LATE-GLACIAL DEPOSITS ON THE CHALK OF SOUTH-EAST ENGLAND

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(With Appendixes by J. F. LEVY and K. P. OAKLEY)

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Subaerial deposits of the Late-glacial Period (*ca.* 12000 to 8300 B.C.) of the Last Glaciation are described at a number of sites in Kent, Surrey and Sussex. The deposits are primarily stratified chalk muds and fine rubbles, produced by frost-shattering and the release of water from melting snow-fields and from frozen ground.

The climatic improvement of zone II, or Allerød Oscillation (10000 to 8800 B.C.), is widely reflected stratigraphically by a rendsina soil, containing fragments of wood charcoal, separating two sheets of chalk muds referred to zones I and III. The age of the soil has been confirmed by radiocarbon dating. It is correlated with the Usselo Layer within the Younger Coversands of the Netherlands. There is evidence from two areas, Folkestone and the Medway Valley, that the climate of south-east England became sufficiently cold during zone III to produce fairly intense frost-heaving (cryoturbation).

The deposits contain virtually no pollen, but yield a fauna of land Mollusca. Columns of samples were collected from six sections and the assemblages they yielded are presented in the form of histograms, showing the changing vertical abundance of each species. The fauna is a remarkable mixture of diverse zoogeographical elements; its relations are with the Alpine area rather than with the Arctic. The ecological and climatic significance of the changes in the assemblages is discussed. During zone II, the assemblages increase in variety and certain relatively thermophilous species were able to spread widely, most notably the West European and Alpine snail *Abida secale.* The climate of zone III was probably more humid than that of zone I, and also less cold. In Sussex, due to the proximity of the open sea to the south-west, the climate of zone I may have been relatively milder than in Kent and Surrey; this is suggested by the appearance of thermophilous species perhaps 1000 years before their general expansion on the North Downs.

Evidence is put forward from several sites for a minor climatic oscillation within zone I; this is equated with the Bølling Oscillation (zone I *b*) of north-west Europe.

The Late-glacial Period is the last for which there is evidence of active erosion in the Chalk landscape.

I. Introduction

In the coombes and dry valleys of the Chalk country of south-east England are found a wide variety of chalky subaerial deposits, formed in several ways and at many periods. This paper deals with one particular set of such deposits, exhibiting a constant stratigraphy and yielding a characteristic fauna; they are assigned to the Late-glacial Period. Sections in four widely separated areas have been studied and are described below. Their locations are shown in figure 1.

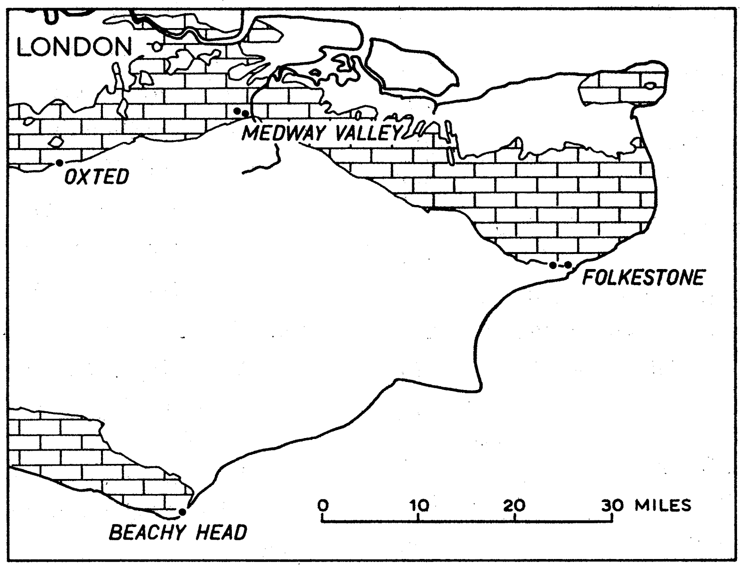

Figure 1. Sketch map of south-east England, showing the outcrop of the Chalk of the North and South Downs (bricks), and the position of the localities described.

II. Folkestone, Kent

(*a*) *Dover Hill*

At Dover Hill, immediately west of the main Folkestone–Dover road, there is a cutting through the infill of a shallow embayment in the face of the Chalk escarpment (National Grid reference TR/235376; figure 2 and figure 19*a*, plate 8). It shows, resting on frost-shattered chalk, a layer of coarse chalk rubble, or 'coombe rock', (*a*), which passes upwards into chalk muds and finer rubbles (*b*), divided into two parts by a grey band about 25 cm in thickness, interpreted as a fossil rendsina soil. All these beds show considerable disturbances, which do not however affect the overlying deposit of chalky hillwash (*d*) and the modern rendsina soil (*e*) developed upon its surface.

The chalk muds and rubbles are crudely bedded, the stratification being picked out by seams and stringers of chalk fragments, a centimetre or so in size, embedded in finer chalky material. The fragments themselves are generally angular, though they are sometimes a little rounded. Large fragments are uncommon. The character of these deposits suggests that they were produced by rapid physical weathering, probably by frost action. Cleanly broken surfaces of the chalky muds show them to be riddled by a network of ramifying rootlet holes, and this suggests that vegetation grew concurrently with accumulation. Some such process as the following seems likely: in spring and summer the ground, frozen and frost-shattered during the preceding winter, thawed, and a slurry of chalky mud and fine rubble was washed down onto the lower slopes and into the hollows. Vegetation, probably mainly grasses and small herbs, grew on these surfaces, to die off towards the end of the year, and finally to be covered during the next thaws by further thin sheets of chalk debris. The bedding, though rough, is frequently fairly close, and it is therefore certain that these deposits were not produced by the mass movement of large bodies of semi-frozen ground, but grew by small increments. The term *solifluxion*, which is commonly used to describe the former process, seems inappropriate here, and the writer would prefer to call these deposits 'chalk meltwater muds'. It is clear that a good deal of water was necessary for their formation. The climate was probably therefore not only cold, but humid, with a fairly high rainfall or snowfall.

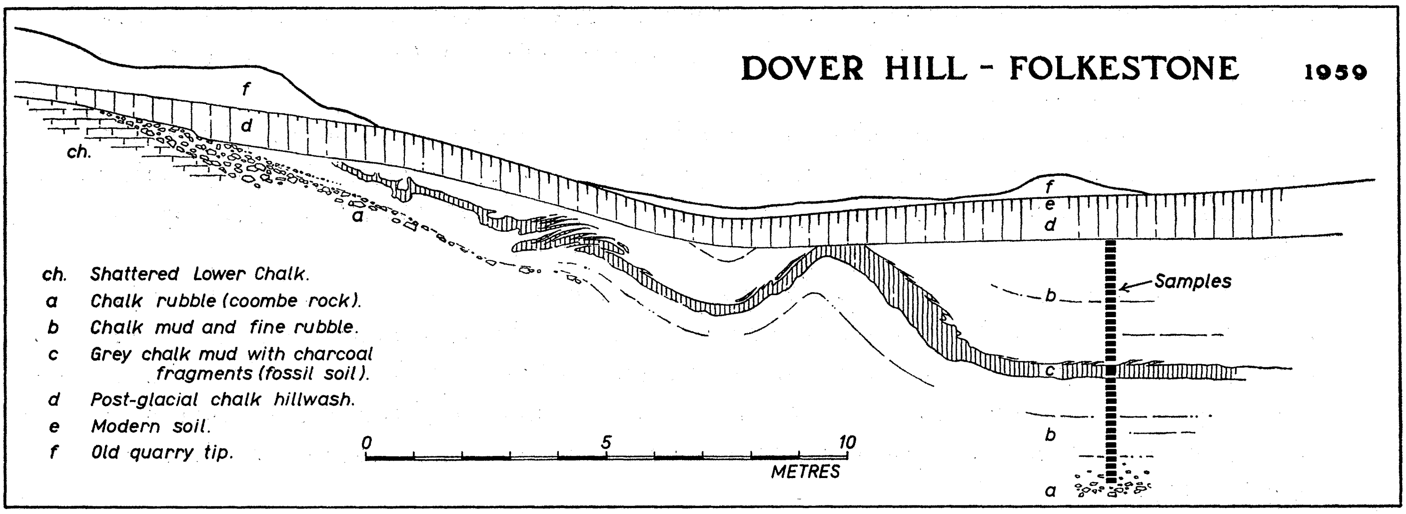

FIGURE 2. Measured drawing of section exposed at Dover Hill, Folkestone, Kent. (TR/235376). The face of the section is not a plane; the right-hand half is approximately parallel to the escarpment, whereas the left part extends somewhat obliquely up the slope.

The fossil rendsina soil (c) must represent a period during which the deposition of the chalk muds ceased. The time-interval was perhaps not a great one, for the soil has a 'skeletal' character and there is little sign of a segregation of the coarser fragments towards the bottom of the profile; on the other hand, this may solely be due to an absence or rarity of suitable burrowing organisms, such as earthworms. It is uncertain at Dover Hill to what extent the Mollusca contained in the soil are representative of the whole period during which the weathering occurred, or were already present in the parent material exposed to weathering, but evidence from other sites where the parent material is very poor in Mollusca makes it seem likely that Mollusca were being added to such soils throughout the period of their formation (see figures 9 and 10). The soil contains much disseminated and fragmentary wood charcoal, amongst which Mr J. F. Levy recognizes the presence of juniper and birch (see Appendix I). The charcoal is associated with occasional burnt fragments of chalk; therefore it was probably produced by local scrub fires on the hillside above. A few carbonized seeds washed from the upper part of the soil (350 to 363 cm) were identified by Miss C. A. Lambert of the Subdepartment of Quaternary Research, Cambridge, as follows:

Viola cf. reichenbachiana Jord., or *V. riviniana* Reichb.	1 seed
Lathyrus or *Vicea* sp.	1 seed
cf. Euphorbia sp.	1 seed
Empetrum sp.	4 seeds

The presence of the calcifuge *Empetrum* is remarkable. It is probable that the plant lived not on the site but on the acid soil of the marine Plio-Pleistocene sands on the crest of the escarpment immediately above; pieces of ironstone from these deposits are scattered throughout the chalk muds.

All these deposits show disturbances of a kind generally ascribed to a process of repeated freezing and thawing in semi-frozen ground (cryoturbation). Their intensity suggests that the climate deteriorated considerably after the period of weathering attested by the soil.

A column of samples, each weighing approximately 2 kg, was carefully cut from the face of the section in the position shown in figure 2. All identifiable Mollusca were extracted and the results have been plotted graphically both in terms of absolute abundance (figure 3) and, where numbers permit, relative abundance (figure 4). In the case of these particular deposits, the former method has been found the more generally useful (see § VIII(*b*)).

The pattern of change is interpreted in terms of a pronounced climatic improvement between 445 cm and 350 cm, which it seemed likely was the well-known Allerød Oscillation (zone II) within the Late glacial Period in north-west Europe. This was confirmed by a radiocarbon assay, kindly carried out by Dr E. H. Willis at Cambridge on 7 g of charcoal fragments obtained by washing some hundredweights of the upper half of the fossil soil (350 to 363 cm). The date was:

Q 463 9984 ± 210 B.C.

According to the limits of the zonal boundaries of Late-glacial Period established in Britain and elsewhere in north-west Europe (Godwin & Willis 1959), this date falls within zone II.

The Molluscan fauna is a restricted one of peculiar character, comprising no more than 14 species. It has an open-country character throughout, grassland and rupestral genera such as *Pupilla*, *Vallonia* and *Abida* predominating. Below 445 cm only five species are present, all of which have Holarctic ranges, extend in Europe to well beyond the Arctic Circle, and are adapted to a wide variety of adverse environments. Above 445 cm these species abruptly increase in numbers, although no change is observable in the deposits; the zone I/II boundary has been drawn at this point. Zone II is distinguished by the appearance of further species. Some of these, it seems likely, were already present in the area at an earlier date and appear merely in response to an improving local environment.

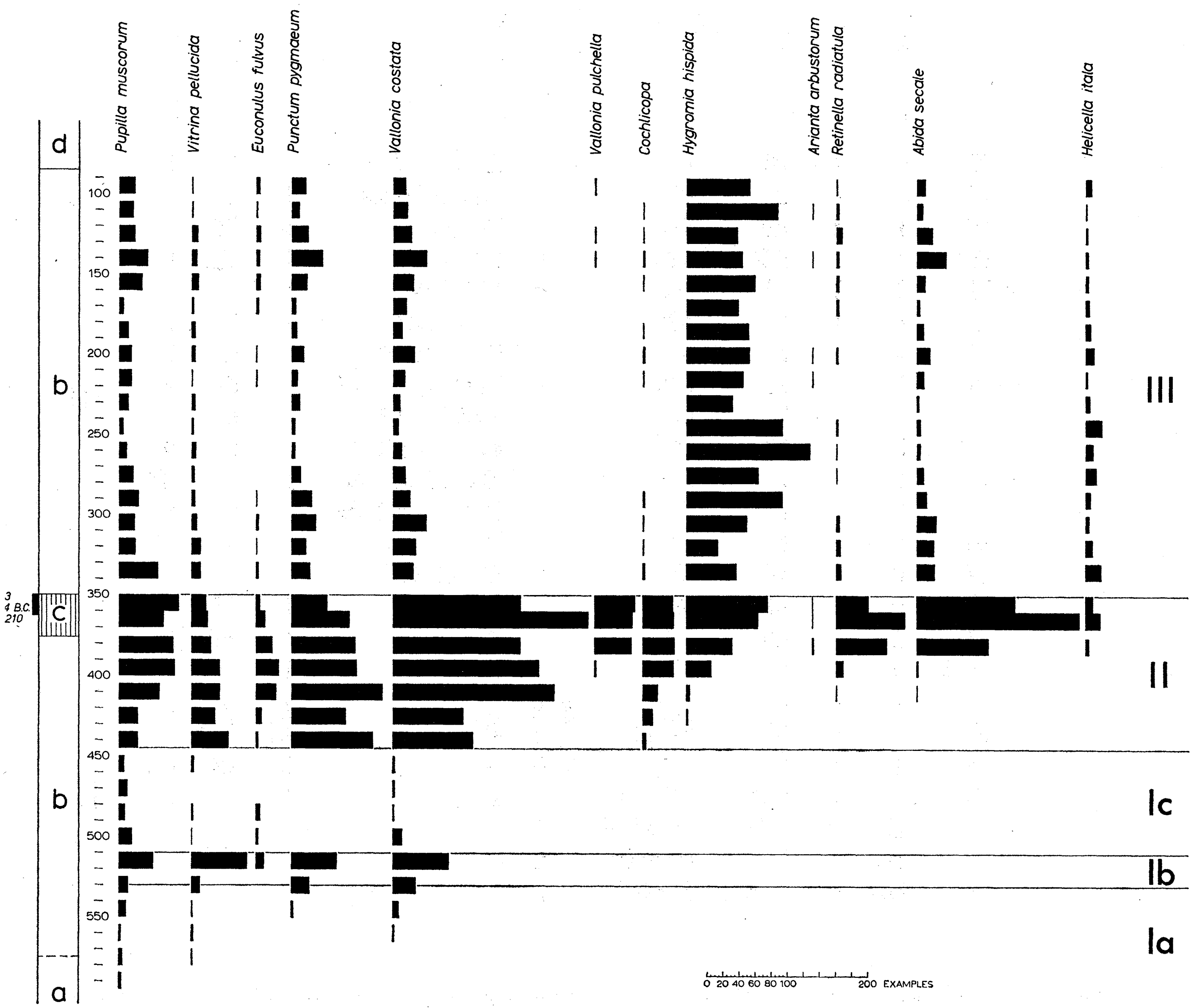

FIGURE 3. Molluscan histogram, Dover Hill, Folkestone; showing absolute abundance of species per 2 kg sample.

But it is equally likely that others, notably the relatively thermophilous *Hygromia hispida*, *Abida secale* and *Helicella itala*, owe their appearance and expansion to rising temperatures.

The base of zone III has been drawn at 350 cm. Nearly all species drop sharply in abundance. *Hygromia hispida*, however, does not decline but becomes the most common species, comprising at times over 70 % of the fauna. It is remarkable that no species disappears entirely. The nature of the deposits suggests that some reworking of older

Mollusca must occasionally have occurred, but contamination from this source is probably not serious. In proof of this, one may point to the virtual absence of *Vallonia pulchella* in zone III, although the species is common in the underlying fossil soil.

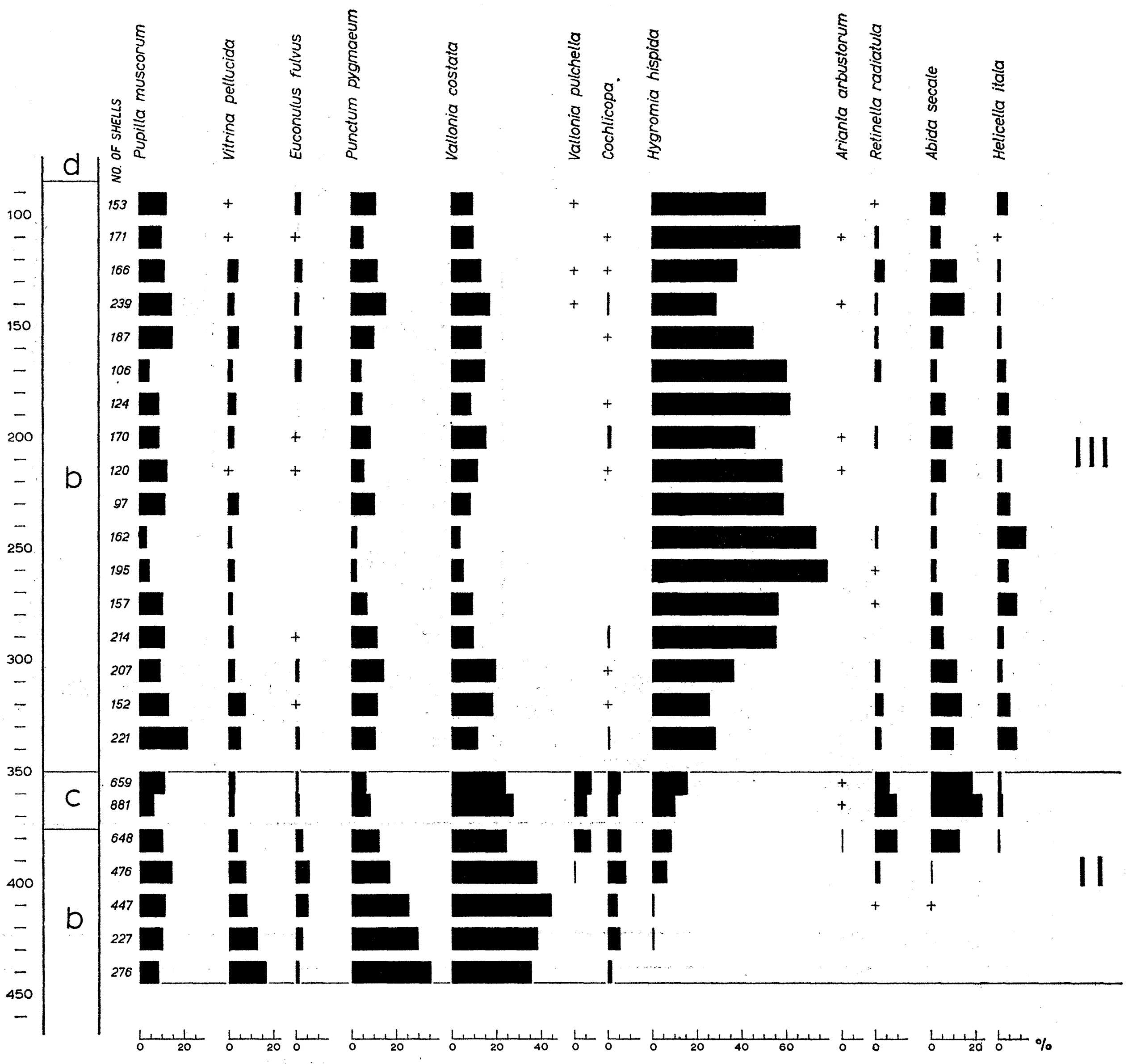

FIGURE 4. Molluscan histogram, Dover Hill, Folkestone; showing relative abundance of species in zones II and III. Crosses represent single shells.

Within zone I, between 530 and 510 cm, there is a sharp increase in the number of Mollusca. From a consideration of the Late-glacial sites in the Medway Valley (§ III), this is correlated with the Bølling Oscillation (zone I *b*) of Denmark.

The chalky hillwash (*e*) shows no features of special interest. It contains the human introduction *Monacha cantiana* (Montagu), indicating a date in the Early Iron Age or later; it is probably an old plough wash.

(*b*) *Castle Hill*

At the foot of the Chalk escarpment at Castle Hill, Folkestone, 1½ miles west of Dover Hill, is a flooded and much degraded pit in the Gault Clay (TR/212375). The following section was cleared at the northern end in 1960:

(*f*)	Modern soil	0 to 90 cm
(*e*)	Chalky hillwash with *Helix aspersa* Müller (probably Roman or post-Roman)	
(*d*)	White chalk mud with seams of fine chalk rubble, particularly in the middle part	90 to 160 cm
(*c*)	Grey chalk mud with charcoal fragments (fossil soil)	160 to 175 cm
(*b*)	Greenish-grey calcareous mud with scattered fragments of chalk	175 to 210 cm
(*a*)	Flint and chalk gravel	210 to 217 cm
	Gault Clay	

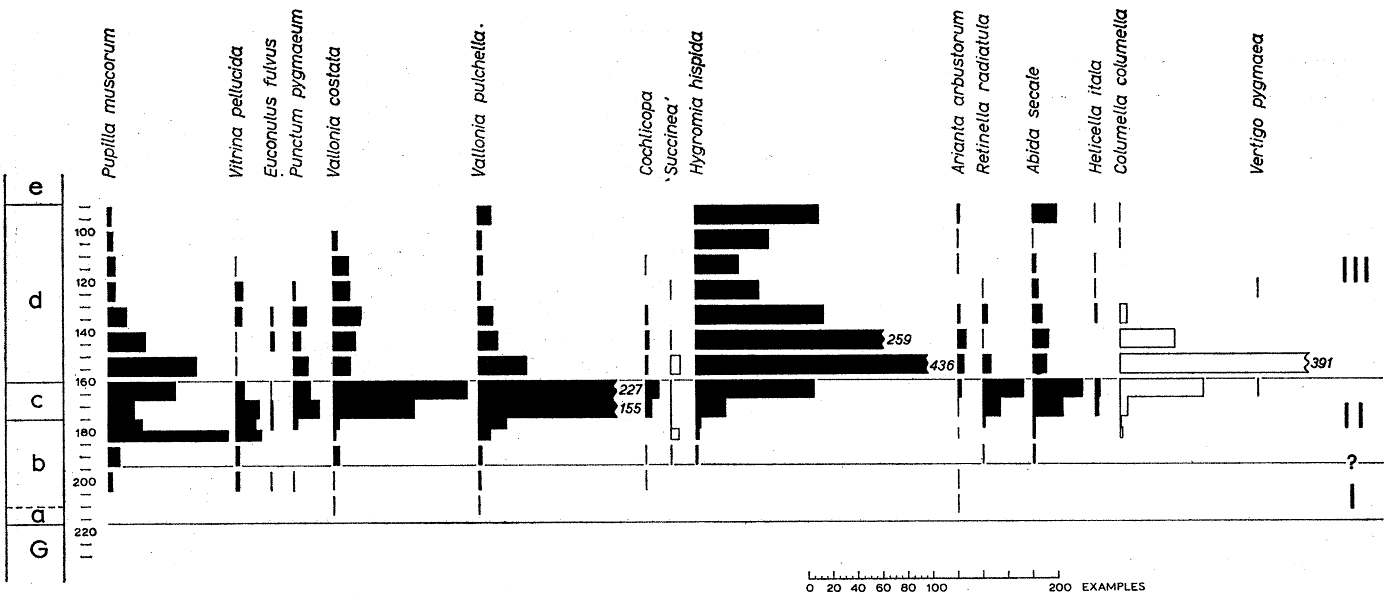

FIGURE 5. Molluscan histogram, Castle Hill, Folkestone; showing absolute abundance of species per 2 kg sample. In order to facilitate comparison with figure 3, those species not present at Dover Hill have been represented as open histograms.

Deposits (*a*) to (*d*) form part of a fan descending from the face of the Chalk escarpment and extending for some distance to the south over the flatter ground of the Gault Clay. The soil with charcoal fragments (*c*) is correlated with the soil at Dover Hill, and the overlying white chalk muds (*d*) with the zone III chalk muds at that place. Division (*d*) is markedly finer in grade than the equivalent deposits lying against the escarpment.

Samples for Mollusca were taken throughout, and the results are plotted in figure 5. The pattern of change in the upper part corresponds with that at Dover Hill, notably in the great expansion of *Hygromia hispida* in zone III. But the general facies is a good deal wetter, both in zones II and III. *Vallonia pulchella* is much more common and the marsh genus *Succinea* occurs. The most interesting species present is the Arctic–Alpine hygrophile *Columella columella*, which, together with *Hygromia hispida*, rises sharply in abundance at the base of the upper chalk muds, and clearly reflects the flooding and waterlogging of the area which must have taken place at the beginning of zone III.

The greenish-grey muds (*b*) contain a good deal of reworked Gault Clay. They are very poor in Mollusca and the base of zone II is uncertain; a somewhat arbitrary line has been drawn at about 195 cm, at the appearance of *Hygromia hispida* and *Abida secale*.

The stratigraphy at this site provides some evidence that erosion of the Chalk escarpment was more vigorous in zone III than in zone I.

III. MEDWAY VALLEY, KENT

(*a*) *Introduction*

North-west of Maidstone, the River Medway flows northwards through a large trumpet-shaped gap in the Chalk escarpment. On the west side of the gap the Chalk is grooved by a number of roughly parallel dry valleys running eastwards or north-eastwards to meet the

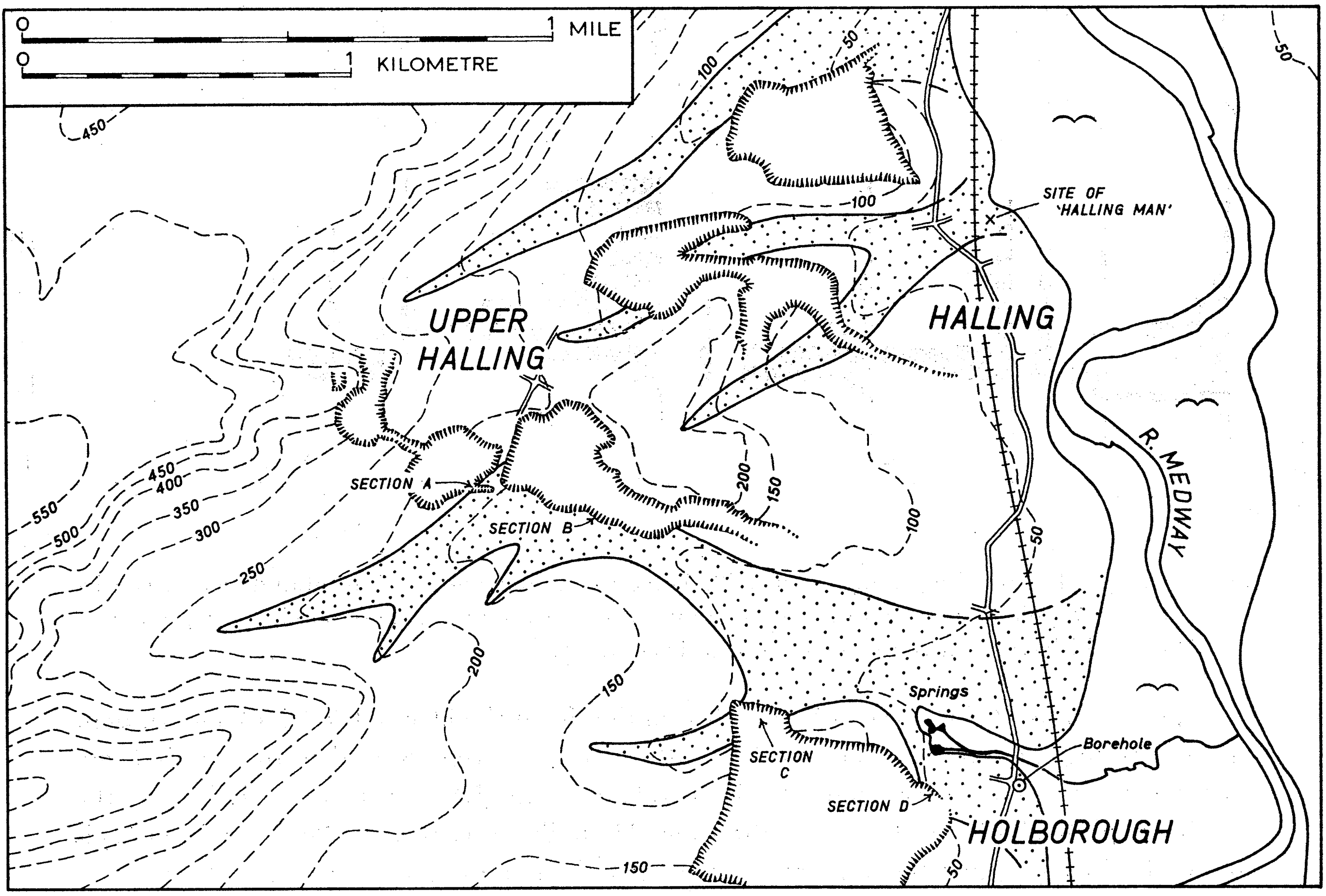

FIGURE 6. Sketch map of part of the west side of the gap of the River Medway, north-west of Maidstone, Kent. Stippled areas represent the approximate extent of chalk meltwater muds and rubbles of zones I and III of the Late-glacial Period. Other drifts, apart from the Post-glacial alluvium of the flood-plain, not shown.

flood-plain of the river (figure 6). These valleys are floored by variable thicknesses of subaerial drift. It shows a twofold division: first, over large areas, immediately below the surface soil, are found spreads of humic chalky muds, light brown or reddish in colour, full of the products of temperate weathering. These accumulations tend not to form continuous sheets, but mantle the hillsides irregularly, and commonly overlap the deposits which lie below to rest directly on the Chalk. Their molluscan fauna has a purely temperate, Post-glacial character. Many of these deposits are relatively modern and some are certainly the result of soil erosion brought about by prehistoric and later ploughing.

The term 'hillwash' is restricted to such accumulations by the writer.

In the valley bottoms, underlying the hillwash, are a very different set of deposits. They vary greatly, but all are the product of physical weathering alone rather than of physical and chemical weathering combined. They belong mainly, probably entirely, to the Last Glaciation. In figure 6 an attempt has been made to indicate the distribution of the uppermost of these deposits, the white chalk meltwater muds and rubbles of zones I and III of the Late-glacial Period. This map has no claim to any great accuracy. It has been constructed mainly by extrapolation from the sections available in the chalk pits; it is always difficult to decide how far up any given hillside such deposits extend, and this is particularly true close to the river.

In the area of the Medway Valley, these Late-glacial deposits, together with Post-glacial hillwashes and drifts of several other kinds, are included by the Geological Survey in the term 'Hillwash Head' (Dines *et al.* 1954). The common subdivision into upper 'brown' deposits and lower 'pale' deposits is however recognized (Dines *et al.* 1954, pp. 127, 129).

The writer has examined the stratigraphy of these deposits in the largest and most southerly of the dry valleys shown in figure 6; excellent sections are available in the chalk quarries around Upper Halling and Holborough.

(*b*) *Upper Halling*

The margin of the infill of this dry valley is well exposed in a chalk pit immediately west of the road running south from Upper Halling (Section *A* in figure 6; TQ/688635). The face, about 70 m in length (figures 20*a*, *b*, plate 9), shows everywhere a clear lithological distinction between brown Post-glacial hillwash (*j*) above, and lighter-coloured Full-glacial and Late-glacial deposits (*a* to *g*) below. The stratigraphy of the latter is essentially similar to that in Section *B*, further to the east (figure 7), except that the white muds there ascribed to zone I (*c* to *e*) are here poorly developed. The soil (*f*) is assigned to the Allerød Oscillation. It yields scattered charcoal fragments. Bed (*b*) contains a good deal of fine quartz silt, sometimes in thin seams uncontaminated by chalk debris; much of this division is probably wind-blown dust redistributed by solifluxion and meltwater. The contact with the overlying white chalk muds is rather abrupt and can be traced throughout the valley. This change may reflect the onset of a rather more humid climate. It also coincides with the first appearance of a molluscan fauna. The Full-glacial/Late-glacial boundary is drawn at this horizon, and this probably corresponds broadly with the widespread stratigraphical boundary between the Older and the Younger Coversands in the Netherlands (van der Hammen 1952; 1957*a*).

The Mollusca extracted from a 2 kg sample taken from the soil (*f*) at the extreme eastern end of this section are given in table 3.

The old chalk pit north-east of Lad's Farm, Upper Halling, exposes on its south side a representative section through the same deposits (Section *B* in figure 6; TQ/692635). A true-scale drawing is given (figure 7), and this is largely self-explanatory. The lowermost horizon (*a*) is a coarse variable chalk and flint rubble, completely ungraded. This passes up into rather finer rubbly material (*b*), sometimes showing traces of bedding; it is characterized by a good deal of limonitic quartz silt, giving it a brown colour. The overlying white muds and rubbles (*c*), (*e*) and (*g*), consist virtually of reconstituted chalk. Bedding is frequently very clearly shown, particularly in division (*g*). Between (*e*) and (*g*) there is a grey fossil rendsina (*f*) containing charcoal fragments (see Appendix I), and locally disturbed by frost-heaving (figures 15 and 16).

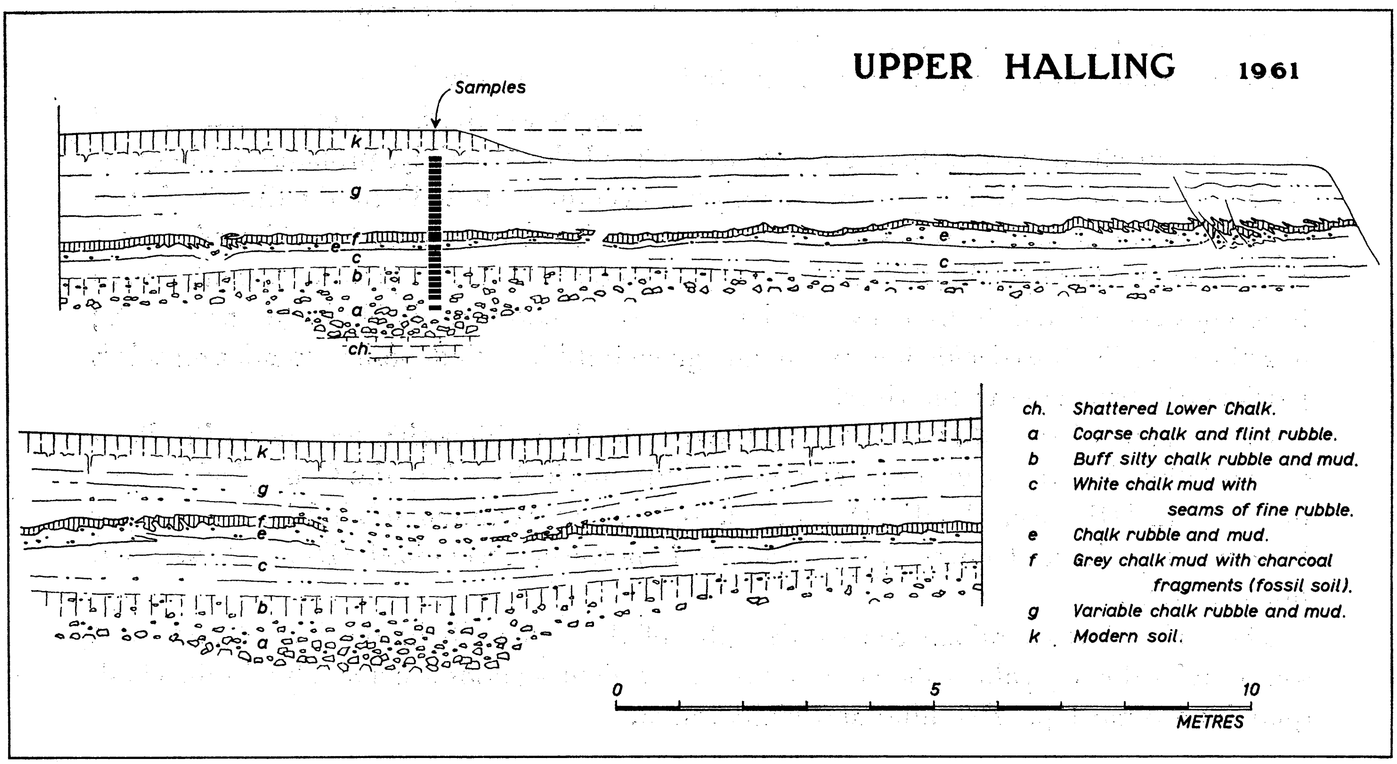

FIGURE 7. Measured drawing of Section *B*, Upper Halling, Kent (TQ/692635).

A photograph of part of the western end of this section is published by the Geological Survey, together with a list of Mollusca identified by A. S. Kennard (Dines *et al.* 1954, Pl. IV*A*, and p. 133, column (4)).

The molluscan histogram (figure 8) was prepared from samples collected at the point marked on figure 7, and illustrated in figure 21*a*, plate 10. It suggests that deposits (*c*) to (*g*) inclusive span the whole of the Late-glacial Period. Compared with Dover Hill, the sequence of changes is greatly condensed. Thus the fossil soil (*f*) represents the whole of zone II, and it is interesting to note how *Hygromia hispida* and *Abida secale*, which at Dover Hill appear and increase gradually through a considerable thickness of deposits, at Upper Halling appear abruptly in the lower part of the soil. In spite of the 40 miles which separate the two areas, the assemblages are remarkably similar. Every species present at Folkestone occurs also at Upper Halling, with one addition, *Helicella geyeri*. There is some indication that at least during zones II and III the habitats available to Mollusca at Upper Halling were rather bare and exposed. The commonest species is the rupestral xerophile *Abida secale*, whereas the hygrophiles *Vallonia pulchella*, *Hygromia hispida* and *Arianta arbustorum* occur only sporadically. Furthermore, the chalk muds (*g*) contain frequent thin seams of chalk silt, indicating some degree of local reworking by the wind of dried-out surfaces. On the other hand, there is abundant evidence that the main agent responsible for these deposits was water, probably released by the thawing of snow-covered ground on the hillsides above. Crude bedding is evident, and, in one place, a shallow rubble-filled channel cut through earlier deposits (figure 7).

Between about 205 and 190 cm in the molluscan histogram there is a well-marked maximum, regarded as being produced by a temporary climatic improvement within zone I, and correlated with the Bølling Oscillation. The faunal change is reflected in the sediments, which is not obviously the case at Dover Hill; division (*c*) becomes progressively finer in grade towards the top, and is then covered, sometimes very sharply indeed, by a bed of chalk mud full of coarser rubbly fragments (*e*), considered to reflect a recurrence of active frost-shattering during zone I*c* (figure 21*a*). This change can be traced through most of the section.

(*c*) *Holborough*

The large chalk quarry at Holborough intersects the Upper Halling–Holborough dry valley system at two places (figure 6).

At Section *C* (TQ/697628), only the white chalk muds of zone III are present, resting sharply on underlying Full-glacial loessic muds and chalk rubbles.

Section *D* was visible until 1961 in the north-east corner of the same quarry (TQ/702626); it has since been largely obscured by a quarry dump. A drawing is given in figure 9. The deposits can be seen to thicken to the left, where they descend into a small channel, not reflected in the present surface of the ground. The stratigraphy corresponds closely with that visible at Upper Halling (figure 7) and the beds have been lettered in the same way. The fossil soil (*f*) is again present, dividing two series of chalk meltwater muds, the lowermost of which (*c*) rests rather sharply on a light brown silty chalk mud (*b*), assigned to the Full-glacial Period; in places the last grades into an almost pure quartz silt, probably largely wind-blown material redistributed to a slight extent by solifluxion and meltwater. The upper sheet of white chalk meltwater muds (*g*) bears on its surface a fossil soil (*h*), unique to this section and preserved for a short distance only. It is taken to represent an early part of the Post-glacial Period, beginning in zone IV, when the underlying chalk muds dried or thawed out and the area became stabilized by a continuous cover of vegetation. Its lower surface is highly irregular, showing many projections penetrating the deposits below, and cutting across the crude bedding. Small cryoturbation structures are intersected. These projections probably formed round tree roots; it is interesting to observe that such features are much less prominent at the base of the Allerød soil (*f*).

A thin calcareous tufa (*i*) overlies the soil (*h*), and overlaps it to rest directly on the chalk muds (*g*). It probably represents a wet period in the Post-glacial when seepages of

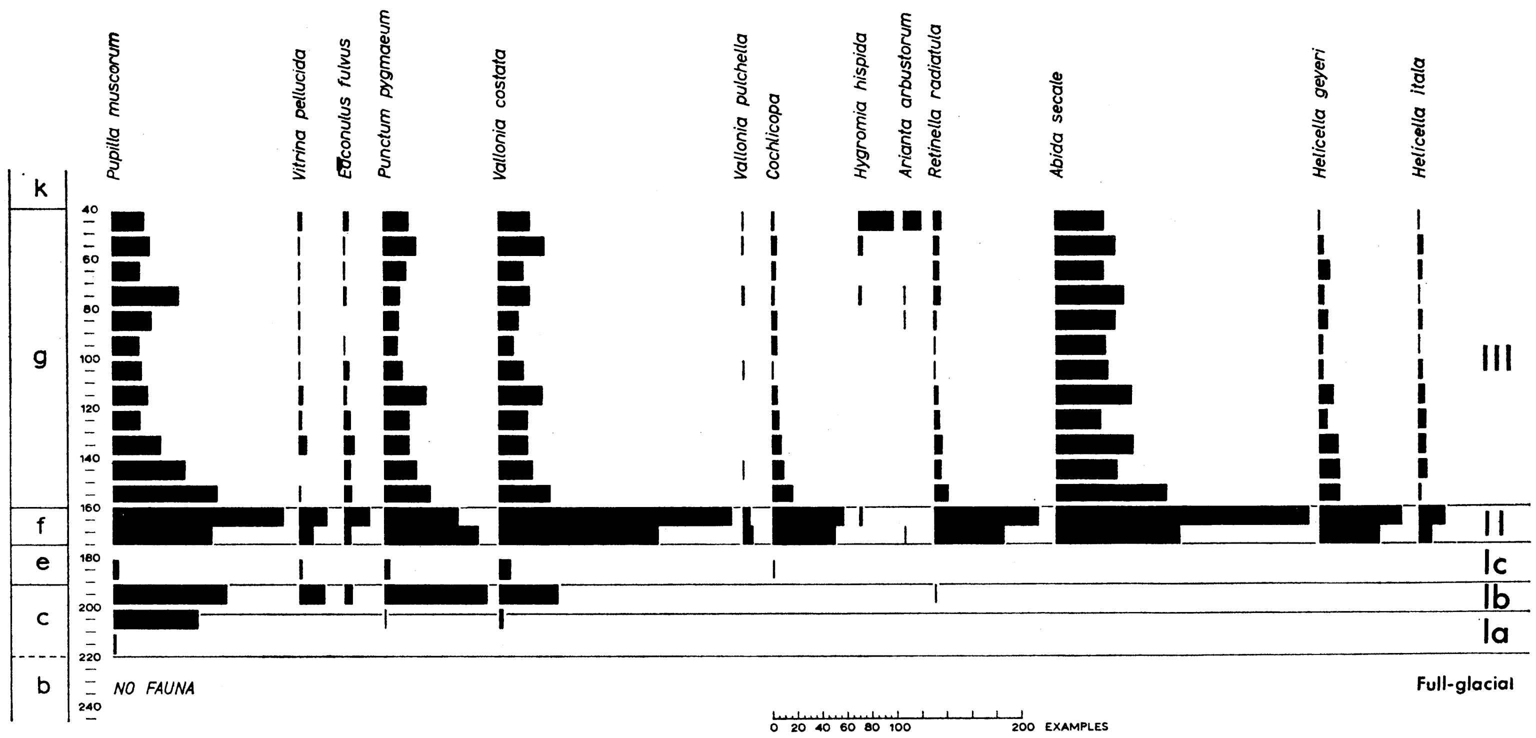

FIGURE 8. Molluscan histogram, Section *B*, Upper Halling; showing absolute abundance of species per 2 kg sample.

calcareous water broke out of the hillside some distance above the present position of the springs in the valley floor (figure 6). An account of the fauna of this tufa is outside the scope of the present paper; it is characterized by the appearance of the thermophilous species *Pomatias elegans* (Müller). The tufa shows a rather indefinite upward passage into the hillwash (*j*).

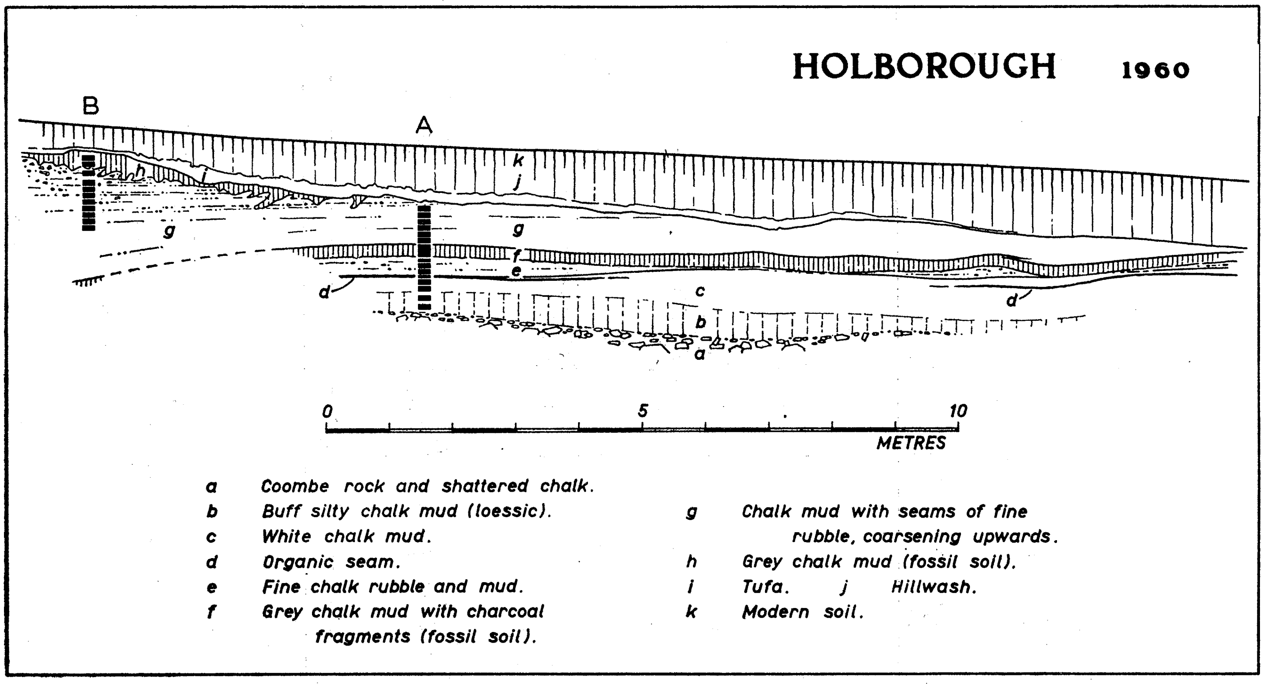

FIGURE 9. Measured drawing of Section *D*, Holborough, Kent (TQ/702626).

Samples from this section were taken at the two sites marked in figure 9. The histogram (figure 10) shows that the pattern of change agrees closely with that revealed at Upper Halling, except that the facies tends to be damper throughout, with smaller numbers of the xerophile *Abida secale*, and larger numbers of hygrophiles such as *Vallonia pulchella*, *Hygromia hispida* and *Arianta arbustorum*. A few *Succinea* appear in zone III.

The fauna of the soil (*f*) is not uniform, but shows marked changes through its thickness, suggesting that the Mollusca found are indeed representative of much of zone II in a highly condensed form. How such internal stratification arises in a soil is at present far from clear. Two sets of samples were taken, and the results, which are closely comparable, are presented in table 4.

Between 220 and 210 cm, at the top of division (*c*), there is a sharp increase in the abundance of Mollusca, without the appearance of any of the more thermophilous species which characterize zone II, exactly as at Upper Halling. The stratigraphy corresponds closely (figures 21*a*, *b*, plate 10). It seemed likely that this might represent the brief preAllerød climatic oscillation recognized within zone I in Denmark, North Germany and the Netherlands, known as the Bølling Oscillation (Iversen 1954; van der Hammen 1953, 1957*a*). The top of (*c*) locally showed a thin seam of dark structureless organic material (*d*). A radiocarbon assay by Dr Willis of a sample of this material, extracted from the section immediately to the left of Site *A*, yielded the following result:

Q 473   11 230 ± 230 B.C.

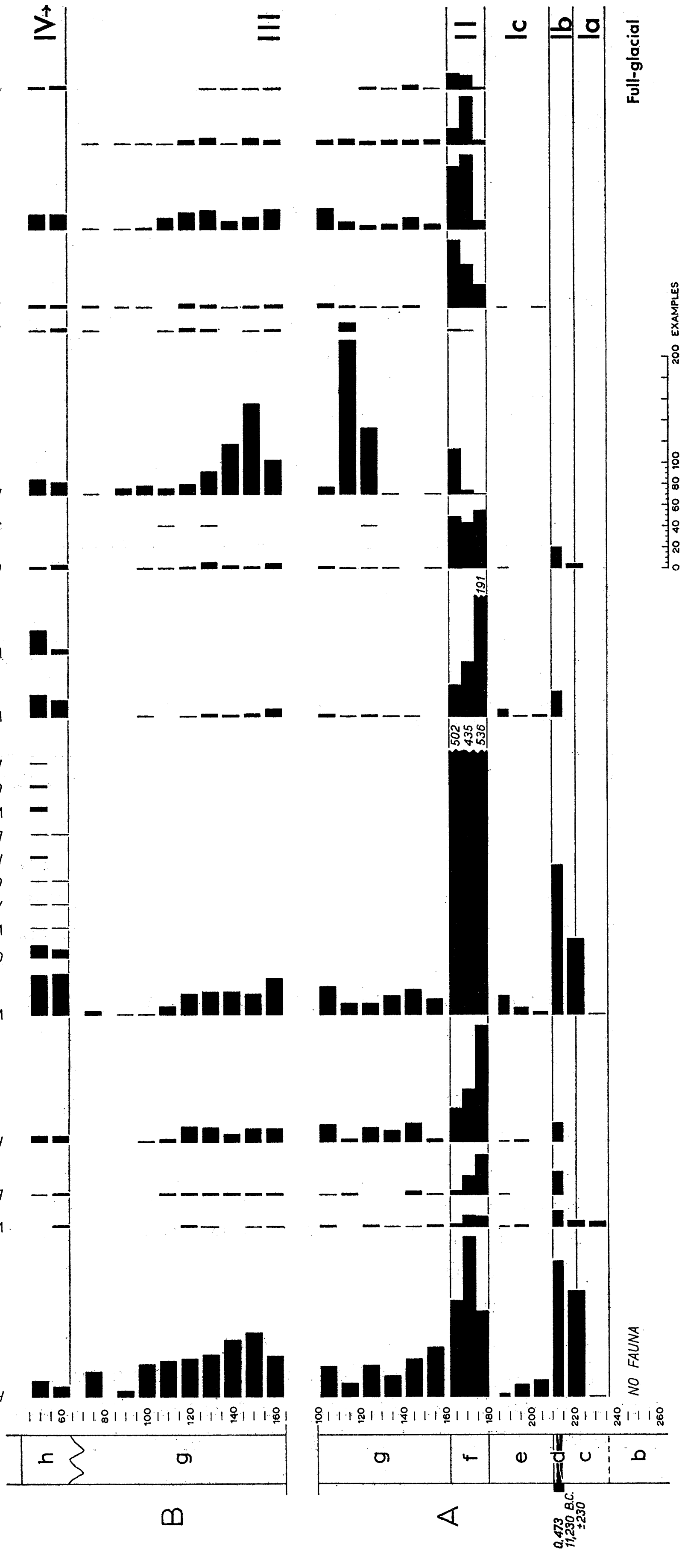

FIGURE 10. Molluscan histogram, Section *D*, Holborough; showing absolute abundance of species per 2 kg sample. In addition to the species shown a single example of *Columella columella* was recovered from a trial sample from the zone II soil.

This date is considerably earlier than the beginning of zone II at about 10 000 B.C., and must clearly be referred to zone I (Godwin & Willis 1961, p. 74). It seems also a little early for the end of the Bølling Oscillation, according to datings for this interval at present available, ranging from 11 300 ± 280 B.C. to 10 120 ± 140 B.C. (Firbas, Müller & Münnich 1955; Tauber 1960). In spite of this, the general parallelism with the north-west European sequence of climatic changes is so close that this evidence in Kent for a minor climatic improvement and subsequent deterioration, reflected both in the sediments and in the fauna, is correlated with some confidence with the Bølling Oscillation (see also § VII below).

A borehole at the Holborough Cement Works (figure 6; TQ/705626) penetrated the following deposits, resting on the Gault Clay at approximately 10 ft. (3·0 m) below Ordnance Datum (Dines *et al.* 1954, pp. 24, 125 and 143):

Loamy chalky rubble with flints	20 ft. (6·1 m)
Fine gravel with chalk	5 ft. (1·5 m)
Gault Clay	

This borehole is slightly less than 300 yards (275 m) east of Section *D*. Unfortunately, it is uncertain what part of the thickness penetrated belongs to the Late-glacial Period.

(*d*) *Other sections in the Medway Valley*

The two more northerly dry valley systems shown in figure 6 have not been examined closely. They contain sheets of Late-glacial chalk meltwater muds and rubbles as does the Upper Halling–Holborough dry valley, and the fossil rendsina representing zone II can be recognized in both. The only section which need be mentioned is one exposed in the north-east part of the large chalk quarry ½ mile N.N.W. of Halling (TQ/700648). Kennard (1944, p. 129) refers to the discovery here of two tusks of elephant, presumably mammoth, in 'well-bedded' chalky muds containing *Abida secale*, clearly referable to zone III.

To the east of the Medway Gap, the Chalk escarpment is mantled by many tongues and fans of similar deposits; they are shown on the recently published Maidstone Sheet of the Geological Survey (Sheet 288, 1958) included under the term 'Head'. At Aylesford, about 2½ miles N.W. of Maidstone, Burchell & Davis (1957) describe, underlying Post-glacial deposits, a section in bedded chalky meltwater deposits which form part of such a tongue, originating on the escarpment. Their molluscan lists, which represent a marsh facies, make it likely that at least zones II to III may be represented, as they suggest. On the other hand, a number of the species listed are otherwise unknown in the Late-glacial Period and it seems possible that some contamination of the samples may have occurred, perhaps from the overlying deposits.

(*e*) *Level of the River Medway during the Late-glacial Period*

No positive evidence is available bearing on this point. Borehole records, such as the one quoted above at the Holborough Cement Works, show that the sub-drift surface in the lower parts of the dry valleys, close to the tidal flat of the river, descends below present sea-level. The valleys are thus presumably graded to a buried channel, cut during the Last Glaciation. Over 30 ft. (9 m) of gravels underlie parts of the flood-plain in this area (Dines *et al.* 1954, pp. 144–5). The infill of the valleys merges into these fluviatile gravels bordering, and descending below, the alluvium of the flood-plain, but to what level or levels the Late-glacial deposits are graded is uncertain. It should be observed that the Full-glacial deposits within the dry valleys are in places rather thick. In the quarry ½ mile N.N.W. of Halling they are exposed to about 20 ft. (6 m), a thickness considerably greater than the overlying Late-glacial chalk meltwater muds at this point.

(*f*) *The site of 'Halling Man'*

In 1912 a temporary excavation immediately east of Halling Station (figure 6; TQ/705643) yielded, in deposits which were interpreted as belonging to a river terrace of the Medway, a human skeleton (Cook 1914). This has subsequently become known as 'Halling Man', and a date within an interstadial of the Last Glaciation has been suggested. The locality itself has been used as the type site of a 'Halling Stage' (King & Oakley 1936, p. 68; Zeuner 1945, p. 133, 1946, p. 193). Figure 6 shows that the Late-glacial deposits infilling the forked, dry valley to the west reach the river at this point, and their relation to the stratum in which the skeleton was found therefore becomes of interest.

Because of the somewhat unsatisfactory nature of the original paper and the present absence of a section, no final conclusions can be come to here, but the following appear likely. First, the appearance of a low river terrace with a surface at 15 ft. (4·9 m) O.D., separated from the flood-plain of the Medway by a bluff (Cook 1914, p. 213, Pl. 21, fig. 1), is illusory. This feature was almost certainly produced by a combination of natural hillwashing and repeated ploughing to the marsh edge. Secondly, it is probable that none of the deposits forming the 'terrace', beds 1 to 5 of Cook (1914, Pl. 22), including the 'skeleton stratum' (5), are fluviatile, but are hillwashes of Post-glacial age. This interpretation is supported by the published molluscan fauna, and by an unpublished photograph of the section at the site of the skeleton taken in 1912, preserved in Cook's MS. notebook in the British Museum (Natural History) and shown to me by Dr K. P. Oakley. It demonstrates clearly that the drawing of this section published by Cook is greatly idealized and that the appearance which is given of fluviatile bedding in the upper deposits is misleading. In fact, everything above bed 6, including the 'skeleton stratum', shows the characteristic aspect of the Post-glacial hillwashes so common in the area. According to A. S. Kennard (in Cook 1914, p. 216), the 'skeleton stratum' yielded examples of five species of land snails, of which four (*Pomatias elegans* (Müller), *Helicigona lapicida* (Linné), *Helix nemoralis* Linné, and *Retinella nitidula* (Draparnaud)) are thermophiles unknown in Britain in the Full-glacial and Late-glacial Periods. *Pomatias elegans* in particular suggests a date not before zone V (Early Boreal), at the earliest. It is interesting to note that in the section at Holborough this species is still absent from the Early Post-glacial fossil soil (*h*) and first appears in the overlying calcareous tufa (*i*), at the base of the hillwash.

In May 1962, two pieces of the actual matrix of the bones, weighing together about 80 g, were made available to the writer by Dr Oakley. These yielded a small molluscan fauna of undoubted Post-glacial character, including fragments of *Pomatias elegans* and *Helicigona lapicida*.


(*a*)

(*b*)

FIGURE 19. (*a*) Dover Hill, Folkestone, Kent (TR/235376). Allerød soil involved in freeze-thaw structures; beds lettered as in figure 2. (*b*) Oxted Limeworks, Surrey (TQ/380544). Beds lettered as in figure 11.

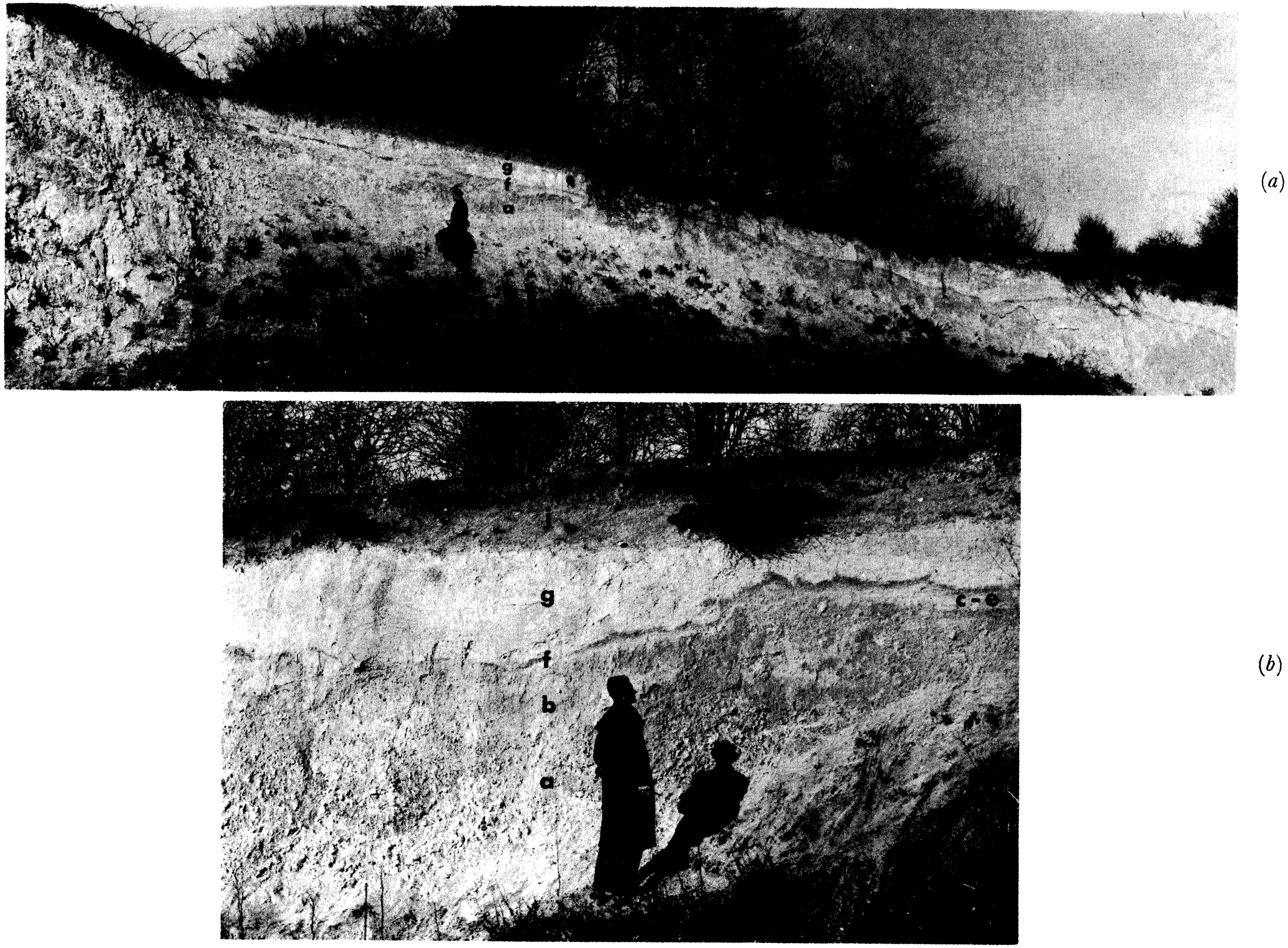

Figure 20. (*a*) Upper Halling, Kent; north face of Section *A* (TQ/688635). Margin of Full-glacial, Late-glacial and Post-glacial deposits infilling dry valley. (*b*) Upper Halling; extreme eastern end of north face of Section *A*. Allerød soil showing freeze-thaw structures. Key to figures (*a*) and (*b*): *a*, coombe rock; *b*, buff silty chalk rubble and mud (Full-glacial); *c–e*, zone I chalk muds; *f*, Allerød soil; *g*, zone III chalk muds; *j*, Post-glacial hillwash.

FIGURE 21. (*a*) Upper Halling, Kent; Section *B* (TQ/692635) at place where samples were taken. Beds lettered as in figure 7. (*b*) Holborough, Kent; Section *D* (TQ/702626) at place where samples '*A*' were taken. Beds lettered as in figure 9.

Beds 6 to 9, underlying the 'skeleton stratum', are of very different character. The upper part of these deposits can be seen in the photograph mentioned above. Coarse stratification is visible, and much chalk is present, contrasting in its whiteness with the darker deposits above. The abundant chalk suggests frost shattering in a cold climate, not the normal processes of weathering in a temperate climate. It is most likely that these deposits are of Last Glaciation age. It is suggested that they may in part represent the Late-glacial chalky infill of the dry valley to the west merging with low-level marginal gravels of the Medway.

If these views are correct, the Halling skeleton post-dates zone III, and is probably not older than the Early Boreal Period. The chemical and archaeological data, although somewhat ambiguous, are not opposed to this view; Dr Oakley has kindly written for this paper a summary of his recent work on these aspects of the Halling skeleton (Appendix II).

IV. Oxted, Surrey

The section shown in figure 11 and in figure 19*b*, plate 8, lies almost exactly 20 miles west of the Medway Valley sites. It is visible in the west face of the large chalk quarry north of Oxted (TQ/380544), and represents the infill of a shallow gully in the face of the escarpment. The deposits, which lie at the remarkably steep angle of about 28°, can be divided into a Post-glacial hillwash above, and into a series of periglacial rubbles and muds below. The meltwater muds (*b*) show clear bedding; they no doubt fan out over the low

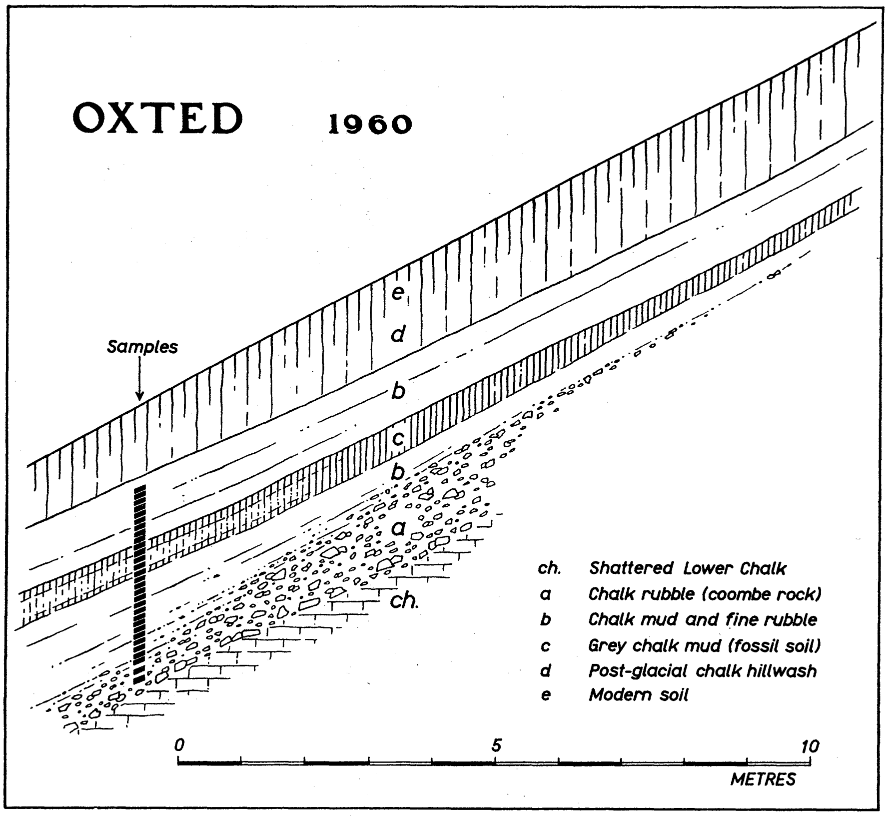

FIGURE 11. Measured drawing of section exposed in west face of Oxted Limeworks, Surrey (TQ/380544).

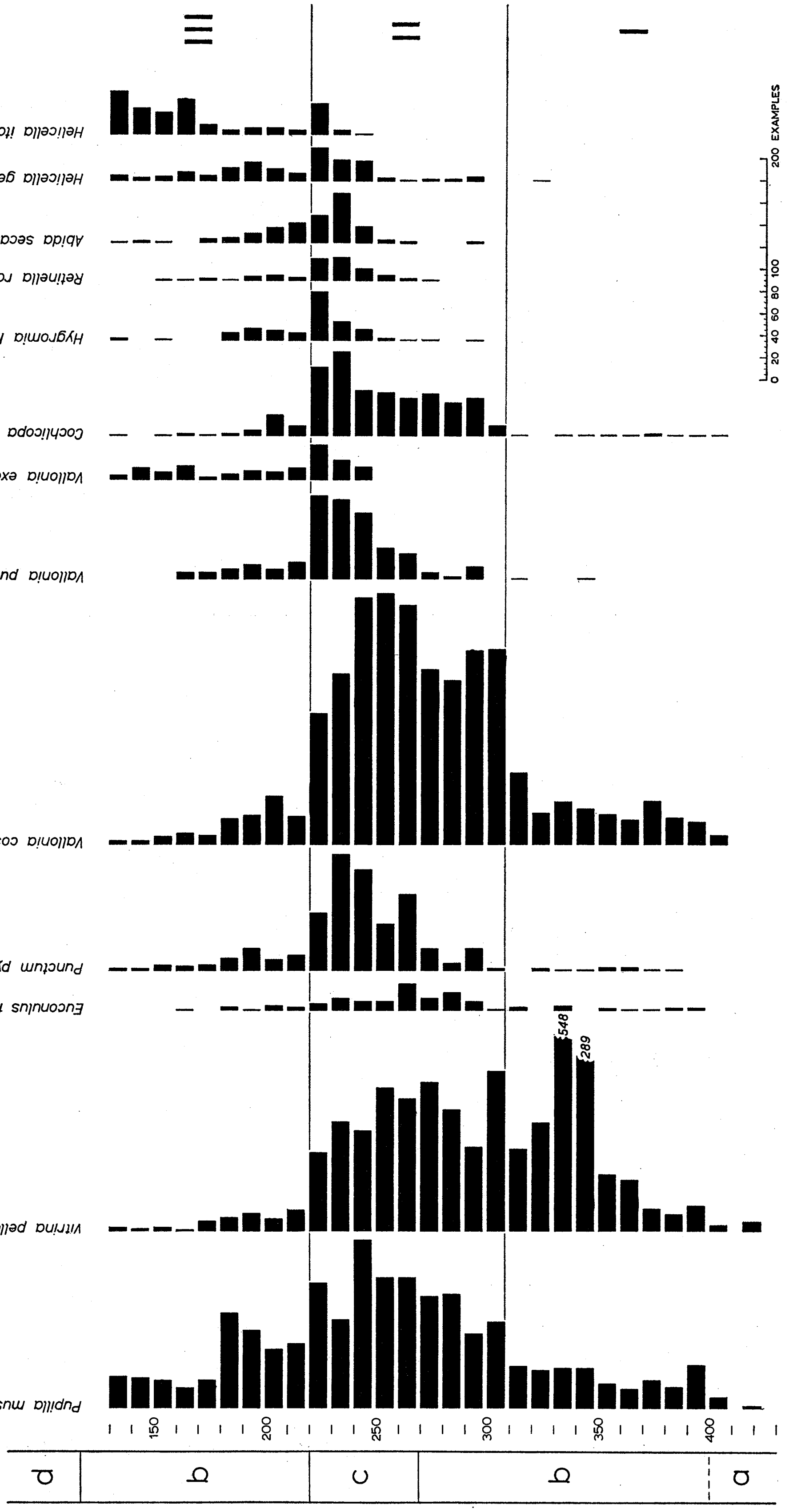

FIGURE 12. Molluscan histogram, Oxted; showing absolute abundance of species per 2 kg sample.

ground at the foot of the escarpment, but there are no sections and much of the land immediately below is obscured by old quarry dumps. The muds are divided by a fossil rendsina (*c*) containing occasional charcoal fragments, and correlated with the later part of zone II. No freeze-thaw structures were observed. The basal rubble (*a*) is locally cemented into a hard rock by crystalline calcite.

The molluscan histogram (figure 12) suggests the presence of zones I to III of the Late-glacial Period. Accumulation did not cease at the beginning of zone II but continued for some while; from the thickness of the soil (*c*), and from the way in which it is divided in places by a band of chalk mud relatively free of humic material, it is clear that a stable surface had difficulty in establishing itself. This is true also at Dover Hill, Folkestone, and the reason in both cases was doubtless the steepness of the hillsides on which the deposits rest. In contrast, on the relatively flat bottom of the Upper Halling–Holborough dry valley accumulation stopped immediately when the climate improved at the beginning of zone II, and the whole of that zone is therefore condensed within a fossil rendsina less than 20 cm in thickness.

Dover Hill and Oxted are the only two sections studied by the writer where a good record of molluscan changes within the Allerød Oscillation is preserved. The Oxted section yielded no clear evidence of the Bølling Oscillation.

V. Beachy Head, Sussex

At Beachy Head, south-west of Eastbourne, Sussex, the Chalk escarpment of the South Downs reaches the sea. This stretch of the escarpment is indented by a series of amphitheatre-like embayments, which Bull (1940) suggested were produced by nivation in an arctic climate. At Cow Gap, immediately to the east of Beachy Head, the infill of the most southerly of these features is to be seen in section along the cliff-top, above a series of terraced landslips (TV/595957). The surface of the solid Chalk beneath the drift is considerably more irregular than the present surface of the ground, showing many small hollows and channels, probably cut by solifluxion or meltwater during the Last Glaciation.

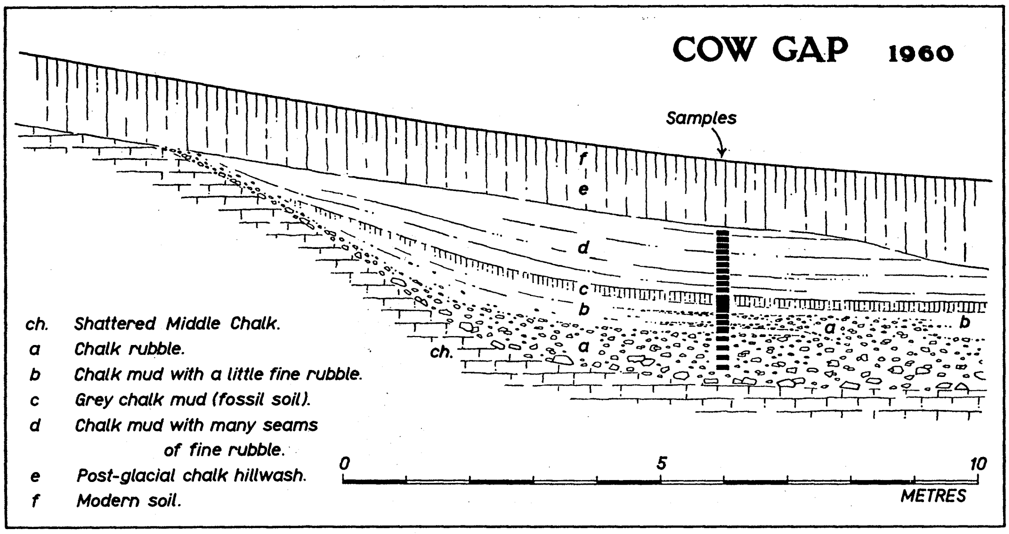

Figure 13. Measured drawing of section at Cow Gap, near Beachy Head, Sussex (TV/595957).

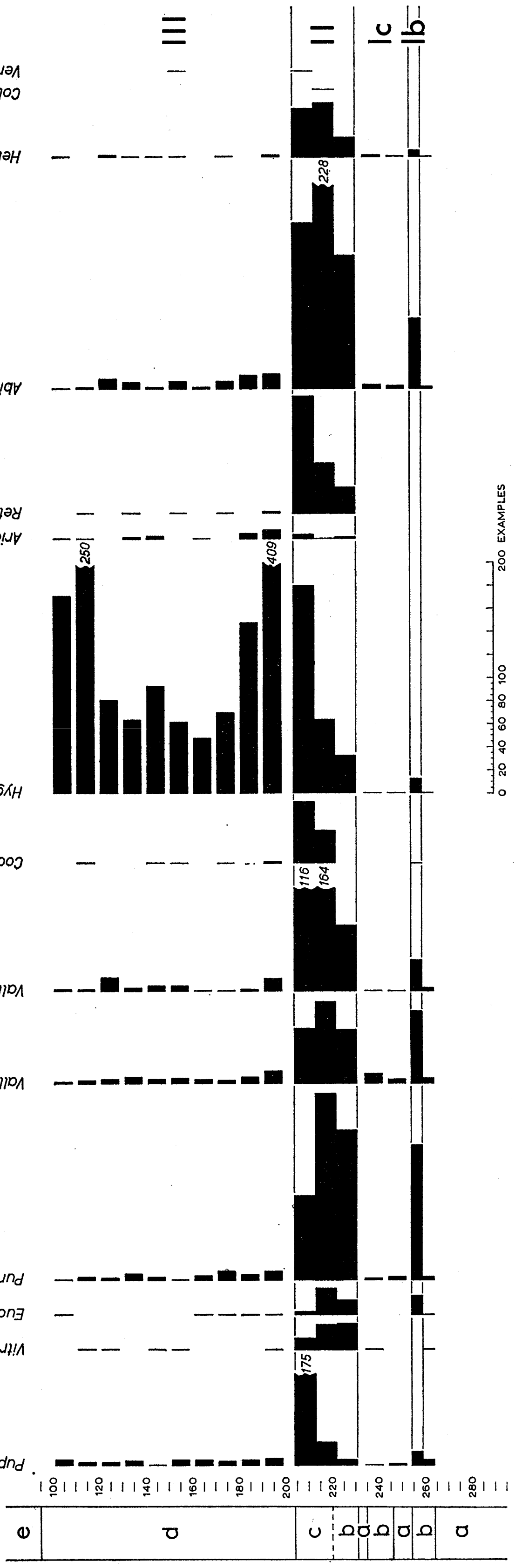

FIGURE 14. Molluscan histogram, Cow Gap; showing absolute abundance of species per 2 kg sample.

TABLE 1. FOLKESTONE, DOVER HILL

cm ...	585–595	570–580	555–565	540–550	525–535	510–520	495–505	480–490	465–475	450–460	435–445	420–430	405–415	390–400	376–386	360–370	350–360
Cochlicopa spp.	—	—	—	—	—	—	—	—	—	—	4	12	18	38	39	38	37
Cochlicopa lubrica (Müller)	—	—	—	—	—	—	—	—	—	—	×	×	×	×	×	×	×
Cochlicopa lubricella (Porro)	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	×	×
Pupilla muscorum (Linné)	3	4	2	8	11	42	16	7	10	6	23	23	50	69	67	55	74
Abida secale (Draparnaud)	—	—	—	—	—	—	—	—	—	—	—	—	1	2	89	202	122
Vallonia costata (Müller)	—	—	1	7	28	69	11	1	2	2	99	87	200	181	158	242	158
Vallonia pulchella (Müller)	—	—	—	—	—	—	—	—	—	—	—	—	—	2	46	47	50
Arianta arbustorum (Linné)	—	—	—	—	—	—	—	—	—	—	—	—	—	—	2	1	1
Hygromia hispida (Linné)	—	—	—	—	—	—	—	—	—	—	—	2	4	31	57	89	101
Helicella itala (Linné)	—	—	—	—	—	—	—	—	—	—	—	—	—	—	4	18	9
Punctum pygmaeum (Draparnaud)	—	—	—	2	22	56	—	—	—	—	101	67	113	81	79	72	44
Euconulus fulvus (Müller)	—	—	—	—	—	10	3	5	—	—	3	7	25	28	20	11	5
Retinella radiatula (Alder)	—	—	—	—	—	—	—	—	—	—	—	—	1	9	63	86	40
Vitrina pellucida (Müller)	—	1	2	1	10	69	2	2	—	3	46	29	35	35	24	20	18
Agriolimax sp.	—	—	—	—	—	—	—	—	—	—	—	—	1	—	—	13	9

cm ...	330–340	315–325	300–310	285–295	270–280	255–265	240–250	225–235	210–220	195–205	180–190	165–175	150–160	135–145	120–130	105–115	90–100
Cochlicopa spp.	2	1	1	2	—	—	—	—	1	2	1	—	1	2	1	1	—
Cochlicopa lubrica (Müller)	—	—	—	×	—	—	—	—	—	—	—	—	—	×	—	—	—
Cochlicopa lubricella (Porro)	—	—	×	—	—	—	—	—	—	×	—	—	—	—	—	—	—
Pupilla muscorum (Linné)	48	20	19	24	17	9	5	11	15	15	11	5	28	35	19	17	19
Abida secale (Draparnaud)	22	21	24	12	8	4	4	2	8	16	8	4	10	36	19	7	10
Vallonia costata (Müller)	25	28	41	21	15	10	6	8	14	26	11	16	25	41	22	17	15
Vallonia pulchella (Müller)	—	—	—	—	—	—	—	—	—	—	—	—	—	1	1	—	1
Arianta arbustorum (Linné)	—	—	—	—	—	—	—	—	1	1	—	—	—	1	—	1	—
Hygromia hispida (Linné)	62	39	75	119	89	153	119	57	70	78	77	64	85	69	63	113	78
Helicella itala (Linné)	19	8	4	6	13	9	20	5	2	10	6	4	3	3	2	1	7
Punctum pygmaeum (Draparnaud)	23	18	30	25	11	4	4	10	7	15	6	5	19	38	20	9	17
Euconulus fulvus (Müller)	3	1	3	1	—	—	—	—	1	1	—	3	5	4	5	1	4
Retinella radiatula (Alder)	6	5	4	—	1	1	2	—	—	2	—	3	3	3	7	3	1
Vitrina pellucida (Müller)	11	11	6	4	3	5	2	4	1	4	4	2	8	6	7	1	1

TABLE 2. FOLKESTONE, CASTLE HILL

cm …	206–214	196–204	186–194	179·5–184	175–179·5	167·5–175	160–167·5	150–158	140–148	130–138	120–128	110–118	100–108	90–98
Catinella arenaria (Bouchard-Chantereaux)	—	—	1	7	1	1	1	—	—	—	—	—	—	—
Succinea pfeifferi Rossmässler	—	—	—	—	—	—	—	8	1	—	1	—	—	—
Cochlicopa spp.	—	1	1	—	—	5	11	2	3	2	—	1	—	—
Cochlicopa lubrica (Müller)	—	—	—	—	—	×	×	—	—	×	—	—	—	—
Cochlicopa lubricella (Porro)	—	—	—	—	—	—	—	—	×	—	—	—	—	—
Columella columella (Martens)	—	—	—	2	1	6	67	391	44	6	—	—	1	1
Vertigo pygmaea (Draparnaud)	—	—	—	—	—	1	—	—	—	—	1	—	—	—
Pupilla muscorum (Linné)	—	3	9	97	27	23	54	71	30	17	6	6	4	3
Abida secale (Draparnaud)	—	—	2	2	2	24	40	12	13	8	5	3	1	20
Vallonia costata (Müller)	1	1	5	2	5	65	106	14	18	23	14	13	4	—
Vallonia pulchella (Müller)	1	2	3	10	23	155	227	39	16	12	2	4	3	11
Arianta arbustorum (Linné)	1	1	—	1	—	1	3	5	7	2	—	1	1	2
Hygromia hispida (Linné)	—	—	2	3	4	24	95	436	259	103	51	35	59	99
Helicella itala (Linné)	—	—	—	—	—	3	4	—	—	2	1	1	—	1
Punctum pygmaeum (Draparnaud)	—	1	—	—	4	21	14	12	6	11	2	—	—	—
Euconulus fulvus (Müller)	—	1	—	—	2	2	1	16	3	2	—	—	—	—
Retinella radiatula (Alder)	—	—	1	—	2	14	33	7	1	4	1	—	—	—
Vitrina pellucida (Müller)	—	3	3	21	16	19	7	1	1	5	6	1	—	—
Agriolimax sp.	—	—	—	—	1	2	5	—	—	—	—	—	—	—

TABLE 3. UPPER HALLING

	Section *B*																			Section *A*
cm …	221–276 (6 samples)	211–219	201–209	191–199	181–189	167·5–175	160–167·5	151–158	141–149	131–139	121–129	111–119	101–109	91–99	81–89	71–79	61–69	51–59	41–49	zone II soil (13 cm thick)
Cochlicopa spp.	—	—	—	—	1	50	57	16	9	7	5	4	1	4	4	2	3	4	2	20
Cochlicopa lubrica (Müller)	—	—	—	—	—	×	×	×	—	×	×	—	—	—	×	×	—	×	×	—
Cochlicopa lubricella (Porro)	—	—	—	—	—	×	×	×	×	×	×	×	—	×	×	—	×	×	—	×
Pupilla muscorum (Linné)	—	2	68	91	4	79	137	84	58	38	22	28	23	21	31	43	22	30	25	69
Abida secale (Draparnaud)	—	—	—	—	—	99	203	89	49	62	36	61	42	40	48	55	39	48	39	62
Vallonia costata (Müller)	—	—	3	47	9	127	187	41	26	23	23	35	20	12	16	25	20	37	25	96
Vallonia pulchella (Müller)	—	—	—	—	—	8	6	—	1	—	—	—	1	—	—	2	—	1	1	4
Arianta arbustorum (Linné)	—	—	—	—	—	1	—	—	—	—	—	—	—	—	1	1	—	—	7	—
Hygromia hispida (Linné)	—	—	—	—	—	—	2	—	—	—	—	—	—	—	—	2	—	3	28	—
Helicella geyeri (Soós)	—	—	—	—	—	48	66	16	16	15	6	11	5	3	7	4	9	4	1	28
Helicella itala (Linné)	—	—	—	—	—	10	21	2	7	6	6	5	3	1	3	1	3	4	1	4
Punctum pygmaeum (Draparnaud)	—	—	1	82	4	75	59	37	26	20	20	34	15	11	12	13	18	26	20	64
Euconulus fulvus (Müller)	—	—	—	6	—	5	20	6	5	8	5	2	4	1	—	2	1	1	4	9
Retinella radiatula (Alder)	—	—	—	1	—	56	84	11	5	6	4	3	1	1	2	5	4	4	6	24
Vitrina pellucida (Müller)	—	—	—	20	2	11	22	1	—	6	2	3	1	1	1	1	1	1	3	3
Agriolimax sp.	—	—	—	2	—	1	2	—	—	—	—	—	—	—	—	—	—	—	—	1

TABLE 4. HOLBOROUGH (SECTION *D*)

	site A																		site B										
								first samples		second samples																		
cm …	242–265 (2 samples)	227–235	217–225	210–215	201–208	192–199	185–190	172–180	162–170	174–180	168–174	162–168	151–159	141–149	131–139	121–129	111–119	101–109	156–164	146–154	136–144	126–134	116–124	106–114	96–104	86–94	71–79	56–64	46–54
Carychium tridentatum (Risso)	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	8	12
'*Succinea*' sp.	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1	—	—	—	—	—	1	—	1	—	—	—	—	—
Cochlicopa spp.	—	—	4	20	—	—	1	60	45	55	43	49	1	—	1	1	1	2	5	2	3	6	2	1	1	—	—	4	2
Cochlicopa lubrica (Müller)	—	—	×	×	—	—	—	×	×	×	×	×	×	—	—	—	—	—	×	×	—	×	—	—	—	—	—	×	×
Cochlicopa lubricella (Porro)	—	—	—	—	—	—	—	—	×	—	×	×	—	—	—	—	—	—	—	—	×	—	—	—	—	—	—	×	—
Vertigo pusilla Müller	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1	1
Pupilla muscorum (Linné)	—	1	100	128	16	13	3	75	106	81	151	91	47	36	20	30	13	29	39	61	54	40	36	34	29	6	24	10	15
Abida secale (Draparnaud)	—	—	—	—	—	—	—	8	83	8	70	59	5	11	5	4	7	20	19	12	8	18	16	11	2	1	1	14	14
Acanthinula aculeata (Müller)	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1	1
Vallonia costata (Müller)	—	1	72	141	3	7	18	458	420	536	435	502	15	24	18	11	11	27	35	20	22	22	20	8	1	1	4	39	38
Vallonia pulchella (Müller)	—	—	—	24	2	1	7	164	58	191	52	30	—	1	1	2	1	3	8	3	2	3	1	—	1	—	—	7 + 9	9 + 13
Vallonia excentrica Sterki	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	2 + 2	9 + 12
Clausilia bidentata (Ström)	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1	1
Arianta arbustorum (Linné)	—	—	—	—	—	—	—	1	4	—	1	2	—	—	—	—	8	—	2	1	—	2	3	1	—	—	1	3	1
Helix nemoralis Linné	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	2
Hygromia hispida (Linné)	—	—	—	—	—	—	—	1	13	1	4	43	1	—	1	63	146	7	33	86	48	22	10	6	9	6	2	12	15
Helicella geyeri (Soós)	—	—	—	—	—	—	—	4	21	4	45	15	4	4	4	3	5	4	4	6	1	6	4	1	1	1	1	—	—
Helicella itala (Linné)	—	—	—	—	—	—	—	1	8	2	13	15	1	4	1	2	—	—	1	1	1	1	—	—	—	—	—	3	3
Punctum pygmaeum (Draparnaud)	—	—	—	9	—	2	1	104	34	110	50	32	3	18	11	14	3	17	11	11	8	14	15	3	1	—	—	6	6
Discus rotundatus (Müller)	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1	1
Euconulus fulvus (Müller)	—	—	—	22	—	—	1	33	13	38	18	4	1	4	—	—	2	1	2	2	2	2	2	2	—	—	—	2	1
Vitrea contracta (Westerlund)	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	4
Oxychillus cellarius (Müller)	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	2
Retinella radiatula (Alder)	—	—	—	—	1	—	1	27	39	22	41	64	—	2	1	1	2	4	3	2	1	3	4	—	1	1	2	3	3
Retinella pura (Alder)	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1
Vitrina pellucida (Müller)	—	5	6	15	—	2	1	5	14	10	11	3	2	1	1	2	—	2	1	1	—	1	2	—	—	—	—	2	—
Agriolimax sp.	—	—	—	8	—	—	—	1	—	1	—	1	—	—	—	1	—	—	—	—	1	—	1	—	—	—	—	—	—

TABLE 5. OXTED

cm ...	430–438	415–423	400–408	390–398	380–388	370–378	360–368	350–358	340–348	330–338	320–328	310–318	300–308	290–298	280–288
Cochlicopa spp.	—	—	1	1	1	2	1	1	1	1	—	1	9	34	30
Cochlicopa lubrica (Müller)	—	—	—	—	×	—	—	—	—	—	—	—	×	×	×
Cochlicopa lubricella (Porro)	—	—	—	×	—	—	—	—	×	×	—	—	—	×	×
Pupilla muscorum (Linné)	—	2	10	39	19	25	17	22	36	36	34	37	78	67	103
Abida secale (Draparnaud)	—	—	—	—	—	—	—	—	—	—	—	—	—	2	—
Vallonia costata (Müller)	—	—	8	20	24	39	22	27	32	38	28	64	176	175	148
Vallonia pulchella (Müller)	—	—	—	—	—	—	—	—	1	—	—	1	—	11	2
Vallonia excentrica Sterki	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Hygromia hispida (Linné)	—	—	—	—	—	—	—	—	—	—	—	—	—	1	—
Helicella geyeri (Soós)	—	—	—	—	—	—	—	—	—	—	1	—	—	4	2
Helicella itala (Linné)	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Punctum pygmaeum (Draparnaud)	—	—	—	—	1	1	3	3	1	1	2	—	2	20	7
Euconulus fulvus (Müller)	—	—	—	2	2	1	1	2	—	4	—	3	1	8	16
Retinella radiatula (Alder)	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Vitrina pellucida (Müller)	—	8	5	23	15	20	46	51	289	548	98	74	145	76	110
Agriolimax sp.	—	—	1	—	—	1	1	1	—	—	—	1	—	1	1

cm ...	270–278	260–268	250–258	240–248	230–238	220–228	210–218	200–208	190–198	180–188	170–178	160–168	150–158	140–148	130–138
Cochlicopa spp.	38	34	39	41	76	62	9	19	5	2	1	2	1	—	1
Cochlicopa lubrica (Müller)	×	×	×	×	×	×	×	×	—	—	—	—	—	—	—
Cochlicopa lubricella (Porro)	×	×	×	×	×	×	×	—	×	×	—	—	—	—	×
Pupilla muscorum (Linné)	101	118	118	152	80	113	58	53	70	86	25	18	25	27	28
Abida secale (Draparnaud)	—	2	3	15	45	25	18	14	9	5	4	—	1	2	1
Vallonia costata (Müller)	158	216	227	223	154	120	25	43	26	23	8	10	7	3	3
Vallonia pulchella (Müller)	6	23	28	21 + 39	22 + 51	20 + 56	5 + 10	5 + 4	3 + 10	3 + 6	1 + 5	2 + 4	—	—	—
Vallonia excentrica Sterki	—	—	—	4 + 8	5 + 12	8 + 23	4 + 7	4 + 3	2 + 6	2 + 4	0 + 3	4 + 9	2 + 5	6 + 5	2 + 2
Hygromia hispida (Linné)	1	1	2	10	17	44	7	9	11	7	—	—	1	—	2
Helicella geyeri (Soós)	2	1	3	18	19	30	7	11	17	12	5	8	4	3	5
Helicella itala (Linné)	—	—	—	1	4	28	4	6	6	4	9	32	20	24	39
Punctum pygmaeum (Draparnaud)	20	69	42	91	105	52	14	10	20	11	5	4	5	2	2
Euconulus fulvus (Müller)	11	26	8	8	11	6	3	4	1	3	—	1	—	—	—
Retinella radiatula (Alder)	1	2	5	11	21	20	3	5	4	1	2	1	1	—	—
Vitrina pellucida (Müller)	135	120	130	91	99	71	19	11	16	12	9	1	3	2	3
Agriolimax sp.	1	1	—	2	3	3	1	1	—	—	—	—	—	—	—

TABLE 6. COW GAP

cm ...	270–322 (4 samples)	259–264	254–259	244–252	234–242	222–231	213–222	205–213	191–199	181–189	171–179	161–169	151–159	141–149	131–139	121–129	111–119	101–109
Cochlicopa spp.	—	1	—	—	—	—	28	53	2	—	1	—	1	1	—	—	1	—
Cochlicopa labrica (Müller)	—	×	—	—	—	—	×	×	—	—	—	—	—	—	—	—	×	—
Cochlicopa lubricella (Porro)	—	—	—	—	—	—	×	×	—	—	×	—	—	—	—	—	—	—
Columella columella (Martens)	—	—	—	—	—	—	1	—	—	—	—	—	—	—	—	—	—	—
Vertigo pygmaea (Draparnaud)	—	—	—	—	—	—	—	1	—	—	—	—	1	—	—	—	—	—
Pupilla muscorum (Linné)	—	5	12	2	1	5	20	175	6	5	4	5	5	1	4	3	3	5
Abida secale (Draparnaud)	—	2	61	3	4	115	228	143	13	12	7	2	7	2	6	9	2	1
Vallonia costata (Müller)	—	5	63	4	9	47	71	48	11	6	3	4	5	4	6	4	3	2
Vallonia pulchella (Müller)	—	3	27	1	1	57	164	116	11	2	1	1	5	5	3	12	2	2
Arianta arbustorum (Linné)	—	—	—	—	—	2	1	4	8	3	—	1	—	3	2	—	1	1
Hygromia hispida (Linné)	—	1	13	1	1	33	64	180	409	148	70	48	62	93	64	81	250	171
Helicella itala (Linné)	—	1	6	1	2	17	47	42	2	—	1	—	1	1	1	2	—	1
Punctum pygmaeum (Draparnaud)	—	3	119	3	2	130	162	73	8	5	8	4	1	3	6	2	3	1
Euconulus fulvus (Müller)	—	1	17	—	—	13	23	3	1	1	1	1	—	—	—	—	—	1
Retinella radiatula (Alder)	—	—	—	—	—	23	44	103	2	—	1	—	1	—	1	—	1	—
Vitrina pellucida (Müller)	—	1	2	—	1	23	22	10	1	—	—	—	1	1	—	1	1	—
Agriolimax sp.	—	—	—	—	—	1	7	15	—	—	—	—	—	—	—	—	—	—

In these depressions lie considerable thicknesses of coarse coombe rock, particularly at the northern end of the section. Above are bedded chalky meltwater muds, and finally, irregularly capping the whole section, is a complex sequence of brown or reddish humic chalk hillwashes belonging to the Post-glacial Period.

The relations of these deposits are simplest at the south end of the hollow, where the section shown in figure 13 was measured in 1960. The meltwater muds are divided by a faint grey fossil soil (*c*), which apart from occasional resistant charcoal fragments has lost the greater part of its organic content, probably through oxidation; it can be seen clearly only in particular states of the weather.

The molluscan histogram (figure 14) reveals a pattern very similar to that of the North Downs sections, with two sharp peaks in abundance which are correlated with the Bølling and Allerød Oscillations respectively. The fossil soil probably reflects the stoppage in accumulation during most of zone II. The seam of chalk mud correlated with the Bølling Oscillation is abruptly covered by coarser material, muds and rubbles with an impoverished fauna, exactly as in the Upper Halling–Holborough dry valley, and probably indicating a resumption of frost shattering on the slopes above during zone I*c*. The four standard samples taken from within the basal rubble yielded only a few shell fragments, but subsequently a larger sample weighing about 6 kg collected from the middle of this division provided the following Mollusca: *Pupilla muscorum* (1), *Vallonia costata* (3), *V. pulchella* (1), *Hygromia hispida* (2), *Helicella itala* (4) and *Punctum pygmaeum* (1).

VI. CRYOTURBATION STRUCTURES

At Folkestone, and in the sections around Upper Halling in the Medway Valley, the Late-glacial deposits show disturbances of a peculiar kind.

At Dover Hill, the Allerød soil is thrown into striking folds (figure 2 and figure 19*a*, plate 8). In the left-hand part of the section this horizon shows evidence of considerable foreshortening by thrusting and imbrication, and it therefore seems probable that the large-scale disturbances were mainly produced by mass sliding down the hillside, at a time when the chalk muds were saturated. It is difficult to envisage this happening under present-day climatic conditions, even with a greatly raised watertable, for drainage on this open hillside is excellent. A process of repeated freezing and thawing in frozen ground is suggested, and that this in fact occurred is demonstrated by the frequent presence within the upper part of the chalk muds of 'nests' of coarser chalk fragments, notably in the core of the bowl-shaped structure visible in the soil (*c*) at the left-hand end of the face. Such segregation of coarse from fine material is characteristic of deposits subjected to frost-heaving (Paterson 1940). It should be noted, however, that it does not necessarily imply the occurrence of permanently frozen ground (*perennial tjaele*, or *permafrost*), but might be brought about by severe repeated annual freezing (*annual tjaele*).

Some of the disturbances exhibited by the Allerød soil at Section *B* at Upper Halling are shown in figures 15 and 16; they were drawn by tracing directly from the face of the section and later reducing with a pantograph. They indicate that a good deal of horizontal movement must locally have occurred, even on a slope only 1° or 2°. Thus figure 15 shows clear evidence of a crumpling and imbrication of the soil caused by a movement from right to left, disrupted slivers being forced over one another. Such disturbances were probably produced by a sliding downhill under gravity of a superficial thawed layer resting on frozen ground. Some must have developed when part of the overlying muds (g) were already in existence, in view of the many flame-like and detached fragments of the soil in the deposit above. It is not easy to see detail within the chalky muds and rubbles; it does appear that most of these particular disturbances die away rather rapidly upwards, but a few can be traced clearly as far as the present surface of the ground. It seems likely that they were being produced *pari passu* with the laying down of the zone III deposits.

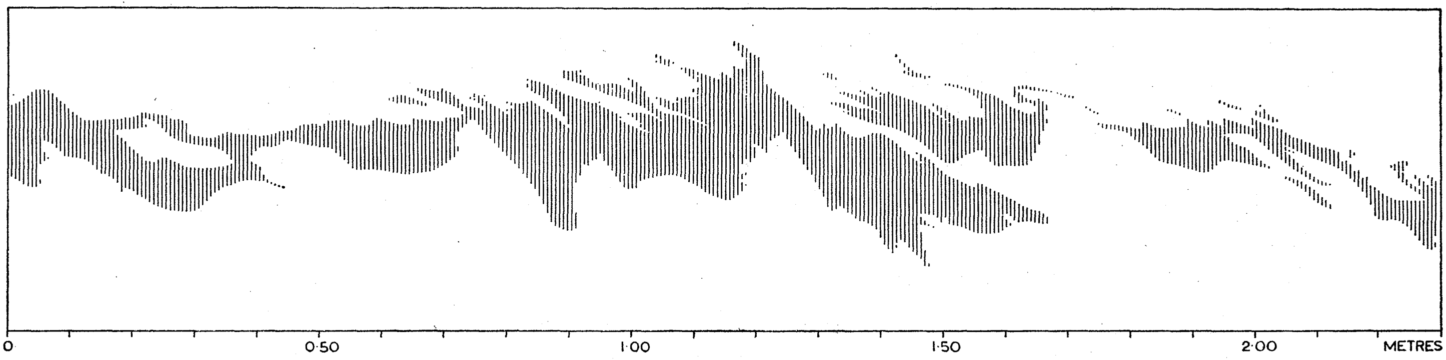

FIGURE 15. Freeze-thaw structures in zone II soil, Section *B*, Upper Halling; visible at right-hand end of figure 7.

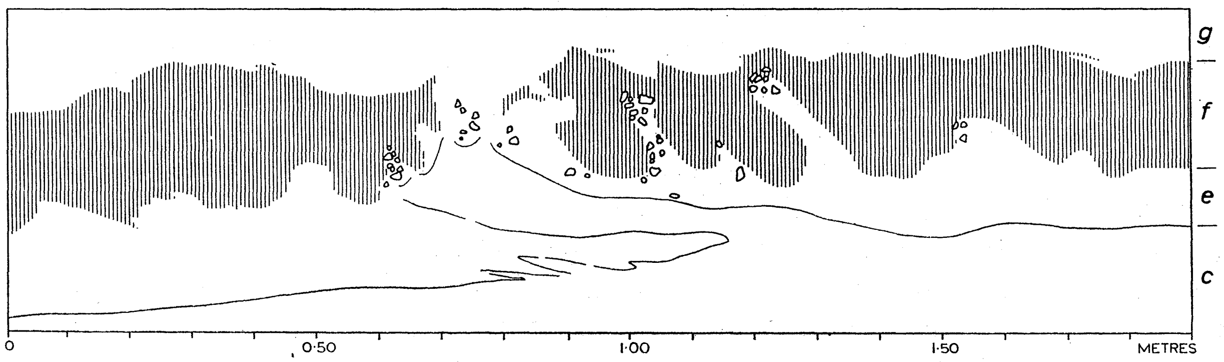

FIGURE 16. Freeze-thaw structures in zone II soil, Section *B*, Upper Halling; visible at left-hand end of figure 7.

The disturbances shown in figure 16 provide evidence of vertical as well as horizontal movements. Within the rubbly chalk mud (e) which underlies the soil, a process of repeated freezing and thawing has brought about a segregation of the coarser fragments into the crests of ridges rising up into the soil; in horizontal section these would probably delimit a pattern of small-scale frost-polygons. The upper surface of the soil is here little disturbed, which suggests that frost-heaving began to occur immediately the climate deteriorated in zone III and before the first sheet of chalk mud had been deposited. The lobe-like sinkings are very similar to structures described from an Allerød layer within the Coversands at Uchelen in the Netherlands, although their extreme form, the 'drip-structures' considered to be diagnostic of a *perennial tjaele*, were not observed at Upper Halling (van der Hammen & Maarleveld 1952).

In Section *A* at Upper Halling further disturbances are visible; those shown in figure 20*b* plate 9, are typical. In places there is evidence of considerable vertical heaving. At one spot, immediately below the road (TQ/689635), a mass of the basal coombe rock can be seen to have burst upwards into the overlying deposits, completely disrupting the Allerød soil.

None of the cryoturbation structures described above provides, perhaps, conclusive evidence for the existence of permanently frozen ground. In aggregate, however, they do suggest that true *perennial tjaele* may have occurred as local patches in south-east England during zone III.

VII. A NOTE ON ZONAL BOUNDARIES

Correlation between these sections depends on two basic assumptions: namely, that the stratigraphy and lithological character of the deposits, and that certain abrupt changes in the abundance of Mollusca within the deposits, are controlled directly by climate; it is based only secondarily on the detailed composition of the molluscan assemblages themselves. It remains to be considered to what extent boundaries established in this way will correspond with those of the standard Late-glacial climatic zones, with which they have been equated.

The two boundaries based on climatic deteriorations, i.e. I*b*/I*c* and II/III, present no difficulty. Such boundaries are likely to be synchronous over wide areas, since the effect of a climatic deterioration should be virtually immediate, whether expressed by a change in the stratigraphy, or in the fauna, or in a drop in the ratio of tree pollen to herbaceous pollen. Radiocarbon dates at present available from north-west Europe suggest a placing of the zone I*b*/I*c* boundary at between about 10150 and 10400 B.C. (Firbas *et al.* 1955; van der Hammen 1957*a*; Tauber 1960) and the II/III boundary at approximately 8800 B.C. (Godwin & Willis 1959; Godwin 1960).

The zone I/II boundary at Dover Hill and at Oxted has been drawn at that level where there is a sharp increase in the abundance of the hardy species of Mollusca already present, not at a rather higher level where less hardy species such as *Abida secale* first appear (figures 3 and 12). Such a boundary is not dependent on migration and is likely to correspond closely with climatic improvement. Possibly, it may tend to be a little earlier than the I/II boundary as employed palynologically, based on a rise in the ratio of arboreal pollen, for trees would take longer than Mollusca to spread and multiply. But this discrepancy is unlikely to be serious.

Only one of the sections studied, Dover Hill, has provided a zone II radiocarbon date. It is uncertain how much time was necessary for the formation of the rendsina soil which lies at the top of zone II at this site, but the date 9984 ± 210 B.C. given by charcoal fragments from its upper part is unexpectedly early. If the opening of zone II has been correctly placed at 445 cm, it seems certain that we must allow rather more time than the dating suggests for the accumulation of nearly a full metre of intervening deposits, for the molluscan changes observed in those deposits, and for the partial formation of the soil itself. In the Netherlands, the Allerød charcoal layers seem everywhere to belong to near the end of the period (Hijszeler 1957; van der Hammen 1957*b*). The anomaly must for the present remain unexplained.

The beginning of the Bølling Oscillation in North-West Europe has not been securely defined. Van der Hammen (1953; 1957*a*) points out that the beginning of Iversen's zone I*b* ('Bølling Oscillation *sensu stricto*') is based palynologically on the first appearance of tree birches, and that this boundary is likely to be diachronous, since it is controlled by migration. He therefore favours a downward extension to include Iversen's zone I*a* ('Bølling Oscillation *sensu lato*') and suggests drawing a lower limit at the first evidence of climatic improvement detectable by pollen analysis—the rising of the *Artemisia* curve at, perhaps, 11 300 to 11 400 B.C. (van de Hammen 1957*a*). For convenience, the writer has retained the terms I*a* and I*b*, drawing the boundary in the histograms at that level where the abundance of Mollusca rises most steeply. It should be noted, however, that it is quite uncertain how this line corresponds with the I*a*/I*b* boundary in the type section at Lake Bøllingso in Denmark (Iversen 1954), or in the sections at Usselo in the Netherlands (van der Hammen 1953; Tauber 1960); since it is not based on a migrational change, it may presumably be somewhat earlier in time.

VIII. Molluscan fauna

(*a*) *Extraction and identification*

All the samples were treated in the following simple way. After thorough drying, the sample is allowed to collapse into mud in a vessel of water, and the mud is gently stirred. Most of the Mollusca commonly float, and are poured off into a sieve with a mesh diameter not larger than 0·5 mm (British Standard mesh no. 30). This is repeated several times. This preliminary procedure is recommended, for it lessens the danger of damage, particularly to shells such as *Vitrina*. The sludge in the bottom of the vessel is then poured into a second B.S. no. 30 sieve and the finer fraction washed through. The residue is then dried, graded for convenience into three or four arbitrary fractions, and finally carefully examined and all Mollusca extracted.

A low-power binocular microscope is essential for accurate quantitative work. Identification presents certain difficulties. By far the greater part of each assemblage commonly consists of juvenile or broken shells. For statistical purposes, apices only are counted. Certain apices, such as those of *Abida secale*, are distinctive down to the smallest size. Others, notably those of the *Helicidae*, present considerable problems and require much practice and patience. Fortunately the assemblages discussed in this paper are restricted ones, and, apart from *Limacidae*, serious difficulties arise in two cases only. It is not possible to separate very small juveniles of *Cochlicopa lubrica* and *C. lubricella*. Nor is it possible to separate immature examples of *Vallonia pulchella* and *V. excentrica*. In most of the sections described *V. pulchella* alone appears to be present, and all juveniles were therefore assumed to belong to that species. But at Oxted both species occur together. The juveniles were therefore counted, and divided in proportion to the number of adults (see table 5)

(*b*) *Graphical presentation*

Statistical data about fossil assemblages may be presented graphically in two ways: either in terms of relative abundance, or in terms of absolute abundance per unit of sediment. In the case of these particular deposits, the latter method has been found the more generally informative. The reasons are various. First, the total number of shells recovered, even from the rather large standard sample adopted of 2 kg dry weight, is frequently inadequate as a basis for statistically valid percentages. Secondly, the species dealt with do not fall into clearly contrasted ecological categories, such as might be plotted as units of a graph. Thirdly, we are dealing with species progressively invading an area; therefore the percentages of the species which occur earliest become depressed as later species appear, even though their true abundance may have remained unchanged or may even have increased. This distortion is misleading, for land Mollusca cannot normally be thought of as 'filling' an environment in the sense of a plant community with its members mutually limited by competition, and in competition with other communities; the individual species may live in a variety of micro-habitats overlapping within the same area, and may increase or decrease in numbers independently. Lastly, it is thought that the absolute abundance of land Mollusca in a fossil assemblage may, under certain circumstances, itself reflect climate. Such data may therefore sometimes be of value, as has been suggested by Burchell (1957, p. 2). In the case of these chalky Late-glacial deposits, one can visualize at least two ways in which a relationship of this kind might come about. In the first place rising temperatures create better conditions for most Mollusca, not only by acting directly on their physiology, but also by encouraging the growth of vegetation and creating a greater variety of habitats. The converse is also true. Secondly, it is clear that the number of shells in a given volume of sediment is partly controlled by the rate of accumulation, and in the case of these particular deposits one would expect there to be a close relationship between this factor and climate. During a relatively mild period, frost shattering and transport by meltwater would decrease or stop, accumulation would be retarded, and a given number of shells living on a hillside would therefore be concentrated within a smaller volume of chalk mud, or in a soil. And the converse would also be true.

It is in any case evident from such a histogram as figure 3 that the number of Mollusca does not fluctuate fortuitously, but shows a consistent pattern, and that this pattern can be interpreted in terms of climatic change. In view of the heterogeneous nature of the deposits, the stability in numbers is sometimes remarkable. For example, the samples taken from zone III at Upper Halling varied considerably in their lithology, yet the totals extracted remain surprisingly constant throughout (figure 8).

(*c*) *Zoogeographical elements*

The Late-glacial fauna of land Mollusca comprises several diverse elements. The sections described have yielded between them 19 specifically determinable species; 2 further species, *Vertigo antivertigo* (Draparnaud) and *V. genesii* Gredler (*sensu lato*), may be added from marsh deposits of zones II and III near Brook, Kent (unpublished). Three of these 21 species, *Columella columella*, *Vertigo genesii* and *Helicella geyeri*, no longer live in England so far as it is known.

For the purpose of this paper, five broad geographical groups may be distinguished:

A. Climatically very tolerant species, having Palaearctic and, for the most part, Holarctic ranges. All extend to beyond 70° N in Scandinavia, into Finnmark.

Succinea pfeifferi
Cochlicopa lubrica
Pupilla muscorum
Vallonia costata
Vallonia pulchella
Arianta arbustorum
Punctum pygmaeum
Euconulus fulvus
Retinella radiatula
Vitrina pellucida

B. Arctic–Alpine species.

Columella columella *Vertigo genesii*

C. Species having wide ranges in Europe, but which fail to reach northern Scandinavia; the northern limits given are taken from Luther (1901), Økland (1925) and Ehrmann (1933).

Vertigo pygmaea	63° 30′ N in Norway.
Vertigo antivertigo	63° N in Finland, 60° N in Norway; also possibly in northern Sweden.
Hygromia hispida	66° N in Norway.

Cochlicopa lubricella and *Vallonia excentrica* may, perhaps, also belong in this group.

D. West European species, absent from the Scandinavian mainland.

Abida secale *Helicella geyeri*
Helicella itala

E. A rare species known mainly from maritime habitats in north-west Europe, and from mountains in central Scandinavia.

Catinella arenaria

Group A calls for little comment, since these are precisely the species which one would expect to be commonest in the Late-glacial landscape. All occur in zone I. The two Arctic–Alpine species of Group B are similarly not unexpected; their rarity in many sections is due solely to facies, since both are obligatory hygrophiles. They are known from the Full-glacial Ponder's End Arctic Bed of the Lea Valley in North London (Kennard & Woodward *in* Warren 1912), and survived in south-east England throughout the Late-glacial Period. There is no evidence that they declined during zone II. In the Lea Valley *Columella columella* persisted as late as zone V (Kennard *in* Allison, Godwin & Warren 1952). *Vertigo genesii* continues to live at the present day in a few relict colonies on the Central Plain of Ireland.

Of Group C, *Vertigo antivertigo* is absent from the sections discussed and *Vertigo pygmaea* is rare. This is due to facies alone; both are common in marsh deposits of zones II and III near Brook, Kent. *Hygromia hispida* is perhaps the most significant species of this group in view of its Late-glacial abundance. It becomes scarce beyond about 60° N in Scandinavia, attaining its extreme limit at about 66° N on the coast of Norway; in such latitudes it is said to show an increasing dependence on favourable habitats created by man (Økland 1925; Waldén 1955). It is interesting to observe that the present distributions in Europe of *H. hispida* and *Columella columella* seem scarcely to overlap, yet in zones II and III at Castle Hill (figure 5) these species occur abundantly together, and are similarly common in Late-glacial deposits at Nazeing in the Lea Valley (Kennard *in* Allison *et al.* 1952).

The geographical distributions of the recently segregated species *Cochlicopa lubricella* and *Vallonia excentrica* are not well known; both may prove to belong within Group A. Judging solely from its fossil record in Britain, *V. excentrica* may be less tolerant of cold than are *V. costata* and *V. pulchella*.

The occurrence of the species of Group D in the Late-glacial Period is of the utmost interest. All are highly characteristic of zones II and III, sometimes forming the greater part of the fauna. Their present-day southerly distribution in Europe (figures 17, 18) would have suggested that they arrived in this country well on in the Post-glacial Period, yet they were in fact already present long before any of a large number of common European species whose ranges are considerably more northerly; for example, *Clausilia bidentata*, *Helix hortensis*, *H. nemoralis*, *Vitrea contracta* and *Retinella nitidula*.

(*d*) *Notes on certain species*

Most of the species discussed below are illustrated on figures 22 to 25, plates 11 to 14.

Catinella arenaria

Of the sites dealt with in this paper, *C. arenaria* was found only at Castle Hill, Folkestone, in zone II. The shells of the *Succineidae* are not easily named with certainty, but these specimens are fully characteristic of the species. They were submitted to Dr H. E. Quick, who supported the determination. *C. arenaria* is recorded also from probable Late-glacial deposits near Cambridge (Sparks 1952, p. 166). It is known living in the British Isles only at Braunton Burrows, North Devon, and in a few places in Ireland, on the Central Plain and among sandhills on the west coast (Stelfox 1911; Quick 1933; Ellis 1951). Abroad it is almost exclusively either maritime or montane. It lives in scattered localities in the mountains of central Scandinavia as far north as about 67° (Odhner 1945), on islands in the southern Baltic, and then along the North Sea coast of Germany, Holland, Belgium and northern France. It is also known from a single locality in Czechoslovakia (Ložek 1956), and possibly also in the Swiss Alps (Ehrmann 1933).

C. arenaria requires less moisture than most of the other British members of the family. At Braunton Burrows it lives in wet hollows in the dunes associated with a sparse flora (Boycott 1921*a*).

Cochlicopa *spp.*

Both *Cochlicopa lubrica* (Müller) and *C. lubricella* (Porro) occur in zones I, II and III. When mature, the Late-glacial shells are usually well characterized and there is seldom difficulty in separating the two forms. Unfortunately by far the greater part of the material consists either of juvenile or of highly fragmentary shells having two whorls or less, and these are not specifically identifiable; therefore presence only has been indicated in the tables. The ecology of British *Cochlicopa* is discussed by Quick (1954).

Columella columella

It is uncertain whether this form is a distinct species, or only a variant, perhaps a subspecies, of the common Holarctic *Columella edentula* (Draparnaud). At all events, *C. columella* has at the present day a very clear, disjunct, Arctic–Alpine distribution, summarized by Forcart (1959). Unlike *C. edentula*, *C. columella* is an obligatory hygrophile, in its northern area living in marshes among birchwoods with an arctic flora (Forcart 1959, p. 11). It is highly characteristic of 'cold' deposits in Britain, and indeed elsewhere in lowland Europe. It is common in the Full-glacial of the Ponder's End stage in the

Lea Valley (Kennard & Woodward *in* Warren 1912) and, on the evidence of the site at Castle Hill (figure 5), was able locally to flourish under damp conditions both in zones II and III of the Late-glacial Period. Stray shells occurred in zone II at Holborough and at Beachy Head.

There is considerable variation; extremes are shown on figures 22*f* and *g*, plate 11.

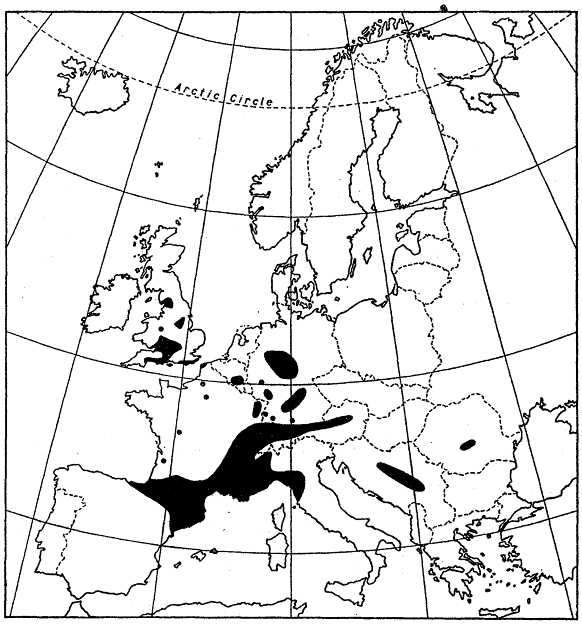

FIGURE 17. *Abida secale* (Draparnaud). Approximate present-day distribution, compiled mainly from published sources. It should be noted that although this species is local over most of France, it is certainly more widespread than is shown.

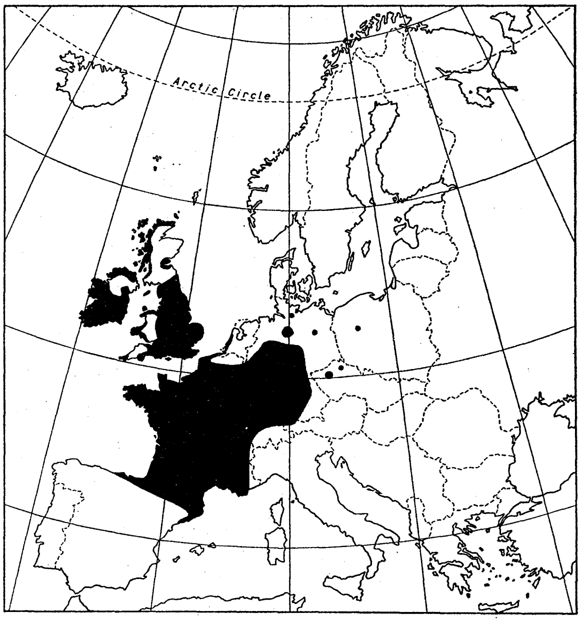

FIGURE 18. *Helicella itala* (Linné). Approximate present-day distribution, compiled from published sources. Closely related forms exist further to the south-east.

Vertigo pygmaea

In the sections described this species occurs only sporadically, as stray shells in zones II and III. In the Late-glacial Period *V. pygmaea* seems to have been an obligatory hygrophile, restricted to marshes, whereas in Britain at the present day it lives in damp or dry places alike, provided they are open, and is common on arid chalk hillsides. In Scandinavia it is mainly maritime, the northernmost limit of isolated colonies being 63° 30′ in Norway, 63° in Sweden (Økland 1925), and 61° in Finland (Luther 1901).

Pupilla muscorum

This species varies considerably. A typical range from a single horizon at Holborough is shown on figure 24*g* to *i*, plate 11. The possibility of more than one species of *Pupilla* occurring in the Late-glacial Period was borne in mind, but all shells appear to belong to a single variable species. The shells tend to be larger, both taller and broader, than the majority of British recent or Post-glacial *P. muscorum*, but otherwise differ from them in no important respect.

Abida secale

Perhaps the most interesting of the Late-glacial species. Its presence is highly characteristic of nearly all samples from zones II and III, and the conical apices are distinctive and easily recognized (figure 23*c*, plate 12). It is locally the most common species, as in zone III at Upper Halling. At Beachy Head, it may occur as early as zone I*b*, though on the North Downs it is not present before zone II. Shells show a good deal of variation (figures 23*a*, *b*, plate 12), but the extremely elongate form illustrated by Favre (1927, Pl. 15, fig. 13) cannot be matched.

The approximate present-day geographical distribution of *Abida secale* is shown in figure 17. The British distribution and ecology is discussed elsewhere by the writer (Kerney 1962). In view of its range, which on the continental mainland does not extend north of central Germany, it is remarkable that this species should have reached southern England as early as the Late-glacial Period. Several points should be made. First, the genus *Abida* lives principally in the Alpine region, where it is represented by many more species than the single one existing in north-west Europe. Secondly, *A. secale* is capable of surviving intensely cold winters. According to Germain (1930), it extends in the Alps up to at least 2700 m, a height which is not far below the permanent snow-line. Thirdly, its ecological requirements are somewhat specialized. It is strongly calciphile, and needs open, relatively treeless environments, preferably with a certain amount of bare or loose rock. It is not a sand-hill form. Favre (1927) describes it in the Geneva area as follows: 'C'est une espèce calcicole-rupicole, qui ne trouve pas dans nos basses régions aux terrains glaciares un milieu qui lui convienne'. It shows a distinct preference for mountain areas, being absent from large tracts of lowland Europe. In Britain, its present range is highly suggestive of a relict distribution, probably having been widely exterminated by the spread of Post-glacial forests (Kerney 1962, Fig. 1). In the Late-glacial Period it seems to have been very much commoner; the predominantly open landscape, with its many areas of bare calcareous ground, proving most congenial. It is now apparently extinct in the vicinity of all the sites discussed in this paper with the exception of Beachy Head, where it still flourishes on the sea cliffs. Outside Kent, Surrey and East Sussex, it is recorded from probable Late-glacial deposits in West Sussex (Kennard & Woodward *in* Palmer & Cooke 1923), Hertfordshire (Sparks & Lewis 1957, p. 33) and Lincolnshire (Burchell & Davis 1957).

Vallonia *spp.*

All three living British species of the grassland genus *Vallonia*, i.e. *V. costata*, *V. pulchella* and *V. excentrica*, were present in the Late-glacial Period. Their abundance demonstrates clearly the open nature of the Chalk landscape. The first two species are widespread, the last occurs only at Oxted, in zones II and III. In the Holborough section, *V. excentrica* appears first in the Post-glacial fossil soil ((*h*), figure 9).

Arianta arbustorum

Specimens tend to be small. One mature shell from zone III at Cow Gap measures no more than 17·5 mm (breadth) × 13·5 mm (height), but this is exceptional. More normal shells are illustrated on figure 25 *g* to *i*, plate 14; they were selected out of a series of 32 from the same locality in order to show the considerable variation in the height of the spire. Many subspecific names have been bestowed on similar form-variants (Ehrmann 1933), but apart from the rather small average size, no consistent racial characters could be detected in the Late-glacial shells.

Hygromia hispida

Much variation is shown by the height of the spire, the size of the umbilicus and the closeness of the coiling. That these characters are not entirely inter-dependent is shown by a consideration of shells from zone III at two sites: Holborough, and Castle Hill, Folkestone (figures 25*a* to *e*, plate 14). In both series, the tightness of the coiling varies greatly, as it does in most helicoids. Generally speaking, shells that are loosely coiled tend to be rather flat (figures 25*a* and *d*), whereas tightly coiled shells tend to have a raised spire and a conical form (figures 25*c* and *e*). But the size of the umbilicus seems not to be related to these features. At Castle Hill, nearly all the shells have a rather narrow umbilicus, whilst those from Holborough have a more widely open umbilicus, and this remains constant throughout zones II and III at both sections. The Holborough shells tend furthermore to be a little larger. In fact, every site studied shows its own particular facies of *H. hispida.* This suggests that once the species had reached an area, local races quickly developed, the individuals sharing certain genetic characters in common. That local colonies persisted is demonstrated at Dover Hill. In two successive samples from zone III at this site (120 to 130 cm, 105 to 115 cm) a single sinistral monstrosity of *H. hispida* was found, out of totals of 63 shells and 113 shells respectively. Such monstrosities are of extreme rarity. In the present case it seems likely that they were produced by the same genetic abnormality persisting in the local population over a period of some years.

No shells have been seen which could confidently be assigned to *H. liberta* Westerlund.

Helicella (Xeroplexa) geyeri

This species was first described living by Soós (1926) from a locality in Thuringia. Its distribution remains poorly known, since the species had previously been confused with the superficially rather similar *Helicella* (*Helicopsis*) *striata* (Müller); neither species occurs at the present day in Britain. *H. geyeri* lives in a number of widely scattered localities in central and southern Germany, Switzerland, southern Belgium and probably also in eastern France. It also lives on the Island of Gotland in the Baltic (Schlesch 1952). Like nearly all the species of *Helicella*, it is a xerophile, favouring dry, open, calcareous places. Its former occurrence in England, where it had previously been confused with *H. striata*, was pointed out by Sparks (1952). '*H. striata*' was recorded from deposits in the Halling area as long ago as 1922 (Kennard & Woodward 1922, p. 135). From an examination of specimens in several collections made by Kennard, Sparks was able to show that the Halling shells include both *H. striata* (*sensu stricto*) and *H. geyeri*, although the latter is the more common (Sparks 1953, p. 374). No examples of *H. striata* were, however, found by the writer in the Late-glacial deposits of the Upper Halling–Holborough dry valley, all specimens being *H. geyeri*. The geological age of the Halling specimens of *H. striata* must for the present remain doubtful. The latter species certainly lived in south-eastern England during some part of the Early Post-glacial Period (Sparks 1953, p. 376; Davis 1954).

Helicella geyeri is present at Upper Halling, Holborough and Oxted, throughout zones II and III; at Oxted a single shell occurred also near the top of zone I (figure 12). There is a good deal of variation. In the zone II soil at Upper Halling (Sections *A* and *B*) most of the shells tend to be small and tightly coiled (figure 23*f*, plate 12). A more normal shell from zone III at Oxted is figured for comparison (figure 23*d*).

Helicella (Helicella) itala

This xerophile occurs at all sections. Like *Abida secale* and *Helicella geyeri*, this species is unexpected in the Late-glacial Period in view of its modern distribution (figure 18). But it should be noted that *H. itala* can tolerate some degree of cold, for it ascends to about 2000 m in both the Alps and the Pyrenees (Mermod 1930; Germain 1930). In Britain, according to Taylor (1921, 4, p. 120), it usually hibernates about November, but he adds that it has been found adhering to exposed plant stems in mid-winter during periods of keen frost. It is also said to breed throughout the winter, as late as January (Boycott 1934, p. 18). In this country it is distinctly maritime, favouring sand-dunes. Species of the *Helicella* group are principally circum-Mediterranean, but have been widely dispersed by man. For example, of the seven species of *Helicella* and *Cochlicella* known to live in Britain at the present day, there is an increasing body of evidence to suggest that six, i.e. all except *H. itala*, have been introduced accidentally by man in the last 2000 years.

The Late-glacial shells show no special peculiarities. They often reach a considerable size; the specimen illustrated from Dover Hill is large by modern British standards (figure 25*f*, plate 14). Half-grown shells may be identified by their sharply angled peripheries, whilst very small juveniles may be distinguished from those of other comparable Late-glacial *Helicidae* by the larger size and characteristic surface texture of the nepionic whorls.

Retinella radiatula

The Late-glacial shells are frequently large (figure 24*a*, plate 13), sometimes considerably exceeding the size which is normally attained by modern British examples, of which figure 24*b* would be fairly typical. In other respects, they cannot be distinguished

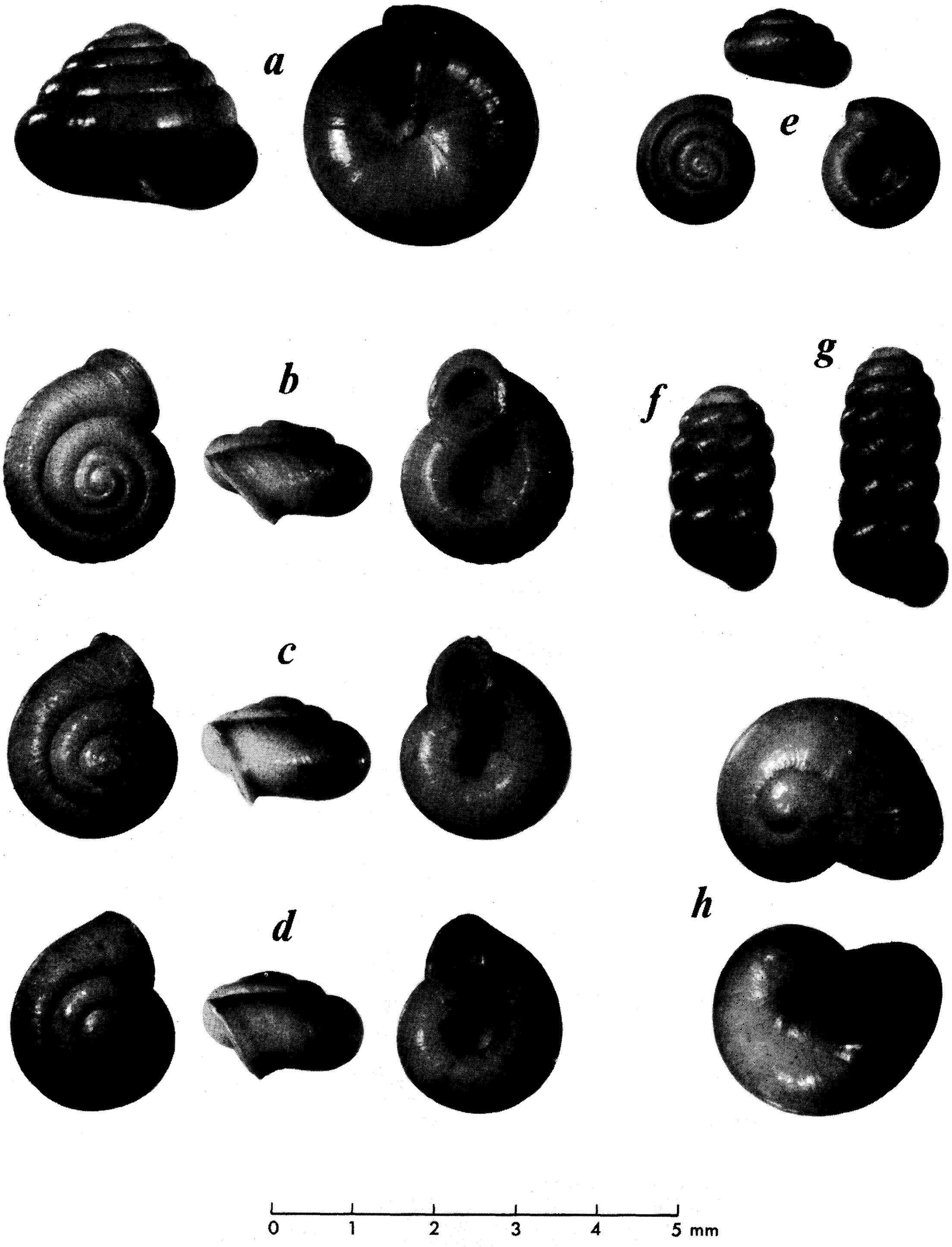

FIGURE 22. (*a*) *Euconulus fulvus* (Müller). Dover Hill, Folkestone. Zone II, 390 to 400 cm. (*b*) *Vallonia costata* (Müller). Holborough. Zone I, 210 to 215 cm. (*c*) *Vallonia pulchella* (Müller). Holborough. Zone I, 210 to 215 cm. (*d*) *Vallonia excentrica* Sterki. Oxted. Zone II, 230 to 238 cm. (*e*) *Punctum pygmaeum* (Draparnaud). Dover Hill, Folkestone. Zone II, 435 to 445 cm. (*f*), (*g*) *Columella columella* (Martens). Castle Hill, Folkestone. Zone III, 150 to 158 cm. (*h*) *Vitrina pellucida* (Müller), half-grown example. Oxted. Zone I, 330 to 338 cm.

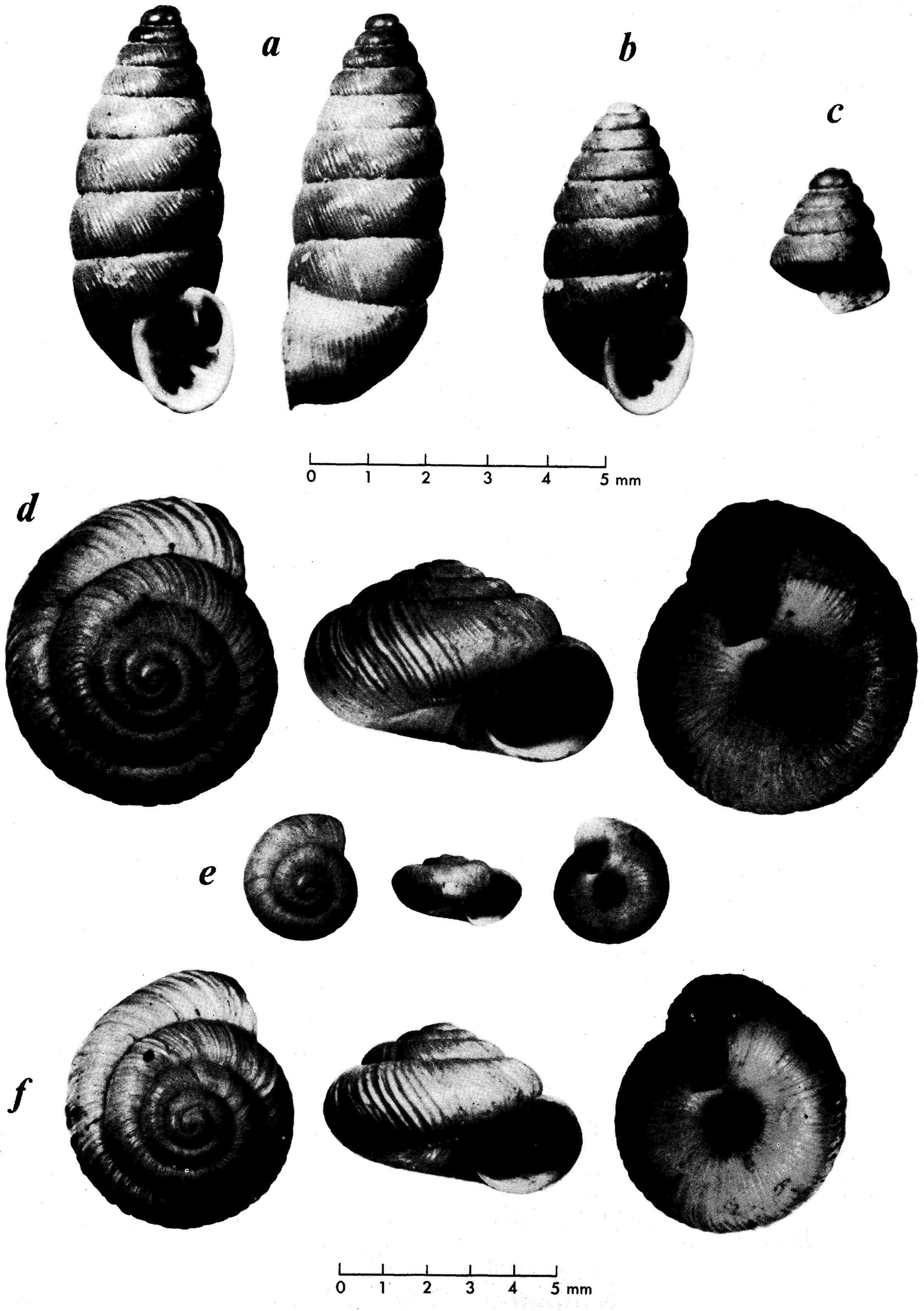

FIGURE 23. (*a*) *Abida secale* (Draparnaud). Holborough. Zone II soil, 168 to 174 cm. (*b*) *Abida secale* (Draparnaud). Section *A*, Upper Halling. Zone II soil. (*c*) *Abida secale* (Draparnaud), apical fragment. Holborough. Zone II soil, 168 to 174 cm. (*d*) *Helicella geyeri* (Soós). Oxted. Zone III, 190 to 198 cm. (*e*) *Helicella geyeri* (Soós), juvenile. Oxted, Zone III, 190 to 198 cm. (*f*) *Helicella geyeri* (Soós). Section *A*, Upper Halling. Zone II soil.

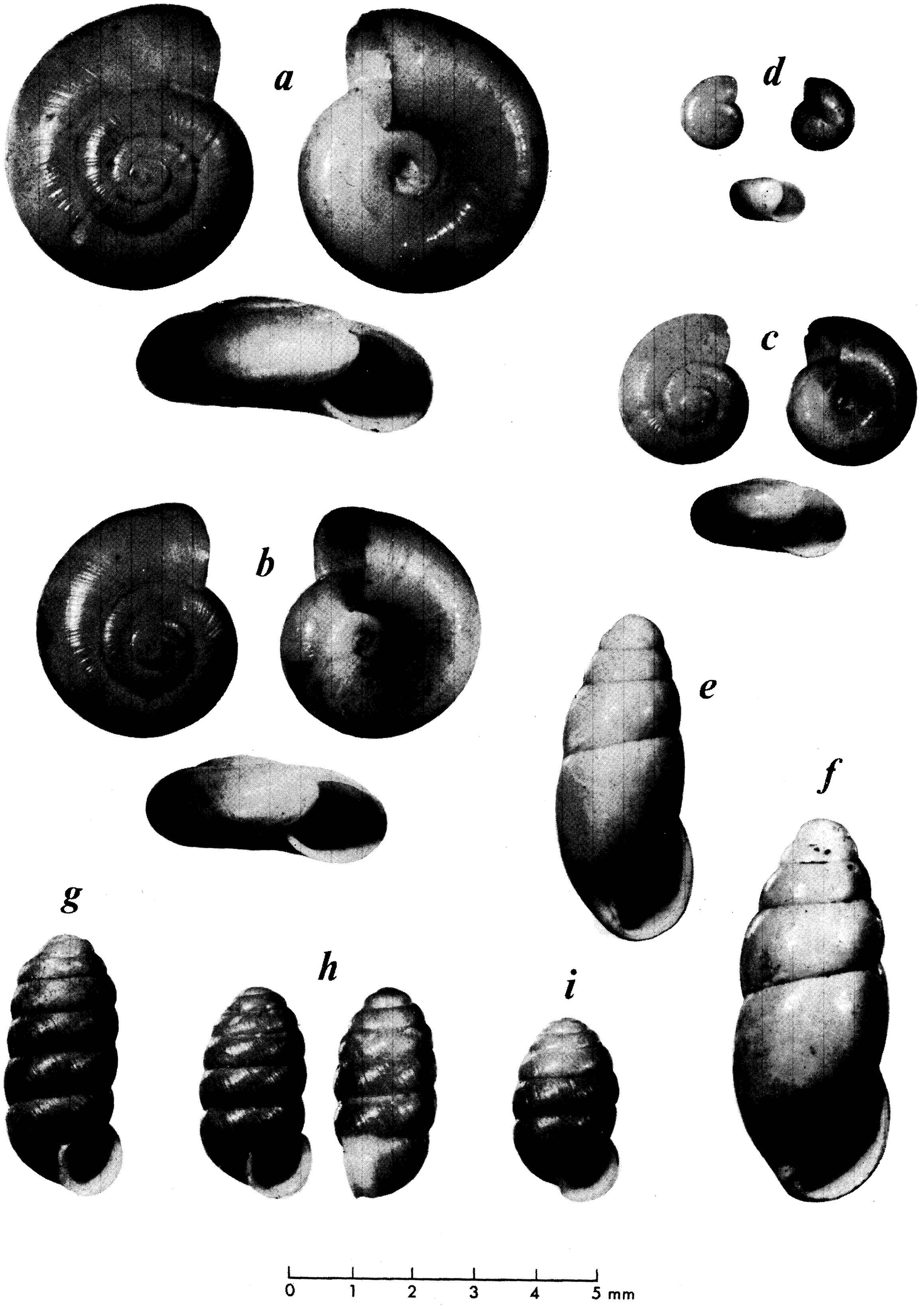

FIGURE 24. (*a*) *Retinella radiatula* (Alder), very large example. Cow Gap, Beachy Head. Zone II soil, 205 to 213 cm. (*b*) *Retinella radiatula* (Alder), normal example. Cow Gap, Beachy Head. Zone II soil, 205 to 213 cm. (*c*), (*d*) *Retinella radiatula* (Alder), juveniles. Cow Gap, Beachy Head. Zone II soil, 205 to 213 cm. (*e*) *Cochlicopa lubricella* (Porro). Cow Gap, Beachy Head. Zone II soil, 205 to 213 cm. (*f*) *Cochlicopa lubrica* (Müller). Cow Gap, Beachy Head. Zone II soil, 205 to 213 cm. (*g*), (*h*), (*i*) *Pupilla muscorum* (Linné). Holborough. Zone II soil, 168 to 174 cm.

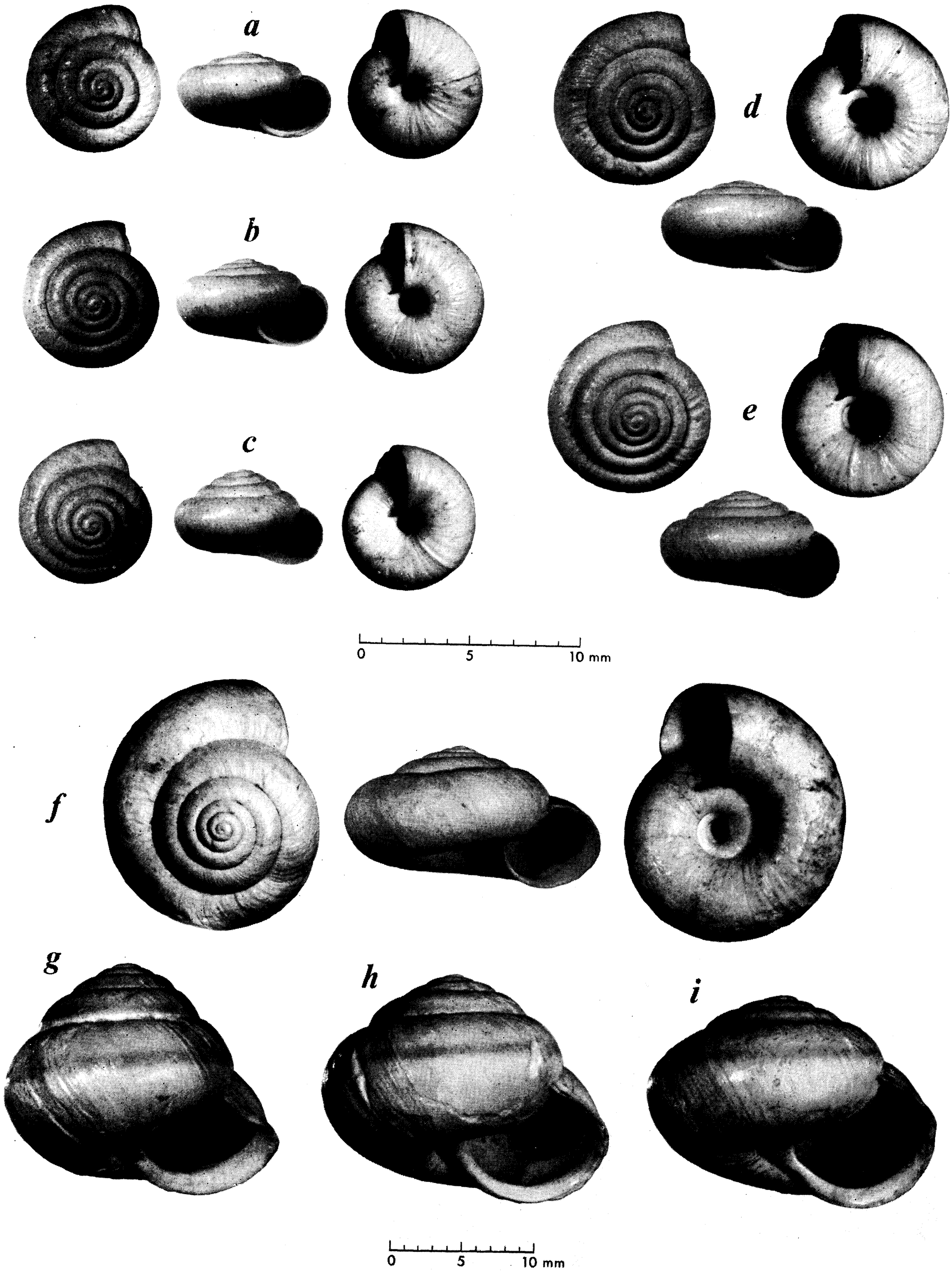

FIGURE 25. (*a*), (*b*), (*c*) *Hygromia hispida* (Linné). Castle Hill, Folkestone. Zone III, 140 to 148 cm. (*d*) *Hygromia hispida* (Linné). Holborough. Zone III (Site B), 146 to 154 cm. (*e*) *Hygromia hispida* (Linné). Holborough. Zone III (Site A), 111 to 119 cm. (*f*) *Helicella itala* (Linné). Dover Hill, Folkestone. Zone III. (*g*), (*h*), (*i*) *Arianta arbustorum* (Linné). Cow Gap, Beachy Head. Zone III.

from them. A specimen from zone II at Beachy Head is 4·8 mm in maximum diameter. Taylor (1908, 3, p. 89) quotes 4·0 mm as normal for British *R. radiatula*, and Ehrmann (1953, p. 84) 3·5 to 4·3 mm for German shells. There is a tendency in these large examples for the sculpture of fine, regularly spaced grooves to become irregular and to degenerate on the last half whorl. The exceptional size may have a climatic explanation. Most small land snails are normally annuals, but if living under adverse conditions with long, cold winters, their life-cycles may be extended over two summer seasons instead of one, with the result that some individuals are able to grow abnormally large.

The possibility that the closely related Arctic–Alpine species *Retinella petronella* (L. Pfeiffer) might be present was considered. However, specimens of this form from Sweden, collected by Dr H. W. Waldén and kindly sent to me by Mr A. E. Ellis, differ materially, notably in their stronger sculpture and the closer coiling of the whorls.

Vitrina pellucida

A highly characteristic Late-glacial species, much commoner than in Post-glacial deposits in Britain. The specimen illustrated on figure 22*h*, plate 11) is only half grown, since owing to the extreme fragility of the shell no larger complete example could be found; the largest seen, from zone I at Oxted, attains 4·9 mm in breadth.

Agriolimax *sp.*

Internal shells of *Limacidae* occur fairly commonly throughout zones I, II and III at all sections. They have not been systematically extracted and the numbers listed in the tables have therefore no statistical value. Most appear to belong to the genus *Agriolimax*.

(*e*) *Interpretation of assemblages*

Interpretation of the molluscan histograms which form the basis of this paper is difficult. It is frequently uncertain whether the appearance or the changing abundance of a species is due to ecological, or to climatic factors, or to a combination of both. It must be borne in mind that land Mollusca normally reflect only the immediate surroundings of a site; broader deductions concerning climate must be made with great caution. Mollusca can provide us with no first hand knowledge about the vegetation of a region, as does pollen. Attempts have been made to date Quaternary deposits directly by equating percentages of certain species of land Mollusca, but this procedure is open to several grave objections. The relative importance of Arctic–Alpine or of thermophilous species, as well as their appearance or disappearance, does provide some indication of the position of a deposit within the Late-glacial/Post-glacial Period (Burchell 1957, 1961), but only in a very broad way. Since the climatic tolerance of Mollusca is poorly known, and modern distributions may be misleading, a circular argument can easily develop. More serious is the objection that the detailed composition of a fauna is a question not primarily of climate, but of local dampness or dryness, soil or vegetation. Thus in stratigraphically continuous deposits of zones II and III within the Upper Halling–Holborough dry valley, the frequency of such a species as *Hygromia hispida* varies erratically from place to place and from time to time in response to purely local factors (figures 8 and 10). To correlate percentage frequencies from one deposit to another is misleading and is only to correlate possible similarities in environment, not in age. A change in environment within a vertical succession in a single section may indeed be a reflexion of a regional climatic change, but the actual expression of this change will differ greatly from section to section, and cannot be interpreted in isolation. A single sample yielding non-marine Mollusca is frequently of small value, unless it can be related to a series from the same site; when a number of such sites have been studied, parallel trends may become evident, and regional changes may be discernible through fluctuating local patterns.

A few generalizations can first be made. All the assemblages lived on highly calcareous ground facing south or east. Relatively open habitats are invariably indicated, for the grassland and rupestral genera *Pupilla*, *Vallonia*, *Abida* and *Helicella* predominate. For much of the period the slopes were subjected to severe disturbance, which must greatly have inhibited plant colonization, although even on the surfaces of the fans of chalky debris some vegetation, probably seasonal, seems to have grown. The development of a soil, such as occurred during at least part of zone II, would bring about local ecological changes. It should further be borne in mind that in the white chalk muds and rubbles the assemblages found probably represent the sweepings of considerable areas of the hillsides, whereas in the fossil soils the Mollusca are more nearly representative of the immediate environment.

It would perhaps be a mistake to attempt to interpret these Late-glacial assemblages too rigidly in the light of present-day ecology in temperate Europe. If this is done, anomalies become apparent. The lack of competition met with by species freshly invading an area may have been an important factor, but one which is very hard to evaluate. There is some evidence that climatic differences may alter the relation of a species to its environment, making it more or less adaptable. For example, it has frequently been observed that in mountain areas, certain Mollusca which usually live in very diverse habitats, come to live together in close proximity, in open country. Germain (1930, p. 45) describes from the Alps unusual associations of xerophiles and hygrophiles, and Favre (1927) makes similar observations in his study of the Mollusca of the Jura mountains. A partial explanation of this phenomenon may be that at high altitudes average temperatures remain low, preventing a too rapid evaporation of ground moisture in open habitats and permitting the existence of species which would normally shun such places. This may have been a factor of importance in the Late-glacial Period.

(*e* 1) *Zone I*

The fauna of zone I is composed characteristically of *Pupilla muscorum*, *Vallonia costata*, *V. pulchella*, *Punctum pygmaeum*, *Vitrina pellucida* and *Euconulus fulvus*. All are Holarctic species, capable of existing under rigorous climatic conditions. *Vitrina pellucida* is sometimes very common, and in the Oxted section is present in enormous numbers for a short time in zone I, forming over 85 % of the total assemblage. Although this species is widely distributed in a variety of habitats in Britain today, it is rarely abundant, with the exception of maritime sand-hills, where it may swarm in profusion (Taylor 1906, p. 14; Stelfox 1911). *Pupilla muscorum* is similarly common on sand-hills, becoming very local inland in Britain and Ireland. The species of *Vallonia*, on the other hand, tend to prefer more normal grasslands and show no preference for the sea coast.

Cochlicopa is present in small numbers at the Medway Valley sites, at Oxted, and at Beachy Head. The scarcity of *Retinella radiatula* in zone I is hard to explain in view of its high Arctic distribution; this point will be commented on later. Isolated shells were present in zones I at Holborough and Upper Halling.

During zone I*b*, as interpreted at Upper Halling, Holborough and Dover Hill, this hardy fauna shows a temporary increase in numbers, but no essential change. But in the section at Cow Gap, Beachy Head, if this has been correctly interpreted, three further species, *Hygromia hispida*, *Abida secale* and *Helicella itala*, are present already in zones I*b* and I*c*, perhaps a thousand years before their appearance in the North Downs sections in Kent and Surrey.

It is uncertain how many of the species found in zone I are fresh Late-glacial immigrants into southern England, or whether any of them were able to survive in this country the cold of the immediately preceding stage of the Last Glaciation. *Pupilla muscorum* is perhaps such a species, but the evidence is inconclusive; it was certainly present during the early climatic amelioration recorded at Upton Warren, Worcestershire (*circa* 40000 B.P.; Coope, Shotton & Strachan 1961) and occurs also in the Ponder's End Arctic Bed north of London (28000 ± 1800 B.P.; Godwin & Willis 1960). But in the Upper Halling–Holborough dry valley the brown loessic deposits which immediately underlie the Late-glacial white muds seem everywhere to be devoid of Mollusca.

(*e*2) *Zone II*

The base of zone II has been drawn at that point where the hardy species which characterize zone I increase sharply in numbers. *Vallonia* usually shows the greatest relative increase, whereas *Pupilla muscorum* and *Vitrina pellucida* tend to decline in relative importance. This suggests the growth of a more permanent grassland cover on the slopes, although at Dover Hill and at Oxted there is no perceptible change in facies and accumulation continued on locally for some time. These two sites are valuable, for they alone show a clear faunal succession within the Allerød Oscillation, elsewhere mostly condensed within a thin soil. Throughout zone II the fauna becomes enriched, both by the increase of forms already present, and by the arrival of fresh species. No single, simple ecological trend can be detected at either site; rather it would appear that the environment became increasingly diversified as the climate improved, as vegetation developed, and as soil formation began to take place. A greater variety of micro-habitats was created. Thus we find, both at Dover Hill and at Oxted, that the relatively hygrophilous species *Vallonia pulchella*, the hygrophile to mesophile *Retinella radiatula*, and the xerophiles *Abida secale* and *Vallonia excentrica* (Oxted only), behave in a similar fashion, increasing markedly towards the end of zone II. As the hillsides became increasingly stable, patches of moist ground-flora would develop, not subject to rapid desiccation, and *Vallonia pulchella* was no doubt able to colonize the slopes from its normal habitats on the low ground below. Conversely, *Abida secale* was able to flourish on intervening drier patches of bare scree or short turf. Scree slopes are probably uniquely favourable to the development of habitat mosaics of this kind.

An interesting comparison can be made between the assemblages contained in the zone II soil around Upper Halling, and at Holborough, in the upper and lower parts respectively of the same dry valley (figures 8 and 10). The percentage frequencies of certain selected species at Sections *A*, *B* and *D* are as follows:

	Upper Halling *A*	Upper Halling *B*	Holborough *D*
Vallonia costata	25·0	21·9	50·6
Vallonia pulchella	1·0	1·0	9·4
Abida secale	16·2	21·0	4·7
Helicella geyeri	7·3	7·8	2·2
	49·5 %	51·7 %	66·9 %

These percentages are based on the total number of Mollusca recovered from the whole thickness of the soil at each section, and ignore vertical changes. Most striking is the great abundance of the grassland form *Vallonia costata* at Holborough compared with Upper Halling. On the other hand, the rupestral xerophiles *Abida secale* and *Helicella geyeri* become much scarcer. It seems clear from this that around Upper Halling the hillsides presented many areas of bare chalky screes with only a scanty vegetation, whereas on the lower and more sheltered slopes close to the river a thicker permanent cover of grasses and herbaceous plants existed. The rather hygrophilous species *Vallonia pulchella* is rare at Upper Halling, but much commoner at Holborough. If we examine the vertical changes which take place within the soil in these two areas, we find that although the relative importance of species differs greatly, a strong parallelism exists (figures 8 and 10). But interpretation of these changes presents several difficulties, as in the Dover Hill and Oxted sections. Some, such as the decrease of *Vallonia pulchella* and *Punctum pygmaeum*, probably reflect purely local changes connected with the development of the soil, but others seem to be of regional significance.

There is evidence that a number of species became widespread in Kent and Surrey for the first time during zone II, probably for climatic reasons. At Dover Hill and at Oxted, where there are good zone II sequences, certain forms behave in a very similar manner. Thus *Hygromia hispida* and *Abida secale* appear low in the zone. The former steadily increases to the top; the latter attains a maximum a little earlier, and then sharply drops to about half its former value, perhaps because the development of a firm soil provided a rather uncongenial substrate for this essentially rupestral species. *H. itala* arrives only near the end. *Helicella geyeri* and *Vallonia excentrica* are not present at Folkestone. At Oxted the former appears in zone I, but becomes frequent only in zone II. The xerophile *V. excentrica* behaves in a manner almost identical to that of *Helicella itala*; there is no clear ecological reason for the absence of either of these species at lower levels.

At all other sections, a much condensed record of zone II is preserved. Thus at Upper Halling and at Holborough, *Hygromia hispida*, *Abida secale* and *Helicella itala* all appear in the lower part of the thin zone II soil. Even here, however, there is a suggestion that these species were behaving in a fashion similar to that at Folkestone and Oxted, becoming more abundant towards the end of the period; this is particularly clear in the Holborough histogram (figure 10). Such a consistently parallel behaviour is of great interest, in view of the fact that the species have somewhat different ecologies: *H. hispida* is normally a hygrophile to mesophile species, whereas *A. secale* and *H. itala* are xerophiles. At Dover

Hill (figure 3) and Oxted (figure 12) their behaviour is in sympathy with the hygrophile *Vallonia pulchella*, whereas at Holborough (figure 10) *V. pulchella* bears them an equally clear antipathetic relationship.

(*e* 3) *Zone III*

The salient fact about the fauna of this zone is that the deterioration of climate caused no extinctions; all the Allerød species persist throughout. At Upper Halling, *Abida secale* becomes the most common species, which is remarkable in view of the associated unequivocal evidence of frost-heaving and of the recurrence of frost-shattering of the Chalk.

A distinctive feature of zone III at several sites is the abundance of *Hygromia hispida*, forming up to 80 % of the assemblages. It seems likely that the large form of this species which is found was one adapted to rather damp environments, and its behaviour is consistent with this. Thus at Castle Hill (figure 5) *H. hispida* fluctuates in sympathy with the obligatory hygrophiles *Succinea pfeifferi* and *Columella columella.* Instructive also is a comparison of Sections *B* and *D* within the Upper Halling–Holborough dry valley. In the former (figure 8), in deposits which represent the sweepings of the slopes near the head of the valley, *H. hispida* is rare in zone III and the assemblages have a strongly xerophilous character, dominated by *Abida secale.* A significant number of *H. hispida* occur only in the topmost sample (41 to 49 cm), linked with a burst of the hygrophile *Arianta arbustorum.* In Section *D* at Holborough, on the other hand (figure 10), where a fan of chalky mud and rubble was spreading out over low ground close to the river, the zone III fauna has a somewhat damper facies. *Abida secale* is reduced in numbers. *Arianta arbustorum* is more frequent and occasional stray *Succinea* appear. *Hygromia hispida* is much commoner than at Upper Halling, flaring up erratically, presumably when suitable conditions temporarily developed.

At Oxted *H. hispida* is rare in zone III, and declines towards the top (figure 12). The rather dry facies exhibited throughout at this section is probably the result of excellent drainage, the site being on a steep hillside on the face of the escarpment. The zone III deposits are here thin, and in the upper part the predominance of the xerophiles *Vallonia excentrica* and *Helicella itala*, the decrease or disappearance of hygrophiles, and the rarity of the rupestral *Abida secale*, suggests that stable areas of dry grassland increasingly covered the slopes.

Taking all the sites together, there is evidence that the climate of zone III was not a return to that of zone I. The chalk meltwater muds are essentially similar and presumably represent the sweepings of the same hillsides, yet the fauna they contain shows clear differences. First, relatively thermophilous species are able to survive throughout. Even hardy species are on the whole more common than in zones I*a* and I*c*. This suggests that it was not as cold. Secondly, the hygrophile element is usually much better represented, notably by the dramatic expansion of *Hygromia hispida* at several sites. *Arianta arbustorum*, *Vallonia pulchella* and *Retinella radiatula* appear consistently. The last species is of special interest. Though occurring sporadically in a wide range of environments, it is characteristic of rather damp places. Boycott (1921 *b*, p. 241) points out that in England it seldom occurs in any numbers in any one habitat, but adds that it seems to flourish much more freely in Ireland. In all sections without exception it is virtually absent from zone I, reaches a clear maximum towards the end of zone II and persists regularly throughout zone III. Study of the Dover Hill or Oxted sections alone (figures 3 and 12) might suggest that *R. radiatula* was migrating into these areas for the first time in zone II, yet this seemed theoretically unlikely in view of the circum-polar distribution of this species at the present day. Later work showed it to be present in zone I in the Medway Valley sites, though very rarely (figures 8 and 10). Some other explanation is therefore needed to explain the apparent inability of *R. radiatula* to live on the chalk hillsides in zone I, and its invariable presence on exactly the same hillsides in zone III. Its expansion in zone II might be explained in terms of the development of suitable habitats as soil formation progressed, but this cannot be true of zone III, when the hillsides were once again subjected to frost-shattering and disturbance. The behaviour of *R. radiatula* suggests, as does the abundance of *Hygromia hispida*, that the climate of zone III was more humid than that of zone I, either because of higher actual precipitation, or because a cover of dense cloud restricted evaporation.

(*e*4) *Zone IV*

The fauna contained in the upper fossil soil at Holborough ((*h*), figure 9) cannot accurately be dated. It is assumed that soil formation began immediately once the zone III deposits ceased to accumulate, but it may well have continued for a very considerable time, perhaps throughout zones IV, V and VI. The Mollusca are in poor preservation. The calcareous tufa (*i*), which overlies the soil, must represent a local rising of the water table, and may belong to the beginning of the Atlantic Period, zone VII*a*.

The fauna is still mainly of open-country character, dominated by *Vallonia*, *Pupilla* and *Abida*. *Helicella geyeri* was not found. A number of common European species appear for the first time, notably *Carychium tridentatum*, *Acanthinula aculeata*, *Helix nemoralis* and *Discus rotundatus*. The most noteworthy fact is the continued absence of *Pomatias elegans*, a species almost ubiquitous in later Post-glacial chalk hillwashes in southern England.

IX. General conclusions

In many areas of the Chalk of south-eastern England, there formed, during the Late-glacial Period, sheets of muds and rubbles having a characteristic appearance and a distinctive molluscan fauna. They may be distinguished lithologically and faunally from underlying Full-glacial deposits, and from overlying chalky hillwashes which accumulated during the Post-glacial Period. They contain a valuable marker horizon: a grey fossil rendsina soil containing scattered fragments of wood charcoal, and which represents all or part of the milder Allerød Oscillation (zone II). The closest stratigraphical parallels are to be found in the Netherlands. Here are the Coversands, aeolian deposits much modified by solifluxion and by the release of water from melting snow (van der Hammen 1953, 1957*a*; Zagwijn *in* Pannekoek 1956); within them, in many parts of the country, there is present a grey horizon containing charcoal fragments, representing a period when accumulation was interrupted, and dated by radiocarbon assay to the Allerød Oscillation ('Usselo Layer'). This is certainly equivalent to the fossil rendsina recognized in south-eastern England, and the same land surface no doubt stretched in continuity over the dry floor of the North Sea. A stratigraphical reflexion of the Bølling Oscillation has also been recognized at a slightly lower level in the Coversands in several places.

The chalk muds in south-eastern England are not solifluxion deposits in the generally accepted sense. They were built up by periodic increments, probably in the form of sheets of chalky slurry carried by the water released from melting snow or by the thawing of frozen ground. Active frost-shattering took place, and sufficient water was available to carry the products considerable distances. Occasional evidence of local aeolian reworking is provided by thin intercalated seams of chalk silt, but this is uncommon; wind action was evidently less important than in the Netherlands, as might be expected from our more westerly position.

H. J. Osborne White well describes Late-glacial deposits of this kind in a dry valley at Lydden, 4 miles north-west of Dover, Kent (1928, p. 63 and Pl. V*B*; TR/270457). He concludes: 'The deposit...is the outcome of successive wet washes, reasonably attributable to the periodic melting of thick snow-drifts on the slope above'.

It has been noticed in many sections that the chalky deposits of the Late-glacial Period, and particularly of zone III alone, are very thick compared with any underlying subaerial Full-glacial deposits. This requires explanation, in view of the trivial period of time covered by the Late-glacial Period when seen in the perspective of the 60000 years of the Last Glaciation (Anderson, de Vries & Zagwijn 1960). There are many signs that erosion on the Chalk became particularly active at this time. Thus throughout the Upper Halling–Holborough dry valley in Kent we find that brown silty loessic deposits (figure 7, horizon (*b*)) are everywhere overlain rather abruptly by bedded white chalk muds (figure 7, horizons (*c*), (*e*), (*g*)), suggesting the onset of more active frost-shattering and transport by water. Erosion of this kind would be favoured by a wetter climate with somewhat higher mean annual temperatures, hovering for much of the year about 0 °C. Much of the later part of the Full-glacial Period was probably both too cold and too dry for very much solifluxion and frost-shattering to occur in south-eastern England; to this time belongs the final phase of extensive loess formation on the continental mainland (Main Würm; Pleniglacial B).

It should be noted that the basal rubbles at Dover Hill, at Oxted, and at Cow Gap probably belong to zone I rather than to the Full-glacial Period.

Such processes of physical weathering everywhere ceased during at least the later part of the Allerød Oscillation. The hillsides became stabilized by vegetation and a soil developed. There is nowhere any evidence from the Mollusca for dense woodlands on the Chalk. The fauna continues to exhibit a grassland or rupestral character. But the frequency of charcoal suggests that the slopes locally bore small trees and patches of woody scrub, insufficient to shade the ground to any extent. Birch is present at Upper Halling, and both birch and juniper at Folkestone (see Appendix I). Charcoal of pine, which is said to predominate in the Usselo Layer in the Netherlands, has not been recognized. The origin of the charcoal is debatable. It is so very widespread that it seems most likely that it was formed during occasional natural fires, at times when the vegetation became unusually dry; such fires are said to be commonplace in the Siberian taiga (Pfizenmayer 1939, pp. 84, 237). A certain amount of redistribution of the charcoal by the wind probably occurred, but that it is essentially local in origin is shown by the presence at several sites, at Folkestone, Upper Halling and elsewhere, of fragments of chalk with burnt surfaces. Although natural fires seem the most probable general explanation, it should be noted that at Usselo itself, where an Upper Palaeolithic industry is known from the Allerød layer, a human origin, deliberate or accidental, has been suggested to explain exceptional local concentrations of charcoal (van der Hammen 1957*b*).

The Late-glacial fauna of land Mollusca assumed its most distinctive character during zone II. The sections along the North Downs, from Folkestone to Oxted, indicate that a number of species, most notably *Hygromia hispida*, *Abida secale*, *Helicella geyeri* and *H. itala*, first spread widely during this period. But at Beachy Head on the South Downs, if the evidence from this site has been correctly interpreted, some of these species were already present in numbers during zone I. This is a remarkable fact, in view of the slight distances involved. It should, however, be observed that a consideration of submarine contours suggests that during the Late-glacial Period an inlet of the open sea may have lain at no great distance to the south-west of Beachy Head, at a time when the Straits of Dover and most of the floor of the North Sea remained land. Such an hypothesis assumes a sea-level lower than that of the present-day by an order of not more than about 200 ft. (Godwin, Suggate & Willis 1958; McFarlan 1961). If this was so, the Beachy Head site, compared with the localities in Kent and Surrey, would have been subject to considerable maritime influence, perhaps allowing relatively thermophilous species to flourish locally at a rather earlier date.

When the climate deteriorated at the beginning of zone III, the Allerød soil was buried by a second series of chalk muds and rubbles. The lowest layer, immediately resting on the soil, is usually a fine chalk mud poor in chalk fragments, presumably representing the fringe of mud at the front of a fan of advancing chalk debris, later overridden by coarser material. It is perhaps partly to this fact that the excellent preservation of long stretches of the soil is due; only occasionally has evidence of destruction by channelling been observed (figure 7). Frost-heaving began almost at once, locally acting on the soil before it was buried, but also continuing throughout zone III. The deposits themselves vary greatly, from fine muds to rather coarse rubbles; sometimes there are seams of well-washed chalk gravel. The deposits tend to differ from those of zone I in showing a clearer stratification, and in usually being thicker, in spite of the shorter period of time, about 500 years, available for their formation. Processes of frost-shattering and transport were clearly particularly active, suggesting considerable volumes of water and a climate with temperatures fluctuating frequently about the freezing-point. The hypothesis that the climate was more humid than in zone I is supported by the fauna. A similar discrepancy in thickness between subaerial deposits assigned to zones I and III has been observed in Somerset, and a like cause is there postulated (ApSimon, Donovan & Taylor 1961, p. 107).

In the Netherlands, there is evidence, both from the stratigraphy of the Coversands and from the flora, that the climate of zone III was more oceanic than that of zone I. Further, it has been suggested that conditions first became significantly more humid about the middle of the Allerød Oscillation (van der Hammen 1952, 1953, p. 110). Certain consistent features shown by the molluscan histograms from south-eastern England, notably the sharp increases of *Retinella radiatula* and *Hygromia hispida*, might perhaps be interpreted as indicating a similar change at this time, comparable to the rise of the oceanic genus

Empetrum in the Netherlands. On the other hand, it should be pointed out that there is at present little evidence for a similar restriction of *Empetrum* in Britain; thus in the pollen diagram for Aby in Lincolnshire by Suggate & West (1959), *Empetrum* extends fairly consistently throughout zones I, II and III.

It has not been possible to arrive at any firm conclusions about Late-glacial temperatures. The evidence provided by the Mollusca is difficult to assess, in that we find associations of Arctic–Alpine species with forms whose distributions are considerably more southerly. As is pointed out by Coope (1961) in the case of beetles, such associations might arise during a period of rapidly ameliorating climate; this would bring about a northward extension of the range of thermophilous species into an area previously dominated by 'northern' species, many of which would for a time survive out of equilibrium with their environment. The molluscan fauna of zone II certainly presents such a mixture of geographical elements. But what is unexpected is the survival of all these species throughout zone III, sometimes in large numbers, in deposits showing unequivocal evidence of frost-shattering and frost-heaving.

Present-day geographical ranges alone may be highly misleading as evidence of climatic toleration. *Abida secale* is absent north of central Germany and abounds in warm calcareous environments in the south of Europe. Yet in the Alps it is also able to live and apparently flourish at high altitudes, considerably above those attained by many species with wider European distributions. *Abida secale* is therefore undoubtedly capable of surviving long periods of intense cold, perhaps of the order of −10 to −14 °C. The same may be true of *Helicella geyeri* and *H. itala*, although the evidence is less clear (see § VIII (*d*)). It is probably significant that all three species were well suited ecologically to the open landscape of south-eastern England during the Late-glacial Period. Their present distribution is almost certainly due to widespread extinction brought about by the elimination of their habitats during the Post-glacial Period, and is not directly related to climatic barriers. *Abida secale* exhibits a probable relict distribution in Britain, while *Helicella geyeri* has disappeared entirely from this country. But exactly why the Late-glacial environment was so suitable, and wherein lay its superiority over perhaps comparable open environments in northern Europe at the present day, is hard to see. *Abida secale* and *Helicella geyeri* have not shared in the widespread accidental dispersal by man in recent times of so many xerophilous land snails ('molluscan weeds'); *H. itala*, on the other hand, is said to be actively extending its range towards the east, and, according to Ložek (1949), is a modern invader in Czechoslovakia with no known geological history. In the southern hemisphere, it has been introduced by man into Australia and New Zealand.

Unfortunately we yet know very little about what temperatures land snails will tolerate. Breeding times vary greatly, and much more work is required on the relations of life-history to climate. For some species, summer temperatures appear to be of importance in restricting geographical ranges; for others, the absence of prolonged winter frosts. Some Mollusca are undoubtedly intolerant of cold. Thus *Helix aspersa*, an adaptable and efficient colonizer which has been distributed by man over much of the civilized world, is almost certainly limited geographically in Europe by low winter temperatures. It does not extend to the north-east beyond the January isotherm for about +2 °C, and in parts of Britain it is frequently killed in hibernation during unusually hard winters. Other species, particularly many small forms with effective modes of hibernation, are much better able to survive through intense frosts. Summer temperatures may be of greater importance to them. For example, *Ena montana* extends northwards to Scania, the Baltic States, and to near Moscow, yet only reaches the extreme south of the British Isles, where its hold is seemingly precarious.

But there are relatively few species whose geographical ranges can be explained in such simple terms. Most show complex distribution patterns which are related in no very obvious way to regional temperatures, but for which a host of other factors are doubtless equally responsible: soil, micro-climates, competition, parasites and predators.

Two species whose presence in zones II and III is perhaps suggestive climatically are *Vertigo pygmaea* and *Hygromia hispida*. Both are today widely distributed in Europe, but to the north, in Norway, Sweden and Finland, their range is restricted in such a way as to make it likely that they cannot tolerate prolonged low temperatures. Their limits coincide, very roughly, with the January isotherm for -5 °C. In the Alps, neither usually extends above about 1400 m. Taken at their face value, these facts suggest that the mean temperatures prevailing during the coldest month in zone III in south-east England were not lower than about -5 °C. But such an argument is almost certainly an oversimplification and other factors may have had an importance equal to temperature. For example, it has frequently been observed that land snails become increasingly restricted to calcareous environments when living under otherwise unfavourable conditions, and many present-day northern limits, including those of such normally moderate calciphiles as *Hygromia hispida* and *Vertigo pygmaea*, may indeed be partly controlled by the scarcity of calcium carbonate in northern Europe; it is noteworthy that *H. hispida* is absent from most of the Scottish Highlands. The abundance of calcium carbonate on the Chalk of southern England may well have been a counterbalancing factor, to be set against possible low winter temperatures.

Similarly, no clear picture can be formed concerning the summer temperatures of zones II and III, but it seems likely that these remained low throughout. The fauna, in spite of its curious composition, is a very restricted one compared to that of the Post-glacial Period, whole families, such as the *Clausiliidae*, being apparently as yet unrepresented. Conversely, a true Arctic–Alpine species, *Columella columella*, was able not only to survive, but locally to flourish.

Because of these many uncertainties, and in view of the limited number of species available upon which deductions can be based, all that can be said at present is that the climate of zone III was probably not as severe as that of zone I. Furthermore, the fall in temperature at the zone II/III boundary seems not to have been very large, for it caused no extinctions. A more important temperature change was that which occurred at the beginning of the Allerød Oscillation, and which brought about a considerable expansion of thermophilous species.

Subaerial meltwater deposits of the Late-glacial Period will almost certainly prove to be widespread on the North and South Downs, and, indeed, in many other limestone tracts of England. Deposits which appear to be of the same age and general character have been described from Cambridgeshire (Sparks 1952; Norris 1962, pp. 109 to 111), Lincolnshire (Burchell & Davis 1957), West Sussex (Kennard & Woodward *in* Palmer & Cooke 1923) and, perhaps, on the Carboniferous Limestone at Brean Down in Somerset (ApSimon *et al.* 1961). This last site is of particular interest, for the section includes a fossil soil tentatively equated with part of the Allerød Oscillation, and which has yielded a considerable mammalian fauna of typical Late Pleistocene facies, including horse, reindeer, giant deer, mammoth, snow lemming, arctic hare and arctic fox (ApSimon *et al.* 1961, p. 130).

The Late-glacial Period was the last during which the Chalk landscape was subjected to severe erosion. With the rise of temperature and the spread of forests in the Post-glacial, all processes of rapid physical weathering ceased. Apart from the effects of solution, local accumulations of hillwash, minor spring-sapping, and slight interference by man, the present features of the Chalk escarpment and its associated dry valleys and coombes are essentially those in existence at the end of zone III, approximately 10000 years ago.

My thanks are due to Professor H. Godwin, F.R.S., for helpful discussion, and for making possible the two radiocarbon datings. The valuable appendixes were kindly written by Mr J. F. Levy and Dr K. P. Oakley. Other assistance was received from Dr T. van der Hammen, Dr W. H. Zagwijn, Dr H. E. Quick, Major J. P. T. Burchell, Mr J. N. Carreck, Mr A. E. Ellis, Miss C. A. Lambert and Mr C. P. Castell; and advice on photography was given by Mr J. A. Gee. Also I should like to thank those many friends, notably Dr D. V. Ager, who helped with the collecting of samples or the measuring of sections. Most of the work was carried out during the tenure of an 1851 Senior Studentship.

Appendix I. Charcoals from Dover Hill and Upper Halling

By J. F. Levy

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The vast majority of the samples examined were small fragments of wood charcoal. In some instances charred bark was also present and a very few pieces of distorted wood which had been incompletely charred. Two species were noted, *Betula* sp. (birch) and *Juniperus* sp. (juniper). The latter occurred from one site only whereas birch was frequent throughout. Birch was characterized by the vessels in the transverse section being solitary or in short radial chains and somewhat oval in cross-section. The rays were narrow, multiseriate and no aggregate rays were seen. The vessels had no spiral thickening, the radial walls were well pitted and scleriform perforation plates were seen.

The juniper was characterized by the presence of tracheids with large bordered pits; resin ducts were absent in all specimens examined; very little late wood was formed giving the growth ring a very uniform appearance. The rays were uniseriate and rarely more than 4 or 5 cells high. The cross field pitting was not seen clearly.

Dover Hill

Soil (*Upper half:* 350 to 363 cm)

37 fragments received, of which 20 were examined microscopically. The largest fragment was approximately 6 mm × 4 mm × 2 mm and the average were some 2 to 3 mm long and 1 to 2 mm square in cross-section. Species present: birch, 11 fragments; juniper, 8 fragments; not identified, 1 fragment (bark (?)).

Soil (*Lower half:* 363 to 376 cm)

28 fragments received, of which 20 were examined microscopically. The largest fragment was 7 mm × 4 mm × 1 mm and the average were some 3 mm × 2 mm × 1 mm. Species present: birch, 13 fragments; wood, not charred, possibly birch, 2 fragments; very distorted, charring incomplete, probably birch, 3 fragments; not identified, 2 fragments.

Upper Halling

Soil (*Upper half:* 160 to 167·5 cm)

Many small fragments (100 to 120) received, of which 27 were examined microscopically. The largest fragment was 5 mm × 3 mm × 1 mm and the average 2 mm × 2 mm × 1 mm. Species present: birch, 14 fragments; not identified, 13 fragments (bark, 12 fragments). The macroscopic estimate of the remainder unexamined suggested that more than half resembled birch fragments and the remainder were bark.

Soil (*Lower half:* 167·5 to 175 cm)

17 fragments received, of which 6 were examined microscopically. The average size of specimens was similar to that in the upper half of the soil. Species present: birch 4 fragments; not identified, 2 fragments (bark, 1 fragment).

Appendix II. Note on the antiquity of Halling Man

By K. P. Oakley

Subdepartment of Anthropology, British Museum (*Natural History*)

After studying the data available in 1951 I summarized the probable status of this skeleton as follows:

'Contracted burial, 6 feet below present surface, in alluvial loam, Lower Flood-plain Terrace. Probably buried from an occupation surface marked by layer of hearths containing flint artifacts of Upper Palaeolithic type (cf. Creswellian), but possibly from a land surface at base of silt layer containing Mesolithic (Maglemosian) artifacts'. (Catalogue des Hommes Fossiles, *C.R. XIXe Sess. Cong. Géol. Internat*, Fasc. V, 1952, pp. 199–200.)

Since 1952 a number of new facts have emerged which necessitate some revision of the statement of dating evidence. There is now much greater probability that the body of Halling Man was placed in a shallow grave dug from the surface marked by hearths at the top of stratum no. 5 (Cook 1914, p. 219), but that the burial occurred in Holocene times, not during the Pleistocene.

Dr Kerney's researches have demonstrated that the so-called Low Terrace of Halling is really an artificial feature, and that the strata termed nos. 1 to 5 by Cook, including the skeleton stratum (No. 5), are Post-glacial hillwashes overlying chalky Pleistocene drift of largely fluviatile origin (Cook's strata nos. 6 to 9, probably in part Late-glacial).

A number of animal bones labelled Halling were rescued from the Collections of the Royal College of Surgeons together with the Halling Skeleton after the bombing in 1941. Some of these bones are undoubtedly Pleistocene, whereas others are Post-glacial. Chemical analyses show that the Halling Skeleton is closer in preservation to the Pleistocene bones from this site than to the Post-glacial series (see table 7 below). This suggests that the human bones were buried not later than very *early* in Holocene times. However, according to Dr Kerney the Mollusca in the matrix of the skeleton are of Post-glacial character, including *Pomatias elegans* which is unlikely to have been present in Britain before Pollen Zone V.

Only six flint artifacts from Cook's excavations at Halling have survived:* two flakes and four blades, on the basis of which it has not been easy to be certain whether the floor represented is Late Palaeolithic or early Mesolithic. There is no evidence that the industry is early Upper Palaeolithic (Aurignacian) as it was authoritatively stated to be in earlier literature. At the earliest the artifacts might be Ahrensburgian, although certainly none is diagnostic of that culture. When I showed the surviving pieces to Mr W. F. Rankine (now deceased) during his work on the Mesolithic industries of the Weald he stated that in his opinion while four of the artifacts were undiagnostic, two (including a burin) were undoubtedly Mesolithic. The flaked axehead from Halling figured by Cook (1914, Fig. 4) appears Mesolithic, but it was from the top of the hillwashes, just below humus, so it is not necessarily of the same age as the floor associated with the skeleton.

TABLE 7. ANALYSES OF BONES FROM HALLING

	% nitrogen	% fluorine	*e*, U_3O_8 p.p.m.
Holocene bones:			
Bos longifrons (S. 69)	1·7	0·1	nil
Caprid—'large sheep' (S. 58)	2·9	0·4	2
Pleistocene bones:			
Equus sp. (S. 67)	1·2	0·8	6
Elephas primigenius (S. 49)	0·6	1·3	4
'Halling Man' ulna (S. 65)	0·9	1·3	5

Note (1). Apart from the specimen of mammoth bone, the division of the bones into Holocene and Pleistocene is based mainly on the matrix. Each specimen in Cook's collection marked 'Halling' is without the stratum being specified. Cook states (p. 215) that no animal bones were found in the stratum containing the human skeleton.

Note (2). The fluorine analyses were made in the Government Chemist's Laboratory (G. F. Phillips), the other analyses in the British Museum (Natural History), 'uranium' by Mrs B. E. Gardiner, nitrogen by G. C. Ross. 'Uranium' content was assessed by radiometric assay and expressed as equivalent uranium oxide in parts per million: *e*, U_3O_8 p.p.m.

The Halling site does not appear to have been excavated or recorded very methodically and consequently it is difficult to be certain that there was only one archaeological horizon at the base of the hillwashes. The published record (Cook & Killick 1924, p. 152) of a humanly scratched rhinoceros bone from the site suggests that an Upper Palaeolithic culture was represented here, but the surviving flint artifacts appear to represent a single industry, and the presence of ochreous matrix on three of them suggests that they came from a floor in loamy hillwash rather than in chalky Pleistocene drift. Indeed it is important to note that the matrix of the skeleton itself is loamy.

In summary I provisionally infer that the Halling Skeleton is that of an Early Mesolithic man buried from a land surface near the base of the hillwashes. The archaeological and chemical data will be published in further detail elsewhere.

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* Only one of these is a figured specimen (Cook 1914, Pl. XX, fig. 1, which is an undiagnostic flake, with incised cortex).

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FIGURE 19. (*a*) Dover Hill, Folkestone, Kent (TR/235376). Allerød soil involved in freeze-thaw structures; beds lettered as in figure 2. (*b*) Oxted Limeworks, Surrey (TQ/380544). Beds lettered as in figure 11.

Figure 20. (*a*) Upper Halling, Kent; north face of Section *A* (TQ/688635). Margin of Full-glacial, Late-glacial and Post-glacial deposits infilling dry valley. (*b*) Upper Halling; extreme eastern end of north face of Section *A*. Allerød soil showing freeze-thaw structures. Key to figures (*a*) and (*b*): *a*, coombe rock; *b*, buff silty chalk rubble and mud (Full-glacial); *c–e*, zone I chalk muds; *f*, Allerød soil; *g*, zone III chalk muds; *j*, Post-glacial hillwash.

Figure 21. (*a*) Upper Halling, Kent; Section *B* (TQ/692635) at place where samples were taken. Beds lettered as in figure 7. (*b*) Holborough, Kent; Section *D* (TQ/702626) at place where samples '*A*' were taken. Beds lettered as in figure 9.

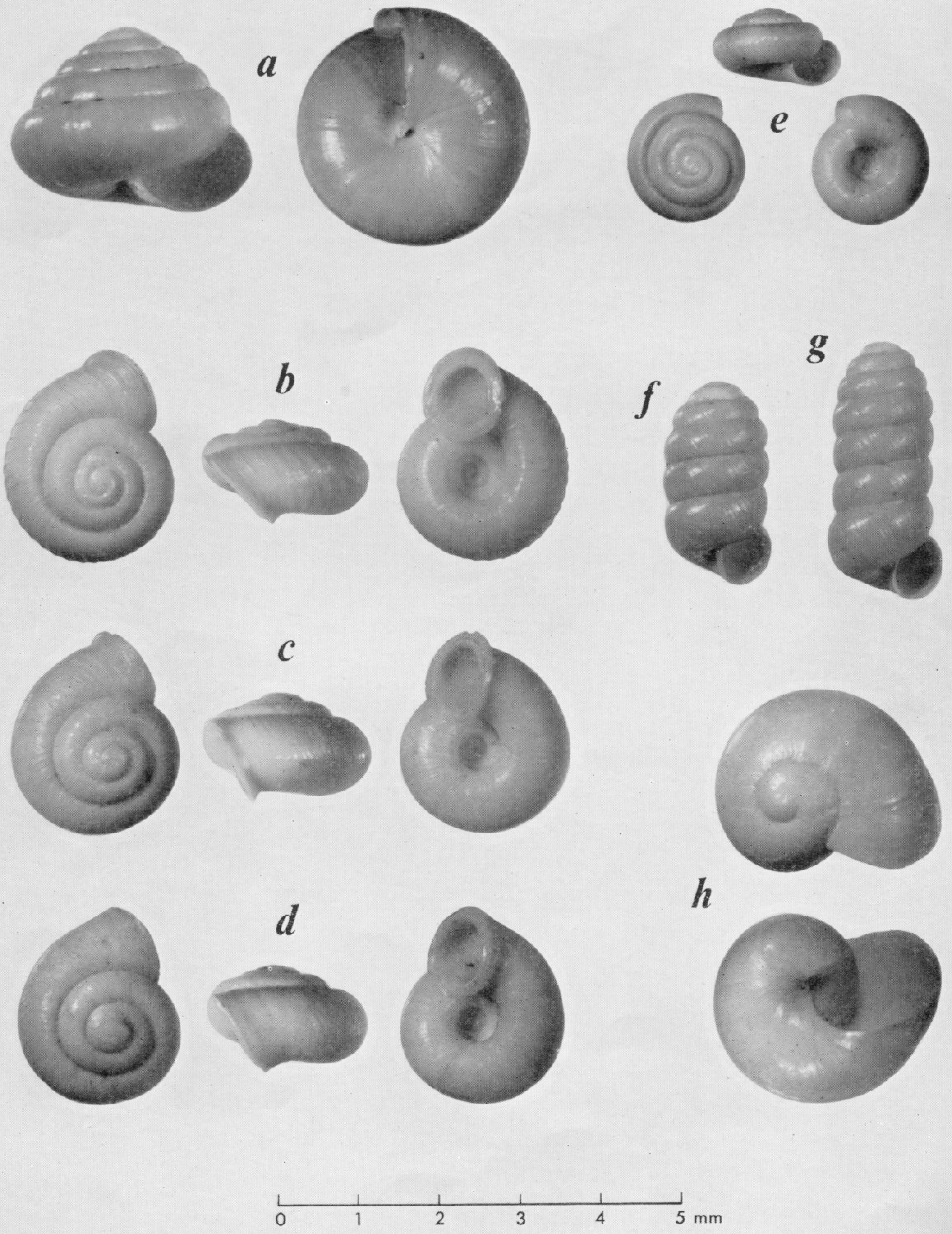

Figure 22. (*a*) *Euconulus fulvus* (Müller). Dover Hill, Folkestone. Zone II, 390 to 400 cm. (*b*) *Vallonia costata* (Müller). Holborough. Zone I, 210 to 215 cm. (*c*) *Vallonia pulchella* (Müller). Holborough. Zone I, 210 to 215 cm. (*d*) *Vallonia excentrica* Sterki. Oxted. Zone II, 230 to 238 cm. (*e*) *Punctum pygmaeum* (Draparnaud). Dover Hill, Folkestone. Zone II, 435 to 445 cm. (*f*), (*g*) *Columella columella* (Martens). Castle Hill, Folkestone. Zone III, 150 to 158 cm. (*h*) *Vitrina pellucida* (Müller), half-grown example. Oxted. Zone I, 330 to 338 cm.

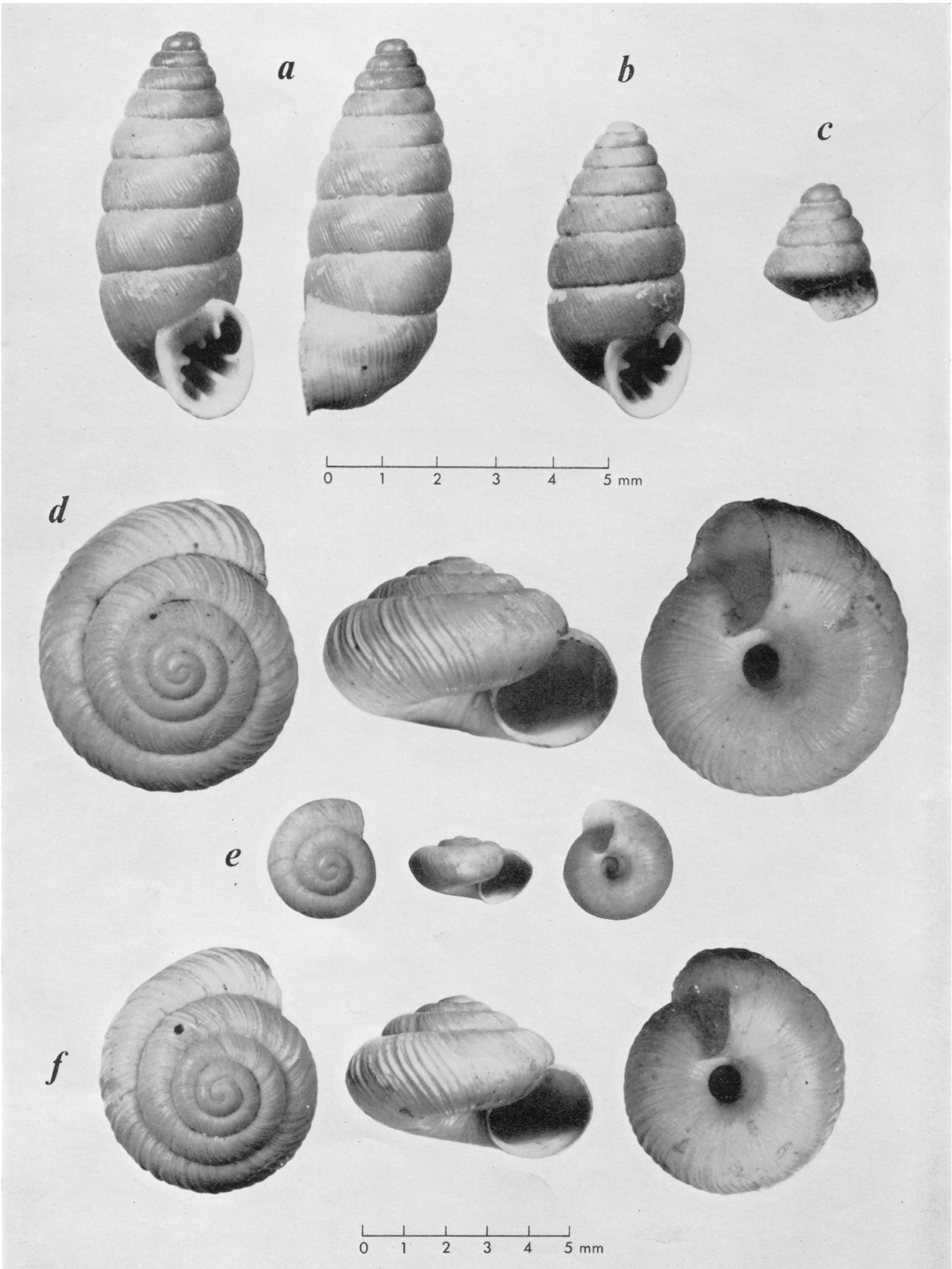

Figure 23. (*a*) *Abida secale* (Draparnaud). Holborough. Zone II soil, 168 to 174 cm. (*b*) *Abida secale* (Draparnaud). Section *A*, Upper Halling. Zone II soil. (*c*) *Abida secale* (Draparnaud), apical fragment. Holborough. Zone II soil, 168 to 174 cm. (*d*) *Helicella geyeri* (Soós). Oxted. Zone III, 190 to 198 cm. (*e*) *Helicella geyeri* (Soós), juvenile. Oxted, Zone III, 190 to 198 cm. (*f*) *Helicella geyeri* (Soós). Section *A*, Upper Halling. Zone II soil.

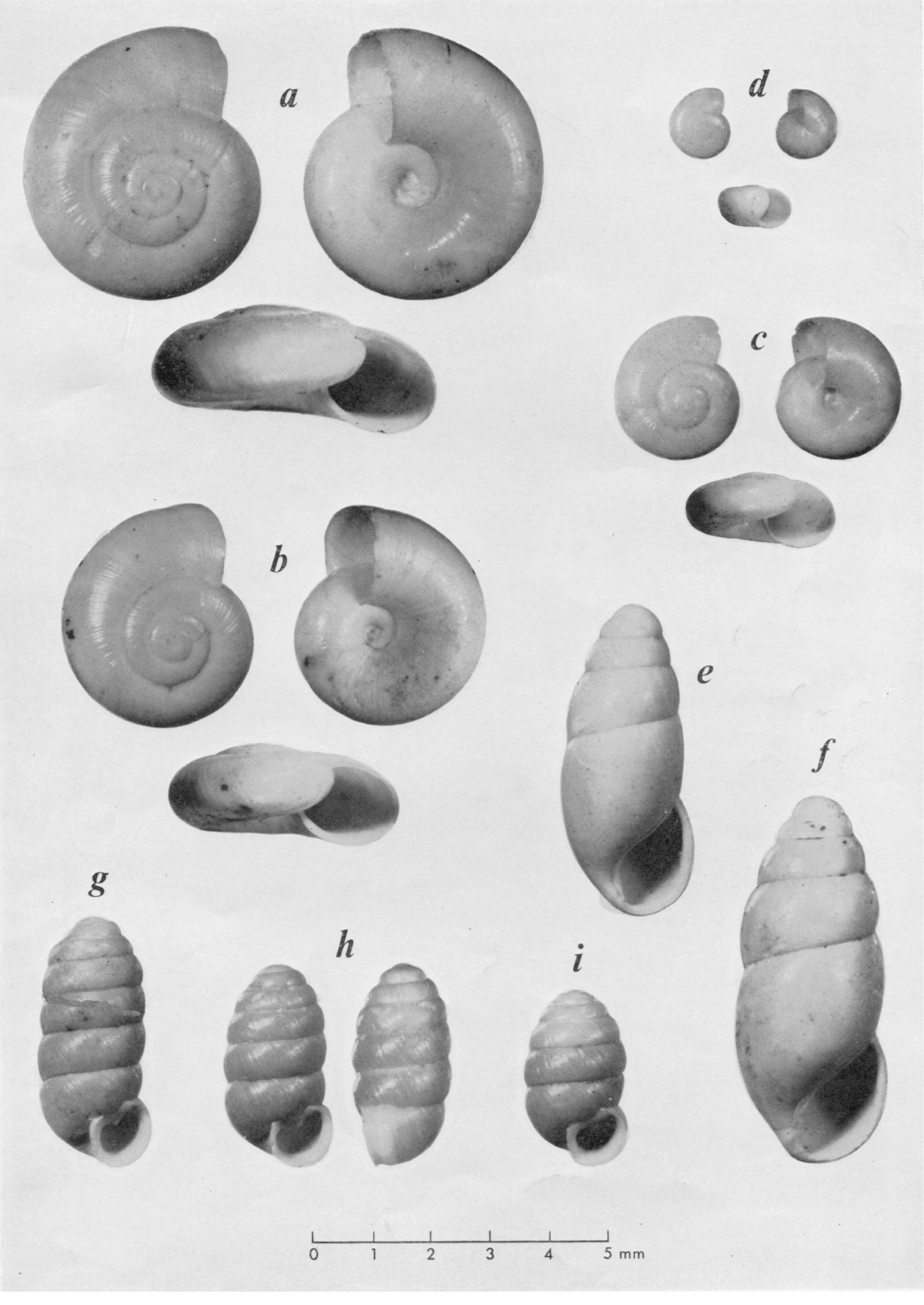

FIGURE 24. (*a*) *Retinella radiatula* (Alder), very large example. Cow Gap, Beachy Head. Zone II soil, 205 to 213 cm. (*b*) *Retinella radiatula* (Alder), normal example. Cow Gap, Beachy Head. Zone II soil, 205 to 213 cm. (*c*), (*d*) *Retinella radiatula* (Alder), juveniles. Cow Gap, Beachy Head. Zone II soil, 205 to 213 cm. (*e*) *Cochlicopa lubricella* (Porro). Cow Gap, Beachy Head. Zone II soil, 205 to 213 cm. (*f*) *Cochlicopa lubrica* (Müller). Cow Gap, Beachy Head. Zone II soil, 205 to 213 cm. (*g*), (*h*), (*i*) *Pupilla muscorum* (Linné). Holborough. Zone II soil, 168 to 174 cm.

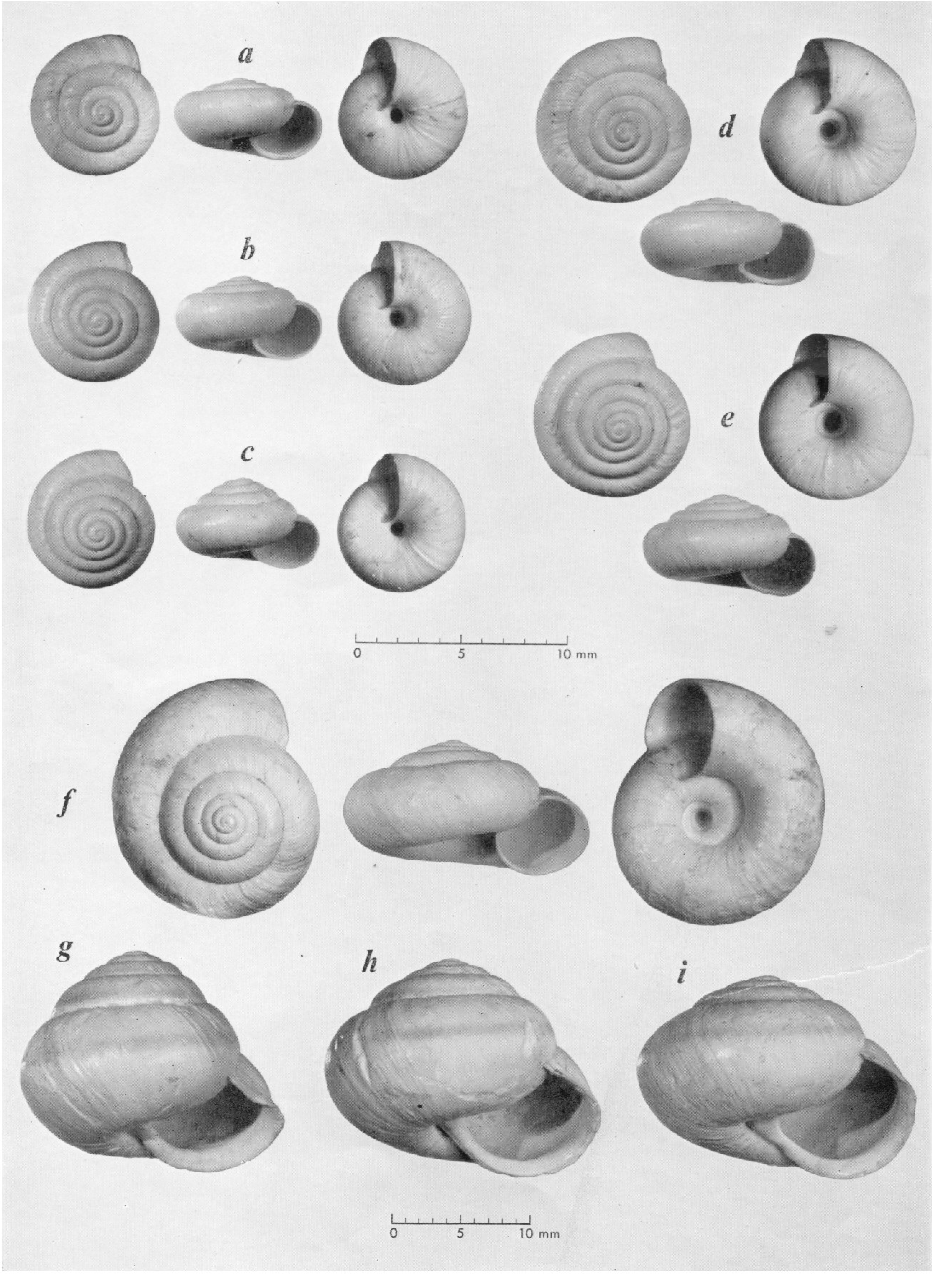

FIGURE 25. (*a*), (*b*), (*c*) *Hygromia hispida* (Linné). Castle Hill, Folkestone. Zone III, 140 to 148 cm. (*d*) *Hygromia hispida* (Linné). Holborough. Zone III (Site B), 146 to 154 cm. (*e*) *Hygromia hispida* (Linné). Holborough. Zone III (Site A), 111 to 119 cm. (*f*) *Helicella itala* (Linné). Dover Hill, Folkestone. Zone III. (*g*), (*h*), (*i*) *Arianta arbustorum* (Linné). Cow Gap, Beachy Head. Zone III.