# Chapter 3

# THE STRATIGRAPHIC SEQUENCE OF SCLADINA CAVE

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## 1. Introduction

A sound knowledge of stratigraphy and an in-depth understanding of the genesis of sedimentary deposits are essential prerequisites for any prehistoric or palaeoanthropological study. This is particularly the case for cave entrances and rock shelters, where recent analyses have highlighted a critical and complex heterogeneity of deposits, including factors such as the diversity of sedimentary sources (Figure 1), the effects of variable local conditions, specific diagenetic phenomena, and the presence of sedimentary dynamics dominated by slope processes that successively redistribute sediment (e.g., Texier, 2000, 2001; Ferrier, 2002; Bertran (dir.), 2004; Bertran, 2005, 2006; Goldberg & Sherwood, 2006; Pirson, 2007; Lenoble et al., 2008; Bertran et al., 2009).

Because of the complexity of these heterogeneous deposits, only detailed stratigraphic studies that are built on a large number of cross-sections from across the entirety of a site are able to provide a sufficient understanding of lateral sedimentary variations and lead to the development of an optimal sedimentary record. Such an approach is also necessary for determining the accurate stratigraphic positioning of anthropological, archaeological, or palaeontological discoveries. A reliable reconstruction of the genesis of deposits — and incidentally the nature and extent of the disturbances and hiatuses that occurred during their deposition — is also fundamental for understanding sedimentary depositional dynamics and evaluating the integrity of the material exhumed during excavation (e.g., Bertran & Texier, 1995, 1997; Texier, 2000, 2001; Lenoble & Bordes, 2001; Lenoble, 2005; Bertran et al., 2006, 2009, 2012; Lenoble et al., 2008, 2009). Finally, a good understanding of sedimentary context is necessary for sampling strategies and analyses such as those that focus on the palaeoenvironmental and chronostratigraphic aspects of the stratigraphic sequence.

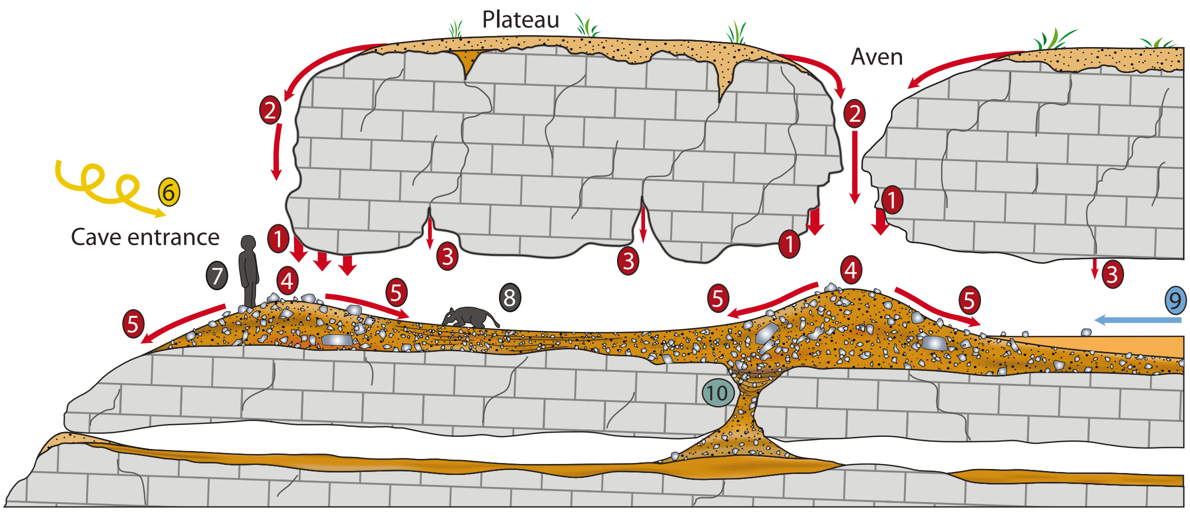



**Figure 1:** The complexity of the genesis of cave entrance sedimentary sequences (modified after Ferrier, 2002). 1. Fracturing of the limestone walls; 2. Gravity input from the plateau through the cave porch or avens; 3. Infiltration through fissures; 4. Main accumulation zone (rock fan); 5. Redistribution from the rock fans by several processes (solifluction, run-off, debris flow, etc.); 6. Aeolian input; 7. Anthropogenic input; 8. Faunal input; 9. Endokarstic alluviation; 10. Collapse of sediments (withdrawing) into a lower gallery. Graphics: Joël Éloy (AWEM).

In Belgium, much of the available data for fossil hominids has been collected from the numerous cave entrances found in the Palaeozoic limestones of the centre part of the country (Pirson et al., 2008). More specifically, all the known Belgian Palaeolithic human remains were found at these karstic sites (Toussaint & Pirson, 2006; Toussaint et al., 2011). However, amongst the 8 Belgian sites that have yielded such remains, only the sites that have been recently excavated have both a detailed stratigraphic log and a good understanding of the genesis of the sedimentary deposits (e.g., Toussaint & Pirson, 2007). Scladina and Walou caves are the most striking of these sites; Neandertal remains were discovered at both locations during the 1990s (Pirson et al., 2006, 2007; Pirson, 2007; Pirson et al. (dir.), 2011; Draily et al. (dir.), 2011). Therefore, Scladina Cave holds a special significance in the study of fossil hominids in Belgium.

## 2. History of the establishment of the stratigraphic record at Scladina Cave

The constitution of the stratigraphic sequence at Scladina Cave can be presented in 3 periods.

The first period began in 1971, the year the cave was discovered and explored by speleologists. Over the course of 7 years (1971–1977), those speleologists removed the top 2 metres of sediment from the first 10 horizontal metres of the site without recording any stratigraphic data. The discovery of lithic material prompted them to contact professional archaeologists and cease their excavations in 1977. As soon as 1978 the University of Liège began its first scientific excavation campaign at Scladina. A few stratigraphic records were taken at that time, which lead to the definition of the main units of the sequence (Otte & Slootmaekers, 1982; Otte et al., 1983).

The second period, during which the initial stratigraphic system was supplemented, began with the collection of the first stratigraphic information from inside the cave by a geologist. These studies, as well as the first sedimentological analyses, were combined and then used as the framework for a university graduate thesis (Deblaere & Gullentops, 1986; Gullentops & Deblaere, 1992). Simultaneously, the geologist P. Haesaerts (1992) studied the stratigraphic sequence of the cave entrance. Several years later, another geologist undertook a sedimentological study devoted to the clarification of the context of the Neandertal remains (Benabdelhadi, 1998), focusing on only 1 small sedimentary profile. Finally, the archaeologist in charge of the excavations published new data about specific areas of the sedimentary sequence (e.g., Toussaint et al., 1994; Bonjean et al., 1996, 1997, 2002) and a synthesis of the stratigraphy was completed (Bonjean, 1998[a]; Figure 2). All in all, by the end of this period a total of about 10 sedimentary profiles were recorded and interpreted.

The third period corresponds with a PhD study in geology (Pirson, 2007). October 2003 saw the beginning of the detailed stratigraphic recording of almost all accessible profiles in Scladina, totalling approximately 70, with each one covering vertical surfaces that ranged from 1 to 45 square metres. Simultaneously, a geological survey of the archaeological excavation was conducted as systematically as possible in close collaboration with D. Bonjean, the archaeologist in charge of the site. Following these new records,

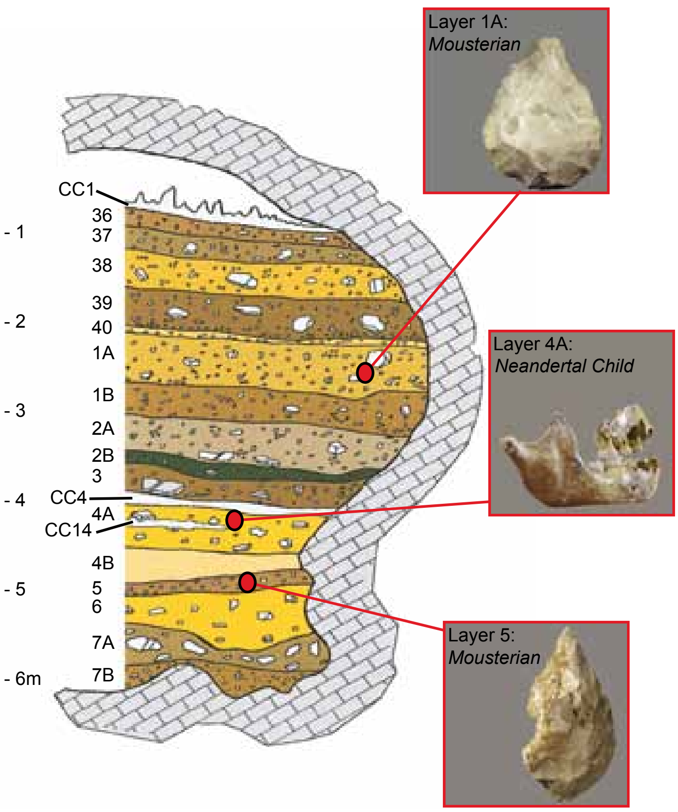



Figure 2: The former stratigraphic sequence of Scladina Cave (after the synthesis of Bonjean, 1998[a] based on Otte et al., 1983 and Gullentops & Deblaere, 1992). Graphics: Joël Éloy (AWEM).

the stratigraphy of the site appeared much more complex than previously thought. The number of identified layers expanded from 30 to almost 120, grouped into 30 distinct units (Figure 3). These units correspond roughly to the former layers (e.g., Unit 2B, which is comprised of 5 layers and corresponds to former Layer 2B). The differences between the new and the previous sequence are particularly striking for former layers 6, 4A, and 1B. The review of these 3 former layers led to the identification of 14 units, encompassing more than 50 layers in total. The field study also revealed complex geometries, numerous lithologies, a large variety of depositional and diagenetic processes, as well as a large number of climatic fluctuations that all demonstrate the exceptional nature of this stratigraphic sequence.

More recently, ongoing excavation and the examination of new profiles has led to the identification of some new layers, but only in the second, upper half of the sequence (e.g., units 1A and T; see Bonjean et al., 2009).

## 3. Lithostratigraphy

Only the deposits that are related to the palaeoanthropological remains — i.e. former Layer 4A — are described below, as well as the layers directly below (former layers 5 and 4B) and above it (former Layer 3). The complete lithostratigraphic description is available in Pirson (2007). It is worth mentioning here that below Scladina Cave another cave has been identified, called Sous-Saint-Paul Cave. Their respective deposits are locally connected through sinkholes, but the two sedimentary sequences are separated by an important hiatus (Haesaerts, 1992; Pirson, 2007; Pirson et al., 2008).

### 3.1. The former stratigraphic record

In the previous stratigraphic system defined for the inside of the cave (Otte et al., 1983; Gullentops & Deblaere, 1992; Bonjean et al., 1996, 1997; Bonjean, 1998[a]; Figure 2) there was, above Layer 5 and below Layer 3, from bottom to top:

— a silty layer, sometimes laminated (Layer 4B);
— a stony layer (Layer 4A);
— a thick in situ Stalagmitic Floor CC4[1].

Towards the entrance, where Stalagmitic Floor CC4 is absent, the top of former Layer 4A is altered. In some publications only a single Layer 4 was identified (Otte et al., 1983; Bastin, 1992; Simonet, 1992; Patou-Mathis, 1998) in the same area where 2 layers would later be mentioned (Gullentops & Deblaere, 1992; Bonjean, 1998[a]). A stalagmitic floor was also described inside Layer 4A (called CC14; Bonjean et al., 1996; Bonjean 1998[a]).

### 3.2. The new stratigraphic record

The careful observation of the sedimentary profiles accessible between metres 23 and 43 led to a more accurate definition of the succession of lithostratigraphic units in former layers 4A and 4B, leading to the definition of Sedimentary Complex 4 (Pirson et al., 2005; Pirson, 2007). Before metre 23 almost nothing remains of this complex and beyond metre 43 it has not been excavated at this time (Figure 4).

To stay as consistent with the previous stratigraphic naming convention as possible it was decided that a trailing dash would be added to the previously given names, followed by letters relating to particular features of each new layer (see Pirson, 2007). The new stratigraphy is presented below, from bottom to top (Figure 3 and Figures 5-7).

#### 3.2.1. Unit 5

**Layer 5-G** is a silt that is rather rich in limestone fragments and contains a few small silicoclastic river pebbles. Much of the coarse components exhibit a strong preferential orientation, from planar to linear (*sensu* Bertran (dir.), 2004). The matrix is either grey-brown, light brown, or grey-beige with frequent iron staining (rust-coloured spots and planes). The structure is generally finely granular. At the bottom of the layer a thin (1 mm) platy structure has been locally observed. Several lithologies superimpose each other (5-GJAC, 5-GBG, 5-GRO, 5-GBLA, 5-GKBR), which are defined by variations in colour and concentration of limestone pebbles; however, their lateral extensions have not yet been ascertained. These lithologies might reflect different layers, but this has not yet been demonstrated. The bottom of

[1] Several "calcitic crusts" ("*croûte de calcite*") were identified in the former stratigraphic sequence, from CC1 to CC8. They correspond to either in situ stalagmitic floor, reworked speleothem or even in situ or reworked calcitic cementation of the matrix; besides, some of these calcitic crusts are lateral equivalent (see Pirson, 2007).

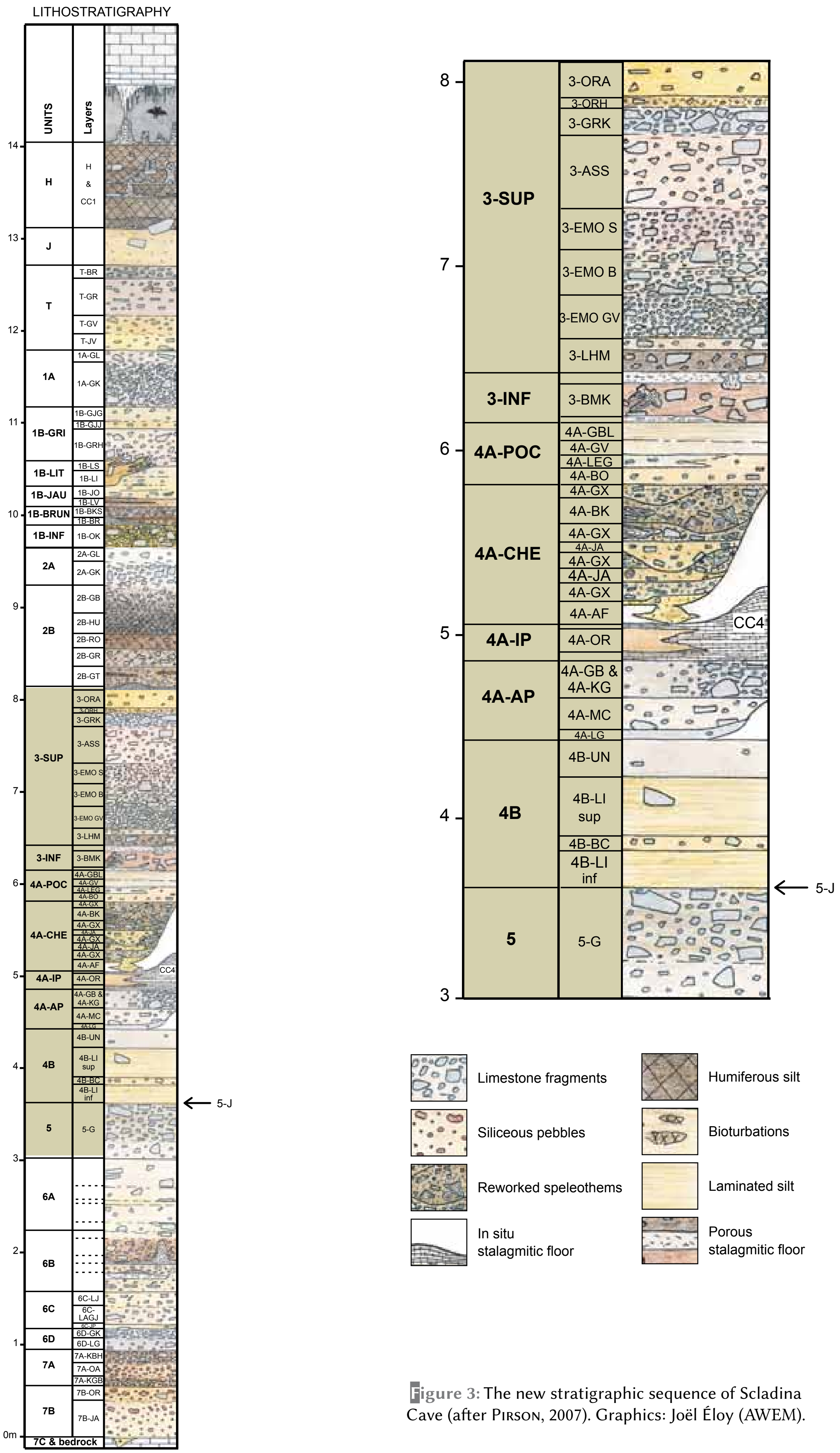



**Figure 3:** The new stratigraphic sequence of Scladina Cave (after Pirson, 2007). Graphics: Joël Éloy (AWEM).

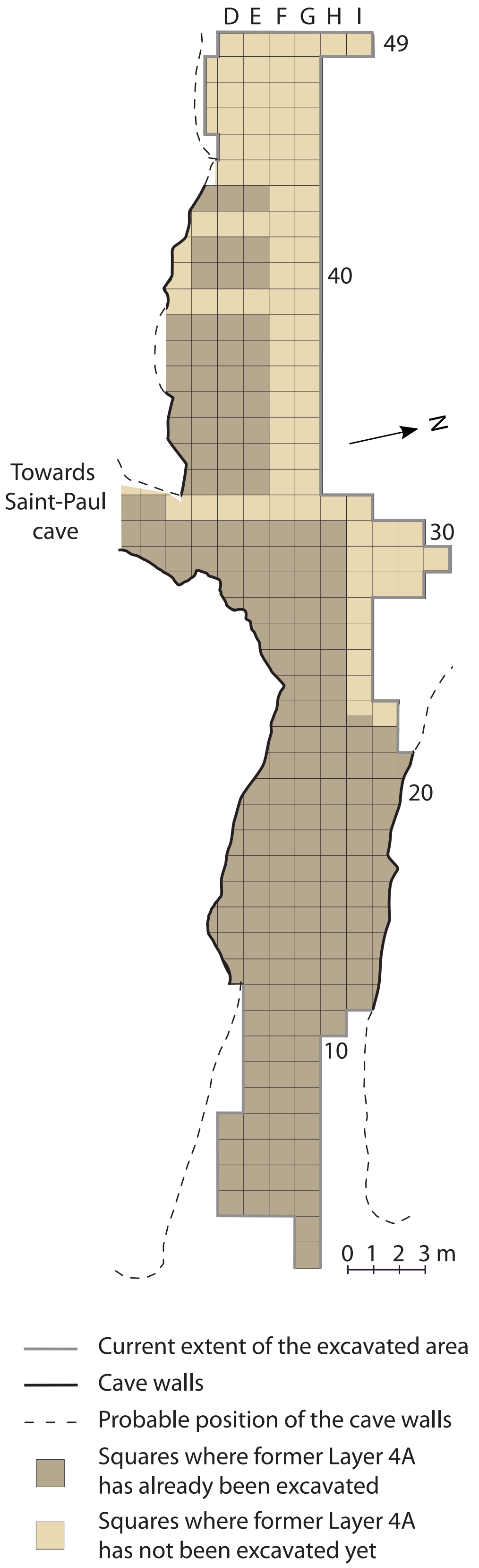



**Figure 4:** Map of the cave showing the extent of the area where Sedimentary Complex 4 has been excavated (modified after Pirson et al., 2005). Graphics: Joël Éloy (AWEM).

Unit 5 has eroded the top of Unit 6A, creating small gullies in the process.

Above 5-G, **Layer 5-J** has been observed at some locations. It consists of a more heterogeneous silt that is grey-yellow in colour and includes numerous orange, grey, or beige aggregates (mud balls). When compared with 5-G, Layer 5-J contains fewer limestone fragments that do not have a clear preferential orientation. The clast-matrix relationship is matrix-supported (see Tucker, 1991 and Bertran (dir.), 2004). The sediment is massive and has a rather coarse granular structure. The top of 5-J is locally hardened by calcite; the layer also locally develops into a gully.

**Layer VB** of the terrace (Haesaerts, 1992) might correspond to a third layer of this unit.

Unit 5 contains the older of the 2 most important Middle Palaeolithic assemblages found in Scladina (Chapter 2).

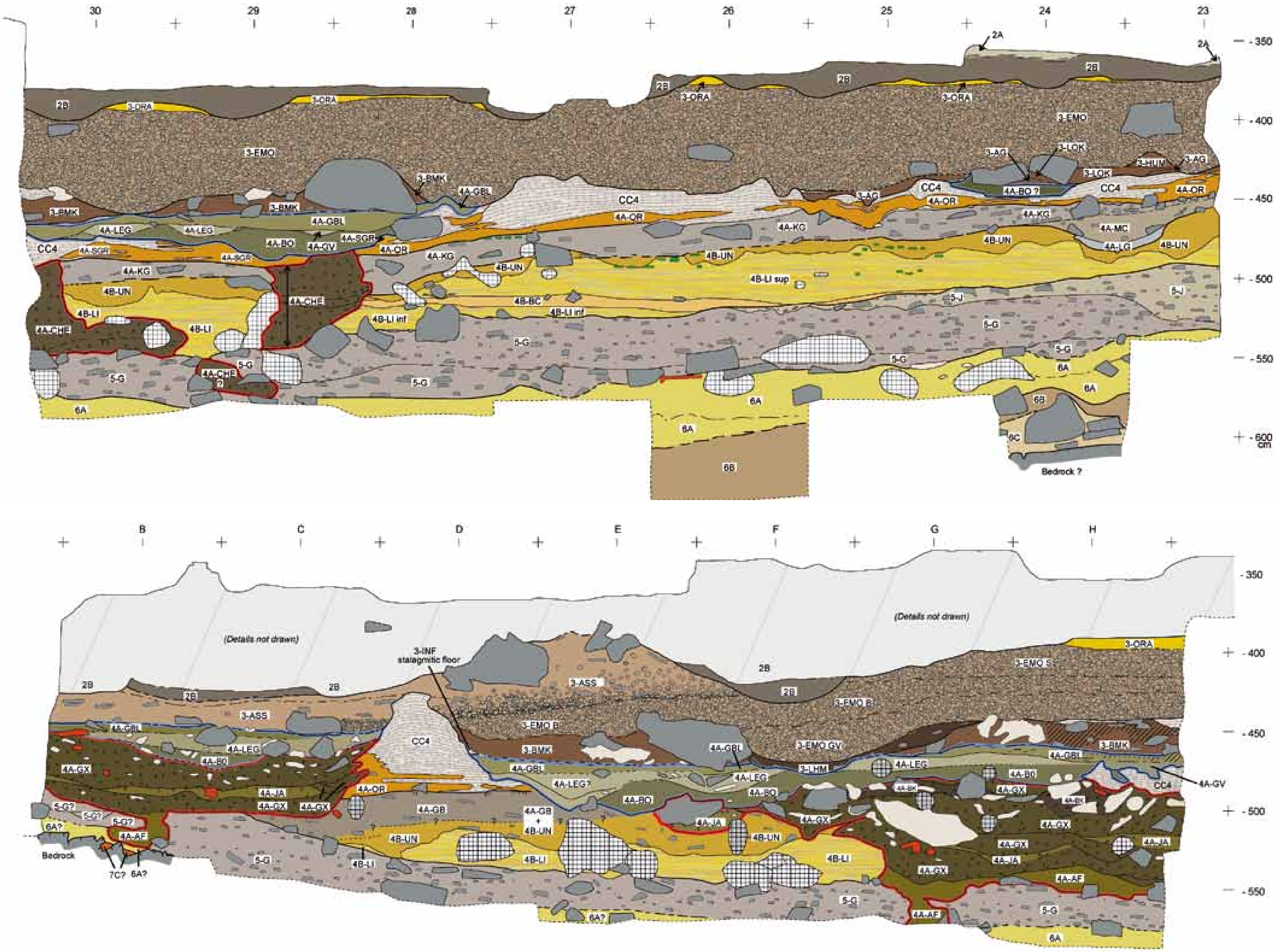
### 3.2.2. Unit 4B

**Layer 4B-LI** is a finely laminated silt with almost no coarse elements. It is composed of alternating doublets ranging from less than a millimetre up to several millimetres thick. Each doublet is composed of a yellowish silty bed at the base and a darker clayey bed at the top. Although the internal stratification is mostly horizontal, the lower and upper limits of Layer 4B-LI dip towards the back of the cave. Massive and thicker (centimetric) laminas can regularly be observed, as well as small (centimetric) erosive phases that locally interrupt the horizontal bedding. Cross bedding can also be seen. The laminations are sometimes less obvious, particularly at the top of the unit. There are very few decimetric limestone fragments; underneath them the laminations are deformed. Some in situ calcareous concretions (1–5 cm) similar to loess dolls are present locally. From the top of the layer, evenly spaced (~30 cm) vertical narrow cracks developed downwards.

Frequently, the laminated Layer 4B-LI is interrupted by a decimetric, non-laminated, beige, silty facies that either contains a few scattered limestone fragments (**layers 4B-BC** and **4B-IL**[2]) or none (**Layer 4B-LR**[3]). Area C-D 40-43 contains a rather loose silt with numerous large limestone slabs ranging in size from several decimetres to over a metre; the dominant type of clast-matrix relationship is clast-supported (**Layer 4B-KK**). The

[2] Facies “4B-LI b” of Pirson et al., 2005.

[3] Facies “4B-LI j” of Pirson et al., 2005.



30
29
28
27
26
25
24
23
- 350
- 400
- 450
- 500
- 550
- 600
cm
Bedrock ?
B
C
D
E
F
G
H
(Details not drawn)
3-INF
stalagmitic floor
Bedrock

presence of these non-laminated layers interbedded in 4B-LI allows for the identification of 3 generations of 4B-LI (upper, middle, and lower). The large blocks from Layer 4B-KK sometimes deform the stratification of the lower generation of 4B-LI, whereas the upper generation fills the porosity between the limestone fragments at the top of 4B-KK.

**Layer 4B-UN** was the last layer of Unit 4B that was deposited. It is comprised of a rather homogeneous, greyish-beige clayey silt and contains few limestone fragments. The matrix is rich in aggregates (sand-sized and coarser) made of grey and compact clayey silt. Calcareous concretions similar to those from 4B-LI have been locally identified as well as some overall cementing of the matrix. A well-developed platy structure, 4–6 mm thick, is visible throughout this layer and the overlying units 4A-AP and 4A-IP. The lower limit of Layer 4B-UN often appears sharp and erosive on underlying Layer 4B-LI. However, in some places the contact is diffuse and the fine lamination gradually disappears. **Layer 4B-UF** is a beige clayey silt with a few grey mud balls and rare limestone fragments. This layer is the likely lateral equivalent of 4B-UN beyond metre 30 (Figures 6 & 7), where it lies under 4A-GB.

**Figure 5 (facing page, above):** Section H/I (after Pirson, 2007). Limestone blocks under 10 cm were not drawn in the field; when they are shown (for units 5 to 3-SUP), it is with a textural pattern. Symbols as in Figure 7. Graphics: Joël Éloy (AWEM).

**Figure 6 (facing page, below):** Section 30/31 (after Pirson, 2007). Limestone blocks under 10 cm were not drawn in the field; when they are shown (for units 5 to 3-SUP), it is with a textural pattern. Symbols as in Figure 7. Graphics: Joël Éloy (AWEM).

### 3.2.3. Sedimentary Complex 4A: units 4A-AP, 4A-IP, 4A-CHE, and 4A-POC

The former Layer 4A, from which the Neandertal remains were unearthed, has been divided into 4 units, each comprised of several layers. The relationships between these 4 units are presented in Figure 8.

**Unit 4A-AP**, which is comprised of layers deposited before the formation of Stalagmitic Floor CC4, starts with **layers 4A-LG** and **4A-MC**. These are only visible in a small gully crosscutting Layer 4B-UN (Figure 5). The sediment is a grey to grey-beige clayey silt, either with a few limestone fragments (Layer 4A-MC) or without (Layer 4A-LG). Mud balls have also been observed. These deposits are affected by a well-developed platy structure (4–6 mm) that developed downwards through Layer 4B-UN and upwards up to Unit 4A-IP. **Layer 4A-KG** superimposes either

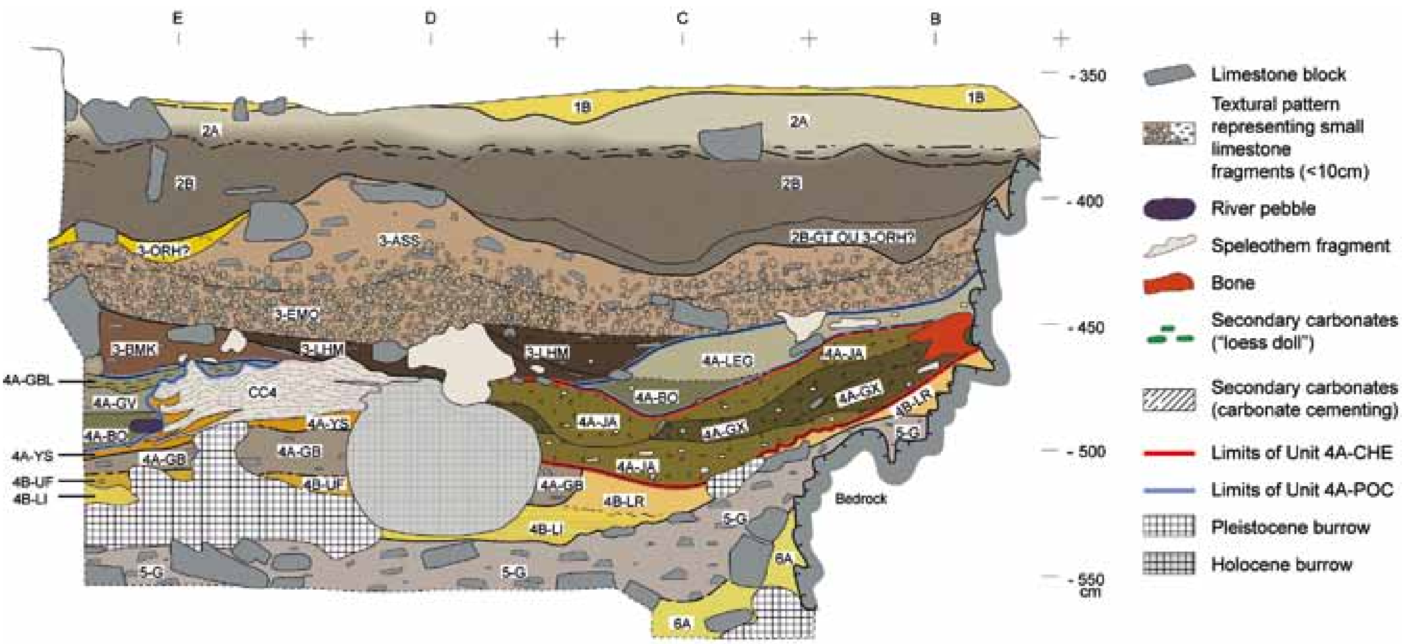



**Figure 7:** Section 32/31 (after Pirson, 2007). Limestone blocks under 10 cm were not drawn in the field; when they are shown (for units 5 to 3-SUP), it is with a textural pattern (see graphic symbols). Graphics: Joël Éloy (AWEM).

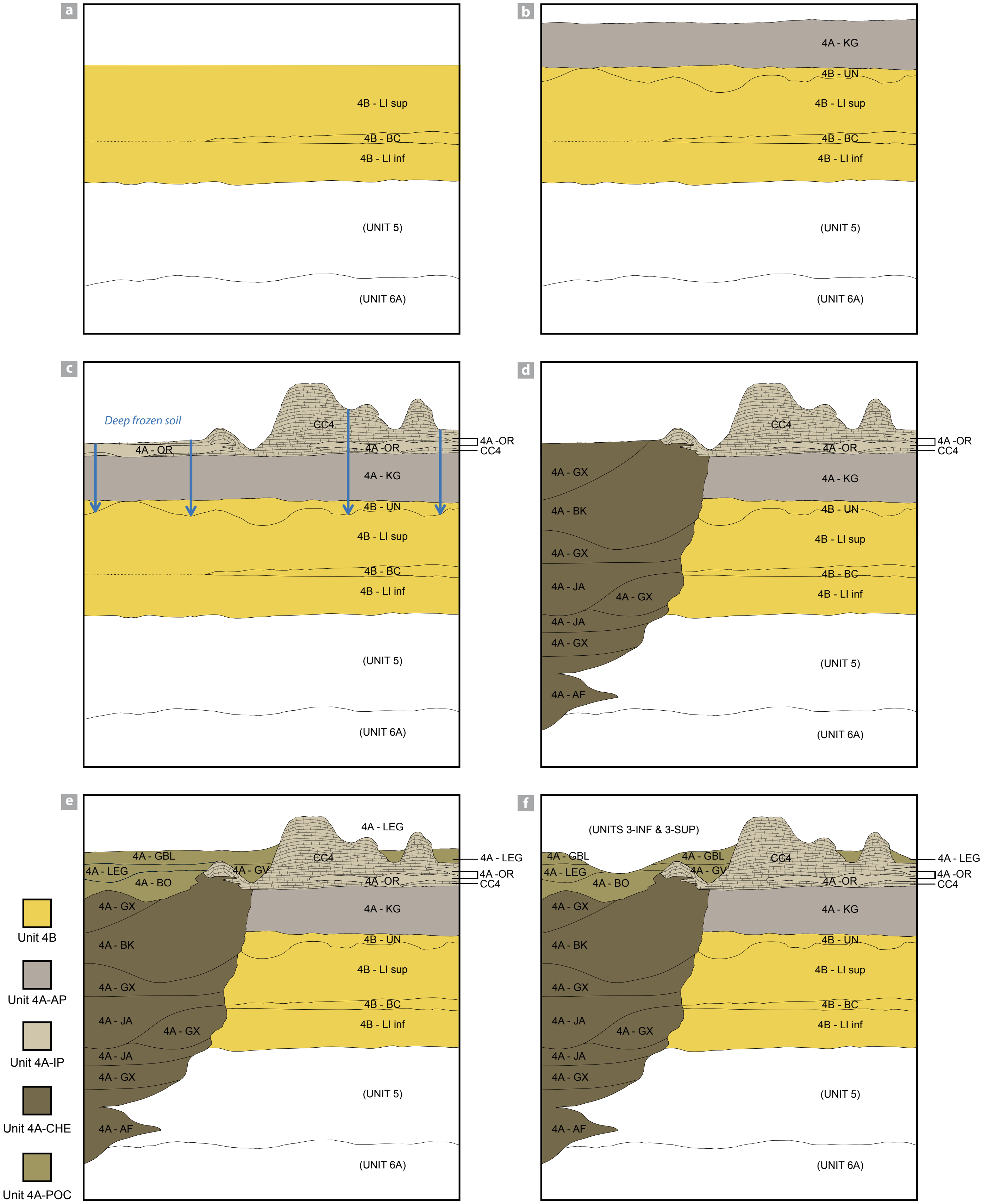



**Figure 8:** Diagrams presenting the stratigraphic relationships between the 5 distinct units of Sedimentary Complex 4. The 6 stages illustrate the succession of sedimentary and pedological events. a) deposition of Unit 4B over Unit 5; b) deposition of Unit 4A-AP; c) deposition of Unit 4A-IP, including the formation of Speleothem CC4; at the end of this stage, development of a deep frozen soil from the top of CC4; d) deposition of Unit 4A-CHE, eroding the underlying units; e) deposition of Unit 4A-POC; f) deposition of units 3-INF and 3-SUP on top of the Complex 4. Graphics: Joël Éloy (AWEM).

Layer 4B-UN or the small gully mentioned above. It consists of grey-beige silt, is more or less clayey, and is rich in limestone blocks ranging from 1 to 10 cm, sometimes up to several decimetres. Locally, at the top of the layer, the amount of coarser elements decreases. The proportion of coarse components also diminishes towards the back of the cave. Throughout the layer the coarse fragments do not exhibit any noticeable preferential orientation. The type of clast-matrix relationship is generally clast-supported, but matrix-supported relationships are not rare. The matrix contains numerous grey centimetric mud balls embedded in a more beige coloured sediment. Beyond metre 30, the likely equivalent of 4A-KG is **Layer 4A-GB**; the matrix is close to that of 4A-KG but with fewer limestone fragments. These 2 layers exhibit a platy structure, particularly well developed (4–6 mm) in 4A-GB.

**Unit 4A-IP** is comprised of CC4, an important stalagmitic floor, and the layers that were deposited during its formation. The thickness of the floor varies between a maximum of several decimetres thick at some locations and a minimum of only a calcitic lens less than 1 cm thick at others; also, it is occasionally completely absent. In some places this speleothem can be divided into three distinct generations. The sediment that was deposited between the generations of calcite is a massive silt, almost deprived of coarse elements. Locally, some small fragments of limestone, calcite, and stalactites have been observed within the silty matrix. The sediment that is interbedded in the speleothem is locally cemented by calcite. Three interbedded layers have been identified in different areas of the site, mainly on the basis of the colour of the matrix. **Layer 4A-OR** is a beige-orange homogeneous silt. **Layer 4A-SGR** is a silt with very few small limestone fragments. The matrix is either homogeneous (grey or orange) or heterogeneous (grey or orange lenses). It contains numerous sand-size aggregates as well as grey mud balls. **Layer 4A-YS** is a beige-yellow silt with no coarse fragments. Layers 4A-OR, 4A-SGR, and 4A-YS are affected by a thick platy structure (2–5 mm) that is often very well developed. The thick platy structure is present particularly where the overlying Stalagmitic Floor CC4 is absent or thin. Sometimes, a rather diffuse vertical component is superposed onto it (sub-angular blocky structure). The platy structure developed downwards to the base of Layer 4B-UN.

**Unit 4A-CHE** is the result of an important erosional phase that reworked both Stalagmitic Floor CC4 and underlying deposits. It consists of a succession of cut-and-filled layers that developed within a large 2 m wide 0.5–1 m deep gully structure. Two distinct gullies have been identified locally. All in all, 4 main lithologies have been observed; they are facies rather than layers, for these lithologies alternate in a diverse order, or are present in different areas without any means of controlling their possible contemporaneity. The limits between these facies are generally quite sharp. Most coarse components do not exhibit any preferential orientation, except for some that are locally planar. Platy structures are absent throughout the whole unit.

— At the bottom of the unit, **Facies 4A-AF** consists of beige heterogeneous silt with no limestone fragments, but with many mud balls and tilted decimetric blocks of a laminated yellowish sediment which is similar to that from 4B-LI. This deposit filled small gullies with irregular walls that were caused by the erosion of underlying layers (units 5 and 6A) by undercutting them locally (scouring). The matrix exhibits a structure which is either massive or finely granular.

— **Facies 4A-GX**, which is particularly heterogeneous, consists of a mix between beige silt (same type as that of 4A-JA) and mud balls of various sizes (from 1 mm to several cm) that are composed of compact greyish clayey silt. These mud balls are sometimes so numerous the overall colour of the facies is grey and the sediment is very compact. Limestone blocks and speleothem fragments (from millimetric pieces to stalagmites several decimetres long) mostly represent the generally abundant coarse fraction. Most coarse components do not exhibit any preferential orientation. The sediment is massive, either clast- or matrix-supported, and the structure is granular, often quite coarse.

— **Facies 4A-JA** is a yellowish beige silt, sometimes slightly orange, with a few aggregates of grey compact clayey silt that are 1 mm to several cm in diameter. When the aggregates are more abundant, the facies is more similar to that of 4A-GX. The coarse elements are of the same nature as those from 4A-GX, although notably less numerous and smaller. The structure is massive or finely granular.

— **Facies 4A-BK** is a brown heterogeneous silt with many large speleothem fragments and a few limestone blocks. The sediment is massive, and either clast- or matrix-supported.

It contains sand-size aggregates and mud balls. The structure is granular.

Last unit of Complex 4A, **Unit 4A-POC**, is comprised of several layers that were deposited after the gully developed. These layers cover the deposits of both units 4A-IP and 4A-CHE. **Layer 4A-BO** is a rather heterogeneous beige-orange silt, often with numerous sand-size aggregates and mud balls, that changes into an orange silt interbedded with lenses of greyish or grey-beige silt (**Layer 4A-LEG**) towards the top. The structure of these two layers is mainly granular. The coarse elements (limestone blocks, speleothem fragments, and a few small silicoclastic river pebbles) are small (millimetric to centimetric), and sometimes quite numerous. **Layer 4A-GV** is a rather homogeneous greenish-grey clayey silt that developed into small gullies that are cutting 4A-BO; locally, the bottom of 4A-GV is pink-beige. Finally, **Layer 4A-GBL** is an often broadly stratified grey-beige silt with a few millimetric to centimetric coarse fragments (limestone blocks or calcite). The top of the layer is locally concretionary.

### 3.2.4 Unit 3-INF

This unit is very localised. Several layers have been identified (**3-BMK, 3-HUM, 3-CGO, 3-AG**, **3-LOK**), but as of now the stratigraphic relationships have not been completely established. There is evidence of carbonate precipitation, both as calcite cementing (within 3-INF and at the top of Unit 4A-POC) and as thin stalagmitic floors at the top and bottom of the unit. These speleothems are highly porous and rather brittle. Blocks that are several decimetres in diameter are particularly frequent in this unit, as well as at the top of underlying Unit 4A-POC. Speleothem fragments, often quite large, have been observed, as well as a few small silicoclastic river pebbles. Layers 3-BMK and 3-HUM are the best represented; they both consist of heterogeneous silt that is middle to dark brown, rather loose, with numerous limestone fragments. The type of clast-matrix relationship is clast-supported. Numerous sand-size aggregates are present, as well as mud balls. The structure is granular.

### 3.2.5 Unit 3-SUP

**Layer 3-LHM**, which is observable only at a few places, exhibits important lateral variations. It is composed of a heterogeneous silt that is quite loose at some locations, and can be a variety of colours: orange-beige, beige, grey, grey-beige, or brown. The concentration of coarse elements (limestone blocks and speleothem fragments) is highly variable. The sediment is massive and the type of clast-matrix relationship is either clast- or matrix-supported. Some facies are rich in sub-millimetric aggregates. The sediment from Layer 3-LHM eroded those of the underlying Unit 3-INF. Layer 3-LHM may in fact be several layers, but the current state of excavation does not make any verification possible.

**Layer 3-EMO** is a very stony deposit composed of very blunt, rounded, and rather well calibrated small limestone elements (1–4 cm), with some sparse blocks that are several decimetres large. The matrix is a rather clayey grey-beige silt composed almost exclusively of well-rounded sand-size aggregates. Under the large blocks, the sediment has an openwork structure; elsewhere, the voids between the clastic limestone elements are partially or totally filled with sand-size aggregates and the sediment exhibits a clast-supported structure. Three facies of 3-EMO are superimposed on sections H/I 23-30 and 30/31 F-H (3-EMO GV, 3-EMO B, and 3-EMO S[4]). The top of Layer 3-EMO is lighter in colour and regularly exhibits very strong iron and manganese staining. Locally, it is cemented by calcite.

From metre 30 towards the back of the cave, the proportion of limestone fragments within Layer 3-EMO lessens progressively upwards, and the gradual change into Layer 3-ASS can be observed. The transition to 3-ASS also happens towards the back of the cave between metres 32–34; there are no more traces of 3-EMO beyond that limit. **Layer 3-ASS** consists of a greyish beige clayey silt with characteristic pinkish shades. The limestone fragments are sometimes abundant, sometimes rather rare; some silicoclastic pebbles (up to 10 cm), as well as speleothem fragments, are also visible. There are traces of some diffuse internal stratification. A platy structure is visible throughout the layer; while rather coarse and noticeable at the top (3–4 mm), deeper it is less visible but sometimes very thick (3–10 mm). Manganese and iron spots as well as iron planes are visible. Similar to its lateral equivalent (3-EMO), the top of the layer is often lighter in colour. On the other hand, the bottom is darker, mouse grey, grey-pink, grey-brown, or red-brown, with a very diffuse boundary. Beyond metre 38, in the lower

[4] = 3-EMO α, β and γ of Pirson, 2007

part of Layer 3-ASS there are many small weathered orange bone splinters almost always lying parallel to the stratification plane.

Unit 3-SUP contains other layers above 3-ASS and 3-EMO (Figure 3); their description is beyond the scope of this presentation.

Sedimentary Complex 4A is often directly superimposed by different layers, either those belonging to Unit 3-INF or Unit 3-SUP, depending on the location in the cave (Figures 5–7).

## 3.3. Correlations between the different stratigraphic records

Table 1 illustrates the correlation between the former stratigraphic interpretations and the current one. Depending on the area in the cave, former Layer 4A corresponds to 1 or several layers from units 4A-AP, 4A-IP, 4A-CHE, and 4A-POC. The comparison between the records that were taken of sections H/I (23-30) and 30/31 (B-H) before the stratigraphic reappraisal (Figure 9) and after it (Figures 5 & 6) helps to better understand the origin of the differences between the 2 systems.

Former Layer 4A was classically defined in the first 20 m inside the cave as a stony silt (Gullentops & Deblaere, 1992; Bonjean, 1998[a]) situated above the silty Layer 4B, which is deprived of any stone, and below the Stalagmitic Floor CC4. This, combined with the analysis of figures 5 and 9a, leads to the suggestion of the equivalence (at least partially) of former Layer 4A and Unit 4A-AP (mostly Layer 4A-KG).

Laterally, the transition to Unit 4A-CHE has not been understood. The huge gully has not been identified, even if cut-and-filled small channels were locally recognized (Bonjean et al., 1997). The sediment from the 4A-CHE gully, rich in coarse components like 4A-KG and situated at similar depth, has been attributed to former Layer 4A (compare Figure 9b with Figure 6). The recent reappraisal of transverse cross-sections 30/31 and 32/31 (Figures 6 & 7) highlighted the important erosive boundary of the 4A-CHE gully, and showed that the coarse elements from units 4B, 4A-AP, and 4A-IP are deprived of any reworked speleothem fragments, while these are very frequent in units 4A-CHE and 4A-POC (Figures 5–7 and Figure 10).

The definition of Unit 4A-POC is linked to the problem of Stalagmitic Floor CC14 (Pirson, 2007). This speleothem was found above a generation of former Layer 4A and below a second generation of former Layer 4A (Bonjean, 1998[a]; Figure 9a). In the system used at the time (Figure 2), former Layer 4A was older than Speleothem CC4.

| TERRACE | | CAVE | | | |
|---|---|---|---|---|---|
| Otte et al., 1983 | Haesaerts, 1992 | Otte et al., 1983 | Gullentops & Deblaere, 1992 | Bonjean, 1998a | Pirson, 2007 |
| | | | DG-16 = 36 / CC1 | 36 / CC1 | ***H*** |
| | II (top) | | DG-15 = 37 | 37 | ***J*** |
| II | II | | DG-14 = 38<br>DG-13 = 39 | 38<br>39 | ***T*** |
| | | | DG-12 = 40 | 40 | transition ***1A-T*** ? |
| IA | IA | 1A | DG-11 = 1A | 1A | ***1A*** |
| IB | IB | | | | |
| I | I | 1B | DG-10 = 1B | 1B | ***1B-GRI***<br>***1B-LIT***<br>***1B-JAU***<br>***1B-BRUN***<br>***1B-INF*** |
| | | 2A | DG-9 = 2A | 2A | ***2A*** |
| III | III | 2B | DG-8B = 2B | 2B | ***2B*** |
| | | | DG-8A = 2B1 | | ***3-SUP*** (3-ORA) |
| IV | IV | 3 | DG-7 = 3 | 3 | ***3-SUP*** |
| VA | VA | | | | ***3-INF*** (3-HUM) |
| V | V ocre | 4 (top) | DG-6A / DG-6B (=CC4) / DG-6C | CC4 | ***4A-POC*** |
| | | 4 | DG-5B = 4A | 4A<br>CC14<br>4A | ***4A-CHE***<br>***4A-IP***<br>***4A-AP*** |
| | V gris | | DG-5A = 4B | 4B | ***4B*** |
| VB | VB | 5 | DG-4 = 5 | 5 | ***5*** |
| VI A<br>VI B | VI a<br>VI b | 6 | DG-3 = 6 | 6 | ***6A***<br>***6B***<br>***6C***<br>***6D*** |
| VII | VII | 7A | DG-2 = 7A | 7A | ***7A*** |
| | | 7B | DG-1 = 7B | 7B | ***7B*** |

Table 1: Attempt at correlating the former stratigraphic systems and the new one (bold italic = units; roman = layers). Light brown background: part of the Scladina stratigraphic sequence concerned by this study.

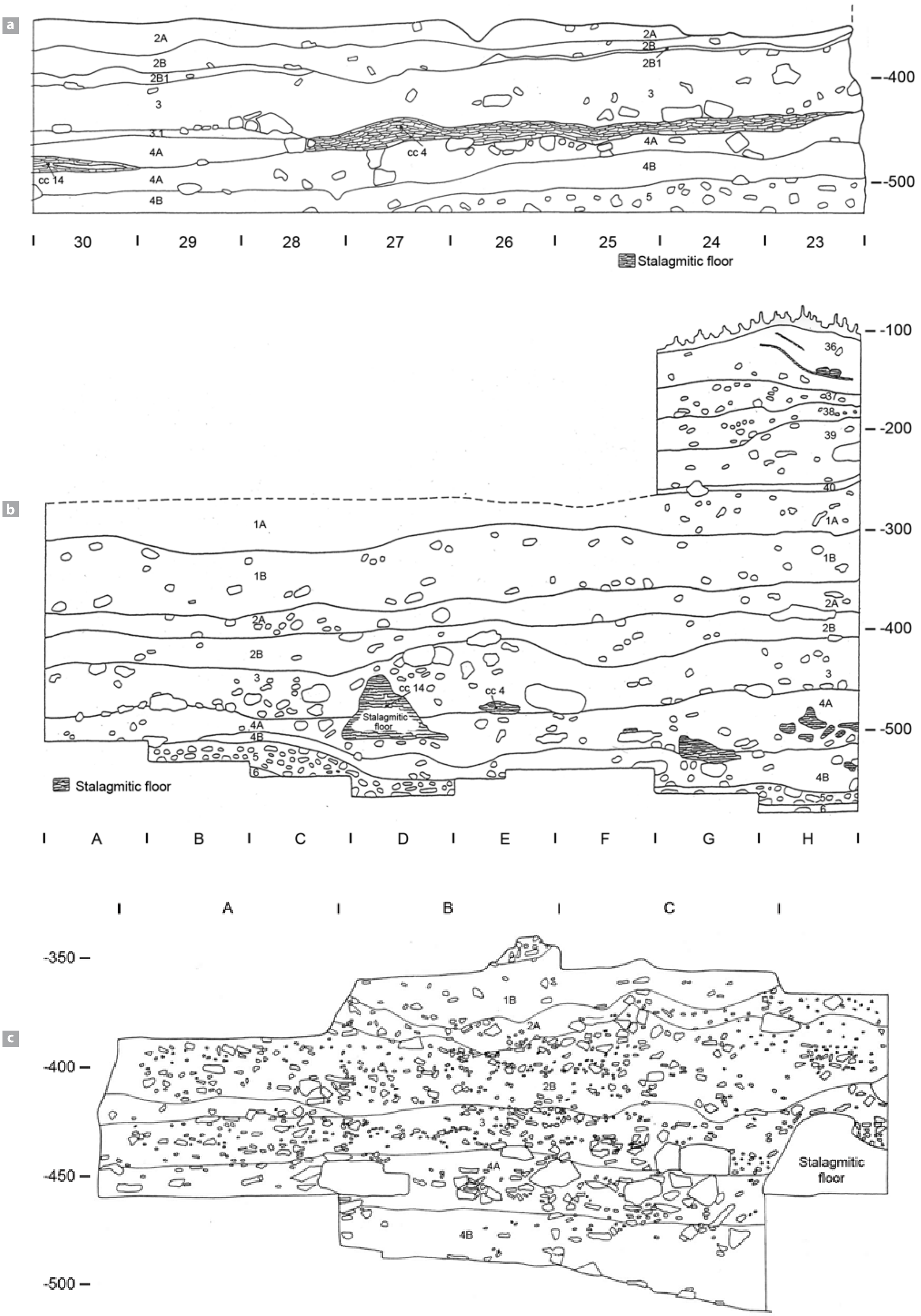



**Figure 9:** Previous stratigraphic records of profiles H/I (a) and 30/31 (b-c).
a and b: after Bonjean (1998[a]); c: after Benabdelhadi (1998).

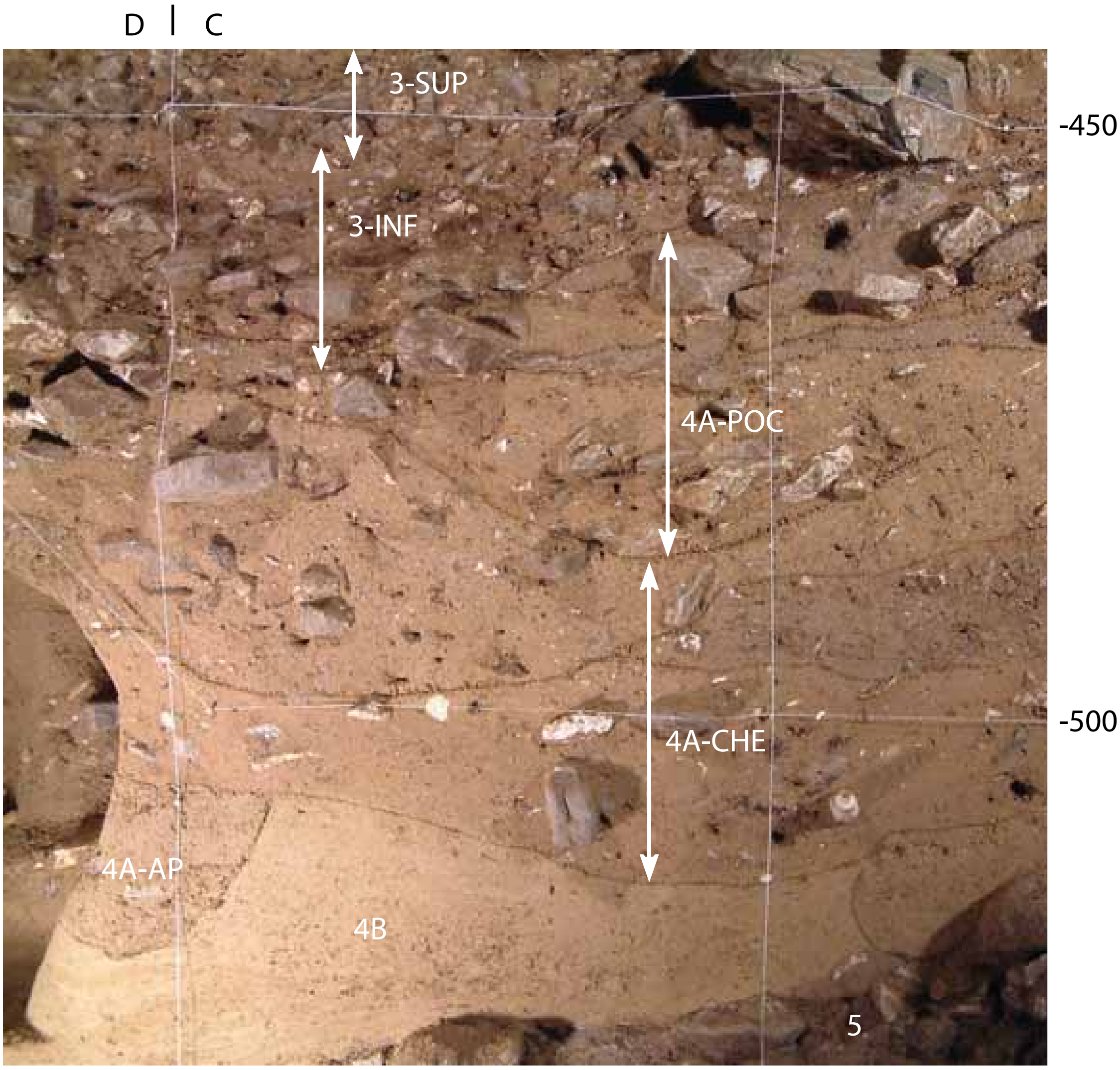



**Figure 10:** Picture of Section 32/31 showing the reworked speleothem fragments, signature of units 4A-CHE and 4A-POC. The labels are referring to units, not layers (photograph Dominique Bonjean, AA).

Therefore, this new speleothem covered by former Layer 4A had to be older than CC4 and had to lie inside former Layer 4A. According to the re-examination of data collected in the field, from the literature, and from documents relating to the previous excavations, nothing corroborates the existence of this Speleothem CC14. On the contrary, everything indicates that CC14 is nothing more than a lateral equivalent of CC4; the overlying sediment of former Layer 4A corresponds to Unit 4A-POC, which covers both CC4 and Unit 4A-CHE (Figures 3 & 5). It is worth mentioning here that the dates obtained from these 2 speleothems are very close (see summary in Bonjean, 1998[b]). This re-evaluation had major implications for the stratigraphic position of the Neandertal remains (see Chapter 5).

In some areas (beyond metre 34), the silty upper part of former Layer 4A (now called Unit 4A-POC) was attributed in the previous stratigraphic system to the bottom part of former Layer 3, and more specifically to Layer 3-ASS. Again, this has implications for the positioning of the Neandertal child in the sequence, as 3 teeth that were apparently found in former Layer 3 probably came from 4A-POC (see Pirson et al., 2005; see also Chapter 5).

## 4. History of the filling: sedimentary and diagenetic processes

The sediment found in the Scladina sequence mainly consists of limestone blocks that have detached from the cave porch and walls and become embedded in loessic silt. A few allochthonous silicoclastic river pebbles and a low percentage of sand, both resulting from the reworking of a terrace of the Meuse River that is preserved on the plateau above Scladina, complement the aforementioned two other dominant components. Slope processes govern the sedimentary dynamics. Blocks from the limestone hillside and sediment from the plateau accumulated together with aeolian deposits below the cave porch, forming a detritic cone from where they were later redistributed towards the inside of the cave ("*éboulis assistés*" *sensu* Bertran et al., 2004). Numerous sedimentary processes have been identified (Pirson, 2007), including: debris flow, run-off, rock fall, solifluction, settling, torrential flow, and speleothem formation. Several post-depositional processes have also been recognised, such as: deep frost, cryoturbation, pedogenesis (on the cave terrace), formation of secondary phosphates, desiccation cracks, cementation of sediments by secondary carbonates, bioturbation, etc. Only the processes identified in units 5 to 3-SUP will be reviewed here, due to their pertinence for understanding the sedimentary context of the Neandertal child.

### 4.1. Unit 5

Layer 5-G may have been deposited by solifluction, as suggested by the overall planar to linear fabric of the limestone clasts (Bertran et al., 1997; Bertran & Coutard, 2004). Also, the underlying deposits have been affected by deep frost, as attested by a thick platy structure visible throughout Unit 6A. It seems probable that Layer 5-G, with its iron staining, granular structure, and locally finely laminated structure corresponds to the upper part of this cryosol (active layer; see Van Vliet-Lanoë, 1988). This is compatible with the development of solifluction in 5-G.

In some sections, Layer 5-J has been observed superimposing 5-G. Its erosive lower boundary (gully) and matrix-supported sediment suggest that the main sedimentary process involved was a debris flow.

### 4.2. Unit 4B

The doublets observed in Layer 4B-LI (§ 3.2.2) exhibit a fining-upward pattern: the light-coloured lamina corresponds to the fast deposition of coarse particles (silt) and the overlying dark-coloured lamina to finer clayey particles. This normal graded bedding and the horizontality of the laminations are two arguments that are consistent with a decantation deposit. Each doublet corresponds to a distinct input of sediments in a pool. The small erosive features and the unstratified massive centimetric lamina are indicative of more dynamic and turbulent phases of sediment input. The deformed laminations under some blocks are attributed to the collapse of these blocks from the cave ceiling into water-filled sediment. Periods of drying are evidenced by vertical cracks (shrinkage cracks). The massive deposits that have a granular structure interrupt 4B-LI and sometimes contain limestone blocks (i.e., layers 4B-BC, 4B-LR and 4B-IL) are probably linked to a decrease of the water depth, the development of rill wash periods, and the resulting transportation of the small limestone fragments. A rock fall episode took place during the decantation period (Layer 4B-KK), as indicated by 2 events: first, the deformation of the stratification by collapsing blocks and second, the covering of the resulting rockslide by new decantation deposits.

The combined observations for this part of Unit 4B allow for the reconstitution of a lateral sedimentary sequence with distinct areas:

— The source area of the sediments (erosion area) corresponds to the sedimentary cone located under the cave porch.

— The transport area corresponds to the first metres of the cave where the silty sediments have been redistributed by run-off. These sediments frequently exhibit diffuse laminations parallel to the slope and laterally change into massive facies (4B-IL); some horizontal laminations are also visible (4B-LI). These elements indicate that in this area the sedimentation took place through alternating periods of run-off and decantation. Some gullies have also been identified in the same area, on top of Unit 4B. Unfortunately, their stratigraphic positioning is delicate because the concerned cross-sections are disconnected from the rest of the site. These gullies might be the first evidence of the important gully 4A-CHE at the cave entrance, or, on the contrary, secondary small gullies related to Unit 4B, which would have transported some of the sediment from the sedimentary cone of the source area to the settling area.

— The third identified area corresponds to the settling area (distal area), where the dominant facies is 4B-LI. The decantation took place in a large closed basin, which evoked the formation of a small lake or a pool.

The deposition of Layer 4B-UN and its lateral equivalent 4B-UF lead to the erosion of the top of 4B-LI. Run-off is probably the process responsible for the deposition of these sediments, but the important period of deep frost that later affected these sediments (cf. infra) has eradicated any characteristic sedimentary structures. Similar cases of eradication of sedimentary structures by frost action have been described in different environments (e.g. Van Vliet-Lanoë, 1987; Lenoble, 2005).

### 4.3. Sedimentary Complex 4A: units 4A-AP, 4A-IP, 4A-CHE, and 4A-POC

Layers 4A-LG and 4A-MC, which have developed in a small gully structure, may be the result of debris flow or hyperconcentrated flow (rill wash). The characteristics of the sediment from Layer 4A-KG also point to deposition by either a debris flow or rill wash. Near the back of the cave 4A-KG changes into 4A-GB, which indicates a diminution of the flow energy and suggests run-off.

An important stabilisation period took place after the deposition of Layer 4A-KG, causing the development of the Stalagmitic Floor CC4 in several phases. The interbedded detritic material observed in some places (layers 4A-OR, 4A-SGR, and 4A-YS) was probably deposited through run-off; as for 4B-UN, any characteristic sedimentary structures have been destroyed by the period of deep frost that later affected these layers (cf. infra).

The formation of Unit 4A-IP was followed by a period of deep frost that affected the sediment, as demonstrated by the thick platy structure identified in the sediments of units 4A-IP and 4A-AP, as well as in Layer 4B-UN, and down to the interface with Layer 4B-LI. In a loessic context, such a thick platy structure is associated with the continuing development of segregation ice lenses in the upper part of a permafrost throughout several seasons (Haesaerts & Van Vliet-Lanoë, 1981; Haesaerts, 1983; Van Vliet-Lanoë, 1988).

The development of this cryosol was followed by an extensive period of erosion that formed a large gully (Unit 4A-CHE), which locally reworked Stalagmitic Floor CC4 as well as the underlying layers from Unit 4A-IP down to Unit 5, sometimes even down to Unit 6A. Fragments of CC4 and underlying sediments have been incorporated into the gully. The different lithofacies present in this complicated unit (§ 3.2.3) reflect important changes in the sedimentary dynamics:

— The facies that is rich in poorly sorted coarse components from 1 to several decimetres in diameter (limestone blocks, speleothem fragments, and mud balls) deprived of any preferential orientation and exhibiting a massive matrix either with matrix- or clast-supported structure (4A-BK and partly 4A-GX) is evocative of a flow with high sediment concentration, similar to a debris flow. The larger components are broken speleothems (up to 50 cm), which have probably not been transported over long distances; they are mostly found near in situ Stalagmitic Floor CC4 where it is broken. They have probably collapsed and been incorporated from the banks of the gully.

— The facies that contains less coarse components (or in which the coarse elements are smaller) exhibits a matrix-supported structure, and often contains numerous mud balls. It might be indicative of a rather strong rill wash (4A-GX *pro parte*). The massive aspect of the matrix is due to the presence of mud balls. In these facies the mud balls, the speleothem fragments, and the limestone blocks all measure about 1 cm. These well-sorted coarse elements are more support for the hypothesis of a rill wash (Lenoble, 2005).

— The facies comprised of more homogeneous silt, either with less or no coarse components at all, would correspond to a lower energy run-off (4A-JA).

— A particular facies of heterogeneous silt (4A-AF) is found at the bottom of Unit 4A-CHE. It is deprived of coarse components and has developed inside a small gully that undercuts the anterior deposits. It may reveal a period of hyperconcentrated run-off reworking the sediment from Unit 4B, which occurred shortly after the debris flow episode that formed the gully.

4A-CHE may be interpreted as the result of the degradation of a deep frozen soil ('melting gully'). Some specific structures seem difficult to explain without this interpretation. The undercutting observed at the base of the gully in Unit 4A-CHE (facies 4A-AF), eroding Layer 5-G at the bottom of Section 30/31 in G (Figure 6), notably suggests the local thawing of frozen sediment. The presence of a well-documented deep frozen soil immediately preceding Unit 4A-CHE (see above) strengthens this hypothesis.

Because of the lack of cross-sections for several areas in the cave, the exact course of the large gully structure in Unit 4A-CHE could not be reconstructed in detail. Its general direction seems to coincide with the longitudinal axis of the cave, at least from metre 25 through metre 43 (see Chapter 5). A small relict section, which is in contact with the cave wall near the porch (Section D13/12), reveals an important erosive structure affecting the deposits of Unit 4B. This structure could correspond either to the gully or to the supply area associated with the decantation phase of Layer 4B-LI (cf. § 4.2). In the former case, this would mean that the gully would originate from the current cave entrance. Unfortunately, previous fieldwork did not provide any evidence of the entrance as the source since the 4A-CHE gully has only been identified during the new research conducted since 2003, after that part of the cave was already excavated. The only transverse section studied in that area before 2003 is Section 16/17 D-F (Gullentops & Deblaere, 1992), but its authors did not record the presence of the gully since the base of that section only reached the top of Sedimentary Complex 4. Benabdelhadi (1998) studied transverse Section 30/31 where the gully would later be identified. He describes Layer 4A as a monolithic entity, homogeneous, subhorizontal, and without any internal stratification, all of which is contradicted by recent observations (Pirson et al., 2005; Pirson, 2007; Figure 6). Therefore, it seems probable that the gully structure in Unit 4A-CHE was excavated in the first 20 m of the cave without having been recognised as such.

After the constitution of 4A-CHE, Unit 4A-POC developed through a phase dominated by run-off. The silty deposits from 4A-POC indistinctly cover the deposits of units 4A-CHE and 4A-IP, including Speleothem CC4 (Figure 5). Some lenses and some stony deposits suggest concentrated run-off and/or debris flow, but the limited extent of these observations suggests that one must be cautious during the interpretation of these structures.

## 4.4. Unit 3-INF

A short period of stabilisation followed the deposition of Sedimentary Complex 4A; it is represented by the formation of a small speleothem and the concretioning of the top of 4A-POC. Unit 3-INF was then deposited. The limited observations in this part of the stratigraphy do not allow for a satisfactory reconstruction of the sedimentary dynamics, although it seems that debris flows played an important role. A period of rock fall was also recorded, with the frequent presence of blocks several decimetres in width. Unit 3-INF ends with a new stabilisation phase marked by the development of a speleothem accompanied by calcitic cementing of the underlying sediment.

## 4.5. Unit 3-SUP

The deposits at the base of Unit 3-SUP (Layer 3-LHM) could not be observed well enough to allow a satisfactory reconstruction of the depositional context. It is probable that debris flow and run-off were the dominant sedimentary processes in this case as well.

On the contrary, the rest of Unit 3-SUP can be described in some detail. Very stony facies are characteristic of Layer 3-EMO, which contains very blunt and relatively well-sorted limestone fragments, with most clasts measuring between 1 and 4 cm. All of the limestone blocks are in contact (clast-supported sediment). The matrix is composed of well-rounded sand-size aggregates. The deposit locally exhibits an openwork structure. The longitudinal extension of 3-EMO is limited (ends around metre 34). These features suggest a 2-stage deposition process for Layer 3-EMO. During the first stage, an energetic flow (torrential flow), with a high sediment concentration, produced the sorting of the coarse elements transported as bottom load. These coarse elements were rounded in the process, while the fine particles were evacuated downstream. During the second stage, this coarse openwork deposit was partially infilled with sand-size aggregates. This second stage is indicative of the decrease of the energy of the flow, or of an additional phase of run-off. This 2-stage deposition process is demonstrated by the local presence of an openwork structure underneath large blocks, several decimetres wide. These large blocks prevented the infilling of the aggregates during the second stage.

Since the sequence was completely excavated between metre 23 and the cave entrance at the time of the stratigraphic revision, the impossibility of observation caused limitations for understanding the genesis of 3-EMO. The strike and dip of the layer situates its origin near the cave entrance. The process was probably initiated from the detritic cone under the cave porch. The related proximal facies could not be observed, nor the longitudinal variations of the facies of 3-EMO. However, data from the previous stratigraphic records allows one to visualise that this thick accumulation talus probably corresponds to the starting point of the torrential flow. There must have been a gully in the area that would have concentrated the flow and allowed the transportation and sorting of the coarse elements, several centimetres large, that have been observed downstream.

The longitudinal Section E/F reveals that Layer 3-EMO ends between metres 32 and 34 and is progressively replaced by Layer 3-ASS towards the back of the cave. This Layer 3-ASS presents a facies that is notably less rich in coarse components and might correspond to the accumulation area of the fine component downstream from the area dominated by the torrential flow. Between metres 30 and 32, Layer 3-ASS also directly superimposes Layer 3-EMO; the facies richer in stones observed locally within Layer 3-ASS in this area may reflect more energetic flow pulses. Near metres 43-42, the bottom of Layer 3-ASS is totally lacking any coarse components and exhibits weak laminations, reflecting a distal phase of unconcentrated wash.

## 5. Conclusions

The meticulous study of the sedimentary profiles available at Scladina and the continuous geological survey of the archaeological excavation that has taken place there since October 2003 have both allowed for the complete reinterpretation of Sedimentary Complex 4. Rather than the previous succession of **Layer 4B/Layer 4A/ Stalagmitic Floor CC4**, more than 20 layers have been identified with very different lithologies, but more importantly with a more complex distribution of the different lithostratigraphic units near Stalagmitic Floor CC4 than previously understood. All the layers that comprise Sedimentary Complex 4 are now divided into 5 distinct units: 4B, 4A-AP, 4A-IP, 4A-CHE, and 4A-POC.

Another major element of the new stratigraphic interpretation is the identification of an important gully (Unit 4A-CHE) in the upper part of Sedimentary Complex 4 that eroded Speleothem CC4 and the subjacent layers, locally down to units 5 and 6A.

The careful observation of sedimentary lithologies, geometries, and structures led to the reconstruction of the genesis of this part of the sequence. Following this genetic reconstruction it seems obvious that the filling of Scladina is quite complex and involves a large number of processes, both depositional and post-depositional. Several examples illustrate the existence of successive lateral facies that were generated simultaneously by different processes intervening in certain specific areas of the cave, from the entrance to the back (e.g., layers 4B-LI and 3-EMO). These successions reflect the vast complexity of lithologies and geometries that can be found in a cave entrance sequence particularly well. They remind one that the isochronous limits are often notably distinct from the lithological limits, following the classic Walther's Law in stratigraphy.

Following the establishment of the new stratigraphic sequence the question of the exact position of the Scladina Neandertal remains became pertinent since all the fossils were found before the stratigraphic reappraisal. Therefore, the re-examination of all the available data was necessary in order to try to determine the objects' stratigraphic position in the new sequence. This is the objective of another chapter of this monograph (see Chapter 5; see also Pirson et al., 2005; Pirson, 2007).

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