Johanna A. de Visser[1] & Gert D. van den Bergh[2]
[1] Helvoirt
[2] NIOZ, Texel

Sedimentology and stratigraphy of Corbeddu Cave (Eastern Sardinia)

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The depositional history of Corbeddu Cave (Eastern Sardinia) is complex. The sediments contain large quantities of fossil remains, which have an unusual taphonomy. The reconstruction of the depositional history in the cave is important for determining how the fossils were introduced into the sediments. This reconstruction was based on a detailed study of the profiles of the excavation pits. Several different facies types can be recognised, which were formed by distinct depositional mechanisms. Locally, calciumcarbonate precipitation resulted in the formation of flowstones during wet periods. Clay deposition took place in pools or subterranean intermittent lakes. Breccia was formed near the inferred entrances of the cave and was transported further into the cave by inflowing water during periods of increased rainfall. Rounded quartz gravel was introduced into the cave by a subterranean riversystem, which originated from a now inactive spring at the back of the cave. At the end of the Pleistocene, coarse breccia formation stopped and subaerial deposition of mainly fine-grained material (silt and clay) took place. Water flow transport of large bones, which are present in the pool facies, seems tobe unlikely in this low-energy environment.

Correspondence: J.A. de Visser, Torenakker 16, 5268 BX Helvoirt, The Netherlands, e-mail hanniede-visser@wxs.nl; G.D. van den Bergh, Netherlands Institute of Sea Research, P.O. Box 59, 1790 AB, Den Burg, Texel, The Netherlands

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INTRODUCTION

In the summers of 1984, 1987-1990, 1993 and 1997 sedimentological investigations were carried out on the fossiliferous deposits in Corbeddu Cave. By studying the sediments a better understanding of the depositional circumstances in the cave was obtained. With available radiocarbon dates, correlation could be established which made it possible to compare the depositional systems of Halls 1 and 2 in the cave. This paper gives a description of the sediments as exposed in a number of profiles, followed by a discussion and interpretation of the sediments.

THE CORBEDDU CAVE

The geographic coordinates of Corbeddu Cave are 40°15'07" N and 2°57'59" W. Its main entrance is situated in the Lanaittu Valley and faces to the northeast. Jurassic limestones surround the Lanaittu Valley. Other openings are present and in the past even more smaller and larger openings might have been present. The plan of Corbeddu Cave (Fig.1) shows the various excavation pits and profiles to which we shall refer in the following paragraphs. Emphasis has been placed on the deposits of Hall 1 and Hall 2, where most fossils have been collected.

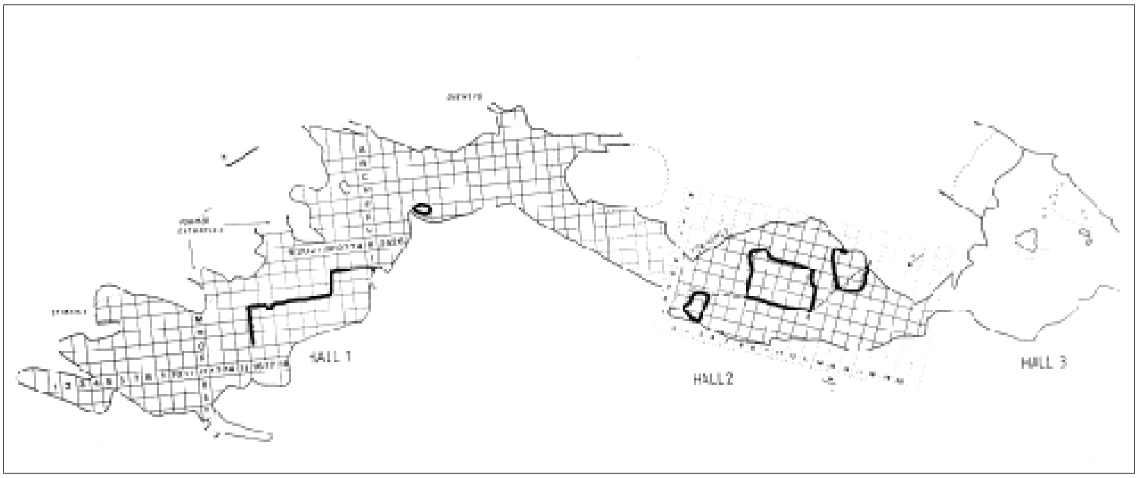

Figure 1 Plan of Corbeddu Cave showing the grid system referred to in the text and the various excavation pits and profiles.

DESCRIPTION OF THE SEDIMENTS OF HALL 1

The sediments in Hall 1, so far excavated, can be divided into seven lithological units, from bottom to top (Figs. 2-3):

Unit G) brown clay with limestone boulders and crystalline carbonate layers

This deposit is exposed in the middle of the profile (L/M 19-22) in the deepest part of the pit and has a thickness of at least 1.45 m as far as it is exposed. It consists of brown, fat clay with strings of pebbles, scattered pebbles and large blocks of limestone. At the bottom continuous or interrupted crystalline carbonate layers occur, which become thinner going upsection. The dip of these layers decreases going upsection.

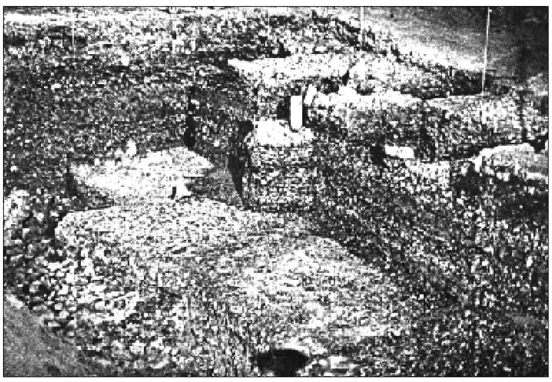

Figure 2 Photograph of profile N-M 15/16 and L/M 16-17.

Unit F) sorted breccia

This unit is found in the northeastern part of the profile (M 15/16 - N 15/16 and L/M 16-19). It consists of a well-sorted fine-grained breccia. Toward the southeast, the diameter of the pebbles increases. The breccia is partly matrix-supported, partly clast-supported. The pebbles have a red coating. The thickness of this unit is minimal 10 cm, but the base of this unit is not exposed.

Unit E) poorly sorted breccia

Unit E occurs in the same part of the profile as unit F. It consists of a poorly sorted breccia, compared to the breccia of unit F. The pebbles have a red coating. In general, the breccia is matrix-supported, but differentiations within the breccia occur, especially in the middle of the profile (L/M 16-19). In this part of the profile (Fig.4), several distinct layers within unit E could be recognised. The difference between these layers is mainly in matrix content and pebble size.

Unit E/F) breccia adjacent to the units E and F

In the southwestern part of the profile (M 18-19, L/M 19-22, L 22-K 22 and K 22-25), it is not possible to distinguish the units E and F. Unit E/F consists of a poorly sorted breccia, partly matrix-supported, partly clast-supported. The pebbles have a red coating. Distinct

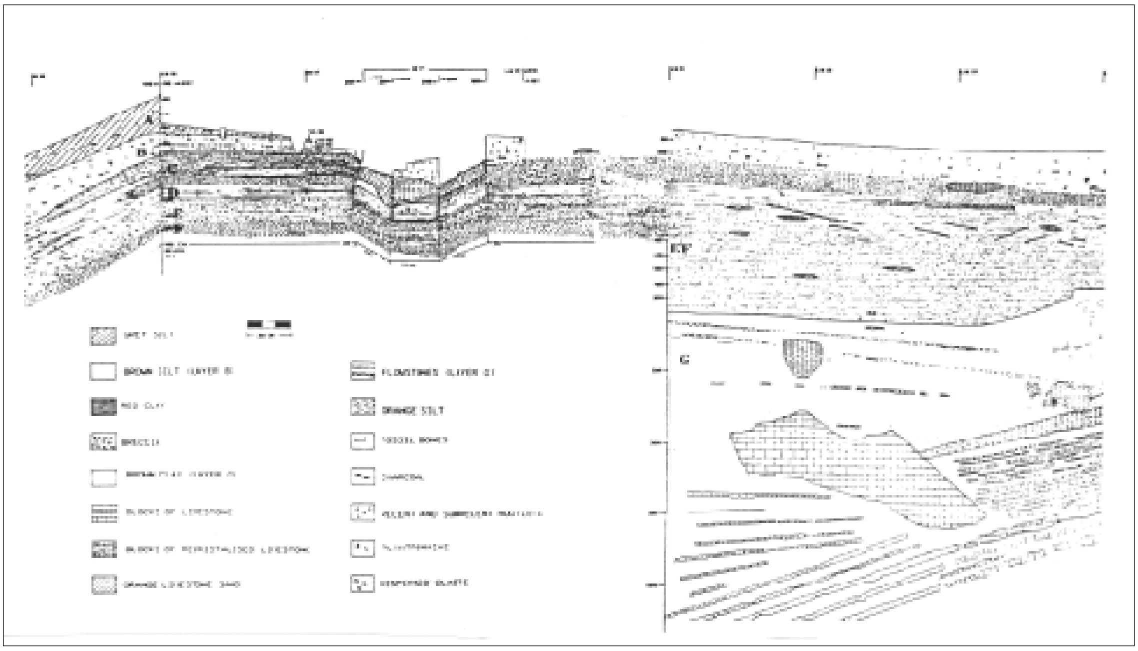

Figure 3 Detailed drawing of profile N 15/16 - M 15/16 - L/M 16-22 - L 22 - K 22 and K 22-25.

layers within the breccia are hardly traceable, if present at all. The thickness of this unit ranges from 50 to 75 cm.

Unit D) red clay
This unit could very well be identified in the longitudinal profile L/M 16-22. It consists of red clay with dispersed, red coated pebbles. Going upsection, the amount of pebbles increases slightly. Unit D becomes thinner toward the southwest, where the thickness is 6 cm. In the northeast the thickness is 10 cm.

Unit C) red breccia
Unit C consists of mainly clast-supported breccia. The pebbles have a red coating. The matrix consists of red clay except for the uppermost 2-10 cm, where brown silt from the overlying unit has been mixed with the red clay. Toward the southwest the thickness of the unit decreases from 25 to 6 cm.

Unit C/D breccia and red clay
In the transverse profiles M 15/16 - N 15/16 and L 22 - K 22, the distinction between the units C and D is not clear. The breccia of unit C becomes more matrix-supported and passes into clay with dispersed pebbles. The clay of unit D becomes more pebbly in these transverse profiles. The pebbles have a red coating. The thickness of the entire unit C/D increases towards the westnorthwest from 35 to at least 42 cm.

Unit B) brown silty layer
Generally, the transition from unit C to unit B is sharp and even erosive in the quadrates M-O 16, but towards the south it may be more gradual. Part of the matrix in the upper part of breccia C consists of infiltrated brown silt from unit B. Unit B consists of crumbly brown silt with dispersed pebbles. These pebbles are composed of the same limestone as the pebbles in the breccia units, but the pebbles in unit B only have a red coating in the lower part. At a higher level the dispersed limestone clasts do not have a red coating. These pebbles are more rounded and they show dissolution features. Several indications of human activity were found: ash layers, charcoal, pottery and the presence of (partly worked) flint and obsidian, material that is not autochthonous in or near the cave. Unit B thickens toward the southwest and westnorth-

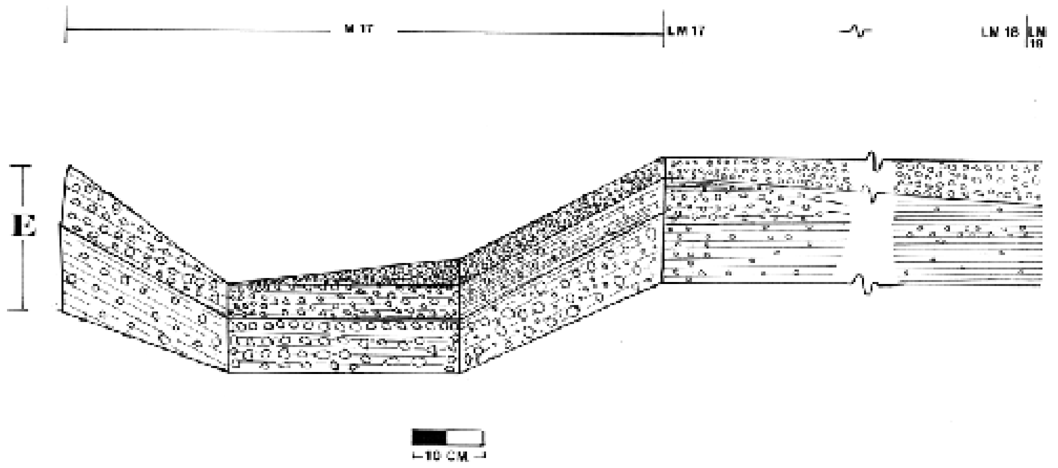

Figure 4 Detailed drawing of the differentiation in unit E in profile M 17 and L/M 17-18.

west, from 25 to 30 and 40 cm, respectively.

Unit A) grey silty layer
The transition between the brown silty layer B and the grey silty layer A is generally sharp and can be distinguished by a change in colour. This unit consists of grey crumbly silt with subrecent plant material, charcoal, ash layers, abundant ceramics and bones of both domesticated and wild animals. In the transverse profile M 15/16 - N 15/16, unit A becomes thinner toward the westnorthwest, decreasing from 27 to 13 cm thickness. In the longitudinal profile L/M 16 -17, unit A pinches out quickly toward the southwest.

DESCRIPTION OF THE SEDIMENTS IN HALL 2

The deposits of Hall 2 have been divided into 4 units. The units 1-3 succeed each other vertically. Unit 4 is locally developed and is situated in the southwestern part of the hall, adjacent to unit 2 and the top of unit 3 (Fig. 5).

Unit 3) clay, sometimes silty or sandy
This unit can be subdivided into red clay in the upper part (3A) separated with a sharp boundary from dark-grey clay in the lower part (3B). Unit 3 consists of bioturbated clay. Locally, it contains small concentrations of quartz and schist particles. Various fossiliferous levels occur in this unit. The most characteristic feature of sub-unit 3B is the presence of mud cracks. These cracks are filled with somewhat darker coloured, less consolidated clay. The transition from sub-unit 3A to 3B is visible as a sharp change in colour from dark-grey to red at an average depth of 2.60 m below R 2 (not shown in Figs. 5 and 6). In the red clay (3A) no desiccation structures are visible. This unit is 30-38 cm thick. In the north (Fig.1: profile C-D; fig.5), red clay of unit 3 is directly overlain by breccia of unit 2. Toward the south (Fig. 1: profile A-C; Fig.5) the transition is less pronounced as the red clay of unit 3 (with various small amounts of quartz and schist granules admixed) is overlain by red clay of unit 2 (with isolated limestone clasts with a maximum diameter of 0.5 cm). At the transition, both limestone, and quartz and schist granules are mixed with the red clay in minor amounts. The transition zone corresponds approximately with the upper fossiliferous level of unit 3. In the northwestern profile (Fig.1: profile B-C; Fig.5) it can be observed that the upper fossiliferous level of unit 3 forms the equivalent of the base of the breccia (unit 2) in the northeastern part. Actually, the fossiliferous level seems to merge into the breccia.

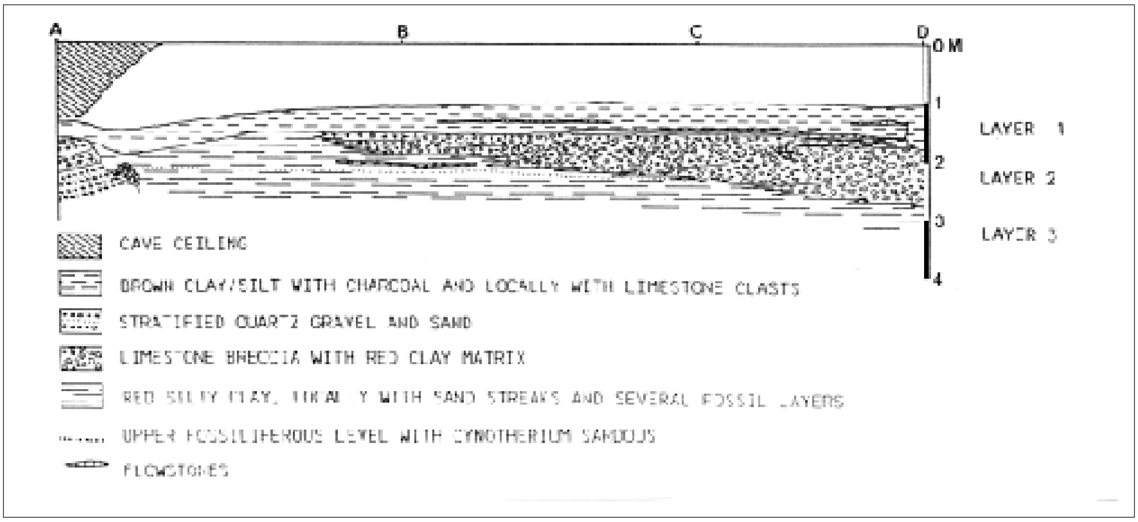

Figure 5 Schematic profile through Hall 2 (see also Fig.1 for profile line), showing the lateral and vertical transitions between units 1, 2, 3 and 4.

Unit 2) clast-supported limestone breccia grading laterally into red clay

Unit 2 consists of a 15-115 cm thick breccia deposit. It consists of limestone breccia with abundant remains of *Prolagus sardus* and terrestrial molluscs. The breccia is clast-supported and consists of angular limestone fragments with a maximum clast diameter of 7 cm. The matrix consists of red clay. Toward the southwest this breccia pinches out and grades into bioturbated red clay with isolated limestone clasts. Within unit 2 the limestone breccia in the north interfingers on a limited scale with the red clay in the south. The breccia progrades over the red clay toward the south and is not present anymore in the quadrates I 13 and I 14. Distinct interval layers within this breccia unit show a maximum dip of 13 degrees southsouthwest to west, the dip angle decreases toward the southwest (Fig. 6).

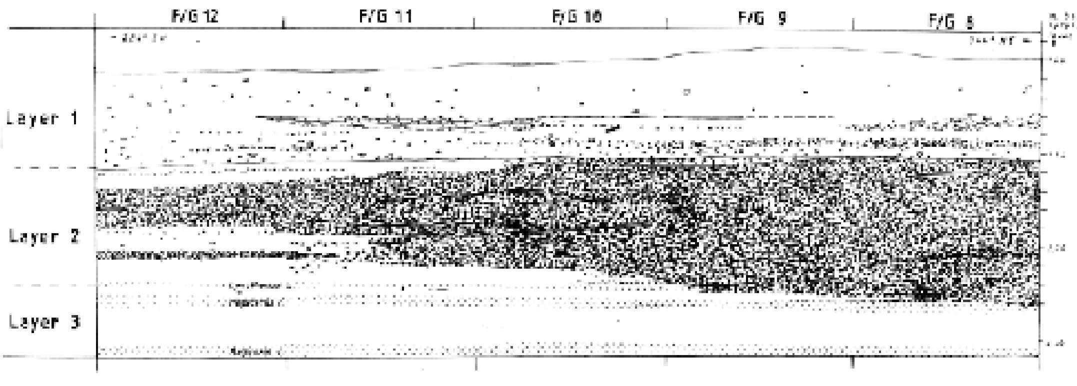

Figure 6 Detailed drawing of profile F/G 8 - F/G 12 in Hall 2.

Toward the southwest the breccia is overlain by red bioturbated clay, which forms the top of unit 2 there. The breccia shows internal bedding due to mean clast size variations, and the intercalation of clay laminae, which have a thickness of 0.5-2 cm (Fig. 6). These clay laminae consist of very pure silty clay. The laminae either merge laterally into the massive clay toward the southwest or can be traced over only short distances due to later erosion.

Unit 1) grey silty clay with dispersed angular limestone clasts
The boundary between unit 2 and unit 1 is sharp and can be clearly distinguished due to a change in colour from red to grey-brown. This unit consists of grey-brown silty clay with angular limestone pebbles, abundant charcoal and bones of both domesticated and wild animals. In this unit mud cracks are present, which are filled with darker coloured material. Thin irregular bioturbation tubes are present only around the lower transition with unit 2. A calcified horizon of variable thickness is locally developed in the middle of unit 1.

Unit 4) rounded quartz conglomerate
This unit can only be observed locally in the southwestern part of Hall 2 and is situated adjacent to unit 2 and the top of unit 3 (Fig. 5). It consists of well-rounded clast-supported quartz and schist gravel with granules of up to 1 cm in diameter. The matrix consists of red clay. The contact between this gravel unit and the units 2 and 3 is a steeply inclined surface. At some places above the present-day floor of the cave, remnants of poorly cemented quartz gravel are attached to the cave wall.

INTERPRETATION AND DISCUSSION: INFILLING HISTORY OF HALL 1

Unit G
The deepest excavated unit in Hall 1, unit G, was probably deposited during wetter conditions than the other units in Hall 1. This is indicated by the formation of flowstones. The gradual upward decrease in the dip angle of these flowstones, and the intercalating clays in the lower part of unit G suggest a depression was filled in. Dewatering processes through a swallow hole situated in quadrate O 20 may have caused the original depression. After sediments had blocked this outlet, the remaining depression could no longer dewater rapidly and a pool or lake could establish periodically in this depression. The brown fat clay that intercalates with the flowstones probably was deposited out of suspension during periods when the pool had become filled with sediment-laden water. During periods of low water level, the flowstones could precipitate on the margins of the depression from trickling water flowing into the depression. Because the dip direction of these flowstones is toward the northeast, the sources of the trickling water must have been situated in the southwest.

The sand layers and pebble layers from the upper part of unit G indicate that the water transported bedloadmaterial periodically into the remaining depression from various sides. This is indicated by dip directions toward the southwest in the northeastern part of the profile and toward the northeast in the southwestern part. Clay deposition out of suspension continued also during this phase. The formation of flowstones did not take place during the final infilling stage of this depression, suggesting that the overall climatic circumstances became drier at the end of the deposition of unit G.

Breccia units C, E and F
The boundary between the units G and E/F is erosional. The breccia units above this contact are characterized by mainly poorly sorted and coarser material. Clast-supported breccias are often encountered near the entrances of caves (‘entrance facies’). Through the entrance of caves, surface material falls, rolls, slides, creeps and flows into caves and becomes interbedded or mingled with autochtho-

nous material that results from the breakdown of the cave walls. During periods with heavy rainfall, water can flow into the cave and the loose material, which has accumulated near the entrances, is washed in further. The angularity of the limestone clasts indicates that they do not originate from dissolution processes and that they were not transported over long distances. It has been observed that the formation of breccia fans near the entrances of caves has been a common feature in the temperate climatic zones. They were formed especially during the colder periods of the Pleistocene (Lais 1941, Butzer 1964, Schmid 1969). Therefore, it is thought that the coarser detritus near the entrances was formed under the conditions of frost weathering. The limestone clasts were partly introduced into the cave together with the inflowing water, partly formed in the cave itself by erosion of the cave walls. As there have been no channel fills recognised in the breccia unit, the transport mechanism must have been unchannelised sheet flows. These sheet flows could develop under circumstances of large amounts of water entering the cave. When part of the transporting water penetrated into the underlying breccia deposits (washing in clay and silt matrix) current power diminished, causing the clasts to be deposited. During more moderate rains or during drier climatic periods only smaller clasts could be transported by the decreased flow, resulting in the pebble size variations seen within the breccia units. Temporal and areal variations of the current strength of the sheet flood caused the differentiation between and within the successive layers. Also the closing and opening of water passages by collapsing and dissolution processes, might have influenced the flow pattern and, therefore, the deposition pattern in the cave.

The slight dip toward the southwest of the units C-F in profile N 16-K 25 suggests that the material was supplied from the northeast. The steepest dips are observed in the quadrates P/Q/R - 7/8/9 (Fig. 1; the profiles in this pit are not described in this paper). The dip in this part of Hall 1 is 13 degrees west, indicating that this site was situated very close to the source of the coarse detritus. The breccia was probably formed near the actual entrance (or supplied from outside the cave through this entrance), and near an opening, which was situated south of the actual entrance, which is closed due to the collapse of its ceiling.

Clay unit D

The pure clay facies, which intercalates with the breccia units, is thought to be deposited out of suspension in pools of standing water that developed in depressions in between the breccia accumulations. The westward transition from breccia dominated to clay dominated facies within unit C (profile N 15/16 - M 15/16), indicates that a pool was formed close to the western wall of Hall 1. Toward the east and closer to the source of the coarse material, greater accumulation of breccia, prevented the development of pools in this area.

Unit A-B

Deposition of unit B probably started around the beginning of the Holocene. The supply of coarse material decreased greatly, probably because the climate at the beginning of the Holocene became warmer, causing the end of frost-weathering. Erosion of the underlying unit C even occurred towards the northwest of the profile. Mainly fine-grained silty material was introduced into Hall 1. Deposition occurred probably under subaerial conditions and was influenced by human activities as indicated by the local occurrence of charcoal and ash. Soil formation also occurred at this stage, possibly up to recent times.

INTERPRETATION AND DISCUSSION: THE INFILLING HISTORY OF HALL 2

Clay facies of unit 2 and 3

The clay, which is present in the cave, originated from the weathering of the Jurassic limestones and was deposited on the cave floor by water, which entered the cave through small fissures. The clay facies of unit 3 is thought to be deposited out of suspension in a low energy environment. The dark coloured clay from sub-unit 3B probably represents a climatic period in which periodic filling and desiccation of the pool occurred. The deepest part of the pool seems to have been situated toward the northeast. The bone levels of unit 3 and the mud-cracked surface at the boundary between sub-units 3A and 3B have a dip of 1-2 degrees toward the northeast (Fig.5). Additional evidence is that the mud cracks are poorly developed in the quadrates G-I 8 that are situated most towards the northeast. The supply direction of the clay remains unknown. Multiple sources might have been responsible for the clay supply. The fossiliferous levels of unit 3 contain large bones but only rarely coarse limestone clasts. The scarcity of coarse sediments suggests that the bones were introduced into the red clay in a different manner than water flow transport.

Breccia facies of unit 2

As indicated by the internal layering and morphology, the breccia facies of unit 2 was deposited on a small fanshaped body. The position of the apex of this little fan was situated close to the actual entrance of Hall 2, possibly a few meters south of it, where the stalagmitic structure forms the lateral boundary of Hall 2. This follows from the fact that the breccia body has its thickest development in the northeast and also because the dip direction of internal breccia layers is towards the southwest to west, the dip-angle decreasing also in this direction. The breccia fan spread out toward the southwest into Hall 2, gradually becoming thinner. During major rainfall, water flowed with considerable velocity into Hall 2 and transported limestone clasts into this hall. After entering the hall through a narrow opening the water could diverge freely, spreading out as a layer of unconfined flow (sheet flow). This is supported by the absence of channel structures.
The fact that the sediment was supplied from the northeast in both Hall 1 and 2, does not imply that the depositional systems in both halls were part of the same breccia fan. The breccia of Hall 2 could have been transported through another formerly existing opening instead of through the entrance in Hall 1. There is an opening in the corridor between Hall 1 and Hall 2 (Fig.1) and it is suggested by others (Spaan & Kalis 1988) that possibly another opening might have been present behind the stalagmitic structure developed at the eastern wall of Hall 2.

Because the red clay facies of unit 2 and the top of unit 3 are situated adjacent to the breccia, the breccia fan must have entered with its toes into the pool in which the clay was deposited. As the sheet flows entered this shallow pool from the breccia fan, they lost their transporting capacity and deposited their bedload along the margin of the pool. This probably explains why various breccia layers interfinger on a limited scale with the red clay but grade very rapidly into the red clay facies laterally. The fact that thin clay laminae interfinger with the breccia indicates that sometimes the water level in the pool rose to an extent where the breccia fan became partly submerged, so that thin clay laminae could be deposited out of suspension. During the winter of 1987 - 1988 a considerable amount of water entered the cave during exceptionally heavy rainfall. It was later observed that thin clay drapes had settled out of suspension in depressions that had been temporarily filled with standing water (De Clercq *et al.* 1991).

The above presented model of a laterally prograding fansystem is confirmed by several radiocarbon age determinations on samples taken from different quadrates within the breccia unit (Klein Hofmeijer *et al.* 1987). Samples CB 84 - 2000 (UtC - 250), CB 85 - 3554 (UtC - 14/237) and CB 85 - 3014 (UtC - 300) are taken from approximately the same depth below the reference point of respectively 171.5, 165.0-175.0, and 169.5 cm. However, C14 dates show considerable differences in the ages of these samples. Sample CB 84 - 2000, which has the most proximal position in the breccia fan system (quadrate I 8) has the oldest age of 11,040 + 130 yBP. The most distally positioned sample (CB 85 - 3014, quadrate I 13) has a much younger age of 8,750 + 140 yBP. Sample CB 85 - 3554, which has an intermediate position in the breccia fan (quadrate M 12), also has an intermediate age, namely 9,820 + 140 yBP. It can be concluded that in about 2.300 radiocarbon years the breccia fan has prograded about 5 meters in southwestern direction. Another sample, CB 88 - 13087 (UtC - 999) from the clay facies of unit 2 in quadrate H 13, was dated to 9,790 + 160 yBP (Klein Hofmeijer 1989, Sondaar *et al.* 1995). This age is relatively young in relation to its depth of 206 cm. It demonstrates the lateral transition from breccia facies to clay facies, which is in perfect agreement with the model as presented above.

Unit 4: Rounded quartz gravel

The gravel was probably supplied by the, now inactive, source at the back of the cave in Hall 4 (Fig.1) and was transported into Hall 3 and 2 by a subterranean river. The gravel unit and the cemented gravel deposits that are locally attached to the cave wall might be the remnants of a complete infill of the cave, deposited before the units 1-3.

Unit 1

Similar to the upper two units in Hall 1, the supply of coarser breccia material decreases greatly at this stage and the deposition of red clay also stopped, possibly due to a warmer climate. A study of the microfossils and the malacofauna also indicates drier conditions during deposition of unit 1 (Sondaar *et al.* 1984). Layer 1 contains mainly airborne deposits. Human activities also played a role, although to a lesser degree than in Hall 1. Human activities are represented by the presence of charcoal and pottery remains.

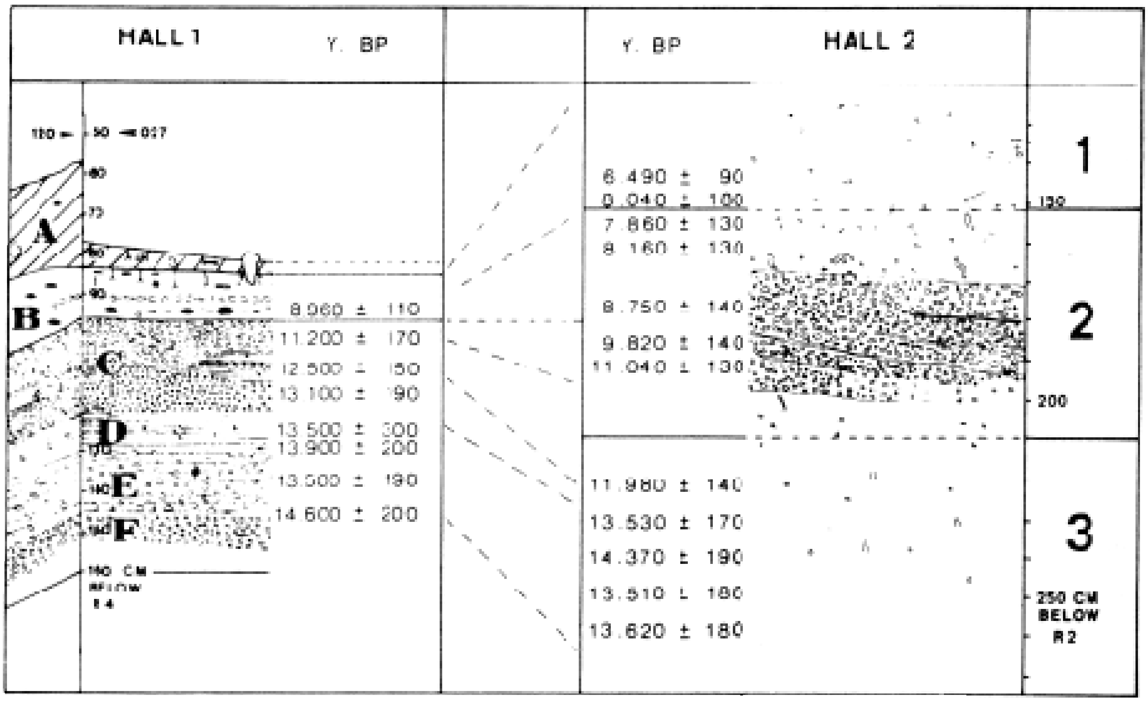

Figure 7 Temporal correlations between the deposits of Hall 1 and Hall 2, based on the interpretations of the radiocarbon dates.

TIME CORRELATIONS BETWEEN HALL 1 AND 2

Samples of fossil bone and charcoal have been collected from several levels in Halls 1 and 2 for radiocarbon dating (Klein Hofmeijer *et al.* 1987, 1989). Several radiocarbon dates are available from the profile in Hall 1. One from the top of unit C gives an age of 11,200 ± 170 yBP, the oldest one from the top of unit G gives an age 22,700 ± 600 yBP, while the other samples from intermediate levels provide intermediate ages (Fig.7). A sample from the upper part of unit F gives a radiocarbon age of 16,200 ± 400 yBP. Because there is an erosive contact between units G and F there might be an hiatus in the sequence at the transition between these units. All we can say is that a depositional change occurred in Hall 1 near the location of the profile from deposition dominated by clay influxes to breccia deposition after 22,700 yBP and before 16,200 yBP. Around 13,500 ± 300 yBP (unit D) there was again a period prevailed by clay dominated deposition, after which breccia deposition had started again at around 13,00 ± 300 yBP (lower part unit C), at least continuing until 11,200 yBP (top unit C). The base of unit B is dated at 8,960 ± 110 yBP but, again, there is an erosional contact present at the transition between unit C and B, which might represent a hiatus. Deposition had again drastically changed at this transition as expressed by the marked change in color and decrease of breccia supply. Unit B and possibly also the uppermost top of unit C is locally disturbed by human activities.

In Hall 2 the oldest age of 42,000 + 3000/-2000 yBP comes from unit 3 at a depth of 559 -569 cm below R2. The transition from unit 3B to 3A at around 260 cm below R2 is dated between 13,620 ± 180 yBP and 13,510 ± 180 yBP. The oldest breccia present in the studied profile in Hall 2, is the lateral equivalent to the upper *Megaceros cazioti* level, which is dated at about 11,980 ± 140 yBP (see Fig. 6). This *Megaceros cazioti* level passes from the clay of unit 3A into the breccia unit in quadrate G 9 at a level of 231 cm below R, where the dated sample was taken.

The oldest age from within unit 2, of a sample from the middle at 171.5 cm below R2, gives an age of 11,040 ± 130 yBP. As was noted before, this sample comes from quadrate I 8, which is proximally on the breccia fan. Other samples from unit 2, but representing more distal parts, gave ages of 9,820 ± 140 yBP (qua-drate M 12, 165-175 cm below R2) and 8,750 ± 140 yBP (quadrate I 13, 169.5 cm below R2). The youngest sample from unit 2 (quadrate I 15, top of unit 2) shows an age of 7,860 ± 130 yBP. While the most reliable date for the base of unit 1 (quadrate I 15) is 6,690 ± 80 yBP, indicating that breccia deposition, which had already decreased at the top of unit 2, stopped around this time. The deposition of clastic material presumably changed from water supplied to airborne supply.

Comparing the chronostratigraphy of the two halls, it can be concluded that breccia deposition started much earlier in Hall 1, after 22,700 yBP, while in Hall 2 the southwestwards prograding breccia fan became active only shortly before 11,980 yBP. Interestingly, the more or less continuous clay deposition in Hall 2 before 11,980 yBP seems to have been interrupted at around 13,500 yBP as expressed by the development of the desiccation cracks at the top of layer 3B. Around the same time breccia formation and deposition stopped in Hall 1 (clay unit D). Both events might correspond to a warming up of the local climate and/or drier conditions. The starting of breccia deposition in Hall 2 had certainly begun at 11,980 yBP. Because the fan system has migrated from the northeast towards the southwest, it is possible that near the source of the breccia (a presumed cave entrance which is now closed by stalagmite formation in the northeastern boundary of Hall 2) breccia formation and deposition started earlier, to reach quadrate G 9 only at 11,980 yBP. If such an interpretation can be proven later, breccia deposition might have occurred in both halls from around 13,100 yBP onwards. In Hall 2 breccia deposition decreased largely around 8,160 yBP and had stopped completely at around 7,000 yBP. This is in contradiction with results from Hall 1, where the minimum age of breccia deposition is 11,200 yBP (at the top of unit C). An explanation might be that erosion, as expressed by the erosive boundary between units C and B, has removed the upper part of unit C.

RECONSTRUCTION OF THE DEPOSITION IN HALL 1 AND 2

In Figure 8 a reconstruction of the depositional systems in Hall 1 and 2 around the boundary between the Pleistocene and Holocene is given. The figure summarises the preceding interpretations and is based on the spacial facies distribution of the upper part of unit C in Hall 1 and of unit 2 in Hall 2. The human skull fragments that were found in Hall 2 (Spoor & Sondaar 1986, Spoor 1988; Spoor 1999) were found in the breccia of unit 2 and correspond in age with the reconstruction. In Hall 1 several breccia sources located at the actual entrance, and the collapsed one to the S are inferred, although further excavations closer to these entrances are necessary to verify this interpretation. In Hall 2 it is evident that there was only one source of breccia located in the northeast to east. Because there are no signs of physical degradation of the ceiling or walls of Hall 2, the breccia must have been supplied from outside. A lower lying intermittent pool of standing water was located toward the southwest of Hall 2, where deposition of mainly clay occurred. The large bones of *Megaceros cazioti* and *Cynotherium sardous*, especially the skulls and mandibles, are not likely to have been transported in this low energy environment. In combination with the uncommon taphonomy of the bones (Klein Hofmeijer 1996) this points to other dispersal mechanisms of the bones, at least in Hall 2.

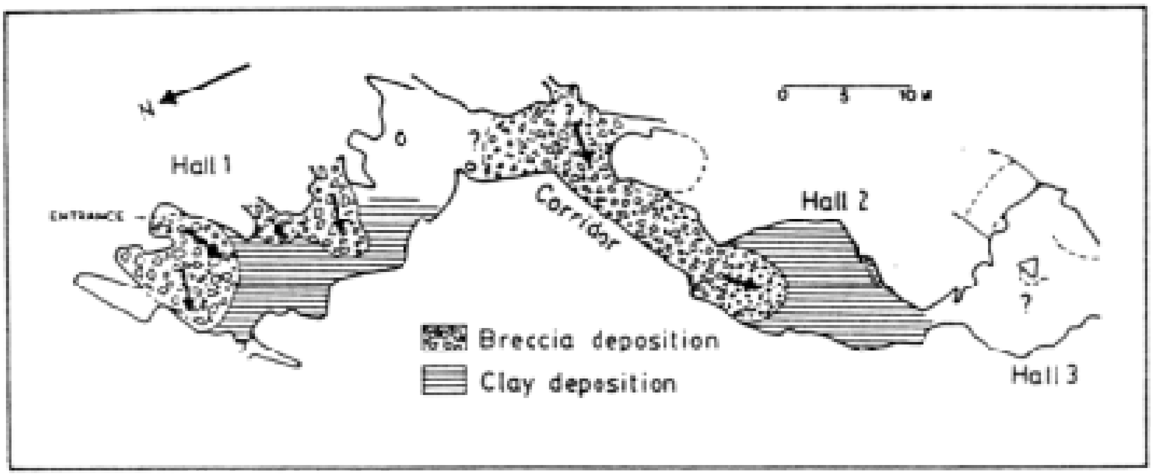

Figure 8 Depositional model for the cave sediments. Reconstuction of the depositional environments in the cave about 12,000 C14 yBP (at the time of deposition of layer C in Hall 1 and the upper bone bearing level in Hall 2). Transport directions of the breccia are infe rred from the dip directions of the breccia layers and the position of the collapsed cave openings.

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