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A TEMPORARY SECTION IN HEAD AT BOURNE, BURRINGTON, SOMERSET

by

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ABSTRACT

Head (alluvial fan) deposits exposed in 1977 at Bourne near the mouth of Burrington Combe are attributed to two distinct cold periods, one before the Ipswichian Interglacial (Marine Oxygen Isotope Stage 5e) and one during the Late Devensian (MIS 2). The Ipswichian (and possibly earlier interglacials) is represented by reddened, clay-enriched soil horizons (paleo-argillic B horizons) developed in decalcified upper parts of the coarse flood gravels and coversand, which together constitute the older Head. The younger Head is thinner and consists of stony loams derived partly from the older Head, but also incorporating Late Devensian loess.

INTRODUCTION

In the 1950s the Geological Survey of Great Britain (now British Geological Survey) updated the 19th century surveys of the Mendip area and, coincidentally, the Soil Survey of England and Wales (now the National Soil Resources Institute) extended their previous work in Somerset onto Sheets 279/280 (Weston & Wells). The joint results, both published in 1965 (Findlay 1965, Green and Welch 1965), provided a better understanding of Pleistocene deposits in the area, particularly those on footslopes of the Mendips. Here the most extensive deposits are classed as Head by British Geological Survey and are best seen near the mouths of the larger combes, at Burrington (ST 4759) and Churchill (ST 4459) to the north and Cheddar (ST 4553) to the south, where they form fans up to 4 km wide. They are mainly gravels 1-5 m thick and composed of Carboniferous Limestone, Dolomitic Conglomerate and Old Red Sandstone clasts. On Sheets 279/280 they cover approximately 1500 ha. Soils on the Gravelly Head were referred to the Langford series by Findlay (1965).

In addition, on gentle concave footslopes below the steep limestone slopes, there are deposits of stoneless sandy loam a metre or so in thickness. These were distinguished on the soil map as Tickenham series developed in Sandy Head, and cover about 1000 ha from Burrington and Axbridge to the coast at Brean Down. They are usually separated from the underlying red Keuper Marl (now part of the Mercia Mudstone Group) by a thin gravel composed of angular limestone clasts.

Green and Welch (1965, p. 113) suggested that the Head deposits are not all of the same age. They noted that in places the deposits split into 2-3 sheets at slightly different levels separated by steeper slopes of Keuper Marl and, near West Harptree (ST 565573) and north of Churchill (ST 444606), isolated remnants of an apparently older Head occur on flat-topped hills above the level of the main spreads. Later, from detailed morphological mapping of the Burrington fan, Pounder and Macklin (1985) identified four named but undated phases of deposition. Green and Welch (1965) suggested a Pleistocene periglacial (gelifluction) origin for the deposits, but found little evidence for age other than that the Head is overlapped by Holocene fluviatile and estuarine alluvium. Donovan (2005) attributed the deposits to two distinct cold periods in the Late Pleistocene, and Campbell *et al*. (1999) grouped the Gravelly and Sandy Head deposits together as the Brean Member of their Middle Hope Formation; they related the Brean Member to the whole of the Devensian Stage (Marine Isotope Stages 5d-2 inclusive).

In this paper we describe a temporary exposure in the main sheet of Head deposits at Bourne (ST 483598), about 1 km north-east of the mouth of Burrington Combe. The sequence seen here in 1976-77 was similar to that in other temporary exposures in the Head seen 20 years earlier south of Churchill church (ST 437600) and in a pit dug near Langford Court (ST 469599) for routine description of the soil profile (Findlay 1965, p. 83). At Churchill, the Sandy Head was seen to overlap onto the gravels, and in places was incorporated into them as stoneless pockets, as at Bourne. Although the Bourne site was included with Langford series (Gravelly Head), both types of head were exposed there and their relationship was clarified. The section was originally summarised in a field guidebook for the Bristol area published by the Quaternary Research Association (Findlay 1977). This paper reports supplementary laboratory analyses of samples from the site for particle size distribution, mineralogy and micromorphology, the results of which helped clarify the origin and age of the two deposits.

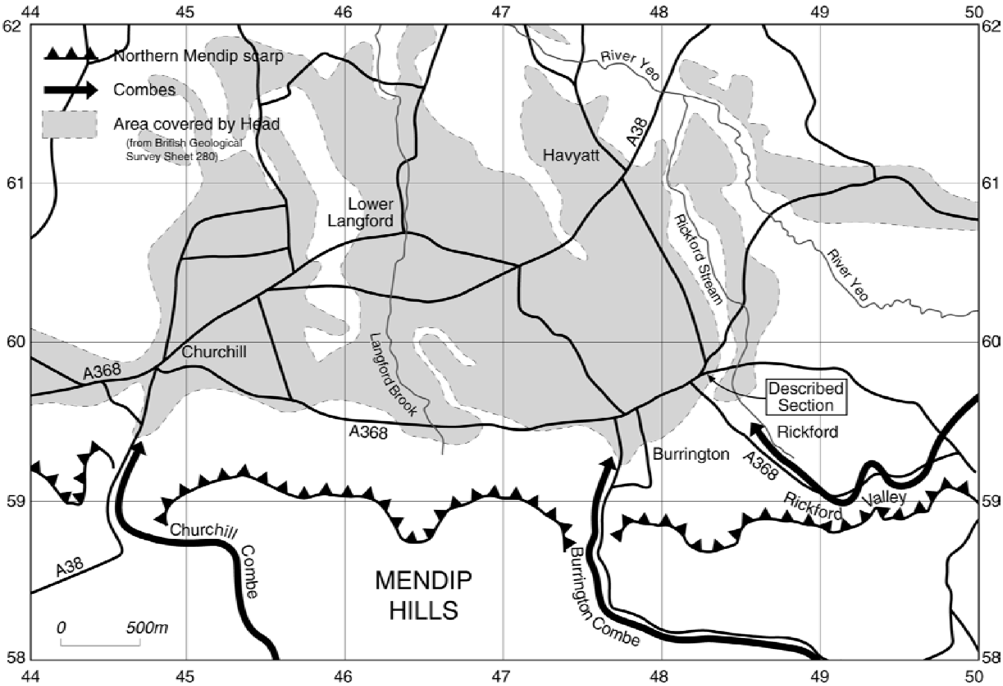

Figure. 1. *Map of the Burrington area showing main geomorphological features and distribution of Head deposits.*

FIELD DESCRIPTION

The section seen at Bourne in late 1976 and early 1977 was located on the south side of Bourne Lane at approximately 48 m OD within the Ashley Lane (second highest) unit of Pounder and Macklin (1985). It was near the eastern edge of the fan that issues mainly from Burrington Combe, but with possible contributions from the Rickford Valley (ST 4859), an unusual meander incised sub-parallel to the northern Mendip scarp slope between Blagdon and Burrington (Figure 1). The fan slopes gently northwards from a height of about 60 m OD near Burrington to 25 m OD north-west of Havyatt Green (ST 476613). The exposed section (Figure 2) was 18 m long and up to 3 m deep and ran parallel to the gentle eastward slope at the edge of the fan surface, where it is intersected by the Rickford stream. It was soon obscured by a house built close to the exposed face and consequently no further work has been possible on the site.

Eight separate layers, numbered downwards from the surface, were identified in the field. Layers 3-6 were penetrated by six narrow tongue-like features (labelled u-z in Figure 2) descending from and filled with material similar to layers 2 and 3. The following summary description was made between features y and z near the western end of the section, where layers 4 and 5 were repeated as layers designated 4A and 5A. The colours quoted are those of the Munsell Colour Chart with the sediment in moist condition unless otherwise stated, and the particle size classes are those defined by Avery (1980, Fig. 2).

1. 0-15 cm: dark brown (7.5YR 3/2) sandy silt loam topsoil

2. 15-35 cm: reddish brown (5YR 4/4) (brown 5YR 4/4 when dry) slightly stony sandy silt loam; small to large sandstone and some chert clasts

3. 35-65 cm: reddish brown (5YR 4/4) (5YR 5/4 when dry) slightly stony clay loam, becoming less silty and more sandy (i.e. sandy clay loam) below; clasts as above

4A. 65-80 cm: reddish brown and red (2.5YR 4/4 and 4/6) very stony clay containing 20 % black ferrimanganiferous coatings on ped faces; clasts as above

5A. 80-100 cm: yellowish red to reddish brown (5YR 4/6-4/4) sandy loam with layers of reddish yellow (7.5YR 6/6) loamy sand; stoneless

4. 100-120 cm: reddish brown and red (2.5YR 4/4 and 4/6) very stony clay with 20 % black ferrimanganiferous coatings on ped faces and stones; clasts are mainly sandstone with some chert and quartz pebbles; those removed from this layer leave a polished imprint (more so than in layer 6); where layer 5 is absent in other parts of the section, this layer merges downwards into layer 6 with decreasing black staining

5. 120-170 cm: reddish brown (5YR 4/4) (yellowish red 5YR 4/6 when dry) sandy loam with layers of reddish yellow (7.5YR 6/6) loamy sand; mostly stoneless but some large sandstone and chert clasts up to 25 cm across; sharp boundaries to layers above and below; here and elsewhere in the section layer 5 forms discontinuous lenses which attenuate eastwards

6. 170-245 cm: reddish brown (2.5YR 4/4) very stony clay; clasts range in size up to 25 cm across and from subangular to rounded, mainly sandstone with some chert and quartz pebbles; clear but very wavy boundary to layer 7

7. 245-300 cm: reddish brown (5YR 4/4) to dark reddish brown (5YR 3/4) extremely stony sandy clay loam; clasts are dominantly Carboniferous Limestone with subordinate sandstone and a little chert; limestone clasts are strongly weathered in top 30 cm to soft sugary masses and usually surrounded by black clay

8. 300 + cm: material excavated from below the depth of the main section in footings for foundations consisted of limestone and sandstone clasts in a sparse, loose, gritty matrix.

The discontinuous nature of layer 5, the eastward attenuation of the lenticular masses and the interfingering of layers 4 and 5 at the western end of the section suggest mass movement towards the eastern margin of the fan. The irregular boundary between layers 5 and 6 suggests syn- or post-depositional cryoturbation of the fan deposits, and the subvertical tongues in the upper 2 m of the section are probably polygonal ice-wedge casts, though it was not possible to confirm this by assessing their spatial pattern.

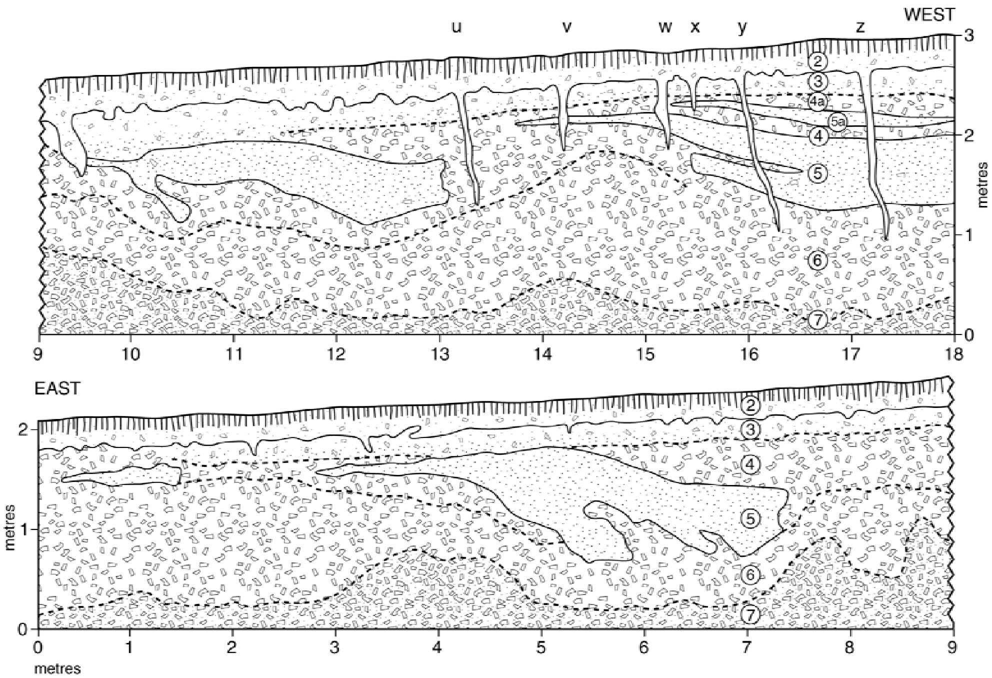

Figure. 2. *Sketch of the section in Head deposits exposed at Bourne 1976-77.*

The generally reddish brown colour of most layers probably reflects derivation from the nearby Dolomitic Conglomerate and from Devonian Portishead Beds (Old Red Sandstone) exposed on higher central parts of the Mendips. The latter source is also indicated by the abundance of red sandstone clasts in most layers. However, parts of layers 4A, 5A, 4 and 5 show brighter red, yellowish red or reddish yellow colours, which are typical of paleo-argillic B soil horizons. As defined by Avery (1980), these horizons should have 'a dominant matrix colour with hue of 7.5YR or redder, value 4 or more that does not increase by more than one unit on drying, and chroma more than 4 (moist or dry)'. Reddening of this type implies weathering in the Ipswichian or an earlier interglacial, which suggests that these layers were originally deposited before the Ipswichian, i.e. in Marine Isotope Stage 6 or earlier.

Although layers 6 and 7 do not show the brighter colours characteristic of a paleo-argillic horizon, they are probably lower horizons of the same interglacial soil. Limestone clasts are absent in layers 6 and above. They occur in layer 7 but have been softened by weathering in the upper 30 cm, and the boundary between layers 6 and 7 has the clear but strongly undulating aspect typical of a decalcification front. It is likely that 6 and all the overlying layers originally contained some carbonate, but have been decalcified by interglacial and Holocene soil development. Layer 8 is probably the best representative of the original gravelly fan deposits unmodified by later pedogenesis.

LABORATORY ANALYSES

Particle size distribution

Samples for particle size distribution and mineralogical studies were taken from layers 2, 3, 5A, 4, 5, 6 and 7 in the described section between features y and z. After removal of clasts >2 mm by dry-sieving, particle size distribution was determined by wet-sieving and the pipette-sampling technique after removal of carbonate with dilute hydrochloric acid and organic matter with hydrogen peroxide followed by dispersion in dilute alkaline sodium hexametaphosphate solution (Avery and Bascomb 1974). Figure 3 shows the results.

Layers 2 and 3 both contain large amounts of silt (2-63 μm), which is much less abundant in all the layers below and decreases downwards in layer 3. This suggests incorporation of Late Devensian loess, which is almost ubiquitous in surface horizons of soils in southern England (Catt 1985). The difference in clay content (<2 μm) between these two layers can probably be attributed to illuviation during Holocene soil development.

Layers 5 and 5A are both composed dominantly of fine sand (63-250 μm) with subsidiary coarse sand (250-2000 μm). The slightly greater silt content of 5A could result from incorporation of a little Late Devensian loess, and its greater clay content suggests some enrichment by illuviation.

Layers 4, 6 and 7 contain more coarse sand and less fine sand than any of the others, and layers 4 and 6 are much more clay-rich than any others. Much of the clay in layer 6 is likely to be illuvial, as deep subsoil horizons greatly enriched in illuvial clay often overlie limestone bedrock or strongly calcareous older gravels such as layer 7. In American soil literature, they have been termed beta horizons (Bartelli and Odell 1960). The most extensive comparable horizon in English soils is the Clay-with-flints *sensu stricto* (Loveday 1962), which has formed by deposition of illuvial clay at the boundary between Upper Chalk and Plateau Drifts with paleo-argillic B horizons. Accumulations of black ferrimanganiferous material like those in layer 7 are also common in Clay-with-flints *sensu stricto* and other beta horizons.

Fine sand mineralogy

Fine sand (63-250 μm) fractions were separated from samples of the same layers by wet sieving, and heavy minerals (specific gravity >2.9) were isolated by settling in bromoform. They were then identified from their optical properties using a petrological microscope. Table 1 gives the percentages of the principal heavy minerals in each layer studied.

Layers 4, 6 and 7 have similar heavy mineral suites dominated by zircon and chlorite, with minor amounts of tourmaline, garnet and rutile; staurolite and epidote are rare or absent. Layers 5 and 5A are different in that they are dominated by garnet, with subsidiary tourmaline and zircon and smaller amounts of rutile and staurolite, but only traces of epidote and chlorite. Layers 2 and 3 are also rich in garnet, tourmaline and zircon, and contain similar amounts of rutile and staurolite to layers 5 and 5A, but also contain more epidote than all other layers and more chlorite than 5 and 5A. This suggests that layers 2 and 3 are composed mainly of material similar in composition to layers 5 and 5A. The additional epidote and chlorite that they contain probably result from the incorporation of Late Devensian loess, the coarser fractions of which are rich in these two minerals (Catt 1985), though it is possible that some or all of the chlorite was derived from layers 4, 6 and 7.

Layer (depth)	Zircon	Tourmaline	Garnet	Rutile	Staurolite	Epidote	Chlorite
2 (15-35 cm)	26	21	28	5	3	5	6
3 (35-65 cm)	27	13	25	5	2	5	14
5A (80-100 cm)	16	20	43	2	5	1	<1
4 (100-120 cm)	43	10	3	9	<1	-	23
5 (120-170 cm)	9	33	39	3	3	<1	<1
6 (170-245 cm)	51	7	3	13	-	<1	17
7 (245-300 cm)	23	6	2	3	-	<1	52

Table 1. *Percentages of the main heavy fine sand minerals in samples from the Burrington fan at Bourne (- = absent)*

Micromorphology

A 3 cm x 5 cm horizontal thin section of layer 6 was made by the techniques given in detail by Murphy (1986). Under the microscope, it showed that the clay occurred mainly as strongly birefringent units containing few or no coarser (silt or sand) particles. The relatively strong birefringence, with first and second order interference colours, indicates a high degree of preferred orientation of 2:1 layer silicate clay minerals, which results from particle-by-particle deposition from percolating water (illuviation). Most of the clay bodies form microlaminated coatings (Stoops 2003), or argillans, lining the walls of irregularly shaped channels and other voids. The pattern of laminations within some voids suggests slumping or flow of the clay into the cavities. In addition, a few of the clay bodies occur as discrete, well-defined units up to 5 mm across embedded within a texturally more heterogeneous matrix containing <15 % clay and almost all the sand and silt particles. These bodies probably originated as papules or fragments of earlier clay coatings (Bullock *et al*. 1985), which have been dissociated by cryoturbation from the voids in which they originated.

These microfabric characteristics are similar to those of many beta horizons, such as the Clay-with-flints *sensu stricto* (Loveday 1962, Thorez *et al*. 1971). The irregularly shaped voids probably originated by dissolution of limestone clasts, and were progressively infilled with illuvial clay as dissolution proceeded. Dispersion of clay in the overlying soil horizons prior to illuviation could only occur once these layers had been decalcified and its redeposition in the beta horizon resulted from the increase in pH at the decalcification front.

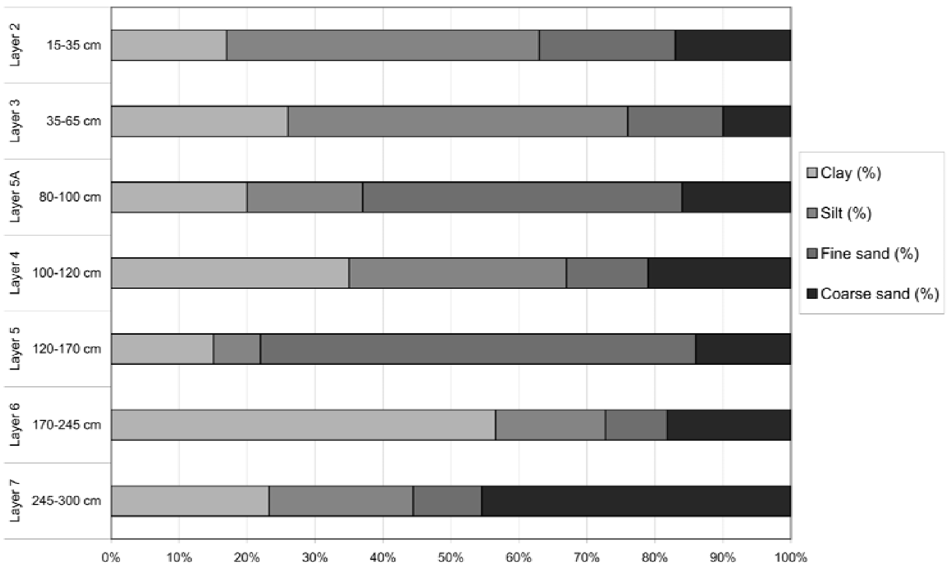

Figure 3. *Particle size distribution (<2 mm) of samples from the Burrington fan at Bourne.*

DISCUSSION

The sequence at Bourne provides evidence for at least two phases of Head or alluvial fan formation, both followed by episodes of temperate soil development. The earlier phase resulted in deposition of layers 4-8. This preceded the Ipswichian (Marine Isotope Stage 5e) and possibly earlier interglacials, when layers 4-6 and the upper 30 cm of layer 7 were decalcified by acid pedogenic weathering and large amounts of clay were moved in percolating water from layers 4 and 5 and redeposited in layer 6 to form a beta horizon. Layers 4 and 5 were also reddened (rubefied) by precipitation of haematite in seasonally warm, oxidizing conditions from iron released by weathering of primary minerals and mobilized by reduction in wet winters. Based on the colour criteria of Avery (1980), these layers qualify as paleo-argillic horizons, implying weathering in a Mediterranean-like climate that was significantly warmer and drier in summer than at any time during the Holocene. Elsewhere in Britain such soil horizons have formed only in deposits dated to pre-Ipswichian periods.

In layers 7 and 8 the abundance of large limestone and sandstone boulders in a coarse sandy matrix suggests that the earlier Head was deposited mainly by a fast-flowing stream, which probably issued from Burrington Combe and the Rickford Valley either during periods of summer thaw in a cold stage of the Middle Pleistocene or immediately after a climatic transition from cold to temperate. As Tratman (1963) originally suggested, during these cold stages the normally permeable bedrock of the Mendips would have been rendered impermeable by a considerable depth of permafrost and its near-surface layers shattered by frost action. However, during periods of brief spring or summer thaw the uppermost few metres of permafrost melted, and together with melting snow provided sufficient water to transport boulders and coarse sand released from the Devonian sandstones along the outlet valleys and onto the low-lying ground beyond the scarp slope.

Late in accumulation of the older (pre-Ipswichian) deposits a change in depositional environment is indicated by what remains of the almost boulder-free and fine sand-rich layer 5. The abundance of fine sand suggests wind-blown coversand deposited in a still very cold but much drier climate. The fine sand of layers 5 and 5A contains more tourmaline and garnet than that of layers 4, 6 and 7, indicating derivation from a slightly different, possibly less local source. On the basis of particle size distribution and mineralogy, Clayden and Findlay (1960) suggested correlation of similar red sandy deposits near Churchill with blown sands flanking the western Mendips and lying above the lowest breccia at Brean Down (ST 290587). Palmer (1934) suggested that the sands associated with Severn estuary breccias, such as those at Brean Down later described in detail by ApSimon *et al*. (1961), were derived from the Tertiary sands of Devon and Cornwall by south-westerly winds. The Mendip footslope blown sands display continuity with the Brean Down breccias and sands, and a south-westerly source is suggested by the fact that they thin eastwards towards the Burrington area.

Cryoturbation during or soon after accumulation of the older Head is indicated by the contorted boundary between layers 5 and 6, and continuing mass movement after deposition of the coversand by the interfingering of layers 4 and 5, particularly at the western end of the Bourne section. These features also suggest a periglacial environment during deposition of the older Head.

Layers 1-3 represent a later loamy deposit, which probably accumulated in the Late Devensian (Marine Isotope Stage 2). It contains more silt than the earlier Head, and this probably resulted from incorporation of far-travelled loess, which was deposited over much of south and east England by periglacial winds during the Late Devensian between about 18,000 and 13,500 radiocarbon years before present (Catt 1985). Loess is widespread on the Mendip plateau (Findlay 1965), and a loess component probably accounts for the larger amounts of epidote and chlorite in the fine sand fraction of layers 2 and 3, as these heavy minerals are common in the Late Devensian loess of southern England. However, layers 2 and 3 contain more clay, fine sand and coarse sand than typical loess, and also some cobbles of sandstone and chert, though fewer than in earlier parts of the older Head. This composition suggests deposition by periglacial mass movement on slopes (gelifluction) of seasonally saturated soil material, including the previously wind-deposited loess. The non-loess components could have been derived from weathered layers of the older Head or from bedrock freshly frost-shattered in the Devensian. The tongue-like features u-z are probably ice-wedge casts formed under periglacial conditions during the latest Devensian after deposition of loess, possibly in the Loch Lomond Stadial (11,000-10,000 radiocarbon years before present; 12,970-11,530 calendar years ago).

A period of temperate, mainly Holocene, soil development after deposition of the upper Head is indicated by the absence of limestone clasts and other carbonate in layers 1-3 and by the illuviation of clay into layer 3. Some of this clay could also have been translocated deeper into layers 4A and 5A of the older Head, as 5A contains slightly more clay than layer 5 below.

Our tentative dating of the older and younger Head deposits at Bourne accords with the ages suggested by Waltham *et al.* (1977, Fig. 5.7) for similar coarse sandstone and limestone gravels in nearby Mendip caves, such as the GB and Charterhouse Caves. Uranium series dates show that flowstones overlying the cave gravels were deposited in warm stages of the Quaternary, when subsoil dissolution of carbonate was accelerated by increased soil CO_2 levels. The intervening gravels are therefore thought to have accumulated in cold stages by gelifluction and debris flows invading cave interiors. Two of the major periods of cave gravel deposition proposed by Waltham *et al.* were at 130-150 ka and 30-45 ka before present, and these could well coincide with the older and younger Head deposits at Bourne.

CONCLUSIONS

The section exposed at Bourne confirms earlier suggestions that the Head (alluvial fan) deposits flanking the Mendips and originating principally from the main Mendip combes are not of a single age, but were deposited in at least two different cold (periglacial) stages of the later Quaternary. At Bourne the earlier deposit is pre-Ipswichian and consists of coarse flood gravels overlain by coversand. There is little direct evidence at this site for gelifluction (downslope mass flowage) at this time, though gelifluction on surrounding slopes was probably the main process delivering coarse stony sediment into Burrington Combe before it was reworked and transported through and out of the combe by summer meltwaters. The younger and thinner overlying loam buries an interglacial soil profile developed in the earlier Head, and probably dates from the Late Devensian. This deposit does seem to have originated mainly by gelifluction, as loess and other materials derived from earlier deposits and/or newly frost-shattered bedrock have been mixed to form an ill-sorted surface accumulation, in which a typical Holocene soil has developed.

Both the earlier and later deposits include materials corresponding to the Gravelly Head of earlier authors. At Bourne the Sandy Head of Findlay (1965) is part of the older (pre-Ipswichian) deposit, but similar deposits elsewhere could be younger, as coversands may have accumulated in various cold periods of the Pleistocene.

The deposits of the Burrington fan are therefore quite variable in terms of source materials and final processes of deposition. Such variability is typical of the periglacial environment, with depositional processes of fluvial, aeolian and downslope mass movement occurring in response to seasonal and longer-term climate change.

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