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AN ANALYSIS OF SEDIMENTS FROM FOX HOLE CAVE, HIGH WHEELDON, DERBYSHIRE

T. J. LAWSON

Abstract

A quantitative characterisation of the sediments from Fox Hole Cave, Derbyshire, provides useful information about the sources of sediment supply, the mode of deposition in the cave and certain post-depositional modifications of the stratigraphy. A low energy environment for deposition has given rise to poorly sorted sediments of both autochthonous and allochthonous origins. Information from the archaeological and biological remains found in the cave suggests a chronological framework in which the earliest deposits sampled seem to date from a Mid-Devensian interstadial period.

INTRODUCTION

The potential of caves as habitation and burial sites for man and beast has long been recognised by archaeologists and palaeontologists. However, little attention was paid to the sediments in which such remains are found until the work of Lais (1941). Much analysis of cave sediments was subsequently carried out by French- and German-speaking archaeologists and geologists (see bibliography in Colcutt, 1979), but little interest was generated amongst English-speaking scholars until more recent times (e.g. Farrand, 1975; Bull, 1976, 1978, 1980; Tankard and Schweitzer, 1976; Campbell, 1977; Nöel *et al*, 1979).

Despite the recent increase of such research it is fair to say that, as yet, little is known about sedimentation processes in caves, the rates at which they operate and the effects on the sediments of the large-scale climatic changes that have occurred during the Quaternary. This only serves to hinder the interpretation of cave stratigraphies. It is the aim of this paper to present information of a quantitative nature in order to study the effects of environmental changes on a sequence of cave deposits from the point of view of their mode of sedimentation and the likely post-depositional modifications of the stratigraphy.

THE SITE

High Wheeldon is a hill 1·3 km south-east of the village of Earl Sterndale, Derbyshire (Fig. 1). The western side of High Wheeldon and other hills to the north-west and to the south-east are constructed of Lower Carboniferous reef limestones, forming the north-east flanks of the Dove valley. To the east lie the lagoonal limestones of the 'White Peak' (Ford, 1977, Fig. 8). To the west lie the shales, mudstones and sandstones of the Millstone Grit Series, forming a parallel eastward-facing cuesta on the south-west side of the Dove valley.

The entrance to Fox Hole Cave (SK 100663) is located on the north-facing slope of High Wheeldon, in the lagoonal 'Bee Low' limestone. The cave extends back into the limestone, towards the reef deposits, for some 60 m. The configuration of the cave is strongly joint-controlled, comprising a series of chambers connected by narrower passages (Fig. 2). The cave was discovered in 1928, and subsequent excavations in the Entrance Chamber produced a variety of animal remains and archaeological finds (Jackson, 1951), but no record of the stratigraphy was made at that time. The Peakland Archaeological Society has been excavating the cave on a part-time basis since 1961. Records of these excavations have been published by Bramwell (1971, and in Ford, 1977, pp. 267–73 and 279–83). When the writer visited the site in August, 1977, work was being undertaken in the First Chamber, where a 1·6 m section had been cut through the deposits, revealing a multi-layered stratigraphy.

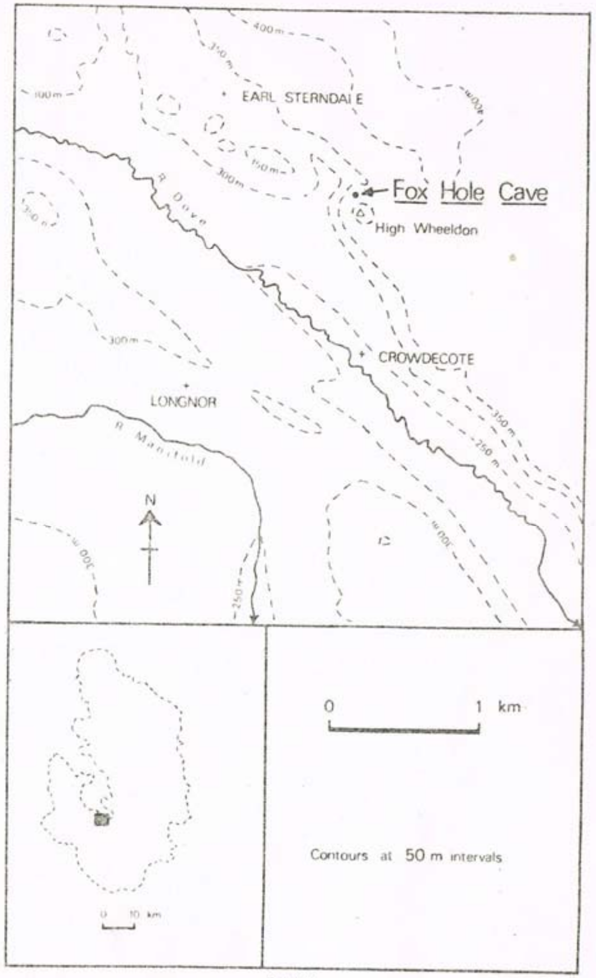

FIGURE 1
The location of Fox Hole Cave. Inset shows the location of the area covered by the map in relation to the boundary of the Peak District National Park.

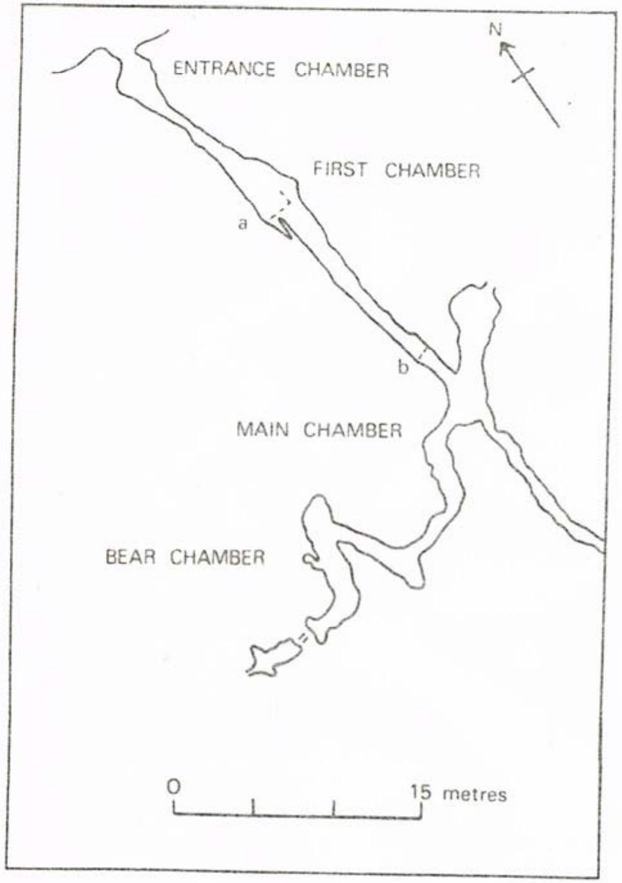

FIGURE 2

Plan of Fox Hole Cave (adapted from Bramwell, 1971, Figure 1) showing extent of surveyed passage. (a) refers to the position of the excavated section in 1977 and (b) to the limit of excavations in 1969.

The Stratigraphy

Six main stratigraphic units were apparent in the section and these may be correlated with the strata recognised in the Main Passage by Bramwell (1971, p. 5). There was no sign of Bramwell's layer F in the 1977 section, but the other layers are directly comparable and are accordingly referred to as A, B, C, D, E_1 and E_2. The colour of each stratum was described using the Munsell notation. Samples from each layer were examined in natural light outside the cave to prevent the inaccurate description of the colour as viewed under the artificial lighting used in the cave (Fig. 3).

Layer A, some 20–30 cm thick, was a dark chocolate-brown, plastic clay (Munsell colour 10YR 3/3), containing small fragments of bone. Extending across the section, dipping from east to west, was a layer of limestone rubble, 5–9 cm in depth, labelled layer B. Beneath this layer was found a lighter brown clay (Munsell colour 10YR 4/4) which showed signs of mottling. Wet and sticky to the touch and 20–25 cm thick, this material contained large amounts of bone fragments and other gritty debris.

Beneath the layer of wet clay (layer C), a layer of angular debris was found (layer D). This consisted of large limestone slabs averaging 30–60 cm across and 10 cm thick, with an interstitial matrix of material that appeared identical to that of layer C. The blocks showed no preferred orientation and were evidently the result of a considerable fall of rock from the roof.

Below the block layer was a mixed deposit some 55 cm thick consisting of a coarse, gritty clay material, varying in colour from 7·5YR 5/6 to 7·5YR 6/6. Wetter and more sticky in its upper levels, it appeared drier and more consolidated lower down the profile. This layer (E_1) merged imperceptibly into a layer of a more reddish colouration, but of similar texture (E_2).

Methodology

In order to test for variations both within and between each of the described layers, sediment samples were taken every 5 cm down a continuous column of the section, excluding layer D, which was considered to be unsuitable for analysis due to the extremely coarse nature of the deposits. Hence twenty-five samples were taken in all, labelled 1–11 above layer D and I to XIV below it.

After dispersal overnight in a weak sodium hexametaphosphate solution, the samples were analysed for their particle size distribution by a combination of the wet-sieve replicate method outlined by Folk (1974, p. 22) for particle diameters greater than 63 microns (4·0 ø), and the hydrometer method for particles of silt and clay size. Results were plotted as cumulative percentage frequency curves on arithmetic probability paper. From these graphs it was possible to read off the percentage of the total weight of each sample in each size grade and to compute various size parameters from each distribution using inclusive graphic statistics (Folk and Ward, 1957; McCammon, 1962). These summary statistics of mean, sorting, kurtosis and skewness are considered to characterise the sediment samples adequately and enable comparison between samples within layers and samples from different layers.

A lithological analysis of the size fraction greater than 2 mm (−1·0 ø) was carried out in order to determine the proportions of each sample that were derived from within the cave system and from external sources (autochthonous and allochthonous sediments respectively: see Ford, 1975). Between 100 and 200 particles were counted in each sample. A rough estimation of the range of particle shapes occurring in each sample was made using the Powers visual comparison chart (Powers, 1953), and particular attention was paid to the presence or absence of chemical weathering or reprecipitation of calcareous material.

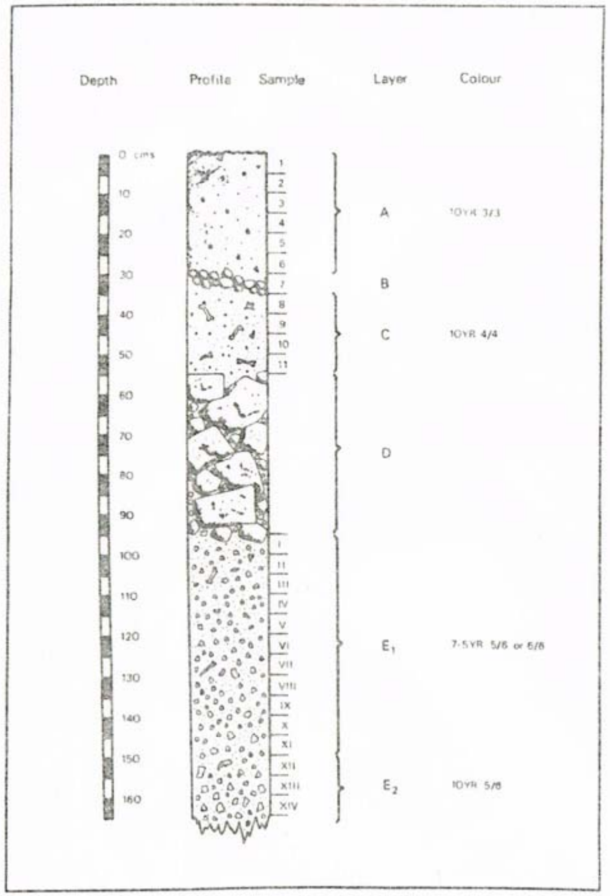

FIGURE 3
Schematic stratigraphic profile of the sampled 1977 section in the First Chamber, Fox Hole Cave.

RESULTS

The results of the various analyses undertaken are presented graphically in Figures 4 to 7.

Bivariate scattergrams of the various size parameters derived from the cumulative percentage frequency curves indicate the degree of similarity between samples from the same and from different layers. In order to show the strength of clustering of the points from each layer of the stratigraphy, a zone was drawn extending for two standard deviations on all sides of the mean value of each size parameter. Three of the scattergrams showed good clustering and are reproduced here as Figure 4. It can be seen that all the samples from each layer fell within the two standard deviation zone except for one sample from layer E$_1$. The rather large zone around the mean value for layer E$_2$ is due to its being based on only three scattered values. Two of these three values plot near to the grouping of the samples from layer E$_1$. Only the sample from the lowest part of the section (sample XIV) plotted away from this group. Layers A, C and E$_1$ all fell into mutually exclusive groups. As might be expected, tha sample from layer B plotted on the margin of the two standard deviation zone for layer A, sediments from the latter having been washed down in between the cobbles of layer B. On the whole it would seem that these results justify the subdivision of the profile into the six parts on the basis of their visible attributes.

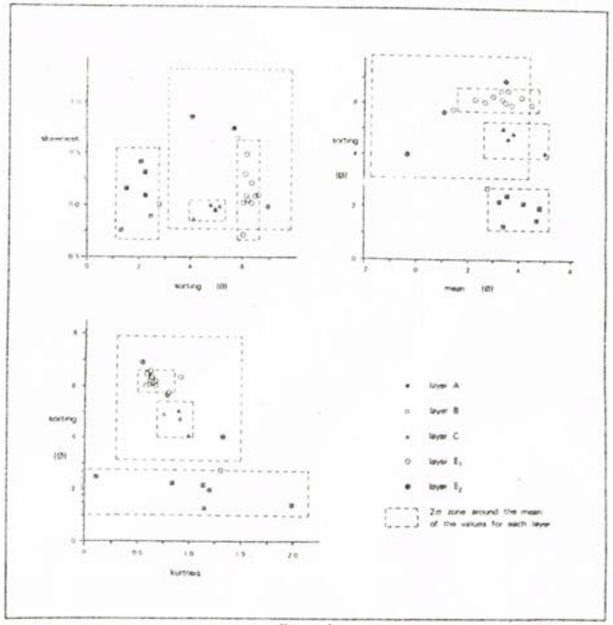

FIGURE 4
Bivariate scattergrams of particle size parameters derived from the analysed samples, showing the degree of similarity between samples from the same layers and inter-layer variations, Fox Hole Cave.

The results of the particle size analysis are presented in Figures 5 and 6. There appeared to be a distinctive coarsening of material down the profile. For the most part the sediments were poorly sorted throughout, especially in the lower levels. However, parameters derived from inclusive graphic statistics cannot discern between unimodal and bi- or multi-modal distributions. Closer scrutiny of the particle size distribution graphs for each sample revealed that only samples from layer A were unimodal, except for sample 5, which was clearly bimodal. All the other samples were multimodal, with strong modes in the coarse fraction (greater than 2 mm diameter) and clay-sized fraction, and weaker modes in the fine sand and coarse silt fractions. No obvious trends occurred in the size of these various modes down the profile. Good sorting in the sand fraction of samples from layer E_1 was apparent from the particle-size distribution graphs, although the calculated size parameters indicated poor sorting for the samples as a whole.

From the lithological analysis of the fraction coarser than 2 mm diameter, four lithological groupings were apparent: (a) limestone fragments, (b) derived quartz and chert particles, released from the limestone by solution, (c) stalactitic material comprising not only flowstone fragments but also aggregates of reprecipitated calcium carbonate and minerogenic particles, and (d) fragments of shale, silistone and fine sandstone, often with ferruginous crusts, derived from the Millstone Grit group. For the purpose of completeness, bone fragments were considered to be a fifth group, as they were such an integral part of the total cave sediments. Results of the lithological analysis are presented in Figure 7. Several striking features are apparent: the high percentage of Millstone Grit material in layer A, replaced by large quantities of bone in layer C; the return to a fairly high percentage of Millstone Grit material in layer E_1, accompanied by large amounts of flowstone fragments and carbonate concretions. On a cautionary note, however, it must be pointed out that the interpretation of the lithological analysis should be made with reference to the particle size distribution, since proportions based on fewer coarse particles may not be as representative as those based on counts of a larger number of particles from samples possessing a much larger number of fragments of coarse size.

Except in layer D, limestone was apparently not a significant constituent of the coarser sediments, appearing in the lower half of layer A and increasing slightly through layer C. The peak in layer B is indicative of the presence of the limestone cobbles. Layer D consisted almost entirely of limestone blocks, but, as has been stated previously, it was impossible to sample from this layer or to place a meaningful figure on the proportion of limestone contained within it. Limestone and flowstone fragments in layer A tended to be small (mean length 0·5 cm) and angular. In layer C, the size of the limestone particles increased (up to 3·0 cm long), consisting of a strange mixture of fresh angular fragments and sub-angular/sub-rounded pieces showing signs of chemical weathering and reprecipitation of calcium carbonate on some surfaces. Classic frost-shattered slabs (see Laville, 1976, Fig. 1) were found at the base of layer C. Limestone was only found in the top 20 cm of layer E_1, and then only as small angular fragments. Flowstone shattered from the walls was found in large quantities (60–95 per cent) in this layer, particle sizes tending to increase down the profile. All calcareous material in the upper half of layer E_1 tended to be angular, with signs of post-depositional chemical rounding of edges and the cementation of particles with calcium carbonate. Such evidence of chemical alteration decreased lower down the profile and was rarely found in the lowest levels (samples VIII to XIV).

Bone fragments varied in both size and shape. The degree of preservation seemed to be directly related to the size of the original bone and to the intensity of weathering processes acting on it since its deposition. Bones were rarely complete and usually found as fragments or flakes. The largest fragments were found in layer C, seeming to represent intensive occupation of the cave by animals when this layer was deposited. Bones in this layer were generally well preserved, yet beneath the slab layer (layer D) bones were much fragmented and crushed. Much

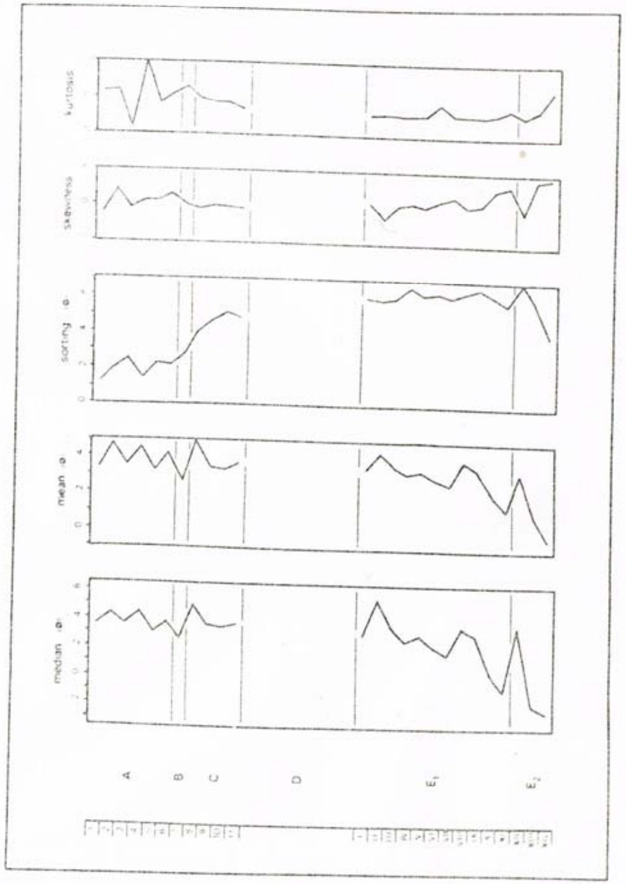

FIGURE 5
Changes in size parameters down the profile, Fox Hole Cave

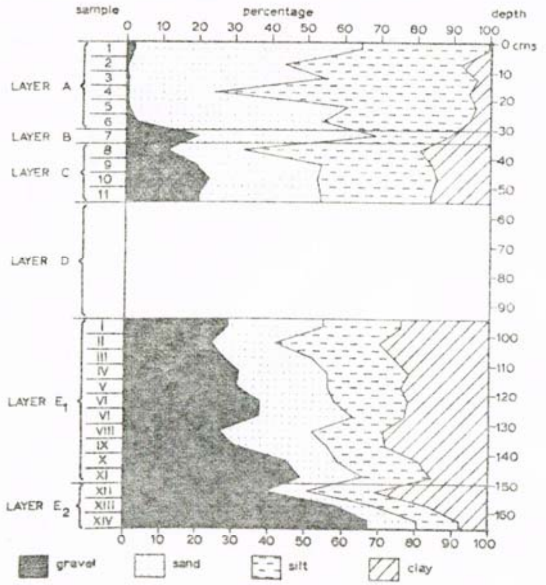

FIGURE 6

Changes in the particle size distribution throughout the profile, Fox Hole Cave.

damage may have been caused by the roof-fall event, but evidence from lower down in layers E_1 and E_2 has shown that crushing may have been effected by mixing and heaving processes that have affected these deposits, as the forces present have split and crushed large teeth and bones of cave bear (D. Bramwell, pers. comm.).

The Millstone Grit material found in the sediments can only have been derived from the patchy veneer of glacial debris that presently occurs on High Wheeldon. This glacial debris, which predates the last glaciation (see below), has entered the cave through the cave entrance by solifluction and/or by washing through the joints and bedding planes in the limestone. Variations in the amount of Millstone Grit fragments in each layer are possibly due to one of two reasons:

(a) differences in the degree of disintegration of the sedimentary particles, largely a function of the amount of throughflow of percolating drip-waters since deposition;
(b) the progressive solutional widening of joints in the limestone.

If (a) is taken to be correct, it can be postulated that the top layer possesses more Millstone Grit material in the coarsest fraction than do layers deposited earlier in the sedimentary sequence, because the sandstone and shale fragments have not been weathered away to the same extent as in the layers beneath. If (b) is thought to be more likely, the same pattern can be explained as being due to an increase in the amount of Millstone Grit debris being washed through joints in the rock as the latter are widened by solution.

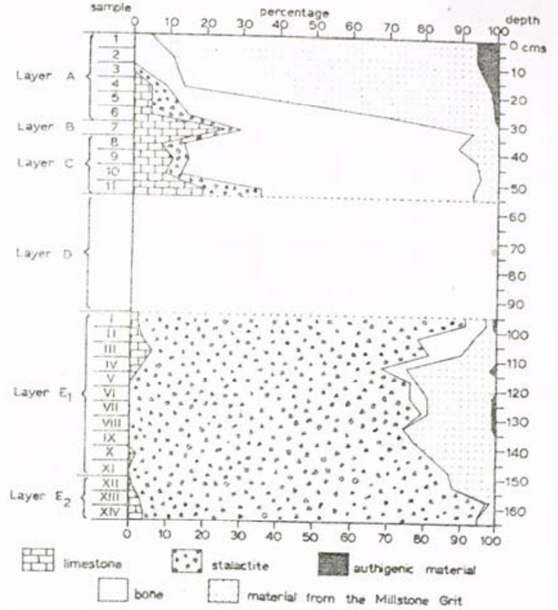

FIGURE 7

Changes in the lithology of the gravel fraction throughout the profile, Fox Hole Cave.

A further point of interest is the presence of chert and quartz in the sediments at levels where limestone is only present in small proportions or entirely absent. This may be indicative of phases of greater solution, with insoluble material present as residue where the limestone has been dissolved.

INTERPRETATION

The results of the various analyses need to be interpreted in terms of the origin, mode of deposition and post-depositional modification of the sediments. The layers will be dealt with in the order in which they were deposited.

Layers E_1 and E_2

A mixture of both autochthonous and allochthonous material is characteristic of most of the sedimentary levels in Fox Hole Cave. The internally-derived component seems to dominate layers E_1 and E_2, being largely composed of angular speleothem fragments. It might be presumed that these have been broken from the roof and walls of the cave by natural processes such as frost shattering or crystal wedging. However, at present the cave possesses few speleothem formations, and it is possible that a large proportion of the material may have come from the destruction of an old stalagmite floor, of which there was no trace at the time the section was sampled. Recent excavations at Fox Hole Cave have suggested that the First Chamber is in fact a plugged shaft, down which water from the back of the cave drained to a lower cave system. Material from the walls farther back in the cave may have flowed forward to contribute to the sediments in the First Chamber. All this indirectly poses the question of whether or not another entrance to the cave exists on High Wheeldon, blocked up and grassed over so that no sign of it exists today.

Bramwell (1971, p.5) has suggested that the mixed nature of these sediments has been caused by sludging. The present writer concurs with this opinion; however, the absence of any clear sedimentary structures and the random orientation of the coarser particles suggest that these deposits may also have been affected by cryoturbation processes. Periodic wetter phases may account for the increased sorting in the sand fraction of certain of the samples taken from layer E_1. The presence of many reprecipitated calcareous crusts and recemented aggregates in the upper samples (I to VII) indicates that leaching processes have not yet reached the material at the base of the profile.

Layer D

A breakdown deposit, caused by a weakening and subsequent fall of rock from the roof of the cave, was laid down on top of layers E_1 and E_2. The reason for the weakening of the roof was probably solution or ice-wedging along a bedding plane, or the release of tensile stresses when permafrost occupying the cave space was removed by a climatic amelioration. Since the roof-fall event, percolating drip-waters have filled the inter-block spaces with material from above.

Layers A, B and C

These uppermost layers are best discussed collectively. Externally-derived sediments are dominant in this part of the profile. In layer C, limestone and speleothem fragments shattered from the roof and walls, possibly by frost action and crystal wedging, are mixed with bone material and particles derived from the drift cover on High Wheeldon, washed into the cave by percolating waters through fissures in the limestone. This would explain the rather poor sorting characteristics of this layer. Any signs of reasonable sorting in a low energy environment such as exists in Fox Hole Cave would have to be inherited from depositional phases prior to the sediments entering the cave. Layer A consists of less coarse material than layer C, but it is also seen as a wash deposit. The intervening layer (layer B) was interpreted by Bramwell (1971, p.5) as a man-made floor of limestone debris.

The sediments of layer A seem to be less stabilised than those of layer C, as indicated by the rapid variations in the skewness and kurtosis values down the profile compared with those of the latter. Percolating drip-water has modified the deposits both by solutional action and the translocation of fine material down the profile. The latter is particularly marked just beneath the anthropogenic layer B, where garbage and human waste have added powerful leaching agents to the sediments, producing an increase in fine material directly below the cobbled layer.

Age of the Deposits

Palaeoenvironmental reconstruction is best based on more than one line of evidence. Fox Hole Cave has yielded important archaeological and palaeobiological evidence that provides a useful chronological framework to which the sedimentary evidence can be fitted. This in turn leads to a greater understanding of the environment at the time of the deposition of each layer.

By the time of the last glaciation (the Devensian), Fox Hole Cave was large enough to provide a home for large carnivores. Remains of the brown bear have been found, and also bones of the cave lion deep down in layer E_2, indicating a date of at least 35,000 years B.P., which is the last time the cave lion is known to have inhabited Britain (Bramwell, in Ford, 1977). Such a date would relate to a

Mid-Devensian interstadial period. The full glacial phase in the Late Devensian is believed to have started around 25,000 years B.P. The Peak District was not covered by the last ice sheet (Burek, in Ford, 1977), but a severe periglacial environment existed. Remains of tundra species such as arctic lemming, northern vole and ptarmigan have been excavated from layer E_1. The shattering of material from the walls of the cave and the possible break-up of a former stalagmitic floor, together with the mixing of these deposits with finer material washed in from the surface, probably represent a cold environment with periodic, perhaps seasonal, runoff associated with snowmelt such as occurs in periglacial areas today (e.g. Embleton and King, 1975; French, 1976).

The breakdown deposits of layer D can be interpreted as dating from either the final stages of the full glacial period or from the Lateglacial. The collapse of the roof was probably caused by frost action and/or the presence of permafrost, which was widespread during both periods. Sissons (1979) has reviewed the effects of the intense periglacial climate in Britain during the Loch Lomond Stadial (Younger Dryas) around 11,000–10,000 years B.P.

Late Upper Palaeolithic occupation of the cave, of perhaps just one winter's duration, occurred some time between 10,000–9,000 years B.P. Several artifacts and the remains of four horses (a food source?) have been uncovered on top of the slab layer. There was no Mesolithic occupation of this cave, but the lowest parts of layer C (termed C_2 by Bramwell, 1971) contain a large fauna of predominantly forest species—brown bear, wolf, wildcat, badger, fox, jackdaw, bullfinch and black grouse. A Late Neolithic 'Peterborough' pot sherd was found at the top of layer C, with some human remains, possibly a burial.

It is possible that a subsequent deterioration of climate caused waterlogging in the cave, and limestone rubble was used to produce a cobbled floor extending from just outside the entrance to the 1969 limit of excavation (Fig. 2). Pottery sherds, flints and food bones found between these cobbles (layer B) date to the early Bronze Age (around 3,700 years B.P.).

Layer A has produced pollen from two shallow pits. Analysis of the pollen shows that one pit dates from the Zone VIIb transition period (around 3,200–2,600 years B.P.) and the other from the onset of wetter conditions around 2,500 years B.P. (Bramwell, 1971). With increasing rainfall, more water percolated into the cave and has caused extensive leaching and chemical alteration of the deposits down to a depth of about 130 cm. The majority of remains in layer A were the bones of domestic animals brought in by foxes and other scavengers.

Conclusions

The deposits in Fox Hole Cave are a mixture of both autochthonous and allochthonous material, the relative proportions of which are a function of the depositional processes at work, in turn largely controlled by environmental changes outside the cave. This type of high level cave provides a low energy environment for sedimentation, demonstrated by poor sorting throughout the deposits. In such a situation any sorting characteristics that do exist are probably inherited from depositional phases prior to entering the cave.

In the case of Fox Hole Cave, three main modes of deposition are apparent:

(a) shattering of material from the roof and walls;

(b) the washing-in of fines from the surface by percolating drip-waters;

(c) the introduction of material associated with the presence of animals and man in the cave.

Modification of the sediments has occurred since their deposition, mainly associated with the throughflow of drip-waters. These are manifest in the translocation of fine material down the profile and the solution of calcareous material associated with the reprecipitation of calcium carbonate at various levels. It is interesting to note the effects of the anthropogenic layer B on the sediments below it, accentuating such processes.

It has been shown that a quantitative study of cave sediments can provide useful information on depositional processes in caves. Linked with research into biological and archaeological evidence, such a study can allow a reasonable reconstruction of the past environment of the area for the period during which sediments were being deposited in the cave.

Acknowledgements

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TEMPERATURE VARIATIONS IN CRESWELL CRAGS CAVES (NEAR WORKSOP)

P. A. SMITHSON

Abstract

Previous work on cave temperatures has shown how it is difficult to generalise about this aspect of cave climate because of the great diversity in the factors which control temperature levels. Observations in two caves at Creswell during the summer of 1981 have shown how temperatures change into the cave and how airflow controls the vertical gradient of temperature within the cave.

Introduction

At Creswell Crags, on the Derbyshire–Nottinghamshire border near Worksop (Figures 1 and 2), the Lower Magnesian Limestone escarpment has been dissected by a west-to-east flowing stream to give a steep-sided, narrow gorge. The valley floor is occupied by an artificial lake but the valley sides have a relative relief of about 30m and a slope angle ranging from 30° to vertical. A number of caves occur in these steeply-sloping surfaces, the majority being on the south-facing slope, with only two major ones on the north-facing slope. The caves vary considerably in their detailed morphology, some having multiple entrances and others only a single entrance. Width and height properties of the caves are variable also.

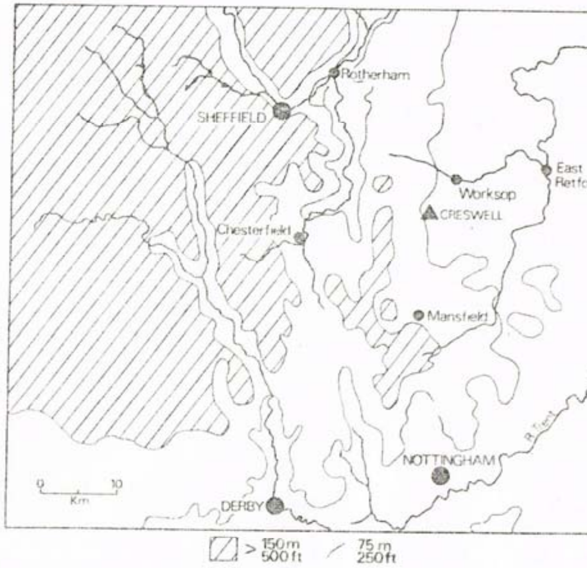

Figure 1
Regional setting of Creswell, near Worksop