exhibit regular spots (84%), large spots (13%), or are sometimes completely covered (2%). This observation allows for the interpretation that the precipitation of manganese occurred after the formation of the speleothem.

The hemimandible Scla 4A-9 has regular spots of manganese (Figures 6 & 20). Through the stratigraphic sequence, bones that exhibit the same trait are very rare or absent in the 8 layers of units 6A and 5. However, the regular spots are frequently found on the faunal remains from units 4A-CHE and 4A-POC. The largest number are found in Layer 4A-KG (Table 1; 84%), which authorises a strong comparison to Scla 4A-9. The spots were determined to be manganese by SEM (scanning electron microscopy), coupled to EDS (Energy-dispersive X-ray Spectroscopy) which was done (by Christian Burlet, Geological Survey of Belgium, Royal Belgian Institute of Natural Sciences) on the 2nd phalanx of *Ursus spelaeus* (Sc 1996-26-12; Figure 20-d) from Unit 4A-CHE.

The fossils Scla 4A-1 and Scla 4A-2 have tiny dark grey spots (Figure 23) that could correspond to the remnants of precipitated manganese. This attribute is strongly associated with the highly lustrous cortical surfaces commented on previously. That peculiar combination is extremely rare and is evident on only 3 faunal remains from units 4A-CHE and 4A-POC (Sc 2004-678-1, Figure 19-h; Sc 2007-668-2, Figure 19-e; Sc 2006-341-1, Figure 19-i).

3.3.6. Carbonate deposits

Although the deposition of carbonates on bone is very rare among the studied faunal remains (15 out of 597 pieces, or 2.5%), their presence is very stratigraphically significant. Only layers that are superimposed by a stalagmitic floor (e.g. 4A-KG, 4A-OR, both covered by Speleothem CC4) and layers that reworked them (e.g. layers within units 4A-CHE and 4A-POC) have yielded some remains that are partially covered by carbonates. This observation, however, has little statistical value and, because there are no carbonate deposits on the Neandertal remains, is not useful for this study.

3.4. Comparative study between the isolated teeth of the Neandertal child and *Ursus* from Sedimentary Complex 4A

Fifteen isolated teeth from the Neandertal child have a crown with light grey enamel as well as a white-yellow root. This colour combination, corresponding to the original colour of a tooth in vivo, characterizes 30.6% (92 out of 300) of the bear teeth from Sedimentary Complex 4A. However, this combination is nearly absent from the teeth collected from Unit 5.

Within Complex 4A, a second study on the same 300 *Ursus spelaeus* incisors was conducted to determine if the unique colour combination was typical of a specific sedimentary unit or units. Of the sample, 52 teeth were excavated through microstratigraphy and 248 were attributed to units 4A-AP, 4A-CHE, or 4A-POC.

The results of the study of the bear teeth indicate that 66.3% of the teeth with this colour combination originate from Unit 4A-POC (61 out of 92 pieces), 16.3% from Unit 4A-CHE (15 out of 92 pieces), and 17.4% from Unit 4A-AP (16 out of 92 pieces). The fact that most of the teeth with the same characteristics as the Neandertal child teeth came from 4A-POC is demonstrated by the comparison of the inferior Neandertal incisor Scla 4A-19 to 26 *Ursus spelaeus* teeth that were excavated from the same square (D34) and Unit 4A-POC (Figure 24).

This step of the analysis attributes the isolated teeth of the Neandertal child to Unit 4A-POC; however, this suggestion must be considered with prudence.

Figure 24: In Unit 4A-POC, Square D34, the 26 *Ursus spelaeus* teeth and fragments of teeth show the same stage of abrasion and the original colour as the permanent mandibular left central incisor Scla 4A-19 (center) of the child.

3.5. Synthesis

The state of preservation of the Neandertal fossils is exceptional and only a small number of similarities are found among the faunal remains from the sedimentary units analysed in this study. However, this comparative taphonomic analysis provides evidence for 7 main taphonomic characteristics (Table 2):

1 the greyish-green and orange colours of the Neandertal mandibular fragments have been observed on 9 remains from layers 5-GRO and 5-GBLA (Unit 5), Layer 4B-UN (Unit 4B), Layer 4A-KG (Unit 4A-AP), Layer 4A-OR (Unit 4A-IP), Layer 4A-GBL (Unit 4A-POC), as well as from layers of Unit 4A-CHE;
2 the small degree of abrasion observed on the hominid remains is primarily present on the fauna from layers 6A-YLO and 6A-YUP (Unit 6A), Layer 4B-UN (Unit 4B), Layer 4A-KG (Unit 4A-AP), as well as from Unit 4A-CHE;
3 the highly lustrous surface is only present on 3 remains from Layer 4A-GBL (Unit 4A-POC) as well as Unit 4A-CHE;
4 the manganese spots typical of Scla 4A-9 are present on the fauna from Layer 4A-KG (Unit 4A-AP), Layer 4A-OR (Unit 4A-IP), layers 4A-BO, 4A-LEG and 4A-GBL (Unit 4A-POC), as well as the layers from Unit 4A-CHE;
5 the tiny dark grey remnants of spots are present only on 3 remains from Layer 4A-GBL (Unit 4A-POC) as well as those from Unit 4A-CHE;
6 the large spots of manganese are frequent on remains from the units 6A, 5, and 4B, and the Neandertal does not exhibit these;
7 the original colour recorded on the enamel and roots of the teeth are mainly present in the layers of the Unit 4A-POC.

Finally, when integrating all the taphonomic characteristics, the faunal remains from the units within the Complex 4A share the most similarities with the Neandertal remains (Table 2). Beyond this, when all of the physical taphonomic attributes are combined, sedimentary units 4A-CHE and 4A-POC have yielded most of the bones and teeth that have the strongest correlation to the Neandertal child. This correlation is in harmony with a stratigraphic analysis (see Chapter 5) that attributed, when possible, some of the bone fragments to the Unit 4A-CHE and some of the isolated teeth to Unit 4A-POC. Among the layers that were deposited before the gully, the objects from Layer 4A-KG have the most taphonomic similarities to the Neandertal child.

4. Discussion: how to interpret the presence of the Scladina Neandertal remains

4.1. Highly preserved hominid remains

The cause of death of the Scladina Child is still unknown. No antemortem or perimortem traces, such as pathological stigma, wounds due to human actions, or carnivore predation are present on the remains.

Some observable postmortem traces are present on the fossils. The cortices of the three

Stratigraphic distribution of the taphonomic criteria observed on faunal remains		Layers cross-cut by the gully												Gully	Superimposing		
		6A-			5-					4B-		4A-AP		4A-CHE	4A-POC		
Bone		YLO	GRV	YUP	GJAC	GBG	GRO	GBLA	GKBR	LI	UN	KG	OR	CHE	BO	LEG	GBL
Colour	greyish-green																
	orange																
Abrasion	low																
Lustre	high																
Manganese	very few spots																
	regular spots																
Isolated teeth																	
Colour	original																

Table 2: Synthesis of the stratigraphic distribution of faunal remains that exhibit the same taphonomic properties as the Neandertal child remains (grey backgrounds). Note that the majority are from Sedimentary Complex 4A (4A-POC and 4A-CHE; black borders).

osseous elements of the child exhibit thin cracks that are the first effects of weathering. Only the left hemimandible Scla 4A-9 has sufficent cracking to be attributed to stage 1 of Behrensmeyer (1978). Weathering can equally affect objects in direct contact with the atmosphere as well as those shallowly buried. However, the remains of the Neandertal child do not exhibit evidence of long exposure to the sun, as they have not been bleached white. If the bones experienced any exposure to the atmosphere, that exposure was necessarily short and may have occurred within the protective environment of the cave.

The break under the alveolus of the right inferior canine, which has separated the two hemimandibles, is a 'green bone' fracture (Figure 11). The presence of a small area of peeling on Scla 4A-9, on the inner side of the break between the two parts of the mandible, is an additional indicator that the breakage occurred on wet or fresh bone (stage 1 of Krovitz & Shipman, 2007), so probably not long after death.

The only possible cut mark observed on Scla 4A-1 is questionable because the position of the mark is quite unusual. Removing the tongue should have created other marks, which are not present. This mark is very close to trampling marks (Behrensmeyer et al., 1986; Domínguez-Rodrigo et al., 2009), which could have been made during the reworking of the right hemimandible by sedimentary processes.

4.2. No fossil in primary spatial position

The mode of the first incorporation of the child in the sediments is currently unknown. The fossils are not in primary spatial position. Since the child died, most teeth were lost postmortem, possibly when the bones were on the surface. The spatial distribution of the remains as well as post-depositional rounding of the right condyle and the absence of the left ramus are all indications of displacement after deposition.

The study of the stratigraphic data that are available for the osseous Neandertal remains further suggests their attribution to the gully of Unit 4A-CHE. The sediment that filled the gully most likely originated from the terrace and the entrance to the cave. The presence of numerous calcite fragments throughout the sediment of the gully is explained by the dismantling of Speleothem CC4 during the event that formed the gully. Therefore, the depositional dynamics had to be high energy enough to destroy the stalagmitic floor, unavoidably affecting the sediment and objects in its path. The reworking and incorporation of the formerly deposited sediment of at least units 6A, 5, 4B, 4A-AP, and 4A-IP provide an explanation for the taphonomic heterogeneity of 4A-CHE.

At the time the child was deposited, at least 20 m separated the entrance (estimated to have been at metre 5) from the location at which the closest fossil was found (metre 26). The spatial distribution of the child's remains does not reflect one reworking event but several successive events of varying intensities. The absence of hominid remains in the first 25 m from the edge of the terrace is possibly explained by an important erosional event, resulting in the 4A-CHE gully, that reworked the layer within or on which the child was deposited. A unique, high-energy erosional event across a large surface does not seem to be a likely candidate for explaining the stratigraphic distribution of the remains into 2 distinct sedimentary units (4A-CHE and 4A-POC) and their spatial distribution into the 3 separate areas of concentration. Furthermore, a powerful erosional event over the long distance of 25 m would unavoidably damage material within it; however, the Neandertal remains are well preserved. The isolated teeth are nearly unaltered, the 2 hemimandibles can be almost perfectly refitted, and on both the hemimandible and the maxilla the main evidence of erosion is only on the alveolar margins. This observation suggests the remains were successively reworked a small distance from their original location by low energy processes. The economical hypothesis is the Neandertal remains were reworked several times from a zone at the entrance of the cave (between the porch and metre 25) and were then buried relatively quickly deeper into the cave.

4.3. The taphonomic message

The taphonomic study of the Neandertal child's remains and their comparison to faunal remains provided information as to whether the hominid fossils were deposited before (e.g. in units 6A, 5, 4B, 4A-AP or 4A-IP) or contemporaneously with the gully.

No evidence permits the attestation of the presence of the fossils in the cave before the event(s) that created the gully.

The taphonomic incompatibility of the fossils with sedimentary units 6A, 5, and 4B is clear when large spots of manganese are observed in high frequency on the objects. This argument is based on the hypothesis that this type of deposit cannot be easily removed.

The differential alteration between the 2 hemimandibles seems to refute Layer 4A-KG as the origin of the objects even though the bone colour and the peculiar deposition of regular spots of manganese are similar between objects from this layer and Scla 4A-9. In fact, Layer 4A-KG and its numerous fossils were protected for several thousands of years by Speleothem CC4, as the thickness of CC4 often reaches 30 cm and can support stalagmites up to 1 m high. The resulting lengthy interment of bones within Layer 4A-KG should have resulted in an intense and uniform alteration of all the osseous elements of the Neandertal child, as has been observed for nearly all the cave bear remains exhumed from it.

The differential alteration of the 2 hemimandibles seems to be a consequence of their interment in different sediments from the beginning of the process and for a long period of time afterward. After this process is complete, a total and radical change of colour is difficult to imagine; the current understanding is only fracturing, surface alteration, and abrasion of edges can be superimposed over the background colour. That hypothesis is based on the concept that the colour exhibited by the fossil and its manganese staining, initially acquired in its primary sedimentary context, are not easily removed, which is reinforced by all the observations made on all the bones throughout the stratigraphy of Scladina since 2005.

According to the evidence provided above, the Neandertal remains were not yet fossilized when they were distributed into the different sedimentary contexts from which they were collected. This scenario would relatively date the fossils to approximately contemporaneous with the event that created the gully.

4.4. The sequence of events

The taphonomic observations do not provide a complete explanation as to why the Neandertal remains were discovered in Scladina. Beyond the fact the objects themselves were not anthropogenically altered, the reworked sedimentary environment in which the fossils were found has erased any potential evidence of anthropogenic structures (e.g. those caused by ritual activity, burials, etc.). However, the fresh state of preservation of the remains when they entered the cave, their spatial and stratigraphic distribution, and their differential alteration all authorize the proposition of a sequence of events. The proposition is the partial or complete body of the child entered the cave when the bones were not yet fossilized. Sedimentary processes linked to the gully most likely caused the separation of the 2 hemimandibles, as the causal fracture exhibits the characteristic peeling of green bones. The low degree of weathering augments this hypothesis; the remains did not have a long direct exposure to the atmosphere nor were they shallowly buried for a long period of time. No proof that the gully-creating mechanisms were what brought the maxilla and mandible into the cave has been discovered; however, the processes that created the gully are known to be responsible for the initial reworking of the bones, likely for fracturing them, and for their dispersal into different layers within Unit 4A-CHE and in superimposing layers in Unit 4A-POC. The child's remains were distributed in several different sedimentary layers that have differentially altered the bones. A proposed succession of events follows.

Stage 0: Layer 4A-KG was deposited. During its deposition, numerous cave bear remains were incorporated in the sediment. They were altered throughout the formation of Speleothem CC4 (directly superimposing 4A-KG) and in the process their colour changed. Evidence for their alteration at this time was provided by the taphonomic study of the remains from the gully (4A-CHE); in fact, numerous bones exhibiting the characteristic colour of remains from 4A-KG were found in Unit 4A-CHE, suggesting that 4A-KG was heavily reworked by the processes that formed the gully.

As of now, according to what has been observed, both stratigraphy and taphonomy do not suggest that the Neandertal remains were present in the cave at that stage.

After the formation of Speleothem CC4, a cryosol developed that is evidence of a phase of deep-freezing, and affected the sediment below the speleothem, including 4A-OR, 4A-KG, and up to the summit of 4B-LI (see Chapter 3).

Stage 1: The processes of the gully caused an important erosional event that included the partial destruction of Speleothem CC4. This event was probably linked to the degradation of the cryosol. This erosional event was followed by phases of erosion and/or sedimentation producing the several layers that constitute Unit 4A-CHE. These layers appear to be responsible for the reworking of the Neandertal remains in the cave. The fossils are well preserved (e.g. there is low abrasion on the fractured edges of the bones) which demonstrates that some of the phases of erosion and/or sedimentation were low energy, although some must have been high energy in order to have fragmented some of Speleothem CC4. The fact that excavation has yet to yield any postcranial elements of the child does not preclude their presence within the cave.

The processes that formed the gully probably broke the mandible while it was still fresh (hence the green bone fracture and peeling). At this time, the possibility exists that the teeth were already disarticulated from both the mandible and the maxilla. Regardless, the cranium and mandible were not on the surface for a long period of time (limited effects of weathering and no evidence of necrophagy). This disarticulation logically occurred in the first 25 metres of the cave, due to the gully's course (see Chapters 3 & 5).

Some erosion/sedimentation phases of the gully (Unit 4A-CHE) could have successively reworked the bone fragments and some isolated teeth:

- a phase of sedimentation transported and deposited hemimandible Scla 4A-1 in Square D29 in one of the 4A-GX lithofacies and maybe also the fragment of maxilla Scla 4A-2 in Square D30;
- a similar process could have deposited the hemimandible Scla 4A-9 in one of the 4A-JA lithofacies, but its stratigraphic context is less secure (see Chapter 5).

Stage 2: After 4A-CHE was deposited, the layers of Unit 4A-POC covered it. Where 4A-CHE is not present 4A-POC directly superimposed Speleothem CC4. Some isolated teeth were reworked from 4A-CHE into 4A-POC:

- a depositional event that is attributable to Layer 4A-BO transported and deposited the tooth Scla 4A-4 (and maybe also Scla 4A-3) in Square C30;
- another event, probably related to 4A-POC (see Chapter 5), transported and deposited 10 teeth in squares F26, F27, G27, and H27, closer to the cave entrance than the bones;
- one or several events distributed 4 teeth in squares C32, D34, E38, further in the cave and in a zone between F35 and F37; one tooth was related to Layer 4A-LEG (E38, see Chapter 5), the others were probably from 4A-POC.

Except for the sedimentation phase that deposited Layer 4A-BO, which is the first in the sequence of Unit 4A-POC, the establishment of a chronological order for the several phases of reworking (stated above) that redistributed the 16 isolated teeth is nearly impossible.

The taphonomic study does not allow for the temporal evaluation of the separation between the reworking phenomena of the gully (Unit 4A-CHE ; stage 1) and those of 4A-POC (stage 2). No variability of preservation is observed between the molars still articulated with hemimandible Scla 4A-1 (deposited in the gully ; stage 1) and the 15 isolated teeth (mostly attributed to Unit 4A-POC; stage 2). Even though some information suggests that these objects remained in their respective sedimentary contexts for at least 85,000 years (see Chapter 5), all of these 15 teeth have maintained their original colour.

Stage 3: From this time, the fossils that were deposited within at least 4 different sedimentary environments (2 different layers of 4A-CHE and at least 2 layers of 4A-POC) were affected by differential alteration and generated the taphonomic variability recorded in this study.

The different sedimentation phases of 4A-CHE seem to have incorporated a large quantity of remains (mainly *Ursus spelaeus*) by the erosion of previously deposited layers. So those bones, already fossilized at the time of their reworking, exhibited their specific taphonomic signature. The best example of this is the taphonomic variability of the fauna inside the gully. On the contrary, the 2 Neandertal hemimandibles, which exhibit 2 different taphonomic signatures, appear to not have been fossilized at the time that they were reworked, suggesting their possible contemporaneity to the deposition of 4A-CHE. After the breakage and reworking of the mandible, and deposition of the various elements in different sediments, the still fresh bone fragments obtained the typical taphonomic signatures of their respective sedimentary contexts.

Based on this proposed scenario, the age of the Neandertal remains is the same as the gully (4A-CHE), which was deposited during the Weichselian Early Glacial and most likely during the second part (see Chapter 5).

5. Conclusions

Although detailed taphonomic descriptions of hominid remains are frequent in the palaeoanthropological literature, few, if any, are compared to stratigraphically contemporaneous fauna. This comparison is only possible if all of the remains are precisely excavated by stratigraphy at the scale of individual sedimentary layers, rather than just the sedimentary unit or complex. This type of study was possible at Scladina because the excavation has been conducted with rigorous stratigraphic control for approximately the last decade. Since then, 1,500 faunal remains have been exhumed, some of which have provided interesting comparisons to the hominid remains. The observation of the taphonomic attributes that are associated to sedimentary dynamics has allowed for the construction of several stages of a complicated depositional history of the Neandertal child, from the first reworking of the hominid remains in the cave until their discovery by archaeologists.

Only a small part of the maxilla has been found so far. This fossil, however, articulates perfectly with the right hemimandible. As no traces of carnivore damage were present on the fossils to support the idea that only the mandible with a small part of the cranium was brought into the cave, the suggestion that at least the entire skull, if not the whole individual, was present seems reasonable. This infers that the possibility still exists for other stimulating palaeoanthropological discoveries to be made at Scladina.

Since the hominid remains were discovered on both sides of the transversal berm B-H 31 (Figure 2) that separates the excavation zones, the presence of other cranial elements or dentition in the berm, which was left for stratigraphic reference, remains a possibility. However, leaving this berm of sediment unexcavated is strategic because the profiles provided by the berm are the only ones still present that document the dimensions of the gully (4A-CHE) in which the Neandertal remains were found. Without these sections, the depositional dynamics of this structure could not be as well understood.

However, stratigraphic analysis allowed the tracking of the gully and the retention of information about where the gully and the layers of Unit 4A-POC are still present in the cave. The gully is divided into two branches, separated by Speleothem CC4 (see Chapter 5, Figure 9). According to the studied sections, the area where the gully was most erosive is localized around Section 30/31 between G and H, where the gully contacts Unit 6A. This northern branch of the gully has not yet been fully excavated beyond metre 30, and has only been reached on the longitudinal Section F/G 32 to 34 (Figure 2), where the erosion of previously deposited sediment and the frequency of reworked stalagmite fragments are high. The southern branch of the gully appears less erosive on sections 30/31 and 32/31 in B-C-D. Deeper in the cave the erosive capability of this left branch of the gully on previously deposited layers decreases (e.g. transversal Profile 41/42 between C and E). This decrease is also exhibited on Section 43/44 between C and E.

All in all, if any other hominid remains are yet to be unearthed, they will most likely be found in the unexcavated zone towards the northern part of the cave (currently located beyond the longitudinal profiles E/F 38 and F/G from 32 to 37) in sedimentary units 4A-CHE, 4A-POC, and 3-INF (see Chapter 5).

6. Annexes

The bones and teeth of the Scladina Child were sampled for different analyses, sometimes several times (see Chapters 8, 17 & 19). The alterations caused by these analyses are now part of the general conservation state of these fossils. The following list denotes the impacts of these alterations.

6.1. Moulding

Most of the fossils were moulded using silicon rubber by Michel Toussaint:

- Scla 4A-1, right hemimandible, 1993;
- Scla 4A-2, maxilla, 1994;
- all isolated teeth except Scla 4A-20.

Because of its fragility, the left part of the mandible (Scla 4A-9) was not moulded using the classic rubber technique but by creating a replica from micro-CT data.

6.2. Palaeodiet (C/N)

The right partial maxilla (Scla 4A-2) was sampled in 1996 by Hervé Bocherens, at Paris Jussieu (see Chapter 17).

6.3. DNA

The superior right M^1 (Scla 4A-4) had its buccal roots destroyed during sampling for DNA analysis in Münich by Svante Pääbo, in 1993. The test was not successful.

In 2001, a sample was taken from the root and the pulpar chamber of Scla 4A-13, the deciduous inferior right M_2, for mitochondrial DNA analysis (see Chapter 19).

In 2007, Johannes Krause, Ludovic Orlando (visitor), and Svante Pääbo at the Max Planck Institute in Leipzig attempted to get a sample for nuclear DNA using the interior of the superior right M^1 (Scla 4A-4) after it was cut for histological analysis (see 6.4). This attempt was not successful.

6.4. Histology

A histological thin section of the superior right M^1 (Scla 4A-4) was prepared in 2006 by Tanya Smith at the Max Planck Institute for Evolutionary Anthropology (Leipzig, Germany) to estimate the biological age of the Scladina Child. The tooth was sectioned with an annular saw and then embedded in methylmethacrylate resin. The tooth was then restored; less than 1.5 mm of the specimen's mesial-distal thickness is missing. In 2007, two other teeth (Scla 4A-6 and Scla 4A-11) were brought to the European Synchrotron Radiation Facility (ESRF) in Grenoble (France), in order to confirm results on the long-period lines periodicity obtained from the physical section of the molar. This technique facilitates non-destructive analysis of the dental microstructure loss (see details in Chapter 8).

6.5. Strontium

Sampling for strontium analysis is limited to a vertical, millimetre scale groove on the crown and one similar groove on the root of the selected teeth. These grooves are nearly invisible to the naked eye. Fourteen teeth have been affected by this procedure: Scla 4A-3, 4, 5, 6, 7, 8, 11, 12, 13, 14, 16, 18, 19, and 20. The sampling was done at the Max Planck Institute for Evolutionary Anthropology, Leipzig (Germany), under the control of Mike Richards and Christine Verna.

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References

Andrews P. & Fernández Jalvo Y., 1997. Surface modifications of the Sima de los Huesos fossil humans. *Journal of Human Evolution*, 33: 191–217.

Beauval C., Maureille B., Lacrampe-Cuyaubère F., Serre D., Peressinotto D., Bordes J.-G., Cochard D., Couchoud I., Dubrasquet D., Laroulandie V., Lenoble A., Mallye J.-B., Pasty S., Primault J., Rohland N., Pääbo S. & Trinkaus E., 2005. A late Neandertal femur from Les Rochers-de-Villeneuve, France. *Proceedings of the National Academy of Sciences of the United States of America*, 102, 20: 7085–7090.

Behrensmeyer A. K., 1978. Taphonomic and ecologic information from bone weathering. *Paleobiology*, 4, 2: 150–162.

Behrensmeyer A. K., Gordon K. D. & Yanagi G. T., 1986. Trampling as a cause of bone surface damage and pseudo-cutmarks. *Nature*, 319: 768–771.

Behrensmeyer A. K. & Hill A. P., 1980. *Fossils in the making. Vertebrate taphonomy and Paleoecology*, University of Chicago Press, Prehistoric Archeology and Ecology Series, 345 p.

Behrensmeyer A. K. & Kidwell S. M., 1985. Taphonomy's contributions to paleobiology. *Paleobiology*, 11: 105–119.

Behrensmeyer A. K., Kidwell S. M. & Gastaldo R. A., 2000. Taphonomy and paleobiology. *Paleobiology*, 26, 4 : 103–147.

Binford L. R., 1981. *Bones. Ancient men and modern myths*. Orlando, Academic Press, 320 p.

Blumenschine R. J., 1986. *Early Hominid Scavenging Opportunities: Implications of Carcass Availability in the Serengeti and Ngorongoro Ecosystems*. Oxford, British Archaeological Reports, International Series, 283: 163 p.

Bonjean D., Abrams G., Di Modica K. & Otte M., 2009. La microstratigraphie, une clé de lecture des remaniements sédimentaires successifs. Le cas de l'industrie moustérienne 1A de Scladina. *Notae Praehistoricae*, 29: 139–147.

Bonjean D., Toussaint M. & Otte M., 1997. Grotte Scladina (Sclayn, Belgique) : bilan des découvertes néandertaliennes et analyse du contexte. In J. Plumier (dir.), *Actes de la cinquième Journée d'Archéologie Namuroise*, Namur, Facultés universitaires Notre-Dame de la Paix, 22 février 1997, Ministère de la Région wallonne, Direction générale de l'Aménagement du Territoire, du Logement et du Patrimoine, Direction de Namur, Service des Fouilles: 19–27.

Boulestin B., 1999. *Approche taphonomique des restes humains. Le cas des Mésolithiques de la grotte des Perrats et le problème du cannibalisme en préhistoire récente européenne*. Oxford, British Archaeological Reports, International Series, 776, 276 p., 4 tables, 65 figures, 50 plates.

Brain C. K., 1981. *The Hunters or the Hunted? An Introduction to African Cave Taphonomy*. The University of Chicago Press, Chicago & London, 365 p.

Craig C. R., Knüsel C. J. & Carr G. C., 2005. Fragmentation, mutilation and dismemberment: an interpretation of human remains on Iron Age Sites. In M. K. Pearson & I. J. N. Thorpe (eds.), *Warfare, Violence and Slavery in Prehistory*, Oxford, British Archaeological Reports, International Series, 1374: 165–180.

Dart R. A., 1957. *The Osteodontokeratic Culture of Australopithecus Prometheus*. Pretoria, Transvaal Museum. Memoir N° 10, 105 p.

Deblaere C. & Gullentops F., 1986. *Lithostratigraphie de la grotte Scladina*. Bulletin de l'Association française pour l'étude du Quaternaire, 2e série, 25-26: 178–181.

Defleur A., White T., Valensi P., Slimak L. & Crégut-Bonnoure E., 1999. Neanderthal Cannibalism at Moula-Guercy, Ardèche, France. *Science*, 286, 5437: 128–131.

Delaunois É., 2010. *L'altération différentielle des vestiges en archéologie paléolithique. Contribution à l'établissement d'une clé de contrôle stratigraphique et d'homogénéité des collections. L'exemple des couches 4A de Scladina (Namur, Belgique).* Unpublished master thesis. Université de Liège, 2 vol., 95 & 110 p.

Delaunois É., Abrams G., Bonjean D., Di Modica K. & Pirson S., 2012. Altération différentielle des ossements de l'ensemble sédimentaire 4A de la grotte Scladina (Andenne, Belgique). *Notae Praehistoricae*, 32: 5-18.

Denys C., 2002. Taphonomy and experimentation. *Archaeometry*, 44: 469–484.

Domínguez-Rodrigo M., de Juana S., Galán A. B. & Rodríguez M., 2009. A new protocol to differentiate trampling marks from butchery cut marks. *Journal of Archaeological Science*, 36: 2643–2654.

Efremov I. A., 1940. Taphonomy: new branch of paleontology. *Pan-American Geologist*, 74: 81–93.

Frayer D. W., Orschiedt J., Cook J., Russell M.D. & Radovčić J., 2006. Krapina 3: Cut Marks and Ritual Behavior. *Periodicum Biologorum*, 108, 4: 519–524.

Grupe G., 2007. Taphonomy and Diagenetic Processes. In W. Henke & I. Tattersall (eds), *Handbook of Paleoanthropology, vol. I, Principles, methods and Approaches*, Berlin Heidelberg New-York, Springer-Verlag: 241–259.

Guadelli J.-L., 2008. La gélifraction des restes fauniques. Expérimentation et transfert au fossile. *Annales de Paléontologie*, 94: 121–165.

Guadelli J.-L. & Ozouf J.-C., 1994. Études expérimentales de l'action du gel sur les restes fauniques. Premiers résultats. In M. Patou-Mathis (ed.), *Outillage peu élaboré en os et en bois de Cervidés IV: taphonomie/bone modification*. Artefacts, 9: 47–56.

Gullentops F. & Deblaere C., 1992. Érosion et remplissage de la grotte Scladina. In Otte M. (ed.), *Recherches aux grottes de Sclayn, vol. 1: Le Contexte*. Études et Recherches Archéologiques de l'Université de Liège, 27: 9–31.

Haesaerts P., 1992. Les dépôts pléistocènes de la terrasse de la grotte Scladina à Sclayn (province de Namur, Belgique). In Otte M. (ed.), *Recherches aux grottes de Sclayn, vol. 1: Le Contexte*. Études et Recherches Archéologiques de l'Université de Liège, 27: 33–55.

Haglund W. D., 1992. Contributions of Rodents to Postmortem Artifacts of Bone and Soft Tissue. *Journal of Forensic Sciences*, 37, 6: 1459–1465.

Haglund W. D., 1997. Rodents and Human Remains. In W. D. Haglund, M. H. Sorg (dir.), *Forensic Taphonomy. The Postmortem Fate of Human Remains*. Boca Raton (Florida): CRC Press: 405–414.

Hill C. A., 1982. Origin of black deposits in caves. *National Speleological Society Bulletin*, 44: 15–19.

Knüsel C. J., 2005. The physical evidence of warfare-subtle stigma? In M. K. Pearson & I. J. N. Thorpe (eds.), *Warfare, Violence and Slavery in Prehistory*, Oxford, British Archaeological Reports, International Series, 1374: 49–65.

Krovitz G. E. & Shipman P., 2007. Taphonomy of Immature Hominid Skulls and the Taung, Mojokerto, and Herto Specimens. In

T. R. Pickering, K. Scick & N. Toth (eds.), *Breathing Life into Fossils : Taphonomic Studies in Honor of C.K. (Bob) Brain*. Gosport, Stone Age Institute Press, 2: 207–232.

Le Mort F., 1988. Le décharnement du cadavre chez les Néandertaliens : quelques exemples. In O. Bar-Yosef (ed.), *L'Homme de Néandertal, vol. 5. La Pensée*. Études et Recherches Archéologiques de l'Université de Liège, 32: 43–55.

Le Mort F., 1989. Traces de décharnement sur les ossements néandertaliens de Combe-Grenal (Dordogne). *Bulletin de la Société Préhistorique Française,* 86, 3: 79–87.

Lenoble A., 2005. *Ruissellement et formation des sites préhistoriques : référentiel actualistes et exemples d'application au fossile*, Oxford, British Archaeological Reports, International Series, 1363, 222 p.

López-González F., Grandal-d'Anglade A. & Vidal-Romani J. R., 2006. Deciphering bone depositional sequences in caves through the study of manganese coatings. *Journal of Archaeological Sciences*, 33 : 707–717.

Lyman L. R., 2001. *Vertebrate taphonomy*. Cambridge manuals in archaeology, 524 p.

Mallye J.-B., Costamagno S., Laroulandie V. & Beauval C., 2009. Impacts des processus périglaciaires sur la préservation des ossements. *Les Nouvelles de l'archéologie*, 118: 26–31.

Marín Arroyo A. B., Landete Ruiz M. D., Vidal Bernabeu G., Seva Román R., González Morales M. R. & Straus L. G., 2008. Archaeological implications of human-derived manganese coatings: a study of blackened bones in El Mirón Cave, Cantabrian Spain. *Journal of Archaeological Science*, 35 : 801–813.

Martin R. E., 1999. *Taphonomy. A process approach*. Cambridge University Press, 508 p.

Noe-Nygaard N., 1989. Man-made trace fossils on bones. *Human Evolution*, 4 : 461–491.

Ortner D. J. & Putschar W. G., 1985. *Identification of Pathological Conditions in Human Skeletal Remains*. Smithsonian Contributions to Anthropology, 28, Washington, Smithsonian Institution Press, 488 p.

Patou-Mathis M., 1997. Analyses taphonomiques et palethnographiques du matériel osseux de Krapina (Croatie) : nouvelles données sur la faune et les restes humains. *Préhistoire Européenne*, 10 : 63–90.

Pickering T., Schick K. & Toth N. (eds.), 2007. *Breathing Life into Fossils : Taphonomic Studies in Honor of C. K. (Bob) Brain*. Gosport, Stone Age Institute Press, 2, 296 p.

Pirson S., 2007. *Contribution à l'étude des dépôts d'entrée de grotte en Belgique au Pléistocène supérieur. Stratigraphie, sédimentogenèse et paléoenvironnement*. Unpublished PhD thesis, Universiy of Liège & Royal Belgian Institute of Natural Sciences, 2 vol., 435 p. & 5 annexes.

Pirson S., Bonjean D., Di Modica K. & Toussaint M., 2005. Révision des couches 4 de la grotte Scladina (comm. d'Andenne, prov. de Namur) et implications pour les restes néandertaliens : premier bilan. *Notae Praehistoricae*, 25: 61–69.

Pirson S., Court-Picon M., Haesaerts P., Bonjean D. & Damblon F., 2008. New data on geology, anthracology and palynology from the Scladina Cave pleistocene sequence: preliminary results. In F. Damblon, S. Pirson & P. Gerrienne (eds.), *Hautrage (Lower Cretaceous) and Sclayn (Upper Pleistocene). Field Trip Guidebook. Charcoal and microcharcoal: continental and marine records*. IVth International Meeting of Anthracology, Brussels, Royal Belgian Institute of Natural Sciences, 8-13 September 2008. Brussels, Royal Belgian Institute of Natural Sciences, Memoirs of the Geological Survey of Belgium, 55: 71-93.

Potter R. M. & Rossman G. R., 1979. Mineralogy of manganese dendrites and coatings. *American Mineralogist*, 64 : 26–30.

Rogers T., 2004. Recognizing inter-personal violence : a forensic perspective. In M. Roksandic (ed.), *Violent Interactions in the Mesolithic*. Oxford, British Archaeological Reports, International Series, 1237: 9–21.

Shipman P., 1981. *Life History of a Fossil. An Introduction to Taphonomy and Paleoecology*. Cambridge, Harvard University Press, 221 p.

Trinkaus E., Maki J. & Zilhão J., 2007. Middle Paleolithic Human Remains from the Gruta da Oliveira (Torres Novas), Portugal. *American Journal of Physical Anthropology*, 134 : 263–273.

Ullrich H., 2005. Cut Marks and other Bone Modifications on Le Moustier 1 Remains. In H. Ullrich (ed.), *The Neandertal Adolescent Le*

Moustier 1. New Aspects, New Results. Staatliche Museen zu Berlin — Preußischer Kulturbesitz, Berliner Beiträge zur Vor- und Frühgeschichte, Neue Folge, Band 12 : 293–307.

Ullrich H., 2006. Krapina — A Mortuary Practice Site with Cannibalistic Rites. *Periodicum Biologorum*, 108, 4 : 503–517.

Villa P. & Mahieu E. 1991. Breakage Patterns of Human Long Bones. *Journal of Human Evolution*, 21, 1: 7–48.

Wakely J., 1997. Identification and analysis of Violent and Non-violent Head Injuries in Osteo-archaeological material. In J. Carman (ed.) *Material Harm, archaeological studies of war and violence*, Glasgow, Cruithne Press: 24–45.

Walker P. L., 2001. A Bioarchaeological Perspective on the History of Violence. *Annual Review of Anthropology*, 30 : 573–596.

White T. D., 1992. *Prehistoric cannibalism at Mancos 5mTURM-2346*. New Jersey, Princeton University Press, 462 p.

White T. D. & Toth N., 1989. Engis : Preparation Damage, not Ancient Cutmarks. *American Journal of Physical Anthropology,* 78 : 361–367.