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Late Pleistocene, Holocene, and Recent ostracods from the Gulf of Argos, Greece

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2 Text-figures, 4 Plates

Abstract

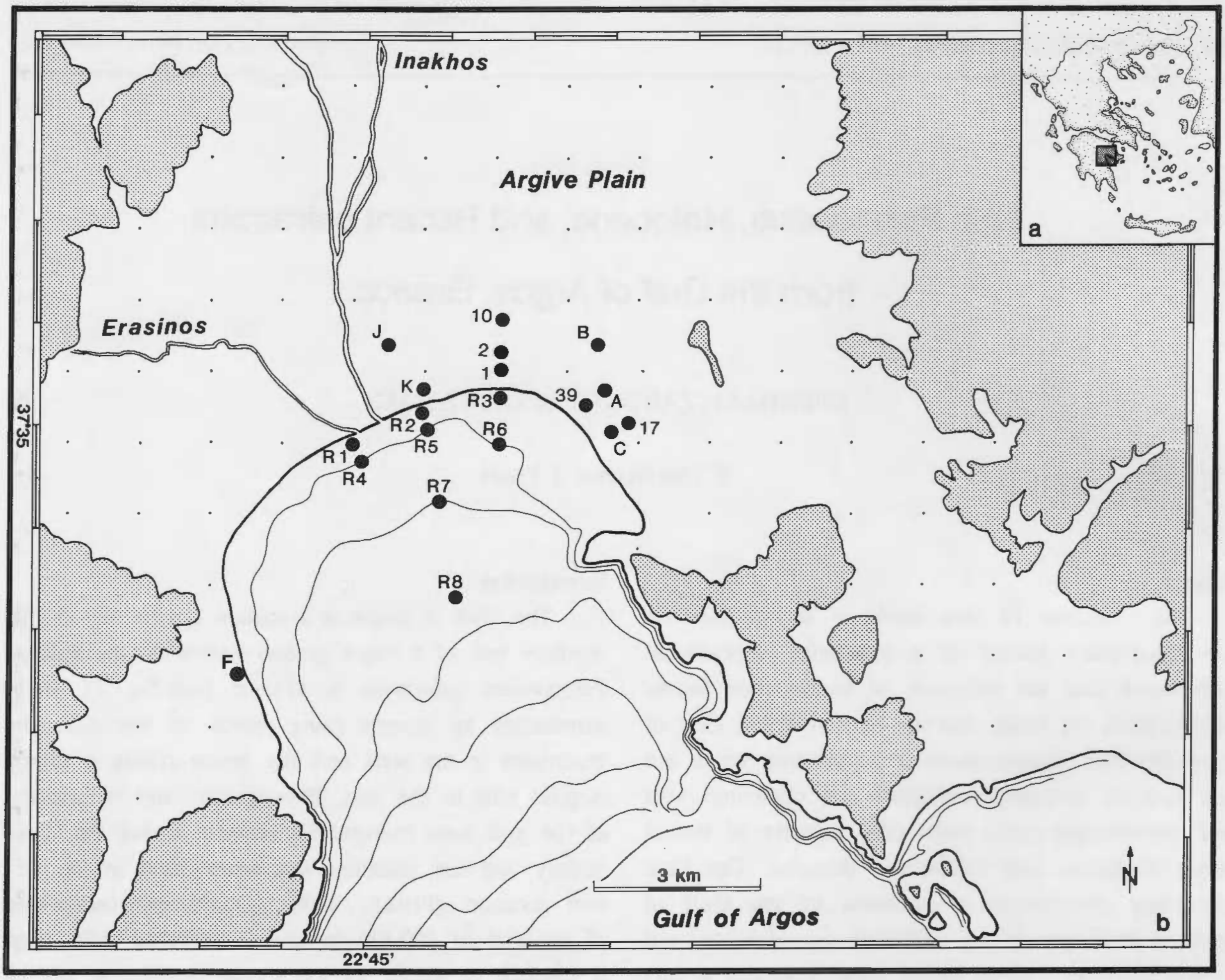
The objective of this study is to outline the Late Quaternary history of a submarine depositional environment and the evolution of its ostracod fauna. Samples from the beach and the bottom of the Gulf of Argos provided Recent ostracod populations, which are used here as ecological indicators and compared with fossil assemblages taken from core samples of buried marine Holocene and Pleistocene deposits. The Late Quaternary depositional environment of the Gulf of Argos is characterised by sediment accumulation and eustatic sea-level changes which have produced a succession of transgressive and regressive sequences. Each transgressive sequence begins with an assemblage of those organisms which first populated the newly formed euryhaline environment, in which the near-shore fauna as a whole can be characterised as a little diversified *Xestoleberis/Loxoconcha* assemblage.

Rising sea-levels during the Holocene and Pleistocene interglacials are indicated by more diversified assemblages occurring at deeper biotopes. In such deposits the *Xestoleberis* and *Loxoconcha* species are associated increasingly, and alternately, with those of *Basslerites, Pontocythere, Pontocypris, Leptocythere, Hiltermannicythere, Aurila, Cytheridea, Cytherella, Cytherelloidea, Cytheretta, Callistocythere, Semicytherura, Urocythereis, Pterygocythereis, Tenedocythere, Carinocythereis, Caudites, Costa, Buntonia, Acanthocythereis* and *Henryhowella*. In regressive sequences, the pure marine populations change upwards into monotonous *Cyprideis* assemblages indicating a change from marine to brackish conditions and recording the withdrawal of the coastline. Some samples near the present surface are rich in freshwater taxa such as *Candona, Cypris* and *Ilyocypris*.

Introduction

The Gulf of Argos is a shallow coastal bay at the northern end of a major graben system on the eastern Peloponnese peninsula in Greece (text-fig. 1). It is surrounded by steeply rising slopes of the Arkadian mountains in the west and the gently rolling southern Argolid hills in the east. Physiography and bathymetry of the gulf have changed significantly during the Quaternary and the coastline was never fixed in its present location (FINKE, 1988). Quaternary oscillations of sea-level of 100-120 m caused shoreline shifts over a distance of about 10 km (VAN ANDEL *et al.*, in prep.). Sedimentation during these sea-level fluctuations produced several transgressive/regressive sequences in the depositional record. Marine sediments were deposited on the originally terrestrial base during interglacial transgressions. Regressions resulted in the superposition of beach and backshore deposits on top of marine sediments, thus preserving the marine facies in the subsurface. Up to four of these transgressive/regressive cycles can be recognized in drillholes, 30 m deep, which were made near the present coastline (text-fig. 2). The cycles correspond to the latest four interglacial high sea-levels, with buried Holocene marine sediments at the top. In this paper we discuss the sedimentology and micropalaeontology of these four marine sequences and compare them with the present situation in the Gulf of Argos.

The availability of Pleistocene, Holocene and modern samples permits an analysis of the Late Quaternary evolution of the marine environment based on its ostracod population. The ostracod assemblages in general and the bathymetrical distribution of species in particular serve as a tool to interpret the palaeoenvironment. During the last decade such palaeo-

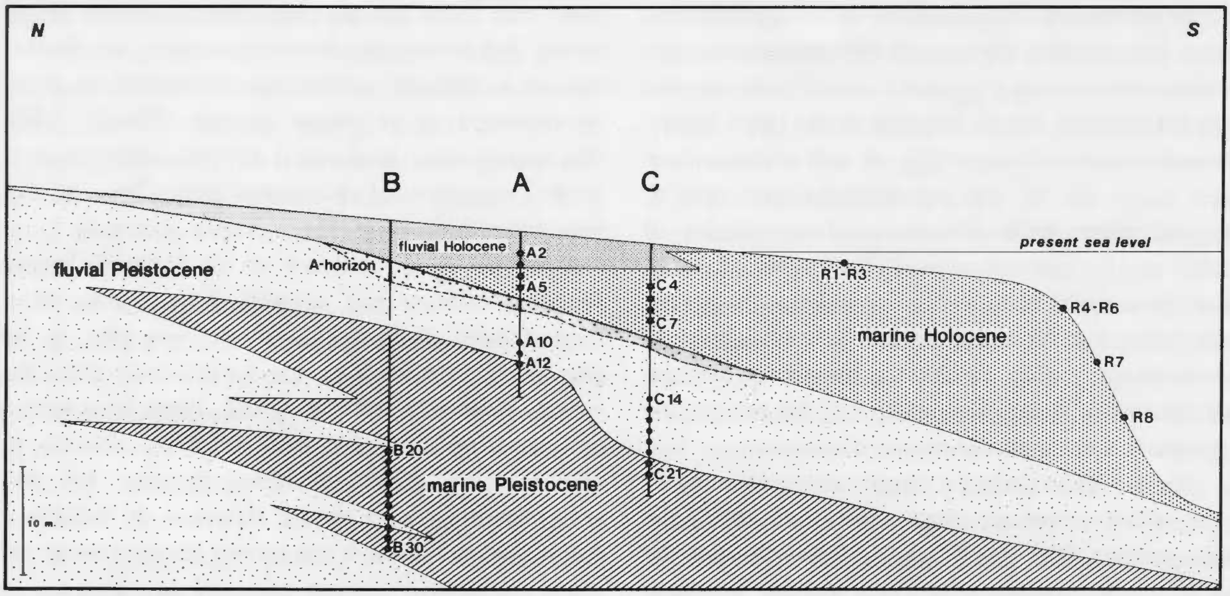


Text-figure 1. The study area is located on the Peloponnese peninsula in Greece (a). The Argive plain is extremely shallow and its 5 m contour lies 2 - 5 km landward of the shore. The shaded area marks the part of the surrounding mountains which is more than 100 m above sea-level. Six land based power drill-holes are shown in this figure (A, B, C, F, J, K). Five hand auger-cores are numbered 1, 2, 10, 17 and 39. The sample locations in the present Gulf of Argos are labeled R1, R2, R3 for 1 m of water depth, R4, R5, R6 for 5 m, R7 for 10 m, and finally R8 for 15 m.

bathymetric studies became widely recognized (e.g. PENNEY, 1987). Similar sea-level studies were carried out by ARANKI (1987), who compared marine Lower Pliocene ostracods with the Recent fauna in southern Spain.

Methods

The Late Quaternary marine sediments examined here are divided into three groups: (1) Recent, (2) Holocene and (3) Pleistocene deposits. Each group required a different method of investigation. (1) Samples from the modern deposits in the Gulf of Argos were collected by skin-diving in 1, 5, 10 and 15 metres depth. (2) A hand drill (auger) was used to take cores of the Holocene sediments. Nine samples for micropalaeontological analysis were taken from five of these auger cores. The sampling depth ranged between 1·9 and 5·3 m. (3) Pleistocene and Holocene deposits were sampled from power drill-holes which were made by a local well drilling company. Larger samples were taken every metre, washed and sieved using mesh sizes of 2·0 and 0·063 mm, which split the material into gravel, sand, and mud fractions of which the latter one was discarded. A small fraction of the original material was preserved for sedimentological description.



Text-figure 2. The location of drill-holes A, B, and C is shown in this schematic north/south cross-section perpendicular to the beach of the Gulf of Argos. The length of the profile is approximately 5 km. Sample locations of modern, Holocene and Pleistocene marine sediments are indicated with black dots. The Pleistocene transgressive/ regressive cycles reflect the eustatic sea-level changes between interglacials and glacials. At the end of the last ice age, 18,000 years ago, the Argive plain extended 10 km farther south. During the subsequent Holocene transgression marine sediments were deposited up to 1·5 km landward of the present shoreline.

The Present Coastal Environment

(E. Zangger)

The coastal plain at the north end of the Gulf of Argos is extremely shallow, with its 5 m contour being 2 - 5 km landward of the shore. Sediment is carried into the plain by several ephemeral streams, most importantly by the Inakhos River in the centre of the valley. The terrestrial depositional environment of the plain is dominated by alluvial fans along its margins with stream and interfluvial deposits in its centre. Due to silting up of the shallow coastal bay, the shoreline has regressed up to 1·5 km since the peak of the Holocene transgression at 2500 BC (FINKE, 1988).

The submarine depositional environment in the Gulf is also controlled by sediment accumulation. Erosion is limited to the east and west flanks of the gulf and is very minor along the shore in the north. There is essentially no tidal range in this part of the Aegean. The beach is stabilized by an elevated road that even severe winter storms cannot affect. Beach sediments are well sorted and fine grained (mud) at the eastern end of the bay and coarse (sand to gravel) in the west. The bathymetry (text-fig. 1) was taken from ship-based seismic studies which were carried out in 1986 (VAN ANDEL *et al.*, in prep.).

Recent Ostracods from the Gulf of Argos

(H. Malz)

Plate 1

Samples R1, R2 and R3 were all taken in one metre water depth and show clearly how the number of ostracod species increases along the beach from west to east (text-fig. 1). A rather poor ostracod fauna of 12 specimens occurs in the west at station R1 consisting of *Pontocythere rubra* and very rare *Xestoleberis* specimens. Station R2 in the centre produced three additional taxa of *Loxoconcha*, *Hiltermannicythere* and *Basslerites*. At station R3 on the east side of the bay the number of specimens (more than 100) and species increases further. The population is dominated by different moult stages of *Cyprideis* (no adults) and includes 20 specimens each of *Loxoconcha* and *Xestoleberis*, followed by frequent *Pontocythere rubra*. Rare specimens of *Hiltermannicythere* and *Basslerites*, as well as some single juvenile specimens of *Aurila* and *Semicytherura* complete the low diversity near-shore assemblage.

The ostracod fauna becomes richer and more diversified in samples taken at 5 m water depth (R4 to R6). Xestoleberids and loxoconchids dominate these samples, producing 75% of a total of 180 specimens at station R4 and 90% (more than 300 specimens) at R6. *Pseudopsammocythere reniformis* occurs rarely at stations R4 and R5, but is frequent at R6 (pl. 1 fig. 2). *Basslerites berchoni* (pl. 1 fig. 3) and *Pontocythere rubra* (pl. 1 fig. 6) are less abundant here than in shallower water, while *Hiltermannicythere,* juveniles of *Aurila* and *Carinocythereis, Callistocythere, Leptocythere, Pontocypris, Sclerochilus* and *Semicytherura* are even rarer. Two *Ilyocypris* specimens in R4 point to the freshwater influx of the Inakhos River, whereas rare specimens of *Cyprideis* at R5 and R6 indicate the adaptability of this species to marine influence.

Sample R7 was taken in 10 m water depth and yielded about 300 specimens - mostly xestoleberids (50%) and loxoconchids (25%) (pl. 1 figs. 4, 5; 10-12). For the first time adult specimens of *Aurila convexa* are found (pl. 1 figs. 13-14) and *Semicytherura inversa* occurs more frequently (pl. 1 figs. 7-9). Furthermore, rare specimens of *Callistocythere, Hiltermannicythere* and *Cytherella* are present.

The ostracod fauna is comparatively impoverished in the deeper biotope of station R8 at 15 m water depth. Although xestoleberids and loxoconchids still occur in large numbers (>150 and about 70, respectively) only rare specimens (<10) of just three other genera were found: *Pterygocythereis, Callistocythere* and *Semicytherura.*

In conclusion, the Recent ostracod population in the Gulf of Argos can be characterised as a *Xestoleberis/Loxoconcha* assemblage in a low energy environment. Near-shore species, such as *Tenedocythere prava* and *Neonesidea longevaginata,* which would point to a high energy depositional environment, were not found. First signs of deeper water fauna are indicated by *Pterygocythereis* (in R8), however, 15 m water depth is evidently still too shallow for living *Cytheropteron* and *Acanthocythereis.*

Holocene Deposits

(E. Zangger)

The Holocene sediments reach their greatest thickness of 8 metres at the north coast of the Gulf of Argos. The base of the Holocene deposits is a well consolidated Pleistocene red bed with a commonly preserved A-horizon (text-fig. 2). This palaeosol had been the stable surface of the coastal plain during the latest glaciation, when sea-level was more than 100 m lower than today and the plain extended 10 km farther south. The subsequent eustatic sea-level rise reached its peak at 2500 BC and shifted the coastline up to 1·5 km landward of its present location (FINKE, 1988). This transgression is recorded by subaqueous deposits in the subsurface of the coastal plain. Core samples were taken from these buried marine sediments to investigate the faunal evolution of the Holocene marine biotope. Sediments and ostracods from a large freshwater lagoon which existed on the west side of the plain during the transgression have already been discussed elsewhere (FINKE & MALZ, 1988). Both marine and lacustrine sediments are commonly covered by several metres of silty floodplain deposits. The present surface is either deeply disturbed or contains a thin marsh deposit which was formed during a recent wet phase.

Holocene Ostracods

(H. Malz)

Twenty samples with Holocene ostracods were collected from drill-holes A, C, J and auger cores 1, 2, 10, 17 and 39 respectively. Drill-hole A (text-fig. 2) yielded four samples which were taken at one metre intervals (2 m, 3 m, 4 m, 5 m). The ostracod faunas in these four samples are dominated by *Cyprideis torosa,* which occurs in hundreds of specimens both adult and juvenile and indicates brackish water. In the lowermost sample (A: 5 m) *C. torosa* is associated with marine species assigned to *Semicytherura, Aurila, Hiltermannicythere* and *Loxoconcha* (as well as sponge spicules and foraminifers). An increasing freshwater influence, which records the regression of the shoreline, is indicated in the uppermost sample by the presence of the freshwater ostracods *Candona* and *Cypris* and by an increasing amount of charophytes (A: 2 m).

Compared with drill-hole A the number of specimens, particularly marine species, increases in drill-hole C, the position of which is located next to the bay. The Holocene samples taken from hole C are dominated by *Cyprideis torosa,* which occurs continuously from 4 m to 7 m depth. This brackish water species is associated with very rare to rare specimens of *Heterocypris* and *Ilyocypris* from 5 m to 7 m, but is more abundant at 4 m depth. In addition to the marine taxa found in drill-hole A, species of *Cytherelloidea, Xestoleberis, Callistocythere* and *Paracytheridea* occur throughout the sequence pointing to the closer proximity of drill-hole C to the open sea.

Three samples from drill-hole J were taken at 5 m, 6 m and 7 m, and produced almost exclusively freshwater species (mainly *Candona*, some *Ilyocypris* and *Sarscypridopsis*), but very rare *Loxoconcha* and *Xestoleberis* also occur. The freshwater genera indicate a lacustrine rather than a fluvial environment (FINKE & MALZ, 1988).

Four samples from auger-hole 1 at 1·9 m, 2·7 m, 3·9 m and 4·6 m depth contain abundant *Cyprideis torosa* associated with species of *Ilyocypris, Heterocypris* and *Candona* (as well as charophytes) - evidently recording a freshwater environment. However, rare specimens of *Loxoconcha* and *Xestoleberis,* as well as occasional *Pontocythere* and *Semicytherura,* point to the former near-shore position of the sampling area, having been later reworked into the freshwater environment.

Cyprideis torosa is again the most common species in auger-hole 2 at 4·9 m, where it is associated with *Ilyocypris, Potamocypris* and juvenile *Candona.* An even more depleted freshwater biotope is indicated by fragments of large *Cypris bispinosa,* which are found in auger-hole 10 at 3·2 m, suggesting a former pond with standing water.

Large numbers of *Cyprideis torosa* in auger-hole 17 at 5·3 m suggest a brackish environment in which also marine ostracod genera such as *Loxoconcha, Leptocythere* and *Aurila* (in combination with some foraminifers) occur mixed with freshwater genera like *Heterocypris* and *Ilyocypris* (and rare charophytes). Due to a regression of the shoreline during the second half of the Holocene, freshwater influence is increasingly dominant higher up in the sequence, as indicated by the occurrence of *Candona* and *Ilyocypris* in auger-hole 17 at 3·8 m.

One sample from near-shore auger-hole 39 at 5·8 m contains only marine species mainly assigned to *Loxoconcha, Xestoleberis* and *Leptocythere,* whereas *Semicytherura, Hiltermannicythere, Aurila, Urocythereis, Parakrithe* and *Bassleriteses* are rare to very rare.

Pleistocene Deposits

(E. Zangger)

Pleistocene palaeosols crop out at the present surface along the edge of the costal plain. The upper boundary of these red beds dips seaward and is found at a maximum of 8 m depth at the present coast (text-fig. 2). The uppermost Pleistocene sediments (at 8-20 m depth) consist of terrestrial interfluve and stream deposits laid down in an environment similar to the present one. Major soil development on these sediments resulted from the long periods of subaerial exposure during low glacial sea-levels.

Palaeosols were also found lower down in the drill-holes below 20 metres depth. Most of the features of these lower palaeosols resemble those of the upper Pleistocene, except for the size of pedogenic calcite which sometimes forms nodules up to 5 cm diameter or calcrete limestone banks. The essential difference from the overlying fluvial deposits, however, is the presence of marine fossils, proving that virtually all coastal sediments below 20 metres depth, no matter how terrigenous their present appearance may be, were originally deposited in shallow marine waters. These marine sediments were laid down during interglacial high sea-level stands. The uppermost of which must have been deposited during the Eutyrrhenian (oxygen isotope stage 5e, about 125,000 BP), when the sea-level was as high as it is today or even a few metres higher (SHACKLETON & OPDYKE, 1973). Interstadial sea-levels were probably too low (CHAPPELL & SHACKLETON , 1986) to reach the present coastal zone where the drill-holes are located. During stages 5a-d (115,000 - 75,000 BP) sea-level had dropped again to 20-30 metres below the present level.

The eustatic sea-level fall resulted in the exposure of a large area of marine deposits along the shore. The falling sea-level also shifted the main zones of sediment accumulation seaward towards the present shelf edge. The resulting long interval of non-deposition in what is today the central plain, provided time for the formation of a deep soil on the exposed marine mud. Palaeosols on marine deposits occur in three cycles (FINKE, 1988). Diagenesis and soil-forming processes have produced a vertical order within each sequence. The secondary differentiation increases upward and in the final stage a calcrete limestone horizon is formed. Since the soil-forming processes decrease in intensity with depth, the lower part of every marine sequence has changed less than the upper part or remained unaltered. The sedimentary petrography of such Pliocene/Pleistocene marine/terrestrial cycles has been described by RICHTER (1984) from other places in Greece, but complete transgressive/regressive cycles are known only from outcrops on Mallorca (BUTZER, 1975).

Pleistocene Ostracods

(H. Malz)

Plates 2 - 4

The Pleistocene ostracods from the Mediterranean region are well-known. Numerous publications beginning with the early works by VON MÜNSTER (1830) up to MOSTAFAWI's report in this volume have produced a substantially complete inventory of species. Nowadays ostracod research in the Mediterranean concentrates on the bathymetrical range and the ecological conditions at which certain species occur. The distribution of Recent ostracods is generally used as an environmental indicator which can be applied to and compared with fossil assemblages. Thus, in this article the discussion of the Recent ostracod fauna of the Gulf of Argos has preceded that of the Pleistocene fauna obtained from various drill-holes in the coastal area of the Argolis.

Numerous samples containing Pleistocene ostracods were taken from drill-holes A, B, C, F, and K (text-fig. 1). As partly discussed above the sequence in these drill-holes consists of Holocene freshwater deposits in the upper part and Holocene marine deposits in the lower part. This change of freshwater to marine is once more repeated in the Pleistocene sequence below.

Fluvial sediments occur in drill-hole A between 6 m and 11 m depth (text-fig. 2). Samples at 10 m and 11 m depth contain exclusively rich but monotonous populations of *Cyprideis torosa* (pl. 3 figs. 11, 12), represented by remarkably well-preserved, translucent and vitreous valves. Another sample at 12 m depth is still dominated by such "clean" *C. torosa*, but contains marine ostracods and foraminifers as well. The marine ostracods include the genera *Loxoconcha*, *Xestoleberis* and *Hiltermannicythere*, as well as rare representatives of *Semicytherura*, *Cytherelloidea*, *Urocythereis* and *Carinocythereis*. These marine ostracods and the foraminifer shells are filled and partly encrusted with sediment, their surfaces are not glassy but whitish opaque. The different preservation of the "clean" fluvial and the reworked marine assemblages documents the age difference between these deposits and the soil processes which have altered the marine sediments.

Marine ostracod assemblages were also found in cores from drill-hole B between 20 m and 30 m depth (text-fig. 2). The diversification of species, the number of specimens and their preservation vary considerably in these samples. The assemblages from 20 m to 26 m resemble the ones obtained from the Recent samples of the Gulf of Argos. The fauna is characterised by low diversity, the number of specimens does not exceed 300 per sample, and the specimens are not well-preserved and partly filled or encrusted with yellowish to brownish sediment. *Xestoleberis* and *Loxoconcha* specimens dominate the population by far; *Cytheridea neapolitana* is common in 20 m and 26 m depth only, whereas specimens of *Pontocythere, Callistocythere, Hiltermannicythere* and *Semicytherura* are rare. The palaeobathymetry of this sample interval (20-26 m) is thought to reflect a 10 m to 15 m isobath for the Pleistocene.

Abundant well-preserved *Cyprideis torosa* and some *Heterocypris* specimens are evidence for a freshwater influence on the ostracod assemblage at 27 m depth; although the marine population is essentially the same as higher up in the sequence. However, since only a small number of marine specimens was obtained from this sample, the assemblage cannot be analysed in more detail. Among the marine species some drilled valves point to predacious gastropods feeding on the dead specimens.

The interval from 28 m to 30 m contains very rich, well-preserved and highly diversified assemblages. More than 1000 specimens in each sample represent about 30 marine species, some of which are shown on pls. 2-4. Near-shore species which dominate in the Recent *Xestoleberis/Loxoconcha* assemblages from the Gulf of Argos, also occur in large numbers in this part of the marine Pleistocene. The actual number of *Xestoleberis* and *Loxoconcha* specimens is even higher in these samples than it is in the modern ones. The relative proportion of both together (ca 25%), however, is about as high as the number of *Hiltermannicythere* (15%) and *Callistocythere* (10%). Four more species increase the diversity of the Pleistocene fauna and are referred to *Pterygocythereis, Semicytherura, Tenedocythere* and *Carinocythereis* - all of which are represented at 5%. *Neonesidea, Aurila, Paracytheridea, Cytherelloidea, Acanthocythereis* and *Cytheridea* occur at less than 5%. - These assemblages are assumed to have lived well below the Pleistocene 20 m to 25 m isobath.

A mixture of marine and freshwater elements occurs in drill-hole C in the interval between 14 m and 21 m. The marine part is represented by several species belonging to *Loxoconcha, Xestoleberis, Hiltermannicythere, Callistocythere, Semicytherura, Pontocypris* and *Basslerites,* which are associated with some foraminifers (mainly *Elphidium*). Even species of *Caudites, Costa* and *Hemicytherura* appear in the deeper part of the hole. The freshwater influx is represented by charophytes (especially at 14 m and 15 m), by large numbers of *Cyprideis torosa* throughout the sequence and by rare *Ilyocypris, Limnocythere, Heterocypris* and *Sarscypridopsis* species. These mixed assemblages reflect interfingering facies and presumably indicate tidal water influence in a river mouth area.

A commercial drill-hole provided the opportunity to collect a sample from a much deeper marine layer at 65 metres depth (drill-hole K, text-fig. 1). The sample contained a very rich assemblage of marine meso-gastropods, foraminifers and ostracods all of which are very well-preserved. The highly diversified ostracod fauna consists of about 450 specimens and is dominated by several species of *Xestoleberis* and *Loxoconcha* which altogether cover about 45% of the population. *Cytheridea neapolitana* occurs quite frequently (40 specimens) and is followed by a decreasing number of *Hiltermannicythere, Aurila* and *Carinocythereis* species, each of which is present at more than 5%. *Acanthocythereis hystrix* was found among the less frequent species (<5%), together with some *Celtia, Costa, Pterygocythereis* and *Tenedocythere* species. Rare to very rare specimens of *Callistocythere, Cytherella, Cytheretta, Semicytherura, Basslerites, Neonesidea* and *Urocythereis* also occur. From the relative proportion of species composing the faunal assemblage, the water depth of the former habitat is presumed to lie well below 25 m. The stratigraphic position of the marine layer sampled in drill-hole K is not known. The palaeo-bathymetry which is reflected in the ostracod population, however, suggests deposition in a relatively deep environment. Since the sample was collected from 65 metres in a subsiding basin, it most likely records a high interglacial sea-level.

Drill-hole F is located at the western side of the Gulf of Argos in an area which is uplifting with a rate of 0·5 metres per 1000 years (FINKE, 1988). Therefore, this drill-hole cannot be correlated with the sequences in the central plain. Marine Pleistocene sediments were penetrated from 16 m to 26 m. The interval from 13 m to 15 m contains rare specimens of *Ilyocypris, Heterocypris* and *Candona* associated with poorly preserved foraminifers which were presumably reworked from the marine sediments below and re-deposited in the freshwater biotope. This assumption is supported by the results gained from drill-hole A in which fluvial Pleistocene also covers the marine sediments below. The marine ostracod faunas from 16 m to 26 m are highly diversified but the assemblages alternate as regards the composition of species. Within the marine sequence:

1) In the upper part (16 m to 20 m) mainly specimens of *Xestoleberis, Cytheridea, Hiltermannicythere, Cytherella* and *Carinocythereis* were found. In association with less frequent to rare specimens of *Cytheretta, Basslerites, Pontocythere, Loxoconcha, Aurila, Buntonia, Pterygocythereis* and *Semicytherura* these assemblages point to a former water-depth of about 20 m.

2) In the lower part (21 m to 26 m) the above mentioned taxa also occur, but frequencies change and other species are newly recorded. *Acanthocythereis hystrix* and *Henryhowella hirta* occur in the assemblages below 21 m for the first time, whereas specimens of *Pterygocythereis, Buntonia* and *Semicytherura,* which were rare in the upper part, are rather common in the lower part. Furthermore, otoliths were found quite frequently in this interval. Therefore the assemblages from the lower part are estimated to represent deeper habitats, presumably at the 50 m isobath or below.

Discussion and Conclusions

(E. Zangger)

The aim of this paper was to reconstruct the Late Quaternary submarine environment of the Gulf of Argos. Any such environmental reconstruction requires a complex multi-dimensional model; in the case of a submarine ecological system this model would include such parameters as space, time, water depth, water temperature, salinity, grain size of substrate, land proximity and current activity. Only one environmental indicator, namely the ostracod fauna, was chosen to determine the evolution of the biotope and its confining physical parameters. It was discovered that the ostracod faunas closely reflect the depositional environments and their ecology.

The west-east increase in Recent ostracod species along the beach is inversely related to the grain size of shore deposits. The low energy beach on the eastern side consists entirely of mud, thus providing a more favourable environment for ostracods than the steep gravel beach on the west side. The gravel is brought to the shore by perennial floods of the Inakhos river which exits in the centre of the plain. A steady long-shore current carries the coarse material farther west.

The numbers of species and specimens increases at 5 and 10 m water depths but drops again at 15 m. The near-shore fauna as a whole can be characterised as a low diversity *Xestoleberis*/*Loxoconcha* assemblage.

The evolution of the coastal biotope during and after the peak of the Holocene transgression is exemplified in samples from drill-hole A: 2-5 m and auger-core 17. Large numbers of *Cyprideis torosa* reflect a brackish biotope. At the lower boundary of the marine deposits, however, *Cyprideis* is accompanied by marine forms such as *Loxoconcha, Leptocythere, Aurila, Semicytherura, Hiltermannicythere,* as well as sponge spicules and foraminifers. These assemblages indicate the predominantly marine character of the beach environment during the advance of the sea. Soon after the Holocene transgression had reached its culmination the newly developed shallow lagoon silted up and the ostracod fauna is increasingly characterised by freshwater genera such as *Candona* and *Ilyocypris.*

A similar fossil record is found in the Pleistocene stratigraphy. The lowermost marine assemblages in drill-hole B are extremely rich and diversified. The fauna becomes more monotonous higher up in the Pleistocene sequence and resembles the Recent *Xestoleberis/ Loxoconcha* assemblage associated with *Hiltermannicythere* and some other, but rare marine species. The pure marine sequence terminates at 11 m depth in drill-hole A and changes into a monotonous *Cyprideis* assemblage, indicating a shift from a marine to a brackish environment due to shoreline regression during the latest glaciation.

A comparison between the upper Pleistocene marine assemblages with the ones from deeper holes (drill-hole K) or uplifted sequences (drill-hole F) shows how the general ostracod population decreased in diversification toward the Holocene. This trend continued regardless of sea-level and depositional environment changes.

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VAN ANDEL, T.H. & ZANGGER, E. & PERISSORATIS , C. (in prep.): Late Cenozoic Sedimentation and Structure, Gulf of Argos, Greece.

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Plates 1 - 4

C = carapace; LV = left valve, RV = right valve.
Numbers in parentheses refer to length of specimens in mm.
Catalogue numbers prefixed by Xe refer to the deposition of specimens in the Micropalaeontology Department, Senckenberg Museum, Frankfurt am Main.
All Stereoscan photographs and prints by Miss D. Klein.

Plate 1

Recent specimens from the Gulf of Naples (Fig. 1)
and the Gulf of Argos (Figs. 2, 3, 6: sample R6 at 5 m water depth;
Figs. 4, 5, 7-14: sample R7 at 10 m water depth).
Sample numbers refer to text-fig. 1.

Figs. 1-2. *Pseudopsammocythere reniformis* (BRADY 1868)

1. ♀ RV (0·51) in transmitted light, a) lateral view, X 118;
b) detail of finely denticulate posterior hinge in dorsal view, X 250;
c) internal view of muscle scars and stringed punctation; X 274. - [Xe 14630.]

2. ♀ C (0·50), right lateral, X 100. - Xe 14631.

Fig. 3. *Basslerites berchoni* (BRADY 1869)

3. ♀ C (O·47), left lateral; X 100. - Xe 14632.

Figs. 4-5. *Xestoleberis communis* G.W. MÜLLER 1894

4. ♀ LV (0·64), external lateral; X 81. - Xe 14634.
5. ♀ C (0·65), dorsal; X 81. - Xe 14634.

Fig. 6. *Pontocythere rubra* (G.W. MÜLLER 1894)

6. ♀ RV (0·68), external lateral; X 82. - Xe 14633.

Figs. 7-9. *Semicytherura inversa* (SEGUENZA 1880)

7. ♀ LV (0·55), external lateral; X 100. - Xe 14635.
8. ♂ C (0·53), dorsal; X 100. - Xe 14635.
9. ♀ RV (0·55), external lateral; X 100. - Xe 14635.

Fig. 10. *Loxoconcha ovulata* (COSTA 1853)

10. ♂ LV (0·77), external lateral; X 77. - Xe 14637.

Fig. 11. *Loxoconcha bairdi* G.W. MÜLLER 1912

11. ♀ RV (0·58), external lateral; X 100. - Xe 14638.

Fig. 12. *Loxoconcha exagona* BONADUCE, CIAMPO & MASOLI 1976

12. ♀ C (0·60), dorsal; X 100. - Xe 14639.

Figs. 13-14. *Aurila (Aurila) convexa* (BAIRD 1850)

13. ♀ C (0·77), left lateral; X 78. - Xe 14640.
14. ♀ C (0·77), left lateral; X 78. - Xe 14641.

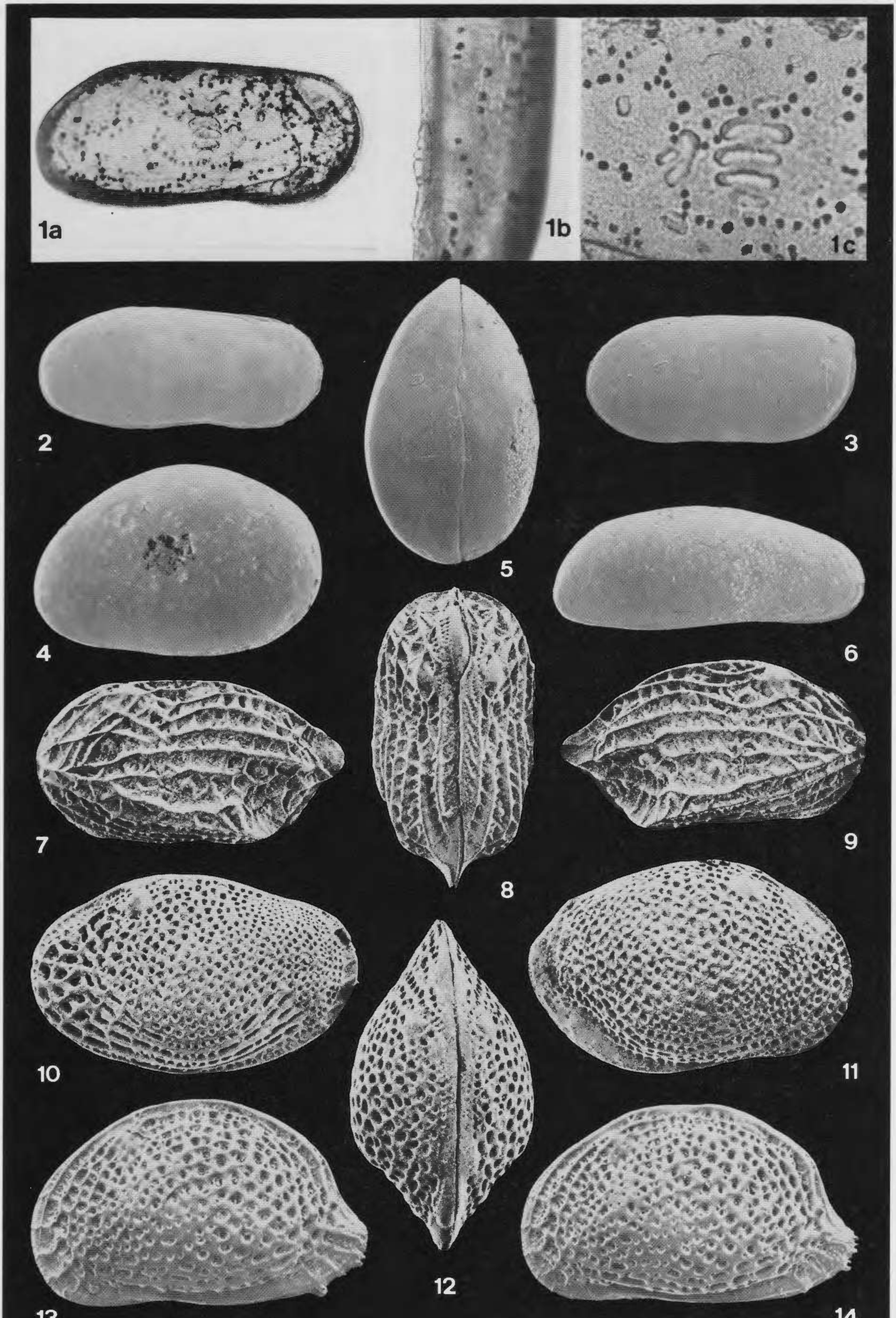
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Plate 2

If not stated otherwise, all specimens from drill-hole B: 28 m; Pleistocene.
All figures about X 80.

Fig. 1. *Semicytherura paradoxa* (G.W. MÜLLER 1894)
1. ♂ LV (0·57), external lateral. - Xe 14650.

Fig. 2. *Callistocythere crispata* (BRADY 1868)
2. ♂ LV (0·68), external lateral. - Xe 14652.

Fig. 3. *Paracytheridea* sp., aff. *P. depressa* G.W. MÜLLER 1894
3. ♂ LV (0·63), external lateral. - Xe 14654.

Figs. 4-7. *Costa batei* (BRADY 1866)
Drill-hole C: 20 m.
4. ♀ RV (0·88), internal lateral. - Xe 14644.
5. ♀ RV (0·87), external lateral. - Xe 14644.
6. ♂ LV (0·88), external lateral. - Xe 14645.
Drill-hole C: 19 m.
7. ♀ C (0·88), left lateral. - Xe 14643.

Fig. 8. *Tenedocythere prava* (BAIRD 1850)
8. ♂ RV (0·97), external lateral. - Xe 14656.

Fig. 9. *Cytheridea neapolitana* KOLLMANN 1960
9. ♂ RV (0·85), external lateral. - Xe 14659.

Fig. 10. *Hiltermannicythere turbida* sensu STAMBOLIDIS 1985
10. ♀ RV (0·85), external lateral. - Xe 14660.

Fig. 11. *Acanthocythereis hystrix* (REUSS 1850)
11. ♂ RV(0·95), external lateral. - Xe 14662.

Fig. 12. *Aurila (Aurila) abscisa* (TERQUEM 1878)
[? = *A. prasina* BARBEITO-GONZALES 1971]
12. ♀ LV (0·85), external lateral. - Xe 14663.

Fig. 13. *Aurila (Aurila) bisinuata* (TERQUEM 1878)
[? = *A. aspidoides* ULICZNY 1969]
13. ♀ RV (0·98), external lateral. - Xe 14664.

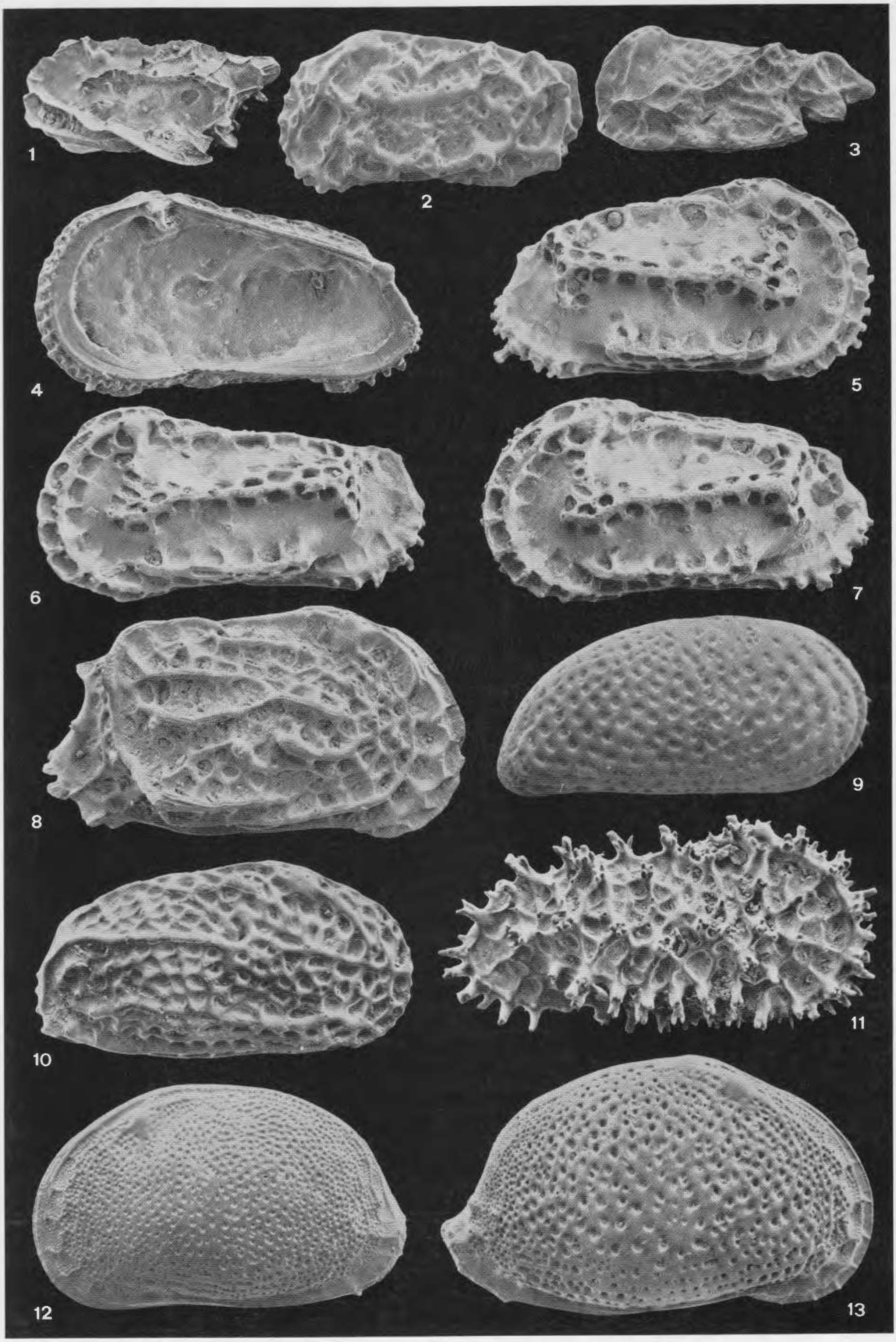

Plate 3

Fig. 1. *Cytherelloidea sordida* (G.W. MÜLLER 1894)
Drill-hole B: 21 m; Pleistocene.
1. ♂ LV (0·78), external lateral; X 75. - Xe 14648.

Fig. 2. *Amnicythere* sp., aff. *A. affinis* (BRADY 1869)
Drill-hole B: 21 m; Pleistocene.
2. ♂ C (0·66), left lateral; X 80. - Xe 14649.

Fig. 3. *Neonesidea longevaginata* (G.W. MÜLLER 1894)
Drill-hole B: 28 m; Pleistocene.
3. ♂ LV (1·32), external lateral; X 50. - Xe 14665.

Fig. 4. *Pontocythere turbida* (G.W. MÜLLER 1894)
Drill-hole B: 24 m; Pleistocene.
4. ♂ RV (0·75), external lateral; X 80. - Xe 14673.

Fig. 5. *Pterygocythereis jonesii* (BAIRD 1850)
Drill-hole B: 24 m; Pleistocene.
5. ♀ LV (0·91), external lateral; X 58. - Xe 14674.

Fig. 6. *Cimbaurila panormitana* (RUGGIERI 1975)
Drill-hole B: 24 m; Pleistocene.
6. ♀ C (0·73), left lateral; X 80. - Xe 14676.

Fig. 7. *Costa edwardsii* (ROEMER 1838)
Drill-hole B: 24 m; Pleistocene.
7. ♀ LV (0·78), external lateral; X 77. - Xe 14677.

Fig. 8. *Henryhowella hirta* (COSTA 1853)
Drill-hole B: 24 m; Pleistocene.
8. ♀ C (0·70), right lateral; X 75. - Xe 14678.

Fig. 9. *Acanthocythereis hystrix* (REUSS 1850)
Drill-hole B: 24 m; Pleistocene.
9. ♀ C (0·85), left lateral; X 75. - Xe 14679.

Fig. 10. *Loxoconcha alata* BRADY 1868
Drill-hole C: 6 m; Holocene.
10. ♀ RV (0·65), external lateral; X 100. - Xe 14642.

Figs. 11-12. *Cyprideis torosa* (JONES 1850)
Drill-hole A: 12 m; Pleistocene.
11. ♀ LV (0·95), external lateral; X 60. - Xe 14647.
12. ♂ C (1·00), right lateral; X 70. - Xe 14647.

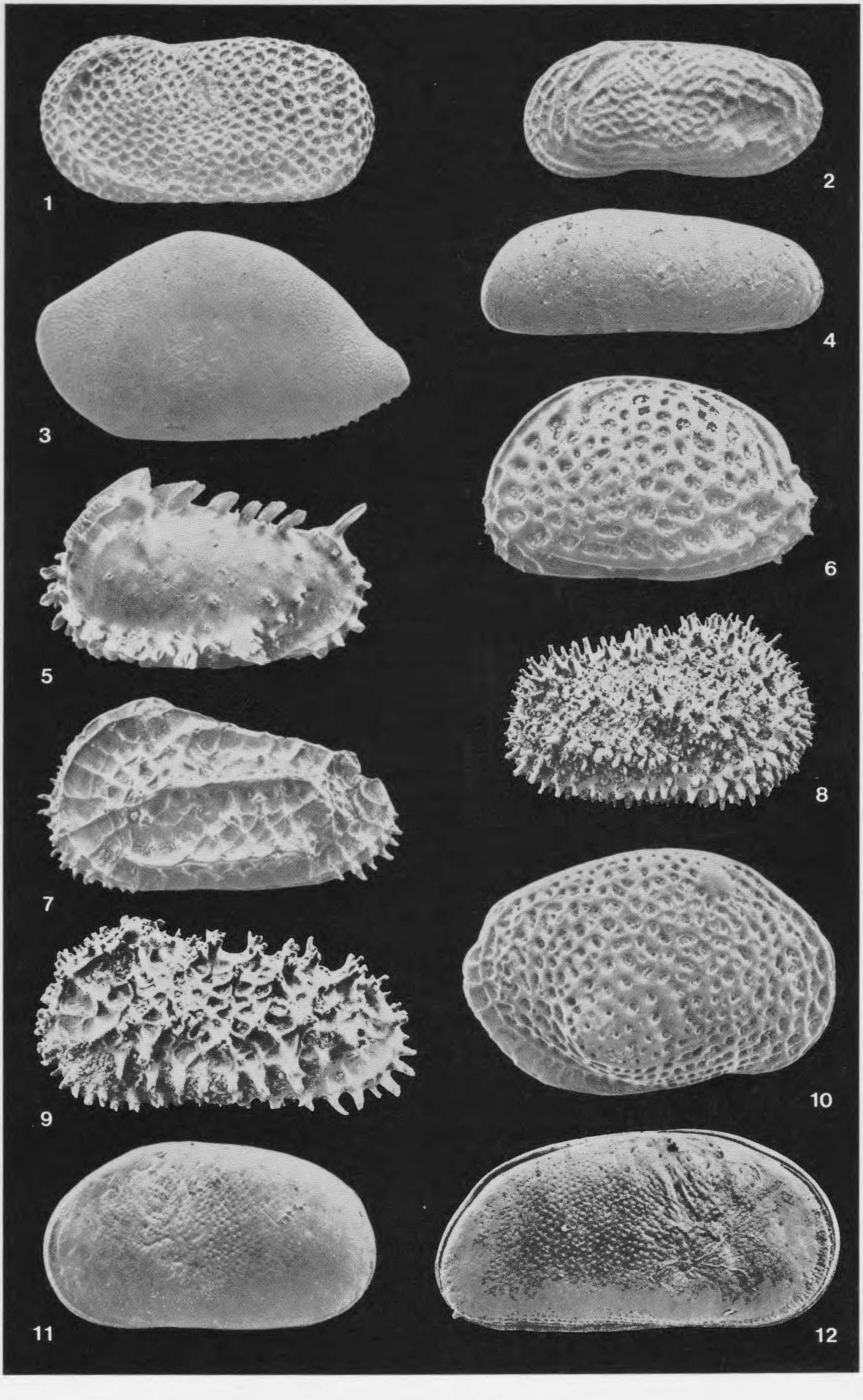
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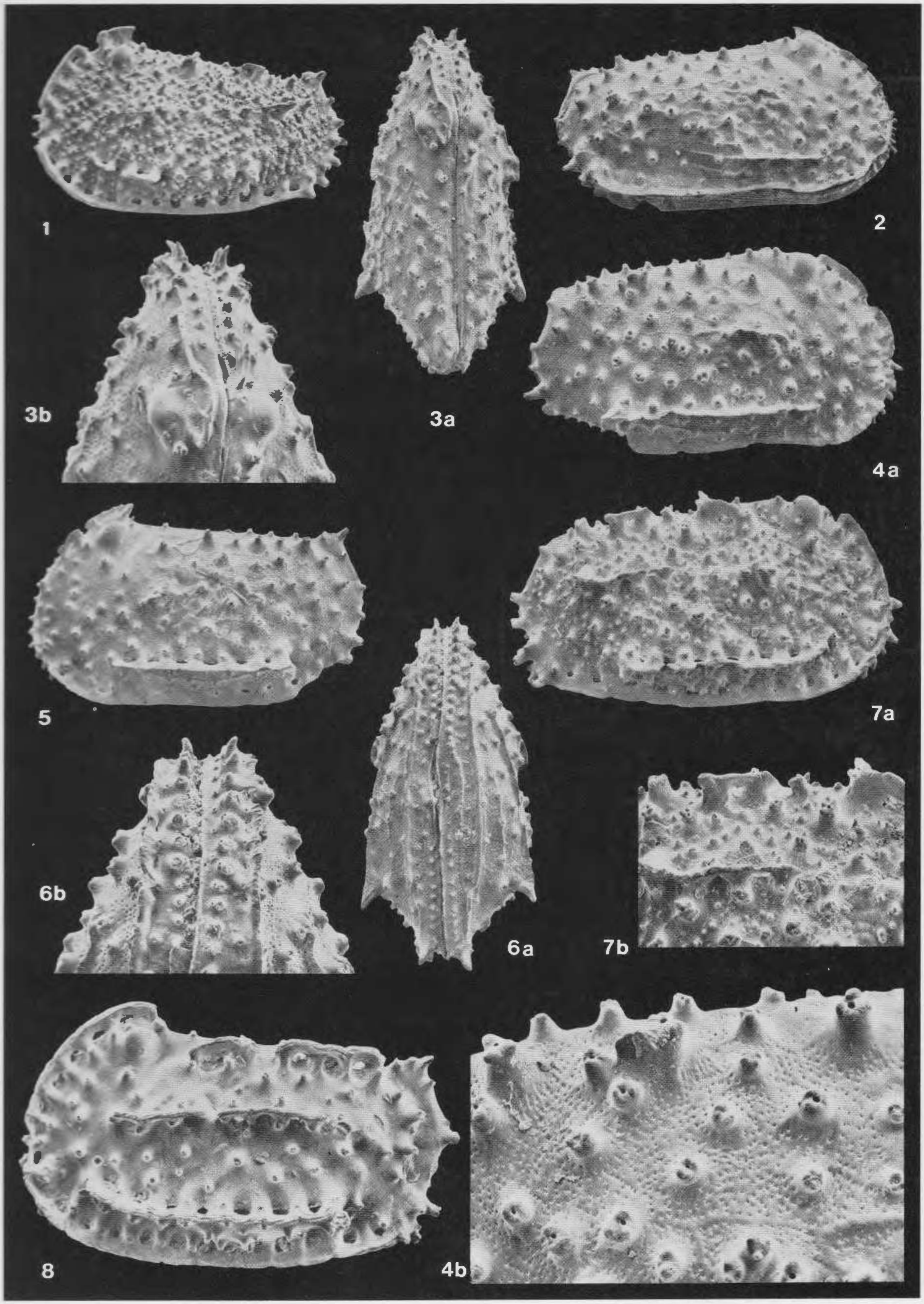
Plate 4

Pleistocene specimens from drill-holes F and B in the Argive Plain.
If not stated otherwise, all magnifications about X 80.

Fig. 1. *Carinocythereis carinata* (ROEMER 1838)
Drill-hole F: 21 m.
1. LV (0·65; juv.), external lateral. - Xe 14672.

Figs. 2-6. *Carinocythereis rhombica* STAMBOLIDIS 1985
[= syn. *Carinocythereis willmanni* MOSTAFAWI 1986]
Drill-hole F: 16 m.
2. ♂ C (0·72), right lateral. - Xe 14669.
Drill-hole F: 26 m.
3. ♂ C (0·75), a) dorsal,
b) detail of anterior part; X 150. - Xe 14680.
4. ♀ RV (0·81), a) external lateral,
b) detail of posterodorsal part; X 255. - Xe 14680.
Drill-hole F: 16 m.
5. ♀ LV (0·72), external lateral. - Xe 14669.
Drill hole F: 26 m.
6. ♀ C (0·75), a) ventral,
b) detail of anterior part; X 175. - Xe 14681.

Figs. 7-8. *Carinocythereis carinata* (ROEMER 1838)
Drill-hole F: 21 m.
7. ♀ RV (0·83), a) external lateral,
b) detail of mid-dorsal part; X 135. - Xe 14672.
Drill-hole B: 28 m.
8. ♀ LV (0·93), external lateral. - Xe 14667.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