DEPOSITIONAL ENVIRONMENT OF LATE-PLEISTOCENE TERRACE GRAVELS OF THE VALE OF BOURTON, GLOUCESTERSHIRE

by

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Summary

The distribution, stratigraphy, and frost structures of limestone terrace gravels in the Vale of Bourton, Gloucestershire, are described. The terrace is shown to be composite in both age and origin. Roman riverine deposits overlie mid- and late-Devensian gravels attributed to solifluction processes on hillslopes, and to fluvial re-working by streams with nival regimes on the valley floors.

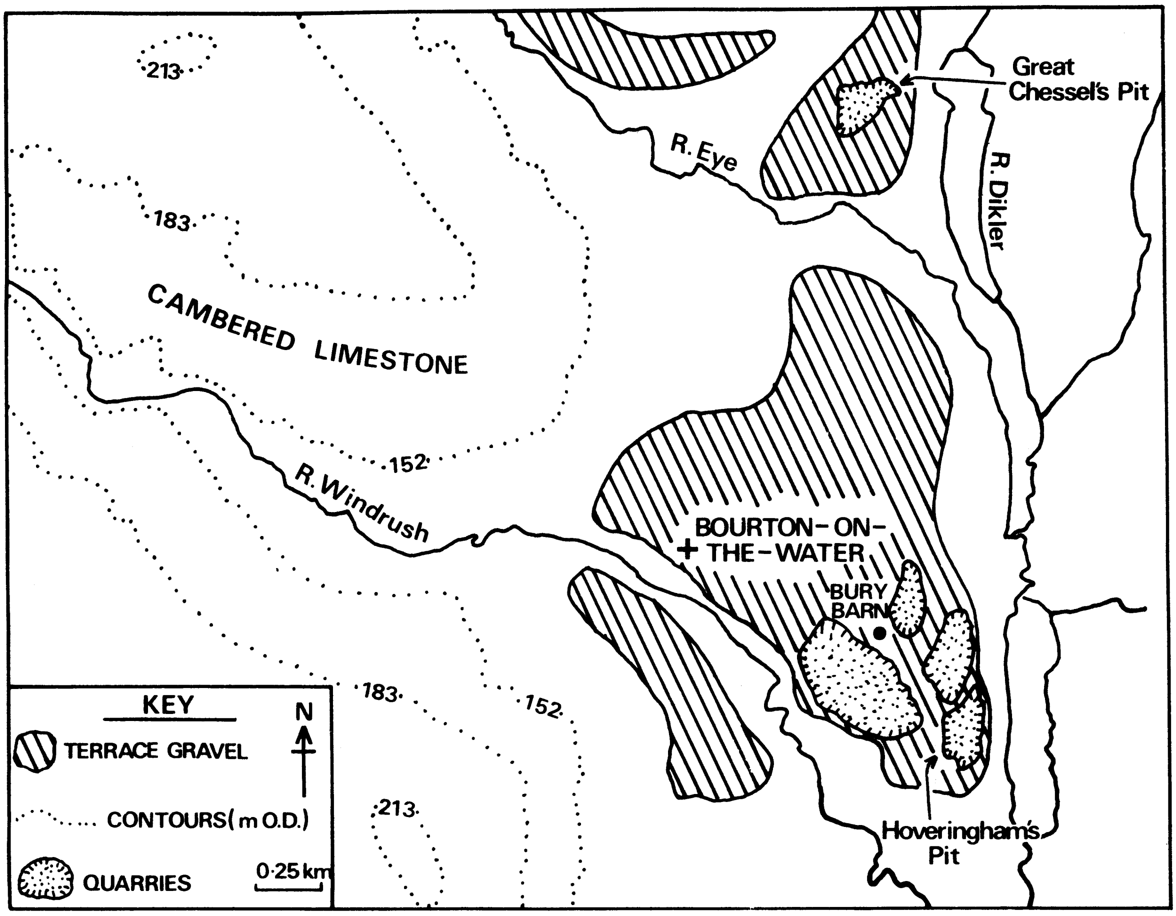
Pollen and non-marine molluscan analyses of a fossiliferous sandy-silt lens in the lower part of the terrace gravels indicate a treeless vegetation cover dominated by grass and/or grass sedge communities with a river flood-plain consisting of a mosaic of marshy, aquatic pools separated by drier gravel ridges. The molluscan fauna was very impoverished whilst the flora contained moderately thermophilous marsh and aquatic species.

The severity of the prevailing climate during the mid-Devensian is difficult to deduce from this evidence since factors other than climate may be responsible for the lack of tree cover. The presence of an ice-wedge cast tentatively correlated with the main Devensian glaciation at about 20,000 years BP, suggests that mean annual air temperatures were in the order of -6°C at that time.

Introduction

Extensive deposits of coarse limestone gravels rest on Lower Lias Clay (Jurassic) in the floor of the Vale of Bourton (text-fig. 1), which is a broad basin eroded into the Jurassic sands and gravels of the Cotswolds. These gravels were described by Richardson and Sandford in 1960, and were attributed to the late Wolstonian/early Ipswichian period on the basis of their textural similarity to the terrace gravels of the Summertown-Radley terrace of the Upper Thames basin (Worsamm & Bisson, 1961). A later investigation of superficial tectonic structures in the north Cotswolds by Briggs & Courtney (1972) linked both the terrace gravels of the Vale, and the tectonic structures, with periglacial conditions prevailing during the Devensian (last) cold stage of the Pleistocene. The results are presented here of a study of exposures in the terrace gravels at Bury Barn (text-fig. 1, Nat. Grid Ref. SP 177208). These studies throw new light on the age and environmental significance of the limestone gravels.

Mercian Geol. vol.7, no.4, 1980
pp.269-278, 2 text-figs.



Text-fig. 1: Terrace deposits of the Vale of Bourton.

The Bourton Terrace

Distribution and sediments

The distribution of terrace gravels in the Vale of Bourton is shown in text-fig. 2. A study of its morphology and fauna indicates that the Vale is composite in both age and origin. The terrace is principally composed of limestone gravels (over 90% of the 4-16 mm fraction). Near the river, the terrace stands about 5 m above present alluvium, and is essentially flat-topped. Away from the present rivers, it rises up the Cotswold scarp and becomes more rubbly and irregular, forming a well-marked solifluction apron at the scarp foot. Morphologically, therefore, the terrace represents a continuum from soliflucted material at the scarp-foot, to fluvially transported material in the more central parts of the valley. In this respect it is akin to the Beckford terrace of the Carrant Valley to the west of the Cotswold scarp (Briggs *et al.*, 1975).

The internal sedimentary character of the terrace similarly alters with a progressive improvement in particle sorting away from the scarp. In overgrown exposures north of Bourton (SP 174226 & SP 175224), the gravels can be seen to be roughly bedded, coarse, and angular. In the more extensive sections at the old Hoveringham Company's pit (text-fig. 1; SP 177208) the gravels are much better sorted and bedded and show features indicative of braided stream deposits (Briggs & Gilbertson, in press). Locally overlying these gravels occur channel sets and enclosed depressions filled with silts and fine sands which are rich in molluscan remains and, near the surface, Roman pottery. The lower gravels are not known to have yielded any pottery, and are poorly fossiliferous. However in the nearby Great Chessil's pit (text-fig. 1, SP 174226), near Bourton-on-the-Water, coarse gravels have yielded a small mammalian fauna, including mammoth (*Elephas primigenius*) and woolly rhinoceros (*Rhinoceros* *tichorinus*), described by Richardson & Sandford (1960). The polygenetic nature of this terrace feature makes it extremely difficult to trace downstream. Consequently it cannot be correlated with other deposits in the upper Thames Basin on simple altimetric grounds alone.

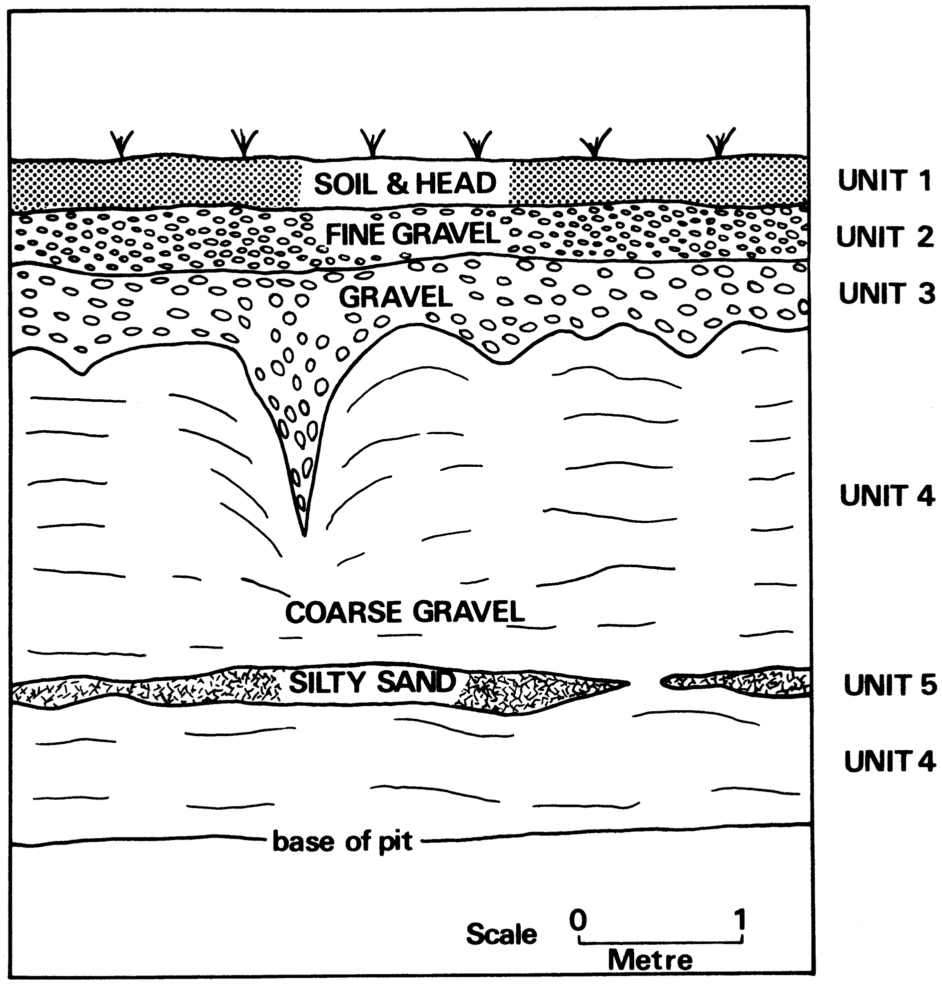
In 1972, the following section was noted in the Hoveringham Company's gravel pit (text-figs. 1 and 2) at Bury Barn (SP 177208).

Unit	Stratum	Depth	Thickness
1	Soil developing on a brown loamy head - a solifluction deposit.	0.3 m	0.3 m
2	Fine limestone gravel, particles up to 0.02 m diameter.	0.6	0.3
3	Coarse, greyish limestone gravel. Particles up to 0.08 m diameter, let down in large ice-wedge cast and involutions into unit 4.	1.0	0.4
4	Plane-bedded, coarse, yellowish limestone gravel, particles up to 0.10 m. diameter: (braided stream deposits).	3.3	2.3
5	Contorted lense of grey-green sandy silt with occasional non-marine Mollusca; discontinuous lens over 30 m. (channel fill).	3.6	0.3
4	Plane-bedded, coarse, yellowish limestone gravel; locally shallow cross-bedded sets; (braided stream deposits?).	4.1	0.5
	Lower Lias Clay.		

Samples taken from this section were investigated using pollen and molluscan analyses.

Periglacial structures

The upper parts of the gravels are disturbed and disrupted by features similar to those normally associated with discontinuous permafrost (Kerney, 1963). These layers are penetrated by substantial ice-wedge casts which occur at the surface of the gravels at Bury Barn, indicating that after aggradation the river gravels have been subjected to more continuous permafrost. Péwé (1966) has indicated that the initiation of ice-wedge growth is dependent upon the size of materials being frozen. The coarseness of the Bury Barn gravels suggests mean annual air temperatures may have been below the -6 to -8°C found necessary for ice-wedge growth in Alaska. As there is no evidence of prolonged weathering between the termination of the main phase of terrace aggradation and the formation of the ice-wedge, it is assumed there is little temporal gap represented between them. In addition, since ice-wedge development at this scale is only possible given a substantial supply of water, it is reasonable to assume that the wedges grew before the terrace was dissected by the river and the regional water table fell.



Text-fig. 2: Section in the river terrace at Bury Barn, Vale of Bourton.

Pollen Analysis

Material from the grey-green sandy silt was prepared for pollen analysis by treatment with 7% HCl, 7% NaOH, 20N HF, a simple acetolysis, and chlorate bleaching. The pollen grains were mounted in silicone oil.

Identification

Unlike some other full-glacial sites from limestone areas, pollen and spores are moderately abundant in the sample analysed, but are often poorly preserved. The taxa identified are listed in table 1 along with unidentifiable material.

Many grains are fragmentary, squashed and distorted, and decay is apparent where pores and furrows have ragged edges and sculpturing has been removed in patches. As a result, identification is difficult and some of the uncommon, poorly preserved grains have only been classified tentatively. A significant quantity of the material is recognisable as pollen but is too poorly preserved to be identified. Many of the better preserved spores could not be ascribed to any group and are probably derived from the Jurassic rocks. Some of the easily recognisable pollen, such as *Pinus*, may be identified even when severely abraded, and is therefore liable to be over-represented in the pollen count (table 1).

Table 1: Pollen identified in late-Devensian river silts from terrace gravels in the Vale of Bourton, Cotswold Hills, England.

Abies fragment	31	? *Nuphar*	1
whole	10	? *Filipendula*	1
Quercus	25	? *Hydrocharis*	1
Pinus fragment	10	? *Dryas*	1
whole	6	*Peplis*	1
? *Salix*	5	*Lycopodium*	6
? *Betula*	1	*Polypodium*	4
Carva	1	*Dryopteris*	2
Ranunculus	59	*Pteridium*	2
Cyperaceae	28	Total	227
Graminae	21		
Plantago maritima	11	(with fragments divided by 2)	
Thalictrum	4		
? Ericaceae	4		
Chenopodiaceae	3		
Sparganium	2		
Saxifraga oppositifolia	2	unidentified pollen	
Polygonum sect. *persicaria*	2		
Artemisia	1	fragments	131
Nymphaea	1	whole	11

Three broad groups of pollen are present:

1. Arboreal

The arboreal pollen is less well preserved than the herbaceous pollen. Most is squashed, of small size and has holes and thin areas as if it was being eaten away. This is particularly true of *Abies* and *Quercus*. Some *Abies* and *Pinus* grains are barely recognisable.

2. Herbaceous - marsh and aquatic group

This pollen is better preserved and includes *Sparganium* type, *Polygonum* sect. *persicaria*, *Nymphaea*, ? *Nuphar*, ? *Filipendula*, ? *Hydrocharis* and *Peplis*. Also included here is *Ranunculus*; although it is a taxon of uncertain habitat, its pollen is well represented in the spectrum suggesting local dominance. Such dominance is usual only by aquatic species, although when open ground is being made available by fluvial processes a substantial cover of *Ranunculus repens* might be anticipated.

3. Herbaceous - terrestrial group

This pollen is also better preserved than the arboreal pollen and includes *Plantago maritima*, *Thalictrum*, Ericaceae, Chenopodiaceae, *Saxifraga oppositifolia*, *Artemisia*, ? *Dryas*, *Lycopodium*, *Polypodium*, *Pteridium* and *Dryopteris*. Most of the Graminae and Cyperaceae pollen also probably belongs to this group, but small amounts might have been contributed by marsh and aquatic species.

Interpretation

The poor state of preservation and low numbers of identified grains, invalidate any but the broadest interpretation. Taken as a whole, the spectrum represents an odd and, superficially, a most unlikely assemblage of northern, arctic-alpine, thermophilous and halophytic plants. It is probable that some of the pollen is derived, although unusual fossil assemblages of halophytic, thermophilous, steppe and northern herbaceous and shrub species have been recorded from interstadial and full-glacial deposits at Brandon (Kelly, 1968), Earith (Bell,

1970) and other sites, and these assemblages have been reviewed by Bell (1969). They probably result from a continental climate and open vegetation conditions in which competition was not severe. Similar assemblages which include the pollen of oak and coniferous species have not been recorded. This factor and the comparatively poor preservation of the arboreal pollen suggest that at least some of it has been derived from a pre-existing sediment. This can only be determined approximately since all the pollen is poorly preserved by normal standards. Additional evidence that some of the arboreal pollen is derived is provided by the intrinsically unusual association of pollen of *Abies*, *Pinus* and *Quercus*, without *Corylus* and with only one doubtful grain of *Betula*, and by the presence of a single grain of *Carya*. Grains of *Quercus* may have been eroded from soils in the area. A few of the *Pinus* pollen grains are better preserved and may be contemporaneous. These exist in quantities which are consistent with them having been blown into the area. The probabilities of long distance transport by wind being responsible for similar representations of *Pinus* in late Devensian deposits in the Lake District of England has been discussed by Pennington (1970).

The pollen evidence suggests that much local vegetation was dominated by marsh and aquatic species. Contemporary aquatic species of *Ranunculus* usually dominate shallow, sluggish streams or pools (except *R. fluitans*) and the remaining aquatic genera are usually confined to still and shallow water. The genera *Ranunculus*, *Polygonum* sect. *persicaria*, *Nymphaea*, *Nuphar* and *Hydrocharis* include species which are only moderately tolerant of severe winter conditions and as a result the whole group, it is believed, could be moderately thermophilous. However *Ranunculus* spp. can dominate aquatic sites in Greenland and it is possible that some of the rarer pollen has been derived along with the arboreal group. The presence of *Hydrocharis* suggests a base-rich situation likely to be found in an eroding limestone terrain, although *Peplis* is usually absent from calcareous areas.

The remaining herbaceous pollen is, with the presence of *Dryas* and *Saxifraga oppositifolia* and a probable absence of arboreal species, indicative of a regional vegetation characterized by plants of open, probably arctic-alpine habitat. This contrasts with the moderately thermophilous aspect of the aquatic vegetation. This pollen is sparsely represented in the sample and was probably sparse in the environment. Most of the genera in the group have arctic-alpine representatives. *Artemisia borealis* has been collected in Greenland in open, dry, riverine gravels and outwash sand, and other *Artemisia* species occur in arctic continental environments. *Plantago maritima* is sometimes regarded as a halophytic coastal species but it can be found at over 914 m O.D. in Scotland in an open habitat. Both *Plantago maritima* and *Artemisia* pollen occur in British full-glacial floras. *Lycopodium* species are often alpine although they might be derived from the Jurassic, in which they were common, for the spores preserve well. Dwarf *Salix* and *Betula*, and ericaceous species are usually present in arctic-alpine associations, yet their pollen is virtually absent from the spectrum. This could be accounted for if, as the moderately high grass and sedge pollen suggest, the regional vegetation was grass and/or grass and sedge dominated, although some of this pollen might have been contributed from the marsh and aquatic group or have been derived along with the arboreal group. Such vegetation associations commonly occur in the arctic-alpine formation, especially in eroding calcareous terrains. The presence of *Saxifraga oppositifolia*, the ferns and possibly Thalictrum suggest that there were rocky niches nearby.

Unfortunately, until more organic layers capable of being dated by radiocarbon are located in this terrace the precise position of this pollen assemblage within the Mid-Devensian cannot be determined.

Non-marine Mollusca

A 4kg air dried sample from the sandy silt (Unit 5) was washed through a 250 μm sieve, and the residue identified under a low-powered binocular microscope. 454 individual molluscs were found and identified as belonging to 5 taxa (table 2).

Table 2: Pleistocene non-marine molluscan fauna from Bury Barn.

	No.	%
Valvata piscinalis (Müller)	1	0.2
Lymnaea peregra (Müller)	1	0.2
Succinea pfeifferi cf var *schumacheri* Andreae	164	36.1
Pupilla muscorum (L)	215	45.2
Agriolimax cf. *agrostis* (L)	73	16.1
Total	454	-

Identification

The specimens of *Valvata piscinalis* and *Lymnaea peregra* are juveniles. The specimens of *Succinea* present are variable in shape recalling both *S. pfeifferi* Rossmassler and *S. oblonga* (Drap.). The range of forms present is similar to those illustrated by Van Regteren Altena (1957) for Weichselian deposits in the Netherlands. This form is extinct in Europe, but is known from 'cold' deposits in the British Isles at Brandon (Shotton, 1968), Wretton (West *et al.*, 1974) and nearby Beckford (Briggs, *et al.*, 1975).

There is a complete size range of *Pupilla muscorum* present. Up to 7 whorls may be present with the typical form being the "more cylindrical, less tapered form with whorls wider in proportion to their height" which Kerney *et al.*, (1964, p.160) and Kerney (1963) have described from late-Devensian deposits in the Chalk Downs of south east England. Large & Sparks (1961) have recorded a similar form at Stroud in terrace deposits. The Bury Barn shells are thin, sometimes broken. 50% of the specimens whose aperture could be examined bore no teeth on the inner lip, and in the remainder, the lip was only poorly developed.

The shells of *Agriolimax* species are not reliably identifiable from shell characteristics only.

Environmental implications

Molluscan faunas associated with riverine situations may be anticipated to be normally rich in molluscan species, since the constant erosion of river bank, stream bed and associated vegetation should contribute specimens from many micro-habitats. The great lack of diversity in the Bury Barn fauna, coupled with the known associations of the particular forms of *Succinea* and *Pupilla* present suggests an exposed, cold, periglacial climate. The combination of so many succineids which favour a marsh environment with the occasional specimens of *Valvata piscinalis* which would favour deeper, quieter running water, indicates the local environment comprised many marshy pools with perhaps the occasional pool or deeper stream. *Pupilla muscorum,* nowadays regarded as a xerophile (see Ellis, 1969), has been identified in this type of Pleistocene cold floodplain environment in other studies (Kerney, 1963; Briggs *et al.*, 1975). It appears probable that the species had a greater tolerance of marshy situations during the Devensian, and that it may have been occupying drier gravelly ridges on the floodplain. Much mixing has no doubt occurred before final deposition in the pool represented by the sandy silts.

The fauna has fairly close parallels with those recorded from Devensian deposits at Beckford (Briggs *et al.*, 1975), Stroud (Large & Sparks, 1961), Brandon (Shotton, 1968), and other sites in the Avon II terrace (Tomlinson, 1925). Notable absentees at Bury Barn are *Lymnaea truncatula* (Müller), *Planorbis laevis* Alder, and *Planorbis leucostoma* Millet. This may be the result of chance rather than any local ecological or climatic cause.

Dating and Correlation

All the evidence presented here indicates that the pre-Roman deposits collected in a periglacial environment characterised by cold but seasonally variable conditions. The stratigraphical evidence found indicates that there is no reason to believe the periglacial sequence found belongs to other than the Devensian (last) cold stage of the Pleistocene, and consequently the view of Richardson & Sandford (1960) and Worssam & Bisson (1961) is rejected.

The sequence of deposits and frost structures found is essentially similar to that at Beckford where a radiocarbon date of 27,650 ± 250 years BP (BIRM 293) has been obtained from woody detritus in a silty lens essentially similar in stratigraphical significance to that at Bury Barn (Briggs *et al.*, 1975). There, the main terrace aggradation was attributed to the mid-Devensian, and the phase of ice-wedge growth associated with the main late-Devensian glaciation of the British Isles, c. 20,000 years BP. Ice-wedge casts are similarly common in the terraces of the Upton Warren interstadial in both the Avon (Shotton, 1968), and the Thames (Briggs & Gilbertson, in press). They have not been widely noted in the younger facet of the Floodplain Terrace of the Thames which has been dated at Northmoor to 11,250 yrs. BP (BIRM 105) to 10,931 yrs. BP (IGS-162). The older Summertown-Radley Terrace of Ipswichian age and Hanborough Terrace of early Wolstonian age (Sandford, 1924; Briggs & Gilbertson, 1973; Briggs & Gilbertson, in press) have been far more severely affected by frost action than the deposits at Bourton or Beckford. Consequently the terrace is regarded as considerably older than the later facet of the Floodplain Terrace and to post-date the Summertown-Radley and Hanborough Terraces; an interpretation supported by the relationship to the modern river level. Thus it seems likely to correlate with the older phase of the Floodplain Terrace of the Thames; dates from this have ranged from 39,300 ± 1,350 radiocarbon years BP at Dorchester (BIRM 333) to 29,500 ± 300 radiocarbon years BP at Standlake (BIRM 334). This dating is possibly supported by the date of 34,500 ± 800 years BP obtained from the gravels of the Windrush at Little Rissington (BIRM 466).

Terrace deposition seems to have been characterised by active mass-movement and rapid aggradation of debris in the valley floor. It is tempting to relate this activity to the development of the tectonic structures (ridge-and-trough topography) preserved on the surrounding valley sides (Briggs & Courtney, 1972). In conditions of repeated freeze-thaw and marked seasonal fluctuations of both temperature and run off, sapping of the Lias Clay exposed in the valley floor may well have caused instability of the slopes, leading to a variety of slope movements including cambering, gulling and planar sliding.

Conclusions

The main (pre-Roman) terrace gravels of the Vale of Bourton are shown to be the result of a combination of a mass movement and fluvial reworking in a periglacial environment during the mid-Devensian, rather than the early-Ipswichian. The pollen evidence suggests that during the aggradation the regional vegetation cover was treeless, and dominated by grass, or grass-sedge communities. Within this landscape, base-rich marshes and streams occurred on limestone gravel floodplains. These were dominated by moderately thermophilous marsh and aquatic species. Arboreal pollen is present in the spectrum, but is interpreted as a result of transportation to the site by stream and wind. Molluscan evidence similarly suggests an open periglacial climate with the river floodplain consisting of a mosaic of drier gravelly ridges, marshy pools, and streams. It is difficult to assess the severity of the climate from the biological remains. The moderately thermophilous marsh and aquatic species present may indicate that warm summers were prevalent, as suggested for other sites by Bell (1969). If such conditions existed the lack of similarly thermophilous tree species, accounted for by factors such as soil instability (Bell, 1970), may be associated with arduous winters; and the presence of arctic-alpines by the lack of severe competition consequent upon the absence of a tree cover.

Climate deteriorated shortly after the main terrace aggradation at about 20,000 years BP, when ice wedges formed. Fluvial incision may be broadly associated with this stage in the late-Devensian, initiating the development of superficial tectonic structures on local hillsides. During the later stages of the Devensian, further mass-movement, perhaps associated with aeolian activity produced a veneer of soliflucted regolith now identified as head.

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