PHILOSOPHICAL TRANSACTIONS OF THE ROYAL SOCIETY B BIOLOGICAL SCIENCES

Late Pleistocene Interglacial Deposits at Tattershall, Lincolnshire

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Phil. Trans. R. Soc. Lond. B 1985 **311**, 193-236
doi: 10.1098/rstb.1985.0152

Phil. Trans. R. Soc. Lond. B **311**, 193–236 (1985) [193]
Printed in Great Britain

LATE PLEISTOCENE INTERGLACIAL DEPOSITS AT TATTERSHALL, LINCOLNSHIRE

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(*Communicated by R. G. West, F.R.S. – Received 2 August 1984*)

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Interglacial deposits exposed in gravel pits near Tattershall Castle and at Tattershall Thorpe, Lincolnshire, are described. These consist predominantly of detritus muds and silts which fill channels cut into the underlying Wragby Till. The interglacial deposits at both sites are overlain by between 3 and 8 m of fluvial gravel and sand in which ice-wedge casts are preserved. Radiocarbon dates from silt lenses within these gravels confirm a Middle Devensian age for this aggradation.

The interglacial deposits from both sites are rich in fossils (pollen, plant macrofossils, Mollusca, Ostracoda) which are described in detail. They also contain some foraminifera and vertebrate fossils in Tattershall Castle pit. The molluscan faunas were unusually rich, with a combined total of 86 taxa recorded including many land snails, two of which (*Cochlicopa nitens* and *Vitrea subrimata*) have not previously been reported from the British Pleistocene.

The fossil evidence from Tattershall Castle pit indicates that the interglacial sediments were deposited by a slow-flowing, well vegetated stream during substage IIb of the Ipswichian Interglacial. An early Ipswichian age is also suggested for the basal calcareous silts, which contain an open-country molluscan fauna, previously ascribed to the late Wolstonian. The correlation is strengthened by uranium-series disequilibrium dates suggesting an age between 75 and 115 ka B.P., a thermoluminescence date of 114 ± 16 ka B.P. and by amino acid racemization data from molluscan shells. The occurrence of brackish-water species of Mollusca, Ostracoda and foraminifera indicates mildly brackish conditions occurred during deposition between −1.8 and −0.2 m O.D.

Several plants and molluscs occur that are no longer present in Britain and these provide some evidence that summer temperatures may have been slightly warmer than those of today. Winter temperatures also appear to have been mild. The banding polymorphism of the snails *Cepaea* spp., analysed here for the first time from a British interglacial site, might also give evidence of a warm climate.

Evidence of interglacial conditions from Tattershall Thorpe comes from infills of two palaeochannels. The fossiliferous detritus muds in the channel studied in most detail (1979–1982) appear to result from deposition in nearly stagnant water under fully temperate conditions with regional mixed oak forest, during substage II of an interglacial. These deposits are at a higher elevation (5–6 m above O.D.) than those at Tattershall Castle and contain no evidence of brackish conditions. Silty clay from the second channel (studied mainly by other workers, in 1971) yielded pollen spectra referred to substage IV of the Ipswichian Interglacial, and a molluscan assemblage indicative of moving water in a river channel.

1. Introduction

Gravel quarries near Tattershall in south Lincolnshire have exposed richly fossiliferous deposits since the late 1960s. Detailed studies have been made of the fossil Coleoptera (Girling 1974, 1977, 1980, 1985) and mammals (Rackham 1978, 1981), which have revealed the presence of interglacial and Middle Devensian deposits.

The present account describes the interglacial beds in more detail than hitherto, and presents the detailed results of studies of the palaeobotany, Mollusca and Ostracoda. Additional information on some of the Middle Devensian deposits will be published later.

2. Location

The gravel quarries at Tattershall lie along the western side of the River Bain, 1–5 km upstream of its confluence with the River Witham (figure 1). The lower part of the Bain Valley is bordered by low-lying drift deposits overlying the Ancholme Clay Group (Jurassic), while the confluence with the River Witham occurs near the northern edge of the Lincolnshire Marsh (figure 1). The ground surface was at about 4.5 m above O.D. at the southernmost of the quarries studied, which was to the south of the confines of the Bain Valley, but at over 12 m O.D. at the northernmost quarry within the Bain Valley.

The location of the quarries that were worked in the period 1969–1983 is shown in figure 1. The quarries of the northern group (lettered A–E) are all in Tattershall Thorpe parish. Previous accounts have referred to some of these quarries as Kirkby-on-Bain (Girling 1974, 1977, 1980; Rackham 1978, 1981). The interglacial deposits at Tattershall Thorpe investigated during the present study were located at X, in quarry A, but previously other interglacial beds had been seen in quarry D.

The quarries of the southern group are in Tattershall Castle parish. The interglacial deposits at Tattershall Castle investigated during the present study were at Y in quarry G. Those investigated by Girling (1974, 1977, 1980) were at Z in quarry F and appear to represent a continuation of those at Y, which also continued downstream to the area marked (Y) in figure 1.

3. Deposits at Tattershall Castle

(a) *Stratigraphy*

A schematic representation of the stratigraphy around site Y and elsewhere in quarry G is shown in figure 2, based upon levelled profiles and detailed drawings.

The floor of the quarry provided extensive exposures of till with a matrix of dark grey clay and abundant Jurassic erratics, notably belemnite guards and ammonites. This till is thus thought to represent the Wragby Till of Straw (1966, 1969, 1982, 1983). Straw & Clayton (1979) regarded this till as being of Wolstonian age, but Perrin *et al.* (1979) argue that it dates from the Anglian. Jackson & Issaias (1982) show that the till in this region is 5–17.2 m in thickness, and that it rests on the (Jurassic) Ancholme Clay Group. At Tattershall Castle pit the level of the upper surface of the till was generally 0.7–0.8 m above O.D., but it descended to 2.2 m below O.D. on the bottom of an elongate depression of the till surface over 300 m wide. This depression is interpreted as a channel because of its form and the infill of sediments that are in part fluvially bedded at their base. All the sediments interpreted as being of interglacial age occurred within this channel.

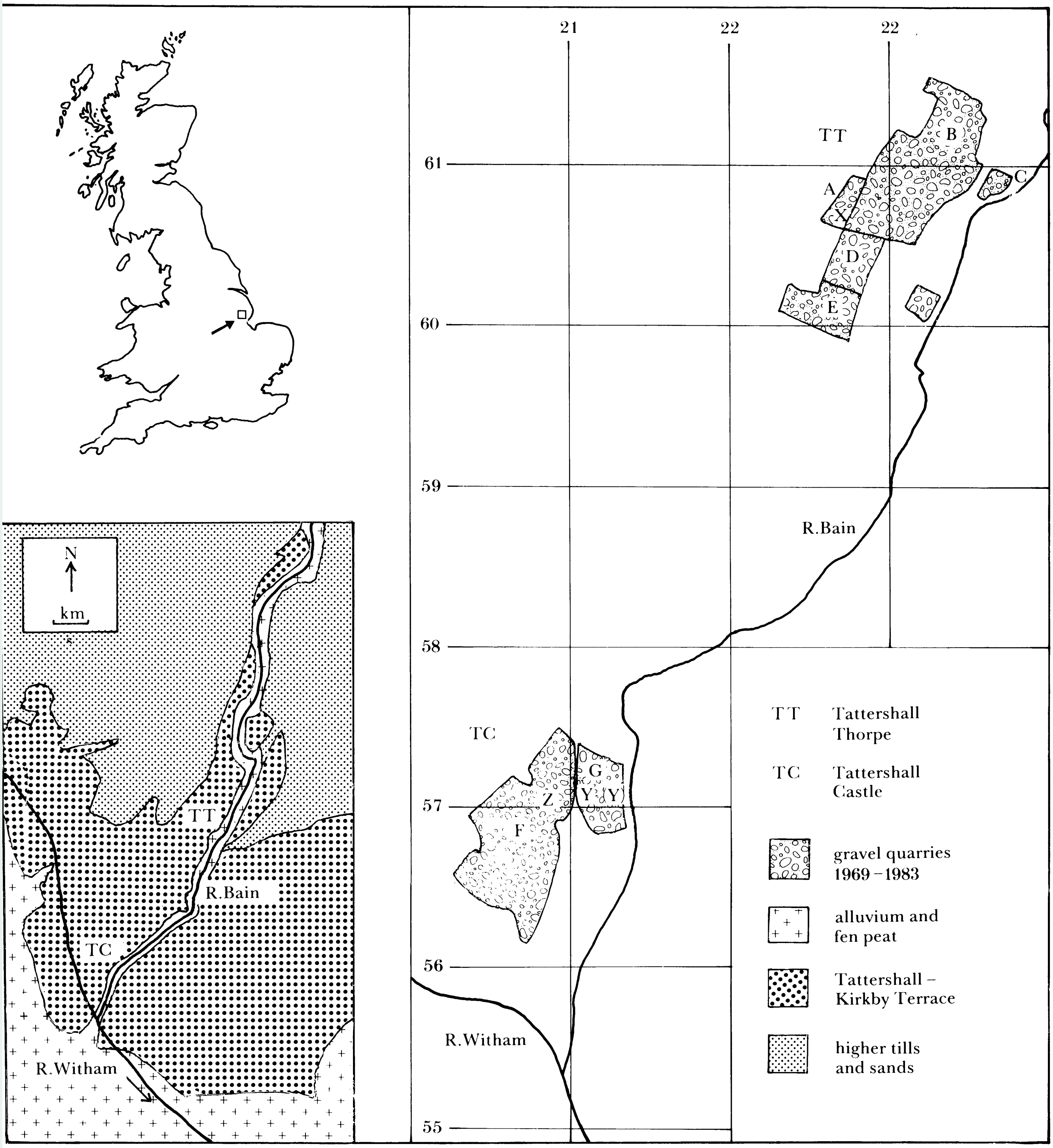


FIGURE 1. Location of gravel quarries at Tattershall.

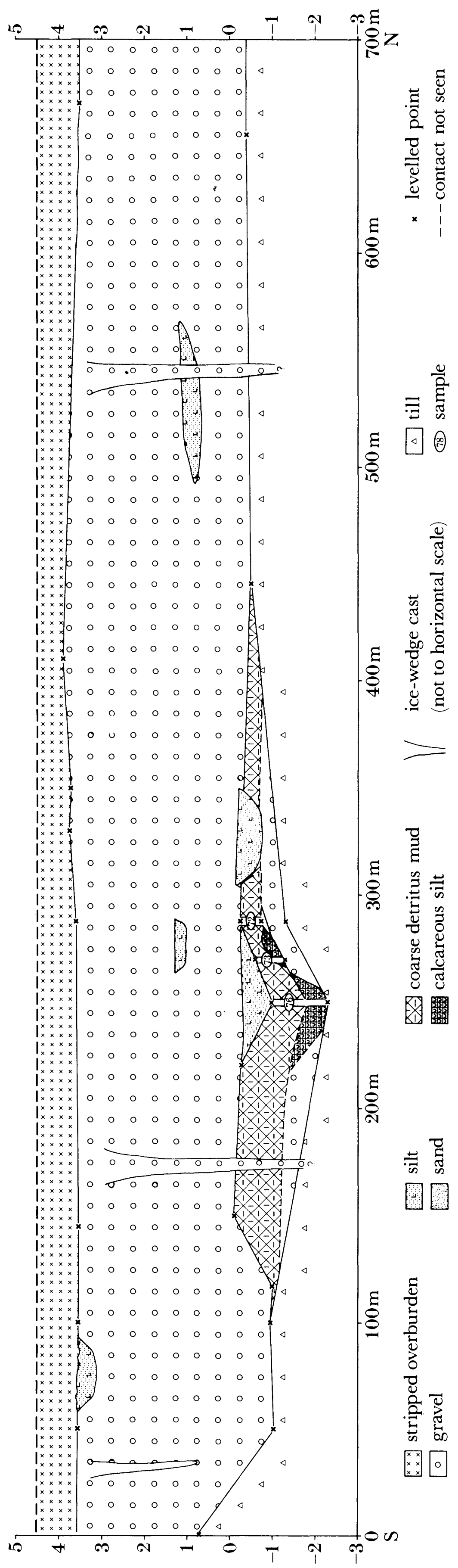


FIGURE 2. Stratigraphy, Tattershall Castle. Schematic representation, vertical exaggeration, ×20.

The basal sediments within the channel were well-sorted medium gravels, rarely exceeding 1 m in thickness, and composed mostly of subangular flints but with some erratics. Bryant (1983*a*) described these gravels in detail and attributed their deposition to a fast-flowing river.

The remainder of the channel infill consisted mainly of detritus muds, with more localized deposits of clay–mud and calcareous silt. These deposits did not show any consistent height relationships to each other and appeared to represent different depositional facies with overlapping ages. This conclusion was strengthened by consideration of their fossil content and is discussed more fully below.

The detritus muds varied considerably in the size and degree of humification of the plant materials, and the extent of admixture with clay and silt grade mineral particles. Previous accounts have described these deposits as peat or wood peat, but they clearly consisted of woody and other drifted materials deposited in water, an interpretation further supported by the fossil assemblages described below.

The calcareous silts were of two types, pale cream and light brown in colour when wet, but weathering to medium brown and orange–brown respectively. They consisted mainly of silt with a high proportion of particulate calcium carbonate producing the light colour. Mollusc shells were abundant. This material was described as shell marl by Girling (1977, 1980), who reported it only from stratigraphically lower than the 'woody peat'. A late Wolstonian age was suggested from the non-marine Mollusca. Our observations show that this calcareous silt has a fossil content (see below) of undoubted interglacial character.

The detritus muds, silts and other interglacial deposits were sampled at three locations on the floor of the quarry, numbered 72, 73 and 76, to allow study of the full thickness of the deposits which was not exposed at any one site. These three locations were within 60 m of each other and their heights were compared by precise levelling. The biostratigraphical evidence discussed below suggests that the height sequence of the deposits is approximately a stratigraphical sequence, but none of our conclusions depends upon precise correlation between the three locations studied. At sites 72 and 73, and the upper part of site 76, bulk samples were collected from dug holes and cleaned exposures. The base of site 76 was sampled with a wing-auger yielding samples of 10 cm diameter.

The interglacial deposits were overlain by 3–5 m of bedded fluvial gravels, within which were numerous channels infilled with sand, silt or silty mud. Sedimentological descriptions of these deposits are given by Bryant (1983*a*), while Girling (1974, 1977, 1980) gives a general account with details of the fossil Coleoptera from silts within the gravels and Rackham (1978, 1981) describes fossil mammals. Ice-wedge casts occur within these gravels; some of the casts descend from within 1 m of the top of the gravels to the underlying till, while the tops of other casts appear to have been truncated at lower levels by the migration of river channels.

Girling (1980; see below) has presented evidence that some of the upper gravels and silty channel infills are of Flandrian age, while the lower silty channel infills within the gravels are of Middle Devensian age. Some of the lower silt-filled channels we observed were cut into the detritus muds of interglacial age (figure 2) or rested on a planed-off surface of the interglacial muds. The Devensian age of these silts was not always clearly evident from height relationships nor the sediments themselves but it was readily apparent from both field and laboratory examination of the fossil assemblages, despite the occurrence of reworked interglacial fossils.

The gravels were capped by 0.5–2 m of Flandrian silts with some peats locally. These were removed before gravel quarrying ('stripped overburden' in figure 2).

(*b*) *Palaeobotany*

(i) *Pollen*

A series of samples for study of pollen and spores was collected from each of the three sites studied. The pollen was prepared by using a standard chemical method (West 1977), modified to include use of sodium pyrophosphate to disperse clay (Bates *et al.* 1978), and identified to the type categories of Andrew (1970) or the *Northwest European pollen flora* (Punt 1976; Punt & Clarke 1980, 1981). The names of plants follow *Flora Europaea* (Tutin *et al.* 1964–1980).

In the basal calcareous silt of series 76 pollen was scarce and very severely corroded. Because pollen is sometimes well preserved in such calcareous sediments as lacustrine marls it is thought that the poor preservation here may reflect drying of the sediment. No counts were possible, but pollen of *Quercus* was present in appreciable quantity among the corroded grains surviving at some levels. This implies that deposition of the calcareous silt occurred at a time when oak forests were present in the region, and is in conflict with the late Wolstonian age hitherto accepted.

Pollen was absent from the basal calcareous silts of series 72, but abundant pollen was recovered from the detritus muds of this and the other two series of samples (figure 3). The preservation of the pollen from the muds varied within each of the samples, some being perfectly preserved, while a proportion was more or less severely corroded. In most samples 10–20% of grains were classed as unidentifiable, mostly corroded, but the proportion rose to 32 and 43.5% in two samples from series 73.

Interpretation of these pollen spectra needs to take account of the likely provenance of the pollen. Some grains no doubt arrived by air from vegetation growing close to the site, but some may have been carried there by water, along with the silt. The water-borne fraction of the pollen could have come from a considerable distance upstream of the site, and it might include a contribution from soil and superficial deposits reworked by fluvial action. However, such reworking may not have been important because pre-Quaternary palynomorphs were virtually absent from the spectra counted (two Jurassic spores), whereas they are common in the Wragby Till that underlies most of the local fluvial deposits.

Sample 72E was overwhelmingly dominated by *Alnus* pollen (91%); some *Alnus* grains were in clusters, and one cluster of about 30 grains was omitted from the pollen sum. Macrofossils of *Alnus glutinosa*, including fragments of male catkins, were common throughout the muds (see below), so the massive representation of *Alnus* pollen in sample 72E can be attributed to deposition of fallen catkins.

With the exception of sample 72E, all of the spectra are fairly similar. Pollen of trees (mostly *Quercus* and *Alnus*) and shrubs (principally *Corylus*) is dominant over rather low percentages of herbaceous pollen. The abundance of pollen of *Alnus* suggests wet woodland or many waterside trees, while woodland on drier ground is suggested by *Quercus* and *Corylus* with lower pollen frequencies of *Acer*, *Tilia cordata* and *Ulmus*. *Acer* and *Tilia* contribute disproportionately little pollen relative to their abundance in forests (Andersen 1970), so they may have been quite plentiful. *Taxus*, *Salix*, *Ilex*, *Cornus sanguinea*, *Rhamnus catharticus* and *Viburnum opulus* might all grow in dry or moist sites in woodland or scrub.

The herbaceous pollen includes appreciable frequencies of Cyperaceae that may have originated in fens or waterside vegetation. Similar frequencies of Gramineae pollen might be from grassland or fens. Shade-tolerant herbs and ferns recorded include *Mercurialis perennis*, *Urtica dioica*, *Polypodium vulgare* agg. and *Pteridium aquilinum*. Herbs typical of unshaded sites probably include the numerous records of Compositae, Cruciferae, Labiatae, Leguminosae, Rubiaceae and Umbelliferae.

The single records of *Artemisia* and *Plantago* cf. *maritima* from sample 72J may imply proximity of salt-marsh habitats, as do the high values of Chenopodiaceae in 72H, 72I and 72K. During interglacial stages species of all three of these taxa are much commoner in salt marshes than any other lowland habitats.

Aquatic plants are well represented by submerged or emergent forms (*Callitriche*, *Nuphar*, *Potamogeton*, *Utricularia*), floating forms (*Lemna*) and helophytes that grow in shallow edges (*Alisma* type, *Sparganium erectum* type, *Typha latifolia*).

There is therefore evidence for regional oak woodland occupying the drier ground, *Alnus* on wet ground, fens and perhaps grassland. Fluvial transport is likely to have been responsible for accumulating material from these varied habitats, perhaps from a considerable distance upstream. Proximity of salt marsh is suggested from samples 72H–K.

Dominance of oak forest pollen, with appreciable frequencies of *Alnus* and *Corylus*, and presence of *Ulmus*, *Acer* and *Tilia*, shows that all of the spectra are from the Early Temperate substage ('zone II') of an interglacial (cf. Turner & West 1968). The spectra resemble substage IIb of the Ipswichian Interglacial in having moderately high frequencies of *Corylus* with a significant representation of *Acer* and only a stray grain of *Picea*, features that allow a Hoxnian age to be discounted (West 1980). *Ilex* is more strongly represented than at most Ipswichian sites. *Taxus* is notably common as at Wretton (Sparks & West 1970), whereas *Pinus* is relatively scarce. *Alnus* was formerly thought to be scarce at Ipswichian sites, but several sites have now been reported where it is abundantly represented (Phillips 1974; West 1980).

Several changes in frequency or representation of tree and shrub taxa appear to be of value in judging age relationships of the three sections studied at Tattershall Castle. These tend to confirm that the site at lowest elevation is oldest and the highest site is the youngest. This is discussed further below; the following evidence from pollen supports the sequence proposed (in stratigraphical order):

73 (1–5)	*Tilia* appears; *Ilex* common;
76N–P	*Taxus* appears and expands;
76L–N	*Ulmus* declines from regular presence at low frequencies to only intermittent records;
76I–L	*Corylus* expanding from low frequencies.

All of these changes occur within substage IIb of the Ipswichian Interglacial.

(ii) *Plant macrofossils*

Plant macrofossils were studied from each of the three sites that were investigated. All identifiable remains were extracted from all or part of the oven-dried samples sieved to over 0.5 mm for Mollusca, and the finer dried residues of these that were sieved to 0.2–0.5 mm. In addition, small subsamples (50–100 g dry mass) were dispersed in 10% (by volume) nitric acid and all material caught in the resulting froth was sieved to over 0.2 mm and searched while wet. The samples treated with nitric acid yielded certain small seeds that were not recovered from the oven-dried samples. However, remains of small fruits and seeds and also bud scales, leaves and other thin or fragile material, were scarce and of rather limited variety, apparently reflecting the oxidation or humification of material in the deposits. A large bulk sample (no. 95, of 6 kg dry mass) from the same location as series 73 was oven-dried and searched for various large fruits and seeds. Results are listed in table 1 and summarized in figure 4. Nomenclature follows *Flora Europaea* for vascular plants and Smith (1978) for mosses.

In fluvial deposits such as the detritus muds studied here, material represented may have floated or been carried in suspension over long distances. The pollen, Mollusca and other fossils may likewise include material that has been carried considerable distances, so there is little information other than that from the sedimentary environment to decide what is of local rather than regional provenance. However, remains of aquatic plants and helophytes that are present in especially large quantities may have originated close by, in and beside the channel in which deposition occurred.

The basal calcareous silts of series 76 mostly lacked identifiable plant remains. However, samples 76G and 76H contained a few corroded remains of *Alnus glutinosa* and a fruit of *Rumex conglomeratus*. The presence of *Alnus* macrofossils supports the scanty pollen evidence in suggesting an interglacial age for these silts.

The basal calcareous silts of series 72 similarly contained very little plant material. None the less, presence of corroded remains of *Alnus glutinosa*, *Ilex aquifolium* and *Salix* sp. indicate interglacial conditions. The scarcity and poor preservation of pollen and plant macrofossils in the calcareous silts (series 72 and 76) is probably attributable to oxidation before deposition of the overlying detritus muds.

A large sample (73–0) from the gravels underlying sample series 73 produced only a fragment of a single seed that is apparently referable to *Chelidonium majus*. This may have entered the gravels as their upper edge was reworked by channel bed scouring not long before deposition of the overlying detritus muds (73–1 to 73–5), the main body of the gravels being unfossiliferous (and of unknown age).

The detritus muds at all three locations were much richer in plant macrofossils. Besides the material listed in table 1, small wood fragments (mostly 1–20 cm in length) were common and included *Quercus*, *Alnus*, and perhaps *Corylus*. In all cases the wood consisted of drifted fragments of twigs and branches, rather than *in situ* accumulations of wood peat.

Among the other macrofossils, trees are represented predominantly by *Alnus glutinosa*, which is abundant at most levels in the muds. Predominance of this species is presumably due partly to its preferring waterside habitats, as suggested in discussion of the pollen record, but it is also due to the abundance of 'cones' and seeds produced, that are identifiable even when corroded. The few macrofossils from other trees include *Acer monspessulanum*, *Fraxinus excelsior*, *Prunus* cf. *avium*, *Quercus* sp. and *Tilia cordata*. Presence of *Acer monspessulanum* is noteworthy in view of the frequent occurrence of *Acer* pollen. Ipswichian sites have yielded *Acer* pollen in conjunction with macrofossils of *A. campestre* as well as *A. monspessulanum* (West 1980, p. 601), the latter being a southern species that does not reach Britain at the present day. The single fruit of *Tilia cordata* from sample 76–5 is perhaps related to the pollen records that are confined to series 76. *Tilia* pollen is generally scarce in Ipswichian deposits, except at Wing (Hall 1980), and there is only one other record of macrofossils from this interglacial (Holyoak 1983*a*).

Shrubs are represented by numerous remains of *Corylus avellana*, *Ilex aquifolium*, *Rubus* spp. and *Salix* spp., with less frequent remains of *Cornus sanguinea*, *Crataegus monogyna*, *Prunus spinosa* and *Viburnum opulus*. *Cornus sanguinea*, *Salix* spp. and *Viburnum opulus* commonly grow in wet places, but the other shrubs listed prefer or require drier sites.

Herbs from varied habitats are present, including taxa characteristic of woodland or wood

TABLE 1. PLANT MACROFOSSILS FROM TATTERSHALL CASTLE PIT

(Sample 95 is a bulk sample from the same location as sample series 73.)

		Series 76							Series 72											Series 73						
sample labels...		G	H	I	K	M	O	Q	B	C	D	E	F	G	H	I	J	K	L	0	1	2	3	4	5	95
dry mass (in grams) of main sample...		250	250	100	100	100	100	100	200	200	500	200	200	100	100	100	100	100	100	550	200	200	200	200	200	6000
of subsample searched while wet...		50	50	50	50	50	50	50	50	50	100	50	50	50	50	50	50	50	50	100	50	50	50	50	50	—
trees																										
Acer monspessulanum L.	f.	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1	—	—	1 ?	—	—	1 ?	1	—
Alnus glutinosa (L.) Gaertn.	f.c.	—	2	9	8	7	2	2	—	—	—	8	7	7	4	6	2	3	4	—	—	3	3	20	7	many
	f.c.b.	1	—	315	183	321	23	30	—	—	—	51	134	79	51	89	86	64	89	—	7	24	14	69	6	—
	f.f.	—	—	—	—	—	—	—	—	—	—	2	—	1	—	—	—	—	—	—	—	—	1	—	—	—
	s.	2	—	132	92	118	20	30	—	—	1	50	56	31	67	56	19	27	61	—	3	7	42	36	63	—
	m.c.f.	—	—	29	2	9	—	—	—	—	—	3	27	11	2	3	2	—	13	—	—	1	—	—	—	—
	m.c.b.	—	—	—	—	—	—	—	—	—	—	15	—	—	14	—	—	—	—	—	—	—	—	—	—	—
	b.s.	—	—	—	—	—	—	—	—	—	—	—	—	—	—	2	—	—	—	—	—	—	—	—	—	—
	tw.	—	—	—	—	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Fraxinus excelsior L.	f.	—	—	—	—	—	—	—	—	—	—	—	—	—	1	—	—	—	—	—	—	—	—	1	—	—
Prunus cf. *avium* (L.) L.	f.s.	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1
Quercus sp.	f.	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	7
	tw.	—	—	2	1	—	—	—	—	—	—	—	—	—	—	—	—	—	1	—	—	—	—	—	—	—
Tilia cordata Mill.	f.	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1	—
shrubs																										
Cornus sanguinea L.	f.s.	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1	—	—	—	—	—	—	—	1	6
Corylus avellana L.	n.	—	—	—	—	2	—	—	—	—	—	—	1	1	—	3	1	—	2	—	—	1	1 ?	—	2	many
	f.f.	—	—	—	—	—	—	—	—	—	—	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Crataegus monogyna Jacq.	f.s.	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1	—	—
Crataegus cf. *laevigata* (Poiret) DC.	f.s.	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1
Ilex aquifolium L.	f.s.	—	—	1	—	—	—	—	1	—	—	2	1	7	—	3	—	1	1	—	5	3	5	9	5	92
Prunus spinosa L.	f.s.	—	—	—	—	—	—	—	—	—	—	—	—	1	—	—	—	—	—	—	—	—	—	—	—	3
Rubus sp.	f.s.	—	—	—	—	—	—	—	—	—	—	—	—	—	1	—	—	—	—	—	1	—	—	—	—	—
Rubus fruticosus agg.	f.s.	—	—	1	1	2	—	—	—	—	—	1	2	—	2	3	4	3	3	—	2	4	7	4	7	14
	th.	—	—	—	—	1	1	1	—	—	—	—	3	—	—	—	1	—	1	—	1	—	2	1	1	—
Rubus idaeus L.	f.s.	—	—	—	1 ?	—	—	—	—	—	—	—	—	—	4 ?	—	—	1 ?	2 ?	—	2 ?	—	—	1	—	—
Salix sp.	b.	—	—	—	—	—	—	—	1	—	—	3	—	1	—	—	—	—	—	—	—	—	—	1	—	—
	b.s.	—	—	—	—	—	—	—	—	—	—	4	2	2	—	10	4	—	—	—	—	—	—	—	—	—
	s.	—	—	—	—	—	—	—	—	—	—	1	3	2	6	3	—	—	—	—	—	—	—	1	—	—
Viburnum opulus L.	f.s.	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1	—
woods, wood margins, scrub																										
Chelidonium majus L.	s.	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1 ?	3	—	2	—	—	
Circaea lutetiana L.	f.	—	—	—	—	—	—	—	—	—	—	1	—	—	—	—	—	—	—	—	—	—	—	—	—	
Silene dioica (L.) Clairv.	s.	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1	—	1	—	—	—	—	—	—	—	
bare ground/ruderals																										
Atriplex sp.	s.	—	—	1	—	1	—	—	—	—	—	—	—	—	1	—	—	—	—	—	—	—	1	—	—	
Atriplex cf. *patula* L.	s.	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1	—	
cf. *Lepidium* sp.	s.	—	—	—	—	—	—	1	—	—	—	—	—	—	1	—	—	—	—	—	—	—	—	—	—	
Polygonum lapathifolium L.	f.+p.	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1	—	
Rumex crispus L.	f.+p.	—	—	—	—	—	—	—	—	—	—	—	—	—	1	—	—	—	—	—	—	—	—	—	—	
Stellaria media (L.) Vill.	s.	—	—	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1	—	—	
Viola cf. *arvensis* Murr.	s.	—	—	—	—	—	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	
grassland																										
Ranunculus cf. *acris* L.	a.	—	—	5	1	1	—	—	—	—	—	—	2	—	—	—	1	—	—	—	—	4 ?	—	1 ?	1 ?	
Ranunculus cf. *repens* L.	a.	—	—	3	—	3	—	—	—	—	—	1 ?	4	1 ?	1 ?	—	—	—	—	—	—	—	—	1 ?	—	
Ranunculus subg. *Ranunculus*	a.	—	—	6	3	2	—	—	—	—	—	4	8	1	4	—	2	—	2	—	1	1	3	2	8	
Rumex acetosella L. agg.	f.	—	—	2	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	
Rumex conglomeratus Murr.	f.	1	—	14	3	2	1	—	—	—	—	6	10	6	1	6	—	2	3	—	—	—	8	5	—	
	f.+p.	—	—	1	2	1	—	—	—	—	—	4	1	—	2	1	—	—	—	—	—	—	1	2	—	
	p.s.	—	—	—	2	—	—	—	—	—	—	1	1	1	1	—	—	—	—	—	—	—	—	1	—	
Trifolium cf. *campestre* Schreb.	s.	—	—	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	

TABLE 1 (*cont.*)

fens, waterside																									
Caltha palustris L.	fo.	—	—	1	1	1	—	—	—	—	—	7	1	—	—	—	—	—	—	—	—	1	—	1	1
Carex riparia Curt.	u.	—	—	—	—	—	—	—	—	—	—	—	—	—	1	—	—	—	—	—	—	—	—	—	—
cf. *Cyperus fuscus* L.	n.	—	—	—	—	—	—	—	—	—	—	1	—	—	—	—	—	—	—	—	—	—	—	—	—
Eleocharis palustris (L.) Roem. & Schult., ssp. *vulgaris* Walters	n.	—	—	1	—	—	—	—	—	—	—	1	—	—	—	—	—	—	—	—	—	—	—	—	2
Eleocharis sp.	n.	—	—	—	—	—	—	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Epilobium cf. *hirsutum* L.	s.	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	2
Eupatorium cannabinum L.	a.	—	—	4	7	11	1	1	—	—	1	12	17	5	8	6	15	11	3	—	3	7	15	14	26
Lycopus europaeus L.	n.	—	—	1	—	—	—	—	—	—	—	1	1	—	—	2	—	—	—	—	1	—	—	2	1
Lythrum salicaria L.	s.	—	—	—	—	—	—	—	—	—	—	—	1	—	—	—	—	—	—	—	—	—	—	—	—
Mentha aquatica L.	n.	—	—	1	2	1	—	3	—	—	—	3	—	—	1	1	3	—	—	—	—	—	1	2	3
Ranunculus cf. *lingua* L.	a.	—	—	—	—	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	2	—	—	3	1
Sonchus palustris L.	a.	—	—	1 ?	—	1	—	—	—	—	—	1	1	—	—	—	—	—	—	—	—	—	—	1	—
Stachys palustris L.	n.	—	—	—	—	—	—	—	—	—	—	—	1	—	—	—	1	—	—	—	—	—	—	—	—
Valeriana dioica L.	f.	—	—	—	—	—	—	—	—	—	—	—	2	1	1	1	—	—	—	—	—	—	1	—	—
wet muddy places, shallow water																									
Alisma sp.	f.	—	—	1	1	—	—	—	—	—	—	—	—	—	1	1	—	—	2	—	—	—	—	—	—
Apium nodiflorum (L.) Lag.	f.	—	—	—	—	—	—	—	—	—	—	—	—	—	2	—	—	—	—	—	—	—	—	—	—
Berula erecta (Huds.) Coville	f.	—	—	6	2	—	—	—	—	—	—	1	2	1	—	2	—	—	—	—	1	1	4	1	4
Callitriche sp.	f.	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1	—	—	—	—	—	—
	s.	—	—	2	4	3	—	—	—	—	—	4	35	9	26	17	34	10	6	—	—	—	—	1	4
Nasturtium microphyllum (Boenn.) Rchb.	s.	—	—	2	1	2	1	1	—	—	—	2	8	2	3	1	2	6	3	—	—	2	—	7	6
Ranunculus subg. *Batrachium*	a.	—	—	—	1	1	2	3	—	—	—	4	1	1	3	4	9	2	2	—	5	6	15	11	42
Ranunculus sceleratus L.	a.	—	—	2	3	2	—	—	—	—	3	115	155	80	96	53	88	36	8	—	6	20	66	64	116
Rorippa palustris (L.) Besser	s.	—	—	5	7	2	—	—	—	—	—	14	34	4	5	2	9	15	1	—	12	4	9	7	23
Scirpus lacustris L. ssp. *lacustris*	n.	—	—	1	1	2	—	6	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Sparganium erectum L.	f.s.	—	—	2	1	1	—	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Typha sp.	f.	—	—	—	—	—	—	—	—	—	—	—	1	—	3	1	1	2	—	—	—	—	—	—	—
aquatic																									
Ceratophyllum demersum L.	f.	—	—	—	—	—	2	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Characeae	oo.	—	—	1	—	6	—	1	—	—	—	22	44	14	21	31	17	22	18	—	28	2	66	4	58
Najas flexilis (Willd.) Rostk. & Schmidt	f.	—	—	—	—	—	—	—	—	—	—	1	—	—	—	—	—	—	—	—	—	—	—	—	1
Nuphar lutea (L.) Sm.	s.	—	—	—	—	—	—	—	—	—	—	—	—	—	1	—	—	—	—	—	—	—	—	—	—
Potamogeton sp.	f.s.	—	—	—	—	—	—	—	—	—	—	—	—	1	1	—	2	1	—	—	—	2	1	1	—
Potamogeton cf. *natans* L.	f.s.	—	—	—	1	2	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Potamogeton cf. *pusillus* L.	f.s.	—	—	1	—	—	—	—	—	—	—	—	—	—	1	—	—	—	—	—	—	—	—	—	—
Zannichellia palustris L.	f.	—	—	—	—	1	—	1	—	—	—	—	—	1	4	2	11	6	5	—	3	3	8	5	7
unclassified																									
Ajuga reptans L.	n.	—	—	—	—	—	—	—	—	—	—	2	2	—	—	—	—	1	—	—	3	1	—	—	2
Cardamine sp.	s.	—	—	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Carex spp.	b.n.	—	—	—	1	—	—	—	—	—	—	3	8	1	—	2	—	—	—	—	—	—	—	1	—
	t.n.	—	—	—	3	4	3	5	—	—	—	4	2	5	14	8	3	4	5	—	4	4	12	1	21
	u.	—	—	—	—	—	—	—	—	—	—	—	—	—	1	—	—	—	—	—	—	—	—	—	—
Epilobium sp.	s.	—	—	—	—	—	—	—	—	—	—	—	2	—	—	—	2	—	—	—	—	—	—	—	—
Epilobium cf. *obscurum* Schreb.	s.	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	3	1	—	—	—	—
Gramineae	c.	—	—	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Myosotis sp.	s.	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1	—
Ranunculus sp.	a.	—	—	—	—	—	—	—	—	—	—	—	2	—	—	—	—	—	—	—	—	—	—	—	—
Rumex subg. *Rumex*	ped.	—	—	—	—	—	—	—	—	—	—	—	2	—	—	—	—	—	—	—	—	—	—	—	—
	p.s.	—	—	—	—	—	—	—	—	—	—	—	1	—	—	—	—	—	1	—	—	—	—	—	—
Solanum dulcamara L.	s.	—	—	1	3	—	—	—	—	—	—	—	—	—	3	6	—	—	2	—	1 ?	—	1	—	—
Taraxacum officinale Weber agg.	a.	—	—	—	—	—	—	—	—	—	—	—	1	—	—	—	—	—	—	—	—	—	—	—	—
Urtica dioica L.	f.	—	—	12	5	4	—	3	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Viola cf. *riviniana* Rchb.	s.	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1	—	—	—	—	2	2	—	—	—

TABLE 1 (*cont.*)

		Series 76							Series 72											Series 73						
sample labels...		G	H	I	K	M	O	Q	B	C	D	E	F	G	H	I	J	K	L	0	1	2	3	4	5	95
dry mass (in grams) of main sample...		250	250	100	100	100	100	100	200	200	500	200	200	100	100	100	100	100	100	550	200	200	200	200	200	6000
of subsample searched while wet...		50	50	50	50	50	50	50	50	50	100	50	50	50	50	50	50	50	50	100	50	50	50	50	50	—
mosses																										
Brachytheciaceae	l.	—	—	—	—	—	1	—	—	—	—	—	6	1	—	—	—	—	—	—	—	—	—	—	5	
	l.s.	—	—	16	—	—	1	—	—	—	—	—	8	7	1	—	—	—	2	—	—	—	—	12	3	(6 mm, g.)
Brachythecium cf. *rutabulum* (Hedw.) Br. Eur.	l.s.	—	—	—	—	—	—	—	—	—	—	1	1	—	—	—	—	—	—	—	—	—	—	—	—	(4 mm, g.)
cf. *Brachythecium* sp.	l.	—	—	—	—	—	—	—	—	—	—	—	—	—	1	—	—	—	—	—	—	—	—	—	—	—
	l.s.	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	2	—	—	—	—	4	—	(8 mm, g.)
Bryum sp.	l.s.	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1	—	—	—	—	—	—	(2 mm, g.)
Eurhynchium striatum (Hedw.) Schimp.	l.s.	—	—	11	—	—	4	—	—	—	—	2	20	1	1	—	—	—	2	—	—	—	6	60	3	(14 mm, v.g.)
cf. *Eurhynchium striatum* (Hedw.) Schimp.	l.	—	—	6	—	—	1	—	—	—	—	—	22	3	1	—	—	—	—	—	—	—	—	8	25	—
	l.s.	—	—	6	—	—	—	—	—	—	—	1	13	4	—	—	—	—	3	—	—	—	3	10	2	(5 mm, g.)
Homalothecium sp.	l.	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	4	—
	l.s.	—	—	2	—	—	—	—	—	—	—	—	2	1	—	—	—	—	2	—	—	—	—	13	—	(7 mm, g.)
cf. *Homalothecium* sp.	l.s.	—	—	—	—	—	—	—	—	—	—	—	1	—	—	—	—	—	1	—	—	—	—	—	—	(6 mm, v.b.)
Hypnum cupressiforme Hedw.	l.s.	—	—	—	—	—	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	(4 mm, g.)
cf. *Hypnum* sp.	l.s.	—	—	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	(2 mm, g.)
Musci undet.	l.s.	—	—	5	—	—	—	—	—	—	—	—	3	2	1	—	—	—	—	—	—	—	1	1	3	(5 mm, v.b.)
Neckera complanata (Hedw.) Hüb.	l.	—	—	—	—	—	—	—	—	—	—	—	2	—	—	—	—	—	—	—	—	—	—	1	—	—
	l.s.	—	—	—	—	—	—	—	—	—	—	—	2	—	—	—	—	—	5	—	—	—	—	1	—	(12 mm, g.)
Neckera cf. *complanata* (Hedw.) Hüb.	l.s.	—	—	—	—	—	—	—	—	—	—	1	—	—	2	—	—	—	1	—	—	—	—	—	—	(6 mm, b.)
cf. *Weissia* sp.	l.s.	—	—	—	—	—	—	—	—	—	—	1	—	—	—	—	—	—	—	—	—	—	—	—	—	(4 mm, b.)

notes

a., achene; b., bud; b.n., biconvex nutlet; b.s., bud scale; c., caryopsis; f., fruit; f.c., fruiting 'cone'; f.c.b., bract from fruiting 'cone'; f.f., female flower; fo., follicle; f.s., fruit stone; l., leaf; l.s., leafy stem; m.c.b., male catkin bract; m.c.f., male catkin fragment; n., nut or nutlet; oo., oospore; p., perianth; ped., pedicel; p.s., perianth segment; s., seed; th., thorn; t.n., trigonal nutlet; tw., twig. u., utricle. Following Dickson (1973) the best preserved fragment of each bryophyte is noted according to its length (in millimetres) and condition (v.g., very good; g., good; b., bad; v.b., very bad).

edges, bare disturbed ground, grassland, fens, waterside vegetation, wet muddy places, shallow water and deeper water.

The woodland and wood edge group is represented by a few fruits of *Circaea lutetiana*, which almost invariably grows in shaded sites, and less certainly by *Chelidonium majus* and *Silene dioica*, both of which also grow in waysides and other partly shaded or unshaded sites.

Ruderals and other plants of bare ground are represented by *Atriplex* sp., *Atriplex* cf. *patula*, cf. *Lepidium* sp., *Polygonum lapathifolium*, *Rumex crispus*, *Stellaria media* and *Viola* cf. *arvensis*. The most likely habitats for these were the drier bare areas on the river floodplain, or bare soil exposed by collapse of river banks upstream.

Grassland plants are well represented, with numerous remains of *Ranunculus* subgenus *Ranunculus* (apparently including *R. acris* and *R. repens*) and of *Rumex conglomeratus*, with few of *Rumex acetosella* and *Trifolium campestre*. The plentiful representation of some of these suggests extensive grasslands, presumably on the river floodplain.

Fen and waterside plants are abundantly represented, with at least 14 species (table 1, figure 4). Tall fen vegetation is implied by the abundant remains of *Eupatorium cannabinum* and lesser quantities of *Lycopus europaeus*, *Lythrum salicaria*, *Mentha aquatica*, *Ranunculus* cf. *lingua* and *Sonchus palustris*. The abundant *Carex* nutlets ('unclassified' as to habitat group) are most likely to have derived from Caricetum in fens because the only *Carex* utricle identified was of the robust fen and waterside species *C. riparia*. Shorter grassy fen vegetation may be suggested by the occurrence of *Valeriana dioica*.

Herbs of wet muddy places and shallow water are the most abundantly represented group of plants. Of the 11 taxa recorded, *Ranunculus sceleratus*, *Ranunculus* subgenus *Batrachium* and *Rorippa palustris* were abundantly represented by macrofossils in the detritus muds of series 72 and 73, but scarcer in series 76. Seeds of *Callitriche* sp. were abundant in series 72, but scarcer in the others. These differences suggest the presence during deposition of series 72 and 73 of a greater extent of waterside areas that were alternately inundated, then exposed and dried. In the lower reaches of modern rivers such drying muddy areas often occur where river discharge varies seasonally or where water is intermittently ponded back upstream by high spring tides. In view of evidence of increased salinity discussed below (Mollusca, Ostracoda), the increased representation of these plants in series 72 and 73 may be most simply attributed to occurrence of extensive muddy areas near the river that were flooded only by fresh or slightly brackish water ponded back by spring tides. Although obligate halophytes are not represented, many of the species present tolerate the intermittent presence of slightly brackish water. Other waterside plants recorded include *Alisma* sp., *Apium nodiflorum*, *Berula erecta*, *Nasturtium microphyllum*, *Scirpus lacustris*, *Sparganium erectum* and *Typha* sp., most of which usually grow in the shallow edges of rivers and other water bodies, although they survive being left above water-level by seasonal or other falls of water-level.

The strictly aquatic flora with eight taxa identified is not especially rich for deposits from the middle part of an interglacial. Some of the species recorded prefer silty or muddy substrates in slow-flowing water (*Potamogeton* cf. *natans*, *Zannichellia palustris*), while Characeae are mostly colonists of bare substrates in clear water, and others such as *Ceratophyllum demersum* require clean hard water with little or no current. However, remains of some of the aquatic plants could have drifted for considerable distances down-river.

(iii) *Notable palaeobotanical records*

The Ipswichian age of the Tattershall Castle interglacial deposits suggested from the pollen evidence is discussed more fully below. Various plants identified have not hitherto been reported from the Ipswichian (cf. Godwin (1975) and subsequent literature):

Cardamine sp., one seed, sample 76I (figure 5*a*, *b*, plate 1);
Circaea lutetiana, one fruit containing two seeds, sample 72E (figures 6*a–e*);
cf. *Cyperus fuscus*, one nutlet, sample 72E;
Dryopteris sp., several spores, series 76, 72, 73;
Epilobium cf. *hirsutum*, two seeds, sample 73–5 (figures 5*g*, *h* and 6*f*);
Epilobium cf. *obscurum*, three seeds, sample 73–0; one seed, sample 73–1 (figures 5*f*, *i* and 6*g*);
cf. *Lepidium* sp., one seed, sample 76Q; one seed, sample 72H (figures 5*d*, *e* and 6*i*);
Linum catharticum, one pollen grain, sample 72J;
Lythrum salicaria, one seed, sample 72F (figure 6*j*);
Myosotis sp., one seed, sample 73–4;
Rhamnus catharticus, single pollen grains in samples 72I, 72J, 73–4;
Sonchus palustris, single achenes, samples 76M, 72E, 72F, 73–4 and perhaps 76I (figures 5*c* and 6*h*);
Tilia cordata, the second record of macrofossils from the Ipswichian: one fruit, sample 73–5 (cf. Holyoak 1983*a*).
Trifolium cf. *campestre*, one seed, sample 76I (figure 6*k*);
Utricularia sp., one pollen grain, sample 72I;
Viola cf. *arvensis*, one seed, sample 76–0 (figures 5*l* and 6*l*);
Viola cf. *riviniana*, seeds, sample 72I (one), 73–1 (two), 73–2 (two) (figures 5*j*, *k* and 6*m*).

(*c*) *Mollusca*

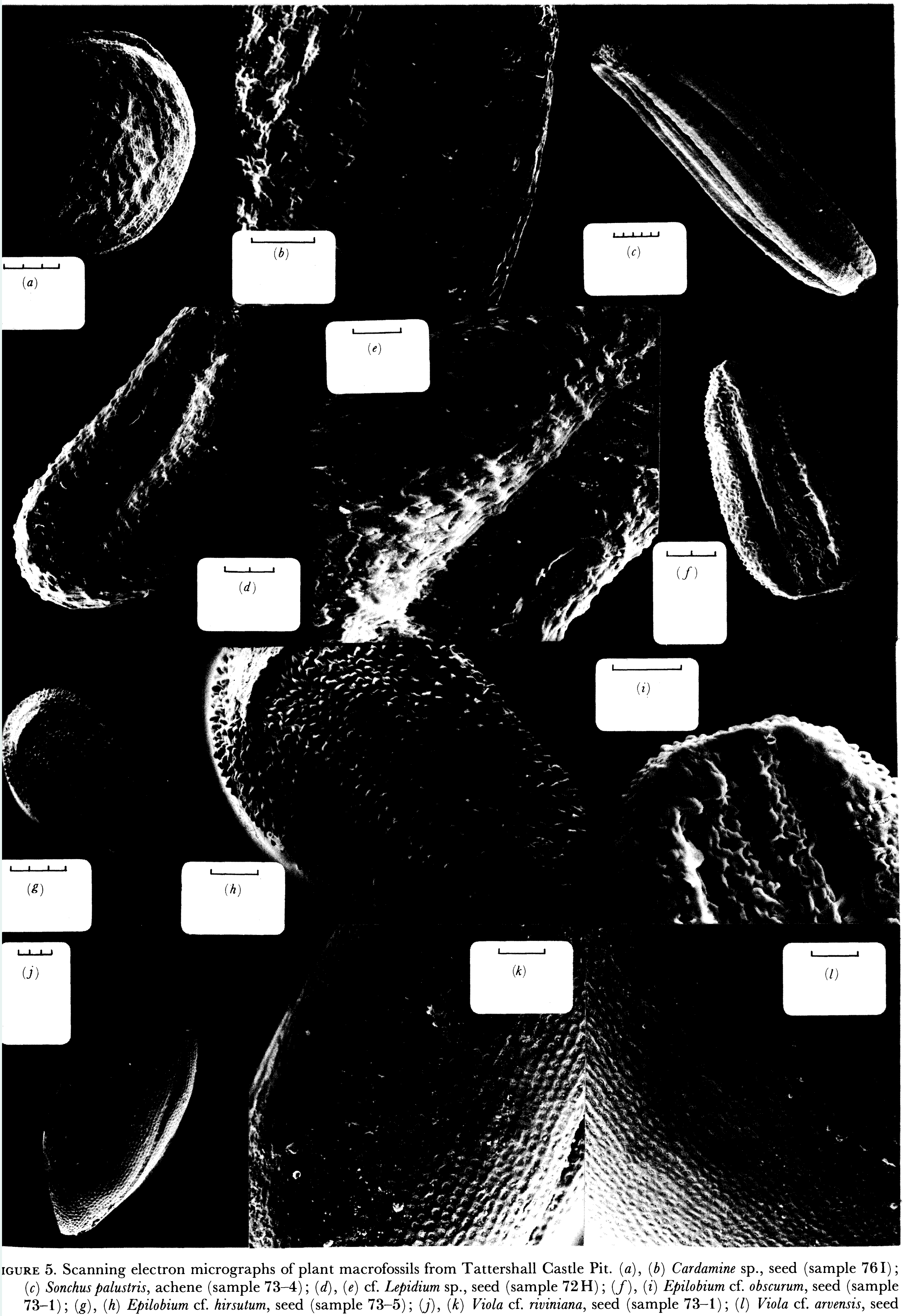
Samples from the same stratigraphic levels as those analysed for plant macrofossils were analysed for Mollusca. After drying, samples (generally of 0.25 kg) were wet-sieved to 0.5 mm mesh. Preservation of the shells was generally good, with only a small proportion (mostly from the detritus muds) having suffered corrosion. The results are listed in table 2 and shown graphically in figures 7 and 8. The nomenclature follows Kerney (1976*a*) for freshwater species and Kerney & Cameron (1979) for terrestrial species. The specimens listed in table 2 have been deposited in the Department of Palaeontology, British Museum (Natural History).

In addition, large bulk samples were collected from the calcareous silts near series 76 (*ca.* 40 kg) and detritus muds from beside series 73 (*ca.* 6 kg). Several additional species were obtained from these samples, as noted below.

The interglacial deposits at Tattershall Castle and Tattershall Thorpe, considered together, proved to be the richest in non-marine Mollusca of any yet reported in Britain. A total of 86 taxa was recorded, including two hitherto unrecorded from the British Pleistocene.

(i) *Problems of identification*

Lymnaeidae. Juvenile *Lymnaea* spp. are variable in shell shape and can be very difficult to identify, especially when two or more species are present. To complicate the situation further, some continental workers (for example, Piechocki 1979) regard the forms *corvus* and *turricula*



IGURE 5. Scanning electron micrographs of plant macrofossils from Tattershall Castle Pit. (*a*), (*b*) *Cardamine* sp., seed (sample 76 I); (*c*) *Sonchus palustris*, achene (sample 73–4); (*d*), (*e*) cf. *Lepidium* sp., seed (sample 72 H); (*f*), (*i*) *Epilobium* cf. *obscurum*, seed (sample 73–1); (*g*), (*h*) *Epilobium* cf. *hirsutum*, seed (sample 73–5); (*j*), (*k*) *Viola* cf. *riviniana*, seed (sample 73–1); (*l*) *Viola* cf. *arvensis*, seed (sample 76–0). All scale bars are marked at intervals of 0.1 mm.

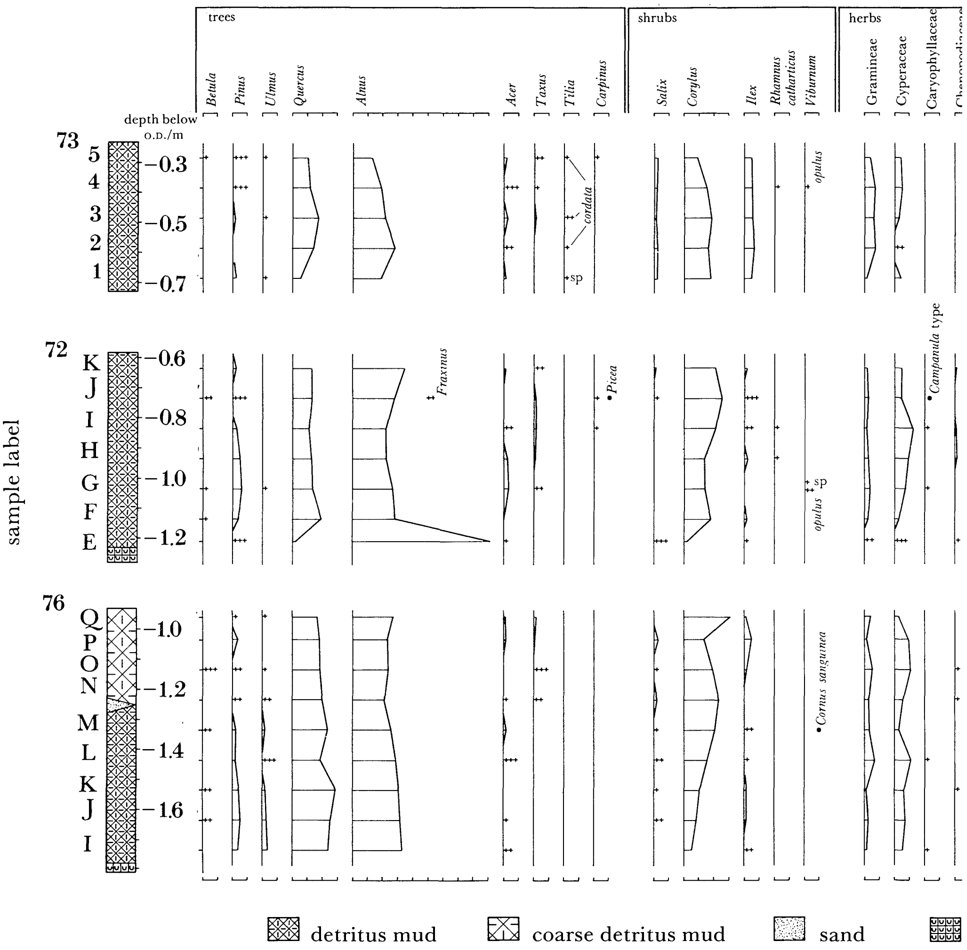
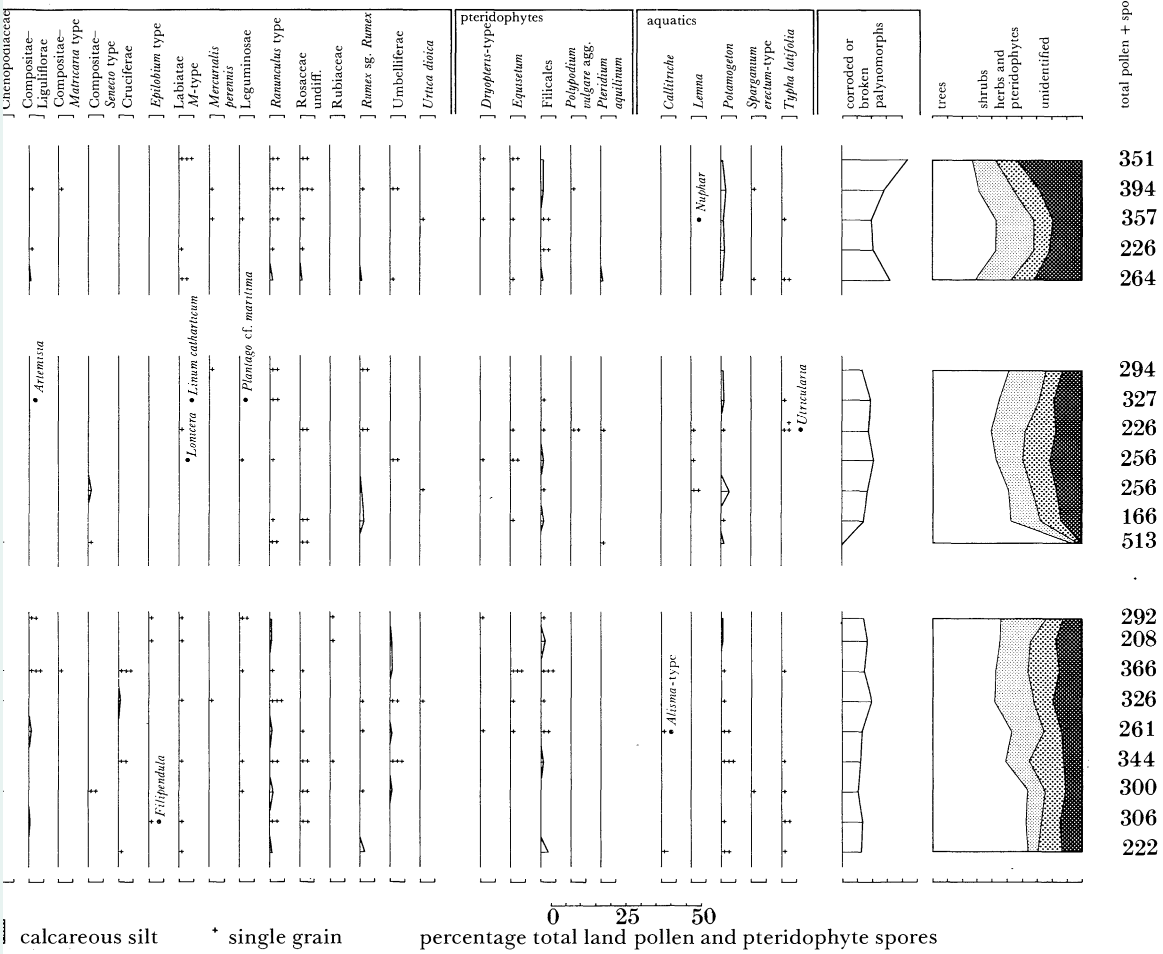

trees
Betula
Pinus
Ulmus
Quercus
Alnus
Acer
Taxus
Tilia
Carpinus
shrubs
Salix
Corylus
Ilex
Rhamnus catharticus
Viburnum
herbs
Gramineae
Cyperaceae
Caryophyllaceae
depth below O.D./m
sample label
73
5
4
3
2
1
−0.3
−0.5
−0.7
cordata
sp
opulus
72
K
J
I
H
G
F
E
−0.6
−0.8
−1.0
−1.2
Fraxinus
Picea
sp
opulus
Campanula type
76
Q
P
O
N
M
L
K
J
I
−1.0
−1.2
−1.4
−1.6
Cornus sanguinea
detritus mud
coarse detritus mud
sand

Figure 3. Po



llen diagram, Tattershall Castle.

(*Facing p.* 206)

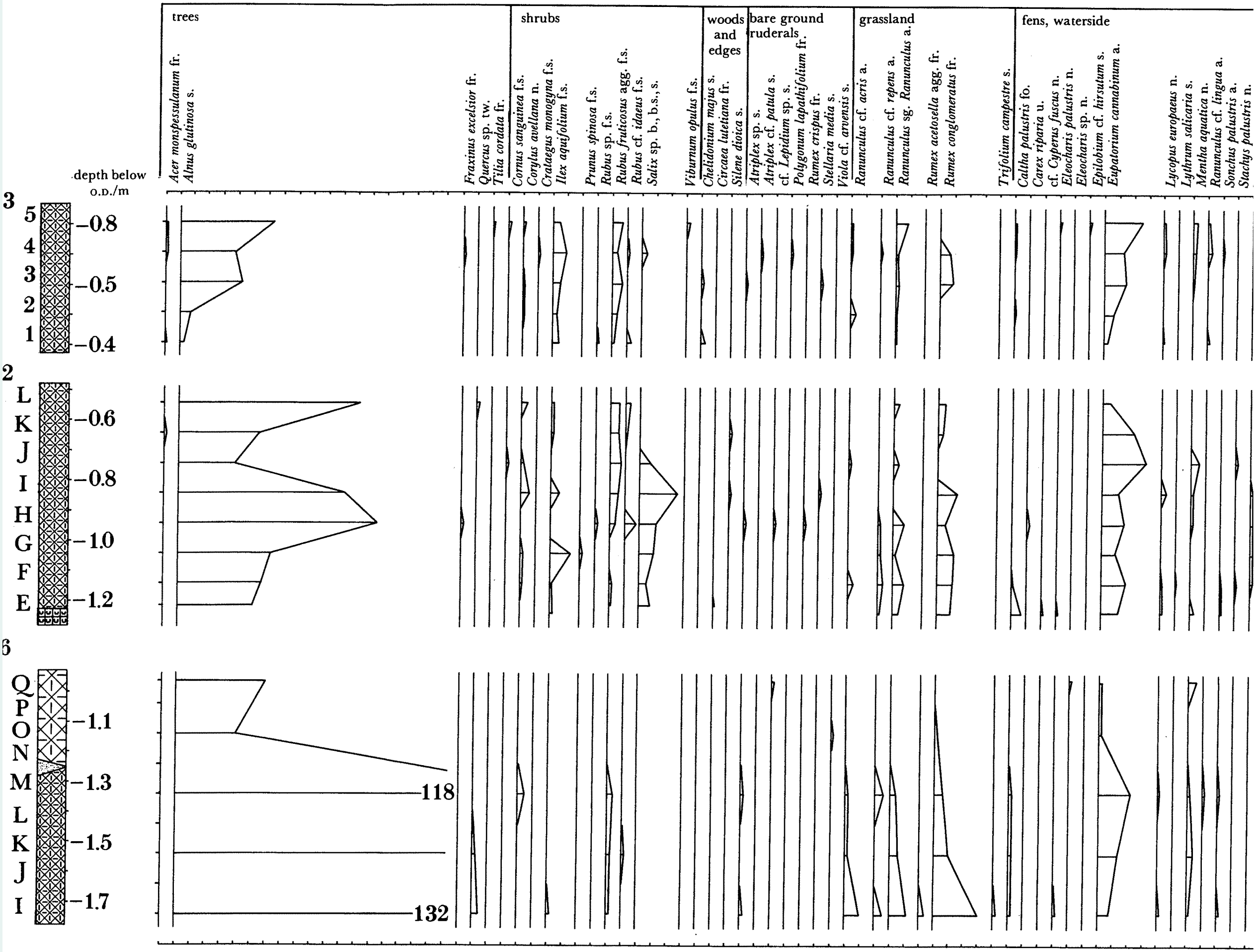
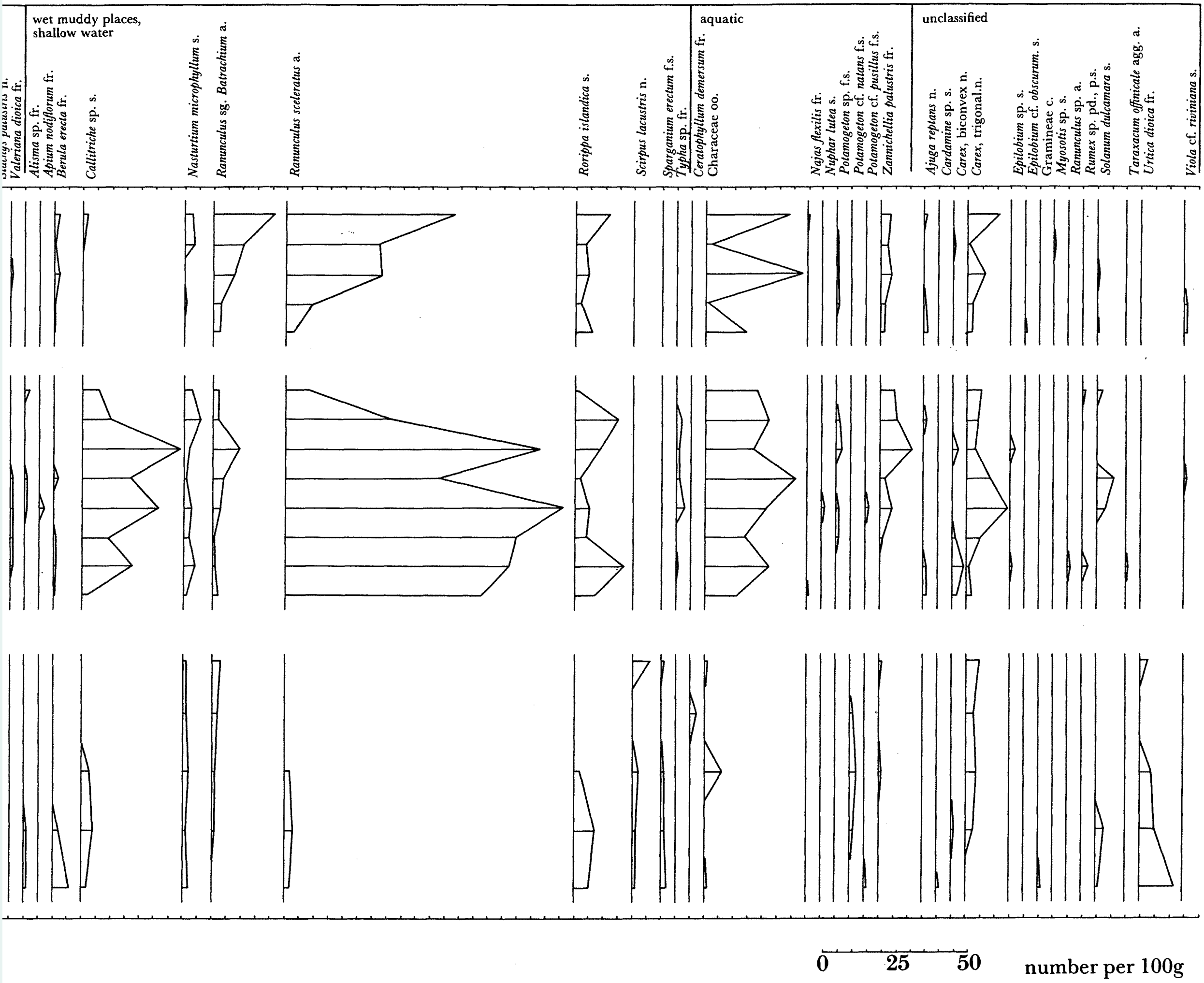


FIGURE 4. Summary of plant macrofossil data, Tattershall Castle. Stratigraphica

fo., follicle; fr., fruit; f.s., fruit stone; n., nut or nutlet; oo., oospore



al symbols as in figure 3. Key: a., achene; b., bud; b.s., bud scale; c., caryopsis;
e; pd., pedicel; p.s., perianth segment; s., seed; tw., twig; u., utricle.

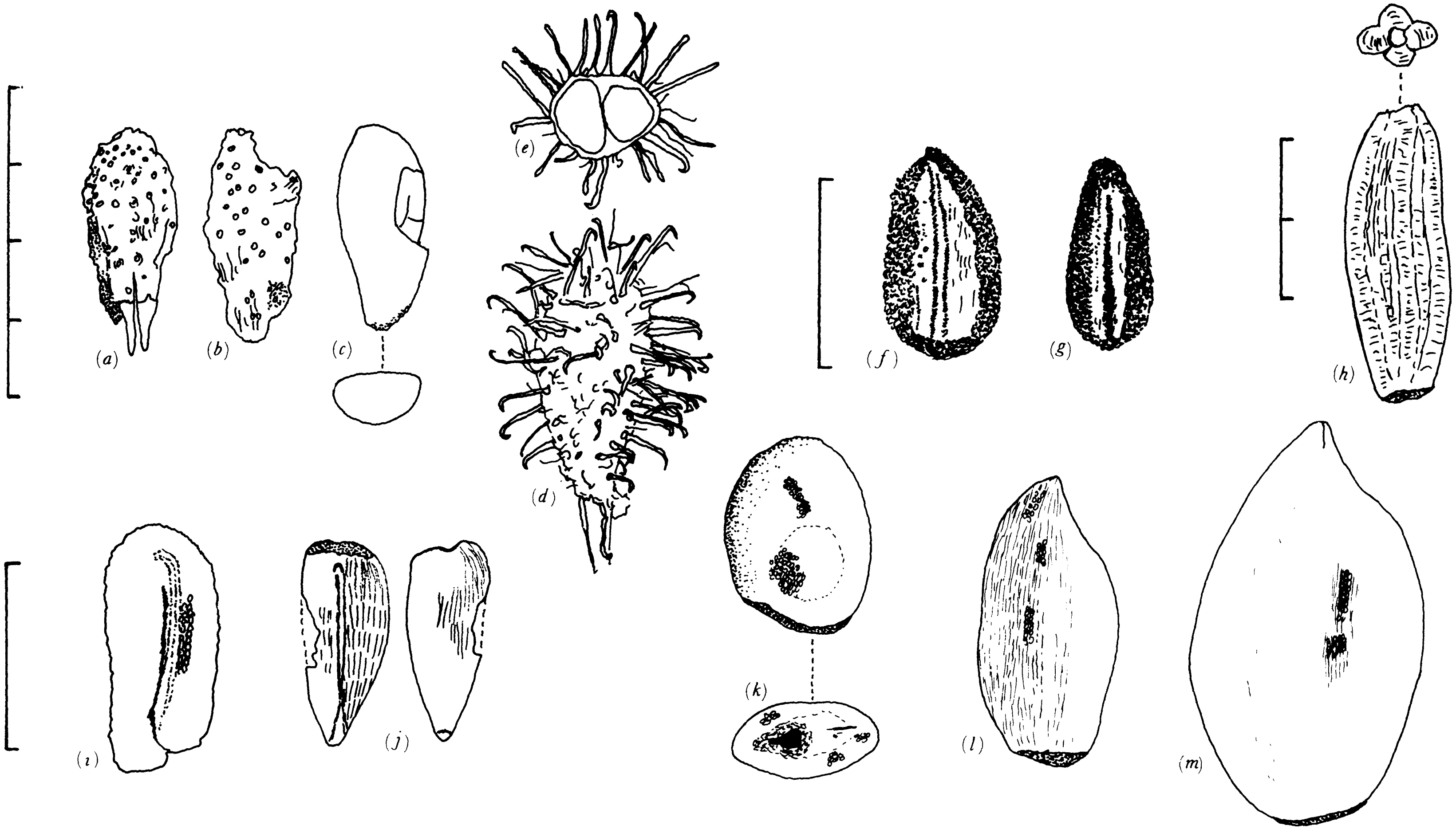


FIGURE 6. Drawings of plant macrofossils, Tattershall Castle. (*a*)–(*e*) *Circaea lutetiana* ((*a*)–(*c*) from sample 72E, (*d*), (*e*) modern; (*a*), (*b*) two fragments of fruit; (*c*) one of two seeds from fruit; (*d*) fruit; (*e*) section of fruit). (*f*) *Epilobium* cf. *hirsutum*, seed (sample 73–5); (*g*) *Epilobium* cf. *obscurum*, seed (sample 73–1); (*h*) *Sonchus palustris*, achene (sample 73–4); (*i*) cf. *Lepidium* sp., seed (sample 72H); (*j*) *Lythrum salicaria*, seed (sample 72F; opposite faces of same seed); (*k*) *Trifolium* cf. *campestre*, seed (sample 76I), (*l*) *Viola* cf. *arvensis*, seed (sample 76–0); (*m*) *Viola* cf. *riviniana*, seed (sample 73–1). The scale bars are to the left of the drawings to which they refer and marked at intervals of 1.0 mm.

Table 2. Mollusca from Tattershall Castle pit

	series 76̂																	series 72											series 73				
sample labels...	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	B	C	D	E	F	G	H	I	J	K	L	1	2	3	4	5
dry mass (in grams)...	500	500	250	250	250	250	250	250	250	250	250	250	250	250	250	250	250	500	500	500	250	250	250	250	250	250	250	250	500	250	250	250	500
Valvata cristata Müller	—	—	—	—	1	—	—	—	43	42	124	72	91	10	1	3	4	4	2	2	4	2	6	13	24	43	24	17	13	10	12	19	42
Valvata piscinalis (Müller)	1	1	1	—	—	—	—	2	41	104	230	162	197	15	45	13	26	—	—	—	1	2	5	4	10	32	16	30	1	—	—	—	4
Hydrobia ventrosa (Montagu) agg.	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	7	3	7	6	19
Pseudamnicola confusa (Frauenfeld)	—	—	—	—	—	—	—	—	7	3	10	4	4	—	—	—	—	1	—	3	200	223	186	67	35	26	44	15	165	297	409	420	571
Belgrandia marginata (Michaud)	1	—	—	—	—	—	—	—	51	157	357	232	361	25	15	11	13	—	—	—	5	2	3	2	6	13	14	9	2	—	1	—	2
Bithynia tentaculata (L.) shells	1	2	3	—	—	—	—	—	35	93	188	107	154	12	17	15	24	2	3	1	1	1	2	24	43	34	35	27	2	—	—	1	4
Bithynia opercula	—	9	4	3	2	3	—	—	38	84	168	148	187	28	20	14	26	—	4	1	1	2	3	13	24	25	22	19	6	—	—	—	—
Carychium minimum Müller	—	—	—	—	—	—	—	—	22	37	78	41	64	4	7	5	2	138	221	229	73	74	53	27	23	32	25	20	33	148	162	172	287
Carychium tridentatum (Risso)	4	2	1	4	29	44	39	79	87	9	20	28	24	11	—	—	—	—	—	—	103	113	100	11	10	17	16	11	120	413	403	457	983
Aplexa hypnorum (L.)	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1	—	—	—	—	—	—	—	—	—	—	2	1	5	5	8
Physa fontinalis (L.)	—	—	—	—	—	—	—	—	—	—	—	1	—	—	—	—	—	—	—	—	—	—	—	—	3	1	—	—	—	—	—	—	—
Lymnaea truncatula (Müller)	1?	2	—	—	—	—	—	—	22	15	39	25	19	4	21	13	8	40	69	119	181	134	102	50	18	21	34	14	34	51	136	91	81
Lymnaea palustris (Müller)	—	—	—	—	—	—	—	—	4	11	6	10	6	—	—	—	—	—	5	7	7	3	8	1	1	3	2	4	12	3	5	11	27
Lymnaea auricularia (L.)	—	—	—	—	—	—	—	—	—	—	—	—	1?	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Lymnaea peregra (Müller)	—	—	1?	—	—	—	—	—	9	34	74	54	79	3	7	3	2	—	35	—	30	66	49	28	18	37	32	15	49	75	69	83	136
Planorbis sp.	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	3	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Anisus leucostoma (Millet)	—	—	—	—	—	—	—	—	11	4	2	—	—	—	—	—	—	—	—	—	13	11	13	6	11	13	9	7	43	180	243	234	368
Anisus vorticulus (Troschel)	—	—	—	—	—	—	—	—	—	16	36	24	27	3	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Gyraulus laevis (Alder)	1	—	1	—	—	1	4	—	5	19	48	19	50	4	100	25	60	—	—	—	1	—	—	—	3	2	3	2	—	—	—	—	—
Armiger crista (L.)	—	—	1	—	—	—	—	—	11	26	55	53	66	5	13	2	5	—	—	—	4	5	3	2	5	6	3	9	—	—	1	—	6
Hippeutis complanatus (L.)	—	—	—	—	—	—	—	—	7	13	28	17	16	1	3	1	1	—	—	—	—	—	—	5	14	10	2	7	—	—	—	—	1
Segmentina nitida (Müller)	—	—	—	—	—	—	—	—	—	4	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1	—	—	1	—	—	—	—
Acroloxus lacustris (L.)	—	—	—	—	—	—	—	—	7	19	47	19	28	2	3	2	—	—	—	—	—	—	2	4	14	6	5	4	2	—	—	—	1
Succinea oblonga Draparnaud	—	—	—	—	2	—	—	1?	—	—	2	1	—	—	—	—	—	3	13	40	4	2	3	3	1	1	—	1	8	6	5	5	1
Succinea putris (L.)/*Oxyloma* sp.	—	—	—	1	—	2	—	1	8	9	17	25	18	1	—	—	1	19	42	14	20	24	20	5	3	2	5	2	63	35	22	27	36
Cochlicopa spp.	2	1	6	12	12	3	6	8	13	3	16	7	8	1	—	2	—	35	46	32	30	33	17	6	9	5	4	3	54	70	69	67	79
Cochlicopa lubricella (Porro)	—	—	—	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	2	—	2	—	—
Columella edentula (Draparnaud)	—	—	—	—	—	1?	—	—	—	—	—	1	—	—	—	—	—	—	1	—	—	2	—	—	—	—	—	—	2?	4	1	4	20
Truncatellina cylindrica (Férussac)	6	15	27	31	24	2	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Vertigo pusilla Müller	—	—	—	—	—	—	—	2	—	—	—	—	2	—	—	—	—	—	—	—	2	1	8	—	—	—	—	—	—	2	4	5	5
Vertigo antivertigo (Draparnaud)	—	1	—	1	—	—	—	1?	4	6	8	5	5	—	—	—	2?	21	101	59	14	5	8	4	8	5	12	—	32	26	28	29	22
Vertigo substriata (Jeffreys)	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1	—	—	1	—	1	1	1
Vertigo pygmaea (Draparnaud)	2	—	—	—	1?	1	—	—	—	—	—	—	2	—	—	—	—	—	—	1	—	—	—	—	—	—	—	—	—	—	—	—	—
Vertigo moulinsiana (Dupuy)	1	—	—	—	—	—	—	—	4	—	3	3	4	1	—	—	—	33	41	41	5	4	1	1	—	3	1?	—	6	6	9	4	10

TABLE 2 (*cont.*)

Vertigo angustior Jeffreys	3	3	3	9	18	12	9	14	9	—	3	3	4	—	—	—	—	162	250	235	34	42	37	15	5	6	13	4	47	108	116	108	244
Pupilla muscorum (L.)	14	16	33	88	50	3	1	2	—	1	—	—	1	—	—	—	—	9	29	24	1	5	8	1	—	—	—	1	4	9	4	5	1
Lauria cylindracea (da Costa)	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1	—	—	—	—	1	—	—	2	3	3	3	9
Vallonia costata (Müller)	7	13	7	27	87	68	43	76	46	4	9	11	13	1	3	1	—	—	—	5	57	35	28	9	5	2	8	9	18	102	75	84	138
Vallonia pulchella (Müller)	1	2	4	9	25	14	9	12	6	1	4	2	1	—	—	—	—	6	2	1	1	10	4	1	3	1	2	—	4	13	16	15	31
Vallonia enniensis (Gredler)	1	1	—	—	4	—	—	1	3	3	2	6	5	7	2	—	1	100	233	320	57	14	21	2	2	4	7	10	18	33	33	28	57
Vallonia excentrica Sterki	—	—	2	4	7	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Vallonia spp.	10	18	22	52	114	86	46	53	63	11	24	13	24	1	6	2	1	38	13	13	21	64	55	13	13	17	15	11	54	139	152	142	343
Acanthinula aculeata (Müller)	—	—	—	—	—	—	—	—	—	—	—	1	—	—	—	—	—	—	—	—	—	—	—	1	—	—	—	1	1 ?	—	2	3	2
Spermodea lamellata (Jeffreys)	—	—	—	—	—	—	—	—	—	1	3	—	4	—	—	—	—	—	—	—	3	2	1	—	—	—	3	2	28	17	21	27	17
Punctum pygmaeum (Draparnaud)	2	4	—	4	6	11	5	12	17	3	5	3	8	—	—	1	—	20	20	27	13	9	17	2	1 ?	3	3	7	21	53	60	60	117
Discus ruderatus (Férussac)	—	—	—	—	—	—	—	—	1	—	1 ?	—	1	—	—	—	—	1 ?	1 ?	—	—	—	—	—	2	—	1 ?	—	1 ?	1 ?	1 ?	1	—
Vitrina pellucida (Müller)	—	—	—	—	1	—	—	3	—	—	2	—	—	—	—	—	—	—	—	—	—	1	—	—	—	—	—	—	2	—	2	—	—
Vitrea contracta (Westerlund)	—	—	—	—	2	3	—	3	4	2	6	2	3	1	—	—	—	4	—	—	13	15	17	3	3	4	6	2	29	25	35	24	57
Nesovitrea hammonis (Ström)	—	—	—	—	1	1	—	—	3	2	3	3	4	—	—	—	—	1	1	—	9	4	7	2	2	1	2	1	28	30	23	33	46
Aegopinella pura (Alder)	—	—	—	—	—	—	—	—	—	—	—	2	1	—	—	—	—	—	—	—	3	1	2	2	—	1	2	1	3	7	6	7	9
Aegopinella nitidula (Draparnaud)	—	—	—	—	—	1	—	—	4	—	2	—	5	—	—	—	—	—	—	—	7	1	9	1	1	2	4	3	25	27	31	26	65
Oxychilus sp.	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1	—	2
Zonitoides nitidus (Müller)	—	1 ?	—	—	—	—	—	—	19	15	18	20	17	3	—	—	1 ?	15	28	9	20	25	19	9	6	7	6	3	83	54	60	66	59
Deroceras/Limax spp.	1	3	5	2	8	8	5	10	6	1	15	5	10	—	—	2	—	62	107	121	32	10	11	7	7	4	5	8	102	36	33	30	—
Euconulus fulvus (Müller) agg.	—	—	—	—	1	—	—	1	—	1	9	2	4	2	—	1 ?	1	—	6	1	5	4	2	—	—	—	3	2	26	14	14	10	7
Cochlodina laminata (Montagu)	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1 ?	1 ?	—	—	—	—	—	—	1	—	2	—	—
Clausilia bidentata (Ström)	—	—	1 ?	—	—	1	1	2	—	2	2	1	—	—	1	—	—	2	2	1	2	1	—	2	—	1	1	1	6	11	3	7	8
cf. *Balea perversa* (L.)	—	—	—	—	—	—	—	—	—	—	—	—	—	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	3	1	4
Bradybaena/Arianta/Cepaea	2	3	1	1	6	1	2	3	1	1	1	—	1	1	—	—	—	7	3	2	3	3	10	4	1	—	2	2	23	8	9	11	3
Helicella itala (L.)	1	2	4	15	13	2	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Trichia hispida (L.) agg.	—	—	—	—	—	—	—	3	1	—	1	1 ?	—	1	—	—	—	—	—	—	1	—	1	—	—	—	—	—	7	4	4	4	4
Unio sp.†	—	—	—	—	—	—	—	—	—	—	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Sphaerium corneum (L.)	—	—	—	—	—	—	—	—	3	8	10	7	6	—	3	—	1	—	—	—	—	—	—	—	2	2	2	2	—	—	—	—	—
Sphaerium lacustre (Müller)	—	—	—	—	—	—	—	—	6	26	25	30	10	—	1	12	1	—	—	—	2	5	1	11	10	10	11	5	—	—	—	—	—
Pisidium amnicum (Müller)	—	—	—	—	1 ?	—	—	—	2	2	11	3	11	4	7	1	1	—	—	—	—	—	—	—	—	—	1	1	1	—	—	—	—
Pisidium casertanum (Poli)	—	—	—	—	—	—	—	—	2	10	5	7	13	4	7	1	1	1 ?	—	1 ?	8	—	2	—	—	—	—	—	—	—	—	—	1
Pisidium personatum Malm	—	—	—	—	—	—	—	—	1	—	3	3	8	—	—	—	—	—	—	—	2	14	5	1	—	3	1	1	202	109	130	125	31
Pisidium obtusale (Lamarck)	—	—	—	—	—	—	—	—	37	4	14	4	17	—	—	—	—	3	1 ?	—	1	—	5	1	—	—	4	1	50	23	21	24	10
Pisidium milium Held	—	—	—	—	—	—	—	—	2	6	16	4	21	—	1	—	—	—	—	—	1	—	—	1	—	4	5	—	—	—	—	—	—
Pisidium subtruncatum Malm	—	—	—	—	—	—	—	—	15	51	147	88	121	2	6	2	3	—	—	—	—	2	—	10	17	10	12	22	1	—	—	—	—
Pisidium henslowanum (Sheppard)	—	—	—	—	—	—	—	—	6	13	27	15	34	2	27	6	6	—	—	—	—	—	—	—	—	5	4	4	—	—	—	—	—
Pisidium hibernicum Westerlund	—	—	—	—	—	—	—	—	—	2	2	2	2	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Pisidium nitidum Jenyns	—	—	—	—	—	—	—	—	9	6	36	21	27	4	7	3	6	—	—	—	—	—	—	3	5	14	16	7	—	—	—	—	—
Pisidium moitessierianum Paladilhe	—	—	—	—	—	—	—	—	1	9	18	21	20	18	2	9	4	—	—	—	—	—	—	—	—	—	1	—	—	—	—	—	—

† Note all counts of Bivalvia are of shell valves.

as species separate from *L. palustris*. Specimens closely resembling these forms were present at Tattershall Castle but they have been assigned to *L. palustris* in view of doubts about whether the various forms represent self-fertilizing populations or separate outbreeding species.

Succineidae. The critical differences between species of this family are mainly anatomical (cf. Quick 1933; Kerney & Cameron 1979). Immatures of *Oxyloma pfeifferi* cannot be separated from *Succinea putris*, although adult shells referred to both species were present. *O. sarsi* immatures cannot be reliably separated from either *O. pfeifferi* or *S. putris* and some adult shells from Tattershall Thorpe showed the characters of this species. Small Succineidae with proportionately large spires to the shells have been referred to *Succinea oblonga* rather than *Catinella arenaria*, since the shell apertures were oval rather than rounded. However, this criterion is not entirely reliable and the determinations are therefore tentative.

Cochlicopa nitens. *Cochlicopa* spp. were plentiful in the interglacial muds and calcareous silts. Besides many shells identified as *C. lubrica* (Müller) and *C. lubricella* (Porro) were larger shells which were attributed to *C. nitens* (Gallenstein), a species that has not hitherto been reported from the British Isles either living or as a fossil.

Small numbers of specimens identified as *C. nitens* were found in series 76, 72 and 73, but only unbroken adult shells could be reliably separated from *C. lubrica*, so the totals (table 2) are made up of both species. Additional large bulk samples were collected to obtain most of the material studied.

Shells attributed to *C. nitens* differed from nearly all shells of *C. lubrica* and *C. lubricella* in being distinctly broader (figures 9, 10). Usually but not always they had less thickening of the peristome, more convex whorls separated by a deeper suture, and a more elliptical less cylindrical outline (figure 9). The consistent occurrence of large and broad shells of this type in association with shells of *C. lubrica* type and *C. lubricella* type at several stratigraphical levels, in both detritus muds and calcareous silts, is in accordance with arguments that *C. nitens* was represented, rather than merely an extraordinarily large form of *C. lubrica*.

Early accounts treated *nitens* as either a form or subspecies of *C. lubrica* (for example, Ehrmann 1933; Zilch & Jaeckel 1962). However, its specific distinctness is suggested not only by detailed studies of shell shape and size (Nilsson 1956) but also by distinctive features of the distal genitalia (Hudec 1960, p. 282). *C. nitens* has a central European modern range, extending from southern Sweden to Czechoslovakia and White Russia; it lives in calcareous fens, less often in damp deciduous woodland (Hudec 1960; Zilch & Jaeckel 1962; Kerney & Cameron 1979).

A single shell from the interglacial deposits at Tattershall Thorpe (breadth 3.2 mm) also appears to be referable to *C. nitens* as typical *C. lubrica* were also found. A survey of specimens of *Cochlicopa* from other interglacial sites in southeastern England revealed only one other specimen, from Block Fen, Cambridgeshire (in collection D. T. Holyoak), where typical shells of *C. lubrica* were also present. The Block Fen detritus muds are apparently of Ipswichian age (R. G. West, personal communication).

Vallonia pulchella and V. enniensis. The shell shape is identical in these species, but in *V. enniensis* the shell has closely spaced, very regular, fine ribbing that is lacking in *V. pulchella* (cf. Sparks 1953). Occasional *V. pulchella* develop strong growth lines that render these individuals hard to separate from *V. enniensis*, especially as juveniles. Doubts have been expressed regarding the specific recognition of *V. enniensis*. At any event, the numbers given are only approximate.

Nesovitrea hammonis and N. petronella. Separation of these species was based on the differences in shell colour (white in *N. petronella*, typically brown in *N. hammonis*), regularity of growth

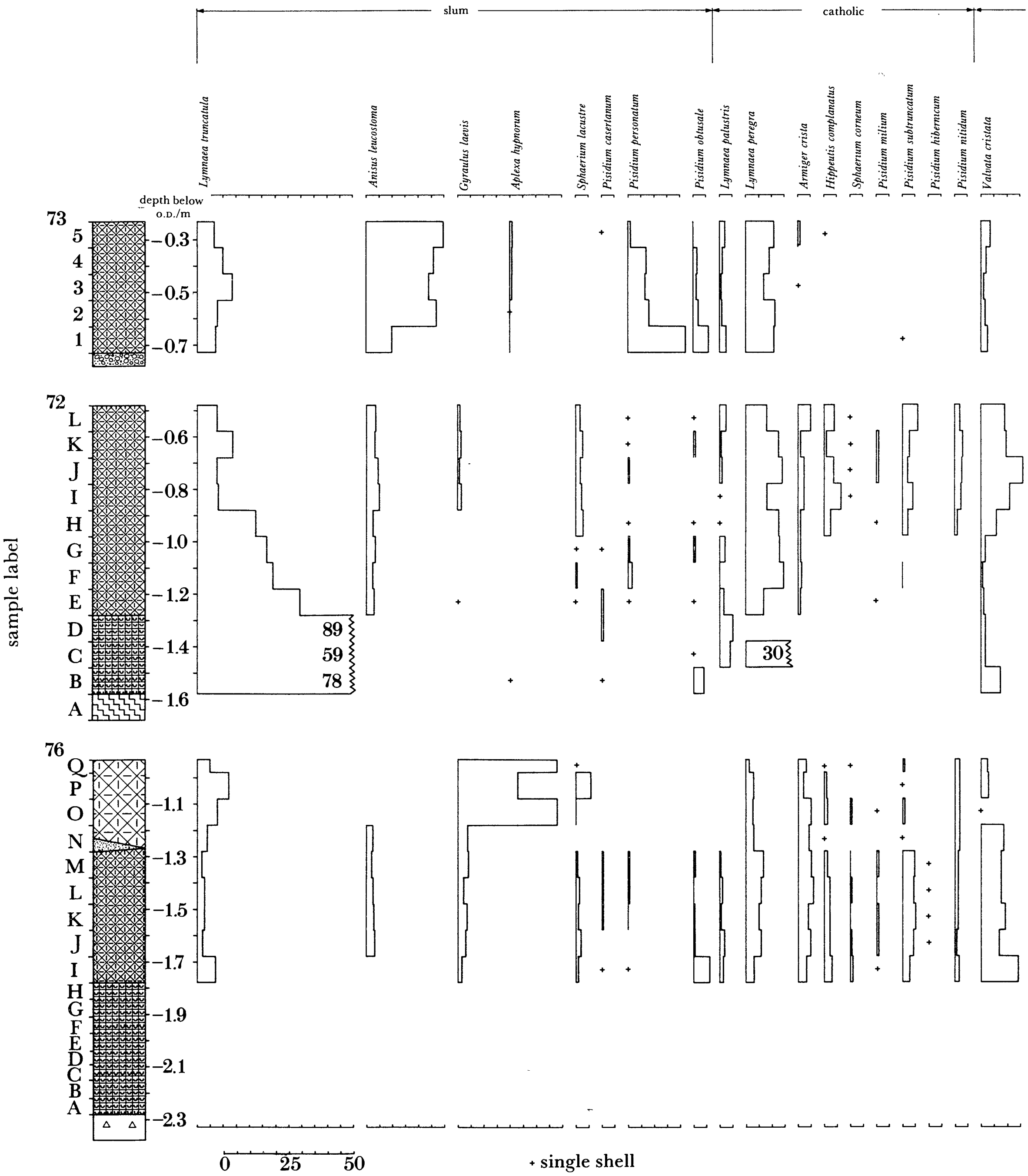
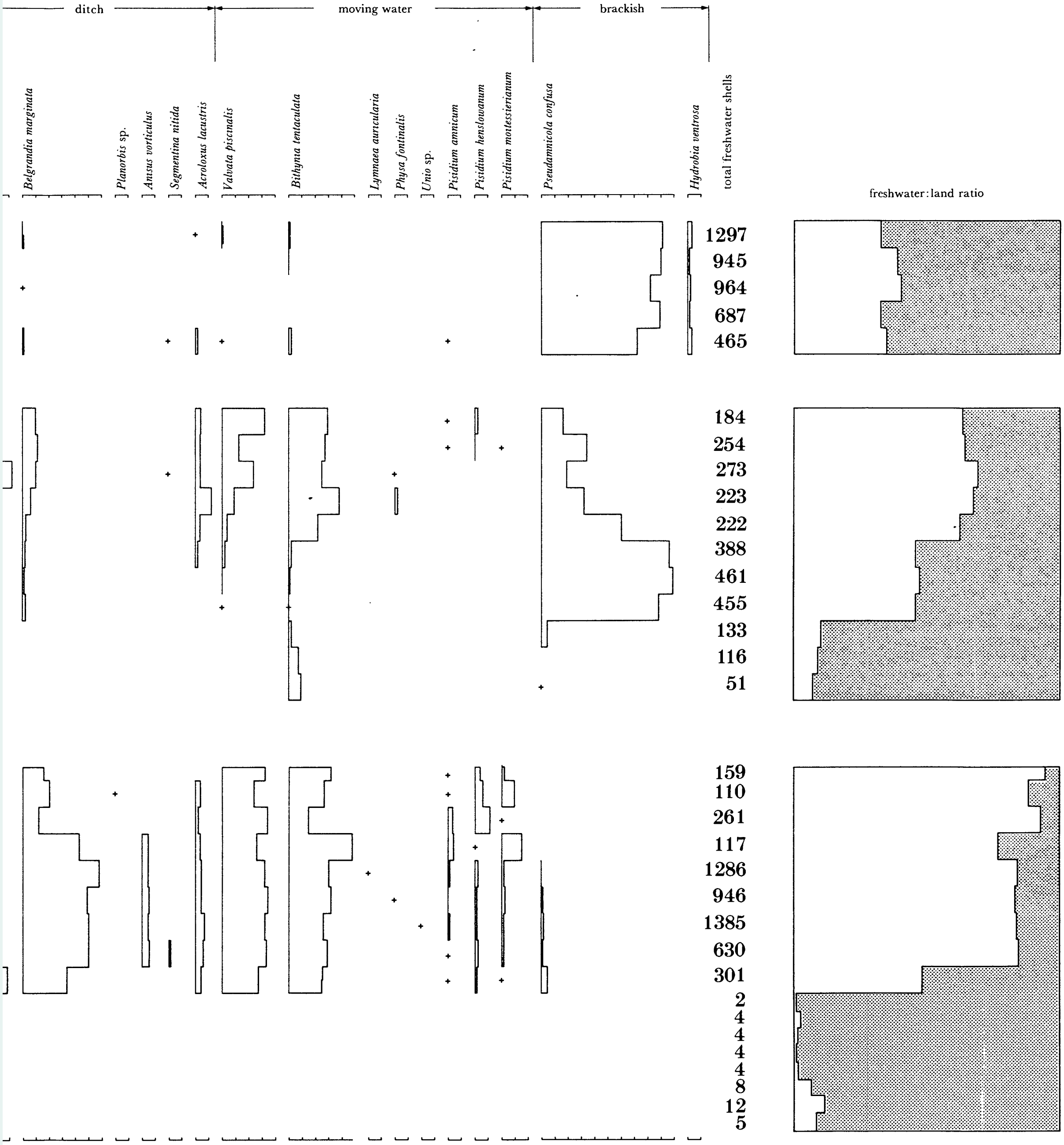


FIGURE 7. Tattershall Castle: summary of data on



n aquatic Mollusca. Stratigraphical symbols as in figure 3.

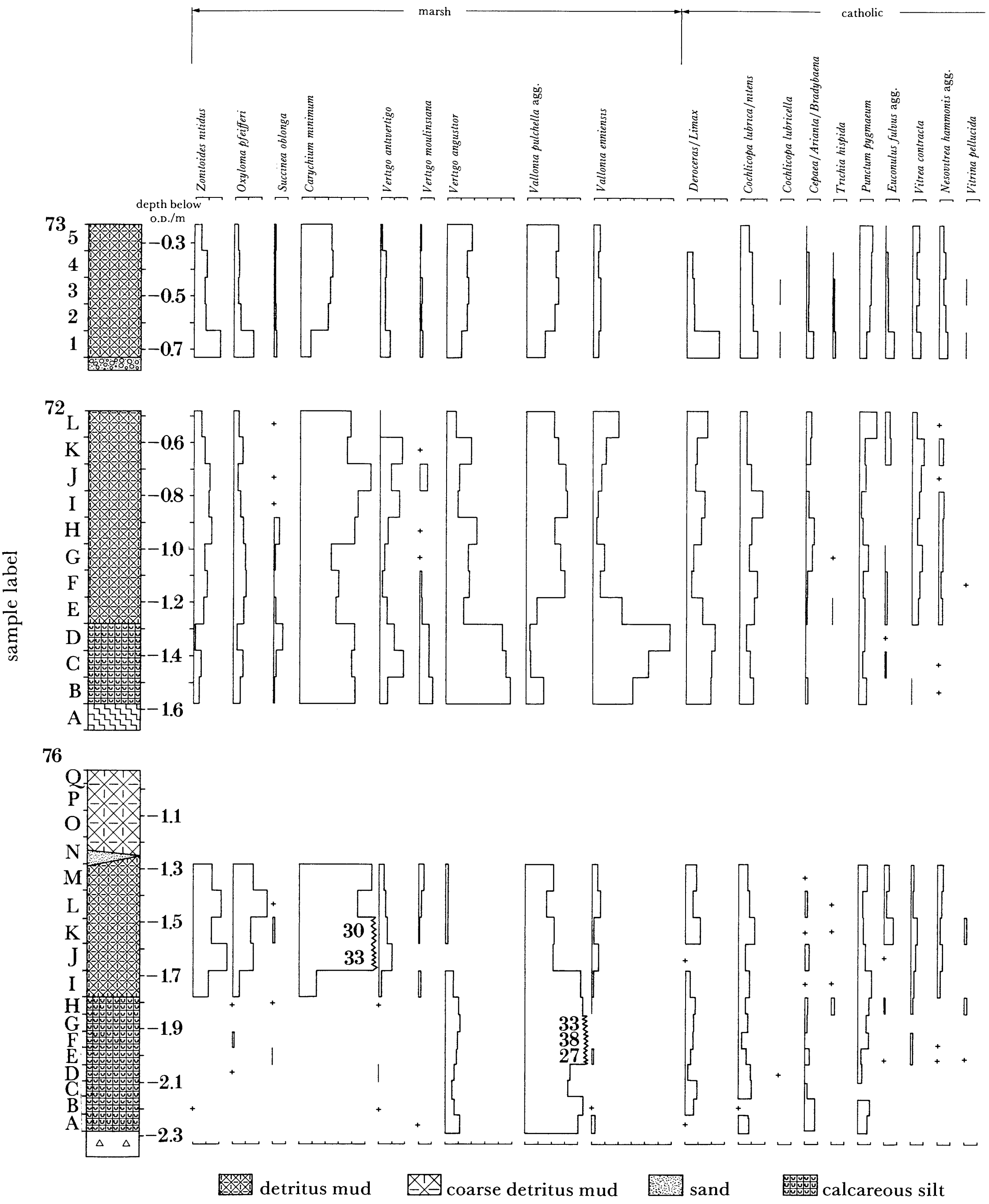
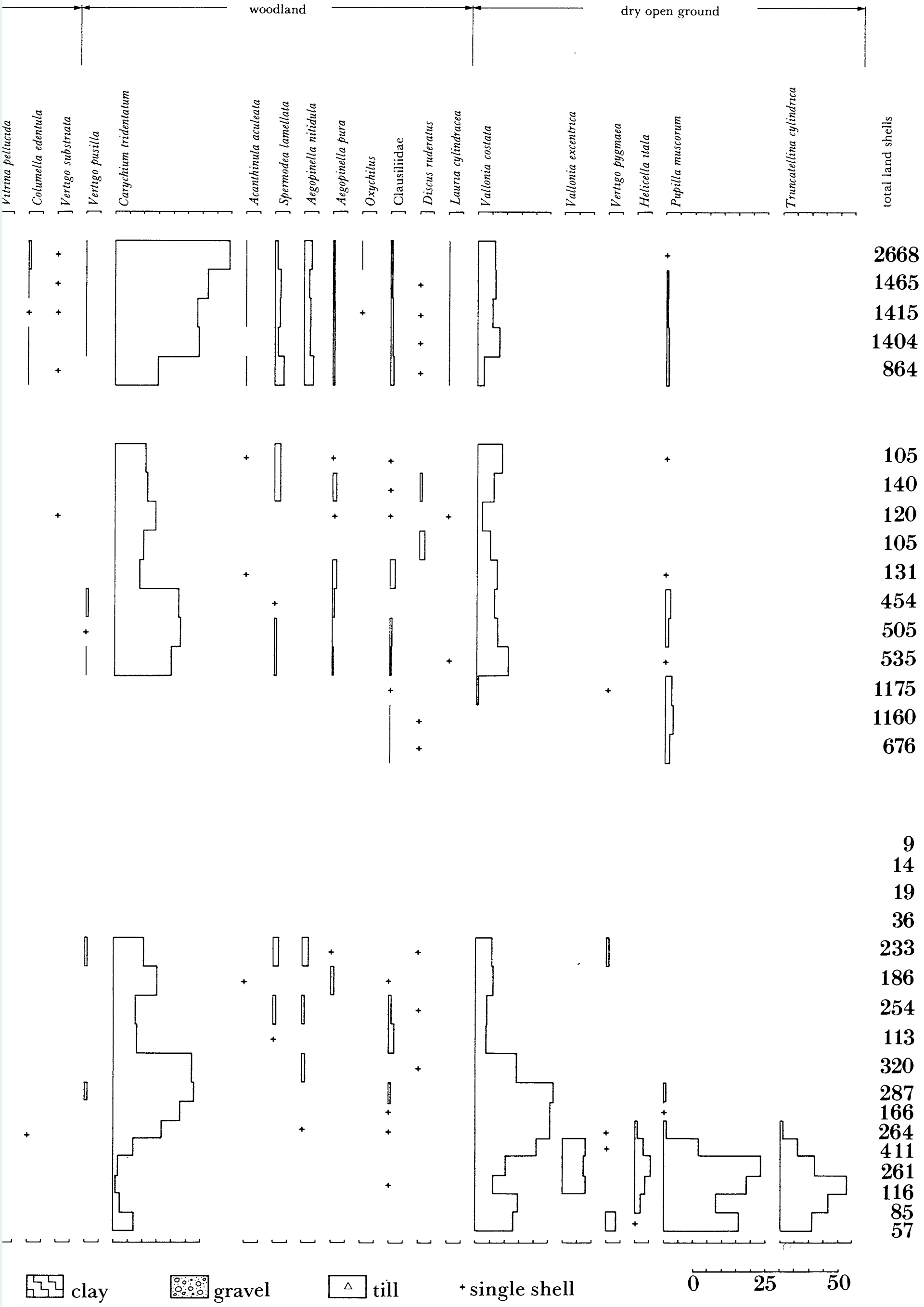


FIGURE 8. Tattershall Castle: summa



nary of data on land Mollusca.

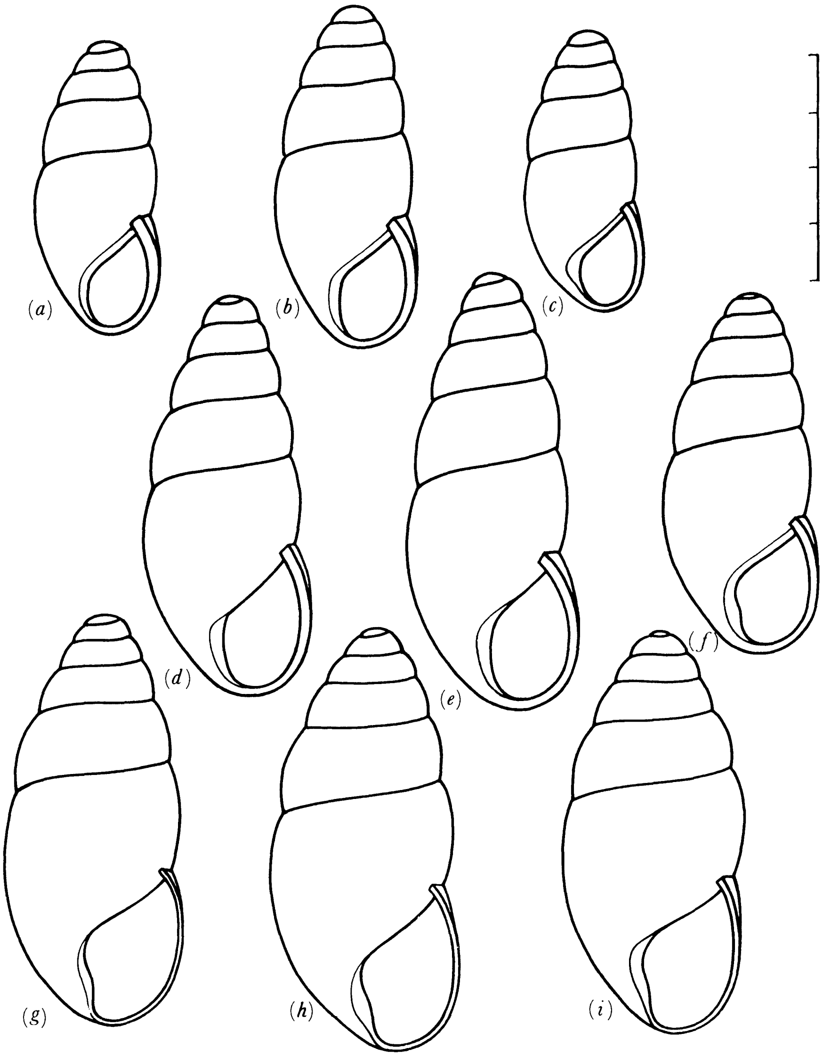


FIGURE 9. Camera lucida drawings of shells of *Cochlicopa* spp. from Tattershall Castle. (*a*), (*b*), (*c*) *C. lubricella*; (*d*), (*e*), (*f*) *C. lubrica*; (*g*), (*h*), (*i*) *C. nitens*. The scale bar is marked at intervals of 1.0 mm.

lines (more regular in *N. hammonis*) and proportionate development of body whorl (larger in *N. hammonis*) described by Waldén (1966) and Kerney & Cameron (1979).

Clausiliidae. The specific identification of the apices of most shells is impossible as the apertures contain the most important identification characters. At least three species were present at Tattershall Castle pit: *Clausilia bidentata* (commonest), *Balea perversa* and *Cochlodina laminata* (rarest). Undoubted specimens of *Clausilia pumila* were present only at Tattershall Thorpe where numerous apertural fragments and several complete shells allowed confident determination. A few *C. bidentata* were also recorded from Tattershall Thorpe.

Trichia spp. All shells from Tattershall Castle pit have been referred to *T. hispida* but a form with a narrow umbilicus was also present at Tattershall Thorpe and this has been referred to *T. plebeia*, although the latter species is so similar to *Perforatella rubiginosa* (Schmidt) (cf. Naggs 1983) that this alternative is difficult to discount. Small juvenile shells cannot be assigned to species.

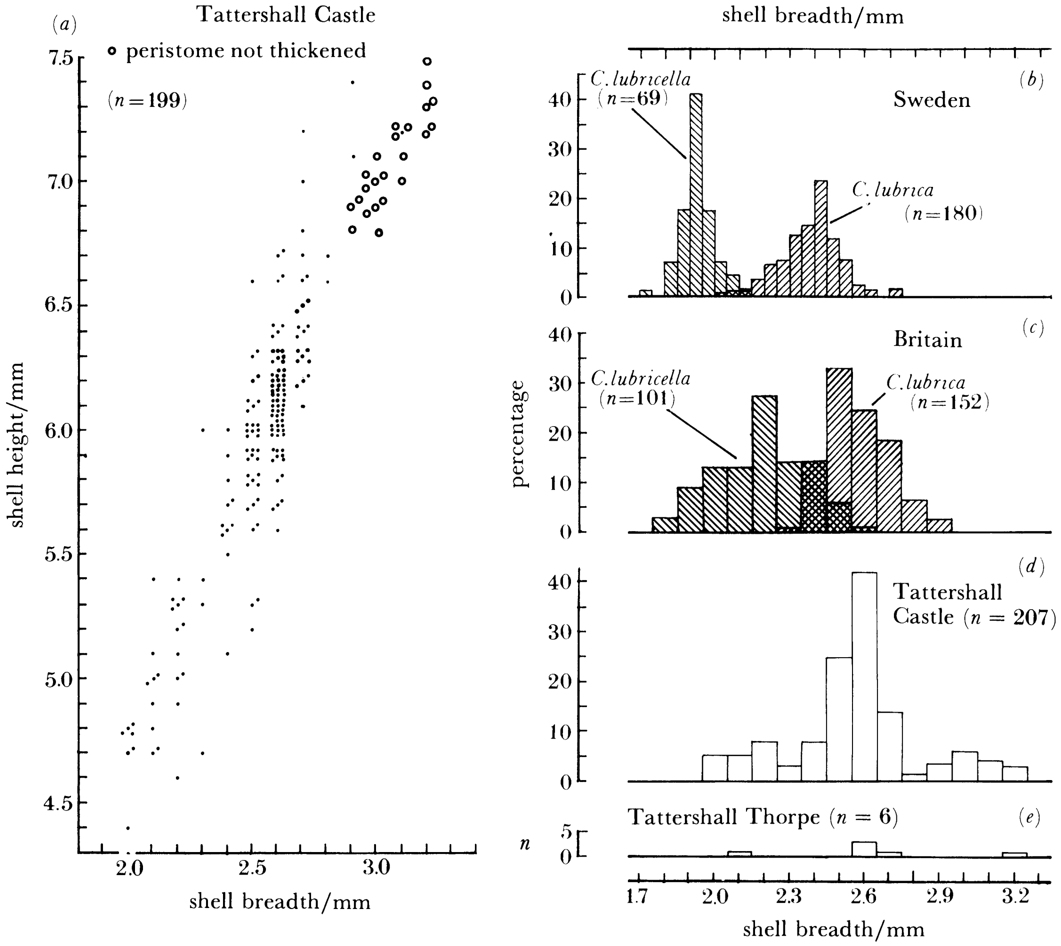


Figure 10. Measurements of fossil shells of *Cochlicopa* spp. from Tattershall, and comparisons with measurements of modern shells from Sweden (Waldén 1955) and Britain. The British shells were measured to an accuracy of ±0.05 mm, the Swedish shells to ±0.025 mm. All measurements are of adult shells.

Bradybaena fruticum and larger Helicidae. Intact shells of *Bradybaena* and the larger Helicidae were well represented in the bulk samples of calcareous silt and detritus mud, allowing confirmation of the presence of *Bradybaena fruticum* (common in silts, one shell from muds), *Arianta arbustorum* (five from silts, one from muds), *Cepaea nemoralis* (common in both silts and muds) and *Cepaea hortensis* (*ca.* 65 shells from silts, none from muds). Small immature shells and apical fragments of these taxa often could not be identified to species, so they are all listed in table 2 as *Bradybaena*/*Arianta*/*Cepaea*. Adult shells of *Bradybaena fruticum* and *Arianta arbustorum* are quite distinct but fragments of body whorl of both are similar in having irregular spirally oriented grooves (Ložek 1964, pl. 30, fig. 3; Preece 1981, pl. 14, fig. 7) and these, therefore, cannot be separated. However, the umbilicus is much wider in *B. fruticum* than in *A. arbustorum* so that umbilical fragments can be readily distinguished.

(ii) *Analysis of faunal changes through the sections*

The changes in the frequency of certain species through the sequence will now be described. The sections are described from the lowest altitudinal level upwards as the pollen data suggests this represents a stratigraphical sequence.

Samples 76A–H. The sediment is a light grey calcareous silt. The Mollusca suggest deposition on the floodplain of a river. The land fauna is dominated by xerophilous species indicative of dry open country, for example, *Pupilla muscorum*, *Truncatellina cylindrica*, *Helicella itala* and species of *Vallonia* including *V. excentrica*. These are particularly common towards the base of this unit but decline above 76E, when *Carychium tridentatum* and a more varied fauna including *Vitrea contracta*, *Nesovitrea hammonis*, *Euconulus fulvus* agg., *Bradybaena fruticum* and *Trichia hispida* becomes established, suggesting a richer herbaceous ground vegetation. *Vertigo angustior* is frequent (*ca*. 5% of total land fauna (t.l.f.)) throughout this unit, indicating rather moist conditions, but other marsh species (except *Vallonia pulchella*) are only present in small numbers. Freshwater Mollusca are rare and have not been plotted on figure 7.

Large bulk samples of the calcareous silts (*ca*. 40 kg) yielded 15 additional taxa: *Carychium minimum* (43 shells), *Lymnaea palustris* (many), *L*. cf. *auricularia* (1), *Anisus leucostoma* (5), *Hippeutis complanatus* (5), *Segmentina nitida* (7), *Acroloxus lacustris* (1), *Columella edentula* seg. (2), *Discus ruderatus* (6), *Zonitoides nitidus* (32), *Sphaerium corneum* (5 valves), *Pisidium casertanum* (1), *P. obtusale* (1), *P. nitidum* (1) and *P. milium* (1). The bulk samples also provided large or intact shells allowing confirmation of the occurrence of *Succinea putris* (4), *Oxyloma* cf. *pfeifferi* (8), *Cochlicopa nitens*, *Euconulus* cf. *alderi* (1), *Bradybaena fruticum* (*ca*. 80), *Arianta arbustorum* (5), *Cepaea nemoralis* (*ca*. 350) and *C. hortensis* (*ca*. 65).

Samples 76I–M. This detritus mud is rich in wood fragments and plant debris. It yielded a rich aquatic fauna dominated by *Belgrandia marginata* (*ca*. 25% total aquatic fauna (t.a.f.)), *Valvata piscinalis* (*ca*. 15% t.a.f.) and *Bithynia tentaculata* (*ca*. 15% t.a.f.), together with *Pisidium amnicum*, *P. henslowanum* and *P. moitessierianum*, an assemblage which indicates deposition by a substantial well-vegetated stream. At Tattershall *Anisus vorticulus* was only present in this unit. *Pseudamnicola confusa*, a species requiring slightly brackish water, is also present but never exceeds 3% t.a.f.

The land fauna is an ecologically diverse assemblage with species from marsh and woodland habitats. Particularly significant is the occurrence of *Spermodea lamellata*, a species of closed forest. The open-country species of the underlying unit have all disappeared with the exception of *Vallonia costata* (although this species is known to live in heavily shaded woods in Finland and it is the most shade-tolerant of the three species of *Vallonia* in Britain).

Samples 76N–Q. This fine organic detritus mud devoid of large plant fragments is separated from the previous unit by a thin bed of fine sand. The fauna is poorer than that of the underlying muds and is dominated by *Gyraulus laevis* which accounts for almost 40% t.a.f. Deposition in a stagnant or slow-flowing environment is suggested. Land Mollusca are rare and have not been plotted on figure 8.

Samples 72B–D. This unit was a whitish calcareous clay–silt 30 cm in thickness, apparently corresponding to the 'white shell marl' of Girling (1980). Although oospores of Characeae were present the deposit is not a lacustrine *Chara*-marl since the molluscan fauna is dominated (*ca*. 90% of total molluscs (t.m.)) by terrestrial species. Of the aquatic species, only *Lymnaea truncatula* is at all frequent and this species occurs on damp ground and semi-aquatic habitats rather than in open water (Boycott 1936). The bulk of the fauna consists of marsh species and it is clear that the deposit formed in an open calcareous fen. The fauna is exceptional in being dominated by *Vallonia enniensis*, *Vertigo angustior* and *Carychium minimum*, together with smaller numbers of *Vertigo moulinsiana*, *V. antivertigo* and *Succinea oblonga*.

Samples 72E–L. This detritus mud is rich in plant debris. The lower half of the unit is dominated by *Pseudamnicola confusa* which occasionally accounts for over 50% t.a.f., indicating a moderate brackish influence. Above sample 72G this species declines to under 20% t.a.f. and species characteristic of a freshwater stream environment become commoner (for example, *Bithynia tentaculata*, *Valvata* spp.) or appear for the first time (*Hippeutis complanatus*, *Pisidium nitidum*, *P. amnicum*, *P. henslowanum*, *P. moitessierianum*). It is noteworthy that *B. tentaculata* and *V. piscinalis* sometimes live in slightly brackish water (Fretter & Graham 1962). *Belgrandia marginata* represents *ca.* 5% t.a.f. These changes seem to indicate a progressive decrease in salinity coupled with a possible increase in the rate of flow. The land fauna is relatively rich and ecologically diverse; *Spermodea lamellata* and *Discus ruderatus* are present.

Samples 73-1–5. The sediment is detritus mud that is rich in large plant fragments. It yielded a fauna dominated throughout by *Pseudamnicola confusa*, which reaches 45% t.a.f., but which is here accompanied by *Hydrobia ventrosa* in low numbers, suggesting development of slightly more saline conditions. The remaining aquatic taxa are predominantly those characteristic of slow-flowing or stagnant conditions, for example, *Anisus leucostoma*, *Pisidium personatum*, *P. obtusale* and *Lymnaea truncatula*. *Aplexa hypnorum*, often considered to have been uncommon in the Ipswichian, was also consistently present in low numbers. The land fauna is very similar to that of the previous unit, being relatively rich and ecologically diverse.

Large bulk samples (*ca.* 6 kg) of the detritus mud from beside series 73 yielded three additional taxa: *Vertigo pygmaea* (1 shell), *Nesovitrea petronella* (1) and *Helicella itala* (1). In addition, large or intact shells were obtained that allowed identification of *Cochlicopa nitens*, *Bradybaena fruticum* (1), *Arianta arbustorum* (1) and *Cepaea nemoralis* (1).

(iii) *General comments on environment*

The Mollusca have been arranged into various ecological groups in figures 7 and 8, and a picture of the general environment can be gained from these. It is clear that the sediments were deposited by a stream that was slow-flowing but not stagnant, which supported plentiful aquatic plants. There is evidence of changes in the rate of flow, but no evidence for rapid flow. Taxa characteristic of quick-flowing rivers are absent (for example, the river limpet *Ancylus fluviatilis*; *Corbicula fluminalis*) and the larger bivalves are represented by one specimen only (sample 76J). The occurrence of *Pseudamnicola confusa* and *Hydrobia ventrosa* indicates mildly brackish conditions, as discussed below.

Correct interpretation of molluscan assemblages from Pleistocene sediments depends on an understanding of their taphonomy. This can rarely be gauged in any great detail, and until studies of modern processes of accumulation and deposition of shells are better understood it is necessary to consider the sedimentology of the deposits as much as the palaeontology. Land shells are exceedingly rare in lacustrine sediments, except in marginal areas, whereas they occur consistently in most stream deposits. Sparks & West (1970, p. 24) have considered this further, commenting that the input of land snails is greatest in those valleys occupied by small streams with little fringing marsh and it is particularly great if the valley sides are steep. This situation did not occur at Wretton, Norfolk, from where they describe Ipswichian deposits similar to those at Tattershall. At Wretton, as expected, the ratio of freshwater to land shells was consistently high and marsh species dominated the terrestrial faunas. At Tattershall, although marsh species are also well represented throughout much of the sequence, the freshwater:land ratio was not consistently high and at several levels in series 72 and throughout series 73, land shells actually outnumber those of freshwater species. The land Mollusca are clearly derived from a wide variety of habitats including marshes and woodland; species of open country are uncommon in these samples, being represented only by *Pupilla muscorum* and *Vallonia costata* (although the latter can live in closed woodland). However, as described above the basal parts of series 76 have faunas characteristic of dry open habitats.

The composition of the terrestrial faunas does not differ appreciably in those levels interpreted as being deposited when stream flow was quicker and it would therefore appear that the faunas described reflect regional conditions within the river catchment. However, it is possible that some shells at certain levels were reworked from older deposits, although no direct evidence of this was obtained.

The numerical richness and ecological diversity of the terrestrial faunas at Tattershall are unlikely to result entirely from local deposition by a sluggish stream or river flowing across low-lying fenland. The striking differences between Wretton and Tattershall in the fresh-water:land shell ratios suggests that the presence of the Bain Valley not far upstream from Tattershall may have provided a diversity of molluscan habitats that is less well represented at Wretton, where deposition occurred on open fenland further from the confluence of tributaries.

(iv) *Evidence of brackish conditions*

Evidence of brackish conditions was apparent in the sections that lie above −1.8 m O.D., but absent at lower levels in series 76. The evidence mainly derives from the presence of *Pseudamnicola confusa*, although *Hydrobia ventrosa* agg. was present throughout series 73. *P. confusa* is very local in Britain today, being found in places were only slight saline influence is evident, such as at Oulton Broad, Suffolk, where the salinity rarely exceeds *ca.* 15‰. It would appear that the deposits between −1.8 and −0.2 m O.D. at Tattershall accumulated in a similar environment, a little above the main brackish influence of spring tides. At many sites *P. confusa* lives on mud under waterside vegetation that is inundated by fresh or slightly brackish water ponded back by all except low neap tides (Holyoak 1983*b*).

(v) *Evidence of climate*

As with most British interglacial deposits, the fauna is composed predominantly of species with broad modern ranges that are tolerant of a variety of climates. The majority of species are part of the modern British fauna, and in this respect the Mollusca resemble the vascular plants. Little or no variation in climate during deposition of the Tattershall interglacial deposits can be detected from the molluscs.

However, in addition to members of the present British fauna there were some species that are now extinct in Britain and have ranges either to the east or south of Britain. The most notable of these are the following.

Belgrandia marginata. A small prosobranch that now inhabits clear-water springs in a small part of southern France (Germain 1930) and in Spain. At Tattershall it was abundant in the upper part of series 76 (reaching over 25% t.a.f.), moderately common (under 10% t.a.f.) in series 72 and scarce (under 1% t.a.f.) in series 73. These variations in frequency apparently reflect changes in the depositional environment, as discussed above, rather than climatic changes. From the general nature of the faunas at Tattershall and elsewhere it is clear that *B. marginata* was an important constituent of interglacial stream or river assemblages and its occurrence should not therefore be taken as an indication of springs or similar environments.

B. marginata is known from many Ipswichian deposits and it usually occurs most commonly in Ip IIb (Sparks & West 1970) although it appears to have survived until late in the interglacial at some localities (Sparks 1964).

Anisus vorticulus. At the present day a rather rare species in Britain, being recorded in rich well-vegetated aquatic habitats such as the marsh drains around Pevensey, Sussex (Hingley 1979) and Lowestoft, Suffolk. It appears to have been quite common in Britain during the Ipswichian, with records from Ip II and Ip III (Sparks 1964). At Tattershall Castle pit it was recorded only from the middle part of series 76.

Segmentina nitida. Another rare and local species in Britain at the present day, although it was more widespread in England in the last century (Kerney 1976*b*). It is now confined to marsh ditches with a rich aquatic flora, principally in Sussex and East Anglia. It was apparently more widespread in the Ipswichian (Sparks 1964), although as at Tattershall Castle pit it did not occur in large numbers.

Cochlicopa nitens. The range of this species (see above) is central European, extending north to southern Sweden.

Vallonia enniensis. This species (or form of *V. pulchella*) occurs at the present day in a few calcareous fens in southern and eastern Germany, southern Sweden and the Geneva Basin in Switzerland (Kerney & Cameron 1979). In Britain it has been recorded from the Cromerian, Hoxnian and Ipswichian interglacials (Sparks 1953). At Tattershall Castle pit it was especially common in the whitish calcareous silt of samples 72B–D, where it formed *ca.* 20% t.l.f.

Discus ruderatus. A montane–boreal species today typical of coniferous woods in Scandinavia and the Alps, but also occurring at low elevations in Poland and in other habitats in Fennoscandia, such as birchwoods, unshaded screes and marshes. In Britain it was present during temperate substages of the Cromerian, Hoxnian and Ipswichian interglacials (Kerney 1977), during the Chelford Interstadial of the Early Devensian (Holyoak 1982; Bryant *et al.* 1983), and for a rather short period early in the Flandrian (Kerney *et al.* 1980). It occurred in low numbers throughout the interglacial deposits at Tattershall Castle pit. It is noteworthy that *Discus rotundatus*, one of the commonest land snails during much of the later Flandrian, was not recorded from Tattershall and it seems to have been rare during the Ipswichian (Sparks 1964).

Nesovitrea petronella. This species was not found in the main samples listed in table 2, but one large shell was obtained from a bulk sample of detritus mud (equivalent to series 73). This is another species with a boreal, east European and alpine modern range. It is not known living in Britain, although recorded from the early Flandrian at several sites in eastern England (Preece & Robinson 1984). Today it lives in a wide variety of habitats (scrub, woods, screes, marshes), often in association with *Discus ruderatus*. There are no other records from British interglacial deposits but this may be due in part to difficulties of identification (see above).

Bradybaena fruticum. This species is apparently extinct in Britain today, although it was present in Kent earlier this century (Kerney 1982). It is common in central and eastern Europe, extending to eastern France and 66° N latitude in Finland (Kerney & Cameron 1979). It lives in woodland, scrub and grassland. As a fossil it is reliably known in Britain only from deposits of Ipswichian age. Numerous adult shells were collected from bulk samples of silt, equivalent to samples 76A–H.

A number of other mollusc species that are generally considered to have been uncommon or rare in deposits of Ipswichian age were also recorded in low numbers throughout the

Tattershall interglacial deposits. These include *Columella edentula*, *Vertigo substriata* and *Lauria cylindracea*.

Several of the Mollusca recorded have modern ranges to the south or east of the British Isles, but no longer extending to Britain. The presence of these, along with such southern plants as *Acer monspessulanum*, suggests summer temperatures may have been slightly warmer than those of the present day. Presence of plentiful *Ilex* suggests the winters were mild (cf. Iversen 1944). The snail *Lauria cylindracea* has a modern range in northern Europe very similar to the range of *Ilex*, so its presence may similarly imply mildness of the winters (Kerney 1968).

(vi) *Banding polymorphism in shells of Cepaea spp.*

Shells of *Cepaea* spp. are commonly marked with dark bands. Any number of bands up to five (rarely six) may occur, or they may be absent. These banding polymorphisms of shells in *Cepaea nemoralis* and *C. hortensis* have provided the basis of some of the most thoroughly analysed studies in the field of ecological genetics (see, for example, Cain & Sheppard 1950, 1954; Clarke 1960; Cook 1967; Carter 1968; Cain *et al.* 1968; Jones *et al.* 1977).

The bands remain visible in well preserved fossil shells. However, although banding polymorphisms of Flandrian shells from Britain have been described by Currey & Cain (1968) and Cain (1971), they have not been described from any samples of interglacial age. Hence it seems worthwhile recording the frequencies of each form of banding at Tattershall because unusually large samples of well preserved fossil shells are available. These samples were collected at random (with respect to shell coloration and banding) from the calcareous silts equivalent to samples 76A–H. The banding of all intact adult or nearly adult shells was recorded, except for a few shells in which the surface was corroded or intensely stained blackish by organic matter.

The banding was scored in the usual manner (Ellis 1969), by assigning numbers to the bands according to their position on a typical five-banded shell, the uppermost band being number 1 and the lowest number 5, so the band formula of a normal five-banded shell was 12345. If one band was absent, say the third, the formula was 12045. Coalescence of bands was represented by parentheses, for example (12345) represented the form with all five bands coalesced.

The sample of 254 shells of *C. nemoralis* consisted mainly of the unbanded form 00000 (229 shells), with 00300 (4 shells), 12345 (7 shells), (123)(45) (6 shells) and (12345) (8 shells). Most of the shells had the dark peristome typical of this species, although some apparently had a white peristome.

The sample of 61 shells of *C. hortensis* had a much smaller proportion of unbanded forms 00000 (18 shells) than in the sample of *C. nemoralis*. Five-banded shells 12345 (18 shells) were equally common, and these were outnumbered overall by various forms with coalesced bands: (12345) (11 shells), (123)(45) (9 shells), (12) 345 (3 shells), (123) 45 (1 shell) and (12)3(45) (1 shell). All of the shells appeared to have the white peristome typical of this species.

Flandrian samples of *C. nemoralis* show only unbanded shells or high proportions of unbanded shells from around the supposed climatic optimum, with increasing frequencies of banded shells since then (Currey & Cain 1968; Cain 1971). *C. hortensis* on the other hand had similar frequencies of unbanded and banded shells throughout. In the Tattershall samples the very high frequency of unbanded *C. nemoralis* shells may have been related to a warm climate, as apparently occurred during the climatic optimum of the Flandrian. However, the frequencies of banded and unbanded shells in living populations of this species appear to show complex relationships to temperatures and to several other environmental variables (cf. Jones *et al.* 1977; Clarke *et al.* 1978). In particular, unbanded shells are often common in open vegetation where shade is scarce, although such conditions are unlikely to have prevailed in southern England during the Flandrian climatic optimum.

(*d*) *Ostracoda*

Ostracoda were picked from samples sieved to 0.5 mm during the extraction of Mollusca. As many immature ostracod valves are smaller than 0.5 mm in their minimum diameter there is no doubt that this sampling incompletely represents the fossil assemblages, although most of the commoner species should have been detected. The specimens were submitted to Dr J. E. Robinson who made all of the determinations and supplied the ecological notes summarised here.

Of the species listed (table 3), all are extant and the majority are part of the living fauna in Britain. Most range back into the Late Pleistocene and some extend into the Middle Pleistocene. Several species provide interesting indications of the ecological conditions at the time of deposition (cf. Absolon 1973).

The ostracod assemblages from Tattershall Castle are basically composed of freshwater species indicative of slow-flowing plant-rich streams with muddy substrates. Both actively swimming (for example, *Cypridopsis vidua*, *Potamocypris* sp., *Prionocypris* sp.) and bottom-dwelling species (for example, *Candona* spp.) occur, including several that are weak and ineffective swimmers (for example, *Ilyocypris bradyi*, *Scottia pseudobrowniana*, *Herpetocypris* spp.). The latter group are usually associated with aquatic plants either as a food source or as shelter.

Particularly noteworthy is the occurrence of *Cyprideis torosa*, which indicates a moderate brackish influence. The type of this species was described from Pleistocene sands near Grays in Essex. The species inhabits modern estuaries and salt marshes including the Blackwater Estuary, Wroxham Broad, The Fleet (S Dorset), Christchurch Harbour and the Thames Estuary (Kilenyi 1969; Kilenyi & Whittaker 1974). *C. torosa* tolerates a salinity range from oligohaline to polyhaline full marine conditions, with a numerical dominance in the 2–10‰ range, a sector otherwise poor in ostracods (cf. Neale 1964). At the lower salinity end of this range it can coexist with freshwater species such as *Candona neglecta* and *C. candida*, as well as specialized euryhaline species such as *Heterocypris salina*. At the seaward end of its range *C. torosa* overlaps with *Leptocythere*, *Paradoxostoma* and *Semicytherura* spp.

Several other species tolerant of brackish water are also present at Tattershall Castle. These include *Heterocypris salina* and *Candona angulata*, both of which Neale (1964) records as having salinity ranges from 0.4–13‰.

The taphonomy of ostracod assemblages in fluvial systems subject to brackish influence is extremely complex and poorly understood, although Kilenyi (1969) has obtained much data from the Thames. Ostracods seem particularly susceptible to *post mortem* displacement due to the hydrodynamic properties of the shell and the possibility of gas being trapped in the carapace. These considerations are particularly relevant to interpretation of the Tattershall sequence where there is a mixture of freshwater and brackish-water species. It may therefore be significant that whereas most freshwater species were represented by many immature specimens of various moult stages as well as by adults, the majority of the *C. torosa* were adults. This suggests that the former were mostly living close to or at the site of deposition whereas *C. torosa* may have been living further away, allowing opportunities for size-sorting of the valves before deposition.

TABLE 3. OSTRACODA FROM TATTERSHALL CASTLE

(c., carapaces; f., fragments; v., valves)

	sample series 76					72											73				
	I	K	M	O	Q	B	C	D	E	F	G	H	I	J	K	L	1	2	3	4	5
dry mass (in grams)	250	125	62	250	250	500	500	500	250	250	250	250	250	250	250	250	500	250	250	250	500
Candona angulata (Müller)	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	6v.	3v.	10v. 1c.	—	2v. 1c.
Candona candida (Müller)	13v.	19v.	10v. 1c.	4v.	5v.	—	—	—	7v.	3v. 1c.	5v.	7v.	8v.	50v.	17v.	22v.	20v.	7v. 3v.	12v.	10v. 1c.	7v. 1c.
Candona compressa Koch	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1v.	3v. 4c.	3v. 1c.	6v.	4v.
Candona cf. *levanderi* Hirschmann	—	—	5v. 1c.	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Candona neglecta Sars	35v.	47v.	25v. 4c.	11v.	4v.	—	1v.	—	6v.	9v.	3v.	4v.	5v. 1c.	50v.	40v. 1c.	37v. 4c.	21v.	12v. 2c.	8v.	6v. 1c.	6v.
Candona pratensis Hartwig	—	—	—	—	—	—	—	1c.	—	—	—	—	—	—	—	—	—	—	—	—	—
Candona sp.	1v.	—	—	—	—	—	—	—	—	1v.	—	—	—	—	—	—	—	—	—	—	—
Cyprideis torosa Jones	15v. 2c.	13v. 4c.	21v.	3v.	—	—	1v.	—	66v. 4c.	80v. 5c.	26v. 10c.	38v.	22v. 8c. 1c.	5v.	29v. 3c.	25v. 4c.	36v. 4c.	14v. 2c.	20v. 1c.	11v. 3c.	8v. 6c.
Cypridopsis vidua (Müller)	2v.	—	—	—	—	—	—	—	—	—	—	—		—	—	—	—	—	—	—	—
Darwinula stevensoni (Brady & Robertson)	1v.	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Eucypris pigra (Fischer)	—	—	—	—	—	—	—	—	—	—	—	—	—	1v.	—	—	10v.	5v. 8c.	11v. 1c.	7v. 3c.	2v.
Eucypris sp.	—	—	—	—	—	—	—	—	1v.	—	—	—	—	—	—	—	—	—	—	—	—
Herpetocypris brevicaudata Kaufmann	—	—	—	—	—	2v.	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Herpetocypris chevreuxi Sars	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	2v.	—	—	—
Herpetocypris reptans (Baird)	1v.	2v. 4f.	5v. +f	1f.	—	—	—	—	1v.	—	4f.	—	—	—	4v. 7f.	—	—	—	5v.	1v.	—
Herpetocypris sp.	—	—	—	—	—	—	—	—	—	—	1c.	1v.	—	—	—	1v.	—	—	—	—	—
Heterocypris salina (Brady)	—	—	—	—	—	—	—	—	10v.	12v. 1c.	4v. 1c.	3v.	2v.	2v.	9v.	6v. 1c.	10v.	5v. 3c.	12v.	11v. 2c.	9v.
Ilyocypris bradyi Sars	—	2v.	4v.	1v.	1v.	1v.	12v.	—	3v.	12v.	—	—	—	6v.	4v.	8v.	8v.	5v.	3v.	5v.	3v.
Nannocandona sp.	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1v.
Notodromas monacha (O. F. Müller)	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	3v. +f.	—	—
Prionocypris serrata (Norman)	—	—	—	—	—	—	—	—	1v.	—	—	—	—	—	—	—	—	—	—	—	—
Potamocypris sp.	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1v.
Scottia pseudobrowniana Kempf	—	—	1c.	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—

Occurrence of *C. torosa* in this manner recalls a situation that can be observed at the present day in tidal creeks and roadside drains in areas fringing The Wash, or the Essex marshes fringing the Thames Estuary. There, at spring tides the salt waters push inland and for a short period the ditches and drains swarm with living *C. torosa*, temporarily displacing the normal fauna dominated by freshwater species. Some salt-tolerant components of the indigenous fauna can survive, but for a time there is intermixing with a brackish-water assemblage, as seen at Tattershall. This mixing has been observed to occur over one high tide period, but it could extend locally through a succession of years of high tide penetration or higher overall sea-level.

Cyprideis torosa from waters of low salinity often have nodes developed upon the valve surfaces (Kilenyi 1972), although the cause of noding is not generally agreed. Nodes were not common in the specimens from Tattershall, although some juveniles from sample 72K did show slight noding.

Examination of the pattern of occurrence of the ostracods at Tattershall Castle (table 3) reveals several changes through the sequence. *C. torosa* occurred throughout the detritus muds in all three sample series. It was particularly common in the basal detritus muds of the 72 series, declining progressively towards the top of this series where the fauna became dominated by *Candona candida* and *C. neglecta*. This decline corresponds precisely with the relative fall in numbers of the brackish-water mollusc *Pseudamnicola confusa* at these levels, providing further evidence for reduced salinities in the upper part of this series.

Heterocypris salina, absent from the 76 series, is also present in the 72 and 73 series where it is joined by *Candona angulata* and *C. compressa*, two other species tolerant of low salinities. The presence of *Nannocandona* sp. and *Notodromas monacha* in the 73 series suggests quieter, more open-water conditions, since the latter species swims on the underside of the surface of the water. This interpretation is in complete accord with the molluscan evidence.

All the ostracods recorded are characteristic of cool-temperature climatic regions, without any clear indication of colder temperatures at the base or top of the profiles studied.

(*e*) *Foraminifera*

Two foraminiferid tests were found in series 73. These were identified by Mr D. J. Carter as *Haynesina germanica* (Ehrenberg) (sample 73–1) and *Elphidium articulatum* (d'Orbigny) (sample 73–5). Presence of these foraminiferids implies brackish conditions.

There can be little doubt that other foraminifera were missed because the samples searched for Mollusca and ostracods were sieved only to 0.5 mm and most foram tests are smaller than this. *H. germanica* favours muddy or epiphytic environments with salinities not normally greater than 30‰ (Banner & Culver 1978), whereas *E. articulatum* lives in the upper layers of sediment on inner parts of the continental shelf, in areas of strong water movement (channels, tidal flats) (Murray 1971).

(*f*) *Vertebrates*

Remains of large mammals were abundant in the Middle Devensian gravels (cf. Rackham 1978, 1981), but relatively scarce in the interglacal deposits. Rackham (1978) recorded *Bos primigenius* Bojanus from the interglacial muds. Our own records comprise (all identifications were made by Dr A. J. Stuart): *Clethrionomys glareolus* (Schreber) (bank vole) left M_3 from sample 72D, right M_2 from sample 76D; unidentified fish vertebrae from sample 72E; unidentified fish tooth from sample 76B; *Scardinius erythrophthalmus* (L.) single pharyngeal teeth in samples 76J and 76L; Cyprinidae undet. (pharyngeal tooth, sample 76J) and *Microtus* sp. (one M_3, sample 76K).

Occurrence of rudd (*S. erythrophthalmus*), today a southern species, shows that a substantial river or lake was present (cf. Maitland 1972; Stuart 1982). The record of *Microtus* sp. suggests presence of open grassland or marsh habitats.

(*g*) *Dating*

(i) *Radiocarbon dates*

A sample of wood from the 'woody peat' of quarry F provided a radiocarbon age of over 42000 a B.P. (Birm-260) (Girling 1980).

Two series of radiocarbon dates were obtained from the silts infilling channels within the gravels overlying the interglacial deposits (Girling 1974, 1977, 1980). Dates from the lower of the two silt units were:

42100 + 1400 or − 1100 a B.P. (Birm-398)
44300 + 1600 or − 1300 a B.P. (Birm-408).

Dates from the higher of the two silt units were:

over 40500 a B.P. (Birm-308);
43000 + 1300 or − 1100 a B.P. (Birm-341);
42200 ± 1000 a B.P. (Birm-409);
†30800 ± 360 a B.P. (Birm-448A);
†28000 ± 800 a B.P. (Birm-448B);
†39400 ± 800 a B.P. (Birm-450);
‡ over 46300 a B.P. (Birm-753).

In view of the similarities of the fossil Coleoptera from these samples to each other and to sites of Upton Warren Interstadial age, Girling (1980) regarded those discrepant dates marked † as likely to be based on samples contaminated with Flandrian rootlets, and the date marked ‡ to be based on a sample contaminated with interglacial materials. Despite these difficulties the radiocarbon dates can be taken as support for the palaeontological evidence of the Middle Devensian age of these silts.

Radiocarbon dates showing a Flandrian age for a channel cut into the top of the gravels and a palaeosol developed high in the gravel sequence are also given by Girling (1980).

(ii) *Uranium-series disequilibrium dates*

Four uranium-series disequilibrium dates were obtained from shells of the land snail *Cepaea nemoralis* collected from the calcareous silt near site 76 (Ivanovich & Holyoak 1982). These dates were as shown in table 4.

Various sources of error could have affected these dates (cf. Harmon & Ivanovich 1982). Uranium could have been added to the shells or leached from them by mobile groundwaters, or detrital thorium could have been incorporated into the shells when the snails were alive. The ratios of ^{230}Th:^{232}U are rather low, implying such incorporation of detrital thorium has occurred, but it could only have had a small effect on samples 78C and 78D (ratios 11.0, 8.0) so these dates may be more reliable than the other two (ratios 4.0, 4.0).

The possible addition or leaching of uranium by mobile groundwater cannot be discounted. However, the relatively consistent series of uranium concentration values and activity ratios would imply that any such addition or leaching was either of no great extent, or of surprisingly consistent extent. Hence, as all of the shell samples are expected to be of generally similar age the determinations can be considered together to give a combined estimate of 75–115 ka B.P.

Gascoyne *et al.* (1983) describe numerous uranium-series dates from speleothem samples collected in caves in northwest England. A period of abundant speleothem growth from 90 to 135 ka was thought to represent the Ipswichian Interglacial, although the dates associated with bones of interglacial mammals from one cave were 114–135 ka B.P.

TABLE 4. URANIUM-SERIES DISEQUILIBRIUM DATES

			activity ratios		
sample	$U/10^6$	$^{234}U/^{238}U$	$^{230}Th/^{234}U$	$^{230}Th/^{232}U$	age/ka
78B	0.13 ± 0.01	1.31 ± 0.10	0.514 ± 0.046	4.0	76^{+10}_{-9}
78/91	0.14 ± 0.01	1.43 ± 0.08	0.602 ± 0.041	4.0	94^{+10}_{-9}
78C	0.08 ± 0.01	1.71 ± 0.24	0.603 ± 0.075	11.0	93^{+18}_{-16}
78D	0.12 ± 0.01	1.26 ± 0.17	0.622 ± 0.086	8.0	101^{+25}_{-20}

The range of experimental error in measurement is stated as 1 σ in each case.

(iii) *Thermoluminescence date*

One sample of basal calcareous silt (series 76A–H) from the interglacial deposit was submitted to Dr A. G. Wintle for thermoluminescence (t.l.) dating. The technique is based on the removal of the geological t.l. signal by exposure of the feldspar in the sediment to light shortly before deposition. The technique has been reviewed recently by Wintle & Huntley (1982). It has mainly been applied to loess and brickearths but is now being applied to interstadial and interglacial silts (see Bryant *et al.* 1983).

Thermoluminescence measurements were made on 4–11 μm grains extracted after treatment with dilute HCl to remove the carbonate. No mineral separation was done and the t.l. signal observed with a Corning 5-58 glass filter was mainly due to feldspar. The t.l. response was linear with dose and the equivalent dose (e.d.) used in the age calculation was obtained by using method (ii) of Wintle & Prószyńska (1983). The e.d. was obtained for the highest peak in the glow curve (260–300 °C) obtained by heating at 5 °C s^{-1} in argon.

Alpha counting and potassium determinations were carried out on the bulk sediment and it was noted that the presence of calcium carbonate in the sediment diluted the effect of the radioisotopes and caused the dose rate to be lower than in other silts (see, for example, Bryant *et al.* 1983). To calculate an age the dose rate must be corrected for the presence of water in the sediment. Unfortunately this sediment had not been collected specifically for t.l. measurements and no measurement of the *in situ* water content had been made. A saturation water content of 0.34 (mass of water/mass of dry sediment) was measured and a fraction (0.75 ± 0.25) of the saturation value was assumed to be the likely range of the past mean water content (Δ). It is important to point out that this assumption can give rise to an error of $\pm 10\%$ in the age; hence from the analyses presented in table 5, a t.l. age of 114 ± 16 ka B.P. was obtained.

Table 5. Measurements for t.l. dating analysis

sample	e.d. / Gy	K_2O (%)	total count-rate / $ks^{-1}\ cm^{-2}$	Δ	dose rate / mGy/a^{-1}	t.l. age / ka B.P.
62a	246 ± 29	0.82 ± 0.01	0.446 ± 0.015	0.25 ± 0.09	2.15	114 ± 16

(iv) *Amino acid racemization data*

Amino acid racemization data from shells were obtained from material submitted to the Amino Acid Geochronology Laboratory of the University College of Wales, Aberystwyth (Professor D. Q. Bowen and Miss S. Hughes) and the Amino Acid Laboratory of INSTAAR, University of Colorado (Dr J. T. Hollin and Dr G. Miller). Both laboratories measured alloisoleucine and isoleucine concentrations by spectrophotometry after separation on ion-exchange columns and staining with ninhydrin. The results are expressed conventionally as the alloisoleucine:isoleucine ratio.

From Tattershall Castle pit (series 76): samples of *Cepaea nemoralis* shell gave ratios of 0.09, 0.10, 0.11 and 0.16 (ABER 234A–D); *Valvata piscinalis* shells gave 0.13, 0.15 (ABER 324A, C) and a mean of five measurements of 0.15 (INSTAAR); a *Lymnaea peregra* shell gave 0.15 (ABER 226A) (other measurements on shells of this species of 0.13, 0.15, 0.20 (ABER 325A–C) are regarded as unreliable because of analytical problems).

From Tattershall Thorpe (site X in quarry A): *Cepaea nemoralis* shells gave 0.12, 0.13, 0.13, 0.15 (ABER 326A–D); *Trichia hispida* shells gave 0.15, 0.19 (ABER 235B, C). Two shells of *Corbicula fluminalis* from quarry D gave: (i) 0.25 (outer growth edge of shell) and 0.34 (hinge of shell) (ABER 353A, B), and (ii) 0.21 (outer growth edge) and 0.31 (hinge) (ABER 352C, D).

The two sets of results from *Cepaea nemoralis* shells suggest that the Tattershall Castle and Tattershall Thorpe deposits are of at least approximately similar age. Interpretation of the other results necessitates full consideration of species differences in rates of epimerization and wider ranging comparisons with other sites; these will be considered in fuller reports on amino acid measurements from the two laboratories concerned.

4. Deposits at Tattershall Thorpe

(*a*) *Stratigraphy*

A schematic representation of the stratigraphy around site X in quarry A is given in figure 11. The general sequence of sediments recorded there was similar to that at Tattershall Castle.

The floor of the quarry exposed a dark grey till which consisted almost entirely of Jurassic clays of the Ancholme Clay Group, although some Cretaceous and other erratics were present. This till is thought to represent the Wragby Till of Straw (1966, 1969, 1982, 1984).

The till surface was exposed at 7–8 m O.D. over much of quarry A, but at the west end of the quarry it fell to just over 5 m O.D. Deposits that are interpreted as being of interglacial age (see below) formed the basal infill of this depression in the till surface, which probably represented a fluvial channel.

The interglacial beds were first exposed in quarry A in 1979. They extended for over 50 m in an east–west direction, but did not exceed 1 m in thickness. The basal 0.2 m consisted of

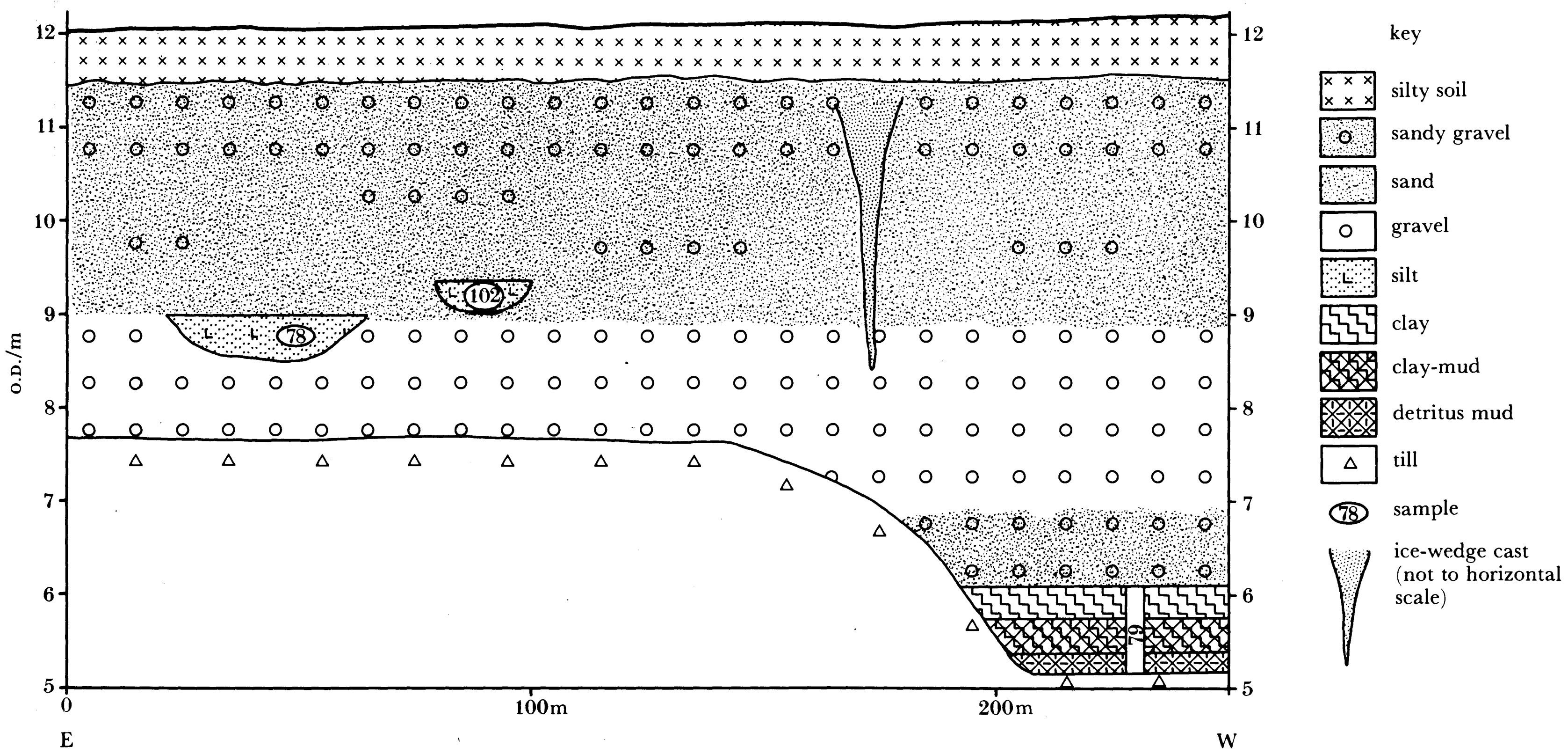


FIGURE 11. Stratigraphy at Tattershall Thorpe. Vertical exaggeration, × 20.

detritus mud with much woody material; above this (0.2–0.65 m) was a clay–mud, with woody detritus within a matrix of silty clay, whereas the upper levels (0.65–1.0 m) were of silty clay without conspicuous plant remains.

Interglacial deposits had previously been recorded in quarry D. These differed from those of quarry A in the presence of the bivalve mollusc *Corbicula fluminalis* (Müller). Notes made in 1971 by Dr Linda Schon (née Phillips) record a total thickness of up to 1.0 m of blue-grey silty clay and blackish-green clayey mud resting on a thin bed of coarse gravel, which in turn rested on the till of the quarry floor. Pollen spectra and Mollusca from these deposits are discussed below.

The interglacial deposits were capped unconformably by 5–6 m of sandy gravel and sand, the sedimentology of which was described by Bryant (1983*a*, *b*). A few channels within the sandy gravels were infilled with silt or silty mud, and those contained pollen and plant macrofossils indicative of the open vegetation of a cold stage (D. T. Holyoak *et al.* unpublished). In addition, several ice-wedge casts extended downwards from the top 1 m of the sandy gravels to depths of up to 4 m. The upper surface of the gravels was covered by less than 1 m of soil with high silt content.

(*b*) *Palaeobotany*

(i) *Pollen*

A series of samples was collected for study of pollen and spores. The samples were prepared and analysed in the same way as described for those from Tattershall Castle; results are presented in figure 12.

The pollen was poorly preserved throughout, with a considerable proportion of corroded grains. The preservation was best in the basal detritus mud and the clay-mud, with 17–32% of grains classed as unidentified. Only one spectrum could be counted from the upper clay and this contained 44% unidentified.

The high proportions of unidentified grains limit the conclusions that can be drawn from the pollen data because of the likelihood of differential preservation. In addition, presence of derived Mesozoic palynomorphs at some levels implies reworking within the catchment. Some Pleistocene palynomorphs may thus have reached the sediments due to erosion of soils or superficial deposits, as well as directly from the local vegetation and by run-off from further upstream in the catchment.

However, the Pleistocene pollen and spore taxa recorded could all have grown contemporaneously within the Bain Valley, if it is assumed that both wet and dry woodlands as well as open fens and perhaps grassland were present. There is no evidence of marked vegetational change during the period represented by the pollen spectra, so they will all be discussed together.

Substantial proportions of *Quercus* and *Pinus* pollen with lesser amounts of *Corylus*, *Betula* and *Ulmus* pollen and traces of *Ilex*, *Fraxinus* and *Acer* pollen, imply woodland on more or less dry ground. The considerable proportions of *Alnus* and *Salix* pollen on the other hand suggest woodland or carr on wetter ground. Plentiful Cyperaceae pollen suggests fen vegetation and the Gramineae pollen may have originated in fens or from grassland, but these and other open-country pollen types are less plentiful than the tree pollen, implying dominance of woodland. Various herb pollen taxa recorded may indicate open grassland, but all except a single grain of *Plantago lanceolata* could have originated from taxa growing in either fens or shaded sites. Occurrence of several *Sphagnum* spores points to development of wet acid habitats somewhere within the region, but many of the other taxa prefer base-rich or neutral soils.

Aquatic pollen types are well represented, with submerged and floating-leaved genera (*Nuphar*, *Nymphaea*, *Potamogeton*), small floating plants (*Lemna*) and emergent plants of shallow edges (*Sparganium erectum* type, *Typha latifolia*).

The dominance of the tree pollen by *Quercus*, *Alnus* and *Pinus*, with lower frequencies of *Corylus*, *Betula*, *Ulmus* and *Fraxinus* points to deposition during the Early Temperate substage (zone II) of an interglacial (Turner & West 1968; West 1980). There are several differences from the Tattershall Castle spectra, notably the greater representation of *Pinus*, *Betula*, *Ulmus* and *Fraxinus* pollen, the lesser representation of *Corylus*, and the absence of *Taxus* and *Tilia* pollen. These differences could be taken as suggesting a different age to the Ipswichian IIb correlation proposed for the Tattershall Castle deposits, and possibly a Hoxnian age. However, the difference might all be due to differences in the local rather than regional vegetation, or to differences in representation of taxa within the spectra. Hence these Tattershall Thorpe pollen data do not provide sufficient evidence to either confirm or refute correlation with the Ipswichian stage.

Five pollen spectra from the interglacial deposits in quarry D were counted in 1971 by Dr Linda Schon (née Phillips). One of these spectra was from a rhinoceros bone stratified near the base of the gravel succession. This contained tree pollen types in similar frequencies to those shown in figure 12, except that pollen of *Quercus* was scarcer (1%) and pollen of *Carpinus* was more plentiful (4%). The higher *Carpinus* value suggests this spectrum may have been from late in zone IIb of the Ipswichian, when *Carpinus* frequencies were rising to the high levels characteristic of zone III of this interglacial. A second pollen spectrum from a thin organic layer within a bed of clay was similar.

The three remaining spectra were from samples of silty clay and clayey mud forming the infill of the palaeochannel noted above. These spectra were dominated by *Pinus* (49–71%), with lesser frequencies of *Betula* (5–10%), 'coryloid' pollen (3–12%), Gramineae (4–7%), *Alnus* (4–7%), and scanty pollen of *Picea* (0–5%) and *Carpinus* (1–2%); *Quercus* pollen was absent. These three pollen spectra can be correlated with zone IV of the Ipswichian Interglacial.

(ii) *Plant macrofossils*

Plant macrofossils were studied from each of the bulk samples collected. The same techniques for extraction of material were used as described for Tattershall Castle. The results are listed in table 6.

The preservation of the macrofossils was generally rather poor, apparently due to oxidation or other chemical processes. Very small fruits and seeds and perishable parts such as leaves and bud-scales were entirely absent, but small wood fragments (mostly under 1 to 5 cm in length) were found in most samples and they were abundant in samples A–G. Most of the wood was *Alnus*, with some *Quercus* represented and one fragment of softwood (probably *Pinus*).

Fruiting 'cones' and seeds of *Alnus glutinosa* were the commonest of the other macrofossils identified. *Pinus sylvestris* (one seed) and *Quercus* (one fruit, twig fragments) were the only other trees recorded, their presence conforming to their substantial pollen representation. Two corroded fruit stones were apparently from *Crataegus monogyna* and this shrub could account for the consistent representation of Rosaceae pollen.

A variety of herb taxa is represented, although each of them is recorded from only a few

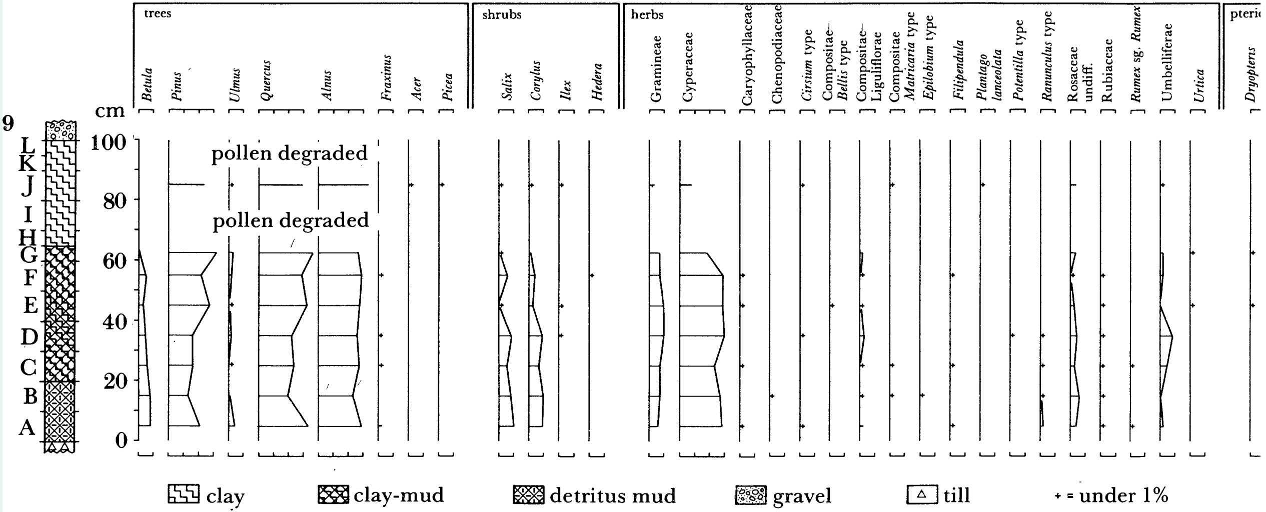
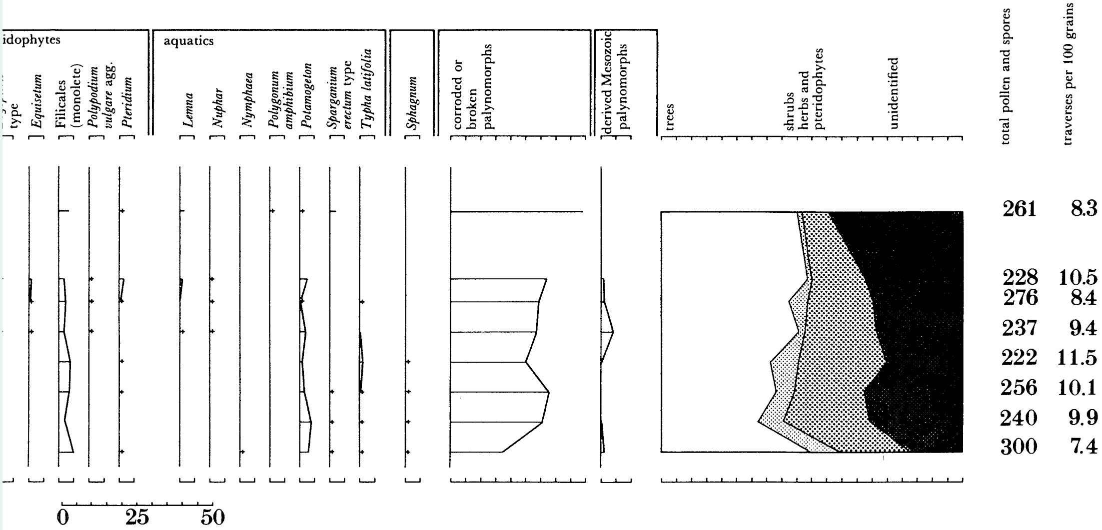


FIGURE 12. Pollen diagram, Tatt



tershall Thorpe.

macrofossils. Herbs of dry land include *Ajuga reptans* and *Ranunculus ficaria*, both of which tolerate considerable shading. *R. ficaria* (one achene) has not previously been recorded from British interglacial deposits. An achene of *Ranunculus* subgenus *Ranunculus* on the other hand provides a clear indication of open vegetation, possibly grassland.

Table 6. Plant macrofossils from Tattershall Thorpe

(Sample series 79; all samples were of 250 g dry mass and all were sieved to 0.5 mm.)

sample label...		A	B	C	D	E	F	G	H	I	J	K	L
trees													
Alnus glutinosa (L.) Gaertn.	f.c.	—	2	2	4	5	2	1	—	—	—	—	—
	s.	—	2	1	2	—	—	—	—	—	—	—	—
cf. *Alnus* sp.	tw.	—	—	—	—	—	1	—	—	—	—	—	—
Pinus sylvestris L.	s.	—	1	—	—	—	—	—	—	—	—	—	—
Quercus sp.	f.	—	1	—	—	—	—	—	—	—	—	—	—
	tw.	—	—	1	—	2	1	—	—	—	—	—	—
cf. *Quercus* sp.	tw.	—	—	—	—	1	—	1	—	—	—	—	—
shrubs													
cf. *Crataegus monogyna* Jacq.	f.s.	—	2	—	—	—	—	—	—	—	—	—	—
shrubs or trees													
Angiospermae	b.f.	—	—	X	X	X	X	—	X	—	—	—	—
	w.	X	X	X	X	X	X	X	X	X	X	X	—
Gymnospermae	w.	—	—	—	—	X	—	—	—	—	—	—	—
herbs of dry land													
Ajuga reptans L.	n.	—	1	1	1	—	—	—	—	—	—	—	—
Ranunculus ficaria L.	a.	—	1	—	—	—	—	—	—	—	—	—	—
Ranunculus subg. *Ranunculus*	a.	—	1	—	—	—	—	—	—	—	—	—	—
Helophytes													
Apium nodiflorum (L.) Lag.	f.	—	—	—	—	—	—	1	—	—	—	—	—
Carex sp.	b.n.	—	1	—	—	1	—	—	—	—	—	—	—
Eupatorium cannabinum L.	a.	—	—	—	1	—	—	—	—	—	—	—	—
Iris cf. *pseudacorus* L.	s.	—	—	1	—	—	—	—	—	—	—	—	—
Sparganium erectum L.	f.	—	—	1	—	—	—	—	—	—	—	—	—

notes

a., achene; b.f., bark fragment; b.n., biconvex nutlet; f., fruit; f.c., fruiting 'cone'; f.s., fruit stone; n., nutlet; s., seed; tw., twig; w., wood. X, present.

Characteristic fen plants are represented by *Eupatorium cannabinum* and *Iris* cf. *pseudacorus* and the *Carex* sp. may also have been from a fen. *Apium nodiflorum* and *Sparganium erectum* normally grow in shallow water, such as the edges of rivers or streams.

The scanty plant macrofossil record thus provides further evidence for a similar variety of habitat types to that inferred from the pollen.

(*c*) *Mollusca*

Mollusca were studied by the same techniques as described above for the samples from Tattershall Castle. Notes on certain problems of identification and on the zoogeographical and ecological significance of certain species are also given above (§3*d*). The Mollusca counted from Tattershall Thorpe are listed in table 7 and the main ecological groupings are summarised graphically in figure 13.

The preservation of the shells at Tattershall Thorpe was inferior to that at Tattershall Castle and many specimens were badly corroded. Shells were also less common and fewer species were represented. Only minor stratigraphic changes were noted within the profile (figure 13),

Table 7. Mollusca from Tattershall Thorpe

(Sample series 79; all samples were of 250 g dry mass.)

sample labels...	B	C	D	E	F	G	H	I	J	K	L
Valvata cristata Müller	—	—	6	4	4	10	4	3	14	8	10
Valvata piscinalis (Müller)	—	1?	—	—	—	—	—	—	1	—	—
Bithynia tentaculata (L.) shells	—	—	—	—	—	—	1	1	2	1	—
Bithynia opercula	—	—	—	—	—	—	2	1	—	—	1
Carychium minimum Müller	—	1	30	36	28	17	14	5	12	12	3
Aplexa hypnorum (L.)	—	—	—	—	—	1	—	—	—	2	—
Lymnaea truncatula (Müller)	—	—	—	1	4	3	1	—	1?	—	—
Lymnaea palustris (Müller)	—	—	3	2	5	3	3	2	2	4	2?
Lymnaea peregra (Müller)	—	—	—	—	—	—	—	—	—	1?	—
Planorbis planorbis (L.)	—	—	3	1	—	3	1	3	—	5	1
Anisus leucostoma (Millet)	—	—	1	7	1	—	7	1	1	2	—
Bathyomphalus contortus (L.)	—	—	—	1	3	—	—	1	—	—	2
Gyraulus laevis (Alder)	—	—	—	2	—	—	—	—	—	—	—
Armiger crista (L.)	—	—	—	—	—	—	—	—	—	—	1
Acroloxus lacustris (L.)	—	—	—	—	—	1?	—	2	—	3	1
Succinea putris (L.)/*Oxyloma* sp.	3	2	15	14	13	9	14	5	16	13	4
Azeca goodalli (Férussac)	—	—	—	2	2	2	—	3	—	—	—
Cochlicopa lubrica (Müller)/*nitens* (Gallenstein)	—	1	6	9	8	3	5	3	1	2	—
Cochlicopa lubricella (Porro)	—	1	—	—	—	—	—	—	—	—	—
Vertigo pygmaea (Draparnaud)	—	—	1	—	—	—	—	—	—	—	—
Vertigo angustior Jeffreys	—	—	—	—	—	1	—	—	—	—	—
Pupilla muscorum (L.)	—	—	—	—	1	—	—	—	1	1	—
Vallonia costata (Müller)	—	—	2	1	4	1	1	1	—	—	—
Vallonia pulchella (Müller)	—	—	2	2	3	2	—	1	3	1	—
Vallonia spp.	—	—	5	16	16	9	5	5	4	5	2
Ena montana (Draparnaud)	—	1	1	—	—	—	—	1?	—	—	—
Punctum pygmaeum (Draparnaud)	—	—	1	2	2	1	1	—	1	—	—
Vitrea subrimata (Reinhardt)	—	—	—	—	—	1	—	—	—	—	—
Nesovitrea hammonis (Ström)	—	—	—	1	1	—	—	—	—	—	—
Zonitoides nitidus (Müller)	—	3	22	32	15	17	13	2	10	11	3
Deroceras/*Limax* spp.	—	1	1	5	9	5	3	2	3	4	2
Euconulus fulvus (Müller) agg.	—	—	—	2	2	—	—	—	1	—	1
Clausilia bidentata (Ström)	—	—	—	—	—	2	—	—	—	—	—
Clausilia pumila C. Pfeiffer	†	—	†	†	†	†	†	—	—	—	—
Clausilia spp.	1	1	2	2	2	5	1	—	—	—	1
Trichia hispida (L.) agg.	—	—	2	3	19	9	6	2	7	—	7
Trichia cf. *plebeia* (Draparnaud)	—	—	—	—	1	—	—	—	1	3	1
Bradybaena/*Arianta*/*Cepaea*	1	3	2	1	4	3	1	1	1	—	—
Sphaerium corneum (L.)‡	—	1	—	—	1	1	3	3	4	12	5
Pisidium casertanum (Poli)	—	—	1	5	1	1?	—	—	—	—	1
Pisidium personatum Malm	—	—	14	4	2	—	—	—	—	2?	—
Pisidium obtusale (Lamarck)	—	—	—	6	4	40	20	29	13	33	14
Pisidium milium Held	—	—	—	2	1	2	—	1	2	—	—
Pisidium subtruncatum Malm	—	—	1	—	13	—	4	—	22	8	—
Pisidium nitidum Jenyns	—	—	—	—	—	—	—	—	—	—	1

† Fragments of body whorl present; ‡ all counts of Bivalvia are of shell valves.

consisting principally of a decrease upwards of terrestrial species favouring swamp habitats and a corresponding increase in aquatic species, particularly those favouring moving water.

The molluscan assemblages differ in several respects from those at Tattershall Castle. Firstly, most of the aquatic species reflect a quieter environment: species characteristic of stagnant pools are common (for example, *Anisus leucostoma*, *Pisidium personatum*, *P. obtusale*). Both *Planorbis planorbis* and *Bathyomphalus contortus*, absent at Tattershall Castle, were present. Species

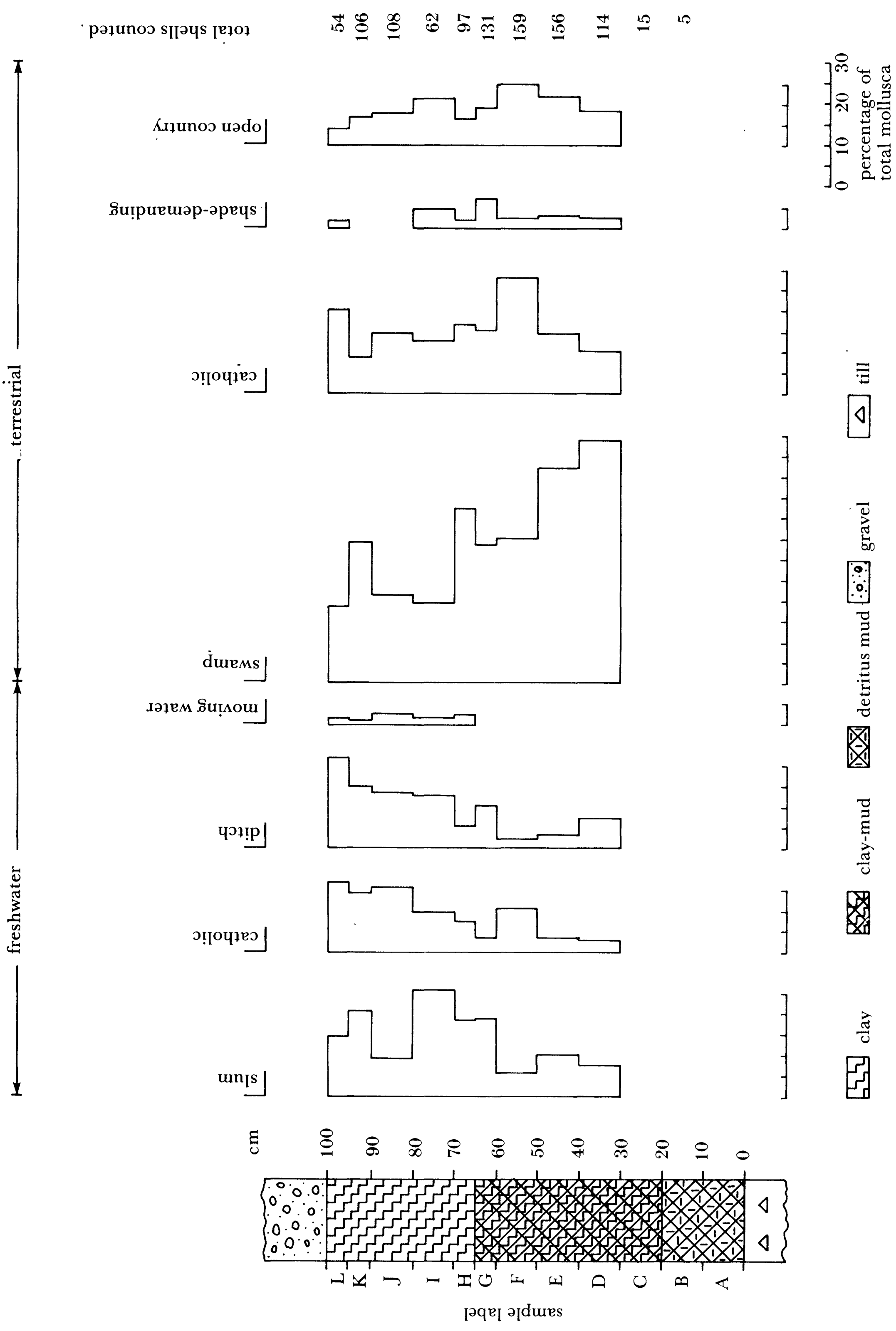


FIGURE 13. Summary of data on Mollusca, Tattershall Thorpe.

indicative of large streams are scarce and the brackish indicators *Pseudamnicola confusa* and *Hydrobia ventrosa* agg. were absent. The terrestrial fauna also differs. Marsh species dominate, especially *Carychium minimum*, *Oxyloma* cf. *pfeifferi* and *Zonitoides nitidus*. Several shade-demanding species are present, including *Azeca goodalli* and *Ena montana*, which were both unrecorded at Tattershall Castle. *Clausilia pumila*, a central European forest species, was unambiguously present and so also was *Trichia* cf. *plebeia*, neither of these having been recorded at Tattershall Castle. *Cochlicopa nitens* was apparently represented by a single shell (figure 10). However, the most notable land snail recorded was *Vitrea subrimata*, for which this constitutes the first British Pleistocene occurrence. In Britain this species is now confined to limestone slopes and screes in the northern Pennines (Kerney & Fogan 1969), although it occurs in montane woodland in much of alpine and southern Europe (Kerney & Cameron 1979).

Large bulk samples (*ca.* 26 kg) were collected to obtain more material of scarce species. These yielded nine taxa not represented in the main samples (table 7), comprising: *Belgrandia marginata* (1 shell); *Carychium tridentatum* (16); cf. *Oxyloma sarsi* (Esmark) (3); *Vertigo antivertigo* (1); *V. moulinsiana* (1); *Arion* sp. (1 granule); *Aegopinella nitidula* (*ca.* 30); *A. pura* (2) and *Bradybaena fruticum* (4). In addition, complete shells of *Cepaea nemoralis* were found.

The absence of several species occurring at Tattershall Castle, and the presence at Tattershall Thorpe of others not occurring at Tattershall Castle is of uncertain importance. However, many species are common to both sites, including some that are not of general occurrence in British Pleistocene interglacial deposits (*Belgrandia marginata*, *Cochlicopa nitens*, *Bradybaena fruticum*). Hence it is thought that the differences between the two sites may reflect local habitat differences rather than a difference of age. Most of the species represented only at Tattershall Thorpe prefer standing water (*Planorbis planorbis*, *Bathyomphalus contortus*) or more of less dry woodland (*Azeca goodalli*, *Ena montana*, *Vitrea subrimata*, *Clausilia pumila*) whereas many of the species represented only at Tattershall Castle require or prefer brackish water, moving fresh water, marshes or fens, or dry open sites (see §3*d*).

A small sample of sediment (dry mass 53.2 g) from the interglacial beds formerly exposed in quarry D at Tattershall Thorpe was collected in the early 1970s by Dr G. R. Coope, and kindly passed to us by Dr J. G. Evans. The following Mollusca were obtained from this sample: *Valvata piscinalis* (Müller) (3); *Bithynia tentaculata* (L.) shells (2); *Bithynia* sp. opercula (4); *Carychium minimum* Müller (1); *Lymnaea* cf. *peregra* (Müller) (fragments); Planorbidae sp. (fragments); *Cochlicopa* sp. (1); *Vallonia costata* (Müller) (1); *Vallonia* spp. (5); *Vitrina pellucida* (Müller) (1); *Vitrea* cf. *contracta* (Westerlund) (1); Zonitidae undet. (fragments); Limacidae (1); *Trichia hispida* (L.) agg. (2); *Arianta arbustorum* (L.) (2); *Arianta* or *Cepaea* sp. (2); *Unio* sp. (fragment); *Corbicula fluminalis* (Müller) (5); *Sphaerium corneum* (L.) (1); *Pisidium amnicum* (Müller) (1); *Pisidium subtruncatum* Malm (*ca.* 5); *Pisidium henslowanum* (Sheppard) (1); *Pisidium nitidum* Jenyns (1).

The presence of *Valvata piscinalis*, *Bithynia tentaculata*, *Corbicula fluminalis*, *Pisidium amnicum*, *P. subtruncatum* and *P. henslowanum* suggests this deposit accumulated in a substantial body of flowing water, in contrast to the predominance of stagnant-water molluscs in the samples from quarry A.

(*d*) *Ostracoda*

Ostracods were extracted from samples prepared in the same way as those from Tattershall Castle. The specimens were likewise submitted to Dr J. E. Robinson who made all of the determinations (table 8) and supplied the notes summarized below.

Table 8. Ostracoda from Tattershall Thorpe

(c., Carapaces; f., fragments; v., valves; all samples were of 250 g dry mass.)

	sample series 79							
	D	E	F	G	H	I	J	K
Candona neglecta Sars	—	2v.	—	1v.	2v.	2v.	4v.	7v. 1c.
Candona sp.	1v.	—	—	—	2c.	—	—	—
Ilyocypris decipiens Masi	—	—	c.f. 1c.	c.f. 4v.	—	—	2v.	19v.
Ilyocypris sp.	—	—	—	—	—	1f.	—	—

The Tattershall Thorpe sections provided a very limited ostracod fauna compared with that from Tattershall Castle, with only two named species. *Candona neglecta* burrows into muddy substrates, and as there are juvenile moult stages associated with adult valves the species probably lived close to the site of deposition. The second species, *Ilyocypris* cf. *decipiens*, like the more frequently found *I. bradyi*, is a weak swimmer which clambers upon aquatic plants. The low species diversity at this profile presumably results from adverse local conditions, possibly disturbance of the bottom sediments.

(*e*) *Radiocarbon dates*

A piece of wood from the interglacial bed formerly exposed in quarry D gave a radiocarbon age of over 45000 a B.P. (Birm-251) (Girling 1980).

Plant materials sieved from silts at the base of the gravels in quarry D gave a radiocarbon age of 34800 ± 1000 a B.P. (Birm-205A), but a humate acid extract from this material gave an apparent age of 28000 ± 650 a B.P. (Birm-205B), suggesting contamination by more recent humic materials.

Other dates from plant materials sieved from silt beds within the gravels are as follows: Quarry A: 33650 + 530 or − 500 a B.P. (SRR-2305); Quarry E: 45720 + 2040 or − 1630 a B.P. (SRR-2306); 28720 + 520 or − 480 a B.P. (SRR-2307); 42800 + 2030 or − 1620 a B.P. (SRR-2308). These dates confirm the Middle Devensian age for deposition of these silts and gravels which is in accordance with information from Coleoptera from the silts (Girling 1974, 1977, 1980) and mammals from the gravels (Rackham 1978).

(*f*) *Amino acid racemization data*

See §3*g* (iv) above.

5. Discussion and conclusions

(*a*) *Depositional environments*

The interglacial deposits at Tattershall Castle and Tattershall Thorpe are regarded as being of fluvial origin. Evidence of brackish conditions, summarized below (§5*c*), shows that much of the deposits at Tattershall Castle accumulated in or beside the lower reaches of a river that was presumably subject to tidal influences. The abundant representation by macrofossils of certain herbs characteristic of drying mud is thought to give evidence of riverside mud inundated only by spring tides. The deposits at Tattershall Thorpe are higher above sea-level and these contain no evidence of brackish conditions. However, the aquatic Mollusca and the Ostracoda give clear indications that the water was locally standing or slow-flowing (quarry A), and locally faster-flowing (quarry D).

The detritus muds at both sites accumulated on the beds or sides of river channels. Besides remains of aquatic plants and animals, they contain a wide variety of inwashed fossils from woodland, fen and grassland environments. At the present day similarly extensive deposition of floated or suspended material often occurs in the lower reaches of rivers due to cessation of movement related to the tidal influence.

The calcareous silts represented locally at Tattershall Castle contain molluscan faunas predominantly of dry unshaded grassland or of open fens, with few aquatic Mollusca represented at some levels. These deposits are therefore regarded as products of overbank deposition on a river floodplain. The great scarcity of pollen and plant macrofossils in these calcareous silts is attributed to their degradation due to oxidation and other processes occurring in a subaerial environment.

(*b*) *Correlation of the deposits*

The pollen evidence discussed above suggests the deposits at Tattershall Castle should be correlated with substage II b of the Ipswichian Interglacial. Presence of macrofossils of certain plants such as *Acer monspessulanum* known only from the Ipswichian in Britain, and of shells of *Bradybaena fruticum* that is likewise known only from the Ipswichian in the British Pleistocene, strengthens this interpretation. In addition, Girling (1974, 1977, 1980) recorded various thermophilous Coleoptera consistent with an Ipswichian age. The thermoluminescence date of 114 ± 16 ka B.P. corresponds well with the uranium-series dates from *Cepaea* shells giving a combined age estimate of 75–115 ka B.P. These are similar to or slightly younger than other measurements from material regarded as being of Ipswichian Interglacial age (Keen *et al.* 1981; Gascoyne *et al.* 1981; Gascoyne *et al.* 1983).

The pollen spectra and molluscan assemblages from Tattershall Thorpe differ in some respects from those from Tattershall Castle, although *Bradybaena fruticum* is represented there and all of the pollen spectra might none the less be correlated with the Ipswichian. The differences between these two sites might be attributed to local environmental heterogeneity rather than to a difference in age.

Several workers have argued that there is another interglacial in the British record between the Hoxnian and the Ipswichian stages (for example, Shotton 1983; Green *et al.* 1984). Until fuller biostratigraphical information becomes available on this interglacial the correlation of some of the Tattershall Thorpe interglacial deposits remains uncertain.

(*c*) *Evidence of sea-level*

In the Tattershall Castle deposits the frequency of *Pseudamnicola confusa* at levels above −1.8 m O.D. indicates brackish influence. This influence becomes stronger at slightly higher levels as indicated by the occurrence of another brackish-water mollusc *Hydrobia ventrosa* agg., and also by the frequency of the ostracod *Cyprideis torosa* and occurrence of foraminifera.

Pseudamnicola confusa first appears in deposits at −1.8 m O.D. and demonstrates that the earliest evidence of brackish influence at Tattershall Castle is at heights that are identical (within the limits of accuracy of the levelling) to: (i) the level of −1.76 m O.D. at Selsey, where the first evidence of brackish conditions is shown by the arrival of *Hydrobia ventrosa* in Ipswichian 'pollen zone f' (that is, Ip IIb) (West & Sparks 1960); and (ii) the levels of −1.95 to −1.20 m O.D. at which *Pseudamnicola confusa* first appears in the early part of Ip II b at Wretton (Sparks & West 1970). Similar elevations of the change from freshwater to brackish-water sedimentation were recorded at two sites in Cambridgeshire (R. G. West, personal communication): −1.5 m at Block Fen, and −1 m at Somersham. The close similarity of these elevations supports the correlation of these sites within the same interglacial. The absence of a brackish influence in the correlative pollen assemblage zone at the Ipswichian type-site at Bobbitshole can apparently be attributed to subsequent downwarping of that region (West 1972, p. 95).

This study was in part carried out while we were in receipt of funding from N.E.R.C., which is gratefully acknowledged. Facilities were made available by the Subdepartment of Quaternary Research, University of Cambridge, Department of Geology, Imperial College, London, the Quaternary Research group, University of Reading and Department of Geography, University of Nottingham. Thanks are due to the following specialists for assistance: Professor D. Q. Bowen, Dr J. T. Hollin, Miss S. Hughes and Dr G. Miller (amino acid racemization data); D. J. Carter (foraminifera); Dr D. D. Harkness (radiocarbon dates); Dr M. Ivanovich (uranium-series dates); Dr J. E. Robinson (ostracods); Dr A. J. Stuart (vertebrates) and Dr A. G. Wintle (thermoluminescence dating). In addition, thanks are due to the following for various assistance or information: Dr I. D. Bryant, Mrs S. Dance, Dr J. G. Evans, Dr P. L. Gibbard, Dr M. A. Girling, Dr M. P. Kerney, D. J. Rackham, Dr L. Schon (née Phillips), J. D. Scourse, Dr M. B. Seddon, B. W. Sparks, Professor R. G. West, Mrs S. Wheeler and Professor P. Worsley.

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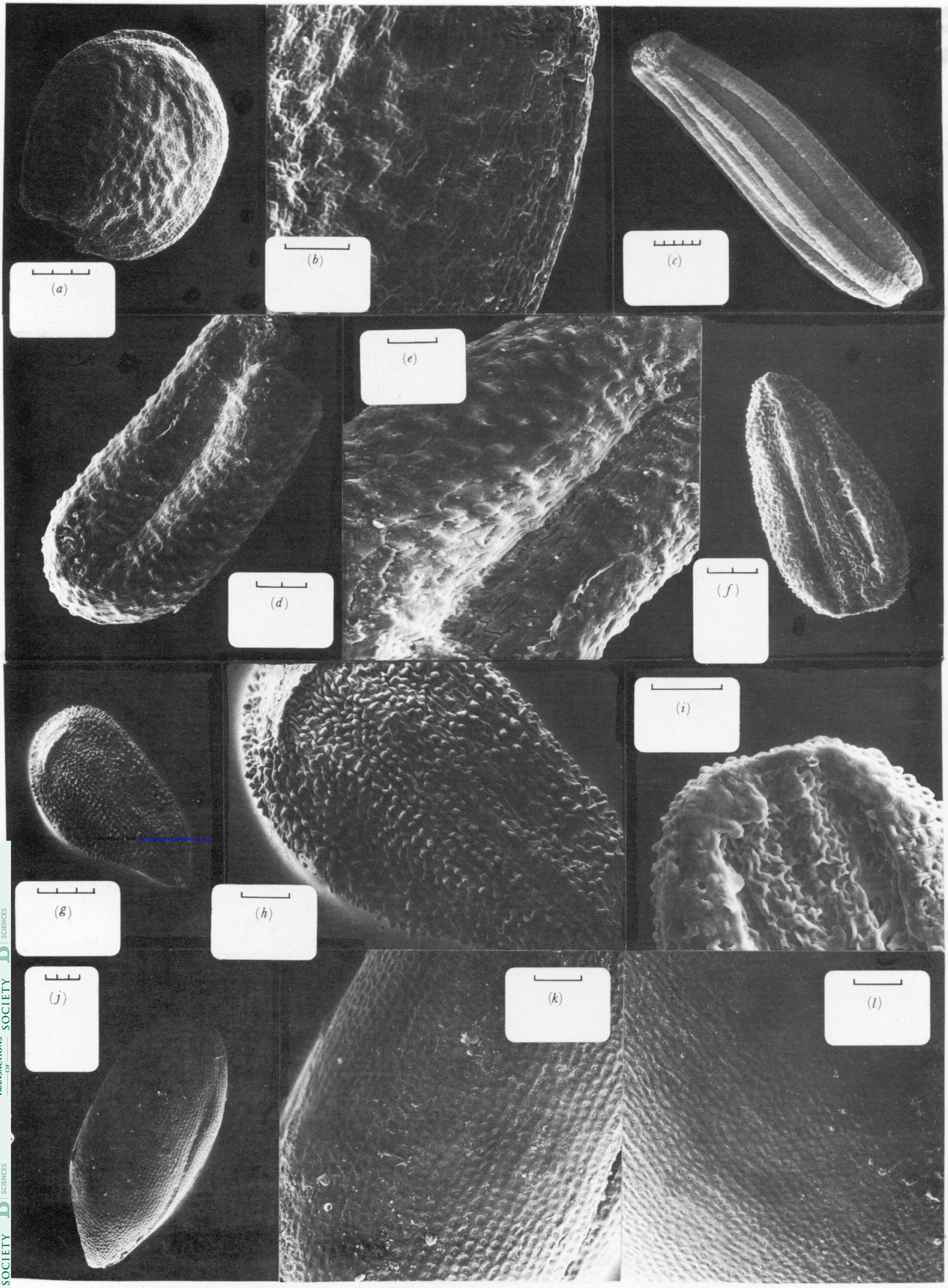

FIGURE 5. Scanning electron micrographs of plant macrofossils from Tattershall Castle Pit. (*a*), (*b*) *Cardamine* sp., seed (sample 76 I); (*c*) *Sonchus palustris*, achene (sample 73–4); (*d*), (*e*) cf. *Lepidium* sp., seed (sample 72 H); (*f*), (*i*) *Epilobium* cf. *obscurum*, seed (sample 73–1); (*g*), (*h*) *Epilobium* cf. *hirsutum*, seed (sample 73–5); (*j*), (*k*) *Viola* cf. *riviniana*, seed (sample 73–1); (*l*) *Viola* cf. *arvensis*, seed (sample 76–0). All scale bars are marked at intervals of 0.1 mm.

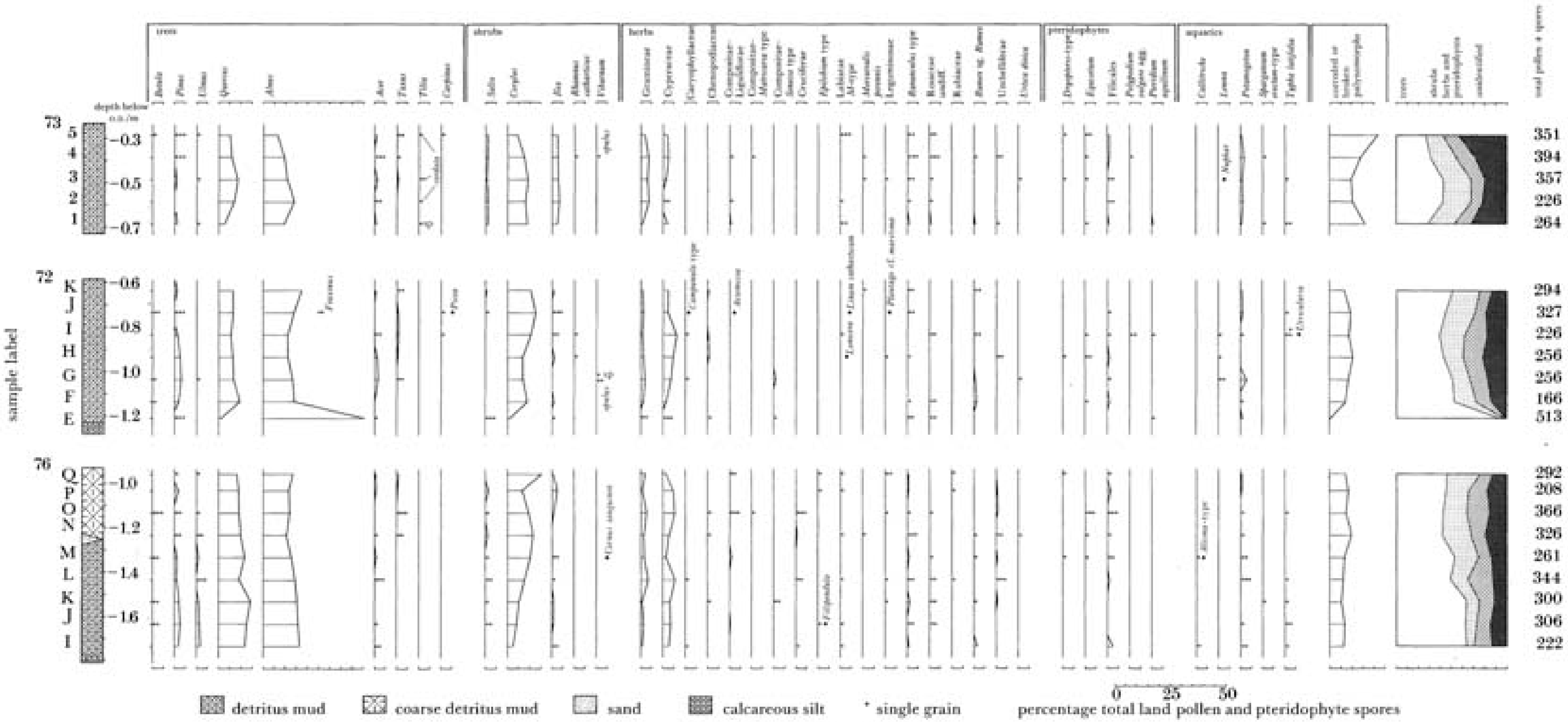

FIGURE 3. Pollen diagram, Tattershall Castle.

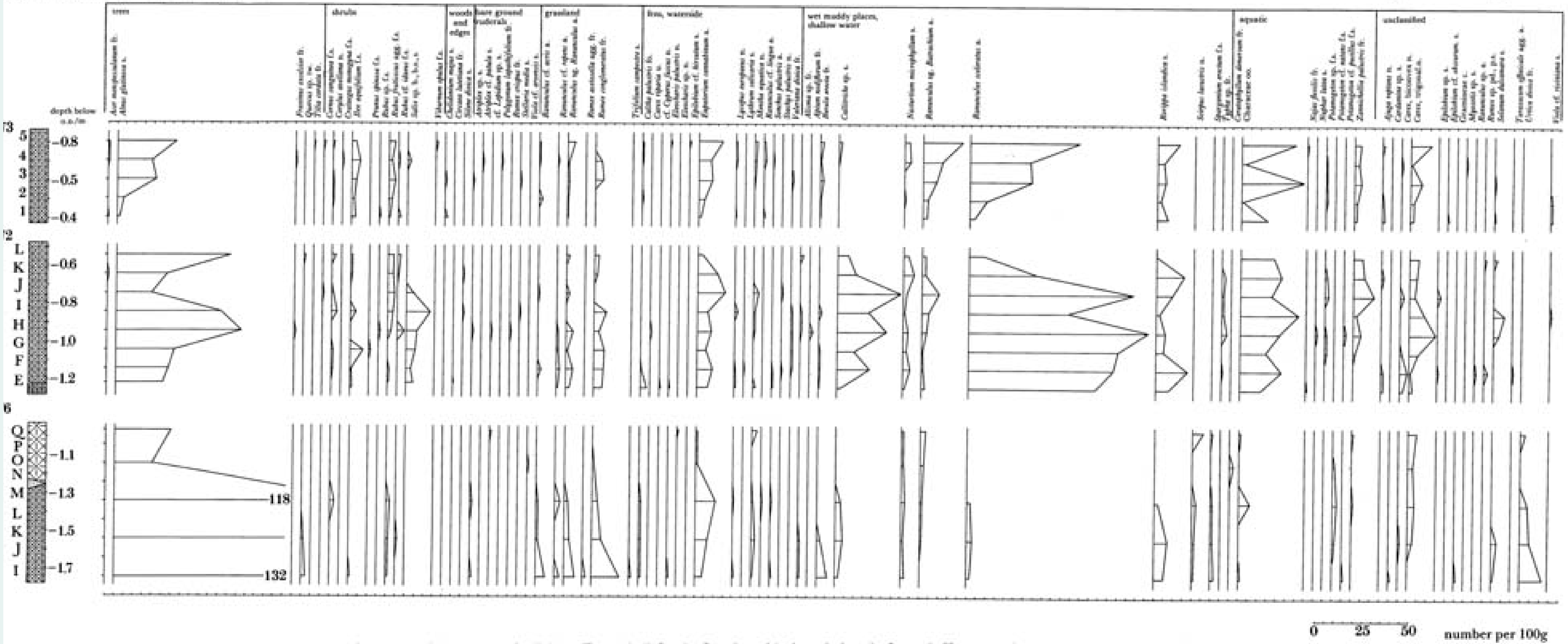

FIGURE 4. Summary of plant macrofossil data, Tattershall Castle. Stratigraphical symbols as in figure 3. Key: a., achene; b., bud; b.s., bud scale; c., caryopsis; fo., follicle; fr., fruit; f.s., fruit stone; n., nut or nutlet; oo., oospore; pd., pedicel; p.s., perianth segment; s., seed; tw., twig; u., utricle.

FIGURE 7. Tattershall Castle: summary of data on aquatic Mollusca. Stratigraphical symbols as in figure 3.

FIGURE 8. Tattershall Castle: summary of data on land Mollusca.

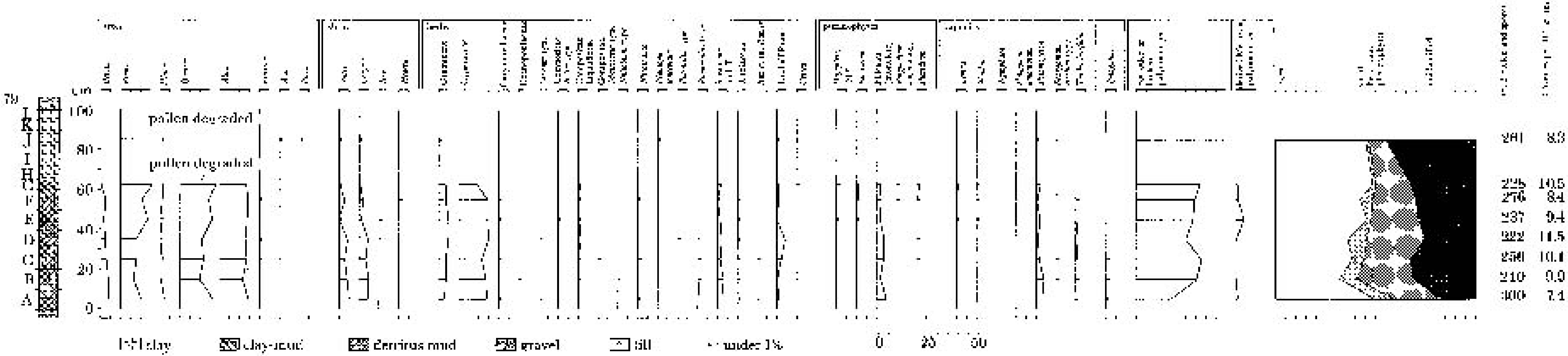

Figure 12. Pollen diagram, Tattershall Thorpe.