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THE OSTRACOD FAUNA OF THE MIDDLE PLEISTOCENE INTERGLACIAL DEPOSITS AT LITTLE OAKLEY, ESSEX

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[Plates 1 and 2]

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The ostracod fauna of the interglacial channel deposits at Little Oakley, Essex, is described from samples collected from four boreholes located at different sites across the palaeochannel. Minor differences between boreholes are explained principally by the contrasting depositional environments reflecting marginal and mid-channel facies. For the most part, the faunas indicate fully temperate conditions although there are suggestions of less temperate conditions earlier in the interglacial. The absence of brackish-water species indicates that the river was upstream of any tidal influence. No ostracod faunas are known from strictly comparable facies from the British Lower or Middle Pleistocene and this makes an age assessment difficult on the basis of ostracods alone. Significant elements include *Candona tricicatricosa*, *Ilyocypris quinculminata*, *Sclerocypris clavata prisca* and *Paralimnocythere compressa*, together with an *Ilyocypris* that appears to constitute an undescribed species. This is described, illustrated and formally named *Ilyocypris papillata*. The critical taxa, in the proportions seen here, are consistent with a Cromerian age although none is confined to this period.

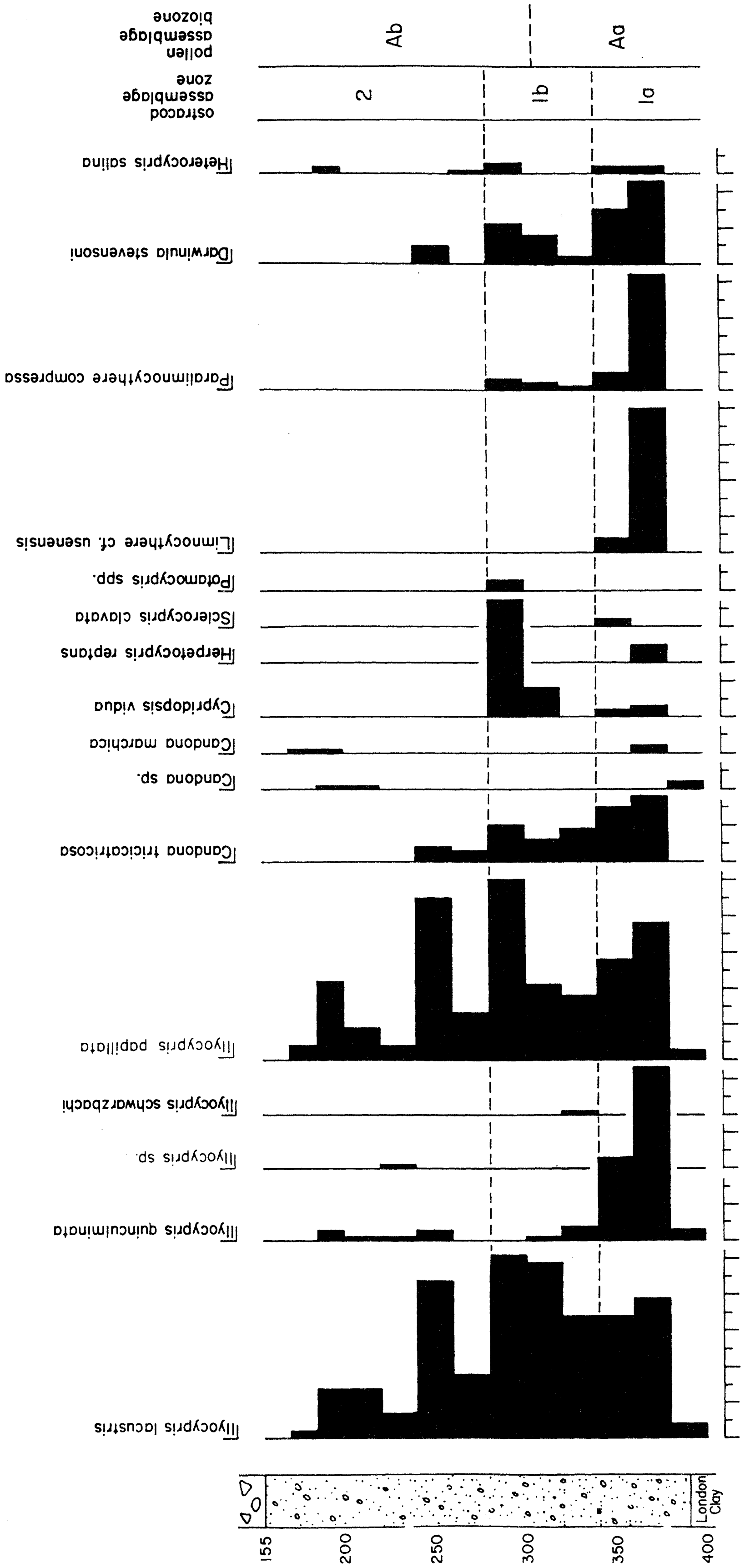


FIGURE 1. Ostracod diagram from borehole LOA plotting absolute numbers per 500 g of dry sediment. Raw data listed in table 1.

1. Sampling and treatment of data

The ostracods were recovered from the same samples as those analysed for Mollusca by Preece (1990). The counts represent the summation of the larger specimens retained by the 0.5 mm sieve during the molluscan analyses together with smaller specimens picked from the fine residues (less than 0.25 mm) that had been kept solely for ostracod analysis.

The results are presented in tables 1–4, where details of the moult stages and occurrence as individual valves or united carapaces are also given. Figures 1 and 2 plot the frequencies of occurrence for the two boreholes (LOA and LOO) studied in most detail. Because samples differed in size, the data have been calculated to show the number of valves per 500 g of dry sediment.

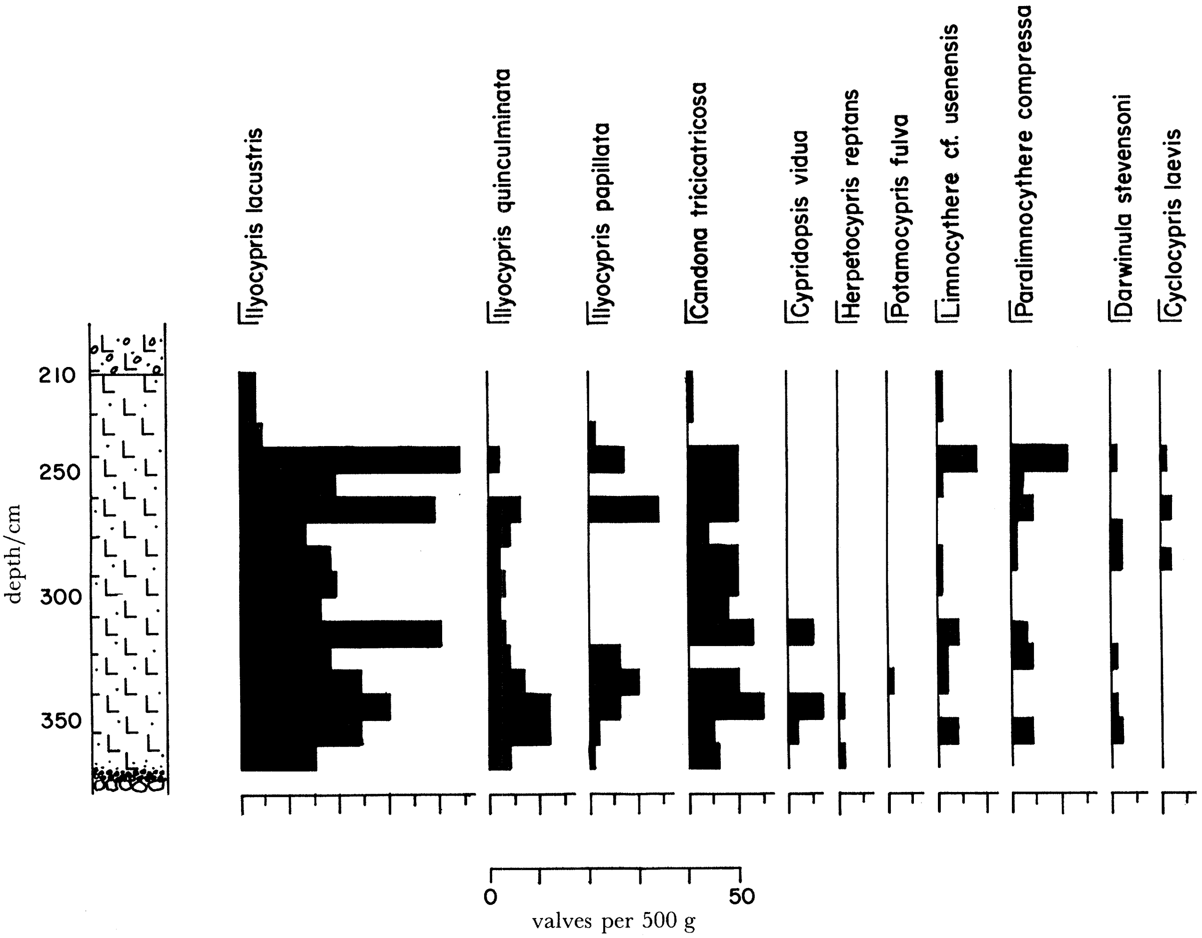


Figure 2. Ostracod diagram from borehole LOO plotting absolute numbers per 500 g of dry sediment. Raw data listed in table 3.

The analyses of the borehole samples have been supplemented by bulk sampling from two excavated pits immediately adjacent to the site of LOA.

The preservation of ostracods was generally good throughout the profiles but was best in the more silty levels. In the sandy levels large (e.g. *Herpetocypris*) or delicate species had suffered breakage, making accurate counts somewhat difficult, but this bias is not thought to be too serious. At some horizons reworked microfauna was recovered mostly derived from the Chalk although some *Cushmanidea* clearly came from the Tertiary. These are readily separable from the Pleistocene taxa.

2. Problems of identification and notes on species of interest

The chief taxonomic problem concerned the specific identity of members of the genus *Ilyocypris*, which dominate the ostracod fauna at Little Oakley. A distinction is usually made between forms with a smooth contour to the valves between the sulcal furrows and those where the same surfaces erupt into tubercles, which may terminate in spines. The extremes of these states are conventionally called *I. bradyi* (smooth) and *I. gibba* (spinose). In practice many faunal assemblages show a gradation between the two extremes. Views differ on the importance that should be attached to these characters. Some authors regard both extremes as conspecific, whereas others regard the intermediate forms as additional taxa. Studies of the anatomy of the soft parts reveals consistent differences between the two end members and their specific distinctness has been upheld (Sylvester-Bradley 1971; Hartmann 1971). Significantly for our later discussion of palaeoecology, one of the differences lies in the length of the swimming bristles on the antennae, which are short in *I. bradyi* and long in *I. gibba*. These structures are related to the crawling/clambering mode of life of the former and an ability to swim in the latter (Van Harten 1979). This makes it difficult to accept the ecological coexistence of the two species that has been suggested by some authors (see, for example, Anadon *et al.* 1986), although the situation is further complicated by the recognition of forms that have been termed 'non-spinose *gibba*' or 'tuberculate *bradyi*' (Van Harten 1979).

In recent years, two aspects of shell morphology, the muscle scar pattern and marginal ripplets, have been used for taxonomic discrimination in ilyocyprids.

Regarding the muscle scars, the ilyocyprid central adductor scar seems to be very stable through a wide range of morphospecies, the apparent differences relating to the strength of the sulcal pit. Deep pits offer only limited surface area on the inside of the valve, causing the separate scars to be closely bunched. The position and shape of the two or three mandibular scars below and in front of the central cluster can produce distinct patterns, although, as for all scars, it is important to recognize that left-valve patterns can differ from those of the right valve of the same individual, making it vital to compare left with left and right with right. For *Ilyocypris*, scar patterns need to be fully recorded for all existing taxa before their potential taxonomic value is firmly established.

Marginal ripplets are structures that were first recognized by Van Harten (1979, p. 72) as occurring only in the postero-ventral quarters of the left valves of adult specimens (absent from the corresponding position in the right valve of the same individual). They are apparently solid structures, not to be confused with hollow tubercles, bearing sensory bristles through the duplicature proper. Effectively, marginal ripplets corrugate the contact surface of the one duplicature against its counterpart opposite. The functional significance of these structures is not clear.

At the time of their original description, Van Harten (1979) used the presence and number of marginal ripplets as a means of distinguishing the otherwise contentious taxa *I. gibba* (four ripplets) from *I. bradyi* (one or two only). A third species, *I biplicata*, was found to possess up to 20 ripplets whereas a fourth species, *I. quinculminata*, appeared to lack them altogether. Scanning electron microscope study of material from Little Oakley has been undertaken as part of a detailed taxonomic study. From all these criteria it appears that one relatively common ilyocyprid from Little Oakley represents an undescribed species. A formal systematic description is now given, followed by brief notes on other selected taxa.

Family ILYOCYPRIDIDAE Kaufmann, 1900

Genus *ILYOCYPRIS* Brady & Norman, 1889

Ilyocypris papillata Robinson, sp. nov.

(Figure 7, plate 1, and figures 19 and 20, plate 2.)

Holotype. British Museum (Natural History) OS 13061.

Dimensions of holotype. Length 0.83 mm, height 0.50 mm (max.), 0.33 mm (min.).

Type locality. Little Oakley, Essex. Boreholes and pits located at TM 223294.

Stratigraphical horizon. The Little Oakley Silts and Sands (Bridgland *et al.* 1990), early Middle Pleistocene (Cromerian interglacial).

Known stratigraphical range. Middle Pleistocene.

Derivation of name. Derived from *papilla* Latin 'teat-shaped', the shape of the strongest spinose node.

Diagnosis. An ilyocyprid of the gibba group, sharing their strongly spined character and the basic pattern of five stronger spines in relation to the sulcus. In this species, the posterior spine is directed backward and cone-shaped, culminating in a point apex. The other spines form a dorsal row of three across the sulcus, with two smaller cones below the line of the sulcus. The valve outline is identical to that of *I. gibba*, with a straight dorsal line and a strongly incurved venter. The valve margins are fringed with a continuous series of fine tubercles. The valve surface is covered entirely with a pattern of rounded-outline shallow pits sunk into thick valves. Internally, the postero-ventral face of the duplicature in the adult left valve bears marginal ripplets in a pattern of four or five spindle-form ripplets running from the external edge to a line about one third of the distance across the duplicature. Between the main ripplets occur bundles of four or five finer, thread ripplets. Muscle-scar pattern is close to that recorded for both *I. gibba* (Diebel & Pietrzeniuk 1969) and for *I. quinculminata* (Sylvester-Bradley 1973).

Remarks. *I. papillata* is clearly very close to *I. gibba*. However, the strength and morphology of the principal spine node, combined with the pattern of marginal ripplets, are thought to justify its specific separation. This form has been recognized from the Cromerian stratotype at West Runton, Norfolk, and from early Middle Pleistocene deposits at Boxgrove, Sussex (J. E. Robinson, unpublished data). Although there are still few localities known to yield this taxon, it is significant that all are Middle Pleistocene in age. Consequently a re-examination of all material assigned to *I. gibba* from critical European Middle Pleistocene sites is prompted. This would apply particularly to material from Süssenborn, DDR (Diebel & Pietrzeniuk 1969, p. 468), and from Tiraspol, Moldavia. At the latter site a subspecies *I. gibba nistruensis* has been described that has a certain resemblance to *papillata*, but the quality of the published plate (Negadaev-Nikonov 1970, plate X, figure 4) is too poor to allow detailed comparisons.

Ilyocypris lacustris Kaufmann

(Figure 13, plate 1, and figure 18, plate 2.)

A non-spinose, non-tuberculate species which has a bluntly truncate posterior margin and a gently symmetrically bowed venter. The sulci and the sulcal pits are very similar to those of *I. bradyi* (Van Harten 1979). *I. lacustris* possesses a pattern of marginal ripplets which appears to be distinctive. There are five stout ripplets laterally buttressed by contingent supports (figure 18) a pattern not unlike that of *I. gibba* (Van Harten 1979, plate 1, figure 1*a*).

This species was first described from depths of around 30–35 m in Bieler See, Switzerland (Kaufmann 1900). Like *gibba*-forms, it has long antennal bristles enabling it to swim actively. Its first fossil occurrence came from early Middle Pleistocene sediments ('Elster I') at Süssenborn (Diebel & Pietrzeniuk 1969). It has subsequently been found at several sites of different ages.

Ilyocypris quinculminata Sylvester-Bradley

(Figure 3, plate 1)

This species stands clearly apart from the debate concerning 'spined' or 'non-spined' ilyocyprids in that it is totally spinose in all aspects of ornament. Not only does it carry the five principal spines of its name quite prominently, but others which erupt from the intersections of many of the reticulae of the valve surface, seemingly as hollow tubercles (figure 3*c*). Moreover, this spinose character extends back to the earliest instars, making them clearly relatable to the adults. The development of spines in ilyocyprids has occasionally been linked with salinity, but the consistent occurrence of spines in all instars of *I. quinculminata* weakens this argument.

Scanning electron microscope study of specimens from Little Oakley confirms Van Harten's comment that this species lacks marginal ripplets.

I. quinculminata was first described from Hoxnian deposits at Trysull, Staffordshire (Morgan 1973; Sylvester-Bradley 1973). It is known from several other Hoxnian sites including Hatfield, Marks Tey, Copford and Hoxne itself (Robinson 1978*a*). It is also recorded from a few other Middle Pleistocene localities in Britain. On the continent it is known from Holsteinian silts near Koblenz (Sylvester-Bradley 1973).

Description of plate 1

Scanning electron micrographs of selected Ostracoda from Little Oakley. The specimens have been deposited in the Fossil Ostracod Section in the Department of Palaeontology, British Museum (Natural History) and bear registration numbers prefixed 'OS'.

Figure 3. *Ilyocypris quinculminata* Sylvester-Bradley. (*a*) left valve, A–IV instar (×75) LOA 340–360 cm (OS 13025); (*b*) left valve, A–II instar (×65) LOA 340–360 cm (OS 13026); (*c*) left valve, adult (×60), LOA 340–360 cm (OS 13027).

Figure 4. *Paralimnocythere compressa* (Brady & Norman). Right valve, adult male (×70), LOA 360–380 cm (OS 13028).

Figure 5. *Sclerocypris clavata prisca* Diebel & Pietrzeniuk. Left Valve, A–I (×40), LOA 340–360 cm (OS 13029).

Figure 6. *Candona marchica* Hartwig. (*a*) left valve, adult (×48), LOA 360–380 cm (OS 13030); (*b*) right valve interior (×48) LOA 185–200 cm (OS 13031).

Figure 7. *Ilyocypris papillata* sp. nov. (*a*) right valve exterior (×60), LOA 240–260 cm (OS 13032); (*b*) left valve exterior (×60), LOA 240–260 cm (OS 13033).

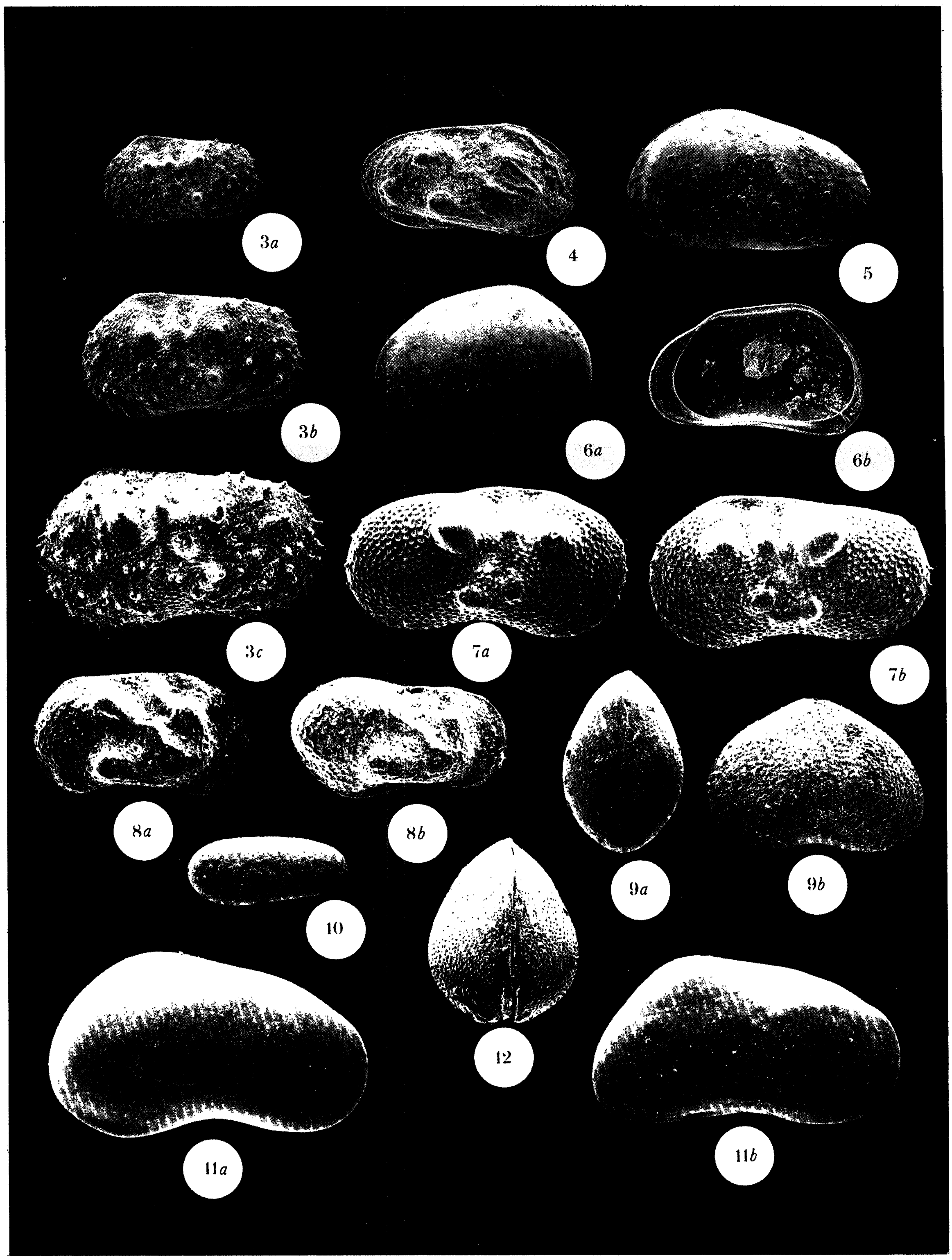
Figure 8. *Limnocythere* cf. *L. usenensis* Karmischina. (*a*) right-valve exterior (×55), LOA 340–360. (OS 13034); (*b*) right valve exterior, male (×55), LOA 340–360 cm 13035).

Figure 9. *Cypridopsis vidua* (Müller). (*a*) dorsal view of carapace (×60), LOA 280–300 cm (OS 13036); (*b*) left valve (×60), LOA 280–300 cm (OS 13037).

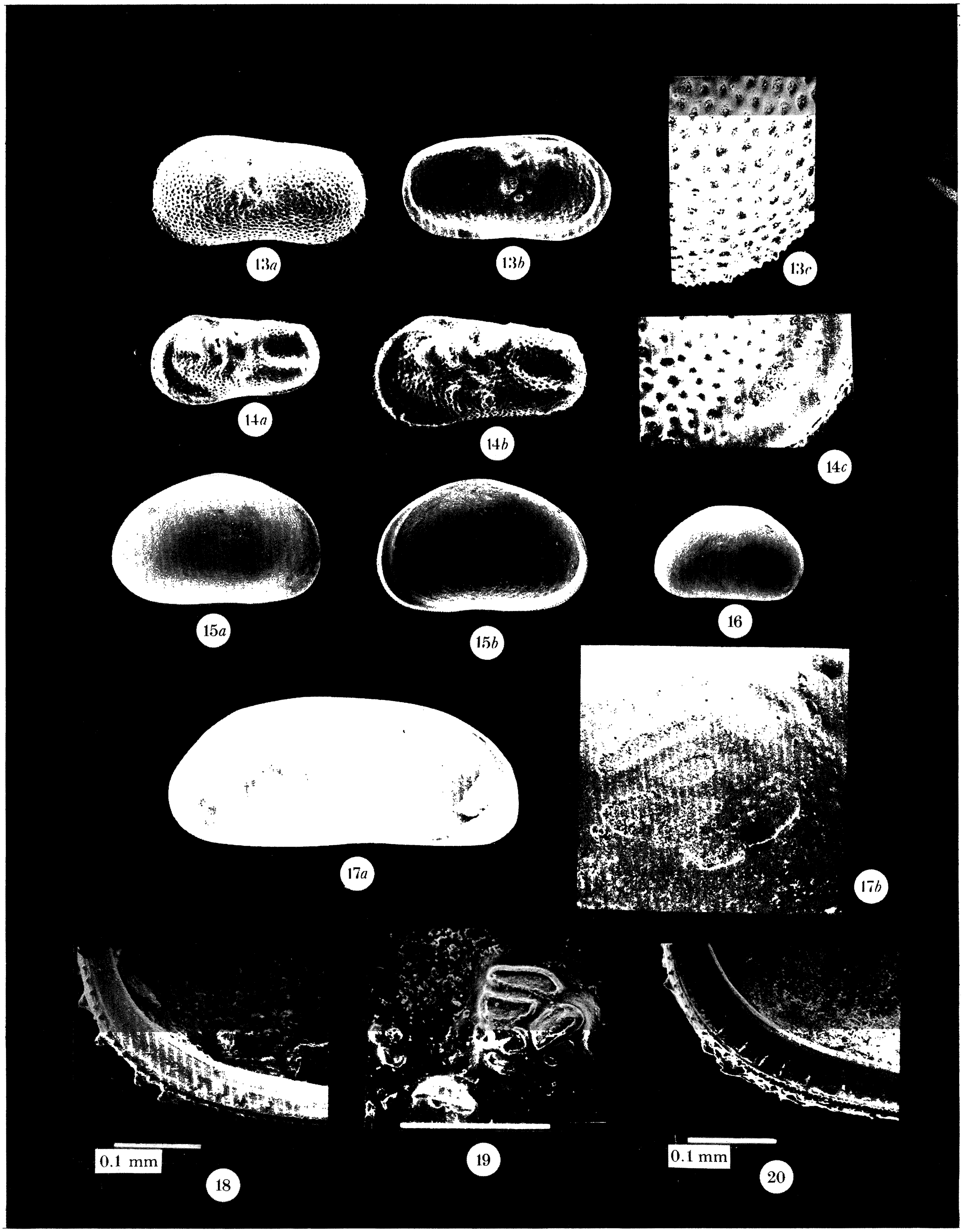
Figure 10. *Darwinula stevensoni* (Brady & Norman). Right valve (×45), LOA 360–380 cm (OS 13038).

Figure 11. *Candona tricicatricosa* Diebel & Pietrzeniuk. (*a*) right valve, male (×50), LOA 340–360 cm (OS 13039); (*b*) right valve, female (×50), LOA 340–360 mm (OS 13040).

Figure 12. *Metacypris cordata* (Brady & Norman). Dorsal view of carapace (×65), LOH 340–360 cm (OS 13041).



FIGURES 3–12. For description see opposite.



FIGURES 13–20. For description see opposite.

Ilyocypris schwarzbachi Kempf

(Figure 14, plate 2)

This species appears to be totally extinct. It differs from related species in its raised marginal convex swelling which follows the outline of the valves, leaving the central area relatively depressed. From the same marginal roll there spring short thorn-like spines, directed towards the posterior margin. These characters are not confined to the adult valves but are a feature of the juveniles as well (figure 14*a*). This species was originally described from Kärlich near Koblenz (Kempf 1967) but has since been found in both temperate and cold stage deposits.

Limnocythere cf. L. usenensis Karmischina

(Figure 8, plate 1)

A strongly ornamented and noded limnocytherid from Little Oakley has the dimorphism characteristic of the genus (cf. *L. sanctipatrici* or *L. inopinata*), but a strength of ornament which is unusual. In this feature it most closely resembles the species figured from the Lower Pleistocene of the Volga Valley and the equivalent terrace deposits of the Dneister as *L. usenensis* Karmischina. The photographs given in the description of the Tiraspol fauna (Negadaev-Nikonov 1970) are an improvement on the originals but still remain too poor for strict comparisons. There remains, however, a striking resemblance sufficient to justify the tentative use of the name here.

Paralimnocythere compressa (Brady & Norman)

(Figure 4, plate 2)

This small, elongate limnocytherid has an ornament pattern not unlike that of *L.* cf. *L. usenensis* but possesses the delicate flattened margins to the valves characteristic of the genus *Paralimnocythere*. The Little Oakley specimens match closely the forms illustrated from the late Beestonian at West Runton by De Dekker (1979) including the elongate and slightly spatulate male dimorph. Other British Middle Pleistocene records include the Cromerian Deposits at Sugworth (Robinson 1980), Anglian silts at Westmill (Robinson 1978*b*) and Hoxnian sediments at Tottenhill, Nar Valley (Robinson 1985), Barling, Essex (J. E. Robinson,

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DESCRIPTION OF PLATE 2

FIGURE 13. *Ilyocypris lacustris* Kaufmann. (*a*) external view of left valve (×50), LOA 210–230 cm (OS 13054); (*b*) interior view of left valve (×50), LOA 210–230 cm (OS 13053); (*c*) surface ornament, anterior-ventral area (×150), LOA 210–230 cm (OS 13055).

FIGURE 14. *Ilyocypris schwarzbachi* Kempf. (*a*) left valve exterior, A–II instar (×52), LOA 200–210 cm (OS 13049); (*b*) left-valve exterior, adult (×58), LOA 210–230 cm (OS 13050); (*c*) surface ornament, right valve, anteroventral margin (×150), LOA 210–230 cm (OS 13051).

FIGURE 15. *Heterocypris salina* (Brady). (*a*) right valve exterior (×42), LOA 260–280 cm (OS 13058); (*b*) right valve interior (×42), LOA 260–280 cm (OS 13057).

FIGURE 16. *Scottia browniana* (Jones). Left valve exterior (×44), LOH 90–100 cm (OS 13048).

FIGURE 17. *Herpetocypris reptans* (Baird). (*a*) left valve interior (×23), bulk sample (OS 13059); (*b*) muscle scar of OS 13059.

FIGURE 18. *Ilyocypris lacustris* Kaufmann. Marginal ripplets, left valve duplicature surface of an adult (×200), (OS 13062).

FIGURE 19. *Ilyocypris papillata* sp. nov. Muscle scar in right valve (×350).

FIGURE 20. *Ilyocypris papillata* sp. nov. Marginal ripplets, left valve duplicature surface of an adult (×200) (OS 13061).

TABLE 1. OSTRACOD DATA FROM BOREHOLE LOA

(A, adult; A–I, last moult stage; A–II, penultimate moult stage, etc.; v, valve; c, carapace; f, fragments.)

depth/cm…	380–400				360–380					340–360					320–340				300–320					
dry mass/g…	700				300					500					500				425					
	A	A–I	A–III	A–IV	A	A–I	A–II	A–III	A–IV	A	A–I	A–II	A–III	A–IV	A	A–I	A–II	A–III	A	A–I	A–II	A–III	A–IV	f
Darwinula stevensoni (Brady & Robertson)	—	—	—	—	7v	7v	—	—	—	14v	1v	—	—	—	2v	—	—	—	5v	—	—	—	—	—
Candona marchica Hartwig	—	—	—	—	1v	—	—	—	—	—	—	—	—	—	—	—	—	—	1c	—	—	—	—	—
Candona tricicatricosa Diebel & Pietrzeniuk	—	—	—	—	4v♀ 3v♂	2v	2v	—	—	7v♀ 2v♂	—	4v	2v	—	3v♀ 1v♂	—	2v	3v	3v	—	—	2v	—	—
Candona sp.	—	—	3v	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Cypridopsis vidua (O. F. Müller)	—	—	—	—	2v	—	—	—	—	2v	—	—	—	—	—	—	—	—	5v 1c	—	—	—	—	—
Herpetocypris reptans (Baird)	—	—	—	—	—	1v	2v	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Heterocypris salina (Brady)	—	—	—	—	1v	—	—	—	—	1v	1v	—	—	—	—	—	—	—	—	—	—	—	—	—
Ilyocypris lacustris Kaufmann	6v	—	—	—	10v	9v	2v	3v	—	10v	16v	8v	—	—	5v	22v	6v	1v	3v	8v	13v	10v	8v	—
Ilyocypris papillata sp. nov.	4v	—	—	—	4v	4v	5v	6v	4v	8v	6v	4v	6v	4v	5v	6v	5v	2v	7v	1v	8v	2v	—	—
Ilyocypris quinculminata Sylvester-Bradley	1v	1v	1v	1v	10v	4v	12v	3v	—	6v	8v	9v	—	—	3v	1v	—	—	—	—	—	—	—	—
Ilyocypris schwarzbachi Kempf	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1v	—	—	—	—	—	—	—	—	—
Ilyocypris sp.	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Limnocythere cf. *L. usenensis* Karmischina	—	—	—	—	6v♀ 6v♂	8v	4v	—	—	3v 1v♀	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Paralimnocythere compressa (Brady & Norman)	—	—	—	—	19v	—	—	—	—	5v	—	—	—	—	1v	—	—	—	2v	—	—	—	—	—
Potamocypris sp.	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Sclerocypris clavata prisca Diebel & Pietrzeniuk	—	—	—	—	—	—	—	—	—	—	2v	—	—	—	—	—	—	—	—	—	—	—	—	—

depth/cm…		280–300					260–280			240–260					220–240		200–220			185–200					170–185	
dry mass/g…		350					375			375					500		450			400					450	
	A	A–I	A–II	A–III	A–IV	A	A–I	A–II	A	A–I	A–II	A–III	A–IV	A	A–I	A	A–I	A–II	A	A–I	A–II	A–III	f	A	A–I	A–II
Darwinula stevensoni (Brady & Robertson)	7v 1c	—	—	—	—	—	—	—	4v	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Candona marchica Hartwig	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1v	—	1v	—	—	1v	—	—
Candona tricicatricosa Diebel & Pietrzeniuk	3v	—	—	4v	—	—	2v	—	1v♀ 2v♂	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Candona sp.	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1v	—	—	—	—	—	—	—	—	—
Cypridopsis vidua (O. F. Müller)	16v	3v	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Herpetocypris reptans (Baird)	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Heterocypris salina (Brady)	1v	—	1v	—	—	1v	—	—	—	—	—	—	—	—	—	—	—	—	2v	—	—	—	—	—	—	—
Ilyocypris lacustris Kaufmann	29v	5v	—	2v	—	6v	5v	2v	12v	13v	8v	—	—	7v	—	5v	8v	—	4v	7v	—	—	—	—	2v	—
Ilyocypris papillata sp. nov.	7v	9v	5v	10v	4v	4v	5v	1v	12v	10v	6v	4v	2v	4v	—	2v	4v	2v	—	10v	3v	1v	4v	2v	—	2v
Ilyocypris quinculminata Sylvester-Bradley	—	—	—	—	—	—	—	—	2v	—	—	—	—	—	1v	1v	—	—	2v	—	—	—	—	—	—	—
Ilyocypris schwarzbachi Kempf	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Ilyocypris sp.	—	—	—	—	—	—	—	—	—	—	—	—	—	1v	—	—	—	—	—	—	—	—	—	—	—	—
Limnocythere cf. *L. usenensis* Karmischina	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Paralimnocythere compressa (Brady & Norman)	2v	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Potamocypris sp.	2v	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Sclerocypris clavata prisca Diebel & Pietrzeniuk	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—

Table 2. Ostracod data from borehole LOH

(Abbreviations as in table 1.)

depth/cm...	340–360				200–215		185–190	130–140	110–120			90–100				70–80		
dry mass/g...	250				250		250	250	250			250				250		
	A	A–I	A–II	A–III	A	A–IV	A	A	A	A–I	A–II	A	A–I	A–II	A–III	A	A–I	A–II
Darwinula stevensoni (Brady & Robertson)	1v 2c	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Candona sp.	—	—	—	2v	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Ilyocypris lacustris Kaufmann	10v 1c	4v	—	—	4v	2v	1v	—	7v	—	—	4v	—	—	—	2v	—	—
Ilyocypris papillata sp. nov.	5v	2v	3v	—	1v	—	—	2v	2v	12v	5v	3v	12v	6v	4v	4v	2v	3v
Metacypris cordata Brady & Robertson	1v	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Scottia browniana (Jones)	—	—	—	—	—	—	—	—	—	—	—	1v	—	—	—	—	—	—

unpublished data), and Hoxne itself (J. E. Robinson, unpublished data). Equivalent records abroad include Süssenborn, G.D.R. (Diebel & Pietrzeniuk 1969), Přezletice, Czechoslovakia (Absolon 1974) and Tiraspol, U.S.S.R. (Negadeav-Nikonov 1970).

Sclerocypris clavata prisca Diebel & Pietrzeniuk

(Figure 5, plate 1)

This species has a strong superficial resemblance to members of the genus *Prionocypris*, frequent elements in the ostracod faunas of flowing waters. However, it has a broader and deeper anterior duplicature which produces a visible change of valve surface even in external view. The species *clavata* was described by Baird (1850) from a ditch in London. From this and subsequent occurrences it appears to be characteristic of temporary water bodies. The subspecies *prisca* was introduced by Diebel & Pietrzeniuk (1969, p. 478) for a Middle Pleistocene antecedent. This form appears to be present at Little Oakley. It is also known from West Runton (Robinson 1978*a*, plate 1, figure 6*a*, *b*; De Deckker 1979, p. 311).

Candona tricicatricosa Diebel & Pietrzeniuk

(Figure 11, plate 1)

This species has the general proportions and outline of *Candona neglecta* Sars including the distinctive sexual dimorphism in which the male is considerably more inflated and boldly rounded in its posterior third. Differences lie, however, in the valve contact seen from above, and in the three-elemental frontal muscle scars instead of the two-element form of *C. neglecta*. *C. tricicatricosa* was originally described from early Middle Pleistocene deposits ('Elster I') of Süssenborn, G.D.R. (Diebel & Pietrzeniuk 1969). In Britain it has since been recognized from the Cromerian of West Runton, Norfolk (Robinson 1978*a*) and Sugworth, Berkshire (Robinson 1980), from Anglian silts at Westmill, Hertfordshire (Robinson 1978*b*) and from other Middle Pleistocene sites at Barling, Essex, and Waverley Wood, Warwickshire (J. E. Robinson, unpublished data).

TABLE 3. OSTRACOD DATA FROM BOREHOLE LOO

(Abbreviations as in table 1.)

depth/cm…	360–368			350–360			340–350						330–340					320–330					310–320						
dry mass/g…	425			475			410						500					500					500						
	A	A–I	f	A	A–I	A–III	A	A–I	A–II	A–III	A–IV	f	A	A–I	A–II	A–III	A–IV	A	A–I	A–II	A–III	f	A	A–I	A–II	A–III	A–IV	A–V	A–VI
Darwinula stevensoni (Brady & Robertson)	—	—	—	2v	—	—	1v	—	—	—	—	—	—	—	—	—	—	1v	—	—	—	—	—	—	—	—	—	—	—
Candona tricicatricosa Diebel & Pietrzeniuk	5v	—	—	2v♀	—	3v	3v♀ 5v♂	—	2v	5v	1v	—	3v♀ 2v♂	1v	—	4v	—	—	—	—	—	—	3v	—	—	10v	—	—	—
Cyclocypris laevis (O. F. Müller)	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Cypridopsis vidua (Müller)	—	—	—	6v	2v	—	4v	2v	—	—	—	—	—	—	—	—	—	—	—	—	—	—	4v	1v	—	—	—	—	—
Herpetocypris reptans (Baird)	—	—	+	—	—	—	—	—	—	—	—	+	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Ilyocypris lacustris Kaufmann	13v	—	—	15v	8v	—	3v	22v	—	—	—	—	12v	5v	2v	5v	—	9v	4v	5v	—	—	14v	9v	6v	3v	2v	5v	1v
Ilyocypris papillata sp. nov.	1v	—	—	1v	1v	—	—	1v	4v	—	—	—	—	1v	2v	3v	4v	2v	1v	1v	2v	—	—	—	—	—	—	—	—
Ilyocypris quinculminata Sylvester-Bradley	—	3v	—	9v	2v	—	—	—	—	3v	—	—	2v	—	3v	2v	—	4v	—	—	—	—	2v	—	—	1v	—	—	—
Limnocythere cf. *usenensis* Karmischina	—	—	—	2v	2v	—	—	—	—	—	—	—	2v	—	—	—	—	—	—	—	—	2	2v♀	2v	—	—	—	—	—
Paralimnocythere compressa Brady & Norman	—	—	—	4v	—	—	—	—	—	—	—	—	—	—	—	—	—	4v	—	—	—	—	3v	—	—	—	—	—	—
Potamocypris fulva (Brady)	—	—	—	—	—	—	—	—	—	—	—	—	1v	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—

depth cm…	300–310					290–300				280–290				270–280				260–270					250–260				240–250				230–240		210–230			
dry mass g…	500					500				460				500				500					500				500				500		460			
	A	A–I	A–II	A–III	A–IV	A	A–II	A–III	A–IV	A	A–I	A–II	A–III	A	A–I	A–II	A–III	A	A–I	A–II	A–III	A–IV	A	A–I	A–II	A–III	A	A–I	A–II	A–III	A–I	A–II	A	A–I	A–III	A–IV
Darwinula stevensoni (Brady & Robertson)	—	—	—	—	—	—	—	—	—	2v	—	—	—	2v	—	—	—	—	—	—	—	—	—	—	—	—	1v	—	—	—	—	—	—	—	—	—
Candona tricicatricosa Diebel & Pietrzeniuk	3v♀ 1v♂	1v	3v	—	—	—	—	10v	—	2v	—	2v	5v	—	—	—	4v	—	—	—	10v	—	—	—	10v	—	—	—	10v	—	—	—	—	—	1v	—
Cyclocypris laevis (O. F. Müller)	—	—	—	—	—	—	—	—	—	2v	—	—	—	—	—	—	—	2v	—	—	—	—	—	—	—	—	1v	—	—	—	—	—	—	—	—	—
Cypridopsis vidua (Muller)	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Herpetocypris reptans (Baird)	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Ilyocypris lacustris Kaufmann	1v	4v	4v	2v	5v	4v	6v	5v	4v	8v	5v	4v	—	4v	6v	3v	—	23v	6v	6v	2v	2v	1v	10v	4v	4v	6v	18v	9v	11v	2v	2v	1v	1v	—	1v
Ilyocypris papillata sp. nov.	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	8v	4v	2v	—	—	—	—	—	—	7v	—	—	—	1v	—	—	—	—	—
Ilyocypris quinculminata Sylvester-Bradley	—	1v	—	1v	—	3v	—	—	—	2v	—	—	—	2v	1v	1v	—	2v	2v	2v	—	—	—	—	—	—	2v	—	—	—	—	—	—	—	—	—
Limnocythere cf. *usenensis* Karmischina	—	—	—	—	—	1v	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1v♂	—	—	—	4v♀ 4v♂	—	—	—	—	—	—	1v	—	—
Paralimnocythere compressa Brady & Norman	—	—	—	—	—	—	—	—	—	1v	—	—	—	1v	—	—	—	—	4v	—	—	—	2v	—	—	—	11v	—	—	—	—	—	—	—	—	—
Potamocypris fulva (Brady)	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—

Heterocypris salina (Brady)

(Figure 15, plate 2)

This symmetrically outlined ostracod resembles members of the genus *Cypris*, particularly in its early moult stages. Its smooth valve surface and the flat curve to the valve cross section are useful distinguishing criteria. This is quite a common species in suitable habitats and has been found in many deposits throughout the Pleistocene.

3. ANALYSIS OF THE PROFILES

(*a*) *Borehole* LOA (TM 22332948)

This was located close to the right-hand bend in Harwich Road near Foulton Hall (Bridgland *et al.* 1990, figure 1). The entire sequence consisted of a coarse-medium silty sand. The ostracod fauna (table 1) is dominated throughout by *Ilyocypris lacustris* and *I. papillata*. Significant biostratigraphical changes are apparent and the sequence can be divided into two zones, the lower of which can be further subdivided into two subzones (figure 1). These are as follows.

LOA 1. 280–400 cm

The unifying feature of this zone is its greater richness in both number of species and individuals. The basal subzone 1 a is characterized by high frequencies of *Ilyocypris quinculminata*, *Paralimnocythere compressa* and *Limnocythere* cf. *L. usenensis*, the last being confined to this subzone. In subzone 1 b, the overall fauna remains broadly similar to that of the underlying subzone but the frequencies of the three critical taxa are much lower. In addition *Cypridopsis vidua* peaks in this subzone.

LOA 2. 155–280 cm

This zone is dominated by *Ilyocypris lacustris* and *I. papillata*. Other taxa occur at low frequency and many others, common in zone 1, are either rare or totally absent.

(*b*) *Borehole* LOH (TM 21972928)

This borehole was located on waste ground halfway along Harwich Road. The ostracod record from here (table 2) was very much poorer overall. Only 5 out of 16 samples yielded ostracods and 4 of these entirely comprised *Ilyocypris*. Single examples of two species, *Metacypris cordata* (figure 12, plate 1) and *Scottia browniana* (figure 16, plate 2), both unrecorded from other boreholes, were present here. The lowest horizon (340–360 cm) also yielded a few specimens of *Darwinula stevensoni*.

The lack of the ostracod fauna is matched by an equally poor and erratic molluscan record (Preece 1990). The coarseness and generally unfossiliferous nature of the sand suggests accumulation in a high-energy environment. The low count precludes detailed comparisons but the limited fauna recovered is essentially similar to that of borehole LOA.

(*c*) *Borehole* LOO (TM 22202925)

This borehole was located on waste ground halfway along Seaview Avenue (Bridgland *et al.* 1990, figure 1). The ostracod fauna from here (table 3) is dominated by *I. lacustris* with

I. quinculminata, *I. papillata* and *Candona tricicatricosa* making up the bulk of the remaining fauna. There are no major biostratigraphical changes and the whole sequence can be considered as one unit (figure 2). It is significant that whereas in borehole LOA, *I. quinculminata*, *Paralimnocythere compressa* and *Limnocythere* cf. *L. usenensis* were principally confined to the lower levels (zone 1a), in this borehole they occur consistently throughout. The palynological evidence (Gibbard & Peglar 1990) indicates that here the entire sequence belongs to the pre-temperate substage, whereas only the very base of LOA falls within this period. The pattern of ostracod occurrence is therefore in complete accord with the pollen sequence.

(*d*) *Borehole* LOM (TM 21822884)

This borehole was located near Newhouse Farm, some 500 m southwest of the others studied. Although *Ilyocypris* still dominates (table 4). *Candona tricicatricosa* occurs at much higher frequencies as does *Heterocypris salina*. *Ilyocypris schwarzbachi* which occurred as odd specimens in LOA, is here present in both samples in much higher numbers.

Table 4. Ostracod data from borehole LOM

(Abbreviations as in table 1.)

depth/cm...	210–230							200–210					
dry mass/g...	500							500					
	A	A–I	A–II	A–III	A–IV	A–V	f	A	A–I	A–II	A–III	A–IV	f
Candona tricicatricosa Diebel & Pietrzeniuk	1v♀	1v	2v	26v 1c	2v	2v	—	—	—	3v	12v 1c	12v	—
Herpetocypris reptans (Baird)	—	—	—	—	—	—	+	—	—	1v	—	—	+
Heterocypris salina (Brady)	—	1v	1v	1v	—	—	—	—	1v	—	—	—	—
Ilyocypris lacustris Kaufmann	11v	6v	—	—	—	—	—	8v	5v	3v	4v	—	—
Ilyocypris papillata sp. nov.	9v	6v	11v	8v	—	—	—	—	14v	4v	4v	—	1
Ilyocypris schwarzbachi Kempf	—	3v	—	—	—	—	—	—	1v	—	2v	—	1
Limnocythere cf. *L. usenensis* (Karmischina)	5v	—	1v	1v	—	—	—	1v	—	—	—	—	—

4. PALAEOECOLOGY

The ostracod assemblages from Little Oakley are dominated by species of the genus *Ilyocypris*, which can account for over 60% of the fauna in many samples. Similar dominance has been reported from Middle and Late Pleistocene sites both in Britain (Siddiqui 1971) and in eastern Europe, for example at Burgtonna, Thüringia (Diebel & Pietrzeniuk 1978) and Přezletice, Czechoslovakia (Absolon 1974). Such assemblages are often said to characterise loamy or muddy substrates which are subject to periodic flooding (Absolon 1974). The sediment at Little Oakley is predominantly a silty sand and it is clear from the associated fossils and other evidence that this was deposited by a large river. The flow must have been slow enough to allow the deposition of silt and the incorporation of a full growth series of ostracods instars indicating an indigenous, rather than transported, assemblage. Taxa that are characteristic of plant-rich (organic) sediments are either rare or absent.

Also absent are taxa indicative of brackish conditions. In particular, no trace of *Cyprideis torosa* could be detected despite careful search. However, *Heterocypris salina* was present at low frequency but this is often found in inland waters and is not characteristic of tidally brackish environments. This suggests that the river here was upstream of any tidal influence.

The ostracod fauna is essentially temperate in character. The occurrence of *Paralimnocythere compressa* and *Ilyocypris quinculminata*, however, may imply less temperate conditions. At Little Oakley these taxa attain their maxima in basal sediments that are assigned to the pre-temperate zone of the interglacial, or in one instance possibly from the preceding late-glacial period (Borehole LOM). Their fossil occurrence elsewhere suggests that they are characteristic of late-glacial–early interglacial transitions in the Middle Pleistocene.

5. Age of the fauna

Correlation of the Little Oakley sediments with other sites is hampered by two factors. First, the lack of any published work describing ostracod faunas from strictly comparable facies in the British Middle Pleistocene. Second, the fact that most ostracods have extremely long fossil records extending the whole length of the Pleistocene to the present day.

The ostracod fauna at Little Oakley differs significantly from both that at West Runton (De Deckker 1979) and Sugworth (Robinson 1980) in being completely dominated by *Ilyocypris*. *Scottia browniana*, the dominant form at both the other sites, is only known from the odd specimen at Little Oakley. This is almost certainly because of contrasting depositional environments which were quieter and more plant-rich at the former sites (De Deckker 1979, p. 313).

Several species, notably *Candona tricicatricosa*, *Ilyocypris quinculminata*, *Sclerocypris clavata prisca*, *Paralimnocythere compressa* and possibly *Ilyocypris papillata* and *Limnocythere* cf. L. *usenensis*, do impart a broadly Middle Pleistocene aspect to the fauna. However, none of these species is confined to any particular stage and several survive to the present day. *C. tricicatricosa* and *S. clavata prisca* were originally described from Middle Pleistocene ('Elster I') sediments at Süssenborn, G.D.R., associated with an assemblage also dominated by '*Ilyocypris gibba*' and *Limnocythere* (Diebel & Pietrzeniuk 1969). There are some similarities to the fauna described from Tiraspol, Moldavia (Negadaev-Nikonov 1970) and the peculiar limnocytherid from Little Oakley appears to be conspecific with a species reported from there. Ostracods are known from the 'Cromerian Complex' of The Netherlands but unfortunately have not yet been described. Further discussion regarding correlation, on the basis of ostracods, must await the publication of such work.

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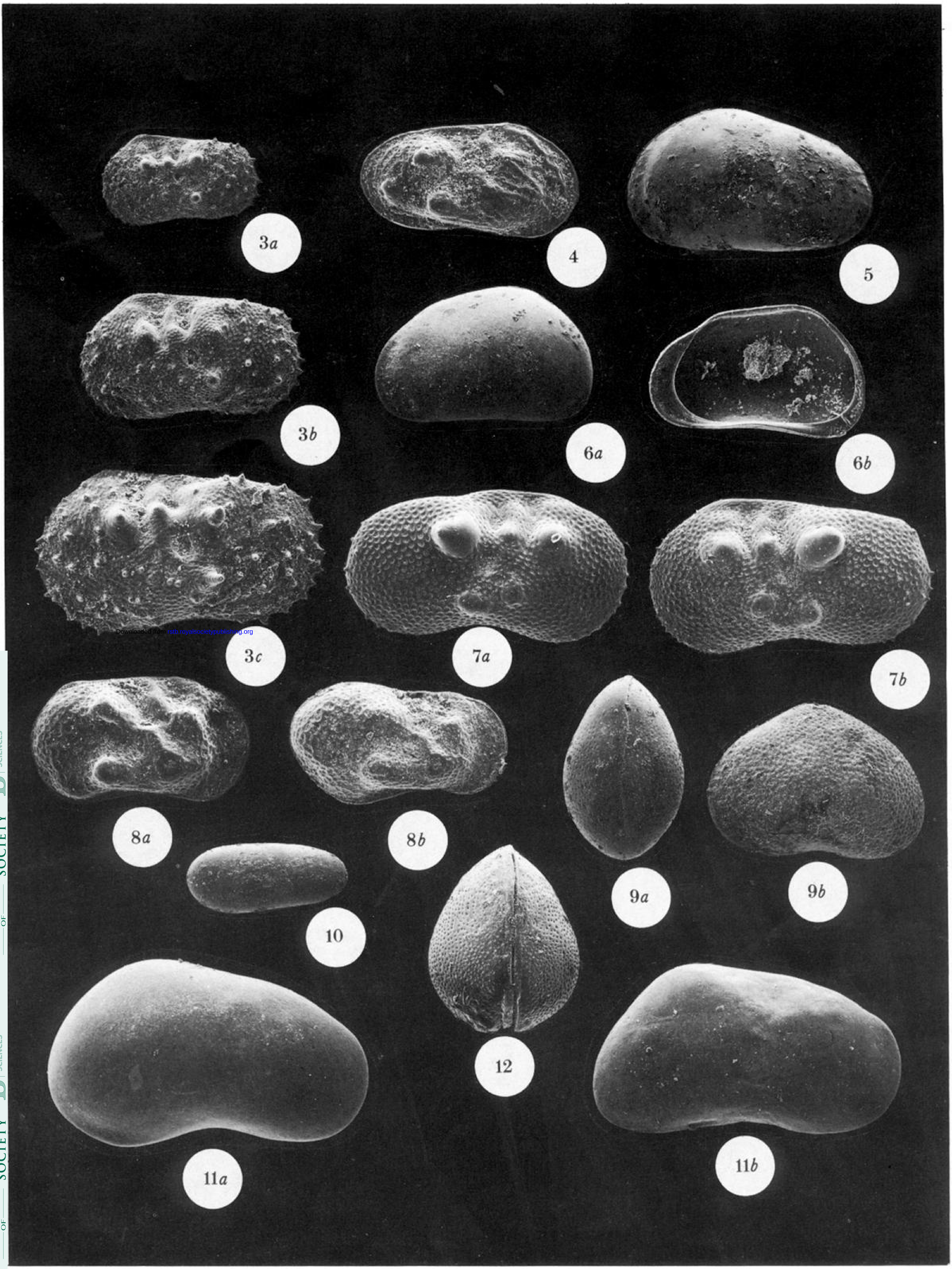
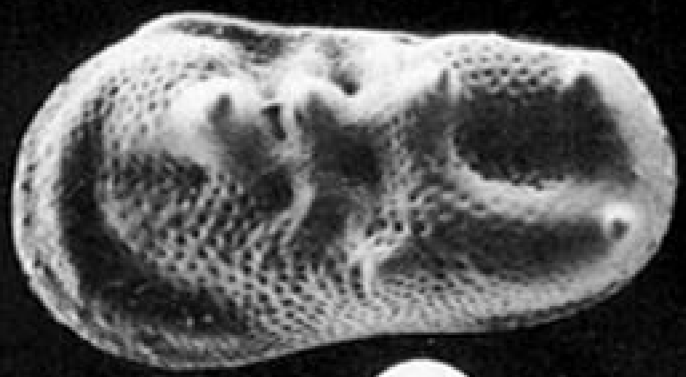


FIGURES 3–12. For description see opposite.


13a


13b


13c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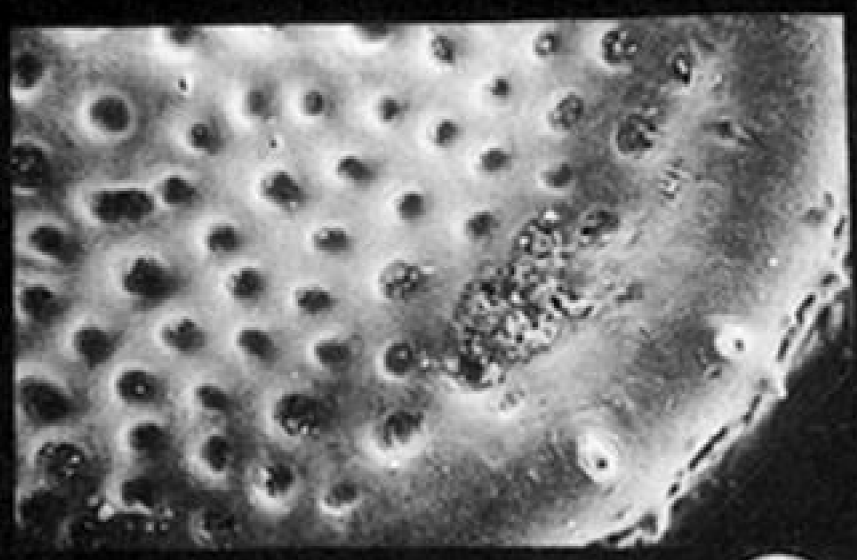
14b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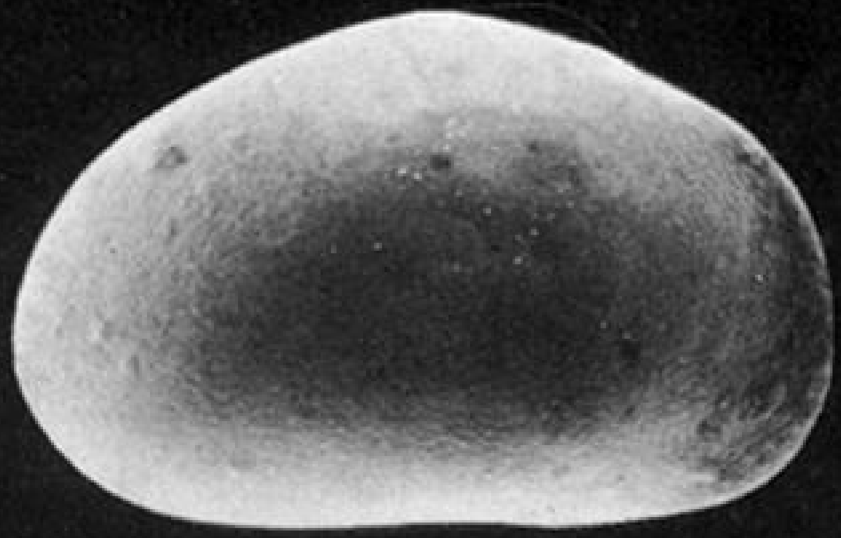
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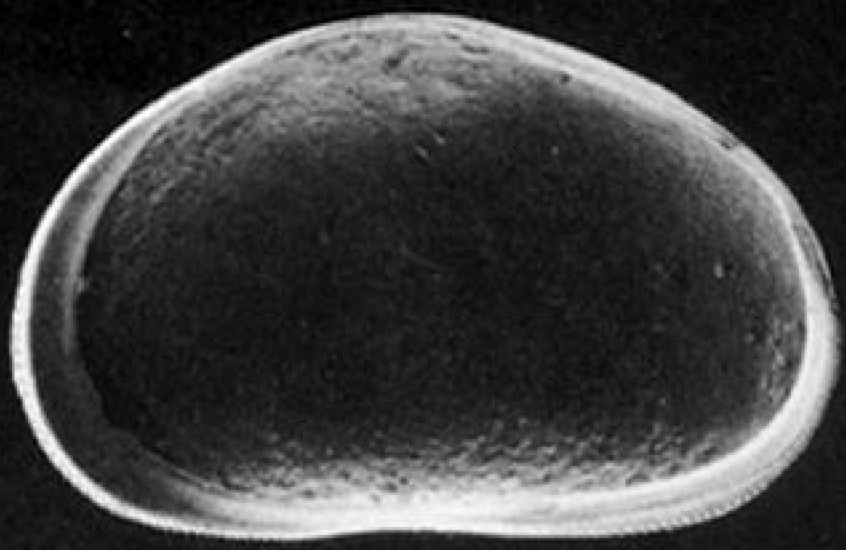
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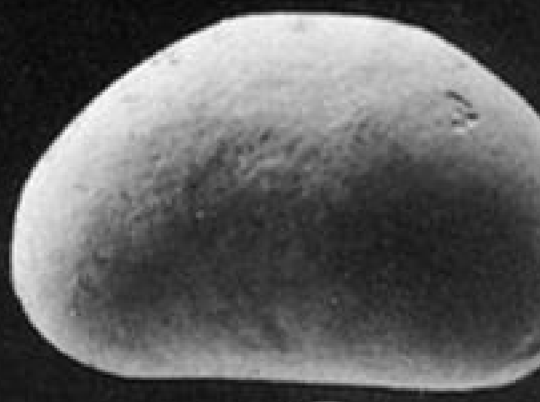
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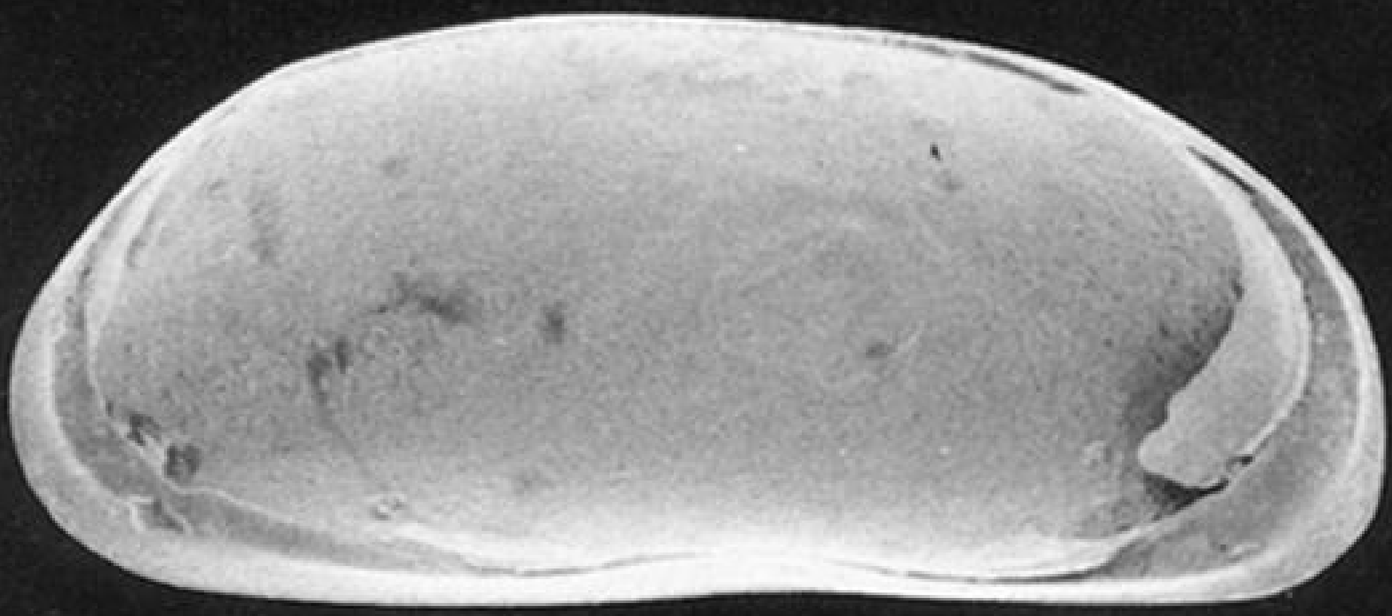
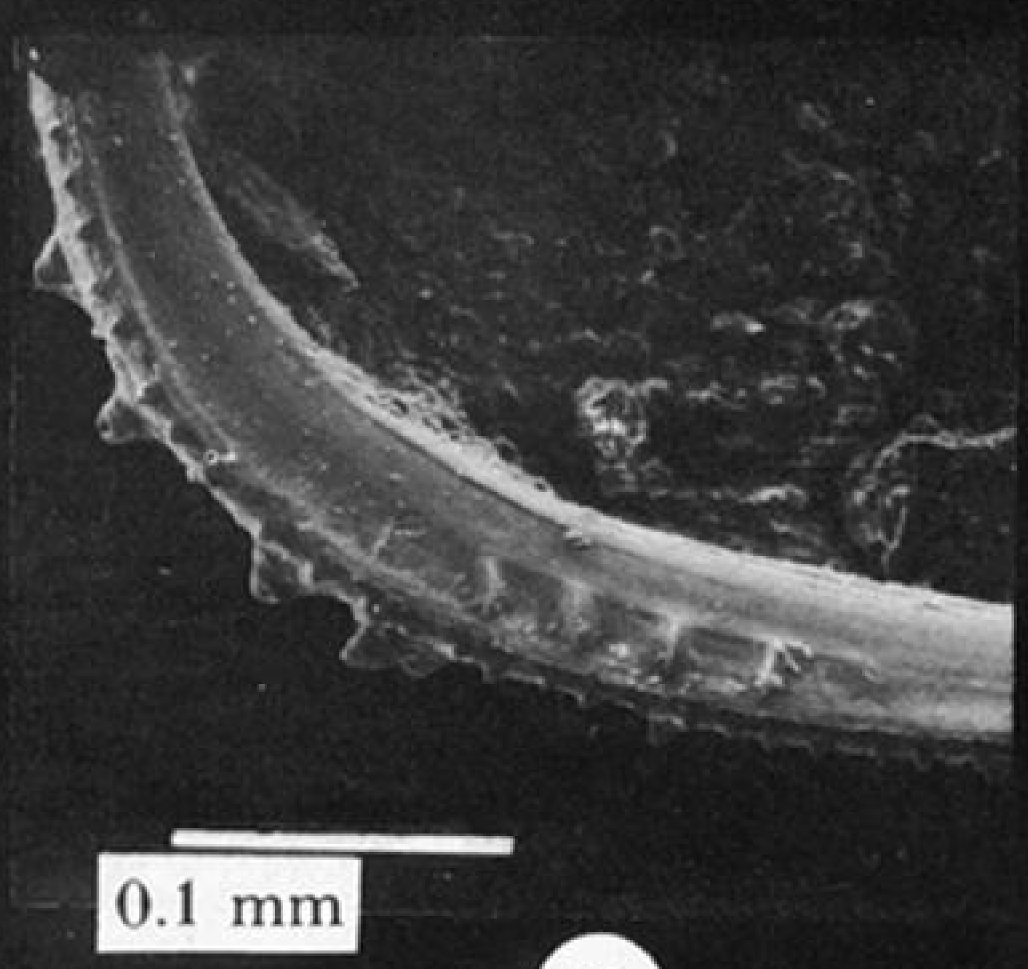

17a


17b



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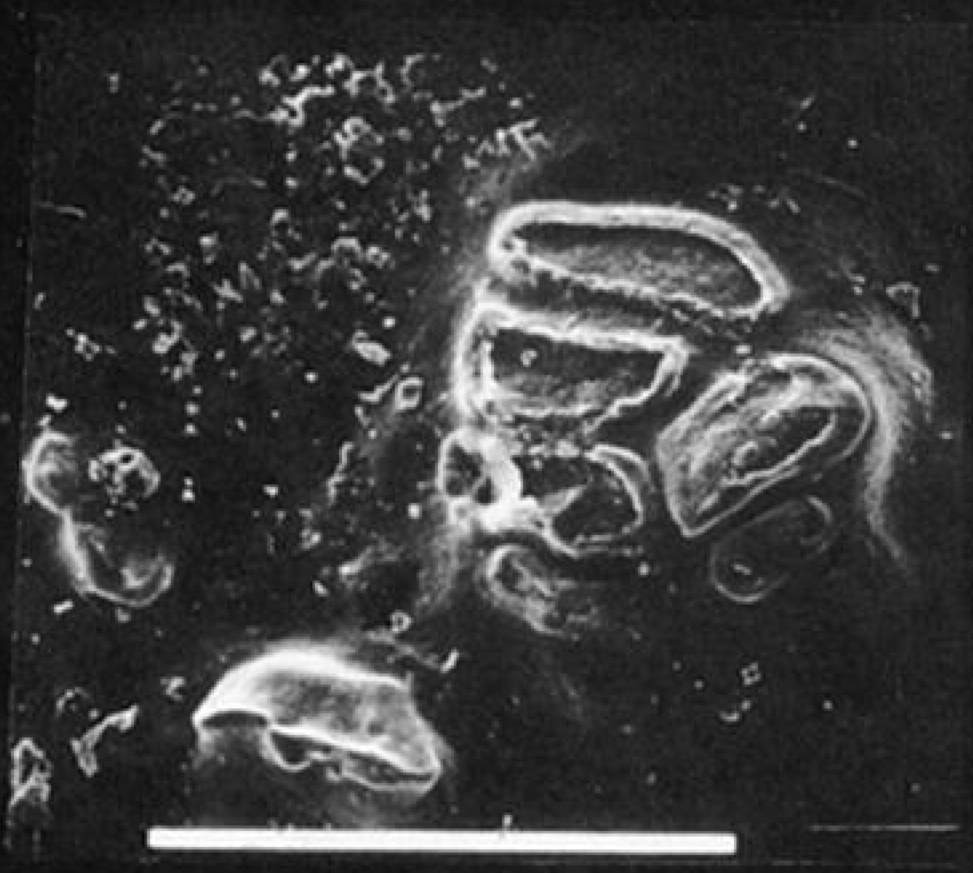
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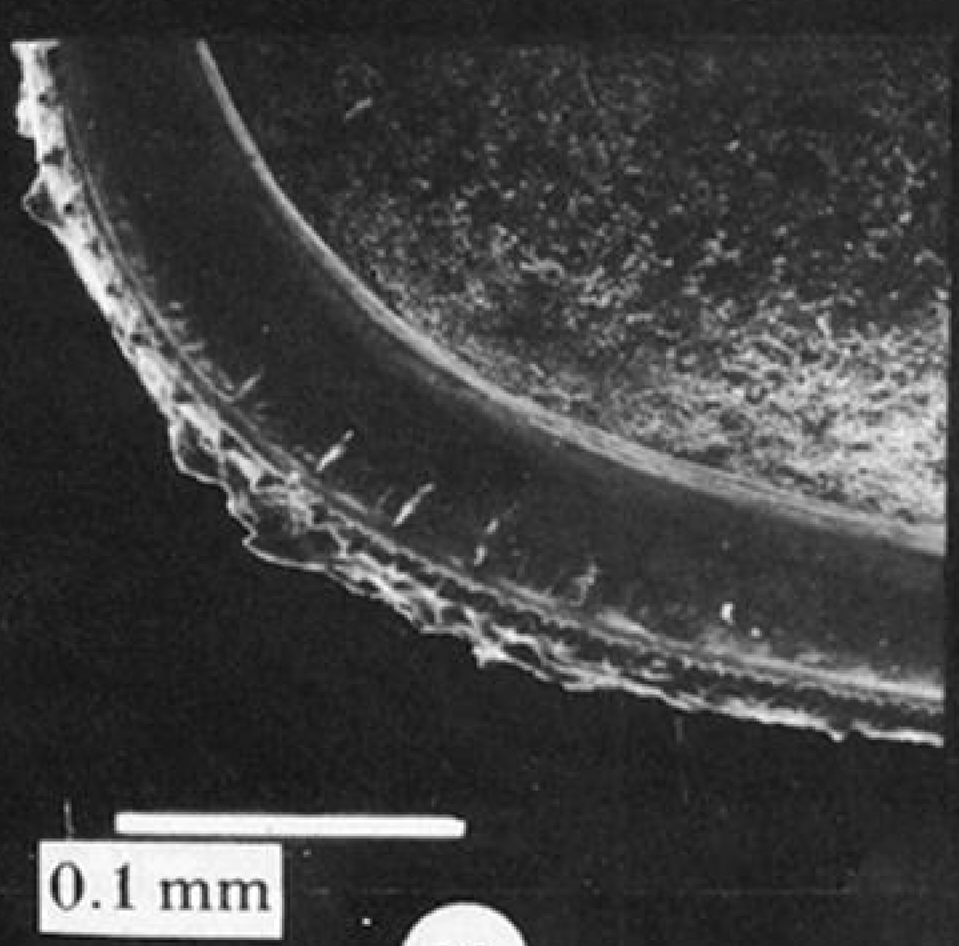

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FIGURES 13–20. For description see opposite.