THE MIDDLE PLEISTOCENE OSTRACOD FAUNA OF THE WEST RUNTON FRESHWATER BED, NORFOLK

by P. DE DECKKER

ABSTRACT. Five freshwater ostracod assemblages, ecologically bound to environmental changes reflected by the sediments, and corresponding to the late Beestonian and early Cromerian pollen assemblage zones, are described. The ecological information recorded from the ostracods conforms to the climatic data offered by the palaeobotanical record.

THE ostracod fauna was analysed from sixty-two samples collected, in a stratigraphical sequence, from a section of Goss's Gap, West Runton, the same locality from which West collected material for his palynological study of the type Cromer Forest-bed Formation (West, in press), and which Stuart (1975) studied for his investigation of the vertebrate fauna of the type Cromerian. For further details on the locality, refer to Stuart's diagram of the schematic section at West Runton (Stuart 1975, p. 65). The position of Stuart's section labelled AJS corresponds to the one studied here.

The sixty-two samples were taken from a 1·625 m section dug along the beach, 15 m north of the gap, in a channel cut in ferruginous gravel and capped with a leached peaty layer, reddish black in colour. All the samples were collected at intervals of 2·5 cm, except for the bottom four samples which were at intervals of 5 cm.

In the laboratory, 40 gr. of each sample were treated in a sodium hexametaphosphate solution for a period of 24–48 hours, and later washed through two sieves of 3000μm and 210μm each. The small fraction (< 210μm) was not studied, as juveniles smaller than 210μm cannot usually be identified at specific level. Every ostracod and ostracod fragment was later picked from the residues under a binocular microscope.

DESCRIPTION OF THE SECTION STUDIED AT WEST RUNTON

A detailed sketch of the profile at Goss's Gap, West Runton, is presented in text-fig. 1. However, the lithology of the section is recorded below:

157·5–162·5 cm: reddish brown to black leached peat with minor sand.

140–157·5 cm: almost entirely plant debris with some dark brown sand.

122·5–140 cm: interlayering of black silt, rich in plant debris, and beige to brown fossiliferous sand (mainly molluscs remain).

100–122·5 cm: brown to beige sandy layers, highly fossiliferous (containing mainly a macroscopic molluscan fauna) with few mud fragments interlayered with some black silty ones with abundant plant debris.

87·5–100 cm: zone of brecciation where beige sand with few black pebbles is mixed in black silt rich in shells and shell fragments, with small lenses of beige to dark grey sandy material.

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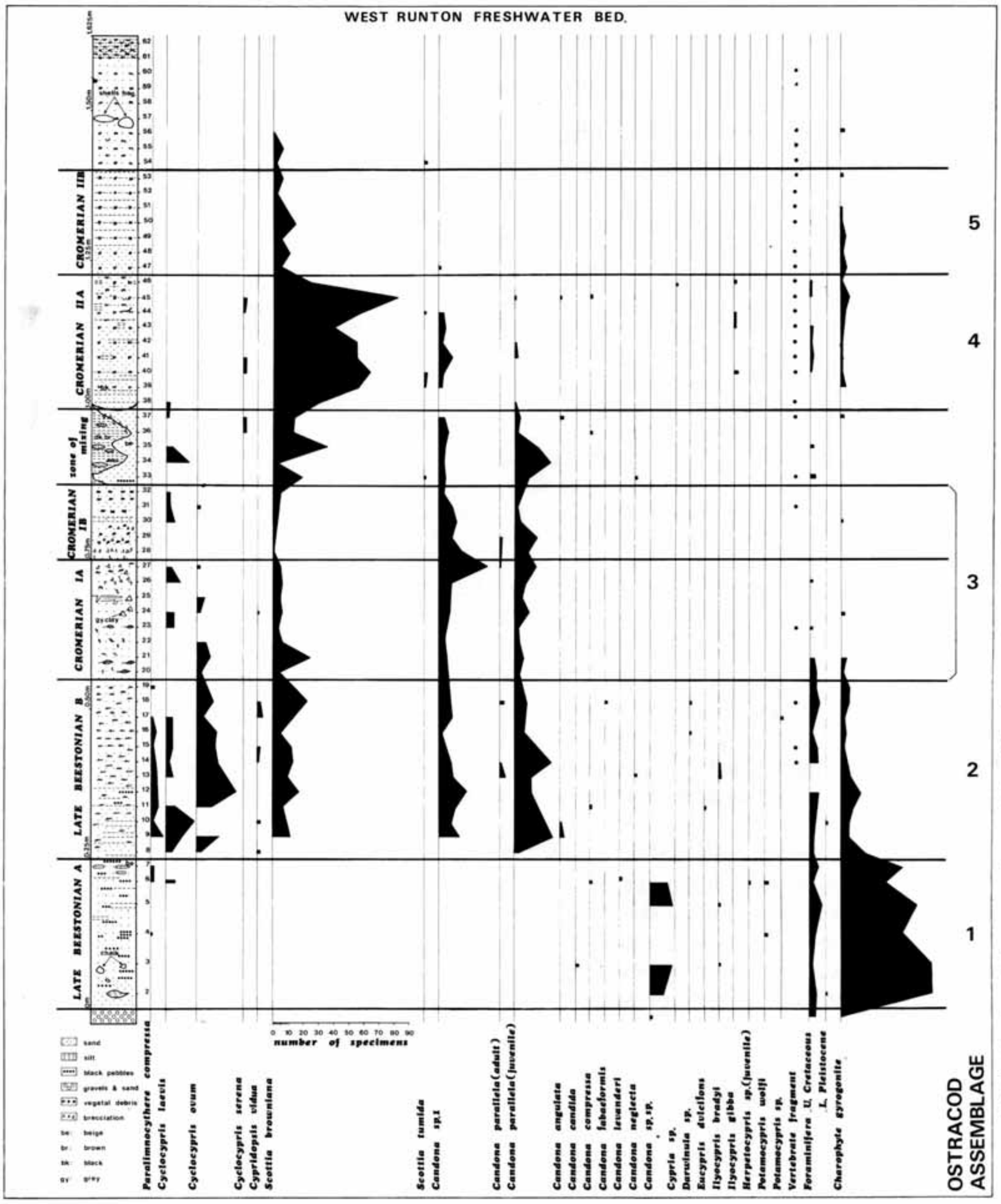


TEXT-FIG. 1. Distribution of the ostracods recorded at West Runton. Note that the ostracod assemblages correspond to the pollen assemblage zones

55–87·5 cm: plant debris. Leaves present in the bottom 10 cm, then small fragments of grey clay common in the next 25 cm. Shells and shell fragments frequent.

25–55 cm: brown to beige silt at the bottom and sand in the top half; few pebbles at the bottom. Plant debris increasing from bottom to top.

0–25 cm: dark grey to black sand becoming silty towards the top with layers of black cherty pebbles (often rounded) and black fragments.

Bottom: ferruginous gravel layer consisting mainly of quartz with fragments of marine shells. This layer is at least 30 cm thick.

West (in press) studied a similar section (labelled WRAQ) at the same locality. Minor differences in thickness of the various lithologies were noticed in comparing this section with the one presented here. The reason for this is that the position of both sections lies within a large channel (see Stuart 1975, fig. 2) accessible at Goss's Gap. Consequently, such small discrepancies were considered as insignificant and correlation between various levels were made, even though small differences between the two sections exist.

TAXONOMY

All the specimens collected at West Runton for this study are deposited in the British Museum (collection OS9230–OS9302). The ostracod species are described in the same taxonomic order as recorded by Hartmann and Puri (1974) in their palaeontological classification of Ostracoda. Much of the data on ecology, stratigraphical range and geographical distribution for most of the species is taken from publications by Diebel and Pietrzeniuk (1969, 1975*a*, 1975*b*, 1977) and Diebel and Wolfschläger (1975).

The following abbreviations are used: L = left valve, R = right valve, C = carapace.

Genus DARWINULA Brady and Norman, 1889
Darwinula sp.

Plate 33, fig. 11

Material. 1 R, 1 L.

Measurements. Length, 0·70 mm, height: 0·25 mm.

Genus PARALIMNOCYTHERE Carbonnel, 1965
Paralimnocythere compressa (Brady and Norman, 1889)

Plate 33, figs. 1–5, 7–10, 13

1889 *Limnocythere inopinata* var. *compressa* Brady and Norman, p. 170.

Material. 21 L, 16 R.

Measurements. Females, length: 0·51–0·60 mm, height: 0·30–0·32 mm; males, length: 0·50–0·56 mm, height: 0·26 mm. Greatest height: females, $\frac{1}{4}$ from anterior; males, $\frac{1}{6}$ from anterior.

Description. Strongly sexually dimorphic; shell very thin and extremely fragile. General outline rectangular, but narrower in males. Externally, various protuberances present on valves (see Pl. 33, figs. 1-3, 7-9, 13); mediodorsally, anterior protuberance slightly smaller in females and posterior one very large in males and pointed towards posterior. Dorsum inclined in adult females and almost horizontal in adult males. Ventrum strongly concave in both sexes, sometimes more incurved in adult males. Shell reticulate all over, following curvature of valves in posterior area. Internally, central muscle scars arranged in vertical row of four. Numerous radial pore canals curved with some branched, as in all *Paralimnocythere* species.

Ecology. At West Runton, *P. compressa* is restricted to cold climates (late Beestonian A and late Beestonian B Zones), accompanied by abundant aquatic plants typical of muddy substrates, and shallow rather still bodies of water. Females are more common. A similar environment was postulated for this species by Diebel and Pietrzeniuk (1969) at Süssenborn.

Geographical distribution. Recent: Great Britain. Fossil: Süssenborn near Weimar, Paludinenbank, near Oranienburg, and Kumro near Neuzelle. Negadaev-Nikonov's (1971) description and illustration of *P.*? cf. *compressa* from fluviatile sediments at Tiraspol (Elster in age) is identical to *P. compressa* found at West Runton. The Tiraspol specimens are larger (length: 0·75 mm, height: 0·4-0·35 mm).

Stratigraphical range. Pleistocene to Recent (Diebel and Pietrzeniuk 1969). The *Paralimnocythere* species need revision before their stratigraphical importance in the Pleistocene can be recognized. The sediments at Süssenborn, in which *P. compressa* is found, are Middle Pleistocene (Elster I) in age.

Genus ILYOCYPRIS Brady and Norman, 1889
Ilyocypris bradyi Sars, 1890

Plate 33, fig. 14

1890 *Ilyocypris bradyi* Sars, p. 59.

Material. 4 L, 2 R, 1 C.

Measurements. Length: 0·812 mm, height: 0·45 mm.

Ecology. Found in cold waters, sometimes slightly saline, in temporary ponds or springs; can withstand only slight changes in water temperature.

Geographical distribution. Recent: holarctic regions.

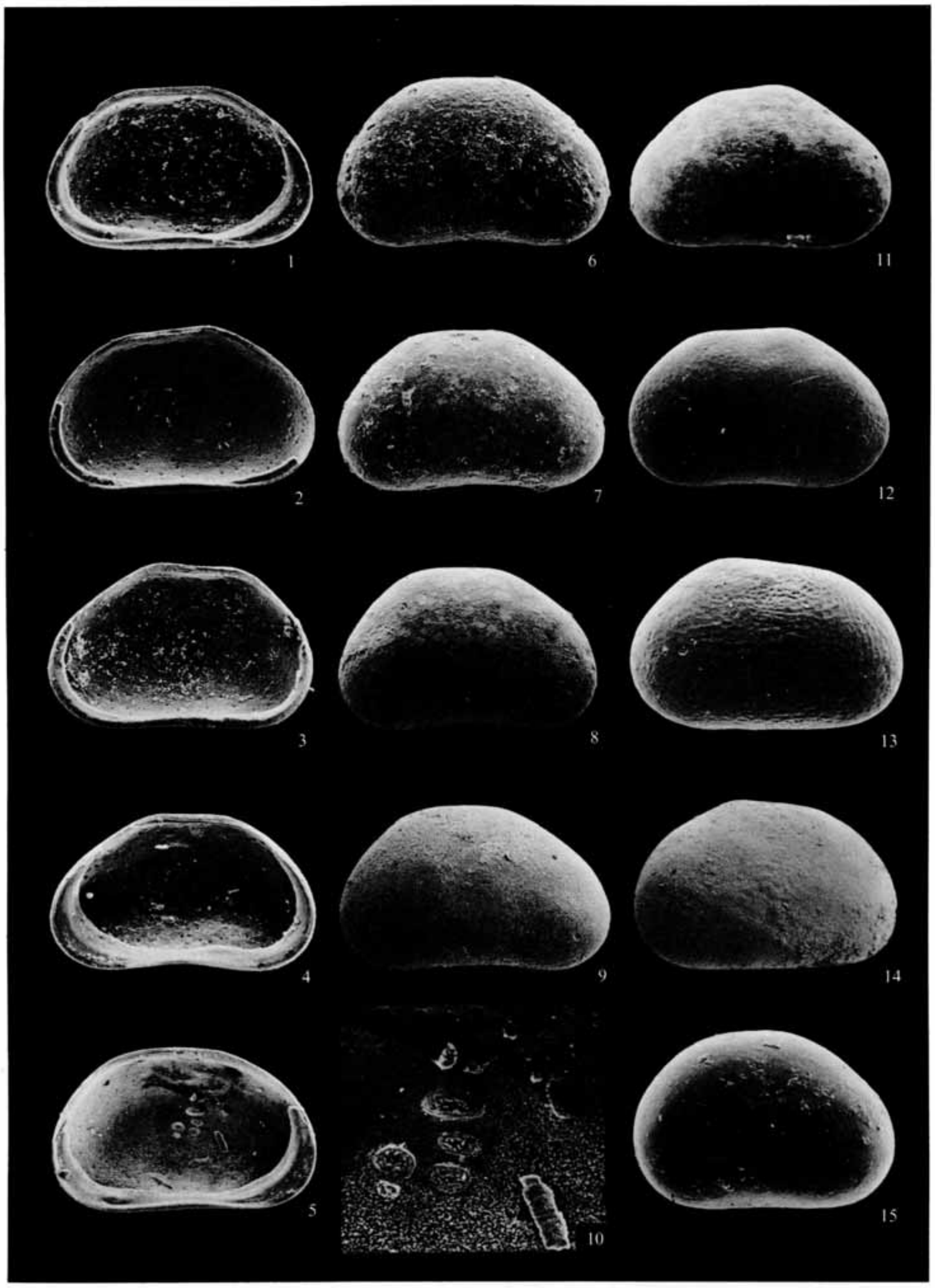
Stratigraphical range. At least Pleistocene to Recent.

EXPLANATION OF PLATE 31

Figs. 1-14. *Scottia browniana*. 1, internal lateral view of juvenile LV, OS 9230, sample CR 39, L: 0·725 mm. 2, internal lateral view of juvenile LV, OS 9231, sample CR 39, L: 0·625 mm. 3, internal lateral view of juvenile RV, OS 9232, sample CR 35, L: 0·70 mm. 4, internal lateral view of juvenile RV, OS 9233, sample CR 35, L: 0·70 mm. 5, internal lateral view of adult LV, OS 9234, sample CR 44, L: 0·885 mm. 6, external lateral view of juvenile RV, OS 9235, sample CR 45, L: 0·725 mm. 7, external lateral view of juvenile RV, OS 9236, sample CR 39, L: 0·725 mm. 8, external lateral view of adult RV, OS 9237, sample CR 39, L: 0·825 mm. 9, external lateral view of adult RV, OS 9238, sample CR 39, L: 0·80 mm 10, enlargement of fig. 5 to show central muscle field. 11, external lateral view of juvenile RV, OS 9239, sample CR 45, L: 0·50 mm. 12, external lateral view of juvenile RV, OS 9240, sample CR 15, L: 0·70 mm. 13, external lateral view of juvenile LV, OS 9241, sample CR 39, L: 0·55 mm. 14, external lateral view of juvenile LV, OS 9242, sample CR 39, L: 0·625 mm.

Fig. 15. *Scottia tumida* External lateral view of adult RV, OS 9243, sample CR 33, L: 0·675 mm.

RV: right valve, LV: left valve, L: length.



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Ilyocypris gibba (Ramdohr, 1808)

Plate 33, fig. 15

1808 *Cypris gibba* Ramdohr, p. 91, pl. 3, figs. 13–17.

Material. 2 L, 1 R, 1 C.

Measurements. Length: 0·975 mm, height: 0·525 mm.

Ecology. Found in small bodies of water, not subject to drying up, with clayey or muddy substrates (Klie 1938); also in quiet flowing water with temperatures ranging between 4 and 19·5 °C (Alm 1916).

Geographical distribution. Recent: Europe, North Africa, and North America.

Stratigraphical range. Middle Oligocene, Pleistocene to Recent.

Genus CANDONA Baird, 1845

Candona angulata G. W. Müller, 1900

Plate 32, fig. 11

1900 *Candona angulata* G. W. Müller, p. 18, pl. 1, figs. 1–5.

Material. 1 L, 3 R.

Measurements. Length: 1·13 mm, height: 0·625 mm.

Ecology. Spring-form found in slightly saline waters (ranging between 0·4 and 13·4‰).

Geographical distribution. Recent: Europe, North Africa.

Stratigraphical range. At least Middle Pleistocene to Recent.

Remarks. Characterized by typically pointed posterior end to right valve in both sexes and faint reticulation covering external posterior part of both valves in both sexes at the adult stage. Greatest height at $\frac{2}{3}$ from the anterior; angle of posterior area of valve steeply inclined.

EXPLANATION OF PLATE 32

Figs. 1–5. *Scottia browniana.* 1, external lateral view of juvenile RV, OS 9244, sample CR 45, L: 0·675 mm. 2, external lateral view of juvenile RV, OS 9245, sample CR 45, L: 0·687 mm. 3, external lateral view of juvenile LV, OS 9246, sample CR 15, L: 0·70 mm. 4, dorsal view of carapace of adult, OS 9247, sample CR 39, L: 0·825 mm. 5, ventral view of carapace of adult, OS 9248, sample CR 39, L: 0·75 mm.

Fig. 6. *Candona candida.* Internal lateral view of adult RV, OS 9249, sample CR 3, L: 0·95 mm.

Figs. 7–9. *C. parallela.* 7, internal lateral view of adult LV, OS 9250, sample CR 13, L: 0·825 mm. 8, external lateral view of LV of adult carapace, OS 9251, sample CR 29, L: 0·825 mm. 9, external lateral view of adult RV, OS 9252, sample CR 13, L: 0·80 mm.

Fig. 10. *C. fabaeformis.* External lateral view of adult carapace, OS 9253, sample CR 18, L: 0·90 mm.

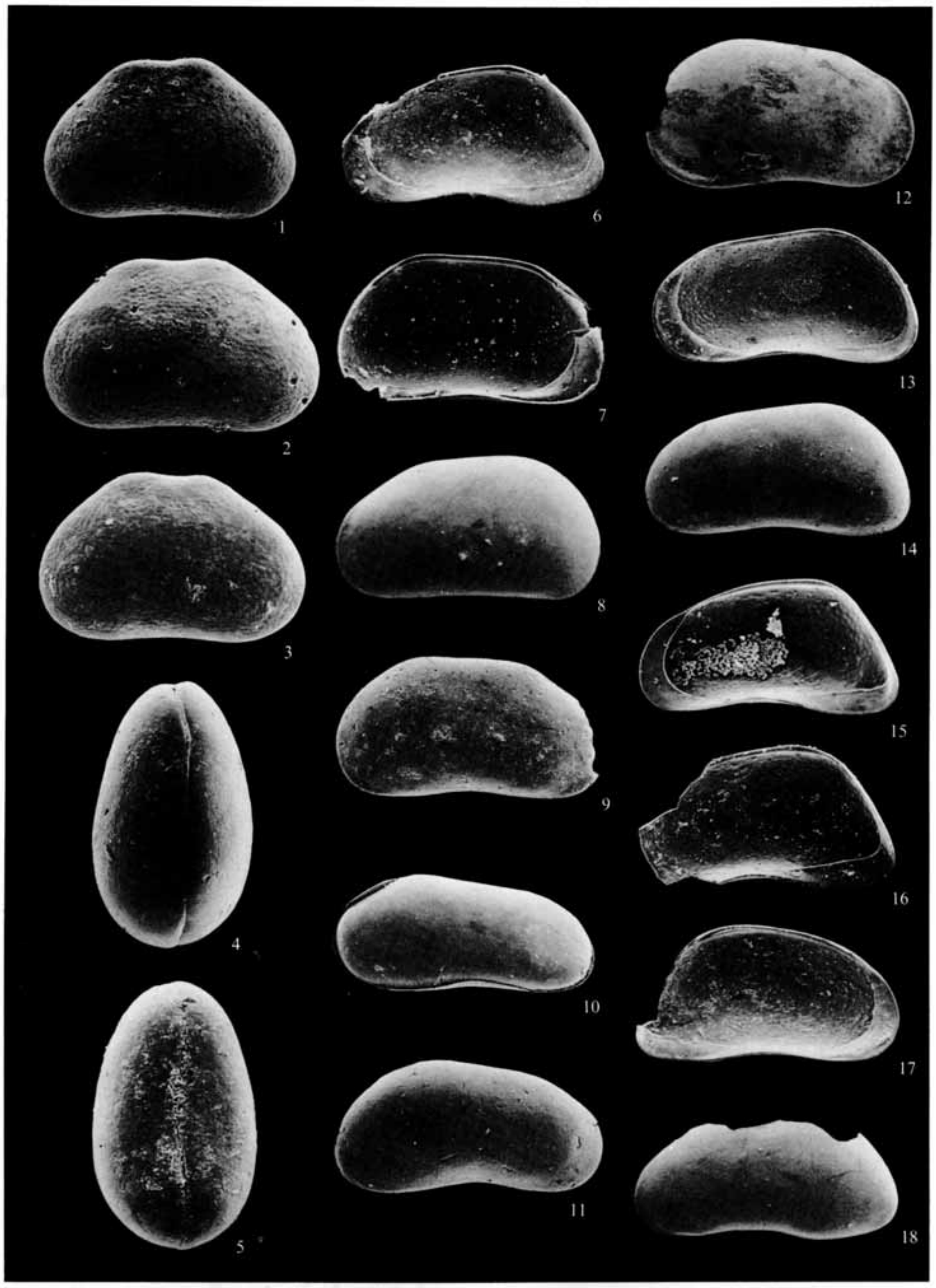
Fig. 11. *C. angulata.* External lateral view of adult RV, OS 9254, sample CR 45, L: 1·137 mm.

Fig. 12. *C. compressa.* External lateral view of adult RV, OS 9255, sample CR 36, L: 0·925 mm.

Figs. 13–14. *C. neglecta.* 13, internal lateral view of adult RV, OS 9256, sample CR 13, L: 1·00 mm. 14, external lateral view of adult LV, OS 9257, sample CR 13, L: 1·10 mm.

Figs. 15–18. *C. levanderi.* 15, internal lateral view of adult RV, OS 9258, sample CR 33, L: 0·91 mm. 16, internal lateral view of adult RV, OS 9259, sample CR 6, L: 0·78 mm. 17, internal lateral view of adult LV, OS 9260, sample CR 6, L: 0·90 mm. 18, external lateral view of adult LV, OS 9261, sample CR 33, L: 1·05 mm.

RV: right valve; LV: left valve; L: length.



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Candona candida (O. F. Müller, 1776)

Plate 32, fig. 6

1776 *Cypris candida* O. F. Müller, 1776, p. 198.

Material. 1 L, 1 R.

Measurements. Length: 0·95 mm, height: 0·55 mm.

Ecology. Typical cold water form, resistant to slight changes of temperature (= stenothermal); occurs in most types of water-bodies and springs, even in saline waters. Often found in marshy vegetation.

Geographical distribution. Recent: holarctic regions.

Stratigraphical range. At least Middle Pleistocene to Recent.

Remarks. Length–width ratio of this species smaller than for *Candona angulata*. Right valve in adults, without pointed posterior end.

Candona compressa (Koch, 1837)

Plate 32, fig. 12

1837 *Cypris compressa* Koch, no. 16.

Material. 2 L, 2 R.

Measurements. Length: 0·925 mm, height: 0·55 mm.

Ecology. Found at present on sandy edges of lakes. Commonly found in Pleistocene travertine sediments, and sometimes in slightly saline lakes.

Geographical distribution. Recent: North and East Europe, Siberia.

Stratigraphical range. Pleistocene to Recent.

EXPLANATION OF PLATE 33

Figs. 1–5, 7–10, 13. *Paralimnocythere compressa*. 1, external lateral view of adult female RV, OS 9262, sample CR 10, L: 0·55 mm. 2, external lateral view of adult female RV, OS 9263, sample CR 9, L: 0·537 mm. 3, external lateral view of adult female RV, OS 9264, sample CR 13, L: 0·525 mm. 4, internal lateral view of adult female RV, OS 9265, sample CR 11, L: 0·55 mm. 5, external lateral view of adult female LV, OS 9266, sample CR 9, L: 0·512 mm. 7, external lateral view of adult male RV, OS 9267, sample CR 9, L: 0·50 mm. 8, external lateral view of adult male LV, OS 9268, sample CR 9, L: 0·525 mm. 9, external lateral view of adult male LV, OS 9269, sample CR 13, L: 0·55 mm. 10, internal lateral view of adult male RV, OS 9270, sample CR 12, L: 0·525 mm. 13, dorsal view of adult RV, OS 9271, sample CR 13, L: 0·562 mm.

Fig. 6. *Potamocypris* sp. External lateral view of carapace showing RV, OS 9272, sample CR 17, L: 0·60 mm.

Fig. 11. *Darwinula* sp. External lateral view of LV, OS 9273, sample CR 16, L: 0·70 mm.

Fig. 12. *P. wolfi*. External lateral view of carapace showing LV, OS 9274, sample CR 4, L: 0·725 mm.

Fig. 14. *Ilyocypris bradyi*. Dorsal view of carapace of adult, OS 9275, sample CR 13, L: 0·812 mm.

Fig. 15. *I. gibba*. Dorsal view of carapace of adult, OS 9276, sample CR 40, L: 0·975 mm.

RV: right valve; LV: left valve; L: length.

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Remarks. Characterized by flat dorsum inclined anteriorly, and by concave impression anterodorsally. When viewed dorsally, right valve slightly pinched at anterior. Length–height ratio 1·8 with greatest height at $\frac{2}{3}$ from anterior.

Candona fabaeformis (Fisher, 1851)

Plate 32, fig. 10

1851 *Cypris fabaeformis* Fisher, p. 146, table 3, figs. 6, 7, 9, 10.

Material. 1 C.

Measurements. Length: 0·90 mm, height: 0·425 mm.

Ecology. Usually found at present, in ponds with muddy bottoms.

Stratigraphical range. At least Middle Pleistocene to Recent.

Geographical distribution. Recent: holarctic regions (found at Přezletice (Czechoslovakia) in sediments of Cromerian age, *sensu* Alsolon 1974).

Remarks. Characterized by the strong overlapping of left valve over right in flattened posterodorsal area of shell.

Candona levanderi Hirshman, 1912

Plate 32, figs. 15–18

1912 *Candona levanderi* Hirshman, p. 13, table 1, figs. 1–15.

Material. 2 L, 2 R.

Measurements. Length: 0·78–1·05 mm, height: 0·475–0·50 mm.

Ecology. Spring-form ostracod.

Geographical distribution. At present in Finland, Bulgaria, north-east Germany, and the Alps (from Diebel and Pietrzeniuk 1969).

Stratigraphical range. Pleistocene to Recent.

Remarks. Shape of shell highly variable (Diebel and Pietrzeniuk 1969). Greatest height at $\frac{3}{4}$ from anterior, with posterior part tapering at steep angle from dorsum. Inner lamella broad anteriorly and posteriorly, very narrow posterodorsally.

Candona neglecta Sars, 1887

Plate 32, figs. 13–14

1887 *Candona neglecta* Sars, p. 107, table 15, figs. 5–7, table 19.

Material. 1 L, 1 R.

Measurements. Length: 1·00–1·10 mm, height: 0·567–0·575 mm.

Ecology. Found in all kinds of water-bodies today (often in marshy vegetation) including saline waters. Recorded in water with a temperature range between 5 and 8 °C (Alm 1916).

Geographical distribution. Recent: Europe, central Asia, North Africa (= Palaeoarctic).

Stratigraphical range. Danian (Hanganu 1977), Pleistocene to Recent.

Remarks. Adult males much larger than females; in lateral view shape of each valve characterized by almost circular posterior area. Females flatter, with inner lamella broader anteriorly; length-height ratio of 2. Dorsum slightly concave.

Candona parallela G. W. Müller, 1900

Plate 32, figs. 7–9; Plate 34, figs. 5–10, 13

1900 *Candona parallela* G. W. Müller, p. 25, table 5, figs. 5, 6, 23–25.

Material. Adults: 3 L, 5 R, 2 C; juveniles: 61 L, 76 R, 19 C.

Measurements. Adults: length: 0·80–0·825 mm, height: 0·467–0·475 mm.

Description. Juveniles characterized by flattened trapezoidal shape in lateral view, with valves nearly always reticulate. Left valve overlaps right, and is taller in dorsal area. Externally, reticulation almost absent in central muscle scars area. Adult forms similar in lateral outline to *C. compressa* but with slightly convex dorsum. Reticulation absent in adults.

Ecology. Spring and early summer form inhabiting high range of temperatures from 3–23·5 °C (Alm 1916). Commonly found in small water-bodies (sometimes subject to drying up) rich in plants; also in small streams close to springs filled with vegetal matter (Diebel and Pietrzeniuk 1975*a*). At West Runton, *C. parallela* lived in abundant fen and reed swamp; an increase in percentage of these aquatic plants is accompanied by an increase in numbers of *C. parallela*. This species occurs in climates ranging from Open (*Betula*) Forest to Boreal Forest.

Geographical distribution. Recent: Europe, North America, and Eurasia.

Stratigraphical range. At least Middle Pleistocene to Recent.

Remarks. Juveniles of *C. parallela* are almost identical in shape and size to juvenile specimens of *C. fertilis fertilis* illustrated by Triebel (1963, pl. 28), which are also faintly reticulate. Triebel's adult specimens have an anteriorly inclined dorsum.

Candona sp. 1

Plate 34, figs. 1, 2, 4, 11, 12

Material. 22 L, 20 R, 22 C.

Measurements. Sizes range for these juveniles from: length: 0·38–0·74 mm, height: 0·26–0·39 mm.

Description. All specimens of *Candona* sp. 1, collected at West Runton are juveniles. In lateral view, shape of a flat ellipsoid, except in the slightly concave ventral area. Anterior rounded, posterior more pointed, especially in youngest juvenile stages. Left valve overlaps right by about 0·03 mm. In dorsal view, carapace narrow with both sides slightly curved except for pointed anterior and posterior ends. Greatest height at about middle of carapace. External surface of shell smooth. Central muscle scars consisting of four, occasionally five scars in front and two in back. Two mandibular scars, well separated from one another, with posterior one situated almost below the four vertical ones.

Ecology. At West Runton, *Candona* sp. 1 is found mostly with *C. parallela*, suggesting similar ecological requirements for both species. At the transition, *Candona* sp. 1, is the most abundant species where fen and reed swamp vegetation was very rich.

Candona sp. juveniles

Many juvenile valves and fragments were found in samples from West Runton, but these could not be identified at species level. They were particularly abundant in four of the six samples from the late Beestonian A pollen assemblage zone, typical of a cold climate.

CYCLOCYPRIS Brady and Norman, 1889
Cyclocypris laevis (O. F. Müller, 1776)

Plate 35, figs. 1–4

1776 *Cypris laevis* O. F. Müller, p. 198.

Material. 31 L, 27 R, 27 C.

Measurements. Length: 0·475–0·525 mm, height: 0·325–0·375 mm.

Ecology. Adaptable to any type of aquatic environment, but usually found in small water-bodies with marshy vegetation, and also in water springs. Found at most times of the year.

Geographical distribution. Recent: holarctic regions.

Stratigraphical range. Danian (Hanganu 1977), Pleistocene to Recent.

Remarks. Almost egg-shaped in dorsal view with right valve slightly smaller anteriorly and posteriorly. In lateral view, dorsum semicircular. Externally, smooth valves except for a few pore canals.

Cyclocypris ovum (Jurine, 1820)

Plate 35, figs. 5–8

1820 *Monoculus ovum* Jurine, p. 179, table 19, figs. 18, 19.

Material. 33 L, 26 R, 52 C.

Measurements. Length: 0·462–0·482 mm, height: 0·30–0·367 mm.

Ecology. Today found in water-bodies of all kinds; able to withstand many environmental changes (temperature, salinity). Found at most times of the year. *C. ovum* is the most common *Cyclocypris* species at West Runton; found where aquatics were abundant and where water-body is shallow.

Geographical distribution. Recent: holarctic regions.

Stratigraphical range. Miocene to Recent.

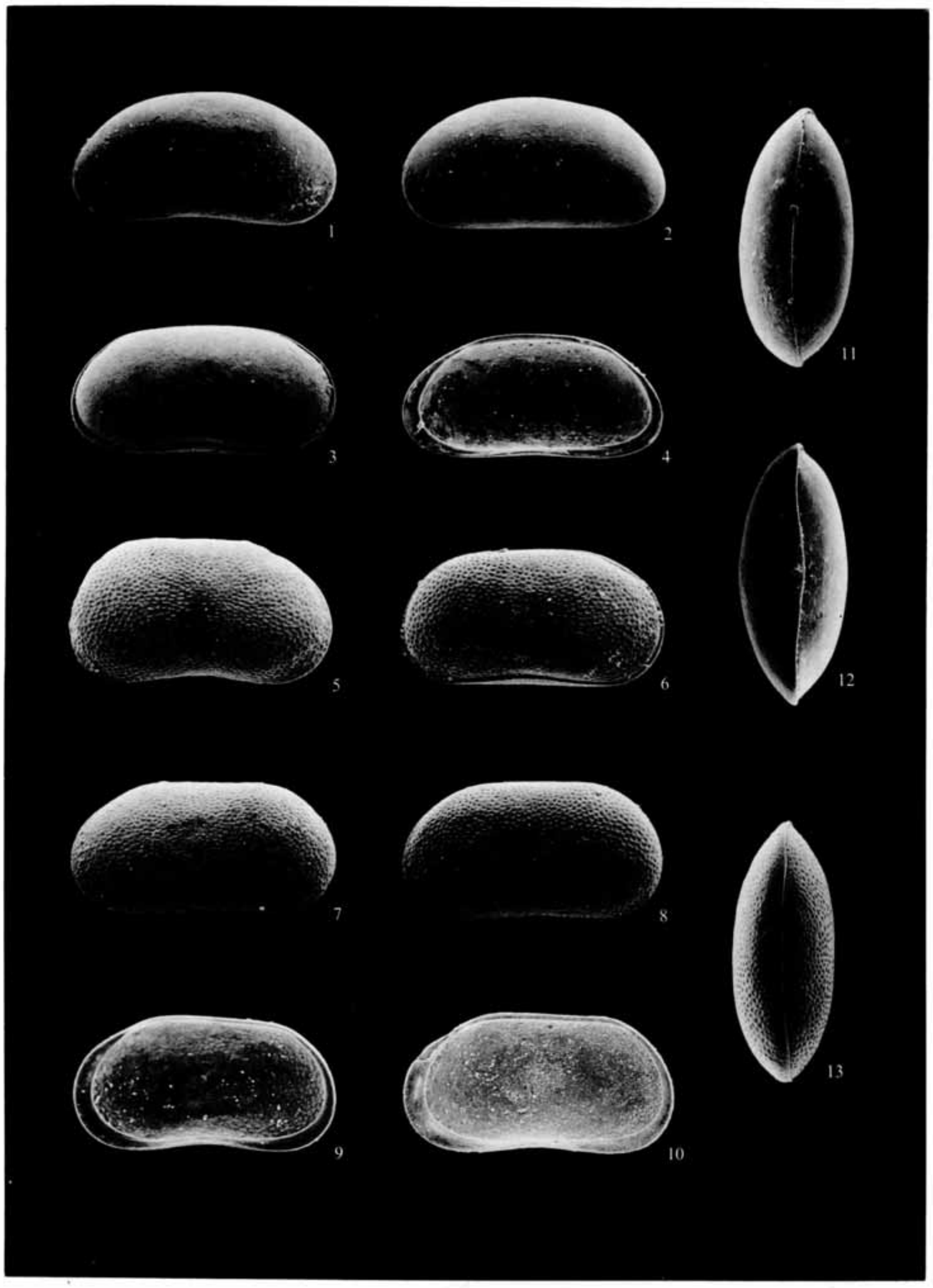
EXPLANATION OF PLATE 34

Figs. 1, 2, 4, 11, 12. *Candona* sp. 1. 1, external lateral view of juvenile RV, OS 9277, sample CR 27, L: 0·575 mm. 2, external lateral view of juvenile LV, OS 9278, sample CR 27, L: 0·567 mm. 4, internal lateral view of juvenile RV, OS 9279, sample CR 27, L: 0·55 mm. 11, dorsal view of carapace of juvenile, OS 9280, sample CR 27, L: 0·515 mm. 12, ventral view of carapace of juvenile (anterior facing downward), OS 9281, sample CR 27, L: 0·60 mm.

Fig. 3. *Candona* sp. 1? External lateral view of carapace of juvenile to show RV, OS 9282, sample CR 27, L: 0·725 mm.

Figs. 5–10, 13. *C. parallela*. 5, external lateral view of juvenile RV, OS 9283, sample CR 12, L: 0·60 mm. 6, external lateral view of juvenile carapace to show RV, OS 9284, sample CR 29, L: 0·537 mm. 7, external lateral view of juvenile LV, OS 9285, sample CR 14, L: 0·687 mm. 8, external lateral view of juvenile LV, OS 9286, sample CR 29, L: 0·65 mm. 9, internal lateral view of juvenile RV, OS 9287, sample CR 29, L: 0·525 mm. 10, internal lateral view of juvenile RV, OS 9288, sample CR 14, L: 0·625 mm. 13, dorsal view of juvenile carapace, OS 9289, sample CR 29, L: 0·537 mm.

RV: right valve; LV: left valve; L: length.



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Remarks. Differentiated from *C. laevis* by being much narrower in dorsal view; greatest width at about middle of carapace; right valve slightly larger, overlapping left one ventrally. In lateral view, slightly less circular than *C. laevis* with both anteroventral and posteroventral areas flatter. Carapace slightly pitted externally.

Cyclocypris serena (Koch, 1837)

Plate 35, figs. 12–13

1837 *Cypris serena* Koch, no. 22.

Material. 4 L, 2 R, 3 C.

Measurements. Length: 0·475–0·50 mm, height: 0·30–0·337 mm.

Ecology. At present found in still waters and temporary ponds; perhaps cold water form able to withstand slight changes of temperature. Found at most times of the year.

Geographical distribution. Recent: North and Central Europe, North America.

Stratigraphical range. At least Middle Pleistocene to Recent. Absolon (1976) stated that this species is typically Holocene but had already appeared during the Pleistocene.

Remarks. Larger than *C. ovum* and *C. laevis*; flatter when viewed laterally.

CYPRIA Zenker, 1854
Cypria sp.

Remarks. Only one specimen found at West Runton (CR 46).

SCOTTIA Brady and Norman, 1889
Scottia browniana (Jones, 1850)

Plate 31, figs. 1–14; Plate 32, figs. 1–5

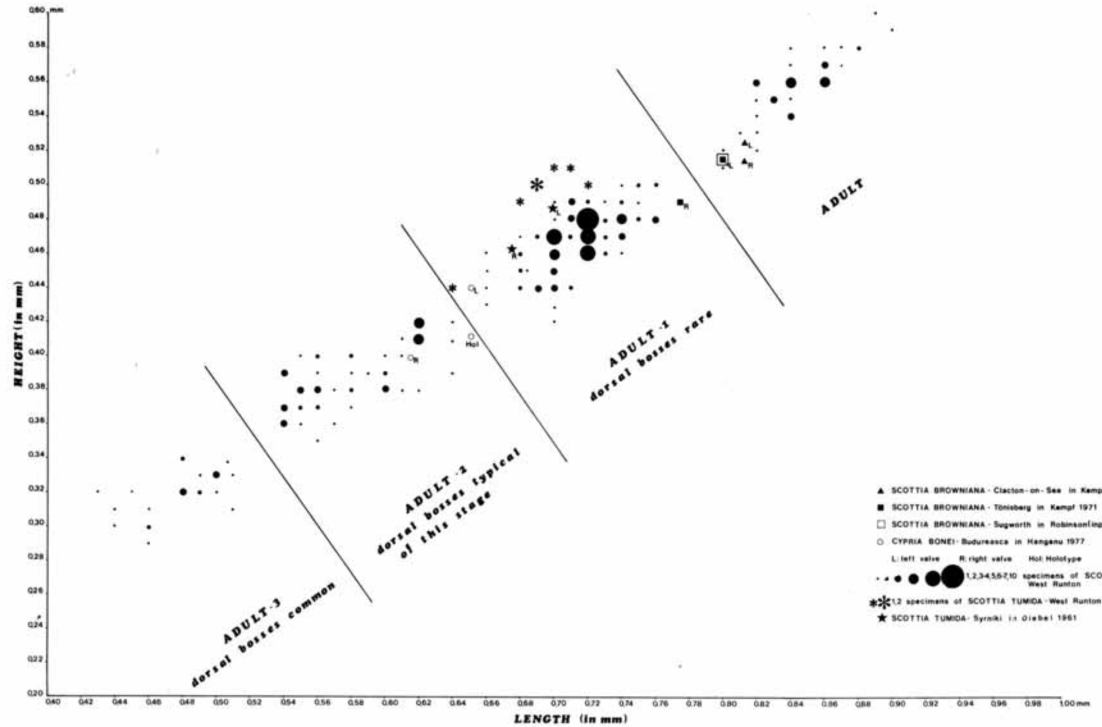
1850 *Cypris browniana* Jones, p. 25, table 3, fig. 1*a–d*.

Material. 305 L, 299 R, 26 C.

Measurements. See text-fig. 2.

Description. Characterized by trapezoidal form, almost horizontal dorsum and thick shell; two bosses on right valve dorsally in juvenile stages, especially in stages A-2 and A-3 (see Pl. 31, figs. 3–4; Pl. 32, figs. 1–3). Usually anterodorsal boss present on right valves in stage A-1. In dorsal view carapace almost ellipsoid in shape. Left valve slightly longer in posterior area, overlapping ventrally and anterodorsally; right valve slightly longer anteriorly, overlapping posterodorsally. In juvenile stages, dorsal overlapping of right valve over left accentuated by two bosses. External surface of shell smooth in adults; reticulate in most juvenile specimens. Internally, many scattered pore canals; inner lamella thick and broader anteroventrally. Ventral area slightly concave. Central muscle scars (see Pl. 31, fig. 10).

Geographical distribution and stratigraphical range. Lower Pliocene (Romania (Hanganu 1977) see below), and Lower and Middle Pleistocene (see Kempf 1971, fig. 5). For size distributions of *S. browniana* at West Runton and at other localities see text-fig. 2. *S. browniana* appears identical to Hanganu's description of *Cypria bonei* from the Upper Danian of Romania (paratypes examined) except the latter is of smaller size (see text-fig. 2). The stratigraphical range of this species is therefore extended from Lower Pliocene to Middle Pleistocene. Hanganu's specimens are found in sandy sediments, a similar environment to that of *S. browniana* at West Runton, Clacton-on-Sea, and Sugworth.



TEXT-FIG. 2. Length–width measurements made on valves of *Scottia browniana* and *S. tumida* recovered from the West Runton section, and compared with *Scottia* specimens from other localities.

Ecology. In most localities from which *S. browniana* is known, the predominant sediment is fine sand (calcareous fine sand and gitja in Kempf 1971). From the present study, it appears that this species could live in varying types of climate, from those associated with Open (*Betula*) Forest to a warm Temperate Forest. It was most abundant under the Temperate Forest climate (where sandy substrate occurred) and numbers decreased drastically in the warm Temperate climate where vegetal matter proliferated (= ? eutrophication of the water body). When *S. browniana* was extremely abundant, very few specimens of other ostracod species were present. Because of its thick shell and tendency to be found within sandy sediment, it is suggested that *S. browniana* was either a benthic or an epibenthic species.

Remarks. *Cypria candonaeformis* (Schweyer, 1949) described and illustrated by Negadaev-Nikonov (1971, tables 9 (10) and 11 (4)) is identical to *S. browniana*. This was confirmed by examining topotype material held in the Senckenberg Museum. The Moldavian specimens are larger than those found at West Runton, and have a greater length-width ratio of the carapace. Note that at Tiraspol *C. candonaeformis* occurs within sandy sediment.

Scottia tumida (Jones, 1850)

Plate 31, fig. 15

1850 *Cypris tumida* Jones, p. 26, pl. 3, fig. 2*a*–*c*.

Material. 7 valves.

Measurements. See text-fig. 2.

Description. Shape almost globular with curved dorsum; ventral area nearly flat. Length–height ratio smaller than for *S. browniana* (see text-fig. 2), and the adults of *S. tumida* are also smaller in size.

Ecology. As for *S. browniana*.

Geographical distribution and stratigraphical distribution. See Kempf 1971, fig. 5.

EXPLANATION OF PLATE 35

Figs. 1–4. *Cyclocypris laevis*. 1, dorsal view of carapace of adult, OS 9290, sample CR 14, L: 0·525 mm. 2, ventral view of carapace of adult, OS 9291, sample CR 14, L: 0·50 mm. 3, external lateral view of adult LV, OS 9292, sample CR 14, L: 0·475 mm. 4, internal lateral view of adult RV, OS 9293, sample CR 14, L: 0·50 mm.

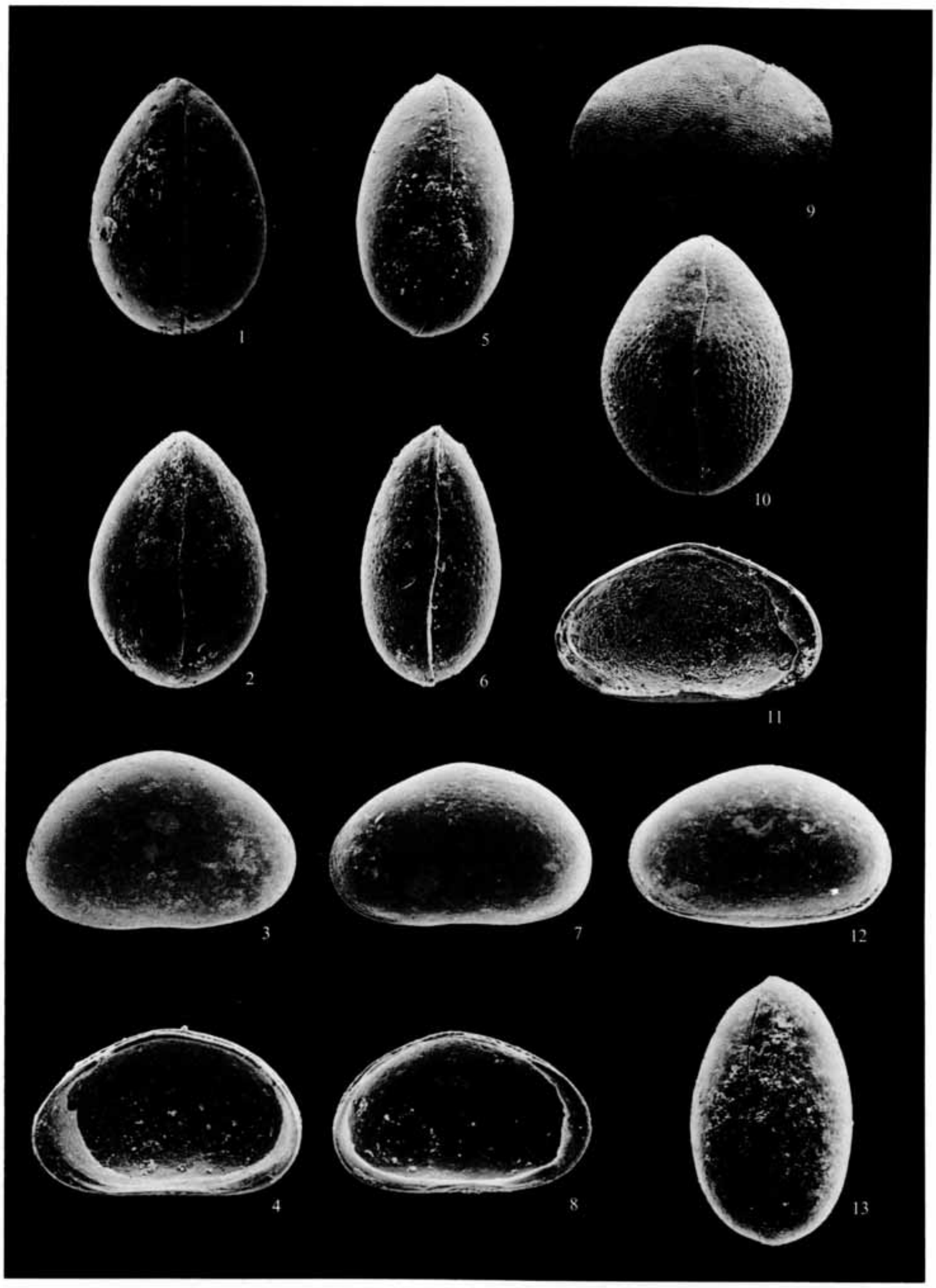
Figs. 5–8. *C. ovum*. 5, dorsal view of carapace of adult, OS 9294, sample CR 9, L: 0·475 mm. 6, ventral view of carapace of adult, OS 9295, sample CR 9, L: 0·487 mm. 7, external lateral view of adult LV, OS 9296, sample CR 9, L: 0·475 mm. 8, internal lateral view of adult LV, OS 9297, sample CR 9, L: 0·462 mm.

Fig. 9. *Eucypris dulcifons*. External lateral view of adult RV, OS 9298, sample CR 11, L: 0·90 mm.

Figs. 10, 11. *Cypridopsis vidua*. 10, dorsal view of carapace of adult, OS 9299, sample CR 10, L: 0·65 mm. 11, internal lateral view of adult LV, OS 9300, sample CR 14, L: 0·725 mm.

Figs. 12, 13. *Cyclocypris serena*. 12, external lateral view of carapace of adult to show LV, OS 9301, sample CR 36, L: 0·475 mm. 12, dorsal view of carapace of adult, OS 9302, sample CR 36, L: 0·50 mm.

RV: right valve; LV: left valve; L: length.



DE DECKKER, Pleistocene ostracods

EUCYPRIS Vavra, 1891
Eucypris dulcifons Diebel and Pietrzeniuk, 1969

Plate 35, fig. 9

1969 *Eucypris dulcifons* Diebel and Pietrzeniuk, p. 479, fig. 9, table 9, figs. 5–8.

Material. 1 R in sample CR 11.

Measurements. Length: 0·90 mm, height: 0·55 mm.

Ecology. Described by Diebel and Pietrzeniuk (1975*b*) from lake sediments and also small water bodies, and by Robinson (in press) from sediments deposited at Sugworth in sluggishly flowing waters, rich in growing vegetation or accumulations of plant debris.

Geographical distribution. Middle Pleistocene: Germany and England; Upper Pleistocene: Germany.

Stratigraphical range. At least Middle to Upper Pleistocene.

Remarks. Characterized by finger print reticulation on outside of the carapace (Robinson, in press). *E. dulcifons* in dorsal view is much narrower than *E. pigra* (Fisher, 1851), but otherwise very similar in outline.

HERPETOCYPRIS Brady and Norman, 1889
Herpetocypris sp.

Remarks. Only one juvenile specimen was found (sample CR 6).

CYPRIDOPSIS Brady, 1868
Cypridopsis vidua (O. F. Müller, 1776)

Plate 35, figs. 10–11

1776 *Cypris vidua* O. F. Müller, p. 198.

Material. 4 L, 1 R, 4 C.

Measurements. Length: 0·65–0·725 mm, height: 0·425–0·45 mm.

Ecology. Found in small and large water-bodies rich in aquatic vegetation; common in entrophic and usually warm waters.

Geographical distribution. Pleistocene: Kashmir, Germany, USA, England (Swain 1976). Recent: cosmopolitan.

Stratigraphical range. Late Pliocene (Swain, 1976) to Recent.

Remarks. Characterized by its large size compared with the three *Cyclocypris* species found at West Runton; strongly pitted surface, pointed dorsum and sinuous hinge in dorsal view; left valve overlaps dorsally at about $\frac{1}{3}$ from anterior.

POTAMOCYPRIS Brady, 1870
Potamocypris wolfi Brehm, 1920

Plate 33, fig. 12

1920 *Potamocypris wolfi* Brehm, p. 6.

Material. 1 C.

Measurements. Length: 0·725 mm, height: 0·36 mm.

Ecology. Typical of cold water springs.

Geographical distribution. Recent: Europe.

Stratigraphical range. At least Middle Pleistocene to Recent.

Remarks. Characterized by length–height ratio 1·95–2·10. Both valves reticulate; right valve overlaps left, especially in dorsal area.

Potamocypris sp.

Plate 33, fig. 6

Material. 1 C (CR 17).

Measurements. Length: 0·60 mm, height: 0·375 mm.

Ecology. Found in sandy sediment rich in vegetal debris; pollen assemblage indicates Open (*Betula*) Forest type of climate and shallow water body.

Stratigraphical range. At least Middle Pleistocene.

Remarks. Characterized by a length–height ratio of 1·6, with dense and deep reticulation on the outside of the carapace; left valve overlaps the right, especially in the dorsal area.

Note. At West Runton, fragments of large cypridid ostracods were found, but were unidentifiable even at generic level. At the same locality, Dr. J. E. Robinson found three additional species of ostracods, namely *Candona tricicatricosa*, *Limnocythere falcata*, and *Sclerocypris? clavata prisca*. These were recovered in the silty beds below the detritus peat, and are believed to correspond approximately with samples CR 8–10 in my section (Robinson, per litt. 28.10.77).

OSTRACOD ASSEMBLAGES

The distribution of the ostracods found in each of the sixty-two samples is represented in text-fig. 1. This chart shows the five main zones based on ostracod assemblages, which correspond almost exactly with West's pollen assemblage zones (West, in press and Funnell and West 1977) and with the lithological changes. These five assemblages are recorded below, in a stratigraphical sequence.

For the ecological notes on the ostracods, refer to the taxonomy section of this paper.

Ostracod assemblage 1: late Beestonian A pollen assemblage zone (0–26 cm)

Pollen assemblage and local macroscopic vegetation. Gramineae–Cyperaceae–*Artemisia* with plants typical of shallow water and muddy substrates (93%). Climate postulated: cold. Herbaceous vegetation existed and charophyte gyrogonites were abundant (from 30 to 60 per 40 gr. of sediment) inferring a still and shallow water-body.

Environment postulated. Small pond(s) and/or intermittent meandering streams consisting of cold water under a cold climate; plants of shallow muddy substrates present. Intermittent occurrence of ostracod species which are few in number, indicating the water body was shallow and often subject to drying up, or was covered by coarser river sediments as shown by occasional black cherty pebbles. The water could have been slightly brackish or stagnant at stages (shown by *Candona candida* CR 3, *C. compressa* CR 6, *Ilyocypris bradyi* CR 3–6). Note the absence of *Scottia browniana*.

Ostracod assemblage 2: late Beestonian B pollen assemblage zone (*26–55 cm*)

Pollen assemblage and local macroscopic vegetation. Gramineae–Cyperaceae–*Betula* as well as plants typical of muddy substrates and shallow water, decreasing rapidly towards top (between CR 9–14 fen and reed swamp with approximately 75% halophytes). The climate was typical of an open (*Betula*) forest. Charophyte gyrogonites present, but less abundant than before.

Environment postulated. Small lake, pond, or swamp, becoming deeper but not connected to a river (no pebbles brought in). Possible episode of brackish water shown by ostracods (*C. angulata* CR 9–10, *C. compressa* CR 11, *C. neglecta* CR 11, *I. bradyi* CR 13–14), between samples CR 9–14 (? proximity to sea or high rate of evaporation), when the halophytes were also abundant. Ostracods seem to indicate the presence of marshy vegetation in places, as well as possible eutrophication of the water (shown by *Cypridopsis vidua*) at some levels. Note that charophytes increase in number when water was probably slightly saline. Water temperature uncertain.

Ostracod assemblage 3: Cromerian IA and IB pollen assemblage zones (*55–87·5 cm*)

Pollen assemblage and local macroscopic vegetation. Cromerian IA: *Betula–Pinus*; plants of shallow water and muddy substrates almost absent; plants typical of fen and reed swamp nearly 30%. Climate postulated is a boreal forest type. Cromerian IB: *Pinus–Ulmus*, few plants of shallow water and muddy substrates (about 20% at one stage) but aquatics abundant with high percentage of fen and reed swamp halophytes. Climate postulated, is a transition between boreal and temperate forest types.

Environment postulated. Climate warming up towards the top as shown by palynological data. Fen and reed swamp type of vegetation abundant (most abundant at transition Cromerian IA–IB, the time during which *Candona* sp. 1 is the most abundant in the section studied, and there is a high number of *C. parallela*). Ostracods give no indication of the depth of the water-body.

Note the two pollen assemblages (Cromerian IA and IB) are here included in the one ostracod assemblage.

Ostracod assemblage 4: Cromerian IIA pollen assemblage zone (*102–122·5 cm*)

Pollen assemblage and local macroscopic vegetation. Pinus–Quercus–Ulmus with aquatics fairly abundant (45%) and fen and reed swamp plants up to 30%. Charophyte gyrogonites present in all samples (except CR 38) indicating a probable decrease in water level.

Other data. Vertebrate fragments occasional, fish scales present in most samples.

Environment postulated. Temperate forest type of climate. Small shallow lake with fairly abundant aquatics, and a fen and reed swamp vegetation. At level CR 45, the water could have been slightly saline as there is an increase in charophyte gyrogonites in that sample. Ostracods offer no data on water temperature except for *Ilyocypris gibba* (CR 40, 42, 43, 46) which can be found in waters up to 19 °C. Supply of sand and vegetal debris very high.

Note that *Scottia browniana* is extremely abundant.

Ostracod assemblage 5: Cromerian IIB pollen assemblage zone (122·5–140 cm)

Pollen assemblage. Quercus–Ulmus–Tilia; no data on macroscopic plants, except that some charophyte gyrogonites are present.

Other data. Vertebrate fragments and fish scales common.

Environment postulated. Warm temperate forest type of climate. Sandy substrate, covered with vegetal debris, possibly preventing *S. browniana* occurring in large numbers. The presence of charophytes suggest that the water was shallow. Vertebrates must have frequented the surroundings of the water body (see Stuart 1975).

Above assemblage 5

140–157·5 cm: plant debris in dark brown sand. 157·5–161·5 cm: reddish brown to black leached vegetal debris with less sand.

Apart from a few specimens of *S. browniana* recovered from samples CR 54–56, and two specimens of *S. tumida* (CR 54), ostracods are absent from this uppermost horizon. This absence is probably associated with leaching of the ostracod valves. Molluscan shells are also absent.

COMPARISON WITH OTHER MIDDLE PLEISTOCENE DEPOSITS IN EUROPE YIELDING OSTRACODS

The only deposit known in the British Isles, apart from the sites around West Runton, yielding ostracods of a similar stratigraphical horizon is at Sugworth, near Oxford. The fauna was described by Robinson (in press) from a deposit formed by a sluggish stream with a strong tendency to stagnation and vegetation overgrowth, broken by intermittent flooding. This description corresponds well with the deposit at West Runton. The Sugworth ostracod fauna is reminiscent of that at West Runton with abundant *S. browniana*. However, at Sugworth *Metacypris cordata* (a species typical of lakes choked with vegetation) is present. At Clacton-on-Sea, an ostracod fauna of Hoxnian age yielding abundant *S. browniana* was found in sandy sediment.

In Europe and the USSR, six Middle Pleistocene deposits appear to be analogous to the one studied here. At Süssenborn (Elster in age) Diebel and Pietrzeniuk (1969) described a fauna with *Paralimnocythere compressa*, similar to that at West Runton. However *S. browniana* is absent, probably because the substrate was not sandy. At Přezletice, north of Prague, a Cromerian deposit (94 cm thick), was described by Absolon (1974), who postulated that the sediment was probably deposited on a flood-plain and that the water had a salinity level of about 3‰. The ostracod fauna was part of a different biotope from that at West Runton even though *I. gibba*, *Cyclocypris laevis*, and *Candona compressa* were present throughout the entire deposit. At Tiraspol in Moldavia, Negadaev-Nikonov (1971) described an ostracod fauna of Cromerian age from fluviatile sediments. Twenty-five ostracod species were recorded from a sequence 14·6 m thick. Most of the species found at West Runton are also represented there including *S. browniana* (= *Cypria candonaeformis*) and *P. compressa* (= *P.* ?cf. *compressa*). Kazmina (1975) described freshwater ostracods from the West Siberian Platform and showed illustrations of *Cypria candonaeformis*, which from descriptions and measurements, appears to be synonymous with *S. browniana*. Kazmina's specimens are middle to late Pliocene in age. At Voigstedt, Diebel (1965) recovered only five ostracod species from four different horizons, the reason being that they form part of a reworked fauna transported in running water. The ostracods give no indication of the age of the deposit known to be Cromerian. Two other deposits, both Holstein in age, yield ostracod faunas strongly resembling that at West Runton. One occurs at Syrniki in Poland, where Diebel (1961) described fifteen ostracods, *S. tumida* being the most abundant species (forming about 50% of the fauna). One major difference from the West Runton fauna is the presence of *Metacypris cordata*. The other deposit, described by Kempf (1967), occurs at Tönisberg, in the lower Rhine district in West Germany where the ostracod fauna is similar to that at West Runton. The presence of *Metacypris cordata*, *Limnocythere sanctipatricii*, and *Cytherissa lacustris*, though small in number, suggests that the body of water could have been more extensive than that at West Runton.

REWORKED FAUNA

The only foraminifera found were derived from Upper Cretaceous and Lower Pleistocene sediments. These were probably contained within the chalk fragments which are present in parts of the section. These fragments, which were brought into the area at West Runton, tend to confirm the idea that intermittent streams were occasionally connected to the water-body where the ostracods were living. The presence of a number of broken ostracod valves (especially candonid ones) at the bottom of the section, as well as occasional fragments of large cypridids, suggests that some ostracods could have been transported. This cannot be substantiated, especially as the type of water body postulated above, would favour partial breakage of ostracod valves by incoming intermittent streams. These were not continuous, as some very fragile ostracod valves (e.g. *P. compressa*) were found intact, as were some ostracod carapaces with both valves still holding together. Partial reworking would have either destroyed or separated the valves. The large cypridid ostracods after death, were often attacked by micro-organisms which render the shell very thin and extremely fragile in places. Slight undercurrents, as for example those created by wind over the water body, could cause the breakage of large fragile ostracod valves.

AGE OF THE DEPOSIT

Unlike the pollen, the ostracod assemblages cannot provide us with accurate dating. The only valuable information is provided by *S. browniana* and *S. tumida* which are absent from the fossil record in late Pleistocene and Holocene sediments. All the other ostracods found at West Runton are still living today.

CONCLUSIONS

The pollen assemblage data infers an improvement in the climate from the bottom of the section towards the top (from cold to warm temperate). Similarly, the ostracod faunal assemblages partly show a change from cold to warm water, but they are also more controlled by local factors. Sedimentological changes, perhaps associated with climatic changes, seem to directly affect the composition of the ostracod assemblages. At West Runton, the deposit studied, represents above the gravel layer at the bottom, a sedimentary sequence deposited in a large channel. With the information provided by the palaeobotanical and ostracod data, as well as a study of the sediments, the following environment is inferred. Initially small ponds and/or intermittent streams meandering under a cold climate occurred at West Runton, where aquatic plants were abundant and ostracods very few but diversified. Water could have been slightly saline at the time. Later, with improvement of the climate (open (*Betula*) forest) ostracods became more abundant amongst typical fen and reed swamp vegetation. The water body could have been enlarged and deepened and the water could have become saline at some stage. For most of the time, fen and reed swamp vegetation prevailed during the boreal forest climate and the transition to a temperate forest type of climate. At that time ostracod species were less abundant. The environment was still that of a swamp with sluggishly moving water bringing in sandy sediments and perhaps fragments of clay. A zone of mixing of sediments and faunas, probably signifying a period of drying up of the water body and perhaps accompanied by erosion, preceded a period typical of a temperate climate during which the shallowing swamp was covered by vegetation, and sandy material was brought into the swamp by flowing water. One species of ostracod *S. browniana*, was extremely abundant. Vertebrates (fish, rodents, and small mammals (Stuart 1975)) frequented the swamp and its surroundings. A small change in salinity of the water could have occurred. Finally the ostracod fauna decreased rather rapidly under the warm temperate forest type of climate where vegetal debris was profuse and covered the still shallowing swamp, in which the remains of many molluscs are found.

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