THE LATE-GLACIAL AND POST-GLACIAL HISTORY OF THE CHALK ESCARPMENT NEAR BROOK, KENT

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This paper describes the morphology of a small piece of the Chalk escarpment near Brook in east Kent, and reconstructs its history since the end of the Last Glaciation. The escarpment contains a number of steep-sided valleys, or coombes, with which are associated deposits of chalk debris, filling their bottoms and extending as fans over the Gault Clay plain beyond. Here the fans overlie radiocarbon-dated marsh deposits of zone II (10000 to 8800 B.C.) of the Late-glacial Period. The debris fans were formed and the coombes were cut very largely during the succeeding zone III (8800 to 8300 B.C.). The fans are the products of frost-shattering, probably transported by a combination of niveo-fluvial action and the release of spring waters; intercalated seams of loess also occur.

The molluscs and plants preserved in the Late-glacial deposits give a fairly detailed picture of local conditions.

The later history of one of the coombes, the Devil's Kneadingtrough, is reconstructed. The springs have effected virtually no erosion and have probably always emerged more or less in their present position. In the floor of the coombe the periglacial chalk rubbles of zone III are covered by Post-glacial deposits, mainly hillwashes. They are oxidized and yield no pollen, but contain rich faunas of land Mollusca, which are presented in the form of histograms revealing changing local ecological and climatic conditions.

During most of the Post-glacial Period, from the end of zone III until about the beginning of zone VIII, very little accumulation took place on the coombe floor. But below the springs there are marsh deposits which span much of this interval. They yield faunas of considerable zoogeographical interest. The approximate beginning of zone VII*a* (Atlantic Period) is reflected by a calcareous tufa, which overlies a weathering horizon, and represents an increase in spring flow.

Two clearance phases are deduced from the molluscan record. The first may have taken place at least as early as the Beaker Period (Late Neolithic/earliest Bronze Age); the second is probably of Iron Age 'A' date.

In Iron Age times the subsoil was mobilized and a phase of rapid hillwashing began. As a result the valley floor became buried by humic chalk muds. The prime cause of this process was probably the beginning of intensive arable farming on the slopes above the coombe; a possible subsidiary factor may have been the Sub-Atlantic worsening of climate. The muds yield pottery ranging in date from Iron Age 'Kentish first A' (*ca.* 500 to *ca.* 300 B.C.) to Romano–British ware of the first or second centuries A.D.

Evidence is put forward for a possible climatic oscillation from dry to wet taking place at about the time of Christ.

In the later stages of cultivation, possibly in the Roman Era, the valley floor was ploughed and given its present-day form.

I. GEOMORPHOLOGY

(*a*) *Introduction*

The escarpment of the North Downs is broken in a number of places. Five major gaps have been cut by the rivers Wey, Mole, Darent, Medway and Stour; four others at Sugar Loaf (223386*), Coombe Farm (170394), Staple Farm (155395) and Merstham (TQ 287545) are now dry but may formerly have been river gaps. There are also twelve cols, perhaps due to scarp retreat (Small 1961, p. 88), eight of them located between the Darent and Mole, one between the Medway and Darent, none in the 22 miles (35 km) between the Medway and Stour, and two, Stowting Coombe (126434) and Staple Lees (083450), east of the Stour.

The Stour, Medway and Darent gaps have substantial funnel like entrances opening to the south (Fagg 1954, p. 118), that of the Medway is, for instance, 12 miles (19 km) wide and 6 miles (10 km) deep, But there is only a faint suggestion of a funnel at the entrance to the Mole gap and in the case of the Wey none at all. Of the four major dry gaps through the scarp only that at Merstham has a funnel entrance; this is 4 miles (6 km) wide and 2 miles (3 km) deep.

The face of the escarpment is also dissected by a large number of coombes, some of which head back into the cols like small funnels, e. g. Stowting and Sugar Loaf coombes east

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* National Grid Reference; this and all subsequent unprefixed references refer to 100 km square TR.

of the Stour, Pebble and Colekitchen coombes east and west of the Mole gap, respectively. Many others, varying in size from small funnels down to mere scallops, head back into an unbroken crest line.

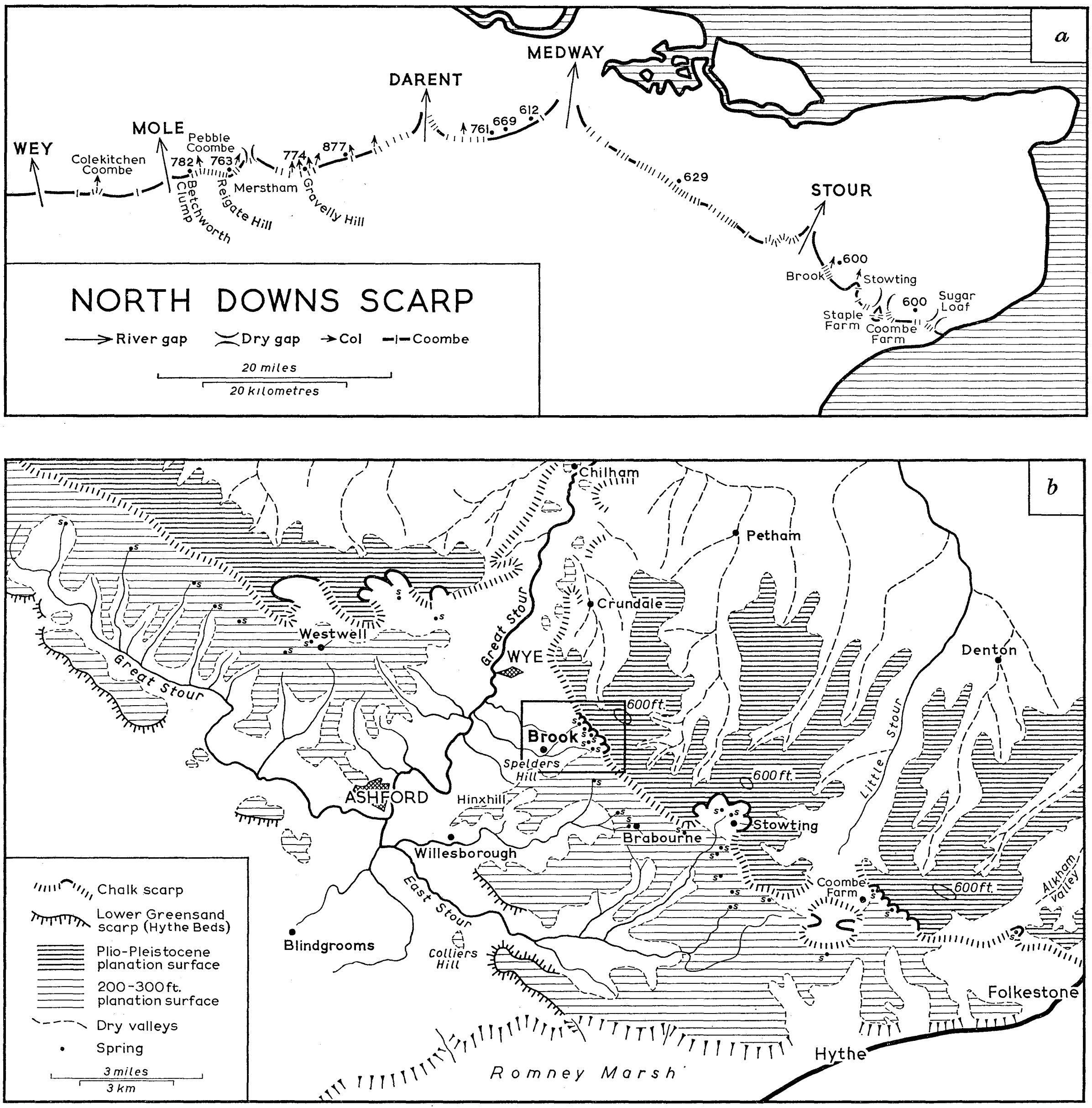


FIGURE 1 (*a*). The North Downs scarp. The position of coombes in the scarp face is indicated by small lines across the run of the scarp (thick line). Heights along the scarp crest are shown in feet. (*b*). The Stour gap through the North Downs. The rectangle shows the area covered by figure 2.

The base of the scarp rises from approximately 200 ft. (61 m) O.D. in the necks of the funnels to 400 ft. (122 m) and over on the divides between subsequent streams draining the scarpfoot Vale of Holmesdale. The crest of the scarp averages 580 to 590 ft. (177 to 180 m) from Folkestone to the Stour gap and 620 to 650 (189 to 198 m) between the Stour and Medway gaps. In both areas it is bevelled by a Plio-Pleistocene wave-cut platform

(Wooldridge & Linton 1955, p. 48). Between the Medway and Darent, west of Trottiscliffe, the scarp crest rises to between 700 ft. (213 m) and 800 ft. (244 m) on the still higher level of the Mio-Pliocene peneplain. It reaches its highest elevation on Botley Hill (877 ft.; 267 m). At Gravelly Hill (774 ft.; 236 m), south of Caterham, Reigate Hill (763 ft.; 233 m) and Betchworth Clump (782 ft.; 238 m) the scarp projects southwards between the funnels of the Mole, Pebble Coombe, Merstham and Darent. It is possible that these projections are synclinal in character, marking lines of north–south flexure in the Chalk. The funnels may be along complementary alined anticlinal flexures as has been suggested by Wooldridge in the cases of the Medway and Stour river gaps (Wooldridge 1926, p. 185). The crest of the Downs declines from its highest points where the scarp foot is highest to less than 500 ft. (152 m) down dip in the funnel necks.

Thus the actual height of the scarp varies from circa 450 ft. (137 m), e.g. at Betchworth Clump to less than 200 ft. (61 m), e.g. at Lenham and averages 300 ft. (91 m).

(*b*) *The Stour gap*

The main component in the Stour drainage system is the Great Stour, a strike stream draining eastwards approximately along the outcrop of the Sandgate Beds and fed by half a dozen obsequent tributaries which rise in springs at or near the base of the Chalk scarp. The East Stour follows a similar subsequent course along the outcrop of the Hythe Beds and is also nourished by spring-fed obsequents. Neither has any south bank tributaries but a trunk stream rises at Blindgrooms 3·5 miles (6 km) south of Ashford on the Weald Clay and flows north, down dip, to the Chalk at Wye. The broad Gault outcrop is drained from the east by three strike streams matched west of the river by six others, but the stream flowing from Brabourne coombe to Willsborough is oblique to the strike.

The funnel leading into the Stour gap is 9 miles (15 km) wide and 3 miles (5 km) deep. Within it the river has cut its present valley floor to a depth of 80 to 90 ft. (24 to 27 m) below a 200 ft. (61 m) high plateau surface which equally bevels the Gault, Lower Greensand and Weald Clay outcrops (Wooldridge 1928, p. 8) as at Spelders Hill, Hinxhill and Colliers Hill. This planation surface rises away from the river to over 300 ft. (91 m) at the foot of the Chalk scarp at Eastwell, Westwell and Brabourne.

The western side of the Stour funnel is indented by two large amphitheatre-like coombes at Eastwell and Westwell, each approximately 1 mile (1·3 km) wide and 1 mile deep. The scarp outside and within the coombes is scalloped. East of the Stour is a coombe of comparable size at Stowting but west of this the scarp sweeps northwards into the Stour funnel at Olantigh. Near Brook the scarp is etched by a remarkable cluster of seven coombes which do little to break the smooth curve of the scarp in plan. These coombes are the subject of the detailed investigation which follows. The local dip is 1° 15′ in a direction 017° N.

Converging from east and west onto the neck of the Stour funnel, between Olantigh and Chilham, are two dry valley systems focused upon Crundale and Chilham, respectively. On the plateau east of the gap a third set of dry valleys heads north-eastwards and is eventually collected by the dry valley through Petham. Between this set and Crundale is a broad interfluve, in places over a mile wide, reaching a height of just over 600 ft. (183 m). Opposite this the scarp face is dissected by the previously mentioned seven coombes north of Brook. Their situation is analogous to that of Stowting coombe, which heads back into a similar but still wider interfluve between the Petham valley and the Little Stour. Further east again the bunch of scarp-face coombes immediately east of Coombe Farm, on the flank of the funnel leading into the Coombe Farm gap, are cut back into a similarly broad interfluve between the Little Stour and the Alkham set of dry valleys. In all three instances the plateau reaches its highest elevation, just over 600 ft. (183 m), about a mile back from the dissected scarp face.

(*c*) *The coombes*

The area studied in greater detail sits astride a spring-line junction between Chalk and Gault which descends northwards with the dip into the Stour funnel. The crest of the North Downs is bevelled by a remarkably even surface between 580 ft. (177 m) and 593 ft. (181 m). Slopes on this Plio-Pleistocene sea floor are never more than ½° while the floor is masked locally by Early Pleistocene marine sands and shingles. The only relief is the Staple Lees col, some 60 ft. (18 m) deep, leading northwards into the head of the Crundale dry valley system. At the foot of the scarp, areas of little or no slope are located on the Lower Chalk outcrop at about 300 ft. (91 m); these are remnants of a scarp-foot bench more extensively preserved further south. At Hampton and on Spelder's Hill there are remnants of a yet lower bench at 240 ft. (73 m) cut in Gault Clay. There are also fragments of lower benches at 170 ft. (52 m) under Spelders Hill and at 127 ft. (39 m) further north, also cut in the Gault Clay. The 300 ft. (91 m) planation surface has been dissected into flat topped knolls by small streams which rise in springs at or slightly above the base of the Chalk, roughly along the line of the scarp-foot road. The 200 ft. (61 m) surface on the Gault is less dissected.

Most of the Gault outcrop shown on figure 2 has been eroded down to a low plain extending two miles (3 km) from the foot of the Chalk scarp. Slopes on this plain are characteristically between ½° and 1½°. It is drained north-westwards by two strike streams which fall from 180 ft. (55 m) to just over 100 ft. (30 m) into what appears to be a low terrace of the Stour, no more than 10 ft. (3 m) above present river level. The two strike streams are fed by five springs. Before nineteenth century re-organization of field drainage the Pickersdane stream, now a roadside ditch through the village of Brook, drained into the northernmost of the two streams. Slopes separating the low plain from the dissected scarp-foot benches are abrupt even where cut in Gault Clay. Thus from Spelders Hill to Hampton the angle of slope is generally 6° to 7° and locally reaches 8½°. Where the break coincides with the scarp of the Lower Chalk it is, at a maximum, 8° to 10°.

North of the area shown on figure 2 the profile of the undissected scarp between the Plio-Pleistocene bevel and the low plain on the Gault is made up of three elements. At the top is a small convex element with slopes of 3° to 8°, below is the steepest section of the scarp made up of a number of straight segments with angles of slope at first 14° but increasing to a maximum of 18° to 20° before decreasing to 9° or 10°. Below this is a long concave pediment with slopes at first 7° or 8° declining to 2° and less before it merges with the low plain. Where the scarp has been dissected by the coombes the scarp profile between the coombes is somewhat different. The upper convexity, with slopes increasing from 1½° to 8° or 9°, is broad and occupies more than half the 300 to 500 yard (274 to

457 m) wide scarp zone. The steepest part of the scarp has angles of 22° to 24°, but a basal concavity is not readily discernible because of dissection by the spring streams and the modification of the surface during the construction of numerous lynchets.

There are seven coombes, the largest of which are cut back 500 yards (457 m) into the scarp face. They are, from south to north, the New Barn coombe, the Old Limekiln coombe, Fishpond Bottom, Newgate Scrubs, the Devil's Kneadingtrough and the two small Pickersdane Scrubs coombes. All have flat or very gently concave floors in cross-section and very steep, straight sides which vary in angle between 20° and 34°. In five coombes, one side slope is steeper than the other by between 1° and 6°. This slight asymmetry cannot be explained in structural terms as it is usually the south facing slope which is the gentler although it is the nearer approximation to a scarp face. The flat floor of Fishpond Bottom rises to over 500 ft. (152 m) and in most coombes the floor reaches to 400 to 450 ft. (122 to 137 m); there are therefore steep longitudinal gradients in all coombes, at their heads this is as high as 17° but gradually decreases down slope to 4° to 5°. In Fishpond Bottom, Newgate Scrubs, the Devil's Kneadingtrough and Pickersdane Scrubs south, the head of the coombe bifurcates and there are two narrow steep-sided tributary channels leading down from the scarp crest into the main coombes.

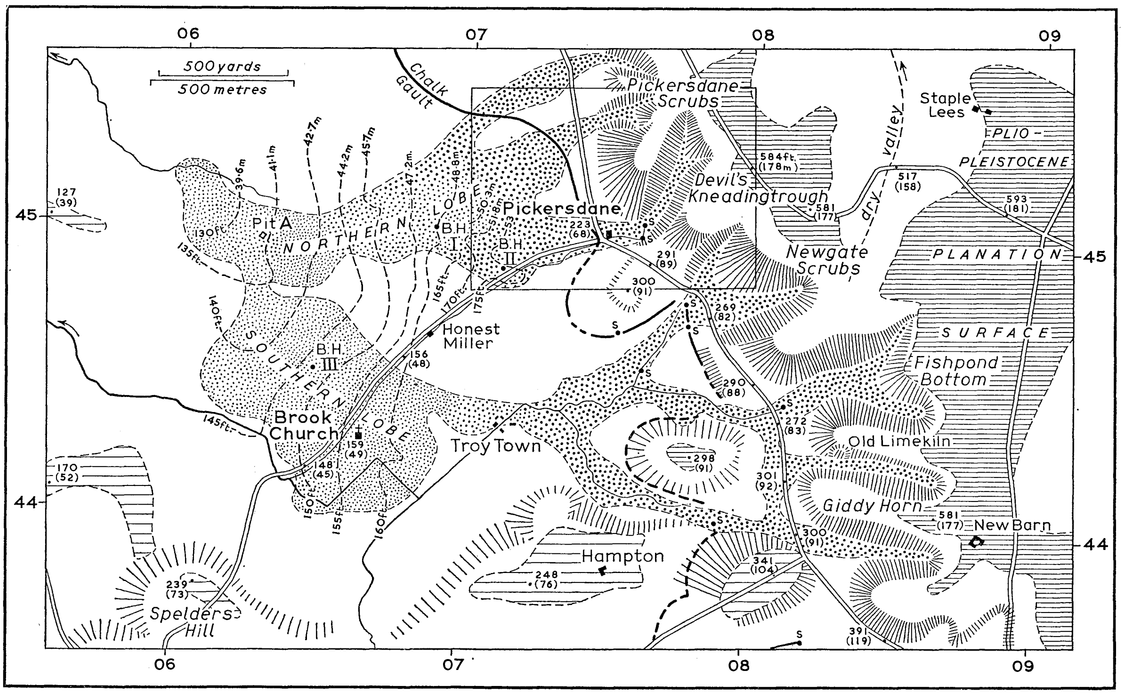


FIGURE 2. Coombes cut into the Chalk escarpment near Brook. Trails of zone III deposits extending from the coombe floors and coalescing into two lobes ahead of the scarp are stippled. The rectangle shows the area covered by figure 4.

An analysis of the orientations and lengths of the coombes is shown in figure 3, in which the axes of the main coombes and their tributaries are distinguished. It is evident that there is a wide range in orientation from 004° to 132°, 128° of the possible 180°. An arc between 324°, the trend of the scarp, and 004°, that of the main tributary of the Devil's Kneadingtrough, is devoid of coombes. Several points emerge. The two longest coombes, Old Limekiln and New Barn, at the southern end of the series and Pickersdane Scrubs at the northern end have approximately the same orientations, between 092° and 097°, and the former is also the trend of the entrance to the Devil's Kneadingtrough, below the springs. The trend of the main axis of the Kneadingtrough, 020°, is within a few degrees that of the dip, 017°, whilst the very long tributary of Fishpond Bottom trends 110° within 3° of the strike. A comparison with the comparable coombes in the scarp near Coombe Farm (170390), where the scarp trends 310°, shows that although the latter all differ in trend amongst themselves, five out of the six can be matched within 5° with coombes at Brook: that which is oriented 050° is no nearer than 10°.

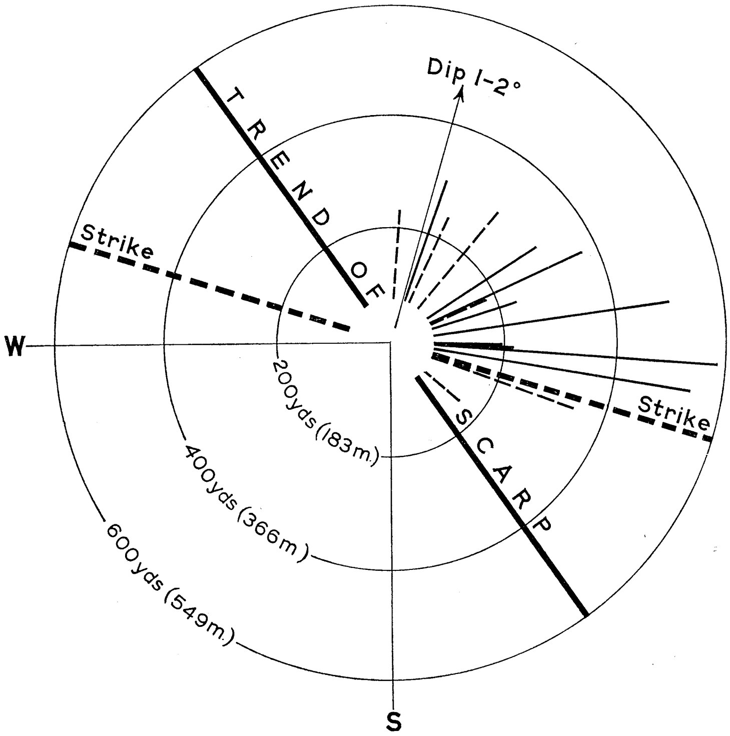


FIGURE 3. Orientation analysis of the escarpment coombes near Brook. The continuous lines give the lengths and orientations of the main coombes in relation to the trend of the scarp and the direction of strike. Broken lines refer to the coombe tributaries.

(*d*) *The Devil's Kneadingtrough*

That the coombe has the form of a kneading trough or more accurately half a kneading trough is readily apparent when it is viewed on the ground. The orientation of the main axis of the coombe is 020° N, within a matter of 3° of that of the regional dip. The fish-tail shape of the coombe end comprises two channels oriented 355° and 035° N, which meet to form the main body of the coombe and a steep triangular spur between them: the principal axes of Fishpond Bottom (357°) and the Old Limekiln coombe (030°) have similar orientations respectively. Below the present springs the entrance to the Kneadingtrough trends 273°, a direction similar to that followed by the New Barn coombe.

The sides of the Kneadingtrough are remarkably straight and smooth (figure 19*a*, plate 19). The west-facing slope has an average inclination of 34°, the east-facing slope and the spur between the channels 32°. Minor irregularities on the sides include horizontal lines of terracettes at 3 to 6 ft. (1 to 2 m) intervals. Minor scars and slips, especially at the head of the coombe, are probably a consequence of mortar explosions during World War II when the coombe was used as a firing range. The Melbourn Rock which outcrops approximately half way up the scarp face makes no feature whatsoever on the sides of the coombe. A slight change of slope running obliquely across the upper part of the west facing slope is too high and slopes into the coombe at too great an angle to be its expression. A similar change of gradient on the east-facing slope descending from near the scarp crest at the head of the coombe towards the entrance is most probably an old trackway leading from the ancient fields above to the springs below. The top edge of the coombe is everywhere distinct and nowhere more so than high up on the east side where it takes the form of an embankment. This is not a natural feature but marks the lower limit of the ancient fields on the convex slope above and may reasonably be regarded as a limit of cultivation. But this eastern edge is still quite sharp lower down, on the scarp face, well below the limit of the ancient fields, where it can owe little if anything to ploughing. It is probably a measure of the recent character of the incision of the coombe into the scarp face. On the west spur the upper edge of the straight coombe side is rather less well marked. On the convexity above it are a number of grassed-over hills and hollows, perhaps the remnants of old diggings in Plio-Pleistocene sands.

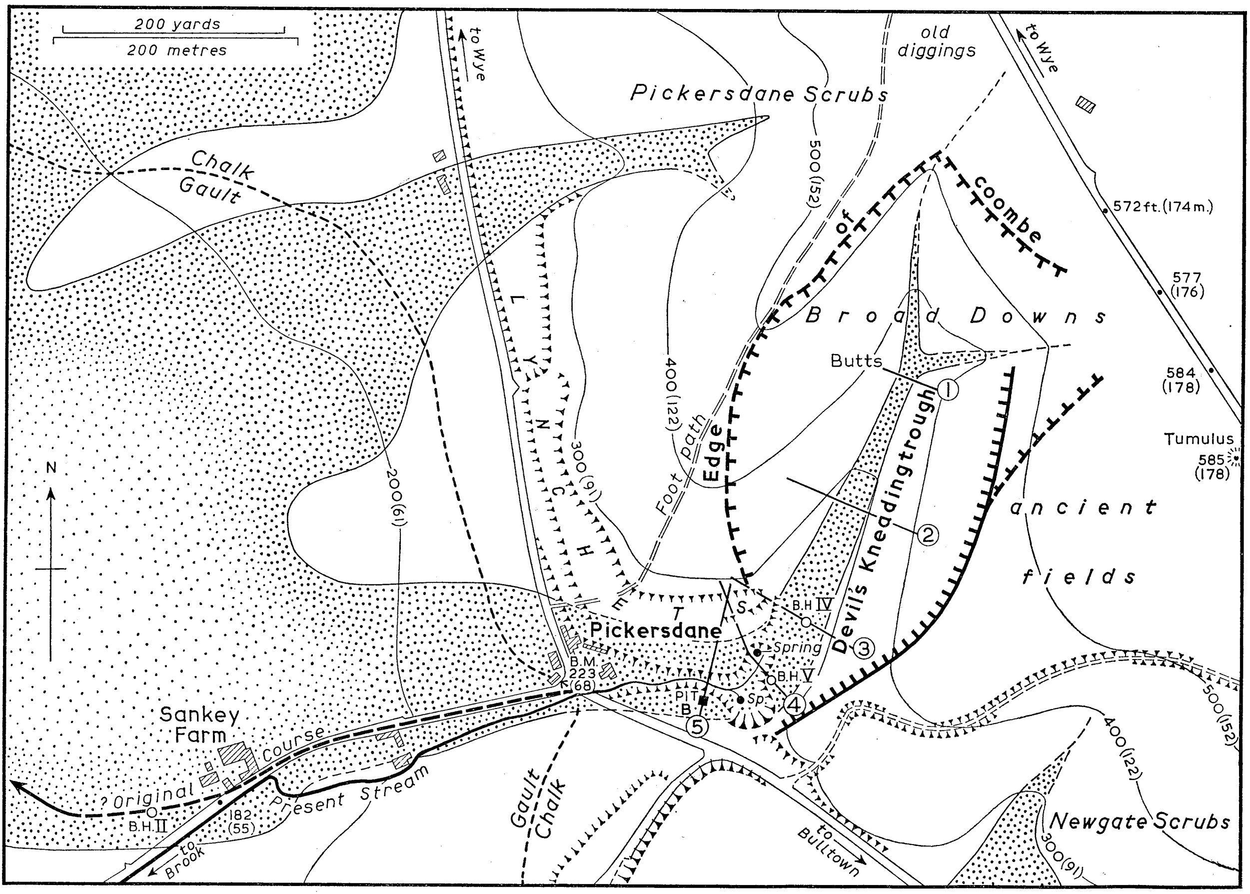


FIGURE 4. The Devil's Kneadingtrough: physical setting. Deposits of zone III in the bottom of the coombes and their extensions out onto the plain ahead of the scarp are stippled. The edge of the lynchets and other steep slopes are shown by conventional barb symbols. Contour and spot heights are in feet and (in brackets) metres.

The floor of the coombe ascends from a height of 262 ft. (80 m) at the entrance to 328 ft. (100 m) at the rifle butts trench. Detailed levelling shows that its long profile is gently concave (figure 5). At the butts trench there is a slackening of this longitudinal gradient masked in the field by the spoil heaps of the butts. Above this change in slope the floor of the west channel ascends steeply but smoothly and nearly straight from 361 to 523 ft. (110 to 160 m) below the summit convexity.

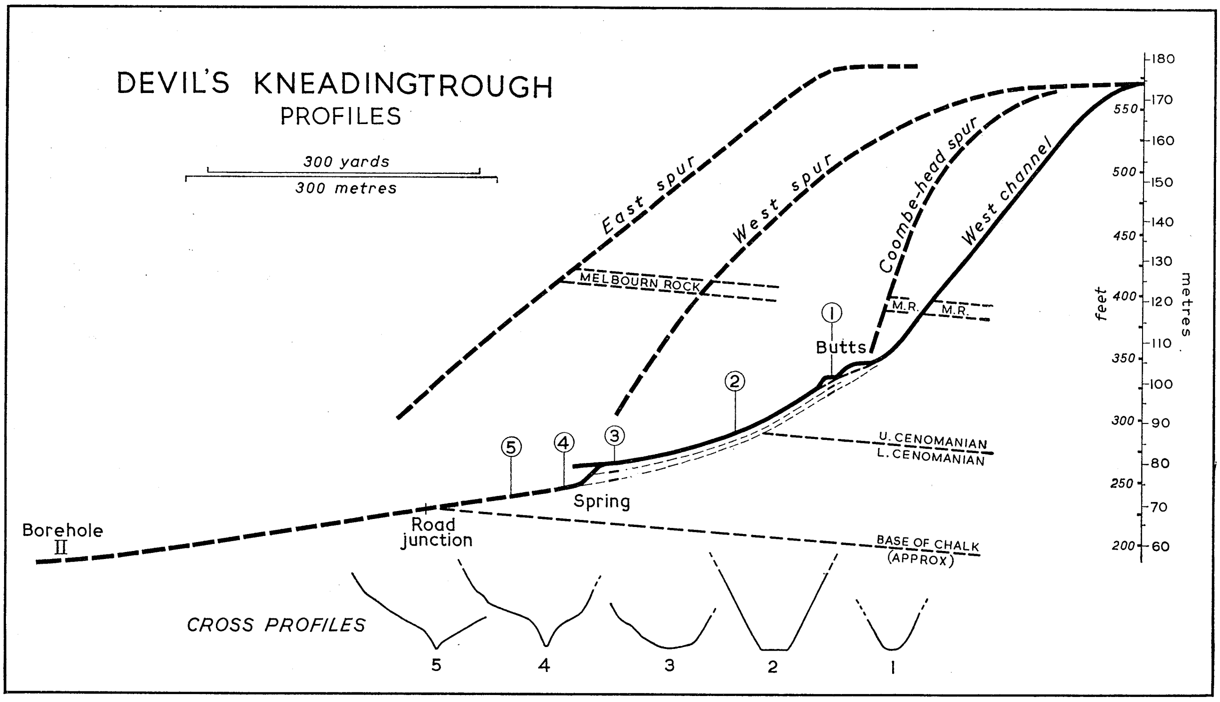


Figure 5. The Devil's Kneadingtrough: long and cross profiles. The encircled Arabic numbers position the cross profiles at the bottom of the diagram.

At the lower end of the coombe, where it changes direction, are two nests of springs. The northern one occupies a marshy amphitheatre cut 17 ft. (5 m) below the level of the floor of the coombe, and slightly west of the axis of the main coombe so that the spring would seem to be operating at the base of the west spur of the scarp. The southern one occupies a broader marshy hollow under the eastern spur at the point where the coombe turns westwards. The valley formed by the two spring heads narrows downstream for a short distance before widening again just above Pickersdane Farm house. Surface forms in this vicinity have been significantly modified by human interference, as may be deduced from the presence of a series of lynchets cut and built in the scarp foot zone on either side of the Kneadingtrough and, as will be shown, extending into its floor.

(*e*) *The morphology of the deposits*

The steep, often forked channels at the upper ends of the coombes are occupied by thin trails of chalky drift which thicken, widen and coalesce down slope into broad tongues occupying the floors of the coombes. These extend, stream like, out onto the plain ahead of the scarp (figure 2). The height of the individual trails where they leave their coombes increases southwards from approximately 233 ft. (68 m) at the mouth of the Devil's Kneadingtrough, to 269 ft. (82 m) at Newgate Scrubs, 272 ft. (83 m) at Fishpond Bottom, 301 ft. (92 m) at the Old Limekiln and 300 ft. (92 m) at Giddyhorn, in accordance with increasing distance from the low plain on the Gault which operates as the local base level. The trails from the Pickersdane Scrubs coombes leave the scarp at approximately 275 ft. (84 m).

From the mouths of the coombes the trails of deposits fall steadily in height away from the scarp along the lengths of shallow valleys cut in the Lower Chalk and Gault. Those from Newgate Scrubs and Fishpond Bottom coalesce above Troy Town where they are joined by the trail from Giddyhorn at a height of approximately 175 ft. (53 m). Downstream from Troy Town the deposits broaden into an extensive southern lobe which extends to a distance of over one mile (1·6 km) from the scarp foot. Those from Pickersdane Scrubs and the Devil's Kneadingtrough descend to approximately 180 ft. (55 m) and coalesce to form a smaller, northern lobe on Sankey Farm. The two lobes are joined by a narrow neck in the northwestern corner of the Church fields.

In the coombes the upper surface of the deposits is slightly concave in cross section (figure 5). Their long profiles are clearly concave, but a slight hump near the mouth of Giddyhorn reverses the otherwise smooth gradient of its floor. The mouth of the Devil's Kneadingtrough is dissected by a spring-head coombe, the character of which has been described previously. In the mouth of Fishpond Bottom there is a similar spring coombe, much modified by recent excavation.

Below Troy Town and Sankey Farm the lobes are flat enough to have given rise to a local view that they are former lake sites. This is, in fact, hardly tenable on geomorphological grounds alone for there is no barrier which might have ponded back such a lake or lakes. In any case the upper surfaces of the lobes are not as flat as at first glance they would appear to be. They slope away from the scarp from approximately 180 ft. (55 m) at Troy Town and Sankey Farm to 130 ft. (40 m) at the distal end of the northern lobe. Contours on their surfaces (figure 2) bulge in a down-lobe direction showing that in cross-section they are slightly convex.

Between the two lobes is a low spur, mostly on Gault clay, extending ahead of a lynchet-girt hill at 300 ft. (91 m) on the Lower Chalk. West of the Honest Miller the spur flattens and the ground surface extends from the northern to the southern lobes without a marked change of slope. The spur is in fact replaced by a very shallow valley, not obvious in the field but revealed in the contour pattern. This once carried a stream which is now diverted at the Honest Miller along the road through Brook.

II. LATE-GLACIAL DEPOSITS

(a) *Introduction*

The fans of chalky debris shown on figure 2 were mapped by detailed augering. Their stratigraphy was further investigated in open sections, and by taking several 4 in. (10 cm) diameter cores through the deposits with a percussion corer. The results of this work, which revealed at the base of the fans the existence of a widespread marker horizon representing the Allerød Oscillation (zone II), are described below.

In order to discover the precise stratigraphical source of the chalky material, a number of representative samples were kindly examined by Mr D. J. Carter for derived Foraminifera in the light of his recent work on the trial boreholes for the proposed Channel Tunnel. The sources of origin given below are in all cases based on his analyses.

(*b*) *Stratigraphy*: *northern lobe*

(*b*1) *Section in Pit A.*

Pit A (figure 2; 06264495) exposed 260 cm of dominantly chalky sediments resting on Gault Clay (figure 6; figure 20*b*, plate 20). Above a basal gravel, 50 cm thick, consisting of coarse chalk and flint debris in a clayey matrix, are a series of fine calcareous muds, virtually devoid of macroscopic chalk fragments and showing traces of bedding. The muds are divided by a dark grey fossil soil (Munsell colour 5Y 3/1; 2/1 moist), containing many fragments of birch charcoal (Appendix II), and assigned on stratigraphical evidence to zone II. The muds below the soil are olive (5Y 7/3; 5/3 moist), and consist mainly of reworked Lower Cenomanian and subordinate Upper Albian, whereas those above are white and consist almost entirely of material from the Upper Cenomanian and Lower Turonian (D. J. Carter). The soil itself locally shows small disturbances which may be due to frost-heaving.

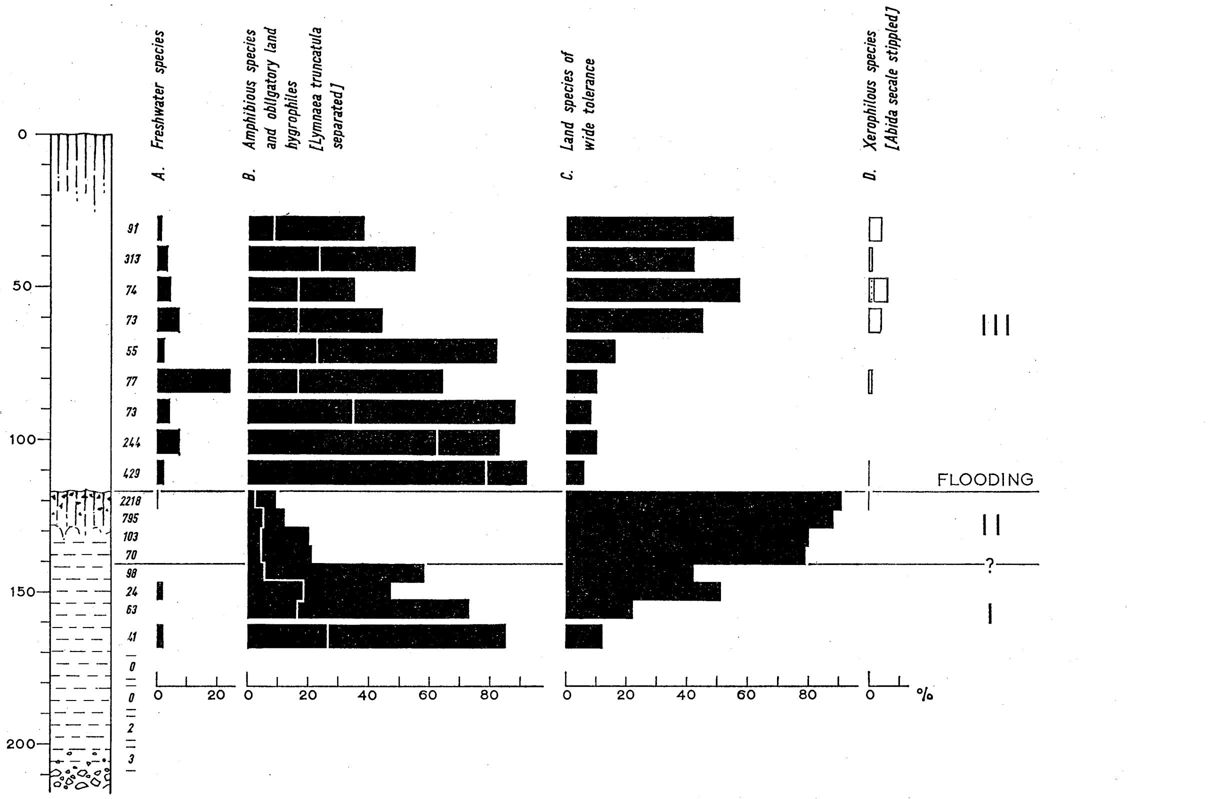


FIGURE 6. Pit A, Brook: stratigraphy and molluscan histogram; the stratigraphical symbols used are explained in figure 9. In ecological group B, the percentage of *Lymnaea truncatula* is shown to the left of the white line.

A series of samples weighing 2 kg was cut from the face of the section and the Mollusca extracted. The full results are shown in table 1; figure 6 illustrates the changing percentage frequencies through the deposits of certain broad groups of Mollusca, arranged in order of decreasing moisture requirements. These groups are as follows:

Group A. Freshwater species: *Lymnaea palustris*, *L. peregra*, *Aplexa hypnorum*, *Planorbis* spp., *Pisidium* spp.

Group B. Amphibious species and obligatory land hygrophiles: *Lymnaea truncatula*, *Catinella arenaria*, *Succinea pfeifferi*, *Vertigo antivertigo*, *V. genesii*. *Columella columella* also belongs in this group, but has been plotted separately where it occurs.

Group C. Land species of fairly wide tolerance: *Cochlicopa* spp., *Vertigo pygmaea*, *Pupilla muscorum*, *Vallonia pulchella*, *Arianta arbustorum*, *Hygromia hispida*, *Punctum pygmaeum*, *Euconulus fulvus*, *Retinella radiatula*, *Vitrina pellucida*.

Group D. Xerophilous species: *Abida secale*, *Vallonia costata*, *Helicella itala*.

These groupings, it should be emphasized, are somewhat arbitrary, and their limits are indefinite. In particular, Group C contains a somewhat heterogenous mixture of species. *Pupilla muscorum*, included here, is almost exclusively a xerophile in Britain today, but has not been placed in Group D because of its apparent tolerance of much damper environments during the Late-glacial Period (see §III).

Note on certain problems of identification

In identifying and counting the Mollusca listed in tables 1 to 7, certain difficulties were met with. They chiefly concern the identification of species of *Cochlicopa*, *Vallonia*, *Helix* and *Arianta*, and *Vertigo*.

An attempt has been made to assign all apices of *Cochlicopa* spp. to their correct segregates, but since this can only safely be done with reasonably well-grown shells, the numbers for each species must be regarded as approximations. The same remark applies to the pair of genera *Helix* (*Cepaea*) and *Arianta*.

Vallonia excentrica can only be distinguished from *V. pulchella* by lip characters, developed at maturity. In those deposits where both species occur in association, all adults were first identified and counted, and juveniles and broken apices then assigned to each species in exact proportion.

In the genus *Vertigo*, it proved virtually impossible to separate apical fragments or juveniles of *V. genesii*, *V. pygmaea* and *V. antivertigo*. The technique used was therefore first to count all complete shells together with all apertural fragments of each species, giving minimum certain totals. It was assumed that most of the apical parts of the broken shells were represented among the unidentified apices, and the numbers of the former were therefore subtracted from the latter; the remaining apices (if any) were then split in proportion to the numbers of secure identifications.

In the tables, added shells of *Vallonia* or *Vertigo* are preceded by a plus sign.

These procedures are probably fairly satisfactory when applied to large numbers of shells, but for obvious reasons become less so when totals are low. Furthermore, certain unknown factors, such as specifically variable infant mortality, may introduce a bias towards one or other of the species, but such an error is likely to be fairly systematic and in any case should not affect the broad statistical results.

The counts given for *Pisidium* are for individual valves; for percentage purposes these numbers were halved.

TABLE 1. BROOK. PIT A

Samples of 2 kg dry weight

cm …	201–209	191–199	181–189	171–179	161–169	153–159	147–153	141–147	135–141	129–135	123–129	117–123	107–115	95–105	87–95	77–85	67–75	57–65	47–55	37–45	27–35
Lymnaea truncatula (Müller)	3	2	—	—	10	10	5	5	3	4	37	55	337	151	25	12	12	12	12	71	7
Lymnaea palustris (Müller)	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1	—	—
Planorbis leucostoma Millet	—	—	—	—	—	—	—	—	—	—	—	1	5	17	2	19	1	4	1	5	—
Planorbis cf. laevis Alder	—	—	—	—	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Catinella arenaria (Bouchard-Chantereaux)	—	—	—	—	25	36	6	32	9	11	51	86	—	—	—	2	—	2	4	24	3
Succinea pfeifferi Rossmässler	—	—	—	—	—	—	—	20	3	5	5	37	57	50	38	34	32	2	5	48	17
Cochlicopa lubrica (Müller)	—	—	—	—	—	—	—	? 1	4	4	42	162	1	—	—	1	? 2	2	1	6	? 3
Cochlicopa lubricella (Porro)	—	—	—	—	—	—	—	—	—	—	—	20	—	—	—	1	—	—	—	4	—
Vertigo pygmaea (Draparnaud)	—	—	—	—	? 1	1	—	—	4	5+1	20+4	78+14	1+3	1+1	—	—	? 1	3+2	4	1+1	1+2
Vertigo genesii Gredler. form 'A'	—	—	—	—	—	—	—	—	—	1	2	12	—	1	? 1	? 1	? 1	8	4	16	3
Vertigo genesii Gredler. form 'B'	—	—	—	—	—	—	—	—	—	—	—	1	—	—	—	—	—	1	1	2	—
Vertigo genesii s.l.	—	—	—	—	—	—	—	—	—	—	—	+2	—	—	—	—	—	+7	—	+10	+5
Pupilla muscorum (Linné)	—	—	—	—	1	11	2	6	12	11	151	343	9	13	2	1	1	5	15	43	4
Abida secale (Draparnaud)	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1	—	—
Vallonia costata (Müller)	—	—	—	—	—	—	—	—	—	—	—	7	—	—	—	1	—	3	2	4	2
Vallonia pulchella (Müller)	—	—	—	—	—	1	8	23	23	50	389	1009	3	4	—	2	—	11	10	45	22
Arianta arbustorum (Linné)	—	—	—	—	—	—	—	—	—	1	1	8	1	—	1	1	1	1	1	1	1
Hygromia hispida (Linné)	—	—	—	—	—	—	—	1	3	3	18	142	6	2	1	1	3	5	5	20	12
Helicella itala (Linné)	—	—	—	—	—	—	—	—	—	—	—	—	1	—	—	—	—	—	1	—	2
Punctum pygmaeum (Draparnaud)	—	—	—	—	—	—	—	1	4	1	18	63	1	2	—	—	1	1	2	2	3
Euconulus fulvus (Müller)	—	—	—	—	3	3	2	8	3	—	7	30	—	1	1	1	—	2	1	4	2
Retinella radiatula (Alder)	—	—	—	—	—	1	—	1	2	6	42	144	—	—	1	—	—	1	1	3	1
Vitrina pellucida (Müller)	—	—	—	—	—	—	—	—	—	—	8	3	—	—	—	—	—	—	1	—	—
Agriolimax spp.	—	—	—	—	×	×	×	×	—	×	×	×	—	—	×	×	—	×	×	×	—
Pisidium casertanum (Poli)	—	—	—	—	—	—	1	—	—	—	—	1	8	1	1	—	—	1	2	4	—
Pisidium obtusale lapponicum Clessin	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1	—	1	2

The molluscan histogram (figure 6) shows a very clear pattern of changes, interpreted in terms of two cycles of increasing dryness, separated, at the level of the base of the upper chalk muds, by an episode of flooding.

The lower olive muds are very poor in Mollusca. Above 170 cm, where the plotting begins, a progressive drying out of a marshy area is indicated, culminating in the soil with its rich fauna of mesophilous species. But the dryness of the environment at this level should not be over-emphasized, for *Catinella* and *Succinea* remain frequent, *Vallonia pulchella* is very abundant, and xerophiles are virtually absent. The environment suggested is of an area covered by luxuriant wet herbaceous vegetation, with occasional puddles between the tussocks. On the evidence of the charcoal, there were local birch trees (Appendix II), but the Mollusca are inconsistent with any considerable shading of the ground. The *Succineidae*, in particular, require well-lit environments. Rather close British parallels to the molluscan fauna are provided by certain of the Irish localities where *Vertigo genesii* survives, on the margins of bogs on the Central Plain in places where the vegetation is dominated by *Schoenus nigricans*, *Juncus* spp. and many species of grasses and sedges (Phillips 1935).

The overlying white chalk muds of zone III reflect a sudden change to much wetter conditions, as the marsh was covered by sheets of chalky slurry, on the surfaces of which temporary pools developed. Small numbers of freshwater species occur erratically throughout. At the base, the percentage of obligatory hygrophiles of group B, particularly of *Lymnaea truncatula*, is very high, but this component gradually falls with time, and the more catholic land species of Group C correspondingly increase. Xerophiles appear towards the top, probably derived from drier environments at some distance. It is interesting to contrast the ecologically rather homogeneous assemblage found in the soil, essentially autochthonous, with the more diverse fauna present in the muds of zone III, containing elements brought together from a wide area.

Neither the stratigraphy nor the fauna gives any very clear indication as to the placing of the zone I/II boundary. Nor can any lower limit be suggested for zone I, although the relatively abrupt change in facies between the gravel and the calcareous muds may have a climatic significance.

(*b*2) *Boreholes I and II*

Borehole I was sunk a little over $\frac{3}{8}$ of a mile (650 m) due east of Pit A (figure 2; 06904500). The stratigraphy here is as follows:

	cm
Surface soil	0 to 45
White chalk mud; a very few chalk pellets between 125 and 135 cm (zone III)	45 to 170
Grey fossil soil (zone II)	170 to 172
Olive (5Y 6/3; 5/3 moist) calcareous clayey mud with scattered chalk fragments	172 to 193
Chalk gravel in a matrix of olive calcareous mud	193 to 202
Gault Clay; intensely brecciated to a depth of about 220 cm; undisturbed and unweathered below this.	

TABLE 2. BROOK. BOREHOLES I AND II

	Borehole I									Borehole II									
cm …	159–168	149–159	139–149	128–137	119–128	110–119	96·5–108	85–96·5	73·5–85	127–136	120–122+124–127	112–120	101–112	91–101	80–91	69–78	60–69	51–60	42–51
dry weight of sample (g)* …	1325	1305	1265	1065	1110	820	1545	1645	1585	1225	605	1030	1360	1355	1375	1255	1250	1250	1260
Lymnaea truncatula (Müller)	—	48	429	198	8	4	40	4	8	1	—	4	—	1	7	3	6	4	5
Lymnaea peregra (Müller)	—	—	—	—	13	11	—	—	—	—	—	—	—	—	—	—	—	—	—
Planorbis leucostoma Millet	—	—	60	—	—	—	4	1	1	—	—	—	—	—	—	—	—	—	—
Catinella arenaria (Bouchard-Chantereaux)	3	55	147	121	1	1	3	—	—	—	—	—	—	—	2	—	—	—	—
Succinea pfeifferi Rossmässler	—	—	161	28	—	—	72	8	4	1	2	13	2	10	17	5	16	7	12
Cochlicopa lubrica (Müller)	—	—	24	13	1	—	5	—	1	2	7	1	2	8	3	3	6	2	3
Cochlicopa lubricella (Porro)	—	—	—	—	—	—	2	—	—	—	—	—	—	—	1	1	—	—	—
Vertigo antivertigo (Draparnaud)	—	—	7+7	—	—	—	—	—	1+1	—	—	—	—	—	—	—	—	—	—
Vertigo pygmaea (Draparnaud)	—	—	3+3	—	1	—	1	—	1+1	—	—	—	—	—	1	—	—	—	—
Vertigo genesii Gredler. form 'A'	—	15	254	123	2	2	11	2	2	? 1	1	1	—	1	? 1	2	3	—	? 1
Vertigo genesii Gredler. form 'B'	—	—	10	3	—	—	—	—	—	—	2	—	2	—	—	1	2	—	—
Vertigo genesii s.l.	—	+10	+253	+162	—	+3	+7	+1	+3	—	—	—	—	+2	—	—	+3	—	—
Pupilla muscorum (Linné)	1	34	82	24	3	2	9	2	7	3	14	2	5	10	20	12	18	—	8
Abida secale (Draparnaud)	—	—	—	1	—	—	1	1	—	—	1	3	1	5	5	3	5	1	1
Vallonia costata (Müller)	—	—	—	1	—	—	1	—	—	6	16	10	8	9	13	7	21	2	6
Vallonia pulchella (Müller)	—	7	119	27	4	2	20	5	9	4	13	5	4	12	10	7	16	5	7
Arianta arbustorum (Linné)	—	—	1	1	1	1	2	2	2	—	7	1	1	1	2	1	2	1	2
Hygromia hispida (Linné)	1	—	1	2	4	7	21	7	19	1	6	7	2	10	13	9	27	9	29
Helicella itala (Linné)	—	—	—	—	—	—	—	—	—	—	2	—	—	—	1	1	2	—	—
Punctum pygmaeum (Draparnaud)	—	—	3	—	—	3	2	2	1	7	19	12	8	14	18	10	12	—	2
Euconulus fulvus (Müller)	—	10	33	11	3	—	9	1	1	2	3	3	3	3	3	4	8	2	1
Retinella radiatula (Alder)	—	—	1	4	—	1	2	—	—	—	2	1	2	3	3	—	2	1	1
Vitrina pellucida (Müller)	—	—	2	—	—	1	—	—	—	1	1	—	—	2	5	1	4	1	1
Agriolimax spp.	—	×	×	×	—	—	—	—	×	—	×	—	—	—	—	×	—	—	×
Pisidium casertanum (Poli)	—	2	13	19	—	1	7	2	1	—	2	1	—	1	4	2	1	—	—
Pisidium obtusale lapponicum Clessin	—	—	18	26	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Pisidium subtruncatum Malm	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1	—	—	—	—

* Given in this and subsequent tables to nearest 5 g.

The chalk muds of zone III yielded a rather erratically developed molluscan fauna of marsh facies (table 2). *Vertigo genesii* was particularly abundant. There is a distinct tendency for the hygrophilous element to decrease upwards, though much less regularly than at Pit A.

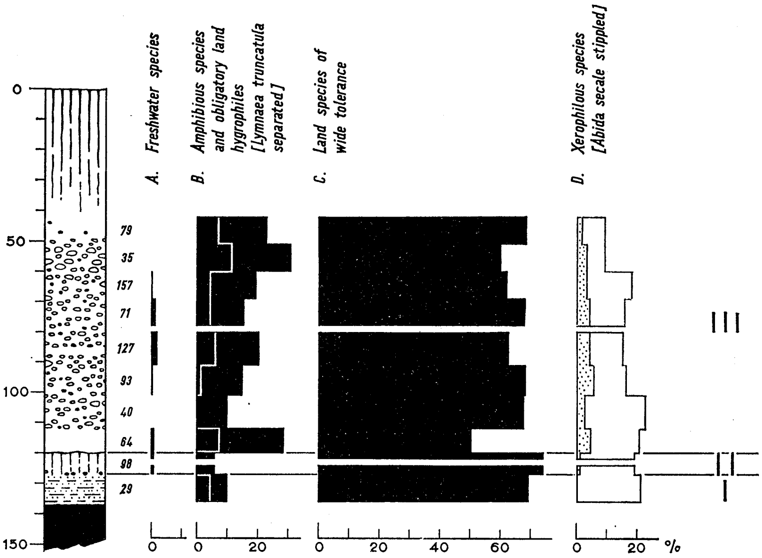


FIGURE 7. Borehole II, Sankey Farm, Brook: Stratigraphy and molluscan histogram. In ecological group B, the percentage of *Lymnaea truncatula* is shown to the left of the white line.

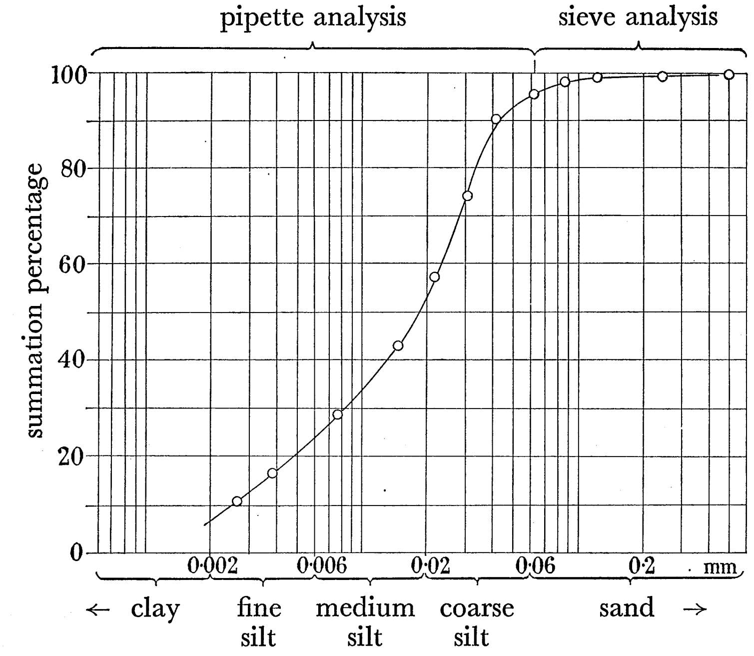


FIGURE 8. Grain-size analysis (pipette and sieve analysis) of seam of chalk silt from zone I (132 to 134 cm), Borehole II, Sankey Farm. Analysis by Mrs F. Kelk.

The fossil soil of zone II, here very thin, was unfortunately lost during coring. The underlying calcareous muds were devoid of Mollusca.

Borehole II was sunk 250 m to the south-east of Borehole I, in the field by the road immediately south-west of Sankey Farm (figure 2; 07014489). The stratigraphy is shown on figure 7. The zone III deposits have here greatly coarsened in facies, and consist mainly of chalk rubble with only subordinate seams of chalk mud. The predominant source is the Upper Cenomanian and Lower Turonian (D. J. Carter). The chalk fragments, which reach 2 to 3 cm in size, are for the most part angular, but many show considerable rounding. The fauna (table 2) contains high percentages of mesophiles and xerophiles, and there is only a weak indication of the initial phase of flooding seen in Pit A (cf. figures 6 and 7). The xerophile *Abida secale* is consistently present.

Beneath the thin zone II soil, and above the Gault Clay, is a peculiar deposit consisting of alternating seams of powdery chalk silt and of a tough olive calcareous mud showing much brecciation on a minute scale. A mechanical analysis of a sample of the former (figure 8) shows an excellent grading, over 60 % of the material lying between 10 and $60\,\mu$m. Such a grading is highly suggestive of wind sorting. It is likely that the seams of mud represent downwashes from bare surfaces of Gault Clay, and that the laminae thus formed cracked and broke-up on drying, and were periodically covered by layers of chalk dust carried by the wind.

The underlying Gault Clay is intensely shattered to a depth of about 50 cm from its surface. Perfectly sharp and angular fragments are to be seen, still maintaining more or less their original juxtaposition, and suggesting that the clay was frozen when shattering occurred.

Going eastwards, towards the escarpment, the fossil soil representing zone II was last observed in two auger holes in the field immediately east of Sankey Farm and north of the Brook road (approx. 073449). That close to the farm buildings showed:

	cm
Surface soil Chalk rubbles and muds	0 to 185
Grey fossil soil	185 to 200
Chalk rubbles and subordinate muds	200 to 255
Gault Clay	

The second auger hole, 50 m further east, showed:

	cm
Surface soil Chalk rubbles and muds; tending to coarsen upwards	0 to 245
Grey fossil soil	245 to 255
Chalk mud	255 to 275
Chalk rubbles and muds	275 to 340
Clayey chalk gravel	340 to 355
Gault Clay	

An auger hole a further 50 m to the east, close to the field boundary, failed to trace the soil and revealed only variable chalk rubbles and muds resting on Gault Clay at a depth of about 350 cm. Further auger holes in the vicinity revealed a similar state of affairs.

(*b*3) *Devil's Kneadingtrough*

The spread of chalk rubbles and muds around Sankey Farm continues eastwards as a tongue running into the bottom of a coombe in the face of the escarpment, the Devil's Kneadingtrough (figure 4). Here they are almost entirely hidden from view by accumulations of Post-glacial age (§IV and figure 11). Where seen, the deposits are generally coarse, though in detail they show extreme variation from fine muds to masses of totally ungraded chalk and flint debris. Broadly speaking, the coarser deposits tend to be in the axis of the coombe, while finer muds, often virtually devoid of macroscopic chalk fragments, line the sides. By the end of zone III, fans of debris probably extended for some distance up the slopes, but these accumulations have been destroyed by weathering and ploughing (figure 11). At the head of the coombe, a rifle butts trench provided a good section. Here the deposits (division (*a*), figure 12) contain horizons of well-washed chalk gravel, showing cross-bedding suggestive of torrent action.

Small assemblages of Mollusca, diagnostic of zone III, occurred near the top of these lower deposits at three places (figure 18; tables 5 and 7). The general scarcity or absence of Mollusca is probably partly due to the fact that the deposits are often unsuitably coarse in facies; moreover, the intense disturbance and scouring during the erosion of the coombe cannot have been favourable to plant and animal life.

(*c*) *Stratigraphy*: *southern lobe*

(*c*1) *Borehole III*

The key section in the Late-glacial deposits was provided by Borehole III, in the middle of the southern, more extensive lobe of debris (figure 2; 06454450). About 415 cm of mainly chalky sediments here overlie the Gault Clay (figure 9).

The basal gravel consists of subangular to rounded pieces of hard chalk and rather scarcer flints, set in a heterogenous matrix containing much clay and sand and stained by iron oxide. At the top, the gravel passes, without obvious break, into a light grey calcareous mud (300 to 308 cm), in which an appreciable molluscan fauna first appears. This is overlain by a grey, highly calcareous quartzitic silt with fine plant debris (295 to 300 cm), and by an organic detritus mud (290 to 295 cm). A radiocarbon dating of this last was carried out at the Cambridge laboratory, with the following result (Godwin & Willis 1962, p. 69):

Q 618 9950 ± 160 B.C.

This represents a date near the beginning of zone II, and confirms the zonation shown in figure 9 derived from a consideration of the lithological, floral and faunal evidence.

The detritus mud is covered by chalk muds (277 to 290 cm), at first finely laminated and containing much comminuted plant material, including small pieces of wood, and reminiscent of flood refuse. Similar detritus appears again near the top. Culminating the deposits assigned to zone II there is a thin marsh soil with charcoal and other plant fragments.

The soil is abruptly covered by a thick series of white chalk muds and silts, assigned to zone III, which extend to the base of the modern soil. The lowest few centimetres of chalk mud show traces of standing vegetation, demonstrating that initial burial was here a gentle process and that no erosion occurred. Apart from a seam of rubble between 85 and 97 cm, and occasional scattered chalk pellets, particularly towards the top, the deposits are fine in grade throughout, less than 5 % of the material exceeding 0·2 mm in diameter. Two distinct lithologies may be recognized: first, a *chalk mud*, plastic and characteristically rather sticky when wet: secondly, a *chalk silt*, not plastic and collapsing readily on immersion in water. Superficially, the two lithologies have a similar appearance, since both consist almost entirely of finely divided calcium carbonate, but their vertical

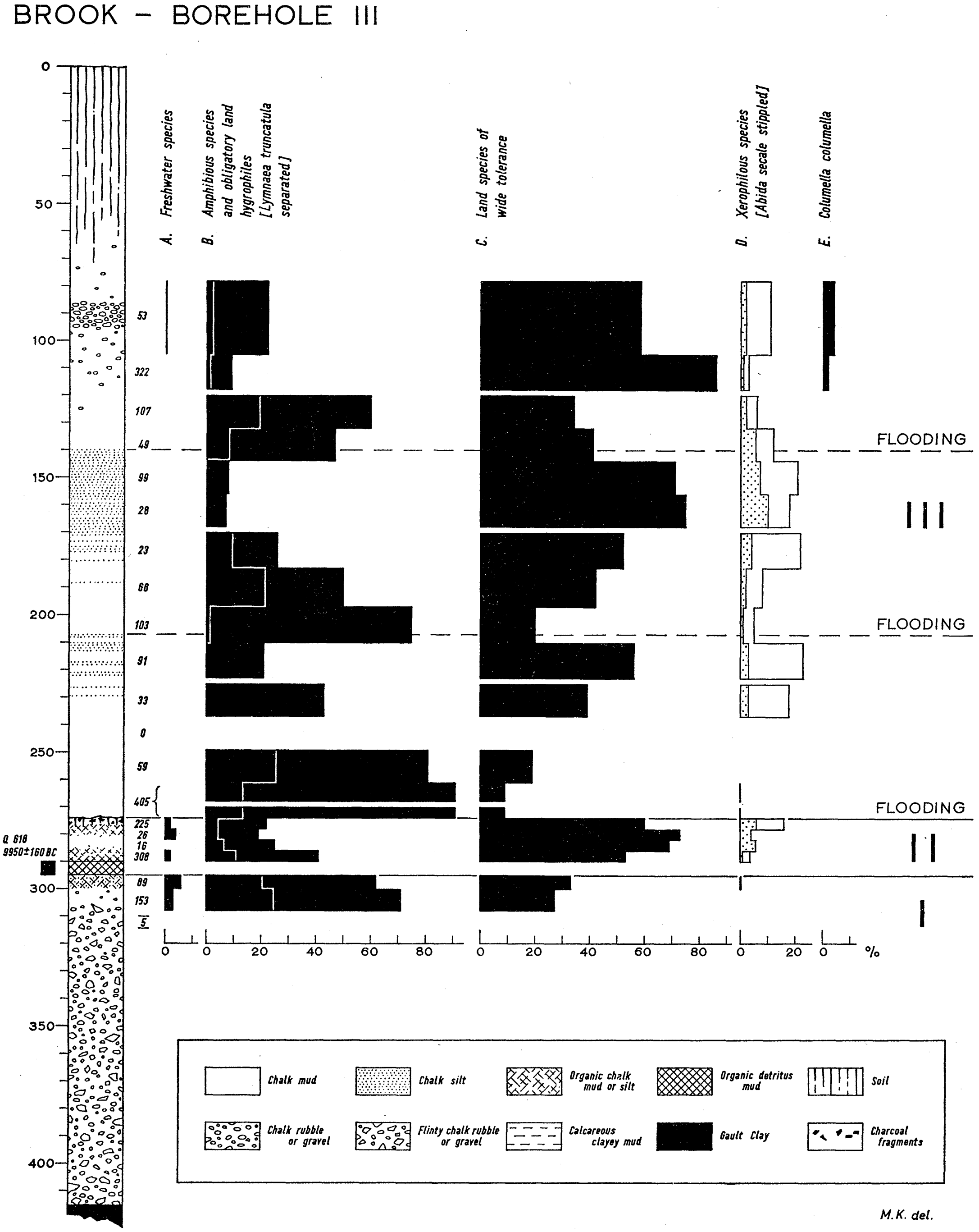


FIGURE 9. Borehole III, Brook: Stratigraphy and molluscan histogram. In ecological group B, the percentage of *Lymnaea truncatula* is shown to the left of the white line.

distribution (figure 9) was easily determined by lightly washing the cores in water, whereupon the silt bands were etched and the intervening layers of chalk mud protruded in relief.

The nature of these two lithologies was confirmed by mechanical analysis (figure 10). A sample of chalk mud from the very base of zone III (curve *a*) revealed a rather poor grading, and contained about 30 % of clay. On the other hand, the analysis for the non-plastic material (curve *b*) showed it to be extremely well graded, mostly in the medium to coarse silt range, and with less than 5 % of clay. The great bulk of the deposit consists of calcium carbonate alone, but a small percentage (6 to 8 %) of quartz silt is also present. About 75 % of the total sample falls between 10 and 60 μm. Such a grading is highly suggestive of wind sorting. Furthermore, the upper, thicker group of silt bands contains numerous minute root-concretions, of the kind characteristic of loess (Pitcher, Shearman & Pugh 1954).

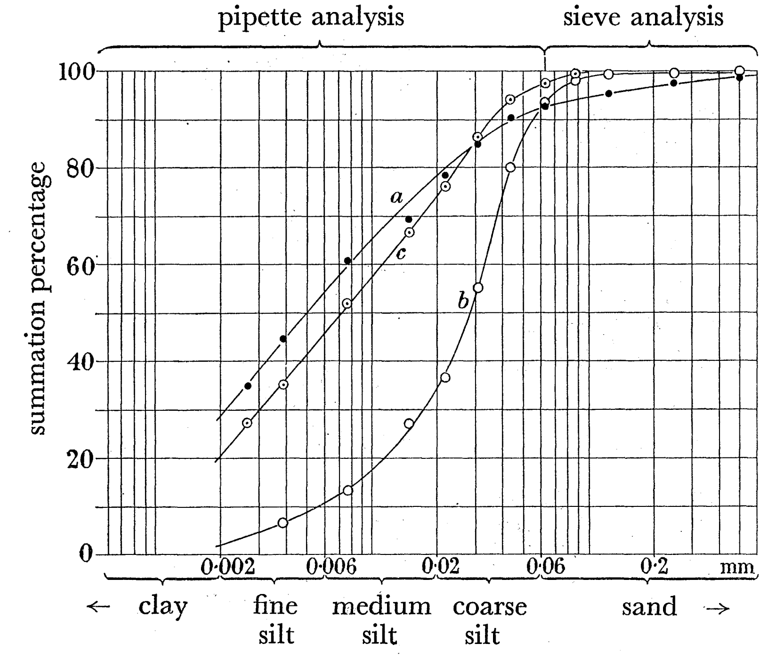


FIGURE 10. Grain-size analyses of Late-glacial deposits in Borehole III, Brook: Curve *a*, chalk mud, zone III (270 to 272 cm); curve *b*, chalk silt, zone III (164 to 168 cm); curve *c*, chalk mud, zone II (280 to 282 cm). Analyses by Mrs F. Kelk.

The faunal and floral remains extracted from Borehole III give valuable additional information about the environment. The Mollusca, although rather sparse, provide the most continuous picture. Identifiable plant fossils were also fortunately preserved below about 270 cm, due to water-logging. The pollen analyses were made by Miss R. Andrew and most of the macroscopic plant remains were named by Miss C. A. Lambert, who has kindly prepared a separate account of the results of this work (Appendix I). A few macroscopic wood fragments were also extracted from zone II (Appendix II).

Mollusca are not abundant. This is doubtless because here, in the thickest part of the debris fan, accumulation was rapid, at least during zone III, and hence conditions for life rather unfavourable. The cores yielded 2270 shells (table 3), plotted in figure 9 on the basis of the same four ecological groups employed earlier. In addition, one species, *Columella columella*, has been shown separately. Some of the percentages are based on very

TABLE 3. BROOK. BOREHOLE III

cm …	310–314	300–308	295–300	286–290	282–286	278–282	274–278	270–274+ 261–268	249–261	237–249	225–237	210–223	197–210	183–197	170–183	156–168	144–156	132–144	120–132	105–118	78–105
dry weight of sample (g) …	—	850	610	420	520	495	515	1200	1505	1530	1490	1670	1695	1730	1735	1585	1595	1615	1700	1810	3635
Lymnaea truncatula (Müller)	—	37	18	33	1	1	8	53	15	—	—	—	1	14	2	—	—	4	20	2	1
Planorbis leucostoma Millet	—	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Catinella arenaria (Bouchard-Chantereaux)	? 1	13	5	9	—	—	2	—	—	—	—	—	—	—	—	—	—	—	—	1	2
Succinea pfeifferi Rossmässler	—	3	4	34	—	? 1	16	183	32	—	13	18	72	16	3	1	4	17	44	24	10
Cochlicopa lubrica (Müller)	—	3	3	18	—	1	16	? 3	—	—	2	3	? 3	4	? 1	? 1	5	4	? 2	2	2
Columella columella (Martens)	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	5	2
Vertigo antivertigo (Draparnaud)	—	1+2	—	1+1	—	—	1+1	—	—	—	—	—	1	1	—	1	—	—	—	—	—
Vertigo pygmaea (Draparnaud)	—	1+2	—	1+1	—	—	1+1	—	—	—	—	—	—	—	—	—	—	—	1	—	—
Vertigo genesii Gredler. form 'A'	1	16	10	25	1	2	10	63	1	—	? 1	? 1	2	? 2	1	—	2	? 2	—	—	—
Vertigo genesii Gredler. form 'B'	—	—	3	4	—	1	1	—	—	—	—	—	—	—	—	—	1	—	—	—	—
Vertigo genesii s.l.	+1	+36	+15	+22	+2	—	+11	+70	—	—	—	—	+1	—	—	—	+1	—	—	—	—
Pupilla muscorum (Linné)	1	9	4	39	3	2	43	8	2	—	2	11	2	7	2	9	19	3	2	66	3
Abida secale (Draparnaud)	—	—	—	3	1	1	13	—	—	—	1	3	1	1	1	3	7	3	2	3	1
Vallonia costata (Müller)	—	—	1	6	—	—	19	1	—	—	5	17	3	4	4	2	14	3	5	8	3
Vallonia pulchella (Müller)	—	16	15	54	5	6	25	8	1	—	2	7	2	1	2	2	11	3	3	5	4
Arianta arbustorum (Linné)	—	—	—	1	—	1	1	1	—	—	—	—	—	—	1	1	—	—	—	3	2
Hygromia hispida (Linné)	—	—	—	11	—	1	16	12	8	—	1	8	3	4	2	3	10	2	22	197	16
Helicella itala (Linné)	—	—	—	1	—	—	3	—	—	—	—	1	1	—	—	—	—	—	—	—	2
Punctum pygmaeum (Draparnaud)	1	2	1	18	2	3	16	3	—	—	4	12	10	11	3	3	19	5	5	3	3
Euconulus fulvus (Müller)	—	4	4	16	1	2	11	—	—	—	1	6	1	1	1	2	6	1	1	1	—
Retinella radiatula (Alder)	—	—	—	5	—	2	4	—	—	—	1	3	—	—	—	—	—	2	—	2	1
Vitrina pellucida (Müller)	—	4	1	—	—	1	2	—	—	—	—	1	—	—	—	—	—	—	—	—	—
Agriolimax spp.	—	×	×	—	—	—	—	×	—	—	—	×	—	—	—	—	—	—	—	—	×
Pisidium casertanum (Poli)	—	4	9	7	—	2	5	—	—	—	—	—	—	—	—	—	—	—	—	—	1
Pisidium obtusale lapponicum Clessin	—	2	1	1	—	—	3	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Pisidium subtruncatum Malm	—	—	—	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—

low numbers, six of the nineteen samples each providing less than fifty individuals, but in spite of this the pattern is sufficiently self-consistent for the results to be considered broadly reliable.

The lithology of the deposits of zones I and II suggests that they accumulated at or near water level in a swamp, and the faunal and floral evidence is in agreement with this. Some freshwater Mollusca occur (mainly *Pisidium*), although they are greatly outnumbered by amphibious species and land hygrophiles such as *Lymnaea truncatula* and the Succineidae. A rich herbaceous vegetation standing in pools of water is indicated. The hygrophile element is considerably higher in zone I than in zone II. A small number of xerophiles occur in zone II, rising to about 15 % in the fossil soil (274 to 278 cm). None of the assemblages can, however, be regarded as strictly autochthonous, for they include associations of ecologically incompatible species, such as *Lymnaea truncatula* and *Abida secale*, adapted to very wet and to dry situations, respectively; the xerophiles were no doubt washed in from drier ground on the margins of the swamp. Two of these latter species, *Abida secale* and *Helicella itala*, are characteristic of zone II in south-east England as against zone I, and their appearance has therefore probably a climatic as well as an ecological significance (Kerney 1963).

The evidence from macroscopic plant remains is in good general agreement with that derived from the Mollusca (Appendix I). The pollen is characteristically Late-glacial, and is most interesting, perhaps, in showing high percentage values for *Pinus* in zone II.

The pattern in zone III (figure 9) is broadly similar to that at Pit A (figure 6) in the northern lobe of debris, in that there is at first a pronounced episode of flooding, and thereafter a slow recovery. But conditions were here not conducive to the development of pools, for true freshwater species are virtually absent. Furthermore, superimposed on the general trend, there is clear evidence of at least two additional flooding episodes, each preceded by a phase of local dryness. This is expressed both lithologically and faunally: the dry periods are reflected by layers of chalk silt with an appreciable xerophilous fauna, whilst the episodes of flooding coincide with the main horizons of chalk mud, in which the character of the fauna suddenly reverts to that of a wet marsh. The evidence strongly suggests that the muds represent slurry produced by frost-shattering on the chalk escarpment, washed by spring and meltwaters out onto the plain, whereas the silts represent periods when the debris fans became locally rather dry and windblown dust accumulated on their surfaces.

(*c*2) *Section in Church Field*

A ditch approximately 200 m south-east of Brook Church (06754415) revealed, on cleaning, the following section:

	cm
Soil	0 to 30
White chalk mud with scattered chalk fragments	30 to 57
White chalk mud with abundant small fragments of chalk	57 to 70
White chalk mud; few or no chalk fragments	70 to 100
Olive clayey calcareous mud, dark grey and organic at top (marsh soil)	100 to 105
Flint and chalk gravel in a paste of weathered Gault Clay	seen to 115 (water level)

This section is close to the margin of the southern lobe of debris. The organic seam at the base of the white muds is assigned on stratigraphical evidence to zone II. Mollusca are uncommonly abundant at this level (table 4); they prove the existence of a swamp with large pools of water, for the freshwater element is well represented and the general facies considerably wetter than recognized elsewhere during zone II at Brook. Xerophiles are entirely absent.

Table 4. Brook. Church Field section

	Samples of 2 kg dry weight							
	100–105	91–99	81–89	71–79	61–69	51–59	41–49	31–39
Lymnaea truncatula (Müller)	2555	45	34	246	132	61	45	2
Lymnaea palustris (Müller)	152	1	—	2	1	—	—	—
Aplexa hypnorum (Linné)	20	1	—	—	—	—	—	—
Planorbis leucostoma Millet	1121	9	3	24	6	7	3	—
Planorbis cf. *laevis* Alder	—	—	—	—	1	—	—	—
Catinella arenaria (Bouchard-Chantereaux)	158	4	—	9	17	6	4	1
Succinea pfeifferi Rossmässler	730	147	72	358	311	121	110	101
Cochlicopa lubrica (Müller)	292	10	5	68	63	21	1	1
Cochlicopa lubricella (Porro)	—	—	—	1	—	—	—	—
Columella columella (Martens)	1	—	—	4	8	16	9	21
Vertigo antivertigo (Draparnaud)*	63	—	—	—	2	—	—	—
Vertigo pygmaea (Draparnaud)*	101	5	2	16	27	5	—	—
Vertigo genesii Gredler. form 'A'*	375	25	1	57	58	28	7	8
Vertigo genesii Gredler. form 'B'*	246	16	5	29	15	6	2	—
Pupilla muscorum (Linné)	230	30	11	71	142	57	11	15
Abida secale (Draparnard)	—	—	—	3	10	4	2	1
Vallonia costata (Müller)	—	—	1	1	24	6	2	1
Vallonia pulchella (Müller)	1417	49	23	206	246	81	6	4
Arianta arbustorum (Linné)	6	1	3	8	11	3	1	2
Hygromia hispida (Linné)	80	23	18	140	192	122	32	8
Punctum pygmaeum (Draparnaud)	275	6	5	41	69	14	9	1
Euconulus fulvus (Müller)	58	4	4	20	18	3	1	2
Retinella radiatula (Alder)	71	4	7	21	34	15	3	1
Vitrina pellucida (Müller)	—	—	—	—	3	1	1	1
Agriolimax spp.	×	—	×	×	×	×	×	×
Pisidium casertanum (Poli)	91	1	2	3	3	1	—	—
Pisidium obtusale lapponicum Clessin	—	—	—	2	—	—	—	—

* Apertures only counted.

The succeeding white muds of zone III contain a rather uniform fauna of generally similar character. An appreciable number of xerophiles, notably *Abida secale*, first occur at about 70 cm, where coarser chalk debris appears, and have no doubt been brought in from drier environments closer to the escarpment. Faunally, this section is of interest in that the Boreal-Alpine species *Columella columella*, present otherwise only at Borehole III, occurs in fairly large numbers (see also §III (*b*)).

III. Late-glacial molluscan fauna

(*a*) *Introduction*

The Late-glacial deposits at Brook yield a distinctive fauna characteristic of the period in south-east England (Kerney 1963). Hygrophiles and freshwater species are well represented, and a few forms in these latter categories deserve special comment.

(*b*) *Notes on certain species*

Catinella arenaria (*figures* 21*i to o*, *plate* 21).

The widely scattered stations of this species in Europe, usually either among maritime sandhills or in mountain habitats, suggest a relict distribution. *C. arenaria* is now apparently extinct in south-east England and lives in these islands only in a very few isolated localities in North Devon and Ireland. It is likely to prove a common component of 'cold' Pleistocene faunas, for it is known from Late-glacial deposits near Folkestone, Kent (Kerney 1963), Barrington, Cambridgeshire (Sparks 1952; 1957, plate VII, figures *a* and *b*), and from a solifluxion gravel, considered to be of Gipping (Riss) age, near Thriplow, Cambridgeshire (Sparks 1957). At all these sites, the common Holarctic *Succinea pfeifferi* is the only associated succineid (figures 21*a* to *h*, plate 21).

Columella columella

This mainly Arctic–Alpine species has a curiously restricted distribution in the deposits at Brook: it was found only in the southern lobe of chalk debris, principally towards the end of zone III. Although undoubtedly a marsh species, it would appear also that it required a habitat of some specialized kind, the precise nature of which is not easily inferable from the associated assemblages. Ehrmann (1933, p. 46) makes the observation that at the present day it favours 'stone rubble'.

Vertigo antivertigo *and* V. pygmaea (*figures* 22*a to e*, *plate* 22).

Both species are now common in Europe, but become sporadic in Scandinavia; this is particularly true of *V. pygmaea*, which there becomes increasingly maritime: the most northerly recorded colony is at about 63° 30′ N on the Norwegian coast (Økland 1925, p. 32).

The inferred ecology of *V. antivertigo* in the deposits at Brook is comparable to that observed today in Britain: permanently very wet places, such as the margins of swamps. But *V. pygmaea* seems to have possessed an adaptive range more narrow then than now for it is found virtually only in the wet facies, not in the scourings of open chalk hillsides on which it would now flourish (Kerney 1963). Yet in the Sub-Atlantic deposits within the Devil's Kneadingtrough it occurs in association with a xerophilous downland fauna (figures 14 and 15). No morphological peculiarities can be detected in the Late-glacial shells.

Vertigo genesii s.l. (*figures* 22*f to s*, *plate* 22).

The systematics of this species or group of closely allied species are much involved, and a competent genetic investigation of living material will probably be necessary before any final conclusions can be reached. Two forms can, however, clearly be distinguished among British Late-glacial shells, and these may merit specific rank. The first (form 'A') is rather narrow and cylindrical, with a highly polished shell, and normally devoid of apertural denticles, although there is sometimes a small parietal tooth (figures 22*f*, *h* to *k*). The second (form 'B') is more conical, has a less polished shell with more visible, irregular striation, and has generally four apertural denticles, though fewer may occur (figures 22*g*, *l* to *s*). In form 'B' a slight external thickening or flexure in the shell, corresponding in

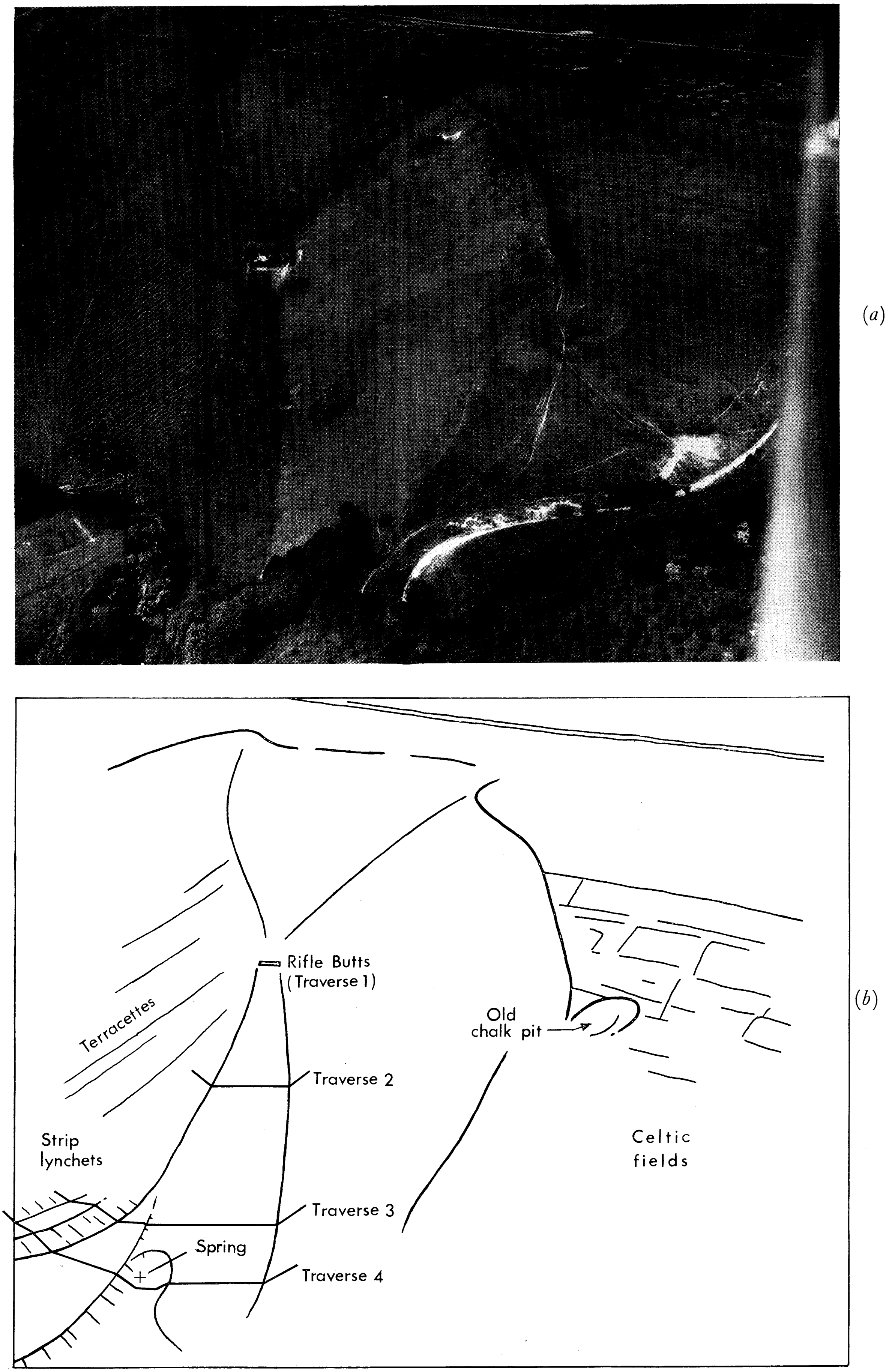
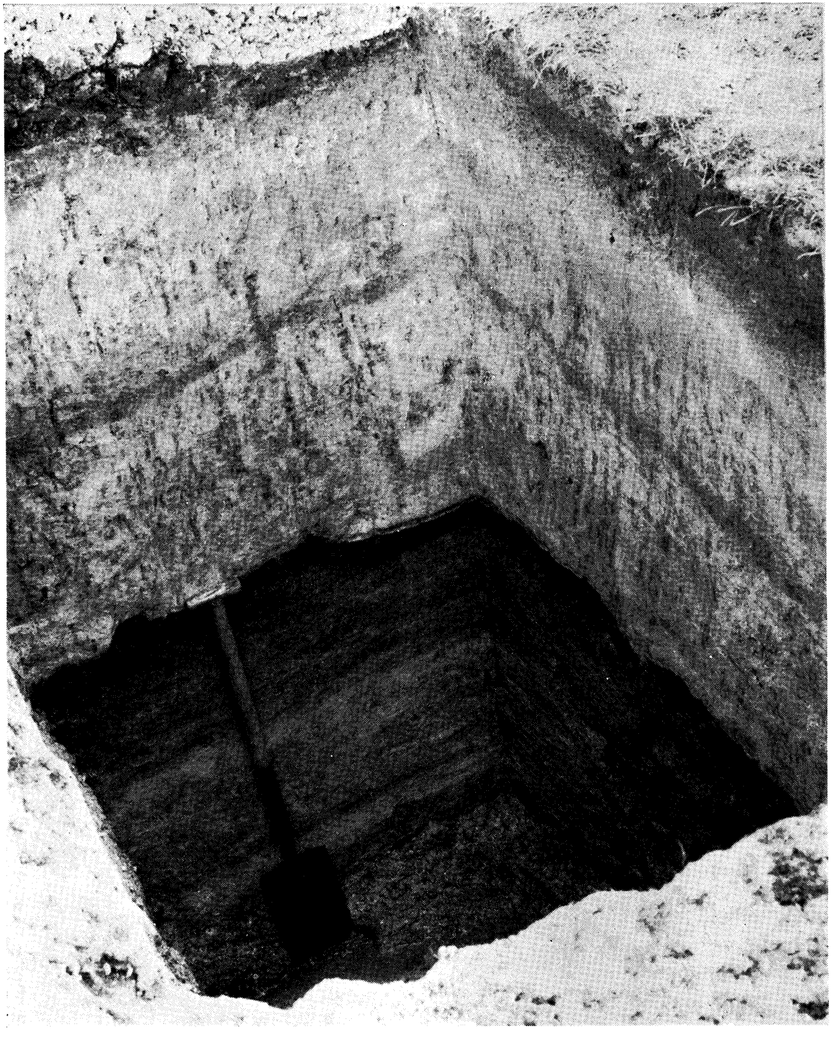


FIGURE 19 (*a*). Aerial view of the Devil's Kneadingtrough, Brook, Kent. Photograph by J. K. St Joseph, 1959.

(*b*) Interpretation of figure 19 (*a*), showing position of Traverses 1 to 4. Traverse 5 lies just out of sight beyond the bottom left-hand corner of the photograph.

(*a*)



(*b*)

FIGURE 20 (*a*). Aerial view of the Devil's Kneadingtrough from the west, taken in 1954. (Crown Copyright reserved.)

(*b*). Section dug at College Farm, Brook, September 1960 (Pit A; 06264495). Late-glacial deposits, showing Allerød soil, overlain by white chalk muds of zone III, and underlain by olive clayey muds assigned to zone I. Basal gravel visible above water. Spade 1 m in height.

FIGURE 21. (*a*), (*b*), (*c*), (*d*), (*e*) *Succinea pfeifferi* Rossmässler. Late-glacial zone III. Brook, Borehole III, 261 to 273 cm.

(*f*), (*g*), (*h*) *Succinea pfeifferi* Rossmässler. Late-glacial zone II. Brook, Church Field, 100 to 105 cm.

(*i*), (*j*), (*k*), (*l*), (*m*), (*n*), (*o*) *Catinella arenaria* (Bouchard–Chantereaux). Late-glacial zone II. Brook, Church Field, 100 to 105 cm.

(*p*), (*q*), (*r*) *Succinea oblonga* Draparnaud. Sub-Atlantic Period. Devil's Kneadingtrough, Borehole V, 25 to 36 cm.

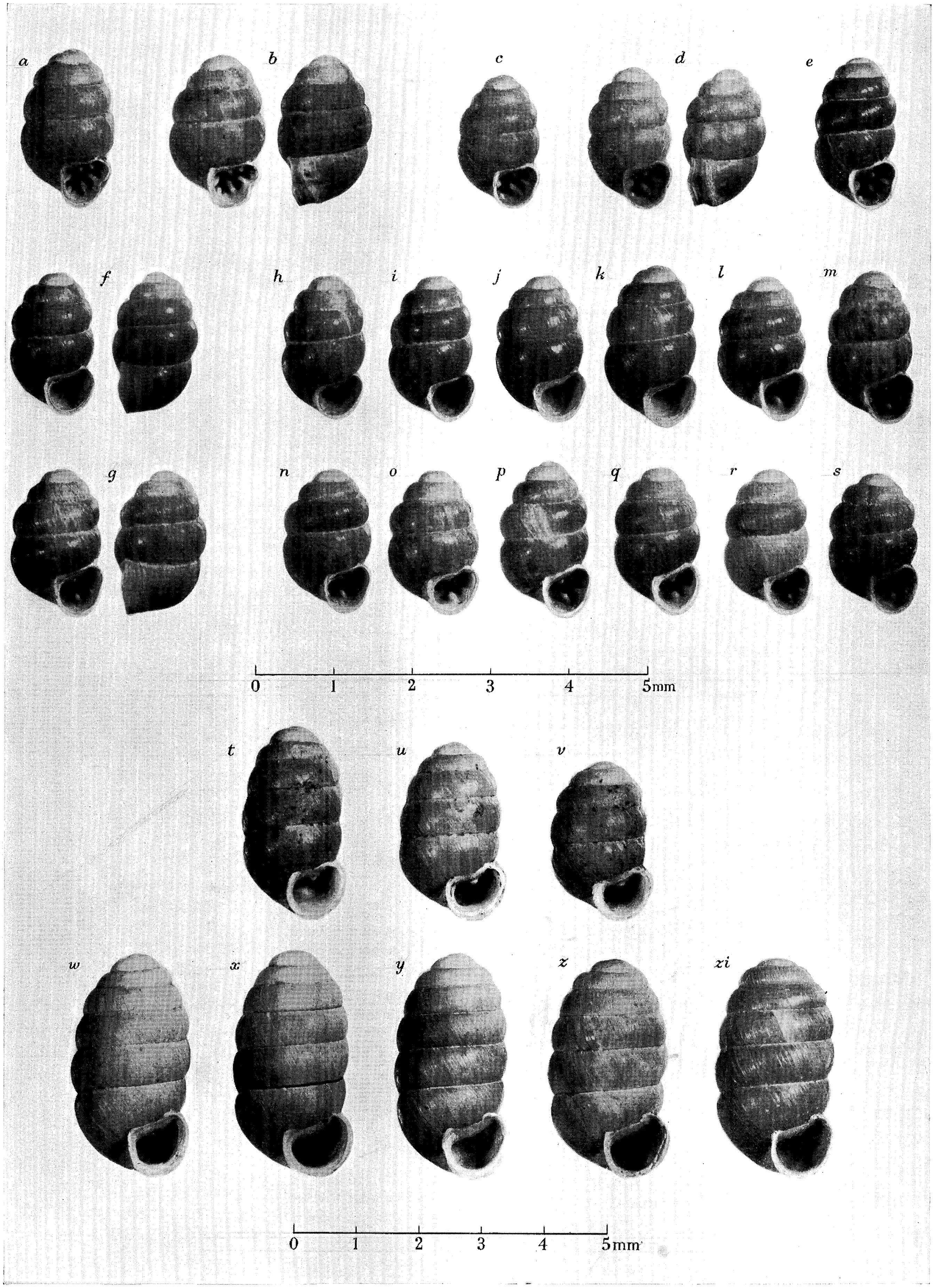


FIGURE 22. For legend see facing page.

position to the internal denticles, is usually visible behind the aperture (figure 22*g*). The whorls also tend to be more tumid, and the suture correspondingly deeper, than in form 'A'. Both 'A' and 'B' show a wide range of variation in shape and size.

The Brook shells can be divided between these two forms with little difficulty, and with but very few apparent intermediates; the totals of each are shown in the tables. It is noticeable that 'A' is always relatively the more common, particularly in the chalk muds of zone III.

The existence of these two forms fossil in Britain has previously been noted by Kennard & Musham (1937, pp. 377–8), who apply the name *Vertigo concinna* Scott 1891 to form 'A', and restrict the name *V. genesii* to form 'B'. *V. genesii* was originally described (Gredler 1856) from an Alpine pasture near Bolzano (Bozen) in the Italian Tyrol. Although described as an edentulous species, both toothed and untoothed shells occur at the type locality (Stelfox & Phillips 1925, p. 239; Kennard & Musham 1937, p. 378; Waldén, personal communication). Lindholm (1925) recognized the existence in northern Europe of two forms which agree closely with those here termed 'A' and 'B', and restricts Gredler's name to the edentulous, more cylindrical form 'A'. Form 'B' he distinguishes as a subspecies—*V. genesii geyeri*. According to Dr H. W. Waldén (personal communication), both are found living in Sweden, where, although they sometimes occur in association, they have somewhat different distributions and ecologies. *V. g. sensu stricto* is restricted to mountainous areas in the north of the country, where it lives in marshy ground on open hillsides. It is highly calciphile. *V. g. geyeri*, on the other hand, occurs locally over the greater part of Sweden and prefers flat fens of lowland type. Though calciphile, it is less demanding in this respect than is *V. genesii s. s.* Dr Waldén kindly examined a series of shells from Brook, and confirmed that the two Swedish forms agree closely with those here termed 'A' and 'B'.

The name *V. parcedentata* Braun 1847 has been widely applied to British and German Pleistocene material. The original description is very poor, and the name is probably best regarded as indeterminate. A shell sent by Dr H. Schlesch from a loess at Amoeneburg, near Wiesbaden, and considered by him to be typical of this species, agrees closely with form 'A' (*V. genesii s.s.* of Lindholm), although it is rather taller than most English Late-glacial specimens. Steusloff (1938; 1942) makes the interesting suggestion that

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DESCRIPTION OF PLATE 22

FIGURE 22. (*a*), (*b*) *Vertigo antivertigo* (Draparnaud). Late-glacial zone II. Brook, Church Field, 100 to 105 cm.

(*c*), (*d*), (*e*) *Vertigo pygmaea* (Draparnaud). Late-glacial zone II. Brook, Church Field, 100 to 105 cm.

(*f*), (*h*), (*i*), (*j*), (*k*) *Vertigo genesii* Gredler, form 'A' (*V. genesii sensu stricto* of Lindholm). Late-glacial zone II. Brook, Church Field, 100 to 105 cm.

(*g*), (*l*), (*m*), (*n*), (*o*), (*p*), (*q*), (*r*), (*s*) *Vertigo genesii* Gredler, form 'B'. (*V. genesii geyeri* of Lindholm). Late-glacial zone II. Brook, Church Field, 100 to 105 cm.

(*t*), (*u*), (*v*) *Pupilla muscorum* (Linné). Sub-Atlantic Period. Devil's Kneadingtrough, Borehole V, 156 to 167·5 cm.

(*w*), (*x*), (*y*), (*z*), (*zi*) *Pupilla muscorum* (Linné). Late-glacial zone II. Brook, Pit A, 117 to 129 cm.

these tall shells, which appear to be the rule in German deposits of the Würm Glaciation, may represent a polyploid state. But more probably this is a purely climatic effect—sexual maturity in *Vertigo* frequently being delayed in cold climates, thus prolonging growth and allowing the development of hypertrophied individuals. At Brook, it is noticeable that the more elongate shells of form 'A', approaching in character German '*V. parcedentata*', are little commoner in zone III than in zone II.

V. genesii sensu lato has a modern distribution which is essentially Boreal–Alpine. Although more information is needed, it would seem from the published literature that the dentate form 'B' is more widespread than form 'A' and is the variety which occurs in the several relict colonies in lowland Europe, stretching from Ireland to Poland. An excellent account of the nature of the Irish habitats is given by Phillips (1935); it is worthy of note that the area of its distribution on the Central Plain is much the same as that of *Catinella arenaria* (Ellis 1951). On the other hand form 'A' may prove to have a more strictly Arctic–Alpine distribution.

Pupilla muscorum (*figures* 22*w to zi*, *plate* 22)

P. muscorum, the most characteristic land snail of the Full-glacial and Late-glacial Periods in Britain, has a Holarctic range and is ecologically indicative of open habitats. In this country it attains probably it greatest abundance on maritime sandhills, becoming rather uncommon in most inland areas. It is generally classified as a xerophile, though it has, very occasionally, been observed living in marshes (Boycott 1934, p. 18).

In the deposits which we are considering it is evident that *P. muscorum* was much more frequent in wet places than is normal at the present day. For example, in the zone II soil in Pit A, *P. muscorum* abounds in association with a marsh assemblage, including *Lymnaea truncatula*, *Succinea pfeifferi* and *Vertigo genesii* (table 1 and figure 6). The fauna is clearly autochthonous. Xerophiles and semi-xerophiles (*Abida secale*, *Vallonia costata* and *Helicella itala*) are very rare—in all, seven shells out of a total of 3013. In this context, clearly it would be misleading to class *Pupilla muscorum* as a xerophile.

The possibility arises that those populations living in wet places might be genetically distinct from normal *P. muscorum*, and therefore perhaps merit separate specific or subspecific rank. It has been pointed out (Kerney 1963, p. 236) that shells of *Pupilla* from Late-glacial deposits in south-east England generally tend to be larger than either Postglacial or living examples from this country. This is notably true of shells from wet environments, of which a series is illustrated from Pit A (figures 22*w* to *zi*). In their extreme form, such shells differ from more normal *P. muscorum* (figures 22*t* to *v*) in being relatively broader; in being more cylindrical, less tapered, in form; in possessing whorls which are wider in proportion to their height, and which are separated by a deeper suture; in having a slightly more pronounced surface sculpture; in the dentition being reduced or absent; in the rib or thickening behind the aperture often being poorly developed; and in having thinner and therefore more easily broken shells. But there is great variation, and whilst some shells (e.g. figure 22*zi*) show these extreme characters well, others (e.g. figure 22*w*) approach more closely to normal *P. muscorum*. The height of the shells may also vary considerably. Comparable forms are illustrated by van Regteren Altena (1957, plate I) from deposits of Early Weichselian age in the Netherlands.

Two views are possible: this broad form of *Pupilla* may represent a genetically distinct race, perhaps a subspecies of *P. muscorum*, widespread in the Late Pleistocene in wet environments. But the existence of frequent intermediates to more normal *P. muscorum*, at least among the British material, makes this view rather unlikely. It appears more probable that in certain circumstances, possibly climatic, *P. muscorum* is able to colonize wet places, which normally it avoids, and that the physiological adaptations which are no doubt necessary are accompanied by slight changes in morphology.

It is worth observing that these Late-glacial *Pupilla* agree rather well with descriptions and illustrations of the form known as *P. alpicola* (Charpentier), living today mainly in the Alps and Carpathians (Mermod 1926; Favre 1927; Germain 1930; Ložek 1956*a*). This mollusc is said to live exclusively in wet places, according to Germain (1930, p. 426) 'habitant les stations très humides: marécages, prairies humides, bord des sources, parfois même sous les objets immergés'. *P. alpicola* is an associate of *Vertigo genesii* in at least one of its Alpine habitats (Favre 1927, p. 227).

Pisidium obtusale lapponicum

This form of *Pisidium obtusale* lives in Arctic Europe and North America. It was very common in Late-glacial deposits at Nazeing, North London (Allison, Godwin & Warren 1952, p. 191) and is now known in addition from several other British sites of this age. A comprehensive account of its morphology and distribution has recently been published by Dance (1961). Like *P. obtusale s.s.*, *P. obtusale lapponicum* is known to inhabit shallow, impermanent bodies of water, such as *Carex* swamps, an ecology entirely in keeping with its fossil occurrences at Brook.

IV. Post-glacial deposits within the Devil's Kneadingtrough

(*a*) *Introduction*

True-scale sections across the infill of the Devil's Kneadingtrough are shown in figure 11; these were constructed mainly by augering, but supplementary information was derived from trenches and from two 4 in. (10 cm) diameter cores (Boreholes IV and V). The surface profiles were carefully levelled and are as accurate as the scale permits.

The deposits fall principally under two headings: (*a*) a lower series of white or pale-coloured variable chalk rubbles and muds; and (*b*), an upper series of brown, humic chalk muds. The former, which are stratigraphically continuous with the zone III deposits on the Gault Clay plain, are considered to be the products of rapid physical weathering in a cold climate; the latter on the other hand accumulated under conditions of temperate weathering and are assigned to the Post-glacial Period. At the contact of these two lithological types in most parts of the coombe there is a fossil soil, resting directly on the white rubbles. But in places, notably at Pit B (figure 17), further deposits intervene.

(*b*) *Stratigraphy of infill*

(*b*1) *Section in rifle butts trench*

At the upper extremity of the coombe floor, there is a section in a disused rifle butts trench. When this had been cleaned, and deepened, an excellent view of the valley infill was revealed (figure 12). The lowermost deposits (*a*) belong to the Late-glacial Period

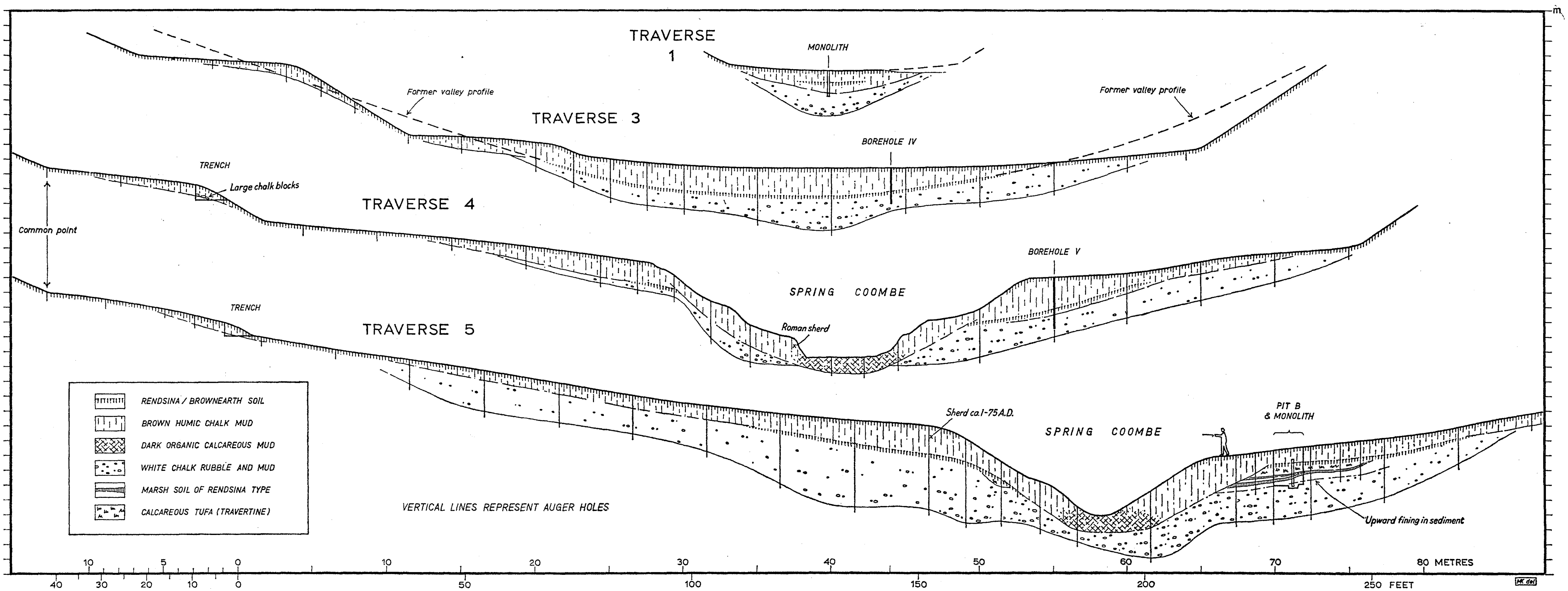

Figure 11. True-scale sections across the floor of the Devil's Kneadingtrough, Brook, Kent. The position of the traverses is shown on figure 4 and on figure 19*b*, plate 19. The bedrock beneath the drift is everywhere Lower Chalk.

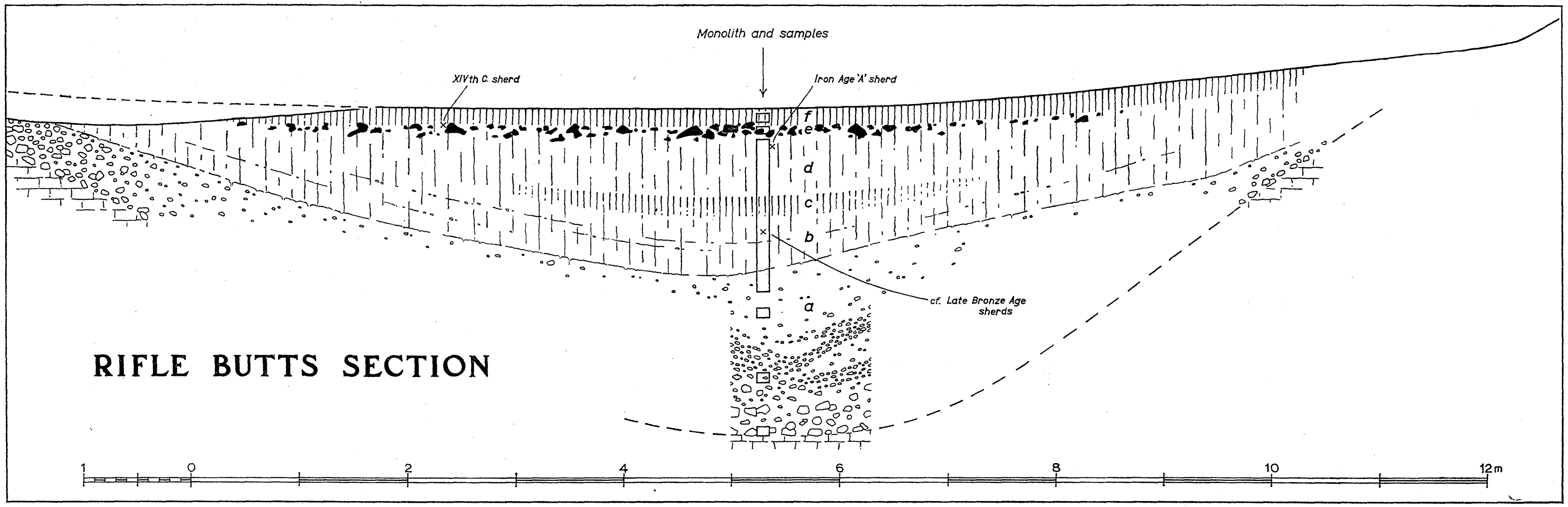

FIGURE 12. Section in south face of rifle butts trench, Devil's Kneadingtrough; measured August 1960. *a*, white variable chalk rubbles and muds, with seams of cross-bedded chalk gravel in middle part; *b*, brown humic chalk mud; *c*, dark brown humic chalk mud with scattered charcoal fragments (immature fossil soil); *d*, brown humic chalk mud; *e*, layer of large flints; *f*, modern rendsina soil.

(§II (*b*3)). Above are brown (approximately 10YR 6/3; 4/3 moist) humic rubbly chalk muds, (*b*) to (*d*), rather structureless but sometimes showing obscure bedding in the form of lines of chalk fragments. The muds include a slightly darker (10YR 5/3; 3/3 moist) and more argillaceous layer (*c*), containing fewer large chalk fragments than the material above and below, and showing occasional flecks of charcoal. There is a well-preserved crumb-structure. This horizon is interpreted as a rather skeletal fossil soil. The muds above this layer tend, on the whole, to be a little paler than those below, and are apparently less humic. The present-day soil (*f*) is a well-developed dark greyish brown (10YR 4/2; 3/2 moist) rendsina, showing a more mature profile than the fossil soil (*c*), and therefore presumably representing a considerably longer period of weathering. A pseudo-mycelium of secondary calcium carbonate is conspicuous throughout division (*d*). In the lower part of the soil there is a layer containing many large flints. Their presence is somewhat of a puzzle, although it is probable that they were originally deposited on the surface and have sunk to their present position through earthworm undermining.

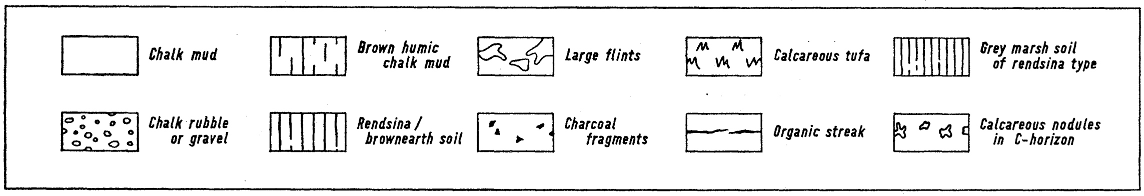

FIGURE 13. Key to lithological symbols used in figures 14, 15 and 18. Fragments of charcoal are widely distributed, but have only been marked in the sections where present in some quantity.

The section yielded some fragments of pottery, kindly identified as follows by Mr S. S. Frere and Professor W. F. Grimes: at the base of the present soil was found a fourteenth-, or possibly fifteenth-century jug handle (S. S. Frere); in (*d*) at 37 cm a rim sherd datable as 'Iron Age "Kentish First A", not later than 300 B.C. or earlier than 500 B.C.' (S. S. Frere); and in (*b*) at 115 cm three sherds most probably of the Late Bronze Age, although possibly referable to the very beginning of the Iron Age (W. F. Grimes). In addition, a considerable number of worked flint flakes and cores were found between about 80 and 130 cm. Mr J. Wymer (Reading Museum) reports that at least two pieces (130 cm and *ca.* 95 cm) are characteristic of the Neolithic tradition. But he adds concerning the assemblage: 'it is impossible to state whether it is early or late Neolithic and it must be remembered that the Neolithic flint industry continued well into the Bronze Age'.

A monolith and associated samples were cut from the face of the section (figure 12). The Mollusca extracted are listed in table 5; figure 14 is a histogram prepared from these results. In order not to make the diagram too complex, certain ecologically related groups of species have been united, most notably a large group of forms which find their best conditions for life in woodland environments, such as under logs or in leaf litter. But it should be noted that few of these species are restricted to such places, but may occur, though normally in small numbers, in habitats of other kinds (Boycott 1934). On the other hand, the species grouped as 'grassland or xerophile' are rarely or never found in shaded places, and are therefore good indicators of open country. Caution is needed in the interpretation of this and similar diagrams. First, from the way in which the deposits were formed one cannot expect the preservation of any very close stratigraphy, as one would in waterlaid sediments. Also, much reworking of older Mollusca may occur, and not be easily detectable. Lastly, a certain amount of vertical mixing, or at least condensation, may have taken place through the burrowing activities of earthworms (Atkinson 1957); this is certainly true in the soils, and would also tend to occur at times when accumulation was slow. It is even possible that selective segregation of Mollusca might be brought about in this way, large shells being undermined and slowly sinking, whereas minute and fragmentary shells might be swallowed and ejected with the surface castings. These possibilities should all be borne in mind, although in the present case it is thought that such processes have not been a serious source of confusion; the molluscan pattern is sufficiently self-consistent to warrant the assumption that the assemblages do essentially represent changing faunas living on the surrounding slopes through successive periods of time.

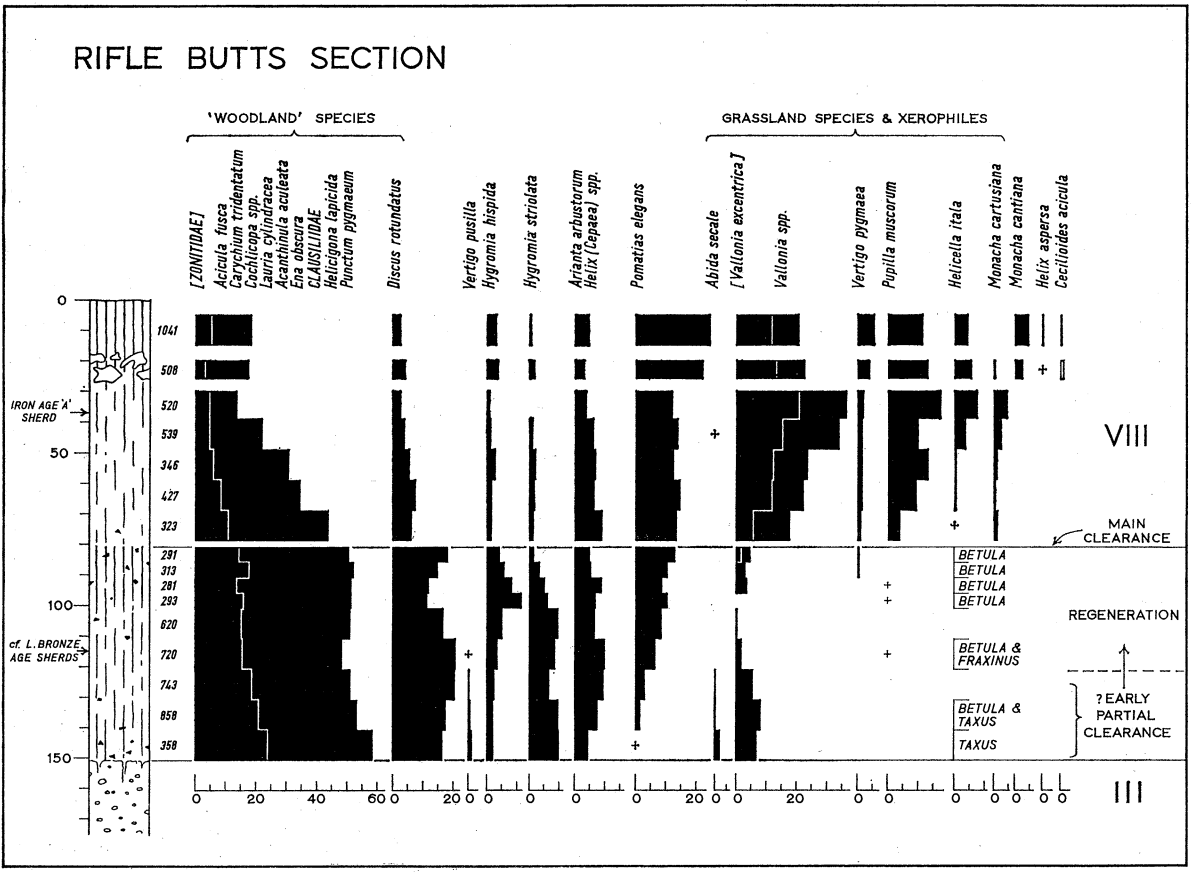

Figure 14. Molluscan histogram, rifle butts trench, Devil's Kneadingtrough. Crosses represent single specimens. Charcoal identifications shown on right.

The few Mollusca present near the top of division (*a*) are suggestive of zone III. The overlying humic muds contain a very much richer fauna and must represent a time fairly late within the Post-glacial Period; there is evidently a considerable hiatus at this level. In divisions (*b*) and (*c*) the assemblages indicate a predominantly woodland environment. The paucity of *Vallonia* and virtual absence of *Pupilla* and *Helicella* show that there was little open ground. Instead, shade-loving species, such as *Carychium tridentatum*, *Discus rotundatus* and members of the *Zonitidae*, occur abundantly. Although there can be no doubt about the general nature of the environment, the fauna shows certain interesting changes which are more difficult to interpret in detail. Near the base, *Vallonia* is fairly common, reaching about 8 %, and *Abida secale* occurs, but above about 120 cm these forms decrease in numbers and ultimately disappear entirely. Some of these shells may possibly be derivatives from destroyed Late-glacial deposits on the slopes of the valley, but for two reasons it is unlikely that most of them can have come from such a source: first, these shells are relatively numerous when contrasted with the extremely sparse fauna found in the zone III deposits, and secondly, one should expect a proportionate incorporation of *Pupilla muscorum* and *Helicella itala*, common zone III species which are, nevertheless, entirely absent from the lower part of division (*b*). We may therefore assume that this grassland element is essentially indigenous, and interpret it as reflecting the existence of a certain amount of open ground on the slopes above (*ca.* 150 cm to *ca.* 115 cm), later becoming invaded by shade-casting trees or scrub (*ca.* 115 cm to *ca.* 95 cm).

Present knowledge of the Post-glacial history of land Mollusca in southern England suggests that the assemblage of species present at the very base of division (*b*) is unlikely to date from before zone VII*a* (Atlantic), at the earliest. The ecological change from grassland to woodland cannot therefore represent the initial spread of Post-glacial forests. There remains the likelihood that we are here dealing with a reflexion of partial clearance by man, and that the succession observed represents a subsequent regeneration of the tree cover. Such an interpretation is supported by Mr Levy's examination of charcoal fragments recovered from within divisions (*b*) and (*c*), which prove to be of birch and (?) ash, with some yew at the base (Appendix II). With the possible exception of yew, which can form pure stable woods on the Chalk (Tansley 1939), these trees are not likely to have been important constituents of the natural Post-glacial climax vegetation. Indeed their occurrence is highly suggestive of regeneration. Birch is unexpected on such calcareous ground, although its role as an early colonist following deforestation is well established in the British pollen record (Godwin 1956, p. 187).

The start of accumulation of the humic muds may itself be a consequence of an artificial breaking of the slopes. The incoming of *Pomatias elegans* seems also to reflect this, for the prime need of this species is for a loose rubbly substrate in which it can burrow.

The presence of *Vertigo pusilla* is of interest, for it is now virtually extinct in southern England (Ellis 1951), and is there probably relict from a former wide distribution during the Climatic Optimum.

Above the fossil soil (*c*) the assemblages show a very considerable change. The genus *Vallonia*, which lives typically at the roots of grasses, rises sharply in abundance, and the xerophile *Vallonia excentrica* becomes of importance for the first time. *Vertigo pygmaea*, *Pupilla muscorum*, *Helicella itala* and *Monacha cartusiana* come in strongly at this level. On the other hand, the 'woodland' component shows a rapid fall. There can be no doubt that this change is the expression of clearance. The first signs can be detected within the soil itself, for in its upper part *Vallonia* reappears and rises to about 5 % of the total fauna. Probably this means that clearance pre-dated by a short while the onset of renewed downwashing, allowing a sufficient interval for the molluscan fauna present previously in the soil to be partially modified by earthworm and root infiltration from its surface.

In the flint layer (*e*) and the modern soil (*f*) *Helix aspersa* and *Monacha cantiana* appear. Both are probably accidental human introductions of about the beginning of the first millenium A.D. *M. cartusiana*, extinct in the area today, disappears. The fauna shows a slight reversal of the trend towards openness and aridity visible through division (*d*) and perhaps reflects the cessation of agriculture.

Apart from Mollusca, all the samples yielded remains of small vertebrates. These were extracted as completely as possible, and are reported on separately by Mr J. N. Carreck (Appendix III).

(*b*2) *Traverse* 3

This section was constructed from a line of eighteen auger holes, and a 4 in. diameter boring (Borehole IV). The stratigraphy is straightforward (figure 11). A marker horizon is provided by the buried rendsina soil, in places almost black, which separates brown (approximately 10YR 6/3) chalk muds above from white Late-glacial deposits below. The latter rest on a somewhat irregular surface cut in the Chalk, whereas the fossil soil, which represents by far the greater part of the Post-glacial Period, forms a smooth curve. At Borehole IV a small fauna diagnostic of zone III occurred between about 170 and 190 cm from the surface (table 5).

The traverse reveals with great clearness the artificial nature of the present form of the coombe floor. This flat surface cannot be separated in origin from that of the two cultivation terraces, or lynchets, on the west flank of the coombe, and is the result of ploughing. The old valley bottom represented by the fossil soil underlying the humic muds had instead a catenary form, reconstructed by a dotted line in figure 11; to produce the present stepped profile, the sides of the coombe have been widened, former aprons of Late-glacial deposits have been removed, and the Chalk has locally been attacked. The lynchets themselves have an internal structure typical of features of this kind elsewhere in southern England (Wood 1961).

The fauna of the soil at Borehole IV (150 to 163 cm; table 5) has a character indicative of mixed scrub and grassland. Some fragments of *Cardium edule* L. (common cockle), undoubtedly human food debris, were recovered from the core at this level. The brown muds above contain a grassland fauna of 'clearance' character, not analyzed in detail.

(*b*3) *Traverse* 4 *and Borehole V*

This traverse (figure 11) includes the secondary coombe in which the principal spring rises. To the north and south, stretches of the old buried surface are preserved, overlain by thicknesses of up to nearly 2·5 m of brown humic muds. On the higher parts of the slopes the surface has been much lowered by ploughing, whilst the lower parts have been correspondingly built up; for example, on the south side of the coombe the angle of slope of the buried soil is about 15°, but that of the modern surface only about 5° to 9°. Extrapolation of the profile of the buried soil makes it likely that it may at one time have extended at a slightly higher level across this part of the present-day spring coombe (see §IV (*b*4)).

A 4 in. diameter core (Borehole V, figure 15) was taken through the deposits on the line of this traverse. The lower white rubbles yielded no Mollusca, but are confidently assigned to zone III. The buried soil does not rest directly upon these rubbles, but is separated by a thin layer of light brownish grey (10YR 7/2; 5/2 moist) humic chalk mud. The overlying dark brown soil (10YR 5/3; 3/3 moist), which is of rendsina/brown-earth type, still

TABLE 5. DEVIL'S KNEADINGTROUGH

	Rifle butts section																		Borehole IV			
cm …	185–195	161–171	141–151	131–141	121–131	111–121	101–111	96–101	91–96	86–91	81–86	69–79	59–69	49–59	39–49	30–39	20–26	5–15	188–198	178–188	171–178	150–163
dry weight of sample (g) …	2000	1160	1110	1215	1080	1170	1140	555	485	575	570	1120	1020	950	1085	900	970	1115	—	—	—	—
Pomatias elegans (Müller)	—	—	1	12	23	47	53	31	25	33	38	44	63	43	75	63	111	251	—	—	—	38
Acicula fusca (Montagu)	—	—	—	3	3	1	7	6	6	16	8	—	2	1	2	—	—	1	—	—	—	—
Carychium tridentatum (Risso)	—	—	69	120	102	126	69	39	31	54	54	70	39	30	42	15	12	24	—	—	—	9
Cochlicopa lubrica (Müller)	—	—	8	40	36	24	44	13	15	9	14	4	12	5	3	—	8	9	—	—	—	2
Cochlicopa lubricella (Porro)	—	—	8	28	37	36	41	14	25	10	7	9	15	22	21	14	19	27	—	—	—	31
Vertigo pusilla Müller	—	—	4	6	5	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Vertigo pygmaea (Draparnaud)	—	—	—	—	—	—	—	—	—	2	2	4	7	6	9	10	20	58	—	—	—	5
Pupilla muscorum (Linné)	—	1	—	—	—	1	—	1	1	—	—	13	40	46	54	90	66	119	—	2	1	2
Lauria cylindracea (da Costa)	—	—	—	1	—	—	—	—	—	—	2	—	—	—	—	—	—	—	—	—	—	—
Abida secale (Draparnaud)	—	1	6	3	2	—	—	—	—	—	—	—	—	—	1	—	—	—	—	4	4	—
Acanthinula aculeata (Müller)	—	—	23	58	34	25	43	15	14	13	11	12	18	11	7	1	12	31	—	—	—	6
Vallonia costata (Müller)	—	1	22	69	39	13	2	—	10	8	10	40	43	40	102	81	43	89	—	1	2	23
Vallonia pulchella (Müller)	—	—	—	—	—	—	—	—	—	—	—	—	1+1	—	—	1+1	4+3	4+4	—	2	1	—
Vallonia excentrica Sterki	—	—	? 2	—	—	? 1	—	—	—	? 1	1+3	5+12	20+29	14+27	26+53	44+61	36+29	61+58	—	—	—	6+41
Ena obscura (Müller)	—	—	2	5	1	—	1	—	—	—	—	—	2	—	1	—	—	1	—	—	—	—
Marpessa laminata (Montagu)	—	—	1	2	3	1	4	3	4	4	3	3	5	3	6	4	6	13	—	—	—	1
Clausilia bidentata (Ström)	—	—	8	15	25	21	17	12	8	12	10	2	13	9	6	8	14	27	—	—	—	19
Clausilia rolphi Turton	—	—	—	—	—	—	2	2	4	2	2	2	4	1	3	4	—	—	—	—	—	4
Cecilioides acicula (Müller)	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	5	5	—	—	—	5
Helicigona lapicida (Linné)	—	—	—	1	5	4	4	1	1	1	2	3	1	2	1	1	1	1	—	—	—	7
Arianta arbustorum (Linné)	—	—	7	21	23	24	13	5	5	3	2	7	7	6	7	4	4	11	—	2	1	9
Helix (*Cepaea*) spp.	—	—	8	41	47	49	27	15	20	13	12	22	20	18	26	15	11	35	—	—	—	16
Helix aspersa Müller	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1	3	—	—	—	—
Hygromia striolata (C. Pfeiffer)	—	—	35	82	49	61	60	18	14	10	4	4	7	7	5	—	8	4	—	—	—	1
Hygromia hispida (Linné)	2	—	7	17	19	25	31	34	23	18	12	5	6	9	6	4	17	32	—	3	4	9
Monacha cartusiana (Müller)	—	—	—	—	—	—	—	—	—	—	—	4	2	3	12	22	2	—	—	—	—	1
Monacha cantiana (Montagu)	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	11	48	—	—	—	—
Helicella itala (Linné)	—	1	—	—	—	—	—	—	—	—	—	1	2	2	20	39	30	44	—	—	—	—
Punctum pygmaeum (Draparnaud)	—	—	5	10	2	2	6	5	4	3	1	3	3	4	6	3	1	5	—	5	3	—
Discus rotundatus (Müller)	—	—	58	148	153	150	104	33	33	46	52	20	31	18	20	13	20	25	—	—	—	13
Euconulus fulvus (Müller)	—	—	—	1	—	—	—	—	—	—	—	1	—	—	—	—	—	—	—	2	4	—
Vitrea crystallina (Müller)	—	—	5	8	5	1	3	—	1	1	—	—	3	—	—	—	—	—	—	—	—	—
Vitrea contracta (Westerlund)	—	—	15	14	14	6	2	2	2	10	6	5	1	3	2	—	—	1	—	—	—	2
Oxychilus cellarius (Müller)	—	—	3	27	30	25	15	4	4	18	11	6	3	3	2	—	—	3	—	—	—	3
Retinella radiatula (Alder)	—	—	2	4	1	—	—	—	—	—	—	1	—	—	1	—	—	—	—	—	—	—
Retinella pura (Alder)	—	—	16	59	54	31	28	11	6	7	8	7	12	6	9	7	7	17	—	—	—	6
Retinella nitidula (Alder)	—	—	39	62	29	44	43	29	24	19	16	14	15	7	7	13	7	29	—	—	—	17
Vitrina pellucida (Müller)	—	—	4	1	2	1	1	—	—	—	—	—	—	—	2	1	—	1	—	—	1	—
'*Limax*' spp.	—	—	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	—	—	—	×

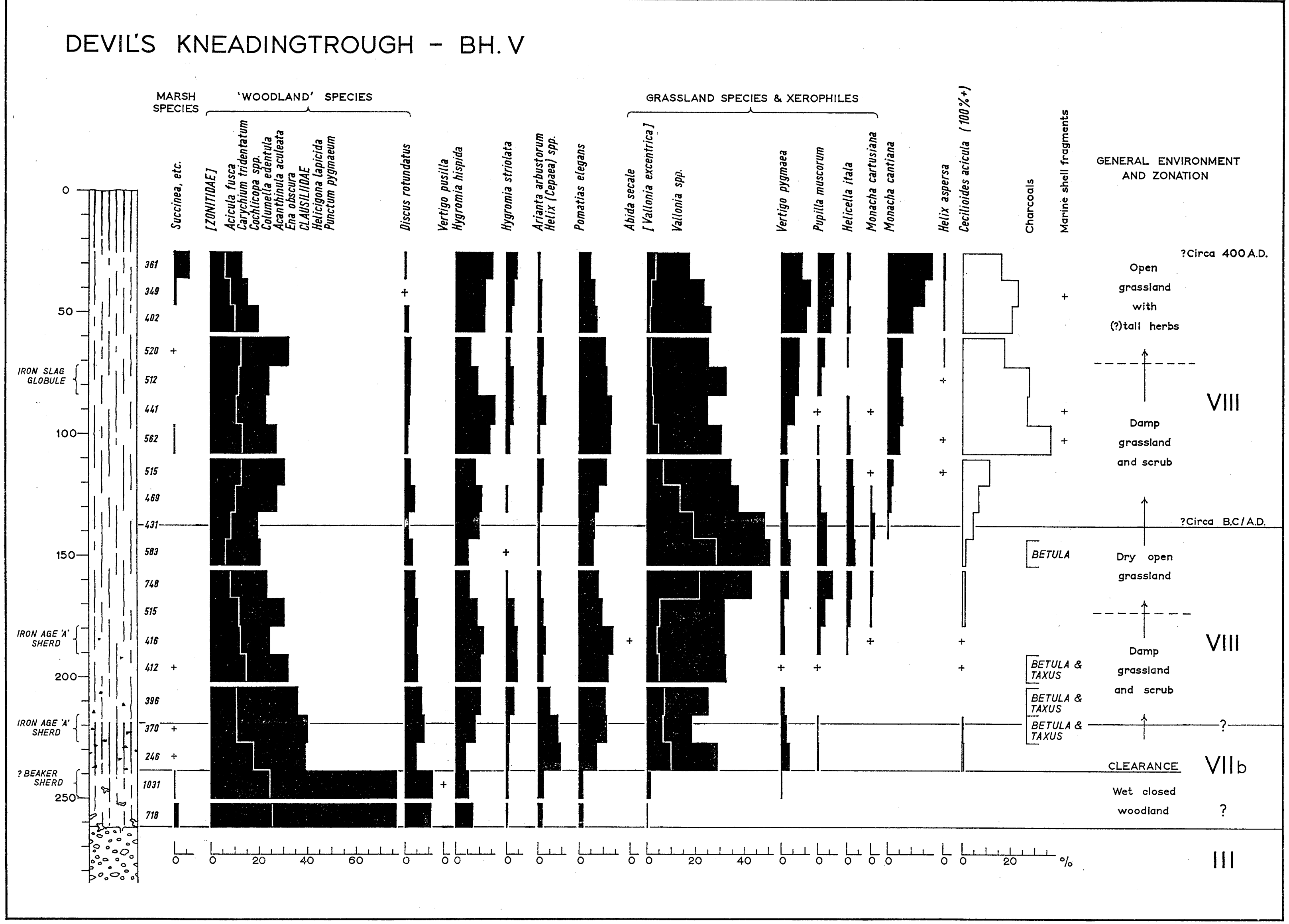

Figure 15. Borehole V, Devil's Kneadingtrough: molluscan histogram. Species and groups of species are presented in the same manner as in figure 14. The 'marsh species' (first column) comprise *Carychium minimum*, *Lymnaea truncatula*, *Succinea oblonga* and *Zonitoides nitidus*.

TABLE 6. DEVIL'S KNEADINGTROUGH

	Borehole V																				base of positive lynchet on Traverse 4	spring coombe; chalk mud under talus
cm ...	252–262	238·5–250	227–238·5	215·5–227	204–215·5	190·5–202	179–190·5	167·5–179	156–167·5	143–154	132–143	121–132	110–121	96–108	84–96	72–84	60–72	47–58	36–47	25–36		
dry weight of sample (g) ...	1410	1275	1415	1450	1470	1415	1525	1510	1495	1430	1365	1320	1435	1435	1405	1415	1400	1350	1385	1435	2000	2000
Pomatias elegans (Müller)	14	19	18	43	44	49	58	49	60	34	27	35	52	53	46	46	48	25	18	15	30	61
Acicula fusca (Montagu)	4	8	1	1	1	2	—	—	7	4	2	2	2	—	1	—	—	—	—	—	—	1
Carychium minimum Müller	2	1	—	—	—	—	—	—	—	—	—	—	—	1	—	—	—	—	—	—	—	1
Carychium tridentatum (Risso)	323	471	21	49	54	25	13	43	56	28	13	29	39	17	9	19	48	10	1	5	3	69
Lymnaea truncatula Müller	2	1	1	—	—	—	—	—	—	—	—	—	—	2	—	—	1	—	—	—	—	—
Succinea oblonga Draparnaud	—	—	—	? 1	—	? 1	—	—	—	—	—	—	—	—	—	—	—	—	3	20	—	12
Cochlicopa lubrica (Müller)	9	10	4	3	—	2	—	5	3	—	1	3	5	11	10	13	18	8	11	12	15	18
Cochlicopa lubricella (Porro)	6	5	11	20	15	17	7	18	20	18	15	16	14	12	9	2	5	1	—	1	3	—
Columella edentula (Draparnaud)	—	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Vertigo pusilla Müller	—	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Vertigo pygmaea (Draparnaud)	—	7	9	8	6	1	7	7	24	23	12	9	14	11	20	29	34	35	35	27	16	20
Pupilla muscorum (Linné)	—	—	2	2	—	1	5	17	48	22	16	6	4	3	1	7	13	19	19	21	38	36
Abida secale (Draparnaud)	—	—	—	—	—	—	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Acanthinula aculeata (Müller)	4	15	2	10	9	10	10	9	9	10	4	10	13	7	3	5	3	4	2	—	1	8
Acanthinula lamellata (Jeffreys)	—	—	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Vallonia costata (Müller)	1	7	38	35	45	40	54	70	125	114	88	79	75	79	62	65	75	70	43	21	54	57
Vallonia pulchella (Müller)	? 2	2+4	2+7	2+7	6+21	14+58	11+50	15+51	12+24	3+13	9+25	6+23	14+40	6+22	2+15	7+51	6+26	6+10	5+14	10+11	3+9	4+21
Vallonia excentrica Sterki	—	1+2	5+19	5+19	6+22	4+16	3+14	6+20	52+105	31+131	21+57	12+46	8+23	4+14	1+7	1+7	1+5	1+1	1+3	6+6	5+16	2+10
Ena obscura (Müller)	—	—	—	—	1	—	1	1	—	—	—	—	1	—	—	—	—	—	1	—	—	3
Marpessa laminata (Montagu)	1	4	—	1	1	1	1	—	—	1	2	3	2	1	1	1	2	2	1	1	1	1
Clausilia bidentata (Ström)	3	6	8	10	8	8	9	7	7	6	3	4	6	1	2	4	4	3	1	1	3	6
Clausilia rolphi Turton	1	1	4	11	6	4	3	7	3	6	3	3	3	4	1	2	2	1	—	—	—	—
Cecilioides acicula (Müller)	—	—	2	2	—	1	1	6	9	8	18	30	52	150	93	110	78	68	65	50	101	66
Helicigona lapicida (Linné)	1	2	1	3	2	3	7	2	3	4	2	1	3	1	2	3	2	1	1	1	1	1
Arianta arbustorum (Linné)	10	14	14	16	5	2	4	2	2	1	1	2	3	1	3	2	1	1	1	—	—	1
Helix (*Cepaea*) spp.	4	10	9	16	15	7	11	12	10	4	3	7	8	3	9	6	9	4	4	3	7	5
Helix aspersa Müller	—	—	—	—	—	—	—	—	—	—	—	—	1	1	—	1	3	2	2	3	1	3
Hygromia striolata (C. Pfeiffer)	4	9	3	6	13	20	20	17	5	1	—	4	—	8	10	12	8	7	9	14	5	131
Hygromia hispida (Linné)	51	55	10	32	42	44	50	47	44	33	42	49	39	59	58	39	28	41	36	49	24	25
Monacha cartusiana (Müller)	—	—	—	—	—	—	1	2	8	5	7	3	1	—	1	—	—	—	—	—	—	1
Monacha cantiana (Montagu)	—	—	—	—	—	—	—	—	—	—	2	6	10	21	22	22	27	35	44	57	14	67
Helicella itala (Linné)	—	—	—	—	—	—	3	9	16	21	13	13	13	6	4	—	2	4	2	4	14	10
Punctum pygmaeum (Draparnaud)	10	7	—	—	4	1	1	5	5	8	3	5	1	4	5	3	6	3	3	1	4	4
Discus rotundatus (Müller)	78	121	12	30	28	22	21	28	31	19	8	19	11	6	7	9	11	6	1	2	3	91
Euconulus fulvus (Müller)	1	5	—	—	—	1	—	—	1	—	—	—	—	—	—	—	—	—	—	—	—	—
Vitrea crystallina (Müller)	3	11	—	1	—	—	1	—	4	—	—	2	1	—	—	—	3	3	—	—	—	2
Vitrea contracta (Westerlund)	24	33	7	4	4	12	19	21	13	5	11	11	23	37	22	20	23	10	11	7	11	27
Oxychilus cellarius (Müller)	46	52	9	7	5	8	3	6	2	2	2	4	3	5	5	10	7	5	1	6	14	44
Oxychilus helveticus (Blum)	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	8
Retinella radiatula (Alder)	4	3	1	2	2	4	—	—	4	1	—	—	3	—	—	1	—	2	1	—	—	—
Retinella pura (Alder)	41	61	6	10	11	12	10	8	11	15	8	8	11	8	5	7	6	5	4	2	10	8
Retinella nitidula (Draparnaud)	59	82	20	15	20	22	16	22	25	12	12	18	16	4	5	5	13	8	6	3	—	26
Zonitoides nitidus (Müller)	8	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Vitrina pellucida (Müller)	2	—	—	—	—	—	1	3	—	—	1	1	1	—	—	3	2	—	—	—	—	4
'*Limax*' spp.	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×

retains a large part of its humic content and is noticeably more clayey than the deposits above and below; on drying, it produced a pronounced hour-glass-shaped waist in the core. Charcoal fragments were prominent.

Nearly 10000 Mollusca were extracted from the cores (table 6), and these have been plotted graphically in figure 15, in the same manner as in figure 14. An elegant and informative pattern of change is revealed.

The fauna of the basal 20 cm is indicative of damp, deeply shaded woodland, with a few stray marsh dwellers such as *Lymnaea truncatula* and *Zonitoides nitidus*. Grassland species are virtually absent. At the base of the soil, there is a sudden change to the fauna of an open landscape, which is maintained throughout the rest of the sequence. This is interpreted as the result of clearance by man. It is noteworthy that the change occurs, not at the top of the soil, but at the base, demonstrating that clearance at this point must of necessity have occurred some considerable while before the succeeding chalk muds began to accumulate, for time was available for the Mollusca previously present in the soil to be entirely altered in their character. Clearance alone cannot here have been the direct cause of renewed hillwashing. The effective factors are more likely to have been a combination of ploughing and the worsening of climate during the Sub-Atlantic Period, although the relative importance of these two factors is hard to assess (see §V).

Charcoal fragments recovered from between 143 and 227 cm are of birch and yew (Appendix II), both suggestive of limited regeneration. According to Tansley (1939, p. 374), yew colonizes chalk scrub very freely.

By a fortunate chance, the cores yielded three small fragments of pottery, marked on figure 15. Mr S. S. Frere's identifications of these are as follows:

179 to 190 cm	Iron Age 'A' (*ca.* 500 B.C. to *ca.* 100 B.C.)
215 to 227 cm	Iron Age 'A' (*ca.* 500 B.C. to *ca.* 100 B.C.)
238 to 250 cm	? Bronze Age, cf. Beaker ware, early (perhaps *ca.* 1700 B.C.)

Although such fragments can only provide a *terminus post quem* for the deposits yielding them, they are consistent with an early Sub-Atlantic date for the lower part of the humic muds above the soil. The soil itself probably represents a large part of the Sub-Boreal Period (zone VII*b*), in spite of the fact that its fauna reflects conditions only slightly drier than those which followed; this, however, may be due to the greater moisture-retaining capacity of a mature soil as against the scanty humus offered by an unstable hillside. It should further be borne in mind that the Mollusca of the soil are essentially autochthonous, whereas those found in the overlying muds lived over a large area of the slopes above the site.

About the middle of the succession (*ca.* 175 to *ca.* 130 cm), conditions became for a while rather dry and perhaps more open. *Hygromia hispida*, *H. striolata* and *Pomatias elegans*, which favour a certain amount of scrubby growth and avoid entirely bare downland, decrease, whilst grassland species, notably *Vallonia* spp., rise to over 50% of the total. More significant, the grassland already in existence became markedly drier, for xerophiles appear in force for the first time: *Vallonia excentrica* shows a striking rise from about 5% to about 25%, and *Pupilla muscorum*, *Helicella itala* and *Monacha cartusiana*, absent or very rare at lower levels, behave in sympathy. Stray marsh species cease to occur.

Above about 130 cm there is a converse trend towards renewed dampness, xerophiles declining and *Vallonia excentrica* in particular dropping to very low numbers. One species, *Monacha cartusiana*, disappears entirely. *M. cartusiana* is now apparently extinct in the area, even in apparently suitable habitats (Taylor 1917).

If the swing from dryness to wetness shown by the Mollusca proves to have a significance which is other than purely local—perhaps merely representing some change in agricultural practice—it would be tempting to equate it with a recurrence surface recognized in a number of north-west European bogs as falling round about 1 A.D. In this country, for example, a recurrence surface of about this date has been described by Godwin (1954) from sites in the Somerset Levels, following on evidence of local dryness. That a similar climatic shift was widespread in Europe is strongly supported by Miss J. Turner's unpublished analyses of available carbon datings (personal communication).

The upper levels of Borehole V are characterized by the appearance and increase of two species which are most probably accidental human introductions into these islands: *Monacha cantiana* and *Helix aspersa*. Reliable evidence bearing on the period of their arrival is unfortunately scanty, and what there is suggests a date not before the very end of the prehistoric Iron Age; this would coincide with the beginnings of large-scale commerce with the European mainland. Both species occur in a context of about 250 to 300 A.D. at Lullingstone, Kent (Kerney, unpublished). Apical fragments of *Monacha cantiana* may be distinguished from those of associated *M. cartusiana* by the presence of hair-pits and by the relatively larger size of the nepionic whorls. Fragments of *Helix aspersa* are distinctive by reason of the rather coarse sculpture of irregular puckers and wrinkles, not shown by any of the associated Helicidae.

Cecilioides acicula becomes abundant only in these upper levels. The species is exclusively subterranean, living on decaying organic matter in rootlet holes and similar situations, and in view of the uncertainty as to how many of the shells are truly contemporary with the associated assemblages, they have been plotted as a percentage over and above the remaining Mollusca (figure 15). In addition, many of the *Cecilioides*, according to their preservation, are obviously modern, burrowers from the present surface, and these have been excluded.

Numbers of the rare hygrophile *Succinea oblonga* appear at the very top. The specimens (figures 21*p* to *r*, plate 21) were verified by Dr H. E. Quick.

Several pieces of *Ostrea* and *Littorina*, clearly food debris, were recovered from the cores above about 110 cm; and between 72 and 84 cm was found a globule of iron slag (Appendix IV).

The dating of these deposits as shown on figure 15 must in detail be regarded as tentative, although probably correct in broad outline. It is suggested that the upper humic muds represent the period of time roughly from 500 B.C. to 400 A.D. Some evidence that accumulation has long ceased is provided by the fact that *Helicella caperata* (Montagu) and *H. virgata* (da Costa), now common on the Chalk of East Kent and living on the slopes of the Kneadingtrough but most probably medieval or post-medieval introductions, are entirely absent.

On the opposite side of the spring coombe, near the north-west end of Traverse 4, a small trench was cut into the edge of the upper strip lynchet (figure 11), exposing about

70 cm of pale brown humic chalk mud with very little coarse debris. At the base, resting on the solid chalk, were several blocks of chalk which gave the appearance of having been deliberately emplaced, perhaps in order to delimit the margin of the future field. A 2 kg sample was cut from the section immediately above the chalk blocks (50 to 60 cm from the surface), and the Mollusca extracted are shown in table 6. The assemblage undoubtedly belongs to the uppermost part of the sequence in Borehole V. *Monacha cartusiana* has disappeared, but *M. cantiana* and *Helix aspersa* are present.

At the bottom of the present-day soil in this trench were found several pieces of thin red tile: 'probably late medieval, fourteenth to fifteenth centuries A.D., or possibly later' (S. S. Frere).

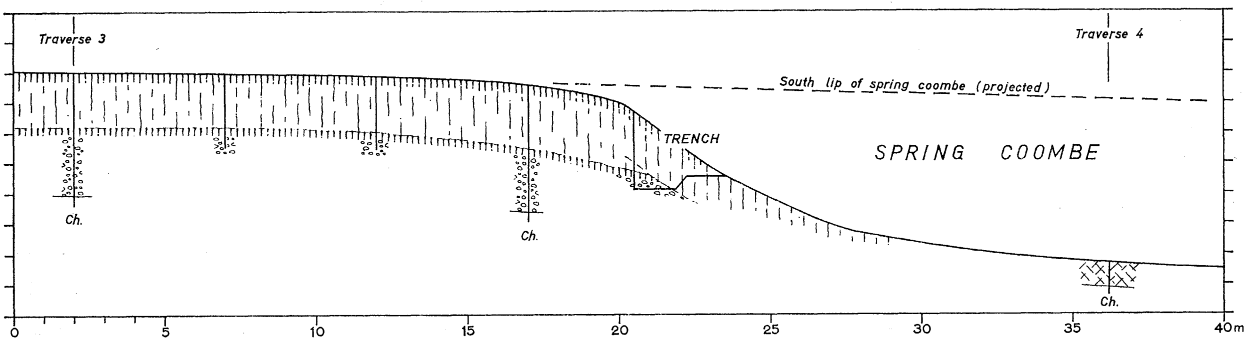

FIGURE 16. True-scale longitudinal section through head of main spring coombe, Devil's Kneading-trough, linking Traverses 3 and 4 (figure 11). Lithological symbols as in figure 11; *Ch*, Lower Chalk *in situ*.

(*b* 4) *Structure of the main spring coombe*

The present main spring emerges at the head of this feature, in an eccentric position close under the north-west corner. In the bottom, there is a marshy flat, where the Lower Chalk is overlain by about 1 m of soft calcareous mud, full of plant debris, and in process of formation today. From time to time, probably, this is scoured away entirely. Whether much headward erosion is taking place is to be doubted. Furthermore, a consideration of Traverse 3 higher up the valley makes it unlikely that at any time during the Post-glacial Period did the spring emerge very much above its present position, since the buried soil is there unbroken and everywhere appears to rest directly on Late-glacial rubbles.

A projection of the remaining stretches of the buried soil encountered on the north and south sides of the spring coombe (figure 11) suggests that the old surface once continued across the intervening space, at a level a little higher than that of the present floor. A trench dug into the back face of the coombe revealed that the soil was truncated; in figure 16 the information derived from this source has been combined with a levelled longitudinal profile and section through the head of the coombe. This drawing, however, does suggest that a depression of some kind formerly existed near the present position, since the gradient of the soil steepens as the coombe is approached. Furthermore in Borehole V obligatory marsh hygrophiles are present in the buried soil and underlying deposits (figure 15), indicating the nearness of water. The evidence tends to show that during the Sub-Boreal Period and earlier the spring emerged at no great distance from its present position, although its appearance must have differed from that of today: it would then have issued, not from the bottom of the present relatively narrow defile, overlooked by high terraces of plough debris, but within a shallow depression, into which the old soil gently sloped.

The sides of the spring coombe are covered by brown humic chalk muds (figure 11). This mantle is mainly the joint product of landslipping, and of ploughing on the surfaces above, causing debris to migrate over the edge. The former process still continues to a limited extent, whereas the latter has long ceased. It is probable, in the light of the evidence discussed below, that the whole of this material reached its present position within the deepened coombe in Roman times or later.

A vertical section was excavated through the talus in the north side of the spring coombe, immediately adjacent to the point of issue of the spring, which emerges at the surface of the Chalk. This showed about 2 m of brown chalk muds, towards the base becoming much 'cleaner' and paler in colour, resting on shattered Lower Chalk. Shells of *Helix aspersa* were conspicuous throughout. A 2 kg sample taken within 15 cm of the bottom yielded a molluscan assemblage (table 6) agreeing closely with those occurring near the top of Borehole V, both ecologically and in the presence of *Monacha cantiana* and *Helix aspersa*. The 'cleaness' of the sediment at this level—the freshness of the included chalk fragments, the low humic content, and the perfect preservation of the Mollusca—demonstrates that the deposit is not an agricultural hillwash as is at least part of the material overlying it, but represents rapid erosion of chalk or chalk rubble. It would seem reasonable to ascribe this basal deposit to a period of vigorous spring action, at a time when the sides of the spring coombe had not become as heavily degraded as they are today. This wet period may tentatively be correlated with the damp phase, possibly of the first few centuries A.D., reflected in the upper levels of Borehole V.

Some fragments of Romano-British reddish granulated ware, perhaps of the first or second centuries A.D. (S. S. Frere), were found *in situ* in this basal chalk mud. Also in the north face of the spring coombe, a rim fragment of similar coarse reddish ware was found embedded in superficial talus (figure 11); Mr Frere considered this, from parallels at Roman Canterbury, to belong to the late first or early second centuries A.D., 'certainly not later than A.D. 150'.

(*b* 5) *Traverse* 5 *and Pit B*

Between this traverse (figure 11) and Traverse 4 the floor of the coombe sweeps sharply round to the west; Traverse 5, which runs approximately north–south, therefore forms an angle of about 40° with Traverse 4, having a common point with it at the foot of the uppermost lynchet. To the north and south of the gully in which the spring waters flow are relatively flat surfaces, whose present form is the result of ploughing. The pre-cultivation surface can again clearly be recognized, under-lying variable thicknesses of brown humic chalk muds. At a depth of 75 cm (figure 11) was found a potsherd, described by Mr Frere as 'porridgy native ware of non-Belgic, "Wealden" character. End of Iron Age (*ca.* A.D. 1 to 75)'.

On the north of the stream, the humic muds and fossil soil rest nearly everywhere directly on Late-glacial deposits, but on the south augering revealed a more complicated state of affairs. A pit was therefore dug, exposing a local intercalation of further deposits (Pit B; figure 17).

At the base of the section, chalk muds intermixed with fine rubbles (*a*) grade upwards into a chalk mud (*b*). Above, are two grey (10YR 6/1; 5/1 moist) fossil soils (*c*) and (*e*), separated by a layer of tufaceous chalk mud (*d*). The lower soil is probably the more mature, for it is thicker, and was exposed to weathering for long enough to bring about some mobilization of calcium carbonate, represented by numerous secondary concretions at the top of the underlying chalk mud (C-horizon). The upper soil has a well defined surface, picked out by a thin seam of yellowish red (5YR 5/6 moist) staining, apparently limonitic. It is overlain by a white calcareous tufa (*f*), a chemical precipitate, entirely devoid of clastic chalk debris. Tubular and ramifying concretions of all sizes, formed around plant stems and leaves and frequently bearing their impress, are abundant. On its surface there rests, irregularly, a brown (10YR 5/3; 4/3 moist) fossil soil 20 to 30 cm in thickness, with many downward projections penetrating the tufa. This soil, although still very calcareous, is tending towards a brown-earth in character; it is rather plastic and in patches shows incipient decalcification. In its lower part the molluscan fauna is very scanty and not well preserved. The pale brown (10YR 7/3; 5/3 moist) chalk muds (*h*) which underlie the present-day soil (*i*) are precisely similar to those elsewhere in the valley.

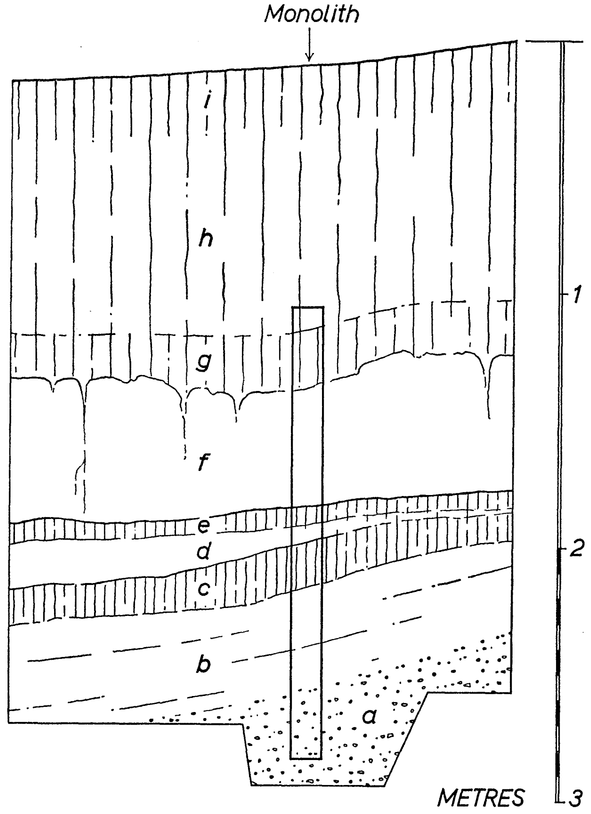

FIGURE 17. Section exposed in east face of Pit B, Devil's Kneadingtrough. *a*, chalk mud and fine rubble; *b*, chalk mud; *c*, grey chalk mud (fossil marsh soil); *d*, tufaceous chalk mud; *e*, grey chalk mud (fossil marsh soil); *f*, calcareous tufa; *g*, dark brown humic chalk mud (fossil brown-earth/rendsina); *h*, pale brown humic chalk mud; *i*, modern brown-earth/rendsina.

A monolith was cut from the section (figure 17). The Mollusca extracted are listed in table 7 and plotted graphically in figure 18. The basal deposits below about 225 cm

TABLE 7. DEVIL'S KNEADINGTROUGH. PIT B

cm ...	259·5–272	247–259·5	237–247	227–237	217–227	207–217	200·5–205	196–200·5	191·5–196	187–191·5	181–185·5	177–181	173–177	161–171	151–161	141–151	131–141	105–125	95–105
dry weight of sample (g) ...	2115	2380	1905	1875	1800	1770	880	645	715	705	650	690	670	1045	1480	1215	1100	2580	1485
Pomatias elegans (Müller)	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1	2	27	39
Acicula fusca (Montagu)	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1	—	—	2	3
Carychium minimum Müller	—	—	—	—	—	—	26	23	19	13	32	50	24	28	72	14	3	—	—
Carychium tridentatum (Risso)	—	—	—	—	—	4	50	251	422	288	100	260	286	151	453	417	227	55	25
Lymnaea truncatula (Müller)	—	—	—	—	—	—	2	10	10	12	14	25	11	10	13	6	—	—	1
Succinea oblonga Draparnaud	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1	1
'*Succinea*' sp.	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Cochlicopa lubrica (Müller)	—	—	—	—	—	1	21	24	44	46	43	110	64	16	42	14	7	15	16
Cochlicopa lubricella (Porro)	—	1	—	?1	?1	?1	7	13	33	65	21	35	26	1	—	1	1	3	8
Columella edentula (Draparnaud)	—	—	—	—	—	—	12	14	15	26	24	19	14	6	19	17	6	—	—
Vertigo pusilla Müller	—	—	—	—	—	—	8	9	27	52	4	4	11	9	20	29	9	—	—
Vertigo substriata (Jeffreys)	—	—	—	—	—	—	20	15	4	6	16	12	6	1	—	2	2	—	—
Vertigo pygmaea (Draparnaud)	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	8	12
Vertigo genesii Gredler. form 'B'	—	—	—	—	—	—	1	—	—	—	—	—	—	—	—	—	—	—	—
Vertigo moulinsiana (Dupuy)	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1	—	—	—	—
Vertigo alpestris Alder	—	—	—	—	—	—	—	—	1	—	—	—	1	2	2	1	—	—	—
Vertigo angustior Jeffreys	—	—	—	—	—	—	1	7	4	1	—	—	—	—	—	—	—	—	—
Pupilla muscorum (Linné)	4	2	1	1	—	1	—	1	—	—	—	—	—	—	—	—	—	—	—
Lauria cylindracea (da Costa)	—	—	—	—	—	—	—	—	5	32	9	14	32	69	41	12	9	—	—
Abida secale (Draparnaud)	2	1	2	1	6	1	2	1	—	—	—	—	—	—	—	—	—	—	—
Acanthinula aculeata (Müller)	—	—	—	—	—	—	7	28	71	25	4	9	19	10	31	24	17	9	7
Acanthinula lamellata (Jeffreys)	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	6	—	—
Vallonia costata (Müller)	3	1	1	1	—	2	54	71	114	26	20	38	31	8	6	3	9	90	85
Vallonia pulchella (Müller)	—	2	1	—	1	2	27	13	1	—	1	—	—	—	—	—	—	7+15	14+35
Vallonia excentrica Sterki	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	10+21	14+34
Ena obscura (Müller)	—	—	—	—	—	—	2	1	5	1	—	1	—	—	1	1	—	—	1
Marpessa laminata (Montagu)	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1	1	1
Clausilia bidentata (Ström)	—	—	—	—	—	—	—	2	20	2	1	5	6	2	8	5	7	3	8
Clausilia rolphi Turton	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	5	5
Balea perversa (Linné)	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1	—	3
Cecilioides acicula (Müller)	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	24	23
Helicigona lapicida (Linné)	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1	1
Arianta arbustorum (Linné)	1	4	7	1	7	8	6	5	6	3	1	2	8	5	14	4	3	14	4
Helix (*Cepaea*) spp.	—	—	—	—	—	—	1	2	3	2	—	3	2	4	10	7	2	19	19
Hygromia striolata (C. Pfeiffer)	—	—	—	—	—	—	4	9	9	8	2	9	6	8	10	12	5	25	98
Hygromia hispida (Linné)	9	17	58	4	11	23	7	8	15	2	2	12	8	3	6	3	7	49	61
Punctum pygmaeum (Draparnaud)	1	1	3	4	21	70	17	37	55	28	8	23	44	26	39	20	8	6	3
Discus ruderatus (Férussac)	—	—	—	—	1	1	7	6	2	1	1	1	—	—	—	—	—	—	—
Discus rotundatus (Müller)	—	—	—	—	—	—	—	—	—	—	—	—	—	15	36	54	89	39	18
Euconulus fulvus (Müller)	—	—	—	1	—	11	19	24	15	25	16	28	37	14	16	4	2	—	—
Vitrea crystallina (Müller)	—	—	—	—	—	—	—	—	—	2	—	3	20	41	95	52	17	—	—
Vitrea contracta (Westerlund)	—	—	—	—	2	3	67	176	129	86	25	111	129	23	32	93	28	15	11
Oxychilus cellarius (Müller)	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	15	11	8
Oxychilus alliarius (Miller)	—	—	—	—	—	—	—	1	2	59	9	29	52	56	22	14	3	—	—
Retinella radiatula (Alder)	—	—	—	1	—	2	71	40	25	10	26	48	18	12	37	9	3	1	—
Retinella pura (Alder)	—	—	—	—	—	—	2	16	71	66	6	20	30	13	18	72	42	6	6
Retinella nitidula (Draparnaud)	—	—	—	—	3	1	88	126	101	80	26	73	56	63	86	120	85	27	21
Zonitoides nitidus (Müller)	—	—	—	—	—	—	4	3	3	6	2	13	9	13	6	—	—	—	—
Vitrina pellucida (Müller)	—	1	—	1	4	4	—	—	4	2	—	1	1	—	—	—	1	—	2
'*Limax*' spp.	—	—	—	—	—	×	×	×	×	×	×	×	×	×	×	×	×	×	×
Pisidium casertanum (Poli)	—	—	—	—	—	—	—	—	4	2	2	3	6	20	10	2	—	—	—
Pisidium personatum Malm	—	—	—	—	—	—	9	—	10	16	19	17	99	154	266	12	6	—	—
Pisidium obtusale (Lamarck)	—	—	—	—	—	—	—	—	—	—	—	—	2	—	—	—	—	—	—
Pisidium tenuilineatum Stelfox	—	—	—	—	—	—	—	—	—	—	—	1	1	8	6	—	—	—	—

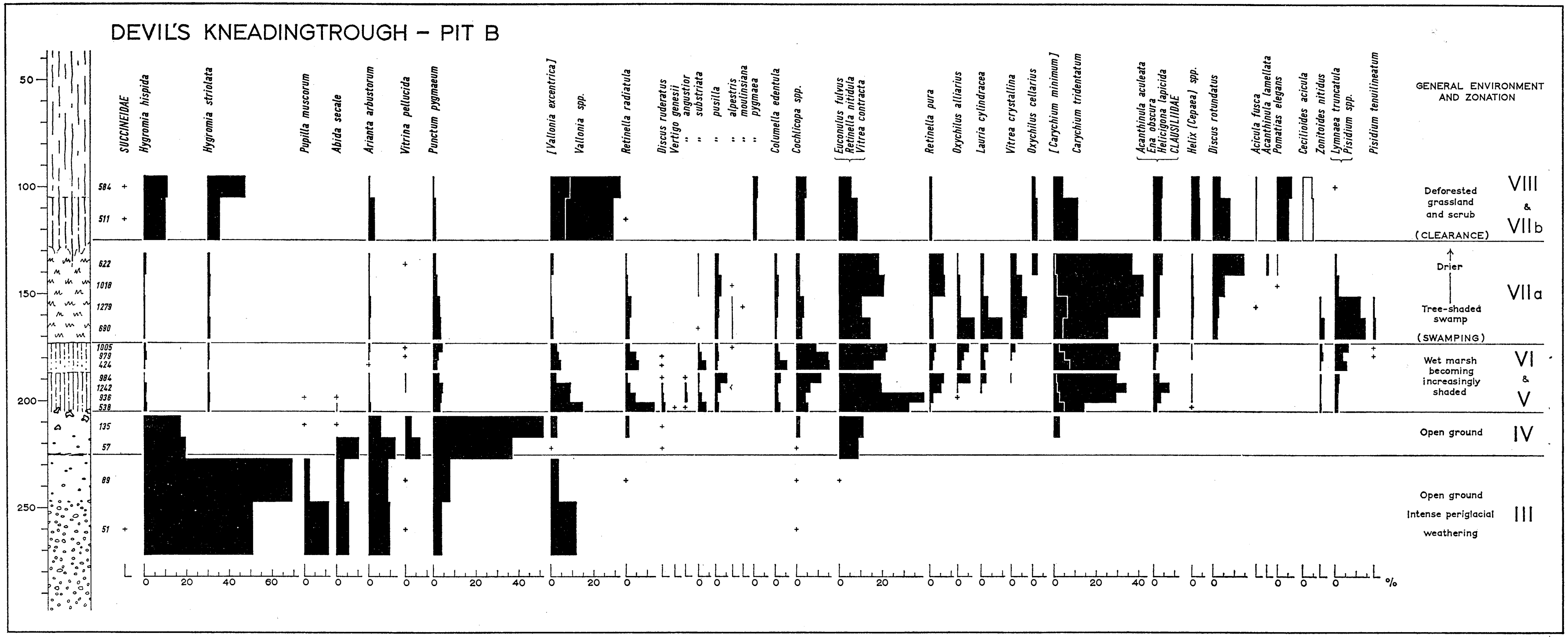

FIGURE 18. Pit B, Devil's Kneadingtrough: molluscan histogram.

belong to zone III, and yield a sparse assemblage, including *Abida secale*, entirely characteristic of this zone, and indicative of open ground. At a much higher level, the fossil soil (*g*) and the overlying cultivation muds (*h*) may broadly be referred to the Sub-Boreal and Sub-Atlantic Periods (zones VII*b* and VIII), as in Borehole V. Their fauna is similar in character and shows to the full the influence of man in stripping the landscape. Interpretation of the intervening deposits is more difficult.

The uppermost part of divison (*b*) contains an assemblage which is still essentially that of zone III, but which differs in including a few species not recorded from the Late-glacial Period, notably *Discus ruderatus*, *Retinella nitidula* and *Carychium tridentatum*. *Punctum pygmaeum* becomes very abundant, forming over 50 % of the total fauna. There is no apparent change in lithology, apart from a faint humic streak at 225 cm. This division is referred to zone IV.

The beginning of soil formation (division (*c*)) suggests that periglacial weathering had entirely ceased in response to an appreciable climatic improvement; indeed the fauna at this level becomes notably much richer both in individuals and in species. Considerable vertical changes occur through divisions (*c*), (*d*) and (*e*). Although it is by no means fully clear how such stratification is produced in soils, it would seem in the present case that colluvial action was of greater importance than the weathering of underlying parent material, and that therefore the soils grew largely by increments added to their surfaces. Very broadly, the faunal changes may be interpreted in terms of two closely related factors: first, rising temperatures; and secondly, a changing environment, a marsh becoming progressively shaded by a 'closed' vegetation. For these reasons, it is suggested that the soil complex should be assigned to the Boreal Period (zones V and VI). The increasingly overgrown nature of the site is most clearly shown by the behaviour of *Vallonia*, falling from 15 % to about 3 %. *Pupilla muscorum* and *Abida secale*, adapted to open ground, disappear entirely above about 195 cm. The evidence for rising temperatures is derived from facts such as the following: near the base of the soil complex there occurs a Boreal–Alpine species, *Discus ruderatus*; its numbers, however, fall rapidly with time, and at the base of the calcareous tufa (*f*) it is replaced by the more southern *Discus rotundatus*, the only species of the genus now living in Britain. A second Boreal–Alpine species, *Vertigo genesii* (form 'B'), occurs at the very base of division (*c*), and is undoubtedly a survivor from the Late-glacial Period. Conversely, there are several relatively thermophilous forms which appear and increase in numbers within the soil complex, without obvious ecological reasons: such are *Oxychilus alliarius*, *Lauria cylindracea* and *Vitrea crystallina*, all species which have climatically restricted ranges in northern Europe.

Superimposed on these major changes are others of lesser importance, having probably a local significance only. For example, the Mollusca of the soils (*c*) and (*e*) reflect two phases of progressive drying, separated, at the level of the tufaceous mud (*d*), by a slight episode of flooding.

At the base of the tufa (*f*) conditions suddenly become much wetter. The marsh was converted into a calcareous swamp, with pools of water between the standing vegetation enabling several aquatic species to flourish. With one exception, these species are forms which would require no more than shallow pools for their existence. Unexpected, however, is *Pisidium tenuilineatum*, a rare European lamellibranch which hitherto in Britain has been recorded exclusively from large bodies of flowing water, canals and rivers in southern England (Ellis 1951). But recently a locality for this species has been discovered in Czechoslovakia (Jasov, near Kosiče; Ložek 1956*a*, *b*) where the environment seems to be much more in keeping with that postulated at Brook; *P. tenuilineatum* there lives in the waters of a shallow mere, fed by karst springs, and bordered by stands of *Carex*. The associated fauna contains many hygrophilous land Mollusca, and it may perhaps be of some significance that Jasov is the only known Czech locality for *Vertigo moulinsiana*, a rare species also present in the Brook tufa.

This change of facies—the flooding of a weathering horizon—almost certainly indicates a local rising of the water table in the Chalk. This, and the onset of chemical precipitation of calcium carbonate, suggests moister, and perhaps warmer conditions, and for these reasons the base of the tufa has been correlated with the beginning of the Atlantic Period (zone VII*a*). It may be noted that elsewhere in Britain at this time there is evidence of a rapid rise in lake levels, due presumably to increased precipitation (Godwin 1956, pp. 329–330).

The land Mollusca represent wet swampy ground, heavily shaded by trees in view of the rarity of *Vallonia* and *Succinea*. The freshwater species fall away rapidly with time and *Pisidium tenuilineatum* disappears, perhaps merely because the surface of the tufa was being built up above the water level.

Discus rotundatus first appears at the base of the tufa and increases rapidly. A few more thermophiles come in at higher levels, notably *Oxychilus cellarius*, *Acicula fusca*, *Acanthinula lamellata*, and *Pomatias elegans*. But it is difficult to decide to what extent the appearance of these species is climatically controlled; *P. elegans*, for example, represented by stray shells near the top of the tufa, is ecologically anomalous in a marsh, and may well have been present in drier and more open situations at a considerably earlier date.

The molluscan fauna occurring in the tufa and in the upper part of the underlying soil complex may broadly be characterized as of 'Climatic Optimum type'. The assemblages are rich in species, mostly marsh and woodland forms, a considerable number of which are today either extinct or very local in southern England: such are *Vertigo angustior*, *V. substriata*, *V. pusilla*, *V. alpestris*, *V. moulinsiana*, *Lauria cylindracea*, *Acanthinula lamellata* and *Acicula fusca*. Many of these species are more prevalent in the western and northern parts of the British Isles, probably because of the more oceanic climate and the smaller effects of human interference. Comparable faunas are recorded from several Post-glacial deposits in southern England, but their geological background still awaits detailed study. A published fauna from Takeley, Essex, is typical of many (Kennard in Warren 1945). A number of these deposits are calcareous tufas (e.g. Bury & Kennard 1940; Bury 1950; Kerney 1956). Evidence for age is at present inferential, except in the case of the Blashenwell tufa in Dorset, where a radiocarbon date of 4490 ± 150 B.C. (early zone VII*a*) was recently obtained from near the middle of the deposit (Barker & Mackey 1961, p. 40). It seems probable that with the onset of the Atlantic Period widespread precipitation of calcium carbonate took place in limestone areas.

The soil (*g*) indicates prolonged weathering, and probably includes the whole of the Sub-Boreal Period (zone VII*b*). Few Mollusca were present in the lower half and vertical subdivision was therefore not attempted. The fauna shows a striking change, interpreted as the result of human clearance; the environment alters from that of a shaded marsh to that of open grassland and scrub. *Vallonia* leaps into prominence, and, conversely, forms characteristic of woodland or marsh, such as the many species of *Vertigo*, decrease or disappear. A general impoverishment is also apparent. As in Borehole V, the fauna of the soil differs in no important way from that of the overlying brown muds, suggesting that a considerable interval of time elapsed between the first clearance of the area and the onset of accumulation.

V. General conclusions

(*a*) *The form of the escarpment*

A single consequent stream eroding through a uniclinally dipping formation, such as the Chalk of the North Downs, will cut a gorge of uniform width. If it has no tributaries and there is parallel retreat of the side slopes, the gorge may be expected to widen uniformly along its length. If, on the other hand, parallel retreat does not occur as incision proceeds, the gorge will simply get deeper and wider in proportion to its increasing depth and the rate of weathering of its sides. But subsequent tributaries are likely to develop on the less resistant rocks below the cuesta as, for instance, on the Gault Clay below the Upper Greensand (if present) and Chalk, and a scarp face will be created. The scarp will create its own obsequent streams, some or all of which may be spring fed. The incision of the concentration of drainage formed by the subsequent and obsequent streams will be greatest where the consequent stream enters the gorge and will decrease with increasing distance away from the consequent stream along the scarp-foot. As a result of this a funnel-like entrance to the gorge will be formed. The inclination of the strata is clearly important (Dewey, Wooldridge, Cornes & Brown 1925, p. 275) and the length of the funnel is inversely proportional to the angle of dip, a fact clearly illustrated by the Wey gap which has no funnel and the dip of the Chalk is approximately 25°. The Mole has only a faint suggestion of a funnel and here again, although the dip of the Chalk is much more gentle, that of the Gault and Lower Greensand opposite the gap is as high as 30° in sympathy with the faulted east–west Rookery monocline. The Darent, dip of the Chalk 1° to 2°, Medway, dip *ca.* 3°, and Stour, dip 1° to 2°, have well-developed funnels.

It is reasonable to suppose that in east Kent the Chalk scarp was initiated by the incision of strike streams into the Gault below the prevailing level of the Plio-Pleistocene wave-trimmed platform, some 3 to 6 miles (5 to 10 km) south of the present position of the scarp at a height of approximately 650 ft. (198 m). Vertical incision resulting from repeated rejuvenation of the Stour drainage since that time has created the funnel without, necessarily, any independent scarp retreat not associated with the successive falls in base levels. A consequence of the incision and creation of the funnel has been the progressive increase in the height of the scarp. It is evident from the fact that the scarp foot bench between 300 and 200 ft. (91 and 61 m) extends to the foot of the Chalk scarp on both sides of the Stour funnel, that the funnel had achieved its present dimensions by that stage. The absence of any sizeable remnants of a bench at 400 ft. (122 m), a well-known stage elsewhere in the Weald, further suggests that any funnel at this stage was smaller and was eliminated by incision and the development of the 300 to 200 ft. (91 to 61 m) stage. The growth of the funnel must have been greatly helped by the development of the three east and six west bank subsequent streams between the East and Great Stours and the scarp. Incision proceeded through stages at 170 and 120 ft. (52 and 37 m) (heights near the river) to that of the Low Plain, developed on the Gault outcrop east of the river, which slopes from just over 100 ft. near the Stour up to 180 ft. (55 m) at the heads of the subsequent streams which drain it. Only in the neck of the funnel have these lower stages been cut down far enough to eliminate the higher bench and even now remnants of the 200 ft. (61 m) bench are traceable through the narrowest parts of the Stour gap (figure 1). South of Wye the Low Plain, including the flood plain of the Stour from which it is separated by a low-angle slope 5 to 6 ft. (2 m) high, forms an embryonic funnel at a lower level, narrowing northwards into the neck of the higher funnel and southwards where it crosses the Lower Greensand outcrop between Willsborough and Ashford. In form it has the appearance of an interior peneplain. The Stour funnel therefore owes its character to the low angle dip of the Chalk, 1° to 2°, and incision, principally that down to the 300 to 200 ft. (91 to 61 m) stage. Since that time periodic downcutting has continued but except in the neck of the funnel this has not, as yet, succeeded in eliminating the scarp foot bench. Between Pickersdane and Olantigh Park, behind Wye village, the scarp-foot bench has been eliminated not by the development of a surface at a lower level but by smoothing off of the 200 ft. scarp-foot bench to form a broad sloping pediment, most probably by solifluxion under periglacial conditions. A litter of periglacial material is liberally scattered over the pediment. In plan, the rather abrupt angle between the alinement of the west side of the funnel and the main scarp at Charing compares with the gentle curve of the east side near Brabourne and the difference may reflect the north–south monoclinal axis which Wooldridge (1926, p. 185) suggested was followed by the Stour gap.

(*b*) *The location of the coombes*

As described on pp. 138–139 the cluster of seven coombes at Brook is analogous to a single very large coombe at Stowting and the almost identical quintet of coombes at Coombe Farm further east. In all three cases the broad plateau bevelling the scarp above them just reaches an elevation of 600 ft. (183 m) approximately 1 mile (1·6 km) back from the scarp crest here, and only here. Extending northwards from these points are broad flat-topped interfluves, also part of the Plio-Pleistocene planation surface, separating major dry valley systems. That this particular combination of landforms should be repeated three times in the same upland and in adjacent areas must surely be more than fortuitous. The coombes are probably located where some structural influence such as a gentle syncline emerges on the scarp face. This would help to concentrate water flow laterally to these points. A similar suggestion is made by Miller (in Sparks & Lewis 1957, p. 37) for the Berkshire Downs escarpment. On the plateau, on the other hand, slight weaknesses along the line of the intervening anticlines probably led, during the period of planation, to exploitation by erosion resulting in a small measure of inverted relief, since accentuated by renewed erosion along the anticlinal axes. The structural control on the main axis of the Devil's Kneadingtrough, oriented with the dip, and on the long tributary of Fishpond Bottom positioned along the strike, have already been described. It is possible that some of the remaining coombes, parts or all of which have a common orientation of approximately 090°, may be subject to joint control. Support for this is seen in the similar trends of five out of six coombes at Coombe Farm. Faults are another possible structural control. A dip fault at Armage Farm just north of the Pickersdane coombes throws the Melbourn Rock approximately 75 ft. down to the east. The fault trace is marked by a shallow coombe in the scarp face in which there is no spring, not surprising in view of the fact that the fault heads into the Big Coombe cut in the plateau within a distance of 200 yards of the scarp crest; there can be little water catchment underground to foster a spring on the fault. As far as can be ascertained, the Melbourne Rock is not faulted in the vicinity of the coombes under discussion.

The coombes are usually related to springs but the two Pickersdane coombes have no springs in their vicinity, perhaps because they head back laterally into the catchment of the Kneadingtrough which has several springs in its lower part where it changes its trend from north–south to east–west. The underground movement of water is probably directed to the much larger Kneadingtrough. In the Newgate coombes there are several springs ahead of but not in the coombes. Fishpond Bottom has a spring feeding the old fishpond in the entrance to the coombe whilst in the cases of Old Limekiln and New Barn coombes, the associated springs are well ahead of their mouths at the edge of the 300 ft. (91 m) bench developed across the Lower Cenomanian. Further east the spring line departs still further from the scarp face as does the outer edge of the scarp-foot bench and the base of the Chalk, although there are at least three shallow coombes cut into this stretch of the scarp. It would appear that the springs get further from the scarp with increasing distance from the Stour gap in which the low plain operates as the base level to which the streams from the springs are working. Further east still the springs at Stowting are in the coombe. They are ahead of the scarp again beyond Stowting but are located in the coombes at Coombe Farm. If the position of the spring line were simply controlled by its relation to distance from base level then the springs at Stowting would be up to 1 mile (1·6 km) in front of the scarp, as the waters from its springs and those as far east as the Staple farm gap form the headwaters of the East Stour. It is consistent with the suggestion that the three sets of coombes at Brook, Stowting and Coombe Farm are located on synclines that the springs in these positions should be the most powerful and that the streams which rise from them should have cut down further, and therefore that the scarp should have been indented by headward erosion in the form of spring sapping at these points. Spring sapping may be the origin of the coombes below the present spring heads, but not of what are in fact the major parts of the coombes above the spring heads. As has been seen, there are many coombes which show little or no relationship with springs at the present day. It has been argued that at some time in the past, the water-table in the Chalk and therefore the scarp-foot spring line stood at a higher level so that the springs would have emerged higher in the coombes than they now do, from this it has been argued that the coombes are fundamentally the product of spring sapping. Further consideration of this hypothesis must await conclusions to be drawn from the shapes of the coombes themselves and the associated deposits.

(*c*) *The form of the coombes*

The orientations of the coombes have already been commented upon. In summary, there is some evidence that structural influences, most probably that of jointing, operate to determine their direction. This is especially evident in the case of the Devil's Kneadingtrough.

Related to the question of orientation is the asymmetry of the coombes in cross-section. Out of the six, the three most nearly east–west coombes have their north-facing slopes steeper than those opposite. This is particularly noticeable in the New Barn and Old Limekiln coombes. The situation is not uncommon, there are many recorded instances of this phenomena which are usually attributed to differential erosion consequent upon aspect. Two coombes are symmetrical in cross section and one has a steeper south-facing slope. In both coombes oriented more nearly north–south the westerly-facing slope is steepest. Many valleys scoring the plateau of the North Downs are asymmetrical in the same sense as are numerous Chiltern dry valleys. The asymmetry of the latter has been attributed to more intense erosion of west and south-facing slopes possibly under a periglacial climatic régime when west- and south-facing slopes would undergo diurnal and seasonal freezing and thawing whilst the opposite slope remained permanently frozen (Ollier & Thomasson 1957, p. 79). But the degree of asymmetry in the coombes is so slight, no more than 6° as compared with 18° in some Chiltern valleys, as not to warrant further speculation as to its origin. In view of this and the small numbers involved it could be a purely random phenomena.

Where the unwooded sides of the coombes, especially in the Devil's Kneadingtrough, slope at angles of 30° and over they are etched by a close pattern of terracettes apparently sloping into the coombes. But the latter appearance is an illusion as instrumental measurement shows that they are horizontal and may be used as rough contours. They would appear to be essentially stable at the present time, although their treads are used by cattle and are only sparsely grass covered. Material moving downslope across them is trapped by tufty grass growing more profusely at their outer edge and in this manner each terracette is being somewhat accentuated. But it is doubtful if they originated solely in this way; most probably they were initiated by small-scale land slipping before the present grass cover was established. In the light of the age of the deposits in the bottom of the Kneadingtrough this must post-date the Iron Age clearance.

The long profile of the surface of the Kneadingtrough has two breaks of slope marking the approximate limits of the Post-glacial infill. The lower is the contemporary spring head; the upper is largely obscured by the spoil heaps at the butts but is evident on figure 5. Clearly the Post-glacial infill is confined to, and rests like a cake on, the bottom of the coombe. It is not related to the fundamental origin of the coombe but merely occupies its bottom. The Late-glacial rubbles on the other hand continue in shallow trails up into the tributary channels above the butts and out on to the plain below the springs and would appear to be remnants left behind by whatever processes fashioned the coombe. The bedrock long-profile is a smooth concave curve and there are no abrupt changes of gradient within it. Particularly noteworthy is the way in which the profiles of the fish-tail tributary channels continue that of the main coombe without any perceptible break. The whole length of the profile from below the convexity on the crest of the scarp down to the road junction and beyond to Borehole II has the form of a water eroded channel. Nothing in its form lends support to the idea that springs have operated higher up in the coombe than they are at present. The abrupt head usually said to be indicative of this does not exist. The conditions under which and when the implied stream flow occurred are best deduced from the contained deposits.

TABLE 8. GENERAL CHRONOLOGY OF EVENTS RELATING TO THE HISTORY OF THE CHALK ESCARPMENT AT BROOK DURING THE LATE-GLACIAL AND POST-GLACIAL PERIODS

	zones	Gault Clay plain	Devil's Kneadingtrough
1960	VIII	Diversion of drainage pattern (19th century)	final stabilization of of coombe bottom
1000		cultivation	
A.D. B.C.			formation of humic muds (mainly Iron Age and Roman)
	VII*b*	slow	clearance
1000			
2000		weathering	? weathering— coombe bottom stabilized by soil
3000	VII*a*	throughout	
4000		Post-glacial	formation of calcareous tufa (Climatic Optimum fauna)
5000			
	VI	period	(rise of water-table)
6000			weathering— complex of fossil soils
7000	V		(*Discus ruderatus* fauna)
8000	IV	initiation of Post-glacial drainage pattern	? minor solifluxion
	III	formation of debris fans; some loess	intense erosion; coombe greatly deepened
9000	II	weathering (marsh soil with charcoal fragments) thin organic deposits	? re-initiation of springs
10000	I	periglacial erosion and aeolian action	

(*d*) *Late-glacial Period*

The general sequence of events relating to the Chalk escarpment at Brook during the Late-glacial and Post-glacial Periods is shown in table 8.

The fans of chalky debris which spread out from the scarp coombes are of Late glacial age. The general picture is clearest for zones II and III, which will therefore be discussed first. During the relatively mild zone II, processes of physical weathering ceased, or were greatly retarded, and thin organic deposits can nearly everywhere be traced below the fans where they overlie the Gault Clay. The fauna and flora enable one to deduce wide expanses of marshy ground mantled by herbaceous vegetation and bearing scattered birch trees, interspersed with swamps and shallow pools. In Borehole III and elsewhere the deposits culminate in a rendsina-like marsh soil containing charcoal fragments. A comparable marker horizon can be traced over a large part of south-east England and the adjacent continental mainland (van der Hammen 1953, 1957; Kerney 1963).

The seam of detritus mud in Borehole III belonging early in zone II is covered by about 15 cm of silty chalk mud, the lower part finely stratified and full of drifted plant debris. This material hints at flooding by calcareous water breaking out of the escarpment; such spring flow may indeed have been induced by a disappearance of perennially frozen ground.

When the climate deteriorated at the beginning of zone III, chalk debris was carried from the escarpment onto the plain, burying the Allerød marsh soil. In places temporary pools developed. Periodically areas dried out and small thicknesses of wind-blown chalk silt accumulated. At Borehole III two such periods of intermittent loess formation can be recognized. At times seams of chalk rubble or gravel succeeded in extending considerable distances from the escarpment, although the bulk of the material on the Gault Clay contains very little macroscopic chalk debris.

When mapped towards the coombes, the deposits of zone III become progressively coarser. In at least the northern lobe the Allerød soil is overlapped, the chalk rubbles extending eastwards to lie directly on the floor of the Devil's Kneadingtrough. Foraminiferal analyses show that most of this material is from the Upper Cenomanian and Lower Turonian stages of the Chalk; this would be expected from a consideration of the V-shaped cross section of the coombe, for the erosion of such a cavity would entail the removal of a proportionately much greater volume of high Chalk zones than of low. If we consider the northern lobe alone (figure 2), a volumetric computation, necessarily very approximate, suggests that the material lying above the zone II soil on the plain would go far towards eliminating the cavity in the escarpment formed by the Devil's Kneadingtrough, whence most of it must have come: the figures suggest that about one third of the chalk eroded is still present within a radius of less than a mile. In view of the considerable amount of calcium carbonate which must have been carried out of the area in suspension or in solution, or which has been lost by weathering subsequently, this ratio is very high. It suggests strongly that most of the necessary erosion was accomplished during zone III. Earlier than this, the coombe, though possibly existing in some form, must have been much shallower and smaller than we now see it.

There is ample proof that the climate of zone III in south-east England was exceptionally conducive to rapid physical weathering of the Chalk. The factors responsible appear to have been a relatively high humidity coupled with temperatures hovering for long periods around the freezing point. That the climate in north-west Europe was more humid than that during the Full-glacial and early Late-glacial Periods is supported by much stratigraphical, floral and faunal evidence (van der Hammen 1953; Kerney 1963), and this increased humidity may be connected with a rising sea level. But precise quantitative information is rather difficult to obtain. On the basis of the probable position of the snowline in the Lake District, Manley (1959, p. 207) estimates the mean January temperature at Windermere during zone III as $-7{\cdot}5\pm1$ °C and the July mean as $+7{\cdot}5\pm0{\cdot}5$ °C. It might be expected that in south-east England temperature conditions would be somewhat more continental. Winters would be colder and summers a little warmer, but the differences would be limited by high humidity and extensive low cloud at all seasons. The mean annual temperature would be about 0 °C.

Climatic evidence derived from the fauna and flora is not altogether easy to interpret, but several lines of reasoning suggest conditions certainly no cooler than this, and in all probability somewhat less severe. For example, the locally high percentages of pine pollen and the presence of pine needles in deposits of zone III in Hampshire and Dorset (Godwin 1956, p. 280) would indicate, by analogy with present-day tree limits in Europe, mean summer temperatures probably not below about +12 °C. For Denmark, Iversen (1954) and Andersen, de Vries & Zagwijn (1960, figure 3) suggest July temperatures of about +10 °C. The fauna of land Mollusca known from zone III in south-east England includes several moderate thermophiles (Kerney 1963) and suggests mean January temperatures probably no lower than −6 °C, and mean July temperatures perhaps as high as +12 or +13 °C (annual mean about +3 °C). Summer temperatures of this rather high order are suggested by Dr H. W. Waldén (personal communication) in the light of his detailed knowledge of the geographical and altimetric distribution of living Scandinavian Mollusca. It is interesting to observe that Dr Waldén further considers that in zone II in south-east England mean July temperatures were close to +14 or +15 °C, and in zones I*a* and I*c* not much below +10 °C.

It is in any case clear that true *perennial tjaele* (permafrost) is very unlikely to have existed in south-east England during zone III. Estimates from various parts of the world for the highest mean annual temperature required for the maintenance of permanently frozen ground vary from −1 to −4·5 °C (Shotton 1962, p. 201). In southern England none of the freeze-thaw structures locally observed disturbing Allerød layers (e.g. Godwin 1956, pl. III; Kerney 1963, figures 2, 15 and 16) are diagnostic of a *perennial tjaele*, but probably developed under conditions of alternating seasonal freezing and thawing within a relatively shallow layer of impermanently frozen ground (*annual tjaele*). Shotton (1962, p. 200), following Troll, claims that in these latitudes structure soils will develop freely if the mean annual temperature falls below +3·5 °C, a condition which by any estimate was almost certainly fulfilled during zone III. Evidence of post-Allerød cryoturbation is however local, and it may either be that mean annual temperatures were rather close to the upper figure quoted, or that heavy snow falls early in the winter helped to insulate the ground and limit the development of *tjaele*.

Whatever the precise climatic conditions during zone III, it is certain on stratigraphical grounds that the Devil's Kneadingtrough at Brook, and probably also the series of associated coombes, were cut in very large part within this zone, that is, in the short space of time between about 8800 and 8300 B.C. (Godwin & Willis 1959). One must infer that only then did the climate offer a certain peculiar and critical combination of humidity coupled with repeated freezing and thawing, in contrast to the rather drier and certainly much colder conditions existing during most of the preceeding 15000 to 20000 years of the Last Glaciation. Some such process as the following seems likely. *Tjaele* developed annually. During the winter and spring, freeze-thaw action and consequent frost shattering would be particularly active on the south facing escarpment. Chalk debris would be carried down the slopes into the gradually widening and deepening coombe, partly by processes of solifluxion, partly by the release of water from melting snowfields. Winter snowfall may have been considerable and drifting by north-easterly winds probably built up large accumulations on the scarp crest, and more especially just in the lee of the greatest height of the land, as happened during the severe winter of 1963. Present-day exposures in the sides of the Devil's Kneadingtrough above the level of the infill show the bedrock to be shattered *in situ*, material which narrowly escaped being carried out onto the plain owing to the final cessation of periglacial weathering.

Transport away from the coombe of the frost-shattered debris was probably accomplished in a variety of ways. First, solifluxion must have been active. But transport by water was undoubtedly of equal if not greater importance, as is shown by the presence within the fans of bedding and, locally, of seams of washed and rolled chalk gravel. A good deal of this water was probably surface water, derived from the periodic melting of snowfields. Deposits formed in this way may be termed *niveo-fluvial*, and are of considerable importance in the Late-glacial of the Netherlands (van der Hammen & Maarleveld 1952; van der Hammen 1953). But at Brook a second factor, perhaps of equal importance, is introduced by the presence of scarp-foot springs. The springs at the entrance to the Devil's Kneadingtrough were almost certainly active throughout zone III, for even in winter the depth of frozen ground can hardly have been sufficient to cause the groundwaters to freeze. Flow from the springs, although reduced, would greatly facilitate transport out onto the plain of the chalk debris, and makes it easier to understand the considerable distances travelled by the slurry away from the scarp face.

There is no reason to suppose that the springs surfaced higher up the coombe than they do now. According to Manley (1959, p. 213), there is no evidence that during zone III the amount of precipitation was seriously in excess of that of today. In point of fact, a rise in the water table does not lead automatically or initially to a rise in the spring line. At first the springs will simply flow more strongly and only when the capacity of the joint system is exceeded will their level rise. Seasonal variations in the volume of the present-day springs without change in their position illustrate the great range in the capacity of the joint system.

The history of the area during zone I, and in the period immediately prior, is less easy to reconstruct. In the western part of the northern lobe of debris the deposits just below the Allerød marsh soil are markedly less chalky than those above (figure 20*b*, plate 20) and according to the foraminiferal analyses consist largely of reworked Lower Cenomanian and Albian, with but very little material from higher divisions. This fact points to erosion from the scarp foot rather than from the coombes themselves. There is no evidence of spring action and this may reflect the existence of deeply frozen ground. In Borehole II, and in Borehole III in the southern lobe, the deposits of zone I are very thin and suggest formation partly by wind.

Although the base of zone I can nowhere be satisfactorily defined, the coarse gravel which underlies the western parts of both lobes has been conventionally assigned to the Full-glacial Period. The clastic fragments it contains are mainly pieces of hard chalk and must represent the winnowings of a considerable volume of destroyed chalk. Similar gravels extend westwards well beyond the area occupied by the chalky muds of zone III and appear to merge south of Wye into low terrace deposits of the River Stour. Judging from their distribution, it is unlikely that these basal gravels have any specific connexion with the erosion of the scarp face coombes.

(*e*) *Post-glacial Period*

Since the end of zone III, the Chalk escarpment at Brook and the fans of debris have suffered no major change in morphology, although several processes of slow wastage have operated. The springs within the Kneadingtrough have effected only negligible erosion. On the plain, minor stream erosion has indeed occurred, for example, along the south-western edge of the southern lobe of debris, where stream incision to a depth of 5 ft. has trimmed the edge of the lobe. Later the channel was filled with an alluvium derived from the Gault. But a much more important cause of wastage, both here and on the Chalk escarpment, has been a general overall lowering by solution, assisted by the action of plant roots and the burrowing of earthworms. This phenomenon, first critically investigated by Darwin (1882), has recently been discussed by Atkinson (1957), who presents excellent evidence from archaeological excavations on the Chalk to show that a lowering of between 15 and 20 in. on level ground during the last 4000 years is by no means uncommon. Although rates of weathering must vary widely in response to local conditions and changing climates, these figures would imply, at a conservative estimate, a lowering of at least 1 m in the Brook area since the beginning of the Post-glacial Period. We may infer that these fans of highly soluble debris have become appreciably thinner, and reduced in area by the etching back of their feather edges. In recent times, this process has probably been accelerated by cultivation.

The Post-glacial history of the Devil's Kneadingtrough itself is now known in some detail. The coombe had, at the end of zone III, roughly its present aspect, but was a little deeper and for the most part lacked the sharp angles at the top and bottom of the slopes brought about by Man's interference. The floor was choked by masses of chalky debris, and had probably a rather irregular, channelled appearance. With the rise of temperature and the growth of vegetation, processes of physical weathering were greatly retarded; over most of the coombe bottom all accumulation stopped, the greater part of the Post-glacial Period being represented only by a fossil rendsina soil developed directly on the surface of the white rubbles. Slow solution continued for some thousands or years, reducing an originally irregular valley profile to a smooth catenary curve (figure 11).

In one area, intersected on the south side of Traverse 5, there are marsh deposits preserved which give important information about conditions during the Pre-Boreal to

Atlantic Periods (zones IV to VII *a*). There is no direct evidence about the site of the main springs in the valley floor at this time, but there is reason to believe that they cannot have been far from their present position; certainly they were no higher. But their appearance would have differed from that of today, for prior to the Early Iron Age the present deep defile did not exist and we must envisage instead broader, shallower, less clearly defined marshy depressions, heavily shaded by trees and scrub. Under such conditions did the deposits revealed in Pit B accumulate (figure 17). At the base, a little down-washing of chalk mud appears to have continued into zone IV. Then follow a set of marsh soils, provisionally assigned to zones V and VI. The Mollusca reflect a decrease of open ground—the Late-glacial genera *Abida*, *Pupilla* and *Vallonia* declining or disappearing—and conversely those forms characteristic of marsh and woodland increase. Thermophilous species progressively appear. The base of the calcareous tufa marks a flooding, presumably in response to increased spring flow. The marsh was converted into a swamp stretching across the area now incised to a lower level. The onset of tufa formation appears to have been due to a climatic change, and is taken to mark the beginning of zone VII *a*. Except around the springs, most of the coombe bottom must by now have been densely forested.

Although the zoning applied at Pit B is largely inferential, it seems very likely that similar studies elsewhere will eventually make more precise climatic interpretation possible. Very few comparable sites have yet been examined in Britain. A possible parallel is provided by an extensive calcareous tufa described many years ago from Skultorp in Vastergötland (Odhner 1910). The stratigraphy corresponds to a remarkable, though perhaps fortuitous, degree with the section in Pit B. The Skultorp tufa is underlain by two fossil soils, the upper generally thinner than the lower. On the evidence of the Mollusca and of macroscopic plant remains Odhner ascribed the principal tufa to the Atlantic Period, and the underlying complex of fossil soils to the Boreal Period. Late-glacial deposits lie below, resting upon moraine.

With the Sub-Boreal Period (zone VII *b*) we enter the phase of prehistoric husbandry. There can be no doubt that clearance of the coombe and its surrounding area was a complex process. Relevant in this connexion is a pollen diagram published by Godwin (1962) from Frogholt, a site near the foot of the Chalk escarpment about 8 miles S.E. of the Devil's Kneadingtrough. This diagram, in conjunction with three radiocarbon datings, shows conclusively that partial clearances of the local downland had been carried out at least as early as about 1000 B.C., and that a phase of great expansion of plants associated with agriculture takes place about 500 B.C., and is probably to be connected with the establishment of the Iron Age 'A' culture in Kent.

The evidence at Brook is quite consistent with a pattern of this kind. In the rifle butts section, the molluscan histogram (figure 14) shows signs of two phases of local clearance, separated by regeneration of the woodland, probably with much birch. The second clearance is by far the more drastic, and probably marks the beginnings of Early Iron Age cultivation. In the lower part of the coombe, on the other hand, at Borehole V and at Pit B, the histograms suggest that complete clearance had been effected by a much earlier date.

The first clearances cannot be dated precisely. At the rifle butts flint flakes of Neolithic character were recovered from the lower part of the section, and at Borehole V a pottery fragment from just below the clearance level suggests occupation at least as early as the Beaker Period (*ca.* 1700 B.C.). It can only be suggested that these early clearances were effected by Neolithic pastoralists; the valley floor may indeed have first been partially deforested so as to provide a pound for livestock, for which it is ideally suited.

It is likely that the onset of accumulation of the main series of humic muds infilling the Devil's Kneadingtrough, which overlie a weathering horizon representing a period of stability, reflects the onset of ploughing, or at any rate of much more efficient ploughing, on the slopes above. At Borehole V the presence of two sherds of Iron Age 'A' pottery near the base of this material provides a *terminus post quem* for this event. An important contributing factor is likely to have been the well-documented worsening of climate at the beginning of the Sub-Atlantic Period (Godwin 1960), a higher rainfall facilitating the transport of hillwash from the sides of the valley into the bottom. It so chances that the beginnings of widespread arable farming in southern Britain in the Late Bronze Age and earliest Iron Age approximately coincide with the opening of the Sub-Atlantic Period (zone VIII) around 500 to 600 B.C.

A pronounced swing from dryness to wetness about the middle of the humic muds, revealed by the molluscan histogram from Borehole V (figure 15), may also perhaps have a climatic explanation, and be correlated with a recurrence surface of about 1 A.D. recognized in a number of west European bogs; on the other hand, there is here no precise evidence of date and in view of the many unknown factors involved in the interpretation of this change, it would be unwise to press this parallel very far.

In the earliest stages, ploughing was almost certainly restricted to the slopes above the upper edges of the coombe, and did not take place on the valley floor itself. This is shown by the generally excellent preservation of the fossil soil. Furthermore, initial burial must have been a fairly rapid process, for otherwise the soil would speedily have been obliterated by plant roots and the burrowing of earthworms from succeedingly higher levels.

To the south of the coombe, an area of 'celtic fields' still exists (figures 19*a*, *b*, plate 19). From surviving indications, fields of this type must originally have closely surrounded the coombe on all sides. Although not easily datable, by analogy with other areas in southern England they were probably farmed during both the Early Iron Age and Roman Periods. A pottery fragment picked up on the surface here belongs to the very end of the prehistoric Iron Age, possibly to the first century A.D. (S. S. Frere). The humic muds of the coombe infill represent in large part plough-debris which slowly migrated downhill across these fields to the edges of the coombe, and was then more rapidly washed down the steep slopes. At a late stage, the coombe floor itself was brought under the plough, when took place the destruction of the aprons of Late-glacial deposits and of some solid chalk at the foot of the slopes, producing the present angled profile. To this time probably also belongs the formation of the strip lynchets (see below).

Judging from the presence of slag in the deposits (Appendix IV), smelting was carried out in the vicinity during part of the Early Iron Age or Roman Periods. About 10 years ago the site of a probable iron ore working was excavated by Mr F. Jenkins, F.S.A., on the crest of the escarpment $\frac{7}{8}$ mile north-north-west of the Devil's Kneadingtrough (072466; personal communication). The material being exploited was limonitic ironstone in the Plio-Pleistocene sands. The workings yielded a few sherds of Iron Age 'A' type.

No traces of smelting were observed, but it may be noted that the sites of furnaces of late pre-Roman date are known from several places in East Kent (Jenkins 1962, pp. 17–18).

The precise age of the strip lynchets on the northern flank of the coombe remains obscure; by analogy with other areas a pre-Roman origin is not likely (Wood 1961). Mollusca from the base of the material composing the upper positive lynchet on Traverse 4 are consistent with this view: they show that accumulation began late within the time span represented in Borehole V (§IV (*b* 3)).

Nor have we any clear information as to when cultivation ceased and deposition effectively came to a halt, to give place to the present régime of weathering and slow solution. But the balance of evidence suggests that the *status quo* has been maintained probably for some centuries. For example, late post-Roman molluscan introductions, notably certain members of the genus *Helicella*, have nowhere been detected. In the rifle butts section, a fourteenth-century sherd was found at the base of the present soil. On the lynchets on Traverses 4 and 5, a considerable number of pieces of thin tile, probably Late Medieval (fourteenth or fifteenth centuries), were extracted from a similar position. All these fragments were doubtless dropped on to the present surface and have sunk through earthworm under-mining. In recent times, although no cultivation seems to have occurred, the area has been kept open by grazing and the depredation of rabbits.

(*f*) *Comparisons*

Scarp-face coombes of comparable appearance occur in other parts of the Chalk country of southern England. Some of these may prove to be of like origin and date. Sparks & Lewis (1957) describe three coombes near Pegsdon, Hertfordshire, which have a strikingly similar morphology to those near Brook. The cross-section of the Pegsdon Valley proper (*ibid.* p. 29, figure 3) shows an upper series of brown humic chalk muds of late Post-glacial date (Late Bronze Age/Early Iron Age, or later), resting on a basal series of white chalk rubbles. The latter have the appearance of periglacial material, but the position is complicated by the presence near the top of these deposits of small molluscan assemblages of Post-glacial type. Sparks & Lewis therefore considered that the whole of this lower material might have been produced in a warm climate, and that the coombes were cut by extremely rapid spring-sapping during a temperate, humid phase, comparable to the Atlantic Period during the Post-glacial.

An examination of Sparks & Lewis's molluscan lists in the light of more recent knowledge suggests that at least some of this lower material is indeed of periglacial origin. Two assemblages from the Pegsdon Valley (*ibid.* p. 33, first column, first list; p. 34, second list), are probably of zone III date. But the remaining three lists are undoubtedly composed mainly of post-Pleistocene species, inconsistent with the apparent periglacial origin of the white rubble. Since the samples came from close to the top of these lower deposits there is a strong possibility that infiltration from the Post-glacial material above may have occurred. Such infiltration, which takes place mainly down rootlet holes and worm burrows, has proved a frequent source of confusion in deposits of this kind subjected to weathering. The contamination may not be evident, for oxidation may remove the darker organic colouring of the infiltering material once the overlying soil has been killed by burial. At Brook, for example, in Borehole IV within the Devil's Kneadingtrough

(§IV (*b* 2)) a considerable number of Post-glacial species were found in the white rubbles of zone III, mixed with the indigenous fauna but usually showing a slightly different, poorer, preservation. From between 5 and 20 cm below the base of the A-horizon of the rendsina, shells of the following were noted in the samples: *Pomatias elegans*, *Carychium tridentatum*, *Acanthinula aculeata*, *Helix* (*Cepaea*) sp., *Discus rotundatus*, *Vitrea* sp., *Oxychilus cellarius* and *Retinella nitidula*. Nor is this surprising if we consider that uninterrupted weathering acted on this surface for a period of over 7000 years. Similarly, the zone III deposits on the Gault Clay plain frequently yield Post-glacial shells however carefully sampling is carried out, often to a depth of 50 cm or more from the present surface. A re-investigation of the Pegsdon evidence is needed, but it is in any case clear from the presence of probable Late-glacial deposits in the floor of the valley that little or no erosion can have occurred at least during the Post-glacial Period.

Sparks & Lewis (1957) make several references to the supposed blunt-ended character of the Pegsdown valleys and suggest that this 'abruptness of the valley heads cannot be reasonably explained by the melt-water hypothesis, as melt-water valleys should start gradually and become progressively incised'. Rake Bottom, a scarp-face coombe under Butser Hill, Hampshire, is regarded by Small (1958, p. 23) as having a similar 'abrupt steepening...difficult to explain in terms of erosion by a stream, normal or composed of melt-water'. But allowing for the fact that the Pegsdon valleys, Rake Bottom and the coombes at Brook are cut into the steep scarp face of the chalk and that in consequence their long profiles must be expected to be steep, they do in fact start gradually and become progressively incised before flattening lower down, without any abrupt steepening or blunt-endedness, as is clearly shown by both Sparks & Lewis (figure 2) and Small (figure 1). In fact the smooth, concave form of the long profiles at Pegsdon, Rake Bottom and the Devil's Kneadingtrough are fully consistent with a melt-water hypothesis, and indeed the absence of any break in their long-profiles strongly suggests that springs have not operated within them.

Much more work will be necessary before any general conclusions can be drawn concerning the dating of chalk valleys. Many scarp-face erosional features originated earlier than the Late-glacial Period. For example, dry valleys on the flanks of the gap of the River Medway (Kent) contain in their floors complete sequences of Late-glacial deposits (zones I*a* to III), underlain by deposits of Full-glacial age (Kerney 1963, figure 6). Again, a cirque-like coombe on the face of the escarpment of the South Downs near Beachy Head (Sussex) contains deposits at least as early as zone I, and its cutting must pre-date this (Kerney 1963, p. 221).

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Appendix I. Late-glacial plant remains

By Camilla A. Lambert

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Pollen analysis

The pollen-bearing material at Brook is of particular interest in that it illustrates for the first time the Late-glacial vegetation of the south-eastern corner of England. The levels between 275 and 300 cm which were analyzed from the base of Borehole III contained pollen which was sparse and poorly preserved. It was therefore only possible for Miss R. Andrew to count the minimal 300 land-pollen grains usual for Late-glacial samples at two levels. The poor state of preservation also made it impossible to distinguish pollen of tree birches from those of the dwarf birch, but the identification, albeit uncertain, of a leaf and fruit as *Betula nana*, suggests that this species was present. The number of grains counted in each sample is recorded in table 9. A diagram, figure 23, has been drawn to illustrate the relative changes in frequency of the various land-pollen types; but since it is based on such small numbers, extreme caution must be exercised both in its interpretation and comparison of it with other Late-glacial pollen diagrams.

In the three lower samples from 300 to 293 cm, pollen of *Betula* and *Pinus* is present in low values. Shrubs are represented by *Salix*—both pollen and macro-remains and a small quantity of *Juniperus* pollen. Gramineae is dominant in two of the samples. Among the abundant herb pollen *Artemisia*, *Empetrum nigrum*, *Epilobium* and *Rumex* are characteristic of Late-glacial samples. Cyperaceae pollen, present in all the samples in quantity is of local origin, to judge from the presence of abundant *Carex* nutlets. The low ratio of tree pollen to herbaceous pollen values is in keeping with an attribution to some facies of zone I.

The very low numbers of pollen counted in the succeeding four samples restrict interpretation. However, at 290 cm there is a definite increase in the proportion of pine pollen relative to that of birch and grasses. Since the pine values are maintained in all four samples, it seems unlikely that this is an effect of the low numbers of grains counted. The high ratio of pine to birch (figure 23) and the high relative values of pine are exceptional for the Late-glacial in Britain. The possibility of the pine pollen having blown from more southerly latitudes cannot be overlooked. However, the recovery of macroscopic remains of birch, including wood and charcoal (identified by Mr Levy, see Appendix II) suggests that birch was locally present and therefore unlikely to have been swamped by long-distance transport of pine pollen. It seems therefore reasonable to assume that some pine was growing in the south of England at this time and, since the Folkestone Beds of the Lower Greensand occur a third of a mile from this site, suitable habitats would certainly have been available. It is interesting to note that the only macroscopic remains of pine so far found in the Late-glacial in England together with pollen, were recovered from zone III deposits at Nursling, Hants. (Seagrief 1959), and Elstead, Surrey (Seagrief & Godwin 1960), both of which are in sandy areas.

TABLE 9. POLLEN ANALYSIS FROM THE LATE-GLACIAL DEPOSITS OF BOREHOLE III

Numbers of grains counted, percentages of the total land pollen in brackets

cm ...	275	280	285	290	293	297	300
Betula	10 (20)	4 (6)	10 (11)	3 (7)	26 (1·1)	31 (4·5)	50 (18)
Pinus	23 (45)	29 (44)	43 (46)	20 (49)	9 (0·4)	29 (4·2)	40 (14)
Picea	—	1 (2)	—	1 (2)	—	—	+ +
Juglans	—	—	—	—	—	—	+ +
Salix	—	—	—	—	12 (0·5)	19 (2·7)	9 (3)
Juniperus	—	2 (3)	1 (1)	—	5 (0·2)	2 (0·3)	3 (1)
Ephedra	—	1 (2)	—	—	—	—	—
Gramineae	3 (6)	4 (6)	4 (4)	—	1768 (70)	432 (62)	13 (5)
Cyperaceae	10 (20)	18 (27)	21 (23)	13 (32)	446 (17·7)	118 (17)	85 (31)
Armeria	—	—	—	—	2 (0·1)	—	—
Artemisia	—	1 (2)	1 (1)	—	5 (0·2)	3 (0·4)	4 (1·5)
Caryophyllaceae	2 (4)	—	—	1 (2)	77 (3·1)	7 (1)	—
Chenopodiaceae	—	—	1 (1)	—	—	—	1 (0·4)
Compositae	3 (6)	3 (5)	9 (10)	2 (5)	—	1 (0·1)	—
Matricaria type	—	—	—	—	14 (0·6)	—	—
Taraxacum type	—	—	—	—	39 (1·5)	23 (3·3)	65 (23)
Empetrum nigrum	—	—	—	—	25 (1)	5 (0·7)	—
Epilobium	—	1 (2)	2 (2)	—	25 (1)	8 (1)	1 (0·4)
Labiatae	—	—	—	—	1 (+)	—	—
Potentilla	—	—	—	—	5 (0·2)	—	—
Rubiaceae	—	—	—	—	—	1 (0·1)	2 (0·7)
Rumex	—	—	—	—	69 (2·7)	13 (2)	—
Thalictrum	—	—	—	—	—	1 (0·1)	3 (1)
Umbelliferae	—	—	1 (1)	1 (2)	—	—	1 (0·4)
Urtica	—	1 (2)	—	—	—	—	—
Valeriana officinalis	—	1 (2)	—	—	—	—	—
Total land pollen	51	66	93	41	2528	694	277
Menyanthes	—	—	—	—	—	1 (0·1)	—
Potamogeton	—	—	—	—	—	—	2 (0·7)
Sparganium or *Typha angustifolia*	—	—	—	—	20 (0·8)	—	—
Filicales	1 (2)	1 (2)	1 (1)	—	4 (0·2)	4 (0·4)	—
Botrychium	—	—	—	—	10 (0·4)	—	—
Lycopodium selago	—	—	—	—	2 (0·1)	—	—
Ophioglossum	—	4 (6)	4 (6)	5 (12)	—	—	—
Selaginella	—	1 (2)	1 (1)	—	—	1 (0·1)	1 (0·4)
Sphagnum	—	—	—	—	—	—	1 (0·4)
Botryococcus	—	—	—	—	+ +	+ +	—
Pediastrum	+ +	—	—	—	—	—	+ +
derived spores	—	—	—	—	—	+ +	+ +
Hystrix	+ +	+ +	+ +	+ +	—	+ +	+ +

It would appear then that a change in the composition of the vegetation has taken place: pine pollen has largely replaced that of grass and the ratio of pine to birch has increased. It is noteworthy that birch charcoal was identified from the same level as the uppermost pollen sample and birch pollen increases slightly at this level. A single grain of *Ephedra* was found at 280 cm; isolated grains have occurred at a number of Late-glacial sites in Britain. The pollen evidence alone from these four samples would be slender grounds on which to suggest a climatic change; however, the molluscan evidence and the radiocarbon date make it difficult to avoid the conclusion, that the pine has increased in response to the climatic change of the Allerød oscillation. It is of interest to note that at Usselo in the Netherlands van der Hammen (1953) records pine values of up to 50% of the total land pollen just below a pine charcoal layer known to be late Allerød in age (8900 B.C.).

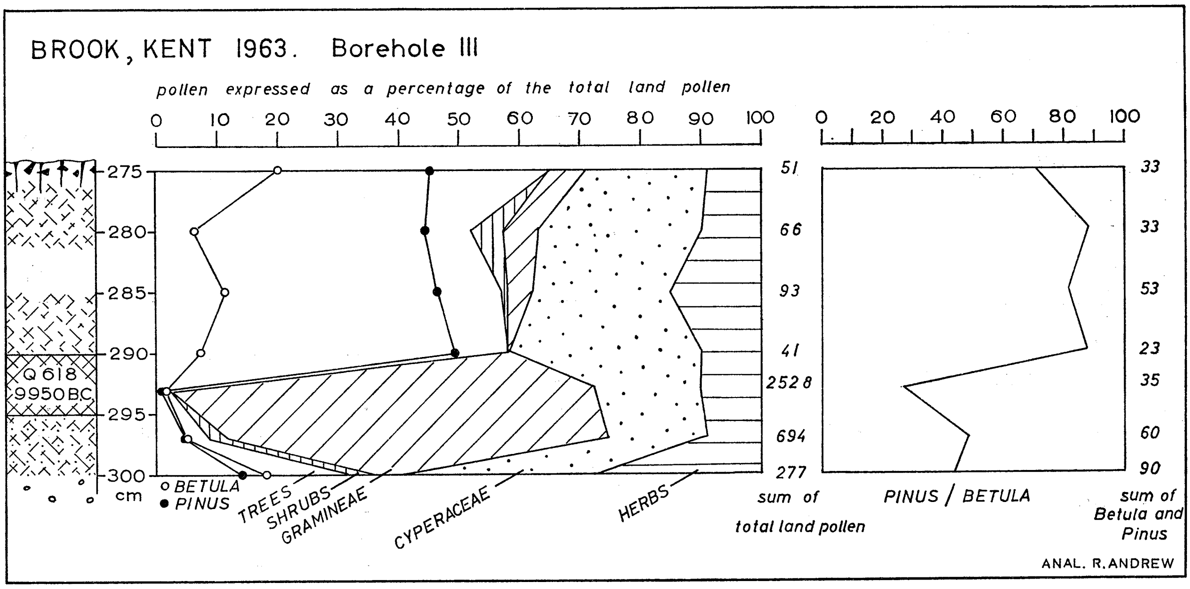

FIGURE 23. Pollen diagram through the Late-glacial deposits of Borehole III.

Macroscopic plant remains

Several of the plants identified by their macroscopic remains are of special interest (table 10). *Arctostaphylos uva-ursi* with *Betula nana* and *Salix herbacea* are plants which, though now restricted to the north and west of Britain, were widespread during the Late-glacial period.

Chaenorhinum minus is now associated with man-made habitats and has not previously been found fossil. The well-preserved light buff fossil seeds are 0·8 mm long (figure 24*b*), with small papillae between the 12 to 14 longitudinal papery ridges.

Pedicularis palustris, a widespread plant of wet heaths and marshes has only one previous fossil record; i.e. from an interstadial deposit at Upton Warren, Worcs. (Coope, Shotton & Strachan 1961). The single seed found shows clearly the inrolled ventral side (figure 24*a*); the clear polygonal network of cells with raised margins easily distinguishes seeds of this species from the faintly reticulate ones of *P. sylvatica* L.

The identification of wood of cf. *Myrica gale* (Appendix II) is noteworthy because the earliest previous record in Britain is that of a leaf from zone IV deposits at Wareham, Dorset (Seagrief 1959).

It is unfortunately not known whether the wood and charcoal of *Betula* and wood of *Salix*, are those of tree or shrub species. The Bryophytes, *Campylium* sp. and *Sphagnum* sp., were kindly identified by Mr J. H. Dickson of the Sub-department of Quaternary Research, Cambridge. Unfortunately, their poor state of preservation prevented specific identification.

Pollen of *Potamogeton* and *Sparganium*/*Typha angustifolia* and fruits of *Schoenoplectus* sp. indicate standing water; species of *Carex* may have been growing marginally or with *Menyanthes*, *Myrica* and *Pedicularis* in rather poor fen. Dry heathy places could support

TABLE 10. LIST OF MACROSCOPIC PLANT REMAINS FROM THE LATE-GLACIAL DEPOSITS OF BOREHOLE III

	type of remains	cm ... 273–278	286–290	*285–300	293–295	295–300	300–308
		dry land					
Arctostaphylos uva-ursi (L.) Spreng.	fruitstone	1	3	1	—	—	—
Betula cf. *nana*	leaf, fruit	—	—	—	—	1, 1	—
Betula sp.	fruit	—	—	—	—	1	—
Chaenorhinum minus (L.) Lange	seed	—	1	—	—	—	8
Rumex acetosella agg.	nut	—	—	—	2	—	—
Salix herbacea L.	leaf	—	—	—	1	—	—
		aquatic and fen					
Carex spp.	nut	1	53	30	3	93	17
cf. *Eriophorum* sp.	nut	—	1	—	—	—	—
Menyanthes trifoliata L.	seed	2	6	26	1	17	—
Pedicularis palustris L.	seed	—	—	—	—	1	—
Ranunculus subgenus *Batrachium*	achene	—	—	—	—	1	1
Schoenoplectus sp.	nut	—	2	—	—	1	—
Sphagnum sp.	leaf	—	—	—	—	+	—
		others					
Cruciferae	seed	—	1	—	—	—	—
Gramineae	caryopsis	—	1	—	—	—	—
Rumex sp.	nut	—	1	—	—	—	—
Salix sp.	budscale	—	3	2	—	2	—
Viola sp.	seed	—	1	1	—	—	—
Campylium sp.	leafy shoots	—	+	—	—	—	—

* A composite sample augured out from the borehole.

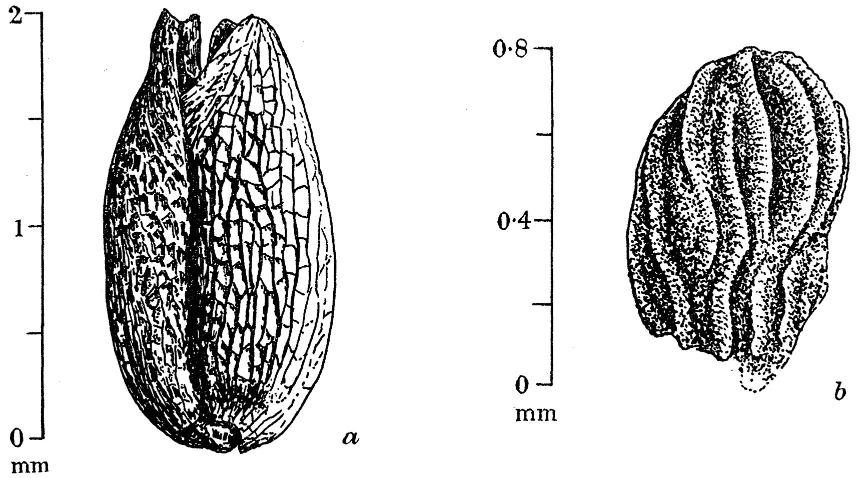

FIGURE 24. Fossil seed of *a*, *Pedicularis palustris*; *b*, *Chaenorhinum minus* from the Late-glacial deposits of Borehole III.

Arctostaphylos uva-ursi, *Betula nana*, *Rumex acetosella* and *Salix herbacea*. It is interesting to note that there are no markedly calcicolous plants represented. The presence of aquatic, fen and dry land plants indicate that this was a marginal or shallow water deposit. Rare oxidized seeds of non-aquatic plants recovered from 273 to 278 cm indicate a drying out of the deposit at this level, thus supporting the lithological and molluscan evidence.

The ^{14}C date, macroscopic plant remains, pollen and lithology are consonant with the view that the bulk of these organic deposits formed during the mild Allerød period and that at this time there was an amelioration of climate which resulted in the local increase of pine.

Appendix II. Woods and charcoals

By J. F. Levy

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The majority of the samples examined were small fragments of wood charcoal, often only a few cubic millimetres in size. One series of samples consisted of distorted wood that had not been charred and these were identified at the Royal Botanic Gardens, Kew.

In the main, the charcoal fragments consisted of two species, *Betula* sp. (birch) and *Taxus* sp. (yew). A few samples of a ring porous hardwood, probably *Fraxinus* sp. (ash), were seen from one level.

Birch was characterized by a diffuse arrangement of vessels in transverse section, the vessels being solitary or in short radial chains. The vessels had no spiral thickening, the radial walls were well pitted and scalariform perforation plates were present. The rays were narrow, multi-seriate and not aggregate.

Yew was characterized by the presence of tracheids with large bordered pits on the radial walls. Resin ducts were not seen. The late wood was not conspicuous and the growth ring rather uniform in transverse section. The rays were uniseriate and no horizontal resin ducts were seen. Spiral thickenings were present on the inner surface of the tracheid walls. The cross-field pitting was not seen clearly.

Late-glacial deposits

Pit A

117 to 129 cm	(fossil soil). About 100 fragments of which the largest was 3 mm × 3 mm × 1 mm; 10 examined. *Betula* sp., 7 fragments; not identified, 3 fragments.

Borehole III

274 to 278 cm	(fossil soil). Wood and charcoal fragments in poor preservation; at least one piece of charcoal of *Betula* sp. identified.
286 to 290 cm	Uncarbonized wood fragments, identified at the Jodrell Laboratory, Royal Botanic Gardens, Kew. (?) *Myrica gale*, twig fragments probably of this species; *Betula* sp., fragments of twigs and bark; *Salix* sp., fragments of twigs and bark.
ca. 275 to 295 cm	(disturbed sample). *Salix* sp., fragment of twig.

Post-glacial deposits

Devil's Kneadingtrough, rifle butts section

81 to 86 cm	*Betula* sp., 4 fragments.
86 to 91 cm	*Betula* sp., 8 fragments.
91 to 96 cm	*Betula* sp., 10 fragments.
96 to 101 cm	*Betula* sp., 10 fragments.
111 to 121 cm	*Betula* sp., 11 fragments; (?) *Fraxinus* sp., 8 fragments.
131 to 141 cm	*Betula* sp., 10 fragments; not identified (probably hardwood), 5 fragments; *Taxus* sp., 3 fragments; softwood (not identified further), 2 fragments.
141 to 151 cm	*Taxus* sp., 5 fragments; softwood (not identified), 4 fragments; not identified, 1 fragment.

In most of the fragments from 131 to 141 cm and 141 to 151 cm there is evidence of fungal boreholes and cavities in the walls of both fibres and tracheids (i.e. in both hardwoods and softwoods). This suggests that the woody material underwent incipient decay at some stage between the death of the tree and the time of burning.

Devil's Kneadingtrough, Borehole V

143 to 154 cm	*Betula* sp., 4 fragments; not identified, 1 fragment.
190·5 to 202 cm	*Betula* sp., 5 fragments; *Taxus* sp., 5 fragments.
204 to 215·5 cm	*Betula* sp., 3 fragments; *Taxus* sp., 6 fragments; not identified, 1 fragment.
215·5 to 227 cm	*Betula* sp., 5 fragments; *Taxus* sp., 4 fragments; not identified, 1 fragment.

Appendix III. Vertebrate remains from the rifle butts trench

By J. N. Carreck

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All the vertebrate remains obtained during the extraction of Mollusca from this site are listed below. The dry weights of the quite small samples are shown in table 5, p. 168.

The vertebrate material is extremely incomplete and broken, but quite remarkable for the abundance of skeletal remains and the number of genera and species represented, and the writer is unable to recall any comparable series of deposits of this age in Britain yielding such a varied fauna of small vertebrates, other than in caves and fissures. The forms represented comprise at least ten genera and ten species, and are: *Sorex araneus* Linné (common shrew), *Clethrionomys* cf. *glareolus* (Schreber) (bank vole), cf. *Microtus agrestis* (Linné) (cf. field vole), *Apodemus sylvaticus* (Linné) (long-tailed field mouse), *A* .cf. *flavicollis* (Melchior) (cf. yellow-necked mouse), bird remains, *Anguis fragilis* Linné (slow-worm), *Rana* or *Bufo* sp. indet. (frog or toad), and an indeterminate Teleostean fish. Many of these forms are to be found sparingly in Holocene chalk rainwashes in southern England, but such scanty records as are available in no way compare favourably with those from the present site.

Whilst it is not practicable to construct a histogram to indicate the relative frequency of the vertebrates, as accomplished for the molluscs, owing to the incomplete and fragmentary nature of this skeletal material, table 11 is given to show the distribution of the latter remains at the successive levels in the section.

In addition, the following larger remains were extracted from the face of the section: *Bos* sp. (ox), left pm_2 (*ca.* 82 cm), left permanent m^2 and left pm^2 (*ca.* 115 cm); and *Cervus elaphus* Linné (red deer), right pm^2 (*ca.* 38 cm).

Notes on certain species

Apodemus cf. *flavicollis*. This has been recognized from 131 to 111 cm (woodland phase), and 49 to 39 cm (grassland phase). The determinations rest only on the characters of the first lower molars, which are insufficiently diagnostic for positive distinction between this species and some extreme examples of the ubiquitous *A. sylvaticus*.

The ecology of the yellow-necked mouse is not known to be distinct from that of the long-tailed field mouse.

Bos. sp. The only bovine remains found are insufficient for precise specific determination.

Aves. It was not practicable to determine closely the occasional bird remains, all but one fragmentary and one rather worn, but their occurrence in the deposits of the woodland phase, and their apparent absence from the later layers, is noteworthy.

Anguis fragilis. Although remains of slow-worm are probably widespread (but overlooked) in deposits of this nature and age in Britain, the writer knows of no comparable occurrence other than those in some cave and fissure deposits.

Rana or *Bufo* sp. The amphibian remains are most probably of the common frog, *Rana temporaria* Linné, although it is possible that toad (*Bufo*) may also be represented. Four bones were found in one sample only (121 to 111 cm), suggesting that all may have come from a single individual.

Conclusions

It must first be decided to what extent the associations of animal remains recovered represent fluctuating natural communities. The paucity of small vertebrate remains in the higher layers is evidently not due to subsequent destruction by solution, as molluscan shells are still numerous and the deposits are highly calcareous. The fragmentary and sometimes weathered condition of the vertebrate specimens does not show whether these animals lived on the site or at a distance, for the destructive effects of subaerial weathering and the action of burrowing organisms may have been important even on the bodies of animals which died where their remains were collected. It may be noted, however, that Dr Kerney considers that little vertical mixing of the layers has occurred.

Apodemus sylvaticus and *Sorex araneus* are very commonly represented in owl pellets and it is possible that some of the vertebrate remains from this locality may have been derived from pellets of owls or other predatory birds, and therefore represent animals living at considerable distances. Also, the single fish vertebra is most probably from a nearby brook or lake, and part of some food brought by a carnivorous mammal or by early man. It is very difficult to assess the importance of transport of this kind, but in proportion to the remains of the indigenous fauna such intrusions are likely to be few.

TABLE 11. LIST OF SMALL VERTEBRATE REMAINS

cm …	141–151	131–141	121–131	111–121	101–111	96–101	91–96	86–91	81–86	69–79	59–69	49–59	39–49	31–39	20–26	5–15
Sorex araneus Linné	*mr*	—	*i*	—	—	—	—	*p*, *m*	—	*mr*	—	*mr*	—	—	—	—
Clethrionomys cf. *glareolus* (Schreber)	—	*mr*, 3*m*	*m*, *mr*	2*m*	4*m*	—	*m*	2*m*	—	*m*	—	—	—	—	—	2*m*
cf. *Clethrionomys* sp. indet.	—	*m*	*m*	—	—	*m*	—	—	*m*	2*m*	—	—	—	*m*	*m*	—
cf. *Microtus agrestis* (Linné)	—	*m*	—	—	—	—	—	—	—	—	—	—	—	—	—	2*m*
Voles, indet.	—	—	—	—	*p* or *mr*	—	—	—	—	2*m*	4*m*	*m*	—	—	*m*	—
Apodemus sylvaticus (Linné)	—	—	—	—	—	—	—	—	*mr*	—	—	—	—	—	—	—
Apodemus cf. *sylvaticus* (Linné)	—	—	—	—	—	—	—	*m*	—	—	—	—	—	—	—	—
Apodemus cf. *flavicollis* (Melchior)	—	—	*mr*	*m*	—	—	—	—	—	—	—	—	*m*	—	—	—
Apodemus sp. indet.	—	*m*	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Muridae, indet.	*i*	2*i*, *v*, *mt*	4*i*, *v*, *c*, *h*, 2*mp*, 2*ph*	5*i*, *oi*, *oi* (?), 6*mp*, 5*ph*	2*i*, 2*v*, *mp*, *ph*	2*i*, 3*v*, 2*mp*, *f*	2*i*, *v*, *mc*, 2 *mc*(?), *c*, *u*, *mt*	2*i*, 2*mc*, *mt*, *tf*, 2*ph*	2*i*, 2*v*, *c*, 5*mc*, *mt*	2*i*	2*ph*	3*i*	—	—	*i*	*i*
small mammals, indet.	×	—	×	×	×	×	×	×	×	×	×	×	—	—	—	—
Aves (*Passeriformes*)	—	—	—	—	*cm*	—	—	—	—	—	—	—	—	—	—	—
Aves	—	*h*	*tt*	—	*ss*? (?)	—	—	*ph*? (?)	—	—	—	—	—	—	—	—
Anguis fragilis Linné	—	2*sc*	*v*?, 4*sc*	2*sc*, 4*sc*?	6*sc*	4*sc*	*sc*	—	—	—	—	—	—	—	—	—
Rana or *Bufo* sp. indet.	—	—	—	*v*?, *h*, *tf*, *ph*	—	—	—	—	—	—	—	—	—	—	—	—
Teleostei, indet.	—	—	—	—	—	—	—	*v*	—	—	—	—	—	—	—	—

Key to abbreviations: *p*, premaxilla; *mr*, mandibular ramus; *m*, molar; *i*, incisor; *v*, vertebra; *mc*, metacarpal; *u*, ulna; *h*, humerus; *oi*, os innominatum; *mt*, metatarsal; *mp*, metapodial; *c*, calcaneum; *tf*, tibio-fibula; *f*, femur; *ph*, phalanx; *cm*, carpo-metacarpus; *ss*, synsacrum; *tt*, tibio-tarsus; *sc*, scales. Crosses represent minute anatomically indeterminate bone fragments. An interrogation mark without parentheses denotes uncertain taxonomic position; the same within parentheses denotes uncertain anatomical position.

It may be noted that the majority of the vertebrate remains are from the deposits of the woodland phase below the main clearance level. It is likely that this represents a true change in abundance of individuals at the time of deposition.

Sorex araneus existed here from the beginning of the woodland phase to early in the grassland phase and this is in accordance with the present ecology of this species. *Clethrionomys glareolus* is chiefly indicative of a woodland biotope and remains almost certainly of this species appear to be most common in the woodland phase deposits, although probably present throughout the succession. *Microtus agrestis* requires a copious grass supply as in damp meadows and woodland clearings. Remains apparently of this species have been found in the deposits of the inferred early partial clearance phase and in the present soil layer, but, unexpectedly, not in the other layers of the grassland phase. *Apodemus sylvaticus* favours woods—although found everywhere normal to wild mice—and was present here at the end of the woodland phase. The remains ascribed to *A. flavicollis* strongly suggest the occurrence of the yellow-necked mouse in Kent in late prehistoric times. If this form is indeed indigenous in Britain, as these finds suggest, it is worth pointing out its possible identity with the Late Pleistocene *A. lewisi* (Newton) of the Ightham Fissures near Sevenoaks (Kent) and other localities (Barrett-Hamilton & Hinton 1910–21, pt. xvii, p. 547; Hinton 1915, pp. 582–3). Indeterminate *Muridae* occurred in the deposits of both the woodland and grassland phases. The bird remains may be of woodland forms since they were confined to layers of the woodland phase. *Anguis fragilis* requires shelter such as woods afford and is here confined to deposits of the woodland phase, with an apparent maximum in the middle. The destruction of the habitats of the birds and slow-worm by human clearance robbing them of protective cover is likely to have caused their disappearance, whilst human disturbance may also explain the scarcity of *Anguis* in the possible early clearance phase. The probable presence of *Rana temporaria* at 111 to 121 cm is suggestive of a temporary damp site in the woodland.

The occurrence of *Cervus elaphus* in a layer representing relatively open downland is rather unexpected but the single specimen may represent food brought from elsewhere by man. The teeth of *Bos*, either of domestic animals or wild cattle, may also be human food debris.

Thus the results obtained from the evidence of the vertebrates confirm and supplement those reached from the evidence of the molluscs.

APPENDIX IV. IRON SLAG FROM BOREHOLE V

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The globule measured approximately 0·75 cm in diameter. A brief examination of the polished section revealed conclusive evidence of early attempts at smelting iron ore. Skeletal dendritic structures of magnetite are the chief evidence of this; these are relatively common in this section, and are found enclosed in areas of matrix of low reflectivity—possibly an iron silicate or spinellid-type phase. Other parts of the section show areas of sintered particles of iron oxides of low reflectivity, sometimes rimmed by layers of magnetite-hematite material. Later changes due to weathering and supergene processes have caused replacement by crystalline goethitic-type iron oxides to occur, as well as some amounts of amorphous limonitic iron oxides.

I am indebted to Mr A. C. Hills (British Iron and Steel Research Association, London) for his expert advice on this specimen.

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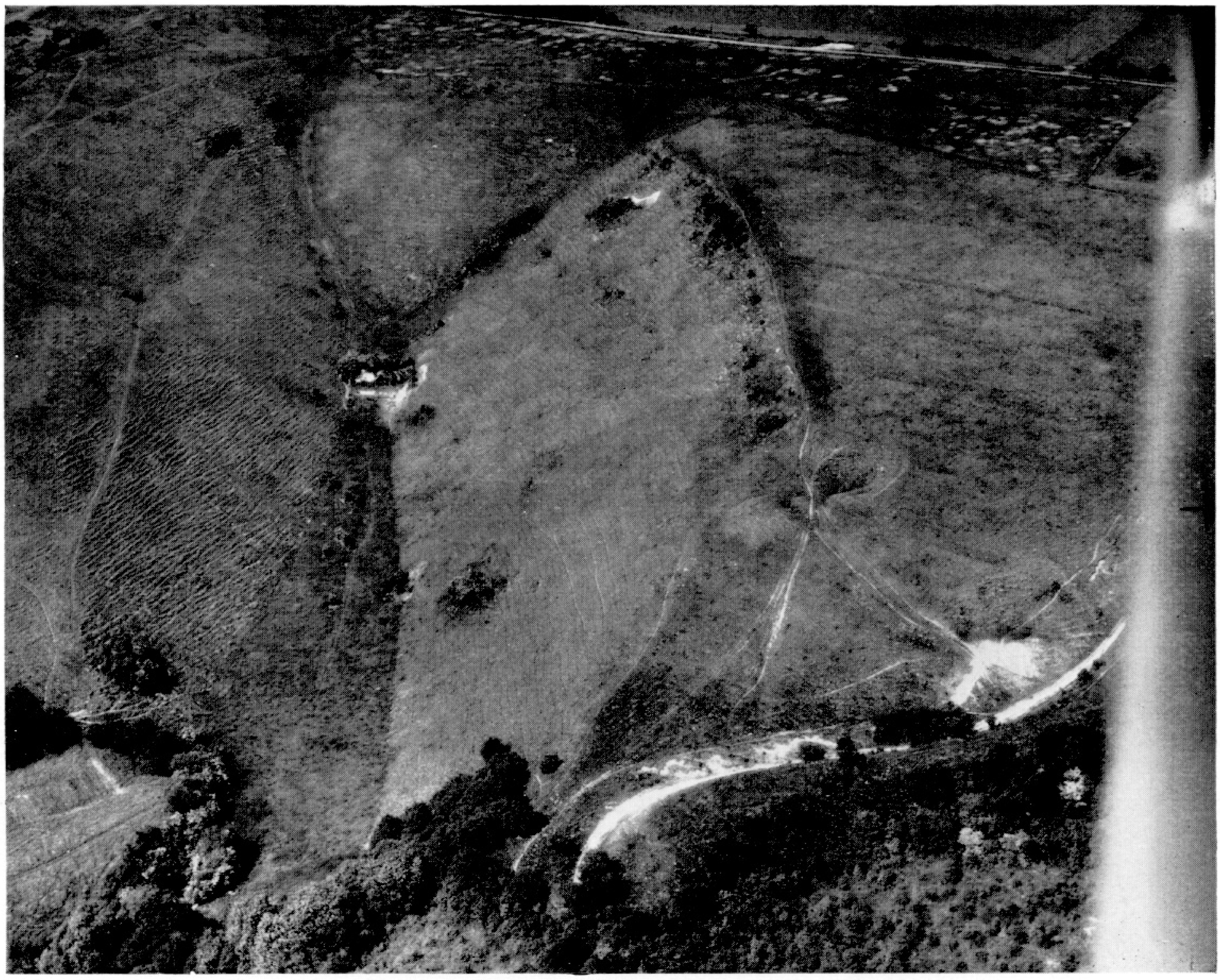

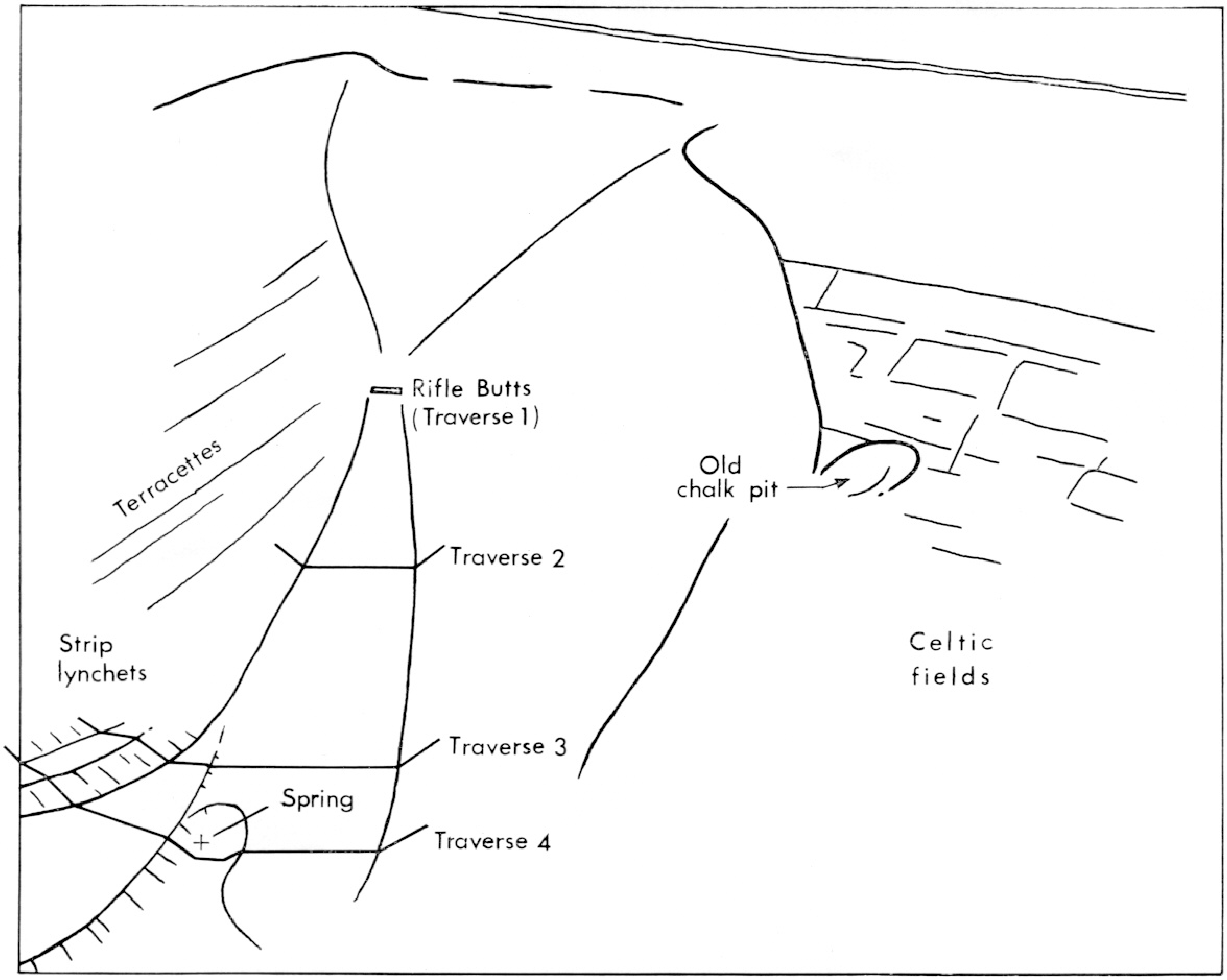

FIGURE 19 (*a*). Aerial view of the Devil's Kneadingtrough, Brook, Kent. Photograph by J. K. St Joseph, 1959.

(*b*) Interpretation of figure 19 (*a*), showing position of Traverses 1 to 4. Traverse 5 lies just out of sight beyond the bottom left-hand corner of the photograph.

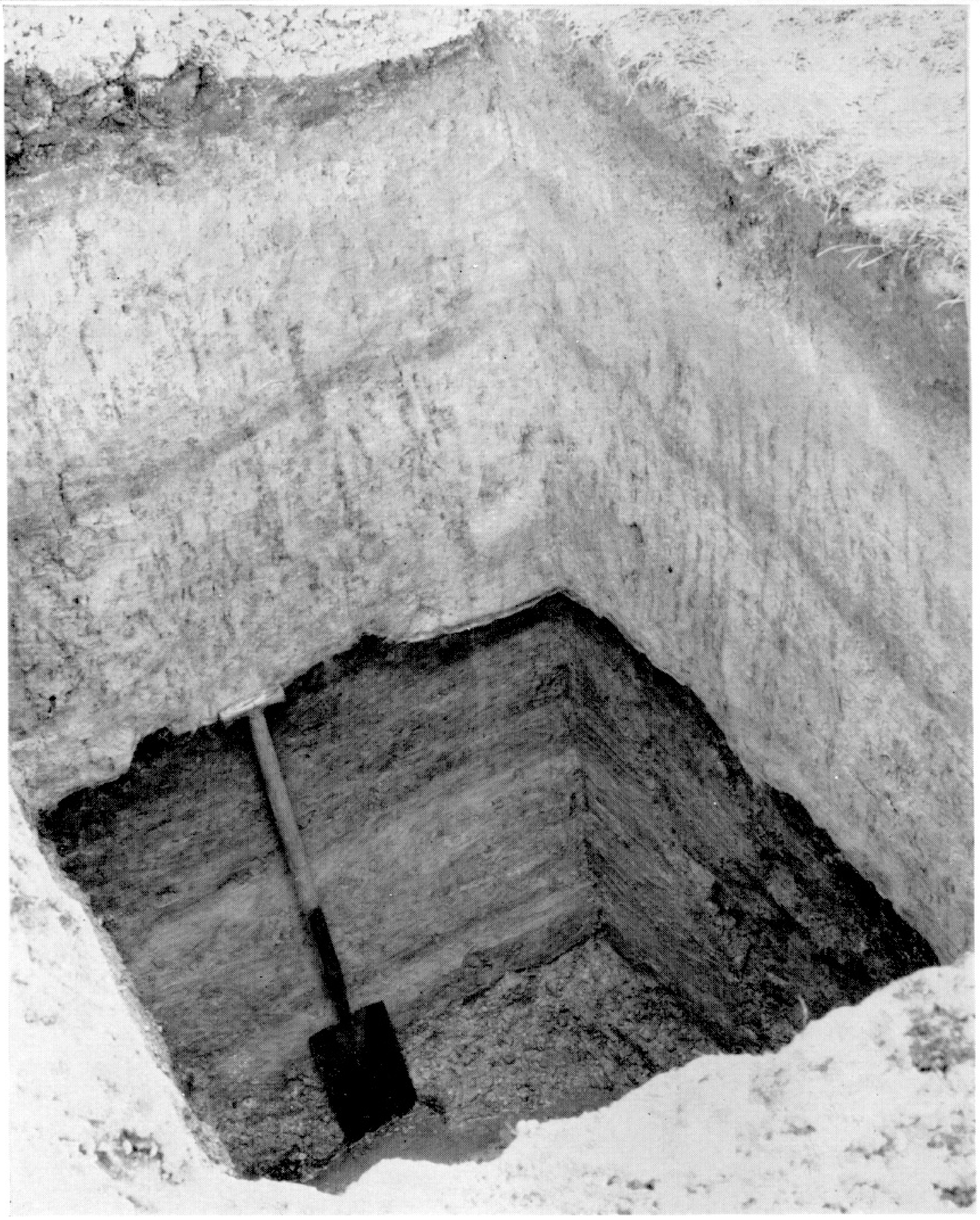

FIGURE 20 (*a*). Aerial view of the Devil's Kneadingtrough from the west, taken in 1954. (Crown Copyright reserved.)

(*b*). Section dug at College Farm, Brook, September 1960 (Pit A; 06264495). Late-glacial deposits, showing Allerød soil, overlain by white chalk muds of zone III, and underlain by olive clayey muds assigned to zone I. Basal gravel visible above water. Spade 1 m in height.

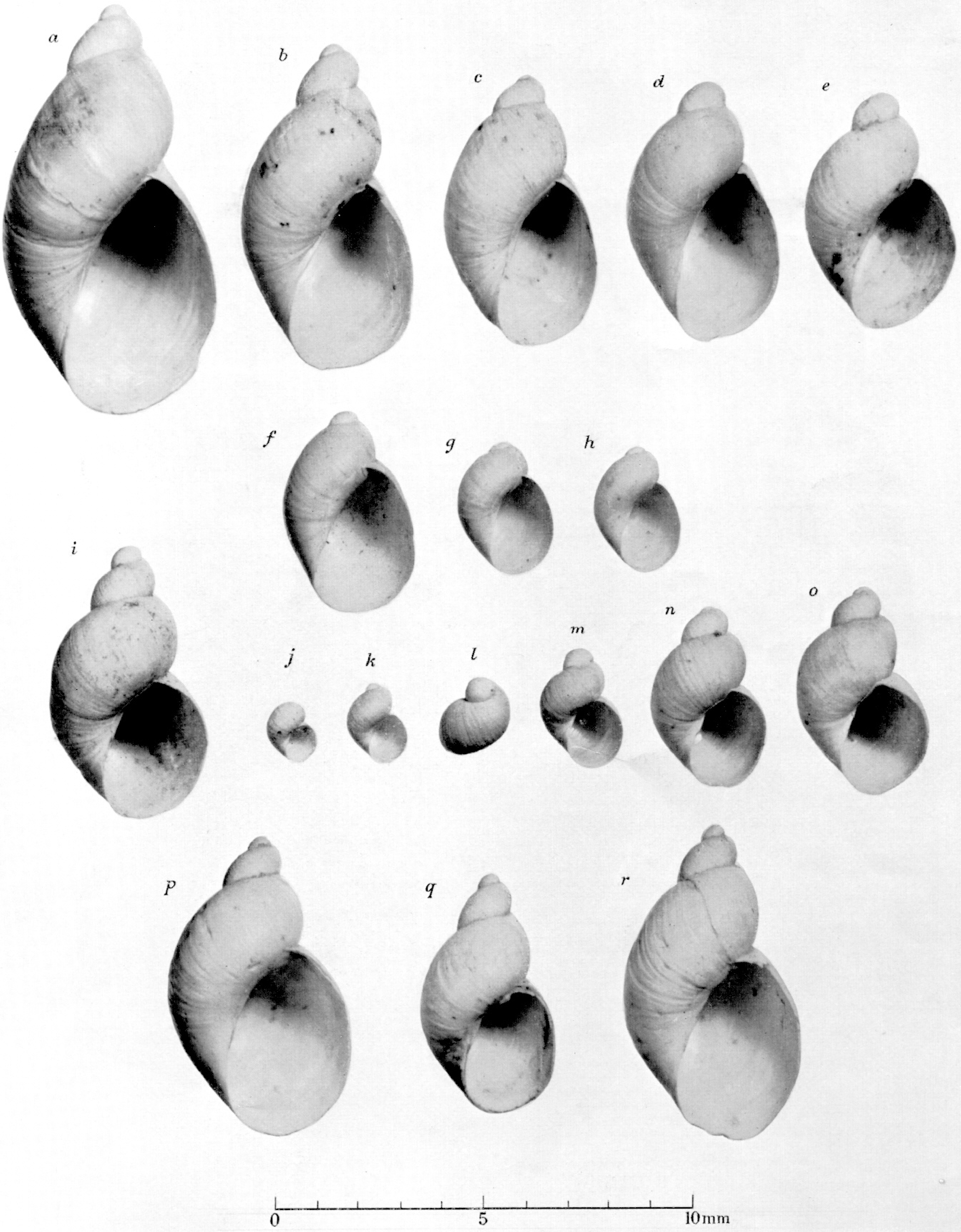

FIGURE 21. (*a*), (*b*), (*c*), (*d*), (*e*) *Succinea pfeifferi* Rossmässler. Late-glacial zone III. Brook, Borehole III, 261 to 273 cm.

(*f*), (*g*), (*h*) *Succinea pfeifferi* Rossmässler. Late-glacial zone II. Brook, Church Field, 100 to 105 cm.

(*i*), (*j*), (*k*), (*l*), (*m*), (*n*), (*o*) *Catinella arenaria* (Bouchard–Chantereaux). Late-glacial zone II. Brook, Church Field, 100 to 105 cm.

(*p*), (*q*), (*r*) *Succinea oblonga* Draparnaud. Sub-Atlantic Period. Devil's Kneadingtrough, Borehole V, 25 to 36 cm.

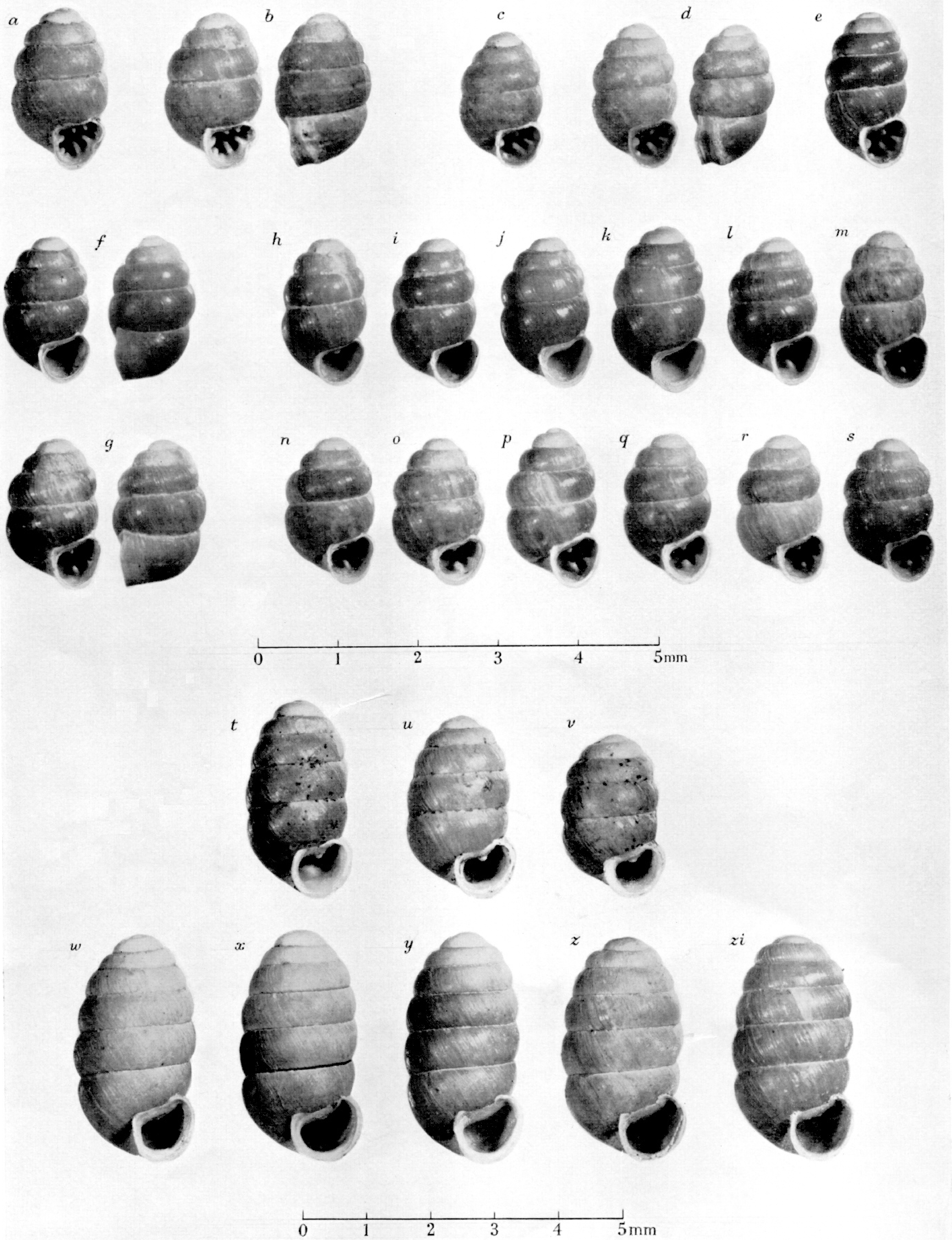

Figure 22. For legend see facing page.