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- KOHN, A. J. 1960a. Ecological notes on *Conus* (Mollusca: Gastropoda) in the Trincomalee region of Ceylon. *Annals and Magazine of Natural History* (13) **2** (17): 309–320.
- KOHN, A. J. 1960b. Spawning behaviour, egg masses and larval development in *Conus* from the Indian Ocean. *Bulletin of the Bingham Oceanographic Collection, Yale University* **17** (4): 1–51.
- THIELE, J. 1910. Mollusca. B. Polyplacophora, Gastropoda marina, Bivalvia. In: SCHULTZE, L. *Zoologische und anthropologische Ergebnisse einer Forschungsreise im westlichen und zentralen Süd-Afrika ausgeführt in den Jahren 1903–1905* **4** (15). *Denkschriften der medizinisch-naturwissenschaftlichen Gesellschaft zu Jena* **16**: 269–270.

(continued inside back cover)

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OSTRACODA FROM QUATERNARY
COASTAL SEQUENCES
IN THE SOUTH-WESTERN CAPE

By

R. V. DINGLE
&
A. HONIGSTEIN

Cape Town

Kaapstad

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OSTRACODA FROM QUATERNARY COASTAL SEQUENCES IN THE SOUTH-WESTERN CAPE

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(With 20 figures and 3 tables)

[MS accepted 18 April 1994]

ABSTRACT

Quaternary sediments from the south-western Cape coastal plain were examined for their ostracod faunas. Seventeen species were recovered, four of which are new: *Paranesidea verloreivleiensis*, *Cytheromorpha milleri*, *Cyprideis draaihoekensis* and *Caudites tankardi*. A new generic name (*Garciaella*) is proposed for the pre-occupied *Bensonina*.

Two sedimentary successions (at Draaihoek, and in the Gypsum Quarry, south of Cape Deseada) contain relatively diverse ostracod faunas and a preliminary palaeoecological assessment is made for each, using a combination of empirical and multivariate (Q-mode factor) analyses based on the known, modern ecological preferences of various species. Both indicate initial sedimentation under normal marine conditions, followed progressively by high-salinity marine and freshwater deposition. At the Gypsum Quarry, the upper part of the sequence consists of a gypsiferous evaporite with evidence of periodic freshwater influxes, whereas at Draaihoek there is a reversion to a high-salinity marine environment, followed by a second period of deposition under freshwater conditions. Strontium isotope analysis of marine molluscs from the base of the Gypsum Quarry indicate an age of < 500 kyr (late Pleistocene–Holocene).

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INTRODUCTION

Tankard (1976, table 2) recorded 23 species of Ostracoda from Quaternary sediments in the coastal region of the south-western Cape. As part of an investigation of Quaternary palaeoenvironments, undertaken in collaboration with the Department of Archaeology at the University of Cape Town (UCT), we have re-examined several of Tankard's original localities, as well as excavating new sections, to verify the previous faunal lists, and to better establish the geographical and temporal ranges of the various species.

Here, we present taxonomic notes on the species that we recovered, including the description of four new species of ostracods. A comprehensive palaeoenvironmental assessment of the faunas, including sedimentological and stratigraphical data, will be presented elsewhere but, in the meantime, summary data on sites, sections and some environmental implications are included herein.

Previous relevant studies on coastal, inner-shelf and continental Ostracoda from south and south-western Africa have been made by Brady (1880), Müller (1908), Sars (1924), Klie (1940), Benson & Maddocks (1964), McKenzie (1971, 1977), Hartmann (1974), Keeler (1981), Boomer (1985) and Dingle (1992, 1993, 1994).

COLLECTING LOCALITIES AND SEDIMENTARY SEQUENCES

We collected sediment samples from the south-western Cape coastal area at 10 sites between Churchhaven and the Olifants River mouth (Fig. 1). Ostracods were present at most sites, but only at Draaihoek and the Gypsum Quarry (south of Cape Deseada) were there sufficiently long sequences for an evolving palaeoecology to be interpreted from the ostracod faunas. Nevertheless, material from the other sites allows us to extend our regional interpretations and supplement previous palaeoenvironmental analyses. Figure 1 also includes the localities of offshore samples utilized by Dingle (1992, 1993, 1994), which contained species recorded in the present study. Sections were excavated, but found to be lacking in ostracods at Malkop Pan (32°8.2'S 18°18.4'E), Soutkloof (32°25.0'S 18°20.0'E), and Churchhaven (c. 33°10.0'S 18°04.0'E). The last site, in particular, was disappointing: Tankard (1976, sampling sites 21, 22, table 2) had recorded an extensive ostracod fauna from Churchhaven, but despite taking 16 samples from a variety of horizons and lithologies, no specimens were found in the present study.

Olifants River mouth (31°42.5'S 18°12.5'E)

A 4.08-m section was excavated in clays and sandy clays 1 300 m south of Papendorp, on the eastern side of a large salt pan. Only sample 64 (soft, light greenish-grey sandy clay with abundant small gastropods and *Solen*, 3.41 m above the quarry floor) contained ostracods.

Verlorelei (Quarry: 32°19.5'S 18°22.25'E; VMS-9: 32°19.0'S 18°20.0'E)

Outcrops of palaeo-estuarine deposits have been described from the southern side of the modern vlei by Tankard (1976: 98-99), Miller (1987) and Miller *et al.* (1993). We collected from a small disused quarry immediately south of the road at Verlorelei settlement, where bedrock with attached oysters at elevations from 4.47 m to 6.78 m above present mean sea-level (Miller 1987: 53) is overlain by a basal shelly, sandy rudite, and shelly coarse sand with occasional rounded quartzite pebbles. These sediments lie on a steeply inclined bedrock surface, and the succession in this quarry has been accurately surveyed by members of the Department of Archaeology at UCT, but remains unpublished

(Miller pers. comm. 1993). Ostracods were recovered from the coarse basal unit (sample 24 at 2.45 m above sea-level) and the overlying sands (sample 26 at c. 2 m above sea-level). We also recorded ostracods from shelly sand horizons of samples 7 and 9 (c. 4 m above sea-level) in the VMS-9 hole sunk by Miller *et al.* (1993).

Gypsum Quarry (site 1—North end: 32°21.15'S 18°19.69'E; site 2—South end: 32°21.20'S 18°19.7'E)

This is a locality originally described by Tankard (1976: 88), c. 4.2 km south of Cape Deseada. It lies between 4.5 and 5 m above sea-level, immediately to the east of the iron-ore railway, and is an abandoned opencast excavation. Tankard (1976: 88) recorded a sequence of shelly calcareous sands overlain by up to 75 cm of 'rhythmically laminated . . . carbonate-gypsum-halite units'. We dug two pits into the sands beneath the gypsiferous horizon and revealed 1.14 m of whitish and yellow shelly sands at site 1 (north), and 1.0 m of greenish sands at site 2 (200 m farther south). The sands in both sequences rest on greenish, nodular clays. Practically the whole sequence at site 1 is ostracodiferous, and a strontium isotope ratio date on whole *Choromytilus* shells from the lowermost sand (sample 78) gives a date of < 500 kyr (Late Pleistocene-Holocene: Lavelle & Armstrong 1993; Lavelle in prep.).

Draaihoek (32°29.0'S 18°20.25'E)

Situated 18.5 km south of Cape Deseada on the farm Draaihoek, immediately west of the coast road. Here we excavated two small pits on the west side of the farm dam and about 200 m apart. Assuming that the local sequences are essentially horizontal, the two reveal a composite section approximately 2.23 m thick consisting of c. 98 cm of whitish clays and sandy clays, overlying 1.25 m of white and green sands with a lower layer of shelly, more clayey sands with abundant paired bivalves (primarily *Venerupis corrugata* and *Choromytilus meridionalis*—J. Pether pers. comm.). Practically the whole of this sequence is ostracodiferous.

Velddrif (32°47.0'S 18°10.0'E)

This is the section described by Tankard (1976, localities 9–10) as the inner, or Velddrif bar. The shelly sands lie in banked units 15–30 cm thick and contained ostracods at two levels (samples 11, 14; 80 cm and 170 cm above the base, respectively).

Laaipek (Refuse Pit: 32°45.0'S 18°10.5'E; Parrot Grit Quarry: 32°44.5'S 18°10.5'E)

These two sites lie on the eastern edge of Tankard's (1976, fig. 10) outer, or Laaipek bar. They expose fine-medium sands with abundant comminuted shells. Ostracods were recovered from one sample in each quarry: Refuse Pit (sample 15; 50 cm above base) and Parrot Grit Quarry (sample 19; 165 cm above base).

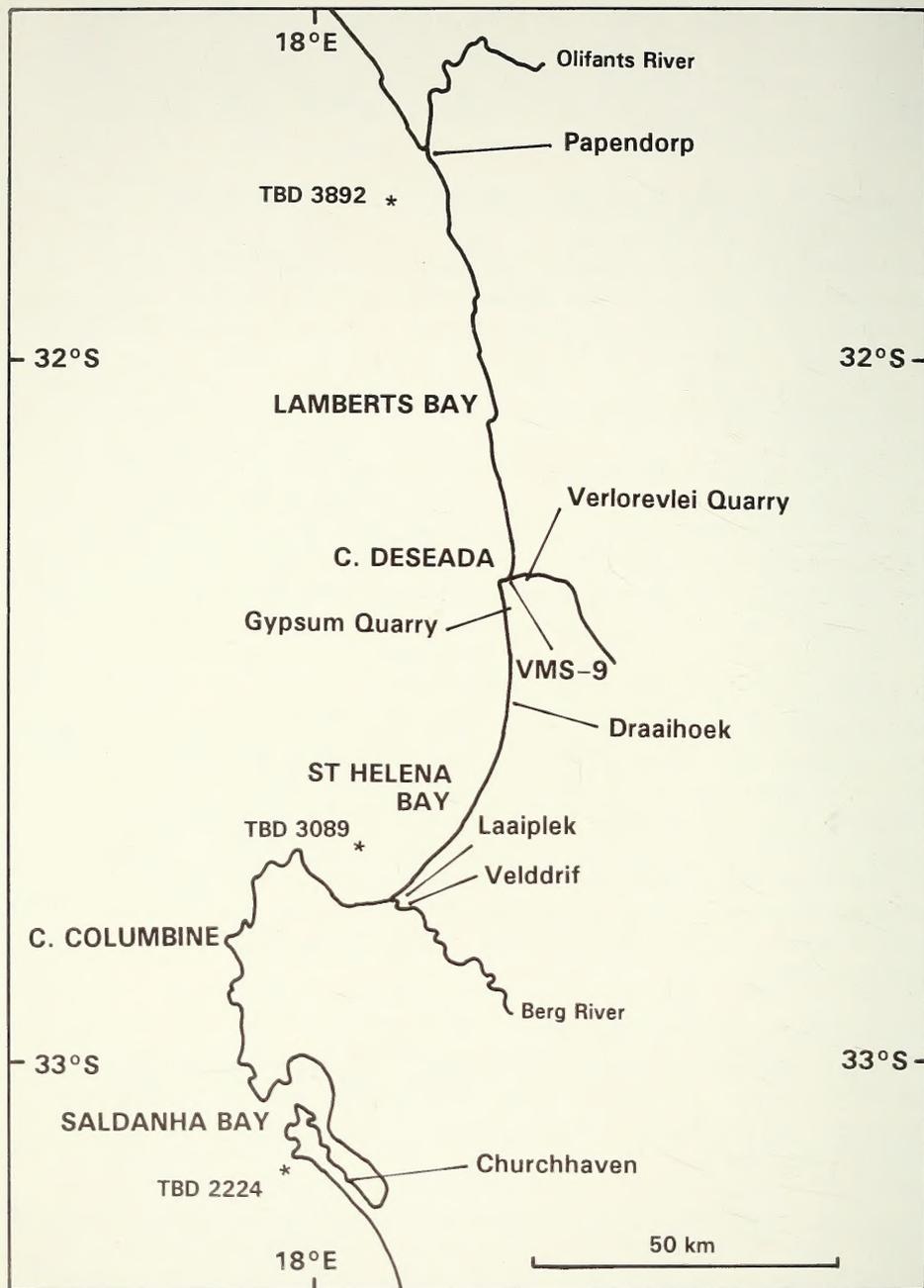


Fig. 1. Ostracodiferous sampling sites in Quaternary sediments, south-western Cape. Coordinates of localities and summaries of the sedimentary sequences are given in the text. TBD sites are offshore samples from the *Thomas B. Davie* dataset used by Dingle (1992, 1993, 1994).

SYSTEMATICS

The classification used here is based on Moore (1961), with various additions necessitated by subsequent work.

Abbreviations used: AM = anterior margin; ATE = anterior terminal element; C = carapace; DM = dorsal margin; LV = left valve; MA = marginal area; ME = median element; MPC = marginal pore canal; MS = muscle scars; NPC = normal pore canal; PM = posterior margin; PTE = posterior terminal element; RPC = radial pore canal; RV = right valve; SCT = sub-central tubercle; TE = terminal element; VM = ventral margin.

Type and illustrated specimens are housed at the South African Museum under catalogue numbers prefixed SAM-PQ-MF-.

Notation for sites: DH = Draaihoek; GQ = Gypsum Quarry (1); VMS = Vlei Mouth Sounding (at Verlorevelei); VQ = Verlorevelei Quarry.

Class CRUSTACEA Pennant, 1777

Subclass OSTRACODA Latreille, 1806

Order PODOCOPIIDA Müller, 1894

Suborder PODOCOPIIDA Sars, 1866

Superfamily CYPRIDACEA Baird, 1845

Family **Cyprididae** Baird, 1845

Subfamily Cypridinae Baird, 1845

Genus *Heterocypris* Claus, 1893

Heterocypris capensis (Müller, 1908)

Fig. 2A-F

Cyprinotus capensis Müller, 1908: 162-163, text-figs 1-7.

Heterocypris capensis (Müller, 1908) Sars, 1924: 118-119, pl. 4 (figs 5-20).

Illustrated material

	length	height
MF-1667, RV, DH sample 43	1.19	0.69
MF-1668, LV, DH sample 43	1.43	0.80
MF-1669, C, DH sample 43	1.30	0.59
MF-1670, LV, DH sample 43	1.20	0.69
MF-1671, RV, DH sample 43	1.35	0.72

Remarks

Adult valves of this relatively large, thin-shelled species occurred mostly fragmented in our samples. As shown by illustrations in both Müller (1908) and Sars (1924), it is characterized by an upcurved AM in the RV, which in dorsal view is wrapped around by the AM of the larger LV. We present SEM micrographs of the MS and hinge of this species for the first time.

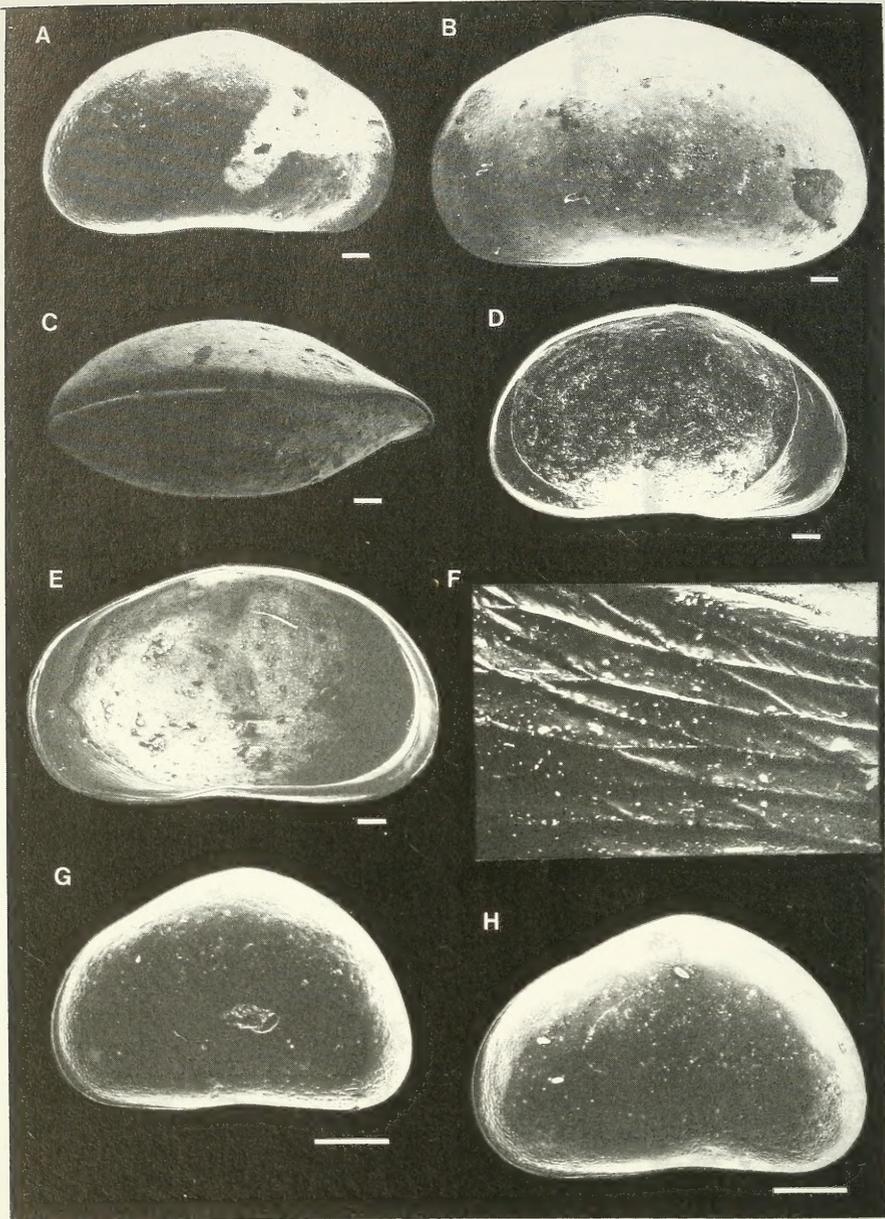


Fig. 2. A-F. *Heterocypris capensis* (Müller, 1908), Draaihoek, sample 43. A. MF-1667, RV, SEM 4414. B. MF-1668, LV, SEM 4482. C. MF-1669, C, dorsal view, SEM AH261. D. MF-1670, LV, internal view, SEM AH253. E-F. MF-1671, RV, internal view. E. SEM 4453. F. Detail, anteroventral area, SEM 4454. G-H. *Sarscypridopsis ?aculeata* (Costa, 1847). G. MF-1672, LV, GQ, sample 80. H. MF-1673, LV, DH, sample 39. Scale bars: A-E, G-H = 100 μ ; F = 10 μ .

Distribution

McKenzie (1971) summarized the localities from which this species had previously been reported, and these were confined to the freshwater ponds and lakes in the region between Saldanha Bay and Fish Hoek: Zeekoevlei, Plumstead, Fish Hoek, Bergvliet and 'near Cape Town' on the Cape Peninsula, and near the old whaling station in Saldanha Bay. In the present study, *Heterocypris capensis* was restricted to Draaihoek, where it forms an important element of the fauna, particularly in the upper section (up to 46%).

Genus *Sarscypridopsis* McKenzie, 1977

Sars (1924) reported 17 species of this genus (as *Cypridopsis*) from the Cape Province, 12 of which he recognized in the south-western Cape. Of these, nine have generally rounded sub-triangular lateral and elliptical dorsal outlines (*Sarscypridopsis gregaria*, *S. spinifera*, *S. aculeata*, *S. reniformis*, *S. tonsa*, *S. ochracea*, *S. echinata*, *S. trigonella* and *S. brevis*), so that subdivision into different species, particularly in juvenile forms, is an uncertain exercise. We have tentatively identified two of the species recorded by Sars (1924), one with a distinctly triangular outline (*S. aculeata*), and the other with a distinctly reniform outline (*S. reniformis*). We feel that it would be inappropriate to attempt to isolate some of the more intermediate types (e.g. *S. tonsa*).

Sarscypridopsis ?aculeata (Costa, 1847)

Figs 2G–H, 3A–E

Compare:

Cypris aculeata Costa, 1847: 11, pl. 3 (fig. 5).*Cypridopsis aculeata* (Costa, 1847) Brady, 1867: 117. Sars, 1924: 160–161, pl. 14 (figs 3–4).'*Cypridopsis*' *aculeata* (Costa, 1847) McKenzie, 1971: 167.*Sarscypridopsis aculeata* (Costa, 1847) McKenzie, 1977: 49. De Deckker, 1981: 81–84, figs 27–28.*Illustrated material*

	length	height	width
MF-1672, LV, GQ sample 80	0.46	0.30	—
MF-1673, LV, DH sample 39	0.52	0.36	—
MF-1674, RV, DH sample 39	0.49	0.34	—
MF-1675, C, DH sample 41	0.48	—	0.24
MF-1676, RV, DH sample 42	0.53	0.38	—
MF-1677, LV, DH sample 47	0.49	0.31	—

Remarks

Sars (1924) distinguished this species from two of his own (*Sarscypridopsis gregaria* (Sars, 1895) and *S. spinifera* (Sars, 1924)) on the basis of its 'somewhat more steeply' sloping posterodorsal margin, and its shorter and stouter spines (which, however, are not preserved fossilized). From his illustrations

(1924, pls 13–14), however, the three species appear to be very similar in outline, and we are not confident of our choice between them. De Deckker (1981) considers *S. spinifera* to be synonymous with *S. aculeata*, and that *S. aculeata* includes both spinose and non-spinose forms (such as *Cypridopsis obstinata* Barclay, 1968, from New Zealand).

Distribution

Sarscypridopsis aculeata has been recognized throughout Europe, Iceland, central Asia and North Africa (Sars 1924), Australia and New Zealand (De Deckker 1981), and in South Africa from the vicinity of the Cape Peninsula, and at one site in the Transvaal (McKenzie 1971). Sars himself recorded it only from a pool on the Cape Flats, whereas he noted *S. gregaria* from Knysna, Bergvliet and Saldanha Bay, and *S. ochracea* from the Cape Flats and near Cape Town.

De Deckker (1981) remarked that this cosmopolitan species is commonly found in temporary pools in Australia. He quoted a salinity range of fresh to 11.2‰ (one exceptional record of 21.3‰), and noted that these values are much higher than recorded from Europe; he suggested that the species has adapted to more arid conditions in Australia. Presumably, a similar logic could be applied to the southern African populations.

In the present study, we recorded this species at three localities: at Draaihoek it occurs throughout the upper section, and is the dominant species in the top part (30–74%); as a minor component at four levels scattered throughout the Gypsum exposure (maximum 8%); and at site 11 at Velddrif.

Sarscypridopsis ?reniformis (Sars, 1924)

Figs 3F–H, 4A–C

Compare:

Cypridopsis reniformis Sars, 1924: 161–162, pl. 14 (figs 7–8).

Illustrated material

	length	height	width
MF-1678, LV, DH sample 39	0.69	0.41	—
MF-1679, RV, GQ sample 86	0.55	0.32	—
MF-1680, C, GQ sample 86	0.60	—	0.29
MF-1681, RV, DH sample 39	0.63	0.40	—
MF-1682, LV, DH sample 39	0.65	0.37	—

Remarks

This species is recognized on the basis of its reniform outline, where Sars (1924) emphasized that the highest point of the valve lies at about mid-length. It is distinguished from *Sarscypridopsis aculeata* by its more elongate outline, and from the similar *S. ochracea*, which has its highest point consistently in the anterior half of the valve.

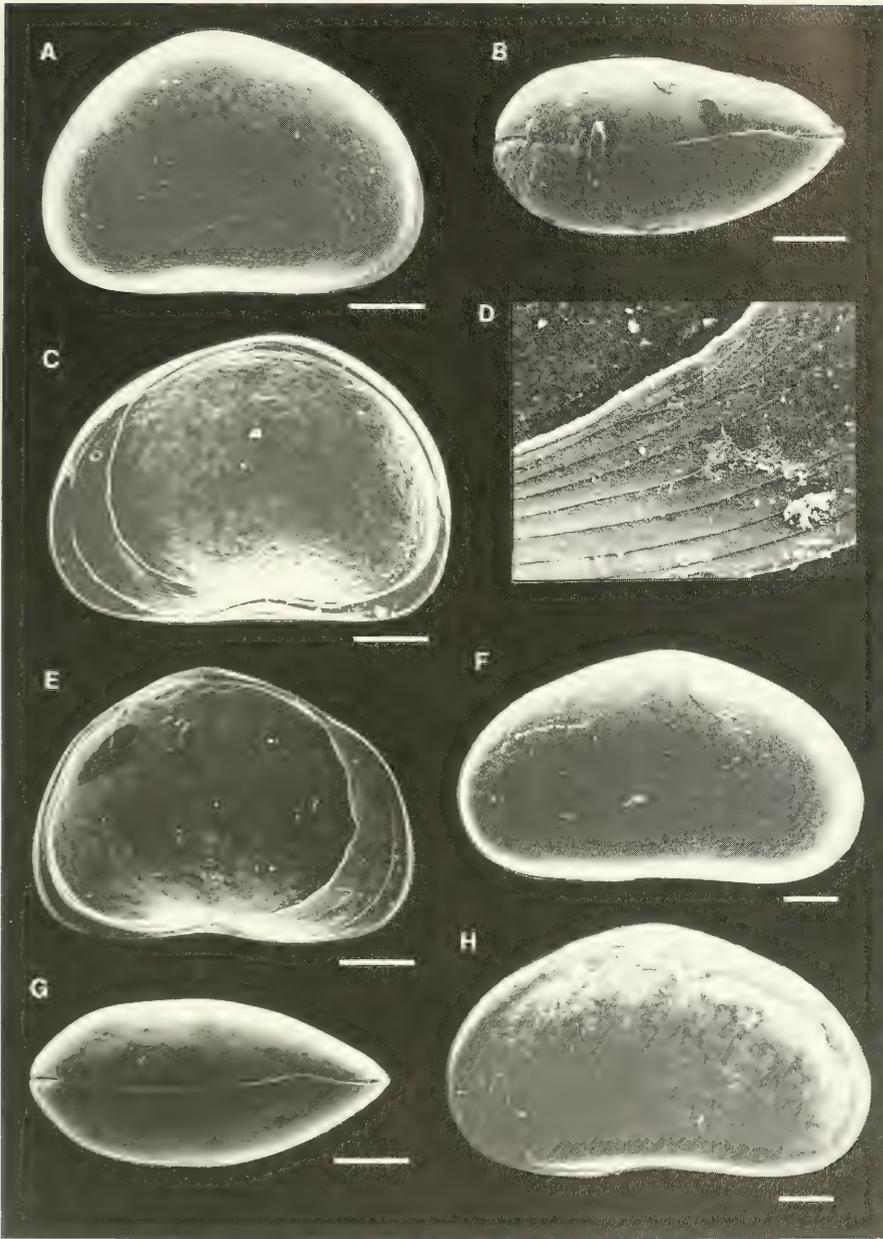


Fig. 3. A-E. *Sarscypridopsis ?aculeata* (Costa, 1847), Draaihoek. A. MF-1674, RV, sample 39, SEM 4412. B. MF-1675, C, dorsal view, sample 41, SEM 4485. C. MF-1676, RV, internal view, sample 42, SEM AH243. D-E. MF-1677, LV, internal view, sample 47. D. Detail, anteroventral area, SEM 4431. E. MS, SEM 4429. F-H. *Sarscypridopsis ?reniformis* (Sars, 1924). F. MF-1678, LV, Draaihoek, sample 39, SEM 4408. G-H. Gypsum Quarry, sample 86. G. MF-1680, C, dorsal view, SEM 4388. H. MF-1679, RV, SEM 4386. Scale bars: A-C, E-H = 100 μ ; D = 10 μ .

Distribution

Sars (1924) recorded this species only from near Fish Hoek station on the False Bay coast. In the present study, we found it at three localities: it is most common at Draaihoek, where the species occurs at almost every level, being most abundant in the lower part of the upper section; in the Gypsum Quarry, where it is moderately abundant at various levels throughout the sequence; and in sample 11 from Velddrif.

Tankard (1976) recorded one species of *Sarscypridopsis* (as *Cypridopsis ochracea*) from the Gypsum Quarry. We suspect that this is most likely to have been *S. reniformis*.

Family **Paracyprididae** Sars, 1923Genus *Aglaiella* Daday, 1910*Aglaiella railbridgensis* Benson & Maddocks, 1964

Fig. 4D-H

Aglaiella railbridgensis Benson & Maddocks, 1964: 16-17, pl. 1 (figs 7, 9-10), text-fig. 7.
Hartmann, 1974: 357-358, pl. 138 (figs 952-961).

Illustrated material

	length	height
MF-1683, LV, GQ sample 85	0.90	0.40
MF-1684, RV, GQ sample 85	0.85	0.35
MF-1685, LV, GQ sample 85	0.90	0.42
MF-1686, RV, GQ sample 85	0.84	0.35

Remarks

Hartmann (1974) described a further species of *Aglaiella* (*A. kenmckenziei*) from the coast of Angola, which is distinguished from Benson & Maddocks's species by having a less strongly arched DM and a slightly different arrangement of the MS. Our material is comparable with *A. railbridgensis* in both these aspects.

Distribution

Previously recorded only from the railbridge and Leisure Island sites in Knysna Lagoon by Benson & Maddocks (1964) and Hartmann (1974), where salinities range 30-31‰ and 33-35‰, respectively, and the substrates are muddy sand and fine sands (Benson & Maddocks 1964).

In the present study, *Aglaiella railbridgensis* is relatively rare, being found only as a single valve in the Verlorevlei Quarry (sample 24), and in small numbers (up to 4%) at the top of the Gypsum Quarry section (samples 85-86). Tankard (1976) listed this species as a minor component at Kruispad (sample 12).

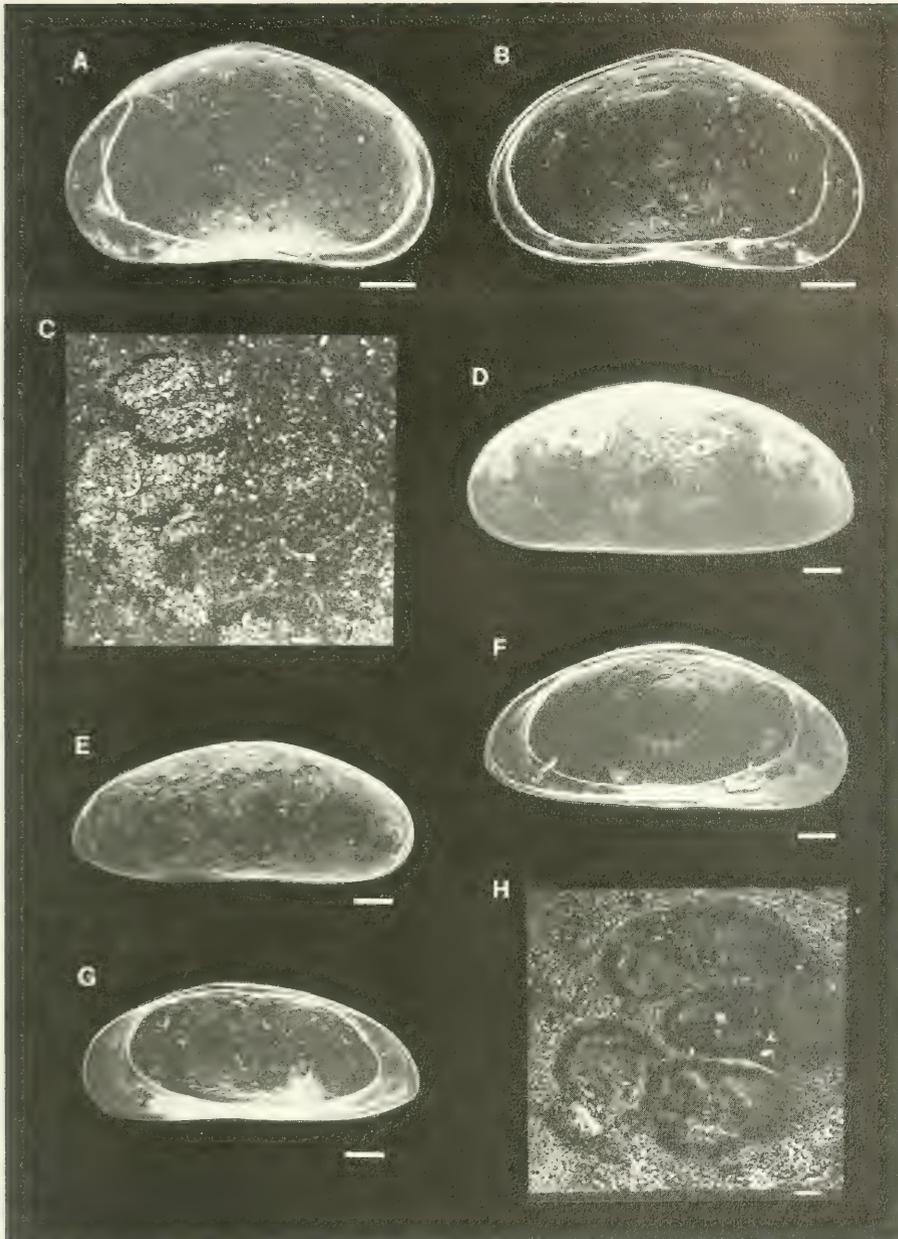


Fig. 4. A-C. *Sarscypridopsis ?reniformis* (Sars, 1924), Draaihoek, sample 39. A. MF-1681, RV, internal view, SEM AH233. B. MF-1682, LV, internal view, SEM 4409. C. MS, SEM 4411. D-H. *Aglaiella railbridgensis* Benson & Maddocks, 1964, Gypsum Quarry, sample 85. D. MF-1683, LV, SEM 4396. E. MF-1684, RV, SEM AH166. F. MF-1685, LV, internal view, SEM AH167. G. MF-1686, RV, internal view, SEM AH172. H. MF-1685, LV, MS, SEM AH171. Scale bars: A-B, D-G = 100 μ ; C, H = 10 μ .

Genus *Paracypris* Sars, 1866*Paracypris westfordensis* Benson & Maddocks, 1964

Fig. 5A-G

Paracypris westfordensis Benson & Maddocks, 1964: 15-16, pl. 1 (figs 4, 11-12), text-fig. 6.

Illustrated material

	length	height	width
MF-1687, LV, GQ sample 86	0.91	0.45	—
MF-1688, RV, GQ sample 86	0.92	0.40	—
MF-1689, C, GQ sample 86	0.96	—	0.40
MF-1690, LV, GQ sample 85	1.00	0.49	—
MF-1691, RV, DH sample 49	0.92	0.40	—

Remarks

The MS of our specimens are identical with those illustrated by Benson & Maddocks (1964), in particular the large 'cap' adductor scar.

Distribution

Previously, this species had been recorded unequivocally only from the Knysna estuary, where it was confined to the upper reaches at the Westford Bridge and Ashford (one, probably transported valve, had been recorded farther downstream at the railbridge) (Benson & Maddocks 1964). Salinity ranges at these two sites are 16.5-22‰ and 18.0-24.0‰, respectively, and the substrates are soft black mud (Benson & Maddocks 1964). Hartmann (1974) did not record it from any of his coastal sites along the southern and south-western coasts of southern Africa, and Dingle (1992, 1993) did not report it offshore. This distribution suggests a strictly brackish water habitat.

In the present study, *Paracypris westfordensis* is never an abundant species, but we have recorded it from three localities. There is a single valve from the Verlorevelei Quarry (sample 24), whereas it occurs in small numbers throughout the Draaihoek section, reaching a maximum of 16 per cent in sample 40 in the middle part. At the Gypsum Quarry, the species also occurs sparsely in the middle and upper parts of the section (maximum of 3% near the top).

Tankard (1976) recorded this species at Laaiplek (5%).

Superfamily BAIRDIACEA Sars, 1887

Family **Bairdiidae** Sars, 1887

Genus *Paranesidea* Maddocks, 1969

Paranesidea verloreveleiensis sp. nov.

Figs 5H, 6A-F

Derivation of name

The name of this species is derived from Verlorevelei, the locality of the type material.

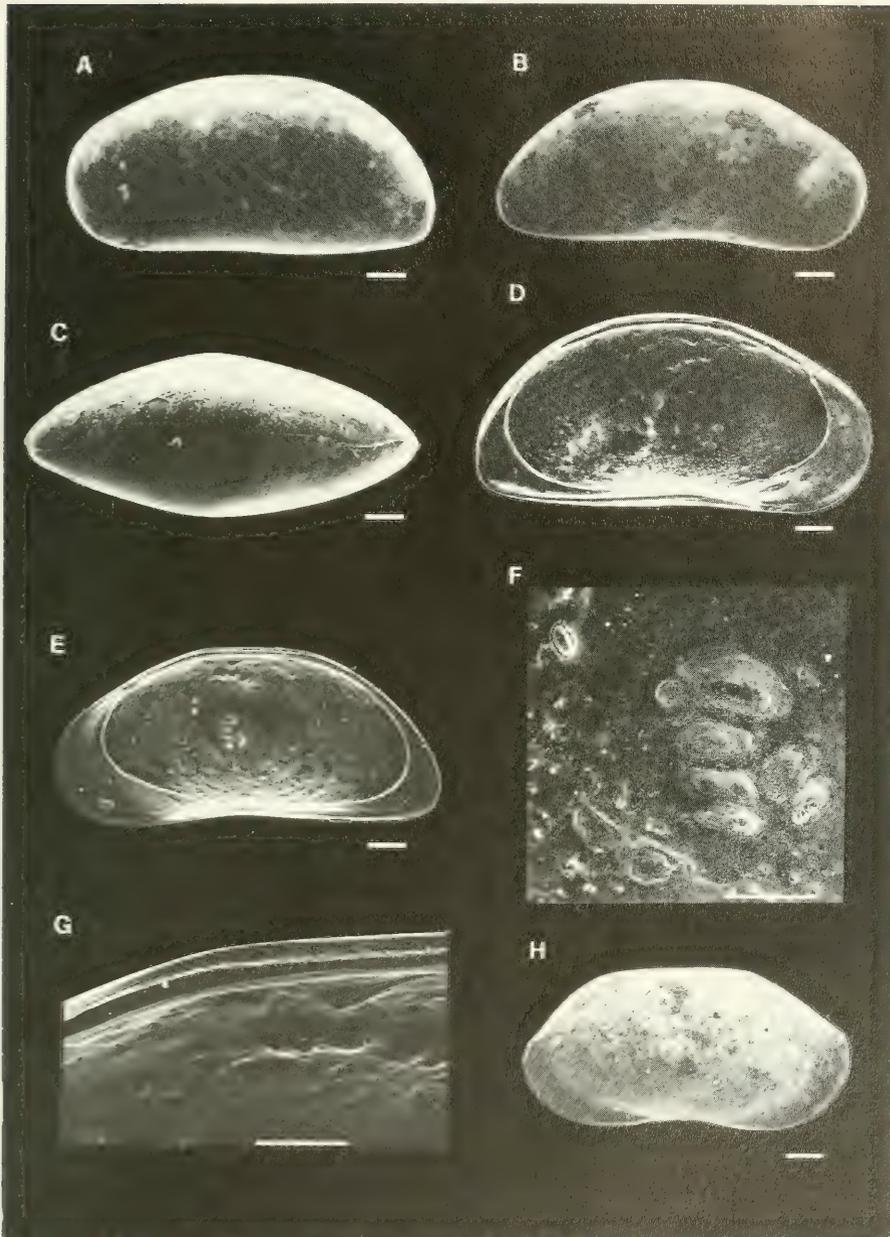


Fig. 5. A-G. *Paracypris westfordensis* Benson & Maddocks, 1964. A-D. Gypsum Quarry. A-C. Sample 86. A. MF-1687, LV, SEM AH064. B. MF-1688, RV, SEM AH066. C. MF-1689, C, dorsal view, SEM 4385. D. MF-1690, LV, internal view, sample 85, SEM AH068. E-G. MF-1691, RV, internal view, Draaihoek, sample 49. E. SEM 4432. F. MS, SEM 4434. G. Hinge and dorsal scars, SEM 4435. H. *Paranesidea verloreveleiensis* sp. nov., holotype, MF-1692, RV, Verlorevelei Quarry, sample 24, SEM 4488.

Scale bars: A-E, H = 100 μ ; F-G = 50 μ .

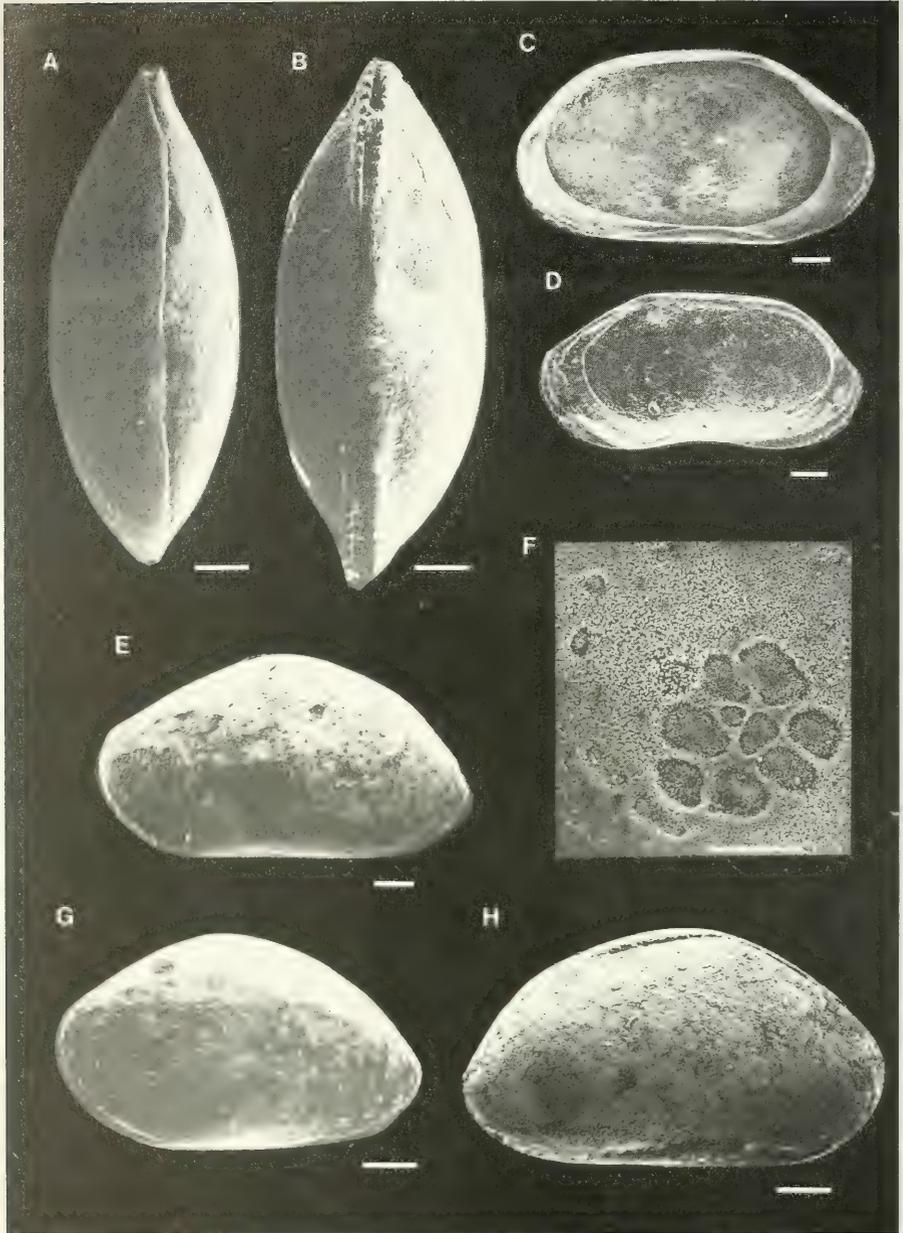


Fig. 6. A-F. *Paranesidea verloreveleiensis* sp. nov., Verlorevelei Quarry, sample 24. A. Paratype, MF-1695, C, dorsal view, SEM 4446. B. Paratype, MF-1694, C, ventral view, SEM 4444. C. Paratype, MF-1696, LV, internal view, SEM 4441. D. Holotype, MF-1692, RV, SEM 4437. E. Paratype, MF-1693, LV, SEM AH437. F. MF-1745, RV, MS, SEM 4460. G-H. Indeterminate bairdiid. G. MF-1697, LV, Gypsum Quarry, sample 78, SEM AH161. H. MF-1698, C, right view, Verlorevelei Quarry, sample 24, SEM 4462. Scale bars: A-E, G-H = 100 μ ; F = 50 μ .

Holotype

	length	height	width
MF-1692, RV, VQ sample 24	0.78	0.38	—

Paratypes

MF-1693, LV, VQ sample 24	0.91	0.48	—
MF-1694, C, VQ sample 24	0.89	—	0.35
MF-1695, C, VQ sample 24	0.85	—	0.34
MF-1696, LV, VQ sample 24	0.86	0.48	—
MF-1745, RV, VQ sample 24	1.05	0.57	—

Diagnosis

Finely punctate species of *Paranesidea* with denticulate posterior and anterior margins and selvages.

Description

External features. Elongate bairdiid outline, RV and LV differ in shape, particularly the DM, which is straight in RV and gently convex in LV. VM in RV is concave, almost straight in LV. AM outline in both valves is truncated dorsally, PM in RV is more drawn out. AM and PM in both valves are denticulate. Carapace in dorsal and ventral views is extended ovate. In ventral view AM and PM both show gapes, with contact along selvage. Overall, valve surface is delicately punctate.

Internal features. Hinge straight, smooth. MS consist of eight round-ovate scars set in tight spiral. In both valves (but particularly in RV) there is a prominent selvage which, anteriorly and posteriorly, is denticulate.

Remarks

Paranesidea verloreivleiensis has all the attributes of the genus as specified by Maddocks (1969), although the DM of the LV is less strongly arched than the type species (*P. fracticorallicola* Maddocks, 1969), and the surface ornamentation is less pronounced than in other species. Our new species is quite distinctive amongst other southern African bairdiid ostracods, with its prominently denticulate PM and AM. Only Hartmann's species *Bairdoppilata mocamedensis* and *?Bairdia problematica* (which Maddocks (1991) tentatively placed in *Aponesidea*) exhibit prominent marginal denticulation. The former is denticulate only along the PM and does not have a straight DM in the RV, whereas the latter has an upturned AM outline in the RV and a different MS pattern to our new species. The genus is represented by several species in the Tertiary of Tanzania (Ahmad *et al.* 1991), but none are as elongate in lateral view as the new taxon.

Distribution

Although bairdiid ostracods have been widely reported from the shelf and coastal areas of southern Africa by various workers (e.g. Brady 1880; Benson & Maddocks 1964; Hartmann 1974; Dingle 1992, 1993), none have recorded a

species similar to *Paranesidea verlorevleiensis* sp. nov., which is confined to one outcrop (Verlorevlei Quarry, sample 24). The only previous record of bairdiids from coastal sediments of the region was by Tankard (1976) of *Bairdia* cf. *B. villosa* from Churchhaven.

Maddocks (1969) suggested that the genus is typical of tropical conditions, and that it is characteristic of very shallow sublittoral waters, and unable to tolerate variable salinities.

Indeterminate bairdiid

Fig. 6G-H

Illustrated material

	length	height
MF-1697, LV, GQ sample 78	0.62	0.39
MF-1698, C, VQ sample 24	0.75	0.42

Remarks

Twenty-nine valves were recovered from sample 24 in the Verlorevlei Quarry; one juvenile valve was recovered from sample 78 in the middle of the Gypsum Quarry section. The latter displays a strongly tapering PM outline, strong posteriorly directed PM denticles, and widely spaced NPC. Bairdiids are generally regarded as marine species.

Superfamily CYTHERACEA Baird, 1850

Family **Loxoconchidae** Sars, 1925

Genus *Palmoconcha* Swain & Gilby, 1974

Palmoconcha? cf. *P. peterseni* (Hartmann, 1974)

Fig. 7A-B

Compare:

Loxoconcha peterseni Hartmann, 1974: 296-297, pl. 67 (figs 477-487), pl. 151 (figs 3-4).

Illustrated material

	length	height
MF-1699, RV, GQ sample 78	0.64	0.48

Remarks

The one specimen available to us compares favourably with Hartmann's species in outline, particularly the prominent posteroventral keel and the drawn-out AM outline. Our specimen has somewhat more distinct concentric ribbing in the central part of the valve, and the surface punctation is stronger.

Distribution

Hartmann (1974) recorded *Palmoconcha peterseni* from sandy boulder beaches in Angola, and speculated that the species is currently confined to the tropical-subtropical sectors of the Benguela system. We recovered one corroded specimen of this species from sample 78 in the Gypsum Quarry, and Tankard (1976) reported Hartmann's species from Laaiplek and Churchhaven. We cannot confirm Tankard's identifications, and there were no negatives of lox-conchid ostracods in Tankard's collection of the Rhodes University SEM archive.

Genus *Cytheromorpha* Hirschmann, 1909*Cytheromorpha milleri* sp. nov.

Figs 7C-H, 8A-D, 9A

Indet. sp. 3412 Dingle, 1993: 149, fig. 84B.

Derivation of name

This species is named for Dr D. Miller, Department of Archaeology, University of Cape Town, for his close association with, and assistance and encouragement during, this study.

Holotype

	length	height	width
MF-1700, RV, DH sample 36	0.60	0.29	—

Paratypes

MF-1701, RV, GQ sample 80	0.60	0.29	—
MF-1702, LV, DH sample JP	0.58	0.28	—
MF-1703, RV, DH sample 37	0.58	0.28	—
MF-1704, LV, DH sample 37	0.59	0.29	—
MF-1705, C, DH sample JP	0.60	—	0.27
MF-1706, C, DH sample JP	0.58	—	0.26
MF-1707, LV, DH sample JP	0.60	0.27	—

Diagnosis

Thin-shelled, sighted species of *Cytheromorpha* with three prominent ribs adjacent to the AM, and a smooth, puncta-free band adjacent to the postero-dorsal valve margin. The hinge ME is finely crenulate.

Description

External features. Elongate-ovate in lateral outline, AM asymmetric, with extended anterodorsal section. PM rounded in RV, more quadrate in LV, with distinct posterodorsal truncation. DM and VM straight, the latter slightly obscured by overhang of inflated central part of valve. In dorsal and ventral views, valves are almond-shaped, tapering anteriorly. There is a shallow sulcus, just anterior to mid-length, which extends obliquely from the dorsal margin

anteriorly to about mid-valve. Surface is overall ornamented with fine puncta and narrow ribs that run sub-parallel to the valve margins. In the central area of the valve, the ornamentation is somewhat coarser, and verges on finely reticulate. The three ribs that extend from the weak eye tubercle adjacent to the AM are particularly prominent, the posterior-most of which crosses ribs running ventrally and extends to the anteroventral margin. Intercostal areas are delicately punctate. The valve margin in the posterodorsal area is free of puncta and, in dorsal view, the valves display a distinctively smooth marginal band. There are numerous prominent normal sieve pores. The MS area is indicated on the lateral surface by a region of elongated, radiating puncta.

Internal features. Typical for the genus. The anterior MA is relatively wide (Fig. 9A), with a prominent vestibulum, and the line of concrescence close to the AM. There are at least 20 very short, fine MPC. The MS show a tick-shaped anterior scar, a prominent fulchral point, and two ventrally lying scars below the adductors. The hinge has a prominently denticulate ME, and the TE are bilobate: the RV PTE and LV ATE consisting of elongate, strongly subdivided teeth.

Remarks

This species is the same as that recovered as a damaged juvenile valve from TBD 3892 on the inner continental shelf off Namaqualand (depth 72 m, north-west of Lamberts Bay) by Dingle (1993), and designated Indeterminate sp. 3412. It was accompanied by specimens of *Propontocypris* (*P.*) cf. *P. subreniformis* (Brady, 1880). The genus was recorded by neither Klie (1940) nor Hartmann (1974) in their surveys of coastal sites off south-western Africa, but Tankard (1976) listed abundant *Cytheromorpha* sp. at Verlorevlei (sample 3), Laaiplek (sample 9) and Churchhaven (samples 21, 22). Because he did not illustrate this material, it is not possible to speculate whether any of these are conspecific with *C. milleri* sp. nov.

Our new species differs from Hirschmann's (1909) type species (*Cythere fuscata* Brady, 1869) in having a crenulate (as opposed to a smooth) ME, and in the MS, which in *C. milleri* sp. nov. have a small, wedge-shaped third adductor (see Fig. 8D).

Cytheromorpha knikensis Forester & Brouwers, 1985, has a more evenly fine reticulate ornamentation, is not sighted, and has a smooth hinge ME. Two species have very similar ornamentation to *C. milleri* sp. nov.: *C. suffolkensis* Hazel, 1983 (Pliocene, North Carolina) and *C. acupunctata* (Brady, 1880) (for example, as illustrated by Ikeya & Ueda (1988), and Yajima & Lord (1990) from the Quaternary of the Sea of Japan, eastern China, Korea and eastern Japan), but both differ in having significantly more tapered posterior outlines, and somewhat coarser ornamentation in the posteroventral region. In addition, the MA of the North American species is much wider than in *C. milleri* sp. nov.

The presence of an eyespot, and a crenulate hinge ME may cast some doubt upon the placement of our species in the genus *Cytheromorpha*, but the typical outline, ornamentation, MS and hingement (other than the ME crenulation) suggest that the creation of a new genus would be premature without additional comparative species.

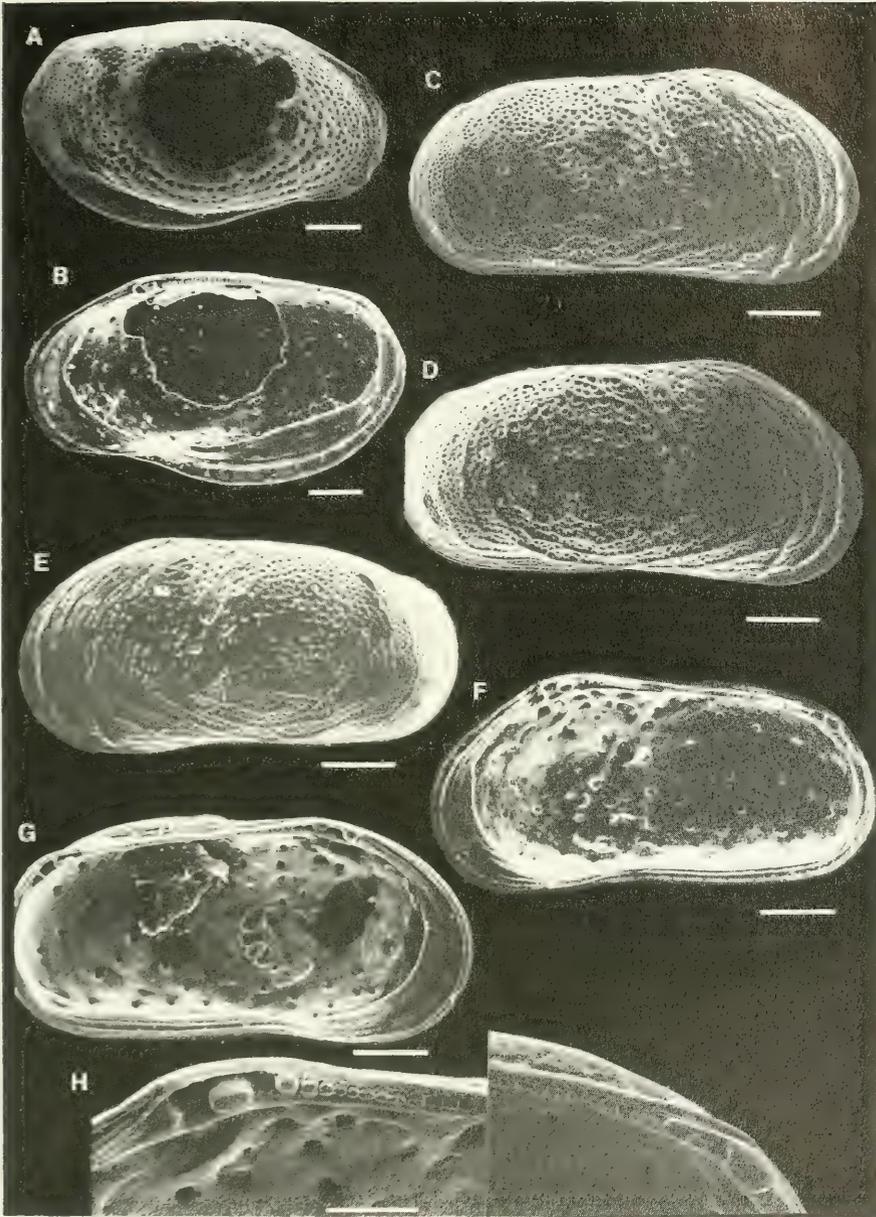


Fig. 7. A-B. *Palmoconcha?* cf. *P. peterseni* (Hartmann, 1974), MF-1699, RV, Gypsum Quarry, sample 78. A. Internal view, SEM 4463. B. SEM AH159. C-H. *Cytheromorpha milleri* sp. nov. C. Holotype, MF-1700, RV, Draaihoek, sample 36, SEM AH331. D-H. Paratypes. D. MF-1701, RV, Gypsum Quarry, sample 80, SEM AH218. E. MF-1702, LV, Draaihoek, sample JP, SEM AH329. F-H. Draaihoek, sample 37. F. MF-1703, RV, internal view, SEM AH283. G. MF-1704, LV, internal view, SEM 4419. H. MF-1703, ATM and PTM, SEM 4426, 4427.

Scale bars: A-G = 100 μ ; H = 50 μ .

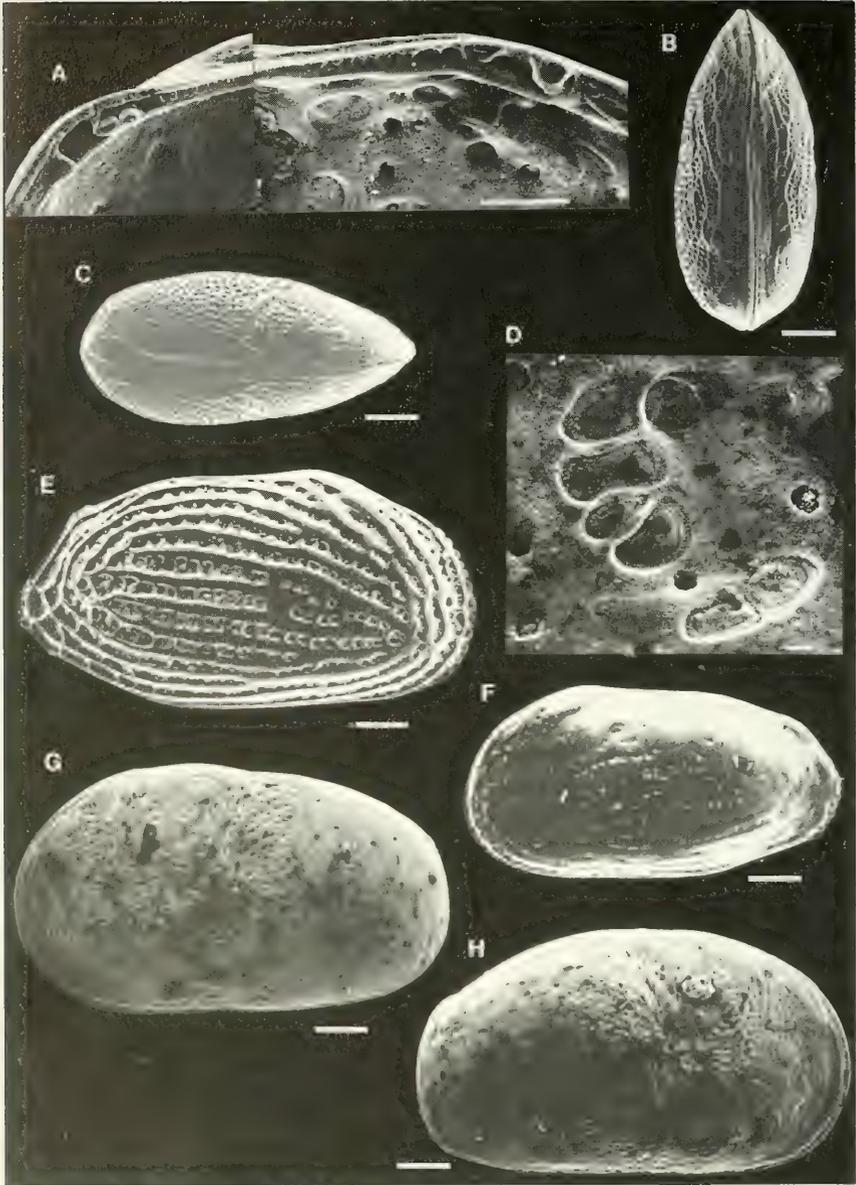


Fig. 8. A-D. Paratypes, *Cytheromorpha milleri* sp. nov. A. MF-1704, LV, ATE and PTE, Draaihoek, sample 37, SEM 4422, 4421. B. MF-1706, C, ventral view, Draaihoek, sample JP, SEM AH291. C. MF-1705, dorsal view, Draaihoek, sample JP, SEM AH338. D. MF-1704, LV, MS, Draaihoek, sample 37, SEM 4423. E-F. *Garciaella knysnaensis* (Benson & Maddocks, 1964), Gypsum Quarry, sample 78. E. MF-1708, RV, SEM AH153. F. MF-1709, LV, juvenile, SEM AH158. G-H. *Cyprideis remanei* Klie, 1940. G. MF-1710, LV, Gypsum Quarry, sample 83, SEM AH199. H. MF-1711, RV, Gypsum Quarry, sample 84, SEM AH203. Scale bars: B-C, E-H = 100 μ ; A = 50 μ ; D = 10 μ .

Distribution

Cytheromorpha milleri sp. nov. has been recovered in large numbers from the lower part of the Draaihoek exposure (samples 37–35 and JP), where it constitutes 5–94 per cent (mean: 70%) of the fauna, and a single valve from the middle part of the Gypsum Quarry exposure (sample 80). The single valve recovered from the inner continental shelf by Dingle (1993—TBD 3892, depth 72 m) lies off the Olifants River mouth.

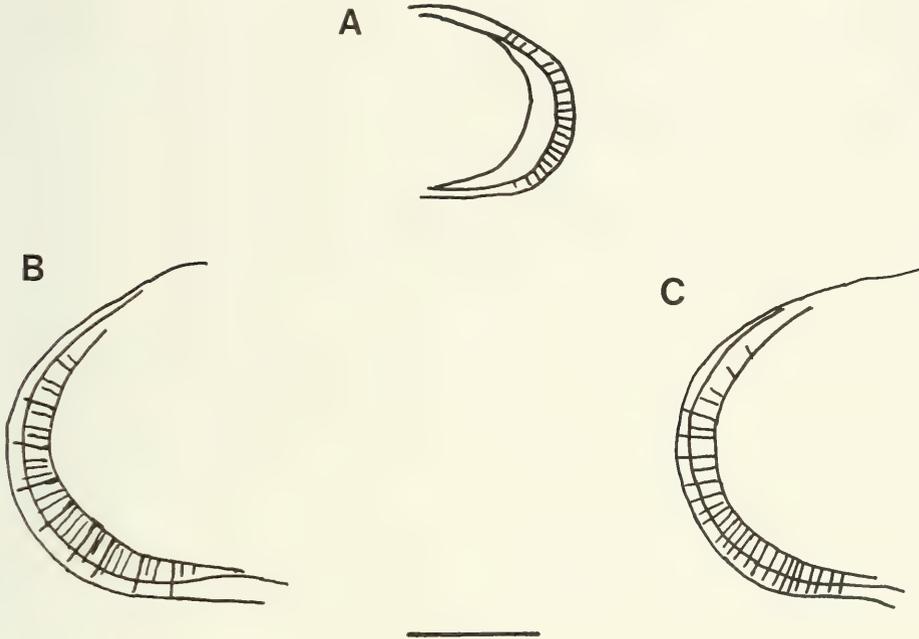


Fig. 9. Anterior marginal areas. A. *Cytheromorpha milleri* sp. nov., paratype, MF-1707, LV, Draaihoek, sample JP. B. *Cyprideis remanei* Klie, 1940, MF-1718, RV, Gypsum Quarry, sample 86. C. *Cyprideis draaihoekensis* sp. nov., paratype, MF-1726, RV, Gypsum Quarry, sample 86. Scale bar: 200 μ .

Family **Cytherettidae** Triebel, 1952Subfamily **Cytherettinae** Howe, 1961Genus *Garciaella* gen. nov.

Bensonia Rossi de Garcia, 1969: 218–219, pl. 1 (figs 1a–c, 3).

non *Bensonia* (Cantor MS) Gray, 1847: 150.

non *Bensonia* Pfeiffer, 1855: 119.

non *Bensonia* Malaise, 1935: 166.

non *Argenticytheretta* Rossi de Garcia, 1969, emend. Sanguinetti, de Ornellas & Coimbra, 1991: 139.

Type species: Cytheretta argentinensis Rossi de Garcia, 1966.

Derivation of name

This taxon is named for Dr Elsa Rossi de Garcia, who first recognized the new genus.

Remarks

Rossi de Garcia (1969) erected the ostracod genus *Bensonia* to accommodate her species *Cytheretta argentinensis*. In the same publication, she also erected two related cytherettid taxa (*Grekoiffiana* and *Argenticytheretta*). The non-availability of the name *Bensonia*, pre-occupied for molluscan taxa (Gray 1847; Pfeiffer 1855) led Sanguinetti *et al.* (1991) to transfer species previously assigned to *Bensonia* to *Argenticytheretta*, because they assumed that the two genera were synonymous (along with *Grekoiffiana*: see Sanguinetti 1979). Correspondence with Dr E. Bertels (pers. comm. 1993) on the subject of the type material, along with our own interpretation of Rossi de Garcia's original descriptions, lead us to believe that *Cytheretta argentinensis* Rossi de Garcia does indeed belong in a genus distinct from the types of both *Argenticytheretta* and *Grekoiffiana*. Hence, we propose the new name *Garciaella* to replace *Bensonia*.

Garciaella knysnaensis knysnaensis (Benson & Maddocks, 1964)

Fig. 8E–F

Cytheretta knysnaensis Benson & Maddocks, 1964: 22–23, pl. 2 (figs 7–11), text-figs 11–12.
Bensonia knysnaensis (Benson & Maddocks, 1964) Rossi de Garcia, 1969: 219. Keeler, 1981: 43–45, pl. 2 (figs 2–4).
Cytheretta sp. Boomer, 1985: 24–25, pl. 3 (fig. 44).
Bensonia knysnaensis knysnaensis (Benson & Maddocks, 1964) Dingle, 1992: 32–34, fig. 18A–F.

Illustrated material

	length	height
MF-1708, RV, GQ sample 78	0.80	0.41
MF-1709, LV, juv., GQ sample 78	0.68	0.35

Distribution

This species has previously been recorded from both estuarine (Leisure Island in Knysna Lagoon) and inner continental shelf environments (between 19°S on the west coast and 24°E on the south coast) (Benson & Maddocks 1964; Hartmann 1974; Keeler 1981; Dingle 1992). Benson & Maddocks (1964) suggested that it can tolerate salinities between 33 and 35‰, and from his study of the environmental parameters tolerated by individual species, Dingle (1994) suggested the following ranges and means for *Garciaella knysnaensis knysnaensis* on the continental shelf: temperature 7.1–13.28°C (10.31°C); salinity 34.6–35.18‰ (34.82‰); dissolved oxygen 0.9–4.3 ml/l (2.53 ml/l); sand content 47.3–95.9 per cent (68.8%); mud content 2.1–46.1 per cent (23%); total organic matter content 0.2–8.8 per cent (3.8%).

In the present study, *G. k. knysnaensis* occurs in small numbers in the middle section of the Gypsum Quarry (samples 78–79) and the lower part of the

Draaihoek sequence (sample 37, JP), whereas it is an important component of the small assemblages recovered from the two quarries at Laaipek (samples 15, 19). In addition, Tankard (1976) recorded the species at his outcrop sample 9 at Velddrif.

Family Cytherideidae Sars, 1925

Subfamily Cytherideinae Sars, 1925

Genus *Cyprideis* Jones, 1857

Hartmann (1974) distinguished three species of *Cyprideis*, each occupying particular sections along the west coast of southern Africa: *C. nigriensis* Omatsola, 1970, confined to the tropical region; *C. limbocostata* Hartmann, 1974, occupying the Angolan–Namibian coast as far south as Sandwich Harbour; and *C. remanei* Klie, 1940, occurring in the vicinity of Lüderitz. He did not recover any species from the Cape Province or east coast of South Africa, where the relevant ecological niches were considered to be occupied by species of *Sulcostocythere*. Furthermore, he suggested that the three species of *Cyprideis* were very closely related and possibly derived from a common ancestor. Environmental data supplied by Klie (1940) and Hartmann (1974) suggest that both *C. remanei* and *C. limbocostata* prefer coastal habitats with relatively high salinities (see pp. 87, 89).

Our studies show that in the late Quaternary, *C. remanei* extended its distribution at least as far south as the south-western Cape, and that it co-habitated with a further species, *C. draaihoekensis* sp. nov.

Cyprideis remanei Klie, 1940

Figs 8G–H, 9B, 10A–H

Cyprideis remanei Klie, 1940: 412–415, text-figs 11–17.

Illustrated material

	length	height	width
MF-1710, LV, GQ sample 83	0.77	0.44	—
MF-1711, RV, GQ sample 84	0.79	0.45	—
MF-1712, LV, DH sample 35	0.80	0.45	—
MF-1713, RV, DH sample 40	0.79	0.45	—
MF-1714, LV, GQ sample 86	0.79	0.45	—
MF-1715, RV, GQ sample 86	0.80	0.45	—
MF-1716, C, GQ sample 86	0.90	—	0.42
MF-1717, C, GQ sample 86	0.80	—	0.42
MF-1718, RV, GQ sample 86	0.90	0.51	—

Remarks

Klie's species has a distinctly quadrate outline, in contrast to the more elongate *Cyprideis limbocostata*, and the intermediate shape of our new species *C. draaihoekensis*. All the specimens available to us are smooth or covered in

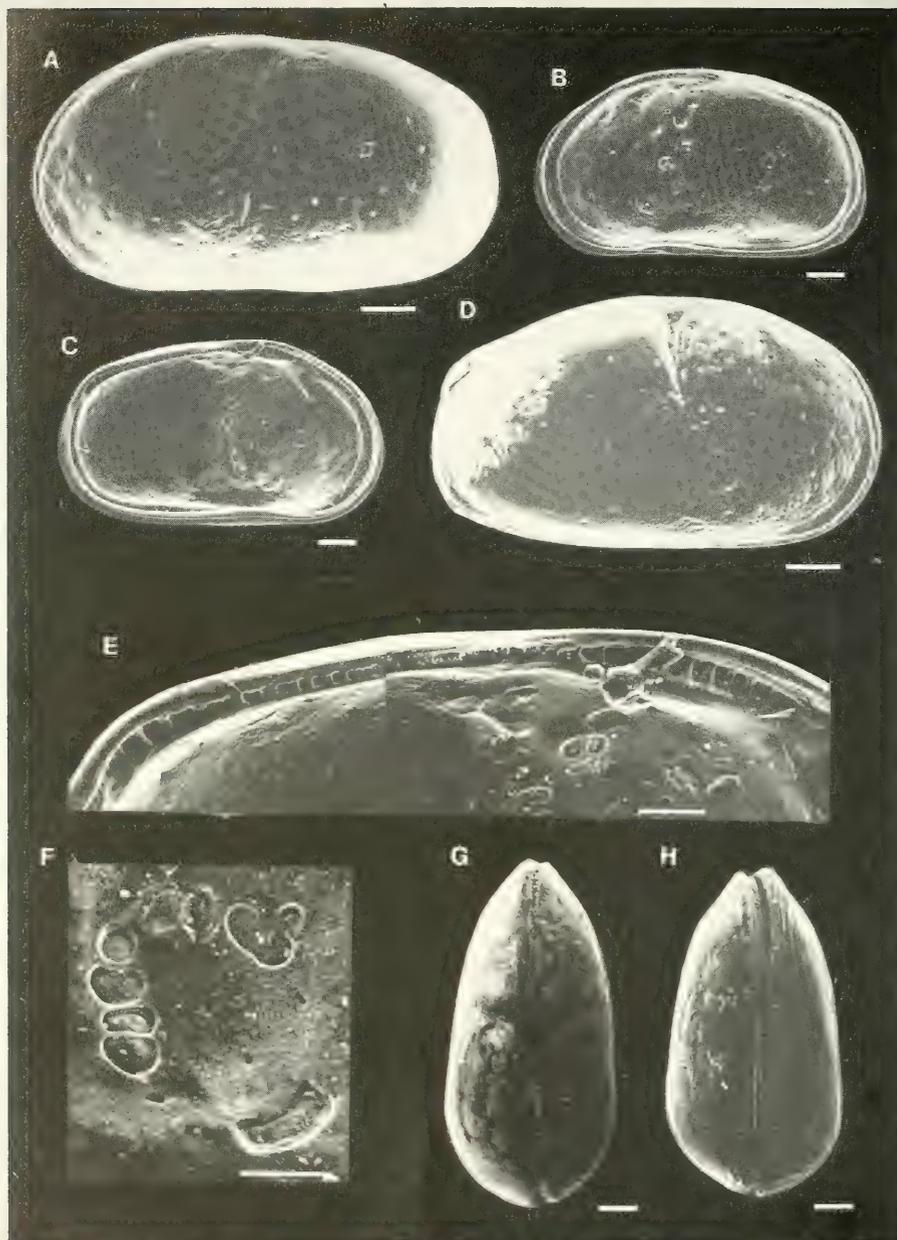


Fig. 10. A-H. *Cyprideis remanei* Klie, 1940. A. MF-1712, LV, Draaihoek, sample 35, SEM AH220. B. MF-1715, RV, internal view, Gypsum Quarry, sample 86, SEM 4373. C. MF-1714, LV, internal view, Gypsum Quarry, sample 86, SEM 4369. D. MF-1713, RV, Draaihoek, sample 40, SEM AH221. E-F. MF-1714, LV, Gypsum Quarry, sample 86. E. ATE and PTE, SEM 4372, 4371. F. MS, SEM 4370. G-H. Gypsum quarry, sample 86. G. MF-1716, C, dorsal view, SEM 4475. H. MF-1717, C, ventral view, SEM AH028. Scale bars: A-D, G-H = 100 μ ; E-F = 50 μ .

relatively small puncta, which lie in a swirl-like pattern in the sub-central region above the MS and adjacent to the dorsomedian sulcus. Females are distinctly bulbous in the posterior part of the valve.

The MS pattern of *C. remanei* is complex, with a loop on the anterior side of the anterior scar (similar to that of *C. stenopora* Triebel, 1952, illustrated by Van Morkhoven (1963: 291)), at least three dorsal scars, a fulchral point, and an elongate mandibular scar.

Distribution

Cyprideis remanei was recorded by Klie (1940) from the lagoon at the southern end of Lüderitz Bay, where Hartmann (1974: 272) noted the temperature and salinity as 9.5°C and 35.00‰, respectively.

This is the most abundant of the two species of *Cyprideis* in our samples, and occurs throughout the Draaihoek and most of the Gypsum Quarry sections. In both, it is frequently the dominant ostracod taxon. We recovered one valve from sample 24 in the Verlorevelei Quarry, but it is absent from Laaiplek and Velddrif.

Cyprideis draaihoekensis sp. nov.

Figs 9C, 11A-H, 12A-B

Derivation of name

The species is named for Draaihoek farm, locality of type specimens.

Holotype

	length	height	width
MF-1719, RV, DH sample 41	1.00	0.49	—

Paratypes

MF-1720, RV, GQ sample 83	0.95	0.47	—
MF-1721, LV, GQ sample 86	0.91	0.46	—
MF-1722, LV, GQ sample 86	0.90	0.45	—
MF-1723, RV, GQ sample 86	0.90	0.44	—
MF-1724, C, GQ sample 86	0.91	—	0.38
MF-1725, C, GQ sample 86	0.90	—	0.39
MF-1726, RV, GQ sample 86	1.00	0.45	—

Diagnosis

Large, ovate, laterally compressed species of the genus *Cyprideis*, in which the valve surface ranges from smooth to delicately punctate.

Description

External features. Large, ovate, thin-shelled species, laterally compressed. Presumed females somewhat inflated posterodorsally. DM broadly arched, VM almost straight. AM symmetrically rounded, PM slightly asymmetric, truncated dorsally. LV tend to be slightly more quadrate posterodorsally. There is only a

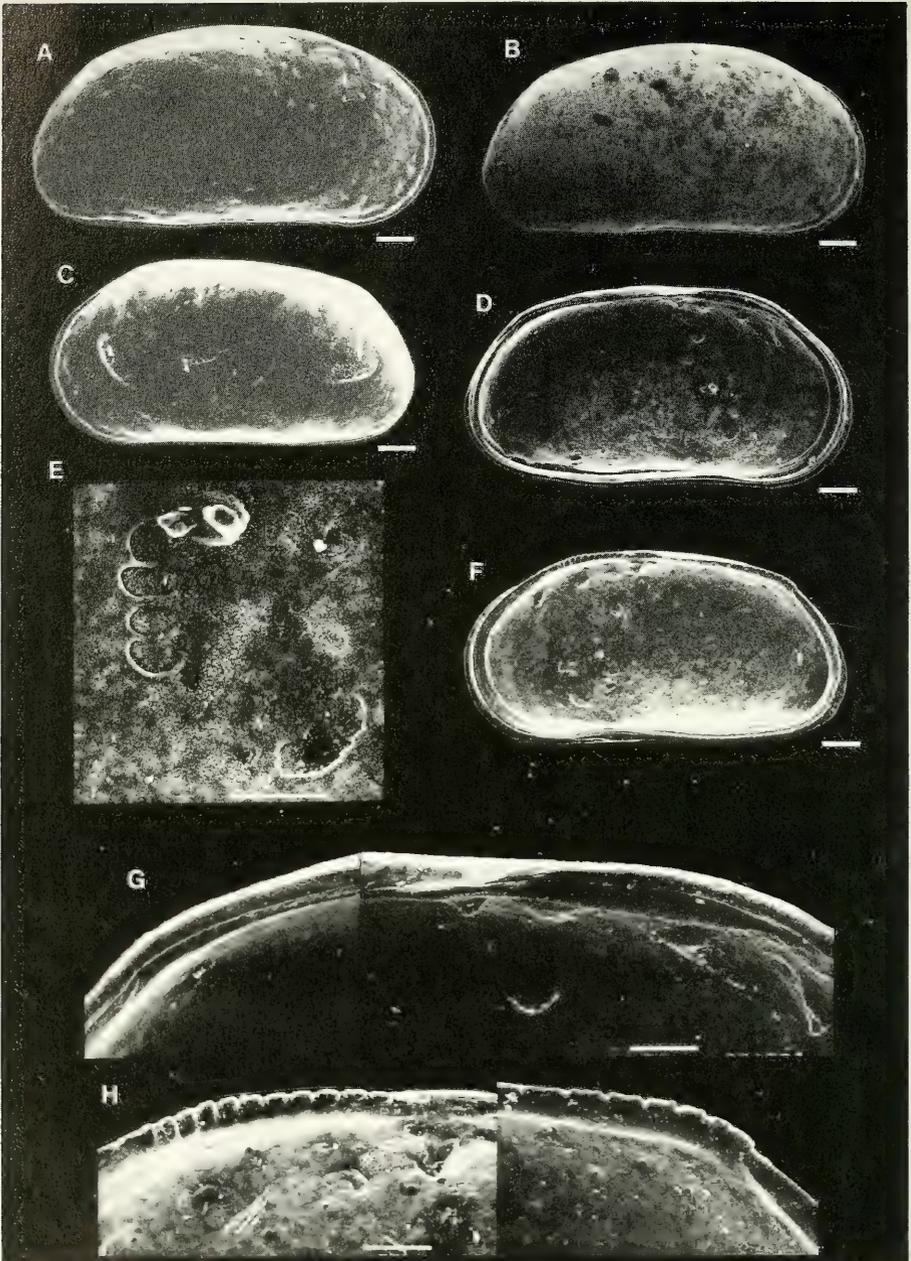


Fig. 11. A-H. *Cyprideis draaihoekensis* sp. nov. A. Holotype, MF-1719, RV, Draaihoek, sample 41, SEM AH227. B-H. Paratypes, Gypsum Quarry. B. MF-1720, RV, sample 83, SEM AH062. C-H. Sample 86. C. MF-1721, LV, SEM AH031. D-E. MF-1722, LV, internal views. D. SEM 4375. E. MS, SEM 4377. F. MF-1723, RV, internal view, SEM 4381. G. MF-1722, ATE and PTE, SEM 4379, 4378. H. MF-1723, RV, ATE and PTE, SEM 4382, 4383. Scale bars: A-D, F = 100 μ ; E, G-H = 50 μ .

weak dorsolateral sulcus, and this lies below the indistinct anterodorsal cardinal angle. NPC small, widely spaced. Valve surface generally smooth, occasionally finely and faintly punctate.

Internal features. Anterior MA narrow, avestibulate, with 30–40 fine MPC. There is a prominent selvage. Hinge long with long, curved, denticulate TEs in RV which taper medianly with only a very short ME groove. MS complex, with prominent dorsal scars. Adductors lie in a short, curved row. The anterior scar is small and U-shaped. The most prominent scar is the single, composite mandibular scar.

Remarks

Cyprideis draaihoekensis sp. nov. is closest to *C. limbocostata*, but differs in being less acuminate posteriorly, and having a less prominent sulcus. It is easily distinguished from *C. remanei*, which is plumper overall and more quadrate posteriorly. Both species have similar hinge structures, although the TE of Klie's species tends to be stronger and in the LV the TE is angled. The anterior MA of the two species is very similar (Fig. 9B–C), although that of *C. remanei* is slightly wider, and has a succession of more prominent RPC (with thickened proximal portions) interspersed with finer, shorter canals that do not always extend to the AM.

Hartmann's (1974) suggestion that the various species of *Cyprideis* along the west coast of Africa could be descendants of a common ancestor applies equally to *C. draaihoekensis*, which is so far known only from the late Pleistocene–Holocene.

Distribution

Cyprideis draaihoekensis is much more restricted in its distribution than *C. remanei*. It occurs in small numbers (up to 5%) in the upper part of the Draaihoek section (samples 40–46) and moderate numbers (up to 9%) in the upper part of the Gypsum Quarry (samples 83–87). It is locally more abundant at two horizons in the lower part of the Gypsum Quarry (samples 49, 51). We did not find this species at either Verlorevlei or the southern sections (Laaipek and Velddrif).

Hartmann (1974: 271) recorded the temperature and salinity ranges for his species *C. limbocostata* as 17–29.3°C and 40–43‰, respectively. Tankard (1976) recorded *Cyprideis* cf. *C. limbocostata* from the Verlorevlei Quarry.

Family Hemicysteridae Puri, 1953

Genus *Ambostracon* Hazel, 1962

Subgenus *Ambostracon* (*Ambostracon*) Hazel, 1962

Ambostracon (*Ambostracon*) *levetzovi* (Klie, 1940)

Fig. 12C–E

Eucythereis levezovi Klie, 1940: 419–421, figs 23–29.

Aurila levezovi (Klie, 1940) Hartmann, 1974: 284, pl. 149 (fig. 7).

Ambostracon (*Ambostracon*) *levetzovi* (Klie, 1940) Dingle, 1992: 46, figs 28E–F, 29B, E, 34A–C.

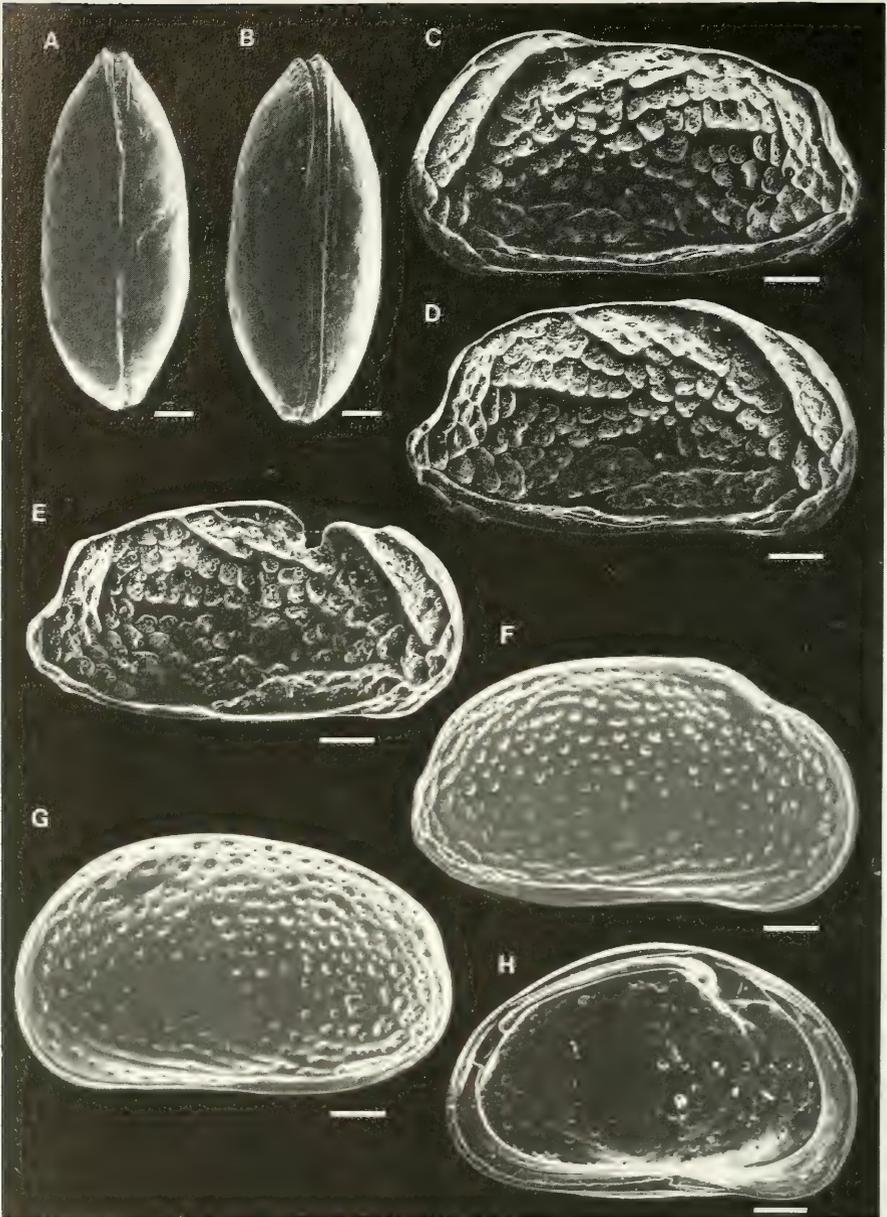


Fig. 12. A-B. *Cyprideis draaihoekensis* sp. nov., Gypsum Quarry, sample 86. A. MF-1724, C, dorsal view, SEM AH045. B. MF-1725, C, ventral view, SEM AH047. C-E. *Ambostracon (A.) levezovi* (Klie, 1940). C. MF-1727, LV, VMS, sample 9, SEM AH462. D. MF-1728, RV, VMS, sample 9, SEM AH466. E. MF-1729, RV, Gypsum Quarry, sample 80, SEM AH210. F-H. *Aurila kliei* Hartmann, 1974. F. MF-1730, RV, VMS, sample 9, SEM AH451. G. MF-1731, LV, Gypsum Quarry, sample 78, SEM AH148. H. MF-1732, LV, internal view, Gypsum Quarry, sample 78, SEM AH134. Scale bars: all 100 μ .

Illustrated material

	length	height
MF-1727, LV, VMS-9	0.80	0.43
MF-1728, RV, VMS-9	0.79	0.42
MF-1729, RV, GQ sample 80	0.78	?

Distribution

This species has previously been recorded from coastal sites in Lüderitz Bay (Klie 1940; Hartmann 1974), and from a water depth of 18 m in St Helena Bay (Dingle 1992, TBD 3089). In the present study, *Ambostracon* (*Ambostracon*) *levetzovi* occurs in small numbers at Verlorevlei (VMS-9), the Gypsum Quarry (sample 80), Velddrif (sample 11) and the two quarries at Laaiplek (samples 15, 19). Preservation of specimens from Verlorevlei and Velddrif is good, but from Laaiplek and the Gypsum Quarry the valves are fragmented and cracked (e.g. see Fig. 12E).

Genus *Aurila* Pokorny, 1955*Aurila kliei* Hartmann, 1974

Figs 12F-H, 13A-B

Hemicythere? sp. Benson & Maddocks, 1964: 27-29, pl. 5 (figs 3-4, 6, 8-9), text-fig. 16.

Aurila kliei Hartmann, 1974: 286-288, pl. 54 (figs 402-411), pl. 55 (figs 412-416), pl. 149 (fig. 10). Dingle, 1993: 98-99, figs 54F, 55A-D, 56A.

Illustrated material

	length	height
MF-1730, RV, VMS-9	0.71	0.40
MF-1731, LV, GQ sample 78	0.77	0.44
MF-1732, LV, GQ sample 78	0.74	0.46
MF-1733, RV, GQ sample 79	0.75	0.44

Distribution

This species has previously been recorded from coastal sites between Lüderitz and Knysna Lagoon, and nearshore sites (15-160 m water depth) between Lüderitz and the Cape Peninsula. In the present study, *Aurila kliei* is an important component of the middle part of the Gypsum Quarry section (samples 77-80) and the Verlorevlei borehole (VMS-9; samples 7-8), and occurs in small numbers at Velddrif (samples 11, 14) and Laaiplek (sample 15).

Aurila dayii Benson & Maddocks, 1964

Fig. 13C-F

Aurila dayii Benson & Maddocks, 1964: 31-32, pl. 5 (figs 10-12), text-fig. 19. Hartmann, 1974: 282-284, pls 51-53 (figs 385-401), pl. 150 (fig. 2).

Illustrated material

	length	height
MF-1734, LV, GQ sample 79	0.70	0.44
MF-1735, RV, GQ sample 78	0.70	0.40
MF-1736, RV, GQ sample 85	0.63	0.37
MF-1737, LV, GQ sample 85	0.60	0.38

Distribution

This species has previously been recorded from Leisure Island in Knysna Lagoon (Benson & Maddocks 1964), and from coastal sites between Cacuaco and Moçamedes in Angola (Hartmann 1974). Dingle (1992, 1993) did not record *Aurila dayii* from any of the continental shelf nearshore sites, so we can be confident that this species inhabits only lagoonal and estuarine habitats. In the present study, *A. dayii* was found in small numbers in the Verlorelei Quarry (sample 24), but as an important component (< 1–38%, mean: 14%) of the fauna throughout the upper part of the Gypsum Quarry section (samples 77–86), and as a minor element in one sample in the lower part of the same section (sample 51). Tankard (1976) listed *A. dayii* from Verlorelei, Velddrif and Churchhaven.

Genus *Caudites* Coryell & Fields, 1937*Caudites tankardi* sp. nov.

Figs 13G–H, 14A–E

Caudites sp. 3329 Dingle, 1993: 122, fig. 67F*Derivation of name*

This species is named for Dr A. J. Tankard, formerly of the South African Museum, for his pioneering studies on the Quaternary sediments of the south-western Cape.

Holotype

	length	height	width
MF-1738, RV, DH sample 37	0.55	0.29	—

Paratype

MF-0717, C, TBD 2224, 58 m	0.59	0.29	0.18
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Diagnosis

Species of *Caudites* with narrow, prominent ridge sub-parallel to AM.

Description

External features. Valve sub-triangular in lateral outline, with an asymmetric, drawn-out AM. Anterodorsally, the outline straight. DM strongly arched,

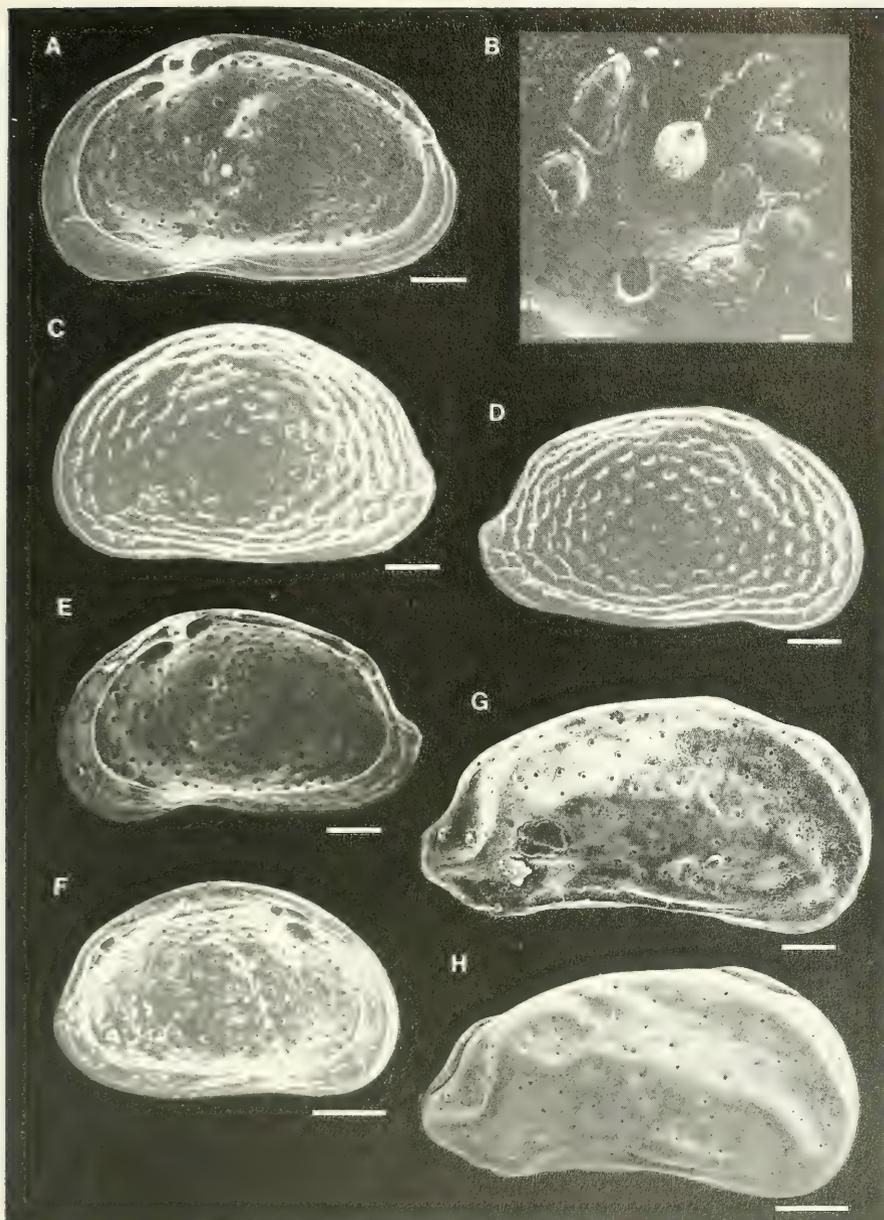


Fig. 13. A-B. *Aurila kliei* Hartmann, 1974, MF-1733, internal views, Gypsum Quarry, sample 79. A. SEM AH138. B. MS, SEM AH141. C-F. *Aurila dayii* Benson & Maddocks, 1964, Gypsum Quarry. C. MF-1734, LV, sample 79, SEM AH128. D. MF-1735, RV, sample 78, SEM AH117. E. MF-1736, RV, internal view, sample 85, SEM 4391. F. MF-1737, LV, internal view, sample 85, SEM 4394. G-H. *Caudites tankardi* sp. nov. G. Holotype, MF-1738, RV, Draaihoek, sample 37, SEM 4418. H. Paratype, MF-0717, C, right view, TBD 2224, SEM 3329.

Scale bars: A, C-H = 100 μ ; B = 10 μ .

VM gently concave. The strongest surface feature is a sharp, narrow ridge that extends from the anterodorsal margin, sub-parallel to the AM, and is continuous with a narrow ridge that runs parallel, and very close to, the VM. There is an indistinct SCT, from which a low curved ridge extends almost to the AM ridge. Further distinctive features are a short longitudinal ridge close to the VM, immediately anterior of mid-length, and a step-shaped ridge that runs from the posterodorsal corner to just below mid-height at the PM caudal process. Overall the valve surface is smooth, with prominent, widely spaced NPC.

Internal features. Details poorly seen. Anterior MA moderately wide. There is a prominent ocular sinus. Hinge holamphidont, slightly bowed dorsally. MS typical of hemicytherids, with the middle anterior scar subdivided.

Remarks

Hartmann (1974) recorded three species of *Caudites* from around southern Africa (*C. knysnaensis*—Knysna, *C. dacunhai*—northern Mozambique, and *C. algicola*—Natal to Mozambique), but none of these appear to be close to our species. Tankard (1976) included *C. knysnaensis* in his species list from Velddrif. As these specimens cannot be located, we have been unable to verify their identity. However, we suspect that they are in reality our new species *C. tankardi*, because negatives of material photographed by Tankard and now in the Rhodes University SEM collection, are only of *C. tankardi*. It is likely, therefore, that *C. knysnaensis* does not extend as far west as the south-western Cape.

The closest species to *C. tankardi* is *C. africana* Omatsola, 1972, which is the only species of the genus recorded from Nigeria. The two species have a very similar lateral outline and overall ornamentation, but differ in the latter lacking the prominent AM ridge and the curved ridge that extends anteriorly from the SCT. *Caudites tankardi* has more prominent NPC. The two species can also be distinguished by differences in MS patterns (compare Fig. 14E with Omatsola 1972, pl. 31 (fig. 6)).

Distribution

This species has previously been recorded from a nearshore site (TBD 2224, 58 m) off Saldanha Bay (Dingle 1993). In the present study, a single valve was recovered from the lowermost level of the section at Draaihoek (sample 37). For reasons given above, we suspect that Tankard's (1976) record of *Caudites knysnaensis* Hartmann, 1974, from outcrop 9 at Velddrif, is in fact *C. tankardi* sp. nov.

Family Xestoleberididae Sars, 1928

Genus *Xestoleberis* Sars, 1866

Xestoleberis capensis Müller, 1908

Figs 14F, 15A–F

Xestoleberis capensis Müller, 1908: 127–128; 1912: 300. Stebbing, 1910: 505. Benson & Maddocks, 1964: 26–27, pl. 2 (fig. 12), text-fig. 15. Dingle, 1993: 144–145, fig. 81E–F.

Xestoleberis ramosa Müller, 1908. Hartmann, 1974 (*part.*—Knysna specimens only).

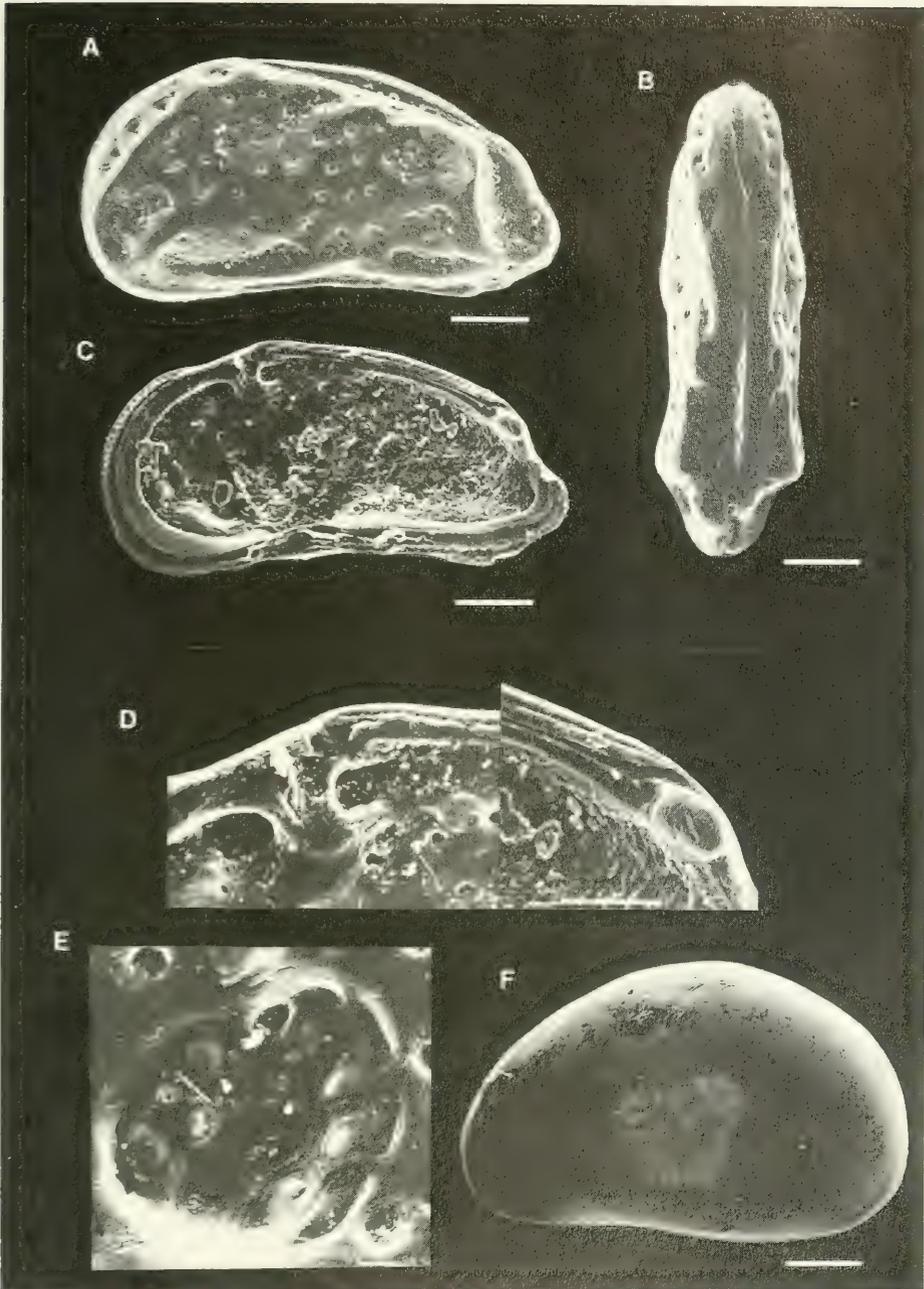


Fig. 14. A-E. *Caudites tankardi* sp. nov. A-B. Paratype, MF-0717, C, TBD 2224. A. Left view, SEM 4467. B. Dorsal view, SEM 4477. C-E. Holotype, MF-1738, RV, internal views, Draaihoek, sample 37. C. SEM 4471. D. ATE and PTE, SEM 4473, 4472. E. MS, SEM 4479. F. *Xestoleberis capensis* Müller, 1908, MF-1739, LV, Gypsum Quarry, sample 78, SEM AH198. Scale bars: A-C, F = 100 μ ; D = 50 μ ; E = 10 μ .

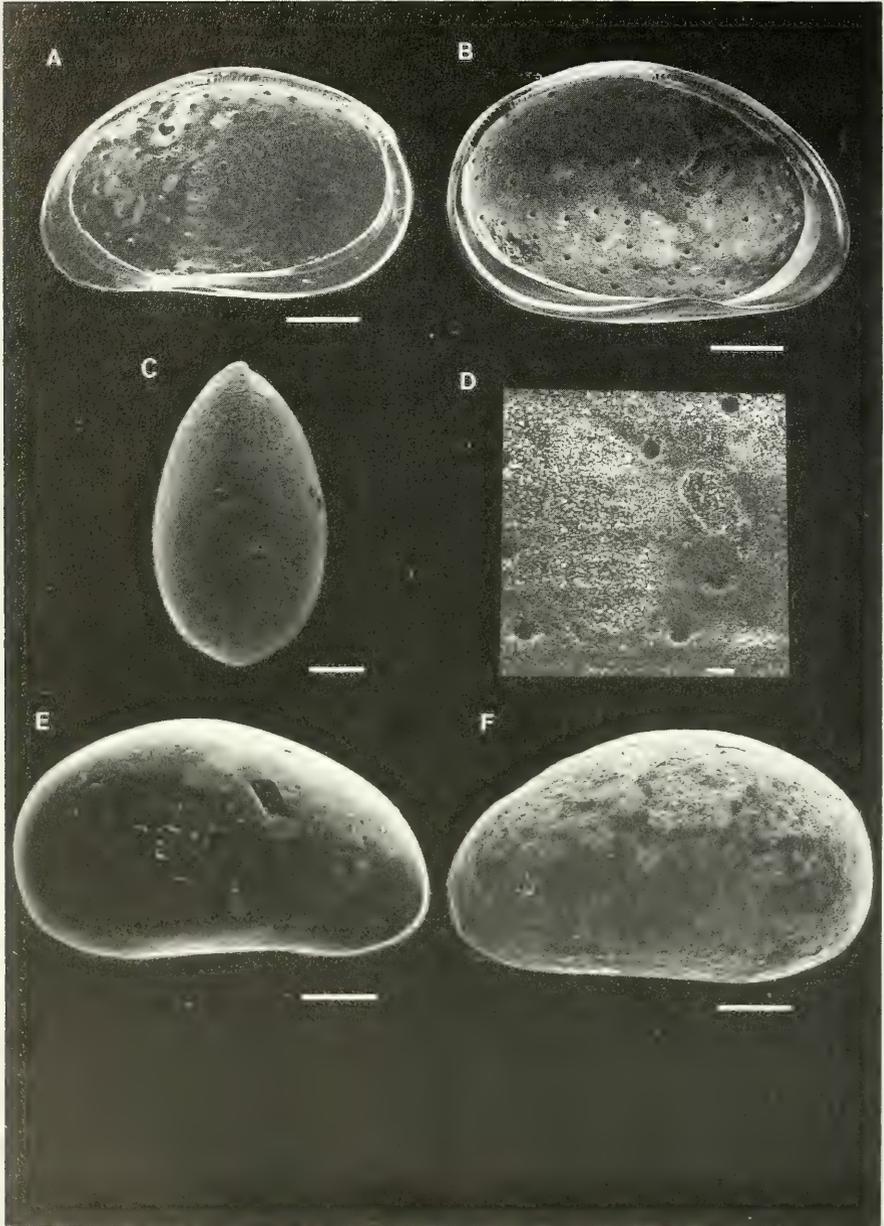


Fig. 15. A-F. *Xestoleberis capensis* Müller, 1908. A-B. Gypsum Quarry, sample 85. A. MF-1742, RV, internal view, SEM AH184. B. MF-1743, LV, SEM 4398. C. MF-1744, C, dorsal view, Verlorevlei Quarry, sample 24, SEM AH398. D. MF-1743, LV, MS, Gypsum Quarry, sample 85, SEM 4399. E. MF-1740, RV, Gypsum Quarry, sample 78, SEM AH196. F. MF-1741, LV, Verlorevlei Quarry, sample 24, SEM AH395. Scale bars: A-C, E-F = 100 μ ; D = 10 μ .

Illustrated material

	length	height	width
MF-1739, LV, GQ sample 78	0.57	0.35	—
MF-1740, RV, GQ sample 78	0.54	0.30	—
MF-1741, LV, VQ sample 24	0.55	0.30	—
MF-1742, RV, GQ sample 85	0.49	0.30	—
MF-1743, LV, GQ sample 85	0.49	0.31	—
MF-1744, C, VQ sample 24	0.59	—	0.33

Remarks

We have distinguished this species from the similar taxon *Xestoleberis ramosa* Müller, 1908, on the basis of its more prominently arched DM, straighter VM, and more acutely rounded AM. Our material allows good illustration of the hinge and MS of *X. capensis* for the first time.

Distribution

This species has previously been recorded from Knysna Lagoon (Benson & Maddocks 1964; Hartmann 1974), False Bay (Müller 1908), and two inshore sites west of the Cape Peninsula (15–90 m) (Dingle 1993). In the present study, *X. capensis* is most abundant in the Gypsum Quarry, where it occurs throughout the sequence, particularly in the middle section (samples 51, 77–80, 84–86). It is also of moderate importance at one level in the Verlorevlei Quarry (sample 24). Tankard (1976) included the species in his list from Verlorevlei Quarry, Laaiplek, Kruispad (sample 12), Saldanha (sample 18) and Churchhaven.

RESULTS AND DISCUSSION

A total of 17 species of Ostracoda was recovered from 88 samples collected at 10 sites between Langebaan Lagoon and the Olifants River mouth. Table 1 shows the distribution and abundance of the taxa.

ENVIRONMENTAL INDICATORS

Because the majority of species have been described previously and some information on their modern habitats is available, estimates can be made for the environmental preferences of the bulk of the fauna, and the tolerances of the four new species can be assessed from their association with the known taxa. These habitat preferences are presented in Table 2, where we can group the species into five broad categories of habitat: marine, normal salinity (< 35‰), inner shelf; marine, normal salinity, lagoonal; marine, high salinity (> 35‰), lagoonal; estuarine, hyposaline (< 30‰); and freshwater.

To test these empirically derived categories against quantitative data, we performed a Q-mode factor analysis on the species distribution and abundance matrix using a version of Oregon State University's CLIMAP/CABFAC program (Imbrie & Kipp 1971). The technique has been described and applied previously to ostracod faunas from the west-coast continental margin by Dingle &

TABLE 1
Distribution and abundance of ostracods from Quaternary coastal sequences in the south-western Cape.

Site	Sample	<i>Ambostracum</i> (A.) <i>leviszovi</i>	<i>Caudites</i> <i>rankardi</i>	<i>Garctaelia</i> <i>k. knysnaensis</i>	<i>Aurtila</i> <i>kliei</i>	<i>Cytheromorpha</i> <i>milleri</i>	<i>Xestoleberis</i> <i>capensis</i>	<i>Palmocoencha?</i> <i>cf. P. peterseni</i>	Indeterminate bairditi	<i>Paranesidea</i> <i>verlorevleiensis</i>	<i>Aurtila</i> <i>dayi</i>	<i>Aglaella</i> <i>raibridgensis</i>	<i>Paracypris</i> <i>westfordensis</i>	<i>Cypridites</i> <i>remanei</i>	<i>Cypridites</i> <i>draathoekensis</i>	<i>Heterocypris</i> <i>capensis</i>	<i>Sarscypridopsis</i> <i>reniformis</i>	<i>Sarscypridopsis</i> <i>jaculeata</i>	Total valves	Thickness of unit (cm)	Lithology
GYPSUM QUARRY																					
1—North end																					
	87	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	11	12.0	laminated gypsum/carbonate/halite
	86	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1302	17.0	pink/white, medium sand
	85	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	140	10.0	light green, sandy clay
	84	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	13	8.0	white, medium sand
	83	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	34	7.0	green, medium sand
	82	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	14	13.0	light green, shelly sand
	81	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	0	10.0	soft, white, shelly sand
	80	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	12	6.0	white, medium, shelly sand
	79	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	39	16.0	white, medium, shelly sand
	78	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	72	15.0	yellow, shelly sand (whole shells)
	77	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	18	?	yellow, shelly sand (whole shells) nodular, green clay
	52	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	0	55.0	laminated gypsum/carbonate/halite
	51	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	166	30.0	mottled, buff sand
	50	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	2	10.0	dark green, mottled sand
	49	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	4	10.0	dark green, clayey sand
DRAAHOEK																					
1																					
	48	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	2	30.0	hard, brown sandy clay
	47	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	48	10.0	soft, brown clayey sand
	46	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	110	10.0	mottled, white sandy clay
	45	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	57	5.0	white clay

Giraudeau (1993). The varimax factor component and varimax factor score matrices that resulted from one rotation of the original matrix are presented in Appendices 1 and 2, respectively. We elected to analyse for six factors, and in Table 3 list the species that comprise the factor associations (FA). The six factors account for 79.5 per cent of the variance of the data set but, as can be seen from the cumulative variance in Appendix 2, a mere 2 per cent increase was achieved by adding the sixth factor, and the addition of several more factors to account for, perhaps 90 per cent of the variance, would not be helpful for the analysis. The reason for this can be seen in the low communality values (< 0.800) for the minority of sites from which only isolated samples contained ostracods (usually in low numbers, and representing environments with no analogues in the richer assemblages). Seventy-eight per cent of the samples have a communality > 0.800 , suggesting that the factor analysis can be used successfully to help interpret the depositional environments of the samples using the FA.

Basing estimates for each of the FA on previously described species habitats (Table 2), the statistical analysis suggests that the faunas in our samples can

TABLE 2
Habitats of south-western Cape Quaternary ostracods.

MARINE (INNER SHELF): NORMAL MARINE	
<i>Ambostracon (A.) levetzovi</i>	inner shelf (St Helena Bay, 18 m), coastal sites (Lüderitz).
<i>Garciaella k. knysnaensis</i>	inner-mid shelf (19°S–24°E), coastal sites (Lüderitz–Leisure Island).
<i>Aurila kliei</i>	inner shelf (Lüderitz–Cape Peninsula), coastal sites (Lüderitz, Kommetjie, Leisure Island).
<i>Xestoleberis capensis</i>	inner shelf (western Cape Peninsula, False Bay), coastal sites (Hout Bay, Leisure Island).
<i>Caudites tankardi</i> sp. nov.	inner shelf (off Saldanha Bay, 58 m).
<i>Cytheromorpha milleri</i> sp. nov.	inner shelf (off Olifants River mouth, 72 m).
MARINE (LAGOONAL): NORMAL MARINE	
<i>Palmoconcha?</i> cf. <i>P. peterseni</i>	coastal sites (Angola).
<i>Aurila dayii</i>	coastal sites (Angola, Leisure Island)
<i>Aglaiella railbridgensis</i>	coastal site (Leisure Island), estuarine site (upper Knysna Lagoon).
<i>Paranesidea verloreivleiensis</i> sp. nov.	
Indeterminate bairdiid	
MARINE (LAGOONAL): HIGH SALINITY	
<i>Cyprideis remanei</i>	lagoonal (Lüderitz).
<i>Cyprideis draaihoekensis</i> sp. nov.	
ESTUARINE: BRACKISH (HYPOSALINE)	
<i>Paracypris westfordensis</i>	upper estuary (Knysna).
VLEIS: FRESHWATER	
<i>Heterocypris capensis</i>	ponds and vleis, south-western Cape.
<i>Sarscypridopsis ?reniformis</i>	ponds and vleis, south-western Cape.
<i>Sarscypridopsis ?aculeata</i>	ponds and vleis, south-western Cape.

be described in terms of three normal salinity marine associations (factors 3, 4, 6), two freshwater associations (factors 2, 5), and a high-salinity marine association (factor 1).

Normal salinity marine environments

The only major difference between the empirical and factor analyses of the marine taxa is the inclusion by the latter of *Aurila dayii* in the same factor association (3) as *A. kliei* and *Xestoleberis capensis*. *Aurila dayii* has been reported previously only from coastal sites, whereas the other two species are known to occur on the inner shelf (in addition to coastal sites). On this evidence, we are inclined to interpret FA 3 as indicating coastal marine, in contrast to inner-shelf environments. This would accommodate *Palmoconcha* cf. *P. peterseni*, which has been recorded previously only from coastal sites (although its inclusion in FA 3 is based on a very low score, which is statistically of no significance). We have insufficient evidence from modern assemblages to differentiate the environments identified by FA 4 and 6, except that we suspect that they are both indicative of the innermost shelf. It should be pointed out that little confidence can be placed on the inclusion within them of the species linked by 'weak' factor scores. It is possible that if a larger number of factors had been specified in the analysis, then some at least would have fallen into different categories. This is particularly the case with *Aglaiella railbridgensis*, which has previously been reported only from two environments in Knysna Lagoon (range, 30–35‰). The latter may be an allochthonous element in an otherwise inner-shelf association. The two bairdiid categories (*Paranesidea verloreveleiensis* and the indeterminate bairdiid) are effectively linked to the other taxa only via one sampling site, so here we may be dealing with an environment that has no analogues in the rest of the data set.

High-salinity marine environment

In our empirical grouping, the two species of *Cyprideis* were placed together and the factor analysis also weakly links them. However, the factor analysis also suggested that *Paracypris westfordensis* has its strongest link (albeit weak) with *Cyprideis remanei*. On the evidence of previous reports on the habitats of these two taxa, such a linkage seems unlikely in an autochthonous assemblage, with *Paracypris westfordensis* having only been found in hyposaline environments, whereas *Cyprideis remanei* occurs in high-salinity coastal sites. The most likely explanation is that the assemblages we have analysed are mixed populations, i.e. FA 1 represents a high-salinity marine setting into which hyposaline elements have been washed.

Freshwater environments

The three species listed under this heading in Table 2 have been recorded previously only from freshwater sites in the south-western Cape, and worldwide exceptionally in very low-salinity conditions (*Sarscypridopsis aculeata*, 11.2‰ in Australia—De Deckker 1981, 1983). The factor analysis identified two freshwater FA (2, 5), differentiating the combination of *S. aculeata* and *Heterocypris capensis* from *S. reniformis*.

TABLE 3

Factor Associations, factor scores and variance of Quaternary ostracod faunas, south-western Cape.

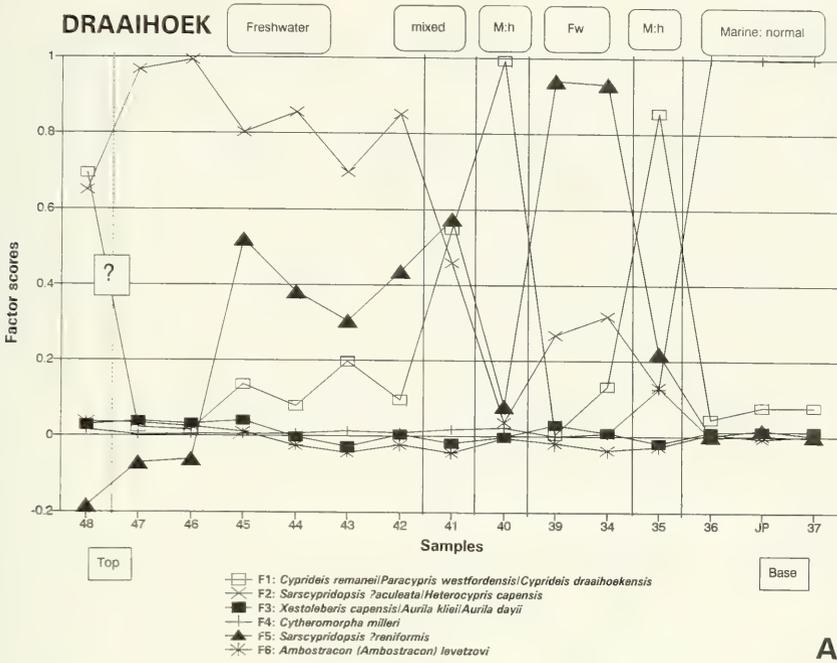
HIGH SCORES		LOW SCORES	
MARINE: NORMAL SALINITY			
COASTAL			
Factor 3 (12%)			
<i>Xestoleberis capensis</i>	0.634	<i>Palmoconcha? cf. P. peterseni</i>	0.006
<i>Aurila kliei</i>	0.624		
<i>Aurila dayii</i>	0.425		
?INNER SHELF			
Factor 4 (8%)			
<i>Cytheromorpha milleri</i>	0.999	<i>Caudites tankardi</i>	0.003
?INNER SHELF (?WITH ALLOCHTHONOUS LAGOONAL ELEMENTS)			
Factor 6 (2%)			
<i>Ambostracon levetzovi</i>	0.617	<i>Garciaella k. knysnaensis</i>	-0.297
		<i>Paranesidea verloreveleiensis</i>	0.185
		Indeterminate bairdiid	0.069
		<i>Aglaiella railbridgensis</i>	0.017
.....			
MARINE: HIGH SALINITY			
LAGOONAL (?WITH ALLOCHTHONOUS HYPOSALINE ELEMENTS*)			
Factor 1 (25%)			
<i>Cyprideis remanei</i>	0.987	* <i>Paracypris westfordensis</i>	0.133
		<i>Cyprideis draaihoekensis</i>	0.075
.....			
FRESHWATER			
Factor 2 (16%)			
<i>Sarscypridopsis ?aculeata</i>	0.907		
<i>Heterocypris capensis</i>	0.358		
Factor 5 (14%)			
<i>Sarscypridopsis ?reniformis</i>	0.948		

PALAEOENVIRONMENTS

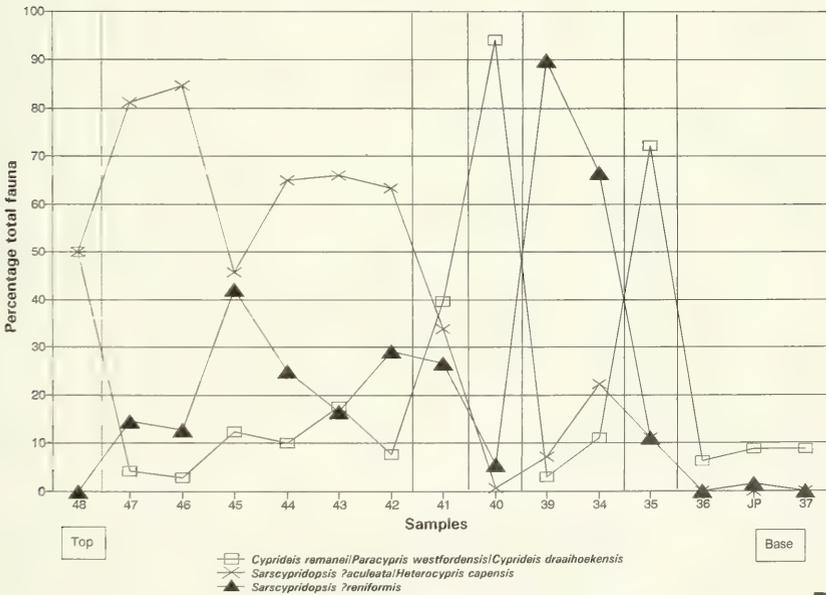
Applying the empirical and statistical estimates to individual samples allows us to suggest depositional environments for the various sites, and to present an analysis of evolving palaeoenvironments for the Draaihoek and Gypsum Quarry sequences.

Draaihoek and Gypsum Quarry (Figs 16–20)

The ostracod faunas at Draaihoek indicate two cycles of salinity change. At the base, the fauna is dominated by *Cytheromorpha milleri*, indicating a normal



A



B

Fig. 16. Ostracod faunas and palaeo-salinity interpretations in the Draaihoek sequence. The significance of the faunal changes between samples 47 and 48 (top of sequence) is unclear because of low valve numbers. In the top panel, M:h = marine, high salinity. A. Varimax factor scores for a listing of factor scores and communalities. B. Variations in percentages of the high-salinity marine and freshwater ostracod species. See Table 1 for data.

salinity, coastal marine environment (FA 4). This passes upward via a high-salinity marine fauna (*Cyprideis remanei* with allochthonous *Paracypris westfordensis*, FA 1) into a freshwater assemblage with *Sarscypridopsis reniformis* and *Heterocypris capensis* (FA 5 and FA 2, respectively). Immediately above (in sample 40), the fauna indicates a reversion to more marine conditions with a flood of *Cyprideis remanei*, rare *C. draaihoekensis* and abundant, presumed allochthonous, *Paracypris westfordensis* (FA 1).

Overlying sediments indicate a second transition to a freshwater environment. Sample 41 has a mixture of high-salinity marine and freshwater faunas (FA 1, 2, 5), suggesting deposition in a vlei subjected to significant marine infiltration, and this passes upwards into 0.5 m of clays and sands with freshwater assemblages dominated by FA 2 (*Heterocypris capensis* and *Sarscypridopsis aculeata*) throughout, but with FA 5 (*S. reniformis*) relatively more important in the lower part. The low number of valves (2) in the uppermost sample (sample 48) precludes any confident interpretation of the fauna.

The salinity fluctuations are schematically shown on the curve in Figure 17. Ostracod abundances fluctuate considerably throughout these faunal changes (Fig. 18). Generally we found < 100 valves/10 g, but at two horizons with freshwater assemblages (samples 39 (*S. reniformis*) and 43 (*Heterocypris capensis*), > 200 valves/10 g), and in sample 40 with a high-salinity marine fauna (*Cyprideis remanei*, > 500 valves/10 g), there are sudden increases in the numbers of a particular species. Only in sample 41 (mixed marine and freshwater) did we recover > 100 valves/10 g, with no domination by one species.

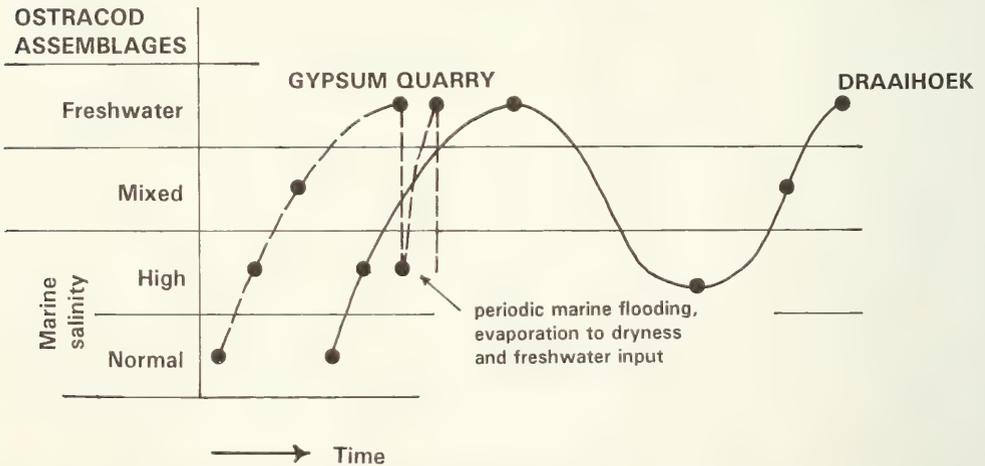


Fig. 17. Schematic representation of cyclical salinity changes at Draaihoek (solid line) and the Gypsum Quarry (dashed line). Dots indicate presence of samples with a particular ostracod fauna indicative of the suggested palaeoenvironment. The degree of contemporaneity of the two sequences is unknown.

In contrast, the ostracod faunas from the Gypsum Quarry (Fig. 19) indicate only a partial cycle of salinity change from normal marine at the base (samples 77–80), through sediments with a high-salinity marine fauna (samples 82–84), via a mixed assemblage (sample 85), to freshwater sands and

gypsiferous beds at the top. We have indicated these changes in Figure 17, but can only speculate that they were contemporaneous with the same part of the cycle at Draaihoek. Ostracod abundances (Fig. 20) are generally lower than found at Draaihoek (< 50 valves/10 g), with the notable exception of the fresh-water sands immediately below the gypsiferous beds (500 valves/10 g), where there is a marked influx in numbers of *Sarscypridopsis reniformis* (plus abundant *Cyprideis remanei* and *C. draaihoekensis*).

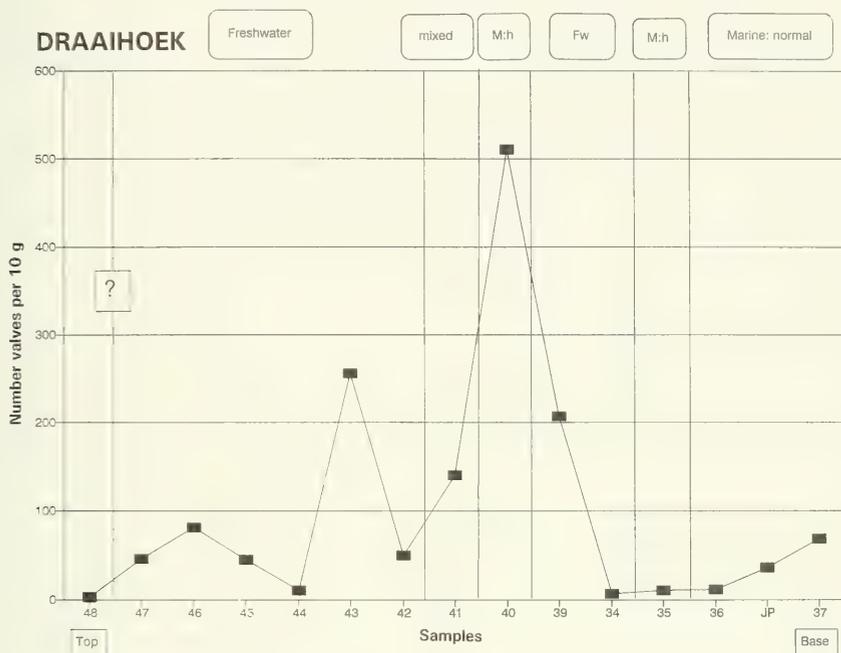


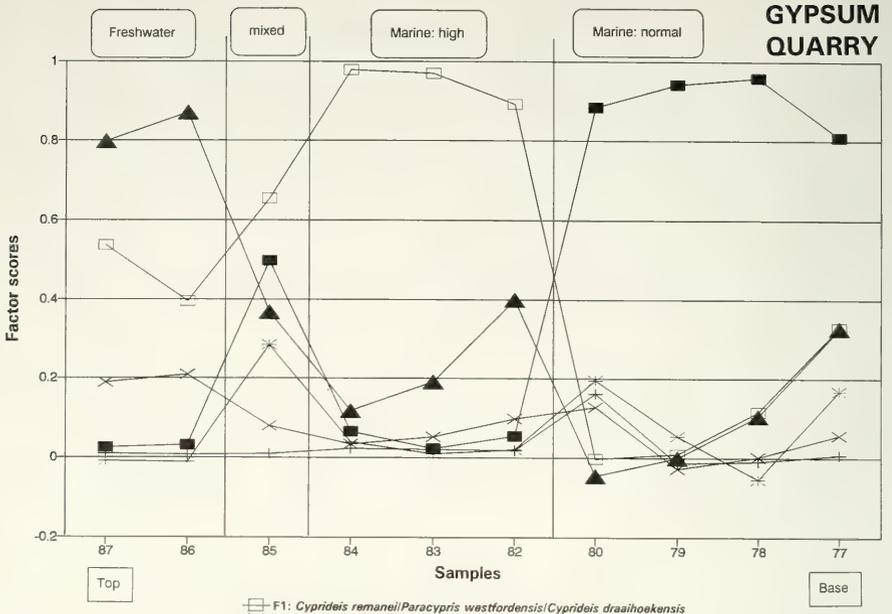
Fig. 18. Abundance of ostracods (expressed as number of valves per 10 g of > 250 μ residue) per sediment sample at Draaihoek.

In detail there are significant differences between the successions at Draaihoek and the Gypsum Quarry.

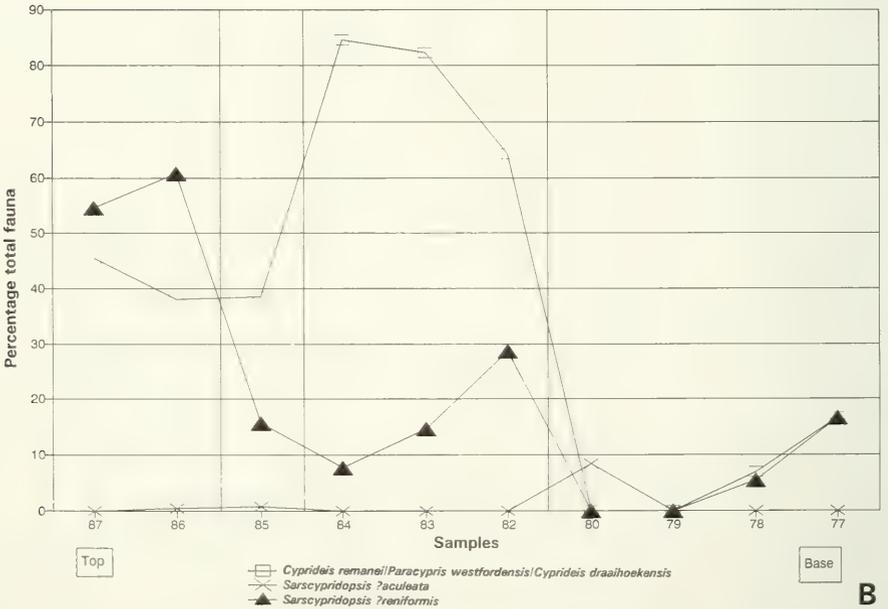
Firstly, the normal salinity marine faunas are not the same. At the beginning of the first cycle at Draaihoek, these are dominated by FA 4 (*Cytheromorpha milleri*), whereas at the Gypsum Quarry they are dominated by the more diversified FA 3 (*Xestoleberis capensis*, *Aurila kliei*, *A. dayii*), which we suspect may represent a less open-water, more coastal assemblage.

Secondly, *Paracypris westfordensis* comprises a larger component of FA 1 at Draaihoek, compared to that at the Gypsum Quarry, suggesting that at the former site there was a more persistent inflow of brackish water (which introduced allochthonous valves of this taxon) into the high-salinity marine lagoon with its autochthonous *Cyprideis remanei* and *C. draaihoekensis* assemblage.

Finally, although the freshwater component of the ostracod assemblages throughout the succession at the Gypsum Quarry is almost exclusively *Sarscypridopsis reniformis* (FA 5), and *Heterocypris capensis* does not occur at this



A



B

Fig. 19. Ostracod faunas and palaeo-salinity interpretations in the Gypsum Quarry (1—North end) sequence. A. Varimax factor scores for samples. See Appendix 1 for a listing of factor scores and communalities. B. Variations in percentages of the high-salinity marine and freshwater ostracod species. See Table 1 for data.

locality, there is more variation at Draaihoek. At the end of the first cycle at Draaihoek, FA 5 (*Sarscypridopsis reniformis*) dominates but, during the course of the second cycle, FA 2 (mixed *Heterocypris capensis* and *Sarscypridopsis aculeata*) becomes progressively more important.

All the samples show a high communality in the factor components matrix, except sample 43 at Draaihoek. This has a particularly high percentage of *Heterocypris capensis*, in conjunction with *Cyprideis remanei*, suggesting that the former may be a largely allochthonous element.

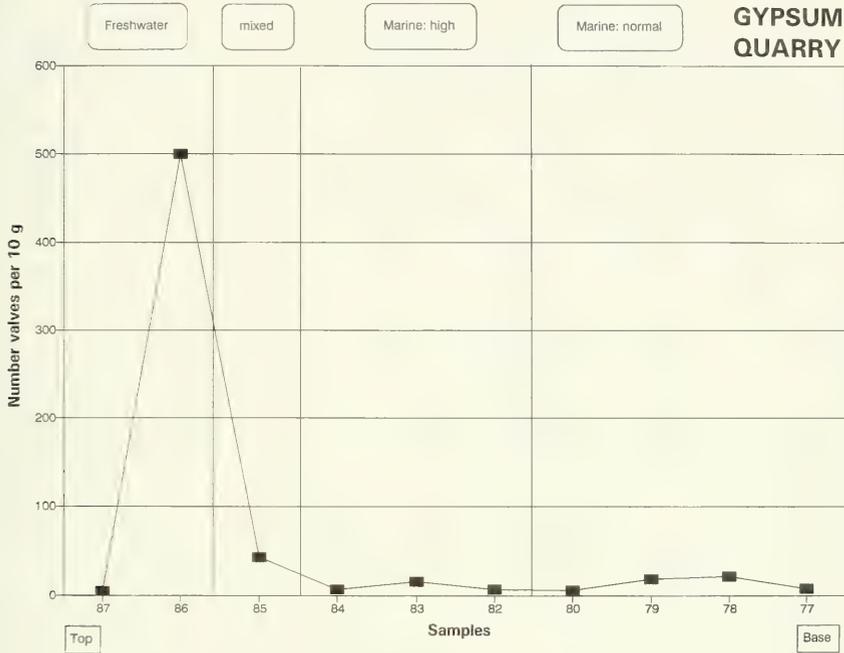


Fig. 20. Abundance of ostracods (expressed as number of valves per 10 g of $> 250 \mu$ residue) per sediment sample at Gypsum Quarry (1—North end).

In his summary of the distribution of ostracods in Australian lakes, De Deckker (1983) noted that *Sarscypridopsis aculeata* and *Heterocypris* spp. are confined to temporary pools, which can occasionally attain a salinity of up to 5‰ (although he also noted that the former can 'withstand slightly saline waters up to 20‰' (De Deckker 1982: 260)). A totally different halobiotant fauna occurs in salt lakes, with salinities of up to c. 180‰ (De Deckker 1983, figs 1–3). Tankard (1976) estimated that salinities must have exceeded 117‰ during the precipitation of the gypsiferous layers at the top of the Gypsum Quarry section, and that the most likely mechanism was the periodic flooding by the sea of a back barrier depression, which then evaporated to dryness. He described the gypsiferous sediment as typically consisting of 2-mm thick calcium carbonate–calcium sulphate–halite cycles. It is not clear from his descriptions which layers at the Gypsum Quarry contained the ostracods listed in his table 2 (1976), but in our examination we recovered only three species from within the gypsiferous sequence (sample 87): *Sarscypridopsis reniformis*,

Cyprideis remanei and *C. draaihoekensis*. There is no evidence in the literature that any of these species can withstand hypersaline conditions and, since no specialized high-salinity species were found (e.g. similar to those described from Australia by De Deckker 1983), we conclude that the assemblage represents a freshwater fauna that re-established itself after the lagoon had evaporated to dryness, and mixed with a marine component brought in during the next invasion of the lagoon by the sea. In the sample immediately below the gypsiferous layer (sample 86), there is a similar faunal combination, only here the freshwater ostracod element is more important, suggesting that during this earlier phase, the inflow of fresh water to the lagoon was on a more substantial scale, and that marine incursions were less frequent. An alternative explanation is that the fauna in the gypsiferous layer represents contamination from the immediately underlying horizon (either naturally as reworking, or during sampling).

A more comprehensive palaeoenvironmental interpretation will be attempted in a later publication, when sedimentological evidence will also be considered.

Other sites

From the other sites, we have data only from isolated horizons, and in the factor analysis communalities for these samples are often low, suggesting that the faunas do not have strong analogues within the data set as a whole.

Olifants River mouth. The fauna in sample 64 has a high communality and falls within FA 1, suggesting a high-salinity marine habitat (*Cyprideis remanei*), with allochthonous hypersaline elements.

Velddrif. The two samples at this site indicate a lower, normal salinity coastal marine fauna (sample 11, FA 3) and an upper freshwater fauna (sample 14, FA 2). Both faunas occur in sedimentologically similar samples, but the communality of sample 11 is low, containing only two valves of marine taxa *Ambostracon levezovi* and *Aurila kliei*, which the factor analysis as a whole places in separate categories. The upper fauna, on the other hand, has a high communality, is relatively abundant, and the thin valves are well preserved. Clearly, the freshwater fauna is either autochthonous (which does not accord with the shelly sand matrix of the sample), or it is a short-travelled allochthonous assemblage (there was one valve of *A. kliei* in the sample).

Laaipek. Faunas are sparse, and communalities low for both ostracod-bearing samples in the Laaipek area. The species present suggest normal salinity, coastal-inner-shelf marine environments (FA 3, 6), with no estuarine or freshwater elements. The closest analogue amongst the other sampling sites is sample 11 at Velddrif.

Verlorevlei. With the exception of VMS-9 sample 7, the factor analysis communality is very low for the ostracod-bearing samples from the Verlorevlei valley. This is not surprising in the case of the samples from the quarry, because they contain a high proportion of bairdiid species that have no analogues in the other samples. In fact, the two species present have not been recorded previously, which makes comparison difficult. Nevertheless, sample 24 contains a moderately diverse fauna, and of the elements for which

we do have previous environmental data, all, bar one valve of *Paracypris westfordensis*, suggest a normal marine, probably lagoonal environment (Table 2: *Xestoleberis capensis* has been found at Leisure Island in Knysna Lagoon, even though it is more usually found on the inner shelf, and the higher salinity *Cypri-deis remanei* is restricted to one valve). There are no freshwater indicators. Sample H1 contained only valves of *Paranesidea verloreivleiensis* which, by deduction, is probably a normal marine, lagoonal species.

The two samples from Miller *et al.*'s (1993) borehole VMS-9 also contain only marine species (particularly *Ambostracon levezovi* and *Aurila kliei*), but the fauna has no elements common with the quarry site (VQ 24, H1) farther up the vlei, and suggests a more open coastal or inner-shelf environment.

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APPENDIX 1
Varimax Factor Components Matrix.

Sites	Samples	Communality	Factors					
			1	2	3	4	5	6
GYPSUM QUARRY								
1—North end	87	0.964	0.537	0.188	0.025	0.009	0.799	-0.011
	86	0.960	0.396	0.209	0.030	0.006	0.871	-0.012
	85	0.901	0.656	0.080	0.498	0.008	0.368	0.285
	84	0.980	0.979	0.033	0.065	0.021	0.117	0.038
	83	0.980	0.969	0.051	0.021	0.020	0.191	0.008
	82	0.968	0.892	0.097	0.055	0.017	0.400	0.020
	80	0.867	-0.003	0.126	0.886	0.160	-0.046	0.196
	79	0.891	0.008	-0.028	0.942	-0.014	0.000	0.054
	78	0.943	0.115	0.002	0.957	-0.010	0.103	-0.056
	77	0.904	0.330	0.057	0.811	0.005	0.326	0.167
	2—South end	51	0.963	0.733	0.159	0.031	0.013	0.632
50		0.976	0.987	0.013	-0.001	0.021	0.016	0.002
49		0.924	0.960	0.014	0.001	0.017	0.036	0.004
DRAAIHOEK								
	48	0.944	0.696	0.650	0.029	0.015	-0.185	0.035
	47	0.942	0.022	0.966	0.039	0.002	-0.072	0.034
	46	0.988	0.016	0.991	0.031	0.003	-0.062	0.025
	45	0.938	0.137	0.804	0.041	0.004	0.520	0.011
	44	0.886	0.078	0.856	-0.002	0.007	0.382	-0.025
	43	0.623	0.198	0.699	-0.028	0.012	0.304	-0.045
	42	0.925	0.095	0.851	0.003	0.008	0.437	-0.024
	41	0.847	0.549	0.459	-0.018	0.017	0.576	-0.045
	40	0.990	0.991	0.035	-0.004	0.022	0.078	-0.005
	39	0.958	0.004	0.269	0.029	0.000	0.940	-0.018
	34	0.986	0.131	0.319	0.009	0.005	0.930	-0.037
	35	0.814	0.855	0.130	-0.020	0.124	0.221	-0.029
	36	0.999	0.044	-0.003	0.011	0.998	0.001	0.006
	JP	0.990	0.077	0.001	0.013	0.996	0.017	-0.005
	37	0.999	0.076	-0.003	0.012	0.997	0.002	0.001
VELDDRIF								
	14	0.858	-0.013	0.890	0.067	-0.001	0.248	0.019
	11	0.163	-0.019	-0.004	0.398	-0.012	-0.013	0.061
LAAIPEK								
	15	0.337	-0.013	-0.004	0.495	-0.005	-0.024	-0.302
	19	0.052	-0.005	-0.005	-0.025	0.008	0.011	0.226
OLIFANTS RIVER								
	64	0.889	0.943	0.015	-0.014	0.022	0.006	-0.011
VERLOREVLEI								
Quarry	24	0.110	0.016	0.003	0.220	-0.010	-0.022	0.247
	H1	0.048	-0.007	0.007	0.115	-0.010	-0.025	0.185
Soundings	7	0.716	-0.010	-0.001	0.617	-0.009	-0.036	-0.578
	9	0.189	-0.019	-0.004	0.434	-0.012	-0.016	-0.001
VARIANCE			25.999	16.946	12.295	8.184	14.072	2.008
CUMULATIVE VARIANCE			25.999	42.945	55.240	63.423	77.495	79.504

* top of sedimentary succession lies towards the top of list for each site.

APPENDIX 2

Varimax Factor Score Matrix.

Species	Factors					
	1	2	3	4	5	6
<i>Ambostracon levetzovi</i>	-0.015	-0.005	-0.061	-0.005	0.018	0.617
<i>Caudites tankardi</i>	0.000	0.000	0.000	0.003	0.000	0.000
<i>Garciaella k. knysnaensis</i>	0.008	-0.002	0.026	0.016	-0.003	-0.297
<i>Aurila kliei</i>	-0.012	-0.001	0.624	-0.012	-0.037	-0.530
<i>Cytheromorpha milleri</i>	-0.021	-0.004	0.011	0.999	0.000	0.005
<i>Xestoleberis capensis</i>	0.008	-0.018	0.634	0.009	0.014	0.376
<i>Palmoconcha? cf. P. peterseni</i>	0.000	0.000	0.006	0.000	0.000	0.002
Indeterminate bairdiid	-0.002	0.001	0.051	-0.004	-0.008	0.069
<i>Paranesidea verloreveleiensis</i>	-0.007	0.007	0.115	-0.010	-0.025	0.185
<i>Aurila dayii</i>	0.015	-0.028	0.425	-0.018	0.020	0.248
<i>Aglaiella railbridgensis</i>	0.004	-0.003	0.014	-0.001	0.005	0.017
<i>Paracypris westfordensis</i>	0.133	0.007	-0.030	0.007	-0.019	-0.028
<i>Cyprideis remanei</i>	0.987	0.013	-0.001	0.021	0.016	0.002
<i>Cyprideis draaihoekensis</i>	0.075	0.007	0.004	-0.008	0.067	0.008
<i>Heterocypris capensis</i>	-0.018	0.358	-0.061	0.010	0.127	-0.069
<i>Sarscypridopsis ?reniformis</i>	-0.019	0.219	0.030	-0.001	0.948	-0.016
<i>Sarscypridopsis ?aculeata</i>	-0.003	0.907	0.042	0.000	-0.278	0.047

6. SYSTEMATIC papers must conform to the *International code of zoological nomenclature* (particularly Articles 22 and 51).

Names of new taxa, combinations, synonyms, etc., when used for the first time, must be followed by the appropriate Latin (not English) abbreviation, e.g. gen. nov., sp. nov., comb. nov., syn. nov., etc.

An author's name when cited must follow the name of the taxon without intervening punctuation and not be abbreviated; if the year is added, a comma must separate author's name and year. The author's name (and date, if cited) must be placed in parentheses if a species or subspecies is transferred from its original genus. The name of a subsequent user of a scientific name must be separated from the scientific name by a colon.

Synonymy arrangement should be according to chronology of names, i.e. all published scientific names by which the species previously has been designated are listed in chronological order, with all references to that name following in chronological order, e.g.:

Family Nuculanidae

Nuculana (Lembulus) bicuspidata (Gould, 1845)

Figs 14–15A

Nucula (Leda) bicuspidata Gould, 1845: 37.

Leda plicifera A. Adams, 1856: 50.

Laeda bicuspidata Hanley, 1859: 118, pl. 228 (fig. 73). Sowerby, 1871: pl. 2 (fig. 8a–b).

Nucula largillierii Philippi, 1861: 87.

Leda bicuspidata: Nicklès, 1950: 163, fig. 301; 1955: 110. Barnard, 1964: 234, figs 8–9.

Note punctuation in the above example:

comma separates author's name and year

semicolon separates more than one reference by the same author

full stop separates references by different authors

figures of plates are enclosed in parentheses to distinguish them from text-figures

dash, not comma, separates consecutive numbers.

Synonymy arrangement according to chronology of bibliographic references, whereby the year is placed in front of each entry, and the synonym repeated in full for each entry, is not acceptable.

In describing new species, one specimen must be designated as the holotype; other specimens mentioned in the original description are to be designated paratypes; additional material not regarded as paratypes should be listed separately. The complete data (registration number, depository, description of specimen, locality, collector, date) of the holotype and paratypes must be recorded, e.g.:

Holotype

SAM-A13535 in the South African Museum, Cape Town. Adult female from mid-tide region, King's Beach, Port Elizabeth (33°51'S 25°39'E), collected by A. Smith, 15 January 1973.

Note standard form of writing South African Museum registration numbers and date.

7. SPECIAL HOUSE RULES

Capital initial letters

- The Figures, Maps and Tables of the paper when referred to in the text
e.g. '... the Figure depicting *C. namacolus* ...': '... in *C. namacolus* (Fig. 10) ...'
- The prefixes of prefixed surnames in all languages, when used in the text, if not preceded by initials or full names
e.g. Du Toit but A. L. du Toit; Von Huene but F. von Huene
- Scientific names, but not their vernacular derivatives
e.g. Therocephalia, but therocephalian

Punctuation should be loose, omitting all not strictly necessary

Reference to the author should preferably be expressed in the third person

Roman numerals should be converted to arabic, except when forming part of the title of a book or article, such as

'Revision of the Crustacea. Part VIII. The Amphipoda.'

Specific name must not stand alone, but be preceded by the generic name or its abbreviation to initial capital letter, provided the same generic name is used consecutively. The generic name should not be abbreviated at the beginning of a sentence or paragraph.

Name of new genus or species is not to be included in the title; it should be included in the abstract, counter to Recommendation 23 of the Code, to meet the requirements of Biological Abstracts.



R. V. DINGLE
&
A. HONIGSTEIN

OSTRACODA FROM QUATERNARY
COASTAL SEQUENCES
IN THE SOUTH-WESTERN CAPE