

"Land snails are not generally thought to be of much account for fixing the age of deposits; but this is probably a mistake; they are likely to prove extremely valuable historic medals for the periods before coins were used or history written. Several of our commonest snails seem to have been introduced by human agency, in all probability by accident. They seemingly did not come in all together, but one by one, and if archaeologists will carefully collect the land-shells, which are so abundant in nearly every grave on the Downs, we ought soon to arrive at the date of their introduction, and so be able to use them for fixing the dates of other antiquities of doubtful age."

Clement Reid, 1896

THE BIOSTRATIGRAPHY OF FLANDRIAN TUFAS
IN SOUTHERN BRITAIN

By

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ABSTRACT

Until recently scientists interested in Quaternary history have relied almost exclusively on botanical evidence, particularly pollen analysis, for environmental interpretation and as a chronological tool. In calcareous oxidized sediments however pollen and material suitable for radiocarbon assay decays rapidly so that an alternative means of analysis must be employed. Non-marine molluscs are extremely common fossils in such deposits and are proving to be valuable environmental indicators. Their preservation is often poor, they are frequently bleached, broken and weathered and have consequently been ignored by many workers. Furthermore the criteria used for naming such material are often rather different from those used when naming living shells. Careful microscopic work (including scanning electron microscope studies) has revealed that characteristic shell micro-sculpture can be used to determine such fossil material with a high degree of precision, facilitating greater accuracy in quantitative studies.

The biostratigraphy (molluscs, ostracods, plants) of a series of Flandrian (post-glacial) tufa sequences (c. 10,000 - 5,000 BP) is described. The results are plotted as histograms of relative (mollusca) and absolute (ostracoda) abundance. The underlying principles and rationale are discussed, together with a consideration of the nature and mode of origin of tufas. By using methods of quantitative analysis, comparable biostratigraphical patterns are recognizable at sites in Kent (Wateringbury), Dorset (Blashenwell), North Wales (Caerwys, Ddôl), Isle of Wight (Totland Bay) and Hertfordshire (Wilstone). It appears that after the last glaciation, land snails recolonized Britain, in response to changing climatic and environmental conditions, in an ordered sequence. A series of molluscan assemblage zones, analagous to pollen zones are proposed, since these patterns seem to have a regional, and not just local significance. Several radiocarbon dates were obtained to establish the

synchronicity of these snail zones in different regions. Attempts have also been made to correlate these snail zones with the standard pollen zones. A critical review of comparable published sites is also given.

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1. INTRODUCTION

The Post-glacial or Flandrian stage embraces the most recent part of the Quarternary and covers the ten millenia since the Devensian glacial stage (Mitchell et al, 1973). The earlier name Holocene is sometimes used synonymously. Much of our knowledge of Flandrian events, the climatic and environmental changes, the fluctuations of sea level and so on, is derived from detailed stratigraphy, especially biostratigraphy. Virtually all species of Flandrian fossil found in Britain still inhabit Britain today. Equipped with knowledge of present-day ecology, the vertical changes in the occurrence and frequency of certain plant and animal species can, with caution, then be translated into climatic, environmental or other terms. Moreover detailed historical knowledge of past distributions (historical biogeography) can give an accurate insight into the origins and status of the present-day distributions of living species.

It was during this period too, that man began to rise to prominence and archaeologists have focussed much attention on his early environment, since there is no doubt that the climate, vegetation and soil type were fundamental in controlling his economy, his use of the land and his place of settlement. This was particularly so during the early phase of his ascent, when as a hunter and food-gatherer his influence on the environment was slight, although not altogether negligible (Smith, 1970). As man developed the means of controlling his environment he became increasingly independent of it, and his impact on the landscape became progressively more pronounced. Thus the development of farming practices, during the so-called Neolithic Revolution, brought about the large scale destruction of the ancient forests and their replacement, through successive stages of land use, by the predominantly open landscape of today. These anthropogenic effects likewise caused dramatic changes in the composition of the fauna and flora.

Naturally it became highly desirable to establish a chronology of events. The macroscopic plant fossils preserved in peat bogs and lake sediments attracted much of the early

research, especially in Scandinavia. As early as 1841 Steenstrup had described four post-glacial periods (Aspen, Pine, Oak and Alder) each characterized by particular trees. In the 1870's Axel Blytt introduced the terms boreal, atlantic etc. for floral elements in the contemporary vegetation which he postulated had immigrated into Scandinavia during periods of continental and oceanic climate respectively. His views were strengthened when during the following decade he discovered alternate tree-stump and peat levels and in addition recognized that those remains from the lower levels were primarily birch and pine whereas those from the upper levels were more warmth-demanding trees such as oak and hazel. R. Sernander subsequently used Blytt's terms in a chronological sense (Boreal Period etc) each characterized by different climate and vegetation. Since then this Blytt-Sernander scheme, with only slight modifications, has come to have a wide chronological usage, albeit divorced from its original climatic significance.

Similar work on the macrostratigraphy of Scottish peat-bogs was carried out by Geikie, Lewis and Samuelsson who each proposed a sequence of Post-glacial environmental changes. They also found alternations of layers of tree-stumps (Lower and Upper Forestian) with peat horizons (Lower and Upper Turbarian) which they interpreted as indicating periods of dry and wet climate respectively.

The development of pollen analysis by von Post and others revolutionised the understanding of environmental history through the Quaternary and gave much greater precision to the recognition of these vegetational changes. Firstly the small amount of material needed enables narrow vertical sampling and a much finer stratigraphy can be established. Secondly, since pollen is subject to long distance wind transport from a wide source area, the pollen spectra obtained reflect to a much greater extent the regional pattern of vegetational changes. It became clear that most macroscopic plant remains merely reflected local environmental conditions since quite large discrepancies were discovered between the pollen frequencies obtained and the frequencies expected from the macroscopic evidence.

It became apparent from the early studies that a threefold division of Post-glacial time could be made into (a) a period of increasing warmth; (b) a period of maximum warmth (the Thermal Optimum) and (c) a period of decreasing warmth. Von Post, the originator of the concept, coined the terms "mediocratic" for vegetational elements which have expanded towards the Thermal Optimum and "terminocratic" for those which have expanded or re-expanded (reverted) since the hypsithermal or that were present very early on in the Post-glacial. Similar cycles of vegetational, climatic and edaphic changes appear to have taken place during each of the major interglacials and similar schemes have been proposed (Iversen 1958; Andersen; 1966). More recently a fourfold division of interglacial vegetation has been proposed (Turner & West, 1968). There have been some attempts to apply this useful concept to Flandrian pollen diagrams (Hibbert et al. 1971; Hibbert & Switzur, 1976). However the much larger numbers of sites studied and the more extensive latitudinal area covered by such studies together with the complications of anthropogenic disturbance have limited its use during this period.

Considerably finer subdivisions (pollen zones) can indeed be recognized over wide areas (Godwin, 1975). However, the precise climatic significance of the zones is by no means always clear. There are numerous reasons for this. Information on the climatic requirements of particular plants may not always be available. Changes in pollen frequencies at different levels within a deposit may not necessarily reflect true changes in forest composition, or, even if this can be assumed, the changes observed may be due to the natural ecological (seral) successions inherent in all plant communities, or to a progressive leaching of the soil, or to interference by man, or to other such causes which are not directly dependent on climate (Iversen, 1960). The recognition of changes in humidity has proved particularly difficult and the evidence for these is usually stratigraphical rather than palaeobotanical (Godwin, 1960). In spite of these uncertainties, the remarkable uniformity of the pattern coupled with the approximate synchronicity across

Europe of many pollen zones, as revealed by radiocarbon dating, does suggest an essentially climatic basis. It was this fact, coupled with the widespread occurrence of pollen-bearing deposits that gave to pollen analysts the power to furnish a time scale against which other Quaternary events could be viewed and measured.

As conceived by von Post pollen zones were intended to be synchronous units of Post-glacial time (i.e. a time stratigraphic system) and indeed they went a long way to meet the urgent need for a pervasive chronological scale. All over Europe there were developed regional pollen-zone systems with this quasi-chronological character, though naturally there were great differences in the expression of the forest succession between the north and south of Europe, and some, though smaller ones between east and west. Thus his zones when compared across large territories did not show identity in different latitudes but rather disclosed regional parallellism in vegetational history, a conclusion that is being progressively confirmed by radiocarbon dating of widely distributed and detailed pollen diagrams. Moreover differential rates of migration and establishment and the destructive effects of prehistoric man have complicated the issue at particular times and places and have modified the intended synchronicity of the zones.

Radiocarbon dating has now largely superceded the chronological importance of palynology for the Late Devensian and Flandrian. Instant correlations can now be made without reference to biological data. There has consequently been an increasing trend towards using well-established terms, such as the Blytt-Sernander periods, with boundaries redefined in absolute radiocarbon years, as formal chronostratigraphic units, eg. Boreal chronozone (Mangerud et al, 1974). It would seem likely that such absolute time zones, based on radiocarbon dates, will eventually replace biostratigraphic assemblage zones as the basic units for describing the Flandrian (West, 1970). Pollen analysis still retains its chronological role in interglacial periods beyond the scope of radiocarbon assay.

Pollen analysis however suffers from a number of fundamental drawbacks. Accurate interpretation depends on the precise understanding of the degree to which the preserved pollen reflects the vegetational history of a particular region and this is not always clear. Differential pollen productivity and transportability as well as resistance to destruction are factors known to distort the picture. Recent studies of contemporary pollen rain have shown that topography is also important, especially since it affects the magnitude of the long-distant component. Thus it is only when the given pollen types form a substantial or generally consistent component, known from general evidence to be of local origin, that its occurrence can be used as an index of presence.

Pollen analysis is not the only means of reconstructing former environments, nor indeed is it necessarily the most precise. Although the climatic inferences drawn from pollen analytical data in general correspond closely with other biological evidence, occasionally there may be discrepancies. G.R. Coope's examination of fossil insect assemblages, especially beetles, from the Devensian has revealed evidence for a number of climatic ameliorations which do not always exactly coincide with the standard interstadia as defined on botanical criteria. He suggests that the response of insects would be more rapid to such transient thermal rises than that of a birch forest and therefore the insects are more sensitive indices of climatic history (Coope, 1977).

Similarly the preponderance of woodland mollusca from levels that suggest open farmland on palynological evidence is hard to explain. The different nature of pollen grains and snail shells may be reflected in their persistence in the soil, pollen being ephemeral in base-rich soils, whilst shells may be more persistent. Different phases of ecological history may be present, with the pollen reflecting the latest, and perhaps transient, phase (Dimbleby & Evans, 1974).

Perhaps the most serious defect of pollen analysis is that it is not generally applicable to calcareous sediments (pH more than 5.5). Clearly in such oxidized deposits where pollen,

and material suitable for radiocarbon assay, decays very rapidly, an alternative means of analysis must be employed and the shells of land snails which occur in such abundance in these sediments would seem an obvious choice. They are small, plentiful and can be easily extracted. There are a manageable number of species which cover a wide range of habitats from open ground to heavy shade and marsh. Land snails are thus extremely sensitive environmental indicators.

Interest in fossil land and freshwater snails has a very long history extending back at least since the time of Morton. A letter from the Rev. J. Morton to Dr Hans Sloane was published in 1706 "containing a relation of river and other shells digg'd up together with various vegetable remains in a bituminous marshy earth near Mears Ashby in Northamptonshire" (Morton, 1706). The deposit was discovered by a Mr Cox who together with Morton made a special excavation in order to examine the deposit. An attempt was made to compare those fossils recovered with the species found living there today, an identical approach to that adopted in modern studies.

From the middle of the last century onwards, the references to the presence of snails in geological and archaeological sites increase. Among the first to notice and comment upon their presence was General Pitt-Rivers when in 1869 he remarked on the abundance of Cyclostoma (= Pomatias) elegans and other species in a ditch in a hill-fort at Cissbury in Sussex, suggesting their use as environmental indicators (Evans, 1972).

Perhaps the first person to realize the potential chronological value of snails was Clement Reid, who ended his account of the Blashenwell tufa (1896) with the paragraph I have quoted on the title page. The central theme of the present thesis is to demonstrate just how prophetic this statement was and is therefore not so much concerned in using mollusca for environmental interpretation as in their zonal use in chronological correlations.

It is perhaps not surprising that the earliest stratigraphical work on non-marine mollusca should have come from Scandinavia. A.C. Johansen in particular, conducted much research on the

freshwater assemblages of lake sediments of Late-glacial and Post-glacial ("Alluvial") age in Denmark. His main interest was not so much in using them for chronological or correlative purposes but rather in their use as climatic indices. He suggested that the present distribution of land and freshwater molluscs is closely connected with the course of the July isotherms. Consequently he proposed a scheme, outlined below, of five Late-glacial and three Post-glacial periods characterized by different assemblages of freshwater molluscs. He postulated the July temperature range for each period and also considered that since freshwater molluscs are widely and uniformly distributed over much of Denmark, they might be used to date deposits with much greater certainty than plants, which show a marked regional differentiation.

TABLE 1. Scheme of Late- and Post-glacial climatic changes in Denmark as reflected by molluscan evidence (After Johansen, 1904).

Periods	July temperatures	
<u>Planorbis corneus</u> (<u>Bithynia leachi</u>)	Temperate island climate 15-17°	Oak Period
<u>Bithynia tentaculata</u> , (<u>Planorbis stroemi</u>), <u>Discus rudersatus</u>)	Temp. rises. Dry mainland climate, fairly warm towards end 14-15°	Fir Period
<u>Valvata cristata</u> , <u>Planorbis "stroemi"</u> , (<u>Physa fontinalis</u>)		Aspen Period
<u>Valvata piscinalis</u> , <u>Sphaerium corneum</u>	Subarctic climate 8-12°	Younger Dryas Period
<u>Lymnaea peregra</u>	Arctic climate below 8°	
<u>Valvata piscinalis</u> , <u>Sphaerium corneum</u>	Subarctic climate 8-12°	
<u>Anodonta cyanea</u> , <u>Planorbis "fontanus"</u> <u>P. "stroemi"</u> , <u>A. lacustris</u> , <u>V. cristata</u> , <u>Physa fontinalis</u> .	Temperature maximum Temperate mainland climate? 12-15°	Allerød oscillation
<u>Valvata piscinalis</u> , <u>Sphaerium corneum</u> .	Subarctic climate 8-12°	Older Dryas Period
<u>Lymnaea peregra</u> , <u>Fossarina (= Pisidium)</u>	Arctic climate below 8°	

Numerous objections have been raised against Johansen's method of determining air-temperature by means of aquatic mollusca. It is necessary to evaluate whether the distribution is in equilibrium with climate, whether immigration is complete and to what extent man has influenced the distribution. Moreover the limits of distribution may be governed by different factors in different parts of its range and coincidence with isotherms may be accidental.

Odhner, also working in Denmark, became interested in the Post-glacial non-marine mollusca, particularly land snails. He undertook an examination of an extensive calcareous tufa from Skultorp in Wastergötland and in a pioneer paper described the stratigraphical ranges of the mollusca and the macroscopic plant remains in terms of the Blytt-Sernander periods (Odhner, 1910).

Similar interest grew in many European countries, especially in Germany and Switzerland, and a voluminous literature began to appear. These early papers were often little more than faunal lists from various sites and there was no attempt to co-ordinate the data within a unifying framework. Favre (1927) attempted such a scheme for sites within the Geneva Basin. He recognized two principal divisions, a lower "Niveau I" with Discus ruderratus and an upper "Niveau II" which included a greater number of "espèces méridionales et occidentales". He split Niveau II into three subdivisions. The lower IIa was characterized by the coexistence of typical elements of I and the immigration of southern and western elements. Arctic-alpine elements (Columella columella and Vertigo genesii) became extinct in IIb. The subdivision of IIb and IIc was largely litho- rather than bio-stratigraphical. However the grassland species expand at the expense of the woodland element.

In Britain most of the early work on fossil non-marine mollusca was done by A.S. Kennard who began working at the end of the nineteenth century. Many of his early papers, several in conjunction with B.B. Woodward, were taxonomic rather than environmental. Having thus established the extent of recent British non-marine mollusca, he set out to distinguish those

of natural status (i.e. those found fossil) from recent introductions. This task involved the compilation of as many faunal lists from as many sites as could be mustered (Kennard, 1897; 1923; 1924; Kennard & Woodward, 1901; 1917; 1922). Using the snails as an index of age, each site was ascribed to a particular period, either in terms of the Blytt-Sernander sequence or those of Lewis. The dangers of this circular procedure, in the absence of corroborative evidence, are obvious.

In latter papers attempts were made to interpret depositional environments from the fossil assemblages. The basis of such interpretations were usually climatic, and generally in terms of the prevailing humidity as controlled by rainfall, less frequently in terms of temperature. The overriding influence of the local habitat conditions was scarcely recognized.

Kennard's pioneer work today seems rather crude and is open to numerous criticisms. Very often only a single sample would be analysed from a given site, and this usually from a visibly shell-rich horizon. His conclusions were then applied to the whole sequence. Moreover many of the samples submitted to him were hand picked during the excavation, with an obvious bias towards the larger and otherwise readily recognizable species. This inevitably led to faulty interpretation as demonstrated by Sparks (1961, fig 1). Very often, insufficient attention was paid to stratigraphy. A uniform lithological "Bed" was assumed to contain a homogeneous assemblage. In fact the stratigraphy of many shell-bearing deposits is often extremely fine, pronounced faunal changes taking place within a small thickness of deposit. If therefore mixed and ecologically meaningless assemblages are to be avoided, samples must be taken on an equally fine basis. As with pollen analytical studies correct environmental interpretation using molluscan evidence depends on an accurate assessment of the degree to which the fossil assemblage reflects the living community from which it was derived. The various agencies responsible for the difference, which are discussed more fully in the next section, were generally not taken into account by Kennard.

when one compares these crude faunal lists with the sophisticated pollen diagrams that the palaeobotanists were then producing, the scepticism that was expressed in the use of snails for climatic and environmental interpretation is understandable.

The earliest graphic record of subfossil snail assemblages in Britain was made by Major J.P.T. Burchell who used sector-diagrams to show the relative proportions of four selected species in Neolithic and Bronze age deposits in Kent (Burchell & Piggott, 1939 , Fig 2). This method is generally unsatisfactory in ecological studies, since only part of the fauna is illustrated, a full understanding of the nature of the fauna, and therefore environment, cannot therefore be assessed. If every species were plotted the resultant diagram would become so visually complex as to become meaningless. The use of sector diagrams should be restricted to either impoverished faunas or to faunal elements whose abundance can be safely assumed to be controlled by climate or to other environmental factors.

In two later papers Burchell (1957; 1961) attempted a synthesis of the Late-glacial and Post-glacial land mollusca of south-east England and suggested that the successive stages of these periods could be characterized by the composition of their faunas. In his earlier paper (1957) he recognized twelve molluscan phases based on the percentage frequency of certain "key-shells". In his later paper (1961) he increases this number to thirty-two which he plots graphically. In addition to these faunal changes, he also records the changing "Distribution Numbers", that is the number of shells in 2lb of matrix. He concluded that increase in the number of species together with an increase in Distribution Number should be ascribed to climatic amelioration.

The success of this scheme foundered on its complexity. The boundaries of each molluscan phase were rather ill-defined. Moreover the dating of deposits directly by equating percentages of certain mollusca is open to several grave objections since one would be correlating similarities of environment (facies) and not necessarily deposits of identical age.

In Britain, the analysis of land and freshwater molluscs was put on a firm quantitative basis by B.W. Sparks who applied the technique of serial sampling to shell-bearing deposits. Individual species and groups of climatically or ecologically related species were plotted as histograms of relative abundance. In the first true molluscan diagram, through the sediments at the Ipswichian type site at Bobbitshole (Sparks, 1957), the histogram was of the "saw-tooth" form often employed by palynologists. In subsequent diagrams it has become customary to plot the thickness of each sample precisely. Vertical changes through the sequence were interpreted in terms of climatic or environmental change and a dynamic picture was thereby gained. Since then Sparks has analysed many more sites, particularly freshwater sequences of Last Interglacial (Ipswichian) age (Sparks & West 1959; 1964; 1968; 1970).

Similar techniques have been applied to terrestrial sequences in south-east England by M.P. Kerney. Many of these studies relate to the impoverished molluscan faunas of the Late-glacial (Kerney 1963; 1965), one refers to a Mid Devensian assemblage (Kerney, 1971 a) whereas only one (Kerney, Brown & Chandler, 1964) systematically traces the sequence from the Late-glacial into deposits of early Flandrian age.

Similar work is now forthcoming from Central Europe and in particular from Ložek's extensive studies on calcareous spring and slope deposits of the Czechoslovakian karst (Ložek, 1964, 1972). Much of his work has focussed on the development of interglacial faunas and their relation to sedimentary and pedological processes (Ložek, 1965). Many Post-glacial sequences have been described, eg. the tufa near Krabina (Ložek, 1974) which, although including a larger variety of species, are clearly analogous to those described in the present thesis. Ložek has proposed various schemes outlining the Late and Post-glacial histories of the mollusca from several provinces, but as yet these have not yet been formalized and defined as biostratigraphic zones per se. The enormous number of sites described by Ložek has necessarily meant that sampling is relatively coarse, and moreover the majority of sites lack radiocarbon dates which at present limits the value of Ložek's work.

During the last decade archaeologists have become very interested in the use of snail analysis on calcareous soils. J.G. Evans in particular has been especially interested in the impact of early man on the landscape particularly in relation to Neolithic forest clearance phenomena and subsequent stages of land use (Evans, 1972). These archaeological investigations are therefore largely concerned with the latter part of the Flandrian. Detailed stratigraphical studies of molluscan assemblages during the early Flandrian (i.e. pre-clearance faunas) are therefore few.

The basis of the present thesis, which aims to remedy this defect, derives from two studies by Dr Michael Kerney from Kent. The first, referred to earlier, outlined the history of the chalk escarpment near Brook as revealed by detailed biostratigraphy (Kerney *et al*, 1964). The second was an analogous study through similar deposits of comparable age near Folkestone. A very close biostratigraphical similarity was revealed. However it could be argued that since these two sites were in identical environmental settings (coombe Valleys) and were only 15 km. apart, one might expect such a result. For a number of reasons it was thought that these parallel trends had a more fundamental significance and the aim was now to show that they had a regional and not merely local importance.

Since both sequences were largely tufaceous it was decided to concentrate on such deposits. There are a number of other very important reasons why tufas are ideal for such a project. Firstly they contain rich snail faunas, the product of a varied lime-rich environment. Secondly the preservation is excellent, greatly facilitating accurate determinations. Thirdly a fine, as well as a lengthy stratigraphy is often preserved. Lastly and perhaps most important, by concentrating on deposits that have formed *in situ*, such as tufas, the likelihood of ecologically mixed assemblages is minimized. The contained molluscan faunas from such sediments are essentially autochthonous, approaching "life assemblages" more closely than those of virtually any other deposit.

The object, therefore, was to examine a series of lengthy profiles in other regions and to compare the results with those from Kent. In choosing which sites were suitable for detailed study, four factors were taken into account:-

- (1) the geological location, in order to examine regional differences
- (2) the thickness of the deposit, giving a rough indication of the length of time represented.
- (3) an indication of a faunal sequence (by an examination of the published lists)
- (4) the possibility of dating the sites by some independent means, either by pollen analysis or ideally by radiocarbon assay. Again this was assessed by reference to the published accounts eg. mention of organic levels.

Very few sites conformed to all of these requirements.

2. PRINCIPLES

The basic principles of snail analysis are the same as those for any palaeoecological research and like them are based on uniformitarianism. Thus by extracting representative samples of an ancient community and by comparing its composition with the closest modern analogue, whose composition is known to be governed by certain environmental factors, a reconstruction of the former environment can be made.

The usefulness of the method depends on:-

- (1) an accurate knowledge of the stratigraphical context of the samples.
- (2) knowing how far the fossil assemblage recovered from a sample is representative of the assemblage contained in the deposit.
- (3) accurately assessing the composition of the living community from the fossil assemblage.
- (4) a knowledge of the factors that govern the composition of the living community.

These principles have been discussed by Sparks (1961, 1964), Kerney (1963), Ložek (1965), and most recently by Evans (1972).

The faunal lists that are so prevalent in the early literature all too often lack details of the stratigraphical provenance of the samples. Such work is consequently of rather limited value if subsequent workers are unable to re-locate the exact origin of the samples. Provided such information is known, new dating techniques can be used to establish the age at particular levels of the deposit.

Ideally the total number of shells on which percentage values are based should be high. The minimum number of shells in a sample needed to establish statistically significant values of abundance for each species depends too on the number of species and their relative abundance in the fauna, that is, the faunal structure. If only one species is present, then a sample size of one would be theoretically sufficient. When two or more species occur the sample size should be larger. In similar palaeo-ecological studies (eg. Evans, 1972) it has

been found that between 150 and 200 shells is a sufficient number to establish the broad composition of the fauna.

In order to establish the repeatability of the results, two tests were carried out:-

- (a) Repetitive assemblage counts from the same sample and
- (b) Repetitive sampling of the same stratigraphic level, (laterally separated).

In the first case, repetitive counts were made from pairs of both rich samples, over 650 shells (Caerwys series A, 520-530 cm) and poor ones, 50 shells or less (Blashenwell 45-50 cm x 3). The three columns in Figs 1 and 2 show the stages in the construction of a molluscan diagram using these results. The left hand column plots the absolute frequencies, the centre one, the relative (percentage) frequencies and the right one groups the fauna into the usual ecological categories. The bottom right hand diagram incorporates all the information and is the one plotted in the final diagram.

A number of interesting features emerge. Firstly the actual number of shells recovered from a particular horizon is roughly constant. Secondly although the totals of the poor samples are low, the differences between them are evened out, to some extent, when the species are categorized into ecological groups in the final column.

In order to quantify the similarity (or otherwise) between the pairs of samples, a simple index giving the percentage of similarity was calculated. This index is based on a comparison of the make-up of the two samples in terms of individuals of various species and as such places the emphasis on the dominant species. This method has proved a useful technique in quantitative ecological studies and its use has been discussed by Southwood (1966). The value of the percentage of similarity for a pair of samples is given by the summation of the smaller values of the percentage of the total individuals ie.

$$\%S = \min (a, b \dots x)$$

Fig 1

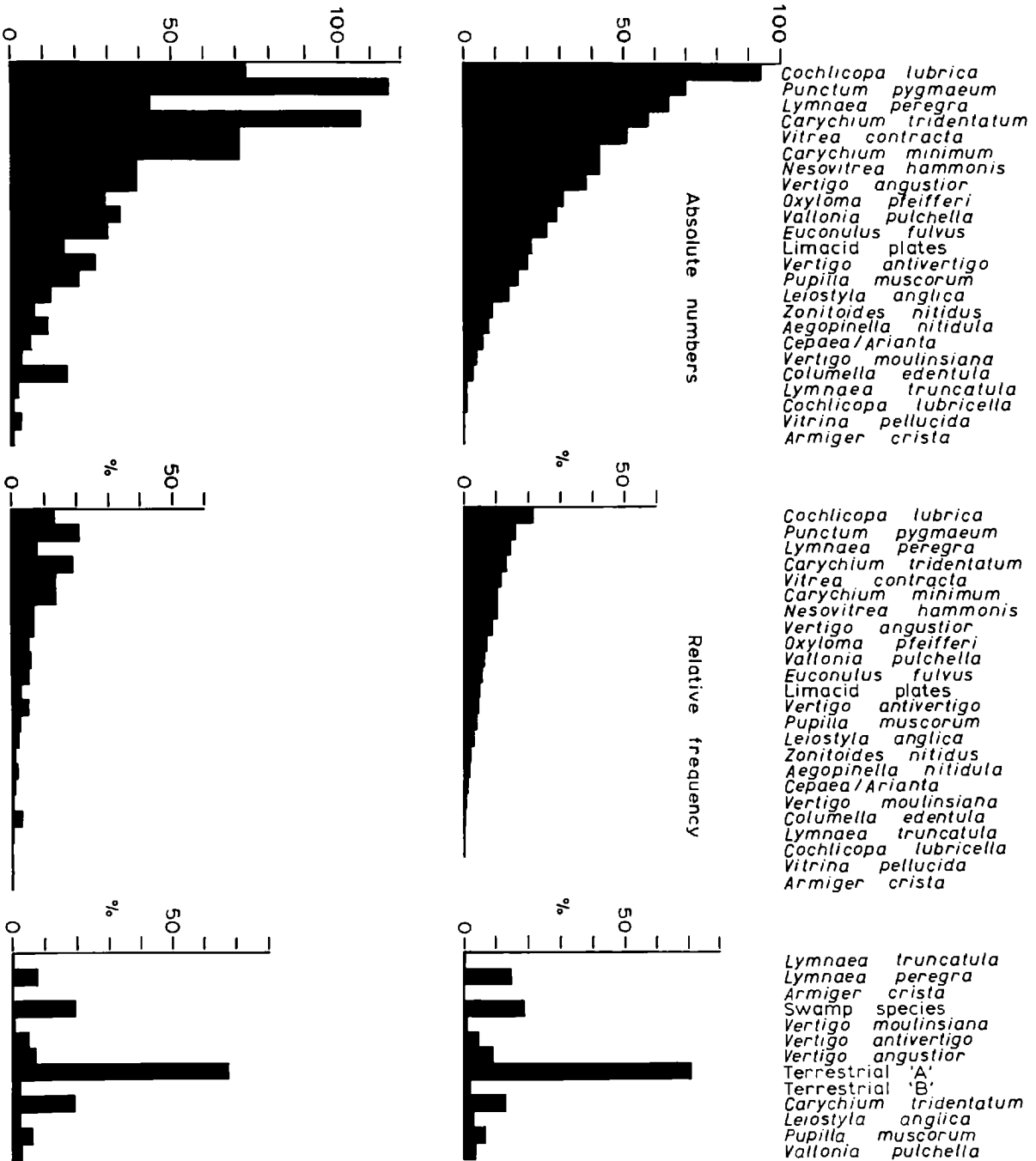
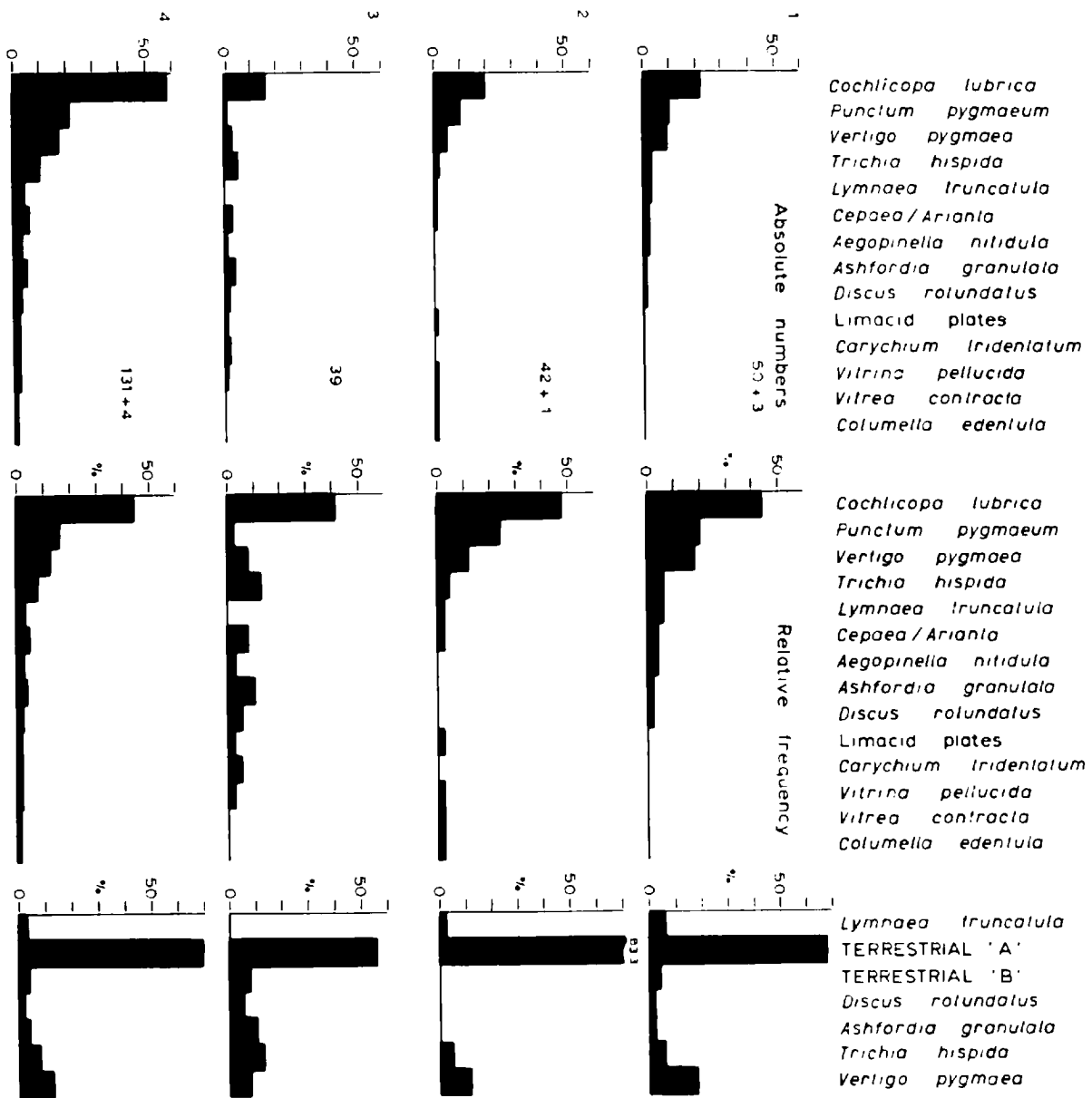


Fig 2



In practice values of $> 80\%$ indicate "identical" assemblages. The results were as follows:

Ca 520-530 cm. %S = 84.23		Bl 45-50 cm.			
1	2	3	4	Sample numbers	
	67.83	83.04	89.29	1	
		63.17	76.43	2	
			83.90	3	

N.B. These similarity indices
compare the land faunas only.

The results show that repetitive analysis of the rich Caerwys samples produced an "identical" assemblage. The poor Blashenwell samples are clearly much less satisfactory. However when all the totals are summed (fourth row on Fig 2) and the constituent samples compared with the final overall total (131), the similarity indices are, as expected, much higher and two are over 80%. Moreover when the species are grouped into ecological categories (third column, Fig 2) the visual differences between the samples are slight.

A statistical comparison of series 'C' with the comparable stratigraphic level in series 'A' from Caerwys was then made using the percentage similarity index. These samples were taken through the same soil horizon, but were separated laterally by some 4 metres. It is hard to match exactly the corresponding samples, since the depositional rates may not necessarily be constant, but for present purposes it was assumed that

<u>Series 'A'</u>		<u>Series 'C'</u>	
c = 375 - 380 cm	≈	3 = 10 - 15 cm	
b = 380 - 385 cm	≈	2 = 15 - 20 cm	
a = 385 - 390 cm	≈	1 = 20 - 25 cm	

The following matrix presents the results

	1	2	3	
	80.81	78.17	74.97	a
	83.80	90.11	86.53	b
	79.50	84.94	86.27	c

The ringed percentages are those for the corresponding samples which, in theory, should be the highest. The high percentages obtained show that the fauna in each of the samples was fairly similar. The reason that the 1/a and 3/c percentages were not even higher, results from the behaviour of Leiostyla anglica which increases in relative abundance through the soil in series 'A', while conversely decreasing through it in series 'C' (See Fig 18 and 20).

These results show that comparable assemblages can be obtained when even low numbers are analysed (although totals of 150 - 200 should still be used) and that when species are grouped together into ecological categories, the visual difference between identical samples is slight. Moreover lateral variation, at least through the soil at Caerwys, was slight. In conclusion it can be said that the fossil assemblages recovered from the majority of samples analysed in this study are representative of those contained in the deposit.

Before any ecological conclusions can be drawn it is imperative that the agencies responsible for the composition of the sample are understood. These agencies will vary from site to site and may even vary from sample to sample within a single site. These agencies fall under two headings, ecological and geological.

The ecological agencies include the genetic and environmental factors that control the abundance of each species in a community. Some species eg. Ena obscura seldom occur in

abundance however suitable the habitat , others eg. Carychium tridentatum are invariably prolific. Thus the ratio of different species in a community is a function of their powers of reproduction and survival and the environmental and climatic factors that directly determine the favourability of the habitat.

The geological agencies are primarily the processes responsible for the difference between the composition of the living community and that of the fossil assemblage. During each stage in the process of fossilization information is lost. Initially the three-dimensional distribution of a living community becomes a two dimensional one at death. The rate of burial or accumulation of the containing deposit will govern the degree to which the fauna will reflect the nature of the living community. Unless buried quickly, many shells will be destroyed by weathering or solution; just how many are lost in this way depends largely on the nature of the local environment. In acidic habitats, few shells survive, in calcareous ones the majority probably would survive, those that do not are likely to be the more delicate, less robust shells. The problem of differential destruction is very important when interpreting fossil assemblages. An interesting discussion of this problem is given by Sparks (1964).

If the shells are transported some distance before they become incorporated into a deposit, further changes in composition are likely. Firstly, differential destruction may occur during transport, accentuating the initial distortion caused by this process. Secondly there may be considerable mechanical sorting by the stream (or transporting medium). TABLE 2 shows the number of opercula and shells of Bithynia tentaculata and Theodoxus serratilineiformis recovered from a river gravel at Swanscombe, Kent. The ratio of Bithynia opercula to Bithynia shells is very high while the converse is true of Theodoxus, which also has a calcareous operculum. Although the discrepancy in the case of Bithynia might be accentuated by the fact that these opercula split parallel to their surface (due to their layered structure) and are

prone to derivation it seems more likely that transport agencies are the cause. It may be due to a sorting action caused by the opercula being deposited before the shells as stream velocity decreases or may conversely be caused by a "winnowing" effect; the relatively light Bithynia shells being carried away more readily than the flat opercula which could remain on the stream bed and require greater current velocities for their transport. Theodoxus opercula would also seem to be preferentially removed. Differential destruction of Bithynia shells is also a possibility but this seems less likely since reversed ratios of shells to opercula are known at certain levels at the nearby Barnfield Pit (Kerney, 1971b). These differences would thus seem to reflect varying current velocities.

TABLE. 2 Number of shells and opercula of two freshwater snails recovered from Pleistocene river gravels at Dierden's Pit, Swanscombe.

	Shells	Opercula
<u>Bithynia tentaculata</u> (L.)	14	337
<u>Theodoxus serratilineiformis</u> (Geyer)	63	-

An examination of the species that float and sink during processing also gives an interesting insight into the possible sorting action of water. The majority of undamaged shells float when immersed in water, bivalves, slug remains and "heavy" shells (eg. Clausiliidae) are exceptions and usually sink together with the damaged debris of other species. However certain species such as Vittrina, Succinea and Lymnaea tend to sink, even though they are undamaged (Fig 3) All these species have comparatively large apertures in relation to shell width, facilitating the rapid entry of water and so sinking. These species may therefore, also be subject to preferential sorting.

During its incorporation into a sediment, the death assemblage is subjected to a variety of physical, chemical and biological processes, which further distort its true

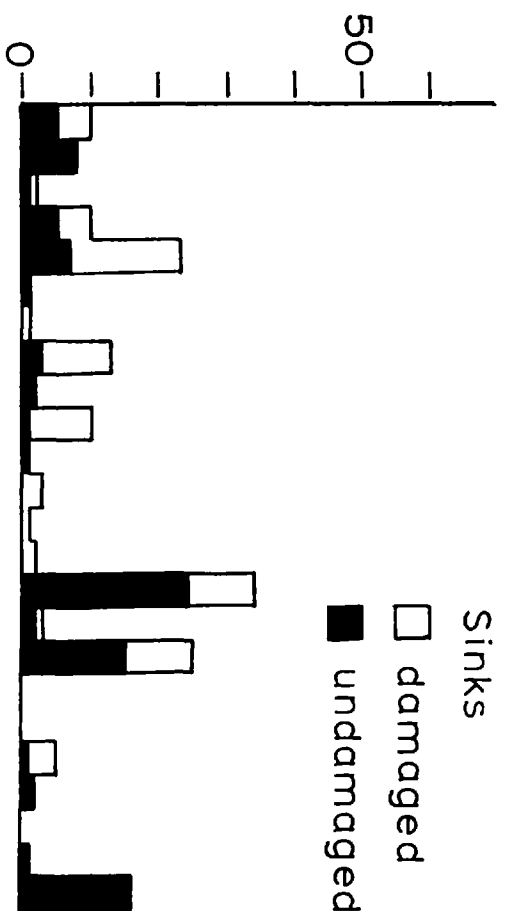
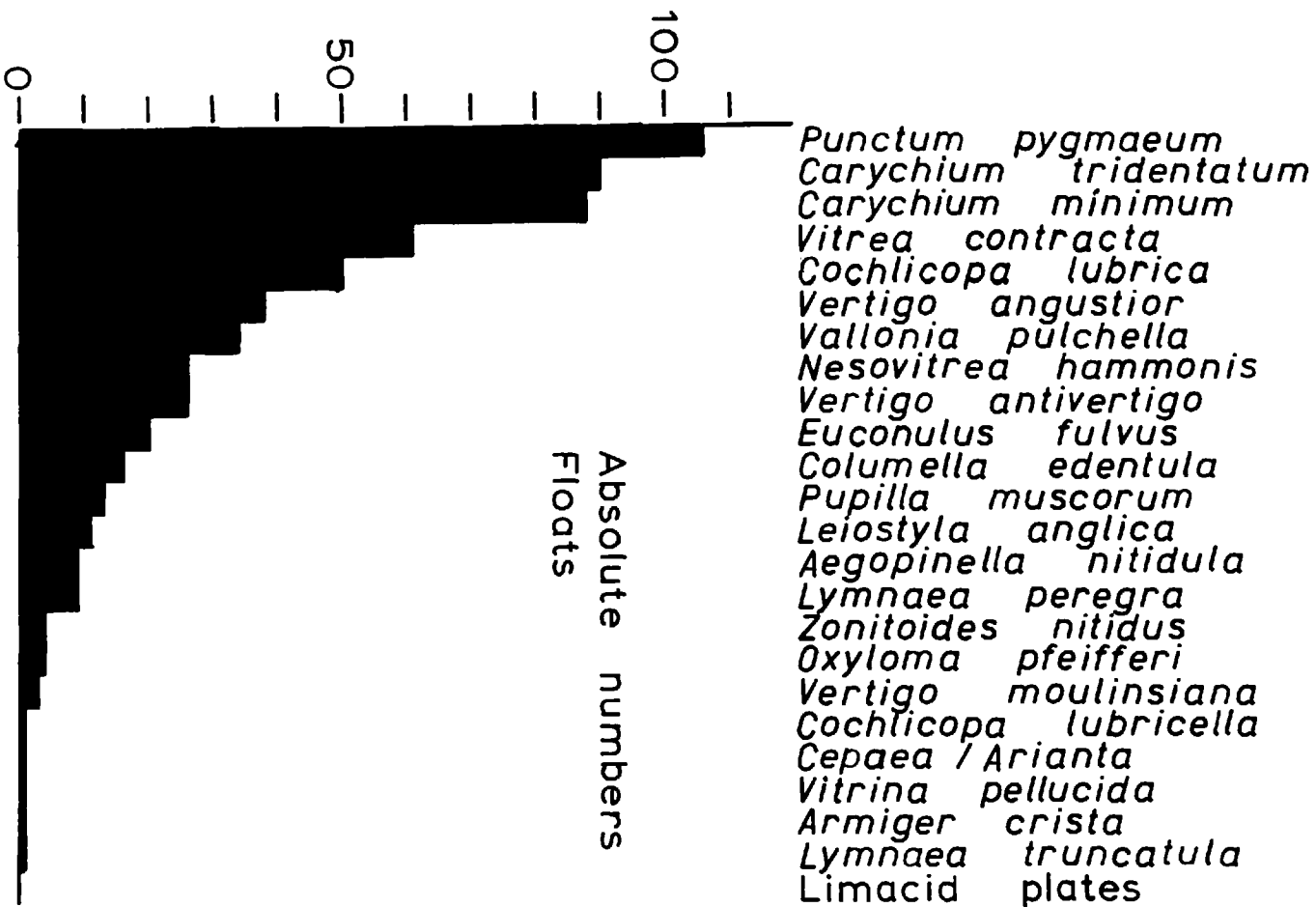


Fig 3

composition. Size (and therefore species) segregation can result from earthworm activity. Moreover penetration of rootlets can cause a mixing of shells of different ages. Because of the way that tufas form and because the land mollusca must have lived, died and been entombed by the actively growing surface, these post-mortem modifications are considered minimal. The contained faunas of tufas consequently approach true "life assemblages" more closely than those of virtually any other deposit. It is interesting to comment however, on the difference between the ecologically mixed assemblages recovered from the sub-aqueous and colluvial layers and the more homogeneous assemblages from the fossil soils.

It is clear therefore that some contamination involving the mixing of communities, may occur, although the degree will vary enormously. In river deposits containing the sweepings from a wide spectrum of freshwater and terrestrial habitats indiscriminately brought together, it is going to be high. In lake and many subaerial deposits and in particular tufas, it will be much lower. A rather common assemblage for example, is one containing freshwater snails characteristic of streams together with a somewhat xerophilous land fauna (viz *Ddôl*). Such a situation results from the gradual erosion of the stream bank that supports the dry-land snails.

Occasionally other ecologically incompatible species are recovered from the same sample. A number of explanations are possible. Either the shells were derived from a mosaic of different micro-habitats, or one or more of them may be derived from earlier deposits as the result of re-working, or they may be recent contaminants that have fallen down cracks or burrows or themselves be burrowing species (eg. *Cecilioides acicula*). When the anomalous shells are consistently present in reasonable numbers, the first explanation would seem the most likely.

A further possibility and perhaps the hardest to prove, is the question of change in the ecological tolerance of a particular species. This has been suggested for at least two

species. Thus Pupilla muscorum is today an obligatory xerophile, but it commonly occurred in marshland contexts during the late-glacial (eg. Wilstone); on the other hand Vertigo pygmaea is only known from such situations during this period, its conquest of dry open habitats seems to have been a comparatively recent event. The frequent occurrence of the calcifuge, Zonitoides excavatus in tufaceous deposits, also suggests that its present day restriction to non-calcareous habitats may be a comparatively recent phenomenon.

A detailed knowledge of the ecology of modern snail communities is an indispensable prerequisite to the interpretation of ancient assemblages. This stems from the fact that every mollusc found in British Flandrian deposits survives somewhere in Europe today, the vast majority (over 90%) still inhabit Britain. The foundations, for much of the ecological work on British non-marine mollusca, were laid by A.E. Boycott in two papers published in the 1930's (Boycott, 1934; 1936). Many autecological studies have been published in the Journal of Conchology and Proceedings of the Malacological Society (now Journal of Molluscan Studies). More recently several papers have appeared on the factors controlling the composition of recent snail populations but such quantitative synecological studies are few. Paradoxically, it is sometimes possible from quantitative studies of fossil communities to form useful hypotheses about ecology which have not yet been tested by appropriate research on living populations.

Climatic interpretation is usually based on knowledge of present-day geographical range. The basic assumptions being that the species is in equilibrium with present climate and secondly that its range is truly limited by it. Very little work, comparable to Iversen's (1944) studies of Viscum, Hedera and Ilex, has been done on the thermal tolerances of mollusca. Until such work is undertaken most conclusions, invoking climatically determined distributional changes, are conjectural. However Sparks (1961) has shown how the changing proportions of groupings based on present distribution can reveal clear

trends of either improving or deteriorating climate within Ipswichian sequences. What these trends mean in precise climatic terms however, remains unknown.

3. METHODS

There are several papers that deal at length with the technique of snail analysis e.g. Sparks (1961, 1964), Kerney (1963) and Evans (1972), so that only the salient points need to be emphasized.

i. Field Recording of Sections

Before sampling, detailed records of the sections were made. Initially the position of each site in relation to local geomorphology, geology and drainage were assessed. This was a crucial first step towards understanding why the deposits were situated where they were and what the possible source of carbonate (used in the formation of tufa) might have been. The exact geomorphological setting would also influence the composition of the molluscan faunas. For example samples taken from the valley axis are likely to be more hygrophilous than those from the valley sides, which would probably contain a higher proportion of xerophiles.

A scale drawing of the cleaned vertical face was then made, using string, spirit level, and tape measure. Each section was then photographed. A record of the colour of each layer was made using the Munsell soil colour chart. This was done before the samples were dried since it was found that wetting after drying did not always produce the original colour hue.

ii. Sampling

Sampling was done at the point where the stratigraphy appeared to be most complete and most representative of the deposits as a whole. Occasionally, as at Caerwys, a soil horizon divided and it was necessary to take two series of samples in order to obtain a complete record.

Because of the fine stratigraphy of tufas, a basic sampling unit of 5cms was used. Where abrupt faunal changes were suspected (e.g. at soil horizons) the sampling interval was reduced, sometimes to 2 cms, the lowest limit for field

sampling. Occasionally, where deposition seemed to have occurred rather rapidly, larger sampling units of 10 cm (or sometimes even larger) were chosen. The samples were cut from the face, using a pointing trowel, starting at the base and working upwards, thereby minimizing the risk of contamination. The samples were then transferred to stout polythene bags (30 x 20 cm) and labelled, the depth below the modern ground surface was the usual datum.

Thus the main factor which governs the sampling interval is the rate of deposition, although the texture of the deposit is sometimes important. A fine-grained, compact sediment can be sampled at closer intervals than coarse-grained material. This is another reason why the nodular tufa was sampled at larger intervals.

During sampling, strict attention was paid to the stratigraphy, ensuring that samples were not taken across pronounced stratigraphical boundaries. Where the stratigraphy was rather "blurred", the transitional zones were omitted, but such instances were very rare.

Where the deposit could not be bottomed by digging, either because of waterlogging or great depth, samples were obtained either by augering (eg. basal samples at Caerwys) or by using a 10cm diameter percussion corer (eg. Wateringbury).

Before undertaking the detailed sampling, a preliminary visit was paid to each site and a series of spot samples were taken (usually from the top, middle and bottom). There were a number of reasons for doing this:-

- (1) it gave some indication that there was a faunal sequence
- (2) since large bulk samples were taken, the occasional rarity, that may be missed in the serial sampling, would be likely to turn up
- (3) a good series of the larger species would be obtained and enable confident determination of both juvenile and fragmentary material
- (4) a large series of Cepaea and Pomatias could be collected, enabling detailed comparisons of fossil material with recent

populations. It is clear that the banding patterns in case of Cepaea and overall size in Pomatias, differ significantly from those of the recent populations that inhabit the various sites today. (see Section 12).

iii. Extraction

Because the molluscan faunas of tufas are generally rich both in terms of species and numbers, a standard dry weight of 0.5 kg was used. This allowed the totals to be directly compared on an absolute basis. After drying, each sample was allowed to collapse in water; the process was aided by gentle stirring. The majority of shells floated and were decanted, together with other organic remains, into a British Standard mesh no. 30 (0.5 mm) sieve. This process was repeated until no more shells could be seen floating. The remaining sediment was then poured into a second B.S. no. 30 sieve and thoroughly washed. Both sieves were then oven dried at 60°C.

The dried residues were then passed through a series of arbitrary sieve fractions (B.S. sieves 8, 12, 16 and 22). Picking of the finer fractions were carried out under a binocular microscope, using a black sorting tray marked with white lines so that the field of view could be efficiently tracked. Every fossil above 0.5 mm was extracted using a pair of home-made tinfoil forceps and a sable-haired paint-brush. Many ostracods and seeds were present in the sub 30 mesh fractions; these residues were therefore retained in particularly organic levels, but have not been analysed in the present study. Minimum totals for every species were then assessed. This usually meant counting every apical fragment or umbonal hinge fragment, in the case of bivalves, (thereby ensuring that the same individual is not scored twice) but occasional non-apical fragments of species otherwise not represented were also detected and counted.

If the number of shells recovered were statistically inadequate, the sample was re-processed in an identical manner. Further treatment such as boiling occasionally helped. Solution and re-crystallization of photographic hypo was used to

disaggregate the hard "granular" tufa from the upper levels at Blashenwell. If the material was sufficiently organic, 100 vols hydrogen peroxide (General Purpose Reagent) was found to be quite effective. If all these methods failed to produce an adequate sample size, a second dried sample (0.5 kg) from the same level was processed and the totals added together.

iv. Identification

The nomenclature and taxonomic order throughout the thesis follow Waldén (1976) and Kerney (1976a). The problems of identification are discussed at length in the Appendix, but a few general points can be made here.

Succineidae. All determinations must be regarded as tentative.

Columella. Dr C.R.C. Paul has examined all the material of this genus. It is not always possible to separate juvenile C. edentula from C. aspera, consequently the presence of C. aspera is recorded as a + in the tables but no individual figures are given.

Vertigo. The determination of apical fragments of this genus becomes extremely difficult when more than one species are known to occur. It is however possible to name a certain number but the rest have been apportioned in relation to the number of diagnostic apertures recovered.

Vallonia. Since juveniles of V. pulchella and V. excentrica cannot be distinguished, the procedure adopted was to divide all juvenile V. pulchella/excentrica in proportion to the number of adult shells present in each sample, adding them to the totals.

Cepaea/Arianta. It has proved impossible to separate apical fragments in any consistent quantitative way. The presence of both genera is usually clear from the characteristic micro-sculpture of shell fragments from the latter whorls, these are recorded by a + in the tables.

Pisidium. Dr M.P. Kerney has examined all the material of this genus. The totals given in the tables are for individual valves,

but for percentage purposes these numbers were halved. This procedure seems advisable in such low-energy environments; in high-energy environments (e.g. river deposits) Sparks (1964) considers it best to score each valve as one individual. In certain very rich samples (eg. certain levels at Ddôl), the numbers given are approximations, obtained by extrapolation from small numbers of randomly identified valves.

v. Graphical Presentation

Statistical data about fossil assemblages may be presented graphically either in terms of relative (percentage) abundance or in terms of the absolute abundance per unit sample. Kerney (1963) has discussed the merits and limitations of each method. In the present study the mollusc diagrams are plotted as histograms of relative frequency, while the ostracod diagrams are plotted on an absolute basis.

The layout of molluscan diagrams is comparable with others employed in micro-palaeontological research (eg. pollen diagrams). A plus sign represents a single shell (apical fragment or otherwise). Fig. 4 is a key to the lithological symbols used. The overall totals of shells counted for each level are shown immediately to the right of the stratigraphical column.

On the far right of the diagram an ecological summary is presented. Evans (1972) in his studies of terrestrial mollusca from archaeological sites, used the following three categories; shade-demanding, catholic, and open-country species. The fluctuating proportion of these groups in response to natural changes and in particular to human interference is often very striking. However in the present study, that deals specifically with pre-clearance faunas, such a scheme is inappropriate. Instead one based on the decreasing moisture requirements of the mollusca is used. Thus the following three categories are distinguished; freshwater; marsh (obligatory hygrophiles) and land snails proper.

Freshwater and swamp species are particularly sensitive to local environmental conditions, thus during periods of comparative dryness they are absent, but will flourish

Lithological Symbols

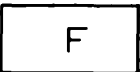
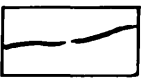
	Tufa		Nodular tufa		Grey horizon / Soil
	Highly organic tufa		Flint artifact		Charcoal fragments
	Organic streak		Sand / Gravel		Clay

Fig 4

in great numbers during flooding episodes. If every species was plotted as a percentage of the total mollusca recovered, these periodic bursts in numbers, as the result of local changes in water regime, would completely mask the regional patterns in the composition of the land mollusca, which are the main concern of the present study. For this reason the percentages of these freshwater and swamp species are calculated as independent percentages over and above the total land count and are plotted as open histograms.

The exact arrangement of species on the diagram has been carefully chosen so that those species with specific ecological requirements and/or interesting geological histories have been separated out and plotted in a given order. This facilitates visual comparison between sites. To prevent the diagrams becoming too congested, other species have been grouped together into a number of ecological categories. These are as follows:-

FRESHWATER SPECIES

The following species were encountered:- Bithynia tentaculata, Aplexa hypnorum, Lymnaea truncatula, Lymnaea peregra, Anisus leucostoma, Gyraulus laevis, Armiger crista, Hippeutis complanatus, Ancylus fluviatilis, Pisidium spp. At most sites only L. truncatula, P. personatum and P. casertanum were found and these are usually plotted individually.

SWAMP SPECIES (obligatory hygrophiles)

Most commonly consists of Carychium minimum, cf. Oxyloma pfeifferi and Zonitoides nitidus but may include Vertigo antivertigo and V. moulinsiana (plotted individually at Caerwys). Also belonging to this group but which are plotted separately are Catinella arenaria, Succinea oblonga, Vertigo genesii, V. geyeri and V. angustior. All these species are included in the "marsh" component in the ecological summary on the far right of the diagram.

TERRESTRIAL 'A'

Includes a heterogeneous mixture of essentially catholic species of wide tolerance, occurring in open ground, marshes, and coniferous and deciduous woods. (Cochlicopa, Columella, Punctum, Vittrina, Vitrea, Nesovitrea, Limacids, Euconulus, Arianta/Cepaea).

TERRESTRIAL 'B'

Species tending to be more critical in their requirements and which are most frequent in deciduous woods and similar well-shaded places. Includes Carychium tridentatum (stippled on the diagrams), Acanthinula, Ena, Aegopinella, Clausiliidae, Helicigona. Carychium tridentatum and Aegopinella form numerically by far the largest part of this group.

4. NATURE, OCCURRENCE AND ORIGIN OF TUFA

i. Definition

The terms tufa and travertine are both of Italian origin, the former is a generic name for porous stones (cf. tuff), the latter is a corruption of tibertino, "the stone of Tibur", which is a former name of the locality now called Tivoli. Both terms have been used rather loosely, but in general they refer to particular kinds of deposits originating through the chemical precipitation of calcium carbonate (generally devoid of clastic and limestone debris) from springs, streams, seeps in caverns and flowing water of waterfalls. The general distinction is based on hardness, the term travertine is applied to harder more compact deposits which can be cut and polished, while tufa is usually reserved for more porous, spongy material. Calcareous sinter (calc sinter) has been used synonymously, while identical deposits in North America have been called marl. In the present thesis, the term tufa has been applied to freshwater carbonates, formed principally by seepages and under shallow films of water, which contain essentially terrestrial mollusc faunas and which generally have a concretionary and porous structure.

ii. Lithogenesis and mode of occurrence

There has been much discussion about the mechanisms involved in the formation of tufa and travertine. There are two schools of thought. One extreme maintains that the deposits have been precipitated purely by inorganic processes and that biological agencies, notably algae, play little or no part; the second maintains that the latter agencies are of paramount importance.

Some of the deposition is certainly chemical and is caused by loss of the equilibrium carbon dioxide necessary to keep calcium bicarbonate in solution. Evaporation even at ordinary temperatures is sufficient for the less soluble carbonate to be re-formed and deposited. The mixing of waters of different temperatures may be important, higher temperatures tending to decrease the solubility of CaCO_3 . A change in pH

is certainly another factor which facilitates precipitation, but alone would probably not account for the whole reaction, except in that it is important in the maintenance of a high $\text{CO}_3^{=}$ concentration. The solubility of carbon dioxide in water is also increased by pressure, so that springs issuing from a deep-seated source, often at a temperature above that of the air, immediately become saturated and deposit their excess calcium carbonate in solid form. Many cave deposits eg. flowstones, dripstones, stalactites and stalagmites, (known collectively as speleothems) are deposited in this manner.

Another form of inorganic calcareous precipitate called caliche occurs in a semi-arid climate where the predominant direction of movement of soil moisture is upward, owing to the excess of evaporation over rainfall. As carbonate-bearing waters are evaporated from the soil, calcite is precipitated between soil particles.

Biological agencies are certainly implicated in other cases, where precipitation is associated with algae and to a lesser extent with mosses. Two mechanisms are possible. Firstly, the algae may directly precipitate the calcium carbonate of tufa as an essential part of their metabolism, or tufa may form indirectly owing to a photosynthetic withdrawal of carbon dioxide which decreases the solubility of calcium carbonate in close proximity to the plants. Since one plant species may cause precipitation while under similar conditions another does not, suggests that the latter mechanism cannot be wholly responsible. There has been much work on the species of plant responsible. The chief algal genera include Phormidium, Lyngbya, Gongrosira, Gloeocapsa, Schizothrix, Rivularia, Oocardium and Ardouinella, or the chroococcoid stages of other Rhodophyta. (Lauterborn 1910; Fritsch 1949, 1950; Butcher 1946; Gessner 1959). Certain mosses, particularly those belonging to the class Musci (eg. Cratoneurum and Eucladium) are also important in certain situations (eg. Macfadyen, 1928). According to Irion & Müller (1968) the incrusting plants determine the fabric of the tufa, and they have classified tufas in the Schwäbische Alb Germany, according to the families and genera of incrusting plants.

Tufa is laid down as crystalline deposits around the cells of algae and it is usually formed only at temperatures above about 14°C (Matonićkin & Pavletić, 1961). At lower temperatures it may even be eroded, especially in places where the current is swift. The pioneer plants are masses of filaments which at first lie tangled on the substratum, but as they become encrusted; they tend to align themselves vertically and to produce a surface which goes on growing outward, laying down calcium carbonate and dying off in the lower layers.

Sometimes two species occur together and grow at different seasons, each growing up through the other and laying down slightly different types of structure. This produces annual laminae which may build up to large numbers, as occurs for example in Doe Run, where Minckley found that the spring and early summer growing Gongrosira alternated with the late-summer growing Phormidium, forming large nodules like water worn rocks with over sixty concentric annual layers (Minckley, 1963). Thin sections of tufa nodules from Wateringbury (and elsewhere) again revealed a large number of concentric laminae but no obvious sign of algal filaments. The chronological significance of these laminae is unknown (ie. whether seasonal or annual.) Analysis with an x-ray diffractometer showed that the mineralogical composition of this nodular tufa to be almost entirely calcite with minor quantities of quartz. Very small spicules (about $30\mu \times 2\mu$) were however abundant at every site examined (Plate 14). They often occur in clusters, they are non-tapering and have a characteristic longitudinal groove (about a third of the total width). X-ray micro-analysis show that they are calcareous, but they possibly may have originally been composed of opaline silica, and are now pseudomorphs. Other acicular structures of much smaller dimensions were seen under the S.E.M. but these were probably ordinary calcite crystals. What role (if any) these spicules play in the formation of tufa remains unknown.

Plants are however not the only organic agency wholly responsible for tufa formation. Insects, particularly Chironomids, are now known to be largely responsible for its formation in a number of hard water mountain streams (Thienneman, 1934; Sourie, 1962). The chief genus involved is said to be Lithotanytarsus which forms a dense mass of tubes on rocks which become encrusted with calcium carbonate forming a rigid but porous tufa. Fossil examples of Chironomid-tufas are also known (Edwards, 1936) which show alternations of tubes and fine tufa suggesting that the growth is seasonal. It should be noted that although the deposition of lime may go on independently of the midge-larvae, the structure of the tufa, which is due to their activity, allows these larvae to be considered as rock-builders and justifies the use of the term "Chironomid tufa".

Occasionally it is suggested that bacteria or some other micro-organism may play a part in tufa formation; however their exact role and importance has yet to be critically assessed. (Williams & McCoy, 1934).

These relationships are shown in Fig. 5.

Sometimes the formation of tufa begins at the spring source, but more usually there is a gap of a few tens of metres between the spring and the most upstream deposit (Symoens 1949; Sourie, 1962). This is doubtless connected with the initially high carbon dioxide content of the water. As the water passes downstream through a tufa-forming area, its chemical content changes rapidly and finally it contains insufficient dissolved bicarbonate to continue deposition, which therefore declines. However some deposition may occur during the warm low-water period of the summer, but this is generally dissolved during the winter. The variations in water chemistry through the zone of tufa formation may well be responsible for the principal species involved. In the Bavarian district where Oocardium produces the spectacular raised streams on "growing stone" the upstream areas tend to be dominated by Rivularia, Pleurocapsa and Gongrosira, with Oocardium taking over further downstream (Gessner, 1959). Such successions in importance of different algae are not, however, always observed.

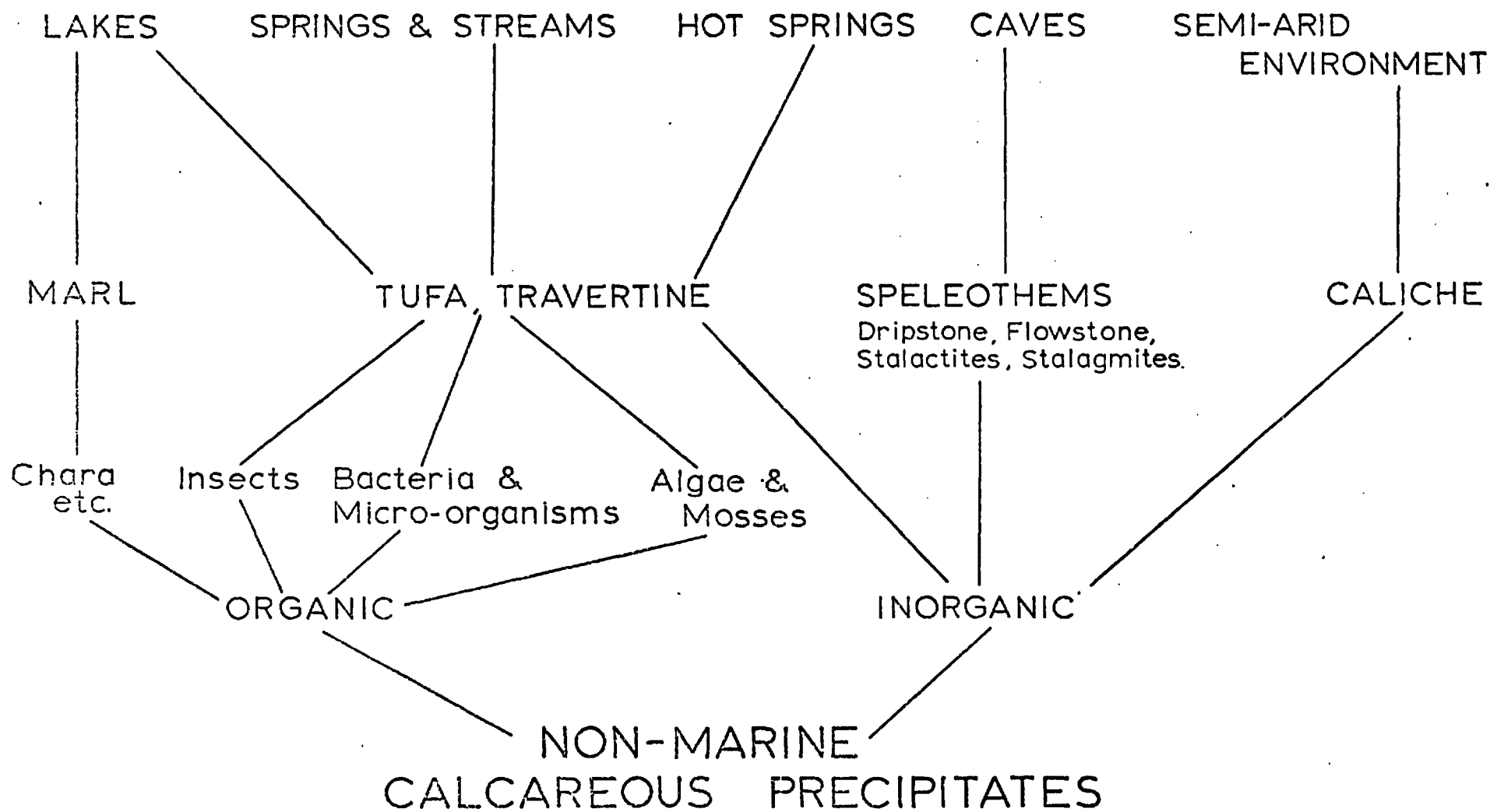


Fig 5

iii. Lithological Variation and Depositional Environment

From the foregoing review of tufa formation, it is clear that lithologically, tufa is very variable. Clearly these lithological variations must reflect differences in depositional environment.

A lithological distinction between a nodular and a non-nodular facies can be made at a number of sites. These nodules are often spherical or cylindrical, the concentric laminae being deposited evenly around a nucleus, commonly a plant stem or shell fragment. In order to achieve such an even coating, the object would either have to be suspended in the water (eg. a projecting twig) or more commonly would have to be rolled along the stream bed. This nodular lithology is therefore interpreted as indicative of flowing water. This contention is further supported by the presence of Ancylus fluviatilis, and various species of Pisidium and ostracods that also suggest flowing water.

The non-nodular tufa is variable; it is sometimes soft and "cheesy" showing fine lamination, or may be rather "biscuity". The mollusca from this material are invariably terrestrial with a high proportion of hygrophilous and swamp species. Clearly this tufa formed in quiet marshes where the water supply was intermittent and then little more than a film. Some faunas suggest that deposition occurred as the result of seepages in shaded (ie. woodland) settings, not unlike that of a modern tufa in Belgium illustrated by Symoens (1949).

It is interesting to note that Ložek (1961) also distinguishes these two main facies of "compact or porous travertines, deposited in running water, especially on the slopes of travertine mounds and walls of cascades, loose sinter-sands which arise in swamps with stagnant water, more or less covered by vegetation."

Occasionally, as at Caerwys, this non-nodular variety of tufa passes laterally into a fine calcareous silt lacking obvious concretionary structure. This material is rich in

Lymnaea peregra with occasional charophytes, suggesting that deposition occurred sub-aqueously in rather more permanent pools. Similar white marls are known from many sites and are especially characteristic of Late-glacial lakes, but these all contain truly freshwater faunas and contain virtually no land snails whatsoever, moreover they lack obvious macro-structure. According to my definition given in section 4i ; these are not tufas but lake marls. This fine-grained facies at Caerwys is intermediate between tufa and these lake marls. Freshwater mollusca characteristic of large bodies of flowing or standing water are generally absent from true tufas.

Much of the tufa at Caerwys must have formed rather rapidly, so rapidly in fact that the stems of reeds and other marsh plants have occasionally been petrified in their position of growth (see Plate 2). The rather homogeneous nature of the fauna from these levels also suggests rather rapid accumulation.

Grey horizons representing standstill phases in tufa growth, when the land surface dried out to some extent, are known from a number of sites. That these horizons represent condensed sequences is suggested by (a) the numerically higher totals of shells recovered, when compared with contiguous samples taken immediately above and below these levels. (b) the ecological change to less hygrophilous assemblages. At Blashenwell, the peaks in the frequency of Vallonia costata in the upper levels coincides with these levels. At Caerwys Lymnaea peregra declines in abundance and is replaced by L. truncatula, together with a whole suite of terrestrial species (c) the abrupt faunal changes that occur at these levels.

iv. Periods of tufa formation

It is often said that in this country, the main episode of post-glacial tufa formation took place in the Atlantic period, when an increase in rainfall caused the water-table to rise, thus converting areas of low-lying woodland into shaded swamp. The warmer climate prevailing at that time was also thought to be conducive to tufa formation. However it is now clear that the onset of tufa formation began very much earlier than this. The radiocarbon dates from Kent (see Fig 37) together with the nature of the fauna and flora are clear evidence that this began in the very early Flandrian. The impoverished molluscan fauna from the tufaceous deposit at Milking Hill, a site within the Brigg complex, is a late-glacial facies rich in Vertigo genesii, Pupilla muscorum etc. (R.C. Preece, unpublished).

Although the onset of tufa formation seems to have begun during the relatively cool but ameliorating climate of the late-glacial, it does seem true to say that tufas are characteristic of interglacial periods generally. There are no records of any Full-glacial tufas. The only known tufas of pre-Flandrian age in Britain, those at Hitchin, Herts (Kerney, 1959) and Icklingham, Suffolk (Kerney, 1976 c) are of interglacial character. The molluscan faunas from both these sites had strong central European affinities and were of probable Hoxnian age. Thus tufas are as significant in recognizing warm periods of the Quaternary as loesses are in revealing the cool periods.

Today most tufa deposits in this country are inactive, though precipitation on a very minor scale can still be observed in certain hard water streams. The faunal and stratigraphical evidence from a number of sites suggests that deposition had ceased by the end of the Atlantic period. Thus a radiocarbon date of 4715 ± 90 BP from a Neolithic ditch cut into the tufa at Cherwell showed that tufa formation had ceased by this time (Evans, 1972). At Brigg, the tufa is overlain by a zone VIIb peat as dated by pollen analysis (Smith, 1958). The Blashenwell tufa is overlain by a Romano-British

soil, but a grave cut into the tufa and pre-dating the Roman layer was discovered by Reid (1896).

The reasons for the cessation of tufa formation are not entirely clear. It could be argued that a climatic change from the warm, wet oceanic Atlantic period to the drier more continental climate of the succeeding Sub-Boreal may have been responsible. However, as previously discussed, tufas were already forming early on in the preceding Boreal Period, and almost certainly well before that, when a similar continental-type climate was prevalent. Alternatively this cessation might be ascribed to the draining of large areas of marsh and swamp by man.

Reid (1896) connected the cessation at Blashenwell with the destruction of the neighbouring forest, but does not elaborate the exact mechanism he envisaged. Perhaps the resultant increased run-off would cut deep channels through the tufa, causing its erosion rather than its aggradation. Certainly deeply incised ravines formed by present streams are a common feature at a number of sites. Bury (1950) suggested an interesting theory also in relation to Blashenwell. He maintains that a mere increase of rainfall, during the Atlantic period, would not lead to precipitation of lime but on the contrary would increase the erosion. He suggested that tufa formation probably began when the temperature was high and the rainfall low. Continuing with his own words "Precipitation of lime might then be rapid enough to keep on blocking the channels, and compel the water to spread out on either side, so that a marshy delta would be formed, which, although small at first, would gradually grow northwards. As it increased in length and breadth, it would be able to meet an increase of rain, by distributing the water over a wider surface, without any stream being formed; but whether the final cessation was due to a reduction of temperature, or to too great an increase in the water supply (or both) is not apparent; but in either event the stream would be re-established and the marsh would be gradually drained" (Bury, 1950).

Jackson (1922) has suggested a theory of base level control connected with the isostatic/eustatic changes of land and sea level. He considered that the tufa at Caerwys was formed as the result of the relative depression of the land in the early Flandrian. This he argues, caused a "stagnation of drainage" resulting in a rise of the water table and the issuing of tufa-forming springs. The cessation he attributes to a supposed later phase of land elevation with the rejuvenation of river erosion and the consequent lowering of the water table. The deeply incised ravines through the tufa he ascribes to this phase. Such a theory however seems unlikely in view of the distance of Caerwys from the sea.

Thus the factors that govern tufa formation are only partially understood. The water-supply and its chemistry, temperature and the nature of the vegetation are clearly implicated, although the precise physico-chemical mechanisms remain obscure. Why one stream should precipitate tufa, while another with an apparently identical water chemistry and vegetation does not, and indeed why the same stream should cease to form tufa remains unanswered.

5. RECORDED SITES

i. GENERAL COMMENTS

In this chapter the principal sites that have yielded Flandrian terrestrial mollusca are summarized. (See fig 6 & 7) Only those that contain pre-clearance faunas are included, the majority of these sites are tufaceous in character. The list is given in alphabetical sequence with the botanical vice-county and National Grid reference together with a reference to the most recent definitive publication or publications dealing with the site. A very short note for each recorded site summarizes the main character of the deposits and the nature of the correlations. In certain instances where re-investigation has been made, it has been possible to correct or sharpen the original dating. Relevant radiocarbon dates are also given in uncalibrated radiocarbon years BP as published in Radiocarbon. From a critical examination of the faunal list it has sometimes been possible to ascribe the sequence to a particular molluscan assemblage zone (y to f), these are defined in a later chapter.

ii. SITE RECORD

Alcester, Warwickshire. SP 099577 (Shotton, Osborne & Greig, 1977)

A sequence of Flandrian marsh deposits (alternating peats and clays). Pollen evidence suggests zone V/VI. A series of radiocarbon determinations gave dates from 7440 $\pm$ 200 BP (Birm-680) to 8480 $\pm$ 140 BP (Birm-709). Molluscan fauna contained Discus ruderratus.

Apethorpe, Northants. TL 0295 (Sparks & Lambert, 1961)

A sequence of marsh deposits covering a considerable part of the Flandrian, from late zone III to zone VIII but with much of zones VI and VII missing. The molluscan fauna was essentially a freshwater one, although land snails were frequent at certain levels.

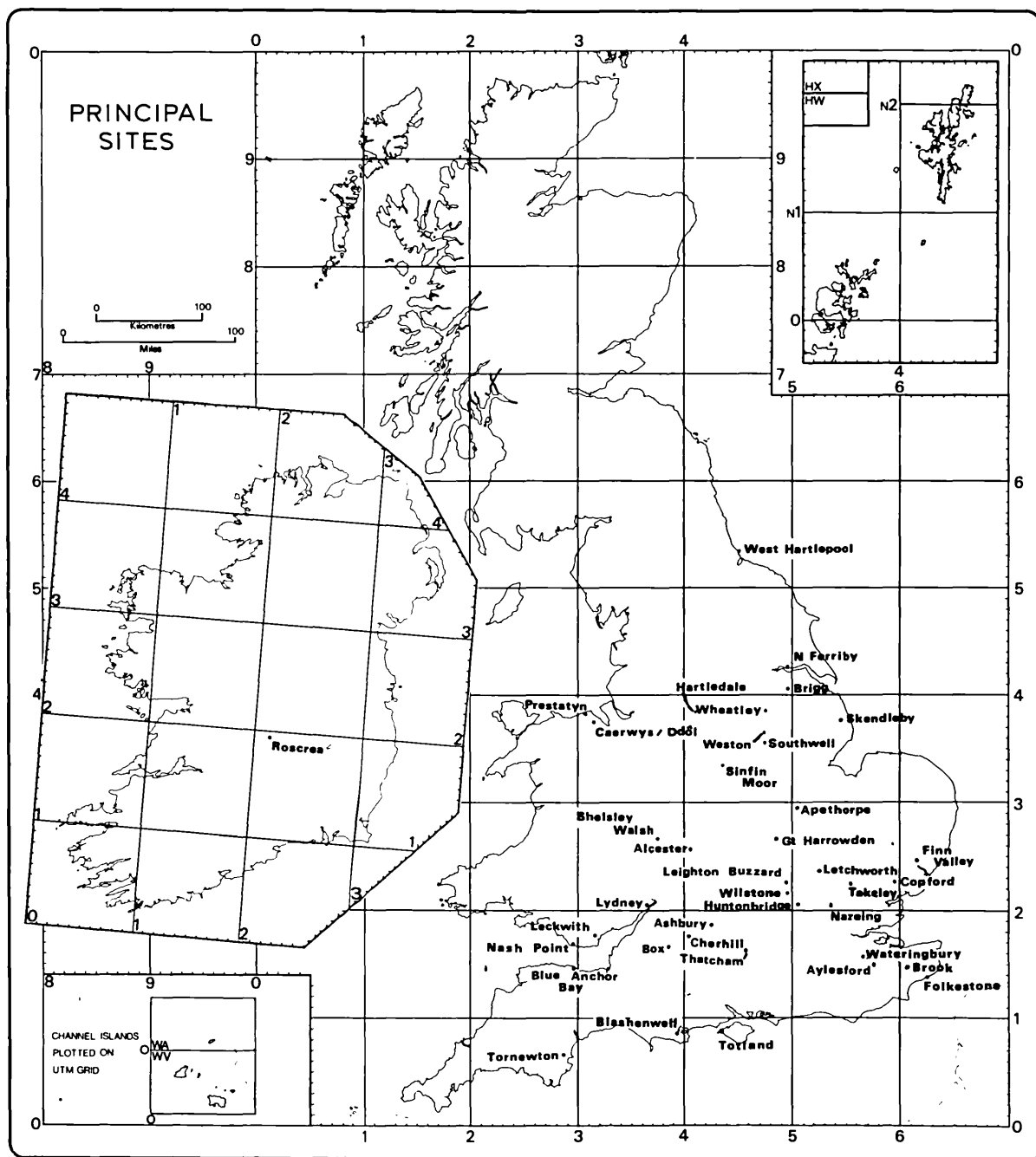


Fig 6

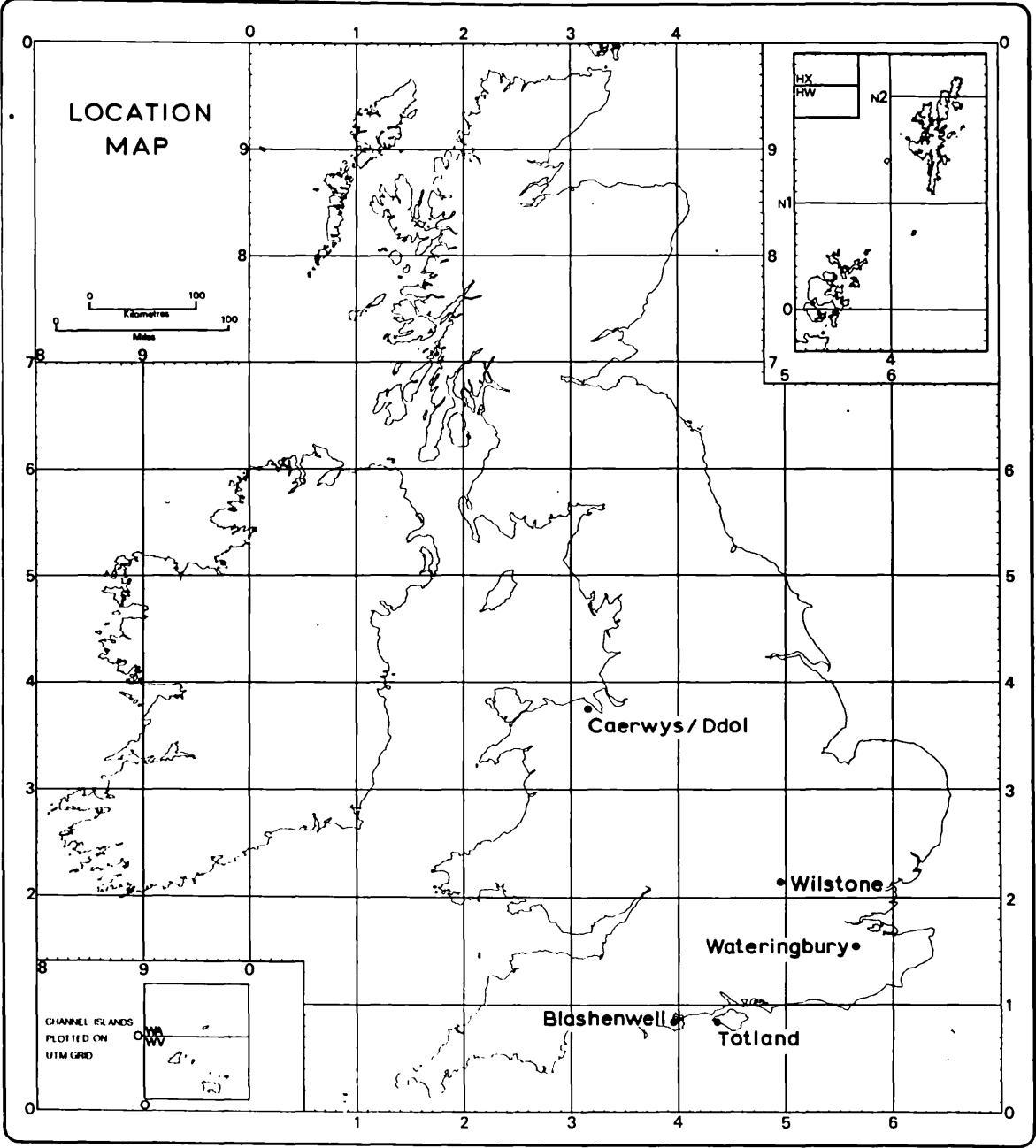


Fig 7

Ashbury, Berks. SU 263856 (Paterson, 1977)

The stratigraphy of a stream section at Kingstone Winslow, near Ashbury in the Vale of the White Horse has recently been given by Paterson (1977 p 196). The molluscan fauna indicates a sequence from the Late-glacial to post-clearance hillwashes. The tufaceous levels in the middle of the deposit have yielded Vertigo pusilla, V. substriata, V. angustior, Leiostryla anglica and Ena montana (R.C. Preece, unpublished).

Aylesford, Kent, E. TQ 736589 (Burchell & Davis, 1957)

A sequence of Late-glacial and Flandrian deposits, containing Trochoidea geyeri, Helicopsis striata, Columella columella, Vertigo genesii sl. in the former and Spermodea lamellata, Acicula fusca, Vertigo pusilla in the latter.

Blashenwell, Dorset (See Section 7)

Blue Anchor Bay, Somerset, S. ST 022438 (Kerney, 1976c)

Organic detritus mud yielding a zone VII (probably VIIa) pollen spectrum. Radiocarbon date 6730 $\pm$ 150 BP (Q-1343). Molluscan fauna includes Vertigo pusilla, Leiostryla anglica and Spermodea lamellata.

Box, Wilts, N. ST 86 (Bury & Kennard, 1940; Hurst, 1968)

Flandrian deposits (including tufa) from which several Mesolithic artifacts (including a microlith) have been recovered. Molluscan fauna contains Leiostryla anglica, Spermodea lamellata and Vertigo pusilla.

Brigg, Lincoln, N. SE 90 (Kennard & Musham, 1937; Smith, 1958a; 1958b)

Extensive tufaceous deposits in neighbourhood of Brigg (Broughton, Hibaldstow etc). Very rich molluscan fauna. Overlain in places e.g. SE 9906 by wood and wood peat dated by pollen analysis to be late zone VIIb. Dug-out canoe and trackway C¹⁴ date 2796-2552 BP (Q-77 to 79).

Brook, Kent, E. TR 04 (Kerney, Brown & Chandler, 1964; Burleigh & Kerney 1978).

Series of Late-glacial and early Flandrian deposits underlying Neolithic colluvium. C¹⁴ date of 4540± 105 BP (BM-254) obtained from clearance horizon.

Caerwys, Flints. (see Section 8)

Cherhill, Wilts. N. SU 031701 (Evans, 1972)

"Mesolithic occupation horizon of bone, flint and charcoal sealed beneath a tufa and resting on a marsh soil. Industry basically a Maglemosian one with a small proportion of microlithic forms of Sauveterrian affinities". A C¹⁴ date of 7230± 140 BP (BM-447) was obtained from charcoal at the base of the tufa and another of 4715± 90 BP (BM-493) from a Neolithic ditch cut into the tufa. Probable zone d.

Copford, see Essex

Cwm Nash see Vale of Glamorgan

Ddôl (see Section 9)

Essex, North.

A number of "shell-marls" have been described from Essex (French, 1889; Kennard & Woodward 1897a; 1897b). The more important of these are Chignal St. James (TL 61); Copford (TL 92); Felstead (TL 62); Shalford (TL 60).

All contain an assemblage rich in Spermodea lamellata with Leiostylia anglica and Acicula fusca at some sites. Pomatias elegans, which is today very rare in Essex, is also present. A pollen analysis from Copford has recently shown it to be referable to zone VIIa (C. Turner, unpublished).

Finn Valley, near Ipswich, Suffolk, E. TM 14 (Kennard, ms)

Organic detritus mud with Discus ruderratus and Nesovitrete petronella.

Folkestone, Kent, E. TR 23 (Kerney, Preece & Turner, 1978)

A sequence of Late-glacial and Flandrian spring and slope deposits rich in mollusca and plant remains. The four C^{14} dates obtained were in ascending stratigraphical order 9960 $\pm$ 170 BP (Q-1508), 9305 $\pm$ 115 BP (St-3395), 8980 $\pm$ 100 BP (St-3411), 7500 $\pm$ 100 BP (St-3410). A Late-glacial flora was present in the basal samples, and zones IV, V & VI assemblages in the upper levels. This site has been adopted as the type site for the molluscan assemblage zones (z to f).

Gerrard's Cross, Bucks. TQ 014880 (Howe & Skeats, 1903-4)

Mesolithic occupation site sealed by a deposit of hillwash in which were numerous fragments of derived tufa.

Great Harrowden, see Northamptonshire.

Harpenden, Herts. TL 1415 (Harper, 1940)

A temporary exposure revealed about 2m of tufa. Zone d.

Hartledale, Derbyshire SK 165803

Cave deposit with Spermodea lamellata.

Huntonbridge, Herts. TL 00 (Kennard, 1943)

Tufa recently re-exposed, two buried soil horizons present. Vertigo pusilla and V. moulinsiana

Leighton Buzzard, Beds. SP 92 (C.R. Bristow, unpublished)

An early Flandrian tufa was discovered during the excavation of garage foundations near Chelsea Green. Fauna contained Vertigo genesii and Discus ruderratus.

Letchworth, Herts. TL 2133 (Kerney, 1955)

Early Flandrian tufa at Norton Common containing Vertigo genesii and Discus ruderratus.

Lydney, Glos. SO 60 (Coysh, 1926)

Tufa, maximum thickness c 4m. Zone d.

Nash Point see Vale of Glamorgan

Nazeing, Essex, N. TL 3807 (Allison, Godwin & Warren, 1952)

Organic muds, marl and peat above terrace gravels of Lea Valley. Late-glacial to Flandrian VIIa. Fauna contains Discus ruderratus and Nesovitreia petronella.

North Ferriby, Yorks, S.E. SE 9927 (E.V. & C.W. Wright, 1933; 1947; Wright & Churchill, 1965)

Peat underlain by white tufaceous marl rich in mollusca including Spermodea lamellata, Leiostryla anglica, Vertigo pusilla, Vertigo angustior. Several sewn boats have been discovered nearby embedded in an estuarine clay overlying a fen peat. Associated C¹⁴ dates 3500 BP (Q-837), 3120 BP (Q-715), 2700 BP (BM-58).

Northamptonshire. (Preece, 1978)

A number of tufas have recently been discovered in Northamptonshire of which the most important are Lumbertubs near Great Billing (SP 795631) and Pythchley (SP 863760). Spermodea lamellata and Leiostryla anglica occur at both sites. A further site at Great Harrowden (SP 875695) was discovered by Dr R.J. Chandler when a sewer trench was excavated. A Late-glacial silt with Catinella arenaria and Vertigo genesii was separated from an overlying tufa of early Flandrian character by a prominent soil horizon. A C¹⁴ date of 9435±610 BP (St-3695) was obtained from this level and another of 11980±145 BP (St-3685) from a peat lens immediately underlying the soil.

Nottinghamshire (Davis & Pitchford, 1958)

Three sites at Southwell (SK 702534), Wheatley (SK 78) and Weston (SK 76) are known. Discus ruderratus present in all, Catinella arenaria from Southwell and Spermodea lamellata from Wheatley.

Oxford (Arkell, 1947)

Deposits of tufa are widespread in Oxfordshire, although none have been studied in detail. At Hill Farm, near Chipping Norton (SP 32) 4m of tufa have been deposited, which was exploited as "alluvial lime". It was said to contain large numbers of land snails together with bones and antlers and "rested everywhere on a layer of black peat about 6" thick, full of hazel nuts." Other sites are known at Shakenoak and Woodstock.

Prestatyn, Flints. SJ 0782 (Clark, 1938; 1939; Neaverson, 1941; McMillan, 1947)

Tufa with Mesolithic artifacts (including microliths).

Roscrea, Co. Tipperary / Offaly S.09 (Kerney, 1957)

A number of sites in the neighbourhood of Roscrea have yielded rich molluscan faunas from tufaceous deposits. Principal sites are at Millpark, Golden Grove, Fancraft, Gloster.

Shelsley Walsh, Worcestershire SO 76 (Lees, 1856)

An extensive mass tufa at Southstones Rock in the Teme Valley has been reported to "enclose within it a multitude of snail-shells".

Sinfin Moor, Derbyshire SK 33 (Champion, 1969)

Series of Flandrian lacustrine deposits with land mollusca (including Spermodea lamellata) present towards margin. Pollen analysis showed that the upper levels of the peat were referable to zone VIIb - VIII.

Skendleby Long Barrow, Lincs, N. TF 4369 (Philips, 1936)

Spermodea lamellata and Leiostyla anglica were among shells recovered from an "infill" made during the construction of the Neolithic Giants' Hills Long Barrow, Skendleby.

Southwell see Nottinghamshire.

Takeley, Essex, N. TL 5221 (Kennard in Warren, 1945)

A very rich molluscan fauna has been described from Tilekiln Green near Takeley, but the site has now been obscured under a lawn (personal observation). Pollen analysis of matrix from museum material yielded a zone VIc spectrum (C. Turner, unpublished).

Thatcham, Berks SU 526656 (Cheetham, 1975)

Section at Avenell's Cottages revealed a silty-clay overlain by a peat and algal marl. Trochoidea geyeri together with an open country assemblage were recorded from the base of the clay but a rather more shade-demanding facies including Discus ruderatus was present in the upper part of the clay. Two C¹⁴ dates of 9223± 100 BP (BM-1136) and 8928± 71 BP (BM-1135) were obtained from the overlying peat.

Tornewton Cave, Torbryan, Devon, S. SX 817673 (Kerney, 1976c)

Indurated tufaceous loam ("Widger's Diluvium") from the cave yielded an essentially woodland snail assemblage with Spermodea lamellata and Leiostylia anglica.

Totland Bay, Isle of Wight (see Section 10)

Vale of Glamorgan

A number of tufas are known in this area e.g. Leckwith (ST 17) and Llancarfan (ST 06) (Strahan & Cantrill, 1902). Nash Point (SS 96) and Cwm Nash (SS 904700) have recently been investigated (Evans 1977, see also Fig 32) and are known to furnish a particularly complete record from the Late-glacial onwards.

Wateringbury, Kent, E. (see Section 6)

West Hartlepool, Durham. NZ 5032 (Trechmann, 1936)

Submerged forest with Mesolithic flints of Maglemose type. Spermodea lamellata and Leiostylia anglica recovered

from marl underlying peat. Antler from "peat"? gave C¹⁴
of 8700 $\pm$ 180 BP (BM-80).

Wilstone, Herts. (see Section 11)

6. WATERINGBURY, KENT

i. Introduction

There are a number of records of the occurrence of tufa in the vicinity of Maidstone, Kent. It is known from several sites around East Malling, from Bradbourne, from a borehole sunk about 200 m SSW of East Barming Church and from a number of smaller sites to the east of Maidstone which have been summarized by Worssam (1963). In the past it has been used in some local buildings, such as the walls of East Malling Church and in St. Leonard's Tower both of early Norman age. However only the deposit at Wateringbury has received any serious attention. E.E.S. Brown first published an account of the site in 1939, which included an appendix reporting the contained non-marine mollusca by A.S. Kennard (Brown, 1939). Some years later M.P. Kerney visited the site and published an enlarged faunal list which included three mammals and forty-one species of mollusca (Kerney, 1956).

ii. Location and Extent

The deposit is situated in the lower part of Love Lane, that leads southwards from the main Mereworth-Wateringbury road to the farm buildings just east of the Mill Pond at TQ 687534 (Fig 8). The tufa occurs on either side of the lane for a distance of nearly 100 m to a maximum height of 2.5 m above road level. Augering and subsequent coring proved the tufa to be rather over 4 m at its thickest point (Fig 9). Trial augerings made in the orchard and adjoining allotment have confirmed Brown's suggestion that "the material occupies a roughly elliptical area 110 yards long by 80 yards wide, is backed up against a clay slope to the west and thins out to the east" (Brown, 1939).

The site is some 4 km away from the chalk escarpment and is situated in a small valley that separates the base of the Hythe Bed escarpment, lying 400 m to the north, from the southerly outlier west of Nettlestead that is considered to be a slipped mass (Brown, 1938). Since the tufa must have formed subsequently to this separation, accurate dating of the tufa could fix the age limits for this slumping. The tufa itself is surrounded and underlain by Atherfield Clay.

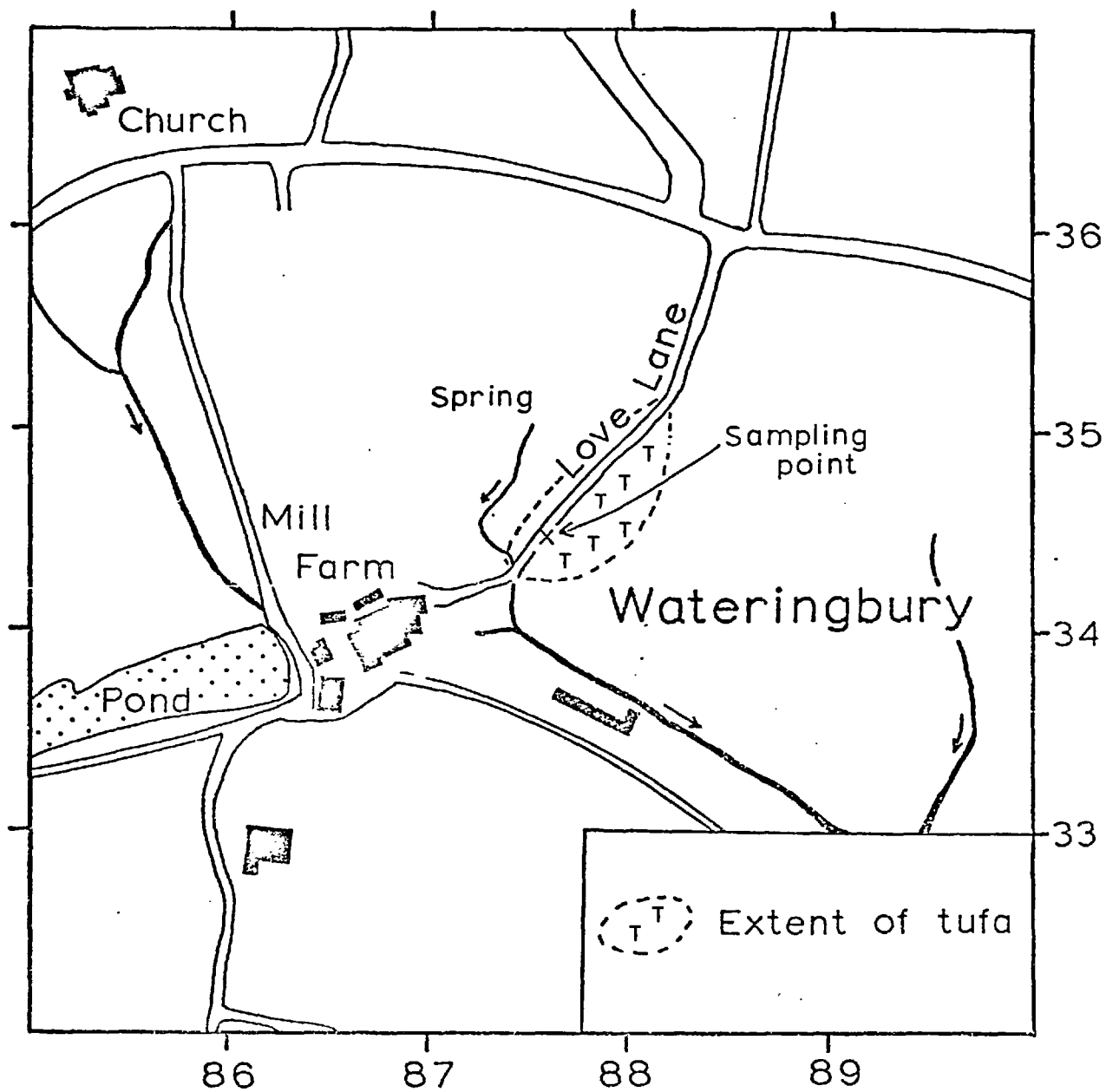


Fig 8

PROFILE THROUGH WATERINGBURY TUFA

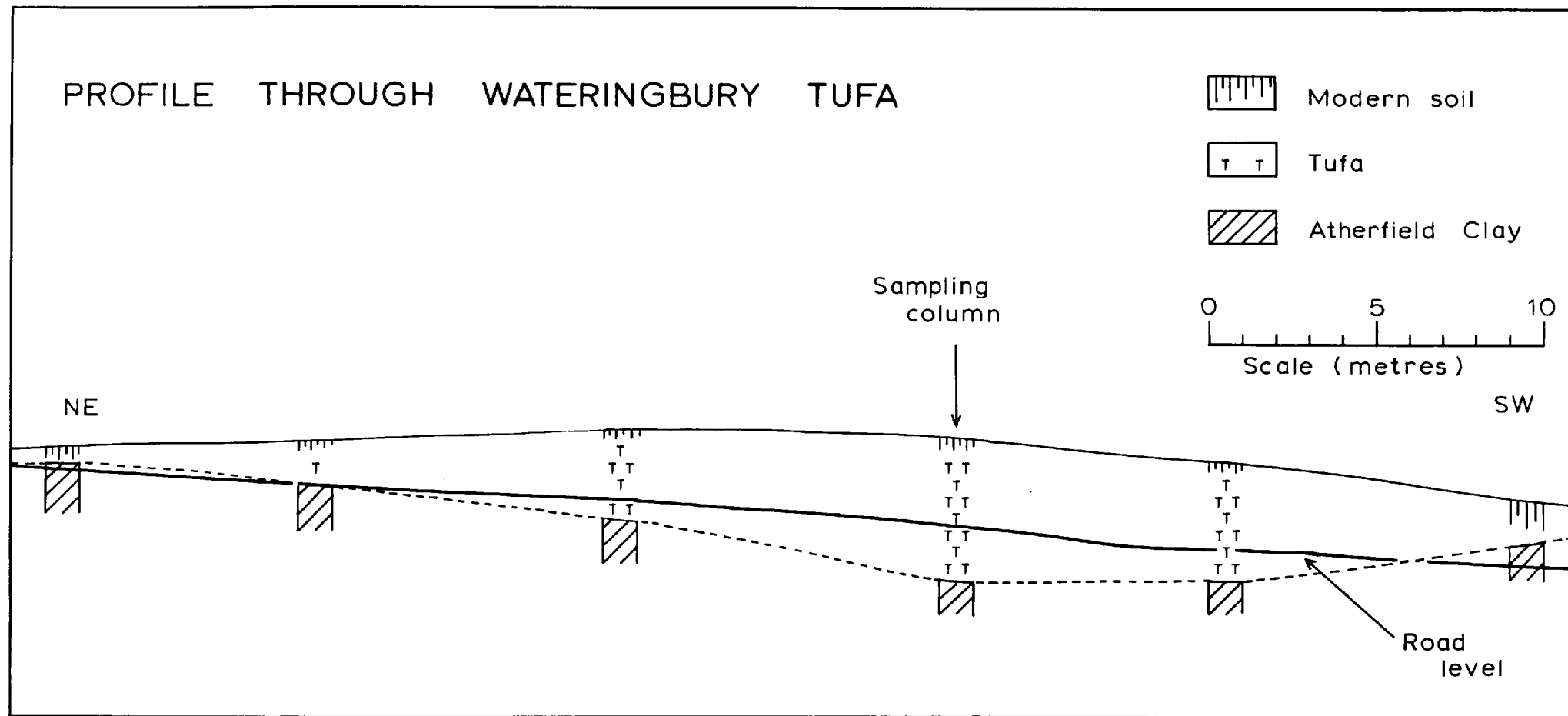


Fig 9

iii. Mineralogy

Analysis with an x-ray diffractometer showed that the mineralogical composition of the tufa was almost entirely low magnesian calcite with minor quantities of quartz. G.W. Himus (in Brown, 1939) also analysed this tufa and stated that it was "substantially a slightly magnesian carbonate of lime with only small quantities of impurities in the form of clay, sand and organic matter." Brown considered that the calcium carbonate was derived from the decalcification of the Kentish Rag (Hythe Beds).

iv. Stratigraphy

The tufa was sampled at its thickest point on the east side of Love Lane (see Fig 9). A clean vertical face was prepared from the modern soil surface to just beneath the road level, where the deposit was waterlogged. Above this point a continuous series of samples were taken at 5 cm intervals, while below it was sampled at rather greater intervals (generally every 10 cm) until the water table was encountered. Augering showed that the deposit extended for a further metre beneath the water table and this was cored in November 1975 using a 10cm percussion corer. Although the upper levels showed signs of disturbance from roots and rabbit burrows, the tufa was sampled where the disturbance was minimal. The occasional intrusive shell was encountered but could be easily distinguished from the tufa fossils.

The following succession was recorded:-

0 - 17 cm	Modern soil (10 YR 4/2), containing fragments of reworked tufa
17 - 120 cm	Soft white tufa 10 YR 7/3 drying to 10 YR 8/2. Strongly oxidized. Nodular in places.
120 - 124 cm	Grey horizon 10 YR 6/2
124 - 132 cm	Soft white tufa
132 - 138 cm	Grey horizon 10 YR 6/2
138 - 190 cm	Soft white tufa
190 - 194 cm	Grey horizon 10 YR 6/2
194 - 220 cm	White tufa, rather "biscuity" in texture

220 - 230 cm	Iron-stained layer of hard, cellular tufa containing occasional leaf impressions (7.5 YR 5/6); corresponds to road level, so the hardening is likely to be secondary.
230 - 410 cm	Loose grey (2.5 Y 5/2) nodular tufa becoming coarser downwards, waterlogged below 270 cm.
410 cm ⁺	Very dark grey clay (5 Y 3/1). Atherfield Clay.

These divisions are shown by the side of Fig 10.

v. Mollusca

The tufa is very rich in Mollusca and the preservation is exceptionally good, allowing even the smallest apical fragment to be determined. Altogether over 42,000 shells were analysed from over 50 different levels, the results are tabulated in Appendix 2i and are expressed as a percentage frequency histogram in Fig 10.

The general nature of the fauna is one of a calcareous swamp. Very few species of freshwater shells are represented. Lymnaea truncatula, Pisidium casertanum, P. personatum and P. obtusale account for most of the freshwater species found, and all of these are more typical of swampy ground rather than any permanent lake or stream. However two other species, Pisidium milium and a fragment of the operculum of Bithynia tentaculata, were recovered from the core samples. The occurrence of these species does suggest the presence of rather more stable water conditions, perhaps even running water.

Conditions were certainly much wetter in the lower portion of the sequence. For example the swamp element, composed of Vertigo antivertigo, V. moulinsiana, Oxyloma pfeifferi, Zonitoides nitidus and Carychium minimum, occasionally amounts to over 50% of the total land fauna. Vertigo angustior (plotted separately on Fig 10) also reaches quite high percentages in these lower levels, but begins to decline at about 185 cm and has completely died out by 155 cm. It is interesting that the V. angustior maxima do not always coincide with the peaks of swamp or freshwater species. Indeed it is totally absent between 335 - 345 cm

when the majority of the fauna is composed of obligatory hygrophiles. It flourishes however in the intermediate situations between true swamp and shaded willow scrub, an interpretation supported by its living occurrences in "rich marshy meadows" (Norris & Colville, 1974).

It is the changes in the composition of the land mollusca however, that are perhaps the most striking. In the basal samples the fauna is relatively impoverished and is represented by a high proportion of catholic species (e.g. Cochlicopa lubrica, Punctum pygmaeum, Vitrina pellucida, Vitrea contracta, Euconulus fulvus etc) of wide ecological tolerance. Also present at these levels are certain species that are characteristic of open country (e.g. Pupilla muscorum, Vertigo pygmaea and Vallonia). Vallonia excentrica is especially diagnostic of open habitats and is characteristic of grassland; it is virtually unknown from woodland or shaded habitats in Britain either living or in subfossil contexts. Vallonia pulchella is also common in these lower levels, this species tolerates rather damper conditions than its congeners, although its occurrence again suggests an open, non-shaded environment. Vallonia costata is thought to be the most shade tolerant of the three British Vallonia and it is the only Vallonia to survive above 345 cm.

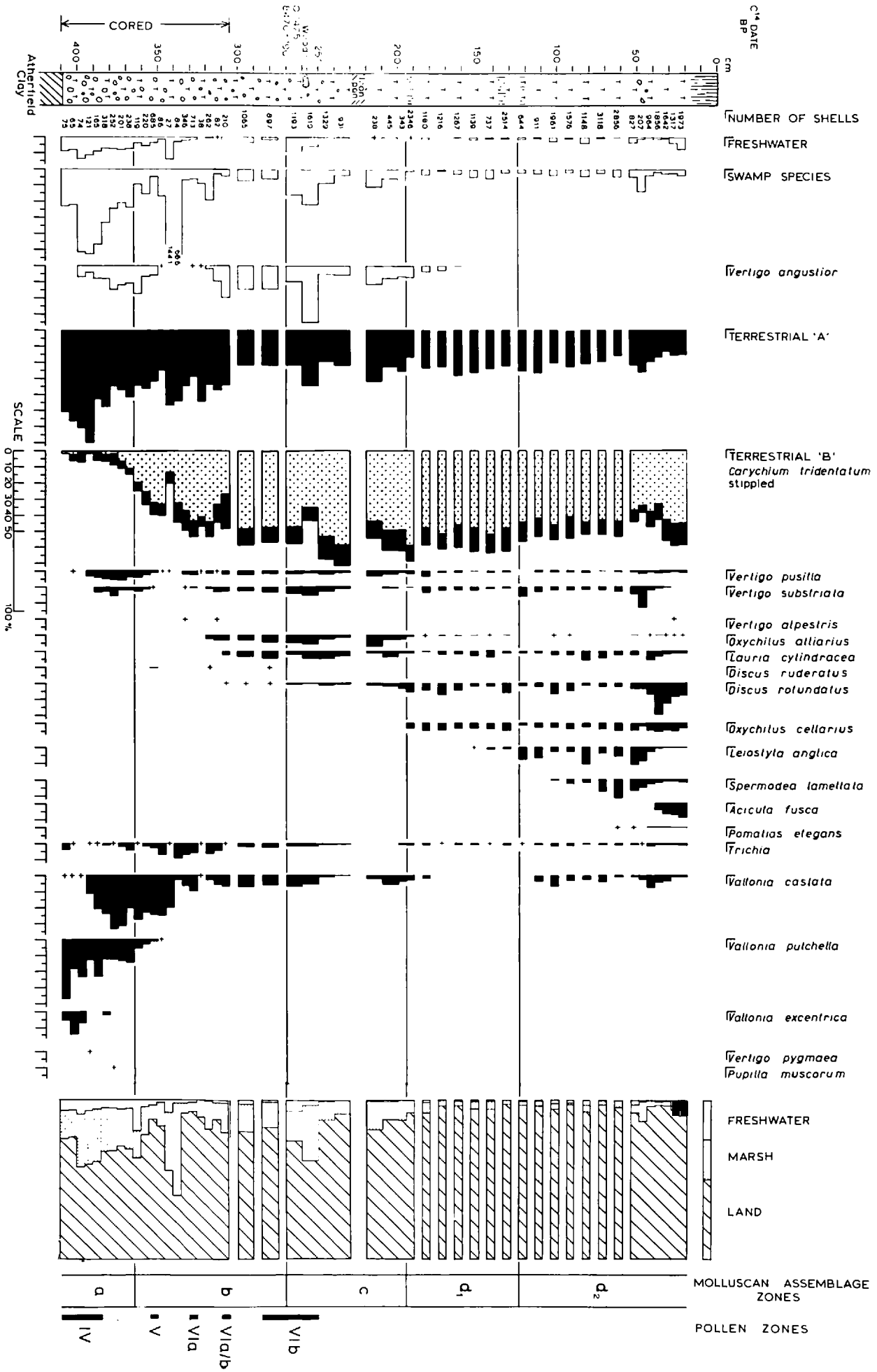
Throughout the lower part of the sequence the population of shade-demanding species (eg. Carychium tridentatum, Acanthinula aculeata, Clausilia bidentata, Aegopinella spp) progressively increases at the expense of the open country forms. Discus rudtatus is present in low numbers at these levels, but is replaced higher in the sequence by much larger numbers of Discus rotundatus. Vertigo pusilla, V. substriata, Lauria cylindracea and Oxychilus alliarius are also present and these are joined by Oxychilus cellarius (and Trichia striolata) at the lowest grey horizon (190 - 195 cm). After its arrival O. cellarius occurred in much greater numbers than O. alliarius in the lower levels and it seemed to virtually replace the latter in the upper levels. This is strange in view of the abundance of O. alliarius in shaded habitats today.

In the upper half of the tufa, Leiostryla anglica, Spermodea lamellata and finally Acicula fusca appear. The occurrence of this suite of species suggests heavy shading; Spermodea lamellata is only known from woodland and is perhaps the most shade-demanding British snail. L. anglica and S. lamellata reach their greatest abundance at about 50 - 55 cm (combined percentage c. 17.5%) and show a progressive decline from that point. It is interesting to note that Vertigo substriata a common associate of these species, that had been consistently present from the lowest samples onwards, is absent from the uppermost two samples, in spite of their numerical richness. Acicula fusca, on the other hand only arrives between 35 - 40 cm and increases in relative abundance to the top of the tufa. A sample of modern soil was also analysed and found to contain both fossil (i.e. derived) and fresh Acicula shells; the species still survives in the hedgerow today.

Pomatias elegans also appears in low numbers in the upper levels. This species would be anomalous in a marsh context and is not common in heavily shaded situations. Its appearance coincides with the decline of S. lamellata and L. anglica. Much greater numbers of Pomatias, some containing the operculum in situ, were detected further up the slope (ie towards the northern limit of the deposit) suggesting that conditions there were rather better drained. The possibility that these shells had burrowed down to these levels (i.e. that they were intrusive) was considered but discounted since many shells that were obviously broken in life were recovered. It was noticeable that many of the fossil Pomatias were considerably larger than the modern shells living on the bank today, this is considered in greater detail in Section 12.

Some brief comments about the stratigraphical source of the previous faunal lists (Kennard in Brown, 1939; Kerney, 1956) can now be made with reference to the detailed molluscan diagram (Fig 10). It is clear that Kennard's material must have come from a level higher than that equivalent to 165 cm (since V. angustior is not listed) but below the level where S. lamellata expands (i.e. 105 cm). Kerney's sample also lack V. angustior,

Fig 10



but includes an abundant S. lamellata and L. anglica fauna together with five shells of A. fusca; clearly this came from a higher stratigraphic level than Kennard's sample.

vi. Insecta

A characteristic fossil, present not just at Wateringbury but at most of the other sites examined, is a minute Dentalium-like tube, which often occurs in great numbers. These are calcareous, average 3.5 mm in length and taper from about 0.5 mm at the wider end, which may be very slightly expanded, to 0.2 mm or less at the narrow end. Both ends are open. All specimens were of roughly the same size, so that they were not juvenile. These were submitted to Mr P. Cranston of the British Museum (Dept. of Entomology) who stated that they were probably Chironomid larval cases. No specific determinations were possible.

vii. Ostracoda

The ostracods picked from the sievings above B.S. 30 mesh (0.5 mm) are plotted on an absolute basis in Fig 11. United carapaces were scored as two individual valves. Sub-30 mesh residues from the core have been retained but have not been analysed. The totals from the core are derived by extrapolation to give the individual valves/0.5 kg. These were submitted to Dr. Eric Robinson who reported as follows:-

The following five species were recovered, Ilyodromas olivaceus (Brady & Norman); Eucypris pigra (Fischer); Candona compressa (Koch); Potamocypris wolffi Brehm; Ilyocypris bradii Sars. All are extant species so that environmental interpretation can be made from present-day ecology. The assemblage is essentially a cool spring fauna and includes elements suggesting flowing water.

The fauna of springs today contains a relatively limited variety of species, perhaps no more than five or six, compared with twenty or thirty characterizing ponds or small lakes. Recently, in reviewing the fauna of the Post-glacial, Absolon (1973) distinguished six assemblages comprising those of subterranean streams, springs, streams, small ponds and temporary or intermitten

pools. Each association is distinct in species make-up, or shares only a few species in common. Ilyodromas olivaceus and Eucypris pigra, the dominant species from the Wateringbury samples, belong to his spring (Quellkalkablagerung) and stream (Bachkalke) assemblages respectively, although other authors would bracket both as indicating cool springs.

Ilyodromas olivaceus was originally described by G.S. Brady and A.M. Norman (1889) from "amongst weeds in the River Lathkill, Derbyshire" and subsequently by G.O. Sars (1928, p. 134) from a ditch near Oslo. To Klie (1938, p. 130), it was "the most characteristic inhabitant of cold springs and associated streams." In more recent years, it has been similarly cited by Diebel & Pietrzeniuk (1975, pp. 38 - 39; 1977, pp. 125 - 126) and Diebel & Wolfschläger (1975, pp 125 - 126) as a krenophile, common in most of the calcareous tufas of southern Germany and Brandenburg. It is a crawling form, rather than a swimmer and indicates cold springs and shallow, flowing waters; it commonly makes up over 70% of the total ostracod faunas in such situations.

Eucypris pigra has a similar record, but according to G.W. Müller, has a particular preference for areas flooded to a depth of only a few millimetres by permanently flowing water (quoted by Absolon, 1973, p. 54). It has been frequently listed as a cool spring species by Diebel & Pietrzeniuk (1975, p. 35, 38 - 39; 1977, p. 133) and Diebel & Wolfschläger (1975, p. 98, p.111). From the literature, it emerges as a cool water, stenothermal species, which like the genus as a whole, lives in shallow films, pools and waterlogged ground.

In the Wateringbury succession, there is a marked dominance by Ilyodromas olivaceus between 180 - 280 cm. The other species listed above occur principally above and below this Ilyodromas-peak. These are by-and-large active ostracods. Accurate ecological interpretation is somewhat premature, but from the foregoing comments it would seem that flowing water conditions were present in the basal and upper parts of the succession while quieter conditions prevailed in the intervening levels. The following additional points may be made on the basis of the ostracod record.

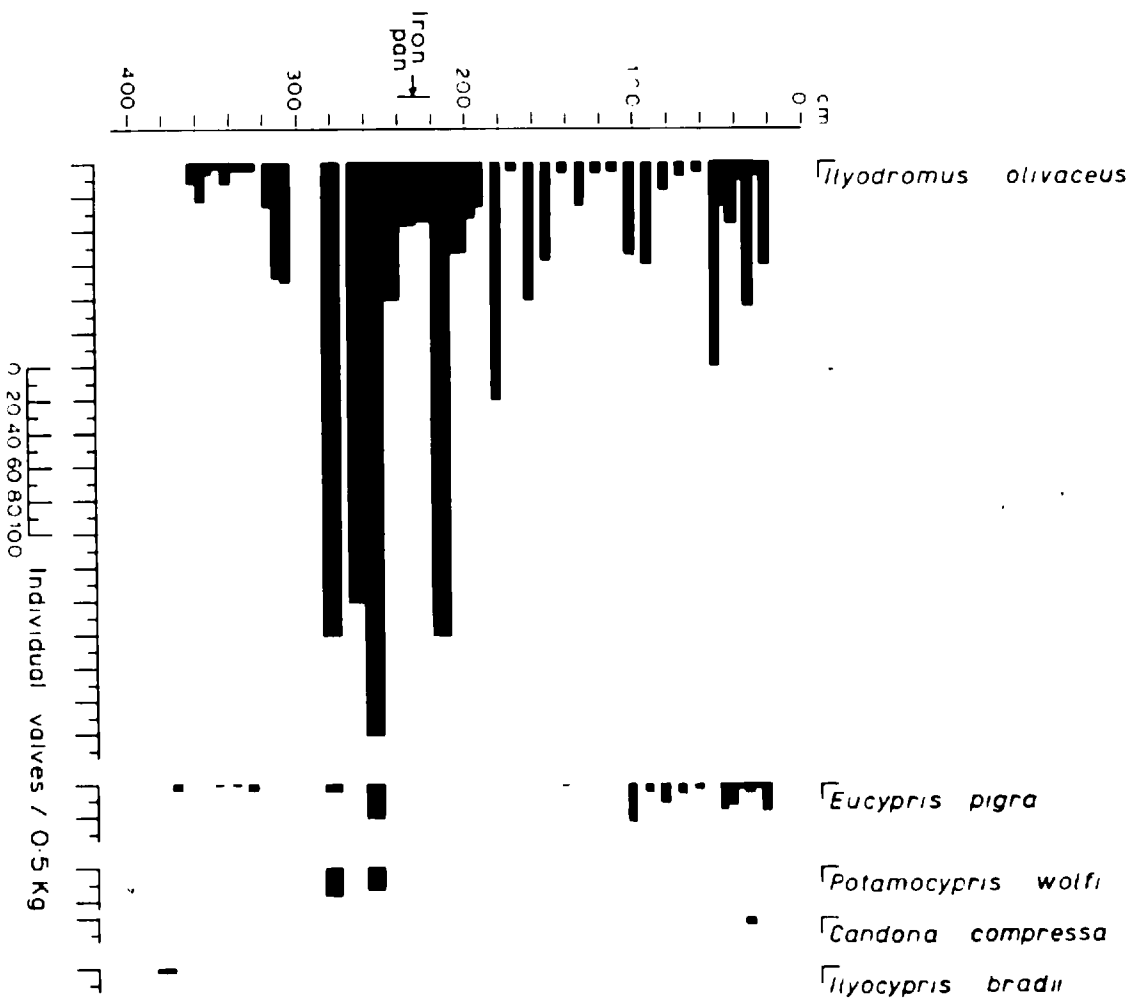


Fig 11

Temperature; all comparisons with European sites suggest cool-to-cold conditions, with the qualification that it is a spring water temperature which is being assessed and not necessarily the prevailing climate.

Substrate; was continuously of a soft silty nature and well-vegetated.

Water Movement; except for Ilyocypris, all the species are delicate valved. To find that for the Ilyodromas-peak more than 10% of the specimens are two valved carapaces, in spite of the weak valve articulation, suggests very quiet, undisturbed conditions of sedimentation. Conversely, the fact that the lower and upper assemblages consist almost entirely of separated valves, only confirms the interpretation, offered above, of early and late flooding periods, when current flow was sufficient to produce some measure of transportation and valve separation.

vii. Vertebrate Remains

Although bone fragments were fairly frequent, readily determinable teeth were rather rare, the stratigraphic position of those recovered are given in the following table (determinations by Dr A.J. Stuart).

Depth (cm)	20-25	90-95	120- 125	160- 165	350- 355
<u>Talpa europaea</u> L. (mole)	-	-	-	m ³	-
<u>Clethrionomys glareolus</u> (Schreiber) (bank vole)	m ³	3m'	-	-	m'
<u>Microtus agrestis</u> (L) (field vole)	-	-	cf.m'+ mandible	-	-

In addition to the above species, a fragmentary right mandibular ramus (lacking teeth) of Neomys (cf. fodiens) is also known (Kerney, 1956).

ix. Plant Remains

The basal part of the tufa, below the iron pan at 230 cm depth, was waterlogged, and this waterlogging has apparently prevented the oxidation of at least part of the organic matter around which the tufa formed. A series of samples was submitted to Dr C. Turner for pollen and plant macrofossil analysis who reported as follows:

(a) Pollen analyses

Certain samples contained relatively abundant pollen, others were devoid of same, but in all cases it was clear that considerable corrosion and differential destruction of pollens of individual species had taken place. It follows that the analyses of the surviving pollen assemblages are difficult to compare directly with typical pollen diagrams from lake and bog deposits, so that the aim of such analyses has not been to produce a detailed pollen diagram recording local and regional vegetational change, but simply to assign and relate certain key horizons to the standard system of pollen zones for the Post-glacial (Flandrian) (Godwin 1975). Unfortunately almost all detailed studies of pollen corrosion have been of assemblages subjected to low pH conditions, so that the nature of differential pollen destruction under alkaline conditions (eg. on tufa surfaces with fluctuating water levels) is virtually unstudied (cf. Dimbleby & Evans, 1974).

250 - 260 cm

Pollen corroded and probably over 50% destroyed beyond recognition, but pollen is nevertheless abundant. The most important surviving taxon is Corylus, but appreciable amounts of Quercus pollen, some barely identifiable, are present, Ulmus, Pinus and Gramineae pollen are also conspicuous. Other taxa that occur include Compositae, Fraxinus, Salix, Sparganium and Filicales and Sphagnum spores. It would be of little meaning to quantify the pollen values as percentages, because clearly at least the major components Corylus and Quercus should also be represented by very many unrecognisable pollen grains. There is no sign of Alnus or Tilia pollen, and in the light of the abundance of Quercus and Ulmus it seems proper to assign this horizon to pollen zone VIc.

275 - 285 cm

Pollen very corroded, at least 80% unidentifiable. Corylus is by far the most abundant pollen type. Relatively few Quercus grains were recognisable with certainty though many partly destroyed grains might have belonged. Ulmus grains are relatively

well preserved and not infrequent, similarly Pinus and Compositae. Other taxa present included Hedera, Salix Ranunculaceae and Gramineae. Again this horizon might be referred to zone VIb, but with less certainty as it is now impossible to gauge the original abundance of Quercus pollen.

305 - 310 cm

Pollen again very badly corroded. The same pollen types were present as in the foregoing sample, except that Betula was also present. The local presence of Quercus is confirmed by the recovery of oak leaves amongst the macrofossils. Again a zone VIb or possibly VIA assignation is suggested.

325 - 330 cm

Pollen content very corroded. The principal taxa present are Corylus and Pinus; Ulmus is moderately frequent and Betula and Gramineae present, but practically no other pollen types were seen. Noteworthy is the virtual absence of Quercus. If this is entirely due to differential destruction a zone VIb age would be possible. otherwise the combination of Pinus, Ulmus and high Corylus frequencies suggest zone VIA.

345 - 350 cm

Sample totally barren of pollen.

350 - 355 cm

Here the pollen was quite abundant, despite the usual intensive corrosion, the most abundant pollen type was Corylus with Pinus, Betula and Gramineae as secondary constituents. Neither Quercus nor Ulmus were seen, and were presumably genuinely always absent since Ulmus is always relatively well preserved in younger samples. Consequently a zone V age is assumed.

365 - 370 cm

This sample was also totally barren of pollen.

385 - 390 cm

In this sample corroded, broken and degraded pollen amounted only to c. 40% of the total, still a considerable figure but less than in the overlying samples. An attempt at a statistical count for this assemblage gave : Pinus 25%, Betula 19%, Salix 13%, Gramineae 26%, Cyperaceae 7%, other herbs 8% (Caryophyllaceae, Epilobium, Filipendula, Ranunculaceae, Rubiaceae, Umbelliferae) Filicales spores 14% (pollen sum = Total land pollen). There is no trace of Corylus; this is basically a pine-birch or birch-pine dominated pollen assemblage, allowing for the fact that Pinus pollen is generally regarded as more resistant to corrosion than that of Betula. The relatively high non-tree pollen is probably mostly of local origin and could indeed be largely derived from marsh herbs. This pollen spectrum is typical of pollen zone IV.

405 - 410 cm

Pollen not very abundant but still well enough preserved to be countable. Only 35% is referable to trees and shrubs - Pinus 16%, Betula 11%, coryloid (Corylus or Myrica) 3.5%. The main component is herbaceous pollen - Gramineae 34%, Compositae 15%, Filipendula 5%, Umbelliferae 5%, Rubiaceae 2%, Filicales spores 16%.

This indicates rather open conditions, at least locally, and again zone IV is indicated.

(b) Plant macrofossils

These are listed in the table below. There are clear indications of a progression from an open unshaded marsh to one strongly influenced by shrubs and forest trees. The extraordinary association of Viola and Chenopodium at the base of the deposit may reflect the original open habitat on which the tufa-forming marsh developed. Later Chelidonium majus, the Greater Celandine, was present growing on the tufa surface, an important and interesting record since this plant which today is associated with damp limestone walls and roadsides, has hitherto been considered to have been introduced to Britain

[illegible]

-	-	-	-	-	4	-	-	-	-	210-220
-	-	-	-	-	-	-	-	-	-	80-85
+	-	-	-	-	c15	-	-	-	-	60-65
+	-	-	-	-	2	-	-	-	-	45-50
+	-	-	-	-	4	-	-	-	-	40-45
+	-	-	-	-	3	-	-	-	-	35-40
+	-	-	-	-	-	-	-	-	-	25-30
+	-	+	-	-	2	-	-	-	-	20-25

in mediaeval times, as a medicinal herb, although there are seeds recorded from last interglacial (Ipswichian) deposits at Wretton and West Wittering. (Godwin, 1975). It is actually present at Wateringbury today and this supports Godwin's conjecture that the plant may actually be native.

Cypselas (fruits) of Eupatorium cannabinum are present at many horizons within the tufa. This reflects both the extraordinary resistance of the walls of the fruit to decay and the ability of the plant both to colonize and dominate an open marsh and to persist beneath willow scrub. Salix leaf impressions occur where the tufa is hard enough for these to be preserved.

Seeds of Sambucus nigra occur in the uppermost levels of the tufa which have been somewhat disturbed by rabbits and other smaller burrowers so that the possibility of modern derivation cannot be excluded.

The occurrence of minute acicular spicules has already been discussed. These are of probably botanical origin.

x. Radiocarbon date

A large piece of oakwood (Quercus), determined by Dr J.F. Levy, was recovered from beneath the water table at 255 - 260 cm. A radiocarbon assay was carried out by the Cambridge Laboratory with the following result:-

Q-1425 8470 $\pm$ 190 B.P.

xi. Conclusions

The molluscan fauna of the basal samples contain Aegopinella, Vitrea and Carychium, species that are as yet unknown from deposits of Late-glacial age in southern England (Kerney, 1963). The deposit is likely therefore to be entirely post-glacial, a conclusion that is supported by the botanical evidence from the basal samples which suggests a zone IV date for the onset of tufa formation. The contention that such tufas formed only during the oceanic Atlantic period must therefore clearly be abandoned, although the reason for the cessation of tufa growth is still not clearly understood.

It would also seem that the formation of the Nettlestead slipped outlier (p. 54) (Brown, 1939) was a pre-Flandrian event. It is interesting to comment on the completely fresh unweathered condition of the underlying Atherfield Clay, a feature that suggests strong periglacial scouring.

The three grey horizons in the upper half of the tufa are thought to represent standstill phases in accumulation, and would therefore reflect minor condensed sequences. This suggestion is supported by the fact that some species (eg. Oxychilus cellarius) first appear at the base of such horizons, without obvious ecological reason. Moreover the total number of shells extracted from these levels is usually considerably greater than from the contiguous samples taken immediately above or below these "soils". The upper "soil" (120 - 124 cm) is an exception in this respect; the two lower soils are rather more substantial and presumably more mature.

The lithology of the tufa changes from a loose greyish nodular form at its base to a rather softer granular variety in the upper levels. The nodular tufa appears to have formed rather rapidly. The faunal record is rather monotonous throughout much of this material suggesting that no great length of time was involved in its formation. This change might well reflect differing water regimes, from a flowing stream (but certainly no more than a film) to a marshy seepage. The faunal evidence of the mollusca and ostracoda is in agreement with this contention; it is noteworthy that no mollusca or ostracods characteristic of large bodies of standing or flowing water were recovered. The sequence includes zones a to d₂.

7. BLASHENWELL, DORSET

i. Introduction

The deposit of tufa at Blashenwell Farm, near Corfe in Dorset, is the most extensive known from southern England and consequently has attracted much attention. It was first described by Mansel-Pleydell in the 1850's and his subsequent account published in 1886 aroused the interest of many geologists including A.R. Wallace. However the first detailed account of the site was published a decade later by Clement Reid (1896) who described a "kitchen midden" containing microlithic flint chips and charcoal, as well as bones of animals and shells of marine molluscs which had evidently served as food. He also described the stratigraphy and lists the non-marine molluscs he obtained from the tufa, ending his excellent account with the quotation I have used on the title page. Bury (1950) visited the site and extended the faunal list (determinations by A.S. Kennard) and reassessed Reid's work in the light of recent knowledge.

ii. Location and Extent

Blashenwell Farm is situated about 2 km SSW of Corfe Castle, at the foot of the Purbeck ridge. The farm buildings are constructed on Upper Purbeck, and the intermittent calcareous spring rises in the stone-beds of the middle Purbeck and flows across the Wealden Beds into a brook that eventually joins the Corfe River.

The tufa fills a shallow depression, some 600 m in length and forms a tongue covering about 20 acres that slopes gently towards the north-west. (Fig.12). The tufa was said to be about 3 m thick at its western margin (Reid, 1896), although augerings have shown it to be somewhat thicker (over 4 m) in the field just east of the road at SY 95228045.

Two pits have been opened in the tufa, which has been used for marling the heavy Purbeck clays in the fields south of the farm. The main pit (200 m north of the farm) was

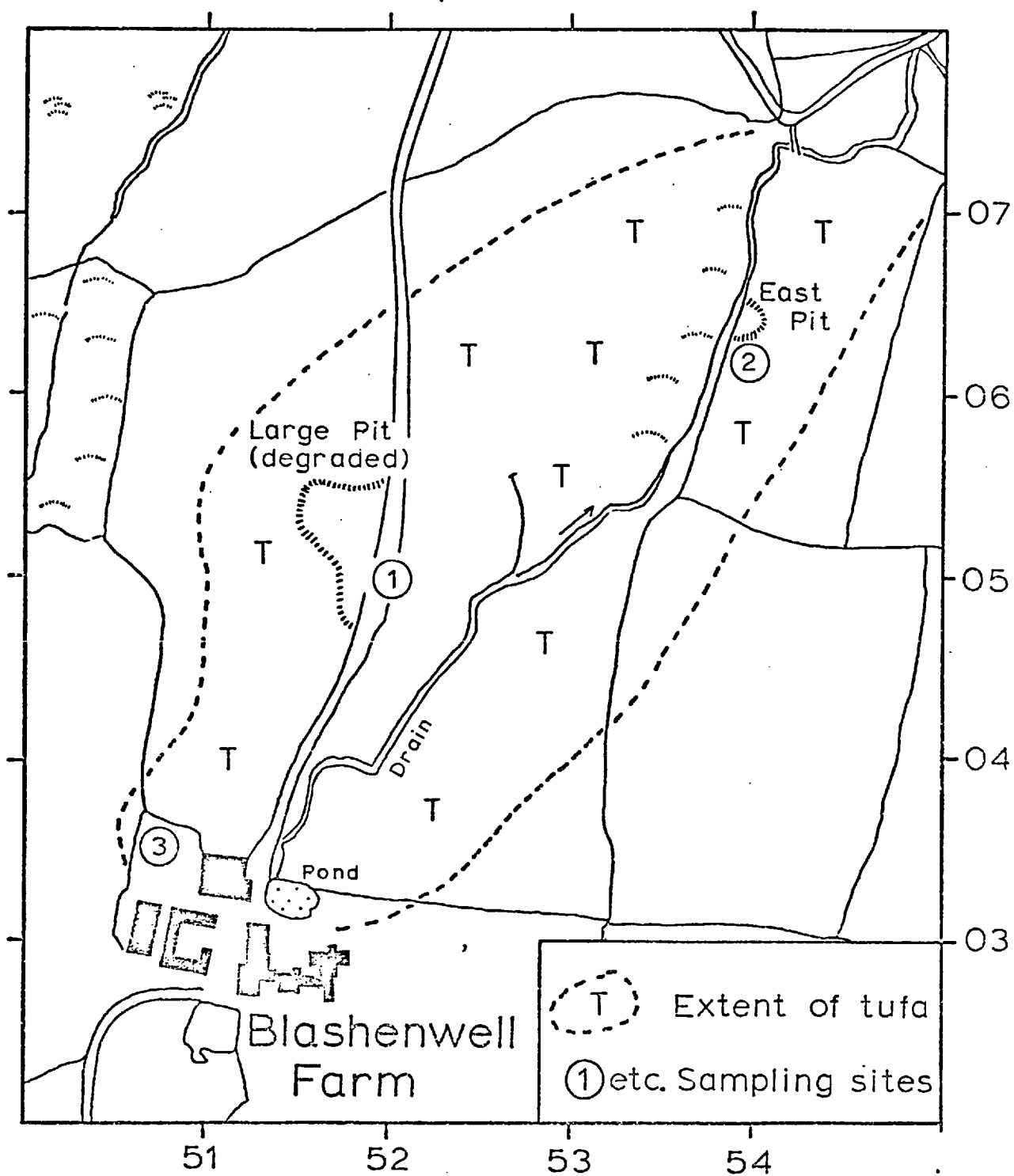


Fig 12

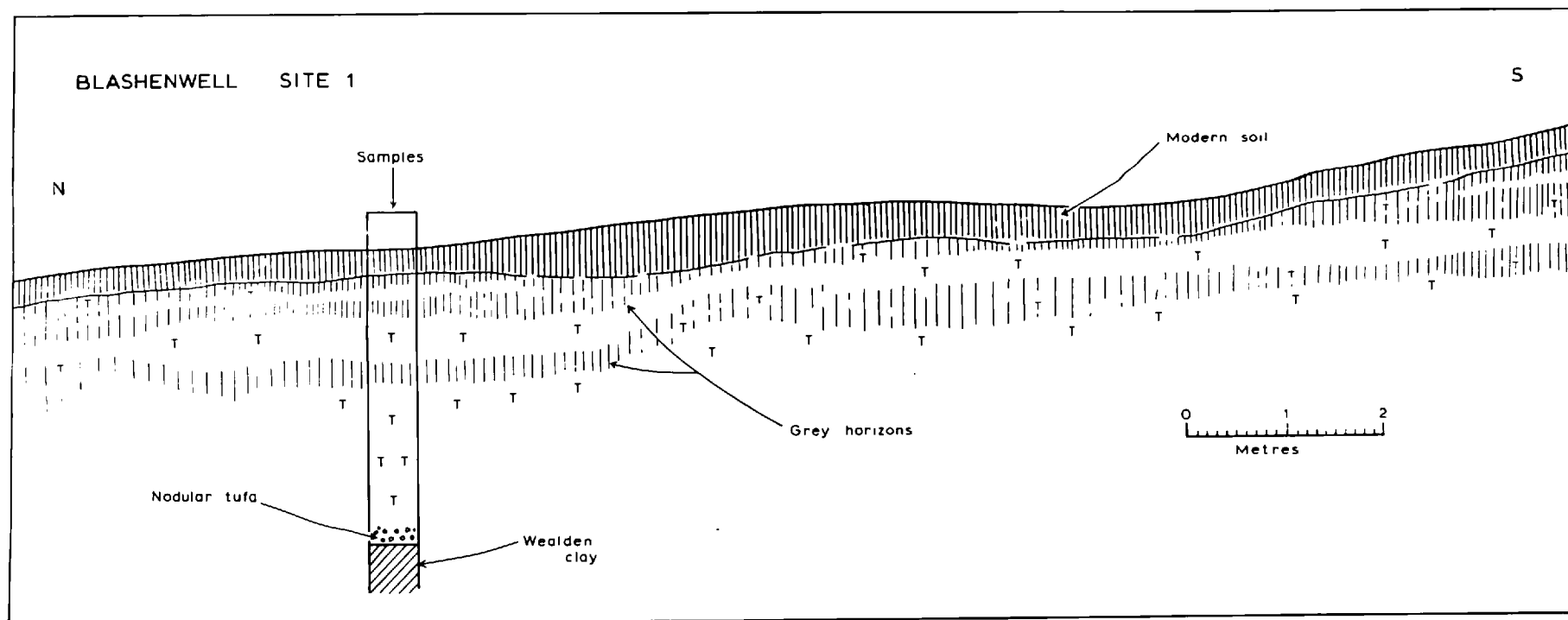


Fig 13

divided by the road into two parts, east and west. The western part was the largest and was the site examined by all previous workers. This has now been infilled and became an arable field in about 1952. Remnants of the eastern part can still be seen forming a bank 1.5 m high, extending for about 25 m at SY952805 (SITE 1).

The second smaller pit (East Pit) was cut in the eastern margin of the tufa at SY95398064. It is now overgrown but a section (SITE 2) was prepared in October 1975 and found to differ in lithology and faunal content (TABLE 4).

Tufa nearly 1 m thick was also exposed during recent building operations at SY95068035 (SITE 3). Detailed sampling was not undertaken, but the fauna was identical to that from the upper levels of Site 1.

These relations are shown in Fig 12

iii. Stratigraphy

The exposure in the roadside bank site 1 (ie. remnants of the eastern part of the large pit) was cleaned and a pit excavated at what seemed to be its thickest point (Fig.13). The following stratigraphy was revealed.

0 - 25 cm	Modern rendzina soil	
25 - 40 cm	Grey tufa 10YR 6/2 Pisolitic in places	"Granular tufa"
40 - 50 cm	Pale white tufa 10YR 7/2	
50 - 70 cm	Grey tufa	
70 - 112 cm	White tufa	-----
112 - 142 cm	Grey tufa	
142 - 300 cm	Pale white tufa becoming nodular towards base	"Loamy and marly tufa"
300 cm ⁺	Brown clay - Wealden Beds 7.5YR 5/4	

Reid comments on the occurrence of "a seam containing enough scattered charcoal to change the normal cream-colour to grey" in the large pit, but does not give any indication as to its thickness. At the present sampling point, (see Fig.13)

from which the above measurements were obtained, three distinct grey horizons were seen, although they were found to merge into two main horizons when traced laterally. Although the horizons contained odd charcoal flecks it seems unlikely that this was the cause of the colour difference. Since these grey horizons represent slow phases of tufa growth when the surface of the tufa dried out to some extent (viz the increase of Vallonia costata and decline of Lymnaea truncatula at these levels), the greyness is more likely to be caused by the release of organic material as the result of weathering.

Reid's stratigraphy was based principally on differences in the hardness of the tufa. He records three types and described the general section of the large pit as follows:-

Black soil at its base Roman coins, Romano-British pottery, shells of oyster, whelk, cockle, Helix aspersa, H. ericetorum, H. virgata etc.

Hard tufa with leaves of hazel, elm, and oak, land-shells, flint-flakes, and charcoal.

Granular tufa, fairly soft, flint-flakes, bones of pig and deer, limpets and other marine shells, land snails, including Clausilia laminata, Bulimus montanus etc., much charcoal.

Loamy and marly tufa, with small land-snails, occasional Limnaea truncatula, rare flint-flakes, and charcoal.

Loam with stony base.

Bury (1950) visited the large pit between 1938-42; and states that Reid's "Hard tufa" occupied only a very small area on the western side, was never more than a few inches thick, and was much broken up: it was far more crystalline than the layers below and the surface was sometimes botryoidal, while concentric rings of stalagmitic calcite were frequent, surrounding holes which had evidently been formed by sticks." He records "granular tufa" to a depth of 4', which he found distinctly hard and which passed down into softer tufa more prolific in shells.

In the present section, the tufa became distinctly harder (a hammer and chisel were needed during sampling) above the lowest soil (cf 112 cm), shells became increasingly more difficult to extract and were badly encrusted. This is presumably Reid's "Granular tufa" and that below his "Loamy and Marly tufa", although there was no visible distinction. No trace of his "Hard tufa" was seen in the present section although very hard lumps were found in the field west of the road. The tufa became rather nodular towards the base and rested on brown Wealden clay. The ovoidal or cylindrical nature of these tufa nodules suggests that the discharge of water was at times sufficient to produce rolling. This view is supported by the molluscan evidence discussed in the next section.

Whether these gross differences in the hardness of the tufa are primary and if so what they represent in terms of depositional environments, it is not possible to say.

iv. Non-marine Mollusca

Shells were very common in the marly tufa and their preservation excellent, many were as translucent as modern shells. Large totals however were hard to extract from the granular tufa and many shells were encrusted. A variety of methods outlined earlier (p 28) were employed to disaggregate this material. Generally the sample size had to be increased to 1 kg in order to obtain a statistically adequate sample. The results are tabulated in Appendix 2ii and plotted graphically in Fig 14 .

The general nature of the fauna is one of marshy ground but not of a well vegetated fen. Succinea is absent and there are no swamp Vertigo (ie antivertigo, moulinsiana and angustior). Vertigo moulinsiana was however recorded from the East pit which clearly reflects a more swampy facies. Lymnaea truncatula however was very common in the basal samples of nodular tufa and frequent throughout the rest of the sequence with the exception of the grey horizons where conditions seem to have become too dry for its survival. It is present in the upper "soil" (25 -

40 cm) where it is joined by Anisus leucostoma and Aplexa hypnorum, which indicate that boggy pools were present on the surface of the tufa towards the end of its formation.

Vallonia pulchella and the marsh element composed of Zonitoides nitidus and Carychium minimum reach their highest proportion in the basal samples. The fauna and nodular lithology suggest wet conditions. There is then a big drop in the proportion of Lymnaea truncatula and a corresponding decline in this marsh element coinciding with an increase in the shade-demanding fauna.

At first this shade-demanding group was composed of Carychium tridentatum, Acanthinula aculeata, Clausilia bidentata and Aegopinella spp, together with Vertigo pusilla, V. substriata, V. alpestris, Oxychilus alliarius and Lauria cylindracea. Discus ruderatus was also present in low numbers but was replaced by Discus rotundatus at 210 cm. Ashfordia granulata first appears at 160 cm and quickly outnumbers Trichia hispida until about 75 cm when the latter becomes more prominent again.

Oxychilus cellarius first appears at 135 cm and seems to replace Oxychilus alliarius. From about this point upwards, which roughly corresponds to the division between "marly" and "granular" tufa, important ecological changes are seen. Firstly there is a significant decline in the shade-demanding element and an apparent disappearance of several other species such as Vertigo alpestris and Oxychilus alliarius.

The proportion of catholic species (eg. Cochlicopa lubrica, Punctum pygmaeum, Vitrea contracta, Nesovitrea hammonis etc.) increases. At the grey horizons there is a minor reversal in this trend, the woodland species that cause this transient reversal represent the hardiest (ie. least shade-demanding) part of the group; Balea perversa, Ena montana, Zonitoides excavatus are not present at these levels. Also at these horizons Vallonia costata increases in abundance while Leiostylia anglica becomes less common, again suggesting considerable drying. Pomatias elegans and Vertigo pygmaea appear for the first time; their occurrence suggests well drained soils and a considerable opening up of the habitat. Pomatias elegans would

be anomalous in a marsh context and dislikes closed woodland. Vertigo pygmaea although occasionally found in marshes, is more characteristic of open grassland. Clearly there has been a considerable reduction of forest cover that has caused the local extinction of several shade-demanding species and permitted the spread of these more open-country species. Since Blashenwell is a well known archaeological site that has furnished many flints (in fact two were discovered in situ during sampling, see Fig 14) it is tempting to ascribe this clearance to man's activity. If this is correct then here is further evidence of man's early impact on the environment that pre-dates the main Neolithic forest clearance phases. It is interesting to note that Reid connected the cessation of tufa growth with the destruction of the neighbouring forests. There are five species listed by Bury that were not found during the present study. These are:-

Acicula fusca

Cochlodina laminata

Vertigo antivertigo

Helicigona lapicida

Vallonia excentrica

These specimens, now in the British Museum (Natural History), were re-examined. The "Vertigo antivertigo" proved on further cleaning to be typical V. pygmaea. This also applied to other material labelled "Vertigo antivertigo" and deposited in the Institute of Geological Sciences. The Vallonia excentrica are correctly named but almost certainly came from the modern soil overlying the tufa, the same applies to Cecilioides acicula which Bury also lists. The remaining three species were all correctly named and their occurrence in the west portion of the large Pit may possibly indicate slightly heavier shading conditions there. The "Romano-British soil" directly overlying the tufa was not sampled. A full account of the mollusca from this level is given by Carreck & Davis (1955, p. 85 -88).

A section of the East Pit (site 2) nearly 2 m thick was cleaned and sampled, the underlying clay was not exposed. Three spot samples were taken from the Top (cf. 0 - 50 cm), Middle (cf. 100 - 150 cm) and Bottom (cf. 190 - 200 cm). The following species were obtained:-

TABLE 4 East Pit

	Top	Middle	Bottom
<u>Carychium minimum</u> Müller	6	1	-
<u>Carychium tridentatum</u> (Risso)	3	9	5
<u>Lymnaea truncatula</u> (Müller)	1	-	-
<u>Cochlicopa lubrica</u> (Müller)	2	13	6
<u>Columella edentula</u> (Draparnaud)	1	4	6
<u>Vertigo pusilla</u> Müller	1	-	3
<u>Vertigo moulinsiana</u> (Dupuy)	10	-	-
<u>Vertigo alpestris</u> Alder	-	-	1
<u>Punctum pygmaeum</u> (Draparnaud)	-	2	2
<u>Discus rotundatus</u> (Müller)	-	-	3
<u>Vitrina pellucida</u> (Müller)	-	2	-
<u>Vitrea contracta</u> (Müller)	2	1	1
<u>Aegopinella nitidula</u> (Draparnaud)	-	2	1
<u>Oxychilus cellarius</u> (Müller)	1	6	-
<u>Oxychilus alliarius</u> (Miller)	1	-	1
<u>Zonitoides nitidus</u> (Müller)	1	1	1
<u>Euconulus fulvus</u> (Müller)	2	-	1
<u>Balea perversa</u> (L.)	1	-	-
<u>Trichia hispida</u> (L.)	1	1	-
<u>Cepaea/Arianta</u>	1	1	-

A more swampy facies is indicated (viz V. moulinsiana)

v. Marine Mollusca

No marine molluscs were recovered during the present sampling, but the following species are known from the kitchen-midden material (Reid, 1896).

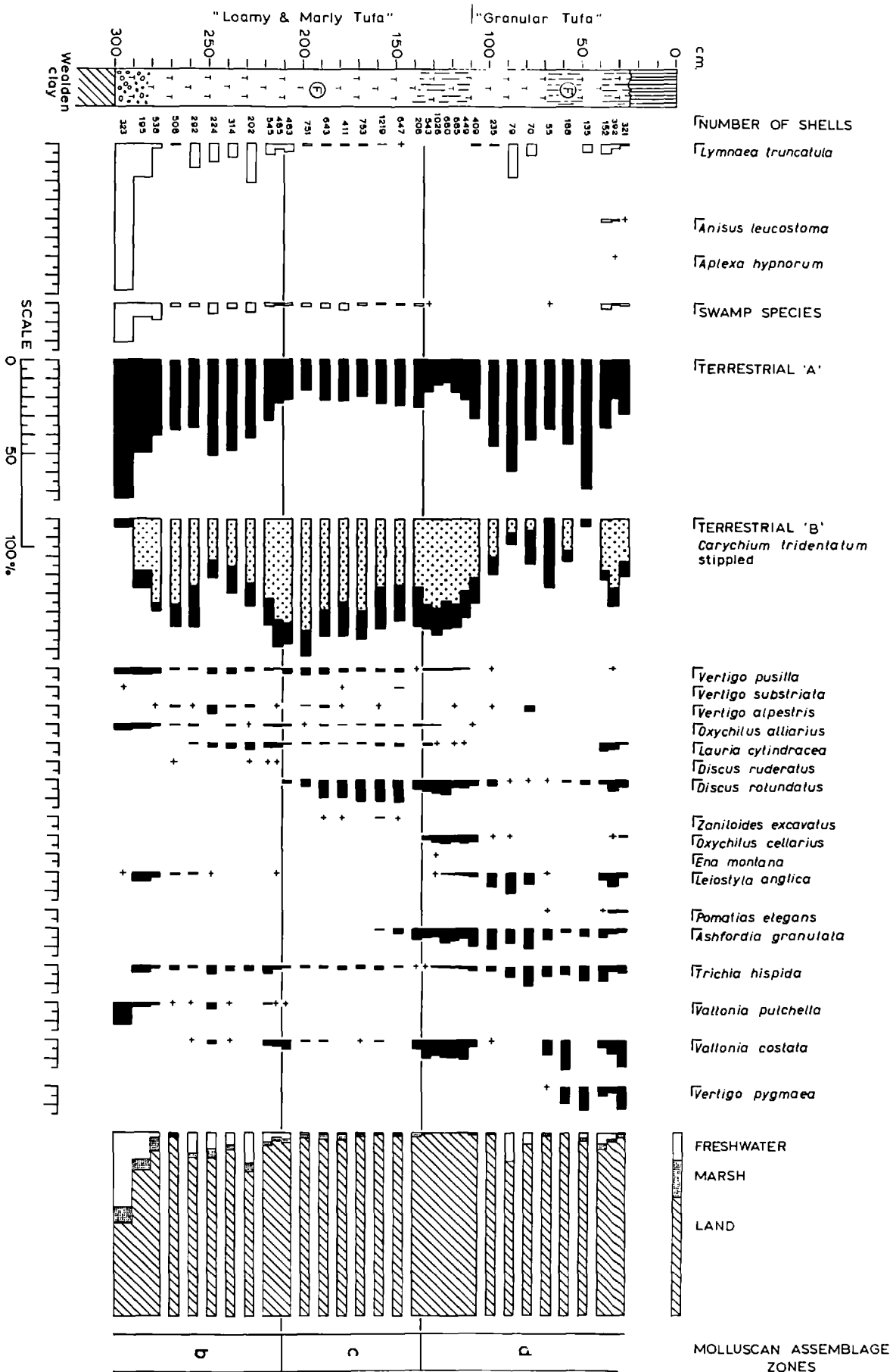
<u>Patella vulgata</u> L	<u>Gibbula tumida</u> * (Montagu)
<u>Littorina littorea</u> (L)	<u>Scrobicularia plana</u> (da Costa)
<u>Littorina littoralis</u> (L)	

From the impoverished nature of the fauna Reid suggests that the original source of the shells was probably in the neighbourhood of Chapman's Pool, about 3 kilometres away from Blashenwell.

* This may be a mis-identification since only Monodonta lineata (da Costa) could be found amongst Reid's material in the I.G.S.

Fig 14

BLASHENWELL



vi. Ostracoda

The following species were recovered (determinations by Dr Eric Robinson).

Depth (cm)	<u>SITE 1</u>			<u>SITE 2 (East Pit)</u>	
	290-300	255-260	110-115	"Top"	"Middle"
<u>Eucypris pigra</u> (Fischer)	2	2	-	1	2
<u>Herpetocypris reptans</u> (Baird)	2	-	-	-	-
<u>Cyclocypris</u> sp	-	-	1	-	-

The numbers refer to individual valves. The presence of boggy pools is suggested.

vii. Vertebrate Remains

The following table lists the vertebrate remains recovered during sampling (determination by Dr A.J. Stuart).

Depth (cm)	55-60	110-115
<u>Apodemus</u> sp (wood mouse)	m ₂	-
<u>Clethrionomys glareolus</u> (Schreiber)		
(bank vole)	-	1'

The occurrence of these species suggests a shaded depositional environment, a conclusion that complements the molluscan evidence. In addition the following species are known (Carreck, 1955):-

- Talpa europaea L. (mole)
- Arvicola sp (water vole)
- Sus scorfa L. (pig)
- Capreolus capreolus (L) (roe deer)
- Cervus elephas L. (red deer)
- Bos sp (ox)

viii. Wood & Charcoal

Minute fragments of charcoal were present throughout the tufa. Those recovered during processing were submitted to Dr J.F. Levy. Many fragments were only a few cubic millimetres in size and lacked sufficient cellular structure to enable confident determination. General descriptions and tentative identifications were attempted on the following:-

- 85-90 cm Vessels: present and solitary. Rays: 3-seriate
Fibres: moderately thick walled. Growth rings:
no complete growth-ring in specimen so cannot
say whether it is a ring porous or diffuse porous
hardwood. Identification: a hardwood.
- 120-125 cm Vessels: small, solitary, showing a radial
arrangement, smaller in late wood. Rays: of two
sizes, (a) uniseriate, (b) 2-3 seriate. Fibres:
small, thin-walled. Growth rings: no complete
growth ring in specimen so cannot say whether
it is a ring porous or diffuse porous hardwood.
Identification: a hardwood.
- 155-160 cm Vessels: present and of two distinct sizes. Large
and solitary in the early wood, but in the late wood,
they are small, partly solitary and partly associated
in groups of 2 or 3, in a radial or oblique
arrangement. Rays: uniseriate. Fibres: either
thin-walled or else thinned by microbial action
prior to charring (i.e. partial degrade). Growth
rings: present, narrow, little wider than twice
the diameter of the early wood vessels.
Identification: a slow grown ring porous hardwood.
Shows many similarities to OAK (Quercus sp), but
no broad rays visible. This may be due to the small
size of the fragments which could have broken between
the broad rays. (Plate 15)

ix. Archaeology

The many flints obtained from the tufa are now housed either in Dorset County Museum (Dorchester) or in the British Museum. The flints are patinated white, mottled with grey patches, but are otherwise in a sharp, fresh condition and are obviously contemporaneous with the tufa. These were examined by Clark (1938; 1939) who suggested that some at least were flaked from beach pebbles. He concluded that "the bulk of the flints certainly belong to a microlithic industry of Mesolithic aspect".

He compares the industry with that from the Prestatyn tufa which he states has Sauveterrian affinities (Clark, 1955).

x. Radiocarbon dates

Although charcoal fragments were conspicuous in the tufa, they were generally very small and insufficient to use for radiocarbon assay. A radiocarbon date of 6450 ± 150 BP (BM-89) had however been obtained from bone material, mainly ox, "from the middle zone" of the tufa. (Barker & Mackey, 1961). Since no sizeable bones were recovered in situ during the present survey, a search was mounted for suitable material from those deposited at various museums, principally Dorset County Museum (DCM), and the Institute of Geological Sciences (IGS). It was hoped that there would be some unwashed bone fragments containing enough adhering matrix, to enable the extraction and analysis of sufficient snails, to yield a spectrum which could then be matched with a comparable level on Fig 14. Three uncleaned bones (labelled Cervus) were discovered in the Dorset Museum and a further two (one Cervus and one Sus) in the Institute of Geological Sciences. The tufa from the interstices (marrow cavities, neural canals etc.) of each bone was then carefully extracted and the contained snails analysed. The results are given in TABLE 5.

Over one hundred shells extracted from 25 g of matrix from one bone (DCM 1). Among these were Pomatias elegans, Oxychilus cellarius and Discus rotundatus. Reference to Fig 14 suggests that this bone must have come from a horizon higher than the level where O. cellarius first appears (i.e. above the level equivalent to 135 cm at site 1). The matrix was distinctly grey (10 YR 6/2) suggesting that it probably came from one of the "soil" horizons. It is interesting to note that Vertigo pygmaea was relatively common in the uppermost grey horizon at site 1, but this species was not represented in the shells extracted from the bone matrix. It is tempting to speculate that one of the lower soils was the possible source (i.e. 50 - 70 cm or 112 - 142 cm). Only a re-excavation and detailed biostratigraphical analysis of the original large pit would resolve the problem. This bone (DCM 1) together with a

smaller fragment (DCM 2) which yielded a similar snail assemblage were submitted to Mr R. Burleigh for radiocarbon assay. The radiocarbon dates so derived were as follows:-

DCM 1	BM-1257	5751 $\pm$ 142
DCM 2	BM-1258	5425 $\pm$ 150

Very low numbers of shells were recovered from the matrix of the other bones which were therefore disregarded as their stratigraphic provenance could not be ascertained.

xi. Conclusions

The sequence can be divided up into three ecological phases:-

- (1) an early marsh ground phase with water flow sufficient to produce a nodular lithology
- (2) the development of a shaded environment
- (3) a partial opening up of the habitat, which has tentatively been ascribed to anthropogenic disturbance. Boggy pools persist throughout.

This sequence embraces mollusc zones b to d. Note, these zone boundaries do not correspond to the three ecological phases.

It is also clear that local environmental factors play an important part in determining the nature of the molluscan fauna. A more swampy facies was present in the East Pit (site 2), while published faunal lists suggests heavier shading on the western extremity of the tufa.

The three radiocarbon dates now obtained cover a period of just over one thousand years (6450 BP to 5425 BP). All were derived from bone material from kitchen-midden debris and suggest a lengthy occupation of the site. Indeed Reid records the occasional flint-flake from the base of the tufa. The occurrence of marine shells of probably local origin in the midden debris suggests that the site was occupied after the main eustatic rise of sea level.

TABLE 5 Shells extracted from the matrix of museum bones
from Blashenwell

Source	Dorset County Museum		
	<u>Cervus</u>	<u>Cervus</u>	<u>Cervus</u>
Specimen / index No.	DCM1	DCM2	DCM3
Dry weight (g)	25	8	15
<u>Pomatias elegans</u> (Müller)	1	1	1
<u>Carychium tridentatum</u> (Risso)	65	11	3
? <u>Lymnaea truncatula</u> (Müller)	1	-	-
<u>Anisus leucostoma</u> (Miller)	-	1	2
<u>Cochlicopa lubrica</u> (Müller)	5	1	-
<u>Columella edentula</u> (Draparnaud)	4	-	-
? <u>Lauria cylindracea</u> (da Costa)	1	-	-
? <u>Vallonia pulchella</u> (Müller)	1	-	-
<u>Acanthinula aculeata</u> (Müller)	1	-	-
<u>Punctum pygmaeum</u> (Draparnaud)	2	-	-
<u>Discus rotundatus</u> (Müller)	3	5	2
<u>Vitrea pellucida</u> (Müller)	-	-	1
<u>Vitrea crystallina</u> (Müller)	10	1	-
<u>Aegopinella pura</u> (Alder)	1	-	-
<u>Aegopinella nitidula</u> (Draparnaud)	4	-	-
<u>Oxychilus cellarius</u> (Müller)	4	1	1
Limacid plates	4	4	1
<u>Euconulus fulvus</u> (Müller)	1	-	-
<u>Cochlodina laminata</u> (Montagu)	1	-	-
<u>Clausilia bidentata</u> (Ström)	1	-	-
<u>Ashfordia granulata</u> (Alder)	1	1	1
<u>Trichia hispida</u> (L.)	1	-	-
<u>Arianta arbustorum</u> (L.)	1	1	-
<u>Cepaea nemoralis</u> (L.) bandless	1	-	-
<u>Cepaea hortensis</u> (Müller) banded	1	1	1
(<u>Patella vulgata</u> L. limpet)	1	-	-
Radiocarbon dates:	BM-1257	-	BM-1258
	5751±142		5425±150

Note, the presence of Cochlodina laminata and Vitrea crystallina, species that were very rare at Site 1.

Institute of Geological Sciences

CervusSusPatella

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8. CAERWYS, FLINTSHIRE

i. Introduction

The deposits of tufa that lie in the valley of the River Wheeler (on the south side of the Carboniferous Limestone ranges of North Wales) are the most extensive known from Britain. They were first described by Maw (1866) and subsequently by M'Kenny Hughes (1885), Strahan (1890), Jackson (1922), Wedd & King (1924) and McMillan (1947). During the 1950's a Committee was established by the Liverpool Geological Society to "encourage and co-ordinate research on the tufa near Caerwys." Despite this obvious interest only a single report appears to have been published (Anon, 1956). The various maps and diagrams that were prepared (but not published) by the committee have been deposited in the Department of Geology, University of Liverpool.

ii. Location and Extent

The tufa occupies two adjacent ravines entering the Wheeler valley on its north side, one at Afon-wen (meaning "white river") in the neighbourhood of Caerwys, the other at Ddôl near Ysceifiog, about a kilometre to the east. According to Maw (1886) the tufa commences against the limestone and expands downwards through an altitudinal range of about 150 feet, in broad delta-shaped masses, towards the main valley, where it seems to have been arrested on the north bank of the Wheeler. Figure 15 shows the location of the principal workings in the tufa. The majority of these are now overgrown but sections can still be seen at SJ 128138 (Site 1, large quarry), SJ 131718, SJ 143143, SJ 142713 (SITE 2) SJ 138142. Detailed sampling was only undertaken at sites 1 and 2. The tufa is still quarried for agricultural lime at Site 1. Jackson (1922) has estimated that the total area occupied by both masses must be at least 200 acres. The streams which have incised the deep ravines through the tufa show it to be nearly 10 m thick in places.

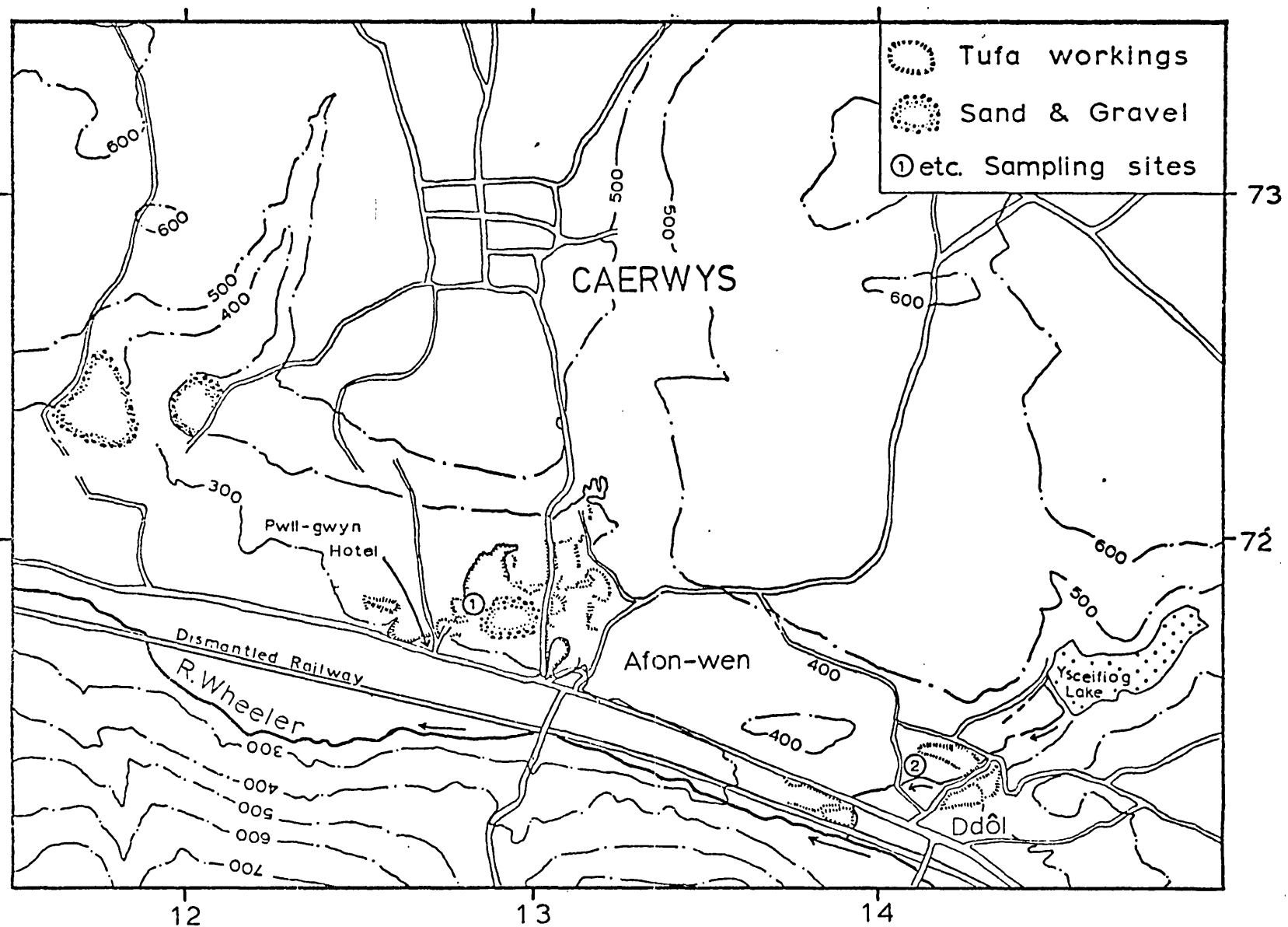


Fig 15

iii. Stratigraphy

SITE 1, CAERWYS, Large Quarry, SJ 128138 (Fig 16)

The stratigraphy of the tufaceous deposits in the quarry is very complex with every lithological gradation from soft "lake marls" with charophytes and Lymnaea peregra through pure tufa with terrestrial mollusca to hard stalagmitic deposits present in caverns beneath the quarry floor. Cummins (in Anon, 1956) has recognized six lithological types: pisolite-crumby tufa - fine granular tufa - tough "cheesy" tufa - grey tufa - peat. The distinction between each member of the series is not sharp and they often grade so imperceptibly into one another both laterally and vertically, that it is not possible to draw a boundary. The beds are often lenticular and where boundaries are definite, may be seen to be interleaved. This means that the differences between the deposits and hence presumably between their modes of deposition, were of degree only and not of kind. Moreover several different types may have been forming contemporaneously and in close proximity.

Some very general comments can however be made. The deposit reaches its greatest thickness in the northern face of the quarry where it is at least 10 m thick. The underlying glacial sands and gravels are exposed in places. Much of this tufa forms very hard ledges and is quite unsuitable for molluscan analysis, although leaf impressions are abundant. Soft "lake marls" are interbedded with these harder masses. The term "lake marl" is used in a rather general sense, the molluscan fauna of these deposits contain abundant freshwater shells especially Lymnaea peregra and are clearly formed sub-aqueously. Land snails are occasionally present although they are invariably absent from true lake marls.

These hard, horizontally bedded, tufa ledges form the upper levels of the succession in much of the quarry. These overlie rather softer material. A prominent soil forms a distinct marker horizon on the east face and the same soil can be traced on the western margin. This "soil" is in fact a soil complex and represents the conjunction of at least three separate soil

horizons (See Fig. 16). It is very hard to trace this horizon across the north face due to the nature of the lithology.

The stratigraphy appeared to be most complete towards the southern limit of the East face, i.e. near the quarry entrance. It was evident that these were marginal deposits of a rather more terrestrial character. A clean vertical face was prepared and a scale drawing made (Fig. 16). The stratigraphy at the principal sampling site (Series A) was as follows:-

0 - 40 cm	Modern soil
40 - 85 cm	Rubbly colluvium
85 - 300 cm	Hard horizontally bedded tufa ledges with occasional interbedded "lake marls"
300 - 312 cm	Grey (10 YR 5/1) horizon
312 - 351 cm	Pale white tufa
351 - 361 cm	Grey (10 YR 6/1) horizon
361 - 375 cm	Pale white tufa
375 - 393 cm	Dark grey (10 YR 4/1) horizon with sharp black (10 YR 2/2) base.
393 - 430 cm	Nodular tufa, many encrusted stems
430 - 460 cm	Pale white (2.5 Y 8/2) tufa
460 - 461 cm	Grey organic streak
461 - 530 cm	Pale white tufa
530 - 533 cm	Grey (10 YR 5/1) organic streak
533 - 565 cm	Hard tufa with leaf impressions
565 - 568 cm	Grey (10 YR 5/1) horizon
568 - 648 cm	Hard tufa (with occasional leaves), nodular in places.
648 - 651 cm	Grey horizon
651 - 836 cm	Tufa, varied coloured hues 10 YR 8/4 to 5Y 6/2, 10 YR 6/4 towards base (waterlogged)
836 cm ⁺	Glacial sand and gravel. 5YR 4/4.

A mechanical excavator was used to construct a pit that extended beneath the quarry floor (i.e. c.530 - 720 cm). The stratigraphy of the deposits below 720 cm was demonstrated by

augering. The tufa forming the east face of the pit comprised several large boulder-size blocks. The stratigraphy of the north face of the pit however was much easier to discern and the material looked far more promising from the molluscan viewpoint. It was this material that was sampled (Series B). The stratigraphy of the north face of the excavated pit was as follows :-

0 - 2 cm	Organic streak (10 YR 5/1)
2 - 42 cm	White (10 YR 8/3) tufa
42 - 62 cm	Nodular tufa
62 - 65 cm	Grey (10 YR 5/1; 4/1 in places) horizon
62 - 93 cm	Nodular tufa
93 - 95 cm	Grey horizon
95 - 120 cm	Nodular tufa
120 - 125 cm	White tufa
125 - 128 cm	Grey horizon
128 - 305 cm	White (10 YR 8/4) tufa, becoming light olive grey (5Y 6/2) below the water table
305 cm ⁺	Glacial sand and gravel 5YR 4/4 (Reddish brown)

The stratigraphy was not horizontal, so that it is not altogether easy to relate exactly this sequence (Series B) with the main sequence (Series A). However the organic streak forming the top of Series B (i.e. 0 - 2 cm) is the same streak the occurs at 460 - 461 cm in Series A. There is therefore a vertical difference of about 60 cm and a slight overlap in sampling. These relationships are demonstrated in Fig 16 which also shows that the prominent grey horizon (375 - 393 cm) divides when traced laterally towards the north. There is a marked lithological break at the base of this horizon which would seem to be an erosion surface. Accumulation seems to have been rather more continuous towards the north and a third series of samples were taken there (Series C). The stratigraphy of the sampling column here was as follows:-

0 - 10 cm	White (10 YR 8/3) tufa (zero is an arbitrary datum)
10 - 29 cm	Grey (10 YR 4/1) horizon
29 - 55 cm	White (10 YR 8/1) tufa

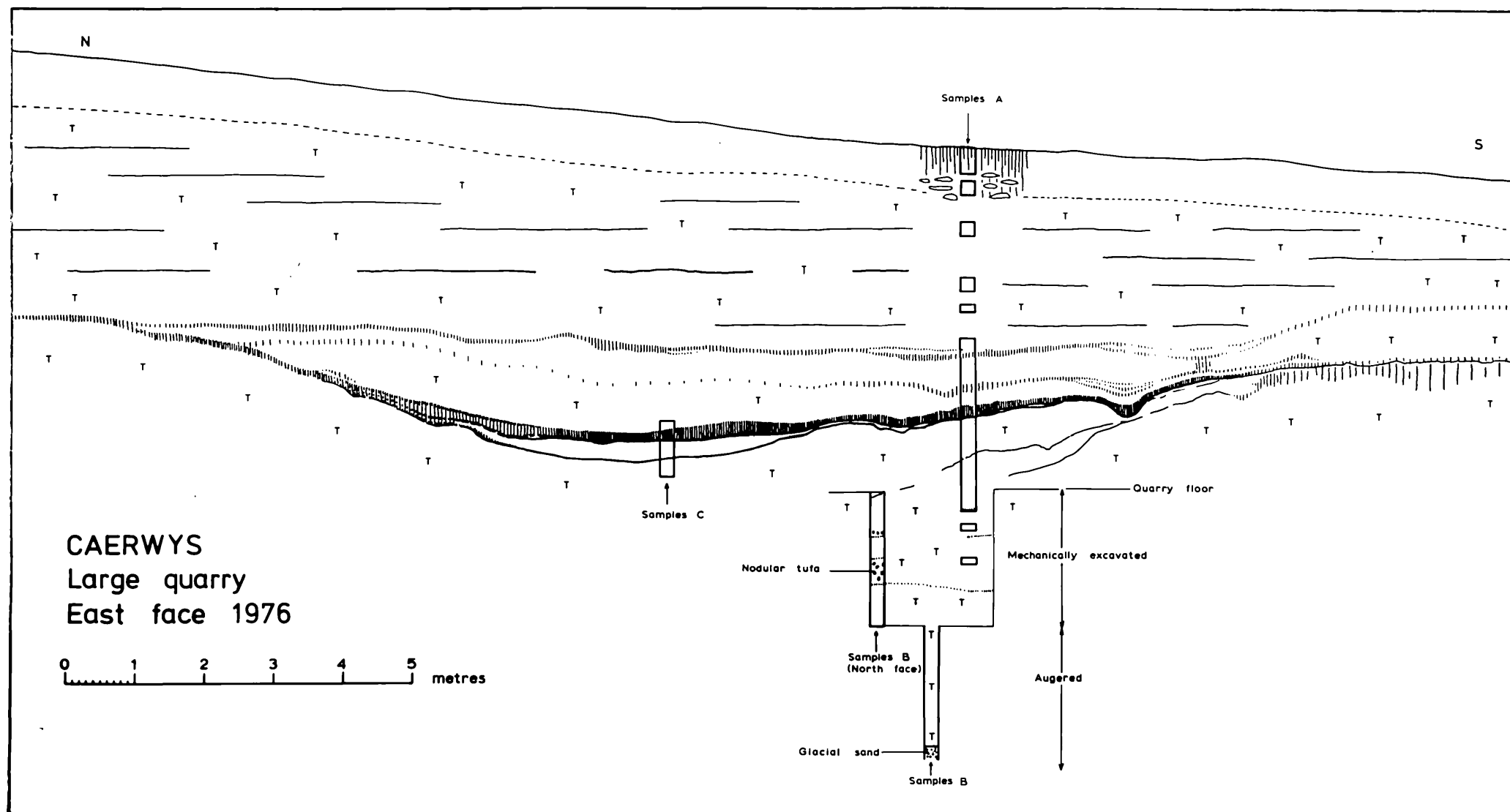


Fig 16

- 55 - 56 cm Organic streak (10 YR 3/1)
 56 - 70 cm⁺ Nodular tufa (10 YR 7/1)

iv. Mollusca

Freshwater and swamp mollusca are common throughout the sequence (Fig 17). In the basal material (Series B) at least three "flooding horizons" are discernable (see far right of Fig 19). The ecological succession changes from an assemblage dominated by freshwater shells to one dominated by marsh species and finally one where land mollusca predominate until the next flooding episode. This is the very sequence that one would expect as the result of the alternate flooding and draining of a freshwater swamp and is analogous to a botanical hydrosere. This ecological sequence is even more clearly demonstrated in Fig 20.

The freshwater species present are those that might be expected in small bodies of well-vegetated water. Gyraulus laevis (and Armiger crista) are pioneer species are quick to colonize newly-created "raw" lakes. These are common, for example in the many lakes that formed in the marshy hollows between drumlins etc. during the late-glacial. Their presence at Caerwys (between 490 - 393 cm, Series A) together with the total absence of any species characteristic of large permanent bodies of water, reinforces the idea that these pools, although well vegetated were transient features. The nodular tufa additionally contains Ancylus fluviatilis (and Pisidium casertanum and P. personatum) which suggests flowing water between 410 - 390 cm.

It is interesting to comment on the antipathetic relationship between Lymnaea peregra, typical of the wetter phases and Lymnaea truncatula which occurs most frequently in the soil horizons.

Both Vertigo genesii and V. geyeri were recovered from the basal levels (Series B). Vertigo moulinsiana was an interesting associate since these species rarely or never co-exist today. The presence of V. pygmaea suggests a rather open habitat but this species is not uncommon in marshes. Vertigo antivertigo

and V. angustior were common throughout much of the sequence, although the latter species was not present above 380 cm.

Specimens of Oxyloma greatly resembling sarsi were also detected in these basal samples. Further specimens of O. cf. sarsi were obtained from the basal levels of the section at SJ 131719, these are illustrated in Plate 3. There are very few fossil records of this species and its former occurrence in North Wales is far beyond its present day range. Succinea oblonga was also present but occurred stratigraphically higher in the sequence, first appearing at the base of the "upper" soil (308 - 312 cm, Series A) and was consistently present thereafter.

The land mollusca from the basal levels (Series A & B) are dominated by climatically tolerant species (Terrestrial 'A') together with those characteristic of open country (Vallonia, Pupilla). At the top of series B Carychium tridentatum and Leiostyla anglica make their first appearance to be joined by Vertigo pusilla and Oxychilus alliarius in the organic streak in the uppermost 2 cms. This sequence compares well with the basal levels in series A (there is a slight overlap in the sampling).

The pronounced lithological hiatus at 393 cm also delineates a marked faunal boundary. As stated earlier this soil (375 - 393 cm) has formed on an erosion surface. The nodular lithology rich in freshwater and swamp species is abruptly replaced by a grey tufaceous silt rich in land mollusca. Several species (eg. Discus rotundatus, Spermodea lamellata) appear for the first time at the base of this soil. Discus ruderratus is also present and conditions favoured the re-expansion of other species eg. Leiostyla anglica, while others declined in numbers or became extinct eg. Vallonia.

Fig 16 demonstrates that when traced laterally this "soil" horizon divides, so that there is about 25 cms present about 4m to the north which is not represented in Series A. A large shed prevented the main sampling column being taken from this point. Additional samples (Series C) were taken through this material in the hope of obtaining a more continuous record for this critical level. The results (Appendix 2v) are presented in Fig 20. Two further specimens of Discus ruderratus were recovered, but D.

rotundatus was also present at the same level. However the real expansion of the latter species did not occur until the base of the main soil (27 - 29 cm). Vertigo alpestris is also present and shows an interesting sympathetic relationship with V. pusilla. The presence of Zenobiella subrufescens and Zonitoides excavatus, suggesting considerable shading, are noteworthy. Z. subrufescens has only been found fossil at two other British sites, at Tornewton (Kerney, 1976 c) and a tufa at Nash Point (J.G. Evans, personal communication).

Oxychilus cellarius appears abruptly between 375 - 380 cm (Series A) and occurs in an identical fashion between 5 - 10 cm (Series C).

Local environmental conditions again clearly effect the fluctuation in the number of certain species. Pupilla muscorum reaches its greatest abundance during the comparatively dry phases while Leiostyla anglica flourishes in the intervening damp intervals. This striking antipathetic relationship is clearly shown in Fig 18.

The presence of Pyramidula rupestris is of considerable interest since there are very few records of this species in stratigraphically well dated contexts. The single specimen was almost certainly derived from ancient populations living on the nearby Carboniferous Limestone, where the species still flourishes today.

Lauria cylindracea is unusually rare throughout much of the sequence, only becoming at all frequent in the upper levels of the tufa.

Towards the top of the deposit, the horizontally bedded tufa had been weathered into small slabs which had become incorporated into a colluvium, giving a rather "rubbly" appearance. This yielded an essentially open-country assemblage, rich in Vallonia (costata and excentrica), Pupilla, Trichia, Vertigo pygmaea and Pomatias elegans. The occurrence of fossil Pomatias at Caerwys is of particular interest for it throws light on the antiquity of the living colonies that survive in that neighbourhood today. These North Welsh colonies are separated by over

150 km from the nearest living population. Fossil Pomatias were also recovered in large numbers from a hillwash to the east of the B 5122 at SJ 131719. No specimen however was detected in the main body of tufa and the stratigraphical context of both Jackson's and McMillan's records require careful checking.

Two samples through the modern soil were taken. Again an open-country fauna, similar to that living on the site today, was present. Helix aspersa, Ashfordia granulata and Candidula intersecta occurred for the first time. Cecilioides acicula was also present but owing to the subterranean habits of this species it was difficult to be sure to what extent the shells recovered were intrusive; though obviously fresh shells were ignored, it is possible that all were modern.

v. Ostracoda

All ostracods retained by a 30 mesh BS sieve were picked and scored in the usual way. Dr Eric Robinson is responsible for the identifications.

Figs 21 and 22 plot the results. The following eleven species have been recovered from Caerwys (Series A, B & C).

Ilyodromas olivaceus (Brady & Norman)

Eucypris pigra (Fischer)

Potamocypris wolfi (Brehm)

Potamocypris villosa (Jurine)

Potamocypris cf. maculata (Alm)

Cypridopsis sp

Herpetocypris brevicaudata Kaufmann

Notodromas monacha (Müller)

Candona candida (Müller)

Candona neglecta Sars

Nannocandona faba Ekman

The interpretation of the results is far from easy. The ecology of these species ranges from Absolon's 'Quellkalke' association, through 'Bachkalke', 'Sumpfkalke' and finally

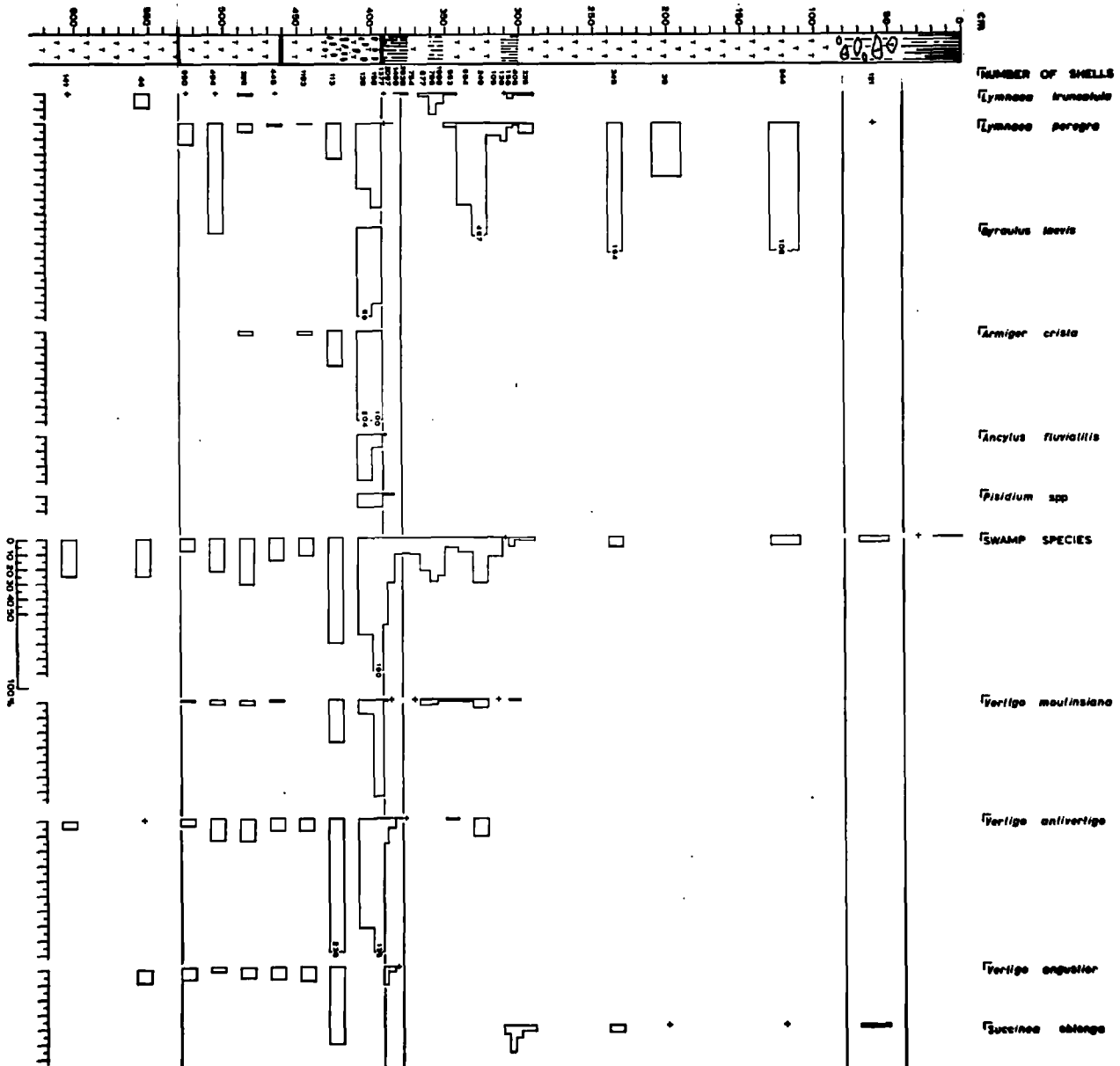
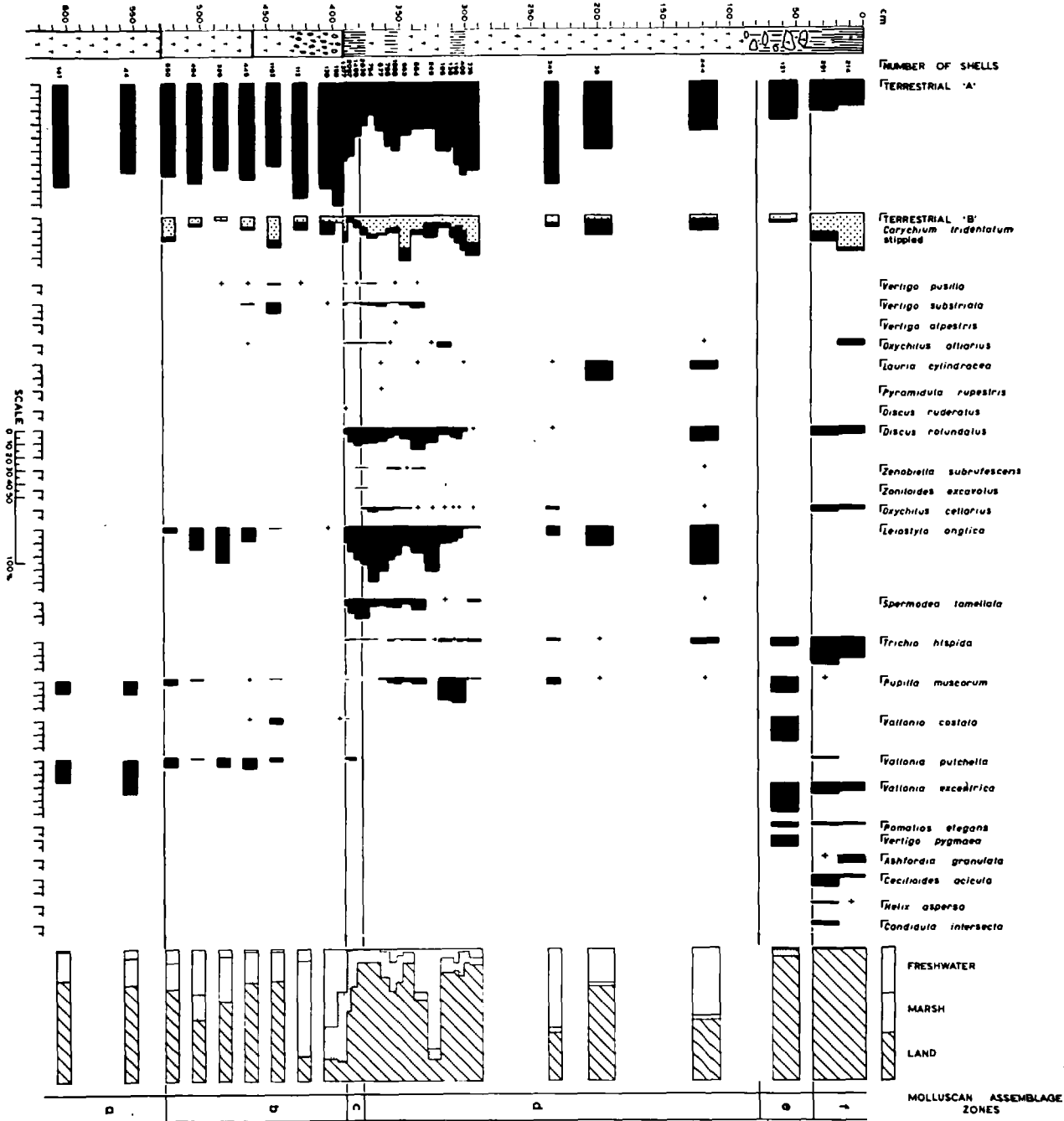


Fig 17

Fig 18



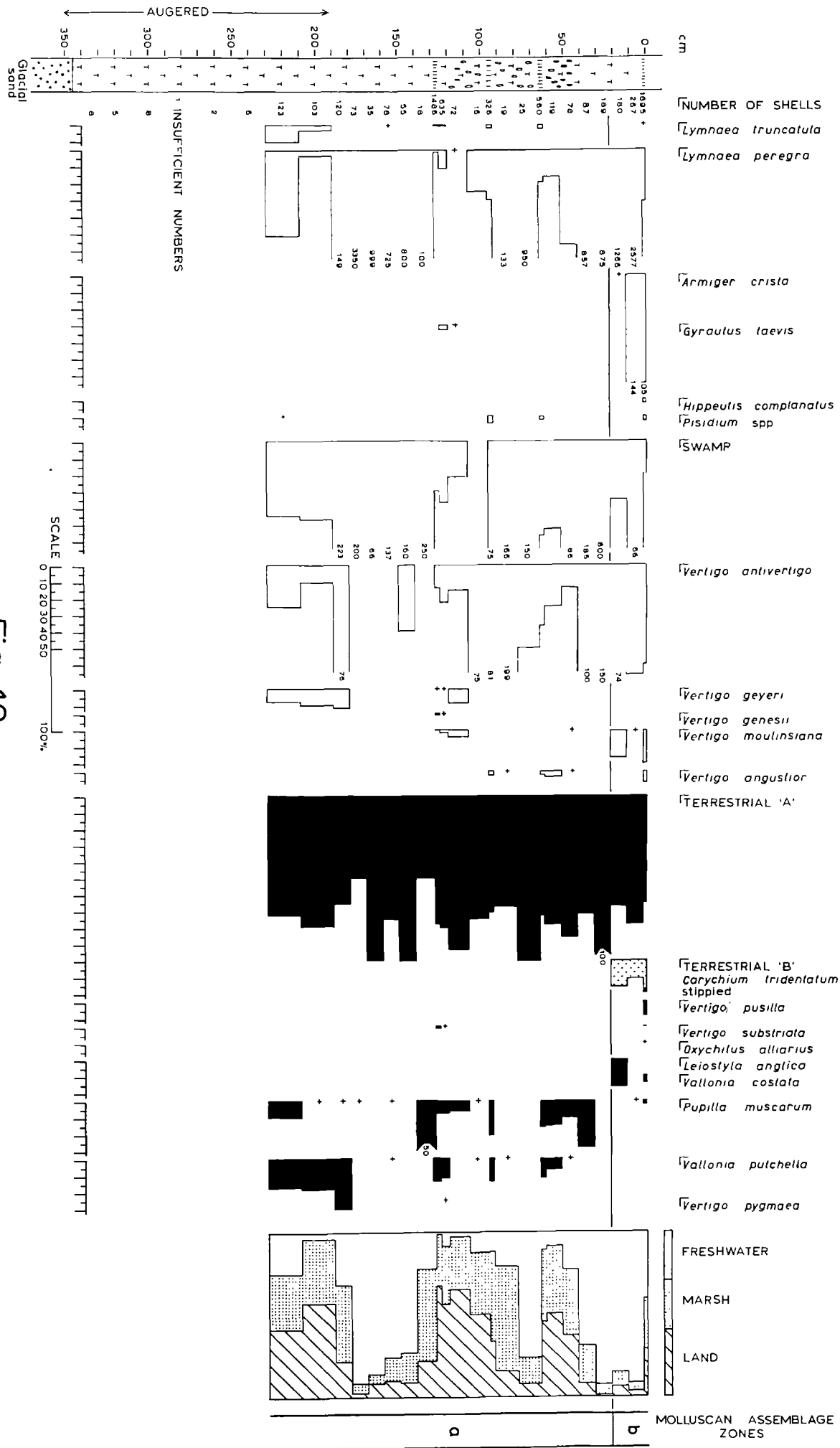


Fig 19

Fig 20

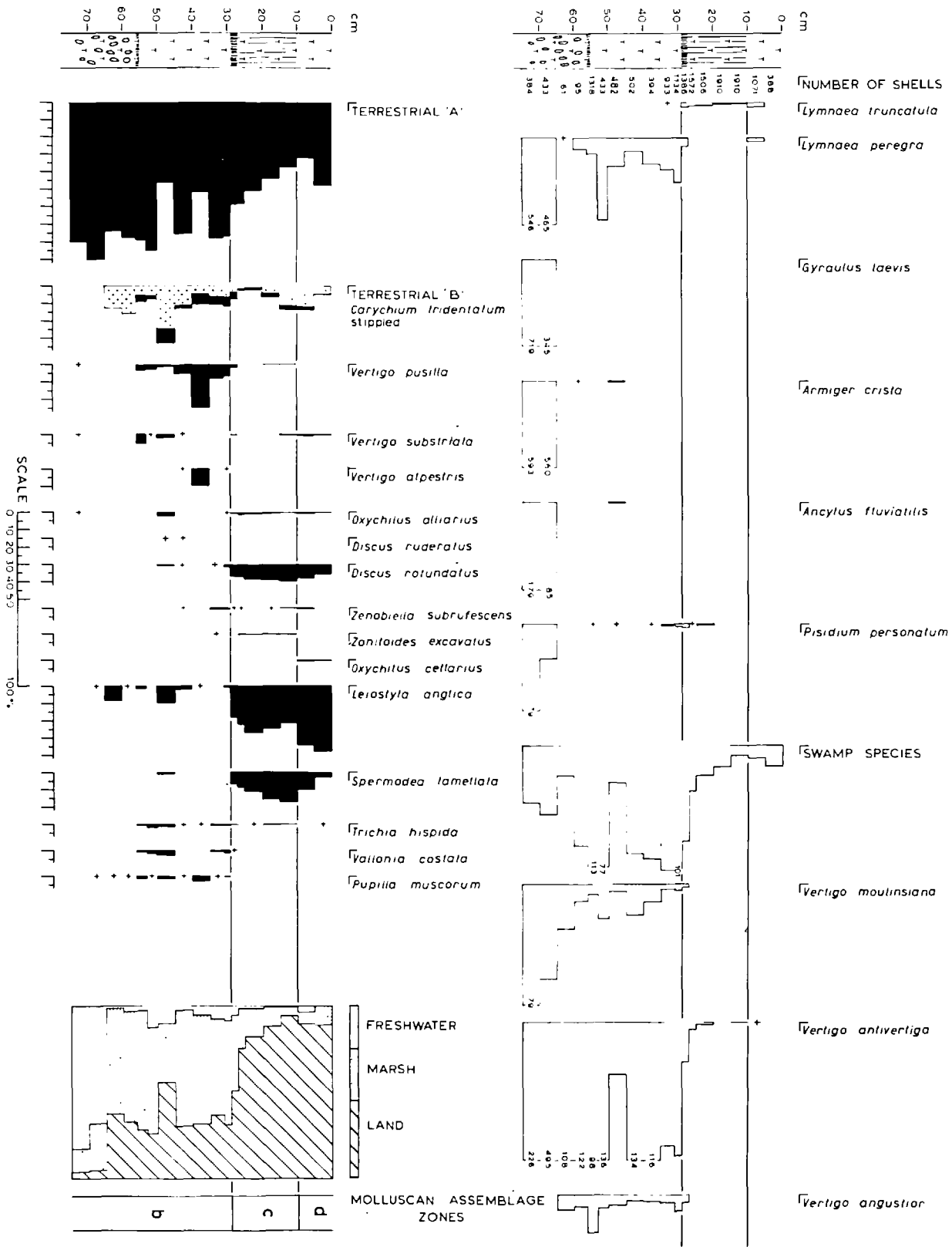
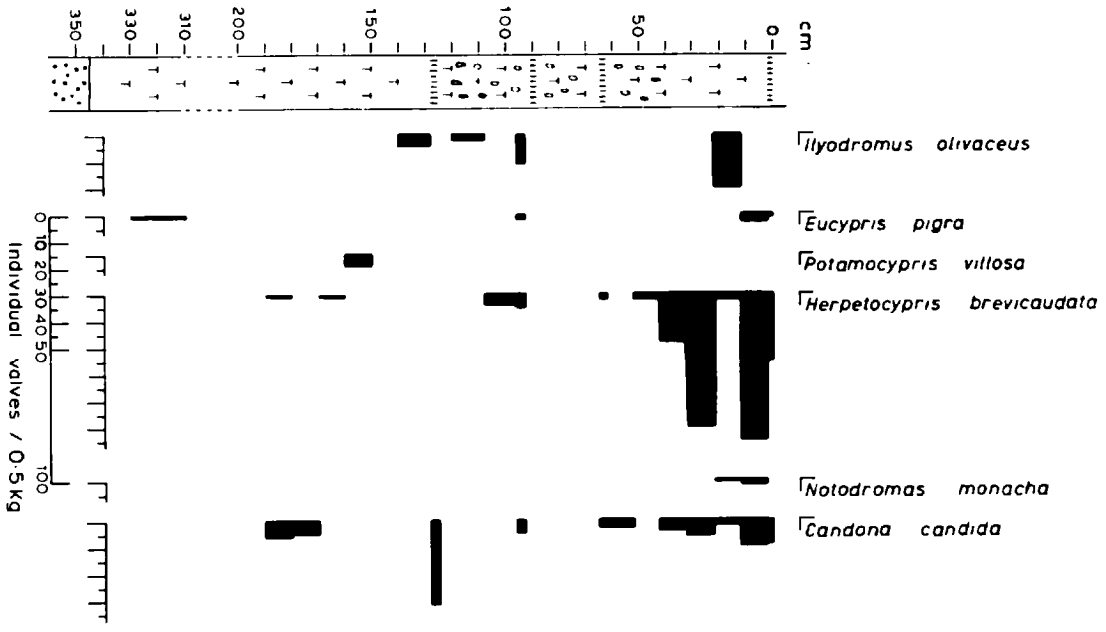
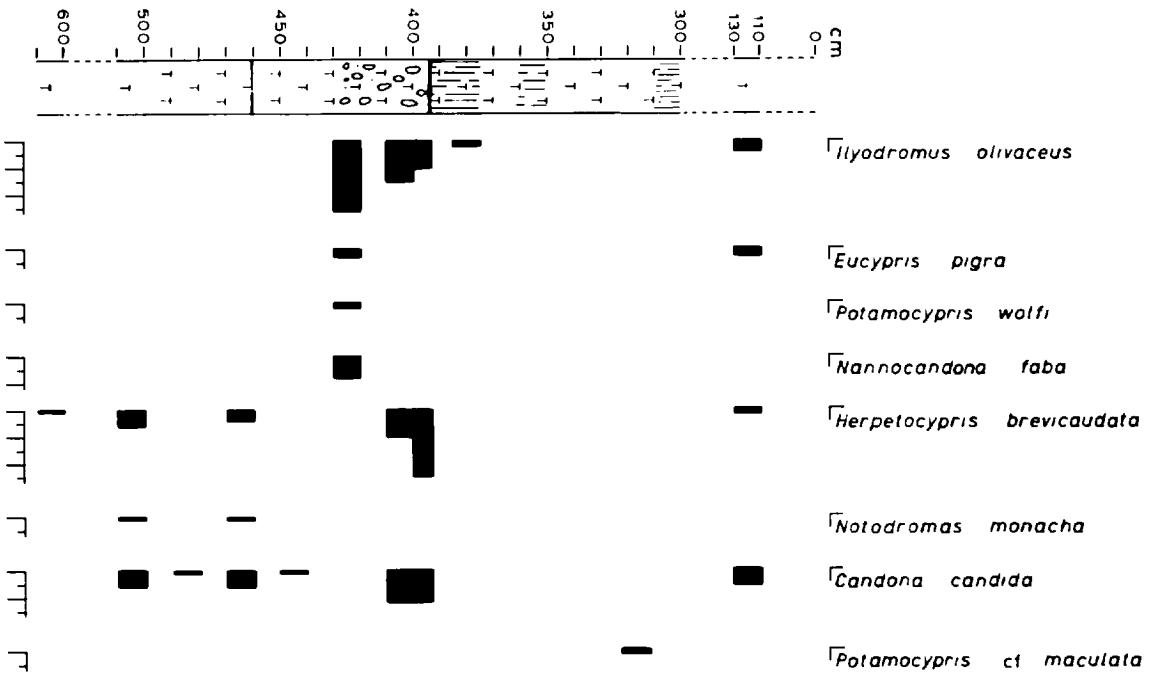


Fig 21



Series A

Series B

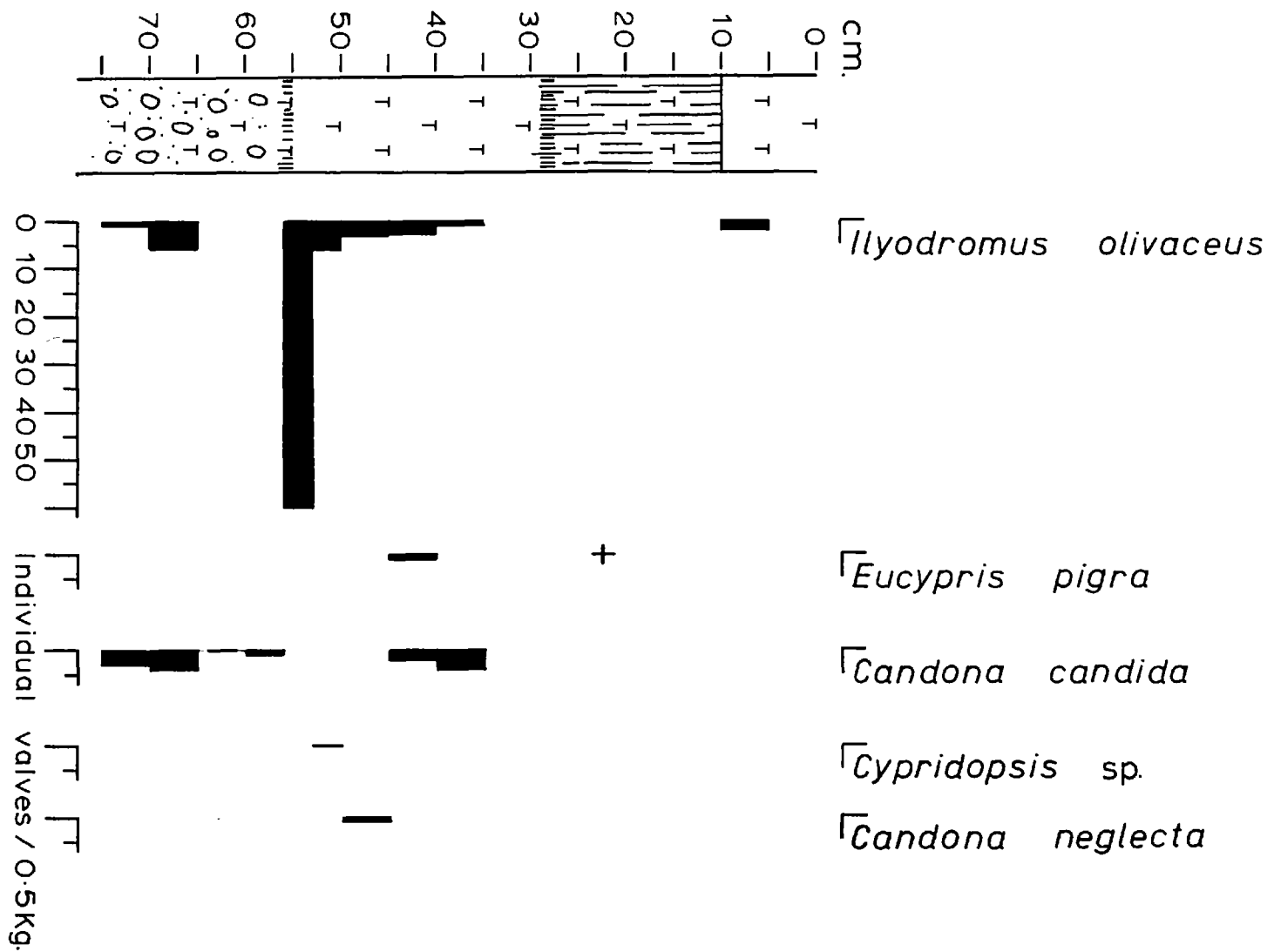


Fig 22

embrace members of his 'Seekalke' assemblage (Absolon, 1973). This again highlights the diverse nature of the depositional environments represented at Caerwys. Herpetocypris brevicaudata is a common species at Caerwys and is easily recognizable on account of the broad duplicature extensions across the ventral angles (broader than in H. reptans). Like others of the genus, it indicates plant-rich waters, but is more a species of spring deposits (Diebel & Wolfschläger, 1968). It appears to show an antipathetic relationship with I. olivaceus. Notodromas monacha can swim, using the surface tension effect, at the water surface, upside down using a flattened ventral surface. Its presence therefore indicates a minimum depth of water where this can occur. Although quite widespread today it is scarce in post-glacial deposits (Absolon, 1973). Nannocandona faba is a rare species belonging to the Sumpfkalke assemblage. It was originally described from a swamp-meadow in Sweden by Ekman in 1914. Both Candona candida and Potamocypris villosa are said to require a cold water temperature (i.e. are stenothermal), and were both widespread during the Late-glacial (Absolon, 1973).

vi. Vertebrate Remains

No bones or teeth were found during the present study but those of the following species are known (Anon, 1956) : wild boar, ox, small horse, cow, pig.

vii. Plant Remains

(a) Pollen analyses

The following organic levels were sampled for pollen; 53 - 56 cm, 27 - 29 cm (both Series C) and 600 - 610 (Series A). Both samples from Series C were devoid of pollen but the sample from an organic lens at 600 - 610 cm contained "a poorly preserved pollen assemblage dominated by Betula and Salix which appears to represent a zone IV age" (C. Turner, personal communication).

(b) Leaf impressions

These were abundant in the harder levels in the N.W. corner of the quarry. A series of these were submitted to

Mr P.R. Crane (University of Reading) who was able to identify the following; Betula, Corylus avellana, Ulmus (cf. glabra), Salix sp. Cummins (in Anon, 1956) records additionally the following species from these Leaf beds: Quercus robur (rare) Populus sp (v. rare), ?Hedera helix (1), Phyllitis scolopendrium and Fagus sylvaticus (uncommon). The preservation of these leaves is generally fragmentary and many specimens lack complete margins making determination hazardous. Cummins' records, especially of beech, require reexamination. These unstratified specimens cannot be related to the main molluscan sequence. Leaf impressions were also present in hard lenses in the excavated pit (i.e. between 533 - 648 cm, Series A). Salix sp was the most abundant leaf type although Betula was also present together with a small narrowly ovate leaf with pinnate venation (indeterminate herb) and the remains of a thallose liverwort. Some unstratified stem impressions closely approached Scirpus lacustris (det. C. Turner).

(c) Wood and Charcoal

Although the organic horizons were generally devoid of pollen, minute macroscopic wood fragments were present. These were submitted to Dr J.F. Levy who gave the following identifications.

- 290 - 310 cm (Series B) Vessels: exclusively solitary, simple perforation plates. Rays : probably of two sizes (a) uniseriate (b) 3-5 seriate. Fibres : relatively thick-walled. Growth rings : present, diffuse vessel arrangement. Identification: Salix sp, possibly Alnus, but unlikely in view of its stratigraphical context.
- 62 - 65 cm (Series C) Species A. Vessels : solitary, considerable reduction in size across specimen. Rays : indistinct. Fibres: either thin walled or thinned by microbial action prior to charring (i.e. partial

degrade). Growth rings : no complete ring present but arrangement of vessels and reduction in size across specimen suggests a diffuse porous hardwood.

Species B. Vessels : absent. Tracheids: present, with large bordered pits.

Crossfield pits small, elliptical and part bordered. Rays : indistinct.

Fibres: absent. Identification: a softwood. The absence of large cross-field pits rules out Pinus sp. The absence of spiral thickening eliminates Taxus. By elimination, Juniperus seems likely. (Plate 16).

viii. Radiocarbon date

Unlike the tufa at Prestatyn, no artifacts have been discovered in the Caerwys tufa. Human remains, including an almost complete skeleton, have however been recovered. A full account of this discovery appears in the Report of the Caerwys Committee (Anon, 1956) while photographs of the skeleton in situ and after extraction are among the papers deposited in the Dept. of Geology, University of Liverpool. Bones from this skeleton submitted to the British Museum for radiocarbon assay gave the following result (Barker, Burleigh & Meeks, 1971)

BM-255 2100 $\pm$ 140 BP

The date confirms that the burial was relatively recent and probably intrusive.

ix. Conclusions

The sparse fauna recovered by auger from the basal samples includes a fragment of ?Zonitoides nitidus (310 - 330 cm, Series B); Carychium minimum was also present at 230 - 250 cm. These two species are as yet unknown from Late-glacial deposits (Kerney, 1963). The rest of the fauna could well be Late-glacial, but in the absence of corroborative evidence, the tufa at the sampling point would seem to be entirely post-glacial. A possible zone IV pollen spectrum was obtained from 600 - 610 cm (Series A).

The molluscan community is directly controlled by the nature of the depositional environment and at Caerwys local conditions fluctuate with great rapidity. Thus shallow freshwater pools supporting many Lymnaea would be forming "lake marl" sediments while a nodular lithology would form where running water is present. The marginal areas would be covered with swamp and where this has drained, a dry land surface supporting a rich terrestrial molluscan fauna would be present. Each facies grades laterally into another. There is also considerable vertical variation in lithology. This suggests that tufa was being formed by a complex braided system of streams that were constantly changing their course as the result of being ponded back by temporary rims of tufa.

A clear environmental sequence can be detected in the land mollusca. The essentially open-country assemblage in the basal levels is gradually replaced by more shade-demanding ones higher in the sequence. An abrupt hiatus occurs at the top of the tufa where the woodland species are replaced by open-country forms in the colluvium and modern soil. This would seem to result from anthropogenic clearance. The tufa embraces zones a to d, while the deposits overlying it contain zone e and f assemblages.

9. DDOL, FLINTSHIRE

i. Location and Extent

The site is about one kilometre east of Afon-wen. A small turning, to the north of the A 541, leads past a Chapel towards some Fish Hatcheries. Old tufa workings are present throughout this immediate area. A Nature Reserve has been created to the west of the road. Here the stream has incised a deep ravine through the tufa. Streams also flow through the artificial cuttings formed when the tufa was worked. It was such a cutting at SJ 142713 that was examined and sampled. The deposit was considerably more organic than the corresponding deposits at Caerwys. Indeed large pieces of wood were seen protruding from the section.

ii. Stratigraphy

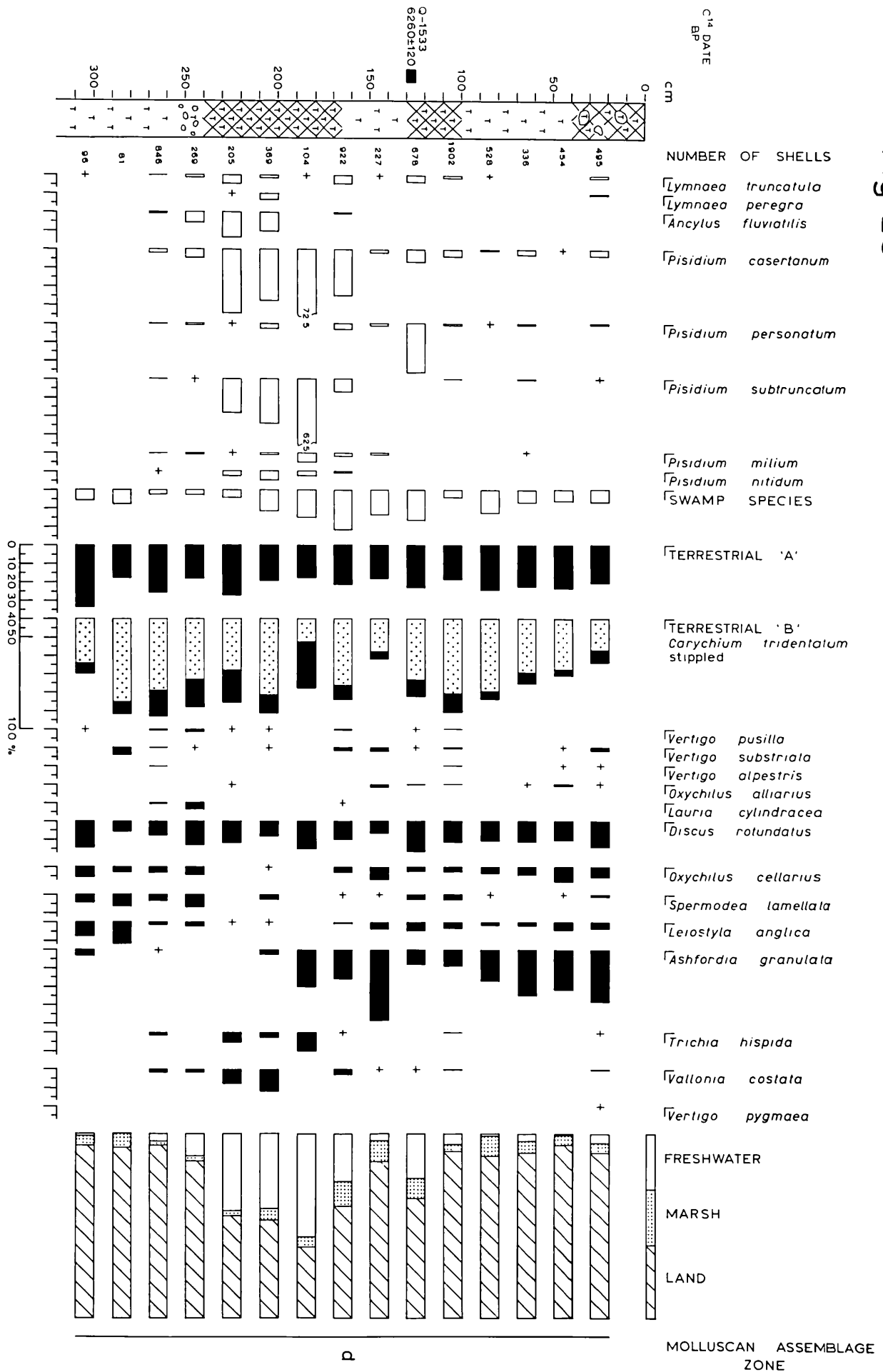
The stratigraphy of the deposit was extremely complex, with no sharp lithological distinctions discernable, the thicknesses given in the measured section below, should therefore be regarded as approximate.

0 - 40 cm	Organic detritus with tufa fragments
40 - 100 cm	Soft tufa with dark grey horizons
100 - 130 cm	Strongly organic horizon
130 - 165 cm	Soft pale tufa with incipient grey streaks
165 - 240 cm	Dark grey (10 YR 3/2) tufaceous silt
240 - 255 cm	Loose white nodular tufa
255 - 280 cm	Soft tufa with grey horizons
280 - 310 cm ⁺	White (10 YR 7/3) tufa

iii. Mollusca (Fig. 23)

The freshwater fauna is that of a small stream. The proportion of swamp species is low in contrast to Caerwys. An examination of the ecological summary reveals that a flooding episode between c. 260 - 150 cm has occurred. Those species most characteristic of streams (eg. Ancylus fluviatilis, Pisidium nitidum etc) only occur between these levels. Below 260 cm freshwater species are very rare or absent, while above c. 150 cm species characteristic of boggy ground (eg. Lymnaea truncatula, Pisidium personatum and P. casertanum) predominate.

Fig 23



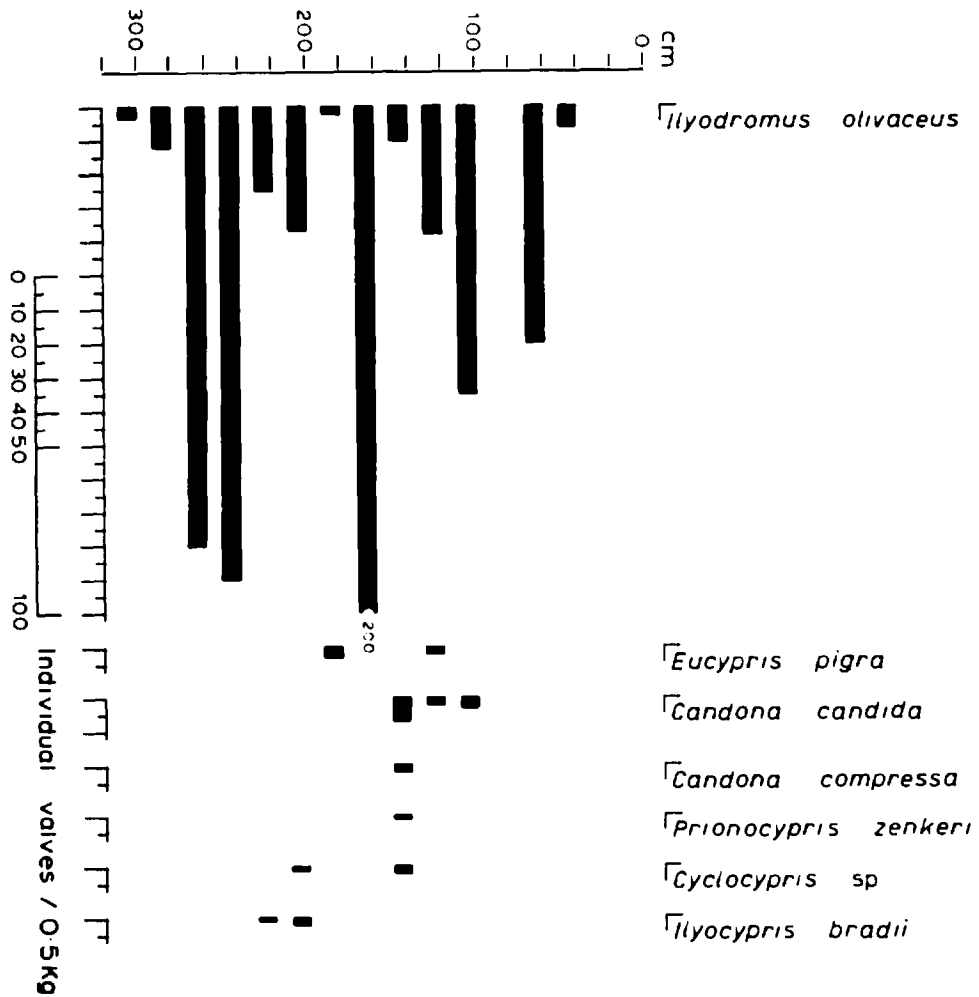


Fig 24

No clear stratigraphical changes can be detected in the land mollusca. Discus rotundatus, Oxychilus cellarius together with Leiostryla anglica and Spermodea lamellata occur throughout. A shaded depositional environment is suggested. Ashfordia granulata, a species absent from the tufa at Caerwys, is also frequent. During the flooding episode (260 - 150 cm) the proportion of xerophilous species (Trichia hispida and Vallonia costata) recovered is greatest; this presumably results from the gradual erosion of the stream banks.

iv. Ostracoda

All ostracods above 0.5 mm were picked and plotted in the usual way (Fig 24); determinations by Dr Eric Robinson. The fauna is dominated by Ilyodromas olivaceus, suggesting spring conditions. However a whole suite of other speices including Eucypris pigra, Candona candida, C. compressa, Cyclocypris sp, Ilyocypris bradli, Prionocypris zenkeri are present in the middle part of the sequence suggesting rather steady water flow. This roughly coincides with the "flooding episode" suggested by the mollusca.

v. Plant Remains

(a) Pollen analyses

Two pollen samples from 120-130 cm and 230-240 cm were submitted to Dr C. Turner, who stated that corrosion had precluded any statistical counts. The assemblages from both samples were similar and contained a varied spectrum including Alnus and Tilia; Ulmus was not seen, although this may be due to differential destruction. Both spectra appear to represent a post zone v date, a conclusion that is in keeping with the radiocarbon date.

(b) Plant macrofossils

Remains of fruits and seeds were abundant throughout the deposit. These have not been critically analysed. Large pieces of timber were also present. A specimen of wood from c. 125 - 130 cm was examined by Dr J.F. Levy. He stated that this specimen (Quercus sp) had undergone considerable degrade making it soft and friable and that it had been subject to substantial

compression. The effect on the cellular structure had been similar to that produced by the lateral shrinkage of so called "waterlogged" wood which has been heavily degraded by removal of most of the secondary wall and dried. When examined the samples were wet and if the interpretation of the structure given above is correct, then they must have been rewetted, perhaps by burial subsequent to the initial degrade and drying. This alternate wetting and drying is the reason for the absence, or extremely corroded state, of pollen in this sequence.

vi. Radiocarbon date

The face of the section was riddled with modern rootlets, so that great care was taken to collect an uncontaminated sample. A fragment of wood from 125 - 130 cm was selected as being free from visible root penetration; this was analysed by the Cambridge laboratory with the following result:-

Q-1533 6260 $\pm$ 120 BP

A further sample from 225 - 230 cm was submitted but was destroyed during the analysis.

vii. Conclusions

A heavily shaded stream environment is suggested. The local conditions have favoured the preservation of much organic debris. The periostraca of many Pisidium and the delicate chitin limbs of Ilyodromas are preserved at certain levels. Conditions however were not suitable for good pollen preservation.

The base of the deposit was well below water table and was not sampled. The molluscan fauna is a zone d assemblage.

10. TOTLAND BAY, ISLE OF WIGHT

i. Introduction

The tufaceous deposit that occurs on the top of the cliff in Totland Bay has been known for well over a century and has attracted much attention. It was first described by Trimmer (1854) and subsequently by Forbes (1856), Bristow (1862), and Reid & Strahan (1889). Kennard & Warren (1904) reexamined the deposit and increased the list of molluscs recorded from it. No further work was done for over fifty years, until A.G. Davis (1955) recorded Spermodea lamellata, at that time the most southerly British record.

ii. Location and Extent

The deposit occurs at the very top of the cliff, some 20m above sea level, between Headon Hill and Widdick Chine. Early accounts suggest that the tufa was much more extensive in the mid 1850's when it could be traced for 350 metres in a north-easterly direction from the base of Headon Hill. By 1890 the section had become overgrown and this is still the case today. The present outcrop of tufa is of very limited extent, only a small remnant could be located at the top of the cliff, behind the old boathouse at (SZ 321867) (Fig 25).

iii. Stratigraphy

0 - 20	cm	Modern Soil (overgrown)
20 - 70	cm	Yellowish-brown decalcified silt 10 YR 5/8
70 - 80	cm	Dark brown clay 10 YR 4/4
80 - 110	cm	Decalcified tufa, 2.5 Y 7/4
110 - 145	cm	Calcareous tufa, nodular towards base. 5Y 7/2
145 cm ⁺		<u>Potamomya</u> sand (Headon Beds). Light olive grey 5Y 6/2.

Fig 26 shows the uneven nodular base of the tufa and the position of the sampling column. The general sequence recorded roughly corresponds to the measured sections of earlier workers. It would appear that the overlying silt is primarily a hillwash

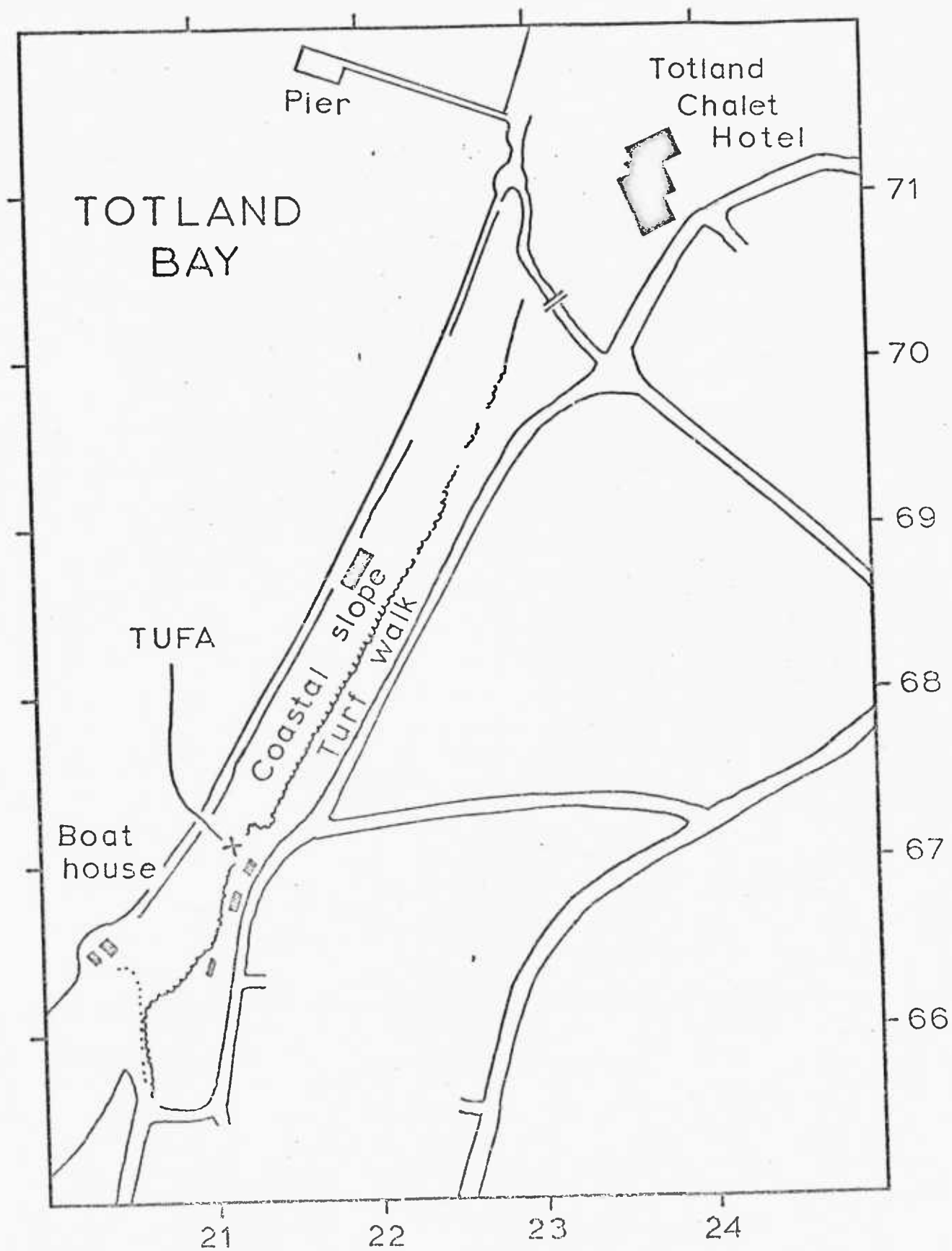
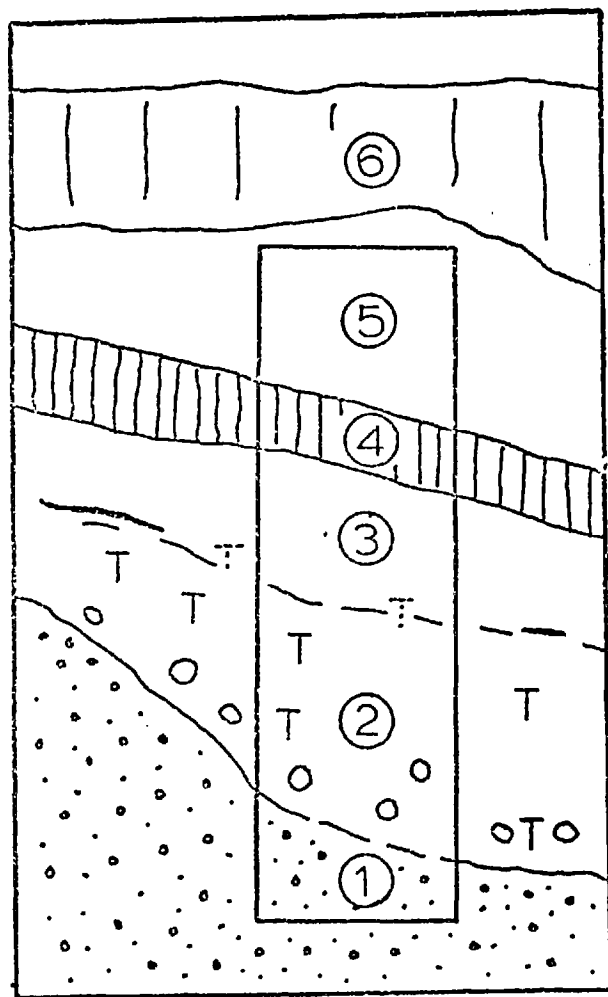


Fig 25



PROFILE THROUGH TOTLAND TUFA

- 6 Modern soil
- 5 Silt
- 4 Clay
- 3 Decalcified tufa
- 2 Tufa, nodular towards
base
- 1 *Potamomya* sand
(Headon Beds)

0 50 100 cm

Fig 26

and is not the result of decalcification caused by post-depositional weathering.

A series of samples, 5 cm thick, were taken from the thickest part of the deposit (see Fig 26). Half kilogram samples were processed and analysed in the usual way. The results are tabulated in Appendix 2vii and plotted graphically in Fig 27.

A further 15 g from each sample was digested in 10% HCl and the approximate percentage carbonate thereby assessed. This percentage increases from about 12% in the Potamomya sands to over 30% in the lower half over the tufa, declining to negligible amounts in the overlying silt and clays. (Fig 27).

iv. Mollusca

Shells were only found in the calcareous tufa and not in the overlying silt or clay. Their preservation was generally very good although some specimens from the upper samples were rather corroded.

The deposit has proved to be very much richer than the earlier accounts suggest. The list of species known has been doubled. The systematic sampling through the tufa revealed little change in the composition of the mollusca. However Vertigo genesii, Vertigo geyeri, Succinea oblonga and Vallonia pulchella were only detected in the basal samples and in very low numbers. This assemblage is characteristic of the Late glacial/early post-glacial and it seems probable that these shells are derived from rather older deposits and did not coexist with the rest of the fauna.

Vallonia costata, not recovered from the sampling column, was detected (a single shell only) in a spot sample taken from the lower half of the deposit; its exact stratigraphical position cannot be given more precisely.

The presence of flowing water is suggested by the nodular lithology at the base of the tufa and the abundance of Pisidium. Seven species of Pisidium are now known including Pisidium amnicum, P. milium, P. subtruncatum, P. hibernicum, P. tenuilineatum. Pisidium amnicum is especially characteristic of slow flowing streams. The published accounts of sand and clay seams interstratified with the tufa also suggest stream action.

The occurrence of Pisidium tenuilineatum is interesting. Early British accounts of the ecology of this species suggested that it is typical of canals or sizeable rivers. On the continent however, it is also known to live in lakes (Favre, 1927) and even a shallow karstic mere (Ložek, 1956). In such environments the shell is thinner and more delicate, with less robust hinge-plate and hinge teeth and it became apparent that the type described by Stelfox (1918) and prevalent in Britain represented an abnormally thickened riverine form, analogous to the var ponderosa of P. casertanum, or the var crassa of P. nitidum. The fossil shells from Totland, together with those from the calcareous tufas of comparable age at Brook (Kerney et al. 1964) and Folkestone (Kerney, Preece & Turner, 1978) are of this thin-shelled form (var alpina Odhner). A further curious feature of the Totland shells was the fact that about half the population were badly distorted, suggesting parasitization. Only P. tenuilineatum were affected. It is interesting to note that living examples of this thin-shelled form of P. tenuilineatum have recently been discovered in a lake in Sussex (Kerney, 1970)

The only other freshwater species found was Lymnaea truncatula, a species characteristic of damp ground. The earlier records of Unio, and Planorbis need checking; they could well be derived fossils from the underlying Headon Beds; such shells were detected in the basal samples of the present sequence, but were clearly Tertiary forms.

The general nature of the land mollusc fauna is one of a closed forest. The depositional environment was clearly a shaded one as well as a wet one. Spermodea lamellata and

Leiostyla anglica are present throughout together with Discus rotundatus, Oxychilus cellarius, Vertigo pusilla and Vertigo substriata. Balea perversa was quite common and Zonitoides excavatus was an unexpected discovery in a calcareous context. A sinistral example of Lauria cylindracea was also detected (90-95cm).

Pupilla muscorum is listed by Kennard & Warren (1904), but this species was not found during the present study. An examination of Kennard's material in the British Museum showed that many of his "P. muscorum" were in fact juvenile Leiostyla anglica. There were some true Pupilla, but judging from the matrix filling the apertures, they apparently did not come from the tufa but presumably from some overlying hillwash.

v. Ostracoda

Only one species was recovered, Ilyodromas olivaceus, a crawling form characteristic of springs. Its occurrence (Fig 28) clearly coincides with the period of tufa formation.

vi. (a) Plant macrofossils

Only one species was recovered, Eupatorium cannabinum.

Depth (cm)	135-140	130-135	125-130	120-125
<u>Eupatorium cannabinum</u> L	4	1	6	3
cypselas				

ctd.	115-120	110-115	105-110	90-95	85-90
	6	10	8	4	3

(b) Pollen analyses

Two unstratified samples from organic lenses were analysed by Dr C. Turner in 1969. The matrix was too oxidised for pollen preservation although the following corroded grains were seen

(a) 1 Alnus, 1 Ulmus

(b) Pinus, Gramineae, Compositae

No attempt was made to count the slide.

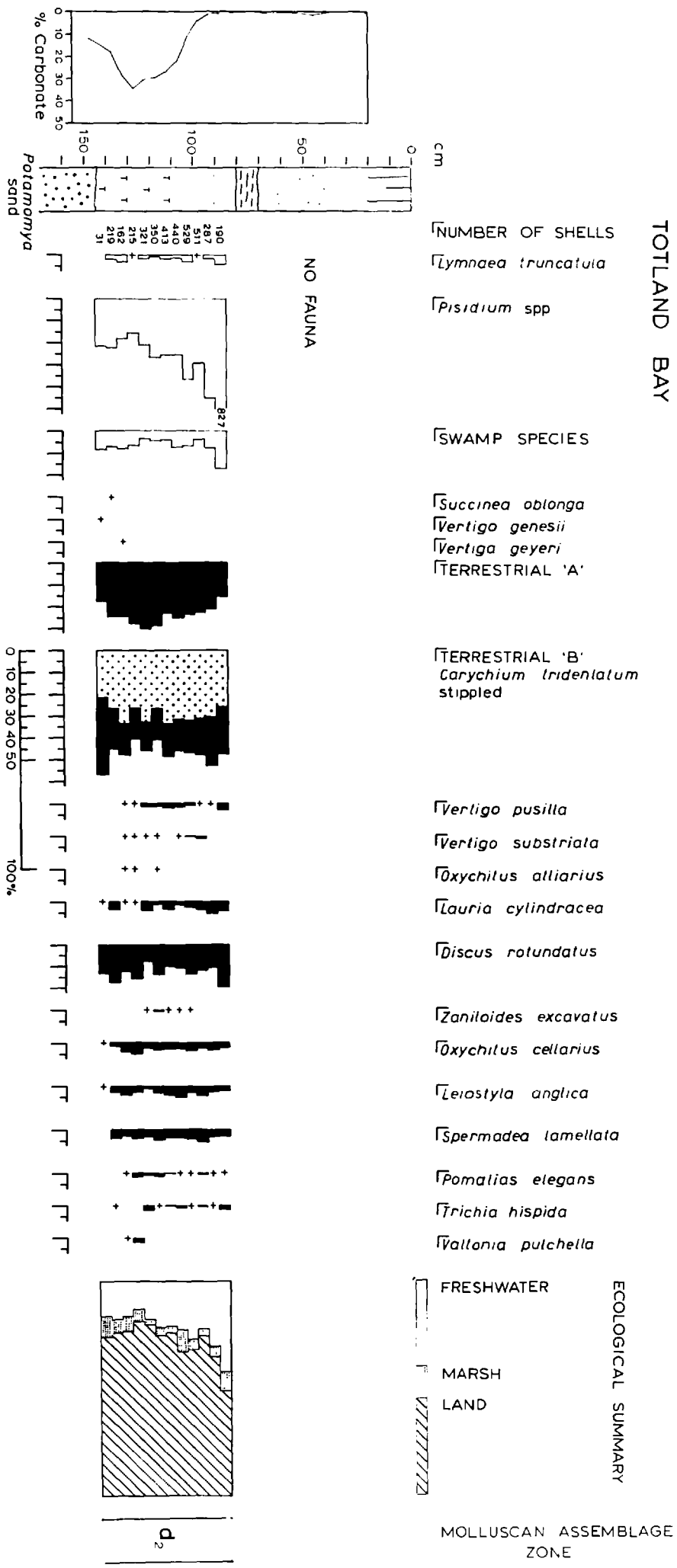


Fig 27

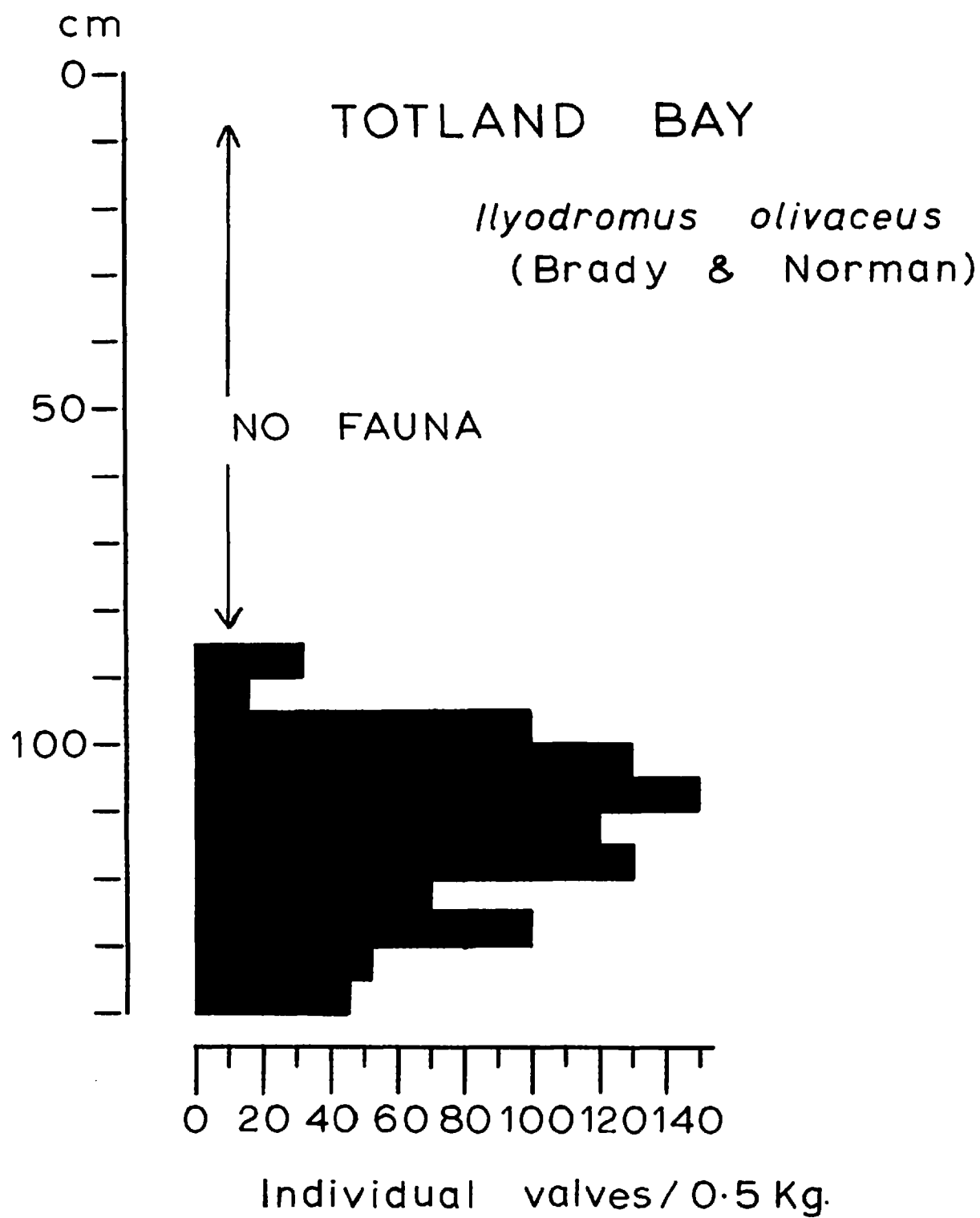


Fig 28

vii. Conclusions

The homogeneous nature of the fauna suggest that no great length of time was involved in the formation of the tufa. The increased knowledge of the fauna and flora only confirming Kennard & Warren's (1904) conclusion that the depositional environment was "a damp land-surface, over which oozed the water, highly charged with carbonate of lime, which was thrown out of the Headon Hill limestones by springs." The cessation of tufa formation has been attributed to the tapping of springs as a result of the cliff recession (Reid & Strahan, 1889). The molluscan fauna is a zone d assemblage.

11. WILSTONE, HERTFORDSHIRE

i. Introduction

The tufaceous deposit at Wilstone was originally discovered by Charles Oldham and was subsequently described by Kennard (1943), from the meadows near Wilstone Reservoir where it was located by the abundance of shells in the molehills. Digging revealed an upper layer of "dark peat soil" (less than 30 cm) overlying a light calcareous deposit (of unknown thickness).

During the present study, a section in the eastern bank of the Reservoir was discovered at SP 910131 which extended south-westward for over 30 metres. No trace of tufa could be found by digging in the field to the south.

ii. Stratigraphy

- 0 - 25 cm Modern Soil
- 25 - 60 cm Tufa, iron-stained in places. (10 YR 8/4) Occasional stem impressions.
- 60 - 70 cm Organic horizon 2.5 YR 4/2
- 70 - 160 cm⁺ Grey clay (2-5 YR 6/2) with derived chalk fossils (Lenticulina rotulata, Inoceramus fgts. Occasional ostracods.

iii. Mollusca

The Wilstone data (Appendix 2vii, Fig 29) have been calculated as individual percentages of the total non-freshwater fauna (i.e. the swamp component has been grouped with the land total). This procedure therefore differs from the other sequences described in the thesis; this was adopted because of the impoverished nature of the fauna, each species could be plotted individually without undue congestion, and to enable comparisons with other Late-glacial sequences (eg. Kerney, 1963; Evans, 1966). A histogram of absolute abundance was not plotted.

The basal clay contained a fauna of Late-glacial type (Kerney, 1963) characterised by Pupilla muscorum, Vallonia pulchella, Vertigo genesii, Catinella arenaria with occasional

Trichia hispida together with a high proportion of catholic species (Punctum, Euconulus, Vitrina etc.) The presence of Pisidium obtusale lapponicum, an arctic form, is noteworthy. Columella columella was also recovered in pilot samples, but was not detected in the serial sampling. The environment suggested is one of open ground with low herbaceous vegetation and swampy patches.

The lithological change at the base of the organic horizon corresponds with a marked faunal boundary. The Late-glacial elements (Catinella arenaria, Vertigo genesii) decline and are replaced by a very high proportion of catholic species. This suggests the development of a more stable and abundant vegetational cover. Trichia hispida reaches quite high percentages. The environment remained open, although Aegopinella nitidula and Discus ruderratus, species with woodland affinities, first appear towards the very top of the tufa. Swampy conditions persist although there is a dramatic decline in Lymnaea truncatula and Pisidium. Vertigo moulinsiana is also known from the tufa (R.B.G. Williams & D. Holyoak, personal communication).

iv. Plant Macrofossils

The following species were recovered (determinations by Dr C. Turner).

Depth (cm)	100-110	80-90	60-70	50-60	40-50
<u>Eupatorium cannabinum</u> L. cypselas	-	-	3	7	8
<u>Ranunculus sceleratus</u> L. seed	-	1	-	-	-
<u>Chara oogonia</u>	+	+	-	-	-
Moss stem (calcified)	-	-	+	-	-

The semi-aquatic habitat of each of these species undoubtedly favours their incorporation and preservation. Ranunculus sceleratus is a boreal-circumpolar montane plant while although widespread through the British Isles, is much commoner in the south and east as also in Scandinavia, possibly reflected the greater frequency in this lowland

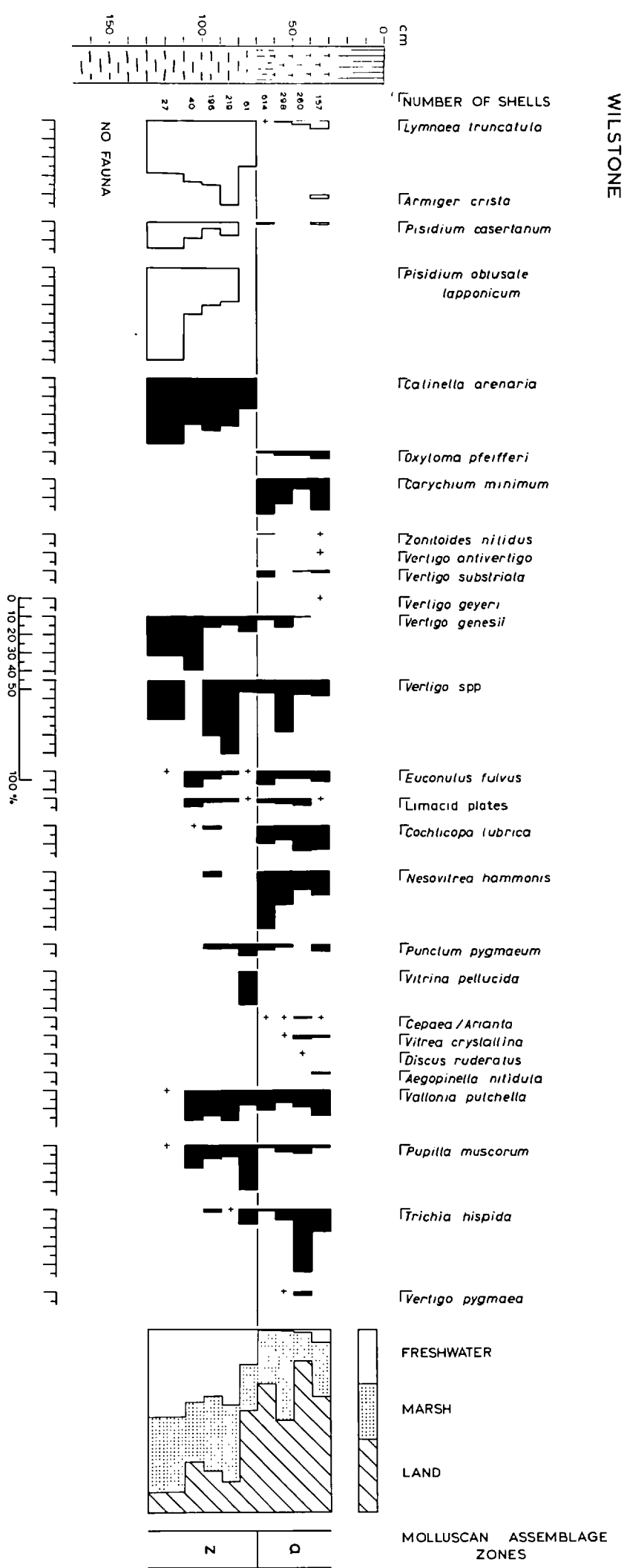


Fig 29

region of "slow streams and ditches and shallow ponds of mineral-rich water with a muddy bottom" (Godwin, 1975).

v. Conclusions

The basal clay is a solifluxion deposit, containing a molluscan fauna of an open marshy environment of Late-glacial character. The abrupt change from the deposition of mineral clays to organic silts probably reflects the ending of periglacial slope processes. The molluscan fauna above the clay (zone a) is more varied and thermophilous and includes some shade-demanding species in the upper levels but lacks several arctic-alpine species present in the clay (zone z). This assemblage compares well with a similar fauna from Pitstone; just a few kilometres away (Evans, 1966).

Kennard lists species (eg. Vertigo pusilla, Discus rotundatus etc) that were not recovered during the present study. This suggests that tufa accumulation post-dating that studied here, occurs nearby.

NOTES ON CEPAEA AND POMATIAS ELEGANS

(i) Cepaea

There is now a voluminous literature on the banding polymorphism of Cepaea and the factors and selection pressures that govern it. It is therefore interesting to comment on the differences between the morph frequencies of fossil Cepaea from the tufas and the modern populations living at or near the sites today. This has been the subject of two quite exhaustive studies by Currey & Cain (1968) and Cain (1971), who have examined material from Wateringbury, Blashenwell, Caerwys and Ddôl as well as many other sites of later date. Table summarizes the results obtained during the present study.

TABLE 6 Fossil and modern samples of Cepaea

O = unbanded, 3 = mid-banded, 3S = mid-banded with spread bands

S = all other banding forms (mainly five-banded)

	O	3	5	5S	Total
Blashenwell, Dorset					
<u>Cepaea nemoralis</u> , fossil	69	-	-	-	69
" from SY953809, modern*	12	5	3	-	20
<u>Cepaea hortensis</u> , fossil	-	-	20	8	28
" modern	1	-	7	5	14
Wateringbury, Kent					
<u>Cepaea nemoralis</u> , fossil	39	5	31	10	85
" modern*	1	1	27	-	29
<u>Cepaea hortensis</u> , fossil	-	-	2	-	2
" modern	9	-	9	5	23
Totland, Isle of Wight					
<u>Cepaea nemoralis</u> , fossil	11	-	-	-	11
" modern	-	-	-	-	-
<u>Cepaea hortensis</u> , fossil	-	-	6	-	6
" modern	13	-	12	-	25

Caerwys, Flintshire

<u>Cepaea nemoralis</u>	fossil	41	-	-	-	41
"	modern ⁺	1	45	-	-	46
<u>Cepaea hortensis</u>	fossil	8	-	7	3	18
"	modern ⁺	35	-	116	77	228

* After Currey & Cain, 1968; ⁺After Cain, 1971.

These results underline the findings discussed in these papers namely;

- (1) that there has been a dramatic decline in the proportion of unbanded morphs of C. nemoralis which has taken place since the period of tufa formation and which may be related to the Post-glacial thermal decline. "The distributions of banding morphs in sub-fossil samples and over western Europe at present were shown by Currey & Cain (1968) to be consistent with each other and with experimental work, and to suggest the prevalence of unbandeds in hotter times and regions, five-bandeds in cooler and wetter areas" (Cain, 1971).
- (2) that there has been a contraction of the distributional range of C. nemoralis that has occurred since the cessation of tufa formation. Although frequent in the tufas, no living C. nemoralis could be found at Watringbury, Blashenwell or Totland. The figures quoted in the table for modern morphs are those given by Currey & Cain (1968) and Cain (1971) presumably derived from colonies up to 1.5 km away. According to Cain (1971, p. 90) this contraction of range took place sometime "between the Mesolithic/Neolithic and the present day". This phenomenon has been ascribed to the induction of strong local climatic gradients and frost hollows in open downland areas, stemming, in all probability from the clearance of forests by prehistoric agriculturalists (Cain & Currey, 1963).
- (3) No clear trend was detected in C. hortensis, although the numbers analysed are rather low.

In these more detailed studies, other characters such as colour and the presence of white lip in C. nemoralis, were also examined. The white lip morph comprised 10% of the population from the Caerwys tufa, although absent in modern shells from the immediate vicinity. In Britain and Europe, white lip is associated with high rainfall areas, or where temperatures are seldom elevated, being particularly common in western or high altitude regions such as western Ireland and the Pyrenees, so that its prevalence in the Atlantic and early Sub-boreal periods may be a reflection of the damper climate at that time.

Cain (1971) also found an increase in brown morphs of C. nemoralis from the Atlantic period to the present day. This morph is virtually absent from tufa sites, for example. The modern distribution of browns in Europe suggests an association with relatively cool summers. This increase, which apparently occurred about 3,000 - 4,000 BP may thus be related to the decline of summer temperatures which occurred at this time (Godwin, 1975).

These inferences are deduced largely from a comparison of the variation in morph frequency between sites of different ages. It has been assumed that any one site belongs to a specific period; the tufa sites examined by Currey & Cain (1968) have all been assigned to zone VIIa, an assumption that is now clearly untenable. A detailed study of the changes in morph frequency at a single site, that covers the greater part of the Post-glacial period, would be particularly revealing. Ideally critical levels at such a site should be readily dateable. Such a project has yet to be undertaken.

(ii) Pomatias elegans

A striking feature of the fossil Pomatias collected from Wateringbury and Blashenwell was their relatively large size, especially when compared with modern populations living on the sites today (Plate 5). A series of both fossil and modern adult shells (i.e. those with thickened peristomes) were measured using a micrometre screw gauge. The altitude was

Fig 30

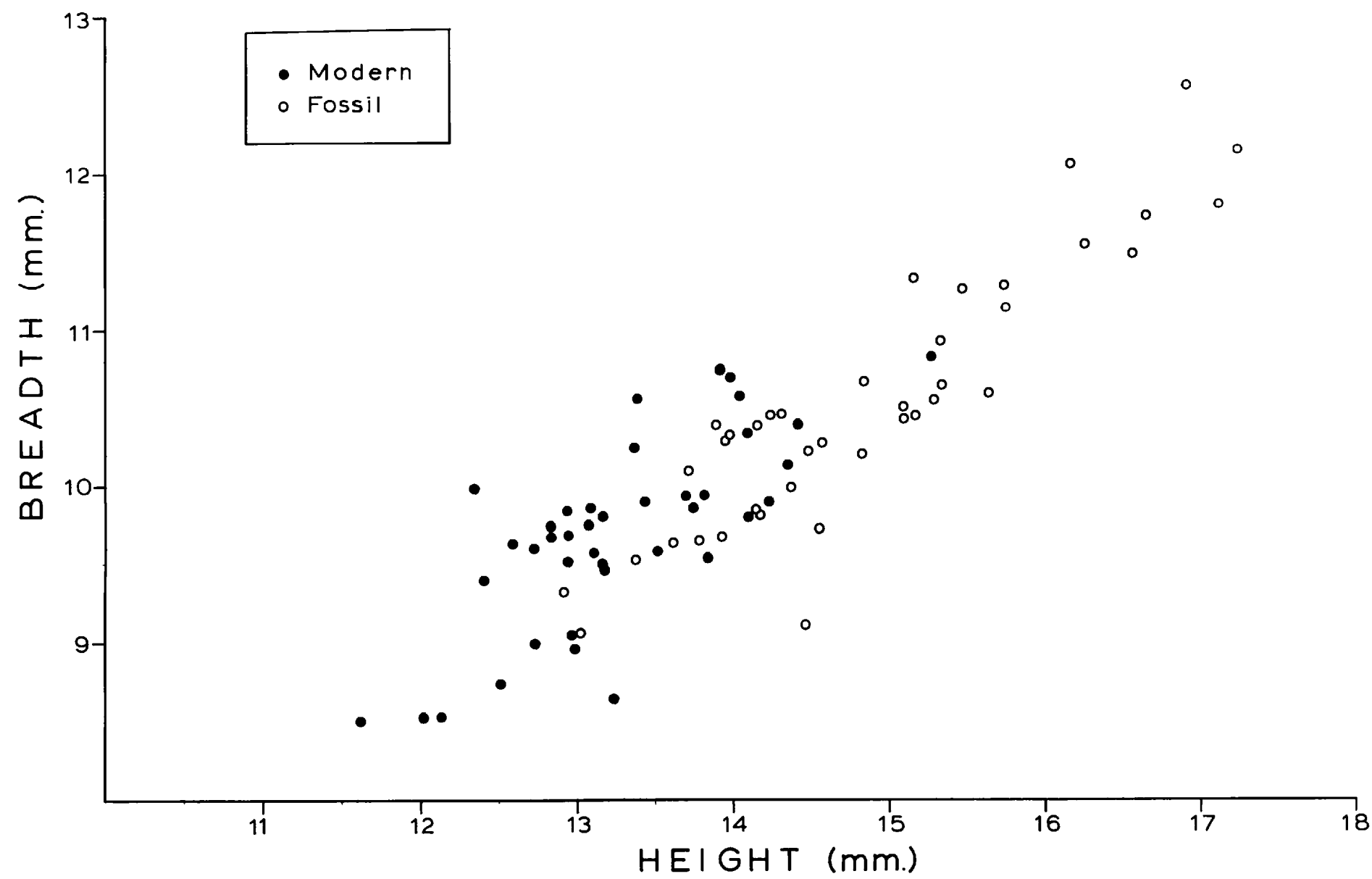
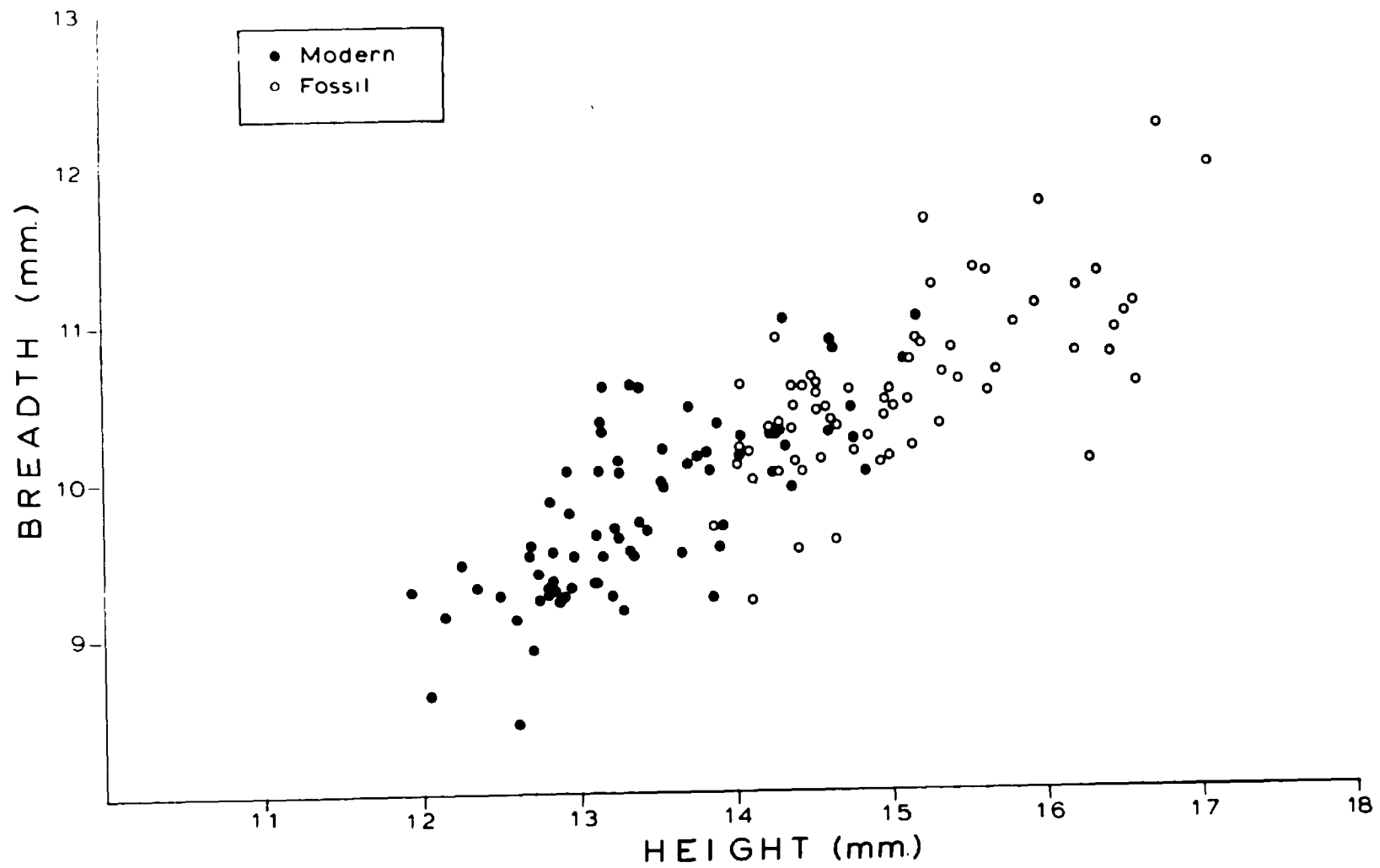


Fig 31



measured from the apex to the most distant part of the peristome along a line parallel with the columella. The breadth was measured at right angles to the axis of the shell, this measurement was more difficult to take since it is rather harder to align the snail exactly, these measurements are therefore only accurate to 0.2 mm. The minimum figures are rather less interesting since subjectivity was involved in deciding maturity. The results from Watringbury and Blashenwell are tabulated below and plotted graphically in Figs 30 and 31

	<u>Fossil</u> (n = 40)			<u>Modern</u> (n = 40)		
	<u>Max.</u>	<u>Min.</u>	<u>Mean</u>	<u>Max.</u>	<u>Min.</u>	<u>Mean</u>
<u>Watringbury, Kent</u>						
Altitude (mm.)	17.26	12.92	14.89	15.28	11.62	13.27
Breadth (mm.)	12.56	9.07	10.53	10.82	8.50	9.93
<u>Blashenwell, Dorset</u>						
	n = 65			n = 75		
Altitude (mm.)	17.07	13.87	15.10	15.19	11.94	13.43
Breadth (mm.)	12.25	9.55	10.59	11.03	8.45	9.82
<u>Brook, Kent</u>						
	n = 150			n = 150		
Altitude (mm.)	17.59	12.42	14.70	15.27	11.15	13.29
Breadth (mm.)	12.91	9.40	10.60	11.08	8.59	9.72

The results from the two tufas compare well with the series recently measured from a Neolithic hillwash at Brook (Burleigh & Kerney, 1978). A radiocarbon date of 4540 ± 105 (BM-254) was obtained from this level.

Similar observations have been made on the Pomatias from tufaceous deposits in France. Bourguignat (1869) considered that the large fossil form reaching 17 mm and 9.5 mm in breadth was specifically distinct and called it Cyclostoma lutetianum. Germain (1912 p. 43 - 46) showed that there was great variation in P. elegans from tufas at Buisse (Isère) and suggested that Bourguignat's C. lutetianum was a large variety of P. elegans. A similar conclusion was reached by Jodot (1908) from interglacial tufas at Celles-sous-Moret. Germain also compared the fossil Pomatias from Buisse with P. elegans living there concluding "les specimens fossiles n'en diffèrent que par leur taille un peu plus forte et leur sculpture parfois moins accentuée" (Germain, 1912, 45, pl IV).

This issue is complicated by the fact that sexual dimorphism occurs in P. elegans. This is the subject of a paper by Boycott (1909) who demonstrated that although there was no sexual difference in the tumidity of the shell, females were larger than males. It was assumed that in the series analysed here, a roughly equal number of male and female shells, both fossil and modern, were measured. The reason for the decrease in size is unknown but may again be connected with the Post-glacial thermal decline.

13. DISCUSSION AND GENERAL CONCLUSIONS

When the molluscan diagrams from the various sites are compared clear biostratigraphical similarities are apparent. It is clear that the re-immigration of land snails into Britain after the last (Devensian) glaciation followed an ordered pattern. The possibility of their use for biostratigraphical zonation, in a way analagous to a pollen zonation, becomes very real. The species most suitable for this purpose should be both regionally widespread and locally common and ideally of rather broad ecological tolerance, so that the effects of facies differences between sites might be partially overcome.

In Kent it has been possible to recognize the following molluscan assemblage zones (Kerney, 1977 a; Kerney, Preece & Turner, 1978) :

Late-glacial and Post-glacial Molluscan Assemblage Zones
(Kent).

- | | |
|---------------------|--|
| Zone z | Open ground fauna. Restricted periglacial assemblage with <u>Pupilla</u> , <u>Vallonia</u> , <u>Trichia</u> , <u>Abida</u> . |
| Zone a | As (z), but with decline of bare soil species (notably <u>Pupilla</u>) and corresponding expansion of catholic species. Appearance of <u>Carychium</u> , <u>Vitrea</u> , <u>Aegopinella</u> . |
| Zone b | Open woodland fauna. Expansion of <u>Carychium</u> and <u>Aegopinella</u> , <u>Discus ruderatus</u> characteristic. |
| Zone c | Closed woodland fauna. Expansion of <u>Discus rotundatus</u> . |
| Zone d ¹ | Closed woodland fauna. Expansion of <u>Oxychilus cellarius</u> . |
| Zone d ² | Closed woodland fauna. Expansion of <u>Leiostyla</u> , <u>Spermodea</u> , <u>Acicula</u> . |

- Zone e Open ground fauna. Decline of shade-demanding species. Re-expansion of Vallonia.
- Zone f Open ground fauna. As (e) but with appearance of Helix aspersa.

At other sites in Kent an additional zone y may be recognized below zone z representing the first appearance of a terrestrial molluscan fauna following the period of maximum cold of the Late Devensian (Kerney, 1977 a). Assemblage y may be defined as having a very simple restricted character dominated by Pupilla and Vallonia only and lacking Abida, Helicella and Trichia. It occurs stratigraphically below zone z at Dover Hill, Folkestone (Kerney, 1963, fig 3), Holborough, Kent (ibid, fig 10) and Oxted, Surrey (ibid, fig 12).

A clear parallelism exists between these sites in Kent (Brook, Folkestone and Waterringbury) and others, further afield, discussed in this thesis. Unpublished data, kindly supplied by Dr J.G. Evans, from a tufa at Cwm Nash in S. Wales has also been plotted in the usual way (Fig 32). Although only 0.25 kg samples were analysed (i.e. lower totals were recovered), the sequence of zones is nevertheless recognizable. Fig 36 summarizes the details from all sites discussed.

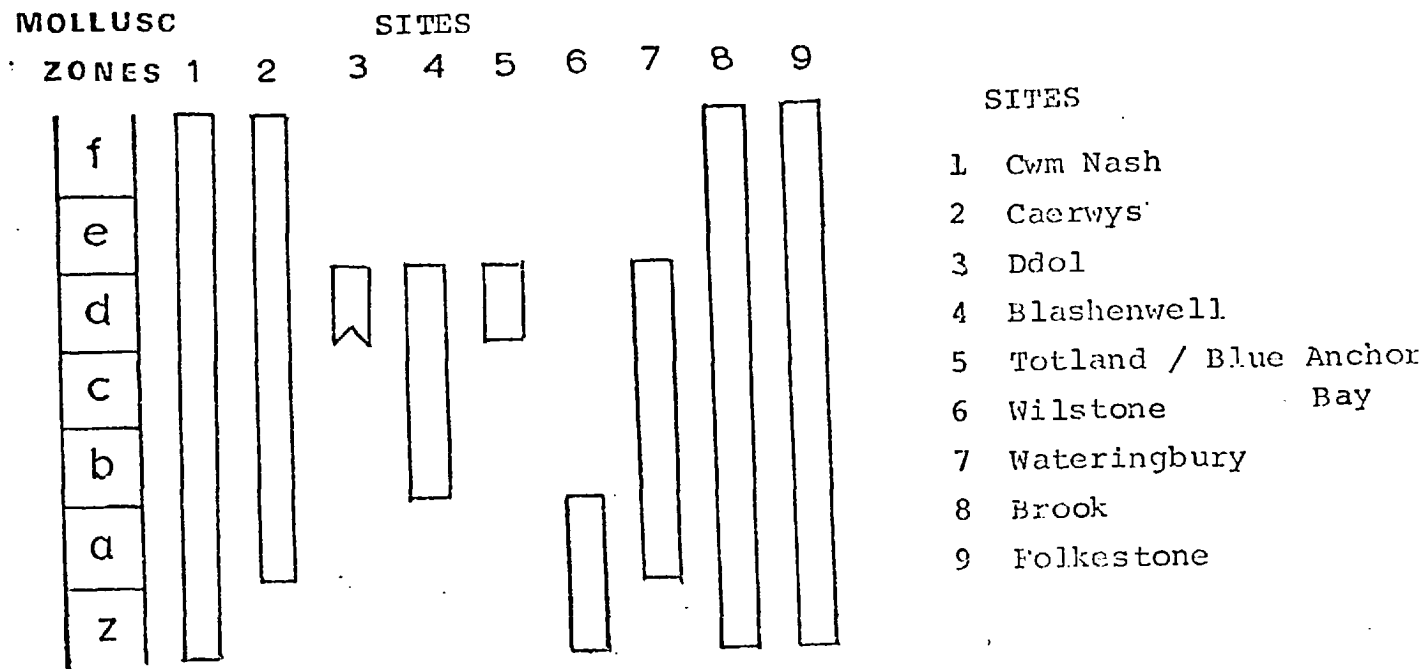
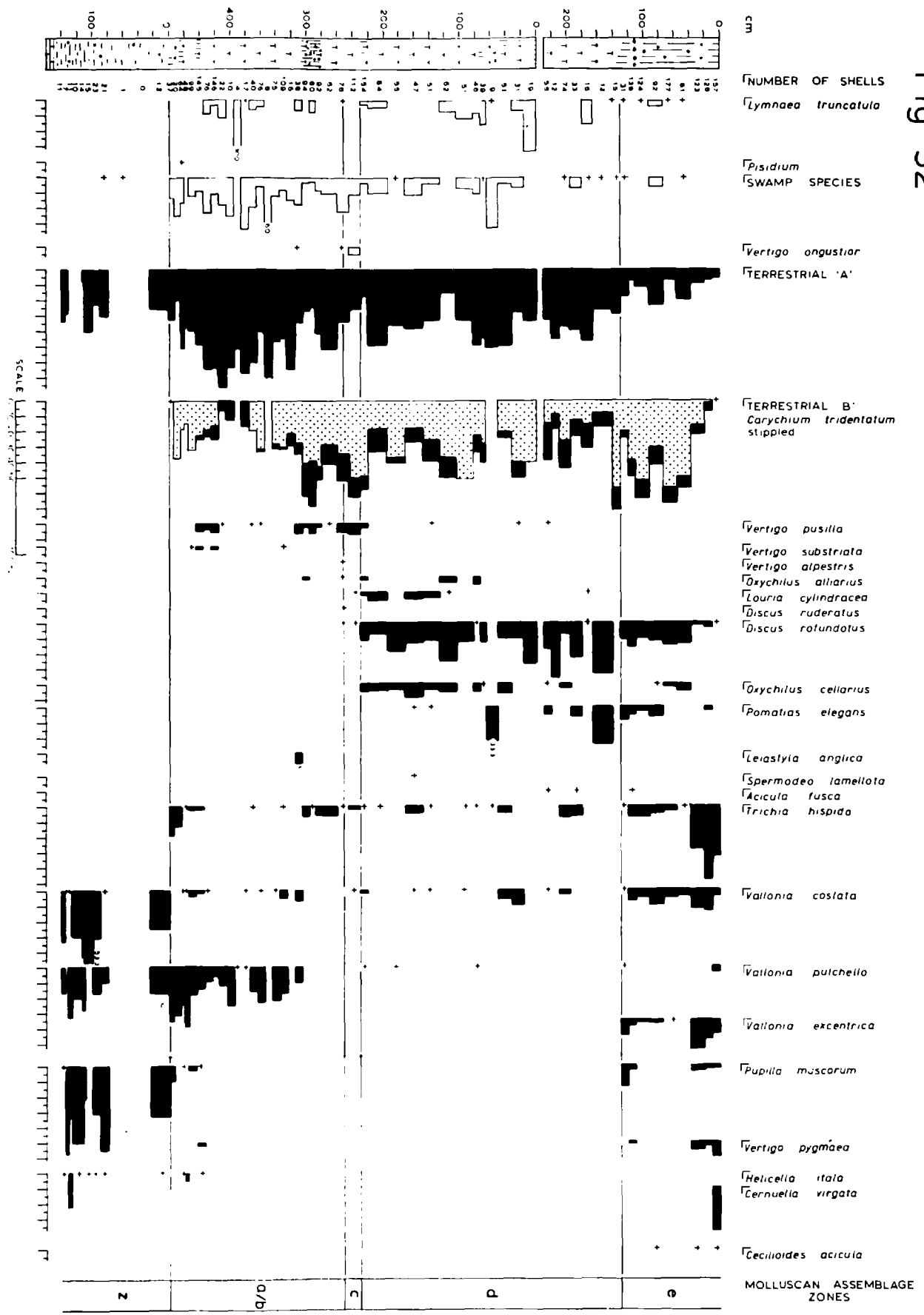


Fig. 36

Fig 32



These assemblages are defined both in terms of the total ranges of certain species, and of their changing dominance. They are therefore analogous to pollen assemblage zones which are based on the geographical migration of terrestrial plants. These zones therefore differ from other biostratigraphic zones of older geological periods based on the evolution and extinction of taxa. Such zones would only be found in one stratigraphical position and would usually have a wide geographical extension. This situation sharply contrasts with these assemblage zones which in theory might be repeated in a sequence and which would have a more limited geographical extension. Clearly regional molluscan assemblage zones need to be established at critical type sites; correlation between such profiles can be made using radiocarbon dating. Before this can be achieved many more sites need to be examined and more radiocarbon dates obtained; the foundations for such a scheme are presented in this thesis.

In the earlier part of the sequence (zones y to d inclusive) the controlling process is clearly one of migration in response to climatic change, acting either indirectly through the vegetation (eg. causing the replacement of open ground species by shade-demanding ones) or more directly by providing suitable conditions for mollusca with particular thermal requirements. Thus, a priori, it might reasonably have been predicted that Discus rotundatus, Oxychilus cellarius or Acicula fusca would appear relatively late, since their present day northern ranges in Europe suggest thermal limitation. Conversely one can draw attention to the decline and disappearance of the northern and alpine species Discus ruderratus (Fig 35), Columella columella and Vertigo genesii (Fig 33), all now extinct in Britain.

The immediate effect of an ameliorating environmental change on a snail population would be a change in the abundance of certain species already present in the habitat. Only subsequently would migrating forms, now able to tolerate the new environment, first appear. These considerations have an important bearing on the definition of zone boundaries. In his

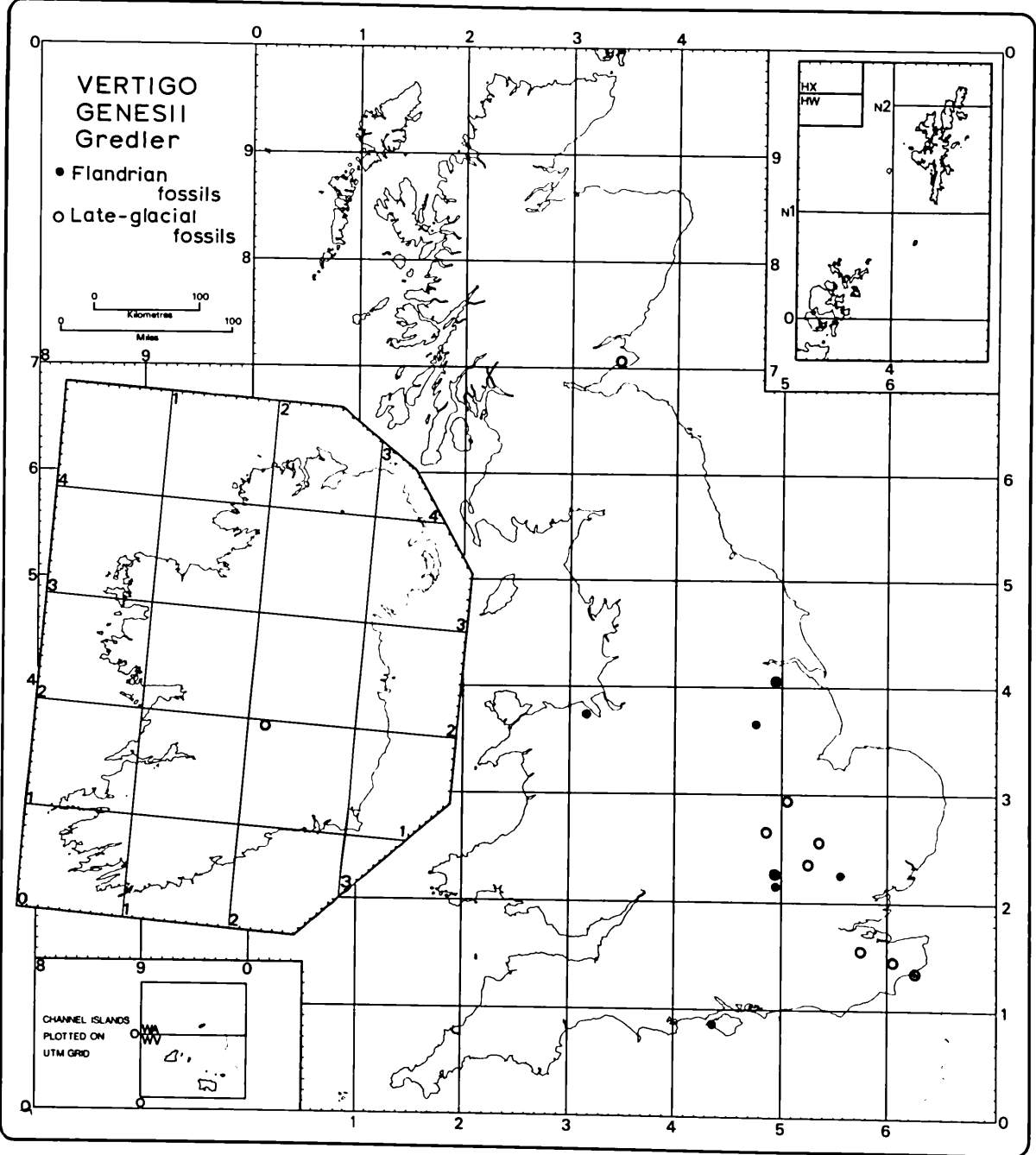


Fig 33

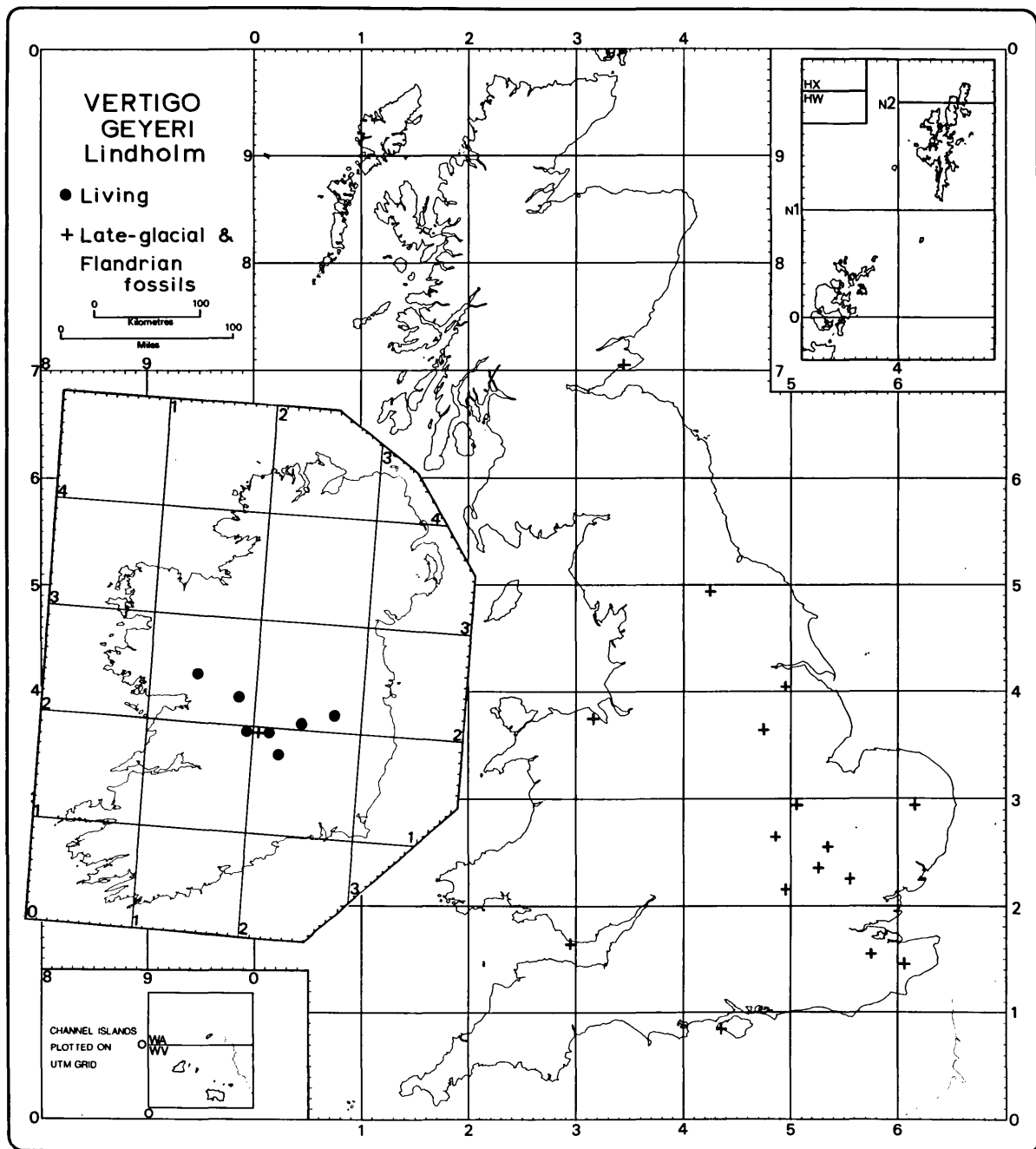


Fig 34

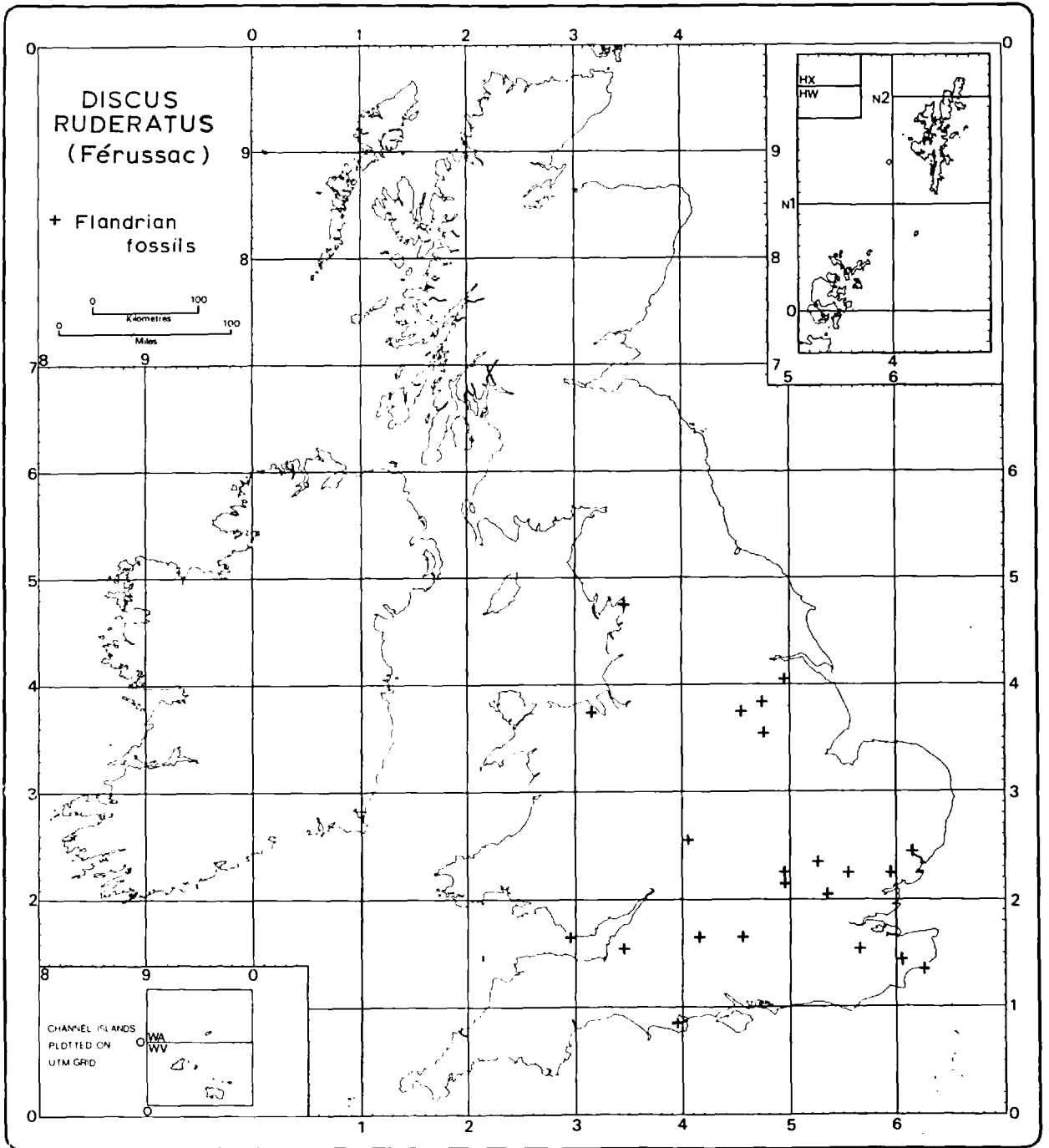


Fig 35

elegant studies of Late-glacial faunas, Kerney (1963) erected zone boundaries at the point where there are significant changes in the abundance of the indigenous fauna rather than at the subsequent arrival of new immigrants. The situation in the Flandrian is rather different for there must have been a considerable time lag between the climatic amelioration, the establishment of suitable woodland habitats and the arrival of shade-demanding snails. Their immigration, although ultimately the result of environmental change is usually not accompanied by significant changes in those species already present.

The ease with which zone boundaries could be drawn varied considerably. Generally those zone boundaries defined by the appearance or expansion of a single species (zones c-f) were relatively straightforward. Those boundaries defined by expansion or contraction of faunal elements were rather more subjective. At Wateringbury, for instance, the increase in the woodland element (Terrestrial 'B') is very marked, while the corresponding increase at Caerwys is much less pronounced. Even during the "forest optimum" the proportion of woodland snails (Terrestrial 'B') at Caerwys reaches only c 35% compared with c.70% at Wateringbury. These individual differences are almost certainly of local origin, although the underlying patterns have a seemingly regional significance.

Detailed correlation of those mollusc zones with the standard pollen zones is not yet possible. The palynological evidence together with the relevant radiocarbon dates is summarized in Fig 37.

Owing to the oxidized nature of the deposits fruits and seeds were generally rare, only cypselas of Eupatorium cannabinum (hemp agrimony) were at all common. The semi-aquatic habitat of this species coupled with the resistant nature of the seed coat undoubtedly favoured its preservation. It was absent however in the Late-glacial clay at Wilstone and from the very base at Wateringbury (zone IV). It was

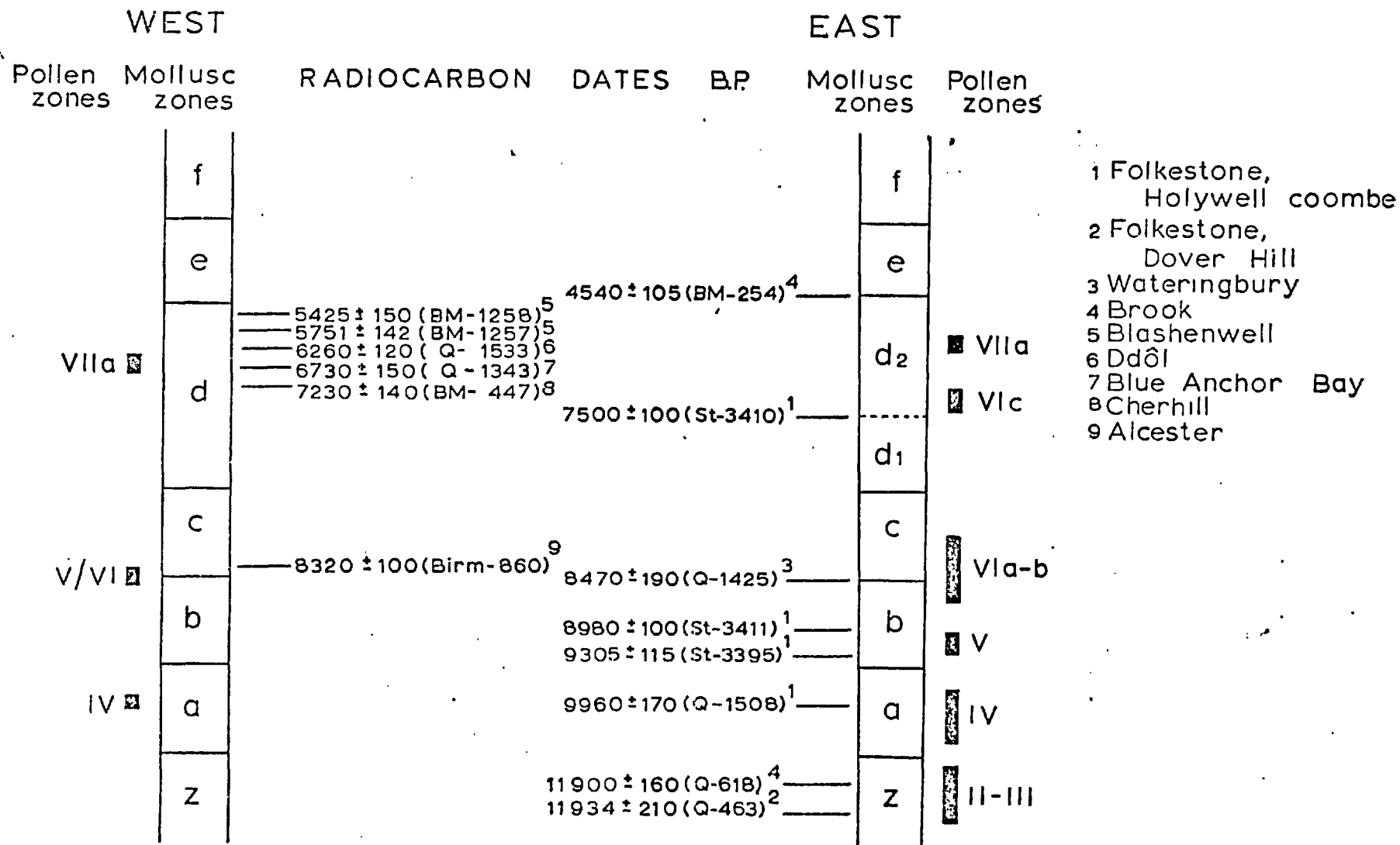


Fig 37. Mollusc Zones from sites in west and eastern Britain with corresponding pollen spectra and radiocarbon dates. The VIIa spectrum from the east refers to Takeley in Essex.

however present from zone V onwards at Wateringbury and occurs in an identical fashion at Apethorpe (Sparks & Lambert, 1961). E. cannabinum occurs throughout most of the British Isles but is less common in the north. In Scandinavia it is common only in the southernmost part, where even local occurrences barely reach 62°N in Sweden or 63°N in Finland. This distribution pattern lends apparent significance to its absence from the late-glacial and its Flandrian extension (Godwin, 1975).

Only much further work on well-dated profiles can show to what extent these assemblage zones are synchronous over large areas. Synchronicity will depend on the rate at which colonization takes place which is a function of numerous factors such as the abundance of the colonizing species in the source habitat, the proximity and the type of terrain over which they have to travel and their rate of dispersal. It is possible that certain species survived in favourable microhabitats well beyond their main range. Rapid dispersal from these refuges could then occur well before the main advance of the species. Little is known however about the dispersal of land snails, although passive dispersal, presumably the most effective means, has been discussed by Kew (1893), and Rees (1965).

Preliminary results presented in this thesis suggest a broad synchronicity within southern Britain, although regional differences certainly exist. The subdivision of zone d (Oxychilus cellarius zone) is of local value only. The oceanic elements (Leiostyla, Spermodea, Acicula) which characterize zone d² may be absent or in western areas may appear at earlier stratigraphical levels (eg. Blashenwell, Caerwys).

This fact leads to some interesting biogeographical considerations. The present day distributions of Leiostyla anglica and Spermodea lamellata are essentially north-western/ Atlantic and fall almost exclusively within the area covered by the Devensian ice sheets. The problem of where these, and similar species (eg. Ashfordia granulata, Zonitoides excavatus) survived during the glacial maxima becomes intriguing since periglacial survival in situ can be eliminated. There are records of similar (possibly identical) species from Portugal.

This present-day distribution coupled with the geological evidence that recolonization occurred much earlier in the west suggest that these species must have spread from western refugia. Indeed there is some evidence that L. anglica was present during the Late-glacial in Donegal (R.C. Preece, unpublished).

The Late-glacial assemblages include a peculiar suite of species including an interesting mixture of arctic-alpine (eg. Vertigo genesii and Columella columella) and rather more thermophilous elements. Catinella arenaria, today a rare species known mainly from maritime habitats in north-west Europe and mountains in central Scandinavia, was also present. It is becoming increasingly clear that the climatic amelioration during the Late-glacial period was extremely rapid. This enabled certain thermophilous species (eg. Helicella itala, Trichia hispida, Abida secale) with good powers of natural dispersal to colonize newly created habitats and to co-exist with cold elements. The European distributions of Trichia hispida and Columella columella seem scarcely to overlap yet they were both present in Late-glacial deposits at Wilstone and Kerney (1963) records their occurrence in similar deposits at Castle Hill, Folkestone. Modern distributions may however be misleading guides to the true climatic requirements of snails. The presence of Abida secale, a species with a rather southern European distribution today, in the Late-glacial suggests that its distribution is controlled not so much by climate as the openness of the habitat (Kerney, 1963).

Other interesting biogeographical associations with no analogous counterparts today can be found in the early Flandrian. The coexistence of Vertigo genesii and V. geyeri with V. moulinsiana at Caerwys has already been mentioned (p 96). Lauria cylindracea has an essentially western European distribution (Kerney, 1968, fig 4) yet it frequently occurs with Discus ruderratus which has a marked boreo-continental range scarcely over-lapping that of L. cylindracea.

Zones e and f owe their character to anthropogenic effects. The base of zone e is defined by the re-expansion of the grassland genus Vallonia, particularly V. excentrica. This expansion coincides with a dramatic decline in the woodland element and results from human forest clearance, an effect which is unlikely to be at all time-parallel (Evans, 1972 : 363). Its base is likely to correspond only in a very general way with the commonly accepted palynological criteria for zone VIIb (the Sub-boreal) at least some of which probably reflect climatic changes taking place around 5000 BP (Hibbert et al 1971).

The base of zone f is defined by the appearance of Helix aspersa (often with Monacha cantiana and Cernuella virgata) an introduced Mediterranean species which seems to have spread rapidly across lowland Britain during the Roman period.

As yet it is not possible to isolate in any clear way molluscan changes subsequent to the forest optimum (zone d) that might be independent of anthropogenic effects. The decline of Leiostyla and Spermodea (and Vertigo substriata) in the upper levels of Wateringbury might well be natural. Certainly these species were widespread in southern Britain at about this time, c. 7000 BP, but today are only found in a few relict colonies within this area. As mentioned earlier they are still frequent in northern and western parts of Britain and Sparks (1964a : 92) has suggested that their range may be "regarded as complementary to the distribution of the most intensively farmed land of Britain". A purely anthropogenic cause would seem unlikely however in view of the virtually ubiquitous occurrence of L. anglica in highly disturbed as well as wild sites in western Ireland and parts of Scotland.

Similar distributional changes are known for several other species eg. Pomatias elegans, Vertigo pusilla, V. alpestris (see maps in Kerney, 1976 d). Although both V. pusilla and V. alpestris still survive in Britain today, these are generally regarded as rupestral species associated with dry stone walls. They are seldom found in woodland habitats, such as suggested by their British Flandrian occurrences, although they are common

in such situations on the Continent. This may be another example of the phenomenon of increasing ecological fastidiousness exhibited by several snails (eg. Helicodonta obvoluta) as they approach the limits of their range. The disappearance of these species from zone e, coupled with their geographical retreat within the British Isles is strongly suggestive of climatic change and is difficult to explain solely in terms of human interference. Other phenomena, such as the change in banding frequencies of Cepaea nemoralis and the decrease in size of Pomatias elegans are also suggestive of climatic change. Kerney (1968) has suggested that Pomatias elegans is intolerant of winter cold and its distributional shrinkage from eastern England is compatible with a decline of winter temperature in this region since Neolithic and Bronze Age times. The retreat of Ena montana on the other hand is attributed to a fall in summer temperatures (Kerney, 1968).

This zonal sequence has been based almost entirely on evidence derived from tufas. The reasons for concentrating on tufas were discussed in the Introduction. Terrestrial deposits of early Flandrian age, other than tufas, are extremely rare so that it remains to be seen just how representative the assemblages contained in tufaceous deposits are of the regional molluscan communities. There is likely to be an over-representation of the hygrophilous element in tufas but the species chosen for zonal purposes have fairly broad ecological tolerances and are likely to have been widespread in other terrestrial environments and therefore regionally representative. Xerophilous species eg. Trochoidea geyeri, Helicopsis striata etc probably survived into the Flandrian in drier more open situations, but these habitats are unlikely to be preserved in the fossil record.

Comparison of this Post-glacial zonal sequence with the much sketchier evidence available from previous interglacials suggests that the pattern did not repeat exactly in each glacial-interglacial cycle. The situation is analogous to that found with flowering plants. The exact order in which

species re-colonize is largely a matter of chance, although climatically tolerant species could become established earlier than those more fastidious and shade-demanding forms. Some of the faunal differences between interglacials may however reflect real climatic differences. The scarcity of Lauria, Oxychilus and Discus rotundatus, coupled with the presence of Bradybaena fruticum (an essentially "eastern" species) in the Ipswichian may reflect greater continentality. The interglacial occurrence of the boreo-alpine-continental Discus ruderatus and the west Mediterranean-Atlantic D. rotundatus is interesting. Their present geographical (or altimetric) segregation is compatible with their segregation in time in the British Flandrian record, but not with their association in the middle parts of interglacials (see Kerney, 1977 b, fig. 3.1). This suggests that factors other than climate are controlling the distribution of D. ruderatus. Until detailed ecological studies, (particularly on thermal tolerances), comparable to the work of Iversen (1944), are undertaken few firm climatic conclusions can be drawn.

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APPENDIX 1 : NOTES ON IDENTIFICATION

Subfossil snails from the majority of geological and archaeological sites are broken, bleached and weathered and have consequently been ignored by many workers who are accustomed only to living material. In the case of the adult specimens, identifications are quite straightforward and reference can be made to the standard texts (Adam, 1960; Ložek, 1964; Ellis, 1969; Gittenberger, Backhuys & Ripken 1970) describing the gross shell morphology. However since the majority of fossils recovered are juveniles or small fragments of larger shells, the problems of identification increase proportionately, and in early works a point was reached where the specimen became too small to be named with confidence, and these shells were listed separately as "indeterminate".

The criteria used for naming the juveniles are often rather different to those used when naming adult shells. Indeed certain species that are quite different when adult are remarkable similar at the 1-2 whorl stage. There are very few accounts that deal specifically with such fragmentary or juvenile material, a notable exception is the book by Evans (1972) which includes a series of outline drawings illustrating the growth stages (and characteristic fragments) of most British land molluscs. But perhaps one of the most useful criteria employed when separating subfossil material are the subtle differences in shell micro-sculpture. Paradoxically it is often easier to separate certain species when fossil than when living. Thus species of Aegopinella and Oxychilus are often more readily distinguished when fossil than in the living state, when the periostracum conceals the all important shell ornamentation.

In quantitative studies, such as this thesis, it is necessary to identify and count every shell apex, although occasionally non-apical fragments of larger species (eg. Helicigona lapicida, Ena montana) are encountered and minimum totals for these are also assessed. It is therefore essential to name as many specimens as possible and to reduce the number

listed as "indeterminate" to a minimum. This is particularly important when low numbers of shells are recovered from poor samples. In practice it has been found that many specimens formerly labelled as "indeterminate" are now readily identifiable. The following notes aim to facilitate specific determination of juvenile and fragmentary material encountered in the course of the present study. A series of SEM photographs are presented which demonstrate in a very clear way the subtle differences in surface relief and whorl form. It should be noted that these characters can be readily detected under a good light microscope: the stereoscan has only been used for illustrative purposes. No photographs however can substitute for a good set of reference material.

Acicula fusca

Unlikely to be confused with any other species, except perhaps Carychium as small juveniles. Acicula however has a blunter apex, shallower suture, lacks denticles and possesses sharply incised vertical striae that are readily detectable in small fragments.

Carychium

C. tridentatum is taller and narrower than C. minimum which often tends to be tumid and rather barrel-shaped. The form of the parietal fold within the body whorl differs markedly in the two species, being more elaborate in C. tridentatum. (Watson & Verdcourt, 1953). This criterion was only used on doubtful specimens. The fine vertical ridges are more pronounced and closer together in C. tridentatum and the aperture is smaller, but the lip is thicker and more strongly developed.

Succineidae

As stated earlier, the determinations of this family should be regarded as tentative. cf. Oxyloma pfeifferi was the most common species encountered. At Caerwys shells resembling O. sarsi with more elongate shells and less inflated body whorls, were recovered (see Plate 3).

Catinella arenaria and Succinea oblonga are readily separated from other succineids by their relatively taller spire and shorter body whorl. The distinction between these two species is much harder; Catinella is rather squatter, and has a slightly deeper and less oblique suture. The aperture is generally more rounded (Sparks 1957b, Kerney et al, 1964). A large series is really needed for more confident determination but even then, there is much variation. To add to the confusion, Lymnaea truncatula can sometimes become rather succineiform.

Cochlicopa

C. lubricella has a smaller, more fusiform shell than C. lubrica, small juveniles are virtually impossible to name. The numbers given in the tables should therefore be regarded as approximations with C. lubricella possibly under-recorded, although it was certainly the rarer species at all sites. The ease with which C. lubricella could be recognized varied considerably; the differences were very pronounced at Blashenwell, but less clear cut at Caerwys and Wateringbury. Another continental species (C. repentina) has recently been described partly on anatomical grounds which is intermediate between lubricella and lubrica, and the possibility has been suggested that all these forms really belong to a large species complex (Gittenberger et al, 1970).

Columella

Even as juveniles Columella can be distinguished from Vertigo by its larger size, coarse growth lines and more loosely coiled apex. The differences between edentula, aspera and columella have been recently discussed by Paul (1975) who also gives a series of stereoscan pictures. Dr C.R.C. Paul kindly examined all the Columella collected during the present study.

Pupilla muscorum

Apex rather larger and more bulbous than Lauria or Leiostyla and the umbilicus more open. The whorl profile is

also more rounded and the suture deeper. The surface is mat but under very high magnification an intricate series of hexagonal raised lines can be seen.

Lauria cylindracea and Leiostyla anglica

Colour can often be a useful initial guide; L. anglica shells are often a rich chestnut colour with a pale underside while those of L. cylindracea tend to be a rather uniform buff colour. This is not a reliable criterion. The apical characters are however quite distinctive. L. cylindracea has a flattened apex (which appears to have a 'flecked' surface) with a very shallow suture. The apex of L. anglica is rather smaller and the suture considerably deeper. The parietal denticle and columellar fold appear early in both species which are therefore readily separated from the larger Vertiginidae and Pupilla.

Vallonia

The distinguishing features of adult Vallonia are described by Sparks (1953) and Ellis (1969). V. costata is strongly ribbed, and has a much deflected aperture. Faint spiral lines can also be seen around the apex. The whorls are considerably more shouldered than in the other two species, a feature which can be used to name even weathered, almost ribless, shells. V. pulchella is more uniformly rounded, when viewed from above, than V. excentrica. The peristome is also more sharply reflected.

Acanthinula aculeata

The apex differs from Spermodea in being slightly larger and its characteristic sunken protoconch distinguishes it from any Pupillid. The periostracal spines present in living shells are not preserved in fossils, but the surface of the latter are covered with a series of irregular spiral raised lines, enabling non-apical fragments to be readily named.

Spermodea lamellata

The coarsely ribbed sculpture of adult shells, coupled with the shouldered whorl profile and squat appearance is unmistakable. The protoconch has a rather rough texture that

gives rise to a pearly iridescence when viewed under the binocular microscope. The ribbing begins at about the $1\frac{1}{2}$ - 2 whorl stage.

Ena

The bulbous, obtuse apices of Ena are quite distinctive. Only Ena obscura occurs at all frequently, and a careful search should be made for non-apical fragments. The surface micro-sculpture of E. obscura is ornamented with a series of oblique flutings; that of E. montana is much coarser, the distinct spiral striation cuts across the crude growth lines, giving a file-like appearance.

Punctum pygmaeum

The apex is very tightly coiled, and the surface has a silky appearance. Under high magnification spirally orientated lines occur.

Discus

D. ruderatus can be distinguished from D. rotundatus by their more widely and regularly spaced ribbing and less keeled periphery. The mottled pattern characteristic of D. rotundatus is absent, but delicate transverse "ribbing" begins at a slightly earlier stage, becoming gradually coarser.

The ribbing in D. rotundatus does not appear under about the 2 whorl stage, and these shells resemble Aegopinella pura, but they lack the spiral sculpture, have a slightly deeper suture; and a more cleft umbilicus.

Vitrina pellucida

The translucence of the shell approaches the Zonitidae but it can be readily separated from them by reason of its rapidly expanding whorls and system of spiral pitting around the apex.

Nesovitrea

The genus Nesovitrea is characterized by the presence of strong radial incisions. The suture is shallower than in A. pura and the whorls less rounded above. Both N. hammonis

and N. petronella have been described from British Flandrian deposits (Kennard & Musham, 1937). There has been much discussion on the specific validity of N. petronella, but in a recent survey, Waldén (1966) asserts their specific distinctiveness on the basis of colour (hammonis are usually brownish, petronella always had hyaline, almost colourless shells) and consistent biometric differences. All British "petronella", from the Kennard colln. housed in the British Museum, were sent to Dr H.W. Waldén (Göteborg, Sweden), who stated (personal communication) that both hammonis and petronella ss. were present in this material (Oxychilus was also present). The confirmed fossil localities for N. petronella are, Brigg complex (Scawby, Hibaldstow), Nazeing, Essex; Finn Valley near Ipswich.

The difference between these two species is so slight, that no attempt has been made to separate them; all Nesovitrea have been ascribed to N. hammonis.

Oxychilus and Aegopinella

Oxychilus can be distinguished from Aegopinella by the whiter, polished, almost porcellaneous shells (glossy rather than waxy), virtual lack of spiral sculpture and differences in the umbilical characters. In juvenile Oxychilus the shallow umbilicus is rounded and generally centrally placed, those of Aegopinella tend to be eccentric. The outline of half-grown Oxychilus is sometimes irregular as if they have been distorted by some unilateral force, this seldom occurs in Aegopinella. The suture of Aegopinella tends to be rather deeper than in Oxychilus.

Oxychilus alliarius can be distinguished from O. cellarius by its smaller size, tighter coiling, more keeled periphery and generally darker colour.

Aegopinella pura also differs from A. nitidula in the tighter coiling of the initial whorls and in possessing a more keeled periphery. The characteristic reticulate micro-sculpture is unmistakable (Plate 12). In life the texture of Aegopinella shells gives the impression of being waxy.

Zonitoides

Both Z. excavatus and Z. nitidus were encountered. Adults of the former are unmistakable by reason of their size, tight coiling and very wide umbilicus. The juveniles are rather harder to detect, the transverse growth lines are often rather coarse in this species which coupled with the wider umbilicus, and lack of spiral sculpture can be used to separate it from A. pura. The brown glossy shells of Z. nitidus are quite characteristic. Where the gloss has gone, the lack of spiral sculpture is again a useful criterion in separating it from A. nitidula. In addition the whorls of Z. nitidus have a strikingly shouldered profile quite unlike that of any other Zonitid.

Limacid plates

Shells resembling Milax with a centrally placed nucleus and bilateral symmetry, were detected but their distinction from those of Deroceras/Limax was not clear-cut, especially in juveniles. No attempt was therefore made to separate them.

Euconulus fulvus agg.

Two species may well be included under one name. Both fulvus and alderi were present at all sites. The latter species is generally smaller and darker shelled with more pronounced spiral micro-sculpture around the umbilicus, but the critical differences have not been firmly established. Adult Euconulus are characterised by a shallow suture and minute umbilicus. The regular minute transverse ribs with subordinate spiral striations make the apices particularly distinctive.

Clausiliidae

The separation of fragments of these sinistral snails is often very hard, not only because of their similarity but also because the apices often become worn in life. The apices of the four species encountered can be arranged on a size basis as follows: Cochlodina laminata, Macrogastra rolpheii, Clausilia bidentata, Balea perversa. The apertural fragments, which are readily identifiable, should give a clear idea of what species occur. The colour and texture of the shells are additional guides. Cochlodina fragments are generally cream-

coloured and smooth, those of Balea are often buff coloured and wrinkled, rather than ribbed, while those of M. rolphii and C. bidentata are dark (often rather reddish) and finely and regularly ribbed. The sculpture of the M. rolphii tend to be coarser and more prominent. Balea apices are quite diagnostic not only on account of their small size but also their markedly conical nature.

Comparison with reference material is really essential.

Ashfordia granulata

Can be distinguished from Trichia by its more swollen, bulbous apex, more prominent and regular hair pits and generally more conical shell. The umbilicus is markedly narrower.

Zenobiella subrufescens

The shell is extremely thin and feebly calcified and as yet no adult has ever been found fossil. Half grown shells are distinguished from Trichia and Ashfordia by their tighter apex. Like Ashfordia it has a minute umbilicus, but lacks the periostracal hair pits. The shell surface is generally rough and possesses irregular spiral and transverse sculpture. The tightness of the coiling is intermediate between Aegopinella and Trichia. The juveniles have a rather mat surface, but faint traces of spiral sculptures can still be seen.

Trichia

The numbers given in the tables for T. hispida and T. striolata must be regarded as approximations. Specimens below c. 2 mm are hard to name. T. striolata tends to have a slightly larger protoconch and sparser hair pits on the initial whorls but there is much variation.

Helicigona lapicida

Apex rather tighter than that of Cepaea or Arianta. Complete shells are unmistakeable by reason of their strongly keeled periphery. The mat shagreen surface sculpture of even tiny fragments is equally diagnostic.

Arianta and Cepaea

The largest apices likely to be found (except Helix aspersa),

but they cannot be separated in any consistent manner. Adults and shell fragments are readily recognizable. Arianta has tortoise-shell patterning, with a white lip reflected at right angles to the body of the shells, and with a small umbilicus (absent in adult Cepaea). The shell is also incised by a series of spiral striae, which appear at about the two whorl stage (also absent in Cepaea), and shell fragments fracture clearly with many right angle breaks (cf. broken hen's egg). The separation of immature Cepaea is virtually impossible, although the brown lip pigmentation of nemoralis is a useful guide when naming adults. This feature is however not totally reliable since the incidence of white lipped nemoralis in subfossil contexts is quite high (Cain, 1971).

Adult hortensis are usually smaller and rather more delicate than nemoralis. It is possible that the banding patterns can be used for separation at certain sites (eg. Blashenwell, Caerwys etc.), where only bandless nemoralis occur.

Appendix 2i
Wateringbury, Kent

Depth (cm.)	405-410	400-405	395-400	390-395
Dry weight (g.)	220	400	350	320
<u>Pomatias elegans</u> (Müller)	-	-	-	-
<u>Bithynia tentaculata</u> (Linné)	-	-	-	-
<u>Acicula fusca</u> (Montagu)	-	-	-	-
<u>Carychium minimum</u> Müller	8	9	15	33
<u>Carychium tridentatum</u> (Risso)	1	1	-	-
<u>Lymnaea truncatula</u> (Müller)	-	-	2	1
cf. <u>Oxyloma pfeifferi</u> (Rossmässler)	3	-	1	1
<u>Cochlicopa lubrica</u> (Müller)	-	1	-	2
<u>Cochlicopa lubricella</u> (Porro)	-	-	-	-
<u>Columella edentula</u> (Draparnaud)	-	-	1	2
<u>Columella aspera</u> Waldén	-	-	-	-
<u>Vertigo pusilla</u> Müller	-	?1	-	2
<u>Vertigo antivertigo</u> (Draparnaud)	-	-	1	-
<u>Vertigo substriata</u> (Jeffreys)	-	-	-	-
<u>Vertigo pygmaea</u> (Draparnaud)	-	-	-	1
<u>Vertigo moulinsiana</u> (Dupuy)	-	-	-	-
<u>Vertigo alpestris</u> Alder	-	-	-	-
<u>Vertigo angustior</u> Jeffreys	-	-	3	3
<u>Pupilla muscorum</u> (Linné)	-	-	-	-
<u>Leiostyla anglica</u> (Wood)	-	-	-	-
<u>Lauria cylindracea</u> (da Costa)	-	-	-	-
<u>Vallonia costata</u> (Müller)	1	1	1	8
<u>Vallonia pulchella</u> (Müller)	8	4	3	3
<u>Vallonia excentrica</u> Sterki	1	3	1	-
<u>Vallonia pulchella/excentrica</u>	15	9	9	6
<u>Acanthinula aculeata</u> (Müller)	-	-	-	-
<u>Spermodea lamellata</u> (Jeffreys)	-	-	-	-
<u>Ena obscura</u> (Müller)	-	-	-	-
<u>Punctum pygmaeum</u> (Draparnaud)	9	9	10	18
<u>Discus rudерatus</u> (Férussac)	-	-	-	-
<u>Discus rotundatus</u> (Müller)	-	-	-	-
<u>Vitrina pellucida</u> (Müller)	9	3	1	6

380	330	400	300	400	500	500	500	800	500	500	500	500
325-330	320-325	315-320	310-315	305-310	290-300	275-285	260-270	250-260	240-250	230-240	210-220	
-	-	-	-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-	-	-	-
24	2	30	2	6	51	29	48	82	85	28	13	
292	14	95	24	45	414	354	421	359	623	499	85	
3	-	1	-	3	14	7	37	40	3	1	-	
-	-	-	-	-	-	-	18	33	1	1	4	
38	2	24	5	6	24	21	33	31	37	30	16	
1	-	-	-	-	-	-	-	-	-	-	-	
10	1	3	1	14	46	40	31	94	35	20	15	
-	-	-	-	-	-	-	-	1	-	-	-	
14	1	3	1	3	20	13	16	10	23	8	6	
-	-	-	-	-	-	-	-	-	-	-	-	
2	-	2	2	4	19	21	32	50	31	6	-	
-	-	-	-	-	-	-	-	-	-	-	-	
-	-	-	-	-	2	1	65	77	3	-	3	
-	-	-	1	-	-	-	-	-	-	-	-	
1	1	4	7	33	125	105	86	350	59	47	22	
-	-	-	-	-	-	-	-	-	-	-	-	
-	-	-	-	-	-	-	-	-	-	-	-	
65	1	5	4	11	55	40	61	50	6	2	4	
-	-	-	-	-	-	-	-	-	-	-	-	
-	-	-	-	-	-	-	-	-	-	-	-	
-	-	-	-	-	-	-	-	-	-	-	-	
3	-	-	-	1	5	1	2	1	19	19	2	
-	-	-	-	-	-	-	-	-	-	-	-	
21	2	1	-	2	34	13	23	99	23	16	3	
-	-	21	-	-	1	-	-	-	-	-	-	
-	-	-	-	1	1	1	4	2	13	4	2	
-	-	-	-	-	-	-	1	-	-	-	2	

200-210	700	500	500	500	500	500	500	500	500	500	500	500	500
195-200	500	500	500	500	500	500	500	500	500	500	500	500	500
190-195	500	500	500	500	500	500	500	500	500	500	500	500	500
180-185	500	500	500	500	500	500	500	500	500	500	500	500	500
170-175	500	500	500	500	500	500	500	500	500	500	500	500	500
160-165	500	500	500	500	500	500	500	500	500	500	500	500	500
150-155	500	500	500	500	500	500	500	500	500	500	500	500	500
140-145	500	500	500	500	500	500	500	500	500	500	500	500	500
130-135	500	500	500	500	500	500	500	500	500	500	500	500	500
120-125	500	500	500	500	500	500	500	500	500	500	500	500	500
110-115	500	500	500	500	500	500	500	500	500	500	500	500	500
100-105	500	500	500	500	500	500	500	500	500	500	500	500	500
-	-	-	-	-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-	-	-	-	-
13	17	18	5	5	32	44	36	48	10	22	40		
194	148	1289	524	609	568	514	362	1177	278	371	853		
-	-	1	6	-	3	10	2	4	1	6	26		
7	2	1	22	2	3	8	2	3	2	2	1		
18	12	55	41	48	51	45	26	80	37	62	78		
-	-	-	1	-	-	-	-	1	-	-	-		
21	11	28	42	21	34	32	17	48	21	48	52		
-	-	-	-	1	-	-	-	-	-	-	-		
6	3	34	35	10	7	3	7	19	-	5	9		
-	-	-	-	-	-	-	-	-	-	-	-		
3	-	2	33	24	18	20	7	16	34	25	23		
-	-	-	-	-	-	-	-	-	-	-	-		
-	1	2	3	2	1	-	-	-	1	1	23		
-	-	-	-	-	-	-	-	-	-	-	-		
30	21	153	42	35	2	-	-	-	-	-	-		
-	-	-	-	-	-	-	-	-	-	-	-		
-	-	-	-	-	-	-	-	-	-	-	-		
14	3	24	4	22	23	32	27	28	7	7	44		
21	11	59	16	-	-	-	-	-	-	34	119		
-	-	-	-	-	-	-	-	-	-	-	-		
-	-	-	-	-	-	-	-	-	-	-	-		
-	-	-	-	-	-	-	-	-	-	-	-		
6	7	65	37	19	34	41	23	89	7	10	38		
-	-	-	-	-	-	-	-	-	-	-	-		
-	-	-	-	-	-	-	-	-	-	-	-		
4	8	51	34	26	55	39	16	69	16	17	82		
-	-	-	-	-	-	-	-	-	-	-	-		
7	10	109	47	83	53	20	12	139	11	20	119		
1	-	-	-	-	1	-	-	2	-	-	1		

95	85	75	65	55	50	45	40	35	30	25
90-	80-	70-	60-	50-	45-	40-	35-	30-	25-	20-

500	500	500	500	500	500	500	500	500	500	500
-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----

-	-	-	1	1	-	2	3	3	2	3
-	-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	62	102	84	149
23	29	27	84	16	6	26	22	39	22	41
636	475	1274	1210	284	61	357	596	686	571	805
5	35	14	3	9	-	2	21	6	33	71
5	3	5	7	2	7	2	5	6	6	20
64	48	143	90	15	2	18	45	38	33	48
-	-	-	-	-	-	-	-	-	-	1
63	41	64	64	43	15	20	32	30	16	23
-	-	-	-	1	1	-	-	-	-	-
14	11	4	11	4	3	7	19	11	5	19
-	-	-	-	-	-	-	-	-	-	-
22	15	59	74	32	23	15	6	4	-	-
-	-	-	-	-	-	-	-	-	-	-
2	14	38	36	20	12	4	4	-	-	-
-	-	-	-	-	-	-	-	-	1	-
-	-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-	-
45	114	115	152	82	15	22	11	7	3	4
34	60	130	66	19	-	49	59	26	21	24
48	27	121	9	5	4	67	76	54	9	17
-	-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-	-
32	6	52	19	11	2	15	31	44	24	38
37	16	228	311	52	9	23	31	9	9	34
-	-	-	-	-	-	-	-	-	-	-
50	26	63	42	14	6	24	18	8	15	23
-	-	-	-	-	-	-	-	-	-	-
75	19	68	54	27	6	65	346	198	102	140
4	-	3	-	1	-	-	5	-	-	2

<u>Vitrea crystallina</u> (Müller)	-	-	-	-
<u>Vitrea contracta</u> (Westerlund)	-	-	-	1
<u>Nesovitrea hammonis</u> (Ström)	3	2	2	3
<u>Aegopinella pura</u> (Alder)	-	-	-	-
<u>Aegopinella nitidula</u> (Draparnaud)	-	2	3	1
<u>Oxychilus cellarius</u> (Müller)	-	-	-	-
<u>Oxychilus alliarius</u> (Miller)	-	-	-	-
<u>Zonitoides nitidus</u> (Müller)	2	2	5	4
<u>Deroceras/Limax</u>	7	7	8	6
<u>Euconulus fulvus</u> (Müller)	1	4	2	10
<u>Cochlodina laminata</u> (Montagu)	-	-	-	-
<u>Macrogastera rolphii</u> (Turton)	-	-	-	-
<u>Clausilia bidentata</u> (Ström)	-	-	-	-
<u>Balea perversa</u> (Linné)	-	-	-	-
<u>Trichia hispida</u> (Linné)	2	1	-	1
<u>Trichia striolata</u> (Pfeiffer)	-	-	-	-
<u>Helicigona lapicida</u> (Linné)	-	-	-	-
<u>Arianta arbustorum</u> (Linné)	-	x	-	x
<u>Arianta/Cepaea</u>	-	2	2	2
<u>Cepaea</u>	-	-	-	-
<u>Pisidium casertanum</u> (Poli)	3	7	7	13
<u>Pisidium personatum</u> Malm	6	-	-	-
<u>Pisidium obtusale</u> (Lamarck)	-	-	-	-
<u>Pisidium milium</u> Held	-	-	-	-

-	-	-	-	-	-	-	-	-	-	-	-
9	22	12	14	19	8	32	96	6	1	3	36
6	16	9	4	4	1	1	9	2	-	4	21
-	-	-	-	-	-	-	-	-	-	2	6
4	8	11	6	6	4	12	41	4	1	2	29
-	-	-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-	-	-
6	8	1	1	5	-	3	5	10	7	33	9
6	6	7	6	19	7	5	13	2	3	-	3
4	7	3	3	5	1	4	12	2	-	2	9
-	-	-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	21	-	-	-
1	2	1	2	7	1	2	16	5	1	3	22
-	-	-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-	-	-
x	x	x	x	x	x	x	x	x	x	x	x
3	4	4	3	3	2	1	9	2	2	2	3
-	x	x	x	x	-	-	x	-	-	x	x
5	7	7	3	7	2	2	16	-	-	-	3
1	9	6	3	5	2	6	16	1	4	1	5
-	-	-	-	-	-	1	-	-	-	-	-
-	-	-	-	-	-	1	-	-	-	-	-

[illegible]

[illegible]

[illegible]

Appendix 2ii

Blashenwell, Dorset

Depth (cm)	290-300	280-290	275-280	265-270
Dry weight (g)	1000	1000	500	500
<u>Pomatias elegans</u> (Müller)	-	-	-	-
<u>Carychium minimum</u> Müller	8	7	26	6
<u>Carychium tridentatum</u> (Risso)	-	43	218	228
<u>Aplexa hypnorum</u> (Linné)	-	-	-	-
<u>Lymnaea truncatula</u> (Müller)	130	28	12	2
<u>Anisus leucostoma</u> (Miller)	-	-	-	-
<u>Cochlicopa lubrica</u> (Müller)	42	30	61	58
<u>Cochlicopa lubricella</u> (Porro)	-	-	2	1
<u>Columella edentula</u> (Draparnaud)	2	-	-	-
<u>Vertigo pusilla</u> Müller	5	5	14	4
<u>Vertigo substriata</u> (Jeffreys)	1	-	-	-
<u>Vertigo pygmaea</u> (Draparnaud)	-	-	-	-
<u>Vertigo alpestris</u> Alder	-	-	?1	3
<u>Leiostryla anglica</u> (Wood)	1	7	13	5
<u>Lauria cylindracea</u> (da Costa)	-	-	-	-
<u>Vallonia costata</u> (Müller)	-	-	-	-
<u>Vallonia pulchella</u> (Müller)	9	3	2	1
<u>Vallonia pulchella/excentrica</u>	10	-	-	-
<u>Acanthinula aculeata</u> (Müller)	2	4	2	10
<u>Ena montana</u> (Draparnaud)	-	-	-	-
<u>Ena obscura</u> (Müller)	-	-	-	-
<u>Punctum pygmaeum</u> (Draparnaud)	23	15	56	54
<u>Discus rudératus</u> (Férussac)	-	-	-	?1
<u>Discus rotundatus</u> (Müller)	-	-	-	-
<u>Vitrina pellucida</u> (Müller)	2	2	9	4
<u>Vitrea crystallina</u> (Müller)	-	-	-	-
<u>Vitrea contracta</u> (Westerlund)	19	13	41	49
<u>Nesovitrea hammonis</u> (Ström)	6	-	-	-
<u>Aegopinella pura</u> (Alder)	-	-	-	-
<u>Aegopinella nitidula</u> (Draparnaud)	5	11	18	44

[illegible]

	500	500	500	500	500	500	500	1000	1000	1000	1000	1000
145-150												
135-140												
130-135												
125-130												
120-125												
115-120												
110-115												
105-110												
95-100												
85-90												
75-80												
65-70												
500	500	500	500	500	500	500	500	1000	1000	1000	1000	1000
5	2	1	-	-	-	-	-	-	-	-	-	1
229	75	248	492	298	305	174	128	48	5	4	18	
1	-	-	-	-	-	-	2	2	12	4	-	
-	-	-	-	-	-	-	-	-	-	-	-	
69	15	27	31	32	42	36	71	65	22	13	12	
4	-	1	-	1	3	1	1	-	-	-	-	
2	1	2	3	2	3	2	2	1	-	-	-	
11	1	6	6	5	4	3	-	1	-	-	-	
4	-	-	-	-	-	-	-	-	-	-	-	
-	-	-	-	-	-	-	-	-	-	-	-	
-	-	-	-	-	1	-	1	-	-	22	21	
-	-	-	-	-	-	-	-	-	-	-	-	
8	-	5	1	2	5	6	8	17	7	4	1	
-	9	50	80	59	59	46	14	1	-	-	4	
-	-	-	-	-	-	-	-	-	-	-	-	
-	-	-	-	-	-	-	-	-	-	-	-	
2	3	6	21	18	14	3	7	1	-	3	-	
-	-	-	21	-	-	-	-	-	-	-	-	
-	-	-	1	-	-	-	-	-	-	-	-	
3	-	2	5	4	5	10	9	7	5	5	5	
-	-	-	-	-	-	-	-	-	-	-	-	
76	10	33	72	52	26	18	12	7	1	1	1	
-	-	-	-	-	-	1	3	4	-	4	-	
-	-	-	-	-	-	-	-	-	-	-	-	
57	14	29	55	28	31	20	19	13	5	3	1	
-	-	-	1	3	2	4	1	1	1	-	1	
22	15	16	34	23	13	11	6	-	-	-	2	
84	24	35	61	49	50	43	41	17	3	7	-	

60	50	40	35	30
55-	45-	35-	30-	25-

1000	1500	1000	1000	1000
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-	-	1	4	3
-	-	3	2	4
31	2	38	138	72
-	-	-	1	-
-	4	7	10	2
-	-	2	3	1
52	58	27	25	37
-	-	-	-	-
-	1	-	1	-
-	-	-	1	-
-	-	-	-	-
16	17	7	12	38
-	-	-	-	-
-	-	5	27	7
-	-	6	13	3
29	-	5	27	44
-	-	-	-	-
-	-	-	-	-
1	-	2	4	4
-	-	-	-	-
1	-	-	1	-
23	21	7	7	15
-	-	-	-	-
2	3	2	21	11
-	2	1	1	3
-	-	-	7	6
7	1	7	17	15
1	-	-	1	-
-	-	-	3	2
9	3	3	27	16

<u>Oxychilus cellarius</u> (Müller)	-	-	-	-
<u>Oxychilus alliarius</u> (Miller)	5	4	6	3
<u>Zonitoides excavatus</u> (Alder)	-	-	-	-
<u>Zonitoides nitidus</u> (Müller)	18	4	16	2
Limacid plates	15	11	20	8
<u>Euconulus fulvus</u> (Müller)	12	4	6	10
<u>Clausilia bidentata</u> (Ström)	-	-	1	4
<u>Balea perversa</u> (Linné)	-	-	-	-
<u>Ashfordia granulata</u> (Alder)	-	-	-	-
<u>Trichia hispida</u> (Linné)	6	-	7	9
<u>Arianta arbustorum</u> (Linné)	-	-	-	-
<u>Cepaea/Arianta</u>	2	2	1	2
<u>Cepaea</u> spp.	+	+	+	+

[illegible]

-	-	10	32	28	16	16	12	1	1	-	-
7	2	2	3	-	-	-	?1	-	-	-	-
1	-	-	-	-	-	-	-	-	-	-	-
1	1	-	-	-	-	-	-	-	-	-	-
10	18	28	34	9	21	15	9	1	3	-	-
1	1	-	-	-	-	-	-	2	-	2	-
10	1	13	30	10	6	6	2	3	1	2	-
1	-	-	1	1	-	1	-	-	-	-	-
19	12	24	42	49	41	21	38	24	5	7	3
4	1	1	6	3	7	6	9	6	4	7	3
+	+	+	+	+	+	+	+	-	-	-	-
16	3	4	13	4	10	5	13	13	4	2	1
+	+	+	+	+	+	-	+	+	+	+	+

-	-	-	1	2
-	-	-	-	-
-	-	-	-	-
-	-	?1	1	-
1	2	4	7	14
-	-	2	7	-
1	-	2	2	2
-	-	-	-	-
3	5	6	8	5
9	10	11	9	11
-	-	-	-	-
2	6	3	4	4
+	+	+	+	+

Appendix 2iii

Caerwys - Large quarry. Series A

Depth (cm)	600-610	550-560	520-530	500-510
Dry weight (g)	500	500	500	500
<u>Pomatias elegans</u> (Müller)	-	-	-	-
<u>Carychium minimum</u> Müller	22	2	28	13
<u>Carychium tridentatum</u> (Risso)	-	-	72	12
<u>Lymnaea truncatula</u> (Müller)	1	3	1	1
<u>Lymnaea peregra</u> (Müller)	-	-	65	168
<u>Gyraulus laevis</u> (Alder)	-	-	-	-
<u>Armiger crista</u> (Linneé)	-	-	-	-
<u>Ancylus fluviatilis</u> Müller	-	-	-	-
<u>Succinea oblonga</u> Draparnaud	-	-	-	-
cf <u>Oxyloma pfeifferi</u> (Rossmässler)	3	5	31	28
<u>Cochlicopa lubrica</u> (Müller)	16	5	94	35
<u>Cochlicopa lubricella</u> (Porro)	-	-	1	-
<u>Pyramidula rupestris</u> (Draparnaud)	-	-	-	-
<u>Columella edentula</u> (Draparnaud) agg.	6	-	3	27
<u>Columella aspera</u> Waldén	-	-	+	+
<u>Vertigo pusilla</u> Müller	-	-	-	-
<u>Vertigo antivertigo</u> (Draparnaud)	5	1	20	33
<u>Vertigo substriata</u> (Jeffreys)	-	-	-	-
<u>Vertigo pygmaea</u> (Draparnaud)	-	-	-	-
<u>Vertigo moulinsiana</u> (Dupuy)	-	-	4	6
<u>Vertigo alpestris</u> Alder	-	-	-	-
<u>Vertigo angustior</u> Jeffreys	-	3	38	7
<u>Pupilla muscorum</u> (Linneé)	9	3	17	2
<u>Leiostyla anglica</u> (Wood)	-	-	14	37
<u>Lauria cylindracea</u> (da Costa)	-	-	-	-
<u>Vallonia costata</u> (Müller)	-	-	-	-
<u>Vallonia pulchella</u> (Müller)	6	2	11	2
<u>Vallonia excentrica</u> Sterki	-	-	-	-
<u>Vallonia pulchella/excentrica</u>	11	6	18	-
<u>Acanthinula aculeata</u> (Müller)	-	-	-	-
<u>Spermodea lamellata</u> (Jeffreys)	-	-	-	-

[illegible]

356-361	500	500	500	500	1000	1000	500	500	500	500	500	500	500
351-356	500	500	500	500	1000	1000	500	500	500	500	500	500	500
342-351	500	500	500	500	1000	1000	500	500	500	500	500	500	500
332-342	500	500	500	500	1000	1000	500	500	500	500	500	500	500
322-332	500	500	500	500	1000	1000	500	500	500	500	500	500	500
312-322	500	500	500	500	1000	1000	500	500	500	500	500	500	500
308-312	500	500	500	500	1000	1000	500	500	500	500	500	500	500
304-308	500	500	500	500	1000	1000	500	500	500	500	500	500	500
300-304	500	500	500	500	1000	1000	500	500	500	500	500	500	500
290-300	500	500	500	500	1000	1000	500	500	500	500	500	500	500
280-290	500	500	500	500	1000	1000	500	500	500	500	500	500	500
230-240	500	500	500	500	1000	1000	500	500	500	500	500	500	500
-	-	-	-	-	-	-	-	-	-	-	-	-	-
102	286	17	23	1	-	-	1	3	1	-	-	-	-
50	128	120	45	2	5	11	9	41	60	-	-	-	7
76	102	3	-	-	-	1	1	3	4	1	-	-	-
-	-	11	227	190	7	14	3	4	19	29	206	-	-
-	-	-	-	-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-	-	-	-	-
43	53	12	12	5	10	-	4	1	1	2	8	-	-
89	217	41	34	1	11	10	14	60	58	-	17	-	-
-	-	-	-	-	-	-	-	-	2	-	-	-	-
-	-	-	-	-	-	-	-	-	-	-	-	-	-
20	50	25	10	5	9	2	3	6	12	-	6	-	-
+	+	-	-	-	-	-	-	-	+	-	-	-	-
-	1	-	1	-	-	-	-	-	-	-	-	-	-
-	-	6	-	5	-	-	-	-	-	-	-	-	-
2	5	7	16	-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-	-	-	-	-
17	12	4	4	2	1	-	-	2	2	-	-	-	-
-	1	-	-	-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-	-	-	-	-
13	57	10	16	-	14	21	1	2	-	-	6	-	-
129	306	65	77	13	10	12	10	4	2	-	8	-	-
-	-	-	1	-	-	-	-	1	-	-	1	-	-
-	-	-	-	-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-	-	-	-	-
7	21	31	7	1	-	-	5	17	22	-	2	-	-
28	90	14	32	-	1	-	-	-	2	-	-	-	-

	650	500	500	500	500
190-210	-	-	3	5	3
110-130	-	3	-	1	2
50-70	1	4	5	40	55
20-40	-	-	-	-	-
0-20	-	-	-	-	-
	10	123	1	-	-
	-	-	-	-	-
	-	-	-	-	-
	-	-	-	-	-
	1	1	2	-	-
	-	4	5	-	-
	-	6	12	12	4
	-	-	-	-	-
	-	-	-	-	-
	8	6	-	-	-
	-	+	-	-	-
	-	-	-	-	-
	-	-	-	-	-
	-	-	9	-	-
	-	-	-	-	-
	-	-	-	-	-
	-	-	-	-	-
	1	1	12	1	-
	4	32	-	-	-
	4	6	-	-	-
	-	-	20	13	30
	-	-	-	1	-
	-	-	7	8	6
	-	-	17	16	6
	-	4	-	5	-
	-	1	-	-	-

<u>Ena obscura</u> (Müller)	-	-	-	-
<u>Punctum pygmaeum</u> (Draparnaud)	13	3	70	46
<u>Discus ruderatus</u> (Férussac)	-	-	-	-
<u>Discus rotundatus</u> (Müller)	-	-	-	-
<u>Vitrina pellucida</u> (Müller)	1	-	-	-
<u>Vitrea contracta</u> (Westerlund)	27	4	51	11
<u>Nesovitrea hammonis</u> (Ström)	4	3	42	5
<u>Aegopinella pura</u> (Alder)	-	-	-	-
<u>Aegopinella nitidula</u> (Draparnaud)	-	-	8	2
<u>Oxychilus cellarius</u> (Müller)	-	-	-	-
<u>Oxychilus alliarius</u> (Miller)	-	-	-	-
<u>Zonitoides excavatus</u> (Alder)	-	-	-	-
<u>Zonitoides nitidus</u> (Müller)	2	1	9	10
<u>Limacid plates</u>	4	3	21	16
<u>Euconulus fulvus</u> (Miller)	8	2	26	21
<u>Ceciloides acicula</u> (Müller)	-	-	-	-
<u>Clausilia bidentata</u> (Ström)	-	-	-	1
<u>Candidula intersecta</u> (Poiret)	-	-	-	-
<u>Ashfordia granulata</u> (Alder)	-	-	-	-
<u>Zenobiella subrufescens</u> (Miller)	-	-	-	-
<u>Trichia hispida</u> (Linné)	-	-	-	-
<u>Arianta arbustorum</u> (Linné)	+	-	-	+
<u>Cepaea/Arianta</u>	3	1	6	11
<u>Cepaea</u> spp.	-	-	-	-
<u>Helix aspersa</u> Müller	-	-	-	-
<u>Pisisium casertanum</u> (Poli)	-	-	-	-
<u>Pisidium personatum</u> Malm	-	-	-	-

-	-	-	-	-	-	1	1	-	-	-	-
19	23	131	4	2	6	56	119	52	87	26	22
-	-	-	-	-	-	1	-	-	-	-	-
-	-	-	-	-	-	26	151	168	281	71	49
-	-	7	-	1	-	1	-	1	1	-	-
29	74	96	-	-	-	79	168	205	263	32	41
20	38	96	-	1	1	62	90	49	61	15	13
-	-	-	-	-	-	13	5	21	27	4	2
-	5	30	-	-	-	19	17	30	55	6	1
-	-	-	-	-	-	-	-	-	22	20	7
-	1	-	-	-	-	2	7	5	9	2	2
-	-	-	-	-	-	-	-	4	5	-	-
7	8	31	2	2	8	54	97	23	35	1	4
5	3	21	-	5	2	23	40	30	40	16	10
18	22	64	3	3	8	34	97	25	58	20	27
-	-	-	-	-	-	-	-	-	-	-	-
-	-	-	1	1	-	7	-	1	3	1	-
-	-	-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	3	5	-	-
-	-	-	-	-	-	5	9	3	10	2	-
+	-	+	-	+	-	+	-	+	+	+	-
3	5	11	1	1	-	6	7	4	8	5	-
-	-	-	-	-	-	-	-	-	-	+	-
-	-	-	-	-	-	-	-	-	-	-	-
-	-	-	-	4	1	-	-	-	-	-	-
-	-	-	-	-	2	8	21	-	-	-	-

[illegible]

1	1	-	-	-
1	11	5	9	10
-	-	-	-	-
-	12	-	19	12
-	-	2	6	-
-	9	2	17	2
1	-	-	-	5
2	1	2	6	2
-	-	-	6	-
-	1	-	11	5
-	1	-	-	8
-	-	-	-	-
-	-	-	-	-
2	1	8	20	15
1	7	-	-	-
-	-	-	24	2
-	3	-	2	1
-	-	-	7	-
-	-	-	1	11
-	1	-	-	-
1	4	6	57	31
-	-	+	-	-
1	1	3	1	3
+	+	+	+	-
-	-	-	3	1
-	-	-	-	-
-	-	-	-	-

Appendix 2iv

Caerwys - Large quarry. Series B

Depth (cm)	330-350	310-330	290-310	270-290
Dry weight (g)	550	150	340	290
<u>Carychium minimum</u> Müller	-	-	-	-
<u>Carychium tridentatum</u> (Risso)	-	-	-	-
<u>Lymnaea truncatula</u> (Müller)	-	-	-	-
<u>Lymnaea peregra</u> (Müller)	1	1	4	-
<u>Gyraulus laevis</u> (Alder)	-	-	-	-
<u>Armiger crista</u> (Linné)	-	-	-	-
<u>Hippeutis complanatus</u> (Linné)	-	-	-	-
cf. <u>Oxyloma pfeifferi</u> (Rossmässler)	-	-	2	1
cf. <u>Oxyloma sarsi</u> (Esmark)	-	-	-	-
<u>Cochlicopa lubrica</u> (Müller)	1	-	-	-
<u>Cochlicopa lubricella</u> (Porro)	-	-	-	-
<u>Columella edentula</u> (Draparnaud) agg.	-	-	-	-
<u>Columella aspera</u> Waldén	-	-	-	-
<u>Vertigo pusilla</u> Müller	-	-	-	-
<u>Vertigo antivertigo</u> (Draparnaud)	-	-	-	-
<u>Vertigo substriata</u> (Jeffreys)	-	-	-	-
<u>Vertigo pygmaea</u> (Draparnaud)	-	-	-	-
<u>Vertigo moulinsiana</u> (Dupuy)	-	-	-	-
<u>Vertigo genesii</u> Gredler	-	-	-	-
<u>Vertigo geyeri</u> Lindholm	-	-	-	-
<u>Vertigo angustior</u> Jeffreys	-	-	-	-
<u>V. genesii/geyeri/pygmaea</u>	-	-	1	-
<u>Pupilla muscorum</u> (Linné)	-	-	-	-
<u>Leiostylia anglica</u> (Wood)	-	-	-	-
<u>Vallonia costata</u> (Müller)	-	-	-	-
<u>Vallonia pulchella</u> (Müller)	-	-	-	-
<u>Vallonia pulchella / excentrica</u>	-	1	1	-
<u>Acanthinula aculeata</u> (Müller)	-	-	-	-
<u>Punctum pygmaeum</u> (Draparnaud)	2	1	-	-
<u>Vitrina pellucida</u> (Müller)	-	-	-	-
<u>Vitrea contracta</u> (Westerlund)	-	-	-	-

250-270	200	210	220	180	500	500	500	500	500	500	500	500	500
230-250	1	10	28	10	-	-	-	-	-	-	260	106	-
210-230	-	-	-	-	-	-	-	-	-	-	-	-	-
190-210	-	5	2	-	-	-	-	-	-	-	4	3	-
180-190	1	2	26	2	39	67	30	58	40	4	14	40	40
170-180	-	-	-	-	-	-	-	-	-	-	-	10	-
160-170	-	-	-	-	-	-	-	-	-	-	-	-	-
150-160	-	2	11	12	4	2	10	-	5	10	27	16	-
140-150	-	-	-	-	-	-	-	-	-	-	-	-	-
128-140	-	11	9	5	-	-	1	2	-	1	182	43	-
125-128	-	-	-	-	-	-	-	-	-	-	-	-	-
120-125	-	2	-	1	-	-	1	1	1	-	79	39	-
	-	-	-	-	-	-	-	-	-	-	+	+	-
	-	-	-	-	-	-	-	-	-	-	-	-	-
	-	14	6	20	-	-	-	-	2	-	133	81	-
	-	-	-	-	-	-	-	-	-	-	12	1	-
	-	-	-	-	-	-	-	-	-	-	-	1	-
	-	-	-	-	-	-	-	-	-	-	3	6	-
	-	-	-	-	-	-	-	-	-	-	5	1	-
	-	2	1	3	-	-	-	-	-	-	1	1	-
	-	-	-	-	-	-	-	-	-	-	-	-	-
	1	2	5	-	-	-	-	-	-	-	18	1	-
	-	1	1	1	1	1	-	1	-	2	76	27	-
	-	-	-	-	-	-	-	-	-	-	-	-	-
	-	-	-	-	-	-	-	-	-	-	-	-	-
	-	-	-	-	-	-	-	-	-	-	-	-	-
	-	5	1	2	-	-	-	-	-	-	32	9	-
	-	4	10	6	-	-	-	1	-	-	101	33	-
	-	-	-	-	-	-	-	-	-	-	-	-	-
	-	10	12	3	-	-	-	-	-	-	113	61	-
	-	1	1	-	-	-	-	-	-	-	4	4	-
	-	-	-	-	-	-	1	2	3	-	171	64	-

[illegible]

<u>Nesovitrea hammonis</u> (Ström)	-	-	-	-
<u>Aegopinella nitidula</u> (Draparnaud)	-	-	-	-
<u>Oxychilus alliarius</u> (Miller)	-	-	-	-
<u>Zonitoides nitidus</u> (Müller)	-	?1	-	-
Limacid plates	4	1	-	-
<u>Euconulus fulvus</u> (Müller)	-	-	-	-
<u>Clausilia bidentata</u> (Ström)	-	-	-	-
<u>Arianta arbustorum</u> (Linné)	-	-	-	-
<u>Cepaea/Arianta</u>	-	-	-	-
<u>Cepaea</u> spp	-	-	-	-
<u>Pisidium casertanum</u> (Poli)	-	-	-	-
<u>Pisidium personatum</u> Malm	-	-	-	-
<u>Pisidium milium</u> Held	-	-	-	-

[illegible]

[illegible]

Appendix 2v

Caerwys - Large quarry. Series C

	70- 75	70- 75	65- 65	60- 60
Depth (cm)	70- 75	65- 70	60- 65	56- 60
Dry weight (g)	500	500	500	500
<u>Carychium minimum</u> Müller	2	5	3	12
<u>Carychium tridentatum</u> (Risso)	-	-	3	5
<u>Lymnaea truncatula</u> (Müller)	-	-	-	-
<u>Lymnaea peregra</u> (Müller)	82	93	1	2
<u>Gyraulus laevis</u> (Alder)	108	69	-	-
<u>Armiger crista</u> (Linné)	89	112	-	1
<u>Ancylus fluviatilis</u> Müller	27	17	-	-
cf <u>Oxyloma pfeifferi</u> (Rossmässler)	2	3	-	5
<u>Cochlicopa lubrica</u> (Müller)	2	1	3	2
<u>Cochlicopa lubricella</u> (Porro)	-	-	-	-
<u>Columella edentula</u> (Draparnaud) agg	-	-	-	3
<u>Columella aspera</u> Waldén	-	-	-	-
<u>Vertigo pusilla</u> Müller	1	-	-	-
<u>Vertigo antivertigo</u> (Draparnaud)	34	99	25	38
<u>Vertigo substriata</u> (Jeffreys)	1	-	-	-
<u>Vertigo moulinsiana</u> (Dupuy)	12	11	6	3
<u>Vertigo alpestris</u> Alder	-	-	-	-
<u>Vertigo angustior</u> Jeffreys	-	-	2	2
<u>Pupilla muscorum</u> (Linné)	-	1	1	1
<u>Leiostryla anglica</u> (Wood)	-	1	2	1
<u>Vallonia costata</u> (Müller)	-	-	-	-
<u>Acanthinula aculeata</u> (Müller)	-	-	-	-
<u>Spermodea lamellata</u> (Jeffreys)	-	-	-	-
<u>Ena obscura</u> (Müller)	-	-	-	-
<u>Punctum pygmaeum</u> (Draparnaud)	1	3	2	1
<u>Discus ruderatus</u> (Férussac)	-	-	-	-
<u>Discus rotundatus</u> (Müller)	-	-	-	-
<u>Vitrina pellucida</u> (Müller)	-	-	-	-
<u>Vitrea contracta</u> (Westerlund)	-	1	-	2
<u>Nesovitrea hammonis</u> (Ström)	-	-	2	-
<u>Aegopinella pura</u> (Alder)	-	-	-	-

53- 56	50- 53	45- 50	40- 45	35- 40	31- 35	29- 31	27- 29	25- 27	20- 25	15- 20	10- 15
500	500	500	500	500	500	500	500	500	500	500	500
343	57	25	54	48	175	268	297	235	193	173	77
20	6	67	17	6	21	22	26	14	14	71	211
-	-	-	-	-	1	-	17	26	21	8	5
35	53	44	12	20	64	93	39	-	-	-	-
-	-	-	-	-	-	-	-	-	-	-	-
-	-	2	-	-	-	-	-	-	-	-	-
-	-	2	-	-	-	-	-	-	-	-	-
64	21	18	34	24	45	41	50	30	10	13	8
45	10	17	9	11	44	51	89	128	140	169	137
-	-	1	-	-	1	-	-	-	-	-	-
73	37	17	26	8	61	55	73	90	62	73	64
+	+	+	-	-	+	+	+	+	+	+	+
12	3	3	8	31	27	22	11	-	-	3	3
371	152	81	207	147	246	274	163	49	13	-	2
19	1	5	1	-	-	-	3	-	-	-	16
21	23	11	28	13	11	14	16	-	-	-	-
-	-	-	1	12	-	1	-	-	-	-	-
84	8	15	5	4	14	33	29	-	-	-	-
4	1	4	1	3	1	2	-	-	-	-	-
6	-	25	3	1	-	2	128	264	335	417	380
4	2	8	-	-	2	5	1	-	-	-	-
2	-	9	-	1	1	8	10	4	4	13	11
-	-	2	-	-	-	-	45	100	135	257	308
2	-	3	1	-	-	1	?1	-	-	-	-
34	12	19	21	18	86	59	69	93	70	64	82
-	-	1	?1	-	-	-	-	-	-	-	-
-	-	2	1	-	1	4	46	80	101	147	168
-	-	-	-	1	-	1	1	-	-	-	-
22	2	35	7	2	9	13	66	237	248	294	254
23	2	7	2	-	1	2	14	31	40	44	45
-	-	1	1	-	5	4	5	5	2	8	9

5-10	5
5-0	0-
500	400
51	41
115	16
20	-
20	-
-	-
-	-
-	-
13	1
73	46
-	-
21	17
+	+
-	-
?1	-
10	2
-	-
-	-
-	-
-	-
327	130
-	-
8	1
95	9
-	-
34	28
-	-
73	19
-	-
106	31
22	16
2	-

<u>Aegopinella nitidula</u> (Draparnaud)	-	-	-	-
<u>Oxychilus cellarius</u> (Müller)	-	-	-	-
<u>Oxychilus alliarius</u> (Miller)	1	-	-	-
<u>Zonitoides excavatus</u> (Alder)	-	-	-	-
<u>Zonitoides nitidus</u> (Müller)	1	-	1	1
Limacid plates	5	3	3	-
<u>Euconulus fulvus</u> (Müller)	3	10	5	15
<u>Clausilia bidentata</u> (Ström)	-	-	-	-
<u>Balea perversa</u> (Linné)	-	-	-	-
<u>Zenobiella subrufescens</u> (Miller)	-	-	-	-
<u>Trichia hispida</u> (Linné)	-	-	-	-
<u>Arianta arbustorum</u> (Linné)	-	-	+	-
<u>Cepaea / Arianta</u>	1	-	2	1
<u>Cepaea</u> spp.	-	-	-	-
<u>Pisidium personatum</u> Malm	23	7	-	-

3	1	6	-	-	2	1	6	6	6	12	11
-	-	-	-	-	-	-	-	-	-	-	-
-	-	5	-	-	-	1	3	18	12	8	10
-	-	-	-	-	?1	-	-	5	4	7	7
21	8	15	8	11	29	51	48	47	19	28	16
13	1	8	11	8	9	10	21	29	18	22	27
74	28	12	34	14	47	73	73	75	50	62	43
7	1	2	1	6	9	5	5	1	-	1	1
-	-	-	-	-	-	-	1	-	-	-	-
-	-	-	1	-	3	3	1	1	-	1	2
2	2	3	1	1	3	2	2	-	1	6	3
+	+	+	-	-	+	+	+	-	-	-	-
13	2	6	6	3	11	7	11	3	3	9	10
-	-	-	+	+	-	+	+	-	-	-	-
1	-	1	-	1	6	12	31	1	9	-	-

Appendix 2vi

Ddol, Clywd

	300-310	280-290	260-270	240-250
Depth (cm)				
Dry weight (g)	500	500	500	500
<u>Carychium minimum</u> Müller	1	3	6	4
<u>Carychium tridentatum</u> (Risso)	22	34	309	76
<u>Lymnaea truncatula</u> (Müller)	1	-	5	3
<u>Lymnaea peregra</u> (Müller)	-	-	-	-
<u>Ancylus fluviatilis</u> Müller	-	-	4	13
cf <u>Oxyloma pfeifferi</u> (Rossmässler)	1	-	12	2
<u>Cochlicopa lubrica</u> (Müller)	5	4	35	5
<u>Cochlicopa lubricella</u> (Porro)	-	-	-	-
<u>Columella edentula</u> (Draparnaud)	3	1	26	2
<u>Vertigo pusilla</u> Müller	1	-	6	4
<u>Vertigo substriata</u> (Jeffreys)	-	3	3	1
<u>Vertigo pygmaea</u> (Draparnaud)	-	-	-	-
<u>Vertigo alpestris</u> Alder	-	-	2	-
<u>Leiosstylyla anglica</u> (Wood)	7	9	12	5
<u>Lauria cylindracea</u> (da Costa)	-	-	7	8
<u>Vallonia costata</u> (Müller)	-	-	13	4
<u>Acanthinula aculeata</u> (Müller)	-	-	17	11
<u>Spermodea lamellata</u> (Jeffreys)	4	5	27	16
<u>Ena obscura</u> (Müller)	-	-	-	-
<u>Punctum pygmaeum</u> (Draparnaud)	1	1	40	10
<u>Discus rotundatus</u> (Müller)	13	4	61	30
<u>Vitrina pellucida</u> (Müller)	-	-	1	-
<u>Vitrea crystallina</u> (Müller)	?1	-	4	6
<u>Vitrea contracta</u> (Westerlund)	13	5	68	8
<u>Nesovitrea hammonis</u> (Ström)	2	1	1	1
<u>Aegopinella pura</u> (Alder)	1	3	42	5
<u>Aegopinella nitidula</u> (Draparnaud)	4	2	50	18
<u>Oxychilus cellarius</u> (Müller)	5	2	24	10
<u>Oxychilus alliarius</u> (Miller)	-	-	-	-
<u>Zonitoides nitidus</u> (Müller)	3	3	?1	-
Limacid plates	-	-	5	3

220-230	200-210	180-190	160-170	140-150	120-130	100-110	80-90	60-70	40-50	20-30
500	500	500	500	500	500	500	500	500	500	500
4	18	-	69	16	58	44	55	17	14	17
32	82	5	202	35	146	699	185	88	117	76
5	3	1	25	1	16	23	1	-	-	6
21	7	-	-	-	-	-	-	-	-	2
15	20	-	4	-	-	-	-	-	-	-
-	2	3	32	3	7	15	3	4	9	8
10	8	2	33	6	21	51	17	6	7	6
-	-	-	-	-	-	-	-	-	-	1
4	6	-	7	1	4	28	9	4	7	8
1	1	-	4	-	1	2	-	-	-	-
-	1	-	10	4	1	13	-	-	1	10
-	-	-	-	-	-	-	-	-	-	1
-	-	-	-	-	-	3	-	-	1	1
1	1	-	5	7	21	60	6	6	18	14
-	-	-	1	-	-	-	-	-	-	-
9	23	-	16	1	1	7	-	-	-	3
15	12	1	9	1	4	30	3	-	-	-
-	5	-	1	1	12	50	1	-	1	5
1	1	-	-	-	-	-	-	-	-	-
6	9	-	9	10	8	22	36	13	13	13
13	16	6	56	13	73	198	50	34	44	62
-	-	-	1	-	-	-	-	-	-	-
3	2	-	5	3	4	53	13	11	3	6
5	6	1	23	4	40	107	27	16	52	42
-	-	1	2	-	5	21	-	2	-	-
1	-	21	15	2	14	49	4	2	3	11
1	5	8	17	4	21	90	9	16	12	16
-	1	-	14	13	10	51	16	13	35	25
1	-	-	-	3	2	3	-	1	4	1
1	3	3	21	7	8	12	-	-	3	2
3	4	-	17	-	4	14	3	3	6	5

<u>Euconulus fulvus</u> (Müller)	4	-	16	-
<u>Cochlodina laminata</u> (Montagu)	-	-	-	-
<u>Clausilia bidentata</u> (Ström)	-	-	3	1
<u>Balea perversa</u> (Linné)	-	-	2	-
<u>Ashfordia granulata</u> (Alder)	3	-	1	-
<u>Trichia hispida</u> (Linné)	-	-	13	-
<u>Arianta arbustorum</u> (Linné)	-	+	+	-
<u>Cepaea/Arianta</u>	1	1	7	7
<u>Cepaea</u> spp.	-	-	+	-
<u>Pisidium casertanum</u> (Poli)	-	-	32	21
<u>Pisidium personatum</u> Malm	-	-	3	3
<u>Pisidium milium</u> Held	-	-	4	4
<u>Pisidium subtruncatum</u> Malm	-	-	4	1
<u>Pisidium nitidum</u> Jenyns	-	-	1	-

-	2	2	18	10	12	18	8	12	9	6
?1	-	-	-	-	-	-	-	-	-	-
1	-	-	1	-	-	3	-	-	-	1
-	1	-	-	-	-	-	1	-	-	2
-	5	8	88	74	35	148	78	74	91	124
6	5	4	1	-	-	2	-	-	-	1
-	+	-	+	-	+	+	-	-	-	-
-	1	1	6	1	3	4	-	1	3	3
-	-	-	-	-	-	-	-	-	-	-
78	110	57	279	5	59	127	4	16	?1	28
2	9	-	33	3	234	32	1	4	-	4
1	3	4	20	3	-	-	-	1	-	-
42	93	49	78	-	-	3	-	3	-	1
6	19	2	7	-	-	-	-	-	-	-

Appendix 2vii

Totland Bay, Isle of Wight

Depth (cm)	140-150	135-140	130-135	125-130
Dry weight (g)	500	500	500	500
<u>Pomatias elegans</u> (Müller)	-	-	1	3
<u>Carychium minimum</u> Müller	-	3	3	6
<u>Carychium tridentatum</u> (Risso)	5	44	42	47
<u>Lymnaea truncatula</u> (Müller)	-	2	4	1
<u>Succinea oblonga</u> Draparnaud	-	1	-	-
cf <u>Oxyloma pfeifferi</u> (Rossmässler)	1	5	4	1
<u>Cochlicopa lubrica</u> (Müller)	1	15	5	11
<u>Cochlicopa lubricella</u> (Porro)	-	-	-	-
<u>Columella edentula</u> (Draparnaud) agg.	-	2	4	8
<u>Columella aspera</u> Waldén	-	+	+	+
<u>Vertigo pusilla</u> Müller	-	-	1	1
<u>Vertigo antivertigo</u> (Draparnaud)	-	-	-	2
<u>Vertigo substriata</u> (Jeffreys)	-	-	1	1
<u>Vertigo moulinsiana</u> (Dupuy)	-	4	-	1
<u>Vertigo genesii</u> Gredler	1	-	-	-
<u>Vertigo geyeri</u> Lindholm	-	-	1	-
<u>Leiostryla anglica</u> (Wood)	1	4	5	5
<u>Lauria cylindracea</u> (da Costa)	1	6	1	1
<u>Vallonia pulchella</u> (Müller)	-	1	2	-
<u>Acanthinula aculeata</u> (Müller)	2	6	3	3
<u>Spermodea lamellata</u> (Jeffreys)	-	7	3	7
<u>Ena obscura</u> (Müller)	-	-	-	1
<u>Punctum pygmaeum</u> (Draparnaud)	1	2	3	4
<u>Discus rotundatus</u> (Müller)	3	29	15	27
<u>Vittrina pellucida</u> (Müller)	-	-	-	-
<u>Vitrea contracta</u> (Westerlund)	1	8	6	12
<u>Nesovitrea hammonis</u> (Ström)	-	1	-	3
<u>Aegopinella pura</u> (Alder)	1	5	2	5
<u>Aegopinella nitidula</u> (Draparnaud)	4	15	8	9
<u>Oxychilus cellarius</u> (Müller)	1	3	5	9
<u>Oxychilus alliarius</u> (Miller)	-	-	1	1

120-125	115-120	110-115	105-110	100-105	95-100	90-95	85-90
500	500	500	500	500	500	500	500
3	4	2	1	1	3	1	1
4	5	10	7	9	8	7	4
85	70	107	94	117	120	57	24
3	2	6	4	12	1	3	4
-	-	-	-	-	-	-	-
1	3	1	7	10	3	3	11
11	11	15	10	8	16	9	4
-	1	1	-	-	2	-	-
12	12	10	13	12	17	2	2
+	+	+	+	+	+	-	+
4	4	7	5	4	1	1	3
1	2	-	1	1	-	2	-
1	1	-	1	2	4	-	-
1	2	2	4	3	3	1	1
-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-
3	8	13	15	11	17	5	2
11	3	12	4	9	14	10	4
-	-	-	-	-	-	-	-
6	7	6	11	8	12	9	2
8	12	11	16	15	21	6	3
-	1	-	-	1	-	-	-
7	7	3	11	13	5	4	1
19	35	31	31	50	44	19	18
-	-	-	1	-	1	-	-
27	33	28	28	30	24	14	3
2	1	1	-	2	1	1	1
7	11	10	14	18	8	12	6
13	12	20	12	15	29	13	8
6	8	9	8	13	9	6	2
-	1	-	-	-	-	-	-

<u>Zonitoides excavatus</u> (Alder)	-	-	-	-
<u>Zonitoides nitidus</u> (Müller)	1	-	3	2
<u>Limacid plates</u>	-	4	6	6
<u>Euconulus fulvus</u> (Müller)	1	6	3	4
<u>Clausilia bidentata</u> (Ström)	1	2	1	2
<u>Balea perversa</u> (Linné)	-	3	3	4
<u>Trichia hispida</u> (Linné)	-	1	-	-
<u>Arianta arbustorum</u> (Linné)	-	+	-	-
<u>Cepaea / Arianta</u>	-	2	3	1
<u>Cepaea</u> spp.	-	-	+	+
<u>Pisidium amnicum</u> (Müller)	-	-	-	-
<u>Pisidium casertanum</u> (Poli)	4	47	19	30
<u>Pisidium personatum</u> Malm	2	-	-	1
<u>Pisidium milium</u> Held	1	3	-	1
<u>Pisidium subtruncatum</u> Malm	-	8	5	3
<u>Pisidium hibernicum</u> Westerlund	-	1	-	-
<u>Pisidium tenuilineatum</u> Stelfox	2	12	20	16

1	2	1	1	1	-	-	-
2	1	-	4	2	1	1	-
4	2	5	4	10	4	3	-
6	4	7	5	8	14	4	2
1	3	2	2	1	1	-	1
5	3	7	3	8	11	7	3
5	1	3	3	1	3	1	2
+	-	-	+	-	+	+	+
8	4	2	3	2	2	2	1
+	+	+	-	-	+	-	-
-	-	-	-	-	1	-	-
67	69	111	154	188	139	87	102
2	5	7	5	11	12	10	3
1	4	3	8	2	-	2	1
4	7	6	9	10	14	12	13
-	-	-	-	-	-	-	-
31	52	31	56	51	55	56	32

Appendix 2viii

Wilstone, Herts

Depth (cm)	120-130	110-120	100-110	90-100
Dry weight (g)	500	500	500	500
<u>Carychium minimum</u> Müller	-	-	-	-
<u>Lymnaea truncatula</u> (Müller)	1	3	8	43
<u>Armiger crista</u> (Linné)	-	-	-	-
<u>Catinella arenaria</u> (Bouchard-Chantereaux)	2	3	6	35
cf. <u>Oxyloma pfeifferi</u> (Rossmässler)	-	-	-	-
<u>Cochlicopa lubrica</u> (Müller)	-	-	1	2
<u>Vertigo antivertigo</u> (Draparnaud)	-	-	-	-
<u>Vertigo substriata</u> (Jeffreys)	-	-	-	-
<u>Vertigo pygmaea</u> (Draparnaud)	-	-	-	-
<u>Vertigo genesii</u> Gredler	-	1	7	7
<u>Vertigo geyeri</u> Lindholm	-	-	-	-
<u>Vertigo</u> spp (not <u>substriata</u>)	2	3	-	38
<u>Pupilla muscorum</u> (Linné)	-	1	3	9
<u>Vallonia pulchella</u> (Müller)	1	-	4	17
<u>Punctum pygmaeum</u> (Draparnaud)	-	-	-	3
<u>Discus rudratus</u> (Férussac)	-	-	-	-
<u>Vitrina pellucida</u> (Müller)	-	-	-	-
<u>Vitrea crystallina</u> (Müller)	-	-	-	-
<u>Nesovitrea hammonis</u> (Ström)	-	-	-	4
<u>Aegopinella nitidula</u> (Draparnaud)	-	-	-	-
<u>Zonitoides nitidus</u> (Müller)	-	-	-	-
Limacid plates	-	-	1	2
<u>Euconulus fulvus</u> (Müller)	-	1	2	5
<u>Trichia hispida</u> (Linné)	-	-	-	2
<u>Cepaea / Arianta</u>	-	-	-	-
<u>Pisidium casertanum</u> (Poli)	-	3	4	8
<u>Pisidium obtusale lapponicum</u> (Clessin)	3	10	11	49
Favre & Jayet				
<u>Columella columella</u> (von Martens)	-	-	-	-
(present in pilot samples only)				

80-90	70-80	60-70	50-60	40-50	30-40
80-90	70-80	60-70	50-60	40-50	30-40
500	500	500	500	500	500
-	-	117	39	14	25
58	12	1	2	5	6
-	-	-	-	-	3
33	8	-	-	-	-
-	-	6	6	5	6
-	-	60	23	35	19
-	-	-	-	-	1
-	-	22	-	2	2
-	-	-	1	5	-
6	4	11	17	1	-
-	-	-	-	-	1
52	3	43	84	20	13
8	12	8	10	11	2
21	4	67	20	23	20
3	3	19	5	-	5
-	-	-	-	1	-
-	9	-	-	-	-
-	-	-	1	5	2
-	-	191	54	25	19
-	-	-	-	-	2
-	-	2	-	-	1
2	1	14	8	9	1
2	1	45	11	10	8
1	4	3	16	87	18
-	-	1	1	2	1
17	-	8	-	-	3
48	-	-	-	-	-
+	+	-	-	-	-



Plate 1 Caerwys, Large Quarry, East Face.

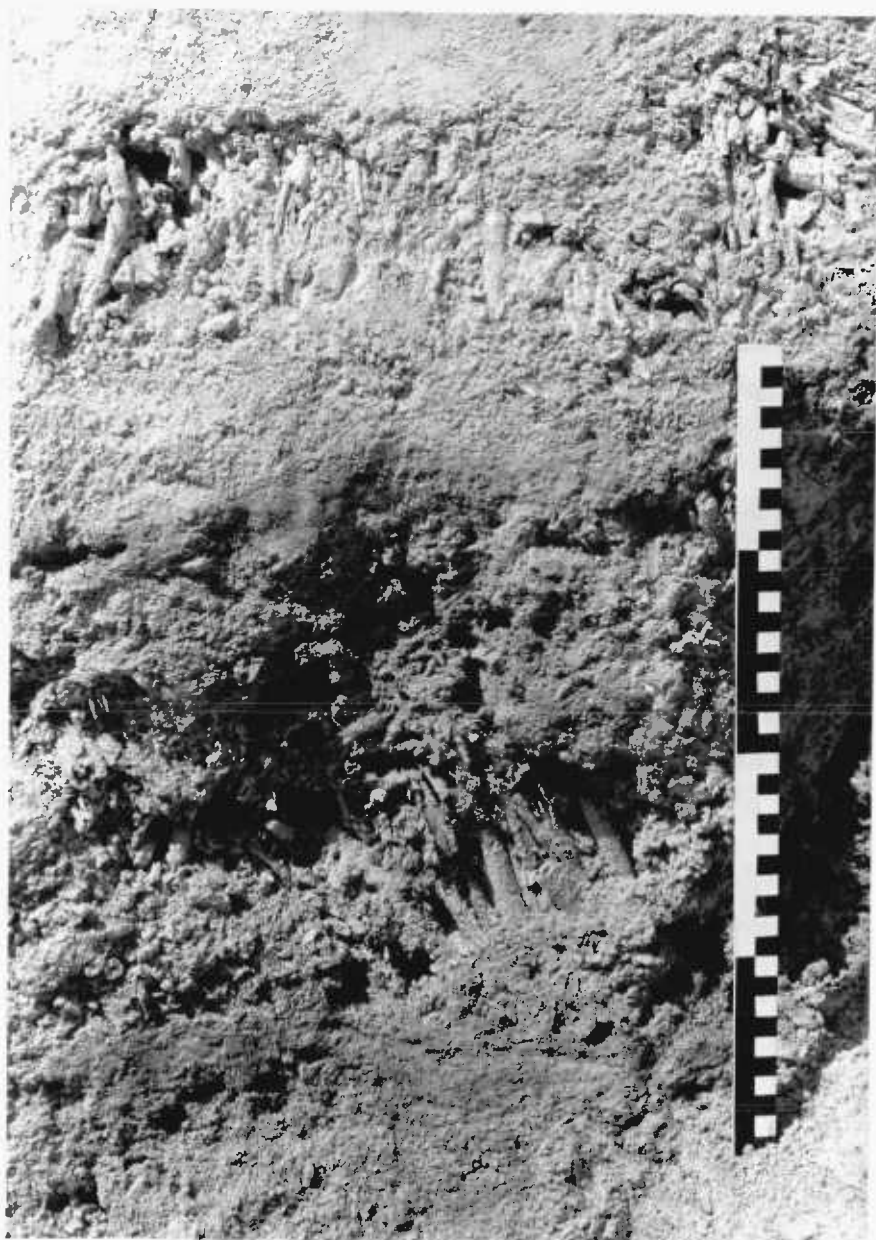


Plate 2 Caerwys. Close up of the north face of pit excavation beneath quarry floor. (Series B). Note the variations in lithology and the impressions of reed stems preserved in their position of growth.

PLATE 3. Succineidae

a - d cf. Oxyloma sarsi (Esmark),
Caerwys.

c - f cf. Oxyloma pfeifferi (Rossmässler),
Caerwys.

g - h Succinea oblonga Draparnaud,
Caerwys.

i - j Catinella arenaria (Bouchard-Chantereaux),
Great Harrowden.

PLATE 3

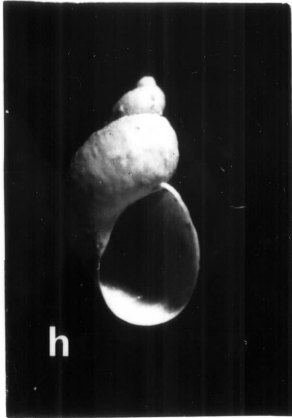
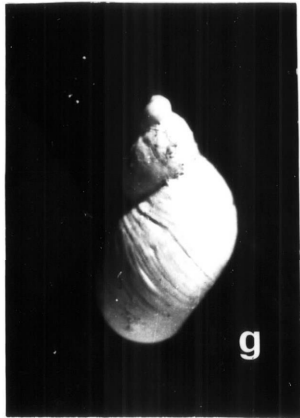


PLATE 4. All specimens from Caerwys

- a. Leiostylis anglica (Wood)
- b. Columella edentula (Draparnaud)
- c. Columella aspera Waldén
- d. Vertigo moulinsiana (Dupuy)
- e. Vertigo antivertigo (Draparnaud)
- f. Vertigo alpestris Alder
- g. Vertigo genesii Gredler
- h. Vertigo geyeri Lindholm
- i. Vertigo pygmaea (Draparnaud)
- j. Vertigo substriata (Jeffreys)
- k. Vertigo pusilla Müller
- l. Vertigo angustior Jeffreys

PLATE 4



2 mm

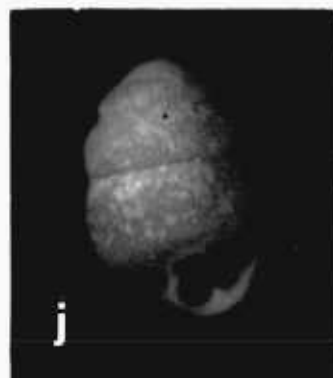
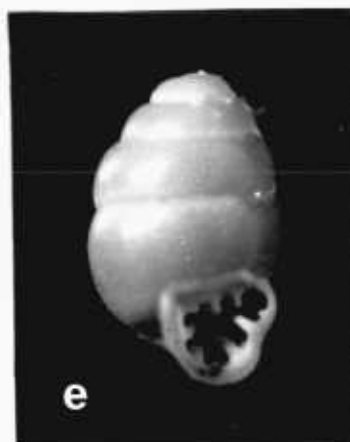


PLATE 5. Scale bars = 5mm (unless otherwise
stated)

- a. Pomatias elegans (Müller)
Fossil. Wateringbury tufa.
- b. Pomatias elegans (Müller)
Modern shell. Wateringbury.
- c - d. Discus rotundatus (Müller)
Wateringbury tufa.
- e - f. Discus ruderatus (Férussac)
Scawby, Lincs.
- g - h. Zenobiella subrufescens (Miller)
Tufaceous loam, Tornewton.
Scale bar = 3mm.

PLATE 5

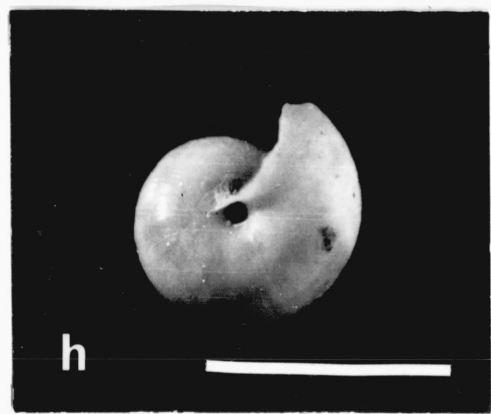
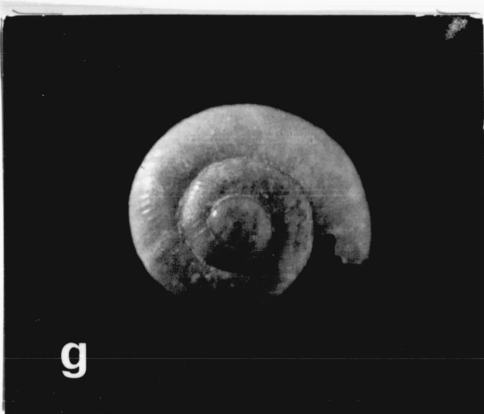
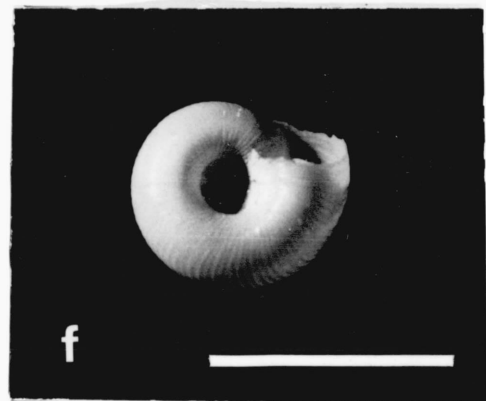
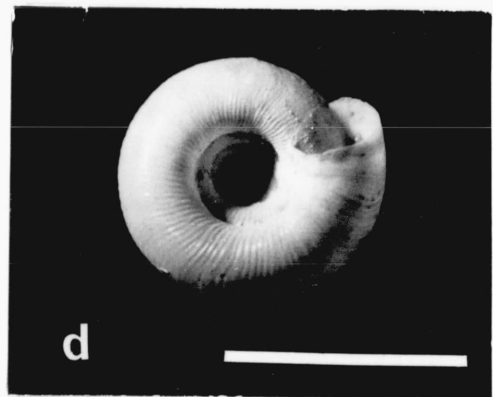
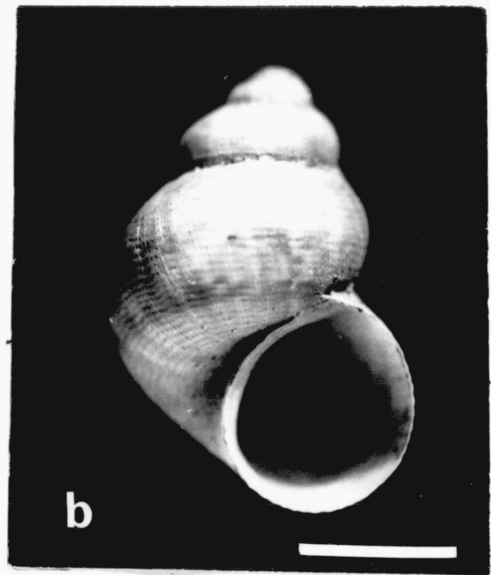
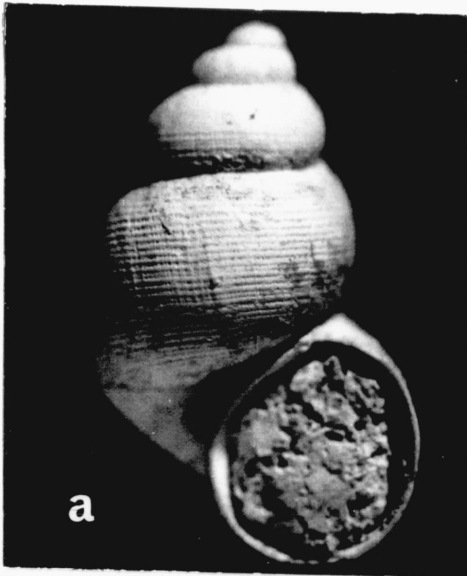


PLATE 6 All specimens from Wateringbury tufa.
Scale bar = 5 mm

a - b. Oxychilus cellarius (Müller)

c - d. Oxychilus alliarius (Miller)

e - f. Aegopinella nitidula (Draparnaud)

g - h. Aegopinella pura (Alder)

PLATE 6

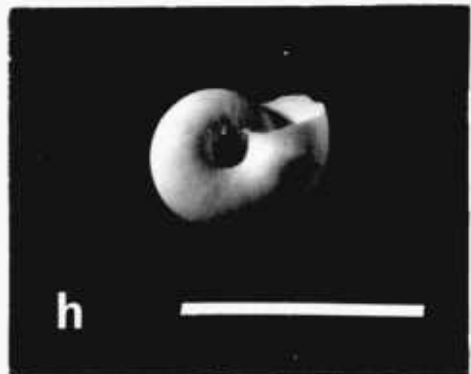
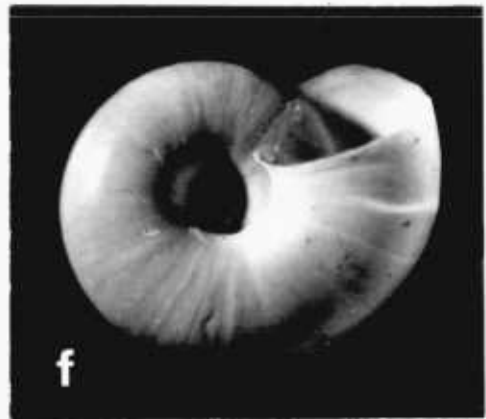
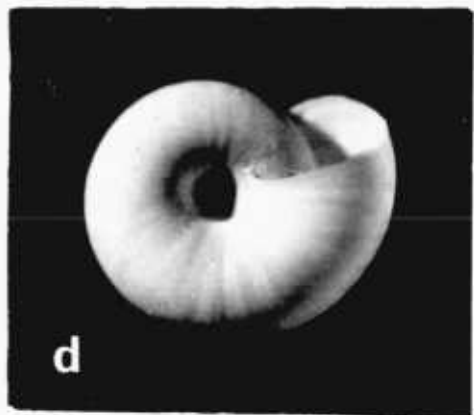
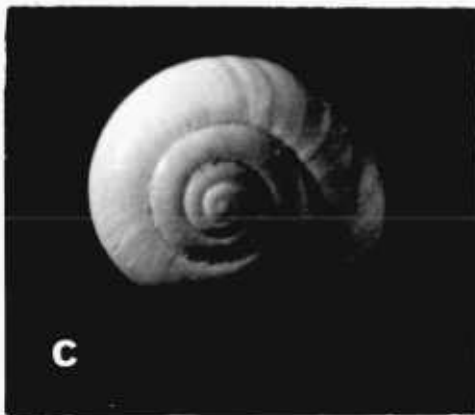
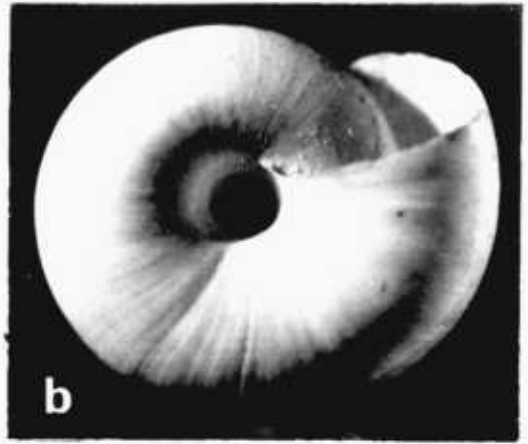


PLATE 7 Scale bar = 5 mm

a - b. Zonitoides excavatus (Alder)
Caerwys.

c - d. Zonitoides nitidus (Müller)
Wateringbury.

e - f. Nesovitrea petronella (L. Pfeiffer)
Brigg, Lincs.

g - h. Nesovitrea hammonis (Ström)
Wateringbury.

PLATE 7

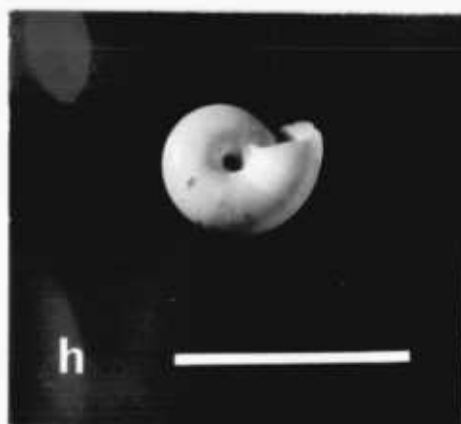
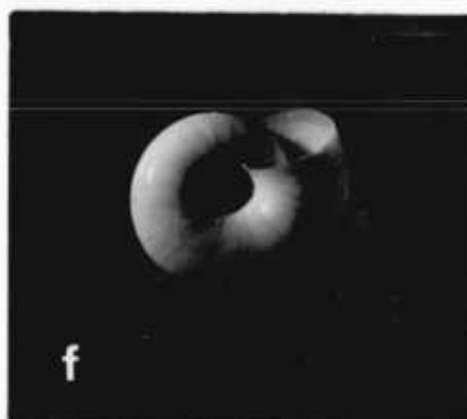
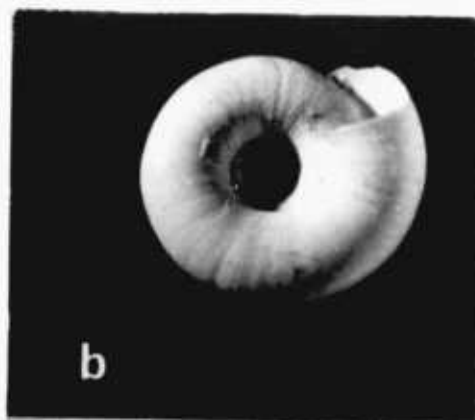


PLATE 8 Scale bar = 2 mm

- a - b. Oxychilus cellarius (Müller)
juvenile, Wateringbury.
- c - d. Aegopinella nitidula (Draparnaud)
juvenile, Wateringbury.
- e. Zenobiella subrufescens (Miller)
juvenile, Caerwys.

PLATE 8

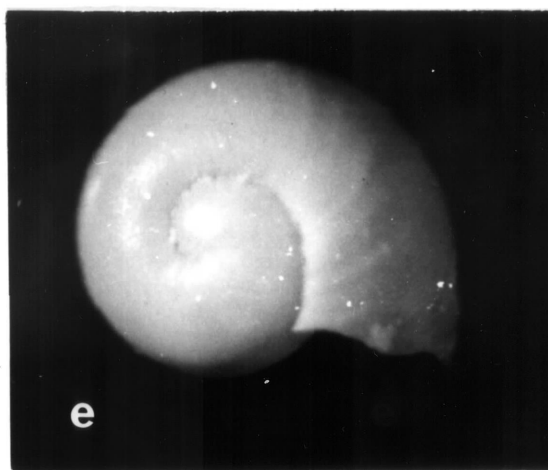
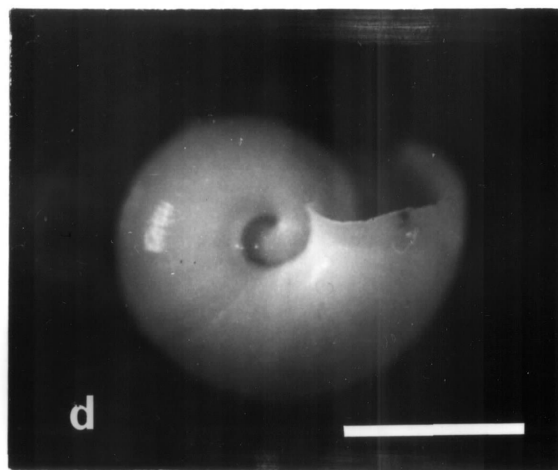
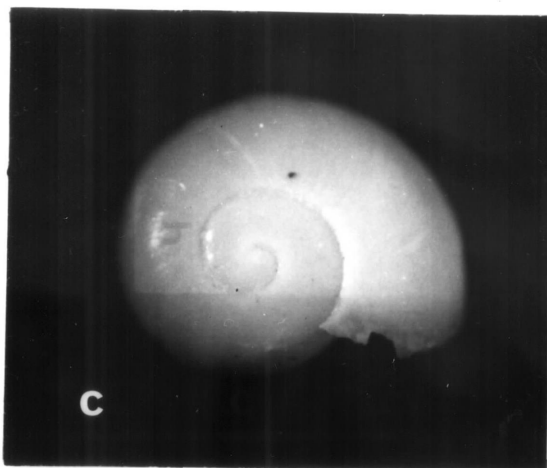
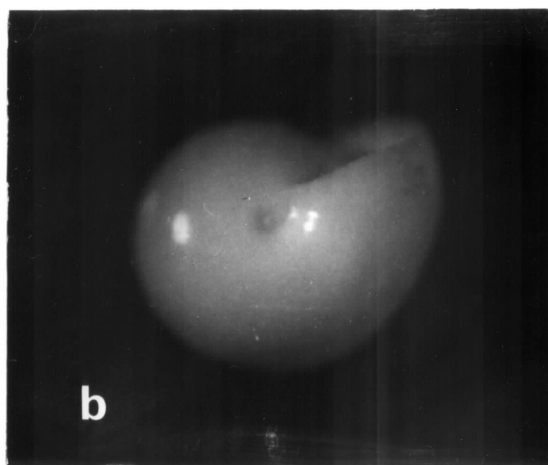
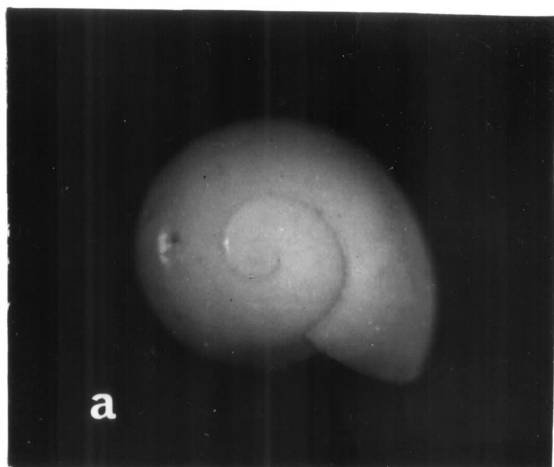


PLATE 9 SEM photomicrographs

Scale bar = 200 μ

- a - b. Ashfordia granulata (Alder)
Blashenwell, Dorset.
- c - d. Trichia hispida (Linné)
Wateringbury, Kent.
- e - f. Trichia striolata (C. Pfeiffer)
Wateringbury, Kent.
- g. Helicella itala (Linné)
Cow Gap, Eastbourne, Kent.
- h. Helicigona lapicida (Linné)
Wateringbury, Kent.

PLATE 9

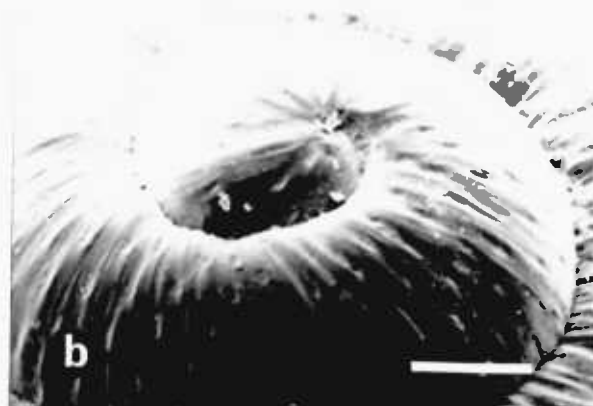


PLATE 10 SEM photomicrographs

Scale bars = 100 μ

- a. Spermodea lamellata (Jeffreys)
Wateringbury.
- b. Acanthinula aculeata (Müller)
Wateringbury.
- c. Punctum pygmaeum (Draparnaud)
Wateringbury.
- d. Vallonia costata (Müller)
Blashenwell.
- e - f. Euconulus fulvus (Müller)
Wateringbury.

PLATE 10

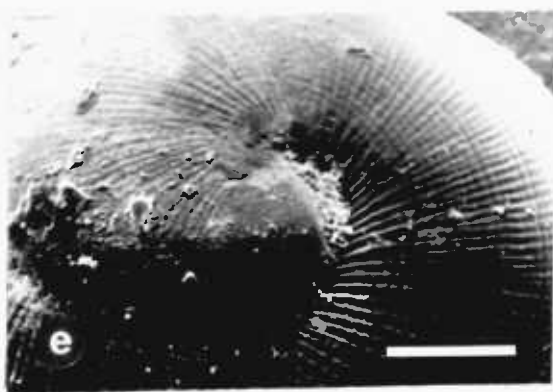
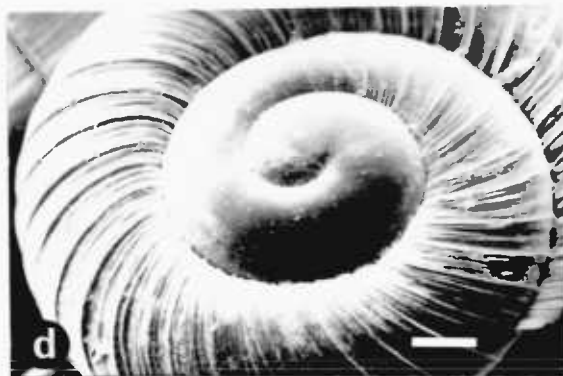
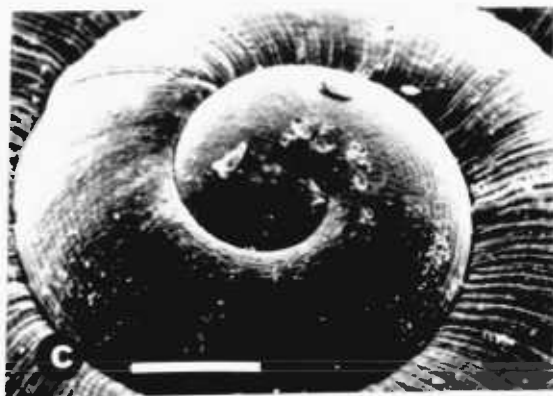
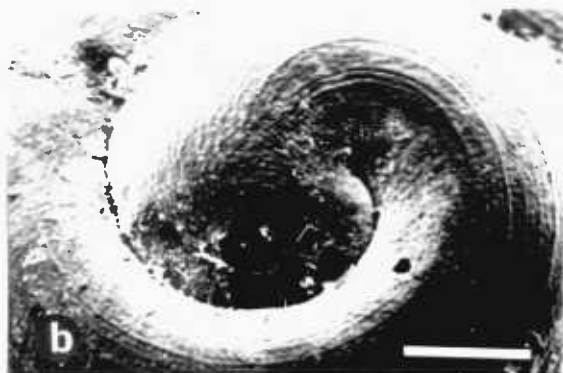
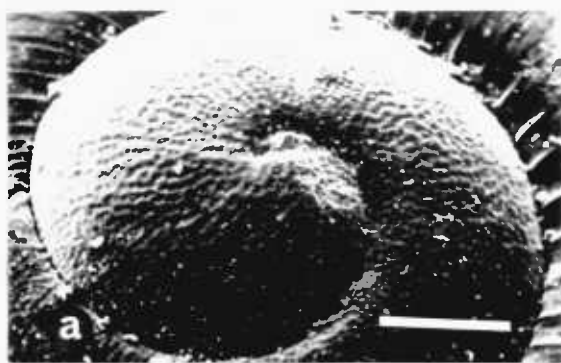


PLATE 11 SEM photomicrographs.

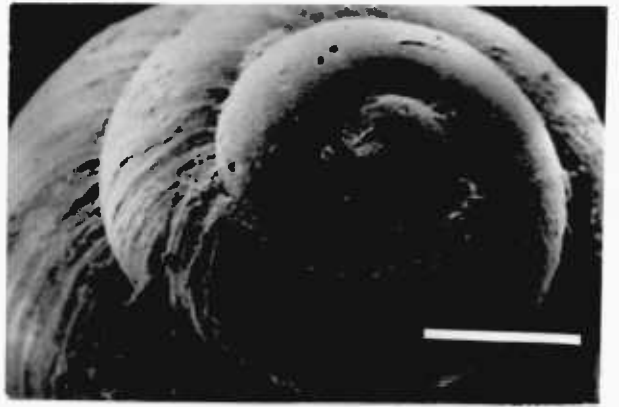
Scale bars = 200 μ

- a. Pupilla muscorum (Linné)
Caerwys.
- b. Columella edentula (Draparnaud)
Wateringbury.
- c. Vertigo substriata (Jeffreys)
Wateringbury.
- d. Abida secale (Draparnaud)
Cow Gap, Eastbourne.
- e. Leiostyla anglica (Wood)
Wateringbury.
- f. Lauria cylindracea (da Costa)
Wateringbury.

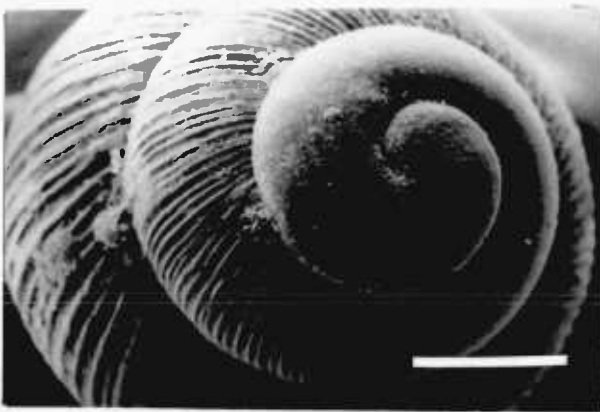
PLATE 11



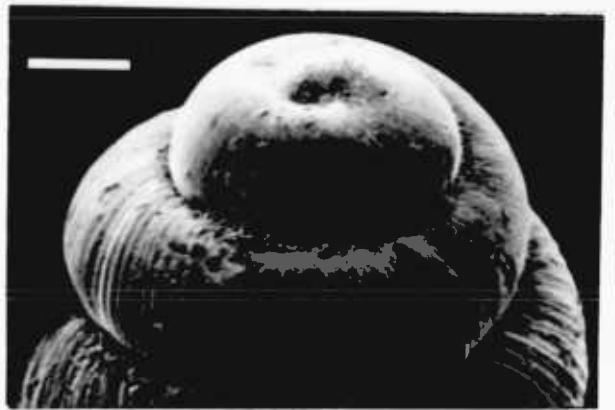
a



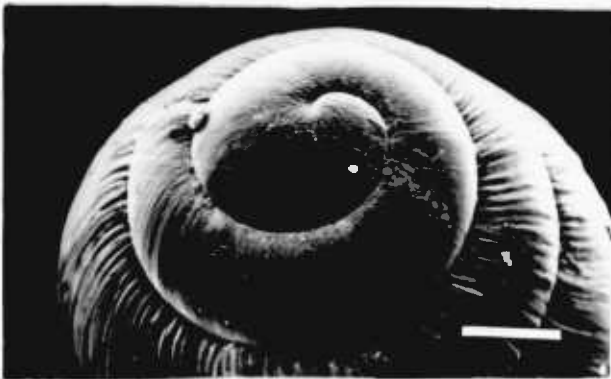
b



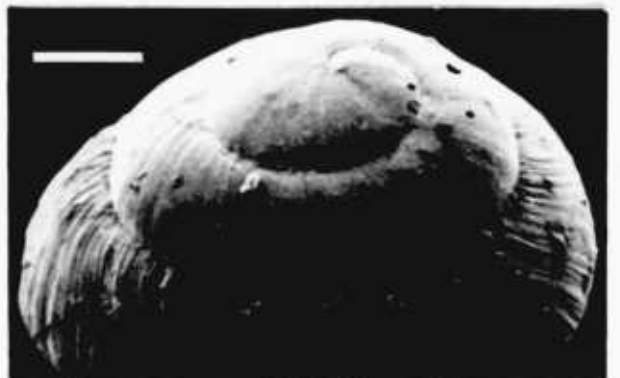
c



d



e



f

PLATE 12 SEM photomicrographs

- a. Ena obscura (Müller)
Wateringbury.
- b. Ena montana (Draparnaud)
Kingstone Winslow.
- c. Helicigona lapicida (Linné)
Wateringbury.
- d. Zenobiella subrufescens (Miller)
Tornewton.
- e. Cepaea nemoralis (Linné)
Blashenwell.
- f. Arianta arbustorum (Linné)
Blashenwell.
- g - h. Aegopinella pura (Alder)
Wateringbury.

PLATE 12

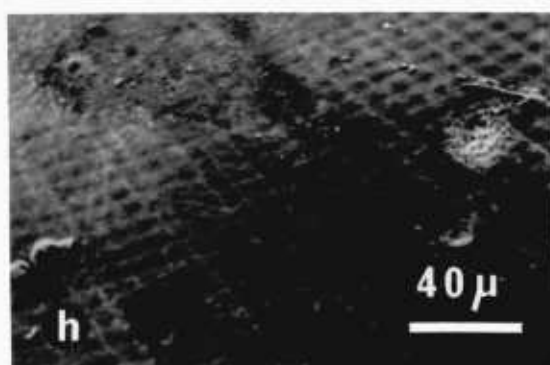
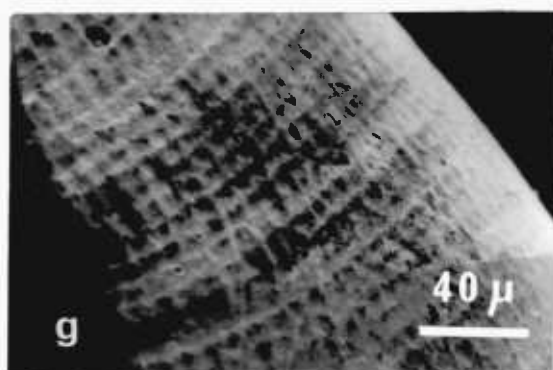
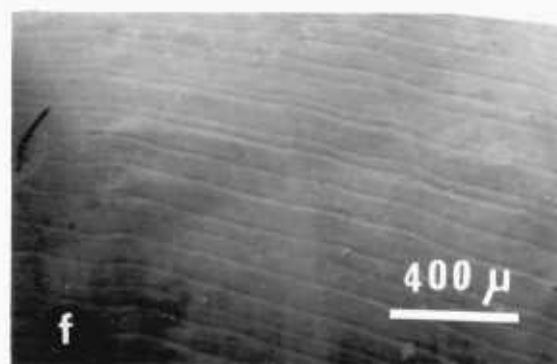
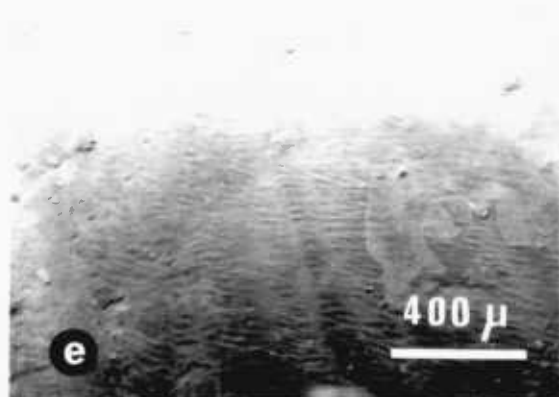
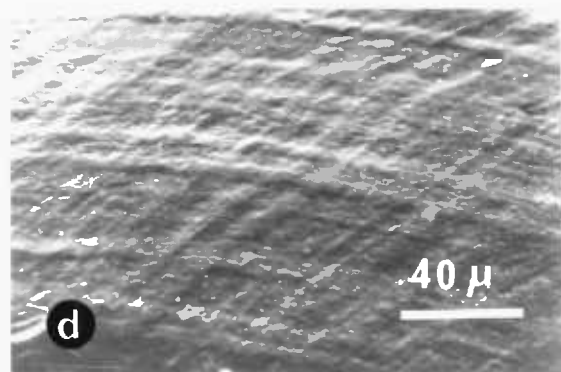
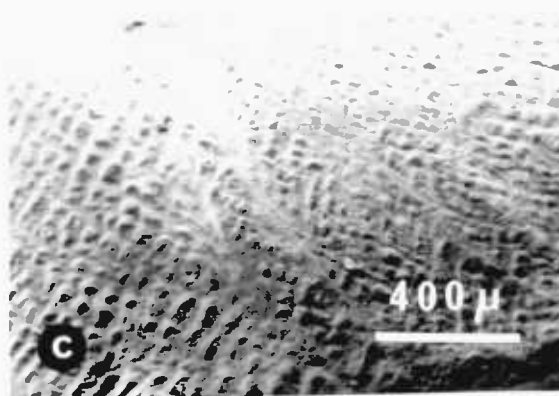
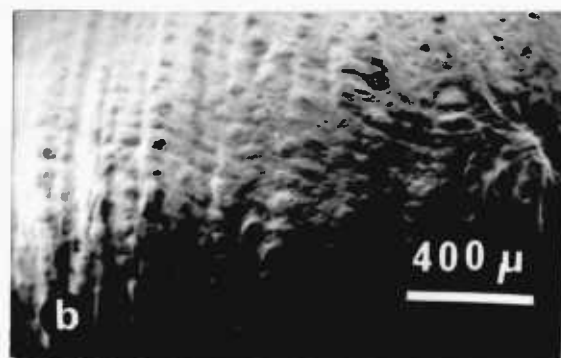
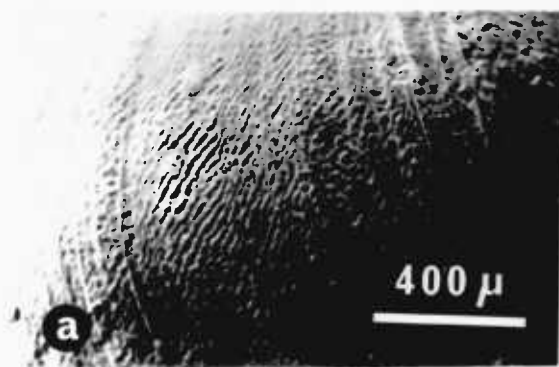


PLATE 13 SEM

- a. Acicula fusca (Montagu)
Wateringbury.
- b. Pupilla muscorum (Linné)
Caerwys.
- c - d. Phenacolimax major (Férussac)
modern, Les Eyzies, Dordogne.
- e - h. Euconulus fulvus (Müller)
Wateringbury.

PLATE 13

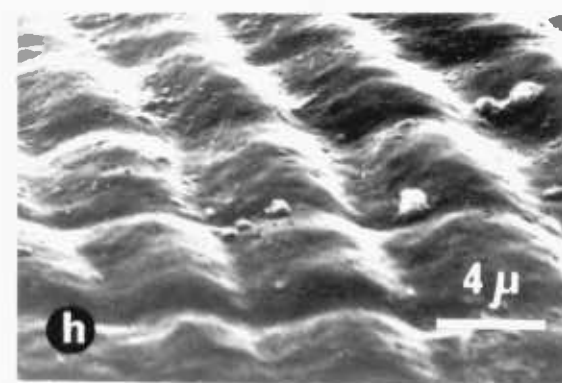
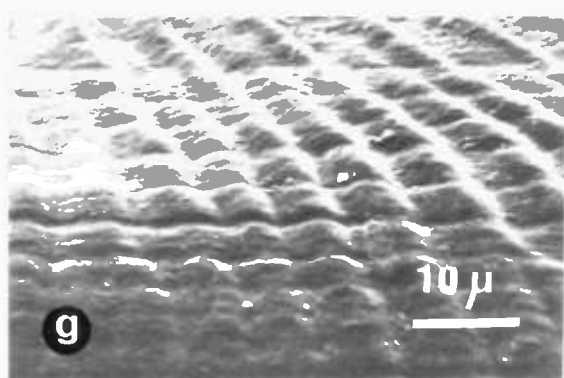
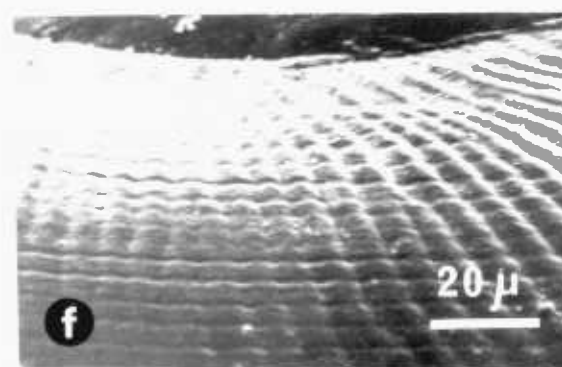
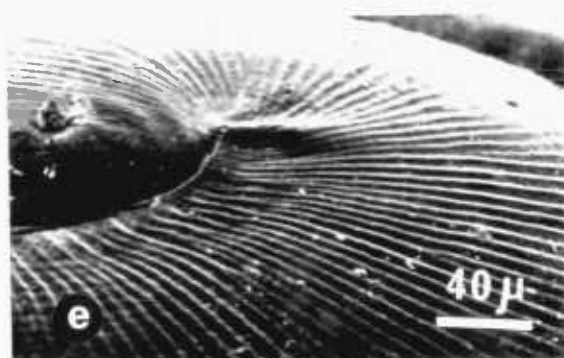
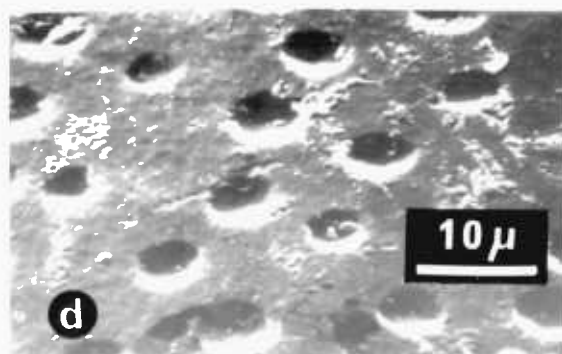
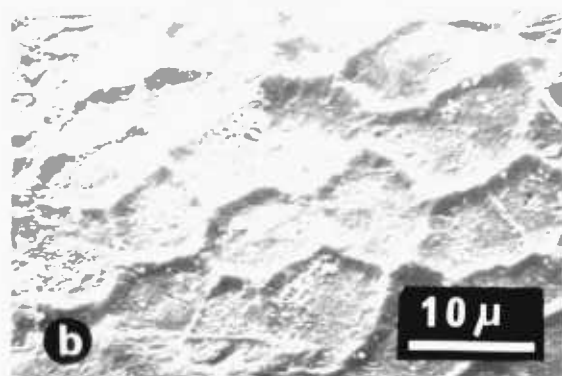
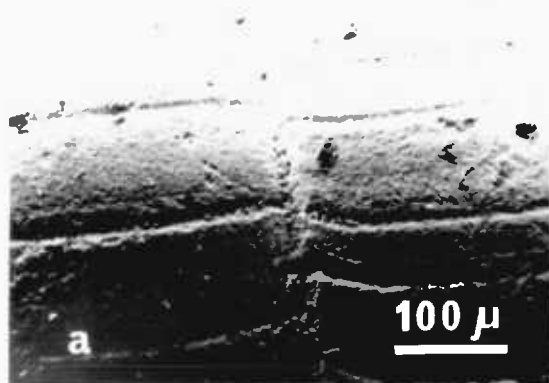


PLATE 14 SEM

Spicules from the matrix of the
Wateringbury tufa (see p 36).

PLATE 14

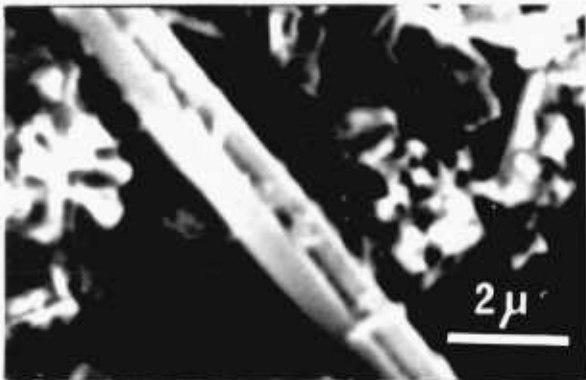
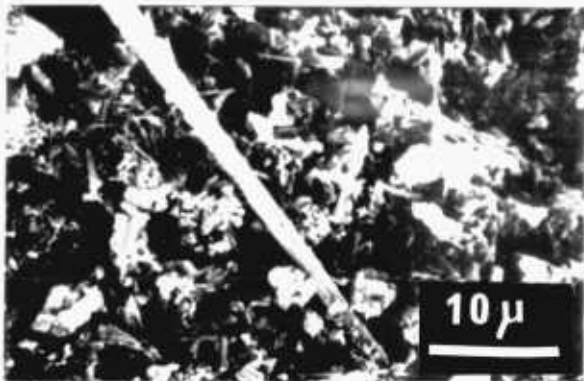
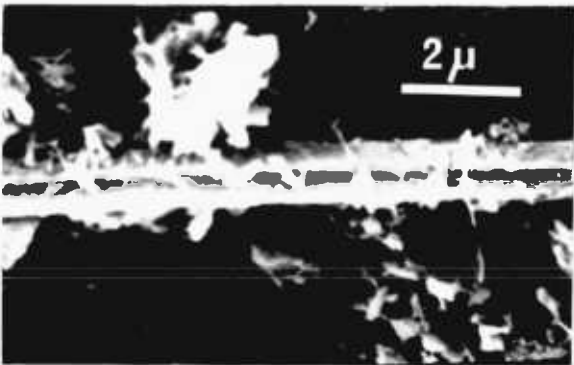
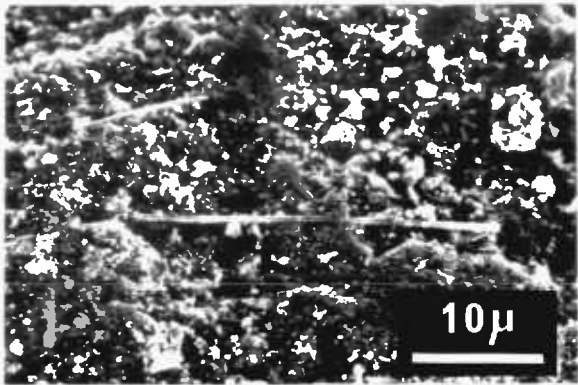
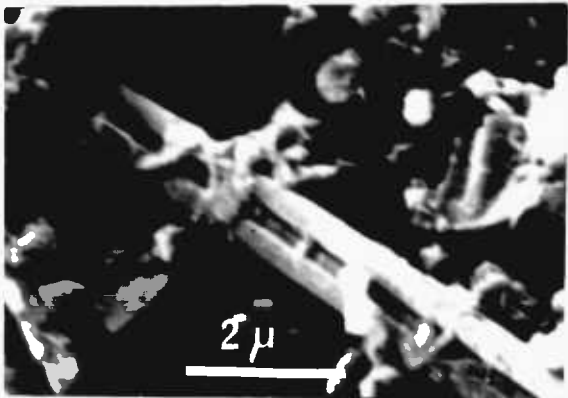
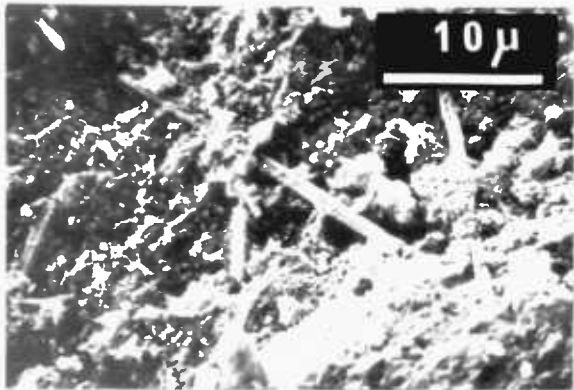
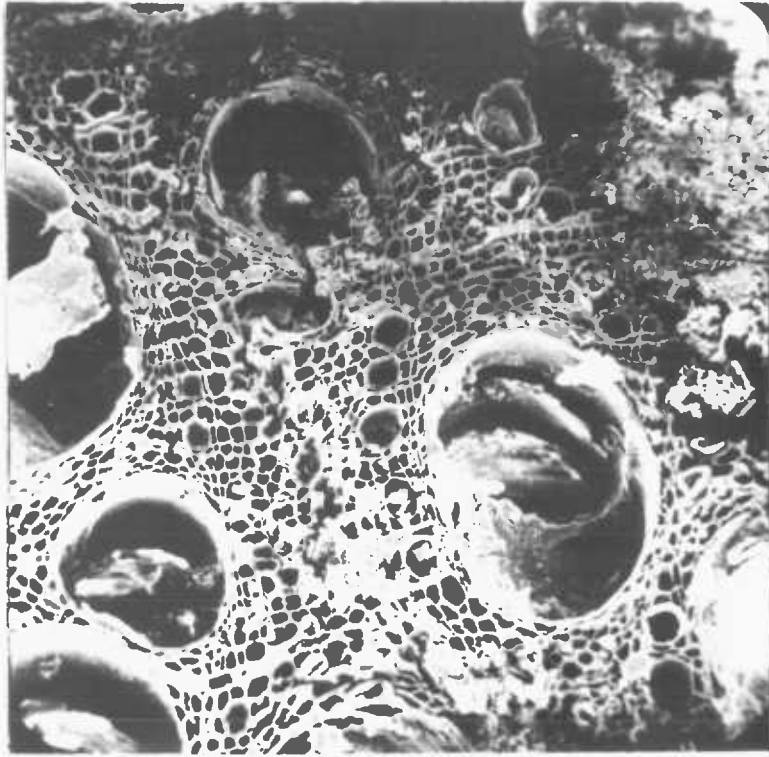


PLATE 15 Macroscopic charcoal
SEM photomicrographs

a - b. Oak (Quercus sp) x 140
Blashenwell 155 - 160 cm



a



b

PLATE 16. S.E.M. photomicrographs

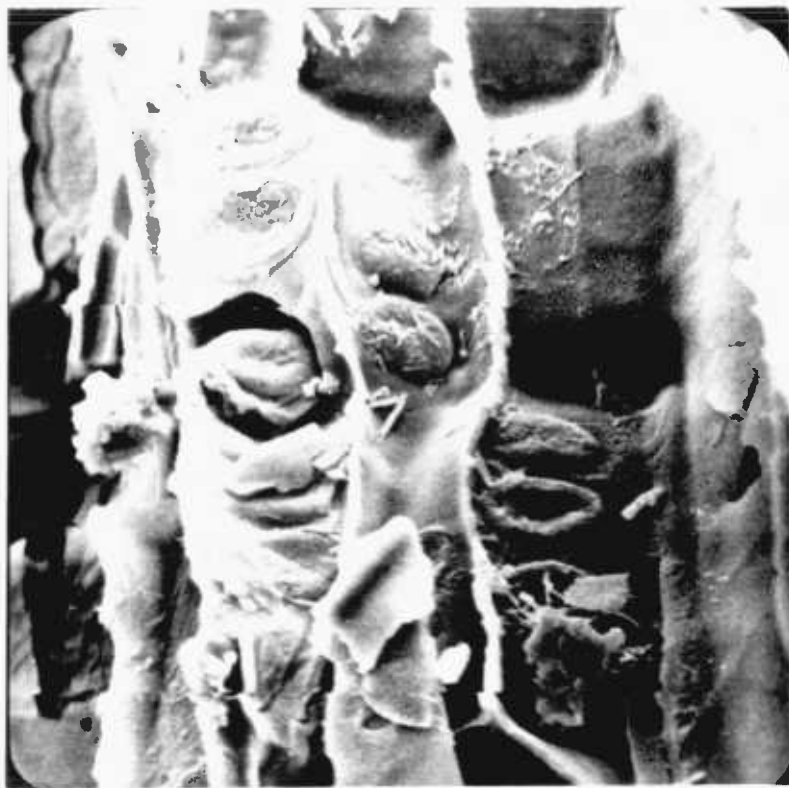
Caerwys 62-65 (Series B)

a Softwood, ? Juniperus x 1150

b " " x 2125



a



b