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PLEISTOCENE DEPOSITS AT EARNLEY, BRACKLESHAM BAY, SUSSEX

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[Plates 1 and 2]

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Pollen, diatoms, foraminifers, molluscs and ostracods are described from a Pleistocene temperate stage channel filling of marine sediments on the foreshore at Bracklesham Bay, Sussex. Pollen analysis indicates the presence of a regional mixed coniferous and deciduous forest during the period of the channel filling, of a type known from the later parts of temperate stages older than the Ipswichian. Diatom and foraminifer analyses both indicate a shallowing sequence of sediments, with higher energy tidal channel deposition at the base of the sequence and intertidal mud flat deposition towards the top. The sediments appear to have been deposited at a time of falling sea level. At the close of sedimentation mean tidal level was about 0.7–1 m below its present position. Evidence for the age of the channel filling is discussed from the point of view of the pollen assemblage, foraminifers and ostracods. It is older than the Ipswichian and may be late Hoxnian or late Cromerian in age.

1. INTRODUCTION AND STRATIGRAPHY (R. G. W.)

In recent years detailed surveys of the Eocene of Bracklesham Bay, Sussex, have been made (Curry *et al.* 1977). In the course of these surveys F. C. Stinton studied fish otoliths from some post-Eocene deposits in the area and identified them as Pleistocene. He drew my attention in particular to a foreshore site with Pleistocene deposits at Earnley (SZ 825947), and he and R. Fowler subsequently demonstrated this site to me. The stratigraphy was examined in August 1978 and March 1979 and samples taken for analysis of flora and fauna. A sketch plan of the site, based on aerial photographs, field sketches and paced and measured distances, is shown in figure 1. The site is exposed from time to time at low spring tides. The outcrop on the foreshore shows the presence of a channel cut in the Bracklesham Beds (beds E12, S2 of Curry *et al.* (1977)), filled with laminated marine sediments, at the base of which may occur a flint cobble bed and a very shelly sand with *Ostrea*. The level of the surface of the channel filling is near 0.65 m o.d.

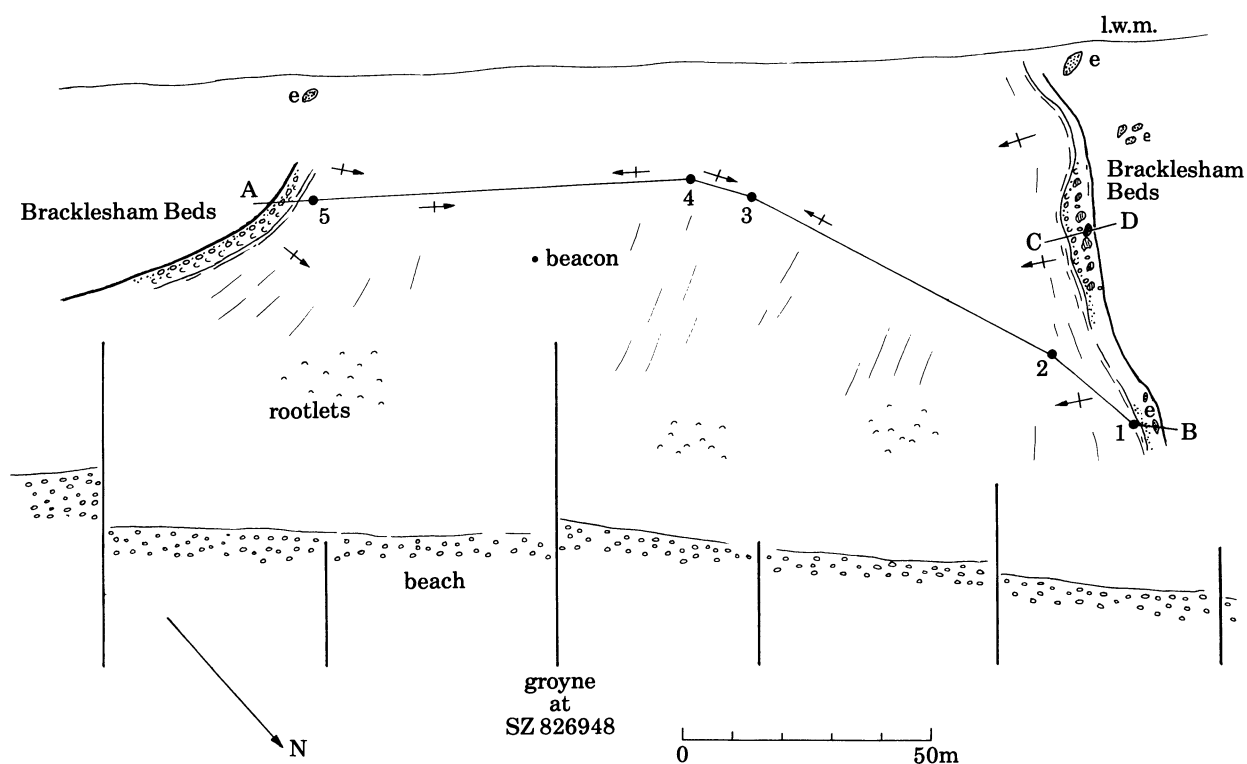


FIGURE 1. Plan of foreshore at Earnley, 1979, showing channel in Bracklesham Beds and direction of dip of Pleistocene channel filling.

The channel is some 200–250 m wide, but its exact configuration is obscured by recent beach sand and gravel. Four boreholes, made with a gouge auger, and an excavation were made in the channel filling, the greatest depth proved being 275 cm.

A section across the channel based on the boreholes and excavation is shown in figure 2. The stratigraphy of the investigated sites is given in the Appendix. The sediments of the channel

filling are largely grey silty clays, with tidal-type bedding. There are also sandy shelly horizons with *Ostrea* near the base and organic detritus-rich sandy horizons. Clay conglomerates, and horizons showing small desiccation polygons also occur. The sediment sequence suggests shallow marine conditions at the base and intertidal conditions higher in the sequence. The uppermost sediments in the channel filling show weathering to a brown colour with penetration by rootlets.

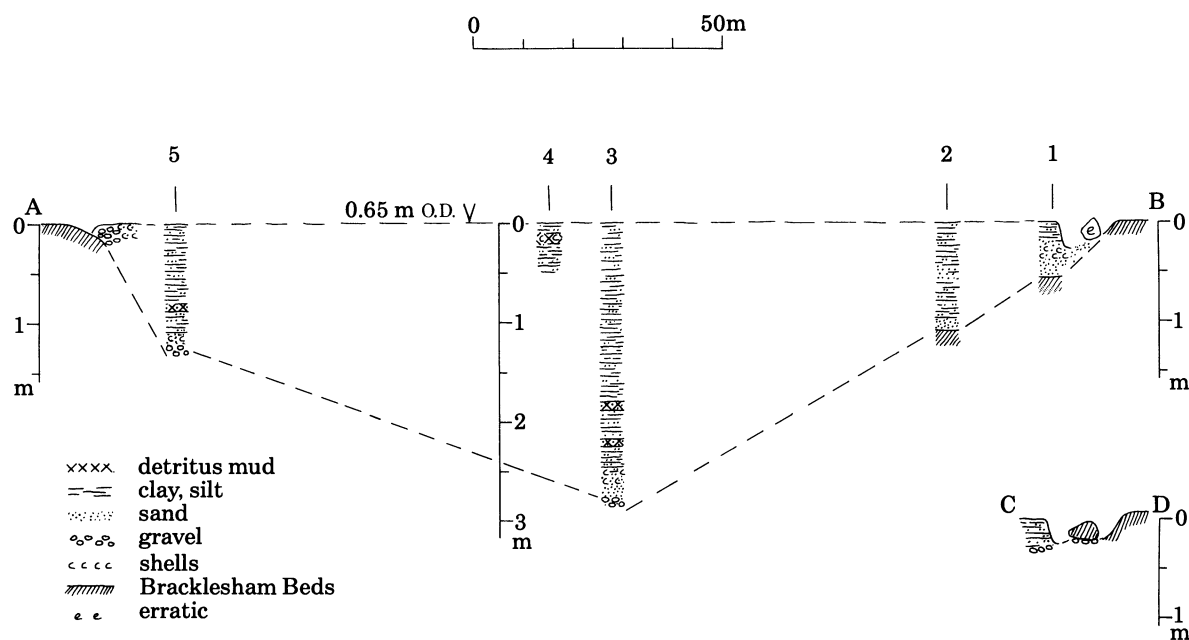


FIGURE 2. Cross-sections of the channel filling at Earnley.

An important stratigraphical question, much discussed by earlier investigators of the area (for example, Reid 1892), concerns the relation of the large erratic blocks of the Bracklesham Bay foreshore to the channel filling. Two large granite erratics were noted resting on the Bracklesham Beds, one to the east, the other to the west, of the channel. Further smaller erratics were seen near the line of junction of the Bracklesham Beds with the channel filling on the west side of the channel. The position of these erratics is shown in figure 1. No erratics were seen resting on the channel filling. This evidence is consistent with the erratics being emplaced before the channel was filled with sediment. But this conclusion must be considered very tentative and further studies of the erratics and their exact positions are needed, taking into account the possibility that their present position may not be the position of original emplacement.

2. PALAEOBOTANY (R. G. W.)

Preliminary pollen analyses were made from the topmost and basal sediments at sites 2, 3 and 5, and from the more organic horizon near the top of site 4. These analyses indicated a general similarity of the pollen assemblages present, so a single more detailed investigation was made in the deepest part of the channel at site 3. The resulting pollen diagram is given in figure 3. The pollen slides were prepared according to the schedule of the Sub-department of Quaternary Research, using hydrofluoric acid to remove inorganic sediment content.

There was a notable lack of plant macrofossils in the sediment of the channel filling. Even washing a considerable quantity of the more organic horizon at site 4 (5–20 cm) produced only *Juncus* seeds, a *Potamogeton pectinatus* fruitstone and a Cyperaceae nut.

The pollen diagram shows percentage representation calculated on the base of total pollen of land plants. The column marked hystrichospheres includes cysts of dinoflagellate and acritarch type. The column marked Foraminifera refers to tests found in the pollen slides. Pollen concentration of the sediment was measured in some of the samples, using exotic (*Lycopodium*) spores added during the preparation.

The pollen assemblages shown in the pollen diagram can be grouped into only one major pollen assemblage biozone, characterized as follows. The pollen spectra show a preponderance of tree pollen (63–87%), with *Pinus*, *Abies*, *Alnus*, *Quercus*, *Carpinus*, *Corylus* and *Taxus* well-represented, and with lower but consistent pollen frequencies of *Picea*, *Betula*, *Ulmus*, *Tilia cordata* and the unknown tricolpate grain 'type x' (Phillips 1976). Pollen of *Salix*, *Fraxinus*, *Acer*, *Ilex*, *Buxus* and *Hedera* is less frequent. Pollen of heath plants is infrequent. Ericales and *Empetrum* are recorded. Of the other non-tree pollen, Gramineae, Chenopodiaceae, *Artemisia* and Compositae Tubuliflorae, show consistent and substantial curves through the diagram. In lower frequency are Cyperaceae, *Armeria*, *Plantago maritima*, *Circaea*, Leguminosae and *Ranunculus*. Filicales spores are consistently present, with *Polypodium* and *Pteridium* spores infrequent. There is also a continuous curve for Foraminifera.

The assemblage must have a wide derivation, partly reflecting the regional forest and partly reflecting the more local salt-marsh communities. The forest component, detailed above, indicates the prevalence of a diverse mixed coniferous and deciduous forest, while elements of the non-tree pollen flora, including Chenopodiaceae, *Armeria*, *Plantago maritima* and probably Gramineae, *Artemisia* and Compositae Tubuliflorae derive from salt-marsh communities.

The forest assemblage with *Abies* and *Carpinus* is characteristic of the later part of the cycle of forest history in temperate stages of the Pleistocene. If we compare the assemblage with those of the Pleistocene temperate stages of East Anglia (West 1980a), we find certain similarities with the pollen assemblages of the Cromerian III and Hoxnian III. However, the distance between the two areas, and the paucity of our knowledge of the vegetational history of temperate stages in southern England, make it impossible to draw firm conclusions about correlation. The following points can be usefully made about correlation: that the assemblage is not one that has so far been recorded in southern England in the few temperate sediments of Ipswichian age that have been studied (West & Sparks 1960); that *Abies* and *Carpinus* together are only so far known from Cromerian IIIb in East Anglia and in Hoxnian III in East Anglia and the Midlands; that a substantial presence of *Abies* has not been recorded in the Ipswichian in England; that in Cromerian IIIb of East Anglia *Abies* occurs with *Carpinus*, but in Hoxnian III the main *Abies* assemblage post-dates the assemblage with *Carpinus*, though there is some little overlap; and that the pollen 'type x' (Phillips 1976) is commonly recorded in the Hoxnian of East Anglia, but has not so far been recorded in the Cromerian of East Anglia. From these points we may draw the conclusion that the Earnley sediments may be Cromerian III or Hoxnian III in age. If pollen 'type x' is characteristic of the Hoxnian, then we might make a choice between these two alternatives and say that the assemblage is to be correlated with Hoxnian III, perhaps late in IIIa or early in IIIb. Alternatively the presence of *Carpinus* and *Abies* at frequencies shown in the pollen diagram would suggest a Cromerian III age. No decision regarding these two alternatives is possible, but we may conclude that the channel filling is older than the Ipswichian.

It is to be noted that marine sediments of Hoxnian III age occur at Clacton and in the Nar Valley, the onset of marine conditions being recorded at +3 m and +6 m o.d. respectively at these sites (West 1972), while marine sediments of Cr III b lie between +0.5 m and about +7 m o.d. in East Anglia (West 1980b). No conclusions about correlation can be drawn from this line of evidence.

3. DIATOMS (R.J.N.D.)

Sediment samples taken for pollen analysis at site 3 were selected for examination of the diatom flora. Sampling was undertaken at between 20–30 cm intervals from 20–270 cm. Approximately 1.0 ml of sediment was taken from each level and treated with hydrochloric acid (10% by mass) and then with hydrogen peroxide (30% by mass) to remove contained carbonates and all organic matter. Differential centrifuging of the samples was carried out to remove the clay (0.002 mm) and silt (0.002–0.06 mm) fractions. A suitable amount of the cleaned and washed material was then mounted in Clearax diatom mountant (refractive index = 1.666). The diatom identifications were made at a magnification of $\times 1000$ under oil immersion, using a Zeiss Amplitival microscope. Counts were made along transverses at regular intervals throughout the mounted fraction. A minimum of 600 diatom valves were counted at each level. Where a valve was broken but recognizable, it was counted as complete if more than half remained.

The results are presented as a relative frequency diagram, figure 4, with each taxon calculated as a percentage of the total count (ΣD) in each sample. Owing to variations in the habitat of some taxa on a seasonal and life stage basis and also consequent upon changing environmental conditions, the recognition here of distinctive planktonic, epiphytic and benthic diatom groups is difficult. However, it may be argued that a useful division can still be made between species which are usually planktonic and those of the benthos, consisting of both benthic and epiphytic taxa (Round 1973). As an aid to interpretation this two-fold division was adopted and the taxa grouped on the basis of both salinity tolerance (Hustedt 1957) and habitat. Presentation within each group is made in ascending order of occurrence. Identification of species and where possible of the general ecology and salinity tolerance was made using principally van der Werff & Huls (1958–1974); Hustedt (1927–1966); Hendey (1951, 1964, 1974); Patrick (1948); Patrick & Reimer (1966) and Round (1960, 1971). Although some inconsistencies and differences of opinion between these authors may remain reflected in the eventual groupings, the divisions are seen as sufficiently accurate to allow recognition of distinctive diatom communities. The majority of the fossil diatom species identified are still common and characteristic today of the southern North Sea and English Channel areas. An exception is *Glyphodesmis williamsonii* (W. Smith), Grun. ex van Heurck, which appears to have a northerly distribution and is typically found in British waters in the region of north west Scotland (Hendey 1964).

Fossil assemblage zones (West 1970) have not been recognized for the diatom spectra, owing to the general uniformity of species composition and frequency through the profile. The assemblage is relatively poor in species, most levels containing less than 20 taxa. The poorest levels occur toward the base of the profile, with species number rising significantly above 150 cm. Many diatom valves were found in a broken or degraded state, those of *Melosira sulcata* (Ehrenberg) Kütz. being least affected. *Podosira stelliger* (Bailey) Mann., *M. sulcata* and *M. westii* W. Smith are dominant throughout, with *M. sulcata* rising to maximum levels of 70% ΣD above 85 cm. *Grammatophora oceanica* (Ehrenb.) Grun. var. *macilenta* (W. Smith) Grun., normally represented by broken valves, forms a consistent component in the assemblage. At 180 cm this species reaches an isolated peak of 85% ΣD . This probably represents an *in situ* localized bloom of the taxon, a view supported by the unusually large number of complete valves of the species identified at this level. Persistent, but normally low frequencies of < 5% ΣD are also maintained by *Coscinodiscus excentricus* Ehrenb., *Actinocyclus ehrenbergii* Ralfs, *Cerataulus smithii* Ralfs, *Auliscus sculptus* (W. Smith) Ralfs and *Raphoneis amphiceros* Ehrenb. Other species occur sporadically through the profile and are represented by frequencies of 1% ΣD or less. *Podosira stelliger*, the main planktonic species identified, varies erratically in frequency between 5–20% of ΣD . This behaviour is probably an artefact of the percentage frequency calculation, with variable suppression of this and other taxa, accompanied by an over-representation of the importance of *M. sulcata* and *Grammatophora oceanica* var. *macilenta* in the diatom flora.

The assemblage is characterised by marine (Polyhalobion) diatoms, the Polyhalobion fraction remaining above 86% of ΣD throughout. Most of the species found belong to the benthos group, many growing upon the sand–mud sediments of the marine littoral region, for example, *M. sulcata*, *M. westii*, *Raphoneis* spp., *Biddulphia* spp. and *Diploneis* spp. By comparison, *Grammatophora* spp., *Synedra tabulata* (Agardh) Kütz., *Coscinodiscus nitidus* Gregory and *Cocconeis scutellum* Ehrenb. among others form a distinct and different community, living attached to rock, sand or plant surfaces. Representatives of both communities inhabit areas of the intertidal zone (Ghazzawi 1933; Round 1971; Körber-Grohne 1967), although some are not uncommon subtidally. In the upper levels the occurrence of isolated Mesohalobian taxa is noticeable with *Diploneis didyma* Ehrenb., *Campylodiscus echeneis* Ehrenb., *Scoliopleura* spp. and *Nitzschia* spp. identified. The taxa were found to be generally in a broken and abraded state. Above 180 cm these species are accompanied by the appearance of black humified organic matter. It is unlikely, however, that this material represents the *in situ* growth here of intertidal vascular plant communities. The near absence of associated saltmarsh diatom species (Aleem 1950; Round 1960; Hodson & West 1972), the sparsity of other Mesohalobion taxa and the broken state of the diatom valves in conjunction with the finely divided nature of the plant material, indicates probably selective inwashing from mudflat and high marsh areas. Similarly a greater development of the attached (epiphytic) diatom community would perhaps be expected with the development of *in situ* halophytic vegetation.

Although a broadly intertidal location for diatom growth and accumulation is indicated a number of factors show alterations within the depositional environment through time. Between 105–225 cm the proportion of broken and unidentifiable or degraded valves attains high values, with maxima of > 38% and 10% ΣD respectively. This, together with the importance of Polyhalobion planktonic taxa in the diatom assemblage, indicates moderate to high energy activity with marine inwashing and sediment instability. The low species number and the significance here of the attached diatom community may similarly reflect such conditions. In

this type of environment the selective preservation of strongly silicified species, for example *C. excentricus* and *M. westii*, is likely to occur. These taxa are found at significant values below 180 cm. Together such evidence may represent sedimentation in the relatively high energy lower intertidal and subtidal zones. Maximum tidal current velocities within such areas today, particularly within the larger incised channel areas, commonly reach values of 0.5–0.9 m s⁻¹ (Ginsberg 1975), sufficient to cause the observed breakage and abrasion of the diatom frustules.

Sediment particle size changes, determined by visual and microscopic inspection of the unprepared diatom samples, further supports the interpretation for the lower part of the profile. Below 180 cm a coarse to medium (2–0.2 mm) sand sized fraction is dominant. Broken fragments of *Ostrea edulis* and angular fine gravel sized (2–6 mm) flint are common, indicating high energy activity. Above this level, however, an increasing proportion of fine sand and silt-sized (0.2–0.002 mm) material appears. The apparent fining upward in particle size parallels a decrease in the number of broken valves to values < 15% ΣD from 105 cm upwards. Species number in each spectrum increases toward the top of the profile and a stronger development of the *Melosira* spp.-dominated epipelagic community occurs. Although the continued inwashing of material is still indicated, this pattern contrasts strongly with that below 150 cm and suggests a reduction in energy levels toward the top of the profile.

The inferred energy changes described would indicate an upward alteration in the zone of accumulation from a lower to upper intertidal environment (Evans 1975; Knight & Dalrymple 1975; Reineck & Singh 1975). Equally, however, the data is consistent with deposition in a progressively infilling large intertidal channel or possibly inlet (Harrison 1975; Terwindt 1975), although none of the diatom species identified are specifically characteristic of life in such an area.

4. FORAMINIFERA AND MOLLUSCA (B.M.F.)

Two samples were analysed, one from the uppermost clays of the channel filling at site 4 (0–10 cm) and the second from the basal shelly facies at the channel margin at site 1.

Sample 1, site 4

The Foraminifera in the size fraction 500–250 μm consist of *Ammonia beccarii* var. (69%), *Protelphidium anglicum* (20%), *Elphidium williamsoni* (10%), and *Ammonia beccarii* (< 1%). Single specimens of *Elphidium excavatum*, *Elphidium margaritaceum* and *Rosalina 'parisiensis'* were also seen (for descriptions of species referred to see Murray 1979).

There is nothing in this assemblage that would distinguish it from a Holocene assemblage; on the other hand it could also be as old as the Hoxnian, but not as old as the Bramertonian.

In palaeoenvironmental terms it strongly suggests an intertidal mud flat (dominance of *A. beccarii* var., lightly calcified, without umbilical boss or associated sutural ornamentation), perhaps towards the upper part of the intertidal range (good proportion of *Elphidium williamsoni*) but falling short of any fringing salt marsh (absence of arenaceous, Textulariine, species). The abundance of *P. anglicum*, and the paucity or absence of *A. beccarii* s.s. and other open marine species, suggests relative remoteness from a main tidal channel. Similar low diversity assemblages dominated by *A. beccarii* var., with accompanying *E. williamsoni* and *P. anglicum* are found in the intertidal mud facies of the estuarine Lower and Upper Clays of the Holocene of Broadland, Norfolk (Coles 1977; Coles & Funnell 1981).

Preparation and picking was made difficult by the high proportion of vegetable material in

the silty clay sediment: 52.62 g of dry sediment was prepared, of which 17.65 g was retained on a 65 μm sieve. Much of the latter was plant material, and most less than 250 μm size. The 500–250 μm fraction (usually used by the present author in the comparative study of East Anglian early Pleistocene Crag deposits) was divided by water flotation in an attempt to separate the plant material. This was not successful as most of the foraminiferal tests were sufficiently lightly calcified to float with the plant material. In the floated portion 1888 foraminifers (estimated on the basis of a 1/8 count of 236) were present and in the entire sink portion of the 500–250 μm fraction 265 were present. Percentages given above are calculated by combining the floating and sinking counts in proportion to a total count of 2153.

No foraminifers, but only a very few small molluscs including *Ostrea* sp., were found in 1000–500 μm fraction.

Small euhedral gypsum crystals were abundant in the 500–250 μm fraction, but there was no accompanying indication of solution of the calcareous tests of the foraminifers. Similar crystals occur towards the top of the Holocene Upper Clay of Broadland and may be a primary or early diagenetic precipitate owing to evaporative processes rather than a weathering product.

Sample 2, site 1

The Foraminifera in the size fraction 500–250 μm consist of *Ammonia beccarii* var. (68%), *Ammonia beccarii* (18%), *Protelphidium anglicum* (7%), *Elphidium williamsoni* (6%), and indeterminate *Elphidium* spp. (1%).

As with the previous sample, there is nothing in this assemblage that would distinguish it from a Holocene assemblage; on the other hand it again could be as old as Hoxnian, but not as old as the Bramertonian.

In palaeoenvironmental terms proximity of intertidal mud flats is strongly indicated by the association of dominant *A. beccarii* var., followed by *P. anglicum* and *E. williamsoni*. The 18% representation of *A. beccarii*, however, indicates local tidal channel conditions. An open coast species, it also occurs in tidal channels (in which current velocities can regularly reach 0.5 m s^{-1} and not infrequently as much as 1 m s^{-1}). In this sample it is unaccompanied by other open coast species suggesting that the tidal waters were not exchanging with a particularly diverse subtidal environment.

The foraminifers (total 349) were picked from 3/64 of the 500–250 μm fraction obtained from 138.53 g of dry sediment, 55.50 g of which was retained on a 65 μm sieve. This represents a 500–250 μm foraminiferal population of 54 g^{-1} of original sediment, compared with 41 g^{-1} for the site 4 sample.

In addition to foraminifers the sample contained numerous remains of bivalves, gastropods, barnacles and ostracods, also one regular echinoid spine. No less than six *Nummulites* sp. reworked from the local Eocene beds, were also obtained from the same sample.

The dominant bivalve is *Ostrea edulis*, which makes up the bulk of the fragmental mollusc material. It is accompanied by *Nucula* sp. (? *N. turgida*) and *Sphenia binghami* in some abundance, *Mysella bidentata*, *Chlamys varia*, and fragments of *Abra* cf. *A. alba*, and occasional 'Cardium' sp. (probably *Cerastoderma* juveniles). *O. edulis* occurs from low water mark to ca. –50 m and frequently occupies immobile bottoms of mud; *N. turgida* occurs to depths of greater than –50 m, but may dominate the bivalve fauna to depths of 10–20 m on fine sand; *S. binghami* occurs offshore to moderate depths in *Laminaria* holdfasts, also from the lower shore to considerable depths in vacated *Hiatella arctica* burrows. *M. bidentata*, interestingly, occurs from

the low intertidal zone, to depths in excess of -100 m, in perforations in old oysters, *C. varia* occurs from the low shore to *ca.* -80 m, *Abra alba* occurs on mud and silty sand from low water mark spring tides (l.w.s.t.) to -65 m depth, but especially down to -18 m, and 'Cardium' is typically intertidal. A source very little below the low tide mark would account for all these species.

The gastropods include *Gibbula* sp., *Odostomia unidentata*, *Turbonilla elegantissima*, *Bittium reticulatum*, and *Akera bullata*. *Gibbula* spp. occur on rocky shores and from l.w.s.t. downwards on muddy sands and other substrates, *O. unidentata* is found on intertidal stones covered with *Pomatoceros*, *T. elegantissima* parasitizes polychaete worms in muddy substrates at l.w.s.t. and below, *Bittium reticulatum* occurs under stones or in crevices at l.w.s.t. and below on rocky shores and occasionally burrows in sandy mud, and *Akera bullata* occurs on mud-flats and on *Zostera* beds. Again the predominant indication is for a shallow subtidal source.

The remains of barnacles, most likely all *Balanus crenatus*, are almost as abundant as the remains of *O. edulis*. *B. crenatus* is typical of the lower shore below the range of the common intertidal barnacle species.

The combined indications of the foraminifers, the bivalves, the gastropods and the barnacles suggest a tidal channel to which shell material from the subtidal zone was contributed in abundance, with an additional contribution coming from intertidal mud flats. There was also a contribution from erosion and reworking of fossils and glauconite from local Eocene deposits, and of chalk and flint fragments from Cretaceous deposits. The likely depth of such a channel, presumably before it was filled in to become the site of intertidal deposition, is difficult to estimate.

The best estimates of level of accumulation of the two samples examined for foraminifera and molluscs are: site 4, sample 1, intertidal mud flat, probably deposited at about mean high water neaps (m.h.w.n.); site 1, sample 2, tidal channel sediment, probably deposited close to mean low water springs (m.l.w.s.). At the present day the tidal levels on this section of coast are (rounded to one decimal place) (Admiralty Tide Tables 1981):

Chichester Harbour entrance	Selsey Bill
m.h.w.s. (mean high water springs) + 2.2 m o.d.	+ 2.4 m o.d.
m.h.w.n. (mean high water neaps) + 1.2 m o.d.	+ 1.5 m o.d.
m.t.l. (mean tide level) + 0.1 m o.d.	+ 0.1 m o.d.
m.l.w.n. (mean low water neaps) - 0.9 m o.d.	- 1.1 m o.d.
m.l.w.s. (mean low water springs) - 2.0 m o.d.	- 2.3 m o.d.

Interpolating between Chichester Harbour entrance and Selsey Bill to obtain an estimate for the Earnley locality gives:

m.h.w.s.	+ 2.3 m o.d.
m.h.w.n.	+ 1.4 m o.d.
m.t.l.	+ 0.1 m o.d.
m.l.w.n.	- 1.0 m o.d.
m.l.w.s.	- 2.2 m o.d.

Assuming a similar tidal range at the time of accumulation of the channel sediments we can estimate that the site 4 sample was deposited (m.h.w.n.) at the equivalent of + 1.4 m o.d. and the site 1 sample (m.l.w.s.) at the equivalent of - 2.2 m o.d.

The site 4 sample is now at +0.65 m o.d. indicating a subsequent relative sea level rise of 0.75 m. The simplest hypothesis would be that sea level at the time of accumulation of sample 1 at site 4 was approximately 0.75 m lower than at the present day. The site 1 sample is now at +0.15 m o.d. indicating a subsequent relative sea level fall of 2.35 m, implying that sea level at the time of accumulation was approximately 2.35 m higher than at the present day. Applying the same presumption of accumulation at about m.l.w.s. to the shelly sediments at the base of site 4 the inferred sea level at the time of its deposition would be (then at -2.2 m o.d., now at -1.95 m o.d.) just 0.25 m higher than at the present day.

Much of the apparent precision of these estimates is of course spurious, because the allocation to specific tidal levels (for example m.h.w.n. and m.l.w.s.) is itself approximate. Nevertheless there is a strong indication that sea level during the time of deposition of the interglacial sediments was within ± 2.5 m of present day levels, and that deposition took place during a period of falling sea level when values may have declined from as much as +2.35 m to -0.75 m, relative to those of the present day.

5. OSTRACODA (J. E. R.)

At the time when the foreshore sequence was augered to provide the samples for the diatom, foraminiferal, molluscan and pollen studies, samples were collected directly from the outcrops exposed and processed for their ostracod faunas. As is conveyed by the plan of the foreshore (figure 1), the channel deposits cut a broad swathe across the Tertiary clays, within which the filling deposits outcrop in a series of ledges, dipping inwards and landwards at a low angle. The basal pebble bed and oyster shell horizon rest with unconformity upon the Tertiary clay and form a disturbed zone along the lateral margins of the channel. From this contact, samples were collected in an upward sequence, collecting prompted by faunal or lithological change to the extent of the seven samples listed below.

- (7) Soft grey clay with *Scrobicularia* valves vertically oriented, as in life (Flandrian).
- (6) Grey silty clay crowded with plant debris.
- (5) Grey clay with shell debris, mainly *Ostrea* (the upper shell bed).
- (4) Grey clay, some 10 cm below the shell bed and a desiccation surface.
- (3) Grey silty clay crowded with plant debris.
- (2) Grey clay with *Pecten* and *Ostrea* shells.
- (1) Basal grey clay with *Ostrea* shells and black flint pebbles.

As sampled, this sequence totalled some 1.2 m and broadly corresponds with the profile at site 5 of the cross section A-B (figures 1 and 2).

The samples were standardized at a mass of 1 kg, disaggregated, wet-sieved and the sieve fractions picked under a binocular microscope down to 120-mesh size. In all samples, ostracods were abundant and were picked, perfect and imperfect alike, to obtain a representative fauna as far as was possible. The presence of specimens derived from the underlying Bracklesham Beds (about the Little Bed of Fisher (1862)) presented no problems, the Tertiary valves having a flat metallic lustre, but served to emphasize the possibility of the transport of ostracod valves into unnatural associations as fossils. In these circumstances, however, *in situ* records would be verified by the presence of immature moult stages (recorded as A-I (one moult pre-adult), A-II, A-III, etc.) remaining alongside the heavier and more bulky adult valves. The presence of articulated valve-pairs (recorded as 'carapaces') would be further affirmation of the minimum

transportation of specimens before fossilization. On these broad criteria, the fauna of the Earnley channel can be assessed as biocoenoses or thanatocoenoses, with a bias towards the first condition.

In ecological interpretations, certain groups of present day ostracods can be classified according to their mode of life. In nearshore communities, one such group is closely associated with seaweeds. These are accordingly known as 'phytal' species (Elofson 1941) and as such will be referred to below in discussion by the letter 'p'. Others are part of the bottom surface infauna, and will be noted by letter 'i'. A further group, active swimmers, would be denoted by letter 'a', but are relatively rare in these samples. This shorthand notation may help in the recognition of possible shore communities in the faunal account that follows. The seven samples are taken in stratigraphical order in the paragraphs that follow.

(1) Basal grey sand clay with flint pebbles and valves of *Ostrea*. This sample contained a total of 28 species, with a total count of 670 valves. The commonest species was *Cyprideis torosa* (19%), represented by male and female adults as well as instars as small as A-V, a prime indication of a stable brackish water environmental situation. In only slightly smaller percentages followed *Hirschmannia viridis* (17%) and *Hemicythere villosa* (15%), both species belonging to the phytal association. *Pontocythere elongata* (11%) is a species usually found in sand shoals, an environment strange to the sedimentary pattern of the Earnley deposits. As most of the specimens are small immature moults (A-V to A-I) however, the likelihood is that these small valves were washed inshore by tides to the place where they were deposited. *Leptocythere* spp. (9%), *Heterocythereis albomaculata* (8%) and *Loxoconcha rhomboidea* (7%) are further phytal species or species associated with algal detritus in the case of *Leptocythere*, here marked 'i-p', and complete the list of species represented by more than 5% of the total. This sample represents an assemblage broadly comparable with one that could be taken at the present day from the margins of the deep water channel into Chichester Harbour: a soft muddy substrate, with patches of weed anchored to flint ballast or gravel shoals.

(2) Grey clay with shells of *Pecten* and *Ostrea*. This sample contained a total of 21 species from a count of 710 valves. The dominant species was *Cyprideis torosa* (17%), followed by *Leptocythere castanea* (= i-p, 14%), *Carinocythereis aspera* (= i, 12%), *Loxoconcha rhomboidea* (= p, 9%), *Hemicythere villosa* (= p, 9%), *Heterocythereis albomaculata* (= p, 8%), *Pontocythere elongata* (= i, but again, all juveniles and so probably washed in, 7%) and *Lindisfarnia* aff. *dertobrevis* (= i, 7%). *Carinocythereis aspera* is an extinct species, but living species of the same genus occur in estuaries with muddy substrates, in offshore subtidal settings. Generally, this seems to be the character of this sample, marking an increased depth of water in the Earnley channel.

(3) Grey silty clay with streaks of plant debris. This sample contained 19 species from a count of 440 valves. The dominant species was *Cyprideis torosa* (= p, 27%), followed by *Pontocythere elongata* (A-V to A-I, 17%), *Heterocythereis albomaculata* (= p, 8%), *Hemicythere villosa* (= p, 8%), *Loxoconcha rhomboidea* (= p, 7%), *Loxoconcha elliptica* (= p, 6%), *Leptocythere castanea* (= i-p, 6%) and *Semicytherura nigrescens* (= p, 5%). To some extent this reduced variety assemblage may reflect the obvious concentrations of plant debris at this horizon, a detail comparable with the lag accumulations which build up in salt-marsh backwaters and creeks around Chichester Harbour today. At this stage in sedimentation, there may have been a slight lowering of sea-level and outward growth of vegetated mud-flats.

(4) Grey silty clay, almost black with included plant fragments. This sample contained 13 species, represented by a total of 100 valves. As with the previous samples, *Cyprideis torosa* (= p,

28%) was the dominant species followed by *Pontocythere elongata* (= i, A-V to A-I, 14%), *Loxoconcha rhomboidea* (= p, 12%), *Hemicythere villosa* (= p, 11%) *Heterocythereis albomaculata* (= p, 8%), *Carinocythereis aspera* (= i, 8%) and *Leptocythere pellucida* (= i-p, 8%). Shallowing, coupled with the concentration of organic debris may be held responsible for this less-diverse fauna, still dominated by the euryhaline and eurythermal *Cyprideis*.

(5) Grey clay, the upper shell bed (about 115 cm above the base of the sequence). This sample contained 20 species, represented by a total of 360 valves. The dominant species was *Cyprideis torosa* (27%), followed by *Hemicythere villosa* (= p, 20%), *Pontocythere elongata* (= i, A-III to A-I, 11%), *Heterocythereis albomaculata* (= p, 9%) and *Aurila* aff. *prasina* (= i, 8%). The increased species diversity reflects an increased marine influence which in turn could be associated with a rise of sea level and the flooding of the channel system from the English Channel.

(6) Grey silty clay, crowded with plant debris, below a desiccated surface. This sample contained only seven species, and a total of 96 valves. In the reduced diversity, *Cyprideis torosa* was still the dominant species (40%), followed by *Pontocythere elongata* (A-IV to A-I, 28%), *Hirschmannia viridis* (= p, 11%) and *Semicytherura nigrescens* (= p, 10%). This sample represents a return to the conditions of the organic-rich layers already described, possibly shallowing, but equally the conditions could reflect slack-water sedimentation as the channel system migrated across the shoreline.

(7) Pale grey sticky clay with *Scrobicularia* in burrowing position. This, the highest horizon in the channel system, appeared to spread laterally on to the surface of the adjacent Bracklesham Beds. Pollen content indicated a Flandrian age. Faunally, it continued 11 species from a count of 165 valves. The dominant species were *Leptocythere castanea* (= i-p, 46%) and *Leptocythere psammophila* (= i-p, 34%). The decline to less than 1% of *Cyprideis torosa* could be taken to indicate that the channel pattern of sedimentation had been followed, in the Flandrian, by a broad intertidal tract, well-oxygenated silty muds with a high content of algal detritus.

Overall, these seven samples offer clear ecological evidence for a complex not unlike Christchurch Harbour and its extensive margins of creeks today (Whittaker 1981). Here too the faunas are dominated by *Cyprideis torosa*, faunal diversity falling away in the often drying out upper margins of the intertidal mudflats. In these last areas, there are often extensive accumulations of salt marsh plant debris which could parallel the build-ups seen in the Pleistocene samples. From this comparison, however, it must be said that the land-derived elements (particularly the valves of freshwater ostracods) so common in the Harbour, are totally absent from the Earnley deposits suggesting that relative to the contemporary shore line, the channel as sampled represented the seaward zone of the Pleistocene shore.

The ecological patterns discussed above are based upon the evidence drawn from the majority of species of the faunal list – species which are alive today and for which we have knowledge of their ecological requirements. Of the total fauna (see tables 1 and 2, figure 5, plate 1 and figure 6, plate 2) however, there remains a small percentage which are apparently not part of living fauna. Some are species that are now part of the fauna of the Mediterranean Sea. Others are species that are now extinct. Both categories allow some speculation as to the relative age of the Pleistocene deposit as a whole.

Of the species which may suggest an age (table 2), several bear a striking resemblance to those that were described by Brady (1865) as making up the fauna of the Nar Valley clays of Norfolk (Lord & Robinson 1978; Robinson 1978), a deposit now recognized as being of Hoxnian age. One such form agrees closely with '*Cythere*' *aspera*, a species which would now be referred to the genus *Carinocythereis*. The type specimens for *C. aspera* have only recently been

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TABLE 1. LIST OF OSTRACODA FOR THE EARNLEY CHANNEL DEPOSITS

<i>Aurila convexa</i> (Baird)	<i>L. psammophila</i> Guillaume
<i>Aurila</i> aff. <i>prasina</i> (Barbeito Gonzalez)	<i>L. tenera</i> (Brady)
<i>Callistocythere littoralis</i> (Müller)	<i>Leptocythere</i> sp.nov.
<i>Callistocythere</i> sp.nov.	<i>Lindisfarnia</i> aff. <i>dertobrevis</i> (Ruggieri)
<i>Carinocythereis aspera</i> (Brady)	<i>L. granulata</i> (Sars)
<i>Cyprideis torosa</i> (Jones)	<i>Loxoconcha cuneiformis</i> (Malcolmson)
' <i>Cythere</i> ' <i>rubida</i> (Brady)	<i>L. elliptica</i> (Brady)
<i>Elofsonia baltica</i> (Hirschmann)	' <i>Loxoconcha</i> ' <i>multifora</i> (Norman)
<i>Finmarchinella finmarchica</i> (Sars)	<i>L. rhomboidea</i> (Fischer)
<i>Hemicythere villosa</i> (Sars)	<i>Pontocythere elongata</i> (Brady)
<i>Hemicytherura cellulosa</i> (Norman)	<i>Sahnia subulata</i> (Brady)
<i>Heterocythereis albomaculata</i> (Baird)	<i>Sclerochilus contortus</i> (Norman)
<i>Hirschmannia viridis</i> (Müller)	<i>Semicytherura acuticostata</i> (Sars)
<i>Leptocythere castanea</i> (Sars)	<i>S. nigrescens</i> (Baird)
<i>Leptocythere ilyophila</i> (Hirschmann)	<i>S. producta</i> (Brady)
<i>L. lacertosa</i> (Hirschmann)	<i>S. sella</i> (Sars)
<i>L. pellucida</i> (Baird)	<i>S. similis</i> (Sars)
	<i>S. undata</i> (Sars)

TABLE 2. OSTRACOD DISTRIBUTIONS BY AGE AND SITE

	Pliocene	St Erth	Red Crag	Earnley	Nar Valley	Sandtietie	Selsey	Recent
<i>Aurila convexa</i>	—	—	×	×	—	×	×	×
<i>Aurila</i> aff. <i>prasina</i>	×	?×	×	×	?×	—	—	—
<i>Callistocythere littoralis</i>	—	—	×	×	×	×	—	×
<i>Callistocythere</i> sp.nov.	—	—	×	×	—	×	—	—
<i>Carinocythereis aspera</i>	—	—	—	×	×	—	—	?×
<i>Cyprideis torosa</i>	—	—	×	×	×	—	×	×
' <i>Cythere</i> ' <i>rubida</i>	—	—	×	×	—	—	—	×
<i>Elofsonia baltica</i>	—	—	×	×	—	—	×	×
<i>Finmarchinella finmarchica</i>	—	—	×	×	×	×	×	×
<i>Hemicythere villosa</i>	—	—	—	×	×	×	×	×
<i>Hemicytherura cellulosa</i>	—	—	—	×	×	—	×	×
<i>Heterocythereis albomaculata</i>	—	—	—	×	×	—	×	×
<i>Hirschmannia viridis</i>	×	—	×	×	×	—	×	×
<i>Leptocythere castanea</i>	—	—	×	×	—	—	×	×
<i>L. ilyophila</i>	—	—	—	—	—	—	—	—
<i>L. pellucida</i>	—	—	×	×	—	×	×	×
<i>Leptocythere</i> sp.nov.	—	?×	×	×	—	—	—	—
<i>Lindisfarnia</i> aff. <i>dertobrevis</i>	—	—	—	×	×	—	—	—
<i>Lindisfarnia granulata</i>	—	—	—	×	×	—	×	×
<i>Loxoconcha cuneiformis</i>	—	—	—	×	—	—	—	—
<i>L. elliptica</i>	—	—	—	×	×	—	×	×
' <i>Loxoconcha</i> ' <i>multifora</i>	—	—	—	×	—	—	—	×
<i>L. rhomboidea</i>	—	—	×	×	×	—	×	×
<i>Pontocythere elongata</i>	—	—	×	×	×	—	×	×
<i>Sahnia subulata</i>	—	—	—	×	—	—	×	×
<i>Sclerochilus contortus</i>	—	—	×	×	—	×	×	×
<i>Semicytherura acuticostata</i>	—	—	×	×	—	—	×	×
<i>S. nigrescens</i>	×	×	×	×	×	—	×	×
<i>S. producta</i>	—	—	×	×	—	—	—	×
<i>S. sella</i>	—	—	×	×	×	×	×	×
<i>S. similis</i>	—	—	—	×	—	—	—	×
<i>S. undata</i>	—	—	—	×	—	—	×	×

rediscovered by D. J. Horne in the collections of the Hancock Museum, Newcastle upon Tyne, and will be crucial in taxonomic work on this and related forms which he and J. Athersuch are researching at present. Having seen the types from the Nar Valley, I find a close agreement with those from Earnley, sufficient to use the Brady species name here. At the same time, I agree with an opinion that eventually it may be correct to see *C. aspera* as a junior synonym

of *Carinocythereis whitei* (Baird) (J. Athersuch, personal communication). For the present, however, I am impressed by the agreement at perhaps varietal level with the Nar Valley specimens.

A hemicytherid in the Earnley deposits is here referred to as *Aurila* aff. *prasina* Barbeito Gonzalez. A lightly ornamented form, with a slight radial ornament about the anterior margin, it has undoubted resemblance to *Aurila hesperiae* as described by Ruggieri (1974), and more especially as illustrated by Mostafawi (1981), but the dorsal outline in lateral view is much more of a smooth curve as in *A. prasina*. Both *A. hesperiae* and *A. prasina* are Mediterranean species (Calabrian-to-Recent and subfossil-to-Recent respectively). Neither are part of British Ipswichian or Recent fauna. The Nar Valley species *Cythere arborescens* Brady, is comparable in some respects with *A. aff. prasina* from Earnley, but it is considered in all probability to be *Aurila woodwardi* (Baird) and different from the Earnley species (J. E. Whittaker and D. J. Horne, personal communication). A further Earnley species has no apparent link with Nar Valley fauna, but rather relates to specimens found in the Red Crag of Suffolk. This is a small, strongly reticulate form of *Leptocythere*, present in both male and female dimorphs as well as instars, ruling out the possibility of reworking of material into a younger deposit. Reticulately ornamented leptocytherids are an important element in the Pliocene St Erth Beds of southern Cornwall, from which some sixteen species have been described (Maybury & Whatley 1980). In another account (Whatley & Maybury 1981), the same authors have seen these same reticulate species as grounds for deriving the modern, less strongly ornamented leptocytherids from a *Callistocythere* root-stock strongly represented in the Miocene of western Europe. While the Earnley leptocytherid has certain affinity with *Leptocythere sainterthenis* Maybury & Whatley, or with *Leptocythere* species G Maybury & Whatley, it and the Red Crag form probably deserve recognition as a new species, when fully studied. For the time being, it stands as another factor in recognising at least a Middle Pleistocene age for the channel deposit in Sussex.

The genus *Callistocythere*, mentioned above, is also part of the Earnley fauna, represented by two distinct species forms. One is strongly ornamented; and agrees closely with *Callistocythere littoralis* (Müller), originally described from the Bay of Naples (Müller 1894) and still recorded from Mediterranean localities but also extending into British waters at the present day. A second species, however, is more lightly ornamented and by that token, is more leptocytherid in character although retaining the hingement of *Callistocythere*. Once again, specimens with the same pattern of ornament and proportions have been recorded from the Red Crag from Butley Neutral Farm Pit and require a new name when that fauna is monographed (D. J. Horne, personal communication). Interestingly, the same new *Callistocythere* species figures in the fauna described from the 'graded sediments' of the Sandettie-Fairey Bank in the Channel off Ostend

DESCRIPTION OF PLATE 1

FIGURE 5. (a) *Callistocythere* sp.nov. male carapace, left aspect, OS 12174, $\times 120$. (b) *Callistocythere littoralis* (Müller) female carapace, right aspect, OS 12171, $\times 140$. (c) *Leptocythere* sp.nov. male carapace, left aspect, OS 12177, $\times 145$. (d) *Leptocythere* sp.nov. female carapace, left aspect, OS 12175, $\times 145$. (e) *Lindisfarnia* aff. *dertobrevis* Ruggieri female carapace, dorsal aspect, OS 12142, $\times 100$. (f) *Lindisfarnia* aff. *dertobrevis* Ruggieri, female carapace, left aspect, OS 12168, $\times 100$. (g) '*Cythere*' *rubida* male carapace, left aspect, OS 12150, $\times 125$. (h) *Aurila prasina* Barbeito-Gonzalez female carapace, dorsal aspect, OS 12146, $\times 90$. (i) *Aurila prasina* Barbeito-Gonzalez female valve, left aspect, OS 12164, $\times 90$. (j) *Aurila prasina* Barbeito-Gonzalez male carapace, left aspect, OS 12145, $\times 90$.

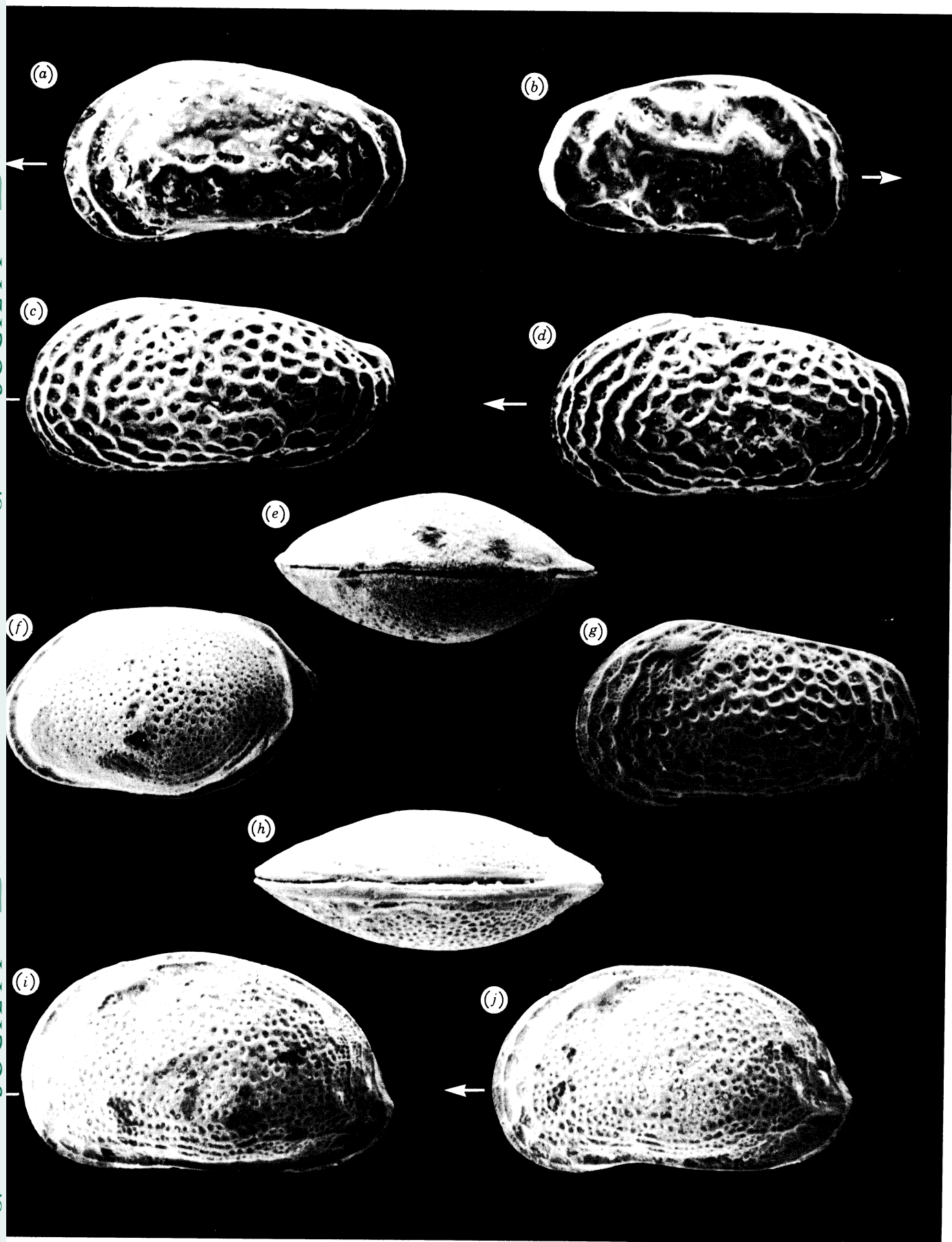


FIGURE 5. For description see opposite.

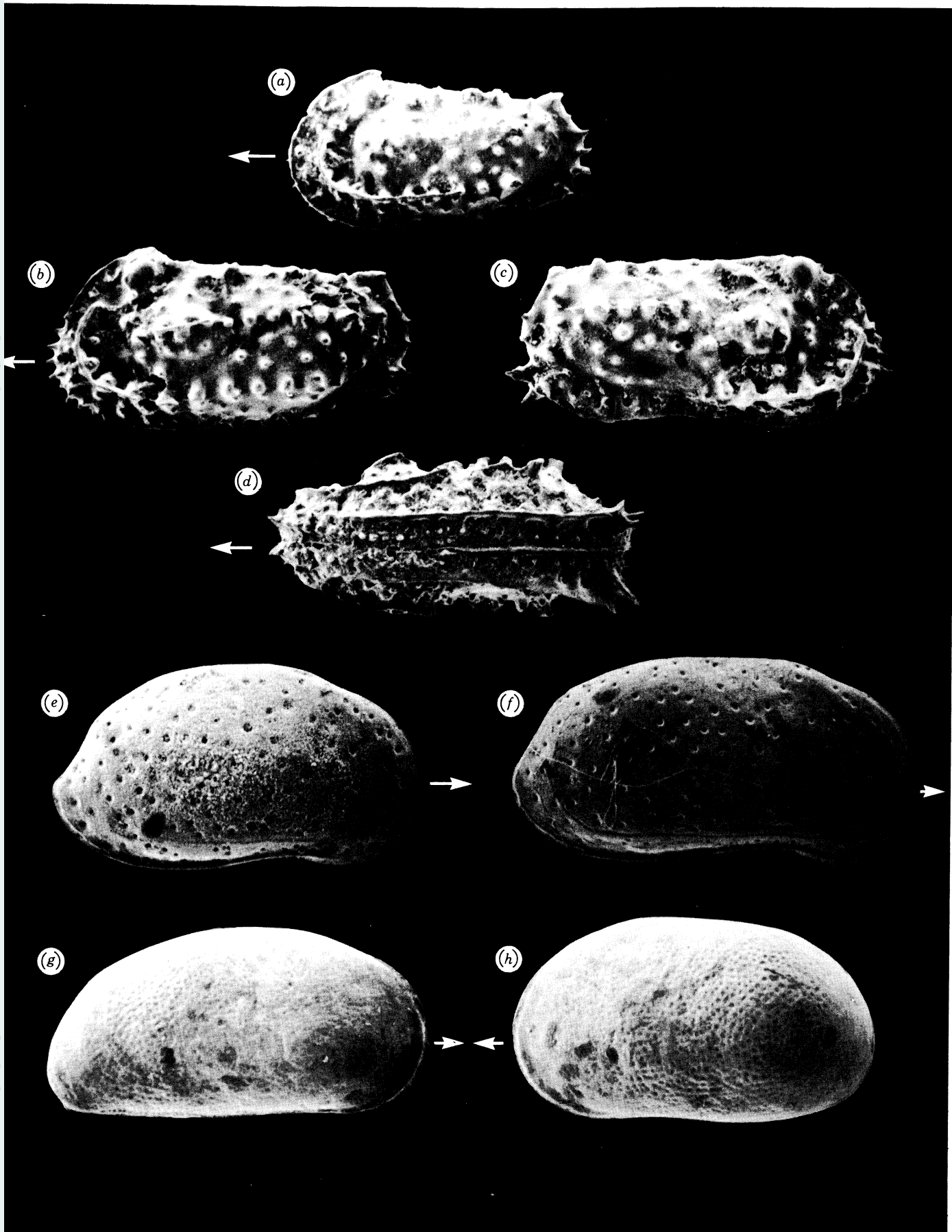


FIGURE 6. For description see opposite.

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(Kirby & Oele 1975), sediments regarded as 'late Pleistocene' and overlain by Holocene sands. Ostracods from this study made available by J. E. Whittaker of the British Museum (Natural History) closely match the specimens from Earnley and Butley, and make feasible a greater age for the Sandettie 'graded sediment' series.

The Earnley samples have a range of loxoconchid ostracods, among which is a form that has recently been identified with a species *Loxoconcha cuneiformis* originally described by Malcolmson from Rockport, County Down (Malcolmson 1886). Malcolmson had only one specimen at the time, a carapace retaining traces of soft parts in chitin, in spite of which there is the possibility that the specimen was derived from an older Pleistocene clay upon the foreshore. To date, Earnley is the only other locality for this morphologically distinct species. It does not appear to be part of the British contemporary fauna (Horne & Robinson, 1982). Taking the view that *Loxoconcha cuneiformis* Malcolmson would have been recognized had it been extant, this fact could be taken as evidence for the greater age of the channel deposit as a whole.

Another loxoconchid is one which has something of the appearance of *Loxoconcha granulata* Sars, a species from Norwegian and northern Scottish waters present day on the basis of the living ostracod survey in progress based upon grab samples collected by the Continental Shelf Unit of the Institute of Geological Sciences. A closer agreement, however, exists between the Earnley specimens and those referred to the Neogene species *L. dertobrevis* Ruggieri by Uffenorde as *L. aff. dertobrevis*. It is with these living forms from the Limski Kanal (Adriatic) (Uffenorde 1972) that a comparison will be made. Both *L. granulata* and *L. dertobrevis*, would now be referred to the genus *Lindisfarnia* of Horne & Kilenyi (1981) and not *Loxoconcha* as in the past.

To put these remarks upon age into perspective, the species that have been commented upon above constitute only some 18% of the total fauna, leaving 82% of species that range on to be part of the living ostracod fauna of the Channel coast today. Nearly all of this majority group could be found in the varied environmental niches of Christchurch Harbour on the strength of recent investigations. For comparison, the extant element calculated for the Pliocene St Erth Beds has been judged to be a mere 2%, or 25% if species now to be found as part of the Mediterranean fauna are included (Maybury & Whatley 1980). Coming to the last interglacial, the very useful account of the ostracod fauna of the Selsey channels (Whatley & Kaye 1970), records only one extinction (*Cytheromorpha cribrosa* Brady, Crosskey & Robertson (Brady *et al.* 1874)) from a fauna of 62 species which make up the total for this Ipswichian site. Of the 61 extant species, one, *Semicytherura arcachonensis*, is now restricted to the southern Bay of Biscay coast, the rest comprise the fauna of the Channel coast today. Between these extremes of 25% (St Erth) and 99% (Selsey), the figure of 82% of Earnley would seem to suggest a Middle Pleistocene position within any calculated progression of change with time. It is interesting to note that in the fauna of St Erth, Earnley, and, to the extent of one species, Selsey, ostracods that are not now part of British fauna are to be found in southern Biscay or in the

DESCRIPTION OF PLATE 2

FIGURE 6. (a) *Carinocythereis* cf. *aspera* (Brady) juvenile (A-II), left aspect OS 12163, $\times 95$. (b) *Carinocythereis* cf. *aspera* (Brady) female carapace, left aspect, OS 12162, $\times 95$. (c) *Carinocythereis* cf. *aspera* (Brady) male carapace, right aspect, OS 12161, $\times 95$. (d) *Carinocythereis* cf. *aspera* (Brady) male carapace, ventral aspect, OS 12149, $\times 90$. (e) *Heterocythereis albomaculata* (Baird) female carapace, right aspect, OS 12169, $\times 90$. (f) *Heterocythereis albomaculata* (Baird) male carapace, right aspect, OS 12147, $\times 88$. (g) *Cyprideis torosa* (Jones) male carapace, right aspect, OS 12155, $\times 80$. (h) *Cyprideis torosa* (Jones) female carapace, left aspect, OS 12156, $\times 80$.

Mediterranean. To some extent this may be a response to climatic changes, a consequence of faunal displacements north and south promoted by the advance and retreat of ice-sheets in northern Europe, with some species failing to migrate and readjust ecologically.

6. CONCLUSIONS AND CORRELATIONS

(a) *Relation to sea level*

Evidence from the sediments, fauna and flora indicate convincingly that the Earnley site was an area of coastal marine deposition in the later part of a temperate stage of the Pleistocene. The diatom, foraminifers, mollusc, ostracod and stratigraphic data point to the development of an intertidal channel. Initial sediment accumulation appears to have been under relatively high energy conditions, possibly close to the channel inlet. The dominantly coarse sized shelly nature of the basal sediments, the broken state of the shells and diatom valves and the clear palaeoenvironmental evidence of continual exchange with the open marine environment supports this interpretation. The laminated nature of the bottom sediments, with interbedded clays and silts within the sand, suggest possible channel migration and the slumping of finer side and supra-channel deposits (Harrison 1975; Reineck 1975). Tidal channel velocities recorded above similar coarse grained lithofacies in modern channels of comparable size from North Sea and North American coasts commonly reach values of 0.5–1.2 m s⁻¹. Such velocities are consistent with both the foraminifer and particle size evidence at the site. The absence of freshwater deposits at the base of the channel such as occur at Selsey in an Ipswichian channel filling (West & Sparks 1960), indicates the channel itself was formed by tidal scour. A fining upward of the sedimentary sequence together with the changes in the flora and fauna, show a replacement of the high energy conditions by a regime corresponding to a higher position in the intertidal zone. A change from about -2.2 m m.t.l. to about +1.4 m m.t.l. may be suggested as a possibility. This shoaling might indicate a depositional regressive sequence formed by infilling of the site under conditions of high sediment supply (Klein 1971), with possible coastal progradation occurring. Alternatively the changes may result from physiographical development of the coastline, perhaps from the formation of blocking beach bar complexes. At the close of sedimentation in the channel m.t.l. was about 0.7–1 m below its present position.

(b) *The age of the Earnley channel filling*

The age of the channel filling is uncertain: the pollen evidence points to a late Cromerian or late Hoxnian date, the ostracod evidence to a period post-dating the St Erth Beds and pre-dating the Ipswichian, and the foraminiferal evidence to a period post-dating the Pre-Pastonian a of the Norfolk coast.

(c) *Relation to neighbouring Pleistocene deposits*

The channel filling at Earnley is very clearly different in age to the Ipswichian channel filling at Selsey, 4.5 km to the south-east (West & Sparks 1960). As discussed above, it must belong to an older temperate stage. The channel filling appears to post-date the emplacement of large erratics on the foreshore at Earnley. No correlation can be attempted with the marine Slindon Sand (Shephard-Thorn & Kellaway 1978), 15 km to the north-east and at an elevation of 33–38 m o.d., though there have been suggestions from faunal evidence that this horizon is Hoxnian in age. If it is, and if the Earnley channel filling is also Hoxnian, a large and rapid

rise or fall in sea level took place in late Hoxnian times. It is also not yet possible to suggest a relation to the recently re-described estuarine clays (Steyne Wood Clay) at Bembridge, Isle of Wight, occurring at 38–40 m o.d. and attributed on palynological evidence to the post-temperate stage of a Middle Pleistocene temperate stage (Holyoak & Preece 1983).

We acknowledge that the comparisons of species could not have been carried out without the help of Dr D. J. Horne and Dr J. E. Whittaker currently concerned with revisions of Plio–Pleistocene faunas (D.J.H.) and with the documentation of living fauna in southern England (J.E.W.). Our understanding of the distributions of present day marine ostracods depends very much upon the grab samples which have been made available to J.E.R. by the Continental Shelf Unit of the Institute of Geological Sciences over the past ten years. Without their materials there could have been no appreciation of live ostracod distributions and in turn, no palaeoecological or age comment here would have been meaningful.

The specimens that have been figured are deposited in the Fossil Ostracod Collection of the British Museum (Natural History), carrying the catalogue numbers quoted. The stereoscan photographs were taken by Dr Whittaker.

The authors are indebted to the late Mr F. C. Stinton of Bournemouth and Mr R. Fowler of East Wittering for introduction to the Earnley channel and for their invaluable assistance in the field, and also to Mr S. G. West for field assistance.

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APPENDIX

Stratigraphical details of the channel filling

site 1	0–15 cm	grey silty clay
	15–35 cm	sand with <i>Ostrea</i>
	35–55 cm	sand
	55–70 cm	hard blue clay (Bracklesham Beds)
site 2	0–60 cm	grey silty clay
	60–100 cm	grey laminated silty clay, with intercalations of coarse sand
	100–105 cm	grey clayey sand
	105–125 cm	hard brown clay (Bracklesham Beds)
site 3	0–5 cm	grey sandy silt
	5–178 cm	grey laminated silty clay with sand intercalations
	178–185 cm	brown-grey organic sandy clay
	185–219 cm	grey laminated silty clay with sand intercalations
	219–220 cm	brown-grey organic sandy clay
	220–255 cm	grey laminated silty clay with thick sand intercalations and fragments of <i>Ostrea</i> shell
site 4	255–275 cm	black clayey sand with <i>Ostrea</i> , stopped by gravel
	0–5 cm	grey laminated silty clay
	5–20 cm	brown grey sand with organic detritus and <i>Ostrea</i>
site 5	20–35 cm	grey laminated silty clay
	0–78 cm	grey laminated silty clay and sand
	78–80 cm	brown-black organic sand
	80–116 cm	grey laminated silty clay and sand
	116–120 cm	brown-black sand with <i>Ostrea</i> , stopped by gravel

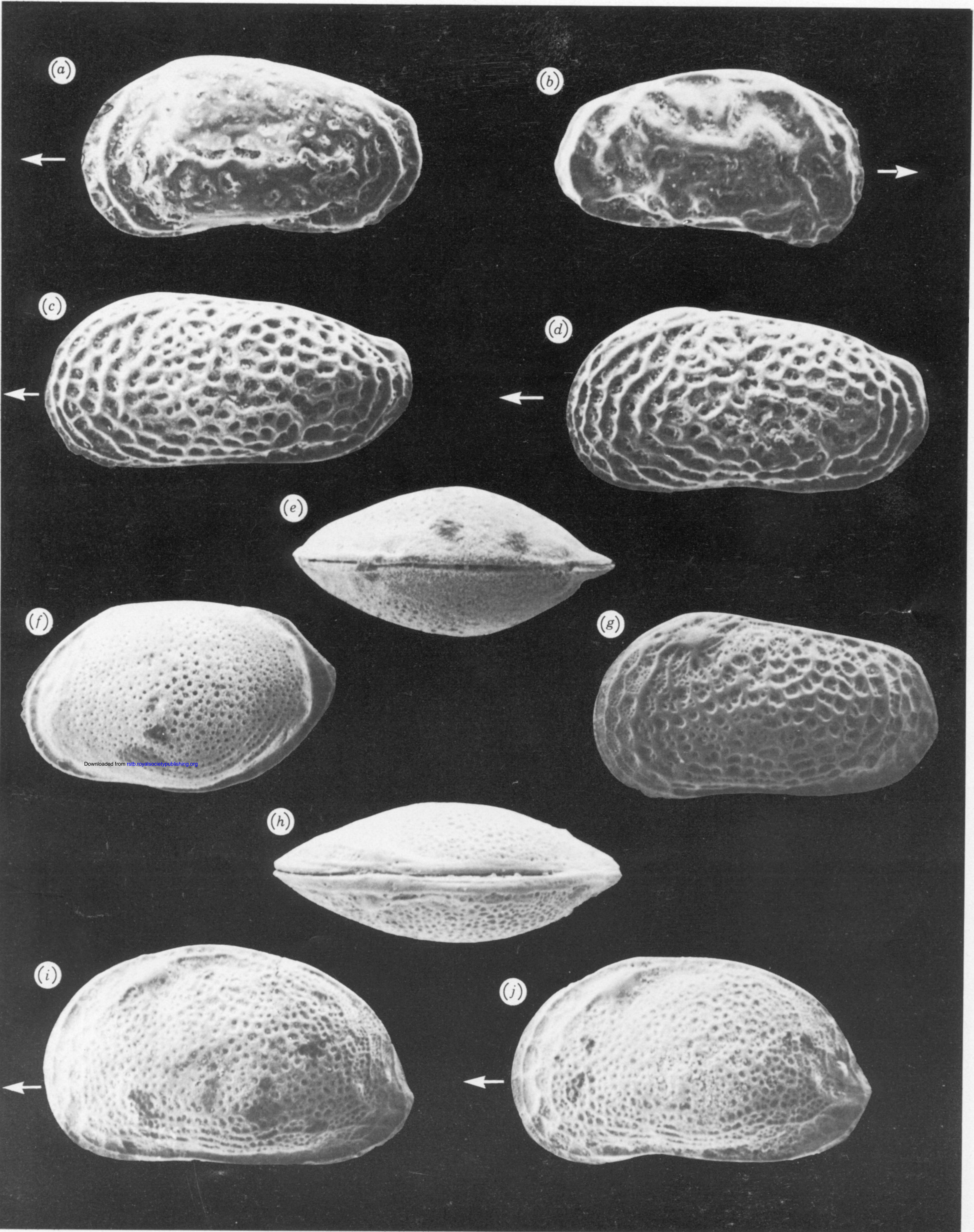


FIGURE 5. For description see opposite.

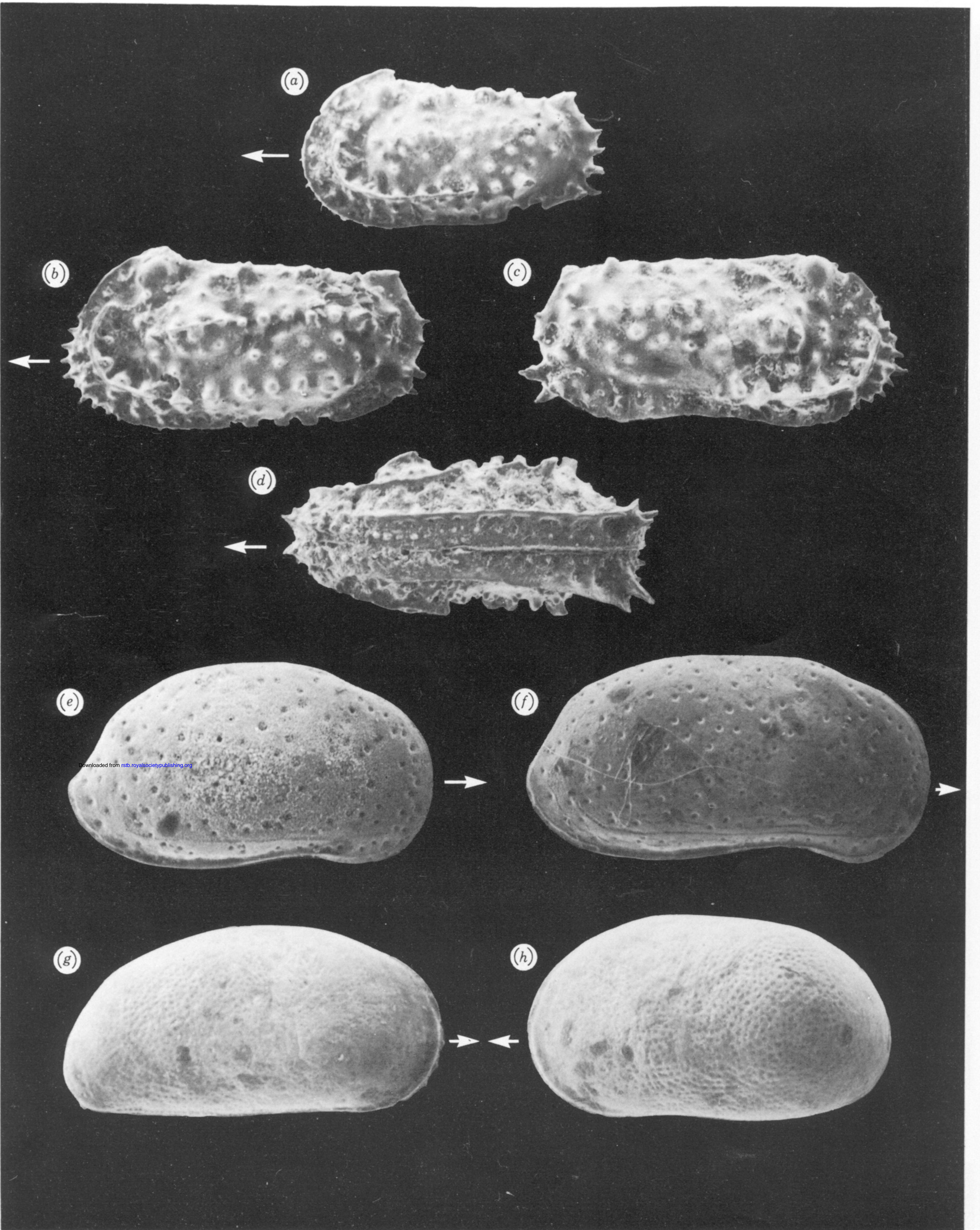


FIGURE 6. For description see opposite.