Original

14/10/81

TAXONOMY, ECOLOGY AND PALAEOECOLOGY OF OSTRACODS FROM AUSTRALIAN INLAND WATERS

by

PATRICK DE DECKKER B.A., M.Sc.(Hons.)

Thesis submitted for the degree of
Doctor of Philosophy undertaken in
the Department of Zoology,
University of Adelaide

JANUARY 1981

awarded Aug 1981

TABLE OF CONTENTS

ABSTRACT

The taxonomy of ostracods from Australian inland waters is reviewed. Three new genera and 21 new species are described and 24 other species re-examined (13 of which are re-described). Notes on the ecology and distribution of Australian non-marine ostracods are provided. There is a high diversity of endemic halobiont species, most of which are planktic. Some elements of the freshwater fauna are endemic, some of which belong to genera found elsewhere, and a number of species are found in New Zealand. Part of the temporary pool fauna consists of cosmopolitan species.

To introduce the palaeolimnological studies, a classification of waterbodies in Australia is provided to assess the best sites for palaeoecological and palaeoclimatological investigations. An examination of the sort of information fossil ostracods can provide is also presented.

To trace past histories of selected lakes, 1,241 samples from Quaternary lacustrine sediments from south eastern Australia are examined for their fossil ostracod remains. From these samples, 12 ostracod species are described, 3 of which are new.

Ostracods and other fossil remains are studied from cores from 4 maar lakes in western Victoria. Results indicate that water salinity of 2 of these lakes (Gnotuk and Keilambete) varied during the Holocene, usually synchronously. As these changes in water salinity relate to water levels, this information follows the postulated changes of levels for the deeper and less saline Lake Bullenmerri. Little information is available from the fourth Lake Purrumbete core as water level remained high and no ostracods are recovered. The data for Lake Keilambete compare well with previous published data from sediment analyses.

The study of ostracods from a profile at Pulbeena and Mowbray Swamps in north western Tasmania provides information on waterflow from springs at both sites for the last 80,000 and 110,000 years respectively. The data are consistent with the previous palynological information from aquatic plants.

The ostracods extracted from a core at Lake George in New South Wales define the presence of high water level phases in the lake for the last 70,000 years. This information differs for some periods with the previous sedimentological and palynological data.

The ostracods taken from a short core at Pillie Lake, situated near the coast in South Australia, indicate changes in water salinity and from permanent to ephemeral water conditions. This change is thought to be related to sea level regression. Additionally, the ostracod fauna demonstrates the unusual formation of dolomite under permanent water conditions.

Changes in lake levels and water flow are then considered in broad climatic terms for south eastern Australia for the Late Pleistocene and Holocene. Brief comparison with changes in lake levels for the same period in Africa shows a similar pattern to the one registered in Australia but with a shift in time of the order of 1,000-2,000 years.

I hereby certify that this thesis contains no material which has been accepted for the award of any other degree or diploma in any university and that, to the best of my knowledge and belief, the thesis contains no material previously published or written by another person, except when due reference is made in the text of the thesis.

Patrick De Deckker

ACKNOWLEDGMENTS

This thesis was prepared during tenure of a three year Commonwealth Postgraduate Research Award.

I particularly wish to thank my supervisor, Professor W.D. Williams, Chairman of the Zoology Department at the University of Adelaide, for the provision of an ideal working niche, and for stimulating my enthusiasm for the study of ostracods and salt lakes. Equipment, and other working facilities such as his invaluable reprint library, were always easily accessible, and I benefited by being able to accompany him on collecting trips to Western Australia, central Australia and Victoria. As well, his comments on the first draft of this thesis have improved the quality and arrangement of the text.

The Research and Publications Committee of the University of Adelaide provided a grant to meet some of the costs incurred in a trip to the Oslo Museum, Norway, to study Sars' ostracod collection.

I am very grateful to Drs. C. Barton and J.M. Bowler at the Australian National University, who made available cores from 4 maar lakes in Victoria, studied in Chapter 5. They also provided unpublished manuscripts. Drs. E. Colhoun and G. van de Geer, from the University of Tasmania, allowed me to work on duplicate samples provided by them from their fossil sites in N.W. Tasmania, studied in Chapter 6. They also generously provided me with a large amount of unpublished data on their pollen studies, and allowed me to refer to it in my work. Dr. G. Singh, at the Australian National University, provided me with duplicate samples from his core of Lake George, studied in Chapter 7, and made available unpublished information from his work on the core with other authors.

Much of the data I now have on Australian ostracods results from numerous collections obtained from the following people: principally from Drs. I.A.E. Bayly and B.V. Timms, and also from P. Bailey, F. Crome, R. Croome, M. Davies, M.C. Geddes, A. Goede, S.A. Halse, D. Hembree, R. Marchant, B.D. Mitchell, D. Morton, R. Shiel, R. Tait, J. Terni, M. Topping, D. Towns, M. Tyler, K.F. Walker, P. Waller, W.D. Williams and W. Ziegler.

The following people have assisted on numerous occasions on the field: J. Bauld, R.V. Burne, M.C. Geddes, B.D. Mitchell and W.D. Williams. All these people, as well as K.F. Walker and D. Towns, have contributed to fruitful discussions on various aspects of this thesis.

Mr. P.G. Kempster's advice and help on many technical matters is much appreciated, especially regarding photography. I also thank Mrs. R. Hughes for her help with diagrams and Mrs. E. Curran for the typing of this thesis.

I especially thank my wife Kerry for her unfailing support and encouragement.

PART 1

INTRODUCTION

CHAPTER 1

INTRODUCTION

The objectives of this investigation are (a) to increase knowledge of the taxonomy and ecology of ostracods living in non-marine waters in Australia, (b) to demonstrate that fossil ostracod shells can readily be recovered from lacustrine cores and that, with knowledge of present day ecology of the same ostracod species, a past history of the cored lakes can be determined, and (c) to extrapolate from lake histories new data on past climates in Australia.

As ostracods are common inhabitants of most types of waterbody in Australia and elsewhere and, as some faunas are characteristic of particular environments, the present work investigates the potential use of these organisms as palaeoenvironmental indicators. Since all ostracods possess a calcareous shell which can potentially become easily preserved as fossil, they appear to be ideal recorders of the nature of the environments in which they lived. This is particularly significant since most investigations done on cores taken from lakes in Australia are based on the recovery of fossil pollen. However, information obtained from palynological studies refers to changes in local vegetation adjacent to the lakes; few data are provided on the history of the lake itself apart from that extrapolated from aquatic algae, pollen and spores. It is not possible, however, to determine whether these have been reworked or transported. Because of their relatively larger size, such information can usually be obtained from ostracods.

Additionally, the study of lake histories is particularly significant since lakes are obvious natural "recorders" of various hydrological regimes which, in turn, result from different climates. This is particularly the case in Australia as, depending on the ratio of precipitation to evaporation, a lake can either have permanent or ephemeral water and retain either fresh or saline water. As some ostracod species are restricted to each of these types of lakes, they appear to be suitable indicators in palaeoenvironmental investigations of lacustrine deposits. The work here sets out to demonstrate this.

Since little work has been done so far on the recovery of non-marine fossil ostracods in Australia, the study carried out here is restricted to Quaternary deposits as it is likely that the ecological requirements of ostracods are very similar for living and Quaternary representatives of the same species. Once a better knowledge of ostracods is acquired for Recent and Quaternary faunas, work on pre-Pleistocene material will then become possible. This type of investigation should be very useful since a large part of the Australian continent is covered by non-marine Cainozoic, or older, sediments, some of which were deposited under aqueous conditions.

Fossil sites have been selected for the present study from those which have previously been investigated by other disciplines in order to check whether data obtained from the study of ostracods are compatible with previous observations and, also, to demonstrate the additional information the study of ostracods can provide.

Firstly, it is necessary to examine the variety of waterbodies occurring on the Australian mainland and determine the geomorphological, chemical and biological criteria which distinguish them. It is also necessary to determine the factors which affect these criteria, those which change through time and those which remain unaltered, and, finally, to find out how to detect such changes in order to understand palaeoenvironments. These are required to decide on sites favourable for palaeolimnological investigations. This is examined in Chapter 2.

Secondly, an assessment of fossil ostracod remains and their interpretation is discussed in Chapter 3.

Thirdly, data on the taxonomy of ostracods found in Australian non-marine waters is presented in Chapter 4, accompanied by ecological information for most species. In the last part of that chapter, general information on Australian non-marine ostracod faunas is given.

Fourthly, in Chapters 5 to 8, the study of ostracod remains, and occasionally of other fossils, is discussed in detail: in Chapter 5, cores from four Victorian maar lakes; in Chapter 6, deposits at Mowbray and Pulbeena Swamps in Tasmania; in Chapter 7, a core from Lake George in New South Wales; and, in Chapter 8, a core from Pillie Lake in South Australia.

Finally, in Chapter 9, the information relevant to palaeoclimates obtained from each fossil site is discussed in relation to previous data on the past climatic history of Australia.

A detailed review of literature relevant to ostracod remains and their interpretation is not given here; relevant material is given in appropriate chapters.

CHAPTER 2

HABITATS AND BIOTA MOST SUITED TO PALAEOLIMNOLOGICAL INVESTIGATIONS

2.1 AQUATIC HABITATS

A classification of aquatic habitats present in Australia is attempted here on the basis of those features which characterize them, those which favour the formation of a waterbody or leave it unchanged and those which alter its condition. Such a classification facilitates the location of sites best suited to palaeolimnological investigation. Emphasis will be placed on waterbodies unaffected by flowing waters since, for the purpose of the present thesis, interest centres on deposits formed under lacustrine aqueous conditions, which therefore suffered little erosion compared to fluviatile deposits. The latter will not be ignored, however, since there are circumstances under which deposition of fluviatile sediments operates when these sediments remain relatively unchanged through time.

Waterbodies which contain water today will be analyzed, and an attempt will be made to characterize their geomorphological, chemical and biological features. These features will be examined to determine whether or not they remain unaltered through climatic changes and related phenomena and through the normal course of evolution of physico-chemical environments. Identification of types of waterbodies not present today in Australia will be carried out and the absence of those types will be explained. The distribution of these waterbodies today and in the past will be investigated bearing in mind the potential information they can yield in palaeolimnological studies. Finally, the organisms and their fossils which are characteristic of each type of waterbody, and which can provide data on palaeoenvironments, will be examined.

All the waterbodies examined here are *athalassic* ones *sensu* Bayly (1967): they are not presently connected to the sea. *Saline water* referred to here has a salinity above 3°/oo following the suggestion of Williams (1964) and this contrasts with *fresh water* with a salinity below 3°/oo. The term *permanent* water is used here to define a waterbody which has not dried in human memory.

A classification of all major types of waterbodies has been attempted previously by Hutchinson (1957) on the basis of their origin. In that review, the little information given on the water chemistry and quality, and the fauna of the various waterbodies, is too diffuse to serve the purpose of the present study. Bayly and Williams (1973), by referring to Australian examples, summarized Hutchinson's (1957) classification and discussed the various processes causing the formation of lakes. Hardie *et al.* (1978) who discussed the sediments of saline lakes, distinguished ten major subenvironments. Their classification will be broadened here to include fresh waters as well and to discuss non-lacustrine waterbodies, giving, whenever possible, additional information on hydrological, chemical and biological data of relevance to palaeolimnological studies.

The following classification is one which relies on several features of aquatic habitats (e.g. size, mode of origin, location, stability). It is an arbitrary classification which is designed, as a matter of convenience, to be of direct relevance to the subject of this thesis, i.e. palaeolimnological studies.

2.1.1 Lentic environments

2.1.1.1 Large closed basins with often extensive internal drainage area

There are many large endorheic basins in Australia, some of which can extend to several hundred square kilometres. The deepest part of the basin is often referred to as a playa in the literature (Reeves, 1968 and papers assembled in Neal, 1975). Lake Eyre is the best local example. Like Lake Eyre, which is tectonically controlled, others often lie in ancient drainage systems (some are also tectonically controlled) such as many elongated lakes in Western Australia (e.g. Lake Moore - for further details see van de Graaf *et al.*, 1978).

Under present climatic conditions, such basins do not retain permanent water although there is evidence that permanent water occurred in Lakes Eyre and Frome.* Either the rate of precipitation and/or evaporation has to be modified or the supply of water from rivers flowing into the basin or rising from the groundwater table to the lake floor has to be sufficient to allow retention of water for a long period of time.

During the early stages of lake filling, processes of fluvial sedimentation, and of partial erosion, operate. These are superseded by a lacustrine phase. Finally, during an arid phase, formation of a salt crust, followed by efflorescence of salts occasionally rising to the surface, and deflation processes usually occur. Pedogenesis and penetration of sediments by roots of phreatophytes can also occur. All these phenomena associated with an arid phase can destroy the

---

* Such a phase of permanent water is postulated because of the presence of the fossil foraminifer *Ammonia beccarii* (which is indicative of permanent water) in sediment of both lakes: in Lake Eyre (Cann and De Deckker, in press) and Lake Frome from material received from Dr. A.R. Jensen and thought to be Holocene in age.

sedimentological and fossil records (e.g. by erosion, dissolution, diagenesis). The palaeolimnological record of such basins is therefore likely to be incomplete since erosion is a common phenomenon and, as a result, only major lacustrine phases with permanent water conditions, resulting from major climatic events and which extend over a long period of time, are likely not to be destroyed. Ephemeral phases could be preserved, however, if rapidly superseded by formation of a salt crust. In those cases, many fossils are likely to suffer dissolution or diagenesis. Pollen studies are useful in this particular case, as demonstrated by Singh (in press) for a Holocene sequence at Lake Frome, but pollen are rarely informative on the history of the lake itself.

The greatest advantage of sequences recorded from large enclosed basins is that they are potential recorders of very long time spans since some basins are quite old (e.g. Lake George which has a continuous record since the Miocene (Singh *et al.*, in press, b) like that of Lake Frome (Bowler, pers. comm.)).

The sediments will reflect the climatic hydrological conditions affecting the lake as illustrated by Hardie and Eugster (1970), Hardie *et al.* (1978), Eugster and Hardie (1978) and Eugster (1980). Similarly, the water chemistry will control the presence of organisms in the lake. This is significant for the fossils as well and this will help in tracing past hydrological regimes of the lakes. This will be further discussed at the end of this chapter.

2.1.1.2 Small closed basins with minor internal drainage area

These small basins can be formed under a variety of circumstances. Some are defined as interdune corridors, often referred to as sebkhas, others are evaporation-deflation pans - some of which can occur in ancient drainage systems - or yet others will result from deflation from older lake floors. In the latter case, lunettes will develop and their sediment composition, as recently reviewed by Bowler (1976), is directly controlled by hydrological and climatic regimes: well sorted quartz sand is found in high rainfall areas, and progression occurs from clay and finally to gypsum as aridity increases.

Sedimentological and palaeontological records for environments such as lunette lakes do not extend over long periods of time because they are affected by phases of erosion during a glacial-interglacial cycle, but also as they are likely to be destroyed before or during the following glacial-interglacial cycle. Records of sebkhas are likely to be destroyed even faster during migration of the dunes which usually separate them.

These smaller basins are likely to fill up with water more frequently than the larger ones as their catchment areas are much smaller. For both types of lakes, geographical location is important: under today's climate, only the lakes close to the coast are likely to fill every year, at least for a short period of time as the periodicity of rainfall is fairly constant there. These particular lakes will yield a particular fauna and flora which either require permanent water (e.g. some ostracods with marine ancestry, fish, bivalve molluscs) or which cannot withstand long periods of drought (e.g. amphipods, isopods, cyclopoids which seek refuge during drought). The lakes further inland will yield a less diverse fauna and flora and erosion of the fossil and sedimentological records, mainly caused by deflation processes and efflorescence of salts and clays, will be extensive.

Geomorphological features associated with these small lakes, such as lunettes and their geographical orientation, and sediment composition, will be of palaeoclimatological and hydrological significance. Fossils, however, will only be useful to recognize permanent (often fresh) water phases as for other phases, they are likely to be destroyed or reworked at some stage.

Contrary to the information obtainable from the large closed basins, minor local climatic and hydrological changes can be recorded in the small closed basins in addition to the regional changes.

2.1.1.3 Coastal lakes

This type of waterbody is most often found by a dune barrier during changes of sea levels, either by closing an embayment (e.g. Sleaford Mere on the Eyre Peninsula in South Australia) or by forming a barrier running parallel to the coast (e.g. Newland Lake on the Eyre Peninsula - note that the Coorong Lagoon in South Australia does not fit into this category as it is indirectly connected to the sea via Lake Alexandrina).

These lakes can be of importance as markers of past sea level changes. Similarly, since they are potential sites of particular formation of carbonates, as water chemistry is affected by the marine-freshwater groundwater interface, the study of past changes of this interface can be developed and therefore be related to sea level changes.

Stratigraphical records for the enclosed bays are unlikely to cover long time spans as barrier dunes can be destroyed easily during subsequent sea level changes. On the other hand, barrier dunes running parallel to the coast, although often being the site of marine sedimentation at times, are recorders of sea level changes (e.g. the Cainozoic sequence near Robe in south-east South Australia (Cook *et al.*, 1977) some of which are even submerged today (Sprigg, 1979)).

In both types of coastal lakes fossil fauna and flora should be diverse (since water should always be present) and contain a proportion of marine components, either having been reworked, or introduced by birds or other processes, or introduced during marine incursions.

2.1.1.4 Solution lakes

Such waterbodies are most commonly found in calcareous terrains producing small or large basins. As they are often deep, valuable palaeolimnological information may be recorded at such sites. In Australia, such "sink holes" are usually fairly small compared to much larger basins known elsewhere (e.g. Lake Banyolas in north-east Spain well studied by R. Margalef and his team). The principle unfavourable feature of such lakes is that as dissolution of the local terrain usually occurs, disturbance of sediments by folding and/or faulting is common.

The extent of lacustrine deposition and local terrain dissolution in such environments is climatically controlled and could therefore be informative in palaeoclimatic studies. The size of the basin and its catchment are important and water chemistry, and consequently, sediment composition, are controlled by the groundwater composition and the local geology. The potential use in palaeolimnology of such sites will be determined by all these factors and it is most likely that small dissolution lakes will only be of local significance. Many fossil types can be recovered from such environments.

2.1.1.5 Springs

The most common and obvious features associated with some springs are the mounds. The best known examples in Australia are the mound springs which occur on the margin of the Great Artesian Basin. The springs are connected to structural features and are fed by artesian water (for review see Habermehl, 1980). The chemistry of the water discharged at the springs will be directly controlled by the composition of the strata in which it was stored and through which it travelled.

A number of springs are sites of travertine deposition, hence the formation of mounds, some of which can enclose a small waterbody. In other instances, water flow from the springs will be sufficient, at times, to inundate adjacent areas and a swamp or shallow lake can form depending on the local topography (e.g. Pulbeena and Mowbray Swamps in Tasmania discussed in Chapter 6 and Dalhousie Springs area in South Australia (Cobb, 1975)).

Such mounds are potentially excellent recorders of water flow regimes and water quality due to the formation of travertine on the edge of the springs where fossils will also be imbedded. Pollen and seed studies should give information on local changes of vegetation directly related to water regimes which, in turn, are controlled by climatic factors on a broader regional scale. As the mounds are often indurated, extraction of most fossils will be a difficult task even though they are sites for a great diversity of fauna and flora (see Mitchell (in press) for a faunistic survey of some springs). Of interest, however, is the endemic character in Australia of the fauna in some mound springs on the south-west edge of the Great Artesian Basin (De Deckker, 1979; Mitchell, in press). This is apparently not the case for the less isolated springs in north-west Tasmania (see Chapter 6).

2.1.1.6 Crater lakes

These lakes which occupy the inside of volcanic craters or craters formed by impact of extra terrestrial objects, can occasionally be very deep in comparison with other lakes in Australia. These basins, which are usually not very large (up to a few kilometres in diameter) are typically characterized by internal drainage. The ideal basins for palaeolimnological investigations are not connected to rivers and the catchment area has to be restricted to the inside of the water only.

Water retained in the craters will result from the combination of precipitation and evaporation over the crater. In all cases, the additional groundwater input has to be also considered in order to understand the water budget of the lakes. The deepest lakes, which have steep flanks, should retain water throughout most climatic periods, since the surface of the lake subject to evaporation is greatly reduced compared to other lakes. This remark applies to deep solution lakes as well. This phenomenon is important for palaeolimnological studies since sedimentation is likely to continue through most climatic periods, meaning therefore that crater lakes are *ideal* sites for recording ancient climates. This has been demonstrated in Australia by the work of Bowler (1970, in press) for the sedimentological history of Lake Keilambete in Victoria relating to the changes of water levels of the lake. Similarly, these changes would affect the composition of the flora (Dodson, 1974, for the same lake) and the fauna (see Chapter 4). Most types of fossils can be used in palaeolimnological investigations of crater lakes.

The most favourable location in Australia to carry out such work is Diamond Crater (formed by an impact of extra terrestrial material) in W. Tasmania since it is estimated to be the site of accumulation of sediments for approximately the past 600,000 years (Colhoun and van de Geer, pers. comm.).

2.1.1.7 Glacial lakes

These comprise a variety of waterbodies formed by action of glaciers: lakes in large glacial valleys, proglacial lakes, inter-moraine lakes, cirque lakes and those formed by the melting of ice trapped in sediment such as kettle lakes. All these features are rare on the Australian mainland except for small inter-moraine and cirque lakes in restricted areas of the Great Dividing Range. The other types of lakes can be found in Tasmania. The palaeolimnological record of most of these lakes will only cover short, interglacial periods (except for the proglacial lake) and it is most likely that the lacustrine deposits will have been eroded away by ice scouring the landscape during the following period of glaciation. Additionally, if preserved, the stratigraphical record in these lakes is likely to be incomplete and difficult to correlate with others elsewhere since they cover short periods of time (exceptions occur for example for the Grande Pile inter-moraine deposit in north-east France which covers the last 140,000 years (Woillard, 1978).

Large lakes formed in glacial valleys should be the most favourable sites for palaeolimnological studies, since they are not always affected by ice during subsequent glaciations. Additionally, work done in alpine lakes (Löffler, 1975) on crustacean remains has demonstrated the possibility of detecting broad changes in lake stratification due to changes of vegetation caused by either climatological or anthropogenic effects. Elsewhere, Löffler (1978) demonstrated the potential palaeolimnological use of studying crustacean chitinous remains collected in an inter-moraine lake in Ethiopia.

2.1.1.8 (Small) pools

Gauthier (1951, p. 154) identified the following types of pools: mare de pluie (rain pool), mare de thalweg (pool in river bed), mare de débordement (billabong), ditches (fosses) and drains or irrigation canals (canaux de drainage ou d' irrigation). It is only the first type of pool (rain pool) which he referred to as temporary pool with, on a few occasions, some ditches along the side of roads. In these temporary pools, water directly results from rain and it is usually present for a very short period of time (1-2 months after the last rain). The other types of pools, on the other hand, are more associated with lotic environments. Since temporary pools are small and ephemeral, and can easily be destroyed, they are of little direct palaeolimnological use. Water chemistry of such pools will be controlled by rain and local soils composition and by local geology. It is important, however, to identify floristic and faunistic elements characteristic of such environments in order to detect whether temporary pools were present in larger basins during fairly dry period (e.g. in the Pulbeena and Mowbray Swamp deposits in Tasmania, no ostracods typical of temporary pools, such as *Bennelongia australis*, have been recovered which further confirms the idea that water was nearly always permanent at both sites - see Chapter 6).

2.1.1.9 Waterbodies in periglacial terrains

Since no waterbodies created by permafrost action have been identified in Australia, either today or in Quaternary deposits, they will not be further discussed. The absence of such waterbodies in Australia results from the fact that only small areas of Australia have been affected by permafrost.

2.1.2 Lotic environments

There is a number of waterbodies associated to lotic environments which can be of some use in palaeolimnological studies. These occur in alluvial fans, stream flood plains, dry river beds and billabongs.

In general, lotic environments will be less informative than lentic ones for the palaeolimnologist since the sedimentary sequences in which fossils could be preserved are few due to drastic mechanisms of sedimentation, erosion and continuous changes of types of deposition. Gauthier (1928, 1951) pointed out that the crustacean fauna, for example, is usually less diverse in pools associated to lotic environments because the occasional waters which fill them are rich in sediments which rapidly bury crustaceans and their eggs. The palaeontological record is therefore usually poor. Sedimentological and geomorphological investigations for these environments, rather than palaeontological ones, will be more valuable to the palaeoclimatologist.

2.1.2.1 Habitats in alluvial fans and stream floodplains

In the alluvial fans and stream floodplains, deposits can be extensive but little biological information is obtainable from them since sedimentation rates can be very rapid at times and potential fossil material is poor. Such environments cover very extensive parts of Australia (e.g. the river channel country in Queensland and a number of alluvial fans in the Flinders Ranges), and their past "active" phases are significant to detect past climatic history. Unfortunately, there is little fossil material in these deposits for palaeolimnological work.

2.1.2.2 Billabongs

Billabongs, or ox-bow lakes, can yield some valuable sedimentological and biological information of relevance to past hydrological phases of a large river but usually they do not cover extended periods of time as these environments are transitory due to the river's continuous meandering. In addition, the sedimentological and biological records can often be eroded away or reworked.

2.1.3 General comments and summary

The relative importance of waterbodies as potential recorders of past hydrological histories and indirectly of climatic histories is summarized below.

It is important firstly to recognize that some environments are only short-lived when compared to a glacial-interglacial cycle [during which all possible hydrological regimes will normally occur]. Additionally, a large number of environments will be partly or even entirely destroyed by a number of phenomena, the most important one being mechanical erosion.

The most favourable location for trapping sediments and fossils of use in study of palaeoenvironments is a crater lake since the catchment area is well defined and the precipitation-evaporation ratio can be adequately estimated. Also, in the most favourable location where a lake will not dry up, a record can cover a long period of time continuously. Such lakes are studied in detail in Chapter 5.

Large closed basins which are tectonically controlled, and are often old geographical features, generally have a less complete stratigraphic record but can sometimes provide very old sequences (see study of Lake George in Chapter 7). The smaller closed basins are usually not long lived compared to a glacial-interglacial phase, but will be indicative of particular climatic events (e.g. an arid climate will cause formation of gypsum lunettes). It is most likely that they would undergo erosion and even be completely destroyed during the following glacial-interglacial cycle.

Langbein (1961) formulated a relationship between annual precipitation, mean annual temperature and annual runoff for closed lakes. His work was further developed by a number of authors and is summarized by Reeves (1968) to demonstrate the use of hydro-climatic study necessary to determine palaeoclimates. Recently, Bowler (in press) attempted to classify present and past hydrological regimes of major Australian lakes. There he showed the importance of the various hydrological factors which control the extension of lakes and the amount of water they yield. He defined a hydrological balance between catchment and lake area. He also examined climatic parameters such as evaporation and precipitation and determined a hydrological threshold which separates lakes with permanent waters from those which are ephemeral. Depending on climatic conditions, the hydrological regime of a lake will certainly fluctuate and, in some cases, cross the hydrological threshold. To be able to distinguish changes of the relative position of a lake in relation to the hydrological threshold is of great importance in palaeoclimatological studies: such changes can be identified by the presence of organisms which can be indicative of permanent or ephemeral water conditions. Perhaps, Bowler's (in press) model should also recognize the importance of the seasonality of rainfall and, more appropriately, the periodicity of rainfall on a long term basis as these have some additional effects on the water budget of lakes in relation to evaporation. It is necessary to recognize rainfall periodicity as this would surely also be a controlling factor on the retention of water in large basins such as Lake Eyre. This, of course, is in direct relation to the position of climatic belts.

Coastal lakes are usually short-lived and the sedimentary record will suffer during sea level changes. Dune barriers, and their enclosed small basins in the interdune areas, can be of palaeoenvironmental significance but they usually register short lacustrine events. Solution lakes and mound springs with associated lakes can provide very long records on the best occasions but there are tectonic phenomena (e.g. faulting in solution lakes) disturbing sedimentation, and induration of travertine making sample treatment difficult. Deposits associated with springs are studied in Chapter 6. In both cases, the palaeolimnological record will be directly controlled by groundwater interference and therefore be, most often, of local significance except for mound springs associated with large tectonic features like those on the edge of the Great Artesian Basin.

The palaeolimnological record registered in glacial lakes and waterbodies created or affected by glaciers is likely to be destroyed during a glacial-interglacial cycle but will be of use to trace past extension of glaciers and therefore relate to past climates.

In addition to the various features of the surrounding environment which affect a waterbody and for its retention of a valuable sedimentological and fossil record, the location of the waterbody on the Australian continent, and its relationship to climatic belts also has to be considered.

2.2 BIOTA

It becomes necessary to decide which are the likely fossils to occur in deposits and those which best provide information on different types of water and water regime. An assessment of the use of remains of animals found in Quaternary lake and bog sediments has been carried out in detail by Frey (1964) and recently this was summarized and updated by Crisman (1978) who emphasized the information obtainable from the study of cladoceran and dipteran larvae remains. All this information will be briefly revised here in the Australian context since, for example, there are many halobiont organisms living in Australian waters which can be of relevance to palaeolimnological work, not dealt with by either Frey (1964) or Crisman (1978).

The organisms present in the different types of lakes in Australia mentioned earlier, which can also be recovered as fossils, are discussed below.

2.2.1 Rhizopoda

Tests of rhizopods can be recovered from sediments, but only foraminifers will be indicative of saline conditions. Apart from the study of Cann and De Deckker (in press) on the use of non-marine foraminifers to determine whether water was either permanent or ephemeral for saline lakes, work is needed to find out the ecological requirements of freshwater rhizopods and to demonstrate their use in palaeolimnological studies in Australia.

2.2.2 Rotifera

The knowledge of ecological requirements and distribution of rotifers in Australian lentic waters is still needed before a study of egg cases can be undertaken (R. Shiel is currently doing some work in this area). Neither is it known whether rotifer eggs can fossilize adequately in all types of environments.

2.2.3 Porifera

Remains of sponges can easily be recovered from sediments and it is likely that these will be of palaeoecological significance for fresh waters. Although the taxonomy of sponges is well known (Racek, 1969), ecological studies are still required before carrying out palaeolimnological studies.

2.2.4 Crustacea

Studies on *cladoceran* remains are numerous for many parts of the world but none deal with Australian deposits. It is certain that similar studies will prove to be of palaeolimnological use in Australia for fresh water deposits but much ecological work is still lacking. Additionally, as there is only one *cladoceran* species, *Daphniopsis pusilla*, which inhabits saline waters in Australia, this crustacean group will not be rewarding in studies of sites where saline water occurred. Emphasis will have to be placed on other organisms which are common halobionts since many waterbodies in Australia are saline. *Ostracods*, on the other hand, are represented by a large number of species in saline waters in Australia (De Deckker, in press a) and in fresh waters as well. Some species have restricted ranges of salinity tolerance and therefore are valuable in palaeosalinity reconstructions.

Ostracods can occur in most types of waters except in lotic habitats where they are usually rare and their fauna is much less diverse (except billabongs - see Shiel, 1976). More details on their use in palaeolimnological studies are provided in Chapter 3.

Remains of *conchostracans* should be indicative of temporary pool conditions as they are typical inhabitants of such environments. Only in one case have they been so far found in a permanent lake (Lake Barrine in Queensland (Timms, 1979)). However, as explained before, temporary pools and their sedimentary records are likely to be easily destroyed and therefore little emphasis ought to be placed on fossil conchostracans.

Fossil remains of aquatic *decapods* and *isopods* have been rarely recovered from lacustrine deposits. This could result from the lack of systematic search for them as remains of the halobiont isopod *Haloniscus searlei* have been found on a number of occasions (see Chapters 5, 8). Since the ecology of many species is adequately known, the remains, if fossilizable, could be valuable to the palaeolimnologist especially for the study of lotic habitats where a number of decapods live.

2.2.5 Mollusca

Gastropods can be easily preserved as fossils and should be useful in palaeolimnological studies but unfortunately in Australia, the ecology of this group of molluscs is still poorly known. As gastropods are common inhabitants of a great variety of lotic environments and, as their shells can often withstand the mechanical abrasion so typical of lotic habitats, they should be one of the best fossil groups for examining and interpreting the past history of such environments. Also, further taxonomic and ecological work on the halobiont gastropods (e.g. *Coxiella*) is necessary before fossils from saline environments can be examined.

The *bivalve molluscs*, and their glochidia, can also be preserved under most conditions and should be of use in palaeolimnological studies but, once again, ecological data are lacking. As for the gastropods, bivalves would be useful in studies of lotic environments because of their strong and solid shells. Glochidia, however, are likely to be easily damaged.

2.2.6 Insecta

Remains of many aquatic insects can be found in a variety of fossil deposits but more basic data (taxonomy, ecology) on many groups are still required to suit the palaeolimnologist. Outside Australia, studies of the remains of dipteran larvae (e.g. chironomids) are common and have proved to be significant in interpreting past histories of lakes. In Australia, only the work of Paterson and Walker (1974) on the distribution of two chironomid species in a short core is available. This sort of investigation should prove to be rewarding since there are a number of aquatic insects which also inhabit saline waters (see Williams, 1978, Table 3) and the remains of which should preserve in fossil deposits.

2.2.7 Vertebrata

As *fishes* are present in most permanent aquatic habitats, their bones, if identified at the specific level, could be of palaeoecological significance since fishes are one of the best studied organisms in Australian waters. To determine species on fossil jaws and otoliths is not yet possible and this is unfortunate since a number of fish are known to occur in saline waters and their range of salinity tolerance is already well known (Chessman and Williams, 1974). More anatomical work is therefore necessary on this group before becoming a useful tool in palaeolimnology.

2.2.8 Others

The study of *pollen* and *seeds* of aquatic plants and *spores* of aquatic ferns need not be discussed in detail here since it is well known that this discipline is the best developed one in palaeolimnological investigations, even in the Australian context (e.g. Yezdani, 1969; Dodson, 1974a, 1974b, 1975; review of Kershaw's work in Kershaw, 1978; Singh *et al.*, in press b; Singh, in press) where examination of aquatic pollen and spores are considered in studies of changes of terrestrial vegetation since samples are taken in lacustrine sediments. Taxonomic and ecological studies of aquatic vegetation are still required before palaeoenvironmental interpretation of lacustrine sequences are well understood.

The study of the ecology of living *charophytes* and of the morphology of their calcareous oogonia is required before they can become useful in palaeolimnological studies. One charophyte species *Lamprothamnium papulosum* is known to occur in saline waters (Burne *et al.*, 1980) and a careful study of the morphological varieties of the oogonia occurring under differing salinities might prove to be of significance in tracing palaeosalinities.

There is no doubt, however, that *diatoms* although not extensively studied in Australia (except for the work of Yezdani (1969) and Tudor (1973),will prove to be one of the best tools in palaeolimnology as demonstrated elsewhere (e.g. for African lakes: Richardson, 1968; Richardson *et al.*, 1978; Gasse, 1974a, 1974b; Hecky and Kilham, 1973). It is expected that diatoms are common in most types of waterbodies in Australia according to evidence in other parts of the world.

2.2.9 Conclusions

In summary, from this discussion, it appears that ostracods are, at present, the best suited aquatic organisms for palaeolimnological studies in Australia since many other groups, which could potentially be good "tools", first need to be better documented, especially their taxonomy and ecology. This is particularly the case for diatoms and to a lesser extent for pollen and seeds of aquatic plants and spores of aquatic ferns. Discussion in Chapter 3 will demonstrate the information obtainable from fossil ostracods and in the following chapter, new and previous taxonomic and ecological information on living ostracods will be presented and summarized. The following chapters will then show examples where ostracods are extracted from fossil deposits and will present the information they provide in palaeoenvironmental reconstructions.

CHAPTER 3

THE VALUE OF NON-MARINE OSTRACODS IN THE RECONSTRUCTION OF PALAEOENVIRONMENTS

3.1 INTRODUCTION

Several previous studies mention the value of ostracods in the reconstruction of past environments. Such studies have dealt mainly with marine faunas, but similar principles can be applied to non-marine ostracods. The information presented here will not be confined to the Australian fauna since many well known examples deal with ostracods from other parts of the world. Although some types of ostracods, yielding particular information for palaeoenvironmental reconstructions are not yet known in Australia, they will nevertheless be considered together with the potential information they can give, as it is possible that they might later be discovered in Australia.

An important initial point to remember is that most marine podocopid ostracods do not swim throughout life; this contrasts with a variety of modes of locomotion developed in non-marine ostracods, most of which are grouped in the family Cyprididae. It is, therefore, necessary to know the mode of locomotion of an ostracod since, for example, the remains of planktic species are likely to be recovered in all types of sediments (and facies) found in a lake. Some truly benthic species are likely to be restricted to some particular sediments and others even might, for example, be found only in areas of low oxygen concentration.

Further, non-marine environments, by contrast with marine ones with the exception of estuaries, are often characterized by broad fluctuations in a number of environmental parameters (e.g. oxygen concentration, pH, temperature, salinity in some cases, supply of food, water level, light, period of desiccation etc.). Such changes usually occur annually: they determine ostracod morphology (e.g. size, shape, shell composition and ornamentation), mode of life, life cycle and distribution. Thus an understanding of the effects of environmental parameters is essential before drawing conclusions from fossil material in palaeoclimatological studies.

3.2 NATURE OF INFORMATION AVAILABLE

Several types of information are available from the study of ostracod remains (mainly valves). The principal types include conditions of sedimentation and water quality. Additionally, a knowledge of ecological requirements of extant ostracods will provide information on past environments in which fossil representatives of the same species are found.

It is also important to be able to detect the variety of sedimentary facies associated with various types of waterbodies. Being able to diagnose facies should explain the composition and type of preservation of the ostracod fauna and vice-versa. It is, therefore, necessary to examine all possible types of environments and establish the ostracod fauna which characterizes them (for the Australian waterbodies, the information presently available will be presented at the end of Chapter 4). A synthesis of this sort of information obtainable from ostracods is presented in Neustrueva (1977) for Palaeozoic and Mesozoic lake sediments of the USSR.

As an example, ostracod "assemblages" (meaning the ostracod faunas which are characteristic of particular waterbodies) are likely to be reworked by wind or wave action in shallow and ephemeral lakes and, as a result, valves will often accumulate on the shores - such facies should be easily recognized in a core as many ostracod valves are likely to be broken, mixed with a variety of debris (of mineral and vegetal origin), sorted and probably arranged without a definite orientation.

3.2.1 Rate of sedimentation

Oertli (1971) pointed out that rate of sedimentation can be assessed by counting the proportion of ostracod valves which are separated from those which are still attached to form a carapace. Since, after the death of an ostracod, valves usually open rapidly and later become disarticulated due to decay, rapid sedimentation is required to prevent ostracod valves from opening. Conversely, Kilenyi (1971) looked at the rate of disarticulation of ostracod valves as a way of assessing the duration and distance of *post mortem* transport. The same author also pointed out that different species should have different rates of valve disarticulation as well (e.g. cytheracean ostracods with often intricate valve hinges should disarticulate less rapidly than cypridacean species). It is also necessary to be aware that interstitial ostracods will rarely have their valves separated after death. Such types of ostracods need to be recognized to avoid spurious results.

3.2.2 Current index

Oertli (1971) suggested that a current index can be estimated by counting ostracod valves and measuring their appropriate sizes. This is a way to detect possible sorting and selection of different size classes caused by currents. This can usually be assessed easily by checking whether a sample represents a biocoenosis (life assemblage) or not: currents which rework a "life" population should, under most conditions, separate adult valves from juvenile ones or some valves from others depending on shapes, sizes, weight etc. (in some cases, where valves are sexually dimorphic or in others, where one valve is quite different from the other, sorting can operate). Some of these factors have been analyzed in detail by Kilenyi (1971).

This type of examination is important in palaeoecological studies since it can provide information on reworking of sediments and associated fauna by examination of the ostracod valves along the bedding plane with the aid of a binocular microscope. This process cannot be applied in studies of pollen or cladoceran remains since they are either too small or too difficult to examine along the bedding plane (e.g. cladoceran remains would be very flaky).

In some cases, orientation of ostracod valves along the bedding plane can be informative concerning the presence of current or current direction. Disturbance of such effects can be caused at a later stage by bioturbation - this should be noticeable with a binocular microscope.

3.2.3 Compaction ratio

This ratio can be estimated, as pointed out by Oertli (1971) by counting the percentage of deformed valves of ostracods. This technique is not usually applicable to cypridacean ostracods which have very fragile valves compared to marine cytheracean ostracods. The presence of broken valves in a core can give information however on the possibility of compacting having occurred during the coring process. Similarly, desiccation of a core would cause the most fragile and largest valves to break.

3.2.4 Information on oxygenation

As demonstrated by Oertli (1971), information on oxygenation of an environment can be detected by the presence or absence of pyrite crystals attached to the ostracod valves. Under special anoxic conditions, pyrite crystals should form on the ostracod valves and usually would stain the valves dark brown or black. Signs of an environment becoming acidic can be detected by traces of dissolution on the ostracod shells, not to be confused with dissolution marks left on ostracods having passed through the alimentary canals of fishes or ducks as illustrated by Kornicker and Sohn (1971).

3.2.5 Biological and physical stability

As it is known that in shallow lakes, where various environmental parameters (temperature, oxygen concentration and availability of food) vary extensively during seasons, sizes of ostracods are known to vary. It is therefore necessary to recognize the *presence or absence of mixed populations* in a sample by examining different size classes, and then to determine whether a sample would represent either one population from one season, or mixed populations. This is best achieved by measuring length-width ratios of ostracod valves, bearing in mind that ostracods molt a number of times before reaching adulthood and that size classes should be very distinct in a population from one season, whereas this is not likely to apply for mixed populations.

Such information would therefore be of use in understanding the processes of sedimentation as demonstrated for the seasonality factor in the formation of lacustrine rhythmites (De Deckker *et al.*, 1979).

3.2.6 Water quality and other environmental factors

Water quality and other environmental factors probably control *valve morphology of most ostracods*. This is already illustrated for many ostracods. Kaesler (1975) discussed this in detail for the cosmopolitan ostracod *Cypridopsis vidua*. The best discussed example, however, concerns the holeuryhaline ostracod *Cyprideis torosa* found mainly in estuaries in the northern Hemisphere. This species is noted for its variation in shell ornamentation where the thickness of external nodes are partly controlled by salinity (Vesper, 1972). Similarly, there is a direct correlation between the shape of the sieve pores on the shell and salinity (Rosenfeld and Vesper, 1977). Both phenomena can therefore be used in tracing palaeosalinities. An understanding and knowledge of the effects of environmental factors on shell morphology would be important for palaeoecological studies. Variations in the morphology of many Australian ostracods have been noted but remain as yet unexplained. [Some specimens of the cosmopolitan species *Sarscypridopsis aculeata* can be spinose whereas others are smooth; the width of the dorsal keel of *Diacypris spinosa* varies between specimens from different populations taken in the same lake at different times of the year - see Chapter 8; variation in size, shape and ornamentation of *Ilyocypris australiensis* is a common phenomenon - see Chapter 4.]

The major difficulty in obtaining information from ostracods demonstrating variation in their morphology is that often a combination of factors will affect the morphology of an ostracod and also, since environmental changes do vary continuously over the life of an ostracod, it will be almost impossible to determine which particular environmental factor is the most important one.

Since it is thought, although not fully demonstrated, that the mode of *reproduction* in some ostracod species will switch from an *asexual to a sexual* one, and *vice-versa*, due to changes in environmental conditions, the detection of such changes in fossil material should yield useful information. Such switches could be observed easily since most ostracods are sexually dimorphic with females usually having the larger shells. Errors of interpretation could arise, however, because adults of one sex in a species do not necessarily live in the same location as the representatives of the other sex during their life span. More data are required on this point to establish its reliability in palaeoenvironmental reconstructions.

For example, in northern Europe, the common inhabitant of temporary pools, *Eucypris virens*, reproduces parthenogenetically whereas in southern Europe and North Africa, both sexes are usually encountered. This is probably a result of the last glaciation when northern Europe was covered by ice, and recolonization of that area has so far been achieved by asexual populations. Different climatic conditions could also have an effect on the mode of reproduction of this species.

Additionally, as some ostracods need *permanent water* to reproduce since their eggs cannot withstand desiccation (these ostracods belong to the Cytheracea, e.g. *Gomphodella* n.gen., *Leptocythere*, *Cyprideis*), the presence of their fossil remains in sediments will indicate permanent water conditions for a lacustrine deposit. This, of course, would be differently interpreted for an estuarine deposit.

In Australia (and to a lesser extent in other parts of the world), where the ostracod fauna inhabiting saline waters is very diverse (De Deckker, in press a), and where some ostracod species are restricted to waters with narrow salinity ranges, the knowledge of such ranges for the halobiont ostracods is useful in the study of *palaeosalinities* (see Chapters 6, 8). One should also be aware that salinity can affect the annual cycles of some ostracods which usually live in fresh waters as demonstrated by Sywula (1966) for two *Candona* species.

3.2.7 Environmental niches

In studying large waterbodies, *diversity of ostracod species* should be accounted for since diversity should normally decrease away from the shores where niches are usually more numerous. For a confirmation of this, combined studies of sediments and ostracods are necessary and this should be palaeoecologically significant. In addition, it would be useful to know present day ostracod population structures, as changes in "assemblages" of ostracods would point to changes in environmental conditions. It is necessary, however, to bear in mind that evolution of species and interactions between species and environments, which would have occurred during the Quaternary when environments constantly changed, are still happening today.

3.2.8 Biogeography

Ostracods can be of little use in dating Quaternary deposits because so few species have become extinct during that period. Provided past and present ostracod distributions are well known, the distribution of biogeographical areas, relating mainly to climatic factors, could be defined to suit the palaeoclimatologist. This has been done already from pollen studies in many parts of the world and from coleopteran studies in the British Isles (Coope, 1977). Dispersal and refuge mechanisms, plus their causes and effects, could then be better understood. As expected in Australia today, for example, diversity of ostracod species generally increases from arid areas towards the coast. Comparisons of areas near the coast of northern and southern Australia, where patterns of rainfall are very different should be rewarding.

3.2.9 Suggestions for the future

Refined studies of the chemical composition of ostracod shells and analyses of a variety of isotope ratios done on ostracod shells, could prove, in the future, to be extremely valuable in reconstructing palaeoenvironments. Similarly, racemization of amino acids contained in ostracod shells should either be used for dating purposes or for studying palaeotemperatures since the water temperature (a factor of prime importance in this type of investigation (Bada and Man, 1980)) of some deep lakes remains constant throughout a whole year (e.g. between 10 and 11° for the deep lakes Bullenmerri and Purrumbete - Timms, 1976).

3.3 PREVIOUS STUDIES

Previous studies of non-marine ostracods, which were used to reconstruct past environments especially those of Quaternary age, are too numerous to allow a complete survey to be made. Only examples which are significant or, in which different approaches have been used, are discussed briefly. Discussion is also restricted to studies of Quaternary deposits and to those which summarize previous data. Most references published on Quaternary ostracods are now available in the copious index of Kempf (1980).

3.3.1 North America

In North America, the Quaternary fauna is well-documented. The work of Delorme follows the best approach by a thorough survey of a large number of waterbodies and their ostracod fauna, in combination with chemical and physical parameters of the waters. After completion of that survey, Delorme examined deposits yielding fossil ostracods and defined palaeoenvironments by presenting data on water quality (Delorme, 1971a, 1971b; Delorme *et al.*, 1977). Work on ostracods by Swain (1977) provided information on changes of water alkalinity for the Holocene and Late Pleistocene evaporative Pyramid Lake in Nevada. The study of Cameron and Lundin (1977) for Late Quaternary sediments of Lake Cochise in south-eastern Arizona illustrated changes in lake levels, water quality and the timing of periods of lake desiccation.

Benson and MacDonald (1963) who studied the Holocene ostracod fauna from Lake Erie suggested a progressive warming up of the lake water which caused a decrease in the population of a species previously described from Pleistocene periglacial lakes. They also illustrated the gradual transition of one species into another through a continuous sequence from the lake.

Stark (1976) discussed the extent of redistribution of fossil ostracods after death in Elk Lake in north-western Minnesota in order to interpret faunal assemblages of ostracods, and other fossils, recovered from a number of cores. She found that littoral organisms, including ostracods, are transported offshore by wave induced currents and are deposited at a depth of 2-10 m. Finally, Stark (1976) discussed the evolution of Elk Lake based on her studies of ostracods, mollusc and chironomid remains.

3.3.2 Europe and USSR

In Europe and the USSR, principally the works of Lüttig (1955), Devoto (1965), Kempf (1967a, 1967b), Diebel and Pietrzeniuk (1969, 1975, 1977, 1978a, 1978b), Diebel and Wolfschläger (1975), Negadaev-Nikonov

(1971), Absolon (1973, 1975), De Deckker (1979c) and Robinson (1980), have illustrated the sort of information obtainable from the study of the ostracod fauna recovered from a variety of non-marine deposits of different periods of the Quaternary. These studies were restricted to exposed sections of sediments compared to the previous ones dealing with cores taken in lakes. In all cases, palaeoecological information had to rely on ecological data for living species. Sometimes, for extinct species, palaeoecological data was obtained through the association of these species with those having extant representatives with available ecological data.

Löffler's (1969, 1975a, 1975b, 1977, 1978b) successive investigation of the fossil ostracod fauna from cores taken in many alpine lakes in Austria and Switzerland have shown that past changes of lake trophy can be determined through the studies of ostracods. Löffler's innovation, however, which consists of studying remains of ostracod appendages from cores taken in Austrian and Ethiopian high mountain lakes (Löffler, 1977, 1978a), combined with the examination of cladoceran and chironomid remains, provides additional palaeoecological information. This approach would certainly be very useful for sediments which became acidic and in which ostracod valves have consequently been dissolved.

3.3.3 Africa

The recent work in the Great African Rift of Carbonel and Peypouquet (1979) and Peypouquet *et al.* (1979) which examined a number of samples from a variety of Plio-Pleistocene and Holocene lacustrine deposits, used fossil ostracods to reconstruct past environments. Their data provided broad generalizations on salinity and alkalinity levels and Ca-Mg ratios for the ancient lakes and the evolution of such parameters was discussed by them in relation to the tectonic setting of the area. Similar studies are few from other parts of the world.

3.3.4 Australia and New Zealand

Of interest to the Australian studies, are the works in New Zealand of Deevey (1955) and Hornibrook (1955) on the Pyramid Valley Swamp deposit where the ostracod fauna typical of a small freshwater lake - peat bog was examined. The significance of those studies is further discussed in Chapter 6.

Published information of Australian Pleistocene ostracods is so far very poor. Only short descriptions of the ostracod fauna collected at few sites have been presented and dates for the deposits are inadequate. These are at Mowbray Swamp (Chapman, 1914), Boneo Swamp (Chapman, 1919) and a small block of limestone from the Mallee (Chapman, 1936). Additionally, the presence of a few ostracods in a small deposit in the Murray Valley was mentioned by McKenzie and Gill (1968).

New data for Australian deposits are presented in Chapters 5 to 8. In these studies, the use of ostracods to reconstruct past environments is demonstrated. In each study, however, the sort of information ostracods provide is variable because the environments of deposition were quite different.

PART 2

OSTRACOD TAXONOMY AND ECOLOGY

CHAPTER 4

OSTRACOD TAXONOMY, ECOLOGY AND DISTRIBUTION

4.1 INTRODUCTION

This chapter is divided into three main sections. In the first, taxonomical and ecological data for new non-marine ostracod species, as well as supplementary remarks, either on taxonomy or ecology, for previously described species are presented. To facilitate usage of this chapter when referring to it in reading Chapters 5 to 8 on fossil ostracods, the ostracods are listed in alphabetical order.
A phylogenetical classification of non-marine ostracods is not used here since that approach has already been examined in De Deckker (1976b, 1979d).

In the second section, general remarks on the ecology of non-marine (athalassic) Australian ostracods are given. In the third section, the distribution of non-marine ostracods in Australia is discussed.

4.2 TAXONOMY, ECOLOGY AND DISTRIBUTION OF NON-MARINE OSTRACODS

The first Australian ostracods have been described by King (1855). These species had been principally collected in the Sydney neighbourhood. A number of King's species have not been rediscovered since, because either his description was too vague or illustrations were insufficient to enable any identification of living species. No type material of King's species was ever found. Some of King's localities cannot be re-sampled either since they have been destroyed (e.g. one of them was a pond in Bourke Street, now one of the city streets of Sydney).

Brady's (1886) descriptions of ostracods, mainly from South Australia and northern New South Wales, referring principally to emptied shells, can be used since a type collection is available (Hancock Museum, Newcastle upon Tyne; British Museum and Sars Collection, Oslo Museum).

The monumental work of Sars (1889a, 1889b, 1896a, 1896b) describes a vast number of ostracod species raised from dried mud and sand collected in many parts of Australia. Many of Sars' lengthy descriptions of ostracods are adequately supplemented by accurate illustrations of ostracod shells, entire animals and appendages, some even in colour! Of importance also is the description by Sars (1894) of ostracods raised from dried mud collected in New Zealand, as some of these species are also found in Australia. Sars' collection, although lacking type material, is available at the Oslo Museum and has been examined by me as have all other collections mentioned above.

Chapman's (1914, 1919, 1936) descriptions of fossil ostracods (Pleistocene in age *fide* Chapman) are of interest here since a number of these species has extant representatives. Hornibrook (1953, 1955) further discussed some of Chapman's species. All types are available from the National Museum of Victoria and have been examined.

Of significance also, since it has usually been ignored in the literature, is the accurate and fully detailed description of one species *Heterocypris gregarius* (Skoksberg, 1917) new comb. from the Kimberley District in Western Australia by Skoksberg (1917).

Henry (1919, 1923) described some new ostracod species and, in her latter publication, reviewed all ostracod species known in Australia, adding new data on their distribution.

Starting with the publications of Herbst (1957, 1958, 1961), knowledge of taxonomy of non-marine ostracods in Australia has increased rapidly till the present day with the main descriptive works of Chapman (1966), McKenzie (1966a, 1966b, 1968, 1978), Hussainy (1969a, 1969b), De Deckker (1974, 1976a, 1978, 1979a, 1979b, 1980a) and Danielopol and McKenzie (1977). Additionally, information on the distribution of ostracods in Australia is reviewed in McKenzie (1971).

Work on New Zealand ostracods published by Chapman (1963), Barclay (1968) and reviewed in Chapman and Lewis (1976) is also of relevance to the Australian fauna since quite a number of species in these publications are also found in Australia. A checklist of all ostracod species described from Australia and Papua New Guinea until 1973, is available in De Deckker and Jones (1978), and from New Zealand until 1971, in Eagar (1971).

New data, mostly on taxonomy, ecology and distribution, is presented below for the following ostracods.

Alboa worooa n.gen., n.sp.
Australocypris dispar n.sp.
Australocypris insularis (Chapman, 1966)
Australocypris rectangularis De Deckker, 1978
Australocypris robusta De Deckker, 1974
Bennelongia australis (Brady, 1886) n.gen.
Bennelongia barangaroo n.gen., n.sp.
Bennelongia nimala n.gen., n.sp.
Bennelongia pinpi n.gen., n.sp.
Candonocypris incosta n.sp.
Candonocypris novaezelandiae (Baird, 1843)
Cypretta baylyi McKenzie, 1966
Cypricercus salinus n.sp.
Cypricercus unicornis n.sp.
Diacypris compacta (Herbst, 1958)
Diacypris dietzi (Herbst, 1958)

Diacypris dictyote De Deckker, 1980
Diacypris fodiens (Herbst, 1958)
Diacypris spinosa De Deckker, 1980
Diacypris whitei (Herbst, 1958)
Eucypris virens (Jurine, 1820)
Gomphodella maia n.gen., n.sp.
Gomphodella australica (Hussainy, 1969) n.gen.
Heterocypris vatia n.sp.
Ilyocypris australiensis Sars, 1889
Ilyocypris perigundi n.sp.
Ilyodromus amplicolis n.sp.
Ilyodromus candonites n.sp.
Ilyodromus dikros n.sp.
Kapcypridopsis asymmetros n.sp.
Leptocythere lacustris n.sp.
Limnocythere dorsosicula n.sp.
Limnocythere miltos n.sp.
Limnocythere mowbrayensis Chapman, 1914
Mytilocypris mytiloides (Brady, 1886)
Mytilocypris praenuncia (Chapman, 1936)
Mytilocypris splendida (Chapman, 1966)
Platycypris baueri Herbst, 1957
Psychrodromus oblongata (Sars, 1896)
Reticypris clava n.sp.
Reticypris herbsti McKenzie, 1978
Reticypris kurdimurka n.sp.
Reticypris walbu De Deckker, 1979
Sarscypridopsis aculeata (Costa, 1847)
Strandesia phoenix n.sp.

Alboa n.gen.

Type species: *Alboa worooa* n.sp., gender masculine.

Diagnosis: Asymmetrical valves: in anterior view, greatest width of right valve at ½ from dorsum and of left valve at ⅔ from dorsum. Selvage prominent in left valve and placed at ½ of width of inner lamella anteriorly. Peripheral groove on the outside of selvage in left valve.

Male maxillar palps strongly asymmetrical; lateral lobe and distal part of copulatory sheath boot-shaped. Geniculate joint between 1st and 2nd thorocopoda I segments with two unequal setae.

Derivation of name: *Alboa* meaning egg in aboriginal language to refer to the egg-shaped shell.

Alboa worooa n.sp.

Fig. 1; Plate IV.1

1919 *Cypris sydneia* King, Chapman, p. 27.

Diagnosis: As for genus.

Description: Carapace (External). Pseudopunctate, oval-shaped with ventral area almost flat except in the mouth area which is slightly concave at about ⅖ from the anterior. In the left valve, other faint concavity, anterior to the mouth region at about ⅕ from the anterior. Greatest height and width at about middle. Left valve larger and overlapping right one anteriorly, posteriorly and ventrally. In anterior view, valves strongly asymmetrical: left valve, broader and larger; greatest width of left valve at ⅔ from dorsum and of right valve at ½ from dorsum. Carapace pilose with a few long hairs in posterior area. Flange broadest in left valve. Normal pore canals simple and rimmed.

(Internal). Inner lamellae broadest anteriorly and ventrally but slightly broader in left valve; posteriorly, inner lamella of right valve very narrow. In the left valve, the selvage is prominent and at about $^{3}/_{4}$ of inner lamella's width from the outer margin. The selvage follows the curvature of the shell except anteriorly where it is less curved. Posteriorly, the selvage is less prominent and at about half of inner lamella's width. Peripheral narrow depression on the outside of the selvage. In the right valve, the selvage is peripheral and faint except anteriorly where it is much sharper and extends further than the edge of the shell. Right valve with faint tubercles posteroventrally along the edge of the shell. Radial pore canals numerous, narrow and straight. Central muscle field consisting of three scars in front and two behind; the upper and lowest scars in front are broad and elongated whereas the other two are almost circular. Mandibular scars below and in front of central muscle field.

Anatomy. Antennula: (Fig. 4.1a) 7-segmented; length-width ratio of last six segments: $^{2}/_{3}$, $^{3}/_{1}$, $^{1}/_{1.4}$, $^{3}/_{2}$, $^{1.75}/_{1}$, $^{2.5}/_{1}$. Most plumose natatory setae as long as all segments together.

Antenna: (Fig. 4.1e) No obvious sexual dimorphism; three long claws plus a smaller one; natatory setae reaching the tip of the claws.

Mandible: (Figs. 4.1b,c) Mandibular coxale with seven teeth; last tooth longer than the penultimate one and near its base externally with three setae of different sizes - the longest one being pilose. Endopod with α bristle short, narrow and barren; β bristle thick, stout and tufted; γ bristle longer than last segment, thick and with short hairs on external side.

Rake-like organ: Six or seven short and stout teeth with an additional bifid one on inner side of each rake.

FIG. 4.1 *Alboa worooa* n.gen., n.sp.

a	antennula
b	mandible - palp
c	mandible - coxale
d	maxillula
e	antenna
f	thoracopoda II
g	maxilla, female
h	maxilla, male
i	maxilla - endopodite, male
j	thoracopoda I
k	hemipenis
l	furca
m	furcal attachment

a - e, h - m: holotype adult male

g: paratype: adult female

Scale: 100 μ


A
C
E
B
D
F
G
J
H
I
K
L
M

Maxillula: (Fig. 4.1d) 3rd lobe with two toothed Zahnborsten; length width ratio of both palps: 3/1.

Maxilla: Sexually dimorphic: in male, palps strongly asymmetrical with right one broader (Figs. 4.1h,i). In female (Fig. 4.1g) endopod with three plumose setae, the longest one in the middle and two others of unequal length. In both sexes, epipod with five long plumose Strahlen and one shorter plumose one near the base of the plate.

Thoracopoda I: (Fig. 4.1j) Penultimate segment weakly divided. Two setae on geniculate joint between 1st and 2nd segment; anterior seta the longest.

Thoracopoda II: (Fig. 4.1f) End of last segment with two unequal setae and terminal pincers.

Hemipenis: (Fig. 4.1k) Lateral lobe boot-shaped with base rather broad and inner distal end of copulatory sheath of similar shape to the lateral lobe.

Zenker organ: Both ends rounded and with 40 rosettes.

Furca: (Fig. 4.1l) Pectinate claws unequal with posterior claw 2/3 of the length of the anterior one and anterior seta 1/6 of the anterior claw and shorter than the posterior seta.

Furcal attachment: (Fig. 4.1m) Long and narrow with distal end bifurcate; ventral and dorsal branches of similar width and length.

Eye: Cups of nauplius eye fused; dark brown in colour.

<u>Colour of shell</u>: green.

<u>Size</u>:

		L	H		L	H
holotype adult male	*LV	1,540 μ	880 μ	RV	1,460 μ	860 μ
paratype adult female	LV	1,700 μ	1,000 μ	RV	1,640 μ	980 μ

---

* LV, RV = left valve, right valve. L, H = length, height.

Type locality: Pool on the side of Light River, 20 m from the Bridge on the Port Wakefield Road, north of Adelaide, S.A.*

Derivation of name: From the aboriginal language, *worooa* meaning green for the colour of the shell.

Ecology and distribution: *A. worooa* inhabits lakes and temporary pools. This species is found in fresh waters and its highest salinity record is 3.5°/oo at the type locality. *A. worooa* has also been recorded from the following localities: roadside pool, 13 km east of Rocky River plus Duck Lagoon, both on Kangaroo Island, S.A., and Granite pool at Newmann's Rocks, 140 km east of Norseman, W.A. Additionally, valves of this species have been found in subsurface sediments at Birchmore Lagoon, Kangaroo Island (in those specimens, the asymmetry of the valves is more pronounced with the right valve forming a broader hump dorsally). This species has also been described by Chapman (1919) as *Cypris sydneia* from Pleistocene (*fide* Chapman) sediments from Boneo Swamp near Cape Schanck, Vic.

Remarks: *A. worooa* is related to the *Heterocypris* species as their anatomy is very similar, in particular the triangular shape of the right maxillar palp in male and the boot-shaped lateral lobe of the hemipenis. The asymmetrical valves and the presence of faint tubucles on the edge of the valve are also similar to the *Heterocypris* species. The major difference is the presence of a prominent selvage in *A. worooa* not seen in *Heterocypris* species nor in the closely allied species grouped in *Cyprinotus*. This feature of the shell is sufficient to warrant separate generic distinction. Additionally, the right valve of

---

* Abbreviation of States:

N.S.W.	New South Wales	Qld.	Queensland
N.T.	Northern Territory	S.A.	South Australia
Vic.	Victoria	Tas.	Tasmania

A. worooa is not curved outwards in the anterior area compared to *Heterocypris* and *Cyprinotus* species.

A. worooa is to be included in the subfamily Cyprinotinae Bronstein, 1947.

Australocypris De Deckker, 1974

Type species: *Australocypris robusta* De Deckker, 1974.

Remarks: The following species are discussed in the present work and can be distinguished on the outline of the hemipenis: *A. dispar* n.sp., *A. insularis* (= *A. hypersalina*), *A. rectangularis* and *A. robusta*. All *Australocypris* species are halobiont and planktic but can also crawl on lake floors. Rarely do two of these species occur together in one lake.

Australocypris dispar n.sp.

Fig. 4.2; Plate IV.2a-i

Diagnosis: Lateral lobe of hemipenis digitate and broad at the base; long distal seta on 4th segment of thoracopoda I.

Description: Carapace. (External) Pseudopunctate, subrectangular carapace with anterior end broadly rounded, dorsum slightly inclined and posterior steeply inclined. Ventrum strongly concave past mid-length from the anterior. Greatest height at about $2/5$ in female and $1/3$ in male. In dorsal view, carapace elongated, length more than twice width, and both extremities slightly pointed. Left valve slightly larger in female and ventral overlap minimal. Both valves extend over one another in the anterodorsal area just before the hinge. Simple normal pore canals.

(Internal) Inner lamella narrow in both valves and selvage faint and peripheral. A depression occurs posterodorsally behind the hinge between the edge of the valve and the selvage which is prominent in that area. Radial pore canals numerous and straight. Central muscle field consisting of five adductor scars and two large mandibular ones in front and below.

Anatomy.* Antennula: (Fig. 4.2c) Length-width ratio of last six segments: $^{2}/_{3}$, $^{2}/_{1}$, $^{1}/_{1}$, $^{5}/_{3.5}$, $^{2}/_{1.4}$, $^{4}/_{3}$. Small wart-like "sensory" organ on the side of the 2nd segment. Natatory setae as long as last six segments together.

Antenna: (Fig. 4.2a) Massive and sexually dimorphic: four claws in male and three in female: smallest one in male attached to last segment and with long comb-like teeth. Natatory setae almost reaching the tip of the claws.

Mandible: Mandibular coxale (Fig. 4.2h) with seven teeth, the last one longer, narrower than the penultimate one and, at the base, three setae occur, two of which are pilose. Endopod (Fig. 4.2d) with α bristle short, narrow and barren; β bristle stout and finely pilose; γ bristle twice as long as others and pilose in the distal half. Distal segment of endopod $^{1}/_{3}$ of length of penultimate segment.

Rake-like organ: Seven short and stout teeth plus one inner bifid one on each rake.

Maxillula: (Fig. 4.2b) Endopod with 23 plumose Strahlen; length width ratio of palps: $^{3}/_{1.3}$, $^{1.5}/_{1.1}$ with last segment slightly trapezoidal. Two toothed Zahnborsten on 3rd lobe.

---

* Only features of the anatomy which are either not illustrated in Fig. 4.2 and those which are of taxonomic importance are mentioned. This procedure will be used for all species described in this chapter.

FIG. 4.2 *Australocypris dispar* n.sp.

a	antenna
b	maxillula - palp and lobes
c	antennula
d	mandible - palp
e	thoracopoda I
f	maxilla - endopodite, female
g	thoracopoda II
h	mandible - coxale
i	hemipenis
j	maxilla - endopodite, male
k	maxilla, male
l	furca
m	furcal attachment

a, c - e, g - m: holotype adult male

b, f: paratype adult male

Scale: 200 μ


A
B
C
D
E
F
G
H
I
J
K
L
M

Maxilla: Sexually dimorphic: in male (Figs. 4.2j,k), palps almost symmetrical, strongly curved and narrow; in female (Fig. 4.2f), palp faintly divided at its extremity and with three short pilose setae, the middle one being twice as long as the others.

Thoracopoda I: (Fig. 4.2e) Penultimate segment weakly divided; distal segment with a long inner seta half the length of the distal claw.

Thoracopoda II: (Fig. 4.2g) Elongate and narrow segments; distal segment with two terminal setae and two pincers; shortest seta hook-shaped.

Hemipenis: (Fig. 4.2i) Lateral lobe digitate and slightly curved inwards and broad at its base; copulatory sheath broadly heart-shaped.

Zenker organ: Long and narrow with both ends rounded and about 67 rosettes.

Furca: (Fig. 4.2l) unequal claws with anterior one 2/3 longer, and anterior seta slightly longer than posterior one.

Furcal attachment: (Fig. 4.2m) Proximal part bifurcate; dorsal branch strongly arched and about the same length as the ventral one which follows the curvature of the median branch.

Eye: Dark brown with two lateral silver lenses.

Colour of shell: Nacreous brown.

Size:		L	H		L	H
holotype adult male	LV	3,600 µ	2,200 µ	RV	3,600 µ	2,060 µ
paratype adult female	LV	4,100 µ	2,240 µ	RV	4,000 µ	2,060 µ

Type locality: Ephemeral salt lake south of the Coorong Lagoon, S.A. (36°26'45"S, 139°47'32"E) = loc.5 in De Deckker and Geddes, 1980, collected on 16.10.1978 at 15.5°/oo salinity.

Derivation of name: From Latin *dispar* meaning different for the unusual long distal seta on the last segment of the thoracopoda I compared to other *Australocypris* species.

Ecology and distribution: *A. dispar* is a halobiont species which occurs in ephemeral saline lakes in South Australia. Near the Coorong Lagoon, its salinity range is 9-52°/oo. For further details on its distribution there see De Deckker and Geddes (1980) where the species is referred to as *A.* n.sp.1. It is also recorded on the Yorke Peninsula at 6°/oo in an ephemeral lake (35°03'11"S, 137°35'50"E) and on the Eyre Peninsula in a swamp south of the road near Lake Horn, north-west of Port Lincoln at 32.4°/oo.

Remarks: *A. dispar* is characterized by the unusually long seta on the distal segment of the thoracopoda I and the faintly divided end of the female maxillar endopodite palp. These characteristics are unknown in other *Australocypris* species but are found in the halobiont ostracod *Limanocypris luridus* Shornikov, 1961, described from the Kuban Delta in the Caspian Sea region of the USSR. Correspondence exchanged with Dr. E. Shornikov has led to the conclusion that other features of the chaetotaxy of many appendages between *A. dispar* and *L. luridus* differ too greatly to justify close relationship between the two species.

Another, but as yet undescribed, species of *Australocypris* with a long distal seta on the last segment of the thoracopoda I has been collected by Mr. D. Morton from Lake William, near Kerang, Victoria.

Australocypris insularis (Chapman, 1966)

1966	*Eucypris insularis* n.sp., Chapman, p. 375.
1974	*Australocypris hypersalina* n.sp., De Deckker, p. 101.
1978	*Australocypris hypersalina* De Deckker, De Deckker, p. 16.
1978	*Australocypris insularis* (Chapman), De Deckker, p. 17.

Remarks: After examination of many collections of *A. insularis* from Western Australia (from where the species had originally been described), it became clear that *A. insularis* and *A. hypersalina* are to be synonymized. Both taxa have very similar hemipenes with the characteristic broad and curved lateral lobe and the bulbous inner distal end of the copulatory sheath. This type of lateral outline of the hemipenis is not found in other *Australocypris* species.

The examination of many specimens of *Australocypris* has led to the conclusion that slight differences in the morphology of many specimens of *A. insularis* and *A. hypersalina* exist. Therefore the minor differences of the outline of the hemipenis for the two taxa originally mentioned by De Deckker (1978) are here considered to be insignificant.

During the revision of all mytilocypridind species (De Deckker, 1978), it appeared that *A. insularis* and *A. hypersalina* differed mainly on characters of the shell but it has since become apparent that the shape of the shell of the *Australocypris* species is also variable in populations taken during different seasons in the same lake. Large specimens collected during winter and early spring months are usually more elongated. For the same reason, the specimens illustrated in De Deckker, 1978, in Figs. 18a, b as *A. hypersalina* show the typical winter form of *A. hypersalina* = *A. insularis* not recognized then, as most collections described in that publication had been taken during summer months.

Ecology and distribution: The distribution of *A. insularis* (plus *A. hypersalina*) was dealt with in De Deckker (1977, 1978) and is updated here. The species is commonly found in ephemeral saline lakes near the Coorong Lagoon (see De Deckker and Geddes, 1980) where it is found between 5 and 131°/oo salinity. It also occurs on the Yorke and Eyre Peninsulas in similar ephemeral lakes at the same salinity range. It has also been widely collected in 15 west Australian salt lakes by Geddes *et al.* (in press) over the range of 2.9-122.6°/oo.

Australocypris rectangularis De Deckker, 1978

1978 *Australocypris? rectangularis* n.sp., De Deckker, p. 17.

1980 *Australocypris rectangularis* De Deckker, De Deckker and Geddes, p. 691.

Diagnosis: Lateral lobe of hemipenis narrow and hook-shaped; copulatory sheath almost semicircular. Carapace rectangular in shape.

Remarks: The original description of this species was incomplete because a number of appendages had dried out and had been damaged. A number of specimens have since been collected in saline lakes near the Coorong Lagoon by De Deckker and Geddes (1980). They examined the appendages of this species and related it with confidence to *Australocypris* on morphological grounds.

Ecology and distribution: This species is a true halobiont form which has never been found in salinities below 50°/oo. Near the Coorong Lagoon, its salinity range is 50-195°/oo and there is evidence there that it even hatched above 73°/oo and 115°/oo in two different localities. On the Yorke and Eyre Peninsulas, *A. rectangularis* occurs in the same range of salinities as in the lakes near the Coorong Lagoon.

Australocypris robusta De Deckker, 1974

1974 *Australocypris robusta* n.sp., De Deckker, p. 75.

Diagnosis: Chitinous pocket on inside of posterodorsal area in female valves; hemipenis with digitate lateral lobe which is of about the same width all along.

Ecology and distribution: The salinity range of *A. robusta* in Victoria, already available in Bayly and Williams (1966), of 53.5-93.1°/oo and of 4.4-132°/oo in Geddes (1976) is broadened to the range of 7-145°/oo obtained from collections made in many lakes in January 1980. This particularly broad range was not reached by specimens of the same species in lakes in the Coorong area of South Australia. There the range is 15-38°/oo (De Deckker and Geddes, 1980). The significance of this difference in salinity tolerance is discussed in section 4.3.2. The query concerning the validity of Geddes' (1976) record of the salinity for *A. robusta* in Victoria, made by De Deckker and Geddes (1980, p. 691) is resolved since further work has demonstrated that the salinity range of *A. robusta* definitely differs between Victorian and South Australian lakes. Similarly, Geddes (1976) could not have misidentified *A. robusta* since it is the only *Australocypris* species recorded in his study area.

In Victorian lakes, *A. robusta* is found in a healthy state and in high numbers at salinities between 45 and 77.5°/oo, and nearly always occurs with *Diacypris compacta* which is found in even higher numbers. At higher salinities, these two species are found with *Platycypris baueri*. *A. robusta* occurs in two permanent salt lakes in Victoria, Lakes Gnotuk and Keilambete, which have salinities in the vicinity of 60°/oo the whole year round (see Table 5.1). This indicates that this species does not necessarily require a sharp decrease in salinity to hatch although Geddes (1976) showed the hatching range for *A. robusta* to be 8.5-108°/oo. This is further discussed in section 4.3.4.

Bennelongia n.gen.

Type species: *Bennelongia australis* (Brady, 1886).

Diagnosis: Adult with strongly asymmetrical valves anteriorly: left valve beak-like anteroventrally with selvage in that region forming a broad but short lip-like structure which does not extend anterodorsally. Anteroventral area of right valve usually smooth-curved and with occasional broad beak-like flange. Posteroventral and peripheral tubercles on the right valve. Juvenile with symmetrical valves and no beak-like structure; external surface either deeply pitted or reticulated often with many wart-like tubercles.

Asymmetrical male maxillar palps; thoracopoda I 1st segment with two unequal setae and penultimate segment weakly divided and lateral lobe of hemipenis broadly boot-shaped.

Derivation of name: From *Bennelong*, the name of the first aboriginal to have had a long association with the first European settlers in Australia.

Remarks: So far five Australian species are grouped in the genus *Bennelongia*. They are *B. australis*, *B. barangaroo* n.sp. (= *Chlamydotheca bennelong* (King) *sensu* Sars 1894, 1896), *B. nimala* n.sp., *B. pinpi* n.sp., and a new species presently being described by Dr. K.G. McKenzie and myself. It is likely that *Strandesia feuerborni* Klie, 1932 and *Strandesia flavescens* Klie, 1932, both described from Indonesia, belong to *Bennelongia*. From Klie's original description and illustrations of the valves (Klie, 1932), it appears that these two species are characterized by the asymmetrical valves so typical of *Bennelongia* species. Two specimens resembling *S. feuerborni* have been collected from Cauckingburra Swamps, at Lake Buchanan, via Charters Towers in Queensland. One specimen is illustrated in Plate IV.8r but no further identification has been carried out.

Bennelongia n.gen. is to be included in the subfamily Cyprinotinae Bronstein, 1947 because of the asymmetrical valves, the presence of peripheral tubercles on the right valve, the asymmetrical male maxillar palps, the presence of two setae on the 1st segment of the thoracopoda I and the broadly boot-shaped lateral lobe of the hemipenis.

Bennelongia australis (Brady, 1886)

Fig. 4.3; Plates IV.3-IV.5

1886 *Chlamydotheca australis* n.sp., Brady, p. 91.

Diagnosis: Area just behind the beak-like feature of the left valve strongly concave and outline of hemipenis as in Figs. 4.3h,j.

Description: Carapace. (External) Adult: Pseudopunctate and pilose carapace, oval in shape with flattened ventrum and concave in the mouth region. Asymmetrical valves: left one beak-shaped anteroventrally with deeply concave depression posterior to the beak. Right valve almost smoothly curved anteroventrally except for a narrow beak-like flange in that area. This flange is overlapped by the beak-like anterior area of the left valves when the carapace is closed. In dorsal view, carapace egg-shaped with both valves slightly pinched laterally at about 1/6 from the anterior. Simple type normal pore canals. Bordering the edge of the right valve anteriorly there are a number of small quadrate tubercles.

Juvenile: Ellipsoidal to subtriangular in shape; symmetrical valves without beak-like feature and surface of shell either deeply pitted or coarsely reticulated with large wart-like tubercles present mostly anteriorly and posteriorly. Reticulation is especially varied in the smallest juveniles with some large sieve-like plates.

(Internal) Adult: Inner lamellae broader anteriorly than posteriorly. In left valve, selvage narrow but near the inner margin posteriorly and ventrally; anteroventrally it forms a broad but short lip-like flap which is absent anterodorsally. Presence of a deep depression anterodorsally near the edge of the shell and following the curvature of the inner margin anteriorly. It is absent in the vicinity of the lip-like flap. There is no outer list in the left valve. Right valve with selvage peripheral except in the anteroventral area where it is slightly broader and further inside the inner lamella. Behind the mouth region, the flange is thin but broad and curves outward to almost reach the tubercles. Outer list faint, running parallel to the curvature of the shell bordered with tubercles in front of the mouth region and posteroventrally. Radial pore canals narrow and straight. Central muscle field consists of a broad horizontal scar above, two parallel ones below and another broad one behind. There are two additional, almost circular scars, one behind the middle posterior one and the other behind the bottom scar. Two broad mandibular scars in front and below.

In juveniles, the inner lamellae are of similar width all around except in the posteroventral area where they are slightly broader. Selvage broad, following the curvature of the shell and with no lip-like flap. Flange narrow but obvious in both valves and of same width as the outer list which runs parallel to the curvature of the shell. Depressions caused by some wart-like tubercles on the outside area are seen inside the valves.

Anatomy. Antennula: (Fig. 4.3a) The natatory setae are as long as all the segments together. The length width ratios of the last six segments are: $^{1}/_{1}$, $^{5}/_{2}$, $^{1.8}/_{1}$, $^{2}/_{1}$, $^{2.3}/_{1}$, $^{2}/_{1}$.

Antenna: (Fig. 4.3d) The natatory setae extend to the tip of the claws. There are three claws plus a shorter one in both sexes; one of the additional short and thin claws attached to the last segment in male is longer and denticulated in female.

Mandible: (Fig. 4.3b) Mandibular coxale with seven teeth; endopod with long, narrow and barren α bristle, thick, stout and pilose β bristle and a long pilose γ bristle which is twice as long as the last segment.

Rake-like organ: (Fig. 4.3e) There are five teeth plus another bifid one on the inside of each rake.

Maxillula: (Fig. 4.3c) Length width ratio of palp segments: $^{4}/_{1}$, $^{4}/_{1}$; 3rd lobe with two smooth Zahnborsten and a tufted thick seta at the end of the 3rd lobe near the Zahnborsten. There are about 17 plumose Strahlen on the epipod plate.

Maxilla: Sexually dimorphic: in female (Fig. 4.31) three unequal plumose setae at the tip of the endopod; in male (Figs. 4.3h,i) grasping palps unequal, the broadest one being on the right side - for chaetotaxy see Fig. 4.3h.

Thoracopoda I: (Fig. 4.3g) Geniculate distal part of the 1st segment with two setae, the proximal one being almost twice as long as the other. Penultimate segment weakly divided. Inner distal seta of 2nd segment shorter than half the length of the 3rd segment and shorter than the distal outer seta of the last segment. Inner distal end of penultimate segment with two unequal setae. The inner distal seta on the 4th segment is about $^{1}/_{3}$ of the length of the distal claw.

FIG. 4.3 *Bennelongia australis* (Brady, 1886) n.gen.

a	antennula
b	mandible - palp
c	maxillula - palp and lobes
d	antenna
e	rake like organ
f	hemipenis
g	thoracopoda I
h	maxilla, male
i	maxilla - endopodite, male
j	hemipenis
k	thoracopoda II
l	maxilla - endopodite, female
m	furcal attachment
n	furca

a - b, d - k, m - n: adult male - creek pool flowing across the road, 2 km N. of Leonora, W.A.

c, l: adult female

Scale: 200 µ


A
D
C
B
E
F
G
H
I
J
K
L
M
N

Thoracopoda II: (Fig. 4.3k) Distal setae unequal: the large one being more than twice the length of the other which is hook-shaped. Broad pincers present distally.

Hemipenis: (Figs. 4.3h,j) Lateral lobe broad with inner distal end pointed and curved inward. Copulatory sheath broadly triangular in shape with the round inner distal end reaching almost the curved tip of the lateral lobe. The outermost point of the sheath forms a hump and corresponds to mid-length of the inner side of the sheath.

Zenker organ: With 33 rosettes.

Furca: (Fig. 4.3n) Claws narrow, long and unequal and posterior seta the longest of the two.

Furcal attachment: (Fig. 4.3m) Bifurcate at the distal end; median branch thickest and other two branches arched inwards.

Eye: Dark brown with two lateral silver lenses.

Colour of shell: Green to pale green.

Size:		L	H		L	H
lectotype: adult left valve	LV	1,980 μ	1,200 μ			
adult male	LV	1,860 μ	1,060 μ	RV	1,740 μ	1,100 μ
adult female	LV	2,220 μ	1,300 μ	RV	2,060 μ	1,220 μ

Remarks: Examination of the type specimens of *Chlamydotheca australis* Brady, 1886 kept in the British Museum necessitates the following clarification. One adult left valve (L 1,980 μ, H 1,200 μ), designated here as the lectotype, is the valve probably illustrated by Brady (1886) on Plate IX.7. The tip of the beak-like feature of this left valve is broken off. In the same slide, there is another left valve which probably belongs to a *Heterocypris* sp. It is likely that this valve is the one thought by Brady (1886) to be the right valve of

C. australis and illustrated by him on Plate IX.8. It definitely lacks the peripheral posteroventral tubercles and the broad inner lamella anteriorly so typical of all *Bennelongia* species and the anteroventral flange of *B. australis* specimens. This would explain the incorrect description of the right valve of this species provided by Brady (1886) on p. 91. Examination of one carapace of *B. australis* from a slide bearing Brady's handwriting in Sars' collection in the Oslo Museum further confirms Brady's misidentification.

Finally, in the same slide from the British Museum, there are two partly broken carapaces of smaller *Bennelongia* species (length 1,360 μ, width 800 μ) with some dried soft parts inside. Their specific identification remains uncertain although it is thought they belong to *B. barangaroo*.

In 1894, Sars synonymized *C. australis* Brady, 1886 with *Cypris bennelong* King, 1855 by arguing that Brady's specimens were the same as those of King, and by saying that the latter author had described the species from juvenile specimens. This was later repeated in Sars (1896a) and Henry (1923). Sars' suggestion cannot be accepted because King (1855) stated on page 63 that *C. bennelong* has "equal valves". This is not the case for adult *Bennelongia* species. Sars' (1894) argument of King's specimens being juveniles cannot be accepted here either since juveniles of *Bennelongia* (which have symmetrical valves) are either deeply punctated all over or are strongly tuberculated. These features are best seen on specimens described by Sars (1896a) as *Cypris lateraria* King, 1855 which are juveniles of *Bennelongia* spp. Either tubercles or pitted shell would have surely been diagnosed by King otherwise.

Sars' specimens described from Australia (Sars, 1896a) and New Zealand (Sars, 1894) as *C. bennelong* are true *Bennelongia* species but do not belong to *B. australis*. Since they cannot be identified as King's species, they are therefore renamed here as *B. barangaroo* n.sp. This species is re-described in this chapter.

Ecology and distribution: *B. australis* was originally collected from Penola in South Australia by Prof. R. Tate. The specimens were empty shells (Brady, 1886). This species inhabits mainly temporary pools and, so far, has been found alive only in Western Australia and South Australia. Adult males have been found in a permanent lake in Western Australia, suggesting that the mode of reproduction is parthenogenetic in ephemeral environments. For further discussion see section 4.3.5.

Localities: W.A.: Roadside pool 2.3 km south of Northcliffe; roadside pool Pfeiffer's Road, 8 km from Mary Peaks; Lake Sadie, east of Wilson Inlet (near Denmark); creek pool flowing across the road 2 km north of Leonora; roadside pool 5 km south of Cunderdin; roadside pool on eastern side of road between Quairading and Corrigin (25 km north-west of Corrigin); Lake Biddy.

S.A.: Roadside pool, 3 km east of Rocky River, Kangaroo Island.

In all localities, water was fresh except in the latter two sites in Western Australia where salinity of the water was 4.4 and 3.5°/oo respectively.

Bennelongia barangaroo n.sp.

Figs. 4.4-5; Plates IV.6-8 a-q

1894 *Cypris bennelong* King, Sars, p. 24.

1896 *Cypris bennelong* King, Sars, p. 49.

1896 *Cypris lateraria* King, Sars, p. 53.

1923 *Cypris bennelong* King, Henry, p. 275.

Diagnosis: Area just behind the beak-like feature of the left valve slightly concave and outline of hemipenis as in Fig. 4.4j.

Description: Carapace. (External) Adult: circular to oval-shaped carapace smooth or covered with faint pustules and pilose. Ventrum flattened. Valves asymmetrical: left valve larger, especially anteriorly with the largest overlap ventrally; anteroventral region of left valve slightly concave to form a beak-like feature whereas the right valve is broadly rounded and with an elongated and narrow beak-like serrated flange anteroventrally. Simple type normal pore canals.

Juvenile: More elongated in lateral view, with symmetrical, pitted or tuberculated valves.

(Internal) Adult: Inner lamella twice as broad anteriorly in both valves compared to posterior but broadest in left valve. In left valve, selvage peripheral posteriorly, away from the outer margin ventrally and forming a lip-like flap far away from the edge of the shell anteroventrally. There it is preceded by a deep, narrow groove. A ridge follows the curvature of the inner margin anteriorly but fades opposite the tongue-like flap. A few small tubercles are visible on this ridge above the concave depression of the shell. Outer list often broad posteroventrally. In right valve, selvage peripheral and sharp posteriorly, broad anteroventrally and faint anterodorsally. In many specimens, the edge of the shell near the flange is distorted to form an obvious concavity which is paralleled by a depression. There is a row of tubercles along the periphery of the shell posteroventrally. Outer list also broader posteroventrally and usually pitted externally near the edge of the shell: this is best seen in the ventral area.

Juvenile: In both valves, inner lamella of almost equal width all around and the selvage which follows the curvature of the shell is prominent.

FIG. 4.4 *Bennelongia barangaroo* n.gen., n.sp.

a	antennula
b	antenna
c	mandible - coxale
d	thoracopoda I
e	maxillula - palp and lobes
f	mandible - palp
g	maxilla - endopodite, male
h	maxilla, male
i	thoracopoda II
j	hemipenis
k	furca
l	maxilla - endopodite, female

a - b, d - k: adult male - Lake Buchanan, Qld.

c, l: adult female - same locality.

Scale: 100 μ


A
B
C
D
E
F
G
H
I
J
K
L

Anatomy: Only the features of the anatomy which differ significantly from *B. australis* and other *Bennelongia* species are mentioned. For other details refer to Figs. 4.4-4.5.

Antennula: Natatory setae slightly longer than all the segments together.

Maxilla: Male grasping palps (Figs. 4.4g,h) of different shape than *B. australis*: left palp shorter and broader at the base and right one with outer edge forming a right angle.

Thoracopoda I: (Figs. 4.4d, 4.5e) Inner distal seta of second segment at least as long as half of the 3rd segment; longest inner seta at mid-length of the 3rd segment (where it is weakly divided) at least as long as the 2nd half of the 3rd and the 4th segments together. The inner distal seta on the 4th segment is 1/2.3 of the length of the distal claw.

Colour of shell: Green.

Size:

			L	H		L	H
material from Lake Buchanan	adult male	LV	1,120 μ	700 μ	RV	1,100 μ	660 μ
	adult female	LV	1,160 μ	700 μ	RV	1,110 μ	680 μ
Newmann's Rocks	adult female	LV	1,390 μ	780 μ	RV	1,320 μ	770 μ

Derivation of name: From the aboriginal name of Bennelong's wife, Barangaroo, since a new combination is required because the species referred to by Sars as *C. bennelong* does not correspond to the original description given by King for *C. bennelong*.

Ecology and distribution: *B. barangaroo* is a common inhabitant of temporary pools and usually is only represented by parthenogenetic females. On one occasion, in Lake Buchanan, both sexes were found. There salinity was 4.1°/oo. In other localities listed below, water was known to be fresh.

FIG. 4.5 *Bennelongia barangaroo* n.gen., n.sp.

a	rake-like organ
b	antennula
c	mandible - palp
d	antenna
e	thoracopoda I
f	maxilla - endopodite, female
g	maxillula - palp and lobes
h	mandible - coxale
i	thoracopoda II
j	furca
k	furcal attachment
l	maxilla - protopodite, female

a - l: adult female - pool in creek bed about 25 km N. of Cue, W.A.

Scale: 1 - 100 μ for b - l

2 - 50 μ for a


A
B
C
D
E
F
G
H
I
J
K
L
1
2

W.A.: granite pool, Newmann's Rocks, 140 km east of Norseman; roadside ditch 37 km west of Esperance (road to Ravensthorpe) and 3.5 km east of Dalyup River; small roadside pool about 18 km north-east of Menzies; elongated pool in bed of Cookarrow Creek, about 5 km west of Wiluna; pool in creek bed about 25 km north of Cue; small farm dam on eastern side of road 9 km south of Cunderdin on the way to Quairading.

S.A.: Farm dam at Frome Downs, near Lake Frome.

Qld.: Creek, 22 km east of Richmond; roadside pool at Miranda; Lake Galilee, near Aramac; Lake Dunn, south of Lake Galilee.

N.S.W.: Specimens raised by Sars from sample of dried mud collected in waterholes by Mr. Whitelegge in Bourke Street, Sydney (Sars, 1896a).

New Zealand: Specimens raised from dried mud sample collected near Kaitaia in the North Island. Chapman (1963) stated that this species had not been found in New Zealand since Sars' (1894) description and no further localities are provided in Chapman and Lewis (1976).

Live specimens with tuberculated symmetrical valves collected in a farm dam at Frome Downs near Lake Frome in South Australia were examined in the laboratory. They resembled specimens illustrated by Sars (1896a) on Plate VII: Fig. 3 and labelled by him as *Cypris lateraria* King, 1855. After a few days, these specimens, which had traces of ovaries inside the valves, were seen to molt into *B. barangaroo* with its typical asymmetrical valves. Eggs of the latter developed into small highly ornamented ostracods like *C. lateraria*. This phenomenon requires the two taxa to be synonymized.

Remarks: *B. barangaroo* is closely allied to *B. australis* but the species can be separated on the basis of size (*B. australis* being much larger), on the outline of the hemipenis and the chaetotaxy of the thoracopoda I.

The specimens of *B. barangaroo* described here are identical in morphology to Sars' specimens from Bourke Street, Sydney and from New Zealand. It is assumed here that the specimens of *Cypris lateraria* King, 1855 raised by Sars (1896a) from dried mud collected in Bourke Street, Sydney are juveniles of *B. barangaroo*.

The shape and width of the anteroventral flange on the right valve of *B. barangaroo* specimens can vary extensively: in the specimens from Lake Buchanan, the edge of the flange is serrated (Plate IV.6p,q).

Bennelongia nimala n.sp.

Fig. 4.6; Plate IV.9

Diagnosis: Oval to subrectangular, pustulose carapace with posterior slightly pointed and ending with one or two spines. Hump-like thickening of the shell anterodorsally. Posterior seta of furca about $7/10$ of the length of the posterior claw and lateral outline of hemipenis as in Fig. 4.6g.

Description: Carapace. (External) Adult: Oval to subrectangular-shaped with posterior slightly pointed and ending with one or two spines. In dorsal view, egg-shaped with anterior end narrow and more pointed than posterior. Valves obviously asymmetrical in anteroventral area: there, the left valve is formed like a pointed beak whereas in the right valve, it is broadly rounded and there is a small beak-shaped serrated flange. Posterior to the flange, the edge of the right valve is slightly concave. The tip of the beak does not reach the horizontal plane formed by the ventral area. Greatest height at about $1/3$ from the anterior. The shell is pilose, pseudopunctated and pustulose nearly all over. Along the edge of the left valve, especially, the pustules are more concentrated and some are even pointed, especially anteriorly.

Juvenile: Pseudopunctate, subtriangular shell with many pointed tubercles scattered all over but with a greater concentration anteriorly and posteriorly. Valves symmetrical. In dorsal view, oval-shaped with both ends pointed.

(Internal) Adult: Inner lamella broadest anteriorly in both valves. In left valve, selvage narrow and peripheral posteriorly, distant from outer margin ventrally and forming a lip-like flap anteroventrally. This flap fades in the anterodorsal region. In front of flap in the ventral area, there is a deep narrow groove. Between the outer margin and just behind the beak ventrally, there is a ridge which is tuberculate in some specimens. In the anterior area, in front of the hinge area, there is a deep groove running parallel to the curvature of the shell which is placed near the outer margin. This groove is absent in the beak-like area. In the right valve, the selvage is narrow and runs parallel to the curvature of the shell except at mid-height anteriorly where it is not visible. Anteriorly, in the region where the serrated flange is present, there is a small ridge running parallel to, and between, the selvage and the inner margin.

Juvenile: Inner lamellae equal in both valves and of same width all along. Selvage broad and peripheral.

Anatomy: Same remarks as for *B. australis*. For details of the anatomy, refer to Fig. 4.6.

Antennula: (Fig. 4.6c) Natatory setae as long as all segments together.

Maxilla: Male palps asymmetrical (Figs. 4.6f,k) with right one broader and less arched. The two external setae on the female palp (Fig. 4.6h) are of equal length and are plumose.

FIG. 4.6 *Bennelongia nimala* n.gen., n.sp.

a	antenna
b	rake like organ
c	antennula
d	maxillula - palp and lobes
e	mandible - palp
f	maxilla - endopodite, male
g	hemipenis
h	maxilla - endopodite, male
i	thoracopoda I
j	thoracopoda II
k	maxilla - endopodite, male
l	maxilla - protopodite, female
m	furcal attachment
n	furca

a - c, e - g, i, k - m: holotype adult male

d, h, j, n: paratype adult male

Scale: 1 - 100 μ for a, c - n
2 - 50 μ for b


A
B
C
D
E
F
G
H
I
J
K
L
M
N
1
2

Thoracopoda I: (Fig. 4.6i) The inner distal seta of the 2nd segment almost reaches the weakly divided area in the middle of the 3rd segment where another seta of similar length occurs. The inner distal seta of the 4th segment is $^{1}/_{5.6}$ of the length of the distal claw.

Hemipenis: (Fig. 4.6g) The lateral lobe broad: greatest length equals its greatest width. Near the base of the lateral lobe on the inner side, the copulatory sheath is in the form of a circular lump.

Zenker organ: Funnel-shaped at both ends, with 30 rosettes.

Furca: (Fig. 4.6n) The posterior seta is long, approximately $^{7}/_{10}$ the length of the posterior claw.

Colour of shell: Green to dark green with broad transversal white stripes best seen in dorsal view.

Size:		L	H		L	H
holotype adult male	LV	1,500 μ	840 μ	RV	1,340 μ	760 μ
paratype adult female	LV	1,640 μ	960 μ	RV	1,540 μ	860 μ

Type locality: Georgetown Lagoon, near Jabiru, Northern Territory.

Derivation of name: The word *nimala* in aboriginal language of the Northern Territory means lagoon, for the typical habitat of this species.

Ecology and distribution: *B. nimala* is a freshwater species found in a number of lagoons in the Northern Territory near Jabiru, east of Darwin. These are: Jabiluka Billabong, Buffalo Billabong and Mudginberri Lagoon. Both sexes were always found in the collections.

B. nimala is closely related to another species found in eastern Queensland, presently being described by Dr. K.G. McKenzie and myself.

Bennelongia pinpi n.sp.

Fig. 4.7; Plate IV.10

Diagnosis: Anteroventral area of left valve strongly beak-shaped extending below the horizontal plane of the flat ventral area. In dorsal view, carapace almost circular with both ends broadly pointed. Outline of hemipenis as in Fig. 4.7e.

Description: Carapace. (External) Adult: triangular to semicircular in shape with flat ventral area; greatest height at about middle. Anteroventral area of both valves beak-like but more pronounced in left valve. Surface of shell smooth to pseudopunctate and barren of hairs except in the mouth region. In dorsal view, carapace almost circular in shape with anterior and posterior ends broadly pointed. At about $\frac{1}{6}$ from the anterior, the shell is pinched being more noticeable in the posteroventral area. Valves strongly asymmetrical anteroventrally where the left valve is larger, elsewhere the left valve is slightly overlapping the right valve.

Juvenile: Subtriangular in shape with ventrum almost flat and greatest height at about $\frac{2}{5}$ from the anterior. In dorsal view, carapace oval to almost circular in shape with both ends pointed. Largest juveniles with pseudopunctated shell and few tubercles. In very small juveniles, shell pitted and thinly reticulated and with some sieve plates. Most tubercles are cone-shaped and a hair protrudes from each of them. Valves almost symmetrical with left one slightly larger.

(Internal) Adult: Inner lamella much broader anteriorly in both valves. In the left valve, the selvage forms a broad lip anteroventrally and is absent anterodorsally. It is narrow ventrally and distant from the outer margin and broader posteroventrally where it is placed in the middle of the inner lamella. Above the concavity behind the beak-like form in the anterior of the shell, there are a few tubercles between the outer margin and the lip-like selvage. There is also a depression in front of the lip-like selvage and another near the outer margin anterodorsally. In the right valve, the selvage is narrow and peripheral. There is a broad tongue-like flange anteroventrally in some valves which is enclosed by the broader beak-like left valve when the carapace is closed. An outer list runs parallel to the curvature of the right valve and is bordered by small tubercles ventrally except in the mouth region.

Juveniles: Inner lamellae twice as broad anteriorly and with broad and prominent selvage following the curvature of the shell. The outer list runs parallel to the curvature of both valves and is bordered inside by faint tubercles in some juveniles.

Anatomy: Same remarks as for other species. For details of the anatomy, see Fig. 4.7.

Antennula: (Fig. 4.7b) The natatory setae are almost as long as all the segments together.

Maxillula: The male palps (Figs. 4.7i,j) are asymmetrical with the right one broader although both are similarly arched.

Thoracopoda I: (Fig. 4.7g) The inner distal seta on the 2nd segment almost reaches the level of the weak division of the 3rd segment. There, the inner distal seta is long extending past the 4th segment. The length ratio of the distal seta of the 4th segment and the distal claw is $1/_{3.5}$.

Hemipenis: (Fig. 4.7e) The outer lobe is broad and digitate and, near its base on the inner side, the copulatory sheath forms a broad trapezoid-shaped extension.

Zenker organ: With 42 rosettes.

FIG. 4.7 *Bennelongia pinpi* n.gen., n.sp.

a	maxillula - palp and lobes
b	antennula
c	antenna
d	mandible - palp
e	hemipenis
f	maxilla - endopodite, female
g	thoracopoda I
h	thoracopoda II
i	maxilla, male
j	maxilla - endopodite, male
k	furca
l	furcal attachment

a - c, c, g - k: holotype adult male

d, f, l: paratype adult female

Scale: 200 μ


A
B
C
D
E
F
G
H
I
J
K
L

Furca: (Fig. 4.7k) The setae are almost equal - the posterior one being longer and about ½ the length of the posterior claw.

Colour of shell: White to transparent when preserved in alcohol.

Size:

		L	H		L	H
holotype adult male	LV	2,480 µ	1,600 µ	RV	2,340 µ	1,420 µ
paratype adult female	LV	2,580 µ	1,640 µ	RV	2,440 µ	1,520 µ

Type locality: Pine Tree Creek Lagoon, via Hughenden, Queensland.

Derivation of name: The aboriginal word *pinpi* in Queensland meaning parrot is chosen for the anteroventral area of the shell which resembles the beak of a parrot.

Ecology and distribution: This freshwater species is known from the following localities in Queensland: Agnes Lake, Salt Lake (fresh) and Louisa Lake, all three via Hughenden.

Candonocypris Sars, 1896

Type species: *Candonocypris novaezelandiae* (Baird, 1843).

Remarks: The species mentioned above is chosen here as the type species of *Candonocypris* because it has priority in the synonymy over *C. candonioides* (King, 1855) which Sars (1894) referred to as the first species in his description of the genus. See further discussion below. Two species are included in *Candonocypris* in Australia: *C. incosta* n.sp. and *C. novaezelandiae* (Baird, 1843). Both are described below.

Candonocypris incosta n.sp.

Fig. 4.8; Plate IV.11

1914 *Candona lutea* King, Chapman, p. 59, Fig. 6 only.

1971 *Ilyodromus* cf. *smaragdinus* Sars, McKenzie, p. 396.

1977 *Ilyodromus* cf. *smaragdinus* Sars, Danielopol and McKenzie, p. 309.

Diagnosis: *Candonocypris* with peripheral selvage anteriorly in both valves and broad and near the outer margin in the posterior of the right valve.

Description: Carapace. (External) Smooth and elongated, ellipsoid shell with dorsum arched and with ventrum flat except in front of the middle where it is slightly concave. Both ends of the valves tapering but posterior more pointed. Greatest height at about mid-length. Shell narrow in dorsal view. Obvious overlap of the left valve antero- and posterodorsally.

(Internal) Inner lamellae similar in both valves anteriorly and approximately twice as broad anteriorly compared to the posterior area. Selvage peripheral anteriorly and only prominent posteroventrally in the right valve. This selvage is met by a depression in the left valve where the selvage is peripheral.

Anatomy: This species has already been fully described by McKenzie (1971b) as *Ilyodromus* cf. *smaragdinus* from New Guinea. The diagnostic features of the anatomy of *C. incosta* are the short 3rd segment of the antennula with a length width ratio of about $^{1.6}/_{1}$ (Fig. 4.8a); strongly arched palps on the male maxilla (Figs. 4.8i,j); outer extremity of copulatory sheath at mid-length forming a broad hump with right angle (Fig. 4.8m) and furca with almost equal claws (Fig. 4.8o).

For details of the anatomy refer to Fig. 4.8 and the discussion below. The only feature different in McKenzie's specimens is the

FIG. 4.8 *Candonocypris incosta* n.sp.

a	antennula
b	antenna
c	maxilla, female
d	mandible - palp
e	mandible - coxale
f	maxillula - palp and lobes
g	rake-like organ
h	thoracopoda I
i	maxilla - endopodite, male
j	maxilla, male
k	thoracopoda II
l	Zenker organ
m	hemipenis
n	furcal attachment
o	furca

a - b, d - e, g - j, l - o: holotype adult male

c, f, k: paratype adult male

Scale: 1 - 100 μ for a - f, h - o

2 - 50 μ for g


A
B
C
D
E
F
G
H
I
J
K
L
M
N
O
1
2

broader extension of the copulatory sheath over the lateral lobe in the New Guinea specimens. This difference is not considered to be important. Comparison with the New Guinea material kept in the British Museum and the one described here indicates that all other details of the hemipenis are the same.

Colour of shell: White to transparent.

Size:

		L	H		L	H
holotype adult male	LV	1,220 μ	600 μ	RV	1,160 μ	560 μ
paratype adult female	LV	1,410 μ	700 μ	RV	1,390 μ	660 μ

Type locality: Spring at base of limework quarry at Pulbeena Swamp in north-western Tasmania.

Derivation of name: From Latin *in* (= without) and *costa* (= ridge) for the absence of prominent selvage in the right valve anteriorly in comparison with *C. novaezelandiae*.

Ecology and distribution: This species has been collected from the type locality only once; it was found crawling on and within the topmost centimetre of sediment in freshwater. It is also recorded from Lake Peunde, near Mt. Wilhelm (about 3,750 m), Bismarck Range in New Guinea.

Remarks: This species differs from *C. novaezelandiae* because of the absence of a prominent selvage at a distance from the edge of the shell in the right valve. Both species, on the other hand, possess the prominent selvage posteroventrally in the right valve. Examination of the anatomy of the living specimens from the type locality confirms the generic identification, as the thoracopoda II possesses the two typical setae at mid-length on the last segment (Fig. 4.8k). This feature is not found in the *Ilyodromus* species. Additionally, the fact that the outline of the hemipenis and the very short two-jointed sensory seta on the 2nd segment of the antennula (in

Ilyodromus species it is very long and three-segmented) are so similar in both *C. incosta* and *C. novaezelandiae*, further justify the grouping of these two species under the same genus.

A few specimens of *C. incosta* are present in Chapman's (1914) slide which yields fossil specimens from Mowbray Swamp in north-western Tasmania. This species has since been re-collected at that site - see Chapter 6.

Candonocypris novaezelandiae (Baird, 1843)

Fig. 4.9; Plate IV.12

1843 *Cypris Novae Zelandiae* n.sp., Baird, p. 268.

1855 *Cypris candonioides* n.sp., King, p. 66.

1889 *Herpetocypris stanleyana* (King), Sars, p. 35.

1894 *Candonocypris assimilis* n.sp., Sars, p. 36.

1894 *Candonocypris candonoides* (*sic*) (King), Sars, p. 35.

1919 *Candonocypris assimilis* Sars, Chapman, p. 28.

1955 *Candonocypris assimilis* Sars, Hornibrook, p. 271.

1956 *Candonocypris candonoides* (*sic*) (King), Hornibrook *in* Gill and Banks, p. 19.

1969 *Candonocypris assimilis* Sars, Hussainy, p. 305.

1971 *Candonocypris novaezelandiae* (Baird), Eagar, p. 55.

1975 *Candonocypris assimilis* Sars, Okubo, p. 157.

1976 *Candonocypris novaezealandiae* (*sic*) (Baird), Chapman and Lewis, p. 95.

1976 *Candonocypris assimilis* (Sars), Chapman and Lewis, p. 95.

Diagnosis: *Candonocypris* with prominent selvage in right valve usually half way between the outer and inner margins and following the curvature of the shell; posteroventrally in the right valve and near the inner margin, selvage is prominent.

FIG. 4.9 *Candonocypris novaezelandiae* (Baird, 1843)

a	antennula
b	antenna
c	mandible - palp
d	maxillula - palp and lobes
e	rake like organ
f	thoracopoda I
g	maxilla - endopodite, male
h	maxilla - endopodite, male
i	maxilla, female
j	thoracopoda II
k	hemipenis
l	furcal attachment
m	furca

a - h, k - m: adult male - Milbrook Reservoir, Adelaide, S.A.

i, j: adult female - same locality.

Scale: 1 - 100 μ for a - d, f - m
2 - 50 μ for e


A
B
C
D
E
F
G
H
I
J
K
L
M
1
2

Description: Carapace. (External) Smooth shell like a flattened ellipsoid with dorsal area slightly arched. Overlap of left valve over right one ventrally and to a lesser extent dorsally at both extremities of the hinge area. Right valve larger and like a flatter ellipsoid compared to left one.

(Internal) Broad selvage all around and placed at a distance from the anterior edge of the right valve; in the left valve, it is faint and peripheral. In both valves, inner lamella twice as broad anteriorly. Posteriorly in the right valve, the selvage is prominent, especially in the posteroventral area where it is near the inner margin: this area is met by a depression in the left valve where the selvage is faint.

Anatomy. Characterized by a long 3rd segment of the antennula with a length width ratio of $^{2.2}/_{1}$ (Fig. 4.9a), male maxillar palps differently arched (Figs. 4.9g,h); outer extremity of copulatory sheath at mid-length forming a narrow but prominent hump (Fig. 4.9k) and furca with unequal claws (Fig. 4.9m).

For other details of the anatomy, refer to Fig. 4.9.

Colour of shell: Green to beige brown.

Size range:	L	H	
adult male	1,400-1,500 μ	700-800 μ	: LV narrower but taller than RV.
adult female	1,650-1,800 μ	750-850 μ	: same as for male.

Ecology and distribution: This freshwater species is usually found in farm dams and eutrophic waters (even sewage lagoons). It is commonly found in high numbers crawling in among decaying vegetal matter and black organic muds, especially near lake shores. Hussainy (1969a) was the first to describe the male of *C. assimilis* (synonymized here to *C. novaezelandiae*) from Lake Purrumbete. Males of this species have since been found in a number of permanent waterbodies (e.g. Milbrook and Kangaroo Creek Reservoirs) whereas males have never been found in ephemeral waters or small waterbodies such as farm dams. This phenomenon is further discussed in section 4.3.5 of this chapter.

Adults of *C. novaezelandiae* are a benthic species and have never been seen to swim. Juveniles, on the other hand, are good swimmers since the natatory setae of their antennae are much longer than in adults.

Remarks: Examination of the type material of *C. novaezelandiae* (emptied valves only) kept in the British Museum confirmed the suggestion of Eagar (1971) that this species is synonymous to *C. candonioides*. Additionally, since in many collections taken in ephemeral waters, both morphs representing *C. candonioides* and *C. assimilis* as illustrated by Sars (1894, Plate V.1 and 2) are found together, it is suggested here that they represent the same species: *C. candonioides* synonymized to *C. novaezelandiae*. For example, forms of *C. assimilis* as illustrated in Plate IV.12n-p from a small farm dam near Gilmandyke, south of Bathurst in New South Wales are considered to be young specimens of *C. novaezelandiae* found in the same collection and illustrated in Plate IV.12 l,m,s. There are no morphological differences in anatomy except that appendages of *C. novaezelandiae* are bigger. In the latter, the colour of the shell is green with yellow to brown diagonal bands caused by the ovaries, whereas shells of *C. assimilis* morphs are beige brown in colour with similar bands for the ovaries. (This is well illustrated by Sars (1894) on his coloured Plate V.) The latter morph is smaller and with a slightly arched dorsum (the greatest height is at the middle) whereas the other morph (*C. novaezelandiae*) is larger, more arched dorsally (greatest height at about ⅔ from the anterior) and with the right valve much larger than the left anteriorly and posteriorly. This synonymy is further confirmed by the fact that the anatomy of male specimens described by Hussainy (1969a) from Lake Purrumbete in Victoria for *C. assimilis* is identical to that of male specimens of *C. novaezelandiae* found in Milbrook Reservoir in South Australia. The presence of well formed ovaries in juveniles in some ostracod species is not uncommon in the family Cyprididae and this would therefore explain why previous authors have considered *C. assimilis* morphs to represent the last molt stage of the species.

From the original illustration and short description of *Cypris sydneia* King, 1855, it appears that King's species represents the *C. assimilis* morph because of the outline and colour of the shell, limited ability to swim and the habit of crawling on mud. Although no type specimens are available to verify this statement, it appears that *C. sydneia* of King (1855, Plate Xm) is not a *Heterocypris*, contrary to McKenzie's (1966) suggestion, since the length width ratio of the shell on King's illustration is much larger than that of the *Heterocypris* species.

C. novaezelandiae is found in New Zealand (Sars, 1894; Chapman, 1963 and Chapman and Lewis, 1976), Australia (Sars, 1894, 1896a; Henry, 1923) and Japan (Okubo, 1975). Originally Sars (1894) stated that this species was also present in South Africa as he had raised it in his aquaria from samples of dried mud collected at Knysna, Cape of Good Hope, but later (Sars, 1924) suggested that this had been caused by contamination of Australian and South African material in his aquaria. Méhes' (1939) description of *Herpetocypris caledonica* Méhes, 1939, from New Caledonia, definitely represents a *Candonocypris* species since he illustrated the distal segment of the thoracopoda II with two setae at mid-length. No type material could be examined (although it has been requested from the Basle Museum) to check whether Méhes' species is identical to *C. novaezelandiae*.

Cypretta Vavra, 1895

Type species: *Cypridopsis* (*Cypretta*) *tenuicandata* Vavra, 1895.

Cypretta baylyi McKenzie, 1966

Fig. 4.10; Plates IV.10, 11m-q

1966 *Cypretta baylyi* n.sp., McKenzie, p. 273.

Diagnosis: *Cypretta* with pitted to reticulated shell and ventral margin in front of the concave mouth region, at ⅓ from the anterior, forming a strongly convex lump in both valves. Anterior to this lump, the shell margin is flattened.

Description: The original description of *C. baylyi* by McKenzie (1966) is sufficient, and does not warrant additional description here except for the diagnostic features of the male anatomy since McKenzie (1966) only dealt with female specimens.

Maxilla: (Figs. 4.10f,g) Male palps broadly arched but of different width.

Hemipenis: For outline see Fig. 4.10j; lateral lobe broad and tongue-like.

Zenker organ: (Fig. 4.10k) One end funnel-shaped, with 11 rosettes.

For further details of the shell and anatomy, refer to Fig. 4.10 and Plates IV.10, 11m-q.

Colour of shell: Green to dark green.

FIG. 4.10 *Cypretta baylyi* McKenzie, 1966

a	antennula
b	antenna
c	maxillula - palp and lobes
d	mandible - palp
e	thoracopoda II
f	maxilla - endopodite, male
g	maxilla, male
h	maxilla - endopodite, female
i	thoracopoda I
j	hemipenis
k	Zenker organ
l	furca
m	furcal attachment

a - b, d - k: adult male - granite rock pool on top of Bonyagin Rock, between Brookton and Pingelly, W.A.

l - m: adult female - same locality.

Scale: 100 μ


A
B
C
D
E
F
G
H
I
J
K
L
M

Remarks: In one male specimen, two inner distal setae, instead of one, were seen on the 2nd segment of the thoracopoda I. The surface of the shell of *C. baylyi* is known to vary extensively from finely punctated, as in Plate IV.14q, to regularly reticulated, as in Plate IV.13 l. The finely punctated specimens are usually smaller, narrower in dorsal view and the convex lump anterior to the mouth region is less pronounced.

Ecology and distribution: *C. baylyi* is a freshwater species and a very common inhabitant of temporary pools in Western Australia (collections from Dr. I.A.E. Bayly and personal ones). It was originally described from near Inverway in the Northern Territory, and has not been recorded in eastern Australia. A brief review of all *Cypretta* species is provided in Sohn and Kornicker (1973).

On one occasion numerous specimens of *C. baylyi* were found crawling on soft mud in a granite pool below 2 cm of water. This is presumably the typical mode of locomotion for this species which is devoid of long natatory setae on the antennae, an unusual feature for *Cypretta* species which are commonly good swimmers.

Cypricercus Sars, 1895

Type species: *Cypricercus cuneatus* Sars, 1895.

Cypricercus salinus n.sp.

Fig. 4.11; Plate IV.14a-1

Diagnosis: Smooth, triangular shell, elongated ellipsoid in dorsal view; distal end of lateral lobe of hemipenis broader than its base.

Description: Carapace. (External) Triangular in lateral view with greatest height at about middle; anterior and posterior ends broadly rounded; anterodorsal area almost straight whereas posterodorsally it is slightly arched; ventral area almost flat except in the mouth region in the middle where it is concave. Left valve slightly larger anteriorly and overlapping ventrally, especially in the mouth region. In dorsal view, like a flattened ellipsoid.

(Internal) Inner lamella twice as broad anteriorly in both valves compared to posteroventral area; selvage near the rounded outer margin in right valve anteriorly, and at about $1/3$ of the width of the inner lamella from the outer margin posteroventrally; in left valve, selvage bordering the rounded outer margin antero- and posteroventrally and separated from it by a broad groove all along; ventrally it is distant from the outer margin.

Anatomy: Antennula: (Fig. 4.11a) Length width ratio of the last six segments: $1/1.4$, $1.7/1$, $1.2/1$, $1.2/1$, $1/6.5$, $2.7/1$; natatory setae slightly longer than all segments together.

Antenna: (Fig. 4.11b) Natatory setae much longer than the last three segments and claws together; four terminal claws in both sexes.

Mandible: (Fig. 4.11c) Endopod with α and γ bristles long, narrow and smooth; β bristle short, stout and pilose; mandibular coxale with seven teeth: inner one slightly longer than the adjacent two others.

Rake-like organ: Seven teeth plus one bifid on the inner side of each rake.

Maxillula: (Fig. 4.11e) 3rd palp with two smooth Zahnborsten; length width ratio of palps: $4.5/1$, $2.5/1$.

Maxilla: Sexually dimorphic: in male (Figs. 4.11h,i) distal palps unequal with the narrow one strongly arched and forming a right angle; in female (Fig. 4.11d) endopod with three unequal setae. For chaetotaxy of epipod, see Figs. 4.11d,h.

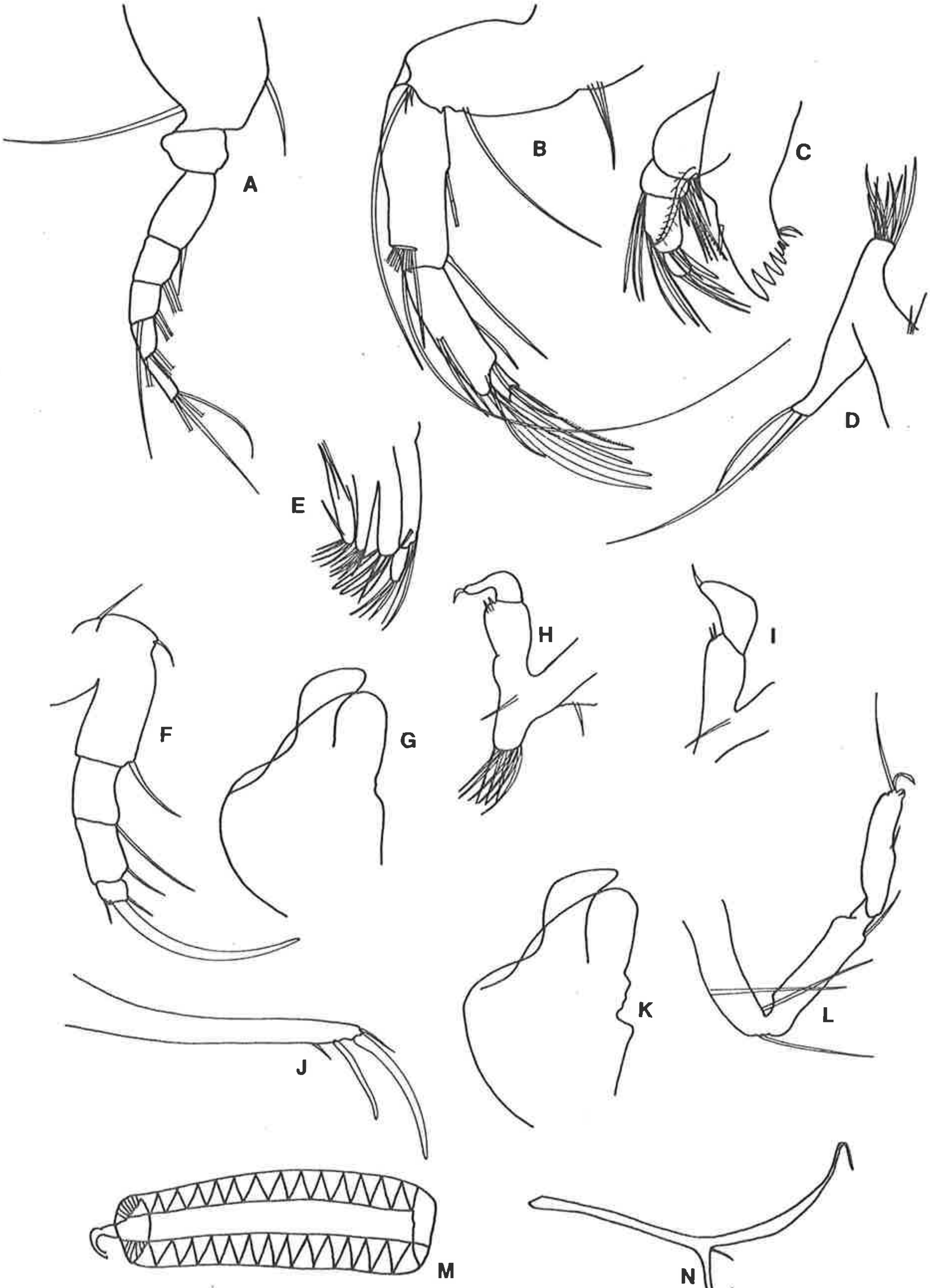
FIG. 4.11 *Cypricercus salinus* n.sp.

a	antennula
b	antenna
c	mandible
d	maxilla, female
e	maxillula - palp and lobes
f	thoracopoda I
g	hemipenis
h	maxilla, male
i	maxilla - endopodite, male
j	furca
k	hemipenis
l	thoracopoda II
m	Zenker organ
n	furcal attachment

a - c, f - n: holotype adult male

d - e: paratype adult female

Scale: 100 μ


A
B
C
D
E
F
G
H
I
J
K
L
M
N

Thoracopoda I: (Fig. 4.11f) 3rd segment divided at mid-length where an inner seta as long as the distal half of the 3rd segment and the 4th one together occurs.

Thoracopoda II: (Fig. 4.11 1) Distal setae unequal with small one hook-shaped; seta at mid-length of the last segment shorter than hook-shaped distal seta; presence of small distal pincers.

Hemipenis: (Figs. 4.11g,k) Outline of copulatory sheath triangular with greatest length on inner side; lateral lobe arched inward and distal end broader than its base.

Zenker organ: (Fig. 4.11m) Elongated with 13 broad rosettes.

Furca: (Fig. 4.11j) Anterior claw 1.6 times longer than posterior one; anterior seta slightly longer than posterior one.

Furcal attachment: (Fig. 4.11n) Ventral branch almost as long as median one and hook-shaped distally; dorsal branch short with a spike at each end on the distal side to form an almost closed eyelet (which is typical of the genus as pointed out by Rome, 1969).

Eye: Cups of nauplius eye fused; dark brown in colour.

Colour of shell: Pale green.

Size:		L	H		L	H
holotype adult male	LV	600 μ	380 μ	RV	580 μ	360 μ
paratype adult female	LV	640 μ	390 μ	RV	620 μ	370 μ

Type locality: Small lake(143°18'47"E, 38°06'06"S) north of Lake Terangpom, west of Lake Corangamite, western Victoria.

Derivation of name: From Latin *salinus* meaning saline as this species has been collected in many slightly saline waters.

Ecology and distribution: *C. salinus* has been collected so far in western Victorian lakes. Salinity of the water at the type locality was 4.9°/oo. It has been collected from a number of lakes in the vicinity of Colac and Camperdown (e.g. Lakes Martin, Koreetnung, Kariah, Wingeel, Terangpom). The salinity range of the species is: 0.34-12.3°/oo.

Cypricercus unicornis n.sp.

Fig. 4.12; Plate IV.15

Diagnosis: Pseudopunctate, ellipsoid shell with asymmetrical valves: left valve longer especially posteriorly where it often tapers to a broad and rounded spike; there is no spike in the right valve; lateral lobe of hemipenis digitate and straight.

Description: Carapace. (External) Ellipsoid in lateral view with greatest height at about middle in the right valve; surface of shell deeply pseudopunctated all over except dorsally and ventrally. Anterior broadly rounded, ventrum almost flat and posterior tapered. Valves asymmetrical: left valve, which overlaps the right one all around, has protuberance posteriorly which extends slightly outward. The extension of this protuberance is variable: in some specimens, it is almost non-existent. In dorsal view, like a flattened ellipsoid except in the posterior area of the left valve where the protuberance occurs. Normal pore canals of two types; some simple and others simple with a broad rim.

(Internal) Inner lamella twice as broad anteriorly compared to posterior; selvage faint and peripheral in the right valve whereas it is broad and follows the periphery of the left valve where it is separated from the rounded outer margin only by a narrow but deep groove. The posterior protuberance in the left valve is hollow. Radial pore canals numerous, narrow and straight.

Anatomy. Antennula: (Fig. 4.12a) Length width ratio of the last six segments: $^{1}/_{1}$, $^{2.6}/_{1}$, $^{1.6}/_{1}$, $^{2}/_{1}$, $^{2.3}/_{1}$, $^{4}/_{1}$; natatory setae slightly longer than all segments together.

Antenna: (Fig. 4.12b) Four terminal claws in both sexes: the claw attached to the small distal segment is strongly pectinate in male; natatory setae extend further than the tip of the claws.

Mandible: (Fig. 4.12c) As for *C. salinus*.

Rake-like organ: As for *C. salinus*.

Maxillula: (Fig. 4.12d) 3rd palp with two toothed Zahnborsten; length width ratio of palps: $^{5}/_{1}$, $^{3}/_{1}$.

Maxilla: Sexually dimorphic: in male (Figs. 4.12f,g) distal palps unequal with the narrow one strongly arched whereas the other is narrow at mid-length and only slightly curved; in female (Fig. 4.12h) endopod palp with three unequal setae. For chaetotaxy see Fig. 4.12g.

Thoracopoda I: (Fig. 4.12e) 3rd segment divided at mid-length with an inner seta slightly longer than half of the 3rd segment.

Thoracopoda II: (Fig. 4.12k) Distal setae unequal with longest seta twice the length of the other; seta at mid-length on last segment almost reaching the tip of the terminal pincers and the distal seta on the penultimate segment slightly longer than half of the last segment.

Hemipenis: (Figs. 4.12i,j) Outline of copulatory sheath triangular with greatest length on inner side; lateral lobe digital and straight with distal end rounded.

Zenker organ: (Fig. 4.12m) Elongated with 17 broad rosettes.

FIG. 4.12 *Cypricercus unicornis* n.sp.

a	antennula
b	antenna
c	mandible - palp
d	maxillula - palp and lobes
e	thoracopoda I
f	maxilla - endopodite, male
g	maxilla, male
h	maxilla - endopodite, female
i	hemipenis
j	hemipenis
k	thoracopoda II
l	furca
m	Zenker organ
n	furcal attachment

a - g, i - m: holotype adult male

h, n: paratype adult female

Scale: 100 μ


A
B
C
D
E
F
G
H
I
J
K
L
M
N

Furca: (Fig. 4.12 1) Length of anterior claw over posterior one 1.7; setae small and almost equal; furcal shaft extremely long: 2.5 times the length of the anterior claw.

Furcal attachment: (Fig. 4.12n) Median branch broad and about three times the length of the ventral branch; dorsal branch curved inward and with a basal eyelet.

Eye: Cups of nauplius eye fused; brown in colour.

Colour of shell: Green to pale green.

Size:

		L	H		L	H
holotype adult male	LV	880 µ	400 µ	RV	780 µ	380 µ
paratype adult female	LV	870 µ	400 µ	RV	790 µ	370 µ

Type locality: Granite pool, Newmann's Rocks, 140 km east of Norseman, W.A.

Derivation of name: From Latin *unus* (= one) and *cornu* (= horn) for the protuberance on the posterior of the left valve.

Ecology and distribution: This freshwater species has been found in three widely separated localities in Australia: Newmann's Rocks in W.A. (= type locality), swamp at Booligal, N.S.W., and roadside pool, 13 km east of Rocky River, Kangaroo Island, S.A.

Remarks: The extension of the posterior protuberance on the left valve is variable: in some valves collected from the type locality, the protuberance was restricted to a slight lengthening of the left valve over the right one.

Diacypris Herbst, 1960

Type species: *Diacypris dietzi* (Herbst, 1958)

Remarks: In Australia, there are seven *Diacypris* species: *D. compacta, D. dictyote, D. dietzi, D. fodiens, D. phoxe, D. spinosa* and *D. whitei.* The taxonomy of all these species has been recently reviewed in De Deckker (1980a). Remarks on ecology and distribution of each species will be presented separately below. An additional species, *D. thomsoni* (Chapman, 1963) is recorded from New Zealand (Chapman, 1963; Chapman and Lewis, 1976) but has not been examined.

All *Diacypris* species are halobiont and have never been collected by me in fresh waters. Therefore it seems likely that the record of three *Diacypris* species from the fresh Lakes Alexandrina and Albert in South Australia by Herbst (1958) is incorrect (*D. compacta* and *D. dietzi* in L. Albert and *D. dietzi* and *D. whitei* in L. Alexandrina). It is probable that these species came from salt lakes and pans which are numerous along the shore of both Lakes Alexandrina and Albert.

Diacypris compacta (Herbst, 1958)

1958 *Pseudocypris compacta* n.sp., Herbst, p. 181.
1960 *Diacypris compacta* (Herbst), Herbst, p. 143.
1980 *Diacypris occidentalis* McKenzie, De Deckker, p. *
1980 *Diacypris paracompacta* McKenzie, De Deckker, p. *
1980 *Diacypris parva* Hartmann, De Deckker, p. *

Diagnosis: Almost circular valves in lateral view and narrow in dorsal view; left valve overlaps right one all along its periphery but overlap more obvious in the dorsal area where a hump is present in the left valve only; the width of the hump is variable and occasionally pointed. Hemipenis with sickle-shaped outer lateral lobe, and broad

---

* This paper, although already published, is as yet unavailable in Australia.

T-shaped inner lateral lobe. Colour of shell: green to dark green.

Ecology and distribution: This is an ubiquitous halobiont species. Like all other *Diacypris* species, it is an excellent swimmer. Its salinity range is very broad and it can be found in large numbers over its entire salinity range. In the lakes near the Coorong Lagoon in South Australia, the range is 8-132°/oo (De Deckker and Geddes, 1980) and in western Victorian lakes it is 14-181°/oo (one specimen was even collected at 0.34°/oo). In West Australian lakes, it has been collected in ten lakes in the range of 2.9-87.9°/oo (Geddes *et al.*, in press).

For *Australocypris robusta*, the salinity range in Victoria appears to be wider because of the absence there of the *Diacypris* species which have a higher salinity tolerance in the lakes near the Coorong Lagoon, e.g. *D. dictyote*, *D. fodiens* and *D. whitei*. *D. compacta* has been found on many occasions in extremely large numbers (e.g. ca. 20-40 ml) of settled ostracods filtered from 1 m^3 of lake water) resulting from "blooms" of that species. This phenomenon, when noted in some Victorian lakes and in the lakes near the Coorong Lagoon, usually occurred when salinity was around 45-77°/oo. It was found once at 124°/oo in Pink Lake in western Victoria. In the Coorong area, the range extends into lower salinities: 21-69°/oo with two higher records at 96 and 123°/oo (see De Deckker and Geddes, 1980).

It is not known whether the wide variations of the dorsum of *D. compacta*, which is a diagnostic feature for the species, is of any ecological significance.

Diacypris dietzi (Herbst, 1958)

1958 *Pseudocypris dietzi*, n.sp., Herbst, p. 177.

1960 *Diacypris dietzi* (Herbst), Herbst, p. 143.

Diagnosis: Triangular shell in lateral view with greatest height at about middle; dorsum steeply inclined and straight behind the highest point of the shell; no strong overlap of left valve over right one in dorsal area; valves narrow in dorsal view. Outer lateral lobe of hemipenis sickle-shaped, broad and with a sharp pointed tip and inner lateral lobe rectangular. Colour of shell pale green or pale orange.

Ecology and distribution: This species is not common in salt lakes: in a survey of 79 lakes in western Victoria it was collected only six times whereas *D. compacta* was collected twenty times and *Australocypris robusta* nineteen times. In the Victorian lakes, the salinity range is 35 to 127°/oo. One specimen was collected once at 0.34°/oo. In the lakes near the Coorong Lagoon, its salinity range is broader: 4-141°/oo with a few specimens found once at 216°/oo (De Deckker and Geddes, 1980). *D. dietzi* has not been collected in Western Australia.

Diacypris dictyote De Deckker, 1980

1980 *Diacypris dictyote* n.sp., De Deckker, p.

1980 *Diacypris* n.sp.1, De Deckker and Geddes, p. 692.

Diagnosis: Pseudopunctate to reticulate, subtriangular shell with ventrum area flat; anterior broadly rounded and posterodorsal area steeply inclined; greatest height at $\frac{1}{3}$ to $\frac{2}{5}$ from the anterior; edge of both valves finely pectinate anteriorly and posteriorly; in dorsal view, widest at $\frac{2}{3}$ from anterior and pointed at both ends; left valve larger and overlapping right one dorsally; above the overlap, there is a vertical "keel"-like extension of the left valve over the entire hinge area (the height of this "keel" is variable). Hemipenis with horse-shoe shaped outer lateral lobe and rectangular inner lateral lobe. Colour of shell: orange.

Ecology and distribution: This species has only been found in South Australia, in many ephemeral lakes near the Coorong Lagoon, some on Kangaroo Island and on the Yorke Peninsula. In the Coorong area, the salinity range of this species, collected over one year, is 12 to 143°/oo with one record at 195°/oo.

Diacypris fodiens (Herbst, 1958)

1958 *Pseudocypris fodiens* n.sp., Herbst, p. 188.

1960 *Diacypris fodiens* (Herbst), Herbst, p. 143.

Diagnosis: Subrectangular to semicircular shell in lateral view; in dorsal view oval-shaped with anterior end pointed and posterior end narrow but round; no dorsal overlap of one valve over the other. Circular to rectangular protuberance between the semi-circular outer lateral lobe and rectangular inner lobe. Colour of shell dark green to dark brown.

Ecology and distribution: *D. fodiens* is the largest of all known *Diacypris* species. This species has not been collected in western Victorian lakes which have been extensively sampled. In Western Australia, it has been found twice at 46.2 and 99.6°/oo salinity. In the ephemeral lakes near the Coorong Lagoon in South Australia, it has been collected on 13 occasions only in three different lakes during a year of sampling between 33 and 195°/oo salinity (De Deckker and Geddes, 1980). In one lake it was the dominant crustacean species and, in two of the lakes, it was among the first crustaceans to appear after the first stage of lake filling.

Diacypris phoxe De Deckker, 1980.

1980 *Diacypris phoxe* n.sp., De Deckker, p.

Diagnosis: Semicircular shell in lateral view with flattened ventral area, and narrow in dorsal view; depression in both valves in anterodorsal area just in front of the hinge area. Hemipenis with rectangular inner lateral lobe and crescent-shaped inner lateral lobe with distal end pointed and with broad digital lobe. Colour of shell pale orange.

Ecology and distribution: This species has so far been collected in a few lakes around the salt works, north of Lake Alexandrina in South Australia. Salinity was only measured once at 18°/oo.

Diacypris spinosa De Deckker, 1980

1955 *Pontocypris attenuata* Brady, Ludbrook, p. 43, fig. 6 (not fig. 5).

1970 Cyprinid, genus C, Bayly, p. 126.

1975 *Diacypris* new, De Deckker, p. 423.

1978 ?*Diacypris* sp., McKenzie, p. 188.

1980 *Diacypris spinosa* n.sp., De Deckker, p.

Diagnosis: Subtriangular to almost circular shell in lateral view; left valve much taller and with a sharp dorsal "keel" over the hinge area: left valve therefore almost subtriangular to circular whereas right valve more rectangular; greatest height in left valve near the middle and between ⅓ and ½ from anterior in other valve; shell narrow dorsally with both ends pointed. In adults, posteroventral edge of valves spinose with one of the spines usually broader and longer; the left valve anteriorly is sometimes faintly spinose. In juveniles, posteroventrally the spines are fewer but there is usually a very long spine (⅓ to ¼ of the length of the shell). In the right valve, there is a smaller spine (about ½ the length of the long one) anteriorly at ⅓ from the top of the shell. Hemipenis with lateral lobes sickle-shaped, the outer one much broader than inner one and with distal end pointed. Colour of shell: green to pale green.

Ecology and distribution: This species has been collected across the Australian continent. In the survey of ephemeral lakes near the Coorong Lagoon (De Deckker and Geddes, 1980), it was found in waters between 5 and 39°/oo salinity with one additional record at 49°/oo, where it was numerous, and another at 89°/oo, where it was rare. In a survey of 79 lakes in western Victoria, *D. spinosa* was found between 5 and 18°/oo salinity. In South Australia, this species is most often found in lakes which have a water salinity usually well below 20°/oo in winter, when the lakes are full. With increase in evaporation during the following season(s), salinity subsequently increases and this explains the high salinity values in which the species is found for short periods of time. *D. spinosa* is not found, however, in lakes which remain constantly above 20°/oo salinity. This means that lower salinities are necessary to either allow hatching from the eggs, or growth and reproduction, or both.

The ecological significance of the extensive variation of features of *D. spinosa* shells (e.g. spines, dorsal "keel") is not known.

Diacypris whitei (Herbst, 1958)

1958 *Pseudocypris whitei* n.sp., Herbst, p. 185.
1968 *Diacypris whitei* (Herbst), Herbst, p. 143.

Diagnosis: Rectangular shell in lateral view with arched dorsum and broadly rounded anteriorly; slight depression dorsally in front of the hinge area; in dorsal view, oval in shape; greatest height just before mid-length. Hemipenis with rectangular inner lateral lobe, narrow, digitate and curved inward inner lobe and much broader sickle-shaped outer lateral lobe.

Ecology and distribution: *D. whitei* is rare in South Australia: it inhabits highly saline lakes, in which halophytes cannot grow, near the Coorong Lagoon. The salinity range for this species in those lakes is 14 to 195°/oo (De Deckker and Geddes, 1980). The low salinity records were taken during winter when water was plentiful for a short period of time and consequently water salinity had been temporarily reduced. This species has not been recorded in Victoria. In Western Australia, on the other hand, *D. whitei* has been collected in 18 localities during a survey of 54 lakes by Geddes *et al.* (in press). In that survey, this species was the most common ostracod encountered. Its salinity range varied between 9.7 and 137.6°/oo. It is of interest to note that the shape of the outer lateral lobe of the hemipenis from these collections varied extensively: in many specimens the tip of the lobe was pointed and the width of the lobe was often unusually large compared to South Australian specimens.

Eucypris Vavra, 1891

Type species: *Eucypris virens* (Jurine, 1820)

Eucypris virens (Jurine, 1820)

Fig. 4.13; Plate IV.16

1820 *Monoculus virens* n.sp., Jurine, p. 171.

1900 *Eucypris virens* (Jurine), Daday, p. 143.

Diagnosis: Subrectangular shell with dorsum arched and greatest height in the middle; length height ratio of carapace: 1.45-1.65; shell

FIG. 4.13 *Eucypris virens* (Jurine, 1820)

a	antennula
b	antenna
c	thoracopoda I
d	maxilla - protopodite
e	maxillula - palp and lobes
f	maxilla - endopodite
g	mandible - palp
h	furca
i	furcal attachment
j	thoracopoda II

a - j: adult female - pond very close to Reel Inlet (coastside), 19 km S. of Mandurah, W.A.

Scale: 100 μ


A
B
C
D
E
F
G
H
I
J

convex ventrally just in front of the slightly concave mouth region; in dorsal view oval in shape with anterior more pointed than posterior; wart-like protuberances (Plate IV.16h,k,l) near the outer margin anteriorly best seen in dorsal view. Colour of shell: pale green.

Remarks: *E. virens* is a cosmopolitan species well known outside Australia; description of the shell and anatomy is therefore unnecessary but illustrations are provided in Fig. 4.13 and Plate IV.16. This species has already been recorded from New Zealand (Barclay, 1968; Chapman and Lewis, 1976). In Australia, it is a common inhabitant of temporary pools and is usually found in fresh waters but has been recorded in slightly saline waters; the highest salinity record for *E. virens* is 4.4°/oo in a Western Australian locality (Geddes *et al.*, in press). So far *E. virens* has been collected in southern Australia (W.A., S.A., Vic.).

Variations in the outline of *E. virens* have been commonly noted, even on specimens collected in the same locality. These variations are illustrated in Plate IV.16. They are best seen in lateral view and correspond to variations in shell outline already noted by Müller (1900) who designated the following variations: *E. virens* var. *acuminata* which has a more elongated shell (see Plate IV.16a,b,f) and *E. virens* var. *obtusa* which has a more compressed shell and more broadly curved outline posteriorly (see Plate IV.16c,d,g). These variations may be ecologically significant but remain as yet unexplained.

It is likely that Eagar's (1970) species, *Eucypris pratensis* Eagar, 1970, recorded only from three localities near Wellington in New Zealand, is also a variant of *Eucypris virens*.

E. virens in Australia is a parthenogenic species although both sexes have been recorded in other parts of the world (North Africa:

Gauthier (1928a); pond in the delta of the River Don, USSR - material received from Dr. E.I. Shornikov).

Gomphodella n.gen.

Type species: *Gomphodella maia* n.sp., gender masculine.

Diagnosis: Carapace. Female carapace in dorsal view triangular with greatest width at about $\frac{2}{3}$ to $\frac{3}{4}$ from the anterior; at about $\frac{2}{5}$ from the anterior, where the central muscle field occurs, the valves are slightly compressed; absence of prominent lateral ridge in the ventral area; sieve pore canals and a few broader normal pore canals in a row parallel to the posterior edge of the shell in both valves. Male, in dorsal view, like a flattened oval with both ends pointed.

Anatomy: Female maxilla and thoracopodae I and II similar, although of different length; female furca with three stout, pointed and thickly pilose setae.

Derivation of name: From a combination of the two names *Gomphocythere* and *Cytheridella* as this genus shares diagnostic features of the two genera.

Remarks: *Gomphodella* is very similar to *Cytheridella* Daday, 1905 except that the shell of the former is less compressed in the area where the central muscle field occurs, and as the maxilla and thoracopodae I and II are similar in *Gomphodella* (in *Cytheridella* the thoracopoda II is transformed into a prehensile palp). The diagnostic feature which *Gomphodella* and *Gomphocythere* Sars, 1924, share is the presence of three stout and thickly pilose setae on the female furca - this is not seen in *Cytheridella*. *Gomphodella* lacks the lateral ventral ridge on both valves on the outside of the shell so typical of *Gomphocythere* species.

Gomphodella is to be included in the family Limnocytherinae Sars, 1925, following the recent regrouping of sub-families in the Limnocytheridae by Colin and Danielopol (1978).

There are two species of *Gomphodella* in Australia: *G. maia* n.sp. and *G. australica* (Hussainy, 1969). They are both discussed below.

Gomphodella maia n.sp.

Fig. 4.14; Plate IV.17

Diagnosis: Surface of shell pseudopunctate with many sieve pores; posterior area of shell broadly rounded in lateral view; in dorsal view, valves only slightly compressed in female at 2/5 from the anterior where the central muscle field occurs. Outline of hemipenis as in Fig. 4.14i.

Description: Carapace. (External) Adult: Subrectangular in lateral view with ventrum flat and dorsum arched; posterior broadly rounded and anterodorsal area flatter and forming a less steep angle; surface of valves pseudopunctate with many sieve pores; normal pore canals either of simple type or surrounded by a rim; a few broader normal pore canals are arranged in a row parallel to the posterior edge of the shell in both valves; in dorsal view, carapace of male like a flattened oval with anterior end more compressed and pointed and greatest width near the middle; in female, greatest width at about 3/4 from anterior which is pointed whereas the posterior is almost flat except in the middle which is slightly convex where both valves meet; at 2/5 from the anterior, where the central muscle field consisting of a row of four vertical scars occurs, the valves are slightly compressed in female; the left valve is slightly longer anteriorly and posteriorly. In some female specimens, occasional faint ridges present ventrally near the outer margin of each valve and running parallel to it.

Juvenile: Almost round in lateral view with a flattened ventrum; oval in dorsal view; some specimens with a broad flange sometimes extending into one or two spines posteroventrally.

(Internal) Inner lamellae much broader anteriorly; selvage prominent and broad all around in both valves: in the left valve, however, it is placed further away from the edge of the valve, especially anteriorly; in front of the mouth region, selvages are very broad and, when interlocking during valve closure, the right selvage is placed externally; shell perforated internally; radial pore canals numerous, short and usually straight.

Anatomy. Antennula: (Fig. 4.14a) 6-segmented; length width ratio of last five segments: $^{1.9}/_{1}$, $^{1.2}/_{1}$, $^{0.8}/_{1}$, $^{1.2}/_{1}$, $^{3}/_{1}$; longest distal seta bifid with one side more than twice the length of the other.

Antenna: (Fig. 4.14b) Three smooth distal claws on terminal segment; pectinate distal claw on inner side of penultimate segment slightly shorter than the other three claws.

Mandible: (Figs. 4.14d,e) Mandibular coxale with seven teeth: inner one slender and twice as long as penultimate one; palp with terminal segment almost trapezoid in shape and with two thick distal setae and a shorter and thinner one.

Maxillula: (Fig. 4.14c) Poorly sclerotized palp with three unequal and broad setae; epipod with 13 long and one small Strahlen.

Maxilla: (Fig. 4.14f) Distal claw stout, short and curved inward; setae on 1st segment smooth, and distal one on 2nd segment finely pectinated.

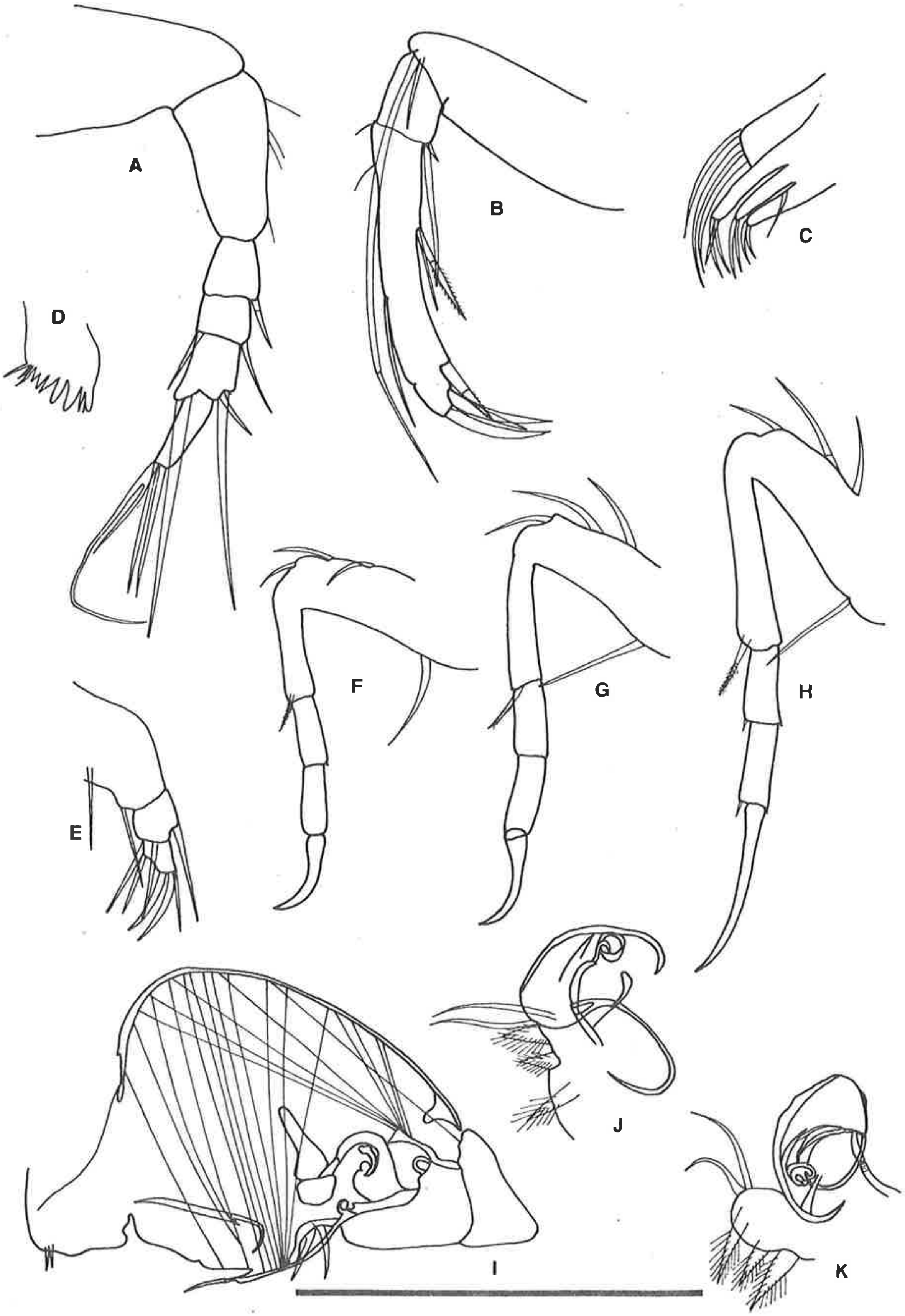
FIG. 4.14 *Gomphodella maia* n.gen., n.sp.

a	antennula
b	antenna
c	maxillula - palp and lobes
d	mandible - coxale
e	mandible - palp
f	maxilla
g	thoracopoda I
h	thoracopoda II
i	hemipenis and furca
j	genital organ and furca
k	genital organ and furca

a, c, e, j - k: paratype adult female

b, d, f - i: holotype adult male

Scale: 100 µ


A
B
C
D
E
F
G
H
I
J
K

Thoracopoda I: (Fig. 4.14g) Similar to maxilla except for slightly larger size.

Thoracopoda II: (Fig. 4.14h) Larger than thoracopoda I with distal claw slender, longer and almost straight; inner distal end of last two segments with a short spine.

Hemipenis: Strongly chitinized; for outline see Fig. 4.14i.

Genitalia: For outline see Figs. 4.14j,k.

Furca: In female (Figs. 4.14j,k)consisting of three short, stout and pointed setae which are densely covered with stiff hairs and two longer and barren setae; in male (Fig. 4.14i), two barren setae.

Colour of shell: Grey to grey brown.

Size:		L	H		L	H
holotype adult male	LV	490 μ	290 μ	RV	460 μ	300 μ
paratype adult female	LV	560 μ	330 μ	RV	520 μ	320 μ

Type locality: Fresh Dip Lake, near Robe, South Australia.

Derivation of name: From Greek *maia* meaning good mother as some adult females from fossil deposits (Pulbeena and Mowbray Swamp in Tasmania, see Chapter 6) were found with juveniles still inside them.

Ecology and distribution: This species only occurs in permanent waters as eggs cannot withstand desiccation (for further details, see McKenzie and Hussainy, 1969). Brood care certainly occurs for this species as quite a number of female carapaces have been found to yield either one or two juveniles inside them. It is likely to be a freshwater species which can tolerate slight concentrations of dissolved solids in the water as, like *G. australica*, it has been collected alive once in Fresh Dip Lake (= type locality) at 2.3°/oo salinity. As a fossil, it has been found with *G. australica*, and other freshwater ostracods in samples from a short core from the Blue Lake at Mt. Gambier, S.A. It is also found in two fossil sites in north-western Tasmania (see Chapter 6). In samples from both sites, a large number of carapaces were recovered and some of these were found with juveniles inside them. The significance of this phenomenon is not properly understood as, usually, after death under water, valves of ostracods separate prior to or during decay of the soft parts. When ponds dry up, ostracods are seen to close their valves tightly and, if this period is long enough to cause dehydration of the ostracods, death would occur. Rapid sediment accumulation is later necessary during a wet phase to prevent carapaces from opening. This process is likely to be one possible explanation for the high percentage of *G. maia* carapaces found in samples from the two Tasmanian sites. Death caused by changes in water chemistry would not prevent carapaces from dislocation. Another possibility is that *G. maia* can in fact burrow in sediment - a phenomenon noticed for a closely related ostracod *Gomphocythere* sp. (with another ostracod *Darwinula sphagna* Barclay, 1968) found in the interstitial waters of the Rotorua lakes in New Zealand by Chapman and Lewis (1976) - and, if it was to remain there until death, valves could not become easily dissociated.

Gomphodella australica (Hussainy, 1969)

1969 *Gomphocythere australica* n.sp., Hussainy, p. 299.

Diagnosis: Subrectangular shell with both dorsum and ventrum almost straight; anterior broadly rounded and posteroventral area more pointed with the furthest extension of the shell at about ⅓ from the dorsum; shell ornamentation consisting of faint but broad reticulation especially at the anterior and posterior ends. In dorsal view, shape of shell in female like an upside down heart and male much narrower with both ends pointed.

Size range:	L	H
adult male carapace	800-900 μ	400-500 μ
adult female carapace	650-750 μ	270-320 μ

Ecology: *G. australica* is best known from its type locality, Lake Purrumbete in Victoria. This is a permanent lake with salinity varying between 0.42 and 0.50°/oo over the 1969-1972 period (Timms, 1976) and 0.37-0.44°/oo over 1979-80. It is only recorded in that lake (greatest depth > 40 m) between 0.5 and 1 m in depth by Timms (1973). It is usually found crawling in among filamentous algae like *G. maia*. It is also recorded from Scott Creek near Adelaide, in South Australia and from the permanent Fresh Dip Lake near Robe in the same state. *G. australica* is considered to be a freshwater species which can withstand a slight amount of dissolved solids in water, with its highest salinity recorded at Fresh Dip Lake at 2.3°/oo. Brooding occurs in this species as demonstrated by Hussainy (1969b). Fossil specimens, with coarse shell reticulation have been recovered with other fresh water ostracods from a short core taken from the fresh Blue Lake at Mt. Gambier, S.A.

Remarks: The transfer of this species to the new genus *Gomphodella* is necessary because it does not possess the peripheral lateral ridge around the flat base of the shell of each valve so typical of *Gomphocythere* Sars, 1924. This species is easily distinguishable from *G. maia* by its larger size, reticulated shell and the very pointed posterior area of the shell which is also steeply inclined posteroventrally.

Heterocypris Claus, 1892

Type species: *Heterocypris incongruens* (Ramdohr, 1808)

Heterocypris vatia n.sp.

Fig. 4.15; Plate IV.18

Diagnosis: *Heterocypris* with anterior edge of right valve bent outward; lateral lobe of hemipenis boot-shaped with "sole" of the boot convex; inner lobe of hemipenis with scattered minute hooks.

Description: Carapace. (External) Bean-shaped in lateral view with dorsum curved; greatest height at $\frac{2}{5}$ to $\frac{1}{2}$ from the anterior; posterior slightly more broadly arched than anterior; ventral area nearly flat except in the mouth region which is faintly concave; in dorsal view like a flattened ellipsoid with both ends pointed - anteriorly the extremity is bent slightly clockwise; anteriorly and posteroventrally the right valve bends outward along the edge; the left valve bends inward to meet the right valve all along its periphery except ventrally where it overlaps the other; shell pseudopunctate with numerous rounded wart-like tubercles on the anterior of the shell; a hair protrudes from each tubercle.

(Internal) Right valve faintly tuberculate all along its periphery except dorsally; inner lamella broadest anteriorly in both valves; in right valve, selvage broad following the curvature of the shell halfway between the outer and inner margins anteriorly, whereas it is near the inner margin posteroventrally; the inner lamella between the outer margin and the selvage is convex anteriorly and posteroventrally; in left valve, selvage faint and peripheral and presence of narrow flange all along; radial pore canals numerous and straight.

Anatomy: Antennula: (Fig. 4.15a) 7-segmented; length width ratio of the last six segments: $^{1}/_{1}$, $^{2.25}/_{1}$, $^{1.5}/_{1}$, $^{1.5}/_{1}$, $^{1.7}/_{1}$, $^{2.5}/_{1}$; small, rod-shaped, sensory organ at mid-length on the 2nd segment; natatory setae slightly longer than all segments together.

Antenna: (Fig. 4.15c) Sexually dimorphic: in female the claw attached to the small 3rd segment is narrower and smaller.

Mandible: (Figs. 4.15e,f) Mandibular coxale with seven teeth (Fig. 4.15f); inner tooth longer than the previous two and pointed and near its base two setae, one of which is pilose; endopod (Fig. 4.15e) with α bristle short and narrow, β bristle of same length, wrinkled and covered with a few short hairs, γ bristle longer than last segment, stout and thickly pilose externally in its distal half; epipod with five plumose Strahlen plus a shorter one half way and a short, stout and pilose seta at its base.

Rake-like organ: With seven teeth and inner one bifid.

Maxillula: (Fig. 4.15d) Endopod with about 17 plumose Strahlen; length width ratio of palps: $^{3}/_{1}$, $^{2}/_{1}$; 3rd lobe with two toothed Zahnborsten and near their base presence of a short and thick tufted bristle.

Maxilla: Sexually dimorphic: in male, palps strongly asymmetrical (Figs. 4.15i,j), with left one the narrower and strongly arched; in female, palp with three plumose setae, the two outside ones being of similar length; for chaetotaxy, see Fig. 4.15i.

Thoracopoda I: (Fig. 4.15g) Penultimate segment weakly divided and distal claw 1.2 times the length of the last two segments together.

Thoracopoda II: (Fig. 4.15k) Distal setae on last segment unequal: the longer one four times the length of the other which is hook-shaped.

FIG. 4.15 *Heterocypris vatia* n.sp.

a	antennula
b	rake-like organ
c	antenna
d	maxillula - palp and lobes
e	mandible - palp
f	mandible - coxale
g	thoracopoda I
h	maxilla - endopodite, female
i	maxilla, male
j	maxilla - endopodite, male
k	thoracopoda II
l	hemipenis
m	furca
n	furcal attachment

a - e, g, i - m: holotype adult male

f, h, n: paratype adult female

Scale: 200 μ


A
B
C
D
E
F
G
H
I
J
K
L
M
N

Hemipenis: (Fig. 4.15 l) Outer lateral lobe boot-shaped with "sole" part of the boot convex and "heel" part slightly angular and forming an obtuse angle; inner lobe broadly rectangular and covered with numerous short hooks.

Zenker organ: Both ends rounded with 48 rosettes.

Furca: (Fig. 4.15m) Setae almost equal with posterior one finely pectinate; claws unequal; anterior one 1.6 times the length of the other.

Furcal attachment: (Fig. 4.15n) Median branch straight; dorsal branch short and at right angle to it; ventral branch curved and 2.5 times the length of the dorsal one.

Eye: Cups of nauplius eye fused; brown in colour.

Colour of shell: Translucent pale brown.

Size:		L	H		L	H
holotype adult male	LV	1,700 μ	1,000 μ	RV	1,710 μ	1,000 μ
paratype adult female	LV	2,400 μ	1,400 μ	RV	2,340 μ	1,360 μ

Type locality: Hexham Swamp, behind the University campus at Newcastle, New South Wales.

Derivation of name: From Latin *vatius* meaning bent outward for the diagnostic feature of the right valve anteriorly.

Ecology and distribution: This species has only been collected once; water at the type locality is known to be fresh.

Remarks: At first, it was thought that this species belonged to *H. leana* (Sars, 1896) because of its large size. The original female specimens described by Sars (1896) were 2.70 mm long and came from Hay, N.S.W. However, after examination of Sars' collections in the Oslo Museum, it became obvious that none of the male specimens labelled

H. leana by Sars have the same outline of the lateral lobe as the specimens from Hexham Swamp: all Sars' specimens have a small and pointed protuberance in the "heel" part, the boot-shaped lateral lobe of the hemipenis. This feature is not seen in *H. vatia.* However, no specimen from Hay was found in Sars' collection; only specimens which are labelled as "Victoria" A or C are found. Therefore, designation of a lectotype will prove to be difficult. However, a 2.4 m long male specimen collected from Goulburn Billabong, Alexandra, Vic. by R. Shiel corresponds to Sars' description of *H. leana* and possesses the pointed "heel" on the lateral lobe of the hemipenis. This substantiates the separation of the two taxa into two different species which have a large shell but different anatomy. *H. vatia* differs also from all other *Heterocypris* species recently reviewed in Victor and Fernando (1980).

Ilyocypris Brady and Norman, 1889

Type species: *Ilyocypris gibba* (Ramdohr, 1808).

Ilyocypris australiensis Sars, 1889
Plate IV.19

1889 *Ilyocypris australiensis* n.sp., Sars, p. 46.

Diagnosis: *Ilyocypris* with club-shaped inner lobe on hemipenis extending to as much as ⅔ of the length of the trapezoid lateral lobe.

Remarks: The original description of *I. australiensis* by Sars (1889a) is sufficient, and does not warrant additional illustrations of the anatomy here. The ornamentation and outline of the valves of *I. australiensis*, however, are extremely variable. Typical variations are illustrated in Plate IV.19 (all SEM photos are at the same scale and only adults are represented). The surface of the shell can be finely (Plate IV.19 1) to coarsely pitted (Plate IV.19c,f,o); acicular but small spines occur, mostly posterodorsally (Plate IV.19h,i) when present, but can also cover the entire carapace (Plate IV.19o). The outline of the shell is also variable anteriorly and dorsally. In dorsal view, anteriorly the shell can be pointed (Plate IV.19j-1,o) or with a squarish blunt end (Plate IV.19m,n). The latter feature is often accompanied by a depression bordering the periphery of the valve anteriorly and posteriorly (Plate IV.19a,d). Depressions are also variable dorsally, a circular one above the central muscle field and the other vertical above and in front of the central muscle field.

The ecological significance of all these variations are not yet understood but this is not a surprising phenomenon since *I. australiensis* is commonly found in temporary pools which are renowned as the sites of broad variations in physical parameters (viz. temperature, pH, O_2). *I. australiensis* can swim but is usually found crawling in or above muddy substrates in ponds. This species usually occurs in ponds which retain water for a few months and which have a very soft substrate. *I. australiensis* has also been collected in a number of shallow and slightly saline lakes in western Victoria. These lakes are characterized by small fluctuations in salinity over the year. This explains the absence of *I. australiensis* in the saline lakes near the Coorong Lagoon studied by De Deckker and Geddes (1980) where salinity of some lakes was close to fresh in winter, but rose rapidly during spring and summer months. In western Victoria, the range of salinity tolerance of *I. australiensis* is usually 4-7°/oo with one record at 10.37°/oo in Lake Kariah. So far, *I. australiensis* has never been collected in deep lakes (fresh or slightly saline) nor in permanent fresh lakes.

I. australiensis has been collected all across Australia. It is also recorded from North Africa (Gauthier, 1928a), Asia and southern Europe (Hartmann, 1964, p. 148).

As the morphology of the hemipenis of *I. australiensis* and *I. decipiens* Masi, 1906, as illustrated in Petkovski (1958), is almost identical, it is suggested here that these two species could be synonymous. Further work is necessary to confirm this hypothesis, but it is important to be aware of the variation in shell ornamentation of the *Ilyocypris* species as illustrated above, and by Diebel and Pietrzeniuk (1975) for *I. bradyi* Sars, 1890, since many *Ilyocypris* species are separated on shell morphology alone. The selection of particular features of the shell as taxonomically important by van Harten (1979) will not prove to be useful for *I. australiensis* specimens since for example, the "marginal ripplets" of van Harten are variable in Australian specimens, and even occasionally absent. Further, distinction of species on features other than the hemipenis is likely to be unreliable since the morphology of many appendages of *Ilyocypris* species are known to vary. For example, Gauthier (1928a) discussed the variations in the anatomy of *I. australiensis* and *I. biplicata* (Koch, 1838) from North Africa and concluded that he was incapable of separating the species, although neither was he prepared to synonymize them.

Ilyocypris perigundi n.sp.

Fig. 4.16; Plate IV.20

Diagnosis: *Ilyocypris* with carapace trapezoid in shape; anterodorsal area at the hinge extremity compressed and forming a hump when viewed laterally; three large protuberances in dorsal area, the posterior one being the largest, pustulose and ending with a number of wart-like tubercles; ventrum concave and at $^{3}/_{5}$ from the anterior. Club-shaped inner lobe of hemipenis reaching the tip of the trapezoid lateral lobe.

Description: Carapace. (External) Trapezoid in shape with greatest height $^{1}/_{5}$ from the anterior where the hinge starts; dorsum straight except at the point of greatest height where both valves form a flattened hump; ventrum concave at $^{3}/_{5}$ from the anterior. Surface of shell highly ornamented: three protuberances dorsally with posterior one the largest and ending with broad wart-like tubercles from which a seta protrudes; below the posterior protuberance and above the ventrum, there is an additional highly ornamented protuberance: this is the point of greatest width of the shell; deep depression dorsally between the middle and posterior protuberances; the shell is covered with broad pseudopunctae which are pustulose inside; pointed tubercles along the margin anteriorly and posteriorly. Dorsally, the shell is like a flattened ellipsoid with anterior compressed and pointed for the width of the inner lamella but tapering posteriorly.

(Internal) Inner lamellae twice as wide in anterior compared to posterior in both valves; narrow selvage at $^{2}/_{3}$ from the outer margin anteriorly and peripheral to the inner margin posteriorly; marginal ripplets broad in left valve posteroventrally.

Anatomy. Antennula: (Fig. 4.16c) 6-segmented: length width ratio of last five segments: $^{5}/_{3}$, $^{1.2}/_{1}$, $^{1.3}/_{1}$, $^{2}/_{1}$, $^{4}/_{1}$; natatory setae as long as all segments together.

Antenna: (Fig. 4.16a) Natatory setae twice the length of the last two segments and the claws together; three long distal claws on the penultimate segment plus another as long as the other three on the last segment with a narrower and shorter one.

FIG. 4.16 *Ilyocypris perigundi* n.sp.

a	antenna
b	maxillula - palp and lobes
c	antennula
d	mandible
e	maxilla - endopodite, male
f	thoracopoda I
g	maxilla, female
h	maxilla, male
i	thoracopoda II
j	hemipenis
k	hemipenis
l	Zenker organ
m	furca

a - f, h - m: holotype adult male

g: paratype adult female

Scale: 100 μ


A
B
C
D
E
F
G
H
I
J
K
L
M

Mandible: (Fig. 4.16d) Length width ratio of last two segments of mandibular palp: $4/3$, $1/1$.

Maxillula: (Fig. 4.16b) Distal segment of palp trapezoid and ending with three broad long setae plus two shorter ones; no Zahnborsten on 3rd lobe but setae short and stout on all three lobes.

Maxilla: Sexually dimorphic: in male (Figs. 4.16e,h) palps two or three-jointed with one seta at the distal end of the 1st segment; in female (Fig. 4.16g) non-segmented, short and narrow palp with three unequal setae. For chaetotaxy see Figs. 4.16g,h; epipod plate with five Strahlen.

Thoracopoda I: (Fig. 4.16f) Last segment undivided; all setae short.

Thoracopoda II: (Fig. 4.16i) 4-segmented with three distal setae, two long equal ones and the 3rd about $2/3$ the length of the others.

Hemipenis: (Figs. 4.16j,k) Outer lobe trapezoid with inner distal end pointed which is nearly reached by the long club-shaped inner lobe; outer lobe triangular in shape with distal end rounded and slightly pinched laterally; inner lobe about $1/3$ of the length of the outer lobe.

Zenker organ: (Fig. 4.16 l) Both ends globular and with 13 rosettes.

Furca: (Fig. 4.16m) Two long equal claws; posterior setae slightly longer than anterior one and placed at $2/5$ of the length of the shaft from the posterior claw.

Colour of shell: Transparent white.

Size:		L	H		L	H
holotype adult male:	LV	580 μ	365 μ	RV	560 μ	355 μ
paratype adult female:	LV	580 μ	380 μ	RV	580 μ	350 μ

Type locality: Lake Warraweena, south of Menindie, N.S.W.

Derivation of name: From the aboriginal language *perigundi* meaning meandering lake or lagoon, as this species has been found in a lake part of an old river system (L. Warraweena) and in a lagoon (Katarapko L.).

Ecology and distribution: This species has only been collected in three localities: L. Warraweena, Katarapko Lagoon, which is a natural billabong converted into an evaporative basin near the River Murray at Loxton, S.A., and from Scott Creek, near Adelaide, S.A. In all three localities only a few specimens have been collected; most specimens were coated with mud particles. The salinity at Katarapko Lagoon was 3°/oo. Salinity of the water from the type locality has not been measured. At Scott Creek, water was fresh.

Remarks: *I. perigundi* differs from *I. australiensis* on the following features: the former species, which is the smaller, has a very different shell architecture characterized by the three highly ornamented dorsal protuberances, a ventrum placed at ⅔ from the anterior of the shell and a flat dorsal hump in the extremity of the hinge anteriorly. The inner lobe of the hemipenis in *I. perigundi* is almost as long as the lateral lobe whereas it is only ⅔ the length in *I. australiensis*.

Ilyodromus Sars, 1895

Type species: *Ilyodromus stanleyanus* (King, 1855)

Remarks: A redescription of the genus *Ilyodromus* has recently been done by Danielopol and McKenzie (1977) who provide a diagnosis for *I. stanleyanus* and redescription of *I. varrovillius* (King, 1855) from New Zealand specimens. Both species were originally described from Australia. These authors also discussed all the other *Ilyodromus* species and their geographical distribution. Three new *Ilyodromus* species are described here and, for the first time, male anatomies of *Ilyodromus* species are illustrated. The transfer of *Isocypris williamsi* McKenzie, 1966 to *Ilyodromus* is also discussed.

Ilyodromus amplicolis n.sp.

Fig. 4.17; Plate IV.21 1-r

Diagnosis: *Ilyodromus* with striated shell; anterior and posterior ends broadly rounded and a slight concavity in front of the hinge anterodorsally; inner lamellae broad anteriorly and posteriorly. Lateral lobe of hemipenis broad and rectangular in shape; maxilla palps of male similar to each other.

Description: Carapace. (External) Weakly calcified; elongated ellipsoid with joint striations all over; dorsum straight along the hinge line and slightly concave anterior to it; dorsally behind the hinge line it is flat and inclined; anterior and posterior broadly rounded but the latter is narrower; ventrum almost flat except in the middle of the mouth region where it is concave; greatest height at $^{1}/_{3}$ from the anterior, left valve slightly larger all around.

(Internal) Inner lamella very broad and similar in both valves: anteriorly, the width of the inner lamella is $^{1}/_{3}$ of the length of the shell; there it is slightly broader and it extends all around the shell except in the hinge area dorsally; selvage faint and peripheral in both valves.

Anatomy. Antennula: (Fig. 4.17a) 7-segmented; length width ratio of the last six segments: $^{1.2}/_{1}$, $^{1.6}/_{1}$, $^{1.2}/_{1}$, $^{1.6}/_{1}$, $^{2}/_{1}$, $^{2}/_{1}$; natatory setae as long as last five segments; 3-segmented sensory organ on 2nd segment with distal end pointed.

Antenna: (Fig. 4.17b) Natatory setae short: two longest ones shorter than the penultimate segment and two minute ones reaching the proximal end of the same segment.

Mandible: (Figs. 4.17i) Mandibular coxale with seven teeth; palps with α bristle short, barren and slim, β bristle stout, pointed and densely pilose, γ bristle thick, slightly longer than the last segment and pilose in the distal half.

Rake-like organ: (Figs. 4.17c,d) Seven to nine teeth with an additional bifid one on the inner side.

Maxillula: (Fig. 4.17e) Distal palp trapezoid and two smooth Zahnborsten on 3rd lobe.

Maxilla: Sexually dimorphic; in male (Figs. 4.17g,h) palps strongly and similarly arched and one slightly narrower in the proximal 3rd of its length; in female (Fig. 4.17f) three plumose setae, the middle one being twice the length of the two others which are equal; in both sexes, epipod with five long and a shorter plumose Strahlen; for chaetotaxy of protopod, see Fig. 4.17 l.

Thoracopoda I: (Fig. 4.17j) 3rd segment well divided; inner distal seta of 2nd segment shorter than half the length of the 3rd segment and outer seta on distal segment 1/5 the length of the claw.

Thoracopoda II: (Fig. 4.17n) 3-segmented with large distal pincers; distal setae unequal: shorter one hook-shaped and about 1/3 the length of the other.

Hemipenis: (Fig. 4.17m) Lateral lobe broad and rectangular; inner lobe broad, subrectangular but about 4/5 the width of the lateral lobe and almost same length; near the base of the lateral lobe on the inside, small knob-like protuberance.

FIG. 4.17 *Ilyodromus amplicolis* n.sp.

a	antennula
b	antenna
c	rake like organ, female
d	rake like organ, male
e	maxillula - palp and lobes
f	maxilla - endopodite, female
g	maxilla - endopodite, male
h	maxilla - endopodite, male
i	mandible - palp
j	thoracopoda I
k	furca
l	maxilla - protopodite, male
m	hemipenis
n	thoracopoda II

a - b, d - e, g - j, l - n: paratype adult male

c, f, k: holotype adult female

Scale: 1 - 100 µ for a - b, e - n

2 - 50 µ for c - d


A
B
C
D
E
F
G
H
I
J
K
L
M
N
1
2

Zenker organ: More than 30 rosettes.

Furca: (Fig. 4.17k) Claws almost equal with pectinate and thick posterior seta half the length of the posterior claw and $3/2$ longer than the pectinate and narrow anterior seta.

Furcal attachment: Median branch long, divided distally and with a broad, but short, spike at right angle near its proximal end ventrally.

Colour of shell: White to transparent ventrally and blueish green dorsally.

Size:		L	H		L	H
holotype adult female	LV	2,000 μ	920 μ	RV	2,020 μ	960 μ
paratype adult male	LV	1,540 μ	720 μ	RV	1,550 μ	-

Type locality: Granite rock pool on top of Boyagin Rock, between Brookton and Pingelly, W.A.

Derivation of name: From Latin *amplus* (= large) and *colis* (= penis) for the unusually large penis.

Ecology and distribution: This species has been collected in the following localities: granite rock pools in Sullivan Rocks, 11 km south of Gleneagle (or 63 km south of Perth on Albany Highway); roadside ditch north of Scadden (56 km north of Esperance on road to Norseman). All these localities are in W.A. *I. amplicolis* appears to be restricted to fresh and temporary pools.

Remarks: *I. amplicolis* differs from *I. varrovilius* (King, 1855) and *I. stanleyanus* (King, 1855), which have similar shell outlines, by the absence of long natatory setae on its antennae (in specimens of these two species examined in Sars' collection, the natatory setae extend past the tip of the antennal claws). No males have been found in the latter two species.

Ilyodromus candonites n.sp.

Fig. 4.18; Plate IV.21a-k

Diagnosis: *Ilyodromus* with subrectangular shell in lateral view with posterior broadly rounded and anterior tapering; valves faintly striated; inner lamella anteriorly almost three times the width of the posterior in both valves; faint selvage peripheral in the right valve and broader, and at $\frac{1}{3}$ from the outer margin on the inner lamella posteriorly and ventrally. Natatory setae of antenna atrophied. Maxilla palps in male similar, hook-shaped and angular; lateral lobe of hemipenis digitate and broadest distally.

Description: **Carapace.** (External) Subrectangular in lateral outline with posterior broadly rounded and almost forming a right angle with the dorsum which is almost flat; anterior tapering but rounded and anterodorsal area inclined; ventrum almost flat except in the mouth region which is slightly concave at $\frac{2}{5}$ from the anterior; surface of shell faintly striated with two generations of striae (Plate IV.21k); in dorsal view, like a flattened ellipsoid with both ends pointed; simple normal pore canals scattered with broad rim.

(Internal) Inner lamella anteriorly almost three times the width of the posterior in both valves; selvage peripheral and faint in the right valve and broader and at $\frac{1}{3}$ from the outer margin on the inner lamella posteriorly and ventrally; anteriorly the inner lamella is faintly reticulated like all *Ilyodromus* species.

Anatomy. Antennula: (Fig. 4.18a) 7-segmented: length width ratio of last six segments: $^{2}/_{3}$, $^{1.8}/_{1}$, $^{1.2}/_{1}$, $^{1.4}/_{1}$, $^{1.8}/_{1}$, $^{1.3}/_{1}$; sensory organ on 2nd segment 3-segmented and short; natatory setae as long as all segments together.

Antenna: (Fig. 4.18b) Three claws on penultimate segment and a 4th one on the distal one; natatory setae extremely short except for the outer one which is as long as half the length of the penultimate segment.

Mandible: (Fig. 4.18g) Mandibular coxale with seven teeth; palp 3-segmented and with α bristle stylet-like, β bristle stout, pointed and densely pilose, γ bristle slightly longer than distal segment, stout and densely pilose in the distal $\frac{2}{3}$; epipod with five long plumose Strahlen plus a shorter one at mid-length and a smaller barren seta near its base.

Rake-like organ: Seven to nine teeth plus a bifid one on the inner side of each rake.

Maxillula: (Fig. 4.18c) Distal part short and trapezoid; 3rd lobe with two smooth Zahnborsten; epipod plate with 22 Strahlen.

Maxilla: Sexually dimorphic: in male (Figs. 4.18d,e) palps similar, narrow, angular and hook-shaped; in female (Fig. 4.18f) three plumose setae with middle one twice the length of the other two which are of almost equal length; for chaetotaxy of protopod, see Fig. 4.18f.

Thoracopoda I: (Fig. 4.18i) 3rd segment divided; distal seta of 2nd segment as long as half of the length of the 3rd segment; outer seta on 4th segment $\frac{1}{4}$ the length of the distal claw.

Thoracopoda II: (Fig. 4.18k) 3-segmented; distal setae unequal with shorter one curved and about $\frac{1}{3}$ the length of the other; distal pincers small.

Hemipenis: (Fig. 4.18h) Lateral lobe digitate with distal end broadest; inner lobe bilobate distally and curved inward.

Zenker organ: With about 27 rosettes.

FIG. 4.18 *Ilyodromus candonites* n.sp.

a	antennula
b	antenna
c	maxillula - palp and lobes
d	maxilla - endopodite, male
e	maxilla - endopodite, male
f	maxilla, female
g	mandible - palp
h	hemipenis
i	thoracopoda I
j	furca
k	thoracopoda II

a - e, h - k: holotype adult male

f - g: paratype adult female

Scale: 100 μ


A
B
C
D
E
F
G
H
I
J
K

Furca: (Fig. 4.18j) Both claws of almost equal length; posterior seta thick; pectinate and ½ the length of the posterior claw; slim anterior seta barren and about ½ length of the other seta.

Furcal attachment: median branch long, divided distally and with a broad, short and curved spike at right angle near its proximal end ventrally.

Colour of shell: Green.

Size:		L	H		L	H
holotype adult male	LV	1,140 µ	600 µ	RV	1,140 µ	600 µ

Type locality: Small granite rock pool at summit of Mt. Chudalup, near Northcliffe, W.A.

Derivation of name: From the genus *Candona* plus the Greek suffix -*ites* (= like) as the lateral outline of this species is reminiscent of many *Candona* spp.

Ecology and distribution: This species has only been collected in Western Australia. It occurs in many temporary granite pools near Northcliffe - at and near summit of Mt. Chudalup, and on and near Muirillup Rock. The size of *I. candonites* is variable: the length of adult specimens can vary between 1,100 µ and 1,400 µ.

Remarks: *I. candonites* differs from *I. viridulus* specimens examined in Sars' collection on the following important details: the natatory setae of the antenna almost reach the tip of the claws in the latter species, and its shell is more elongated: it is faintly concave dorsally in front of the hinge (*I. candonites* is flat) and the selvage is near the inner margin posteriorly in the left valve and is broader posteriorly in the right valve. The greatest extension of the shell posteriorly in *I. viridulus* is at mid-height whereas it is near the ventrum in *I. candonites*. The latter species differs from type specimens of *I. substriatus* Sars, 1894 and *I. obtusus* Sars, 1894 from Sars' collection (which have short natatory setae on the antenna extending to the middle of the penultimate segment), on the following features of the shell: *I. substriatus* has a broad selvage posteriorly in the right valve which is met by a depression in the left valve where the selvage is faint and along the periphery of the inner margin; in *I. obtusus* the selvage is faint and along the outer margin in both valves. No males are known for Sars' species.

Ilyodromus dikros n.sp.

Fig. 4.19; Plate IV.22

Diagnosis: *Ilyodromus* like an inclined parallelogram with rounded ends in lateral view; obvious depression anterior to the hinge dorsally, and with the greatest extension of the shell anteriorly at 2/5 from the dorsum plane. Inner lamella broad all along in both valves. Male maxilla palps asymmetrical, the narrower one being more arched; outer seta of 4th segment thoracopoda more than 1/2 the length of the distal claw; hemipenis with digitate lateral lobe and inner lobe like an elongated rectangle reaching almost the tip of the lateral lobe.

Description: Carapace. (External) Inclined parallelogram with rounded ends in lateral view with obvious depression anterior to the hinge dorsally; shell with longitudinal striations of two generations (Plate IV.22n) all over except in the anterior area near the margin; simple type normal pores; greatest extension of the shell anteriorly at 2/5 from dorsum plane and 3/5 posteriorly; ventrum concave just before mid-length. In dorsal view extremely narrow and with both ends pointed.

(Internal) Inner lamella similar in both valves and of similar width anteriorly and posteriorly: it is broadest anteriorly where the valve extends the furthest, and narrowest in the mouth region above the concavity.

Anatomy: Antennula: (Fig. 4.19a) 7-segmented: length width ratio of last six segments: $^{1}/_{1}$, $^{1.8}/_{1}$, $^{1}/_{1}$, $^{1.3}/_{1}$, $^{1.7}/_{1}$, $^{2.5}/_{1}$; natatory setae as long as last six segments, sensory organ on second segment elongated.

Antenna: (Fig. 4.19b) Three distal claws on the penultimate segment with a shorter one on the distal segment; natatory setae extending much further than the tip of the claws.

Mandible: (Figs. 4.19i,j) Mandibular coxale with seven teeth; palp with α bristle stylet-like, β bristle stout and densely pilose, γ bristle broad, almost twice the length of the distal segment and pilose in the distal half; epipod plate with four pilose Strahlen.

Rake-like organ: Seven to nine teeth plus one bifid on inner side of each rake.

Maxillula: (Fig. 4.19c) Distal segment of palp trapezoidal and 3rd lobe with two smooth Zahnborsten; epipod with about 18 plumose Strahlen.

Maxilla: Sexually dimorphic: in male (Fig. 4.19g,h) palps asymmetrical with the narrower more strongly arched; the other is broadest at mid-length; in female (Fig. 4.19f) palp with three short plumose setae, the middle one being almost twice the length of the other two which are of similar length; for chaetotaxy of protopod see Fig. 4.19f.

Thoracopoda I: (Fig. 4.19d) Seta at mid-length on outer side of 4th segment thick and more than $^{1}/_{2}$ the length of the distal claw; proximal seta on 1st segment $^{1}/_{3}$ the length of the distal one.

FIG. 4.19 *Ilyodromus dikros* n.sp.

a	antennula
b	antenna
c	maxillula - palp and lobes
d	thoracopoda I
e	hemipenis
f	maxilla, female
g	maxilla - endopodite, male
h	maxilla - endopodite, male
i	mandible - palp
j	mandible - coxale
k	Zenker organ
l	thoracopoda II
m	furcal attachment
n	furca

a - b, d - e, g - h, k - l, n: holotype adult male.

c, f, i - j, m: paratype adult male.

Scale: 100 μ


A
B
C
D
E
F
G
H
I
J
K
L
M
N

Thoracopoda II: (Fig. 4.19l) 3-segmented; distal pincers small and distal setae unequal: longest seta 1.6 times the length of the shorter and slightly curved one.

Hemipenis: (Fig. 4.19e) Lateral lobe digitate and inner lobe like an elongated rectangle reaching almost the tip of the lateral lobe; the broad tip of the inner lobe is covered with small hooks.

Zenker organ: (Fig. 4.19k) Elongated and with 25 rosettes.

Furca: (Fig. 4.19n) Claws almost equal; posterior seta slim, pectinate and twice the length of the other barren seta and ⅔ the length of the posterior claw.

Furcal attachment: (Fig. 4.19m) Median branch thick, bifurcate distally and with broad spike at right angle near its base.

Colour of shell: White.

Size:		L	H		L	H
holotype adult male	LV	1,270 µ	560 µ	RV	1,270 µ	560 µ
paratype adult female	LV	1,470 µ	660 µ	RV	1,470 µ	660 µ

Type locality: Dam at Wasley Well, near Nallan, 21 km NNE of Cue, W.A. (118°09'06"E.27°16'54"S).

Derivation of name: From Greek *dikros* (= forked) for the forked appearance of the distal end of the thoracopoda I which has a long outer seta on the last segment.

Ecology: This species has only been collected once from the type locality: water was fresh and turbid.

Remarks: Although this species appears at first glance to resemble the elongated *I. varrovillius* (King, 1855), it is easily separated from the latter by its diagnostic long seta on the last segment of the thoracopoda I and by its inclined parallelogram outline in lateral view. *I. varrovillius* in Sars' collection has short natatory setae on the antenna.

Ilyodromus williamsi (McKenzie, 1966)

1966 *Isocypris williamsi* n.sp., McKenzie, p. 266.

Remarks: The transfer of this species to *Ilyodromus* is suggested here because this species possesses many typical anatomical features of that genus. These are: 3-segmented sensory organ on the 2nd segment of the antennula; slim stylet-like α bristle, stout, pointed and densely pilose β bristle, thick, stout γ bristle which is pilose in its distal half; trapezoid palp and smooth Zahnborsten on maxillula; presence of two setae on 1st segment of thoracopoda I; thick and pectinate posterior seta on furca and furcal attachment with stout spike forming a right angle with the median branch near its base.

McKenzie (1971a) has already pointed out that *I. williamsi* was not an *Isocypris sensu stricto* on shell characters alone. This species in fact is closely related to *I. dikros* as they both have a similar shell outline but *I. williamsi* has a faint selvage at a distance from the outer lamella anteriorly in the left valve and has a very short outer seta on the distal segment of the thoracopoda I.

I. williamsi is only known from the type locality, at about 16 km west of Inverway, N.T.

Kapcypridopsis McKenzie, 1977

Type species: *Kapcypridopsis barnardi* McKenzie, p. 46.

Kapcypridopsis asymmetros n.sp.

Fig. 4.20; Plate IV.23

Diagnosis: *Kapcypridopsis* with valves asymmetrical posteriorly: right valve with posterodorsal hump extending well beyond the smoothly curved left valve; lateral lobe of hemipenis digitate and with a concave and blunt distal end.

Description: Carapace. (External) Pseudopunctate, subrectangular in lateral view with dorsum gently arched and ventrum almost flat except in the mouth region where it is slightly concave; right valve larger than left one and overlapping it slightly all around; posterodorsally, however, the right valve possesses a hump which extends well beyond the edge of the left valve in that area, which is also the furthest point of extension of the valve. Edge of both valves rounded all around; normal pore canals rare and scattered.

(Internal) Inner lamella broad anteriorly and narrow posteriorly; selvage peripheral in both valves except posteroventrally in the right valve, where it borders the inner lamella which does not follow the curvature of the shell in that area; narrow groove outside and all along the selvage in both valves.

Anatomy: Antennula: (Fig. 4.20a) 7-segmented; length width ratio of last six segments: $^{1}/_{1}$, $^{1}/_{1}$, $^{1}/_{1.3}$, $^{1}/_{1}$, $^{1.3}/_{1}$, $^{4}/_{1}$; natatory setae as long as all segments together.

Antenna: (Fig. 4.20b) Four claws: three almost equal on penultimate segment and a shorter pectinate one on distal segment nearly reaching the tip of the other claws in male; in female it is barren and shorter; unequal natatory setae reduced to three and not reaching the distal end of the penultimate segment.

FIG. 4.20 *Kapcypridopsis asymmetros* n.sp.

a	antennula
b	antenna
c	mandible - palp
d	thoracopoda I
e	maxilla, male
f	maxilla - endopodite, male
g	maxillula - palp and lobes
h	thoracopoda II
i	furca
j	hemipenis
k	Zenker organ
l	maxilla - endopodite, female

a - f, h, j - k: holotype adult male.

g, i, l: paratype adult male.

Scale: 100 μ


A
B
C
D
E
F
G
H
I
J
K
L

Mandible: (Fig. 4.20c) Mandibular palp with α bristle slim, long and barren, β bristle thick, short, pointed and densely pilose, γ bristle slim, twice the length of the distal segment and pilose in its distal ⅓.

Rake-like organ: Six to seven teeth plus one inner bifid on each rake.

Maxillula: (Fig. 4.20c) Epipod with about 17 Strahlen; distal palp rectangular and 3rd lobe with toothed Zahnborsten.

Maxilla: Sexually dimorphic: in male (Figs. 4.20e,f) palps asymmetrical but both strongly and similarly arched; in female (Fig. 4.20 l) middle seta faintly plumose and twice the length of the other equal setae; for chaetotaxy of protopod, see Fig. 4.20e.

Thoracopoda I: (Fig. 4.20d) 3rd segment divided; distal seta on 2nd segment and inner seta, at mid-length of the 3rd segment where it is divided, of equal length and longer than ½ the 3rd segment; inner distal seta of 3rd segment slightly shorter than the other two mentioned above.

Thoracopoda II: (Fig. 4.20h) Distal pincers narrow but long; distal setae unequal with shorter curved one ⅖ the length of the other straight one.

Hemipenis: (Fig. 4.20j) Lateral lobe digitate with blunt and concave end; inner lobe like a broad and pointed hump reaching half the length of the outer lobe; copulatory sheath like a narrow tongue near the outer lobe and almost completely covered by it.

Zenker organ: (Fig. 4.20k) Both ends rounded and with 12 rosettes.

Furca: (Fig. 4.20i) Weakly chitinized, whip-like and with a short seta near its base.

Furcal attachment: Thin and bifurcate distally.

Colour of shell: Dark green to almost black, except in the eye region where it is reddish brown.

Size:		L	H		L	H
holotype adult male	LV	580 μ	340 μ	RV	590 μ	360 μ
paratype adult female	LV	640 μ	400 μ	RV	680 μ	410 μ

Type locality: Natural granite rock pool near Frenchman's Bay Road, Albany, at turn off to The Blow Holes, W.A.

Derivation of name: From Greek *asymmetros* (= asymmetrical) for the asymmetrical valves posterodorsally.

Ecology and distribution: This species has only been collected twice, in the same year, at the type locality under 2.5 cm of water; it is not found in nearby artificial holes dug in granite.

Remarks: This species differs from the type species described from the Cape Province in South Africa by its obvious asymmetrical valves and the outline of the hemipenis. Another species of *Kapcypridopsis*, as yet undescribed, has been collected by Dr. I.A.E. Bayly from a shallow granite pool, ridge south of Mt. Oberon Summit, Wilson's Promontory, Vic. This species has a dark coloured shell, long natatory setae on the antenna and helmet-shaped lateral lobe on the hemipenis.

Leptocythere Sars, 1925

Type species: *Leptocythere pellucida* (Baird, 1850)

Leptocythere lacustris n.sp.

Fig. 4.21; Plate IV.24

1919 *Cythere lubbockiana* Brady, Chapman, p. 29.

Diagnosis: *Leptocythere* with deeply pitted external surface of shell, large circular depression posteroventrally outside and where the inner lamella is the broadest on the inside; posterodorsally near the termination of the hinge, the shell is slightly concave and posterior to it; the shell is thick and smooth especially in the left valve. Outline of hemipenis as in Figs. 4.21j,k.

Description: Carapace. (External) Subrectangular shell, coarsely pitted and with at least two elongated grooves: the anterior one is straight and forms an obtuse angle with the hinge line and the other, at the posterior, runs almost parallel to the curvature of the shell; a deeper and broader notch is often visible in the posteroventral area in both valves; ornamentation of shell varying from fine to coarse ribbing; dorsum almost straight and inclined except in the posterodorsal area, just before the termination of the hinge where it is slightly concave; behind this, the shell is thick and smooth, especially in the left valve; greatest height at about $\frac{1}{4}$ from the anterior; mouth region concave and at $\frac{2}{5}$ from the anterior. In dorsal view, the shell is compressed and has almost straight sides except where the grooves occur anteriorly and posteriorly; hinge area almost smooth externally.

(Internal) Inner lamella broad and widest in the posteroventral area opposite the external deep notch; selvage faint and peripheral in both valves; hinge crenulated all along with a broad tooth at both ends in the right valve and matching sockets in the left one; behind the anterior socket in the left valve, there are two smaller teeth and in front of the posterior socket, with a matching depression in the right valve, there is also a small tooth; central muscle field with a vertical row of four scars: the two in the middle are elongated and parallel to the hinge line whereas the two others are almost circular.

FIG. 4.21 *Leptocythere lacustris* n.sp.

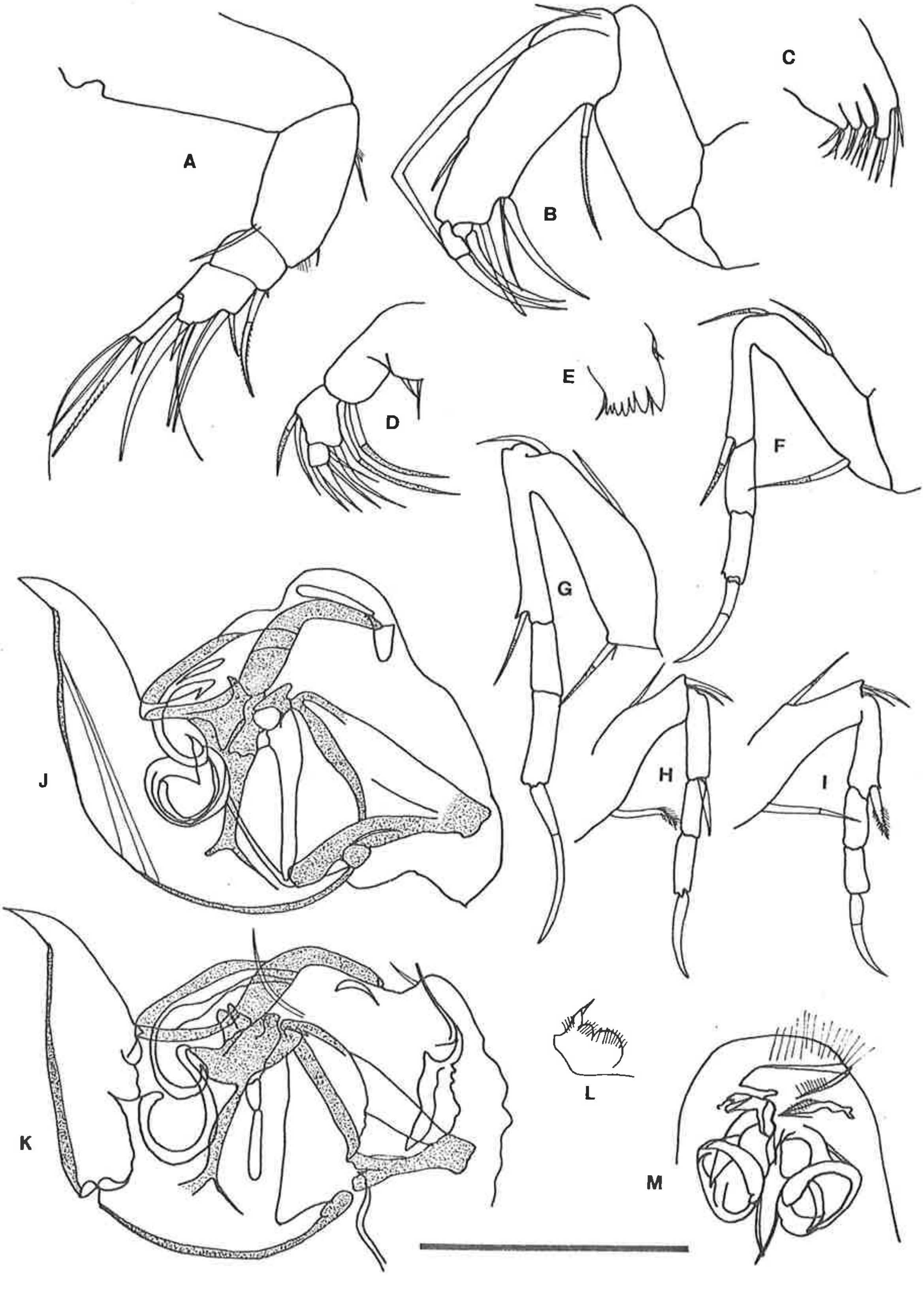
a	antennula
b	antenna
c	maxillula - palp and lobes
d	mandible - palp
e	mandible - coxale
f	thoracopoda I
g	thoracopoda II
h	maxilla, male
i	maxilla, female
j	hemipenis
k	hemipenis
l	end of body
m	genitalia

a - e, g - h, j - k: holotype adult male

f, i, m: paratype adult female

l: paratype adult male

Scale: 100 μ


A
B
C
D
E
F
G
H
I
J
K
L
M

Anatomy: Antennula: (Fig. 4.21a) 6-segmented: length width ratio of last four segments: $^{1.6}/_{1}$, $^{1}/_{1.4}$, $^{1}/_{1}$ to $^{1.4}/_{1}$, $^{4}/_{1}$; distal thick seta pectinate.

Antenna: (Fig. 4.21b) Two smooth distal claws on terminal segment slightly shorter than inner claw near distal end of penultimate segment.

Mandible: (Figs. 4.21d,e) Mandibular coxale with seven teeth and a long acicular seta on the inner side near the base of the smaller tooth; epipod with terminal segment small and square-shaped.

Maxillula: (Fig. 4.21c) Epipod with 14 long and a short Strahlen; terminal segment of palp small, rectangular and with one distal seta jointed.

Maxilla: (Figs. 4.21h,i) Distal claw short and slightly curved: in female inner seta on 2nd segment pilose in its distal half (Fig. 4.21i) whereas it is barren in male (Fig. 4.21h).

Thoracopoda I: (Fig. 4.21f) Slightly larger than maxilla but with only one distal seta on the 1st segment.

Thoracopoda II: (Fig. 4.21g) Similar but slightly larger than thoracopoda I and with distal claw more slender.

Hemipenis: See outline in Figs. 4.21j,k.

Genitalia: See outline in Fig. 4.21m.

Furca: (Figs. 4.21k,m) One long seta near the hemipenis and genital organ.

End of body: (Fig. 4.21 l) With one small seta and densely pilose.

Colour of shell: Light brown.

Size:		L	H		L	H
holotype adult male	LV	500 μ	270 μ	RV	490 μ	270 μ
paratype adult female	LV	485 μ	270 μ	RV	480 μ	270 μ

Type locality: Fresh Dip Lake near Robe, South Australia.

Derivation of name: From Latin *lacustrinus* (= of lakes) as this species, which belongs to a typically estuarine genus, is found in lakes.

Ecology and distribution: This truly benthic species has been collected in only four localities near Robe in South Australia apart from the type locality. All localities are characterized by permanent water with only slight salinity fluctuations. The salinities were 19 to 28°/oo. In addition, at the type locality, salinity was 2.8°/oo. So far, *L. lacustris* has not been found in permanent water around 35°/oo as no such lakes have yet been sampled in the search for this ostracod. Attempts to find it in the permanent and saline Lakes Keilambete and Gnotuk in western Victoria (salinity ca. 55-62°/oo) were unsuccessful, suggesting that the salinity range of *L. lacustris* does not reach such values. This species, as for all others in the typical estuarine genus *Leptocythere*, is indicative of permanent water as it does not produce eggs which can withstand desiccation.

Remarks: The description of *L. lacustris* definitely corresponds to the specimen identified by Chapman (1919) as *Cythere lubbockiana* from the fossil site at Boneo Swamp. The two rounded tubercles on the postero-ventral area of the shell as illustrated by Chapman (1919) on Plate IV.9 are two sand grains which have been removed by me from the specimen kept in the National Museum of Victoria. The shell architecture of *L. lacustris* varies from almost smooth to coarsely reticulated (Plate IV.22n,p): at times, reticulation is so thick that the shell has a smooth appearance. Such variations have been mentioned for other estuarine and marine species of *Leptocythere* by Shornikov (1966) and Hartmann and Kuhl (1978). This is not surprising as environmental conditions, such as water salinity in salt lakes, can fluctuate over time.

L. lacustris is closely related to *L. hartmanni* (McKenzie, 1967). Unfortunately, no males of the latter species have ever been found, as analysis of the hemipenis morphology would have confirmed this distinction. The valves of *L. hartmanni*, however, are not coarsely pitted and reticulation is more sparse (see Hartmann, 1979, Plate III: Fig. 3-8). The anterior and posterior grooves are present in both species. The posteroventral notch is much deeper in *L. lacustris* and the smooth posterodorsal hump is absent in *L. hartmanni*.

Limnocythere Brady, 1867

Type species: *Limnocythere inopinata* (Baird, 1843)

Limnocythere dorsosicula n.sp.

Fig. 4.22; Plate IV.25a-j

Diagnosis: *Limnocythere* with three to six small spines along the dorsal edge of the right valve at the posterior end; two small dorsal bosses separated by a main depression in the middle and never higher than the hinge in lateral view. Outline of hemipenis as in Fig. 4.22h.

Description: Carapace. (External) Rectangular, faintly reticulated and pitted to smooth; three main depressions on each valve: one in the centre where a vertical row of four muscle scars is often visible, another just above and a 3rd in front just below the hinge line; greatest height at about $^1/_4$ to $^1/_5$ from anterior; greatest width at about $^3/_5$ from anterior; right valve with three to six small spines along its edge posterodorsally; in dorsal view, anterior narrow and pointed; two small dorsal bosses, separated by the main depression in the middle, are smooth and never obvious as they are never higher than the hinge line when examined in lateral view. Sexual dimorphism pronounced: length height ratio of valves greater in males.

(Internal) Hinge with a broad tooth in right valve and a matching depression in the left one at both ends; inner lamella broadest anteriorly and peripheral selvage faint; radial pore canals numerous and straight from which many hairs protrude at a distance from the outer lamella anteriorly.

Anatomy: Antennula: (Fig. 4.22a) 6-segmented; length width ratio of the last five segments: $^{2}/_{1}$, $^{1}/_{1}$, $^{1}/_{1.3}$, $^{2}/_{1}$, $^{4.2}/_{1}$; longest distal seta bifid at about mid-length.

Antenna: (Fig. 4.22b) Two pectinate distal claws and another thinner and barren; distal segment small and squarish.

Mandible: (Fig. 4.22d) Mandibular coxale with seven teeth; palp with distal segment very small and squarish and with three thin setae; distal seta on penultimate segment thicker than the other three and pectinate.

Maxillula: (Fig. 4.22c) Distal palp elongated with three setae and 3rd lobe with three others, two of which are biramous.

Maxilla: (Fig. 4.22f) Short and stocky; no setae on 1st segment.

Thoracopoda I: (Fig. 4.22g) Longer than maxilla; distal end of 1st segment with two unequal setae plus one at proximal end and another at mid-length.

Thoracopoda II: (Figs: 4.22e,j) Longer than thoracopoda I with distal claw almost twice its length and three times that of the maxilla claw;

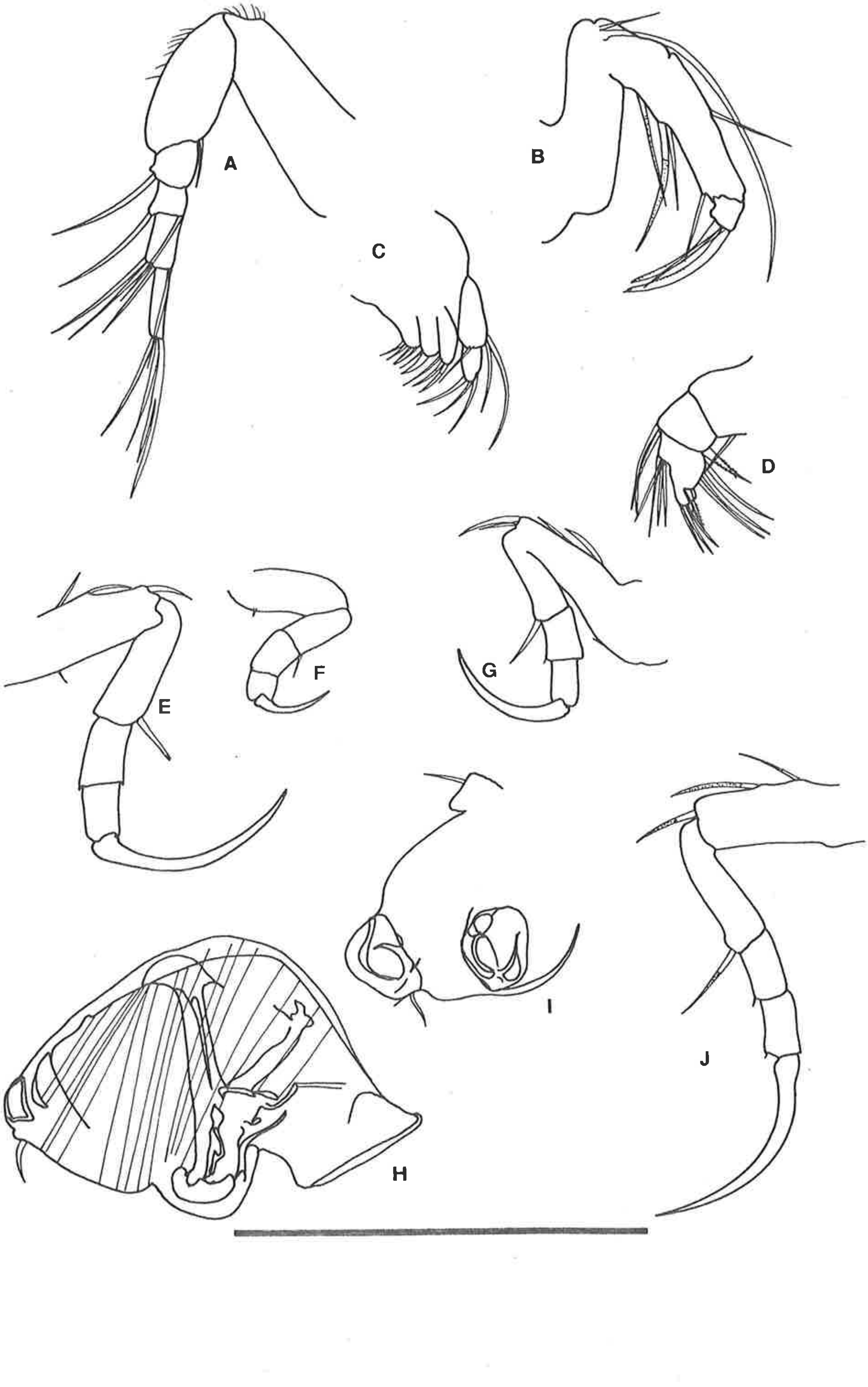
FIG. 4.22 *Limnocythere dorsosicula* n.sp.

a	antennula
b	antenna
c	maxillula - palp and lobes
d	mandible - palp
e	thoracopoda II, male
f	maxilla
g	thoracopoda I
h	hemipenis
i	genitalia
j	thoracopoda II, female

a - b, e - h: holotype adult male

c - d, i - j: paratype female

Scale: 100 μ


A
B
C
D
E
F
G
H
I
J

in female setae pectinate, and barren in male where the distal seta on the 2nd segment has a bifid tip.

Hemipenis: For outline see Fig. 4.22h.

Genitalia: For outline see Fig. 4.22i.

Furca: (Figs. 4.22h,i) One small and barren seta near the reproductive organs.

Colour of shell: Light brown to transparent.

Size:		L	H		L	H
holotype adult male	LV	410 μ	230 μ	RV	410 μ	230 μ
paratype adult female	LV	450 μ	230 μ	RV	450 μ	230 μ

Type locality: Lake Terangpom, west of Lake Corangamite, western Victoria.

Derivation of name: From Latin *dorsum* (= back) and *sicula* (= small spine) for the diagnostic posterodorsal spines on the right valve.

Ecology and distribution: This species has only been collected twice: at Lake Terangpom at 2.03°/oo salinity and at South Nerrin Nerrin Lagoon at 1.96°/oo, both in western Victoria. At first glance, it appears that this species is indicative of freshwater (<3°/oo) despite the fact that some *Limnocythere* species can be found in saline waters (see *L. miltos* n.sp. below and De Deckker, in press, a). However, *L. dorsosicula* which has been recovered in many samples in a core from Lake George in N.S.W. (see Chapter 7), is found in some samples co-occurring with other ostracod species indicative of either fresh water or water of salinity <10°/oo.

Remarks: *L. dorsosicula* is easily distinguishable from *L. notonda* Vavra, 1906 described from west Java which possesses, at the maximum, four spines posterodorsally on the right valve. The anterior of the

shell of the former species is narrow and pointed and, in the latter species, it is much broader and rounded at both extremities.
L. dorsosicula differs from *L. mowbrayensis* Chapman, 1914 as the latter has broad alae, which are rounder or pointed and curved backward at about mid-height near the centre of the shell. Dorsal spines have also been noticed on one fossil juvenile specimen of *L. mowbrayensis* from Lake Pillie, S.A. (see Chapter 8), whereas this feature appears common on specimens from Pulbeena Swamp illustrated by Brehm (1939) for *L. percivali* (later synonymized to *L. mowbrayensis* by Hornibrook (1955)) and Deevey (1955). Hornibrook (1955), however, did not mention any spines on his specimens from the same locality. In addition, *L. mowbrayensis* is characterized by a dorsal boss at mid-length which extends above the hinge line when seen in lateral view. *L. stationis* Vavra, 1891, which inhabits European waters, also possesses postero-dorsal spines but these are only found on the left valve.

Limnocythere miltos n.sp.

Fig. 4.23; Plate IV.25k-r

Diagnosis: *Limnocythere* with faintly reticulated valve with a vertical depression above the central muscle scars separating a small smooth boss anteriorly from the broad posterior; depression above and in front of the boss; row of fine denticles along the posteroventral margin of left valve. Maxilla and thoracopodae I and II with three long and pectinate setae on the inside of the 1st segment.

Description: Carapace. (External) Subrectangular and finely reticulated all over except for the anterior boss above and in front of the central muscle field and along the dorsal margin anteriorly; this boss is separated from the posterior of the shell by a vertical groove just above the central muscle field; there is a depression adjacent to the boss dorsally which gives it a bilobate appearance in dorsal view; greatest height at about $^{1}/_{4}$ to $^{1}/_{3}$ from the anterior; mouth region concave and at about mid-length; dorsum gently curved; in dorsal view shell narrow, anterior pinched and pointed; greatest width at about $^{2}/_{3}$ from the anterior; left valve slightly longer than right one posteriorly; shell compressed posteroventrally where the inner lamella is broad.

(Internal) Inner lamella broad anteriorly in both valves and of almost similar width posteroventrally; posteriorly at mid-height and above, selvage absent; numerous straight radial pore canals from which many hairs protrude anteriorly at a distance from the outer margin; central muscle field with a vertical row of four scars: two narrow horizontal ones in the middle separated by two circular to oval ones; one antennal scar in front of the row at the level of the top scar and an additional scar above the vertical row of four; all these scars are met by depressions on the outside of the shell. Four to six minute spines along the margin of the left valve posteroventrally; hinge with broad tooth at both ends in the right valve with matching socket in the left valve; the posterior tooth is the largest.

Anatomy: Antennula: (Fig. 4.23a) 6-segmented: length width ratio of last five segments: $^{2}/_{1}$, $^{1.2}/_{1}$, $^{1}/_{2}$, $^{1}/_{1}$, $^{5}/_{1}$; longest seta bifid at $^{1}/_{3}$ from its base.

Antenna: (Fig. 4.23b) Three barren distal claws; distal segment almost rectangular.

Mandible: (Figs. 4.23c,d) Mandibular coxale with seven teeth, the inner two acicular; palp with distal segment almost squarish; at the distal end of the 1st segment, thick seta (α bristle?) stout, pointed and pilose; on 2nd segment there are four setae, two long ones and two

FIG. 4.23 *Limnocythere miltos* n.sp.

a	antennula
b	antenna
c	mandible - palp
d	mandible - coxale
e	maxillula
f	maxilla
g	thoracopoda I
h	thoracopoda II
i	genitalia
j	end of body

a - j: holotype adult female

Scale: 100 μ


A
B
C
D
E
F
G
H
I
J

pectinate and shorter (one is a β bristle?); distal end of 3rd segment with one long and barren seta and another ½ its length and pectinate (γ bristle?); three unequal setae on distal end of last segment.

Maxillula: (Fig. 4.23e) Epipod with 14 long and one small plumose Strahlen plus a shorter barren one; palp 2-segmented with distal segment rectangular; for chaetotaxy see Fig. 4.23e.

Maxilla: (Fig. 4.23f) Distal claw stout and curved; three thick and pectinate setae on inner side of 1st segment and a longer pectinate one near its base outside.

Thoracopoda I: (Fig. 4.23g) Similar to maxilla but larger.

Thoracopoda II: (Fig. 4.23h) Similar to thoracopoda I but larger and with no basal seta on the outside of the 1st segment.

Genitalia: Weakly chitinized (see Fig. 4.23i).

Furca: (Fig. 4.23i) Single barren seta.

End of body: (Fig. 4.23j) With tuft of hairs and one biramous short seta.

Colour of shell: Yellow to light brown.

Size:

		L	H		L	H
holotype adult female	LV	545 µ	310 µ	RV	540 µ	310 µ

Type locality: Small lake north-west of Lake Werowrap, Red Rock area, near Colac, western Victoria (143°29'35"E, 38°15'23"S).

Derivation of name: From Greek *miltos* meaning red earth as this species has been collected from the Red Rock area near Colac.

Ecology and distribution: *L. miltos* has only been collected once. At the type locality salinity was 15.42°/oo and pH 9.5. This lake is known to dry up. No males have yet been found.

Remarks: *L. miltos* differs from *L. aspera* Henry, 1923, as the latter does not possess the typical posteroventral spines along the margin of the left valve.

Limnocythere mowbrayensis Chapman, 1914

1914 *Limnicythere* (*sic*) *mowbrayensis* n.sp., Chapman, p. 60.
1955 *Limnicythere* (*sic*) *sicula* Chapman, Hornibrook, p. 268.
1955 *Limnicythere* (*sic*) *mowbrayensis* Chapman, Hornibrook, p. 268.
1978 *Limnocythere mowbrayensis* Chapman, McKenzie, p. 181.
1980 *Limnocythere mowbrayensis* Chapman, De Deckker, p.
1980 *Limnocythere* sp., De Deckker and Geddes, p. 691.

Diagnosis: *Limnocythere* with almost straight dorsum and deeply concave ventrum; two large dorsal bosses, which in lateral view extend above the hinge line, are separated by a vertical groove which is situated above a vertical row of four muscle scars; in front of the row there is a broad lateral process which, on most occasions, is pointed and curved backwards.

Discussion: *L. mowbrayensis* has recently been re-described by De Deckker (1980a). *Limnocythere* sp., briefly described by De Deckker and Geddes (1980) from an ephemeral salt lake near the Coorong Lagoon, is here considered to be *L. mowbrayensis* as it is almost identical to the specimens of *L. sicula* described by Chapman (1919), later synonymized by Hornibrook (1955) to *L. mowbrayensis*, as it has poorly developed lateral processes.

Ecology and distribution: *L. mowbrayensis* cannot swim: it is usually found crawling in among filamentous algae. It is a fresh water species which can tolerate slightly saline waters up to 6°/oo. This upper record refers to the *L.* sp. of De Deckker and Geddes (1980) mentioned above, and is not surprising as some other *Limnocythere* species can inhabit saline waters (e.g. *L. miltos*; see De Deckker, in press a).

L. mowbrayensis has also been recorded at 2.8°/oo in Fresh Dip Lake, near Robe, S.A. Apart from the ephemeral locality near the Coorong Lagoon where *L. mowbrayensis* was collected only once, all other localities are permanent; this species has never been found in temporary pools.

L. mowbrayensis is recorded from southern Australia (even Kangaroo Island) and as fossil from north-western Tasmania (from where it was originally described) and New Zealand (see Chapter 6).

Mytilocypris McKenzie, 1966

Type species: *Mytilocypris tasmanica* McKenzie, 1966.

Remarks: *Mytilocypris* species have recently been reviewed by De Deckker (1978). Since then, an additional subspecies *M. tasmanica chapmani* has been described by McKenzie (1978) from Western Australia. Only notes on ecology and distribution of relevance to this thesis are presented below for *M. mytiloides* (Brady, 1886), *M. praenuncia* (Chapman, 1936) and *M. splendida* (Chapman, 1966). Diagnoses for these species are provided in De Deckker (1978) and are therefore, not repeated here.

Mytilocypris mytiloides (Brady, 1886)

1886 *Cypris mytiloides* n.sp., Brady, p. 89.

1978 *Mytilocypris mytiloides* (Brady), De Deckker, p. 24.

Ecology and distribution: This species has been collected in temporary and permanent waters of salinities less than 4°/oo. Timms (1977) recorded it from three coastal dune lakes in western Victoria

(Lake Bong Bong, Sheepwash Lagoon and Lagoon no. 4) between 0.3 and 0.4°/oo. These are the lowest salinity records for the species. It is present in Lakes Edward and Leake near Mt. Gambier, S.A., at 2.6 and 3.5°/oo salinities respectively and on Kangaroo Island in a roadside pool near Vivonne Bay at 2.1°/oo salinity. Dwarf specimens of *Mytilocypris* which appear, on the basis of shell morphology, to be transitory between *M. mytiloides* and *M. minuta* De Deckker, 1978, have been found at higher salinities in collections from Kangaroo Island (Birchmore Lagoon at 25°/oo, Lake Ada 13.8°/oo).

Mytilocypris praenuncia (Chapman, 1936)

1936 *Cypris praenuncia* n.sp., Chapman, p. 298.

1975 *Mytilocypris* sp. nov. aff. *M. tasmanica*, De Deckker, p. 424.

1978 *Mytilocypris praenuncia* (Chapman), De Deckker, p. 24.

Ecology and distribution: *M. praenuncia*, which is only found in Victoria and South Australia, can swim easily but is often seen on the lake floor or in among beds of halophytic plants such as *Ruppia* sp., *Lepilaena* sp. and the alga *Lamprothamnium papulosum*. The salinity range of this species is between 7 and 42°/oo in western Victorian lakes whereas in the Coorong area in South Australia, it is between 12 and 35°/oo with an additional record at 43°/oo (De Deckker and Geddes, 1980). It is usually found in samples with *Platycypris baueri* Herbst, 1957 and can occur with *Diacypris spinosa* De Deckker, 1980 (range 5-16°/oo) at low salinities.

Mytilocypris splendida (Chapman, 1966)

1966 *Eucypris splendida* n.sp., Chapman, p. 369.

1978 *Mytilocypris splendida* (Chapman), De Deckker, p. 26.

Ecology and distribution: *M. splendida* is only recorded from eastern Australia. It is a common inhabitant of the low salinity lakes near Camperdown in Victoria: there, during a bimonthly survey during one year, it has been found between 5 and 18°/oo whereas during a survey of 79 lakes sampled once in the same area, the salinity range was 1-21.5°/oo. Very few specimens were found at 1 and 2°/oo salinity; above 2°/oo, they were common in the collections. In some of the lakes which had been sampled over one year, *M. splendida* was present during the winter and spring months when salinity was at the lowest and this species was replaced by *M. praenuncia* when salinity rose. This phenomenon is not surprising since *M. praenuncia* has a higher salinity tolerance.

Platycypris Herbst, 1957

Type species: *Platycypris baueri* n.sp., Herbst, p. 217.

Diagnosis: Smooth and thin, rectangular to oval in shape; greatest height at about ⅔ from the anterior and ventrum slightly concave at about ⅔ from the anterior; in dorsal view, the valves are narrow and pointed at both ends; inner lamellae very narrow except in the anterodorsal region; vestibulum also very narrow all along; central muscle field small. Juveniles usually more circular in outline but the slight concavity in the ventral area is still present at ⅓ from the shell anterior. Maxilla with trapezoid palp and 3rd lobe with five smooth Zahnborsten; thoracopoda I with two distal claws of equal length; hemipenis with curved and digitate lateral lobe with four to six transversal folds on the convex side. Colour of shell: light to dark brown.

Discussion: This species has been described adequately by Herbst (1957) and does not warrant an additional description here.

Ecology and distribution: *P. baueri* is a halobiont, planktic ostracod which can also burrow into the upper layer of sediment on lake floors. It has the broadest salinity range of any ostracod found in Australia. The data for Victorian lakes are 5-182°/oo (Geddes' (1976) data: 9.3-176°/oo), for lakes adjacent to the Coorong Lagoon, S.A.: 5-195°/oo (De Deckker and Geddes, 1980) and in Western Australia: 2.9-87.9°/oo (Geddes *et al* , in press). This species is present in low numbers at low salinities and is usually much more abundant at salinities above approximately 70°/oo. This phenomenon is apparent in Geddes' (1976) study where the species was the dominant or co-dominant one among crustaceans in lakes where salinity never went below approximately 70°/oo. This was also noticeable in the lakes near the Coorong Lagoon, studied by De Deckker and Geddes (1980), where *P. baueri* was rarely common in the lakes at salinities below 50°/oo - few of these lakes, in fact, remained continuously at a salinity above 70°/oo.

P. baueri is found all across southern Australia. In some collections the outline of the carapace is variable (e.g. elongated rectangle to almost squarish). It is postulated that this variation is attributable to the changes in physical conditions of lake waters, so typical of the saline lakes which the species inhabits.

Some fossil specimens of *P. baueri* have been recovered with both valves still attached in the hinge area from lacustrine cores in Victoria and New South Wales (see Chapters 5, 7). This phenomenon is surprising as valves, especially of this species, become separated fairly rapidly after death of the animal. Consequently, it is suggested here that the fossil carapaces belong to animals which were burrowing in sediments and remained there until death. This would prevent valves from becoming easily separated.

It is interesting to note that the Australian endemic genus *Platycypris* is monospecific whereas other halobiont and endemic genera (e.g. *Australocypris, Mytilocypris, Reticypris*) group many species. This is probably the result of *P. baueri* having a very broad salinity tolerance, therefore being adapted to most environments, and perhaps of good dispersal mechanisms and the ability to burrow in lake sediment to seek moisture to emerge during wet periods as an adult. The latter hypothesis has not been verified.

Psychrodromus Danielopol and McKenzie, 1977

Type species: *Psychrodromus olivaceus* (Brady and Norman, 1889)

Psychrodromus oblongata (Sars)

Fig. 4.24; Plate IV.26

1896 *Cypris oblongata* n.sp., Sars, p. 29.

1923 *Amphicypris oblongata* (Sars), Henry, p. 268.

Diagnosis: Smooth ellipsoid shell with posterior narrower than anterior and ventral area almost flat; in dorsal view, shell narrow and greatest width at about ⅓ from the anterior; inner lamella broad anteriorly and posteriorly in both valves; two toothed Zahnborsten on maxillula; maxilla palps of male asymmetrical; 1st segment of thoracopoda I with one long seta; lateral lobe of hemipenis crescent shaped; Zenker organ with 42 rosettes.

Discussion: This species is easily identifiable from Sars' (1896) original illustration of the shell but, since Sars provided only a drawing of the furca, the anatomy is illustrated here in Fig. 4.24. Only the significant features of the shell and the anatomy and those which warrant the transfer of this species into the genus *Psychrodromus* will be discussed below.

Carapace. Valves similar with left one slightly longer and slightly overlapping the other ventrally; inner lamella is broad anteriorly and posteriorly in both valves and the selvage is faint and peripheral except in the right valve ventrally; thin flange along the periphery of the right valve.

Anatomy. Antennula: (Fig. 4.24b) 2nd segment with 2-segmented short sensory organ.

Mandible: (Fig. 4.24g) Palp with α bristle smooth and slim, β bristle longer (but not stout) and densely pilose, γ bristle longer than last segment, stout and pilose in its distal half.

Rake-like organ: (Fig. 4.24d) Seven teeth plus one inner bifid tooth.

Maxillula: (Fig. 4.24f) Distal palp rectangular, and two toothed Zahnborsten on the 3rd lobe.

Maxilla: Sexually dimorphic: in male (Figs. 4.24i,j) palps asymmetrical: one broad triangular with outer side forming a rounded right angle and with two long bristles near the base of the palp; other smaller, narrower and more arched plus, at the base of the palp, with two shorter and also smooth bristles.

Thoracopoda I: (Fig. 4.24h) Proximal end of 1st segment with a long seta only.

Hemipenis: (Fig. 4.24m) Outer lobe crescent-shaped.

FIG. 4.24 *Psychrodromus oblongata* (Sars, 1896)

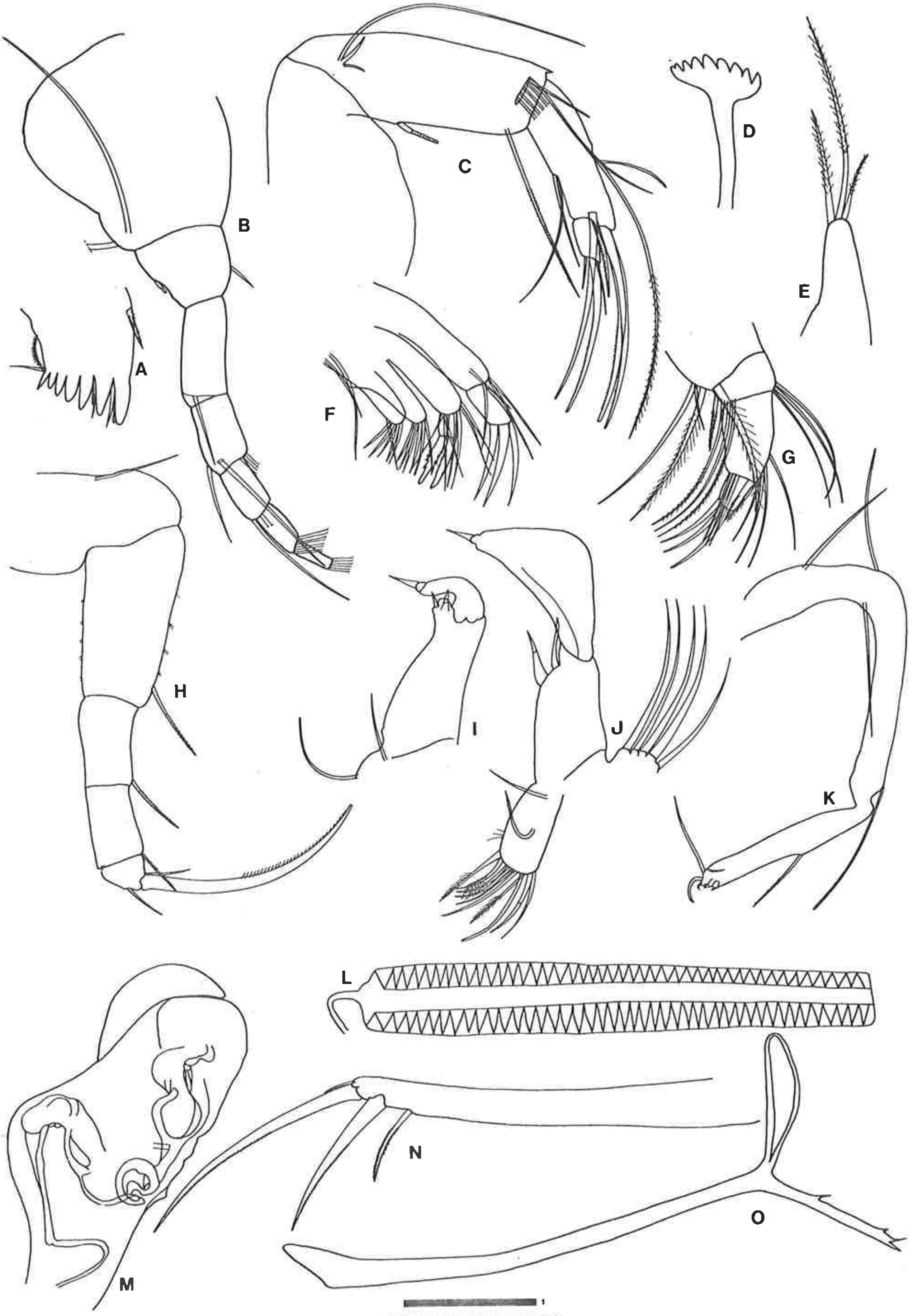
a	mandible - coxale
b	antennula
c	antenna
d	rake like organ
e	maxilla - endopodite, female
f	maxillula - palp and lobes
g	mandible - palp
h	thoracopoda I
i	maxilla - endopodite, male
j	maxilla, male
k	thoracopoda II
l	Zenker organ
m	hemipenis
n	furca
o	furcal attachment

a - d, g - n: adult male - roadside pool,
Gibb River Road, 58 km E. of Derby, W.A.

e - f, o: adult female - same locality.

Scale: 1 - 100 μ for a - c, e - o

2 - 50 μ for d


A
B
C
D
E
F
G
H
I
J
K
L
M
N
O
1
2

Zenker organ: (Fig. 4.24 1) Narrow and long with a large number of rossettes: 42.

Furca: (Fig. 4.24n) Distal claws unequal; posterior seta much thicker and longer than anterior one and pectinate.

Furcal attachment: (Fig. 4.24o) Median branch long and slightly curved with dorsal branch like a narrow and elongated loop at right angle to the median branch and forming an obtuse angle with the straight ventral branch.

Colour of shell: Beige brown.

Size:

			L	H
from Sars' (1896)	female:	carapace	1,900 μ	800 μ
	male:	carapace	1,600 μ	-
Specimens examined here:	adult female:	carapace	1,840 μ	880 μ
	adult male:	carapace	1,520 μ	760 μ

Ecology and distribution: This species had been raised by Sars (1896) from a dry sample of sand collected 64 km east of Roebuck Bay in W.A. In Sars' collection, there are a number of samples of *P. oblongata* for which the given locality is Central Australia. The specimens described here have been collected in a roadside pool on the Gibb River road, 58 km east of Derby, W.A.

Remarks: After the original description of *Cypris oblongata*, Sars (1896) remarked that his placement of the species into the genus *Cypris* (*sensu stricto*) was only provisional as he thought it to be in many ways related to *Cyprinotus*, although features of the shell for the latter genus were absent in *C. oblongata*. This species is transferred to the genus *Psychrodromus* here, because the shell has similar and almost equal valves with broad inner lamellae, faint selvages and a hollow inclusion above and in front of the adductor scars; the anatomy is also characterized by the following features: short 2-segmented sensory organ on 2nd segment of antennula; β bristle on mandibular palp long, narrow and densely pilose; rectangular palp and toothed Zahnborsten on maxillula; geniculate 1st segment of thoracopoda I with one distal seta; thick, long and pectinated posterior seta on furca; loop-like ventral branch on furcal attachment.

This represents the 1st record of a *Psychrodromus* species in the Southern Hemisphere.

The specimens labelled *"Eucypris"* cf. *oblongata* (Sars, 1896) by McKenzie, 1966 do not belong to the species described here as one of the specimens studied by McKenzie (1966) has peripheral tubercles on the right valves.

Reticypris McKenzie, 1978

Type species: *Reticypris herbsti* McKenzie, 1978.

Discussion: *Reticypris* is an Australian endemic genus which groups the following halobiont species: *R. herbsti* McKenzie, *R. walbu* De Deckker, 1979, *R. clava* n.sp. and *R. kurdimurka* n.sp. *R. dedeckkeri* McKenzie, 1978, has been synonymized to *R. herbsti* by De Deckker and Geddes (1980) as both taxa have an identical hemipenis (see discussion below). All *Reticypris* species, which are easily distinguishable from one another by the outline of the hemipenis, are discussed below.

Reticypris clava n.sp.

Fig. 4.25; Plate IV.27

1980 *Reticypris* sp.nov.1, De Deckker and Geddes, p. 692.

Diagnosis: *Reticypris* with lateral lobe of hemipenis crescent-shaped and broadest at the base where two lumps are visible on the inner side.

Description: Carapace. (External) Subrectangular with dorsum gently arched and ventrum almost flat except in the mouth region which is concave; anterior broadly rounded and posterior tapering with posterodorsal area inclined; slight depression at the extremity of the hinge anteriorly; left valve slightly larger all along and overlapping the right valve in the mouth region dorsally, especially where the slight depression occurs; surface of shell with small, dense reticulation usually all over and thickness of reticulation variable; outer flange close to the outer margin, narrow and thinly denticulated except in the mouth region where it is straight; greatest height at about $^{2}/_{5}$ from the anterior; in dorsal view like a flattened oval and both extremities slightly pointed. Normal pore canals of simple type and rimmed.

(Internal) Inner lamella equal in both valves and broadest anteriorly, tapering to $^{2}/_{3}$ of the width posteroventrally. Hinge consists of a broad groove in the left valve in which interlocks the right valve; radial pore canals numerous and straight.

Anatomy. Antennula: (Fig. 4.25a) 7-segmented; length width ratio of last six segments: $^{1}/_{1.5}$, $^{1}/_{1}$, $^{1}/_{1}$, $^{1}/_{1.8}$, $^{1}/_{2}$, $^{1}/_{1}$; natatory setae slightly longer than all segments together.

Antenna: (Fig. 4.25b) Three long and equal claws on penultimate segments with a shorter claw on distal one which is pectinate in male; natatory setae extending past the tip of the claws.

Mandible: (Fig. 4.25d) Seven teeth on mandibular coxale: last one longer than the other three adjacent to it and, near its base, two short pilose setae; length width ratio of palps: $^{4.5}/_{1}$, $^{1.7}/_{1}$; 3rd lobe has two smooth Zahnborsten; epipod with five plumose Strahlen and a smaller barren one.

FIG. 4.25 *Reticypris clava* n.sp.

a	antennula
b	antenna
c	mandible palp
d	maxillula, palp and lobes
e	maxilla, male
f	maxilla, endopodite, male
g	thoracopoda II
h	thoracopoda I
i	hemipenis
j	maxilla - endopodite, female
k	furcal attachment
l	furca
m	Zenker organ

a - i, k - m: holotype adult male

j: paratype adult male

Scale: 100 μ


A
B
C
D
E
F
G
H
I
J
K
L
M

Rake-like organ: Eight teeth with an additional bifid one on inner side.

Maxillula: (Fig. 4.25c) Distal segment squarish; α, β and γ bristle of equal length and slim: α smooth, β pectinate, γ smooth.

Maxilla: Sexually dimorphic: in male, palps asymmetrical (Figs. 4.25e,f): the broadest forming a right angle on the outside whereas the other is more arched; in female (Fig. 4.25j) setae unequal with shortest one smooth whereas the other two are plumose; for chaetotaxy of protopod see Fig. 4.25e.

Thoracopoda I: (Fig. 4.25h) Penultimate segment undivided and all inner setae long and of about equal length.

Thoracopoda II: (Fig. 4.25g) Distal pincers small and distal setae unequal: the shorter one curved and ¼ the length of the other.

Hemipenis: (Fig. 4.25i) Lateral lobe crescent-shaped and broadest at the base where two lumps are visible on the inner side; inner lobe squarish with three sides concave.

Zenker organ: (Fig. 4.25m) Elongated with 16 rosettes.

Furca: (Fig. 4.25 l) Pectinate claws thick and equal; setae equal, pectinate and ⅓ the length of the claws.

Furcal attachment: (Fig. 4.25k) Median branch straight and of about same length as the curved inward dorsal branch; ventral branch forming an obtuse angle with the dorsal one and hook-shaped distally; short rod-like, extension at right angle on the base of the median branch.

Eye: Cups of nauplius eye fused.

Colour of shell: Light green to white.

Size:		L	H		L	H
holotype adult male	LV	700 μ	430 μ	RV	690 μ	430 μ
paratype adult female	LV	720 μ	445 μ	RV	700 μ	440 μ

Type locality: Ephemeral salt lake south of the Coorong Lagoon, S.A. (36°13'36"E, 139°41'29"S) = locality three of De Deckker and Geddes (1980).

Derivation of name: From Latin *clava* (= club) for the diagnostic shape of the outer lobe of the hemipenis.

Ecology and distribution: In collections from western Victorian lakes, *R. clava* was always accompanied by low salinity ostracods such as *Mytilocypris splendida* or *M. praenuncia*, and occasionally with *D. spinosa*. Salinity for these collections ranged between 4 and 42°/oo. In the lakes adjacent to the Coorong Lagoon in South Australia, the salinity range for *R. clava* is 5-131°/oo but it was never found in high numbers above 68°/oo. Only in one lake near the Coorong Lagoon (locality 7 of De Deckker and Geddes, 1980) was *R. clava* found together with *R. herbsti* - this co-occurrence persisted throughout the year. *R. clava* has been collected once in Western Australia between 14.6 and 59.5°/oo (Geddes *et al.*, in press).

Remarks: It has proved almost impossible to distinguish *R. clava* and *R. herbsti* on features of the shell as reticulation of the shell and even shape and size are known to vary (see Plate IV.25 for *R. clava* and Chapter 5, Plate V.3 for *R. herbsti*). The outline of the hemipenis is a good diagnostic feature for separation of the two species. When dealing with fossil material (see Chapters 5, 8), the species can only be identified by association with other species: *R. clava* can be associated with *M. splendida*, *M. praenuncia* and *D. spinosa* whereas *R. herbsti* can be associated with *D. compacta* which is usually found in large numbers.

Reticypris herbsti McKenzie, 1973

1973 *Reticypris herbsti* n.sp., McKenzie, p. 188.

Diagnosis: *Reticypris* with lateral lobe of hemipenis boot-shaped.

Description: See McKenzie (1973), p. 188-189.

Ecology and distribution: *R. herbsti* is tolerant to higher salinities than *R. clava*. In western Victorian lakes it was found with *D. compacta* at salinities between 99 and 172°/oo whereas, in the lakes near the Coorong Lagoon, it occurred at salinities between 12 and 141°/oo with three supplementary records at 195, 216 and 218°/oo. It is found in high numbers between 104 and 124°/oo salinity.

In a number of specimens, collected in lakes near the Coorong Lagoon, specimens with thin and faintly reticulated shell were seen, whereas others were thicker with a coarse reticulation. Similarly, a ventral ridge was occasionally associated with a coarsely reticulated shell, or also with juveniles. The ecological significance of these differences is not known.

Reticypris kurdimurka n.sp.

Fig. 4.26; Plate IV.28

Diagnosis: *Reticypris* with outer lateral lobe of hemipenis spout-shaped and copulatory sheath heart-shaped.

Description: Carapace. (External) Subrectangular to squarish in lateral view with both valves usually thick; reticulation resembles broad punctation; anterior and posterior similar and broadly rounded; ventrum flat except in the mouth region where it is concave; dorsum arched or depressed in front of the point of greatest height, and at $\frac{1}{3}$ from the anterior, and behind it, it slopes gently; outer lamella thin and peripheral; left valve slightly larger all around and in some specimens the overlap of the left valve over the right one is obvious, at both extremities of the hinge, as it forms smooth elongated humps.

(Internal) Inner lamella slightly broader anteriorly compared to posteroventral area; selvage faint and peripheral in the right valve whereas it is at a distance from the outer margin in left valves; radial pore canals narrow and straight; the hinge consists of a broad groove in the left valve in which the right valve interlocks.

Anatomy. Antennula: (Fig. 4.26a) 7-segmented: length width ratio of last six segments: $^{1}/_{1.25}$, $^{1}/_{1}$, $^{1}/_{2.5}$, $^{1}/_{2}$, $^{1}/_{2}$, $^{1}/_{1}$; natatory setae longer than all segments together.

Antenna: (Fig. 4.26b) Three equal long claws on penultimate segment; 4th claw on distal segment reaching the tip of the other claws and pectinate in male, whereas it is shorter and with smaller teeth in female; natatory setae reaching the tip of the claws.

Mandible: (Fig. 4.26h) Mandibular coxale with seven teeth; palp with distal segment squarish, α bristle short, slim and smooth β bristle short, stout and pilose, γ bristle twice the length of the distal segment and pilose in its distal half.

Rake-like organ: Eight teeth with an additional inner one which is bifid.

Maxillula: (Fig. 4.26c) Distal palp almost squarish and 3rd lobe with two smooth Zahnborsten.

Maxilla: Sexually dimorphic: in male (Figs. 4.26e,f) almost symmetrical: one slightly more arched and narrower than the other; in female (Fig. 4.26g) three smooth setae, the middle one being more than twice the length of the other two which are equal.

FIG. 4.26 *Reticypris kurdimurka* n.sp.

a	antenna
b	antennula
c	maxillula - palp and lobes
d	thoracopoda I
e	maxilla - endopodite, male
f	maxilla - endopodite, male
g	maxilla, female
h	mandible - palp
i	thoracopoda II
j	furcal attachment
k	hemipenis
l	hemipenis
m	furca
n	Zenker organ

a - b, d - f, h - n: holotype adult male

c, g: paratype adult female

Scale: 100 µ


A
B
C
G
D
E
F
H
I
J
K
L
M
N

Thoracopoda I: (Fig. 4.26d) 3rd segment undivided; inner setae small and unequal.

Thoracopoda II: (Fig. 4.26i) As for *R. clava.*

Hemipenis: (Figs. 4.26k,l) Lateral lobe spout-shaped and broadest at mid-length; copulatory sheath heart-shaped.

Zenker organ: (Fig. 4.26n) Elongated with 11 rosettes.

Furca: (Fig. 4.26m) Claws equal and thick; setae equal and small, about ¼ the length of the claws.

Furcal attachment: (Fig. 4.26j) Median branch and long dorsal one gently curving; ventral branch forming a right angle with the dorsal branch and forming a loop distally; vertical rod-like extension near the base of the median branch.

Eye: Cups of nauplius eye fused.

Colour of shell: White when preserved in alcohol.

Size:		L	H		L	H
holotype adult male	LV	565 μ	350 μ	RV	560 μ	330 μ
paratype adult female	LV	600 μ	400 μ	RV	590 μ	375 μ

Type locality: Madigan Gulf, Lake Eyre, South Australia.

Derivation of name: *Kurdimurka* is an aboriginal name for a legendary creature supposed to inhabit the bottom of lagoons and creeks in the Lake Eyre district.

Ecology and distribution: One specimen of *R. kurdimurka* had been originally collected from Lake Eyre North on 28.4.1975 at about 40°/oo salinity when the lake was last flooded (see Bayly, 1976, p. 664 where it is referred to as "undescribed cypridid genus"). Subsequently, it has been collected twice from Madigan Gulf, at Lake Eyre by

Mr. W. Ziegler on 11.12.1974 and 2.12.1975 - no salinity records for these collections are available. Recently, the same species was collected from Lake Annean, 40 km south of Meekatharra, in Western Australia, at 21.3°/oo salinity (see Geddes *et al.*, in press). The Western Australian specimens had a much thinner shell than those from Lake Eyre.

Reticypris walbu De Deckker, 1979

1979 *Reticypris walbu* n.sp., De Deckker, p. 162.

Diagnosis: *Reticypris* with lateral lobe of hemipenis banana-shaped and inner lobe cudgel-shaped.

Description: See De Deckker (1979b) p. 162-164.

Discussion: *R. walbu* was originally described from samples collected in mound springs between Strangways and Curdimurka, near Lake Eyre South in South Australia. Since then it has been recognized from a collection made by Drs. I.A.E. Bayly and W.D. Williams in Lake Buchanan, via Aramac in Northern Queensland, in January 1965. Water salinity was 87.6°/oo (Bayly and Williams, 1973). It has not been found in subsequent collections made at the same lake by Dr. B.V. Timms. Similarly, it is surprising that *R. walbu* has not been collected in Lake Eyre instead of *R. kurdimurka*. Such patchy distribution remains unexplained.

Sarscypridopsis McKenzie, 1977

Type species: *Sarscypridopsis gregaria* (Sars, 1896)

Sarscypridopsis aculeata (Costa, 1847)

Fig. 4.27; Plate IV.29

1847 *Cypris aculeata* n.sp., Costa, p. 11.

1867 *Cypridopsis aculeata* (Costa), Brady, p. 117.

1900 *Cypridopsis aculeata* (Costa), Müller, p. 85.

1977 *Sarscypridopsis aculeata* (Costa), McKenzie, p. 49.

Diagnosis: Subtriangular shell in lateral outline with dorsum straight along the hinge line and forming a sharp obtuse angle with the almost straight posterodorsal area; surface of shell pitted with or without spines; shallow depression above the hinge line as both valves are higher than the hinge line; ventral overlap of right valve over left.

Description: This cosmopolitan species has already been described on numerous occasions. It is therefore unnecessary to provide a description here but it is fully illustrated in Fig. 4.27 and Plate IV.29 as it is recorded for the 1st time in Australia.

Ecology and distribution: *S. aculeata* is a cosmopolitan species which is commonly found in temporary pools. In Australia, it has been collected so far in many pools in Western Australia, South Australia and rarely in Victoria. The salinity range for the species is freshwater to 11.2°/oo with one additional record at 21.3°/oo. This record is much higher than in European waters where the upper salinity is 1.95°/oo (see De Deckker, in press a). This might be the result of an acclimatization to Australian conditions where water in temporary pools is commonly saline.

FIG. 4.27 *Sarscypridopsis aculeata* (Costa, 1847)

a	antennula
b	antenna
c	thoracopoda I
d	maxilla - endopodite
e	maxillula - palp and lobes
f	mandible - palp
g	thoracopoda I
h	furca

a - h: adult female - pond very close to Reel Inlet (coastside), 19 km S. of Mandurah, W.A.

Scale: 100 µ


A
B
C
D
E
F
G
H

Remarks: *S. aculeata* is definitely not a *Cypridopsis* since its right valve overlaps the left one ventrally - this is the opposite in *Cypridopsis*. The difference is also reflected in the male anatomy where the right prehensile palp of the maxilla is larger than the left in *Cypridopsis*, the opposite of *Sarcypridopsis* and *Plesiocypridopsis* Rome, 1965. Unfortunately, no males of *S. aculeata* have yet been found to confirm the transfer of this species to *Sarscypridopsis*.

S. aculeata has a green to dark green shell and often many large pseudopores. In addition, between these pseudopores, either hairs or small spines, are present (see Plate IV.29o,p). These differences are presumably controlled ecologically. It appears therefore that species which are almost identical to *S. aculeata* but which are extremely spinose, as described by Sars (1924) for *Cypridopsis spinifera* Sars, 1924 from South Africa, are to be synonimized to *S. aculeata*. The same applies for the non-spinose species *Cypridopsis obstinata* Barclay, 1968, described from New Zealand by Barclay (1968). The anatomy of the type specimen of the latter species has been examined and is identical to the specimen of *S. aculeata* illustrated in Fig. 4.27.

Strandesia Vavra, 1895

Type species: *Strandesia mercatorum* (Vavra, 1895)

Strandesia phoenix n.sp.

Fig. 4.28; Plate IV.2 j-q

Diagnosis: *Strandesia* without shell ornamentation with left valve larger than right valve all along and overlapping it ventrally except in the anterodorsal area at the extremity of the hinge, where the opposite occurs; ellipsoid in lateral view and oval with pointed end in dorsal view. Valves asymmetrical when viewed from the anterior: greatest extension of the right valve at about $^1/_3$ of the height from the dorsum and of left valve at $^2/_3$.

Description: Carapace. (External) Pseudopunctate ellipsoid shell with dorsum and ventrum gently curved, anterior slightly more rounded than posterior which tapers gently; in dorsal view oval in shape with both ends pointed; in anterior view, valves asymmetrical: greatest extension of the right valve at about $^1/_3$ of the height from the dorsum and of left valve at $^2/_3$. Left valve larger than right one all along and overlapping it ventrally except in the anterodorsal area at the extremity of the hinge where the opposite occurs; normal pores of simple type, some rimmed, others funnel-shaped.

(Internal) Inner lamella broadest anteriorly and almost absent posteriorly in both valves; in left valve flange broad all along except dorsally; inner lamella near the outer margin perpendicular to the flange in anterior of left valve and curved inward in its middle; this flat area is met by the broad selvage of the right valve; selvage faint and peripheral in left valve and broad all along in right valve.

Anatomy: Antennula: (Fig. 4.28a) 7-segmented: length width ratio of last six segments: $^1/_{1.8}$, $^1/_4$, $^1/_1$, $^{1.6}/_1$, $^2/_1$, $^3/_1$; natatory setae as long as last six segments together.

Antenna: (Fig. 4.28c) Four almost equal claws: three on penultimate segment and one on distal segment; natatory setae extending past the tip of the claws.

Mandible: (Figs. 4.28d,f) Mandibular coxale with seven teeth; distal tooth acicular; epipod with five long and one short Strahlen; distal segment of palp rectangular and with long, slim and barren α bristle,

FIG. 4.28 *Strandesia phoenix* n.sp.

a	antennula
b	maxillula - palp and lobes
c	antenna
d	mandible - coxale
e	thoracopoda I
f	mandible - palp
g	maxilla
h	thoracopoda II
i	furcal attachment
j	furca

a - j: holotype adult female

Scale: 100 µ


A
B
C
D
E
F
G
H
I
J

β bristle stout and pilose, γ bristle thick and twice the length of the distal segment and pilose on the inside of its distal half.

Rake-like organ: Six teeth plus one bifid on the inside of each rake.

Maxillula: (Fig. 4.28b) Length width ratio of palp segments: $^{3}/_{1}$, $^{3}/_{1}$; two toothed Zahnborsten on 3rd lobe.

Maxilla: (Fig. 4.28g) Middle seta more than twice the length of the other two which are of almost equal length.

Thoracopoda I: (Fig. 4.28e) 1st segment with two unequal setae, the distal one being pectinate and half the length of the other; 3rd segment undivided in the middle where a long seta occurs.

Thoracopoda II: (Fig. 4.28h) Distal pincers large and distal setae unequal: shortest one curved, with distal half comb-like and half the length of the other smooth one; middle seta on last segment less than half the length of all other setae which are of similar length.

Furca: (Fig. 4.28j) Very long furcal shaft, twice the length of the longest claw; anterior seta more than twice the length of the other seta.

Furcal attachment: Median branch narrow and gently curved; dorsal branch forming an eyelet whereas ventral branch straight.

Colour of shell: Purple.

Size:		L	H		L	H
holotype adult female	LV	840 µ	510 µ	RV	860 µ	540 µ

Type locality: Coastal dune lake at Evans Head, south-west of Lismore, New South Wales.

Derivation of name: From Greek *phoenix* (= purple) for the colour of the shell.

Ecology and distribution: *S. phoenix* has only been collected from the type locality. Water was fresh. No males have been found and no sperms were noticed in the ovigerous females suggesting that the species was parthenogenetic in that locality.

4.3 GENERAL REMARKS ON OSTRACOD ECOLOGY

All studies of non-marine ostracods prior to 1966 in Australia were of a taxonomical nature. No information was ever provided on quality of the water, nor on the environment in which the ostracods had been found. In fact, a great number of ostracod species had been described by Sars who hatched ostracods in his Norwegian laboratory from dried samples of mud and sand sent to him (Sars, 1889a, 1899b, 1896a, 1896b).

The surveys of athalassic (*sensu* Bayly, 1967) saline waters in south-eastern Australia by Bayly and Williams (1966) and Bayly (1970), supplemented by identification of ostracods by De Deckker (1975a), mentioned in these two works, are the first studies to present ecological data for Australian ostracods. More complete information on similar halobiont ostracods was later provided by Geddes (1976) in his seasonal survey of the crustacean fauna of a number of Victorian salt lakes, although not all species of ostracods had been identified at the specific level. In western Victoria also, Timms and Brand (1973) gave some information on the distribution of ostracods in two small saline maar lakes.

The survey of Shiel (1976, 1980) has dealt with the seasonal changes in the composition and abundance of the microcrustacean fauna, among which ostracods were considered, from billabongs in the Murray-Darling river system, and Timms (1970a, 1970b, 1980) mentioned the presence of ostracods in reservoirs and farm dams in eastern Australia. Morton and Bayly (1977), in their study of the ecology of some temporary freshwater pools in Victoria, discussed the presence of ostracods in such habitats and described the seasonality of some of the ostracod species. The taxonomic descriptions of freshwater ostracods from north-western Australia by McKenzie (1966), supplemented by the physico-chemical data of Williams and Buckney (1976) and additional remarks of Williams (1979), for the same localities from which the ostracods had been originally collected, are of interest. Similarly, the descriptions of ostracods from mainly athalassic saline waters from Western Australia and South Australia by McKenzie (1978), supplemented by the same work of Williams and Buckney (1976) for the ostracod localities, are informative on salinity tolerance of some species.

Finally, the work of De Deckker and Geddes (1980) deals with the seasonal study, over one year, of the ostracod fauna, and other crustaceans, from a number of athalassic salt lakes near the Coorong Lagoon in South Australia. The survey of athalassic saline lakes in Western Australia by Geddes *et al.* (in press) supplies more ecological information on halobiont ostracods.

The data presented here relies on the abovementioned works in addition to that obtained from collections made mainly in southern Australia, some of which were received from a number of colleagues.

Also of interest to studies on Australian ostracods is the work of Barclay (1966) in New Zealand in which the seasonal fauna of freshwater temporary and permanent pools is studied, which includes some ostracod species also found in Australia.

The following remarks relate to the Australian ostracod fauna.

4.3.1 Athalassic saline water fauna

Compared to other parts of the world, the ostracod fauna inhabiting athalassic saline waters in Australia is unusually diverse. In Europe, 44 species are known from athalassic saline waters (five are of marine ancestry and another 10 are halobiont species); in Australia there are 37 species (2 of marine ancestry and 30 others halobiont); in North America 14 species (1 marine) and Canada at least 13 (no marine). Data for other countries are lacking (De Deckker, in press a). Only one ostracod of marine ancestry, *Cyprideis torosa* (Jones, 1850) is found mainly in the Northern Hemisphere in waters of salinities higher than that of the sea, whereas many non-marine species can tolerate high salinity values. The diversity of halobiont species in Australia is probably the result of a long history of aridity. This fauna is grouped into six endemic genera (*Australocypris*, *Diacypris*, *Mytilocypris*, *Platycypris*, *Reticypris* and *Trigonocypris*) which have no marine or direct freshwater ancestor (however, one species *T. timmsi* De Deckker, 1976, has been collected once and was found in freshwater, and *D. thomsoni* (Chapman, 1963) is recorded from New Zealand but has not been examined). It is worth noting too that only two species of halobiont ostracods in Australia, *Cyprideis australiensis* and *Leptocythere lacustris*, are of marine ancestry. These two species are not found in ephemeral waters, for their eggs cannot withstand periods of desiccation, whereas the other halobiont ostracods, grouped in the family Cyprididae, are found in both ephemeral and permanent waters.

There are also a few euryhaline species found in saline waters in Australia. Some of these are cosmopolitan species (*Sarscypridopsis aculeata*, *Eucypris virens* and *Ilyocypris australiensis*) whereas others are endemic to Australasia (e.g. *Limnocythere mowbrayensis*).

The range of salinities in which ostracods are found in Australian waters is summarized in Table 4.1. Data for western Victoria only are presented in Table 4.2 and for South Australia in Table 4.3. For the Victorian localities, the data update the ranges for the ostracods obtained by Geddes (1976) and Williams (1978). Examination of these

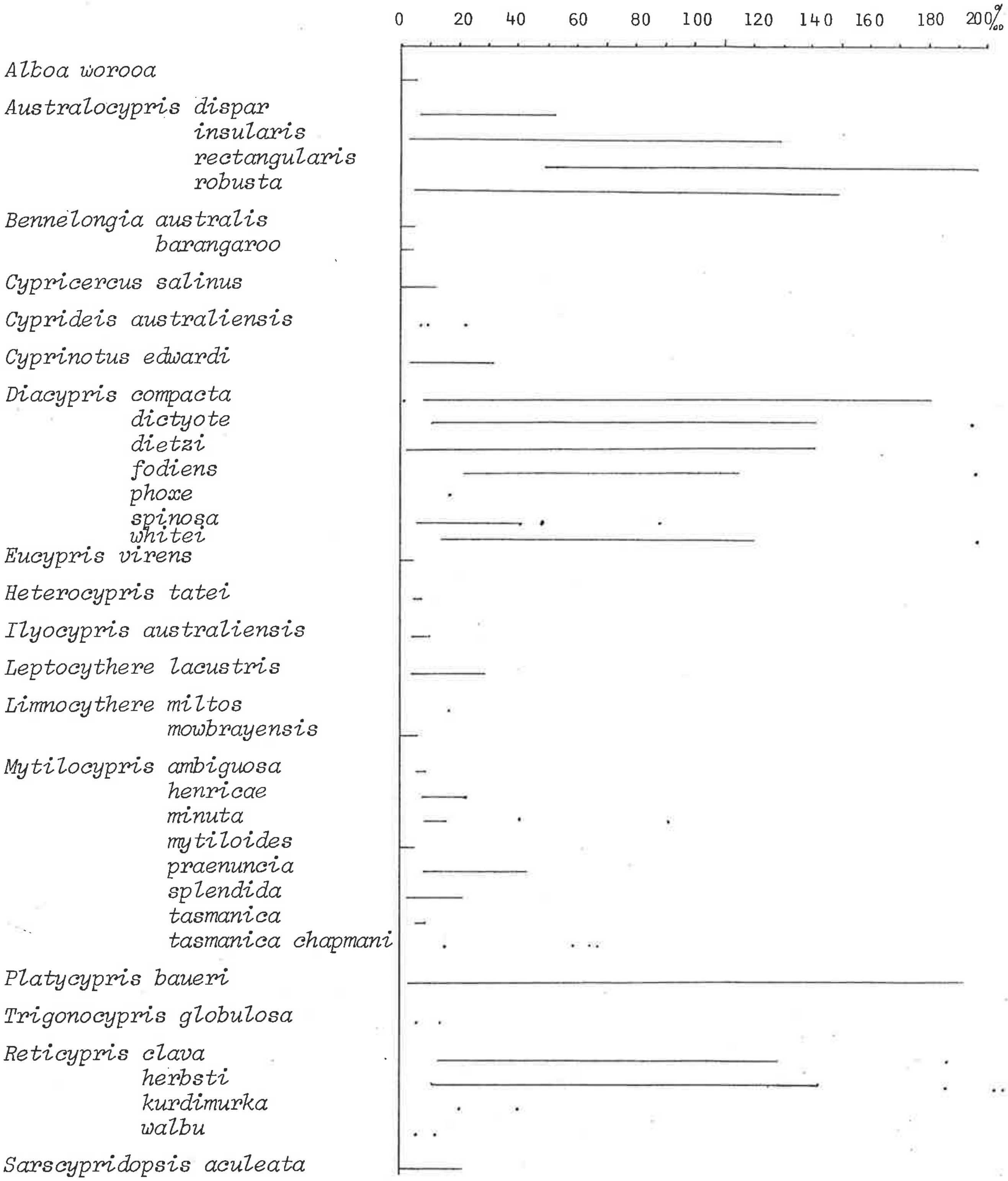


TABLE 4.1 Salinity ranges for ostracods found in Australia above 3°/oo.

Field data from Bayly (1970), Bayly and Williams (1966, 1973), De Deckker (1975), De Deckker and Geddes (1976), Geddes (1976), Geddes *et al.* (in press), McKenzie (1966b), Williams (1978), Williams and Buckney (1976) and from personal collections.

The Australian ostracods not recorded in this table have never been collected in waters of salinity above 3°/oo.

tables, reveals that the range of salinity tolerance of the Australian ostracod fauna is much greater than for other halobiont and euryhaline ostracods in other parts of the world as discussed by De Deckker (in press a) with the exception of *Limnocythere staplini* Gutentag and Benson, 1962, in Canada, where it can live in water up to 205°/oo salinity (see De Deckker, in press a).

4.3.2 Salinity tolerance

From Tables 4.2, 4.3, it is possible to see that the salinity range of some species varies from one area to another. For example, *Australocypris robusta* is found in waters of a more restricted salinity range in the lakes near the Coorong Lagoon in South Australia (15-38°/oo), than in western Victoria near Colac where the range is 7-145°/oo. This phenomenon could be explained by the fact that since no other large mytilocypridinid ostracod occurs in highly saline waters in western Victoria near Colac, *A. robusta* has developed a tolerance to a broader range of salinities there, whereas in the lakes near the Coorong Lagoon, the range is narrower since there are three other *Australocypris* species present in that area: *A. insularis*, *A. rectangularis* and *A. dispar* (it is important to note that two species of *Australocypris* are rarely collected together in Australia - these large ostracods appear to be exclusive of one another).

4.3.3 Species diversity in different areas

Another phenomenon is noticeable when comparing western Victorian and South Australian ostracod faunas from athalassic saline lakes: ostracod species are more diverse in the lakes near the Coorong Lagoon. In many of the salt lakes near the Coorong Lagoon, five of six co-occurring species were commonly collected (seven was the maximum

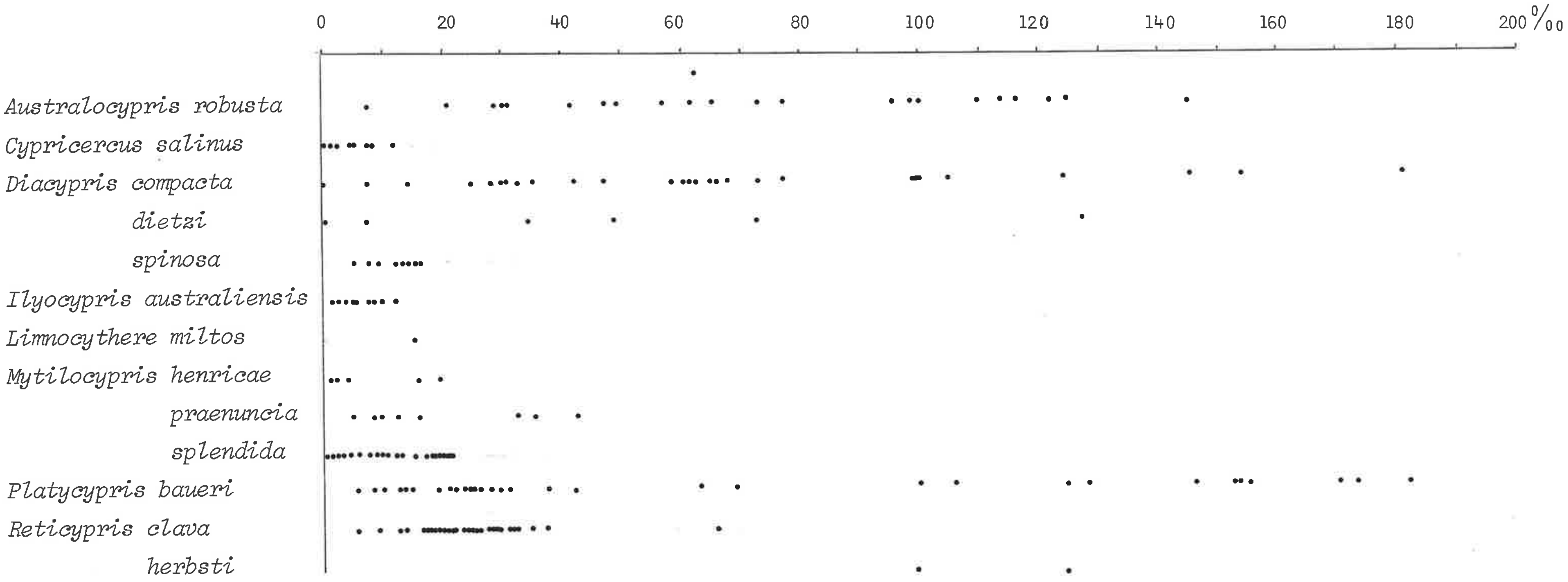


TABLE 4.2 Salinities at which ostracods have been recorded in saline lakes in western Victoria during bimonthly sampling of 12 lakes over one year (1979-1980) and a survey of 65 lakes in January 1980.

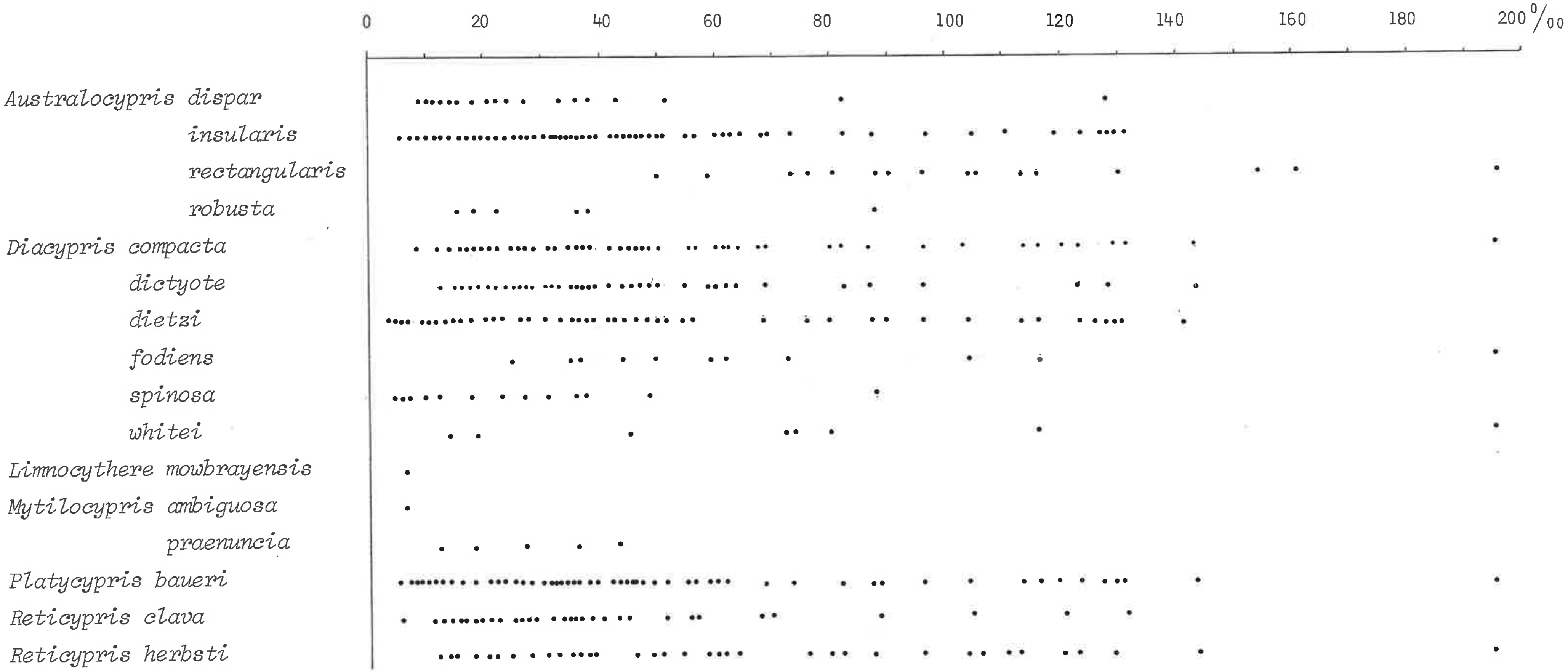


TABLE 4.3 Salinities at which ostracods have been recorded in ephemeral saline lakes near the Coorong Lagoon, South Australia. (Data from De Deckker and Geddes, 1980)

number ever recorded) (De Deckker and Geddes, 1980) whereas in a survey in western Victoria of 79 lakes sampled once and of 12 lakes sampled bimonthly over one year, four co-occurring species of ostracods were often found (only once, in Lake Kariah, were seven species collected together at salinity 4.83°/oo - note that some of these species are euryhaline and the lake seems to retain permanent water). The probable explanation for this is that lakes near the coast are more favourable sites for species establishment since they are likely to be filled every year, compared to lakes inland which are filled less often. This would explain the paucity of ostracod fauna recorded by Bayly (1976) from his collections taken at Lake Eyre when it was filled. This remark is even more applicable to animals which cannot withstand extensive periods of desiccation (e.g. the gastropods *Coxiella* spp., the halobiont isopod *Haloniscus searlei*, the amphipods *Austrochiltonia* spp. and the foraminifers *Elphidium* sp. and *Trochammina* sp.). These organisms are at present not found in the central area of Australia, whereas ostracods, which have eggs adapted to withstand long periods of desiccation, can be found there.

It is also likely that the lower diversity of ostracod species in western Victoria compared to South Australia results from the rapid and drastic changes in climates which operated during Holocene and pre-Holocene times and which must have affected lakes in western Victoria (for Holocene, see Chapter 5) more than those near the coast. This effect is again related to periodicity of rain, lakes near the coast receiving more rain. The presence of one species only of the anostracan *Parartemia* in western Victoria and two species in the lakes near the Coorong (see De Deckker and Geddes, 1980) could be explained in similar terms.

Species diversity for the collections taken in Western Australian lakes by Geddes *et al.* (in press) cannot be accounted for since the four major areas, which they sampled and which are well separated from one another, had been sampled only once at about the same time of the year. Therefore, presence or absence of species in these collections could have been the result of the amount of rain the different areas had received prior to collecting that year, rather than being a direct reflection of their geographical position in relation to rain periodicity.

4.3.4 Hatching of ostracods

Observations resulting from intense sampling of athalassic ephemeral saline lakes near the Coorong Lagoon led to the conclusion that hatching of ostracod species in such lakes is likely to be triggered by particular salinity levels of the water in which the eggs occur. Rarely did the ostracods hatch rapidly after rainfall filled the lakes when salinities were high (resulting from dissolution of salt present at, or below, the surface of the lakes) compared to later stages when salinities were lower. Hatching usually occurred during the periods of low salinities registered in the lakes.

Additionally, it was noticed that some species of halobiont ostracods can hatch at high salinities. This has already been pointed out by Geddes (1976) who gave ranges for hatching of *Australocypris robusta* (8.5-108°/oo), *Diacypris* sp. (18-94°/oo) and *Platycypris* sp. (= *P. baueri*) (12-126°/oo). It is apparent, however, that *A. robusta* does not need to hatch at low salinities since this species is present in the permanent Lakes Keilambete and Gnotuk, where salinity is known to remain in the vicinity of 60°/oo (see data in Table 5.1). It is worth pointing out here that the cytheracean ostracods

Leptocythere lacustris and *Cyprideis australiensis*, which require permanent water to reproduce, are not found in either of these two lakes. These species must therefore require much lower salinities to either reproduce, or live for a long period of time.

Additionally, *A. rectangularis* was never collected during bimonthly sampling trips over one year in athalassic saline lakes near the Coorong Lagoon, below 50°/oo (De Deckker and Geddes, 1980). There is even evidence that this species hatched in two different lakes above 73°/oo in one and above 115°/oo in the other (De Deckker and Geddes, 1980). Although *Platycypris baueri* can hatch at low salinities (Geddes, 1976; De Deckker and Geddes, 1980), it seems that this species is usually more numerous at high salinities (see De Deckker and Geddes, 1980). This phenomenon cannot be explained because it could be the result of either a better hatching potential at high salinities or of other factors which would control its numbers at different salinities (e.g. elimination of some competitive or predating species at high salinities) or of a combination of these factors.

The situation is different for temporary pool fauna. Since temporary pools (*sensu* Gauthier, 1951; see Chapter 3) are short-lived, and since, in many areas of Australia, rainfall is erratic, it would seem appropriate for the ostracods to hatch rapidly after the filling of the pools. This appears to be the case since hatching of ostracods has been noticed in pools soon after filling with rain. This is an obvious adaptation to the Australian climatic conditions, like those of Algeria and Tunisia as pointed out by Gauthier (1928a). Therefore, there is no apparent seasonality in hatching and population composition compared to that of pools in Europe, well illustrated by Alm (1919) and Tetart (1974). Furthermore, Gauthier (1951, p. 316) pointed out that temperature only has a secondary effect, if any, on the fauna of temporary pools which are eurytherm in North Africa. This is likely to be the case in Australia whereas in Europe, the fauna is definitely controlled by temperature (see Alm, 1916; Tetart, 1974).

4.3.5 Fauna of permanent and ephemeral waters

There is a certain element of the ostracod fauna which is only found in permanent waters. These ostracods have eggs which cannot withstand desiccation. Some of them have already been mentioned earlier in this chapter: the cytheracean species *Gomphodella maia*, *G. australica*, *Leptocythere lacustris*, *Cyprideis australiensis*. In addition, two undescribed species belonging to *Darwinula* and *Gomphocythere* have been collected in Queensland in Toomba Swamp, via Charters Towers (21.6.1974). Although they are known to occur in ephemeral waters elsewhere (Klie, 1938), species of *Limnocythere* in Australia occur mainly in waterbodies which have retained water, at least for many years (there is one rare record, however, of *L.* sp. in De Deckker and Geddes, 1980 (= *L. mowbrayensis*) in an ephemeral lake).

The rest of the ostracod fauna in Australia can be found in both permanent or ephemeral waters. There is a difference, however, in some species depending on the type of water they inhabit. For example, species of *Candonocypris novaezelandiae*, when present in permanent waters such as large reservoirs (e.g. Milbrook Reservoir, near Adelaide in South Australia) or lakes (e.g. Lake Purrumbete where it was originally described as *C. assimilis* by Hussainy, 1969a) are represented by both sexes whereas in farm dams, where *C. novaezelandiae* is often found, only females are collected. This appears to be the same for *Bennelongia australis* in Western Australia which was represented by a bisexual population in permanent water and for which only females were found in temporary pools. This phenomenon was partly substantiated by Sars' work in which species of *Bennelongia*, *Ilyodromus* and *Candonocypris novaezelandiae* raised in aquaria from dried mud, were never represented by males. In ephemeral environments, the mode of reproduction for some species is parthenogenetic. Both sexes of the halobiont ostracods, namely those mentioned in section 4.3.1, are always found in ephemeral and permanent salt waters but only the sex ratio varies during the year.

4.3.6 Mode of locomotion

An unusual feature about the ostracod fauna in Australia is the large number of planktic species. This particular group of ostracods is represented by the halobiont species belonging to *Australocypris*, *Diacypris*, *Platycypris*, *Trigonocypris*, *Mytilocypris* and *Reticypris*. Species in the latter two genera can swim actively but are usually found swimming near the bottom of waterbodies. Some species of *Australocypris*, *Diacypris* and *P. baueri* have also been observed to burrow in the upper few millimetres of soft sediment covering lake floors. The planktic mode of locomotion is thought to have evolved for halobiont ostracods in Australia because many organisms (e.g. fishes), which could prey on these slower moving ostracods in the open water, are usually absent in saline waterbodies, especially those which benefit from a closed drainage system. The diet of these ostracods has probably changed accordingly with the planktic mode of life. Many remains of the red planktic copepod *Calamoecia* sp. have been found in the gut and faeces of large *Australocypris* sp. specimens. Nothing is known of the diet of *Diacypris* spp.

There are also free-swimming ostracods in Australia which occupy the pleuston by swimming upside down near the surface film of water and often adhere to it (e.g. *Newnhamia* and *Kennethia*) as in other parts of the world (e.g. *Notodromas, Oncocypris, Centrocypris*).

Interstitial ostracods have also been recognized in Australia with species of *Ilyodromus* collected in the psammon of Lake Pedder (Bayly, 1973). *Platycypris baueri* and *Gomphodella maia* are also thought to be interstitial ostracods (see Chapters 6 and 8 respectively). Additionally, a number of undescribed ostracods has been collected in water percolating in holes dug in dry river beds in the Flinders Ranges in South Australia.

Terrestrial ostracods also occur in Australia (De Deckker, 1980b, and in press b).

4.3.7 Variation in size and ornamentation of the shell

Size and ornamentation of ostracod shells are known to vary. This is best illustrated for the shell of *Leptocythere lacustris* (Plate IV.25) which has a variable external reticulation. Similarly, the width of the dorsal "keel" of *Diacypris spinosa* can differ on specimens in one population (see De Deckker, 1980a). The extension of the lateral lobe of *Limnocythere mowbrayensis* has already been the focus of many discussions (see Chapters 6, 8 and Hornibrook (1955), De Deckker (1980a)).

During the monthly survey over one year of athalassic saline lakes near the Coorong by De Deckker and Geddes (1980), it was noticed that in the same lake, the size of adults of *Australocypris* and *Diacypris* species were much larger during winter months than in spring and early summer. In the latter case, the temperature was much warmer, salinity higher and water depth rapidly receding.

Therefore, it appears, although this is not proven, that variations in temperature, salinity, oxygen and food supply (and perhaps other factors), are likely to have a direct controlling effect on size, shape and ornamentation of ostracod shells. This is especially the case in ephemeral and/or saline environments where the abovementioned factors are known to vary during the year.

4.3.8 Habitats

The following habitats can usually be recognized by their ostracod fauna.

Temporary pool which can occasionally retain slightly saline water (up to ~5°/oo).

Eucypris virens
Sarscypridopsis aculeata
some *Bennelongia* spp.
Heterocypris spp.
Ilyodromus spp.

Permanent and fresh waterbody.

Newnhamia spp.
Cypretta spp.
Candonocypris novaezelandiae
in large waterbodies also *Gomphodella* spp.
Limnocythere spp.

Semi-permanent (= filled for more than a few months) pools and dams.

Ilyocypris australiensis
Candonocypris novaezelandiae
Cypretta spp.

Slowly flowing waters.

Cypretta spp.

Permanent salt lake (salinity $\sim$ sea water or below).

Cyprideis australiensis
Leptocythere lacustris

Ephemeral or permanent salt lake.

Australocypris spp.
Diacypris spp.
Mytilocypris spp.
Platycypris baueri
Reticypris spp.

their distribution is controlled by salinity - see Tables 4.1-4.3.

4.4 DISTRIBUTION OF OSTRACODS IN AUSTRALIA

It is important to be aware that information on distribution of ostracods in Australia is likely to be fragmentary since many areas have never been sampled and extensive study has not been made of those which have. For example, collections from Queensland, the Northern Territory, central Australia, north-western Australia, western New South Wales and Tasmania are few. Additionally, many areas have only been sampled once (e.g. the survey of Western Australian lakes by Geddes *et al.* (in press)).

From the information already published on the distribution of ostracods (most of it, up to 1973, is provided in De Deckker and Jones, 1978) and from collections made during the preparation of this thesis (see section 4.2 for individual species) and, finally, from others received from various colleagues all over Australia, it is possible to provide the following generalities.

4.4.1 Diversity

As discussed earlier, ostracod species appear to be more diverse near the south-east coast, partly because this area is more intensively sampled, but also because rainfall periodicity is more constant in that area. Diversity also appears to decrease towards the arid centre of Australia, this also being related to rainfall periodicity. There are exceptions to this generalized rule since, for example, the Nullarbor Plain, although in its southern part bordered by the sea, is so arid that it probably has a very poor ostracod fauna (samples from that area have been restricted to a few permanent water holes used by aborigines and have yielded many specimens of *Sarscypridopsis* sp. and *Heterocypris tatei*).

4.4.2 Endemic fauna versus other faunas

The most characteristic feature of the Australian fauna is its large endemic halobiont fauna. It includes many endemic genera: *Platycypris*, *Reticypris*, *Mytilocypris*, *Australocypris*. Another genus, *Diacypris*, groups seven species in Australia but is represented by one species *D. thomsoni* in New Zealand.

Part of the ostracod fauna in Australia is characterized by a great number of endemic species which belong to genera found elsewhere (e.g. *Cyprinotus*, *Heterocypris*, *Cypretta*, *Ilyodromus* etc.). These are mainly freshwater species.

Other species which occur in Australia are also found in adjacent areas, such as New Zealand and south-east Asia (e.g. *Newnhamia fenestrata*: Australia, New Zealand, Java; *Candonocypris novaezelandiae*: Australia, New Zealand and New Caledonia; *Cypretta viridis* and *Limnocythere mowbrayensis*: Australia, New Zealand).

Finally, there is a number of cosmopolitan species (e.g. *Sarscypridopsis aculeata*, *Eucypris virens*) which is also found in Australia. However, it is not known whether this fauna has been introduced to Australia by European man since no fossil material of these species has yet been found. It is expected that this fauna has been in Australia for more than 200 years because of its wide distribution.

The ostracod *Ngarawa dirga* which has so far only been found in a few mound springs on the southern margin of the Great Artesian Basin in South Australia (De Deckker, 1979b; Mitchell, in press) belongs to an endemic sub-family. This ostracod must have evolved for a long period of time in these mound springs which are characterized by permanent water, and it has developed a particular adaptation to live and crawl in mound seeps where only a film of water usually occurs (De Deckker, 1979b).

It appears also that the Australian continent is the centre of radiation for a number of species which belong to genera represented by fewer species in other areas. *Ilyodromus* is more diversified in Australia than in New Zealand and even more than in other parts of the world (see data in Danielopol and McKenzie, 1977, and section 4.2); similarly *Bennelongia* is more diversified in Australia than in New Zealand and south-east Asia.

4.4.3 Gondwana fauna

There does not seem to be any obvious group of ostracods in common with southern continents' (having formed parts of the old Gondwana Land) faunas apart from the terrestrial ostracods grouped under the genus *Mesocypris* and some members of the Limnocytherinae *Mesocypris* species occur in Africa, Madagascar, New Zealand and Australia (De Deckker, in press b) (No data on litter fauna is available for South America). Since they are unlikely to be transported by birds, because few migratory birds frequent rainforests where terrestrial ostracods are found, they must have evolved separately since the break up of Gondwana. The Limnocytherinae, *sensu* Colin and Danielopol (1978) group some of the following species: *Gomphodella* spp. and *Gomphocythere* sp. (an undescribed species is recorded from Toomba Swamp, via Charters Towers in Queensland) in Australia, *Gomphocythere* spp. in New Zealand, *Cytheridella* spp. and *Gomphocythere* spp. in Africa. Since it appears that these ostracods cannot be dispersed effectively by birds, contrary to the statement of McKenzie and Hussainy (1968) - otherwise identical species would be found in Australia, Africa and New Zealand today - they must therefore be part of an ancient group already present in Gondwana before the break up of this large land mass.

4.4.4 Poorly diversified candonine fauna in Australia

Danielopol (1977) illustrated the large diversity and radiation of species belonging to the Candoninae in European waterbodies and interstitial waters. There is no evidence so far of the occurrence of such diversity in Australian waterbodies (however, interstitial waters have rarely been investigated here), although ostracods grouped in the Candoninae have been found (*Candona lutea* King, 1855, *C. stobarti* (King, 1855), *Candonopsis tenuis* (Brady, 1886), *Candona tecta* n.sp. (see Chapter 6)). Undescribed species have also been found in the interstitial waters in a dry creek in the Flinders Ranges and in Franklin Cave in Tasmania. This apparent low diversity in Australia could result from the high proportion of saline waters here unfavourable to most candonine species which are more adapted to live in fresh waters.

PLATE IV.1

Alboa worooa n.gen., n.sp.

a	RV internal, female paratype
b	LV internal, female paratype
c	RV external, female paratype
d	LV external, female paratype
e	RV internal, male holotype
f	LV internal, male holotype
g	LV external, male paratype
h	RV external, male paratype
i	C showing RV, female paratype
j	C showing LV, female paratype
k	C dorsal, male paratype
l	C ventral, male paratype
m	C showing RV, male paratype
n	C showing RV, posterior detail of h
o	C anterior, male paratype
p	C dorsal, anterior detail of k

Scale: 1 - 500 μ for a - m
2 - 50 μ for n
3 - 50 μ for p

LV, RV = left valve, right valve
C = carapace
All views are lateral ones except when indicated.

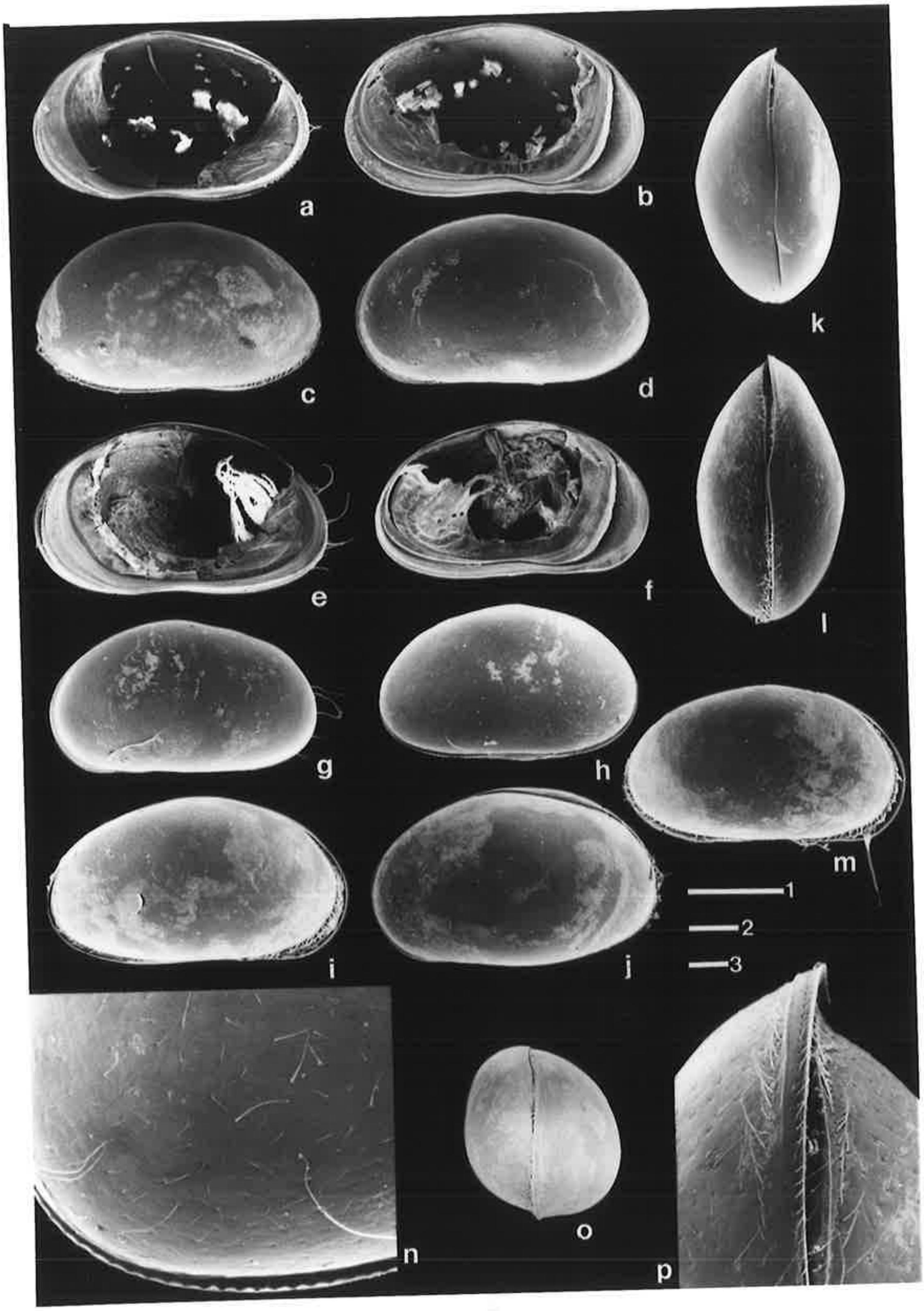

a
b
k
c
d
e
f
l
g
h
m
1
2
i
j
3
n
o
p

PLATE IV.2

Australocypris dispar n.sp.

a	LV internal, female paratype
b	RV internal, female paratype
c	LV internal, male holotype
d	RV internal, male holotype
e	C showing LV, female paratype
f	C showing RV, male paratype
g	C dorsal, female paratype
h	C dorsal, male paratype
i	C ventral, female paratype

Strandesia phoenix n.sp.

j	LV internal, female holotype
k	RV internal, female holotype
l	C showing LV, female paratype
m	C showing RV, female paratype
n	C dorsal, female paratype
o	C anterior, detail of p
p	C anterior, female paratype
q	C ventral, female paratype

Scale: 1 - 1,000 μ for a - i
2 - 200 μ for j - n, p - q
3 20 μ for o

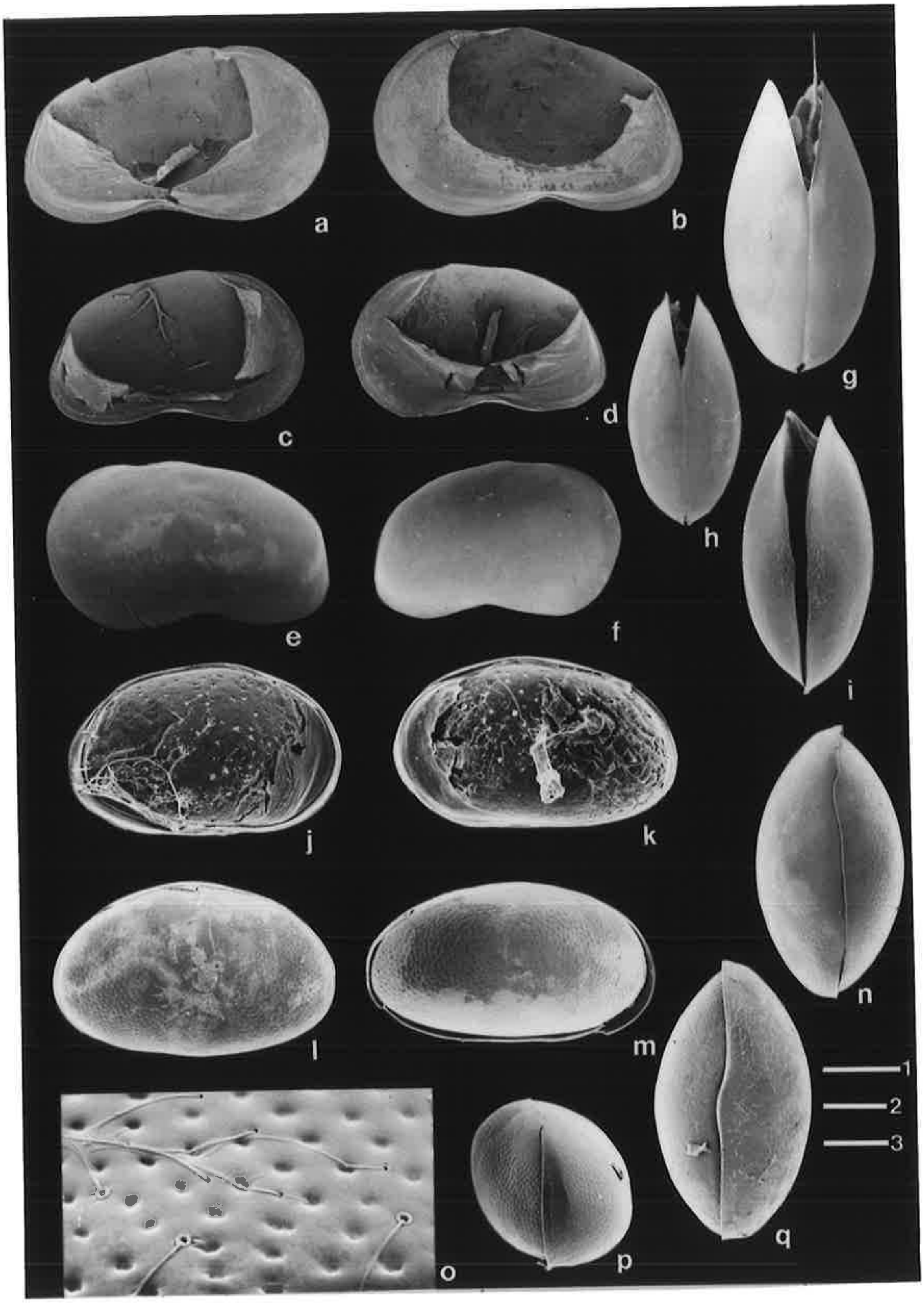

a
b
g
c
d
h
e
f
i
j
k
n
l
m
1
2
3
q
o
p

PLATE IV.3

Bennelongia australis (Brady, 1886) n.gen.

a	LV internal, male
b	RV internal, male
c	LV internal, female
d	RV internal, female
e	LV external, female
f	RV external, female
g	LV internal, juvenile
h	RV internal, juvenile
i	C showing RV, female
j	C showing RV, male
k	C dorsal, female
l	C ventral, female

a - l: Creek pool flowing across the road, 2 km N. of Leonora, W.A.

Scale: 500 μ

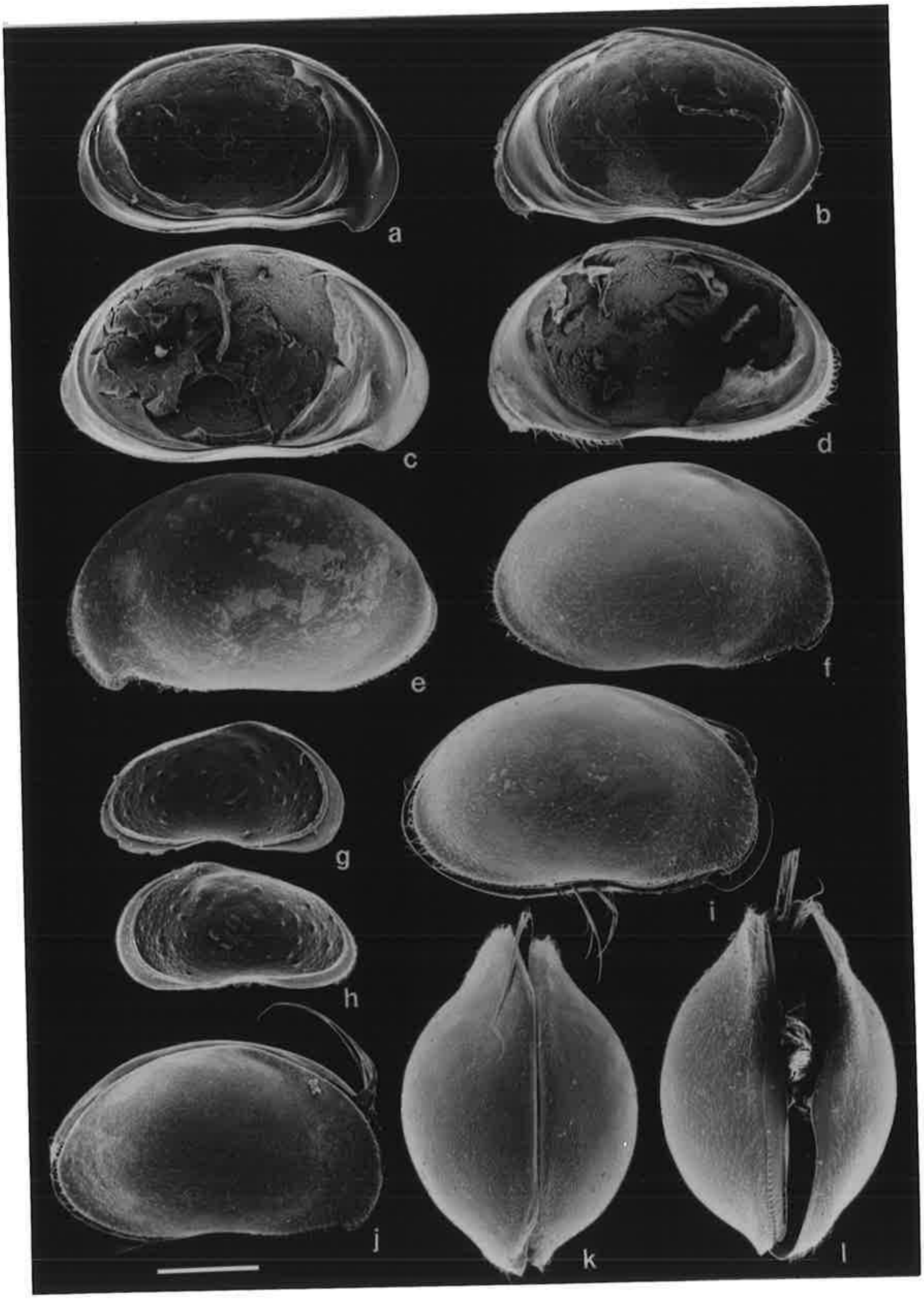

a
b
c
d
e
f
g
h
i
j
k
l

PLATE IV.4

Bennelongia australis (Brady, 1886) n.gen.

a	RV internal, detail anterior of Plate IV.3d
b	LV external, detail anterior of Plate IV.3e
c	LV internal, detail anterior of Plate IV.3a
d	C showing RV, detail anterior of Plate IV.3i
e	LV internal, detail central muscle scar area of Plate IV.3g
g	C dorsal, enlargement of Plate IV.5 1
h	C ventral, detail anterior of Plate IV.5k
f	C dorsal, enlargement of Plate IV.5o
i	C ventral, detail anterior of Plate IV.5p
j	C dorsal, detail of Plate IV.4f

a - e: Creek pool flowing across the road, 2 km N. of Leonora, W.A.

f - j: Roadside pool, 5 km S. of Cunderdin, W.A.

Scale: 1 - 100 μ for a - d, h
2 - 50 μ for e
3 - 100 μ for f
4 - 50 μ for g
5 - 20 μ for i

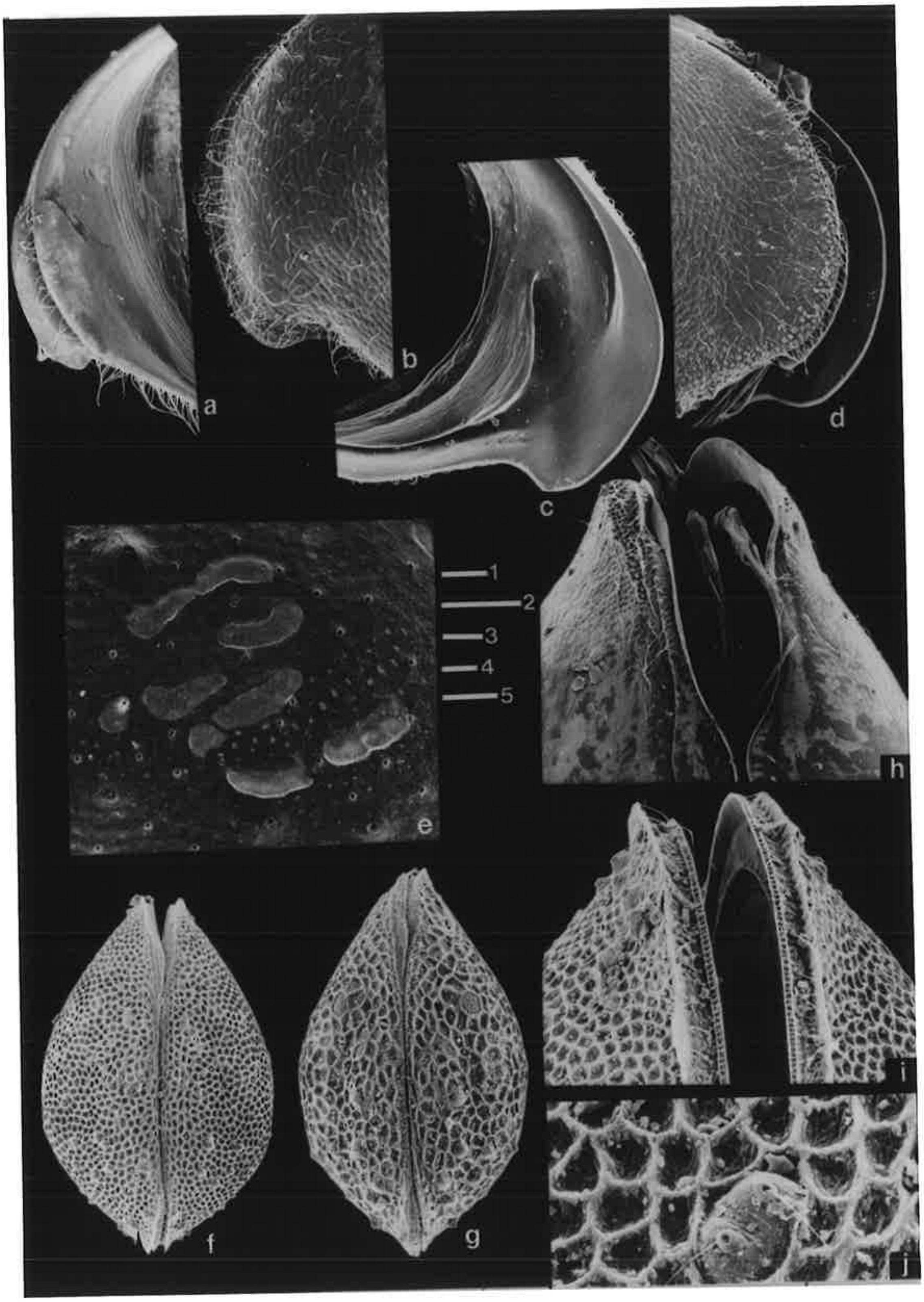

a
b
c
d
1
2
3
4
5
e
h
i
f
g
j

PLATE IV.5

Bennelongia australis (Brady, 1886) n.gen.

a	RV internal, female
b	LV internal, female
c	LV external, female
d	RV external, female
e	C dorsal, female
f	C showing RV, female
g	RV internal, juvenile
h	LV internal, juvenile
i	LV external, juvenile
j	RV external, juvenile
k	C ventral, female
l	C dorsal, juvenile
m	C dorsal, juvenile
n	C dorsal, juvenile
o	C ventral, juvenile
p	C ventral, detail posterior of k
q	RV internal, detail anterior of a
r	LV internal, detail anterior of b
s	RV internal, detail posterior of a

a - s: Roadside pool, 5 km S. of Cunderdin, W.A.

Scale: 1 - 250 μ for a - o

2 - 100 μ for p - s

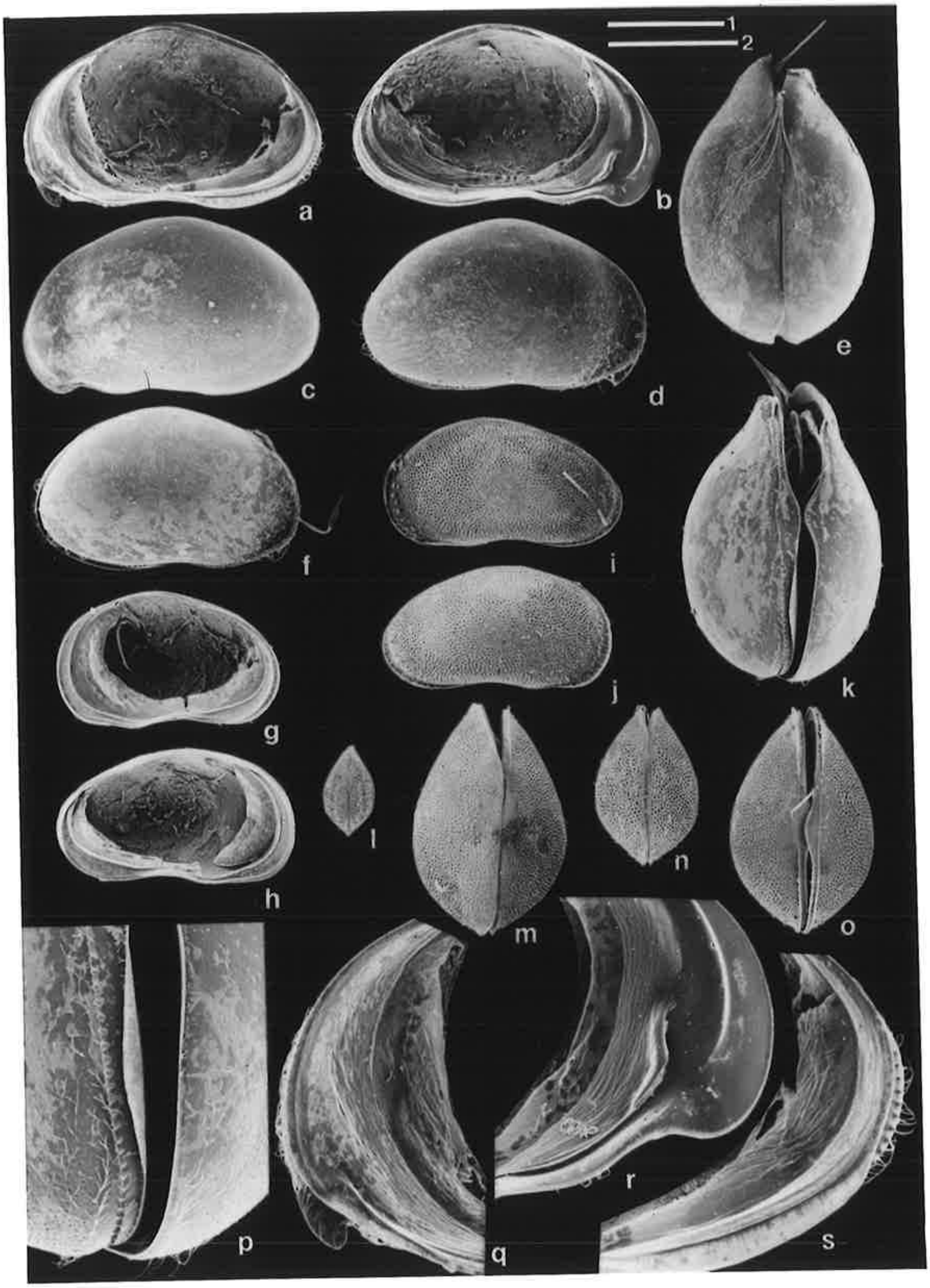

1
2
a
b
c
d
e
f
i
k
g
j
h
l
m
n
o
p
q
r
s

PLATE IV.6

Bennelongia barangaroo n.gen., n.sp.

a	LV internal, male
b	RV internal, male
c	LV external, female
d	RV external, female
e	C dorsal, female
f	LV external, male
g	RV external, male
h	C dorsal, juvenile
i	C showing RV, male
j	C showing RV, female
k	C dorsal, male
l	C ventral, female
m	C ventral, juvenile
n	LV internal, detail anterior of adult female
o	RV internal, detail anterior of adult female
p	C showing RV, detail anterior of j
q	RV external, detail anterior of d
r	RV internal, detail posterior of b

a - r: Lake Buchanan, Qld.

Scale: 1 - 250 μ for a - m
2 - 100 μ for n - o; 50 μ for q
3 - 50 μ for p
4 - 100 μ for r

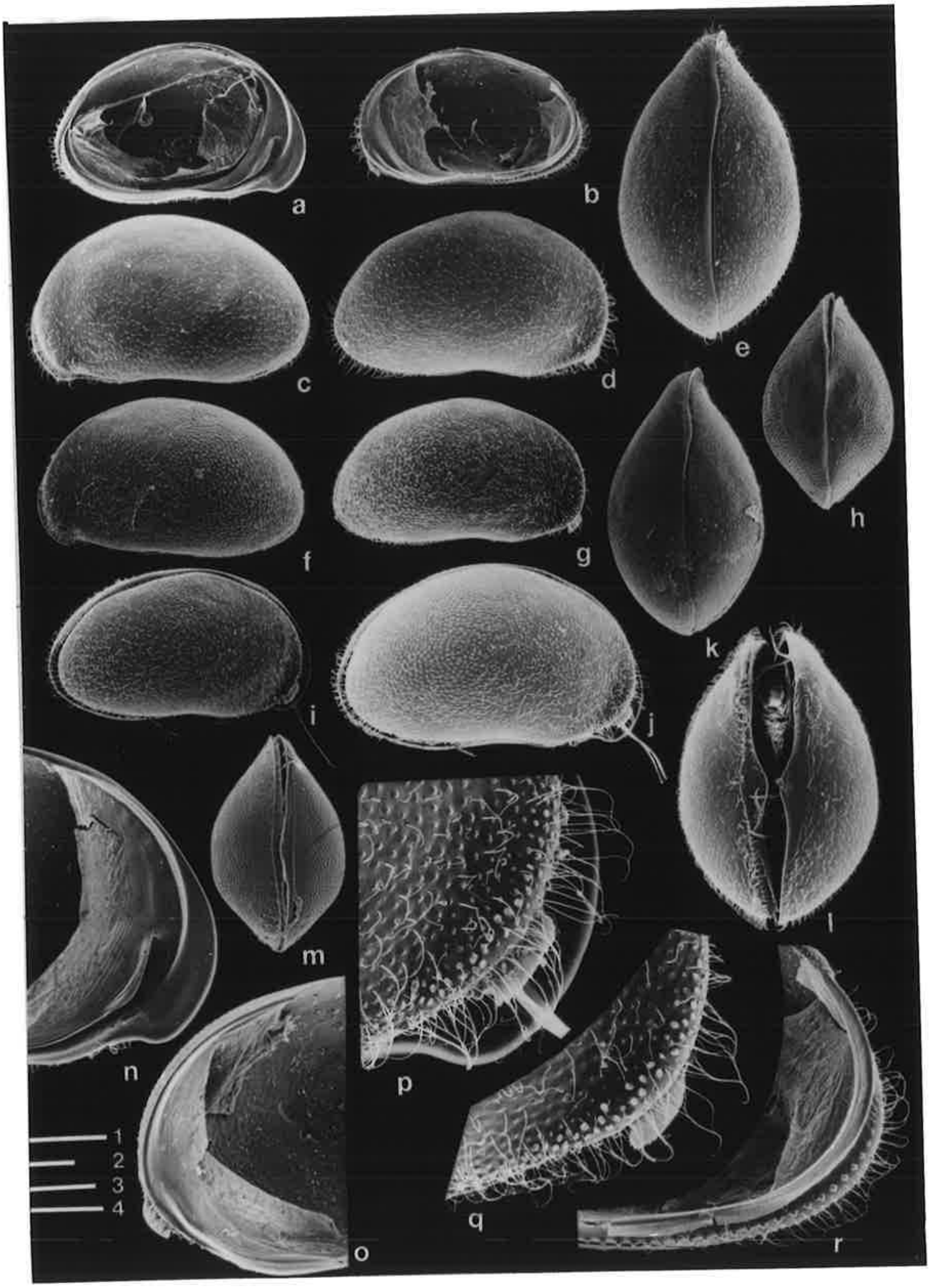

a
b
c
d
e
f
g
h
i
j
k
l
m
n
o
p
q
r
1
2
3
4

PLATE IV.7

Bennelongia barangaroo n.gen., n.sp.

a	LV internal, female
b	RV internal, female
c	C dorsal, female
d	RV external, female
e	LV external, female
f	C ventral, female
g	C showing RV, female
h	LV internal, juvenile
i	RV internal, juvenile
j	C dorsal, juvenile
k	C showing RV, juvenile
l	C showing RV, enlargement of k
m	C showing RV, juvenile
n	LV internal, anterior detail of a
o	C dorsal, anterior detail of j

a - o: Granite pool at Newmann's Rocks, 140 km E. of Norseman, W.A.

Scale: 1 - 500 μ for a - k, m

2 - 200 μ for l, n

3 - 50 μ for o

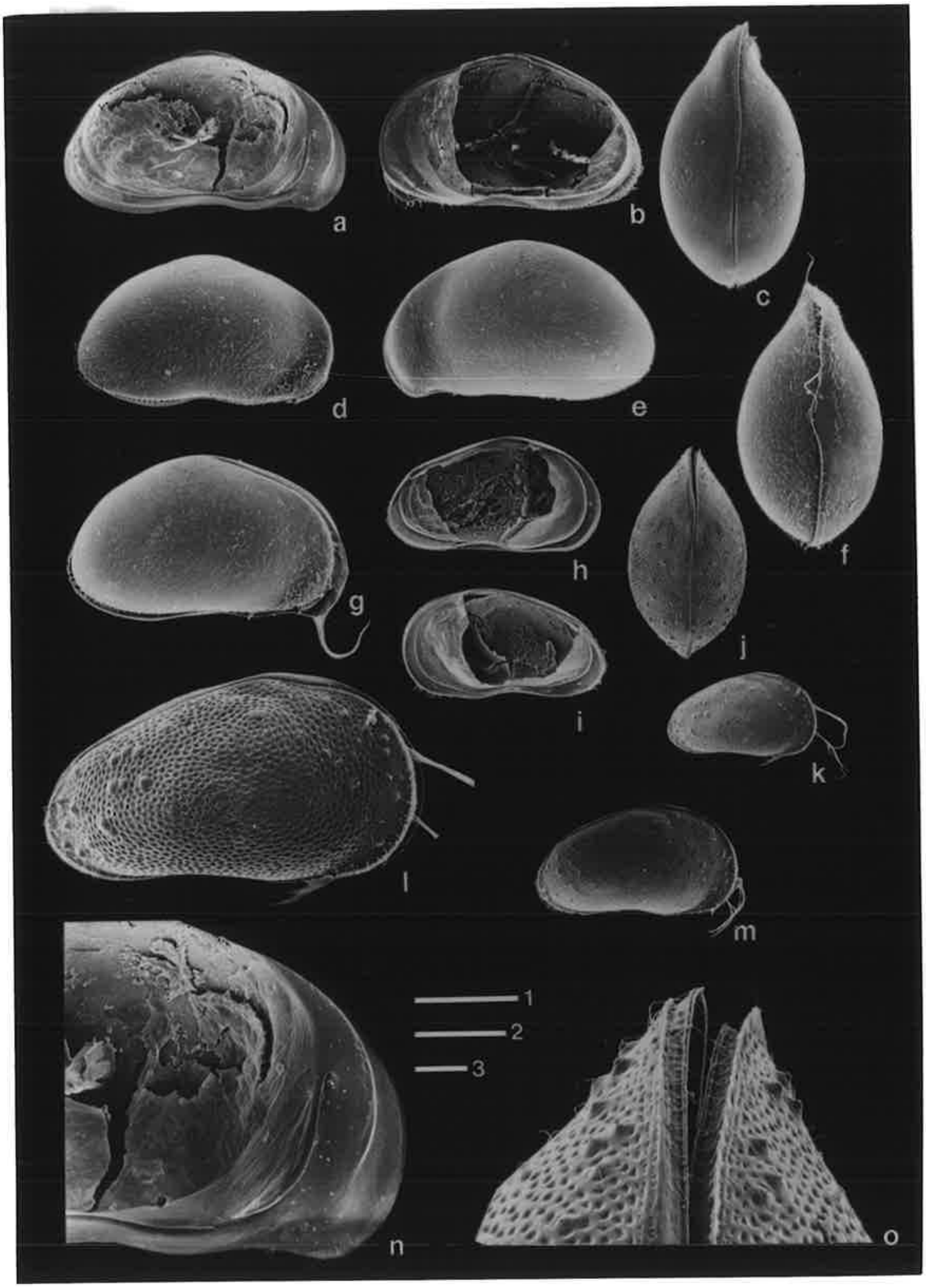

a
b
c
d
e
f
g
h
i
j
k
l
m
n
o
1
2
3

PLATE IV.8

Bennelongia barangaroo n.gen., n.sp.

a	LV internal, female
b	RV internal, female
c	LV external, female
d	RV external, female
e	C dorsal, female
f	C dorsal, juvenile
g	C showing LV, juvenile
h	C showing RV, female
i	LV internal, juvenile
j	RV internal, juvenile
k	C ventral, female
l	C ventral, juvenile
m	LV internal, posterior detail of a
o	RV internal, anterior detail of b
p	LV internal, anterior detail of a
q	C dorsal, detail of e

a - q: elongated pool in creek bed, about 25 km N. of Cue, W.A.

Bennelongia sp.

r	C showing RV

r: Cauckingburra Swamp, at Lake Buchanan, Via Charters Towers, Qld.

Scale: 1 - 500 μ for a - k
2 - 100 μ for m - p; 20 μ for q
3 - 500 μ for r

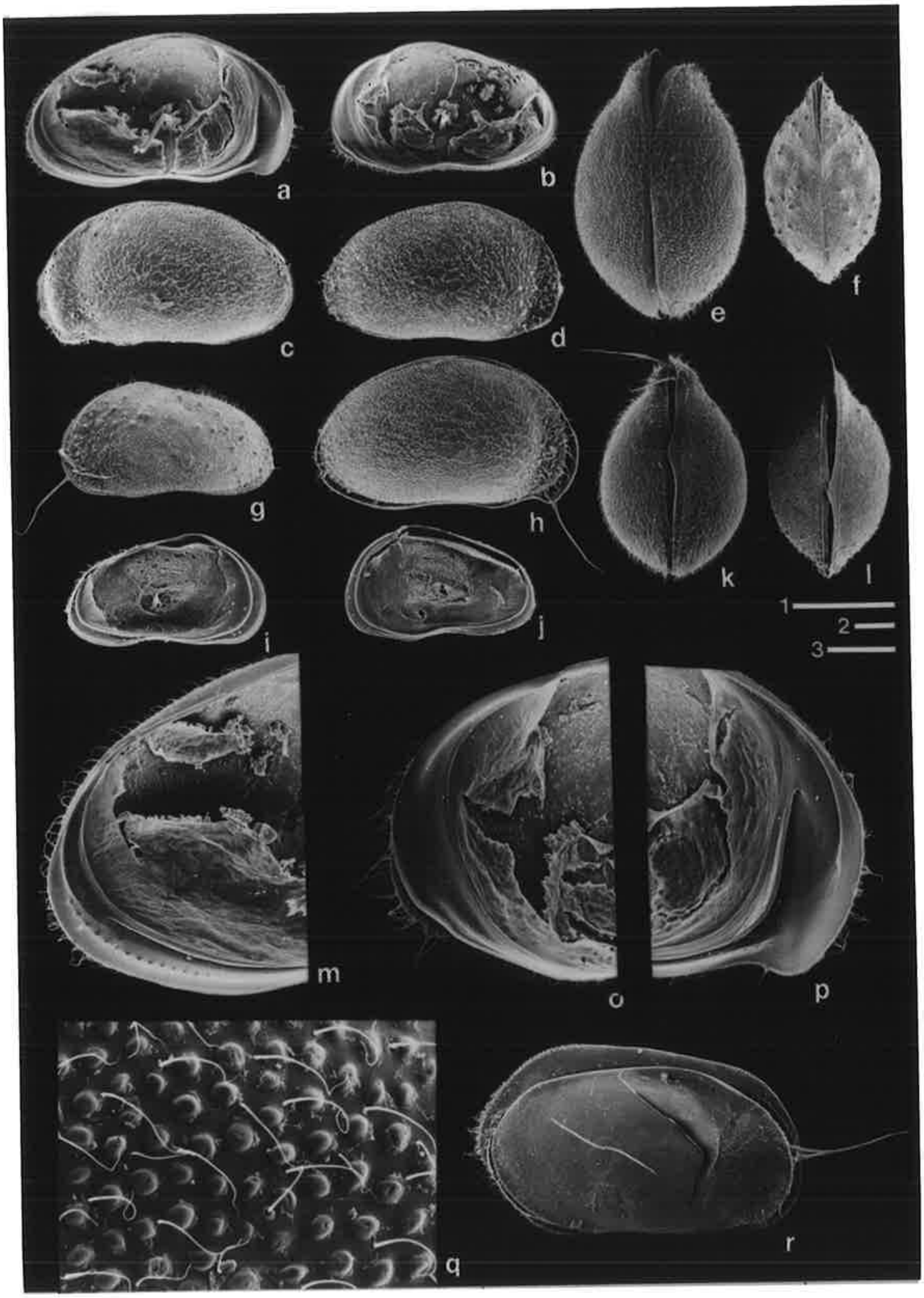

a
b
e
f
c
d
g
h
k
l
i
j
1
2
3
m
o
p
q
r

PLATE IV.9

Bennelongia nimala n.gen., n.sp.

a	LV internal, female paratype
b	RV internal, female paratype
c	C dorsal, female paratype
d	C showing RV, male
e	C showing RV, female paratype
f	C showing LV, female paratype
g	RV internal, male holotype
h	C ventral, male paratype
i	C dorsal, juvenile
j	RV internal, anterior detail of g
k	LV internal, anterior detail of a
l	LV internal, anterior detail of male paratype
m	C showing RV, anterior detail of d
n	C dorsal, anterior detail of c
o	LV internal, posterior detail of male paratype

a - c, e - h, j - l, n - o: Georgetown Lagoon, near Jabiru, N.T. (type locality)

d, i, m: Buffalo Billabong, near Jabiru, N.T.

Scale: 1 - 500 μ for a - i
2 - 200 μ for j - m, o
3 - 100 μ for n

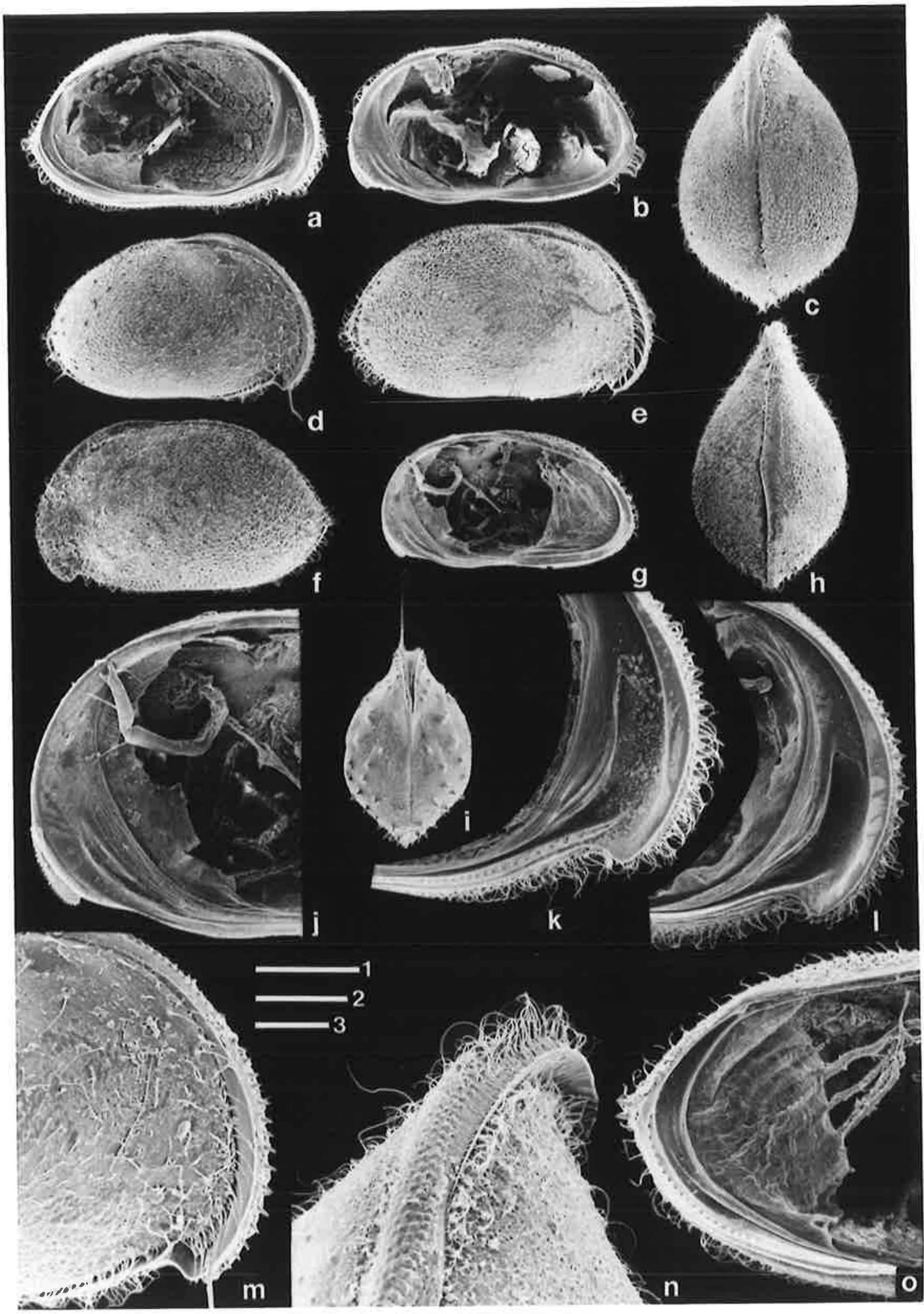

a
b
c
d
e
f
g
h
i
j
k
l
1
2
3
m
n
o

PLATE IV.10

Bennelongia pinpi n.gen., n.sp.

a	RV external, female paratype
b	LV external, female paratype
c	LV internal, female paratype
d	RV internal, female paratype
e	C ventral, female paratype
f	RV external, male holotype
g	LV external, male holotype
h	C dorsal, male paratype
i	C showing RV, male paratype
j	C showing RV, female paratype
k	C showing RV, juvenile
l	C showing RV, juvenile
m	C dorsal, juvenile
n	C ventral, juvenile
o	C showing RV, juvenile
p	RV internal, juvenile
q	LV internal, juvenile
r	C ventral, juvenile
s	C dorsal, juvenile
t	C ventral, enlargement of r

Scale: 1 - 500 μ for a - j, l - n, p - s
2 - 200 μ for k; 300 μ for t
3 - 150 μ for o

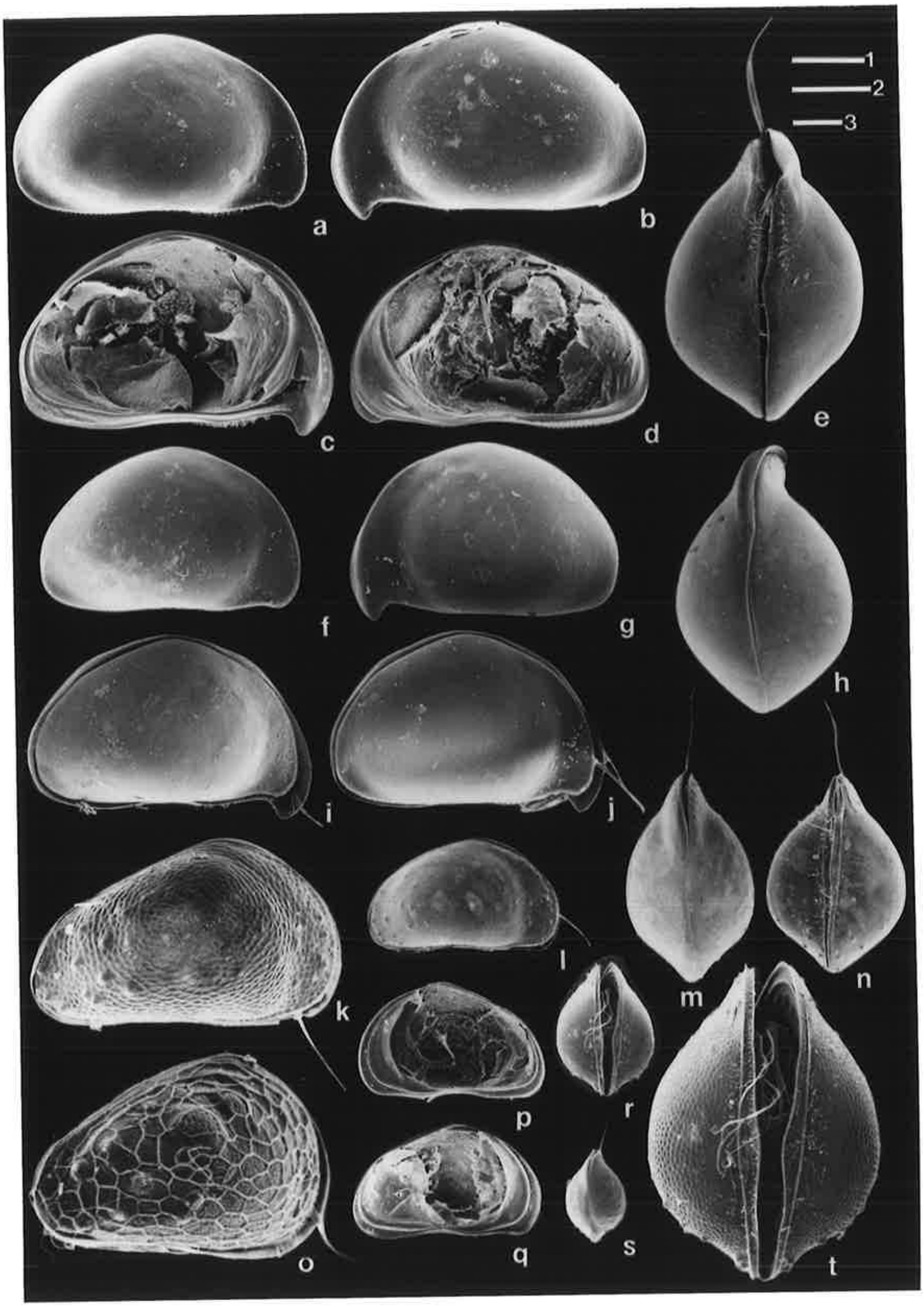

1
2
3
a
b
c
d
e
f
g
h
i
j
k
l
m
n
o
p
q
r
s
t

PLATE IV.11

Candonocypris incosta n.sp.

a	LV internal, female paratype
b	RV internal, female paratype
c	LV internal, male holotype
d	RV internal, male holotype
e	RV external, male paratype
f	RV external, male paratype
g	LV internal, male paratype
h	RV internal, male paratype
i	C dorsal, female paratype
j	C dorsal, male paratype
k	C showing LV, female paratype
l	C showing RV, male paratype
m	C showing RV, female paratype

Scale: 1,000 μ

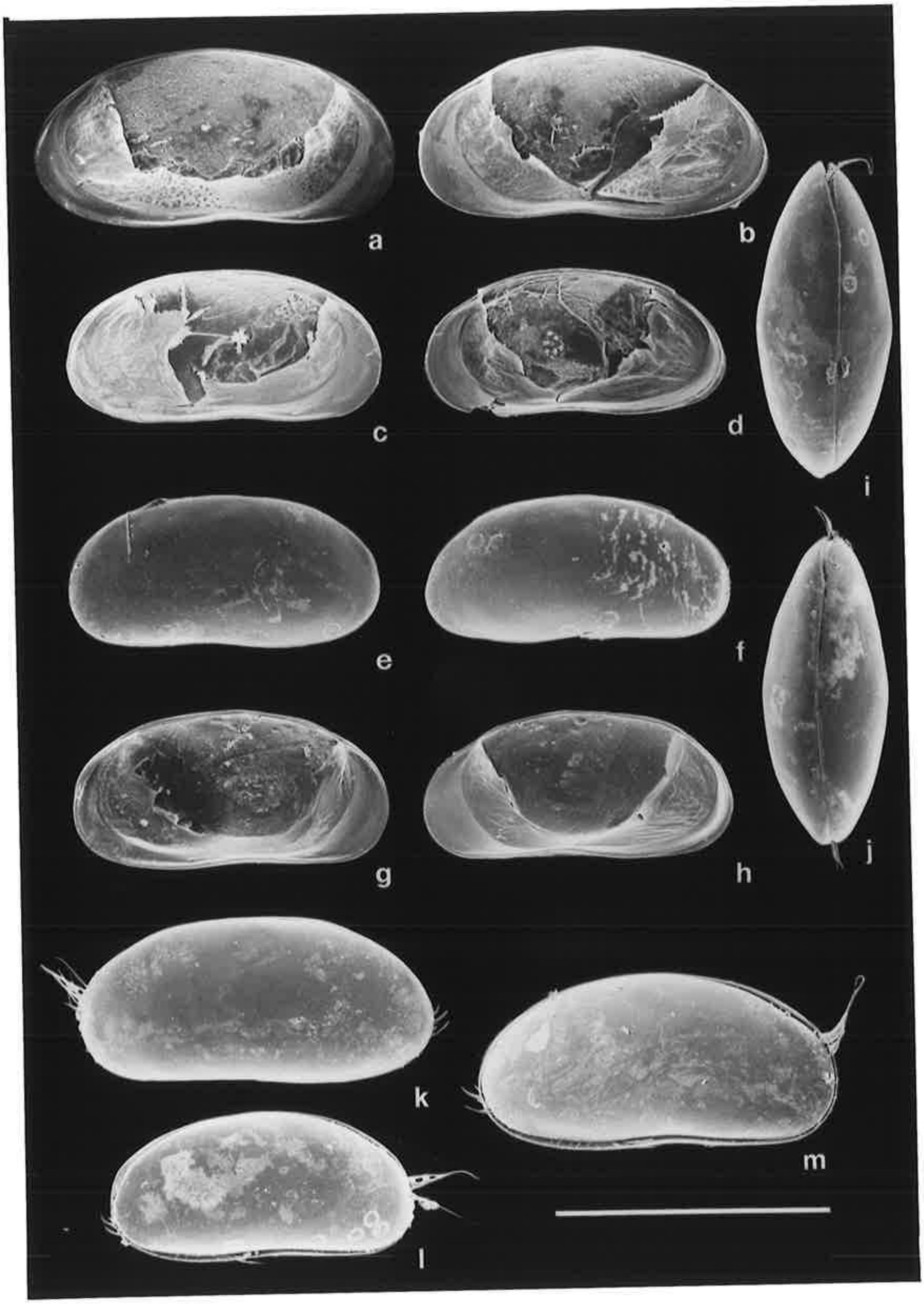

a
b
c
d
i
e
f
g
h
j
k
m
l

PLATE IV.12

Candonocypris novaezelandiae (Baird, 1843)

a	RV internal, male
b	LV internal, male
c	RV internal, female
d	LV internal, female
e	C dorsal, female
f	RV external, male
g	LV external, male
h	C showing RV and hemipenis, male
i	LV external, female
j	RV external, female
k	C showing LV and hemipenis, male
l	RV internal, female
m	LV internal, female
n	RV internal, juvenile female
o	LV internal, juvenile female
p	C showing LV, juvenile female
q	C showing LV, juvenile
r	RV internal, anterior detail of n
s	C showing LV, female
t	C showing LV, female

a - d: Kangaroo Creek Reservoir, Adelaide, S.A.
e - k, t: Milbrook Reservoir, Adelaide, S.A.
l - s: Small farm dam near Gilmandyke, S. of Bathurst, N.S.W.

Scale: 1 - 500 μ for a - q, s - t
2 - 50 μ for r

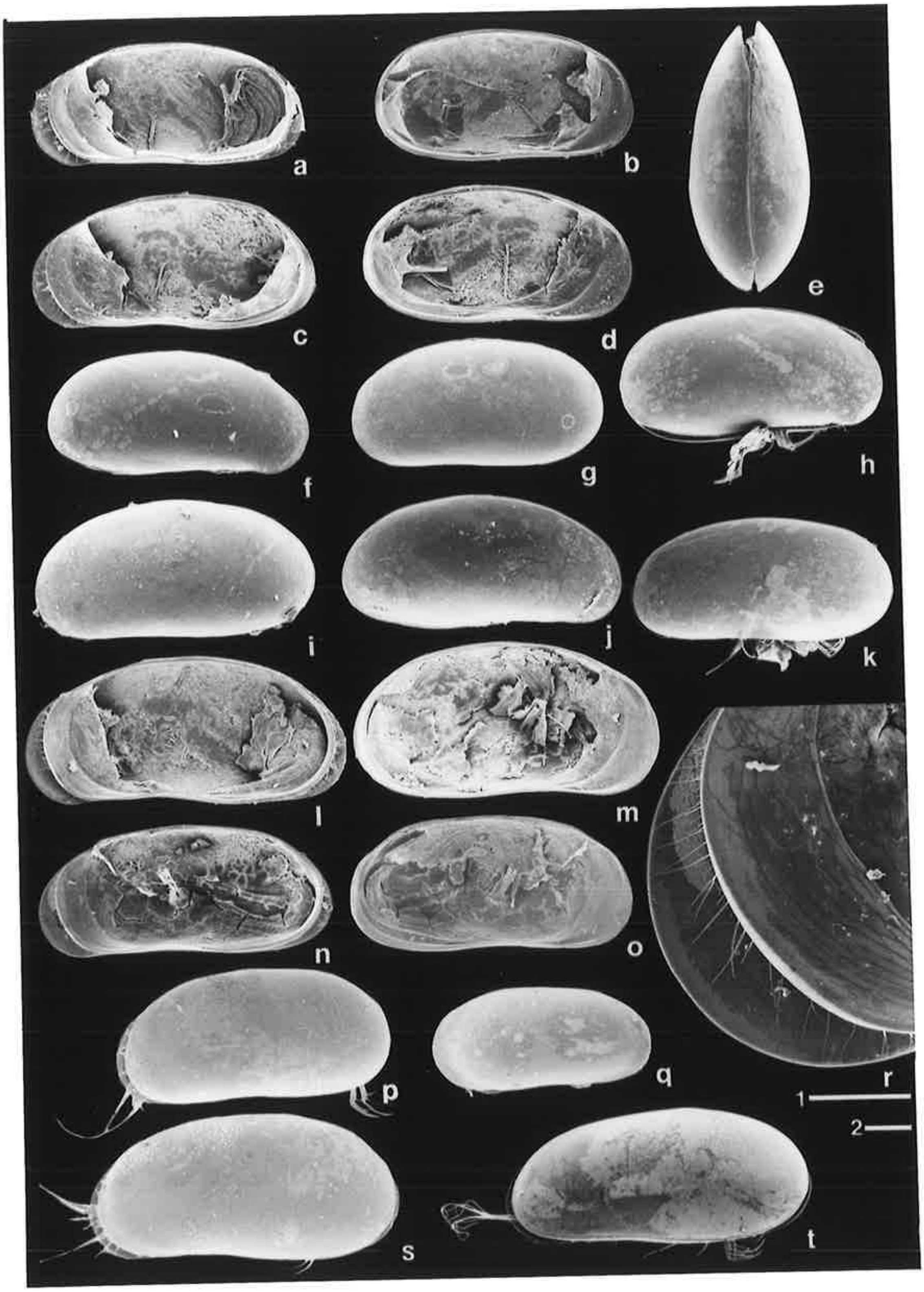

a
b
e
c
d
f
g
h
i
j
k
l
m
n
o
r
p
q
1
2
s
t

PLATE IV.13

Cypretta baylyi McKenzie, 1966

a	RV internal, female
b	LV internal, female
c	C dorsal, female
d	LV external, female
e	RV external, female
f	C ventral, female
g	RV internal, male
h	LV internal, male
i	LV external, male
j	RV external, male
k	C dorsal, male
l	C dorsal, detail of c
m	RV internal, posterior detail of a

a - m: Granite rock pool on top of Boyagin Rock, between Brookton and Pengelly, W.A.

Scale: 1 - 100 μ for a - k; 10 μ for l
2 - 50 μ for m

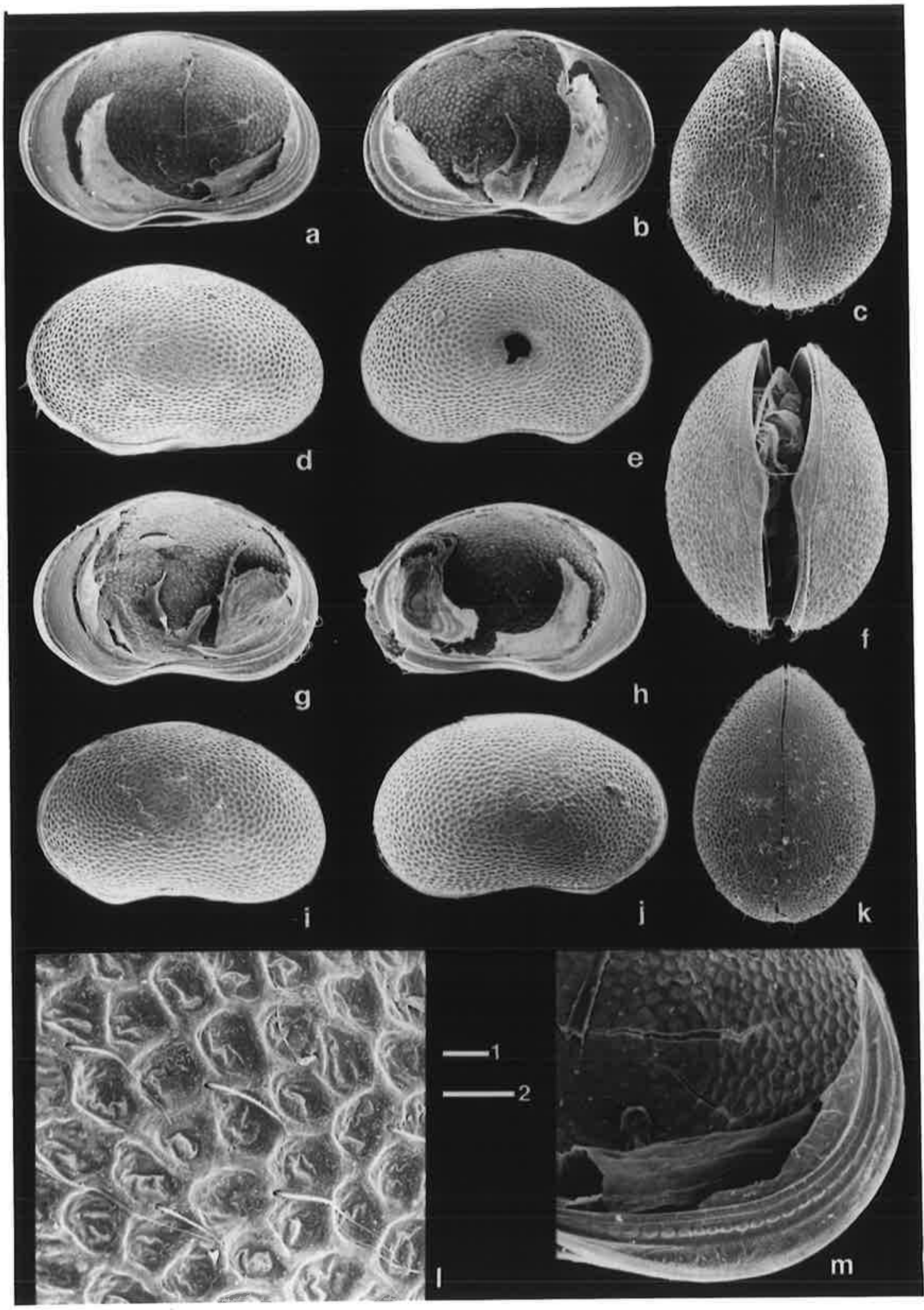

a
b
c
d
e
f
g
h
i
j
k
l
1
2
m

PLATE IV.14

Cypricercus salinus n.sp.

a	RV internal, male holotype
b	LV internal, male holotype
c	LV external, male paratype
d	RV external, male paratype
e	C showing LV, male paratype
f	LV internal, female paratype
g	RV external, female paratype
h	LV external, female paratype
i	C dorsal, male paratype
j	C ventral, male paratype
k	C dorsal, female paratype
l	C anterior, female paratype

Cypretta baylyi McKenzie, 1966

m	RV internal, male
n	LV internal, male
o	LV external
p	C dorsal
q	LV external, detail of o (central muscle scar area)

m - q: Granite rock pool on top of Boyagin Rock, between Brookton and Pingelly, W.A.

Scale: 200 μ for a - p; 40 μ for q

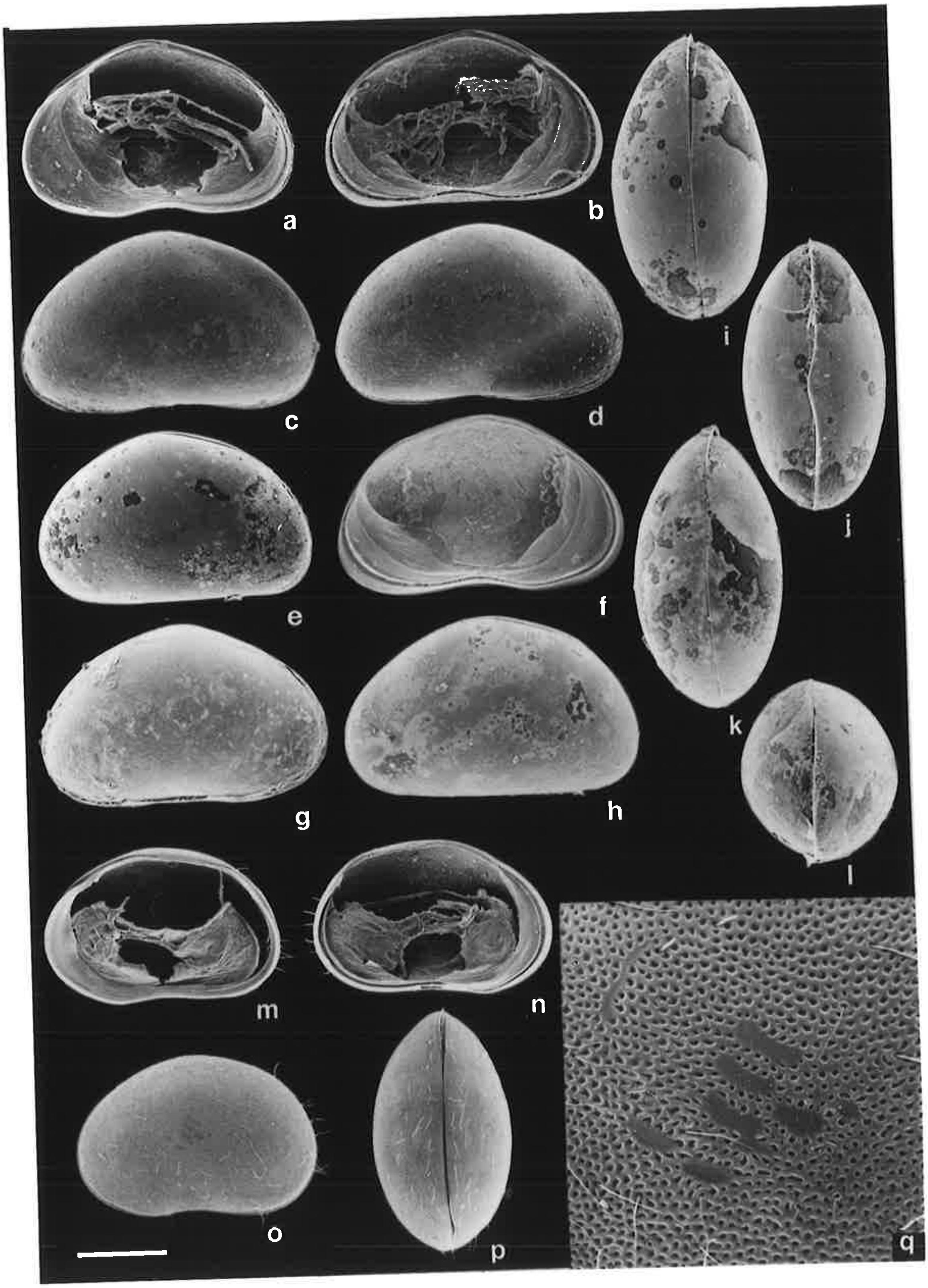

a
b
c
d
e
f
g
h
i
j
k
l
m
n
o
p
q

PLATE IV.15

Cypricercus unicornis n.sp.

a	RV internal, female paratype
b	LV internal, female paratype
c	RV internal, male holotype
d	LV internal, male holotype
e	RV external, female paratype
f	LV external, female paratype
g	RV external, male paratype
h	LV external, male paratype
i	C showing LV, male paratype
j	C showing R, female paratype
k	C dorsal, female paratype
l	C ventral, female paratype
m	C dorsal, male paratype
n	C ventral, male paratype
o	C ventral, posterior detail of n
p	C ventral, anterior detail of l
q	RV external, detail of g
r	LV internal, posterior detail of d

Scale: 1 - 500 μ for a - n

2 - 40 μ for o; 20 μ for p; 60 μ for r

3 - 10 μ for q

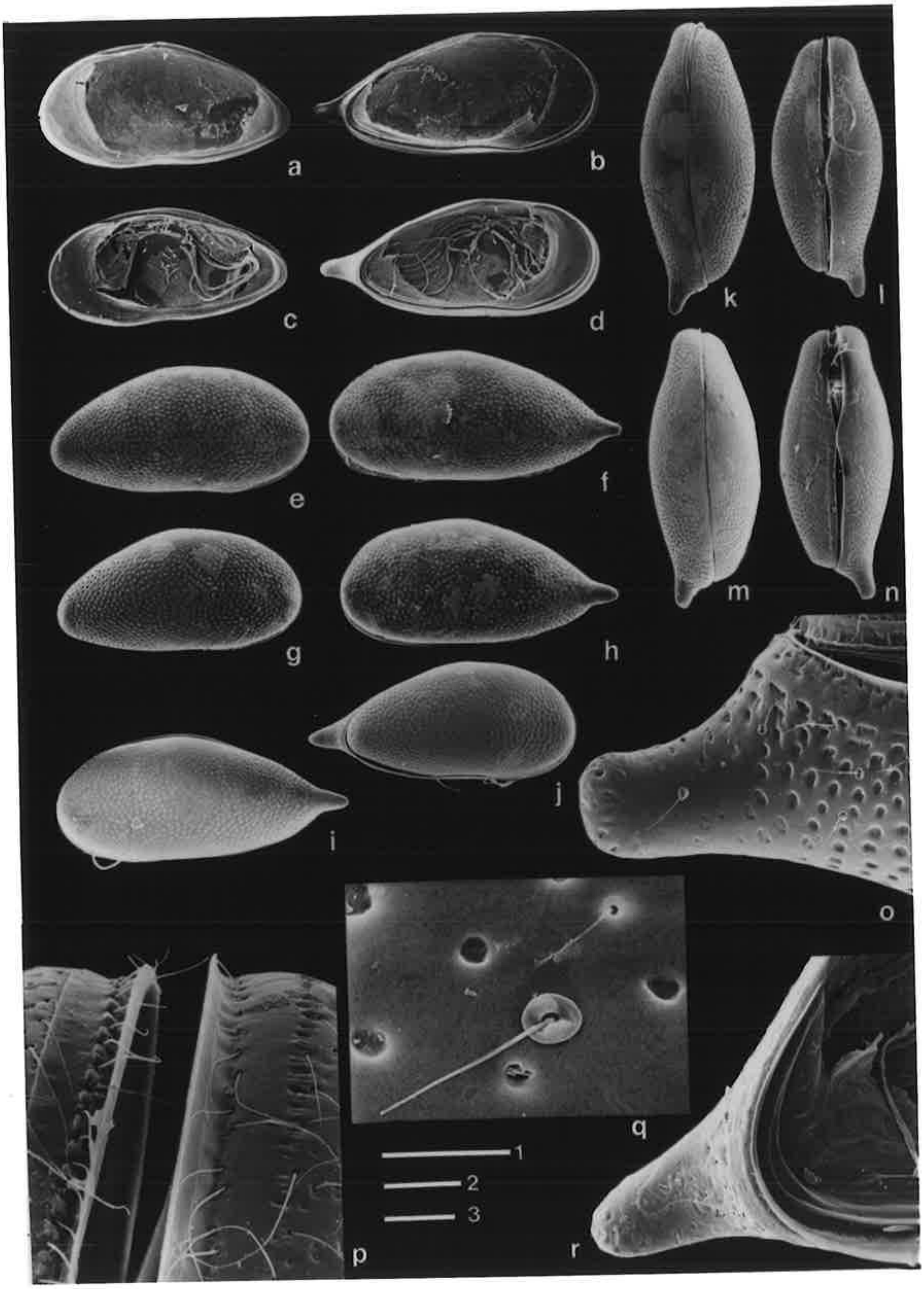

a
b
c
d
e
f
g
h
i
j
k
l
m
n
o
p
q
r
1
2
3

PLATE IV.16

Eucypris virens (Jurine, 1820)

a	LV internal, female
b	RV internal, female
c	LV internal, female
d	RV internal, female
e	C dorsal, female
f	C showing RV
g	C showing LV
h	C dorsal, anterior LV detail of j
i	C ventral
j	C dorsal
k	C showing RV, posterior detail of f
l	C showing RV, anterior detail of f

a - l: Pond close to Reel Inlet (coastside), 19 km S. of Mandurah, W.A.

Scale: 1 - 500 µ for a - g, i - j

2 - 40 µ for h; 20 µ for k; 30 µ for l

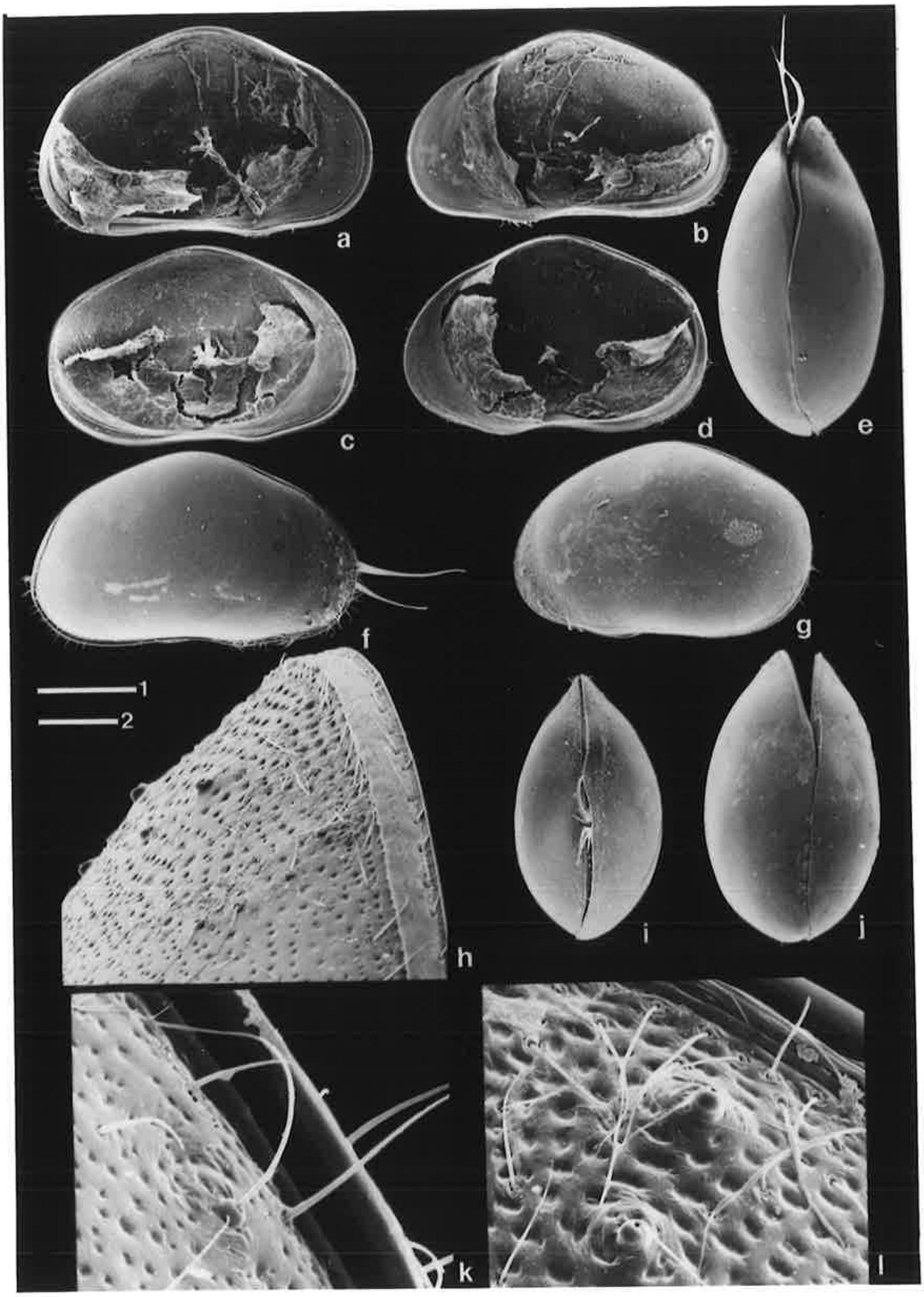

a
b
c
d
e
f
g
1
2
h
i
j
k
l

PLATE IV.17

Gomphodella maia n.gen., n.sp.

a	RV internal, female paratype
b	LV external, female paratype
c	C dorsal, male paratype
d	RV internal, male holotype
e	LV external, male holotype
f	RV internal, juvenile
g	LV external, juvenile
h	RV dorsal, female
i	C dorsal, male
j	C dorsal, female
k	C dorsal, female
l	RV internal, anterior detail of d
m	LV external, detail of e
n	LV external, detail of g

a - g, l - n: type locality

h - k: fossil, Blue Lake, Mt. Gambier, S.A.

Scale: 100 µ; 15 µ for l; 5 µ for m, n

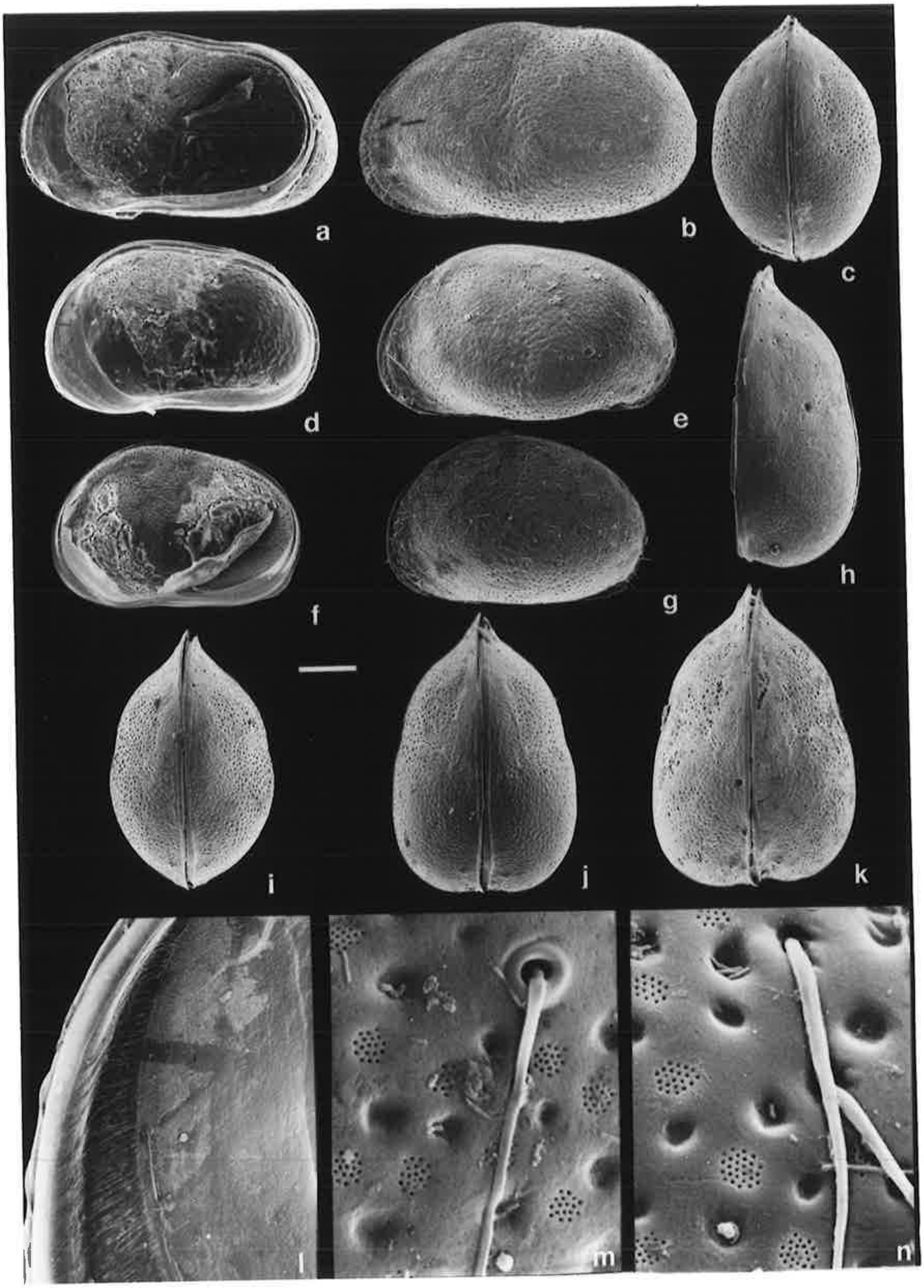

a
b
c
d
e
h
f
g
i
j
k
l
m
n

PLATE IV.18

Heterocypris vatia n.sp.

a	LV external, female paratype
b	RV external, female paratype
c	LV internal, female paratype
d	RV internal, female paratype
e	RV internal, anterior detail of d
f	LV external, male paratype
g	RV external, male paratype
h	LV internal, male holotype
i	RV internal, male holotype
j	C dorsal, female paratype
k	C ventral, male paratype
l	C dorsal, female paratype
m	C ventral, male paratype
n	RV external, anterior detail of g
o	RV internal, posterior detail of d
p	C dorsal, anterior detail of j
q	C ventral, posterior detail of k
r	C ventral, anterior detail of k

Scale: 1 - 500 μ for a - d, f - m; 200 μ for e, o; 40 μ for n
2 - 100 μ for p - r

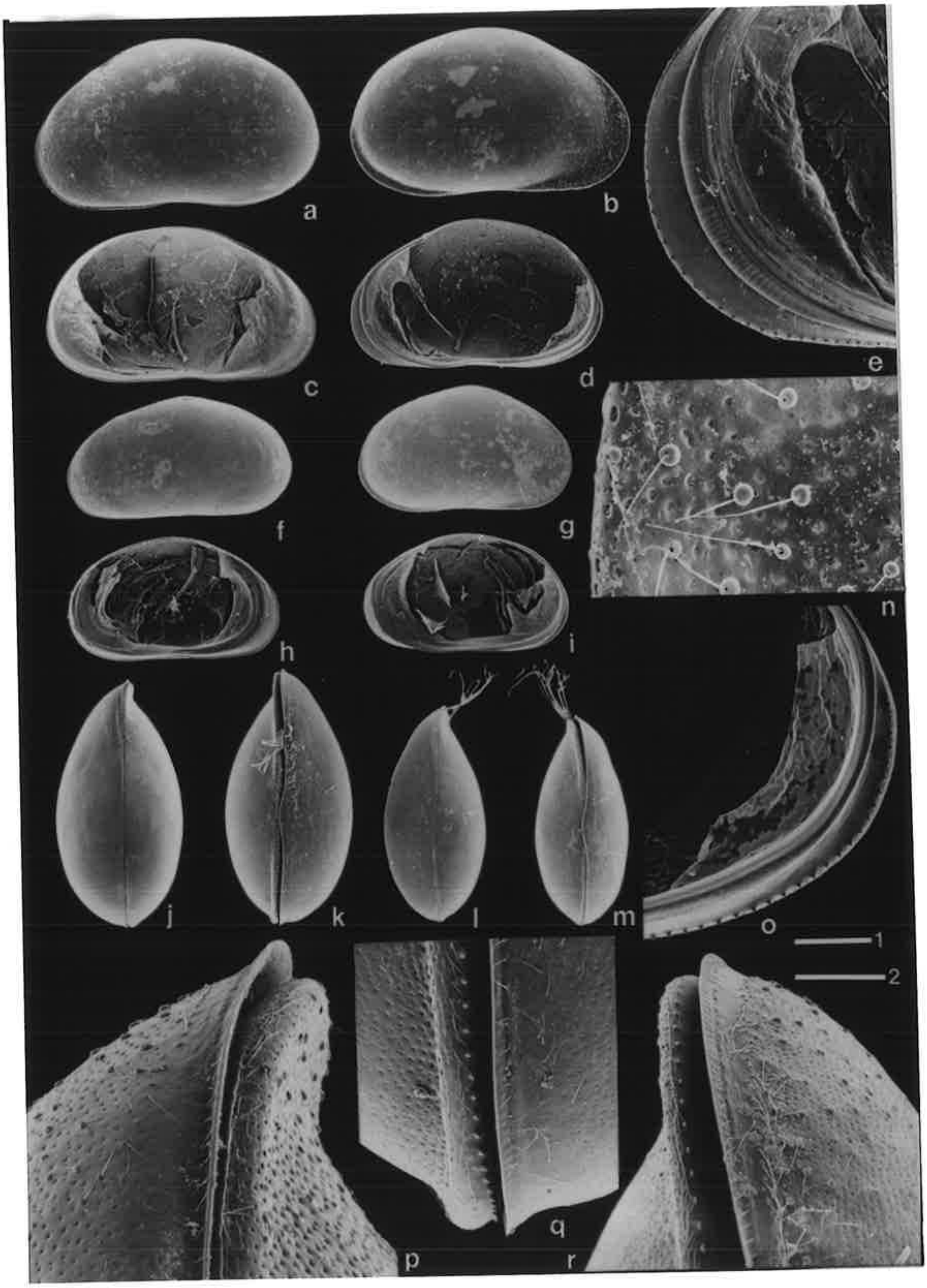

a
b
c
d
e
f
g
n
h
i
j
k
l
m
o
1
2
p
q
r

PLATE IV.19

Ilyocypris australiensis Sars, 1889

a	C showing LV, female
b	RV external, male
c	C showing RV, female
d	C showing LV at dorsolateral view, male
e	C showing RV, male
f	C showing LV, male
g	LV internal, male
h	LV internal, female
i	RV internal, female
j	C dorsal, female
k	C ventral, male
l	C dorsal, female
m	C dorsal, female
n	C dorsal, male, same specimen as d
o	C dorsal, female
p	LV internal, female
q	C showing LV, male

a, d, h - i, m: Pool in creek bed at 25 km N. of Cue, W.A.

b, e, g, j - k: Martin Lake, Vic.

c, f: Lake Warraweena, N.S.W.

l, p - q: Pool in creek bed, 12 km S. of Menzies, W.A.

o: Pond very close to Reel Inlet (coastside) 19 km S. of Mandurah, W.A.

Scale: 200 μ

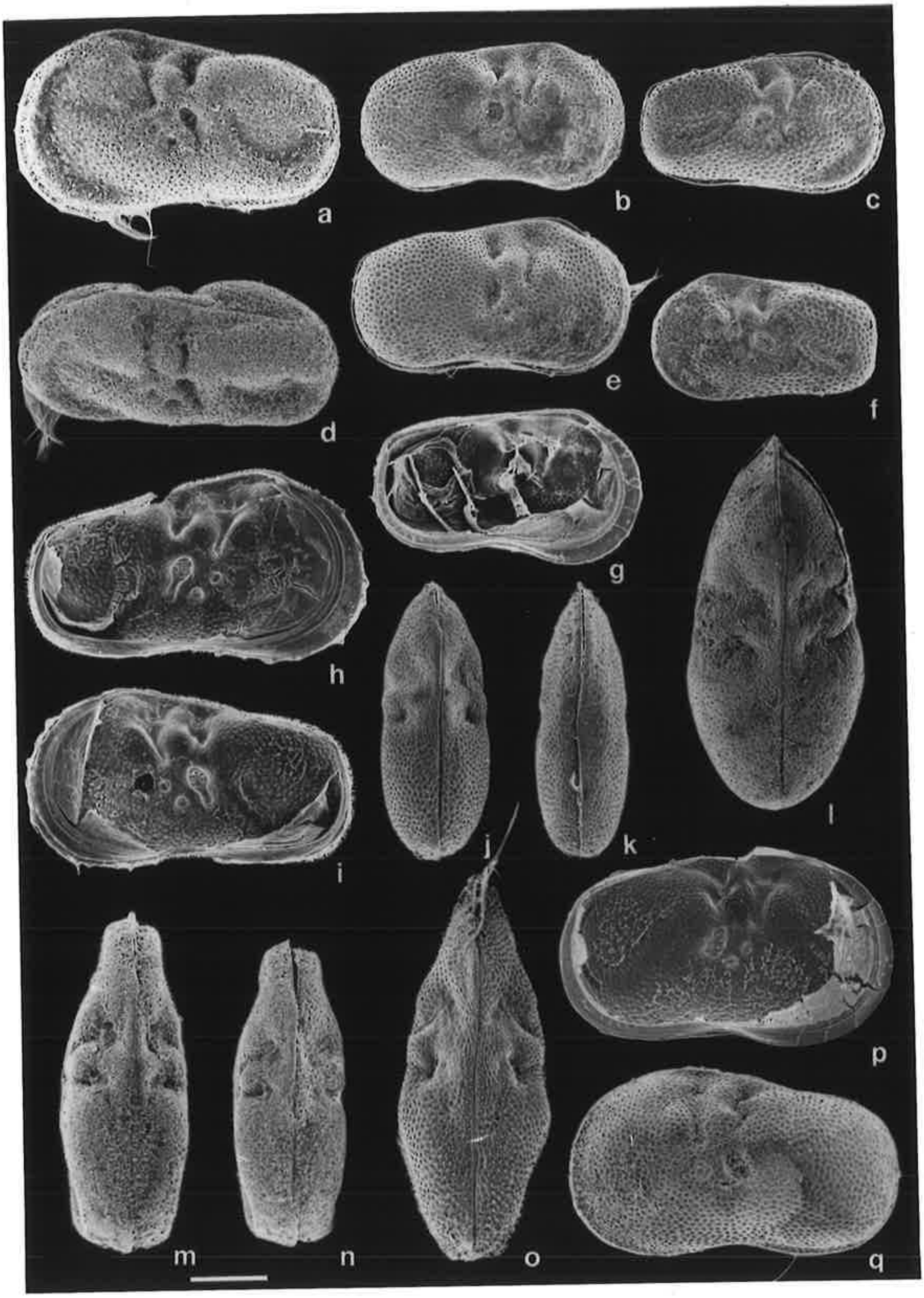

a
b
c
d
e
f
g
h
i
j
k
l
m
n
o
p
q

PLATE IV.20

Ilyocypris perigundi n.sp.

a	LV external, female paratype
b	RV external, female
c	LV external, female
d	RV external, male holotype
e	C dorsal, female paratype
f	RV internal, female paratype
g	LV external, male holotype
h	LV external, juvenile
i	LV external, detail of a
j	LV external, posterior detail of C
k	LV external, dorsal detail of a

a, d - g, i - k: Type locality
b - c, h: Katarapko Lagoon, near Loxton, S.A.

Scale: 1 - 200 μ for a - h
2 - 50 μ for i - k

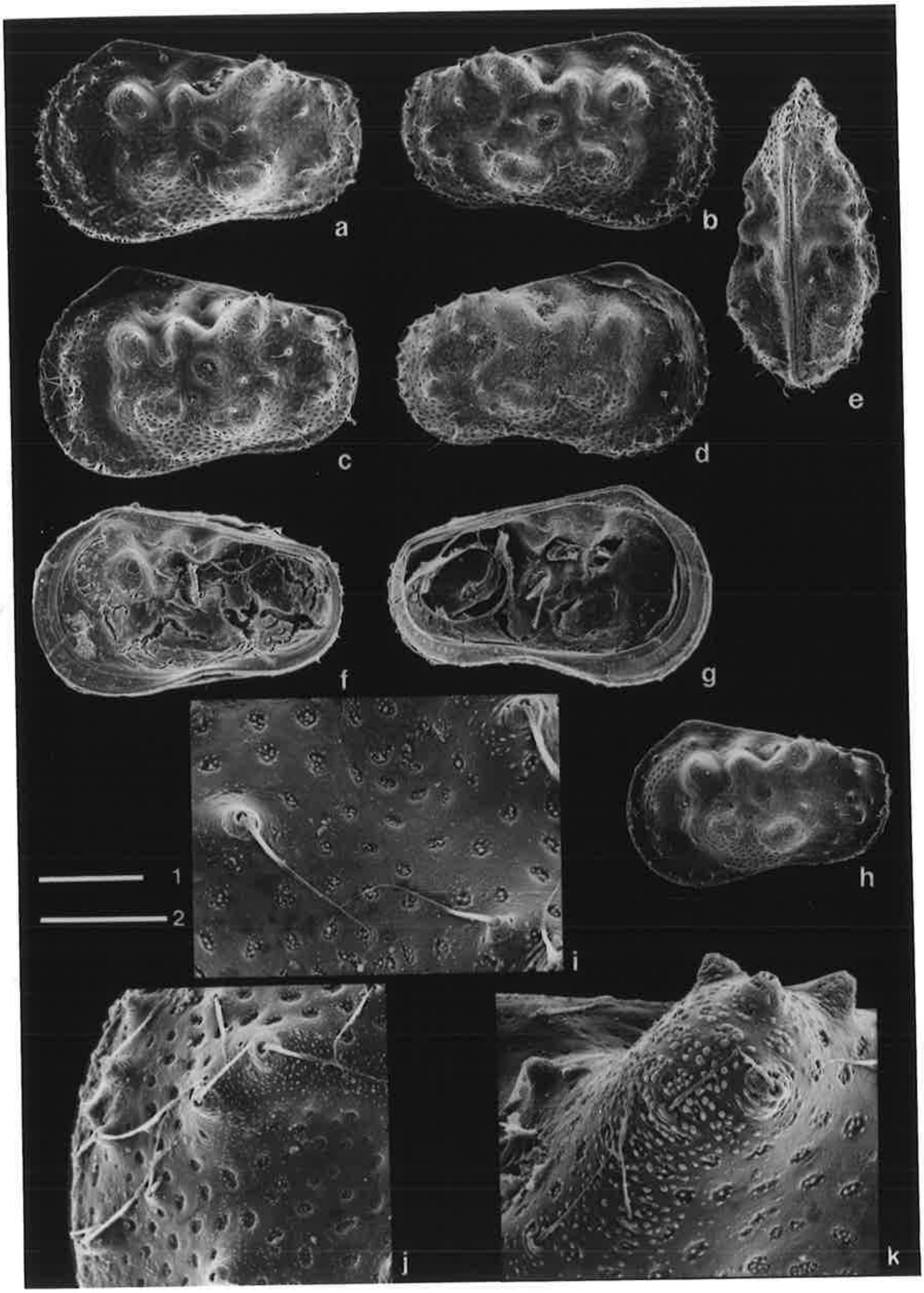

a
b
e
c
d
f
g
1
2
i
h
j
k

PLATE IV.21

Ilyodromus candonites n.sp.

a	LV internal, female
b	RV internal, female
c	C dorsal, female
d	C showing LV, female
e	C showing RV, female
f	C showing RV, male paratype
g	LV internal, male holotype
h	RV internal, male holotype
i	RV external, male paratype
j	LV external, male paratype
k	C showing RV, detail of d

a - e, k: Small granite rock pool on Muirillup Rock, near Northcliffe, W.A.

f - j: Type locality

Ilyodromus amplicolis n.sp.

l	RV internal, holotype female
m	LV internal, holotype female
n	LV internal, paratype male
o	RV internal, paratype male, specimen distorted
p	C dorsal, paratype female
q	C showing RV, same specimen as p
r	C showing LV, paratype female, specimen distorted

Scale: 1 - 500 μ for a - j, l - r

2 - 10 μ for k

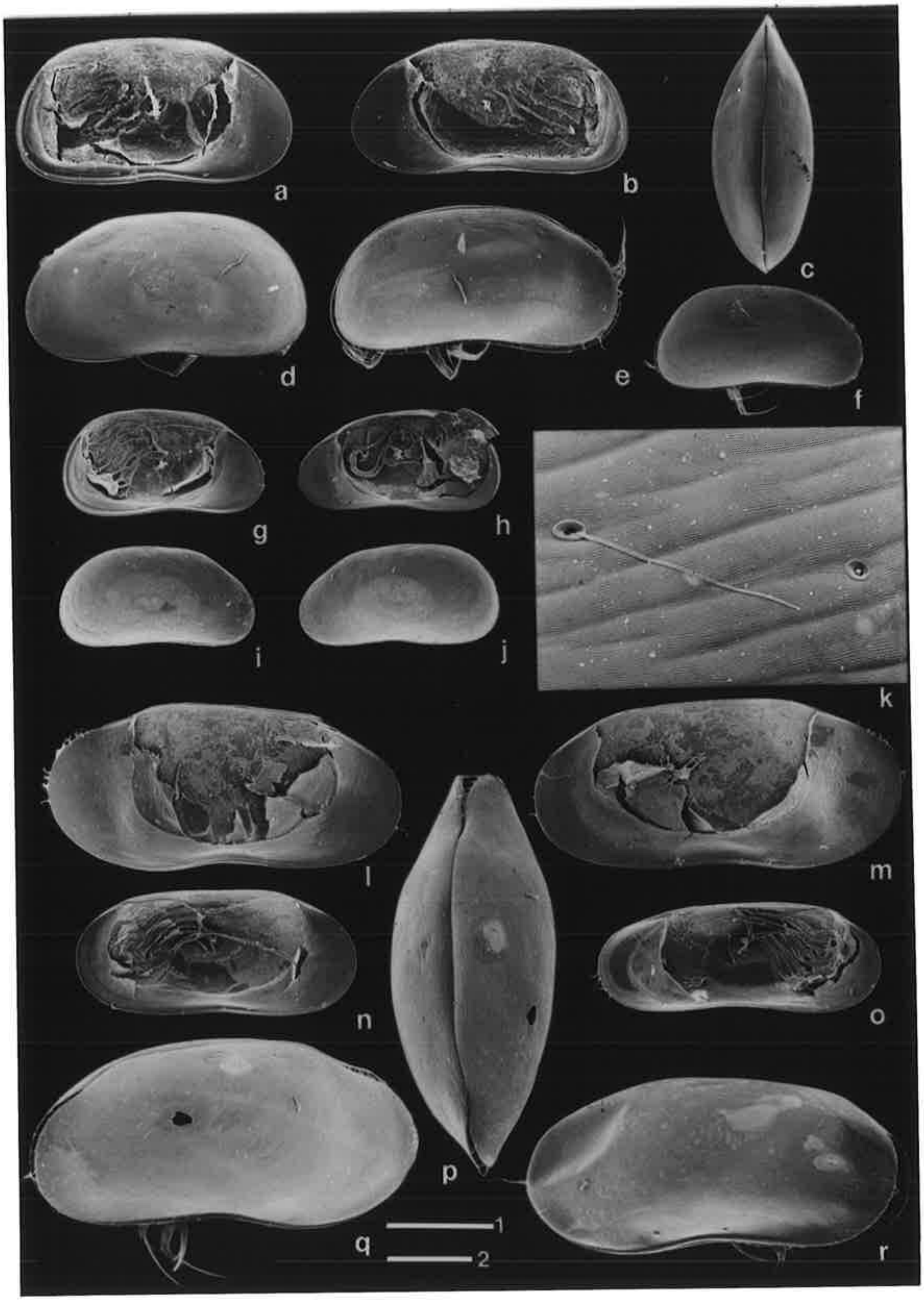

a
b
c
d
e
f
g
h
i
j
k
l
m
n
o
p
q
r
1
2

PLATE IV.22

Ilyodromus dikros n.sp.

a	LV internal, female paratype
b	RV internal, female paratype
c	LV external, female paratype
d	RV external, female paratype
e	RV internal, male paratype
f	LV internal, male paratype
g	LV external, male holotype
h	RV external, male holotype
i	C dorsal, male paratype
j	C ventral, female paratype
k	C showing LV, penis and some appendages, male paratype
l	C showing RV, female paratype
m	LV external, posterior detail of g
n	LV external, detail of g
o	C showing RV, anterior detail of l

Scale: 1 - 500 μ for a - l
2 - 100 μ for m; 20 μ for n; 200 μ for o

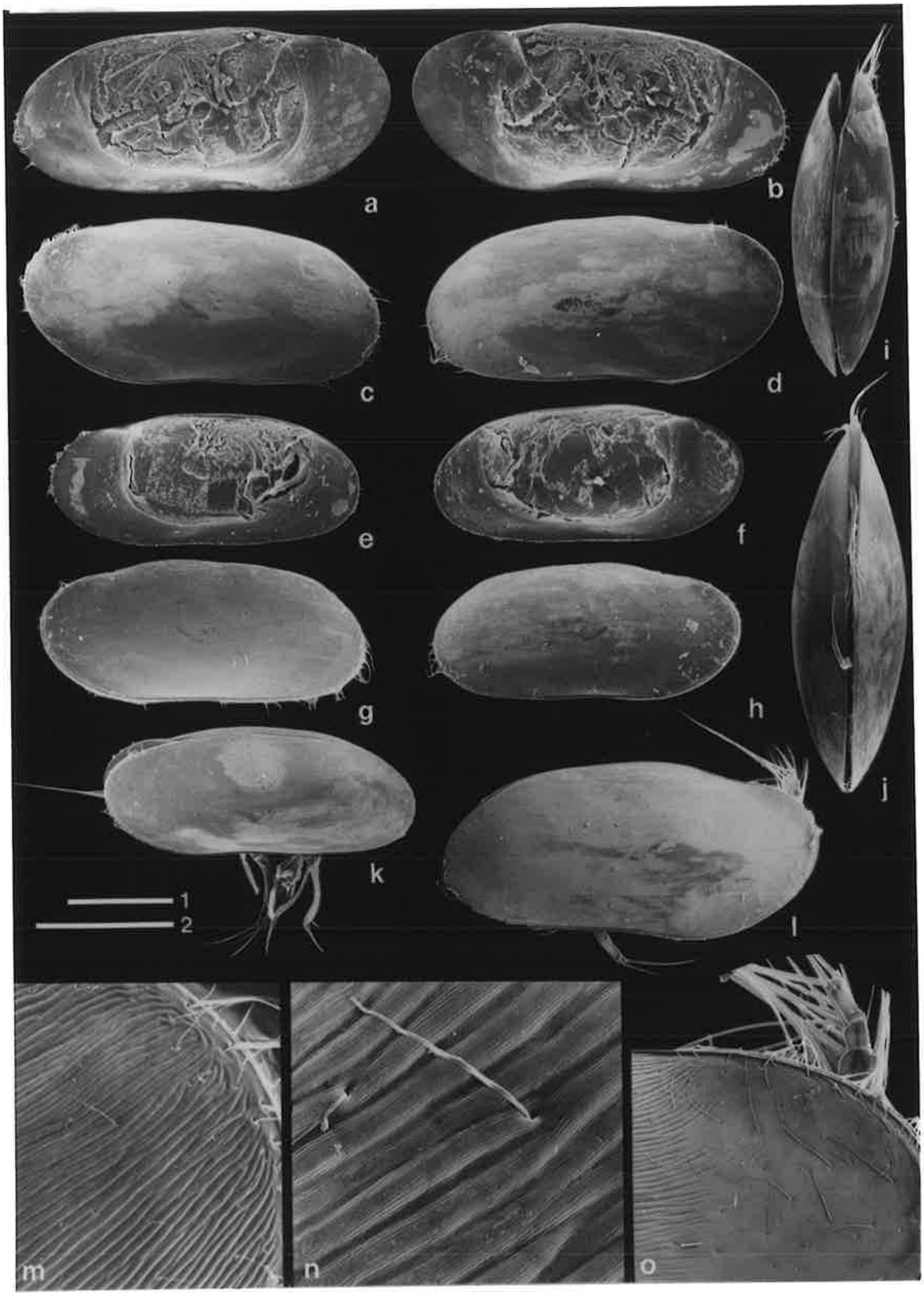

a
b
i
c
d
e
f
j
g
h
k
l
1
2
m
n
o

PLATE IV.23

Kapcypridopsis asymmetros n.sp.

a	RV internal, male paratype
b	LV internal, male paratype
c	C showing LV, male paratype
d	RV external, male paratype
e	RV internal, posterior detail of f
f	RV internal, female paratype
g	LV internal, female paratype
h	C dorsal, male paratype
i	C showing LV, female paratype
j	C showing RV, female paratype
k	C ventral, female paratype
l	C showing RV, posterior detail of c
m	C ventral, posterior detail of k

Scale: 1 - 200 µ for a - d, f - k

2 - 50 µ for e, l; 20 µ for m

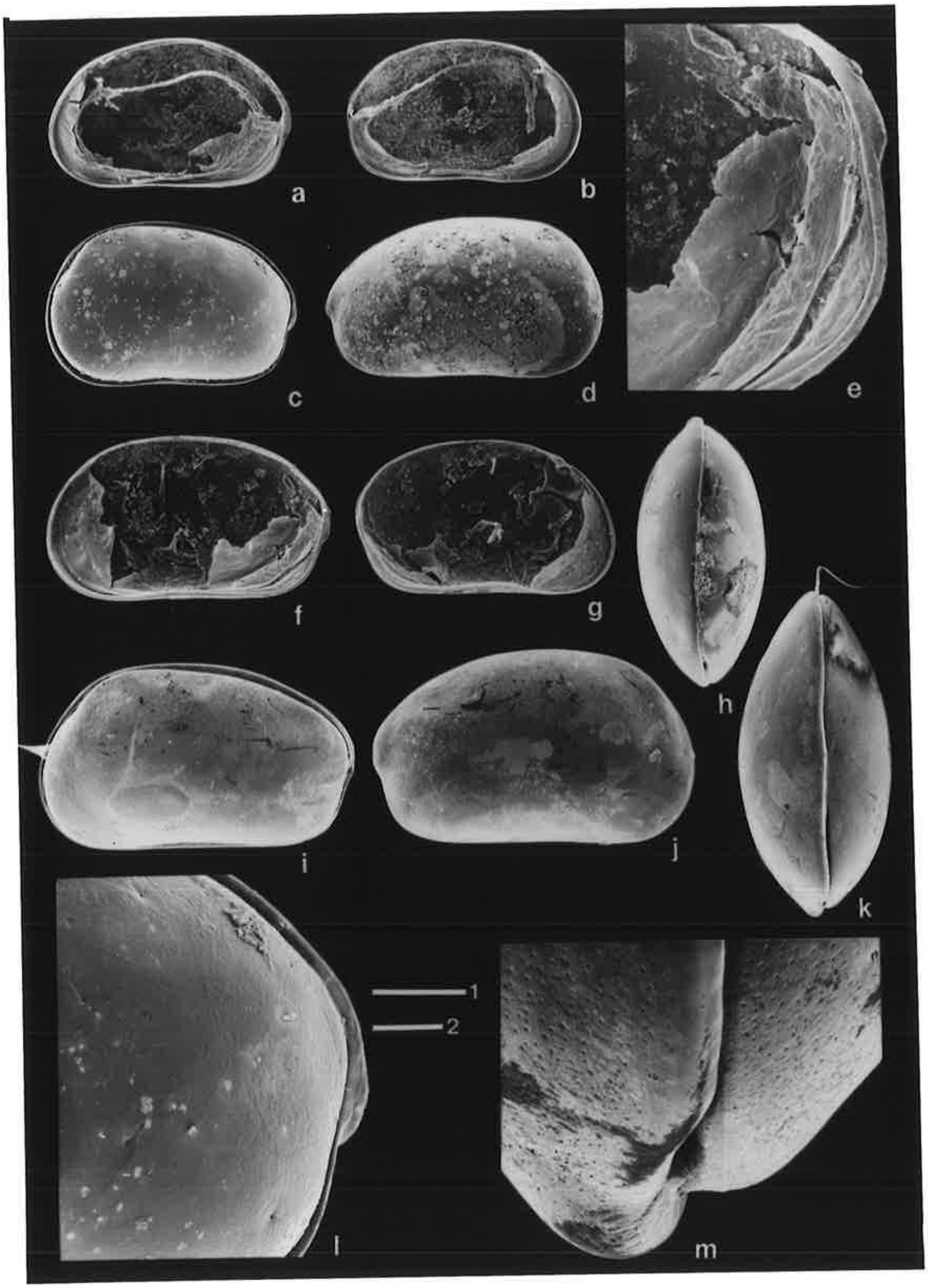

a
b
c
d
e
f
g
h
i
j
k
l
m
1
2

PLATE IV.24

Leptocythere lacustris n.sp.

a	RV internal, male holotype
b	LV internal, male holotype
c	C showing LV, female paratype
d	LV external, male paratype
e	LV external, female paratype
f	C external showing RV, male paratype
g	C external showing RV, male
h	RV external, male paratype
i	RV internal, hinge posterior detail of a
j	RV internal, hinge posterior detail of a
k	LV internal, hinge posterior detail of b
l	LV internal, hinge anterior detail of b
m	C dorsal, male paratype
n	C external, detail of g
o	RV internal, detail central muscle field of a
p	LV external, detail of e

a - f, h - m, o - p: Type locality
g, n: Chara Lake, near Robe, S.A.

Scale: 1 - 200 μ for a - h, m
2 - 50 μ for i - l, o; 25 μ for n, p

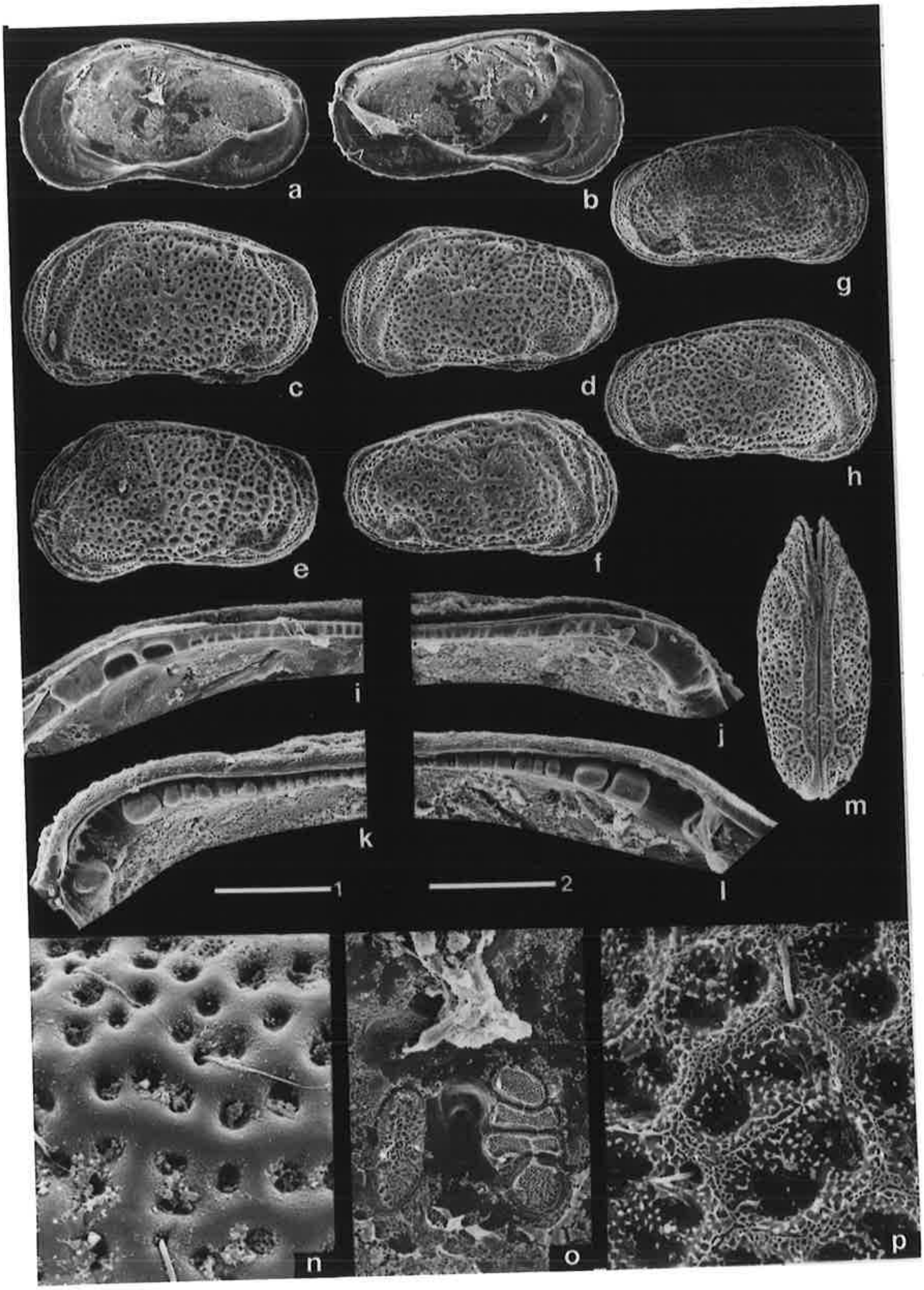

a
b
g
c
d
h
e
f
m
i
j
k
l
1
2
n
o
p

PLATE IV.25

Limnocythere dorsosicula n.sp.

a	C showing RV, female paratype
b	RV external, male paratype
c	LV external, male paratype
d	C showing RV, male paratype
e	C dorsal, female paratype
f	C dorsal, male paratype
g	RV internal, female paratype
h	LV internal, male holotype
i	LV internal, female paratype
j	LV internal, anterior detail of i

Limnocythere miltos n.sp.

k	C showing RV, female paratype
l	LV external, female paratype
m	LV internal, female holotype
n	RV internal, female holotype
o	RV external, female paratype
p	C showing LV, female paratype
q	C dorsal, female paratype
r	C ventral, female paratype

Scale: 1 - 200 μ for a - i; 35 μ for j
2 - 200 μ for k - r

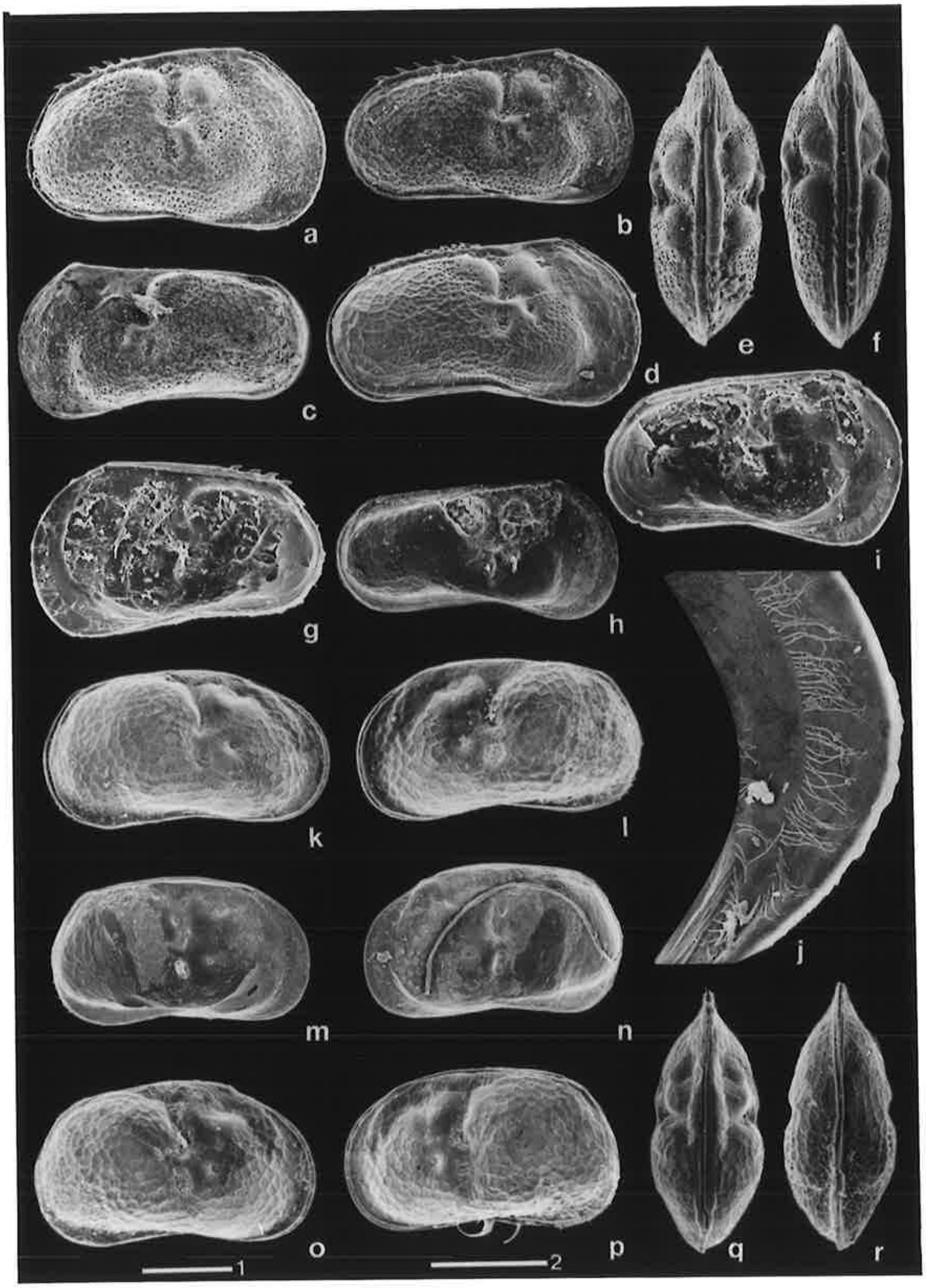

a
b
e
f
c
d
i
g
h
j
k
l
m
n
o
p
q
r
1
2

PLATE IV.26

Psychrodromus oblongata (Sars, 1896)

a	C showing LV, female
b	C showing RV, female
c	C showing LV, male
d	RV internal, male
e	LV internal, male
f	LV external, male
g	RV external, male
h	C dorsal, female
i	C dorsal, male
j	RV internal, female
k	LV internal, female
l	LV external, female
m	RV external, female
n	C ventral, male

a - n: Roadside pool, on Gibb River Road, 58 km E. of Derby, W.A.

Scale: 500 μ

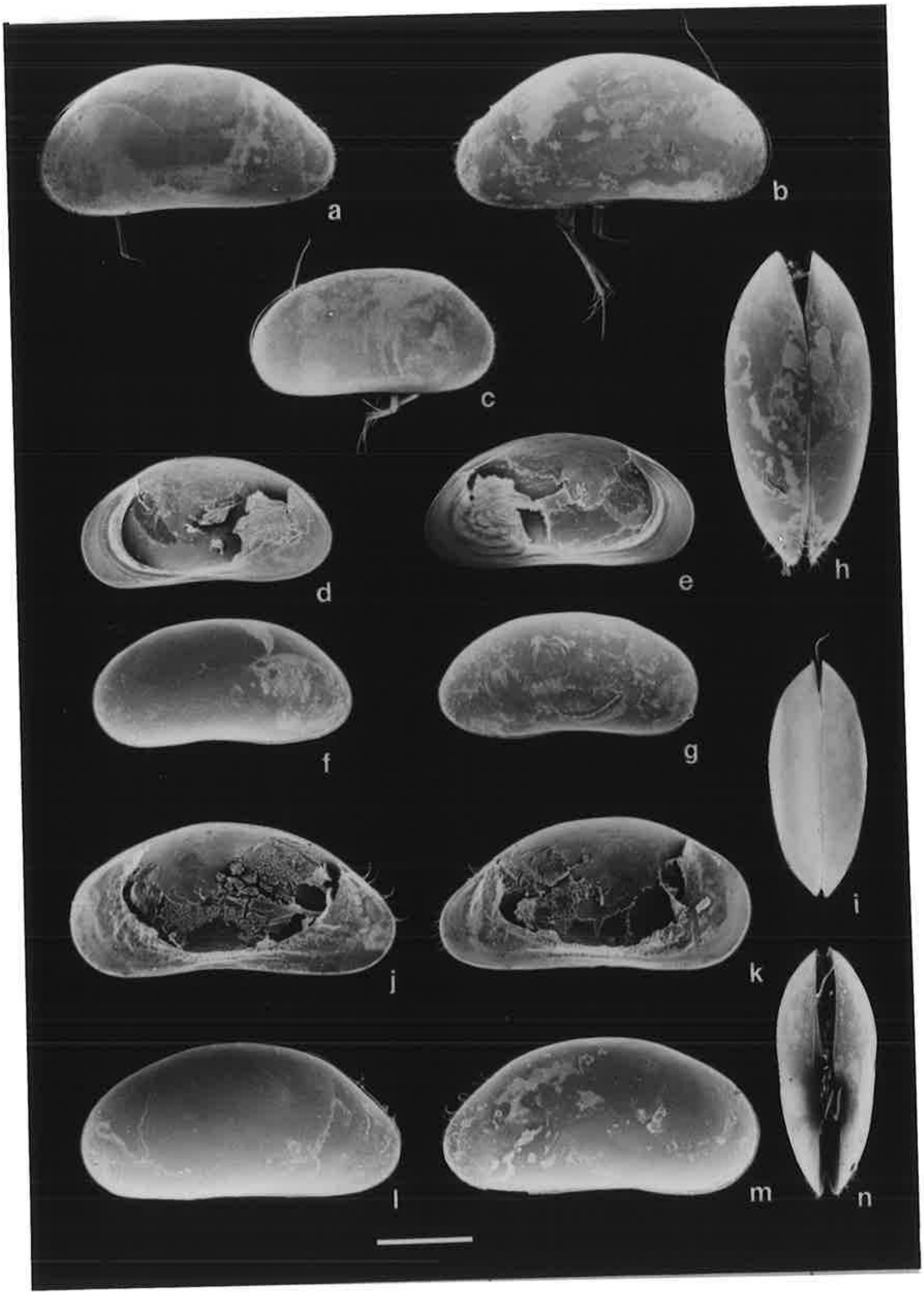

a
b
c
d
e
f
g
h
i
j
k
l
m
n

PLATE IV.27

Reticypris clava n.sp.

a	RV external
b	LV external
c	LV internal, male paratype
d	RV internal, male paratype
e	C dorsal, male paratype
f	C dorsal, male
g	LV external, female paratype
h	RV external, female paratype
i	LV external, female paratype
j	RV internal, female paratype
k	C ventral, female paratype
l	C showing RV, female paratype
m	C dorsal, female paratype
n	C showing LV, male
o	LV external, anterior detail of i
p	C ventral, anterior detail of k

a - e, g - m, o - p: Type locality

f, n: Lake Weeranganuk, Vic.

Scale: 1 - 200 μ for a - n

2 - 100 μ for o; 50 μ for p

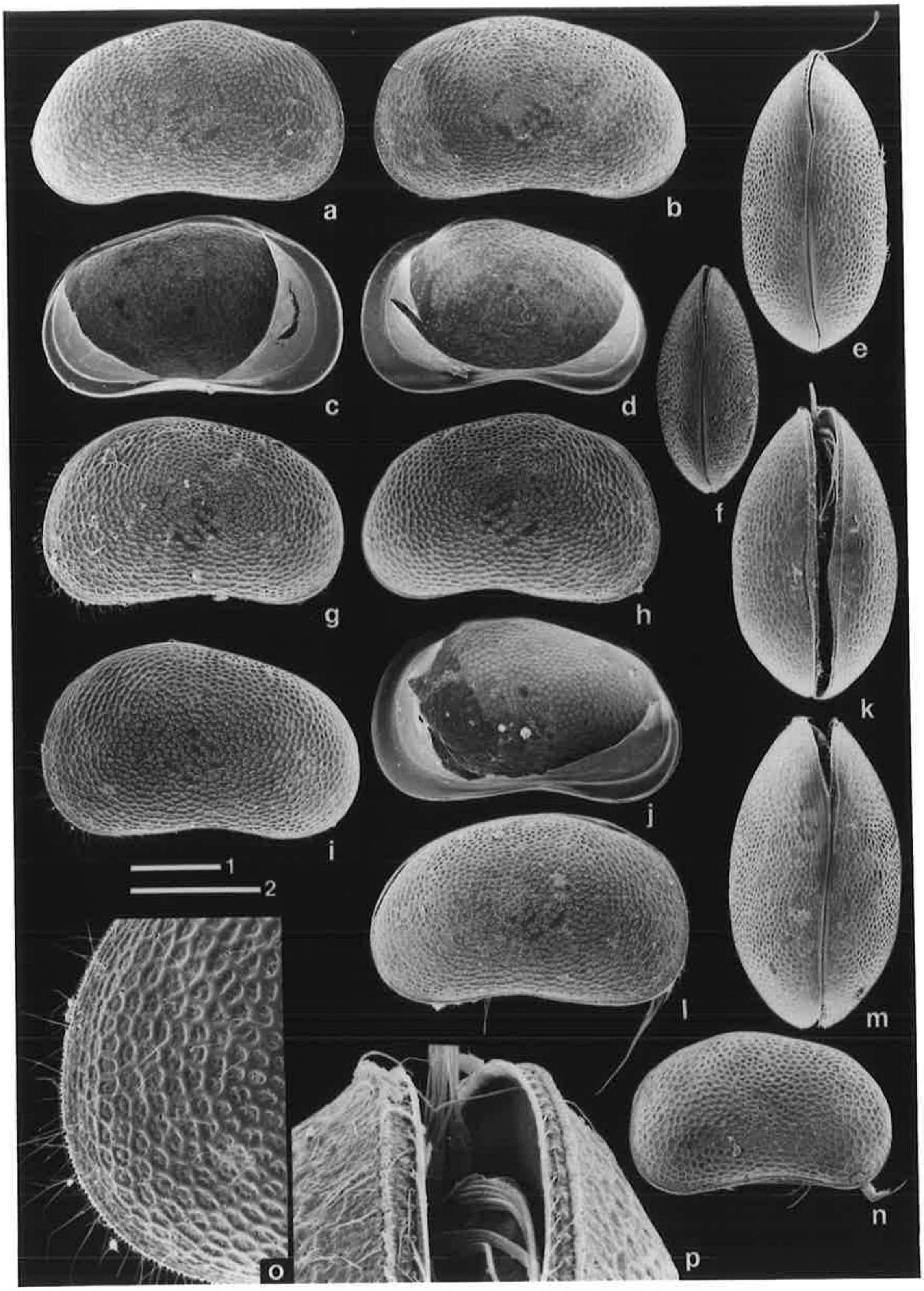

a
b
e
c
d
f
g
h
k
i
j
1
2
l
m
n
o
p

PLATE IV.28

Reticypris kurdimurka n.sp.

a	RV external, male holotype
b	LV external, male holotype
c	LV internal, male paratype
d	RV internal, male paratype
e	LV external, female paratype
f	RV external, female paratype
g	LV internal, female paratype
h	RV internal, female paratype
i	C showing RV, male paratype
j	C showing RV, female paratype
k	RV internal, male
l	C showing LV, male
m	C dorsal, male paratype
n	C ventral, male paratype
o	C dorsal, female paratype
p	C dorsal, male

a - j, n - o: Type locality

k - l, p: Lake Annean, 40 km S. of Meekatharra, W.A.

Scale: 200 μ

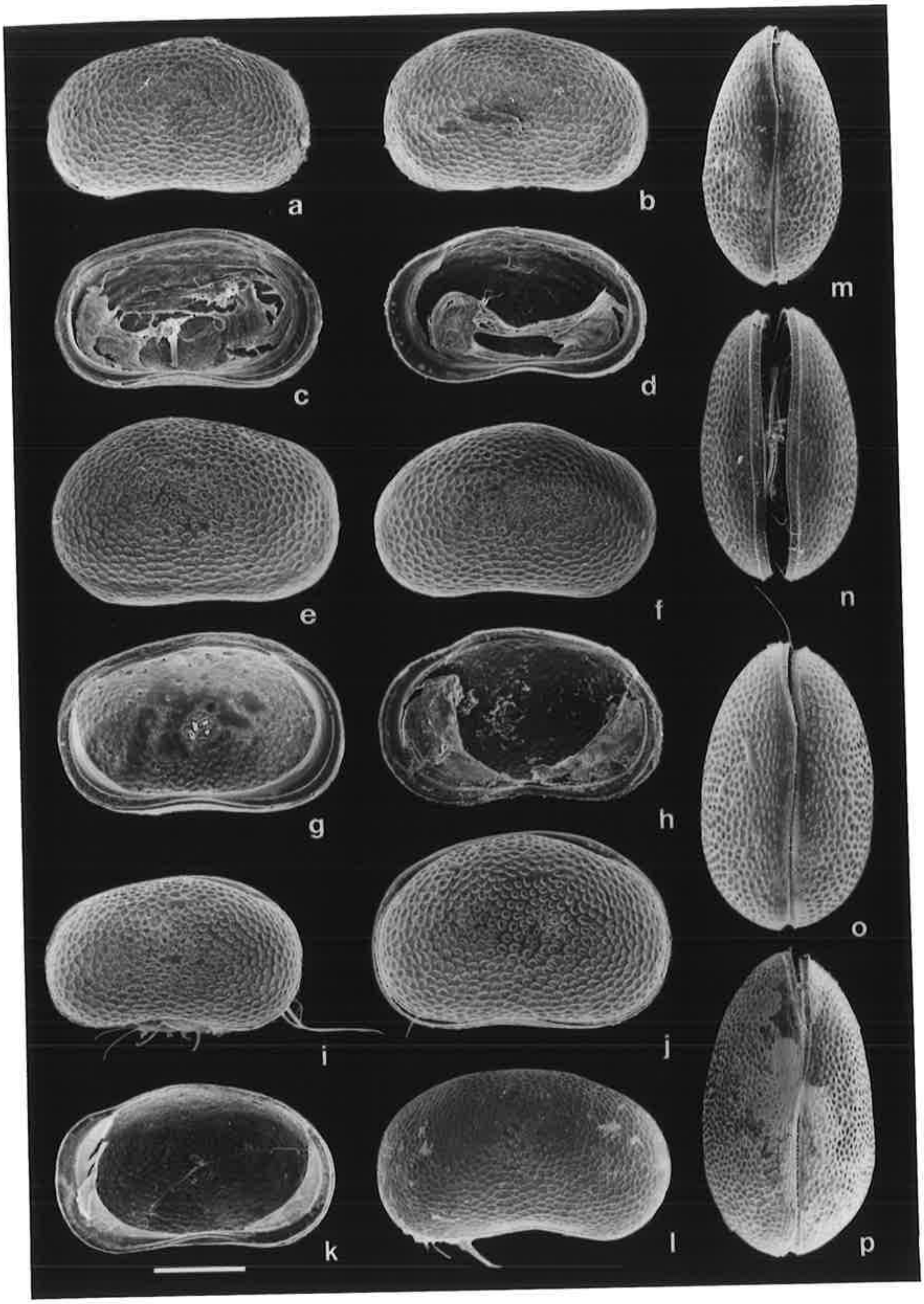

a
b
m
c
d
n
e
f
g
h
o
i
j
k
l
p

PLATE IV.29

Sarscypridopsis aculeata (Costa, 1847)

a	RV internal, female
b	LV internal, female
c	C showing LV, female
d	C showing RV, female
e	RV internal, female
f	LV internal, female
g	C showing LV, female
h	C showing RV, female
i	RV external, juvenile
j	LV internal, juvenile
k	C ventral, female
l	C dorsal, female
m	LV dorsal, female
n	RV dorsal, female
o	C showing RV, detail of h
p	C showing LV, dorsal detail of g
q	C showing RV, juvenile

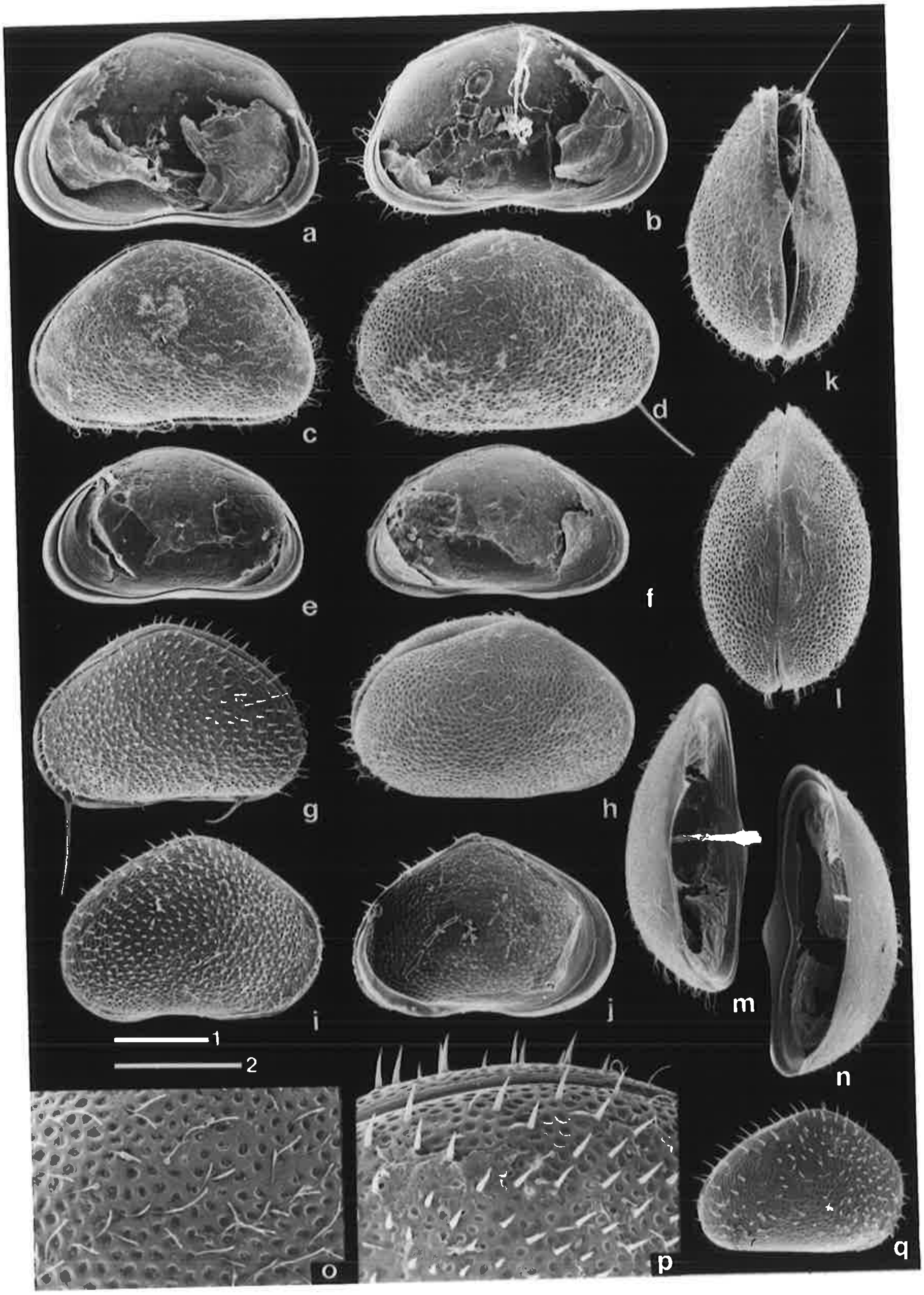
a - d, h, k - n, o: Pond very close to Reel Inlet (coastside), 19 km S. of Mandurah, W.A.

e - f: Shallow lake near south-western Highway, 15 km N. of Horney or immediately S. of Yarloop, W.A.

g, i - j, q: Lake Sadie, E. end of Wilson Inlet, near Denmark, W.A.

Scale: 1 - 250 µ for a - n, q

2 - 100 µ for o - p


a
b
k
c
d
e
f
l
g
h
m
i
j
n
1
2
o
p
q

PART 3

OSTRACOD PALAEOECOLOGY

In the next four chapters, fossil ostracods extracted either from lacustrine cores or from exposed fossil deposits are examined in detail.

In Chapter 5, the fossil fauna, consisting mainly of ostracods, extracted from cores representing Holocene sequences taken from four maar lakes in western Victoria is studied.

In Chapter 6, the ostracod fauna is analyzed from samples taken on a profile dug in two older deposits in north western Tasmania: Pulbeena Swamp and Mowbray Swamp (covering the last 80,000 and 110,000 years respectively).

In Chapter 7, a core taken at Lake George in New South Wales, which covers the last 70,000 years, is examined for its ostracod fauna.

Finally, in Chapter 8, the ostracod fauna is analyzed from a short core, thought to cover part of the Holocene, taken from Pillie Lake in South Australia.

In each chapter, when fossils (either ostracods or others) are discussed for the first time in this thesis, a description accompanied by ecological data, of relevance to palaeolimnology, is presented. Palaeoecological information referred to for the ostracods in Chapters 5 to 8 is taken from the data on their ecology presented for each species in Chapter 4.

In Chapter 9, a summary of the palaeoenvironmental reconstructions for all the sites studied in Chapters 5 to 8, is given in the light of palaeoclimatic studies of significance for Australia and elsewhere.

CHAPTER 5

ANALYSIS OF CORES FROM FOUR MAAR LAKES IN WESTERN VICTORIA

5.1 INTRODUCTION

The availability of a core from each of the four maars, Lakes Bullenmerri, Gnotuk, Keilambete and Purrumbete, made possible the present palaeolimnological study of each lake in order to find out how the fluctuations in climate in the past 10,000 years affected each lake and if such fluctuations were recorded synchronously. This was of special interest as the lakes cover a broad spectrum of water salinities (see Table 5.1) and correspondingly have different faunas. Thus the recovery of different ostracod shells from the cores, and a knowledge of the salinity tolerance of the corresponding species today, could provide palaeosalinity data. In addition, with information on the present hydrology of each lake, a correlation of the salinity curve with that of a climatic one could be attempted as many radiocarbon dates, already available in the works of Barton *et al.* (in press), Bowler and Hamada (1971) and Dodson (1974a) have facilitated and confirmed correlation between the cores. Some fossil taxa, other than ostracods, indicative of different salinities have also been examined, when available.

Lakes Bullenmerri, Gnotuk, Keilambete and Purrumbete are located in the Camperdown area, approximately 170 km west southwest of Melbourne and about 30 km from the sea (Fig. 5.1). They are situated within the Western Victorian Newer Volcanic Province which is of Pliocene to Recent age (Ollier and Joyce, 1964) and overlies Miocene limestone (Joyce, 1975).

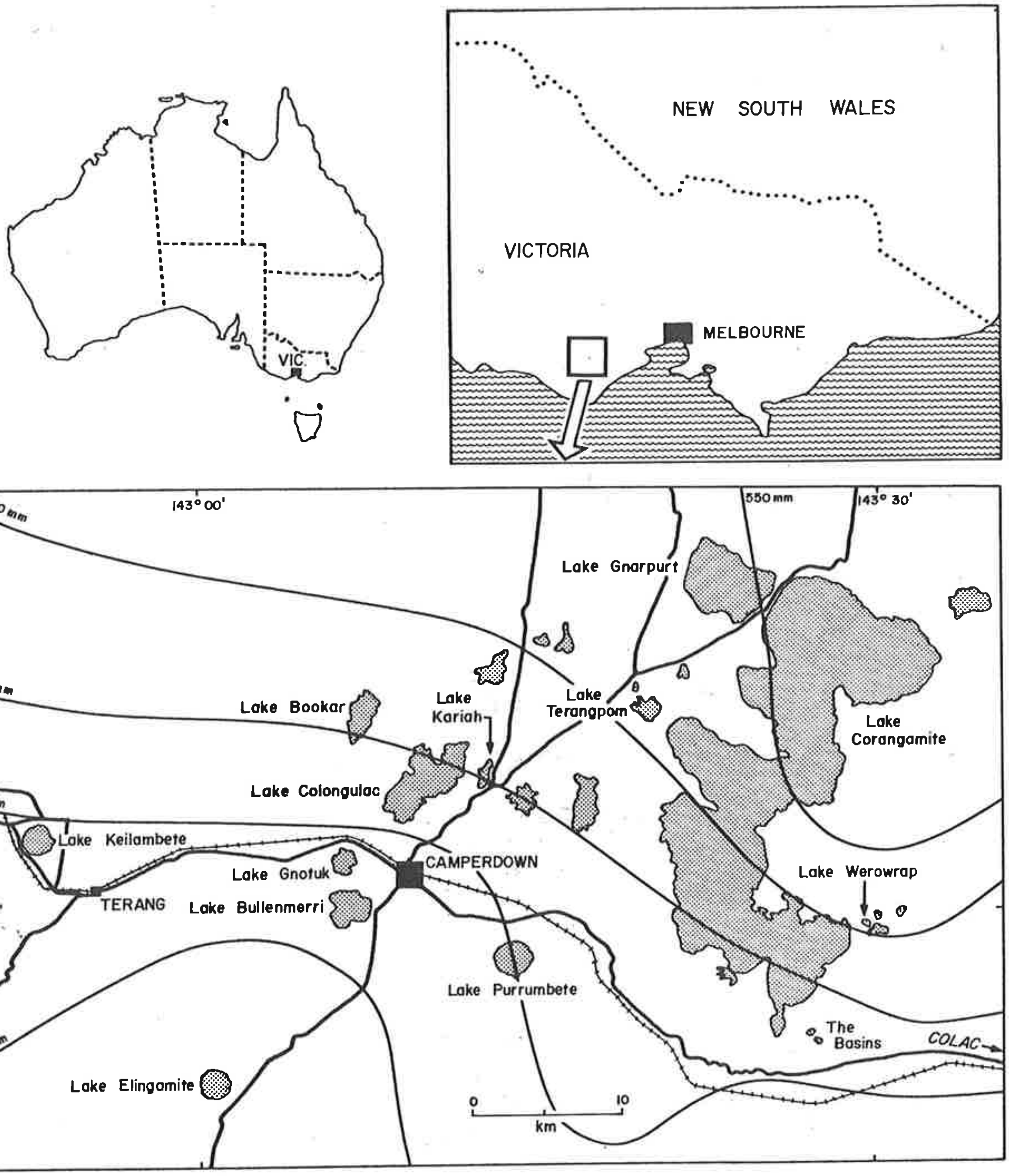


FIG. 5.1 Map showing the location of the 4 maar lakes in Victoria.

Each lake occurs inside a shallow volcanic crater best described as a maar. According to Ollier (1968), a maar is a landform caused by volcanic explosion, consisting of a crater which reaches, or extends below, general ground level; it is considerably wider than it is deep and has a surrounding rim constructed of material ejected from the crater.

Near Camperdown, Lakes Bullenmerri and Gnotuk are adjacent craters formed by distinct volcanic explosions (Ollier, 1970) and only once in human memory is Lake Bullenmerri known to have overflowed north into Lake Gnotuk (Currey, 1970). Lake Bullenmerri is clover-leaf shaped, 66 m deep and has steep sides (Fig. 5.2). Present water level is some 21 m below the point of overflow where it can flow into Lake Gnotuk. The salinity of the water ranged between 55-63°/oo in 1979-80. For additional detail see Table 5.1. Lake Gnotuk is much smaller, oval shaped, 18.5 m deep and flat-bottomed (Fig. 5.2 and Table 5.1). The water level is about 30 m below that of Lake Bullenmerri. Water salinity in 1979-80 ranged between 4.49-8.57°/oo. For other data see Table 5.1.

The circular shaped Lake Keilambete lies to the west near Terang. It is 11 m deep and also flat-bottomed. Salinity was measured once in January 1980 at 62.4°/oo but its value has varied between 55.3 and 62.4°/oo in the last 15 years (Maddocks, 1967; Hussainy, 1969; Bowler, 1970).

Lake Purrumbete, to the east of Camperdown, is the largest of the four maars. It is 45 m deep and has steep flanks with a gentle slope towards its centre (Fig. 5.2). Water salinity fluctuated between 0.37-0.44°/oo in 1979-80. For other data see Table 5.1.

Lakes Bullenmerri, Gnotuk and Keilambete are internal drainage

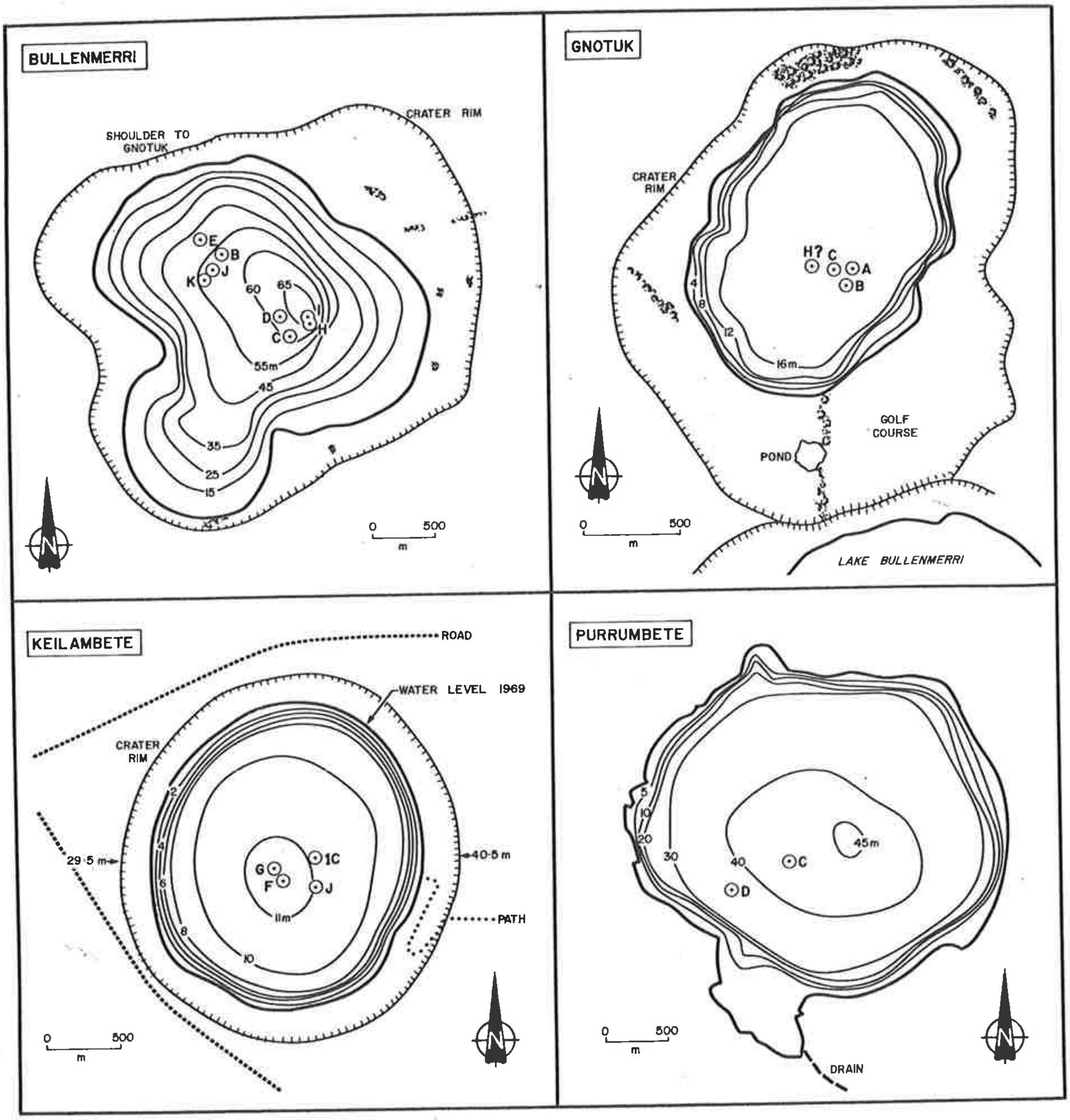


FIG. 5.2 Bathymetry and location of core sites for each of the 4 maar lakes.

basins: water in the lakes results from precipitation and crater slope run-off and in each case there does not seem to be much interference with groundwater (Bowler, 1970; Currey, 1970). An exception occurs when Lake Bullenmerri overflows into Lake Gnotuk. Lake Purrumbete can also overflow into the Curdies River which is at about the same altitude as the lake at its present level. Water chemistry of the four lakes has been studied by Maddocks (1967). The fauna of Lakes Bullenmerri, Gnotuk and Purrumbete has been extensively studied during the 1969-1972 period by Timms (1974, 1980, in press) and to a lesser extent by Hussainy (1969) between the 1967-68 period. The flora of the four maars was examined by Yezdani (1970) and Tudor (1973). The latter concentrated on the diatoms.

Some palaeolimnological work has also been carried out on these four maar lakes. Yezdani (1970) described changes in aquatic flora (using pollens and diatoms) for Lakes Gnotuk and Bullenmerri. Bowler (1970, in press) examined the distribution and composition of sediments in cores from Lake Keilambete and its margins. A water level curve for the last 30,000 years resulted from this study (Bowler and Hamada, 1971; Bowler, in press). Additionally, Dodson (1974a) presented a palynological curve for the same lake for the last 10,000 years. His data reveal changes in vegetation surrounding the lake accompanied, at times, by modifications in the aquatic vegetation due to changes of water salinity. Tudor (1973), using diatoms only, described changes in water quality for some periods of the history of Lakes Keilambete and Gnotuk. Recently Barton (1978) and Barton *et al.* (in press) have collated palaeomagnetic curves on many cores from each of the four maars. From these studies, a water level curve resulted for Lake Keilambete for the last 10,000 years; it demonstrated a strong correlation with the natural remanent magnetization intensity curve.

Finally, Dodson (1979) presented a pollen record from a core taken from the deepest part of Lake Bullenmerri and covering the 8,000 to 16,000 yBP period. All these results will be discussed in the latter part of this chapter.

5.2 METHODS

A 6 m long pneumatic corer, similar to that designed by Mackereth (1958) fitted with an orientating device (Barton and Burden, 1979) was used to core each lake. The 54 mm in diameter cores were originally taken for a palaeomagnetic investigation of the sediments (Barton, 1978). Cores were later cut into 1 to 2 m sections to facilitate transport. Rubber bungs were inserted at the ends of most sections, compressing sediment therefore by about 2 cm each time. The cores were later split open lengthwise and sedimentological description was completed, often under a binocular microscope. Sampling of each core was later carried out by extracting 3 g of sediments each time. The numbering of each sample for all cores refers to their appropriate levels in cm below the top of the core. Each sample was kept in a sealed 200 mℓ jar in a 10% hydrogen peroxide solution for about one to two weeks depending on the separation rate of clays and dissolution of organic matter. The content of the jar was then gently washed with water jet over a 200 μ sieve. (It was decided not to use a finer sieve which would have retained valves of juvenile ostracods for these are often unidentifiable.) The residue was then dried in a low temperature oven and finally picked under a binocular microscope. Every ostracod was therefore examined and later counted. When specimens were particularly numerous (>1,500 individuals), an estimate of the number was made.

TABLE 5.1 Morphometric and salinity data on the four maars (after various authors)

	Bullenmerri	Gnotuk	Keilambete	Purrumbete
co-ordinates	143°02'50"E 38 12'30"S	143°02'50"E 38 11'42"S	142°22'54"E 38 12'24"S	143°16'40"E 38 13'30"S
Surface area (ha)	448•	208•	277□	552•
Volume (10^{6}m^3)	192•	32•	13.3*	157•
Maximum depth (m)	66•, 67×	18.5•, 20×	11□, 10×	45•, 42⊕
Mean depth (m)	39.3•	15.3•	9.5×	28.5•
Salinity (TDS °/oo) 1979-80	4.49-8.57	55-63	62.4 (Jan. 1980)	0.37-0.44
Other periods	7.8 -8.5•	56-62•	55.3○, 61.3×	0.42-0.50•

•	Timms, 1976
□	Bowler, 1970
*	calculated from Bowler, 1970
○	Maddocks
⊕	Barton, 1978
×	Hussainy, 1969

5.3 DESCRIPTION OF THE CORES

5.3.1 Lake Bullenmerri

A core 533.5 cm long was taken on 1.III.1977 at a depth of 55.5 m in the northwestern part of the lake (Fig. 5.2, location K). The coring site could differ from this location by about 100 m (Barton, pers. comm.). The original label BK for the core referred to by Barton *et al.* (in press) is kept here. A detailed lithological description of the core and the position of the 279 samples studied is given in Fig. 5.6. The core consists mainly of fairly homogeneous organic mud. Two colourations were noticed:

a - brown to dark brown to grey brown organic mud with abundant fine (100-200 μ thick) or occasionally coarse (ca. 1 mm) laminations. The five laminations were usually black whereas some of the coarse ones varied from beige brown to orange brown to white in colour.

b - dark grey to black organic mud below level 400 cm. Laminations were not seen.

After treatment of some of the samples with H_2O_2, small grains (>200 μ) consisting mainly of scoria fragments were found. Their presence in the core is referred to in Fig. 5.9 and their significance will be discussed later. The "sulfureous orange muds" described by Barton *et al.* (in press) at the bottom of their much longer cores (ca. 10 m long) were not encountered in core BK.

5.3.2 Lake Gnotuk

A core 362.5 cm long was taken on 7.III.1977 at a water depth of 19 m near the centre of the lake. Its exact location was queried by Barton (1978). The original label GH for the core referred to by Barton *et al.* (in press) is retained here. A full lithological description of the core and the position of the 219 samples taken is given in Fig. 5.3.

A variety of sediment types was encountered and these types are described in descending order from the top of the core:

- brown to dark brown organic mud with numerous white to beige carbonate bands (ca. 1 mm) down to 32 cm. A small hiatus with contorted bedding was noticeable at level 21 cm.
- dark brown to black organic mud with alternation of light and dark thick layers (ca. 1 cm) yielded many ostracod shells (*Diacypris compacta*) down to 88 cm. Sometimes the shells were so abundant that the layers had a sandy appearance.
- brown to dark brown to black organic mud with some pale brown to olive green layers and many very fine black laminations (ca. 100 μ) down to 175 cm. The average distance between these thin black laminations ranged between 450 μ and 600 μ.
- dark brown to black organic mud with thin (<1 mm) grey or black or brown layers at irregular intervals down to 231 cm.
- between 231 cm and 266 cm, dark brown to black organic mud with abundant white to grey layers, especially between level 231 and 250 cm. (Large crystals of aragonite were found in some of these light coloured layers.)
- grey-green organic mud down to 285 cm grading into grey to dark grey organic mud down to 325 cm. Pale coloured thin bands were more common in the upper part. A small truncation of bedding was noticeable around level 295 cm.
- grey to dark grey organic mud down to 333.5 cm. No sediments were recovered between that layer and level 346 cm.

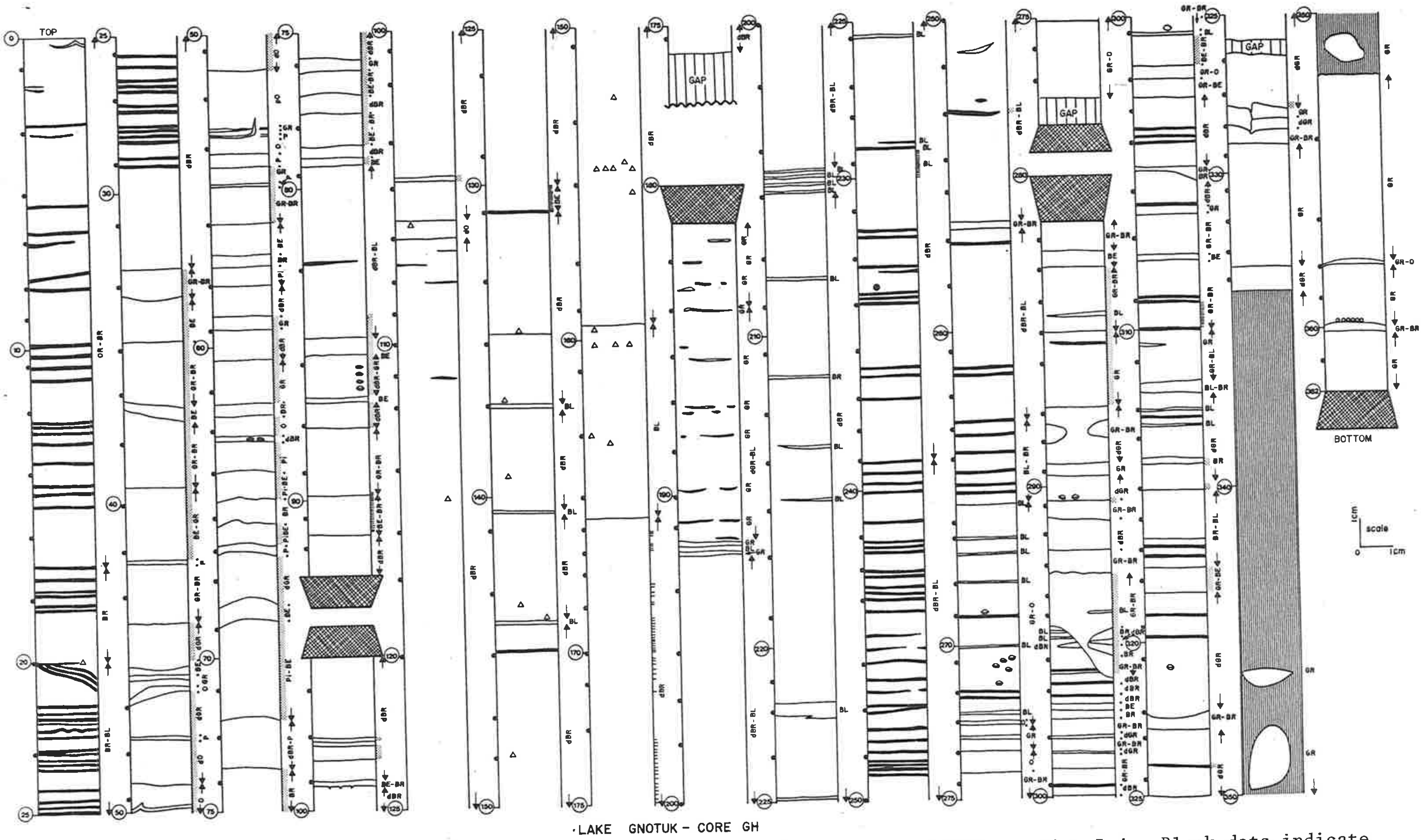


FIG. 5.3 Detailed lithological description of core GH from Lake Gnotuk. For legend see Fig. 5.4. Black dots indicate the position of samples in the core.

- grey clay from 346 cm to 362 cm. The upper 6 cm appears to have been mixed. This entire layer is probably displaced as suggested by the gap above it.

5.3.3 Lake Keilambete

Two cores were taken: a short one, labelled KIC by Barton *et al.* (in press) was collected on 5.XII.1976, slightly east of centre of the lake where it is about 10 m deep. It was 127 cm long. This core was taken to obtain the uppermost layers of sediments not recovered in the longer core. The latter, labelled KG in Barton *et al.* (in press) and collected on 29.IV.1975 is 419 cm long was taken at the centre of the lake at a depth of 10.5 m. For location of both cores, see Fig. 5.2, and their lithological description, see Figs. 5.4, 5.5. The top of core KG is at about 40 cm below the water sediment interface (see correlation between the two cores - Table 5.3 and Figs. 5.4, 5.5, 5.8 and 5.9). Forty-nine samples were examined from core KIC and 172 from core KG. Bowler (1970, in press) provided a detailed stratigraphic log of a 440 cm long core (labelled K4) from Lake Keilambete. This will not be repeated here as the core was taken from another part of the lake with distinct facies differences. Notably, the grey mud recovered at the bottom of core KG (see Fig. 5.5) was not found by Bowler in core K4. Additionally, the sandy layers mentioned by Bowler (*op. cit.*) in his cores K4 and K5 are not found in core KG. The broad sedimentary divisions given by Bowler (in press) are used here:

- top of core to 200 cm (core K4) = Upper Keilambete Muds consisting of fine grained dark calcareous muds with paler carbonate rich bands and occasional sandy horizons (150 cm, 100 cm). This unit apparently terminates at level 153 cm in core KG and comprises the whole of core KIC.

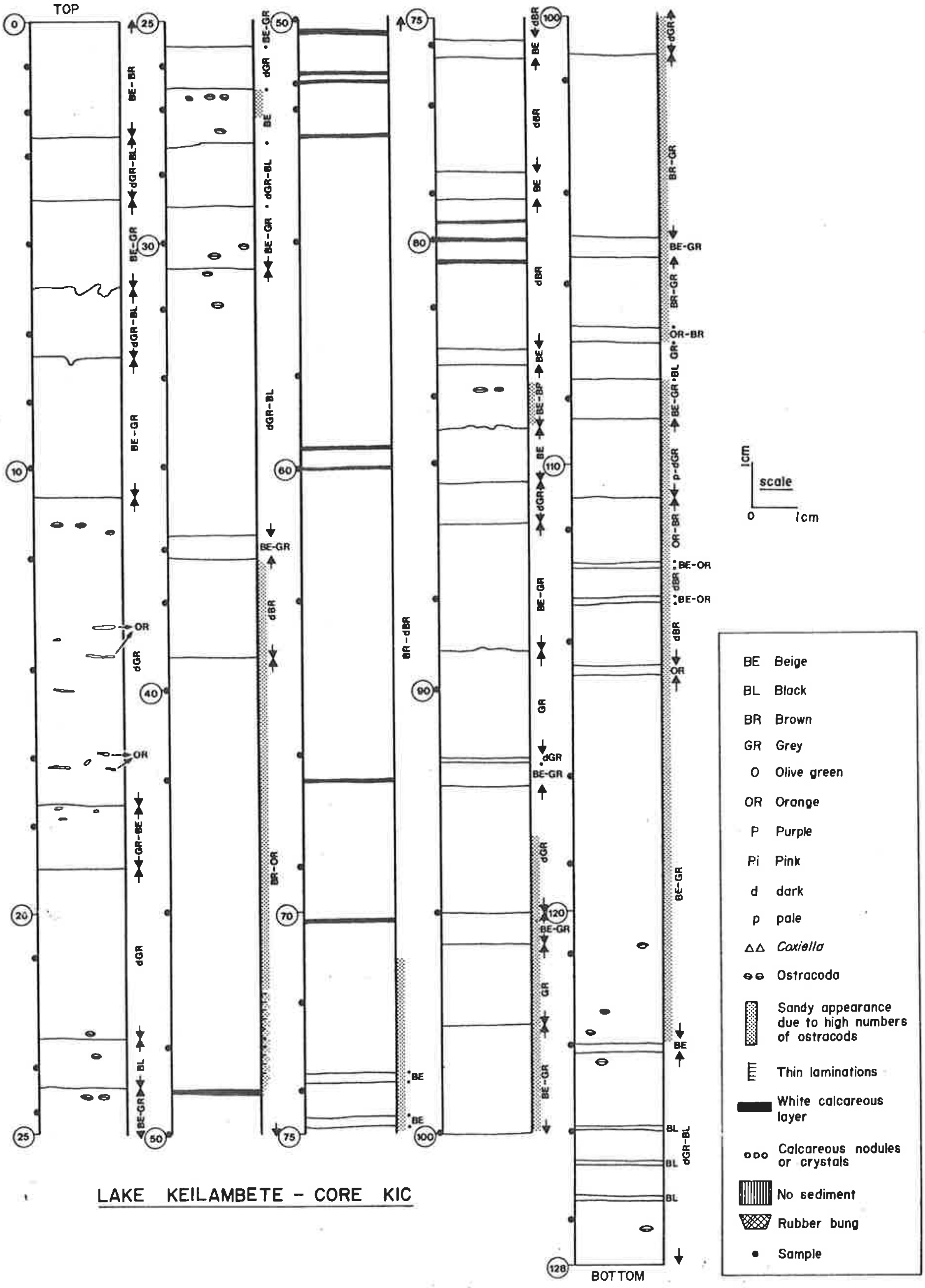


FIG. 5.4 Detailed lithological description of core K1C from Lake Keilambete.

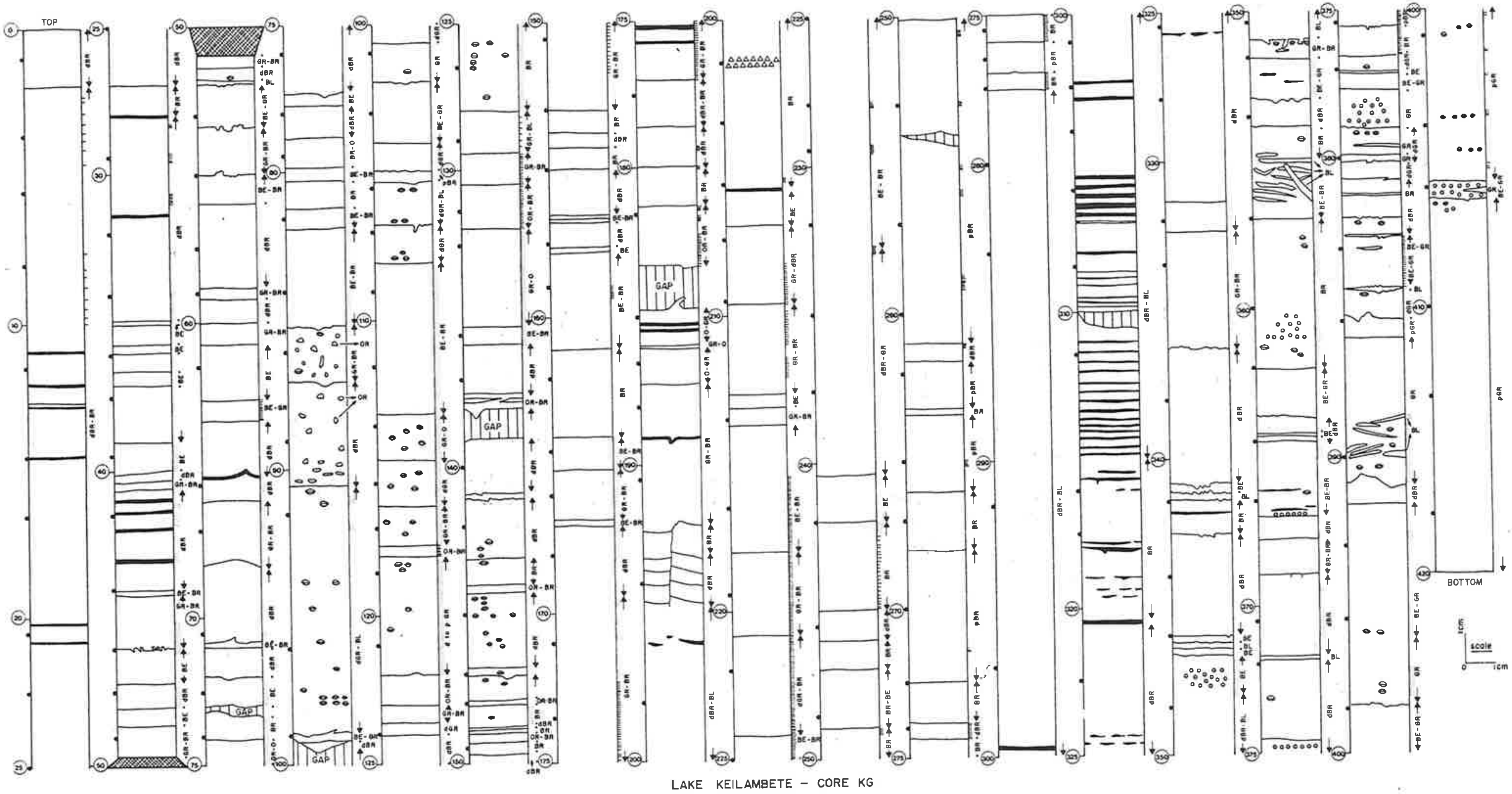


FIG. 5.5 Detailed lithological description of core KG from Lake Keilambete. For legend see Fig. 5.4.

- 200 cm to 375 cm (core K4) = Lower Keilambete Muds consisting of fine grained dark muds which are weakly calcareous. The basal part of this unit cannot be defined in core KG as the other two units described by Bowler (in press) as the basal saline sands (zone 375-440 cm) and the basal soil (400-440 cm) are missing in core KG. It is thought that the basal soil probably is facies equivalent to the grey to brown mud found in core KG below level 350.5 cm and finally grading into the grey mud below level 385.5 cm.

Throughout the entire core, there are many bands, sometimes more than 1 cm thick, which consist mainly of ostracod shells (Fig. 5.4). Their palaeoecological significance will be dealt with in a later part of this chapter. Below levels 355 cm and 387 cm in core KG, bedding is disturbed: these are probable signs of aerial exposure of the lake floor.

5.3.4 Lake Purrumbete

A 581 cm long core, labelled PC by Barton *et al.* (in press), was taken on 2.V.1975, at a depth of 40.8 cm near the centre of the lake (Fig. 5.2). Note that the bathymetric map provided by Barton (1978), is different from that of Timms (1976). Only homogeneous dark brown organic mud has been recognized throughout the entire core. Small gas vesicles are common in the more fluid upper 113 cm of the core; below that level, the organic mud becomes more compact with increasing depth. 195 samples, usually taken at 3 cm intervals were analyzed from core PC (Fig. 5.10).

5.4 RESULTS

Taxonomic and ecological information relevant to the fossil remains recovered from all the cores and not yet discussed in Chapter 4, will be presented in the section 5.4.1. In the second part 5.4.2, diagrams representing the distribution of these fossils in each core (Figs. 5.6-5.10) will be given and their significance later discussed.

5.4.1 Systematics

5.4.1.1 Ostracods

None of the ostracods recovered from the samples studies here have been recorded as fossils in Australia except for *Mytilocypris praenuncia* which was originally described from a Pleistocene site by Chapman (1936). This species was later rediscovered as living in some Victorian lakes by De Deckker (1978). Description of taxa will refer to fossilized material only: no reference to animal soft parts will be made.

The ostracods dealt with here can be easily recognized by the following features. Adults with large carapaces (ca. 3 mm), thin and fragile shells belong to the tribe Mytilocypridini: these are *Australocypris robusta* De Deckker, 1974 (Plate V.2: Figs. 13-15) which is rectangular in shape and *Mytilocypris praenuncia* (Chapman, 1936) (Plate V.2: Figs. 1-12) which is more triangular. A smaller ostracod, *Platycypris baueri* Herbst, 1957 (Plate V.2: Figs. 26-38), has a very brittle shell, and is rectangular to oval shaped. Two much smaller ostracods, *Diacypris compacta* (Herbst, 1958) (Plate V.4: Figs. 1-16) and *D. dietzi* (Herbst, 1958) (Plate V.3: Figs. 21-27, 36) have a smooth shell; the former species is circular in shape and the latter is triangular. In addition, there are two large *Diacypris* species: *D. whitei* (Herbst, 1958) (Plate V.3: Figs. 28-30) is rectangular in shape and has a smooth shell, whereas *D. dictyote* De Deckker, 1980 (Plate V.3: Figs. 31-35, 37) is triangular and has a reticulate shell which is finely pectinate anteriorly and posteroventrally.

Reticypris herbsti McKenzie, 1978 and *Reticypris clava* n. sp. can be recognized by their reticulated, rectangular to squarish shell (Plate V.3: Figs. 1-20, 38, 39). They cannot be distinguished on shell features alone. The following three ostracod species have an almost rectangular shell with obvious ornamentations, and differ on the following features:

(a) *Limnocythere dorsosicula* n.sp. (Plate V.1: Figs. 17-24) is the smallest species and is characterized by the presence of three to six spines in the posterodorsal area of the right valve; the rest of the shell is mostly smooth.

(b) *Ilyocypris australiensis* Sars, 1889 (Plate V.1: Figs. 26-33) is the largest species; it has a pitted shell with three broad depressions, one in the middle and one above it and a longer vertical one in front of the two.

(c) *Leptocythere lacustris* n.sp. (Plate V.1: Figs. 1-16), with the thickest shell, possesses the coarsest reticulation and has one anterior groove following the curvature of the shell and a deep notch posteroventrally.

(d) *Candonocypris novaezelandiae* (Baird, 1843) (Plate V.1: Fig. 25) has a smooth shell, is broadly oval in shape and is characterized by the largest length height ratio for its shell.

5.4.1.2 Foraminifera

Foraminifers have recently been recognized as common benthic inhabitants of salt lakes in Australia, especially near the coast (De Deckker and Geddes, 1980; Cann and De Deckker, in press). These organisms can be found in salt lakes not connected to the sea and, because of their marine affinity, they are thought to prefer salinities close to that of sea water. However, they are known to "survive" fluctuating salinities and some of them can even withstand periods of lake desiccation (Cann and De Deckker, in press).

It is not surprising to find living forams in salt lakes which have salinities similar to that of sea water as many salt lakes in Australia have similar ionic composition to that of the sea. It is suggested that the most likely transporting agent of these organisms into lakes are birds, a process recently reviewed for the transport of ostracods in Australia by De Deckker (1977).

Two groups of foraminifers are recognized, firstly those which can survive periods of desiccation, namely *Elphidium* sp. *sensu* Cann and De Deckker (in press), and *Trochammina* sp. *sensu* Cann and De Deckker (in press); and secondly those which apparently cannot as they are only found in permanent waters: *Ammonia beccarii*, *Triloculina rotunda* and *Trichohyalus tropicus*. The latter species was not recovered in any of the cores.

It is expected that *Trochammina* sp. will not be recovered in core samples because this agglutinated foraminifer disintegrates very rapidly when kept outside water. Treatment of the sample, requiring drying in an oven, would cause the specimens, if present, to break apart.

The following foraminifers have been found in the cores:

Ammonia beccarii (Linné, 1758)
Plate V.4: Figs. 23-32

1758 *Nautilus beccarii* n.sp., Linné, p. 710.

1949 *Ammonia beccarii* (Linné), Frizzell and Keen, p. 106.

Description: Finely perforated, trochospiral test more convex dorsally; sutures usually thick and smooth; ventrally gradation of umbilicus from empty to a plug and often finely to coarsely spinose. Some aberrant growth forms (Plate V.4: Figs. 28, 32) have been found in some samples.

Size range: Up to 600 μ for greatest length.

Ecology: This cosmopolitan species, found in cores of Lakes Gnotuk and Keilambete, indicates permanent water conditions and salinity close to that of sea water, although it is known to survive a broad range of salinities, from 7-67°/oo (Bradshaw, 1957), as it can only reproduce in, and grows best at, salinities between 20-40°/oo (Bradshaw, 1957). Therefore, at level 362-367 cm in core KG from Lake Keilambete, the large numbers of *A. beccarii*, which are recognized as forming living assemblages as specimens of all sizes were found, represent a series of thriving populations. Salinity must therefore have been at an optimum for the species, that is, similar to that of sea water.

Elphidium sp. *sensu* Cann and De Deckker, in press

Plate V.4: Figs. 17, 18, 21, 22

Remarks: No specific name has so far been given to living representatives of this organism as its morphology is very variable. Ecological parameters which appear to affect test architecture are not yet fully understood (for further taxonomic discussion see Cann and De Deckker, in press). The uneven periphery of the test is thought to result from "harsh" conditions such as great salinity fluctuations: in Little Dip Lake near Robe, South Australia where water is permanent and the salinity range is 12-24°/oo, specimens of that species, identified by Cann and De Deckker (in press) as *Elphidium* sp. "Group B" usually have a round and smooth test; additionally, retral processes in these specimens are most often faintly visible. *Elphidium* sp. can survive periods of lake desiccation but, as mentioned above, it can also live in permanent waters.

The salinity range of this species is not yet known but it is considered here that fossil material found in the cores ought to indicate salinities around that of sea water for the same reasons given for *A. beccarii*, even though it is known to "survive" higher values: at 88°/oo no pseudopodia were seen protruding from the test but the same specimens, put later in sea water, became active.

Size range: Up to 500 µ for greatest length.

Triloculina rotunda d'Orbigny, 1893
Plate V.4: Figs. 19, 20

1893 *Triloculina rotunda* n.sp., d'Orbigny, p. 20.

Description: Triloculine test, oval in shape, but flattened at the aperture; ellipsoid in cross section with edges rounded. Aperture with narrow bifid tooth.

Size range: Greatest length slightly less than 500 µ, and greatest width 250 µ.

Ecology: This species, rarely found in the core samples, so far has only been collected in one lake, Little Dip Lake, where salinity fluctuates between 17-24°/oo and water is permanent. These parameters are thought to apply to the fossil material. *T. rotunda* was never found in the ephemeral Coorong lakes samples, collected over a one year period by De Deckker and Geddes, 1980.

Discorbis sp.
Plate V.4: Fig. 33

Remarks: One specimen only has been found at level GH135 in the Lake Gnotuk core. No ecological information is considered for this species not yet found in present day salt lakes.

5.4.1.3 Mollusca

Only the shells of the halobiont gastropod *Coxiella* sp. have been recovered in the cores. Their palaeoecological significance is discussed below. Attention will also be given to the gastropod *Potamopyrgus niger* (Quoy and Gaimard, 1835) and the bivalve *Sphaerium* sp., both found today in Lake Purrumbete. Their absence in the cores bears some relevance to the lake histories.

Coxiella sp.

Plate V.6: Figs. 16-26, 30, 31

Description: Conical to elongate shell with up to 7 whorls; round to oval aperture with broad lip in adults; extent of umbilicus variable; shell finely ribbed and sutures deep.

Size range: Up to 10 mm in length.

Ecology: *Coxiella* sp. can withstand lake desiccation phases and also survive high salinity ranges by sealing its aperture with the operculum at the appropriate time. No salinity information can be obtained from its presence in sediment except that its presence excludes fresh water as *Coxiella* is a halobiont genus. In salt lakes below 100°/oo salinity *Coxiella* spp. have commonly been seen grazing on algal mats on lake floors or crawling in among halophytes such as *Ruppia* sp., *Lepilaena* sp. and *Lamprothamnium papulosum*. *Coxiella* specimens have never been found at great depths: in Lake Bullenmerri, Timms (1973) collected *Coxiella striata* (Reeve, 1842) juveniles (length <5 mm) down to 25 m below the lake level and larger specimens of the same species rarely below 6 m. He also recorded large numbers of emptied juvenile shells between depths of 12 and 25 m. Consequently, the presence of many *Coxiella* shells at a particular level, such as 201.5-202.5 cm in core KG from Lake Keilambete, seems to indicate that the lake level was probably less than 25 m and most probably less than 6 m above the flat lake floor at the time since adult shells were found.

After the death of the animal, shells become filled with gas resulting from body decay and consequently float to be more often blown by the wind to the lake shore. Extensive layers of *Coxiella* shells are common on many lake shores. Such layers should be easily recognizable in cores if present. Juveniles of *Coxiella* on the other hand have been seen to float upside down at the surface tension of some lakes. Their failure to remain near the surface and subsequent death by sinking to the bottom of the lake, would explain the presence of few shells of juveniles found in a number of samples: their occurrence in sediments in this case adds no information on the depth of the lake at the time of their death.

Remarks: As pointed out by Mellor (1979) and De Deckker and Geddes (1980), the taxonomy of all *Coxiella* species is in a confused state. Doubt is cast on the value of diagnostic features of the shell. Plate V.6: Figs. 16-26 illustrates the variations in shell morphology and this is the reason for which no specific identification is attempted here.

The data of Timms (1973) for *C. striata* living in Lake Bullenmerri today are used to interpret the fossil material. Ecological requirements are likely to have been the same for both the fossil and living material as they are from the same geographical area.

Chapman (1919) identified the fossil *Coxiella striatula* (Menke, 1842) from the Pleistocene (*sic* Chapman, 1919) deposit at Boneo Swamp in Victoria but he gave no consideration to the fact that it is found with other molluscs, apparently freshwater inhabitants.

The freshwater gastropod *Potamopyrgus niger* (Quoy and Gaimard,

1835) commonly found in Lake Purrumbete (Timms, 1973) occurs over a wide depth range: 0.5-33 m but is most common between 1 and 6 m (Timms, 1973). As this gastropod was never recorded in any of the cores, it appears that in the case of Lake Purrumbete, which is thought to have remained fresh for the period covered by the core, the shore of the lake has never been close to the coring site, otherwise shells of *P. niger* would have been found. This remark also applies to the freshwater bivalve *Sphaerium* sp., found today in Lake Purrumbete between 0.5 and 21 m in depth (Timms, 1973) and never recovered in any of the cores.

5.4.1.4 Cladocera

Only ephippial sac remains have been recorded from the cores - cuticular fragments of cladocerans were noticed in some samples but have not been studied here. Two main types of ephippium were found: one belonging to the halobiont *Daphniopsis pusilla* and the other to the mainly freshwater inhabitant *Daphnia* spp.

Daphniopsis pusilla Serventy, 1929
Plate V.5: Figs. 1-4

1929 *Daphniopsis pusilla* n.sp., Serventy, p. 65.

Description of ephippium: Ephippial sac almost rectangular and asymmetrical: the posterior side forms almost a right angle with the small extension of the dorsal chitinous rod (which is occasionally bifid) whereas the anterior side forms an acute angle with the longer and often bifid chitinous rod. The greatest length of the ephippial sac is at about 2/3 from its dorsal side. In dorsal view, it is very compressed.

Ecology: The ecology of *D. pusilla*, which is endemic to Australia, has been recently reviewed by De Deckker and Geddes (1980). The salinity range of this cladoceran in the lakes near the Coorong Lagoon in South Australia is 5.8-68.1°/oo, although few specimens were recorded at the 68.1°/oo which is the highest ever recorded for the species. Geddes (1976), in his study of Victorian lakes noted that hatching of the species occurred between 4.4 and 33.4°/oo. The presence of ephippial sacs at a particular level in a core would imply that the lake water, for that particular time, should have been at some stage between 4.4 and 33.4°/oo. In lakes today, occasional bundles of 20 or more ephippial sacs of *D. pusilla* entangled together with the bifid chitinous rods are found on the lake floor. This phenomenon was not observed in fossil material.

Remarks: The most diagnostic feature of the ephippium for this species is the acute angle formed by the anterior dorsal chitinous rod and the anterior side of the ephippial sac.

Daphnia spp.
Plate V.5: Figs. 5-8

Description of ephippium: Ephippial sac ellipsoid in shape and at least twice as long as it is wide; in dorsal view narrow to bulbous; external surface sometimes faintly reticulated. Dorsal chitinous rod longer anteriorly and forming a right angle with the posterior side of the ephippial sac; posterior angle obtuse. Internal capsule often with a ridge along its periphery (broadest anteriorly and posteriorly) and with a vertical groove in the middle separating the two egg spaces; external surface of capsule reticulated.

Ecology: Identification at the species level of the daphniid species to which the fossil ephippial remains found in the cores, belong is not possible at the present stage. Their presence, however, indicates a water salinity between fresh and 5.8°/oo. The upper record refers to a collection made in January 1980 from a small lake near Lake Coragulac in Victoria. Five records of *Daphnia* spp. observed in a survey of 80 lakes, at the same period, range between 1.90 and 4.91°/oo. *Daphnia carinata* King, 1853 has also been identified by Geddes *et al.* (in press) from three localities in Western Australia where salinity values ranged between 3.57 and 4.76°/oo. The value of 5.8°/oo is the upper value recorded so far in Australia for a *Daphnia* species and it will be regarded as the maximum value for the fossil material studied here.

Remarks: Sars (1885) accurately illustrated the morphology of the ephippium of *D. lumholtzii* Sars, 1885, providing adequate illustrations of ephippial sacs and its internal egg capsules. These resemble many of the specimens recovered in the Lakes Bullenmerri and Purrumbete cores, and were deflated or partly shrunk after drying prior to picking and preparation for SEM photography. However, Sars' illustrations show a double row of tiny spines along the dorsal chitinous rod attached to the ephippial sac. These were rarely seen on the specimens recovered from the cores except on one occasion (Plate V.5: Fig. 6). No further identification has been carried out.

5.4.1.5 Isopoda

Remains of the aquatic halobiont isopod *Haloniscus searlei* have been recovered from a number of core samples. These are described below.

Haloniscus searlei Chilton, 1920
Plate V.4: Figs. 34-42

1920 *Haloniscus searlei* n.sp., Chilton, p. 724.

Description of fossil remains found in the cores

- Cones: Slightly arched and hollow cones, partly calcareous? and brittle; external surface consisting of parallel rows of disconnected and alternating faint and arched grooves; occasional rimmed triangular pores with two small pores inside and one at base of the triangle. These cones with pores correspond to the distal segments of the posterior appendages of the animal, and those without pores belong to spines attached to the telson.

- Others: These are of various shapes and are illustrated in Plate V.4: Figs. 37-42. The fragment illustrated in Plate V.4: Fig. 39 belongs to one of the proximal segments of one of the appendages whereas fragments illustrated in Plate V.4: Figs. 40-42 are thought to be part of ventral parts of the animal's head. In most cases, the external surface of these fragments is characterized by faint grooves similar to those found on the cones (Plate V.4: Figs. 34-35).

Ecology: The biology of *Haloniscus searlei* has been thoroughly reviewed recently by Williams (in press). It is an Australian endemic oniscoid isopod which is aquatic and tolerates high water salinities range: 3.6 to 191.7°/oo. It is known to survive periods of lake desiccation (De Deckker and Geddes, 1980; Williams, in press).

Remarks: Similar fragments have been found in other lacustrine deposits (see Chapter 8 on Pillie Lake). Their presence cannot provide much ecological information as *H. searlei* can be found in ephemeral saline lakes as well as in permanent ones. Although *H. searlei* can be found in ephemeral lakes, annual rainfall is necessary each year for the animal to survive in such lakes as it cannot survive complete desiccation (Ellis and Williams, 1970). This explains its absence in ephemeral lakes in Central Australia.

5.4.1.6 Porifera

Only three specimens of the asexual reproductive bodies of spongillid sponges have been recovered from the Lake Purrumbete core.

These gemmules are all distinct and will be briefly described below. They all belong to the Australasian genus *Heterorotula* Penney and Racek, 1968. All three indicate freshwater conditions as none respond to the description of *H. capewelli* (Bowerbank, 1863) which is known to tolerate athalassic saline environments from Central Australia to the Dividing Range (Racek, 1969).

Heterorotula nigra (Lendenfeld, 1887) (Plate V.5: Figs. 16-18) is distinguished by the usually granulated gemmoscleral shafts and the absence of megascleres from the pneumatic layer. The foramen has not been examined.

Heterorotula multidentata (Weltner, 1895) (Plate V.5: Figs. 15,20) is recognized here by its smooth to microspined megascleres and the occasional reinforcement of the outer coat of the pneumatic layer by megascleres. The foramen is simple and bears no colar.

The gemmule of *Heterorotula* sp. (Plate V.5: Figs. 14, 19) resembles *H. capewelli* in that many megascleres are present around its periphery. It is distinguished from the latter species, on the other hand, by the following details: the gemmoscleres are present only on the outside of the pneumatic layer in *H. capewelli* (for comparison see Penney and Racek, 1969, Plate 8, Fig. 5); the megascleres in *H.* sp. are more pectinate and the edge of the gemmosclere rotules is spinose rather than crenulate as in *H. capewelli*.

<u>Remarks</u>: Few megascleres, cemented on tricopteran cases were noticed in samples from the Lake Purrumbete core (Plate V.6: Figs. 32-34). These belong to *Heterorotula* spp., and although megascleres recovered from lacustrine sediments can provide some palaeoecological information as demonstrated by Racek (1966) for Guatemalan material, no similar attempt was made to recover systematically spongillid remains.

No remains of *Radiospongilla sceptioides* (Haswell, 1882) have been found in the cores even though the species has been recorded twice from Lake Purrumbete (Nov. 1969, May 1970) by Timms (1973).

5.4.1.7 Vertebrata

Various vertebrate remains have been found in the cores. Four types, all from fish, are recognized: jaw bones, scales, otoliths and other bone fragments. Only some items of the first type could be identified and subsequently give palaeoecological information. The presence of other remains is still of some significance for the three lakes (Bullenmerri, Gnotuk and Keilambete) which are in no way connected to rivers: water must have been permanent when fish were present.

Two categories of jaws have been recognized: those with a single or a double row of teeth (Plate V.6: Figs. 1-3, 6, 7) and those with more than two rows along most of their length (Plate V.6: Figs. 5-10). For classification see Table 5.2. Also a few remains bearing teeth (Plate V.6, Figs. 4, 8, 11) are identified as being part of the mouth of fishes - they usually consist of straight rods with fewer teeth and occasionally have a flat base (Plate V.6: Fig. 4); others are large vomer plates covered with many teeth (Plate V.6: Fig. 8). These could not be identified at the generic level.

Table 5.2 lists the species which are found today in Lakes Bullenmerri and Purrumbete. In addition, the hardyhead *Craterocephalus stercusmuscarum* (Günther, 1867) is included in the list as it is commonly found in slightly saline lakes in Victoria.

From the different types of jaw mentioned in Table 5.2, and the salinity tolerance for the corresponding species, some palaeoecological information can be obtained. Jaws with more than two rows of teeth belong to fish which live in water of salinities between <3 and 13.4°/oo.

TABLE 5.2 Record of native fishes in the maar lakes with notes on salinity tolerance of each species and on jaw morphology.

	Present day occurrence[1,2]				Salinity tolerance	Type of Jaws		
	Lake Purrumbete	Lake Bullenmerri	Lake Gnotuk	Lake Keilambete	°/oo[2]	single or double row	more than double row along most of length of jaw	vomer plate with many teeth
Philypnodon grandiceps	+	+	+[3]	none found[2]	<3-7.3		+	
Pseudophrites urvilli	+	+	+[3]		<3-3.3		+	
Nannoperca australis	+		none found[2]		<3-3.3		+	
Anguilla australis occidentalis	+				<3-13.4[5]		+	+
Galaxia maculatus	+				<3-30.3	+		
Retropinna victoriae	+				<3-8.8	+		
Craterocephalus stercusmuscarum					<3-8.8[4]	+		

[1] Timms (1973).

[2] Chesman and Williams (1974).

[3] Timms (1973) said that these two species were collected once from L. Gnotuk on 8.12.1916 - record from National Museum of Victoria.

[4] *Craterocephalus eyeresii* (salinity 3.8-30.9°/oo in Chesman and Williams (1974) and up to 110°/oo in Glover and Sim (1978)) has been recorded in the Murray Darling drainage system in northern Victoria. This species will be ignored here as it has not been recorded in any of the salt lakes in central Victoria.

[5] Record for *A.* cf. *australia* in Chesman and Williams (1974).

For the other jaws, the salinity range referred to is between <3 - 30.3°/oo.

Although Lake Gnotuk is devoid of fish today it is suggested that it is more likely that fish would be introduced there - compared to Lake Keilambete - as the former lake can receive overflowing waters from the adjacent less saline Lake Bullenmerri. The record of two species of fish (see Table 5.2) from Lake Gnotuk in 1916 probably resulted from the last overflow recorded in 1841 mentioned previously. As the lake level has continuously dropped since 1841 (Currey, 1970), salinity would have progressively increased and eventually fish would not have been able to survive the highly saline waters such as those found today.

From Fig. 5.7 it is possible to say that the salinity of Lake Gnotuk was between 3 - 13.4°/oo at the time of deposition of level 6.5 cm, a period probably occurring after an overflow from Lake Bullenmerri as jaws with more than two rows of teeth are found in the samples. Such a phenomenon must have occurred on a number of occasions since fish remains are sparsely distributed in the upper 200 cm Lake Gnotuk core.

5.4.1.8 Diptera - Chironomidae

Few head capsules with associated labia of chironomid larvae were recovered from the cores. This paucity might result from the treatment of the samples with dilute hydrogen peroxide which is inappropriate for the recovery of chironomid remains.

Head capsules, mandibles and labia of chironomid can be useful in tracing past changes in lake productivity levels as some chironomid species are very sensitive to changes of sediment types and oxygen concentration. The only work dealing with the recovery of chironomids in Australia is that of Paterson and Walker (1974) from Lake Werowrap in Western Victoria. They recovered head capsules of *Procladius paludicola*, *Chironomus duplex* and *Tanytarsus barbitarsis* from two one metre long cores. The latter two species were mutually exclusive. *T. barbitarsis* appears to be restricted to highly saline waters (in Victoria up to 82°/oo - Paterson and Walker, 1974) whereas *C. duplex* is an indicator of a freshwater condition, although it has been found by these authors in Lake Coragulac between ca. 5.1 - 5.8°/oo.

In the present study, three head capsules were found but these could not be identified at the species level. They are illustrated in Plate V.5: Figs. 9-13.

5.4.1.9 Coleoptera

Many fragments of coleopteran beetles have been recovered but none have been identified. It is of interest to note that their occurrence, in the cores of Lakes Gnotuk and Keilambete, corresponds to the less saline or even freshwater phases for the lakes as extrapolated by other fossil remains such as ostracods and pollens. No systematic search for coleopteran remains was conducted; only large fragments such as elitra, thoraxes, and more rarely cephalon fragments and some appendages were recovered.

5.4.1.10 Trichoptera

Only trichopteran cases were found in samples from Lakes Bullenmerri and Purrumbete (Plate V.6: Figs. 27-29, 32-34). These most likely belong to the family Leptoceridae (A. Neboiss, pers. comm.). Some leptocerids are good swimmers and therefore their presence in the samples is not surprising even for those which are thought to have been deposited in deep water (>30 m) far away from the shore. The leptocerid cases found here cannot be indicative of water salinity as some species occur in saline waters. It is worth noting, however, that no leptocerid cases have been found in Lakes Gnotuk and Keilambete even in the samples representing freshwater phases.

5.4.1.11 Unidentified cones

Small calcareous cones (average diameter: 50-100 μ) (Plate V.5: Figs. 21-26) have been found attached to vegetal fragments in samples from Lakes Bullenmerri, Gnotuk and Purrumbete. They have not been identified. They are not part of fern sporocarps and it is suggested that they could be of fungal origin (H. Aston, pers. comm.). It is interesting to note that they occur in the samples in Lake Gnotuk where a freshwater phase is postulated. The presence of these cones in the samples studied here is recorded in Figs. 5.6, 5.7, 5.10 but not discussed further until they are identified.

5.4.1.12 Diatoms

A few specimens of the large mesohalobic diatom *Campilodiscus* sp. were found. A systematic search for them was not undertaken as they have been dealt with by Yezdani (1970) and Tudor (1973) for various portions of cores from the four lakes studied here. Their palaeoecological significance, however, will be discussed in the final part of this chapter.

5.4.2 Sequence of fossil remains in the cores and their palaeoecological significance*

5.4.2.1 Lake Bullenmerri

Many of the 279 treated samples did not yield ostracods. The main components of the fauna were more diversified, however, than for the other three lakes. These were: ostracods: *Limnocythere dorsosicula*, *Ilocypris australiensis*, *Leptocythere lacustris*, *Platycypris baueri*, *Candonocypris novaezelandiae* and in addition one valve of *Diacypris compacta* and one fragment of a large mytilocypridinid ostracod; fish remains (jaws, scales and bones); the gastropods *Coxiella* spp.; ephippia of *Daphnia* spp.; insect fragments consisting mainly of coleopterans, a few trichopterans cases; some fragments of the isopod *Haloniscus searlei*. A few large diatoms *Campilodiscus* sp. were also recovered.

Major zones can be distinguished in the cores on the basis of faunal assemblages and also because of the presence or absence of some species (Fig. 5.6). These will be examined in descending order from top of core to bottom and the water depth refers here to the height of the water column above the core site.

0-112 cm: Fossil remains were extremely rare; this part of the sequence is thought to represent a sequence of sediments deposited at a great depth (50-60 m) with lake level and therefore water salinity similar to that of today. No ostracods therefore would be found at such a depth as there are no truly planktonic ostracods living at such a salinity with few fluctuations, nor would any be

---

* Note that salinity values estimated in this section represent annual averages, bearing in mind that salinities for Lakes Gnotuk and Keilambete fluctuate by ca. 8-10°/oo each year, whereas for the less saline Lake Bullenmerri, the fluctuation is by about 3°/oo.

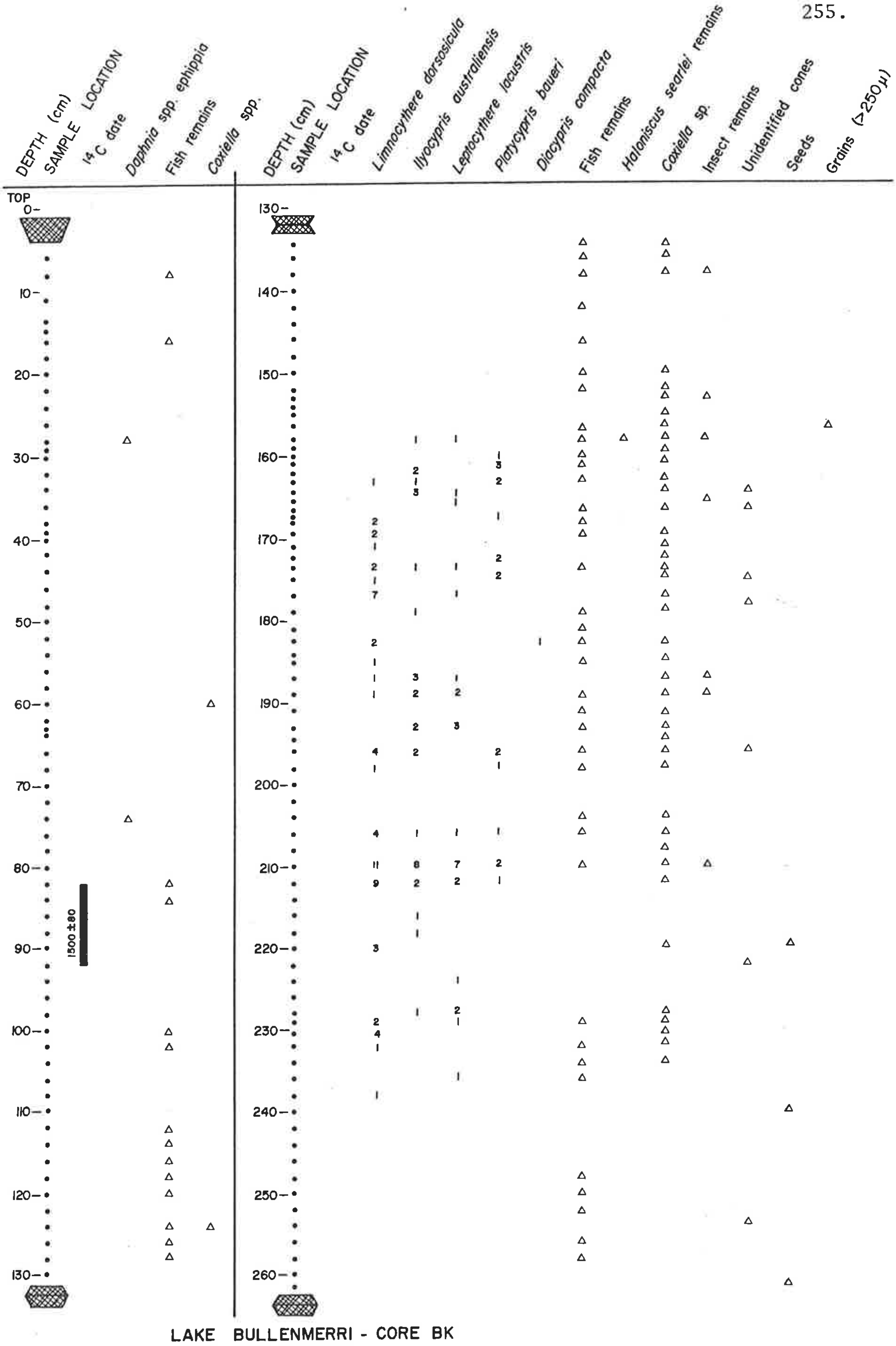


FIG. 5.6 Distribution of fossil remains and grains in the upper part of core BK from Lake Bullenmerri. Numbers in the ostracod columns refer to the quantity of ostracod valves recovered per 3 g of sediment. Triangles record the presence of other remains in the core. Black dots indicate the position of samples taken from the core. ^{14}C dates are those referred to in the text.

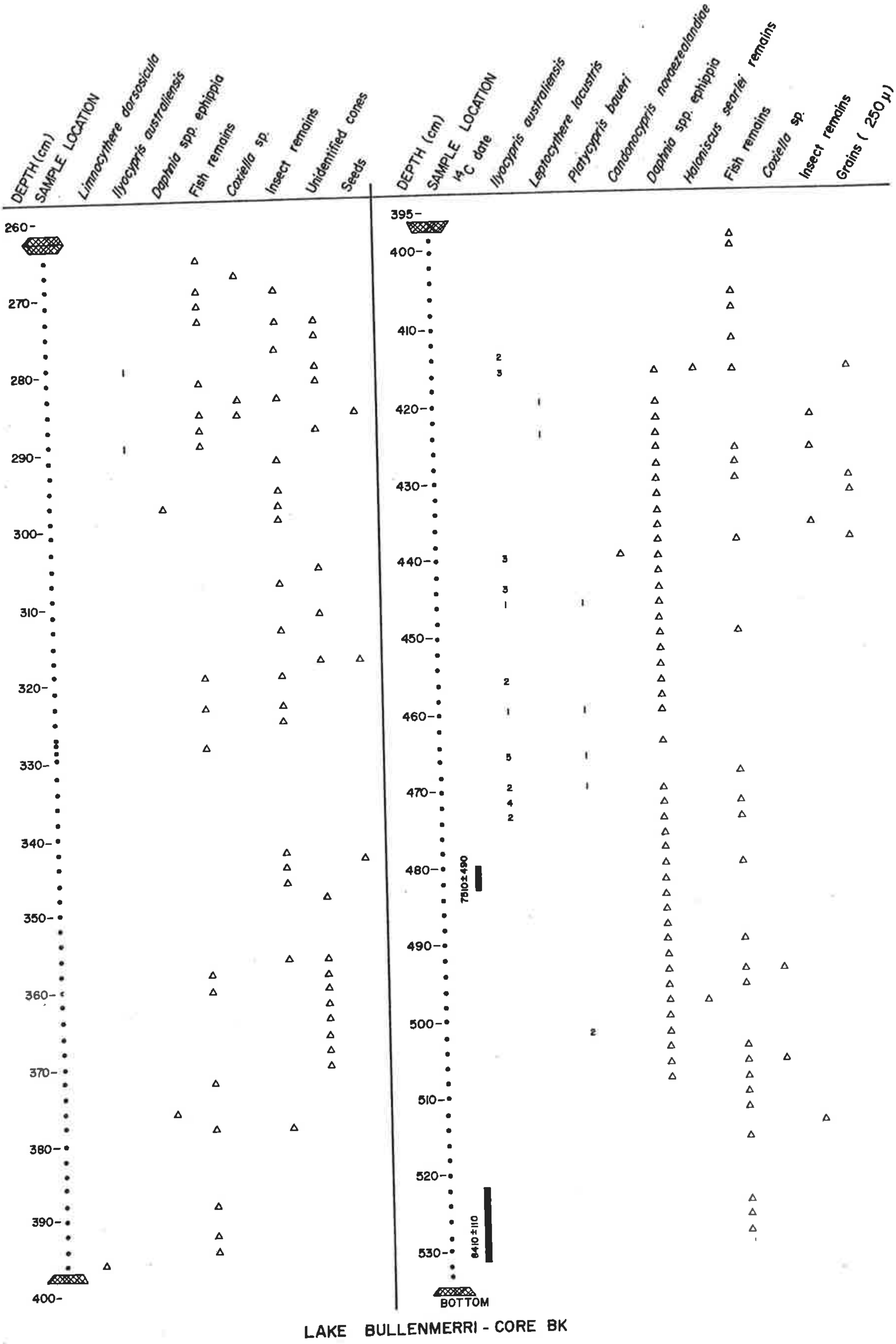


FIG. 5.6 cont. Distribution of fossil remains and grains in the lower part of core BK from Lake Bullenmerri.

found living at such a depth because the lake would be anoxic. (Although some ostracod species, such as *Diacypris spinosa* and *Mytilocypris splendida*, inhabit lakes of low salinity, it appears that they only live in lakes with fluctuating salinities.)

112-144 cm: Fish bones and scales were found in most samples but few other fossils were encountered. The fish jaw at level 128 cm has more than two rows of teeth so the salinity of the water was less than 13.4°/oo at the time. The presence of few *Coxiella* sp. could indicate that the water level was lower as *Coxiella striata* is restricted to depths less than 25 m in Lake Bullenmerri today (Timms, 1973). Their small numbers might only indicate that the lake level was in the vicinity of 25 m and that this sequence is a transitory one between the deep water one above and the shallow one below.

144-238 cm: This sequence yielded the most diversified fauna: all the ostracod species recorded throughout the core were present here; fish bones and scales were more abundant than above; *Coxiella* sp. were present in substantial numbers in nearly all samples, and a few insect fragments and one body of a water mite were encountered. A few unidentified cones are also scattered throughout this sequence. In some samples, fine scoria material and other terrigenous grains (>200 μ) were found. These indicate that the core position was a short distance from the lake shore and consequently registers a major drop in lake level: the water level was less than 25 m because *Coxiella* sp. abound. This is confirmed by the diversified ostracod fauna which consist mainly of benthic animals requiring oxygenated sediments to live on, except for *Candonocypris novaezelandiae* (level 154 cm).

Only two specimens of the latter ostracod were found. Lake salinity during this period probably fluctuated more, a change supported by the presence of some species with different salinity tolerances in the same samples. Salinity was most often between 2 and 7°/oo as *L. dorsosicula* and *I. australiensis* are the most common species. It is also thought that the salinity could have gone higher at times (either for some years or during parts of some years) as indicated by the presence of more salt tolerant species such as *P. baueri* and *L. lacustris*. The presence of the latter species points to permanent water conditions. On two occasions (198-204 cm, 214-226 cm), water levels must have increased as ostracods and other fossils are either absent or rare.

238-413 cm: No ostracods are recorded from this sequence so very little can be said about water salinity. Three subdivisions, probably indicative of three different phases of the lake, can be drawn.

238-290 cm: Fish are present as well as a few insects; *Coxiella* sp. are rare which in turn indicates a high water level as for sequence 114-145 cm. At level 285 cm, the vomer plate of an eel (*Anguilla* sp.) suggests water salinity of less than 13.4°/oo. *Coxiella* sp. are in large numbers at that level - water level could have dropped for a short period of time. A few unidentified cones are also recorded between 274 and 282 cm.

290-346 cm: Fish bones are rare and insect fragments present in most samples. Little information can be extrapolated.

346-413 cm: Few fish bones were found, insect fragments were rare and between 348 and 370 cm unidentified cones were abundant in every sample. Unfortunately no ecological information can be obtained from these. Although little palaeoecological information is available, the absence of many fossils, especially in level 370-413 cm where very few were found, *could* indicate a general increase in water level causing lake stratification which in turn would render the lake bottom anoxic, stagnant and inhospitable to organisms such as ostracods. At level 410 cm the large *Campilodiscus* sp. diatoms were recovered.

413-474 cm: Ostracods were found in some samples: the commonest species is *I. australiensis*; few specimens of *L. lacustris* and *P. baueri* are also encountered. In one sample, three partly decalcified valves of *C. novaezelandiae* were found. The most obvious faunal component of this sequence, however, consists of ephippia of *Daphnia* spp. in nearly all samples treated (sometimes up to 50/3 g of sediment). Salinity of the lake extrapolated for this sequence ranges therefore from fresh to 5.8°/oo. It is most likely, on the other hand, that salinity remained lower than 5.8°/oo for a number of seasons. Some of the *Daphnia* spp. which are all truly planktonic species, can tolerate at times slightly saline waters. In central Victoria, Martin Lake was sampled bimonthly for one year and yielded *Daphnia* sp., *I. australiensis* and *P. baueri*. Water salinity fluctuated between 3.26°/oo and 7.92°/oo although adult *Daphnia* sp. were only found at 4.83°/oo. Additionally, in the same sample, halobiont ostracods (*sensu* De Deckker, in press) were recorded: *Reticypris clava*, *M. praenuncia*, *M. splendida* and *D. spinosa*. Thus, the lower diversity of ostracod species in the Lake Bullenmerri core samples and the absence of the halobiont species mentioned above lead to the conclusion that the lake salinity was probably less than 3°/oo at most times. This could explain the absence of the halobiont *Coxiella* spp. in the samples. For level 460-474 cm, however, the presence of an ostracod fauna accompanied by daphniid ephippia would indicate a salinity range similar to the one mentioned above for Martin Lake (3.26-7.92°/oo). Fish were also present at times in the lake as bones and scales were found in some samples.

The presence of ostracods in many samples indicate a decrease in water level and this is substantiated in most cases by the presence of scoria fragments (found especially at levels between 430 and 438 cm where, surprisingly, ostracods are absent) and other terrigenous grains in some of the samples. The shore of the lake was, at times, close to the coring site.

474-535 cm: Ostracods were absent except for two valves of *P. baueri* at level 502 cm; fish bones and scales are common in most samples; *Daphnia* spp. ephippia are present in all samples from level 474-508 cm and none are found below 508 cm. The absence of ostracods could indicate a high water level with associated lake stratification. Water remained near fresh between at least level 474-508 cm.

Good correlation exists with other cores ^{14}C dated by Barton (1978) and between cores BK and BB of Barton (1978) (with levels 480 cm dated at 7,510 ± 490 yBP ANU-1659 and 525 cm at 8,410 ± 110 yBP ANU-1657). It is assumed that cores BK and BB cover similar time sequences as they are located close together (Fig. 5.2), and that the rate of sedimentation was fairly uniform through time as shown for other cores taken in the lake by Barton *et al.* (in press). It becomes therefore, possible to estimate the timing of events described for Lake Bullenmerri. These are summarized below.*

<u>0-112 cm</u> (0-1,800 yBP): High water level and lake stratification similar to that of today.

<u>112-144 cm</u> (1,800-2,300 yBP): Water level lower than that of today but more than 35 m and lake stratification.

<u>144-238 cm</u> (2,300-3,800 yBP): Water level less than 35 m and water salinity most often between 2 and 7°/oo with possible periodic fluctuations to fresh (level 154 cm = 2,500 yBP) and more than 8°/oo (3,000 yBP). Water level higher at least on two occasions: 3,200 and 3,450-3,600 yBP.

<u>238-290 cm</u> (3,800-4,700 yBP): Water level lower than that of today with stratification of water. At level 285 cm (4,600 yBP) salinity was below 13.4°/oo and water level could have been below 35 m.

<u>290-413 cm</u> (4,700-6,600 yBP): Water level probably equivalent to that of today and lake stratified - level probably shallower at level 290-346 cm (4,700-5,600 yBP) and the highest at level 370-413 cm (6,000-6,600 yBP). Between 348-370 cm (5,600-6,000 yBP) cones abound.

<u>413-474 cm</u> (6,600-7,700 yBP): Drop in lake level and at times, especially between 430-438 cm (6,950-7,100 yBP) and 460-474 cm (7,400-7,700 yBP) probably of the order of 35 m or less. Salinity less than 3°/oo at most times.

---

* Comparisons of lake levels here refer to the height of the water column above the deepest part of the lake for today and the past. The additional 5 m of sediments deposited on the lake floor in approximately the last 8,000 years is not considered in the calculations.

474-508 cm (7,700-8,200 yBP): Water level probably similar to that of today or above it and salinity less than 3°/oo; lake stratification present.

508-535 cm (8,200-8,700 yBP): Water level probably similar to that of today with salinity more than 3°/oo and lake stratification. Therefore the lake level was likely to have been lower than for period 7,700-8,200 yBP.

Yezdani (1970) who studied a 5.5 m core from Lake Bullenmerri and, on the basis of one ^{14}C date 1660 ± 90 yBC at depth 210-230 cm and assuming that sedimentation rate was constant throughout the lake's history, obtained fairly similar results as those presented for core BK.

The drop in water level of the lake at around 1,800 yBP postulated here is further substantiated by the presence of tree stumps dated at 1,865 ± 85 yBP by E.D. Gill and mentioned in Yezdani (1970). It is suggested that lake level rose after that date to submerge the trees until the drop in lake level, which started more than a century ago, caused the stumps to emerge.

Between 5,200-4,000 yBP, he postulated a "brackish-freshwater" phase (*sensu* Yezdani, 1970) based on the diatoms indicative of salinity between 4 and 5°/oo, and between 3,500 and 3,000 yBP he diagnosed a freshwater phase by the presence of *Pediastrum*. He also stated that the *Botryococcus* dominant phase in Lake Bullenmerri at 400-370 cm corresponds to the freshwater phase he described for Lake Gnotuk in his core at level 230-210 cm and dated at 4,360 ± 115 BC (= ∿6,300 yBP). From his pollen diagram, it is possible to see that the halophytes *Lepilaena*, when present, were very rare, and that *Ruppia* was recorded in the lower portion of his core (below 500 cm) and around level 220 cm dated 1,660 ± 90 yBC (= ∿3,600 yBP). All these results are consistent with those obtained from core BK.

Churchill *et al.*'s (1978) curve for surface water level for Lake Bullenmerri reconstructed from Yezdani's (1970) data, and presumably not from Tudor's (1973) on diatoms, cannot be interpreted as Yezdani's data appears to be out of sequence: e.g. his *Pediastrum* phase indicating freshwater at 3,000 to 3,500 yBP is presumably represented by the high water level peak at 4,000 yBP of Churchill *et al.* (1978). These two dates do not refer to a freshwater phase interpreted here in core BK.

Dodson's (1979) reconstruction of the vegetation near Lake Bullenmerri based on the study of pollen from the basal 5.73 m of the 11.73 m long core BI (Fig. 2) taken in the deepest part of the lake is of no direct concern here as it deals with the period 16,000-∿8,000 yBP. As Dodson (1979) does not have a ^{14}C date for the upper portion of the core he studied, it is not possible to compare his data with that of the lower part of core BK.

5.4.2.2 Lake Gnotuk

The lithological units described previously for the 362.5 cm long core correspond to most zones defined by ostracod assemblages apart from one section of the core (92-230 cm) which yielded very few ostracods. All the ostracod assemblages are described as for Lake Bullenmerri, from the top to the bottom of the core.

0-22 cm: A few *D. compacta* as well as rare *Diacypris* juveniles. Insect fragments and *Coxiella* sp. are common at some levels. At level 6.5 cm, two jaws with more than a double row of teeth were found among abundant fish remains (Plate V.6: Figs. 5, 9). These two indicate a salinity less than 13.4°/oo. Note that fishes with similar types of jaws (see Table 5.2) were recorded from the

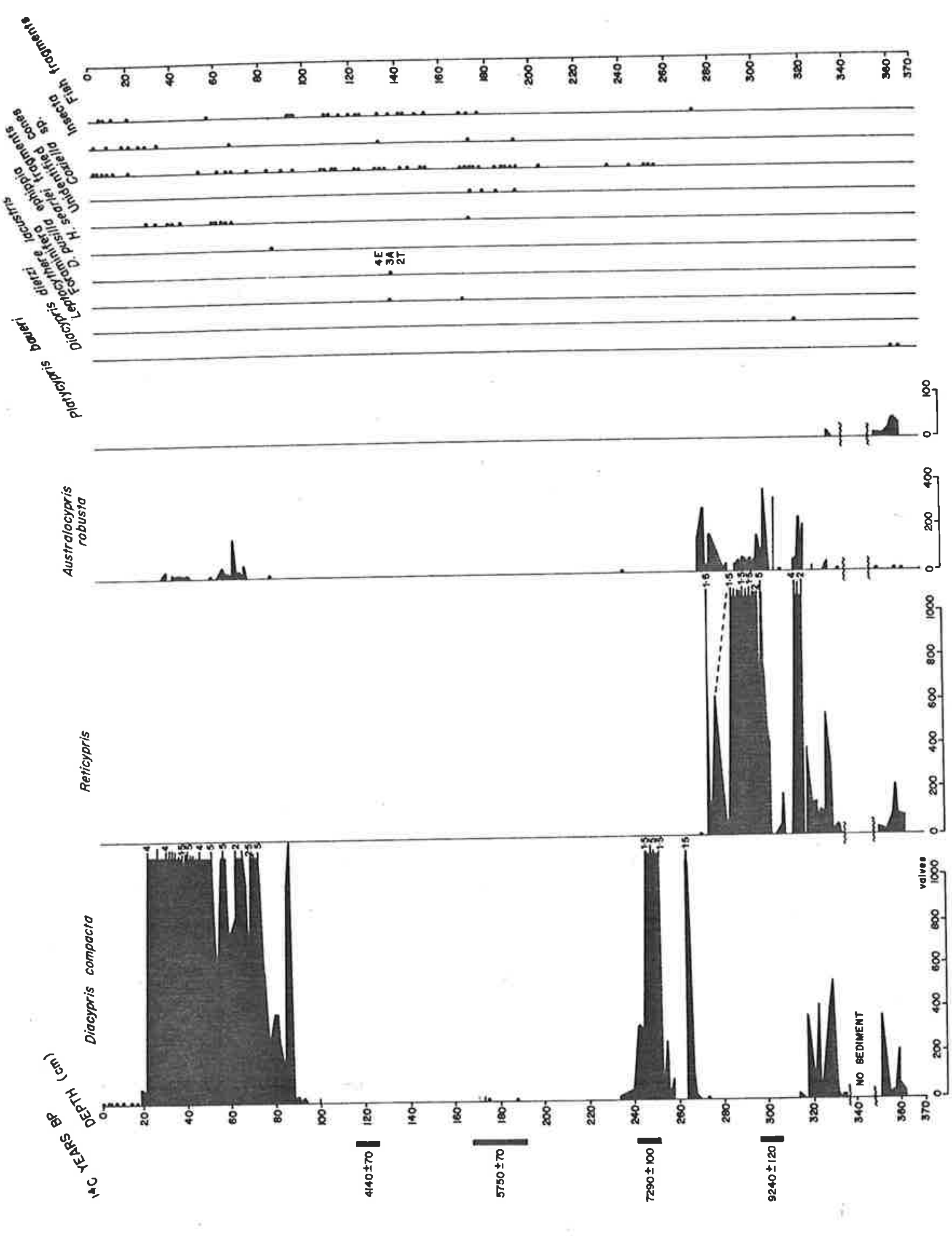


FIG. 5.7 Distribution of fossil ostracods and other remains in core GH from Lake Gnotuk. Numbers in the ostracod columns refer to the quantity of ostracod valves recovered per 3 g of sediment. Dots in the other columns refer to the presence of remains recovered only in low numbers. In Foraminifera column: E = *Elphidium* sp., A = *Ammonia beccarii*, T = *Triloculina rotunda*. For ^{14}C dates refer to Table 5.3.

lake in 1916; it is likely that these would result from Lake Bullenmerri overflowing into Lake Gnotuk and consequently would allow fish to populate both lakes.

22-92 cm: *D. compacta* is present in high numbers (often 1,000/g of sediment) in nearly all samples. Two small zones (33-43 cm and 53-67 cm) are characterized by the additional presence of *A. robusta*. *H. searlei* fragments are present in many samples whereas fish bones are rare.

The great abundance of *D. compacta* results from "blooms" of that species, usually registered at salinities between 45 and 77.5°/oo today. Samples taken during such phenomena contained *A. robusta* as well but in lower numbers. Salinity values for corresponding fossil material are in the vicinity of 45-77.5°/oo whereas when numbers of *D. compacta* were lower, the salinity range should be broadened as the two species have been found together in some Victorian lakes at 98-100°/oo, and 144°/oo salinity.

At level 82.5 cm *D. pusilla* ephippia were recovered. They indicate a salinity of 4.4-68°/oo, and the water would have had to go at least below 33.4°/oo for the cladoceran to hatch.

92-233 cm: This large portion of the core is depauperate in ostracods. Its upper part, however, is fossiliferous down to 202 cm whereas it is barren below it. In most upper samples *Coxiella* shells are present and even numerous at times (ca. 10/3 g sediment) and fish bones are occasionally found. At level 166.5 cm, two jaws were recovered but little information on salinity can be drawn from them as they only possess one or two rows of teeth meaning the salinity range is 3-30.3°/oo. At level 135 cm, three carapaces of *L. lacustris* and four species of foraminifers (*A. beccarii*, *Elphidium* sp., *T. rotunda* and *Discorbis* sp.) were found. They indicate permanent saline water conditions in the vicinity of 35°/oo. On three occasions, a few valves of juvenile *Diacypris* were found (171, 185, 198.5 cm) but these offer no ecological information. Finally, at four levels (171, 175.5, 182, 190 cm) unidentified cones are present. They are commonly found in samples from Lake Bullenmerri and especially at the same period (between 5,500-6,000 yBP) between levels 348-370 cm in BK. From extrapolation with salinities recognised in that lake for the levels where the cones are found, water in Lake Gnotuk for the four levels mentioned above must have been in the vicinity of 2-7°/oo.

<u>233-270 cm</u>: *D. compacta* valves are present in most samples, and in some, their numbers are extremely high (247 and 248.5 cm with about 9,000 and 5,000 valves/g of sediments respectively). This zone was probably deposited under similar conditions as those for zone 22-92 cm except that *A. robusta* valves were rare as only fragments were recovered. For section 245-260 cm, where *Coxiella* juveniles are also found, salinity was somewhere between 45 and 77.5°/oo. For the other levels, where *D. compacta* are found, the salinity range is <3-182°/oo which is that of the species in Victorian lakes.

<u>270-317 cm</u>: *Reticypris* valves are common in most samples and are present in great numbers at times. As explained before, the absence in these samples of the low salinity ostracods *Mytilocypris* spp. and *D. spinosa* warrants the specific identification of *R. herbsti* for the specimens found here (this remark applies to all the *Reticypris* specimens found in this core). Salinity of the lake during the presence of *R. herbsti* in high numbers (levels

272, 284-300, 313-316 cm) was of the order of 99-172°/oo. At level 315 cm, the presence of two valves of the highly saline *D. whitei* supports the values suggested above. Salinity values were probably lower for the lake when *R. herbsti* numbers were lower and when *A. robusta* was co-occurring. When the latter species was common (>200 valves/3 g sediment) salinity was between 45 and 77.5°/oo. At the proximity of level 294 cm, disruption in the bedding resulted from the lake being dry.

317-333.5 cm: *R. herbsti*, *A. robusta* and *D. compacta* are found together in most samples. Salinity of the lake must have varied because of the different associations and variations in abundance of ostracods. The salinity range was probably similar to that of level 270-317 cm. This is supported by a collection made once in an unnamed lake near Lake Bolac where the three species were collected together at 99.4°/oo.

333.5-346 cm: No sediments.

346-349 cm: Mixed sediments.

350-363.5 cm: *R. herbsti*, *D. compacta* and *P. baueri* are found together in most samples. These three species have been found together in various lakes in Victoria at salinities between 99-172°/oo. *A. robusta* and *D. dietzi* are rare in numbers and occur only in a few samples. Their presence does not contradict the salinity range postulated for this zone.

Lithological correlation of core GH was possible with Barton *et al.*'s (in press) core GB for which ^{14}C dates are available.

In core GB, the alternation of light and dark coloured bands with diffused carbonate rich layers between 84 and 109 cm ends at level 79 cm in core GH. Dodson (1974a) identified this band in his core from Lake Gnotuk and dated it between 3,790 ± 100 yBP (I-4611) and 3,530 ± 100 yBP (I-4612). He suggested that this layer, which he described as being dolomite-rich, represented a period of low water level and hypersalinity. From the data obtained from the ostracods, it appears that salinity was between 45 and 77.5°/oo.

The carbonate layer in core GB at level 130 cm could not be correlated with any layer in core GH. On the other hand, the 10 cm thick layer below this carbonate layer, and dated at 4,140 ± 70 yBP (ANU-1987), probably corresponds to level 115-125 cm in core GH.

The well defined zone characterized in core GB by black to dark grey mud at 188-210 cm with the upper part 190-200 cm, and dated as 5,750 ± 70 yBP (ANU-1988), corresponds to layer 166-191 cm in core GH. Also, the base of the approximately 17 cm thick layer consisting of white laminae in dark grey to black organic mud at level 263 cm in core GB, correlates with level 249 cm in core GH. 10 cm of this layer above level 260 cm in core GB was dated as 7,290 ± 100 yBP (ANU-1989). It appears that layer 300.5-301.5 cm (rich in *R. herbsti*) in core GH corresponds to the one labelled "ostracod layer" in core GB (at about 316 cm) by Barton *et al.* (in press). If this is correct, the date of 9,240 ± 120 yBP (ANU-1990) relates to level 295-305 cm in core GH. This correlation remains uncertain though as the description by Barton *et al.* (in press) of that section of the core does not mention the conspicuous alternation of dark and pale layers seen in GB. Finally, the pale grey layer in core GB below 323 cm is not recorded in core GH until below level 346 cm (note that there is a gap of 12 cm above that layer in core GH). This discrepancy can only be solved by further dating of portions of core GH.

As it appears that the levels in core GB which are equivalent to those in core GH, are always on the average 15 cm above the latter ones in respect to the top of each core, the top of core GH should be 25 cm below the water sediment interface, as the top of core GB is said to be 10 cm below the same interface by Barton *et al.* (in press). The results are summarized below:

0-22 cm (700-1,300 yBP): Little information available but probably low salinity (around 10°/oo) most of the time as halobiont ostracods are rare and insect fragments are present. At level 6.5 cm (850 yBP) salinity was below 13.4°/oo.

22-92 cm (1,300-3,400 yBP): Increase in salinity which was maintained between 45 and 77.5°/oo except for one occasion at level 82.5 cm (3,500 yBP) when water salinity had to go below 33.4°/oo for a short period of time. Note that the date 3,400 yBP has to be approximate as there is some disagreement between Dodson's dating for the carbonate rich layers (between dates I-4611 and I-4612) and the date of 3,400 yBP extrapolated from the dates given by Barton *et al.* (in press) for level 92 cm in GH.

92-233 cm (3,400-7,250 yBP): Return to less saline conditions and probably water salinity was around 10°/oo. Between 171-190 cm (5,500-6,000 yBP), the presence of unidentified cones points to a salinity range of 2 to 7°/oo, a value extrapolated from their co-occurrence with ostracods in Lake Bullenmerri.

233-270 cm (7,250-8,250 yBP): Salinity of the water ranging definitely between 45 and 77.5°/oo for levels 246-250 cm (= 7,700 yBP); at other times (except for levels 258-262 cm and 268 cm in which ostracods are absent and therefore no salinity data are available), the salinity range was still in the proximity of 45-77.5°/oo, otherwise other ostracod species would have been present.

270-317 cm (8,250-9,500 yBP): Salinity of the water fluctuated; it was often high - ranging between 99-172°/oo when *R. herbsti* was present alone: 272 cm (8,300 yBP), 284-300 cm (8,650-9,100 yBP), 313-316 cm (before and after 9,500 yBP); and sometimes between 45-77.5°/oo when *A. robusta* was present in high numbers (270.5 cm (before 8,300 yBP), 300.5 cm (after 9,100 yBP), 304 cm (9,200 yBP), 315 cm (9,500 yBP). Note that these dates are approximate. There is evidence at level 294 cm (8,900 yBP) of a dry phase shown by disrupted bedding.

317-335.5 cm (9,500-10,000 yBP): Salinity of the water fluctuated but the range remained constantly high and in the vicinity of 100°/oo.

350-363.5 cm (>10,000 yBP): (No date available because there is a gap in the core.): Salinity very high (>100°/oo and probably up to 170°/oo). It is likely that the lake was subject to drying up at times as no definite lamination was noticed.

Yezdani (1970) studied the vegetation record from a 5 m core from Lake Gnotuk and examined also the diatom content for a portion of the same core (170-270 cm). His results are generally compatible with the ones obtained from the recovery of ostracods although accurate correlation is difficult. He described a freshwater phase (depth 230-200 cm) at around 6,400-5,600 yBP characterized by the presence of *Pediastrum* (upper salinity tolerance 3.5°/oo). At level 210 cm (∿5,900 yBP), colonization of the waters by *Scenedesmus* indicates lower salinity (upper salinity tolerance 1.7°/oo). His "Clypeus Lagoon" phase at a depth of 200-170 cm and dated between 5,600-4,800 yBP, which is indicative of slightly saline conditions (= "brackish water" *sensu* Yezdani, 1970) is compatible with the data obtained from the ostracods.

Tudor (1973) analysed the diatom content in samples from the upper

170 cm of a core from Lake Gnotuk. His results are similar for the upper 70 cm of his core with the ostracod data but the changes in events in the lake history cannot be pinpointed on the ostracod diagram as lithological correlation is impossible due to the insufficient description of the lithological log of Tudor's core. The diatom flora recovered from the 80-120 cm portion of the core by Tudor (1973) which indicates saline conditions (30-60°/oo) is not recognized in core GH.

Churchill *et al.*'s (1978) curve for Lake Gnotuk's water level reconstructed from Tudor's (1973) data on diatoms (and presumably on Yezdani's (1970) as well) cannot be compared here as there appear to be discrepancies with Yezdani's (1970) data, e.g. the *Pediastrum* phase recorded by him at 6,400-5,600 yBP cannot be located on Churchill *et al.*'s curve (1978). No explanation was offered by these authors. Additionally, the plotted curve for corrected annual salt accumulation of Churchill *et al.* (1978) should be revised in the light of Timms' (1975) remarks on Currey's original data (1970).

5.4.2.3 Lake Keilambete

The short core KIC, which represents the youngest sedimentary sequence of the lake, will be dealt with first. The overlap in sequence of this core with the top of the long core KG will then be examined before the description of the rest of core KG. The sequence of events of the lake history will be extrapolated from the combination of results obtained from the two cores.

Core KIC (Fig. 5.8)

0-38 cm: Water salinity lower than that of today.

0-10 cm: The range of *Reticypris clava* in Victoria today is 12-42°/oo, with one rare record at 5°/oo; at salinities below

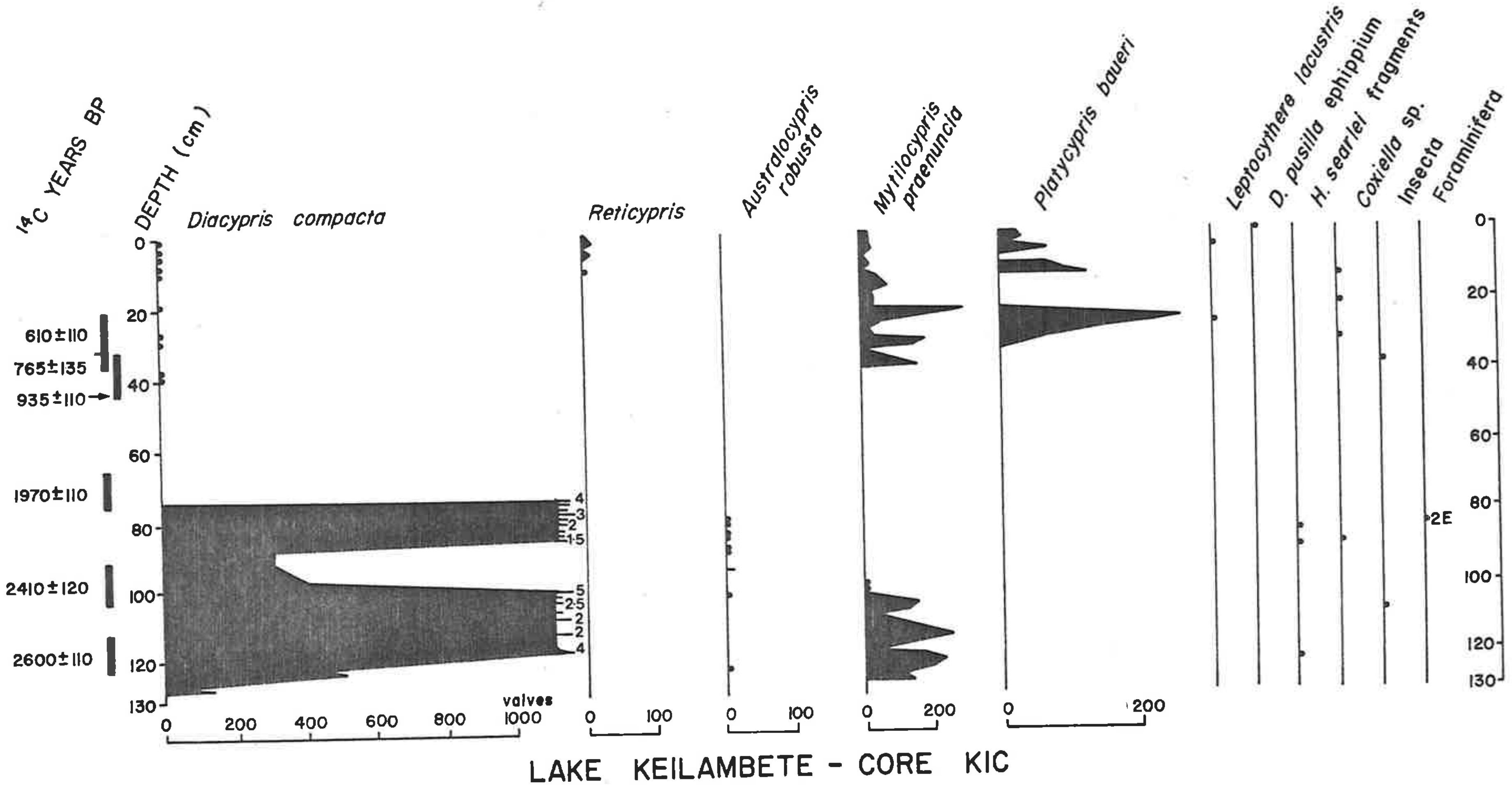


FIG. 5.8 Distribution of fossil ostracods and other remains in core K1C from Lake Keilambete. Same remarks as for Fig. 5.7 except for Foraminifera column.

17.5°/oo, the species was never found with *M. praenuncia* but always accompanied by *D. spinosa.* (This species was never recorded in the core.) It seems plausible therefore to infer that salinity was between 17.5-42°/oo. One *L. lacustris* was found at level 5 cm indicating permanent water conditions and a salinity range 17°/00-sea water.

10-38 cm: The range of *M. praenuncia* in Victoria today (8-42°/oo, with an additional collection with very few specimens at 5°/oo) is postulated for the water during this period of sedimentation. It is likely that salinities below 10°/oo were rarely reached as no low salinity water inhabitant such as *D. spinosa*, *M. splendida* and *I. australiensis* have been found in the samples. The absence of *P. baueri* in some samples cannot be explained since that species is tolerant to a broad range of salinities. In addition, the presence of this species in high numbers at other times indicates temporary fluctuations to higher salinities (70°/oo) for levels 10-12 and 25-30 cm. The presence of *M. praenuncia* in this level indicates that salinity must have also gone below 43°/oo at times. At level 27 cm, one *L. lacustris* was found indicating permanent water of salinity range 19-35°/oo at the time. No explanation can be provided for the poor representation of *D. compacta.*

38-72 cm: Only a few valves of *D. compacta* were recovered at level 45 cm - this record gives no information on salinity nor do other levels which are barren of ostracods. Note that a few quartz grains were found at level 69 cm in KIC - this level is probably facies equivalent to the sand lens occurring at level 100 cm in Bowler's (1970) core K4. The water level must have been low at that particular time. The absence of ostracods suggests the presence of a stratified layer and water not very saline otherwise saline ostracods, if present, would have been found in the core since they are planktic species.

Cores KIC and KG (Figs. 5.8, 5.9)

32-140 cm in KG (- 72-127 cm at least in KIC): This zone, characterized by the high numbers of *D. compacta* (1,500 valves/3 g sediment) in nearly all samples, can be subdivided into a few distinct events as registered by changes of ostracod species.

32-62 cm in KG (72-101 cm in KIC): *D. compacta* "bloom" - this phenomenon has been described before for portions of the Lake Gnotuk core (e.g. level 22-92 cm in GH). Salinity of the lake water during the "bloom" was probably between 45-77.5°/oo as *A. robusta* was present. However, the salinity range could have fluctuated up to 144°/oo as *A. robusta* were few in number. At level 49-53 cm in KG (88-91 cm in KIC) *D. compacta* was less abundant: the salinity range for the lake water at the time has to be broadened to 42-145°/oo (it is likely that salinity did not go below 42°/oo as *M. praenuncia* was absent). Note that fragments of *H. searlei* are recorded in core KIC during this short event.

62-140 cm in KG (102-127 cm in KIC - no record below): Water salinity below that of today for most of the time. The numbers of *D. compacta* and *M. praenuncia* varied during this phase. The salinity range was approximately 19-43°/oo as *D. spinosa* and *M. splendida* (both with a range of 5-18°/oo) are absent. The recorded high numbers of *D. compacta* representing "blooms" of that species at various levels in KG (99-102 cm, 108-112 cm, 131-134 cm) can be explained by temporary excursions to high salinities ranging between 45 and 77.5°/oo. At level 104 cm, two *Elphidium* sp.

(Plate V.4: Figs. 21, 22) were found: salinity was probably around that of sea water. Only once, at level 99-102 cm, were high numbers of *M. praenuncia* found associated with a *D. compacta* "bloom". As such a phenomenon has never been recorded in the Victorian lakes today, it is thought that this level represents two distinct events. The occurrence of the fragile shells of *P. baueri* in low numbers is consistent with the salinity values given above since this animal can be found over a broad range of salinities and is usually recorded in small numbers below 70°/oo salinity. At level 81-84 cm in KG (= 114-123 cm in KIC), few *A. robusta* valves were found. This event, recorded in both cores, represents fluctuations to higher salinities (up to a maximum possible value of 145°/oo for *A. robusta* for short periods of time during a phase which saw salinities remaining generally between 19-43°/oo salinity (for *M. praenuncia*). Some insect fragments are found in a few samples from both cores. The presence of *D. pusilla* ephippia at level 92.5 cm in core KG, having a salinity range of 4.4-68°/oo, with water of the lake having to go below 33.4°/oo, at least temporarily, for the animal to hatch, is consistent with other data as for this level *D. compacta* numbers are very low.

Core KG (Fig. 5.9)

141-280 cm: This zone covers two distinct events:

141-210 cm: Numbers of *M. praenuncia* fluctuate often and *D. compacta* valves are present in most samples but their numbers are very low (<10 valves/3 g sediment). Valves of *P. baueri* are also found in some samples. Salinity postulated for this event is of the order of 19-43°/oo as explained for other levels before. The low species numbers cannot be explained when compared to the

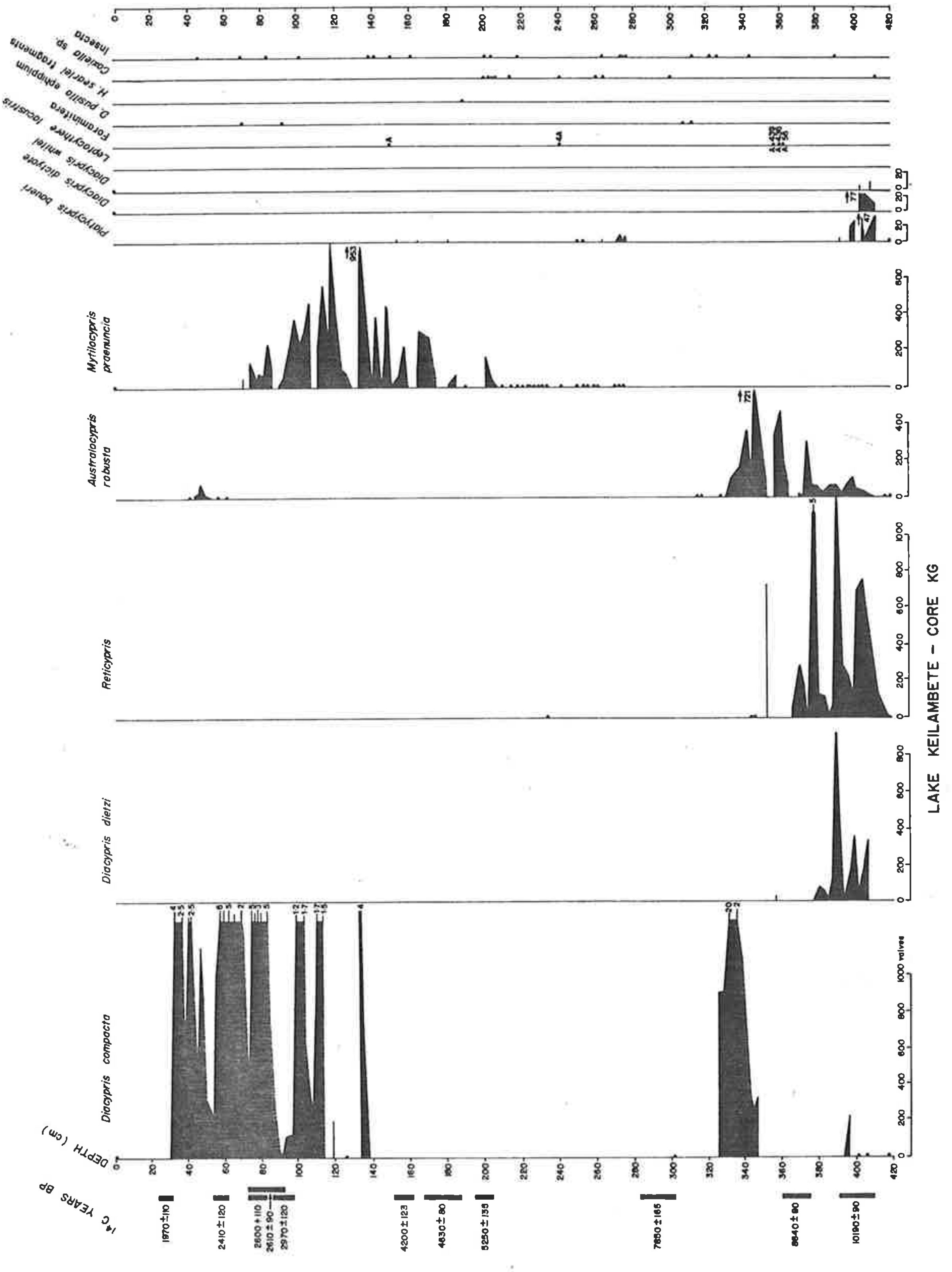


FIG. 5.9 Distribution of fossil ostracods and other remains in core KG from Lake Keilambete. Same remarks as for Fig. 5.8.

zone above, except by a suggestion that salinities were low (20°/oo) as this would explain the presence of very few *D. compacta.* Insect fragments are present in a number of samples. At level 201.5-202.5 cm the very obvious layer rich in *Coxiella* shells, which is also recorded in Bowler's core K4 (Bowler, 1970) is considered to represent a phenomenon registered over most of the lake floor: water depth was probably less than 6 m as shells of adults were found. A few quartz grains (>250 μ) also found in this layer in core KG confirms this assumption.

210-280 cm: The low numbers of *M. praenuncia* and *P. baueri* probably indicate unfavourable conditions for both species. The absence of *P. baueri* between 210 and 245 cm is considered to represent the less saline portion of this event.

280-323 cm: No data available as no ostracods were recovered except for level 302 cm where a *D. compacta* was found.

323-348.5 cm: Zone characterized by fairly high numbers of *D. compacta* and subdivided into a series of events:

323-325.5 cm: *D. compacta* present alone in fairly large numbers - salinity ranged between 43-182°/oo (the range of this species is 3-182°/oo in Victorian lakes, but *M. praenuncia* is absent here).

325.5-332 cm: *D. compacta* and *A. robusta* co-occur and both are abundant at times. Salinity range 28-145°/oo (this corresponds to the present day range of *A. robusta* in Victorian lakes when it is found only in large numbers).

332-336 cm: *D. compacta* "bloom" (at level 332: 6,000 valves/g of sediment!!) accompanied by many *A. robusta.* Salinity 45-77.5°/oo.

336-348.5 cm: *D. compacta* in fair numbers and *A. robusta*, at times, in high numbers for the species (at level 346 cm: 720 valves). Presence of *R. herbsti* in small numbers (species identification extrapolated because of the co-occurrence of *A. robusta* and *D. compacta* as explained before - this refers to all *Reticypris* specimens found in the samples below level 342 cm). Salinity range broadened to a maximum value of 145°/oo (= upper limit of *A. robusta*) when *A. robusta* is found in high numbers (341.5 cm, 346 cm) and between 45-77.5°/oo for other times.

348.5-393 cm: Period of high salinity at most times with extensive fluctuations: when *R. herbsti* is the most abundant species, salinity was about 99-172°/oo (level 351 cm, 377 cm). High numbers of *A. robusta* (357-362 cm, 375.5 cm) represent a range of 45-77.5°/oo salinity. The presence of few *D. dietzi* is consistent with the salinity values given above. When it is found in high numbers (level 390 cm) with *R. herbsti* and quite a few *A. robusta*, salinity was around 75°/oo. At levels 362-367 cm, abundant numbers of all sizes of *A. beccarii* indicate permanent water around 35°/oo. On two occasions (levels 355-357 cm and 387.5-392 cm) the lake dried as shown by the disturbed bedding.

393-419 cm: Salinity fluctuations and values often very high. At levels 401 cm, *P. baueri* are numerous and accompanied by many *R. herbsti* and a few valves of three other species (*D. compacta*, *D. dietzi* and *A. robusta*) - this indicates a salinity range of 99-172°/oo. This is confirmed by the presence of *D. dictyote* at levels 404 and 410 cm and *D. whitei* at 410 cm. Level 404 cm probably experienced a higher salinity like level 401 cm as *P. baueri* and *R. herbsti* are numerous. The same range is

TABLE 5.3 Correlations for levels of cores K1C and KG with corresponding ones already ^{14}C dated in cores studied by Bowler (1970), Bowler and Hamada (1971), Dodson (1974) and Barton *et al.* (in press).

^{14}C date	Lab.	K1C	KG	K4 Bowler (1970)	KF Barton *et al.* (in press)	KJ	Dodson Dodson 1974a	Justification of correlation
610±110	N517	19 - 30.5		10- 20				Marl band at 15-20 cm in K4 = 24-30.5 cm in K1C.
765±135	I5245	30.5- 35.5					105-110	5 cm below marl band in Dodson = 30.5-35.5 in K1C.
935±110	N518	30.5- 42		21- 33				Start at 1 cm below marl band - see sample N517.
1,970±110	N519	63.5- 73.5	24.5- 34.5	55- 65				4 cm below 2 thin carbonate layers (52 cm in K4 = 20.5 cm in KG and 60 cm in K1C).
2,410±120	N520	90 -101	53 - 63	79- 90				4 cm below start of ostracod rich mud and 8 cm below beige layer in both cores.
2,600±110	N521	110 -120	72 - 82	102-112				10 cm band with strong lamination; this level is compressed in K1C as many distinctive layers are much thinner than in KG.
2,610± 90	ANU2053		72 - 92		90-110	50- 70		
2,970±120	N522		85 - 97	130-140				132-141 in K4 with dark brown to black weakly calcareous mud = 87-98.5 in KG.
3,500±100	ANU2054		?		141-161	110-120		Cannot be correlated as no diagnostic layer present.
3,580±125	N523		?	165-175				
4,200±125	N524		151 -161	190-202				End of lamination and start of weakly calcareous mud at 202 in K4 = 161 in KG.
4,630± 80	ANU2055		~167 -187		202-222	160-180		5 cm band of thin lamination at around 210 cm in KF is probably similar layer at 173-176cm in KG.
4,930±200	I5244						275-280	Cannot be correlated as no diagnostic layer.
5,250±135	N525		193.5-204.5	235-245				Shell layer of *Coxiella* at 242 in K4 corresponds to 158 in KG.
5,980±110	ANU2056		?		267-287	225-245		Cannot be correlated as no diagnostic layer in the middle of the black mud of KF.
6,440±145	N526		?	290-300				Cannot be correlated as no diagnostic layer.
6,470±110	I6225		?				370-375	
7,850±165	N527		283 -303	335-345*				The 2 carbonate bands ending at 355 cm in K4 = those ending at 303 in KG.
8,640± 80	ANU1807		360 -375		390-405			The "striated" layer of Barton *et al.* (in press) at 389 cm in KF = the layer with disrupted layering at 355-357 cm in KG.
9,670±135	I6226						480-485	Cannot be correlated as no diagnostic layer.
10,190± 90	ANU1808		390 -410		420-440			The "striated" layer of Barton *et al.* (in press) at 420 cm in KF = the band with disrupted layering at 388.5-392 cm in KG.
14,300±300	N528			395-412				This level (swamp plant debris) is not present in KG.

* Erroneously labelled as 325-345 by Bowler & Hamada (1971).

Layers which are underlined are those which were originally dated.

extrapolated for level 413 cm where *A. robusta* and *D. compacta* were absent and with *R. herbsti* in smaller numbers and *P. baueri* more common than usual. Between levels 401 and 413 cm, salinity probably remained high as *R. herbsti* and *P. baueri* were either abundant or common in the samples. Salinity was probably lower at level 417 cm, when *A. robusta* was recorded with few *D. compacta* and *R. herbsti*, but it cannot be adequately defined. Between levels 407 and 419 cm, the lake was probably subject to drying up at times, as no lamination is visible in the grey clay.

Only correlation with other cores which is necessary for the dating of events in cores KIC and KG will be considered here. A number of dates associated with cores from Lake Keilambete are available. These cores are: K4 of Bowler (1970) and Bowler and Hamada (1971), KF and KJ of Barton *et al.* (in press) and a core from Dodson (1974a). All dates which could be referred to cores KIC and KG are presented and justified in Table 5.3. The results are summarized below:

0-10 cm in KIC (0-300 yBP): Salinity of the water between 17.5-42°/oo. At level 5 cm, permanent water conditions and salinity 19-35°/oo.

10-38 cm in KIC (300-900 yBP as level 30.5-42 = 935 ± 110 yBP): Salinity of the water between 10-42°/oo; at level 27 cm, same conditions as for level 6 cm and temporary fluctuations to higher salinities at 10-12 cm (300 yBP) and 24-30 cm (600-750 yBP).

38-72 cm in KIC (900-2,000 yBP): Little data. At level 69 cm in KIC (= 2,000 yBP) ostracod numbers are depauperate and sand grains are also present - this layer is facies equivalent to Bowler's (1970) sand layer - water level was probably low. For the period prior to 2,000 yBP, water level was probably high.

72-101 cm in KIC (= 32-62 cm in KG) (2,000-2,500 yBP): *D. compacta* "bloom" therefore salinity of the water 45-77.5°/oo. When *A. robusta* was present for level 80-101 cm in KIC (= 2,250-2,500 yBP) salinity range has to be broadened to 42-145°/oo.

62-140 cm in KG (2,500-(3,800-4,000) yBP): Water salinity below that of today and of the order of 19-43°/oo; possibility of records of higher salinities up to 45-77.5°/oo for levels 99-102 (2,900 yBP), 108-112 (3,100 yBP), 131-134 (3,600 yBP). Also, at levels 81-84 (2,600-2,800 yBP), the presence of a few *A. robusta* suggest higher salinity: up to a maximum of 145°/oo. At level 92.5 cm (2,800 or 3,000 yBP), water salinity was below 33.4°/oo at least once.

141-210 cm in KG (4,000-5,500 yBP): Salinity between 19-43°/oo but probably around 20°/oo. At level 201.5-202.5 cm (5,300 yBP) a *Coxiella*-rich layer signifies a water level below 6 m.

210-280 cm in KG (5,500-7,200 yBP): Conditions of slightly saline to nearly fresh or fresh water, at times, are interpreted by the poor numbers of *M. praenuncia*. Between 210-245 cm (5,500-6,400 yBP), the absence of *P. baueri* reflects the less saline portion of this phase. The absence of low salinity ostracods could be explained by the stratification having set in the lake.

280-323 cm (7,200-8,300 yBP): No ostracods recovered except for a few valves at level 302 cm (7,800 yBP) - no salinity data available. The suggestion of the presence of stratified layer, as for level 210-280 cm, also applies here.

323-348.5 cm (8,300-9,000 yBP): Water salinity fluctuations around today's value.

323-325.5 cm (8,300 yBP): Salinity 43-182°/oo.

325.5-332 cm (8,300-8,500 yBP): Salinity 28-145°/oo.

332-348.5 cm (8,500-9,000 yBP): Salinity 45-77.5°/oo.

348.5-393 cm (9,000-10,100 yBP): Salinity values high and extensive fluctuations of water level.

351 cm (9,000 yBP): Salinity 99-172°/oo.

355-357 cm (9,100 yBP): The lake dried temporarily.

357-362 cm (9,200 yBP): Salinity 45-77.5°/oo.

362-367 cm (9,350 yBP): Permanent water 35°/oo salinity.

375 cm (9,550 yBP): Salinity 45-77.5°/oo.

377 cm (9,600 yBP): Salinity 99-172°/oo.

387.5-392 cm (9,900-10,050 yBP): The lake dried temporarily sometimes during that period.

Around 390 cm (10,000 yBP): Salinity around 75°/oo.

393-419 cm (10,100-10,750 yBP): Wide fluctuation of salinity which was often very high as for the 348.5-395 cm section.

401 cm (10,250 yBP): Salinity 99-172°/oo.

404 cm (10,300 yBP): Salinity 99-172°/oo.

407-419 cm (10,400-10,750 yBP): Lake subject to drying up.

413 cm (10,600 yBP): Salinity 99-172°/oo.

The water level curve for Lake Keilambete, calibrated by ^{14}C dates, was first schematized by Bowler and Hamada (1971) and later a more detailed version was produced by Bowler (in press). Barton *et al.* (in press) also presented a comparison between Bowler and Hamada's (1971) curve and a natural remanent magnetization (= NRM) intensity curve (Fig. 5.11). All three curves will be examined here for comparison with the data obtained from the fossil ostracods. In addition, data on aquatic vegetation available from Dodson's (1974a) pollen, spores and algal microfossils diagram for Lake Keilambete will be discussed. However, some of Dodson's (1974a) data, for some of his levels, could not be used here as lithological correlation between the cores was, at times, difficult.

The following remarks are necessary prior to reconsideration of the water level curve and salinity ranges for Lake Keilambete:

1. The assumption of Bowler (in press) that water depth has a direct relationship with water salinity at all times is queried here as, during the overflow period of the lake, water must have been below 3.5°/oo salinity as *Pediastrum* was present (Dodson, 1974a).

2. The significance of the presence of the halophyte *Lepilaena* in Dodson's (1974a) diagram has been omitted in Bowler's (in press) diagram. This aquatic grass indicates saline water conditions (salinity 3-60°/oo M. Brock, pers. comm.) like *Ruppia*, except that the latter has a higher salinity tolerance (up to 115°/oo, M. Brock, pers. comm.).

3. The general shape of the NRM intensity in sediments curve from Lake Keilambete in Barton *et al.* (in press), which is easily paralleled with Bowler and Hamada's (1971) curve, shows oscillations which are not recorded in Bowler's (in press) detailed curve. This is explained by the fact that the two cores have different locations in the lake: Bowler's (1970) K4 core was not recovered from the deepest part of the lake whereas Barton *et al.*'s (in press) cores, placed in the centre, yielded a greater variety of sediments resulting from changes in lake levels which in turn registered on the NRM intensity curve. It appears that Barton *et al.*'s equipment is very sensitive to changes in sediment types.

The ostracod data appears to be too imprecise in core KIC to detect the change in lake level recorded in core KF at 700 yBP. Around 1,300 yBP, an increase in salinity, seen in core K4, is not found in cores KF and KG and between about 900 and 2,000 yBP, when ostracods were few in numbers and of little use in providing information on water salinity, the water level was apparently high as demonstrated in cores K4 and KF.

From 2,000-4,000 yBP, the water level has fluctuated but remained generally low. There is an exception around 3,000 yBP. The two peaks of high salinity and low water level between 2,000 and 3,000 yBP registered in cores K4 and KF are also recorded in core KG and the two opposite peaks (lower salinity and higher water levels correspondingly) are detected in cores KF and KG.

From 4,000-8,300 yBP, the less saline conditions prevailed as interpreted from cores K4 and KF. Very little information is available from the ostracods in core KG. Dodson's (1974a) record of *Pediastrum*, which indicates salinity less than 3.5°/oo salinity for the period 5,000-6,500 yBP, is slightly inconsistent with the ostracod data obtained in core KG as for the 4,000-5,500 yBP period, the salinity range is extrapolated as 19-43°/oo with a probable lowering of the lake level to 6 m or less at about 5,300 yBP (*Coxiella*-rich layer). It appears therefore, that the water level must have fluctuated at times between less than 3.5°/oo and more than 19°/oo. During that period of time, *Pediastrum* numbers were low.

The oscillation at around 4,800 yBP in Barton *et al.*'s (in press) curve is not registered by the ostracod fauna.

From 5,500-6,500 yBP, freshwater conditions were maintained most of the time as *Pediastrum* is present in high numbers but occasional returns to slightly saline conditions are necessary to justify the presence of *M. praenuncia* in some samples. From 6,500-7,200 yBP, slightly saline conditions seem to have prevailed at times as *Pediastrum* is absent while *P. baueri* and *M. praenuncia* co-occurred. *Botryococcus*, found in these samples, indicates oligotrophic conditions.

Dodson (1974a) recorded *Ruppia* between approximately 6,900-8,200 yBP (calculated from his diagram) with the highest value around 7,800 yBP.

It is likely that this phenomenon corresponds to the lowering of the lake level registered by Barton *et al.* (in press) at about 7,800 yBP and around 7,900-8,000 yBP by Bowler (in press). For that period of time, only a few valves of *D. compacta* are found at level 302 cm in KG. The absence of ostracods at other levels remains unexplained. *Lepilaena* is also represented in low numbers throughout this period of time.

The highest lake level ever extrapolated by Barton *et al.* (in press) for around 8,200 yBP, which is recorded by Bowler (in press) by a smaller peak, could be explained by a period of lake stratification which would exclude benthic ostracods.

From 8,300 to about 10,500 yBP, the generally low and fluctuating water level drawn by Bowler (in press) and the periods of low salinities reached on Barton *et al.*'s curve (in press) are in agreement with the ostracod data especially during the period older than 9,500 yBP which experiences the highest salinities and the consistently lowest water levels. Barton *et al.* (in press), however, failed to recognize the periods of lake desiccation (= levels labelled "striated" in core KF) at 9,200 and 10,000 yBP. The low levels for the lake registered in Bowler (in press) and Barton *et al.*'s (in press) curves are compatible with the suggestion of a period between 10,400 and 10,750 yBP during which the lake was subject to drying up.

It is interesting to note that Tudor (1973) failed to recover diatoms from the upper 200 cm of his core from Lake Keilambete, and that this portion of the core corresponds to the one from which Bowler (1970, in press) recorded the presence of dolomite. Similarly, Tudor (1973) could not recover diatoms in the dolomite bands from Lake Gnotuk (between 125 and 170 cm). On the other hand, the same author described a rich diatom fauna from the grey clay (labelled by Tudor (1973) as a volcanic ash layer) at the bottom of his core from Lake Keilambete. The corresponding water level phase, higher than the present day one, mentioned by Tudor (1973) is contradictory to the evidence obtained from ostracods and shown on Bowler (in press) and Barton *et al.*'s (in press) curves.

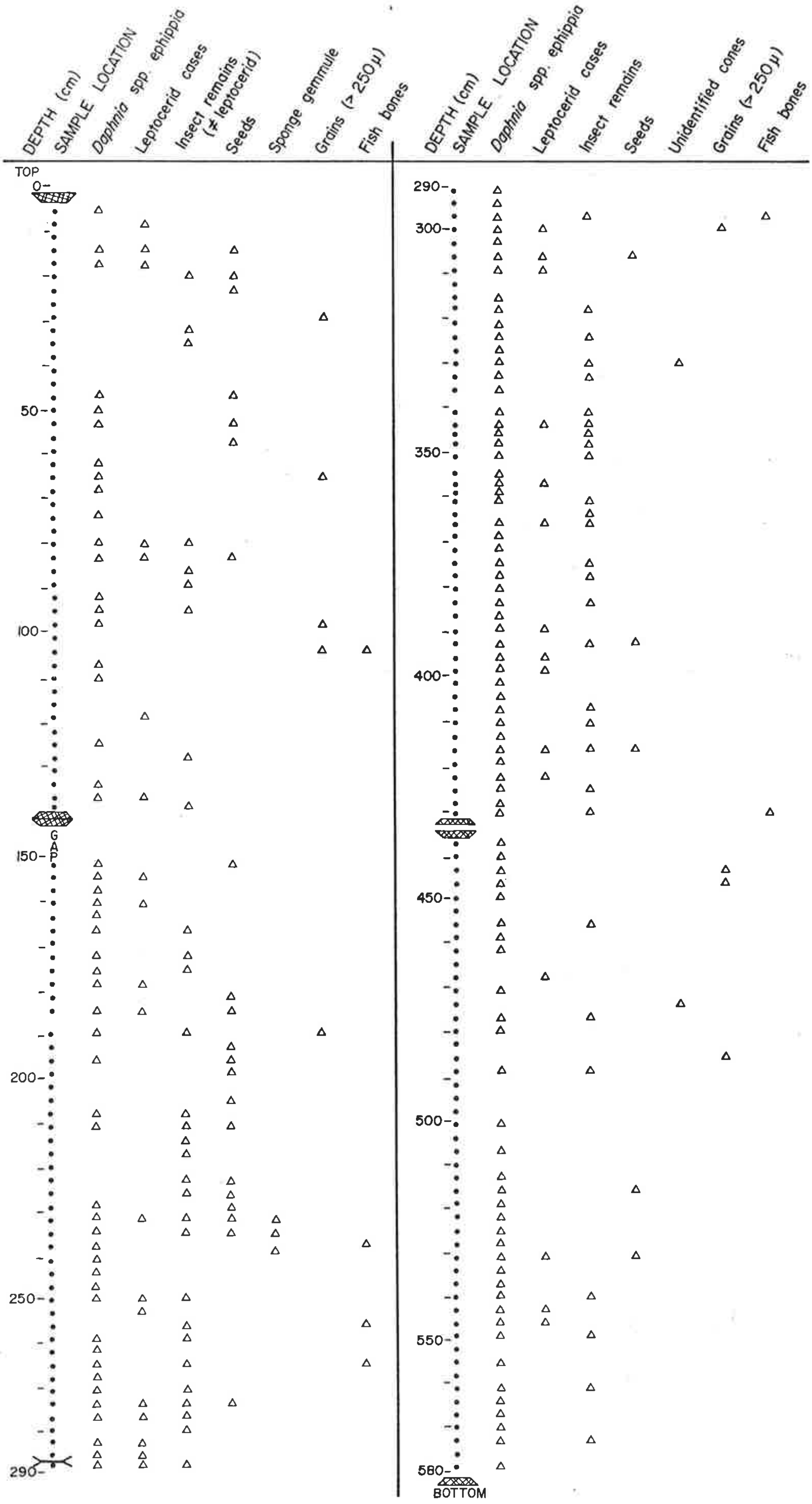
Dodson (1974a), who discussed the formation of the creamy yellow band of dolomite at depth 96-103 cm in his core (= marl band of Bowler, 1970), stated that this band marked a dry period in the lake history. In the corresponding band in core KIC, at level 24-30.5 cm, valves of *P. baueri* abound and those of *M. praenuncia*, common on either side of this band, are numerically low. Salinity of the lake must have been high therefore, at times above 70°/oo with fluctuations down below 43°/oo. At level 27 cm, water must have been permanent and of lower salinity (17-35°/oo) as indicated by the presence of *L. lacustris*. It appears unlikely, therefore, that the lake did not dry during the period of the formation of dolomite but that salinity could at times have been high.

5.4.2.4 Lake Purrumbete

No ostracods have been recovered in the 195 samples taken throughout the core which consists of homogeneous dark brown organic mud. At first glance, therefore, there is no indication that the lake ever became saline. On the other hand, most of the samples yielded daphniid ephippia and egg capsules (Fig. 5.10). Their state of preservation was often very good as most sacs or capsules were still swollen after treatment in H_2O_2 and prior to the drying of the residues in the oven. It appears, therefore, that during approximately the last 7,000 years*, waters of Lake Purrumbete remained either fresh or in the

---

* Barton (pers. comm.) suggested that by using intensity of magnetization correlation with one of his ^{14}C dated core PD, level around 5 m in core PC studied here, is approximately equivalent to 6,140 ± 110 yBP.



LAKE PURRUMBETE - CORE PC

FIG. 5.10 Distribution of fossil remains and grains in core PC from Lake Purrumbete. Dots indicate the position of samples taken from the core. Triangles indicate only the presence of remains and grains in the cores.

vicinity of freshwater as the upper limit recorded for *Daphnia* spp. is 5.8°/oo. As mentioned before, the absence of shells of the freshwater gastropod *P. niger* and the bivalve *Sphaerium* sp. in the samples suggest that the shore of the lake was never close to the coring site and that the height of the water column above this site remained higher than 35 m at all times. This would also explain the absence of the benthic ostracods *Gomphodella australica* (Hussainy, 1969) found today in the lake by Timms (1973) in collections between 0.5-1 m, *Candonocyrpis novaezelandiae* (= *C. assimilis* in Hussainy 1969a, Timms 1973) recorded down to 33 m by Timms (1973), and of the free swimmer *Newnhamia fenestrata* King, 1855 usually now inhabiting waters near the shore of the lake.

5.5 INTERPRETATION OF THE DATA FOR THE LAKES

The location of the four maar lakes is an ideal one for palaeoclimatological study as they are situated in a subhumid area of Australia, which is also close to a semi-arid area today. Any change caused either by an increase or decrease in evaporation or precipitation in the area is likely to affect levels of lakes, especially those which have closed basins, such as maars. Unfortunately, at the present stage, a change of this ratio cannot be properly assessed for a number of reasons. First of all, it is not possible to plot an accurate water level curve deducted from known past salinities for various phases of the lakes as it appears that the amount of total dissolved salts (TDS) did not remain constant in the lakes (Lake Purrumbete is ignored here as it remained fresh for approximately the last 7,000 years); the waters of Lakes Bullenmerri and Gnotuk which now have a similar volume of TDS must have mixed at some stage and prior to that the volume of TDS in Lake Bullenmerri must have been different as water salinity is thought to have been between 3.26-7.92°/oo when the lake level was considered to be less than half of today's between 7,400-7,700 yBP. Similarly, at a particular time when the level of Lake Keilambete was thought to be below 6 m, salinity was between 19 and 43°/oo. It appears that TDS are either lost or introduced into the lakes by percolation and via the water table.

Finally, it is not possible to assess how much of the TDS volume is lost periodically by precipitation of salts especially in Lakes Keilambete and Gnotuk.

Although no hydrological budget can, at present, be presented for the four maar lakes, the synchronous fluctuations of water levels and water salinities, recognized mainly with fossil ostracod data, in Lakes Bullenmerri, Gnotuk and Keilambete warrant a suggestion as to the climate in central Victoria during the last 10,000 years. This is schematized in Fig. 5.11 and comments are given below. It is interesting to note, however, that Lakes Gnotuk and Keilambete, which have similar salinities and faunas today, registered almost identical changes of ostracod faunas at most times. Water levels and, correspondingly, salinities, responded to changes of climates. Unfortunately, it is not yet possible to state how these changes related to either evaporation or precipitation.

(a) In about the last 100 years, lake levels for the three maars (Lake Purrumbete will not be discussed here) have decreased drastically (Currey, 1970; Bowler, 1970, in press) but it is not known whether this is an anthropogenic induced effect or not.

(b) At 300 yBP and around 600-750 yBP, there were fluctuations of salinity to higher values noted in Lake Keilambete (no record for Lake Gnotuk available).

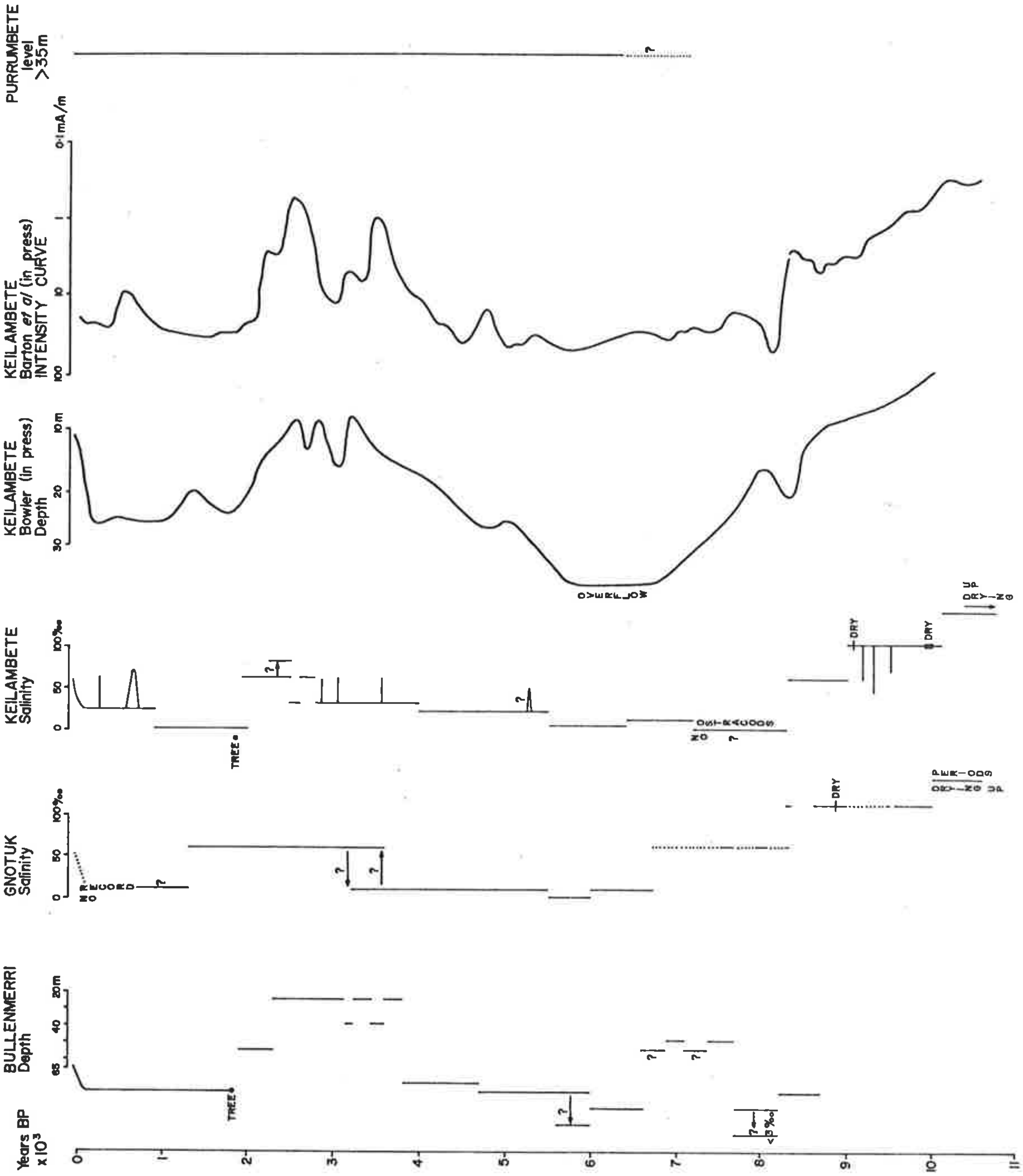


FIG. 5.11 Lake level curves for Lakes Bullenmerri and Purrumbete, and salinity level curves for Lakes Gnotuk and Keilambete postulated from the data obtained from fossil ostracods and other remains. These curves are compared with those for Lake Keilambete of Bowler (in press) [water level] and Barton *et al*. (in press) [intensity].

(c) At 1,300-1,800 yBP there is a discrepancy for Lake Gnotuk with high salinity values whereas the other lakes have a high water level (Keilambete with a suspected very low salinity).

(d) At 1,950 yBP a change in water level in Lakes Keilambete and Bullenmerri is supported by ^{14}C dated trees which were drowned at the time (Yezdani, 1970; Bowler, 1970).

(e) At 1,900-3,800 yBP a progressive decrease in water levels in all three lakes is recorded.

(f) At about 3,800 yBP there is a change in level in Lakes Bullenmerri and Gnotuk; it is noticeable at 4,000 yBP in Keilambete.

(g) Between 3,800 and 6,000 yBP the changes in water levels are synchronous in all three lakes and these correspond to Yezdani's (1970) palaeoecological reconstructions (Clypeus Phase and freshwater phase).

(h) The obvious changes in water levels recorded at about the same time in Lakes Gnotuk and Bullenmerri between 6,000 and 7,700 yBP were not detected in Lake Keilambete.

(i) There is a drastic change of water level for Lakes Keilambete and Gnotuk at 8,300 yBP. This corresponds to a probable change in level seen by a change of fauna in Lake Bullenmerri at the same time.

(j) Before 8,300 yBP salinities in Lakes Keilambete and Gnotuk were the highest ever recorded in the lakes for the last 10,000 to 11,000 yBP. Lake Keilambete water level and salinity seemed to have fluctuated more.

(k) At 10,000-10,100 yBP a similar change in water salinity in both

Lakes Keilambete and Gnotuk is evident. Before then, the lakes were probably often subject to drying up.

The significance of all these results for past climates in Australia will be discussed in Chapter 9.

PLATE V.1

Leptocythere lacustris n.sp.

1 LV external, BK158
2 LV external, BK210
3 RV external, K1C27
4 RV external, BK210
5 LV external, GH135
6 RV external, BK177
7 RV external, GH135
8 LV internal, K1C5
9 LV internal, BK187
10 LV internal, BK210
11 LV internal, BK210
12 RV internal, BK187
13 C dorsal, GH135
14 C dorsal, BK193
15 LV internal, hinge posterior of 9
16 LV internal, hinge anterior of 9

Limnocythere dorsosicula n.sp.

17 LV external, male, BK187
18 LV external, male, BK171
19 LV external, female, BK210
20 LV external, female, BK206
21 RV external, juvenile (female?), BK210
22 LV external, juvenile (male?), BK210
23 LV external, female, BK175
24 C dorsal, BK182.5

Candonocypris novaezelandiae (Baird, 1843)

25 RV internal, juvenile, BK187

Ilyocypris australiensis Sars, 1889

26 RV external, BK187
27 RV external, BK187
28 LV internal, BK470
29 RV external, BK210
30 LV external, BK210
31 LV external, BK472
32 RV internal, juvenile, BK193
33 LV external, juvenile, BK158
34 RV internal, juvenile male, BK206
35 RV internal, juvenile, BK189
36 RV internal, juvenile, BK193

Scale: 1 - 200 μ for 1 - 14
2 - 50 μ for 15 - 16
3 - 200 μ for 17 - 25
4 - 250 μ for 26 - 33

BK, GH, K1C, GH, PC = Core label followed by depth in cm from top of core

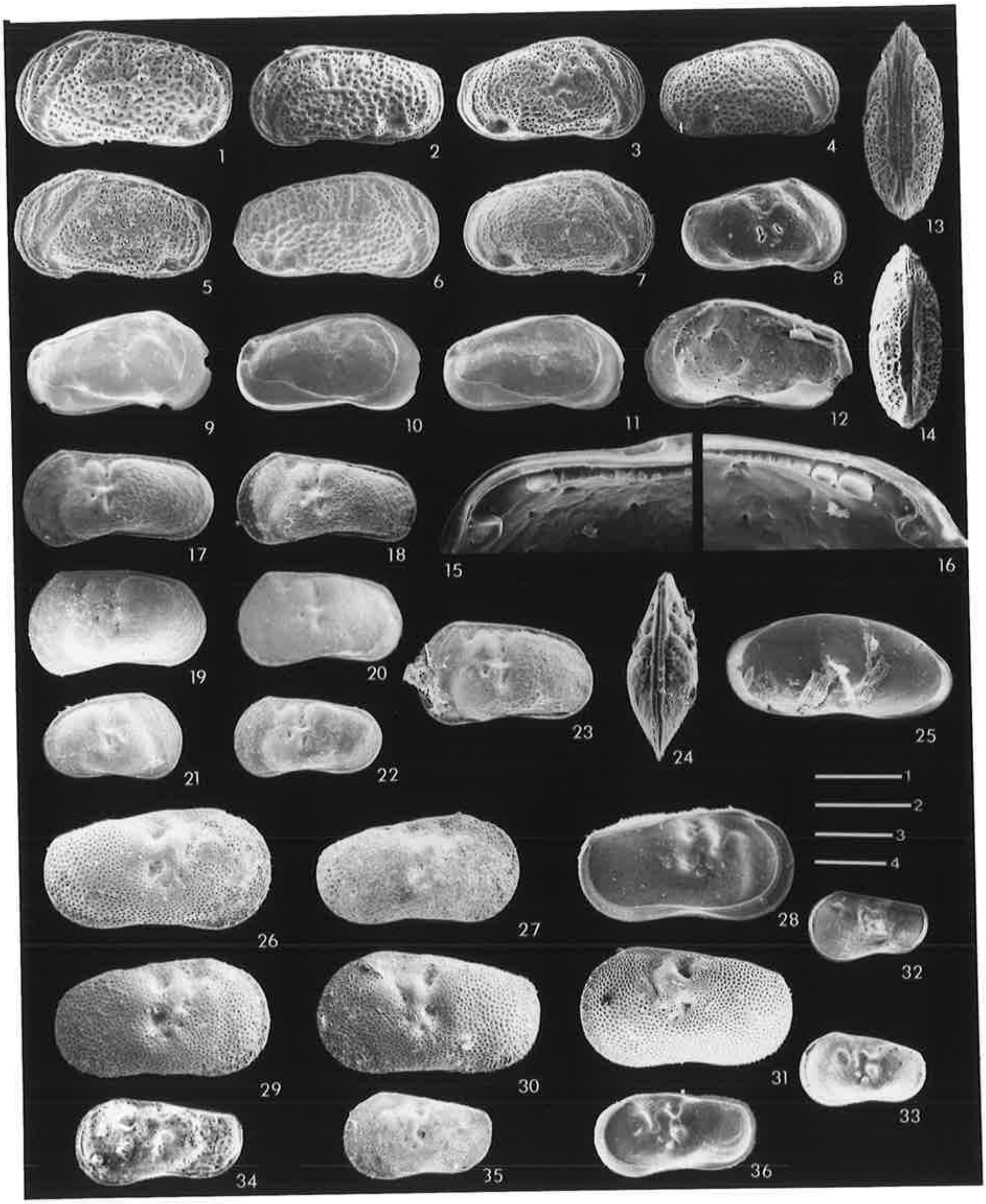

1
2
3
4
13
5
6
7
8
9
10
11
12
14
17
18
15
16
19
20
23
24
25
21
22
1
2
3
4
26
27
28
32
29
30
31
33
34
35
36

PLATE V.2

Mytilocypris praenuncia (Chapman, 1936)

1 LV internal, KG135.5
2 RV internal, KG135.5
3 RV internal, KG135.5
4 RV external, juvenile, KG201.5
5 LV internal, KG164.5
6 LV internal, KG181.5
7 RV internal, KG181.5
8 RV internal, juvenile, KG201.5
9 LV internal, juvenile, KG135.5
10 LV internal, juvenile, KG135.5
11 LV internal, juvenile, KG135.5
12 RV external, juvenile, KG135.5

Australocypris robusta De Deckker, 1974

13 LV external, juvenile, KG380
14 LV internal, fragment, GH62.5
15 LV internal, juvenile, KG362
16 RV internal, GH300.5 (note juvenile *Diacypris* sp. inside)
17 LV dorsal, juvenile, KG377
18 RV internal, KG362
19 LV internal, fragment, K1C95
20 RV external, juvenile, K1C95
21 LV internal, juvenile, K1C95
22 LV dorsal, juvenile, KG360
23 LV external, partly broken, juvenile, KG360
24 RV external, juvenile, KG360
25 RV internal, partly broken, KG360

Platycypris baueri Herbst, 1957

26 LV internal, partly broken, juvenile, KG274
27 RV internal, partly broken, KG404
28 LV internal, partly broken, KG404
29 RV internal, KG404
30 RV internal, juvenile, KG393
31 LV internal, juvenile, KG393
32 C dorsal, K1C26
33 LV external, juvenile, K1C26
34 LV external, juvenile, K1C26
35 RV external, juvenile, K1C26
36 LV external, ? juvenile, K1C26
37 LV external, K1C26
38 RV internal, anterior detail of 29

Scale: 1 - 1,000 μ for 1 - 12, 14, 16 - 20, 25
2 - 500 μ for 13, 21, 27 - 37
3 - 500 μ for 15; 250 μ for 22
4 - 100 μ for 38

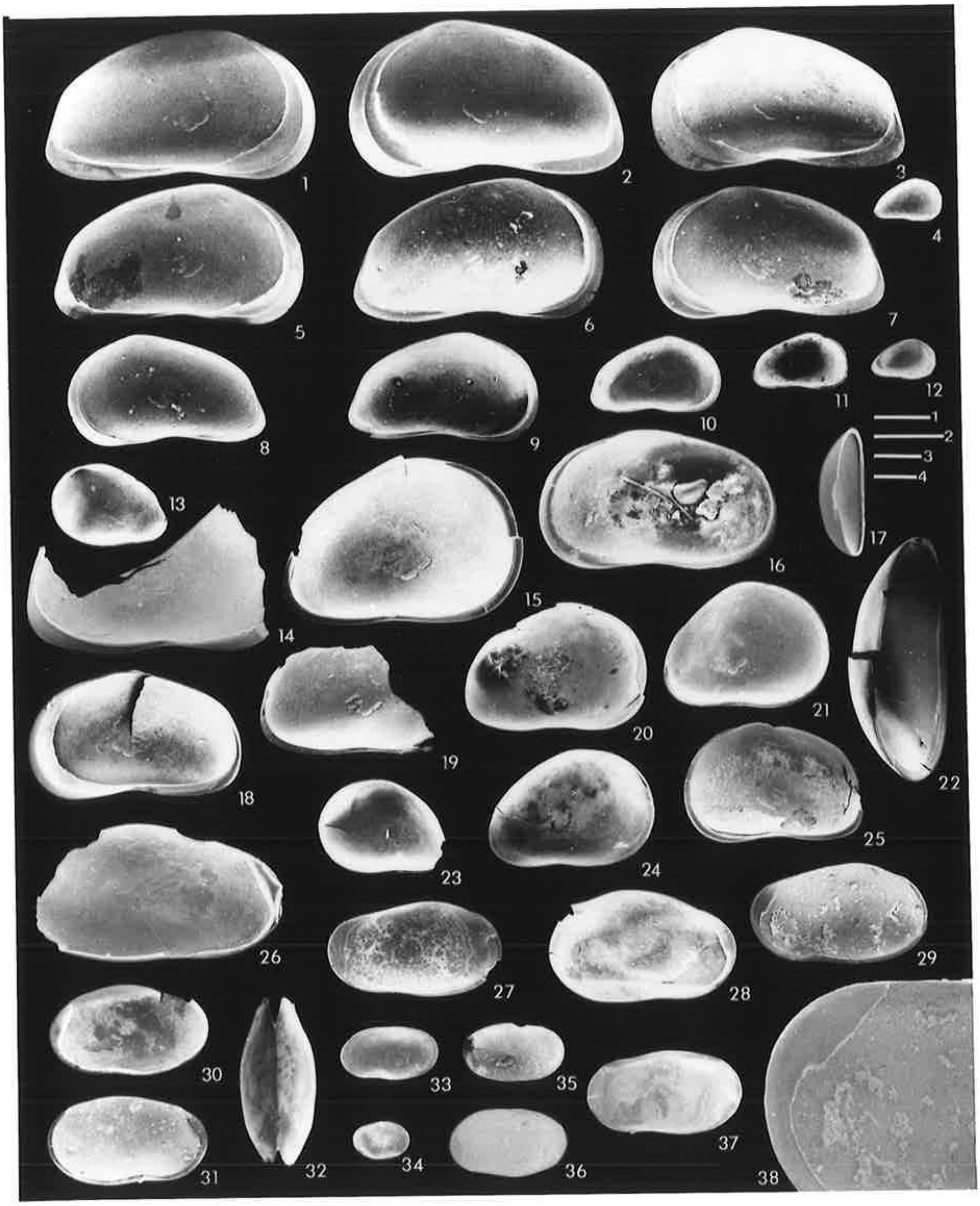

1
2
3
4
5
6
7
8
9
10
11
12
1
2
3
4
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38

PLATE V.3

Reticypris sp.

1 RV external, KG372
2 LV external, KG372
3 C showing RV, juvenile, KG372
4 C showing RV, KG372
5 C dorsal, KG372
6 RV external, KG372
7 LV external, KG351.5
8 LV internal, KG372
9 LV internal, KG351.5
10 RV external, KG372
11 LV external, KG372
12 RV internal, KG351.5
13 RV internal, KG351.5
14 C ventral, KG351.5
15 LV external, juvenile, KG372
16 LV external, juvenile, KG372
17 LV external, juvenile, KG372
18 RV internal, juvenile, KG351.5
19 LV dorsal, KG351.5
20 RV dorsal, KG351.5
38 RV external, anterior detail of 10
39 RV external, anterior of 6

Diacypris dietzi (Herbst, 1958)

21 LV internal, KG393
22 LV internal, KG393
23 LV external, KG398.5
24 LV external, KG398.5
25 LV external, KG398.5
26 RV external, KG398.5
27 LV dorsal, KG398.5
36 LV external, anterior detail of 23

Diacypris whitei (Herbst, 1958)

28 LV external, KG410
29 C dorsal (note valves dislocated), KG410
30 RV external, KG410

Diacypris dictyote De Deckker, 1980

31 RV external, KG410
32 LV external, KG410
33 C dorsal, KG410
34 LV internal, KG410
35 RV internal, KG410
37 LV external, anterior detail of 32

Scale: 1 - 200 μ for 1 - 18
2 - 250 μ for 21 - 35; 20 μ for 36; 10 μ for 37
3 - 50 μ for 38 - 39

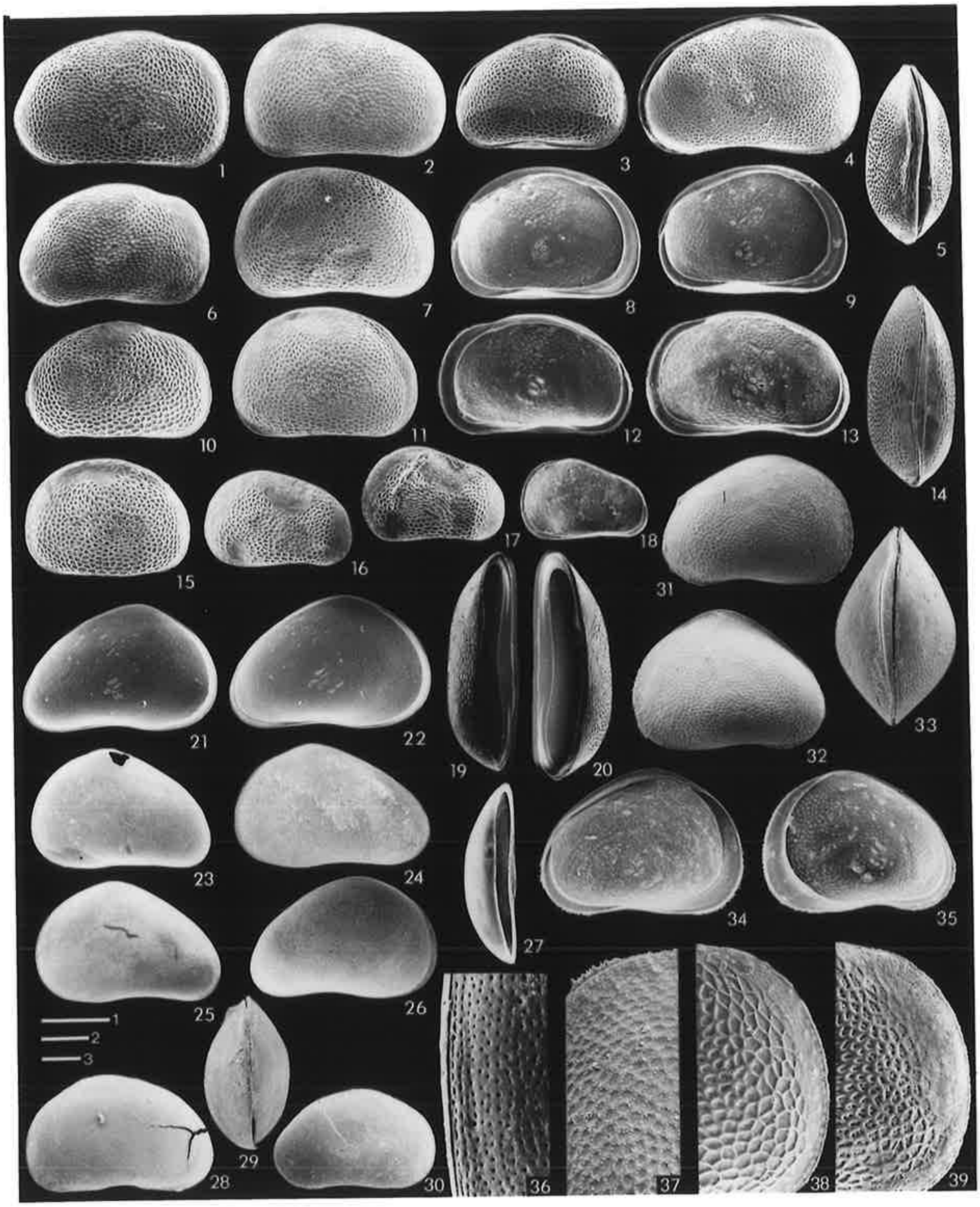

1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
31
19
20
21
22
32
33
23
24
27
34
35
25
26
28
29
30
36
37
38
39
1
2
3

PLATE V.4

Diacypris compacta (Herbst, 1958)

1 LV internal, GH62.5
2 LV internal, KG346
3 LV internal, GH361
4 RV internal, KG338
5 RV internal, juvenile, GH62.5
6 LV external, GH350
7 LV external, KG346
8 LV external, KG338
9 LV external, juvenile, GH350
10 C dorsal, KG338
11 C ventral, KG338
12 RV external, KG47.5
13 LV external, KG39.5 (note aragonite crystals)
14 RV external, KG39.5
15 LV internal, juvenile, GH62.5
16 RV external, detail of 12

Elphidium sp.

17 side view, GH135
18 side view, GH135
21 side view, K1C104
22 side view, K1C104

Triloculina rotunda d'Orbigny, 1893

19 side view, GH135
20 apertural view, GH135

Ammonia beccarii (Linné, 1758)

23 spiral view, KG362
24 spiral view, KG362
25 spiral view, KG362
26 umbilical view, KG362
27 umbilical view, KG362
28 spiral view, KG362
29 spiral view, KG362
30 spiral view, KG362
31 spiral view, KG362
32 apertural view, KG362

Discorbis sp.

33 spiral view, GH135

Haloniscus searlei Chilton, 1920

34 detail of 38
35 detail of 36
36 fragment of spine attached to telson, K1C90
37 fragment of distal segment of a posterior appendage, GH29
38 fragment of distal segment of a posterior appendage, GH29
39 fragment of proximal segment of an appendage, K1C90
40 fragment of ventral portion of cephalon, GH29
41 fragment of ventral portion of cephalon, GH29
42 fragment of ventral portion of cephalon, GH29

Scale: 1 - 200 μ for 1 - 15, 36, 39 - 42
2 - 20 μ for 16; 40 μ for 34 - 35
3 - 100 μ for 17 - 33
4 - 200 μ for 37 - 38

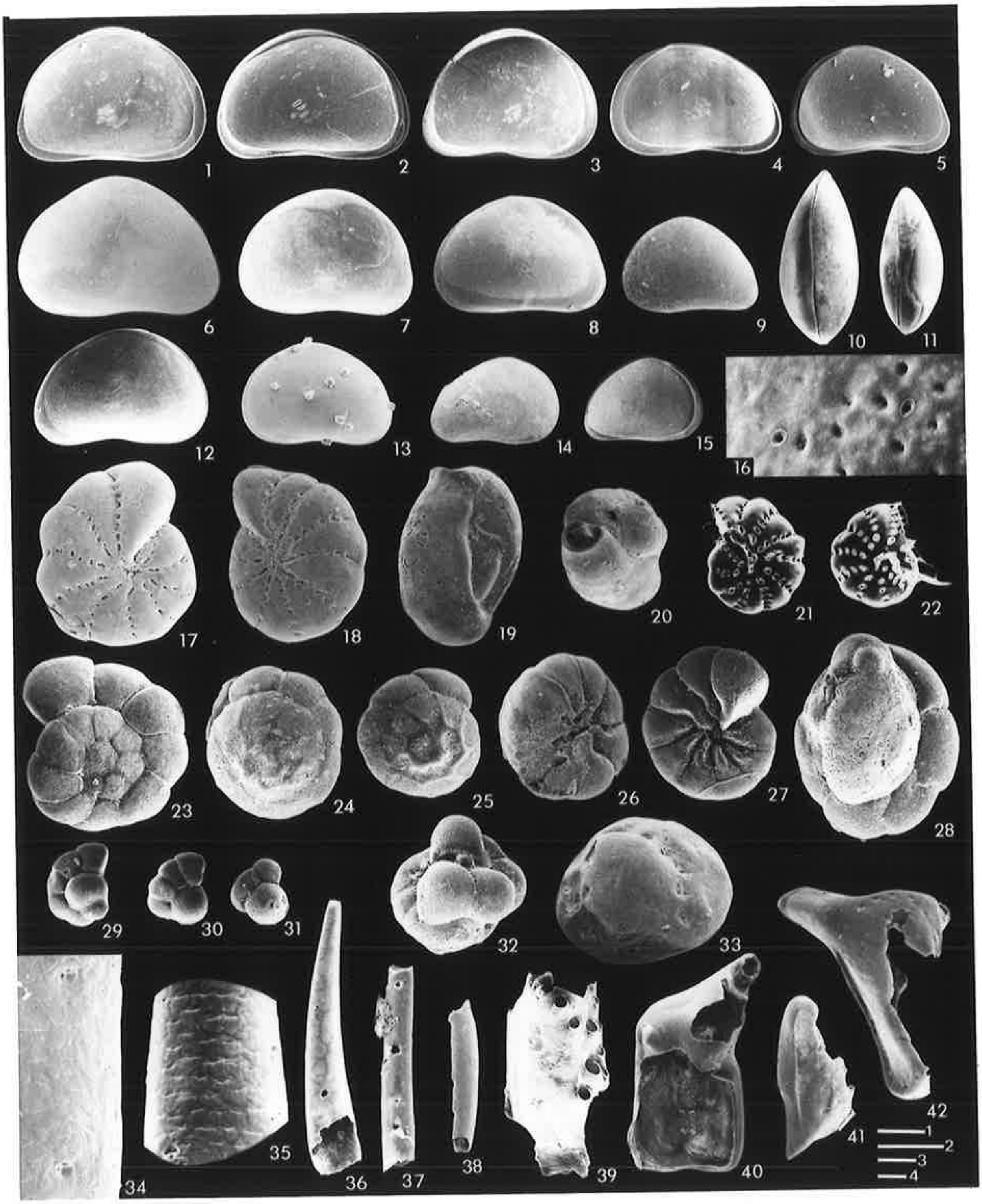

1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40
41
42
1
2
3
4

PLATE V.5

Daphniopsis pusilla Serventy, 1929

1 ephippial sac, GH87.5
2 ephippial sac, GH87.5
3 ephippial sac, KG92.5
4 ephippial sac, KG92.5

Daphnia sp.

5 ephippial sac, PC579
6 ephippial sac, PC167
7 internal capsule of ephippial sac, BK416
8 ephippial sac, PC137

Chironomidae

9 head case, PC417
10 head case, GH129
11 head case, GH1
12 head case, detail of 10
13 head case, detail of 11

Porifera

14 *Heterotula* sp., gemmule, PC229
15 *Heterotula multidentata* (Weltner, 1895), gemmule, PC235
16 *Heterotula nigra* (Lendenfeld, 1887), gemmule, PC232
17 *Heterotula nigra*, detail of 16
18 *Heterotula nigra*, detail of 16
19 *Heterotula* sp., detail of 14
20 *Heterotula multidentata*, detail of 15

Unidentified cones

21 BK177
22 BK356
23 BK194.5
24 BK356
25 BK362
26 BK362

Scale: 1 - 200 µ for 1 - 4; 100 µ for 9 - 11, 23 - 24;
40 µ for 17, 19; 20 µ for 18; 400 µ for 25 - 26

2 - 200 µ for 5 - 8, 14 - 16

3 - 40 µ for 12 - 13, 20; 100 µ for 21 - 22

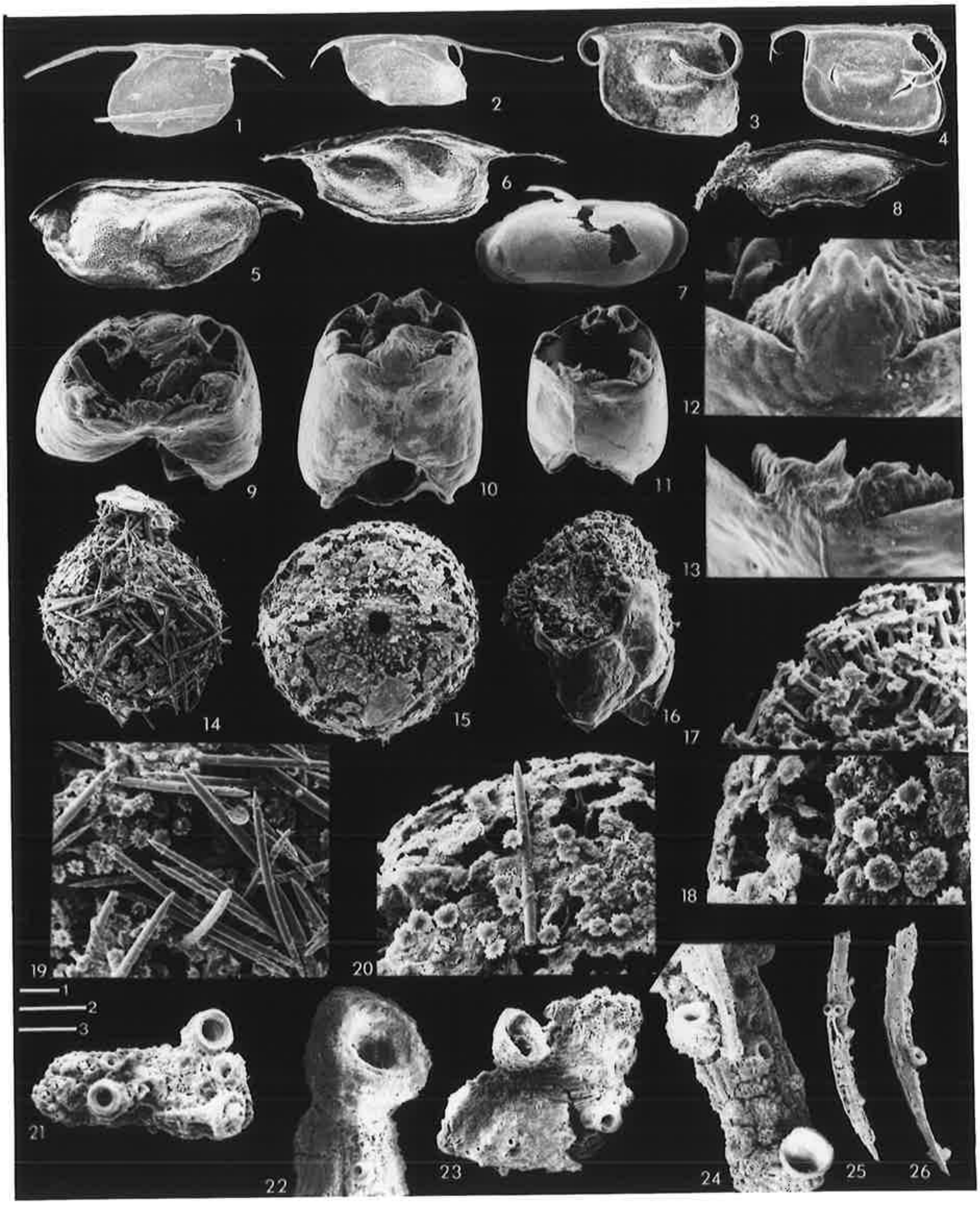

1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
1
2
3
21
22
23
24
25
26

PLATE V.6

Fish

1 jaw, BK189
2 jaw, GH166.5
3 jaw, GH166.5, fragment of 2
4 jaw?, BK358
5 jaw, GH6.5
6 jaw, GH166.5
7 jaw, BK114
8 vomer plate, *Anguilla* sp., BK285
9 jaw, GH6.5
10 jaw, BK128
11 jaw?, BK398.5
12 scale, BK126
13 scale, GH117
14 scale, BK126
15 scale, GH117

Coxiella sp.

16 apertural view, BK169.5
17 dorsal view, KG201.5
18 apertural view, KG201.5
19 apertural view, BK189
20 apertural view, KG201.5
21 apertural view, KG201.5
22 apertural view, GH170
23 apertural view, KG201.5
24 apertural view, BK126
25 dorsal view, GH187
26 umbilical view, BK158
30 detail of 25 showing gnawing or leaching marks on shell surface
31 detail of 24 showing aragonite crystals on shell surface

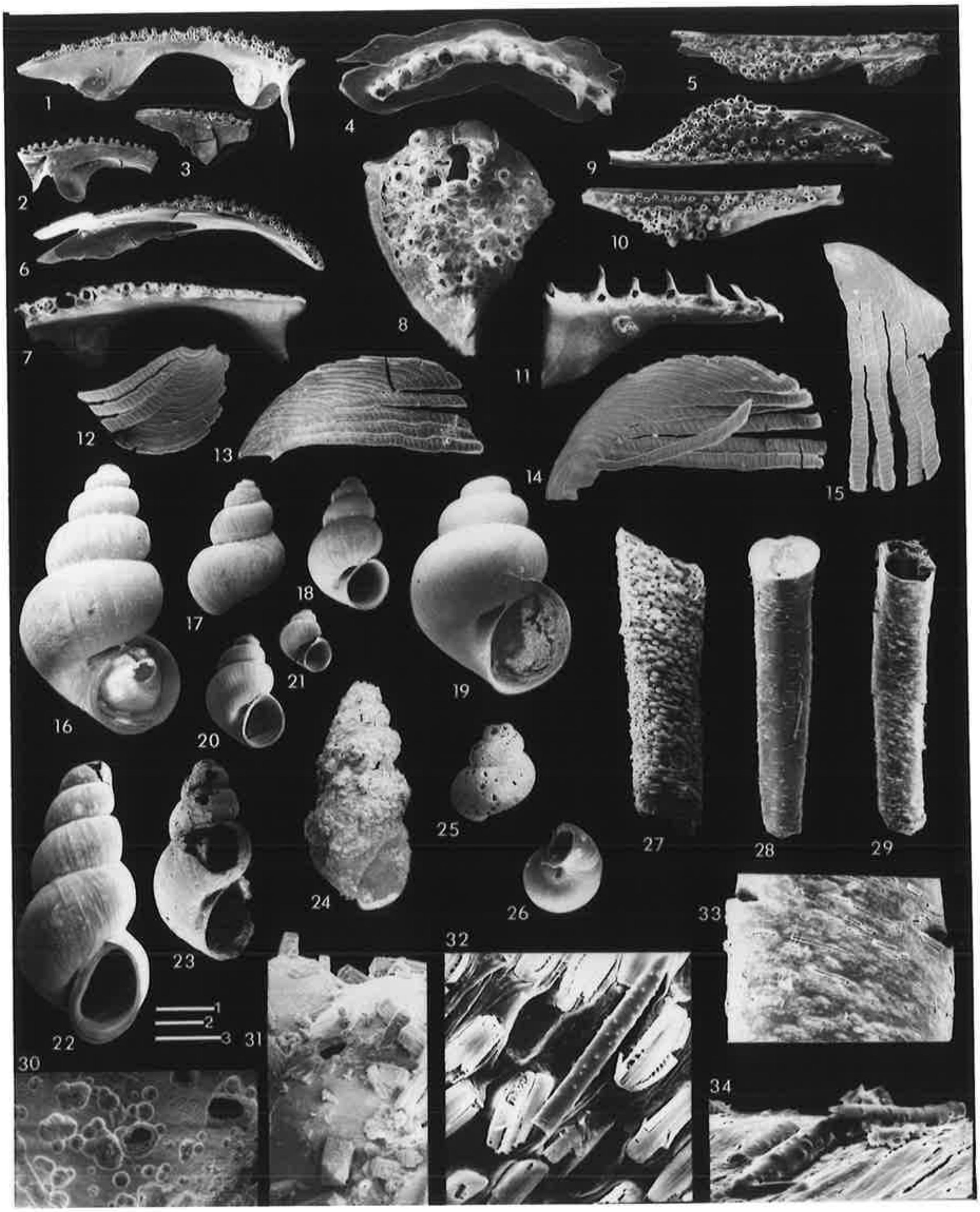
Trichoptera

27 case of leptocerid, PC17
28 case of leptocerid, PC185
29 case of leptocerid, PC179
32 case, detail of 27 (note sponge megasclere)
33 case, detail of 29 (note sponge megasclere)
34 case, detail of 34 (note sponge megasclere)

Scale: 1 - 400 μ for 1 - 3, 6, 8; 200 μ for 4;
300 μ for 5, 9, 11; 600 μ for 7, 16, 22, 25, 28 - 29;
30 μ for 32

2 - 200 μ for 10, 12 - 15, 26 - 27; 100 μ for 17 - 18, 20,
21, 23 - 24; 100 μ for 30 - 31; 20 μ for 34

3 - 20 μ for 33


1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
1
2
3

CHAPTER 6

ANALYSIS OF OSTRACODS FROM TWO PROFILES FROM PULBEENA AND MOWBRAY SWAMPS, N.W. TASMANIA

6.1 INTRODUCTION

The study of ostracods recovered from two sites in N.W. Tasmania was undertaken for a number of reasons. Firstly, both sites represent a continuous sedimentary record over a long period of time; Pulbeena Swamp covers about the last 80,000 years and Mowbray Swamp about the last 110,000 years. Such long and continuous records are rare. Secondly, as the pollen sequence at both sites is known (Colhoun *et al.*, in press; van de Geer *et al.*, in prep.), palaeoclimatic information can be compared against the fossil ostracod data and, in turn, the palynological information should improve our knowledge of the use of ostracods as palaeoecological indicators.

Each site will be examined separately, starting with Pulbeena Swamp where the ostracod fauna is more diverse and richer. Comparisons between the ostracod record for both sites will follow and finally the use of ostracods as palaeoecological indicators, and consequently as tools for palaeoclimatological reconstruction, will be assessed for deposits of spring fed swamps.

6.2 DESCRIPTION OF THE STUDY SITES

6.2.1 Pulbeena Swamp

At the Pulbeena limeworks, located between Smithton and Irishtown in N.W. Tasmania and about 30 m in altitude, a deposit of interbedded marls and swamp peats occurs over an area of about 1.7 km (Fig. 6.1). An L-shaped quarry called Pulbeena Swamp at the limeworks (Fig. 6.1) exposes a 5 m thick section consisting of chemically precipitated algal-rich marl, peat (some with standing tree stumps) and peaty marl which overlie thin alluvial sands and gravels of Quaternary age. In turn, these rest on Precambrian dolomite (Colhoun *et al.*, in press). The site is characterized by low spring mounds scattered throughout the deposit. As the spring pipes are seen to penetrate the entire sequence on most occasions, it is likely that these springs fed the swamp continuously until it was drained early this century. At the base of the deposit near the quarry section, highly mineralized water of a fairly constant temperature (around ∿17°C) flows freely throughout the year from a number of springs (Colhoun and van de Geer, pers. comm.). Amphipods and the ostracod *Candonocypris incosta* n.sp. are common in these waters. The latter is also found as a fossil in the swamp deposits.

The alternating layers of peat and marl can be followed laterally along the quarry face but their thickness can vary locally - e.g. in places, some peat layers are dividing to interfinger with marl bands. This probably arose from the subsidence of areas between the low mounds and, depending on water depth, facies varied laterally. This is particularly the case at the studied site where an extensive peat bed, usually found over the entire swamp between 50 and 100 cm in depth, is divided into three layers separated by marl and peaty marl (Colhoun *et al.*, in press). In other places, where spring mounds have collapsed, the sequence is often compressed and the adjacent beds are usually steeply inclined towards the subsided mounds.

Further information on local climate, geomorphology, soils and ground water is given by Colhoun *et al.* (in press) who also provide, for

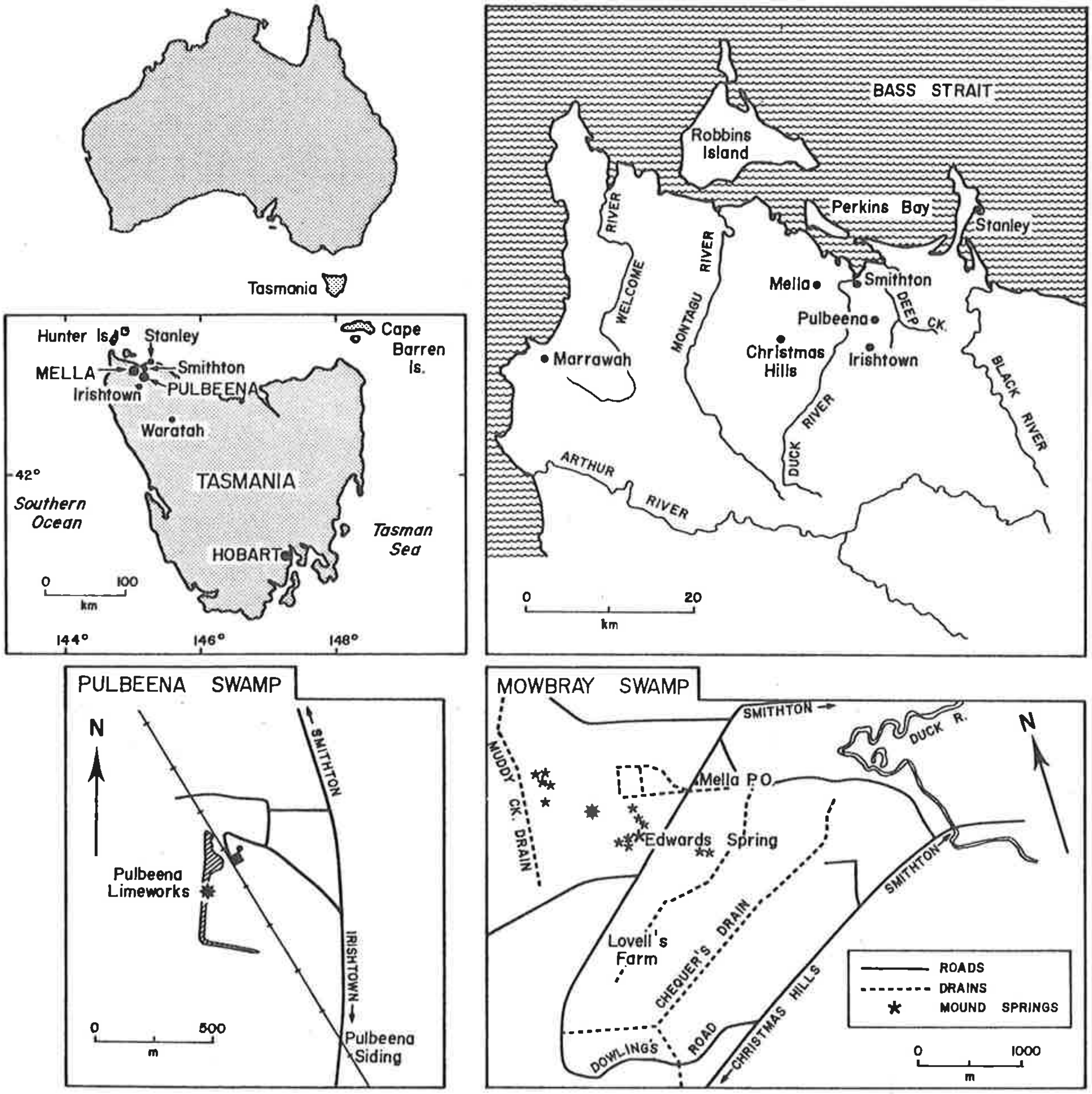


FIG. 6.1 Map showing location of Pulbeena and Mowbray Swamps. Large asterisks indicate the position of the 2 profiles studied.

the Pulbeena Swamp deposit, a detailed palynological diagram accompanied by ^{14}C dates.

A lithological description of the 4.80 m thick section (Fig. 6.2) studied here is also given by Colhoun *et al.* (in press) who made available duplicate samples of those studied by them.

Prior to the work of Colhoun *et al.* (in press), little had been written on Pulbeena Swamp. However, Banks *et al.* (1976) described from the site a right incisor and a mandible of the extinct marsupial *Porchestes azael*. Twenty years earlier, Gill and Banks (1956) also paid some attention to the site in their review of the Cainozoic history of Mowbray Swamp and adjacent areas, and mentioned the record of three fossil ostracods which had been identified by Hornibrook (1953, 1955). These were *Candona lutea*, *Ilyodromus stanleyanus* and *Limnocythere mowbrayensis*.

6.2.2 Mowbray Swamp

The Mowbray Swamp deposit, located south and south west of Smithton at an altitude of 15 m (Fig. 6.1) covers a much larger area than Pulbeena Swamp. It is approximately 10 km wide and extends 20 km inland (Gill and Banks, 1956). The swamp deposits overlie interglacial marine sands which rest on Precambrian dolomite. The site studied here occurs at about 500 m west of Mella (Fig. 6.1), where spring mounds are common. These are larger and taller than at Pulbeena Swamp as they can reach up to 7 m in height and have low angle slope profiles between 5 and 10 degrees (Colhoun *et al.*, 1979). Few springs have flowing water since the swamp has been artificially drained. Prior to that time, water originating from the mounds, and which is highly mineralized* and has a

---

* When compared to fresh water, TDS is, however, less than 3°/oo.

constant temperature of 19°C (van de Geer, pers. comm.), caused swampy conditions in the area (Colhoun, 1979). The swamp and sides of the mounds consist generally of alternating layers of marl, peat and peaty marl. For further data on the site refer to van de Geer *et al.* (in prep.).

Gill and Banks (1956) reviewed the work done at Mowbray Swamp deposits where remains of extinct marsupials such as two species of *Nototherium* and one of *Palorchestes* have been found. They also reported a few ostracods, including one species, *Limnocythere mowbrayensis*, originally described from the site by Chapman (1914).

A ^{14}C dated 2 m thick section, dug in an inter-mound depression (for location see Fig. 6.1), was studied for pollen by van de Geer *et al.* (in prep.). Duplicate samples of those used by them are analyzed here for ostracods. A lithological log is given in Fig. 6.4 but more detailed stratigraphical and lithological descriptions of the section are available in van de Geer *et al.* (in prep.).

6.3 METHODS

Treatment of the samples for the recovery of ostracods follows the same procedures used for the Victorian samples from the maar lakes (Chapter 5) except that the immersion time in diluted H_2O_2 was much longer (up to 6 weeks) to allow disaggregation of the often indurated marls to occur. For the Pulbeena Swamp study, 10 g samples were used and when less material was available, especially for the Mowbray Swamp study from which most samples weighed 5 g, data on ostracod abundance have been proportionately adjusted to permit adequate comparison between all samples from both deposits.

6.4 RESULTS

6.4.1 Systematics and ecological information

All the ostracods listed below have been found in the deposit at Pulbeena Swamp, whereas some of the species have not been recovered from the Mowbray Swamp deposit. The most distinctive ostracod, although uncommon, is the rectangular-shaped *Limnocythere mowbrayensis* (Chapman, 1914) with a characteristic prominent lateral process which is most often pointed and curved backwards (Plate VI.3: Figs. 1-12). *Limnocythere* sp. has a slightly larger shell with no alar process but also with two dorsal humps (Plate VI.3: Figs. 13-16). *Leptocythere lacustris* n.sp. on the other hand has a much more reticulated shell with one distinct anterior groove running almost parallel to the anterior margin of the shell (Plate VI.4: Figs. 1-8). *Darwinula* sp. is cigar-shaped with the anterior of the shell more pointed than the broadly rounded posterior (Plate VI.4: Figs. 9-17). *Gomphodella maia* n.gen., n.sp. has a pseudopunctate shell and a flat ventrum. In dorsal view, females have an upside down heart-shaped carapace whereas males are pointed at both extremities and have a flattened shape (Plage VI.1: Figs. 1-18). *Gomphodella australica* (Hussainy, 1969) is much larger than the former species and has a faint but broad reticulation over most of the shell (Plate VI.1: Figs. 19-21). *Sarscypridopsis proxila* n.sp. has an obvious pseudopunctate shell which is subtriangular in shape and with the greatest height of the shell at about ⅓ from the anterior (Plate VI.6: Figs. 1-9). *Cypretta viridis* (Thompson, 1878) is globular in shape and is characterized by internal radial septae visible at the anterior of the shell (Plate VI.6: Figs. 10-16). *Candona tecta* n.sp. is characterized by the greatest height of the shell at about ⅔ from its anterior inner lamellae and by the adductor scars arranged in a circle with all scars of about the same size (Plate VI.7: Figs. 13-15). The ellipsoid shaped *Candonopsis tenuis* (Brady, 1886) on the other hand has a large scar at the top of the circularly arranged adductor scars which are situated at ⅓ from the anterior and ⅓ from the dorsal area of the shell (Plate VI.7: Figs.7-12, 16-17). The greatest height of the shell of this species is at ⅔ from the anterior. *Ilyodromus multifarius* n.sp. has a more arched dorsum and broader inner lamellae, especially anteriorly (Plate VI.7: Figs. 1-6). *Ilyodromus smaragdinus* Sars, 1894 is more ellipsoid in shape than the latter species and has broad inner lamellae of almost equal width anteriorly and posteriorly (Plate VI.5: Figs. 1-10). Faint longitudinal striations are visible externally, sometimes on adult shells but, most often on juveniles (Plate VI.5, Fig. 10). *Candonocypris novaezelandiae* (Baird, 1843) is more elongated than the previous species and is characterized by a broad selvage placed far away from the anterior edge of the shell in the right valve only; in the left valve anteriorly, it is faintly visible at the periphery of the shell (Plate VI.5: Figs. 17-22). *Candonocypris incosta* n.sp. differs from the latter species by the absence of an anterior broad selvage and by a more arched dorsum (Plate VI.5: Figs. 11-16). The selvage is broad and near the edge of the shell posteroventrally in the right valve in both *Candonocypris* species. *Mesocypris* sp. possesses the thickest shell which is oval shaped and flat ventrally. The greatest height of the shell is at about ⅖ from the pointed anterior (Plate VI.2). The diagnostic feature of this ostracod is the depressed area between the selvage and the edge of the shell posteroventrally in both valves.

Only the fossil ostracod taxa which are not discussed in detail in Chapter 4 will be described below.

Candona tecta n.sp.

Plate VI.7: Figs. 13-15

Description: Smooth oval shell with the ventrum nearly flat and slightly concave in the middle; greatest height at about $^2/_3$ from anterior. Length height ratio about 2. Shell narrow in dorsal view. Anterior broadly rounded and posterior more tapered. Posterodorsal area more steeply inclined than the anterodorsal one. Internally, inner lamellae similar in both valves and almost three times broader anteriorly than posteroventrally. Central muscle field consisting of six scars of almost equal size and closely arranged.

Size range: Holotype: L: 615 μ; H: 280 μ.
Paratypes: L: 530-520 μ.

Type locality: Pulbeena Swamp deposit, level PS 180 - pollen zone 3 of Colhoun *et al.* (in press).

Derivation of name: From Latin *tectus* meaning hidden as this species is uncommon at both sites studied here.

Ecology: No data are available as no living representatives are known.

Remarks: This species is different from the misidentified *Candona lutea* King, 1855 illustrated by Chapman (1914) from Mowbray Swamp. After examination of Chapman's material kept at the National Museum of Victoria, it is possible to say that Chapman's (1914) Fig. 6 represents *Candonocypris incosta* n.sp. and Fig. 7, labelled as *C. lutea* juvenile, is *Darwinula* sp. Valves of *Ilyodromus smaragdinus* are also present in Chapman's collection from the same site, but they are too small to fit Chapman's (1914) description and illustration of *C. lutea*.

Candonopsis tenuis (Brady, 1886)

Plate VI.7: Figs.7-12,16-17

1886 *Candona tenuis* n.sp., Brady, p. 92.

1896 *Candonopsis tenuis* (Brady), Sars, p. 62.

Description: Smooth, flattened ellipsoid shell with anterior end more tapered. Greatest height at about $2/3$ from the anterior. Dorsum more arched in male which is also larger. Concave part of the ventrum at about $2/5$ from the anterior. Shell narrow in dorsal view. Internally, inner lamellae similar in both valves: broadest anteriorly and about twice as wide posteroventrally. Selvage faint and peripheral. Central muscle field placed at about $1/3$ in height from the dorsum and above the convex area of the ventrum. Adductor scars consisting of six scars: the much larger one is above a row of three in front and two behind.

Size range: L: 700-1,200 μ.

Ecology: This species is only known to be a freshwater form.

Remarks: This is a true *Candonopsis* species as it possesses the typical broad scar at the top of the adductor scars as illustrated by Krstic (1976) for *C. kingslei pliocenia* Krstic, 1976, in her comparison of Candoninae adductor scars. The species illustrated and described here is identical to the one illustrated by Sars (1896). The original illustration of *Candona lutea* King, 1855, strongly resembles the fossil material studied here but King's (1855) description is insufficient to engage in further discussion since there seems to be no type material for the species.

Cypretta viridis (Thomson, 1878)

Plate VI.6: Figs. 10-16

1878 *Cypris viridis* n.sp., Thomson, p. 253.

1894 *Cypridopsis viridis* (Thomson), Sars, p. 32.

1912 *Cypretta viridis* (Thomson), Müller, p. 206.

1955 *Cypridopsis viridis* (Thomson), Hornibrook, p. 273.

Description:

- Adult: Pseudopunctate shell, globular in shape with flatter ventrum which is concave in the mouth region. Pseudopunctation more obvious anteriorly and posteriorly. Greatest height and greatest width at about middle. In dorsal view, anterior of shell narrower. Length height ratio of both valves: ∿1.45. Right valve larger anteriorly and strong overlap of both valves in the mouth region with the right valve placed on the outside. Posteriorly both valves are almost equal. Internally, right valve with broad selvage all along and with a deep narrow groove adjacent to it on the inner edge of the shell. The selvage is tuberculate posteroventrally and curved inward in the middle of the ventrum. In the left valve, selvage faint and near the edge of the shell anteriorly and slightly away from the edge posteriorly. Inner lamellae at least twice as broad anteriorly where radial septae are also visible through the shell.

- Juvenile: Globular in shape and greatest height at about ⅔ from the anterior.

Size range: Adults: L: 920-960 μ.

Ecology: *C. viridis*, as other *Cypretta* species, is a good swimmer which is found in a variety of fresh water bodies and even in slowly flowing rivers. It is not common in temporary pools and is usually found swimming near the water's edge especially in among aquatic vegetation.

Remarks: This species is distinguishable from *C. minna* (King, 1855), *C. turgida* (Sars, 1896) and *C. globula* (Sars, 1889) on the following features: *C. minna* has a smaller length height ratio of the valves ($\sim$1.1-1.2); *C. turgida* is rounder in dorsal view and *C. globula* has small tubercles (*sic* Sars, 1896) on the posteroventral edge of the valve. The latter three species have a length height ratio of both valves similar to that of *C. viridis*. Further anatomical work is necessary in order to check whether *C. turgida* is a juvenile of *C. viridis* or not.

Darwinula sp.

Plate VI.4: Figs. 9-17

1914 *Candona lutea* King, Chapman, p. 59, Plage 2, Fig. 7 only.

Description: Flattened oval shell, smooth externally, with anterior pointed and posterior broadly rounded. Greatest height and greatest width of the shell at about 4/5 from the anterior and length height ratio averaging 2. Left valve larger all along its periphery. Central muscle field consisting of a rosette of radially arranged scars: three to four each in front and behind and one small triangular scar positioned between the two lowest ones. Shell faintly reticulated internally, especially in the posterior area.

Size range: L: 620-800 μ.

Ecology: Little direct information is available for this species as it has not been identified, with certainty, among the living species (see remarks below). Most *Darwinula* species, however, are found only in fresh water, and because their eggs cannot withstand desiccation, they are found in permanent waters. However, it is not known whether the sometimes semi-terrestrial *D. sphagna*, which can live in damp moss of a sphagnum swamp, requires permanent water to reproduce - this might not be necessary as brooding occurs in this species (Barclay, 1968).

Remarks: No *Darwinula* species have been described so far from Australia although the presence of this genus has only been reported by Chapman (1967). From New Zealand, however, two *Darwinula* species have been described: *D. repoa* Chapman, 1963 from swamps and particularly from peaty areas, and *D. sphagna* Barclay, 1968 from damp moss of a sphagnum swamp and the interstitial waters of the Rotorua lakes (Chapman and Lewis, 1976). Although type specimens of these species have not been examined yet, it appears that *D. repoa* resembles the fossil specimens studied here. On the other hand, Hornibrook (1955) pointed out that the fossil *Darwinula* sp. (= *D. repoa* by Chapman, 1963) found by him in the Pyramid Valley Swamp deposits occurs only in the blue green mud immediately overlying the lower peat layer. The environment where such type of sediment would occur is very different from the one described for living specimens of *D. repoa* by Chapman (1963). This is further complicated by Deevey's (1955) work which stated that, after comparison of fossil *Darwinula* from Mowbray Swamp and Pyramid Valley Swamp, the specimens appeared identical. No specific determination will be provided until living specimens of *D. repoa* are compared side by side with the fossil *Darwinula* sp. as so few diagnostic features of the shell useful in taxonomy are known for darwinulids. The pattern of the adductor scars, for the specimens studied here (see Plate IV.4: Fig. 17), so different from the elongated ones found in *D. stevensoni* (Brady and Robertson, 1870), such as illustrated by Sohn (1976), might help in specific identification. Note that *Darwinula* sp. illustrated by Hornibrook (1955) from the Pyramid Valley deposit bears nine adductor scars.

Ilyodromus multifarius n.sp.
Plate VI.7: Figs. 1-6

Description: Smooth shell, oval in shape, and with a flat ventrum. Greatest height at about middle. Dorsal area more steeply inclined than the anterior area but both ends are rounded. Length height ratio greater in female. Inner lamellae very broad anteriorly and characterized by the inner margin forming a straight line in the part to the hinge area, at least in females. Ventrally and posteroventrally, the width of the inner lamellae can vary but it is narrower than anteriorly. Selvage faint and peripheral in both valves. Central muscle field with a vertical row of three scars and one behind plus two large mandibular ones below and partly in front.

Size range: Holotype: L: 800 μ; H: 400 μ.
Paratypes: L: 600-815 μ.

Type locality: Pulbeena Swamp deposit, level PS 455 - pollen zone 10 of Colhoun *et al*. (in press).

Derivation of name: From Latin meaning multifarious for the various shapes of the shell.

Remarks: As this species has only been recorded from the Pulbeena Swamp deposit no ecological information is available. It is very likely to be a freshwater species.

Ilyodromus smaragdinus Sars, 1894
Plate VI.5: Figs. 1-10

1894 *Ilyodromus smaragdinus* n.sp. Sars, p. 43.

Description:

- Adult: Flattened ellipsoid shell which is smooth externally. Dorsum arched. Left valve slightly larger than the right valve. Overlap of left valve dorsally at both extremities of the hinge area. In dorsal view, it is compressed and both ends are pointed. Inner lamellae very broad in both valves but they are broadest anteriorly. Ventrally they are half of anterior width. Selvage faint and close to the edge in both valves.

- Juvenile: Similar shape to adults but more flattened and with a faint notch in front of the hinge area anteriorly. Most valves possess fine longitudinal striations externally.

Size range: Adults: L: 1,000-1,250 μ.

Ecology: This is a freshwater species not yet found living in Australia. It was originally described by Sars (1894) who raised the species from a sample of dried mud from lagoons near Dunedin in New Zealand. The species has not been collected since.

Remarks: This species is a typically *Ilyodromus* species as it possesses the basic vertical row of three (sometimes two) large adductor muscle scars with one behind and two broad mandibular ones in front and below. The specific identification relies on Sars (1894) illustrations and description of *I. smaragdinus* which indicate that the inner lamellae are broad at both ends of the valves. This is different for *I. viridulus* (Brady, 1886) which possesses broad inner lamellae only at the anterior. Unlike most *Ilyodromus* species described by Sars (1894), the shell of *I. smaragdinus* is smooth in adults; juvenile specimens, however, are faintly striated longitudinally, a common feature for the genus.

Juveniles of this species differ from those belonging to *Candonocypris* by their greater length height ratio of the shell. Note that the overall shape of the shell can be quite variable (compare Figs. 1-4 and 7 on Plate VI.5).

Limnocythere sp.

Plate VI.3: Figs. 13-16

Description: Rectangular shell, elongated in male and compressed in female with the dorsum slightly arched and the ventrum concave. Ornamentation of shell faint with normal pores more obvious posteriorly and two narrow dorsal bosses, when viewed from above. Presence of a deep indentation above and in front of the anterior boss and of a horizontal groove just below and parallel to the hinge posteriorly. Inner lamellae broader anteriorly.

Size range: L: ♂ 540 μ; ♀ 480-520 μ.

Remarks: Only a few specimens of this species, which is likely to be new, have been found at level PS 250 in the Pulbeena Swamp deposit. Because of the paucity of material, no further description is provided.

Mesocypris sp.

Plate VI.2

Description: Smooth oviform shell, arched dorsally and with a flat ventrum which is slightly concave in the mouth region. Anterior of the shell more pointed than the posterior which is broadly rounded. Greatest height at about the middle. Left valve overlaps the other all along its periphery with the largest overlap at both extremities of the hinge. Internally, inner lamellae broader anteriorly in both valves; selvage broad anteriorly and posteriorly in the left valve but faint and more distant from the edge of the shell in the right valve. Presence of a deep groove between the edge of the shell and the selvage in the left valve, especially posteroventrally.

Size range: Adults: L: 650-850 μ.

Ecology: Little is known about *Mesocypris* sp. as no living representatives have been identified with certainty. This species, however, is included in the Scottinae (*sensu* De Deckker, 1979, 1980b) which groups all *Mesocypris* and *Scottia* species. These are found either in fresh waters and swampy areas (e.g. *S. pseudobrowniana* Kempf, 1967) or which are terrestrial and require little moisture (for a review see De Deckker, in press b).

Remarks: The overall shape and size of adult specimens of *Mesocypris* sp. vary extensively - for variations, see Plate VI.2. The specimens identified here as *Mesocypris* sp. probably belong to *M. insularis* (Chapman, 1963) comb. De Deckker, 1980b. Unfortunately, no material of this species is available at present for comparison. This species is found today in New Zealand in peaty swamps and the bed of a Wellington stream (Chapman *in* Chapman and Lewis, 1976). These environments are similar to those postulated for Pulbeena and Mowbray Swamps (peaty swamps and slow flowing springs) where *Mesocypris* sp. is very common. In addition, Eagar (1969) described a Pleistocene mummified specimen of that species from the Wairarapa Valley in New Zealand. This is of interest as quite a few specimens of *Mesocypris* sp. were found, at both fossil sites studied here, with many sensory hairs still attached to the shell and protruding from the normal pores, especially in the ventral area (Plate VI.2: Fig. 19).

Sarscypridopsis proxila n.sp.

Plate VI.6: Figs. 1-9

Description: Subtriangular shell, pseudopunctate all over except in the dorsal area; greatest height at about 2/5 from the anterior and anterior part of the dorsum more steeply inclined. Posterodorsally, the shell is almost straight. In dorsal view, the shell is narrow with both ends pointed. Right valve larger anteriorly and posteriorly with a small overlap in front of the hinge area dorsally and larger overlap ventrally at mid length. Selvage narrow and at about ⅓ of total inner lamellae width in the right valve antero- and posteroventrally and curved inward ventrally where both valves overlap. Selvage faint and peripheral in the left valve.

Size range: Holotype: L: 690 μ; H: 390 μ.
Paratype adults: L: 640-700 μ.

Type locality: Pulbeena Swamp deposit, level PS 390 pollen zone 8 of Colhoun *et al*. (in press).

Derivation of name: From Latin: *proxilus* meaning elongated. This refers to the shape of the shell compared to *S. aculeata* (Costa, 1847).

Ecology: As this is a new species, not recorded before, no accurate ecological information is yet available. It is likely, however, to be a good swimmer like the other *Sarscypridopsis* species and therefore indicative of open water conditions.

Remarks: On shell morphology alone, this species appears to be closely related to *S. aculeata* (Costa, 1847) new comb. (see Chapter 4). The latter species is found in temporary pools and can withstand slightly saline waters up to 20°/oo (De Deckker, in press a). *S. proxila*, however, differs by its more elongate shell (length height ratio: 1.7 for *S. proxila* and 1.5 for *S. aculeata*). Additionally, the selvage in *S. aculeata* is placed much further away from the edge of the shell at both ends of the left valve and is broader in both valves; the inner lamellae are broader in both valves posteriorly in *S. proxila*. The outline of *S. proxila* resembles that of the South African species *S. striolata* (Sars, 1924) illustrated by McKenzie (1977) - the latter species, however, differs from *S. proxila* by the diagnostic longitudinal striations on its shell.

6.4.2 Ostracods from Pulbeena Swamp

All the ostracods larger than 200 μ and picked from the 97 samples collected at Pulbeena Swamp (labelled PS here and followed by the appropriate depth in cm from the top of the section) were counted and their numbers are represented in Fig. 6.2. When samples yielded less than 10 g of sediment, the numbers of ostracods were proportionately adjusted. In nearly all samples which yielded more than 50 valves, adults and juveniles of each species were found together and both left and right valves were present in about equal numbers. This indicates that no selective sorting of ostracods has occurred at the site studied. In addition, as most fragile shells belonging to species like *Ilyodromus multifarius*, *Candona tecta*, *Candonopsis tenuis* and *Darwinula* sp., were found intact in the samples, it seems likely that little or no reworking of the sediments and ostracods occurred. All the species at Pulbeena are usually poorly represented except for *Gomphodella maia* and *Mesocypris* sp. which are the commonest species in nearly all samples and which are often found in similar proportions. The abundance of these two species appears to be significant. When conditions were favourable, such as the presence of permanent water, their numbers were much higher and this is further confirmed in such samples which yield a more diversified ostracod fauna. These phenomena surely must result from the fact that more niches become available in the water body. This could occur because of an increase in aquatic plants resulting from a deepening of the permanent water body and, perhaps, warmer conditions. Correspondingly, when species numbers were low, conditions were less favourable, such as the occurrence of little permanent water and little or no aquatic vegetation. All this is substantiated by a comparison between the pollen diagram and the ostracod diagram. No inference concerning temperatures can be made as it is not known whether dry conditions are to be associated with either cold or warm temperatures. Thus the interpretation of the presence of the ostracod species in the samples is attempted below on the basis that the ecological information obtained on living species today equally refers to fossil material.

As the distribution of many of the ostracod species corresponds almost exactly to the distribution of some of the aquatic plants for the section studied at Pulbeena Swamp (see Fig. 6.3), the biostratigraphic zonation based on pollen abundance and the distribution of Colhoun *et al.* (in press) is kept here for the ostracods. This should also facilitate comparison between the present work and that of Colhoun *et al.* (in press). Ten zones have been recognized by these authors and they are examined in a descending order starting with the youngest samples. All the pollen data mentioned here are taken from Colhoun *et al.* (in press).

Zone 1 (20-65 cm) (The upper 20 cm are not considered here as they have been disturbed by human activity.)

Marl was being precipitated during this period and conditions for ostracods were unfavourable at most times except for the bottom 15 cm. There, at sample PS 50 and PS 60 especially, the presence of *Mesocypris* sp. and *G. maia* in substantial numbers for this zone (and in lower numbers at level PS 65) indicates that water was permanent* and plentiful for that particular time. This is further

---

* The presence of *G. maia* is considered here to indicate permanent water conditions bearing in mind that this is a generalization as there is probable evidence of (?short) periods of desiccation as indicated by the presence of carapaces of this ostracod in a number of samples (see remarks in taxonomy section). However, as all *Gomphodella* species, and most likely *Darwinula* sp., require permanent water to reproduce, it seems justifiable to say that water must have been permanent somewhere at Pulbeena for the species to survive (?short) periods of desiccation.

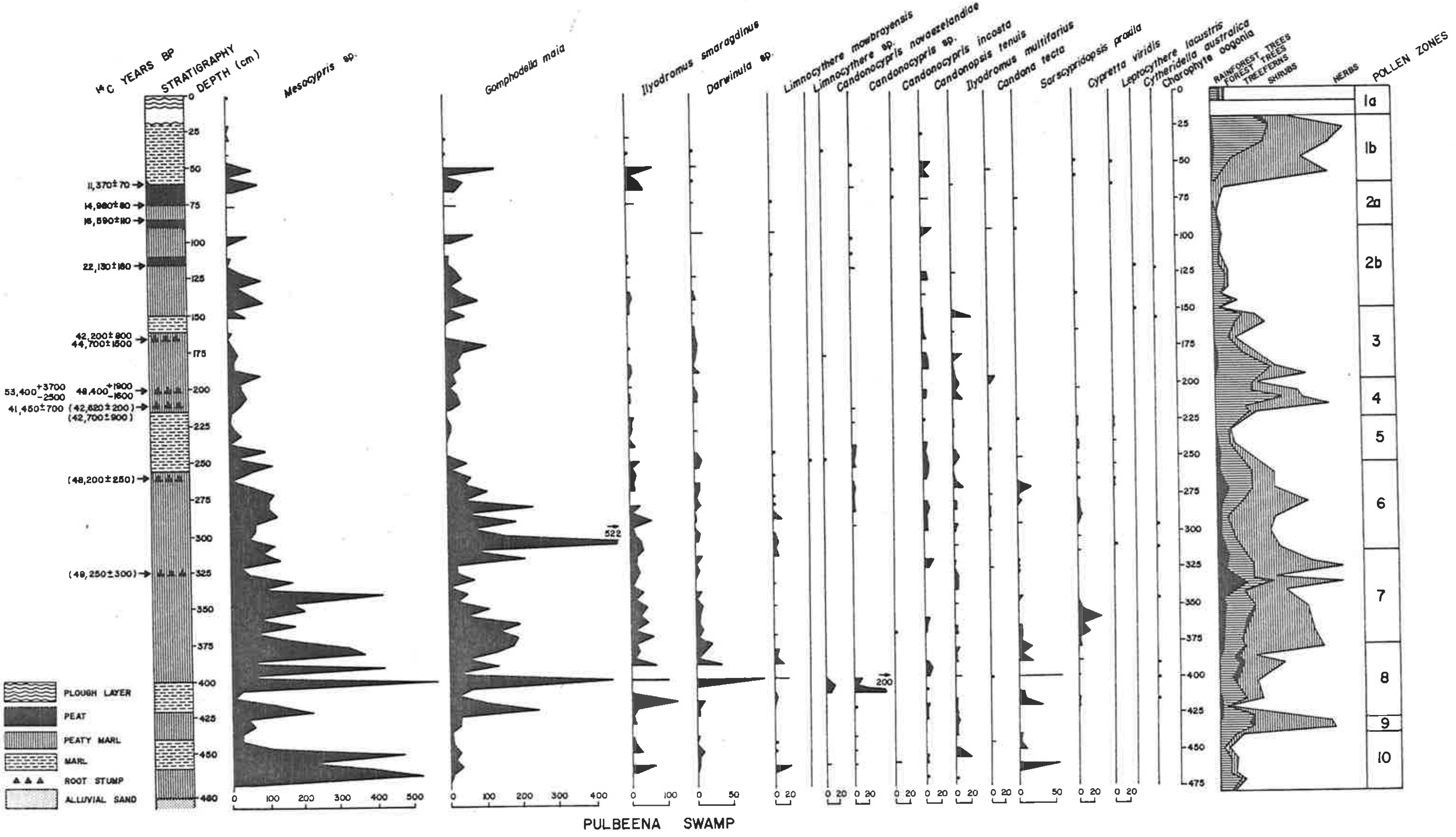


FIG. 6.2 ^{14}C dates, stratigraphy and distribution of fossil ostracods and total pollen plus pollen zonation of the Pulbeena Swamp profile. Numbers of ostracods represent the quantity of valves per 10 g of sediment; dots indicate the presence of 1 valve only. Data on ^{14}C dates, stratigraphy and pollen zonation from Colhoun *et al*. (in press).

substantiated by the presence of *C. viridis* at levels PS 50 and PS 60. For the other levels, on the other hand, water was probably ephemeral as shown by the absence or paucity of *G. maia* and the occasional presence of rare specimens belonging to species other than *Mesocypris* sp. The occurrence of three *L. lacustris* at level PS 50 probably indicates waters rich in mineral content.

Zone 2 (65-150 cm)

Ostracods are rare or absent and therefore there was little water at most times between PS 65 and PS 115 except for two levels PS 75 and PS 95, where water was permanent but not as plentiful as for levels PS 50 and 60 as *C. viridis* is absent and Cyperaceae are poorly represented. Level PS 95, however, could have been deposited under more open water for a short period of time, as *S. proxila* is recorded there with a few pollen of *Potamogeton-Triglochin.** Between PS 115 and PS 150, ostracods are more numerous than at levels PS 50 and PS 60. Water was permanent but rarely deep. The high numbers of *Mesocypris* sp. and *G. maia* coincide with moderate percentages of Cyperaceae and very low values of *Potamogeton-Triglochin.* The significance of high percentages of Portulaceae pollen (cf. *Claytonia australasica, sic* Colhoun *et al.* in press), which is terrestrial to aquatic in habit, is not understood with regard to the ostracod abundance.

Zone 3 (150-200 cm) + 4 (200-225 cm)

These two biostratigraphic zones based on pollen are considered together here as they differ very little in their yield of

---

* *Potamogeton* and *Triglochin* are referred to together for the Pulbeena Swamp section as Colhoun *et al.* (in press) did not differentiate between them.

ostracod faunas and numbers.

The top of this zone is characterized by a layer of marl which is depauperate in ostracods. Apart from the two valves of *G. maia* found in sample PS 155, there is no indication that water was permanent and probably there was very little of it. Below level PS 160, water was permanent at most times except perhaps at level PS 215 cm where *Darwinula* sp. was absent and *G. maia* poorly represented. The high percentages of Cyperaceae and *Potamogeton-Triglochin* pollen between levels PS 160 and PS 185 do not coincide with high numbers of ostracods compared to other zones below zone 5. Only once, at level PS 165, where *C. viridis* is found and consequently open water is postulated for that level, are the percentages for the aquatic pollen highest for zones 3 and 4. At the same level, Colhoun *et al.* (in press) recognized charred root stumps in positions of growth meaning that fire had burnt across part of the swamp (Colhoun *et al.*, in press).

Zone 5 (225-255 cm)

This particular zone is characterized by a fair percentage of Cyperaceae and low numbers of *Potamogeton-Triglochin* and ostracods reflected mainly by the small values of *Mesocypris* sp. and *G. maia*. The difference in the pollen diagram between this zone and the others is shown by the high percentage of Cyperaceae coinciding with even higher values of Graminae. This phenomenon, particular to zone 5, was probably caused by dry conditions even though water was probably still permanent at all times (except for level PS 240) and fluctuated a lot as it probably was high for levels PS 225-230, PS 240-245 and PS 255. The presence of *L. lacustris* could indicate high mineral content in the water at levels PS 225-230, PS 240 and

PS 255. Note that marl was being deposited during the entire period representing zone 5 and that ostracod numbers were low. This phenomenon is identical for the other marl layers above (levels PS 150-160 and PS 20-60) although water depth is considered to have been lower for the latter two layers.

All the zones discussed below are characterized by much richer ostracod faunas at most levels. Richer samples can be explained by more favourable conditions at Pulbeena which prevailed for all these zones (more water, more vegetation etc.) rather than by slower sedimentation rates as demonstrated by the ^{14}C data - for further details see Colhoun *et al.* (in press).

Zone 6 (255-315 cm)

This zone, based on ostracod data only, probably should be extended further below, down to level PS 320 where a drop in numbers of *Mesocyris* sp. and *G. maia* is more noticeable. Numbers for these two species fluctuate greatly during the entire period covered by this zone but they remain generally high. Diversity is also high. The presence of *C. viridis* and *S. proxila* is significant at quite a few levels as both species indicate open water conditions. This is confirmed by the abundance of Cyperaceae (up to 26% of the total pollen in Colhoun *et al* , in press) and *Potamogeton-Triglochin*. One of the highest percentages for these aquatic plants corresponds to the small peak of *C. viridis* at level PS 290. Note that charophyte oogonia have also been recovered at two levels in this zone.

Zone 7 (315-380 cm)

The low numbers of *G. maia* and slightly higher values for *Mesocypris* sp. between levels PS 320-335 are met by low percentages of Cyperaceae and increasing percentages of *Potamogeton-Triglochin*. Conditions must have been less favourable, e.g. less water, and this is further substantiated by the high numbers of Graminae indicating drier conditions, with a peak at level PS 330. The highest values recorded for *C. viridis* between levels PS 355-370 correspond to an abundance of aquatic plants (Cyperaceae and *Potamogeton-Triglochin* at least) - the highest percentages recorded for these aquatic plants at level PS 365 coincide with the highest peak for this ostracod indicative of open water. The area at Pulbeena could have been a shallow lake during that period (PS 355-370).

At other times, conditions were of permanent water accompanied often by high water levels to allow aquatic plants to grow and accommodate a diversified ostracod fauna.

Zone 8 (380-430 cm)

Numbers of *Mesocypris* sp. and *G. maia* fluctuate extensively during this period. The rest of the ostracod fauna is diversified for most samples. The environment postulated therefore is similar to that which prevailed during zone 7 except that the water level must have been lower for zone 8. Here Cyperaceae values are very high and *Potamogeton-Triglochin* are only present in large numbers in the top 25 cm of the zone. At level PS 400 especially, ostracod diversity and numbers are extremely high - conditions must have been at their optimum. Between levels PS 400 and PS 420, marl was being formed and at least during part of that time (levels PS 405-410), the presence of *C. novaezelandiae* (and probably some of the *Candonocypris* sp., which cannot be identified further, particularly at level PS 410) indicate that decaying vegetation was present at the bottom of the "lake" floor. Water could have been eutrophic during that time and this would explain the rarity of other ostracods.

At level PS 420 ostracod numbers are high and the fauna is much diversified although, to a lesser extent than at level PS 400. This coincides with the highest peak of Cyperaceae and very few *Potamogeton-Triglochin*. *C. viridis* and *S. proxila* point to a high water level.

Zone 9 (430-440 cm)

Ostracod numbers are low and poorly diversified and this corresponds to a low percentage of Cyperaceae. The other aquatics are almost non-existent. Apart from the presence of *Leptospermum* pollen in large numbers in this zone, there seems to be little difference based on the ostracod data alone between this zone and other levels such as PS 385, PS 395 in zone 8.

Zone 10 (440-480 cm)

The bottom 10 cm of this zone, which is characterized by a high amount of terrigenous sediment, is devoid of ostracods. Water must have been permanent at most times for levels PS 440-470, even though *G. maia* is poorly represented, since *Darwinula* sp. is found in nearly all samples. *C. novaezelandiae* hints at eutrophic conditions for level PS 460, a period when ostracod diversity was very high and open water conditions prevailed. This is seen by the large number of *S. proxila* which are accompanied by substantial numbers of Cyperaceae. *C. viridis* is absent at that particular level and this coincides with the absence of *Potamogeton-Triglochin*.

All these results are summarized below:

Dates mentioned here are taken from the work of Colhoun *et al.* (in press).

The most interesting result coming from this study is that the curve for total numbers of ostracods can easily be paralleled to the Cyperaceae curve combined with that of *Potamogeton-Triglochin* (see Fig. 6.3). When the latter are absent or in low numbers, ostracods are few as in zone 5. There Graminae are abundant. The ostracod data therefore, like the aquatic pollen combined, appear to be good indicators of water regimes. Similarly, absence of ostracods here seem to indicate either a low water level or little water as this is further confirmed by low percentages, or none at all, of the aquatic pollen.

Zone 1 which covers most of the last 11,000 years saw little or no water except for the earliest part of the Holocene (level PS 50-60) when water was permanent and the water level high for short periods of time.

Zone 2 covers the 35,000-11,000 yBP period which was probably the driest one experienced at Pulbeena for the last 80,000 years (apart from the Holocene) as indicated by the absence or very low ostracod numbers in the samples, especially for most of the 18,000-12,000 yBP period. This is supported by the high percentages of Graminae. In the lower part of this zone, however, between 35,000 and 22,000 yBP (level PS 150-115) water was present as ostracods are commonly found in the samples - but water level was never high. Similarly for short periods of time (level PS 95 and PS 75) at ∿19,000 yBP and ∿15,000 yBP, some water was flowing from the springs but the entire area at Pulbeena was not covered by water.

During zone 3 and 4 which cover approximately the 50,000 to 35,000 yBP period, ostracod numbers and diversity were generally poor - water

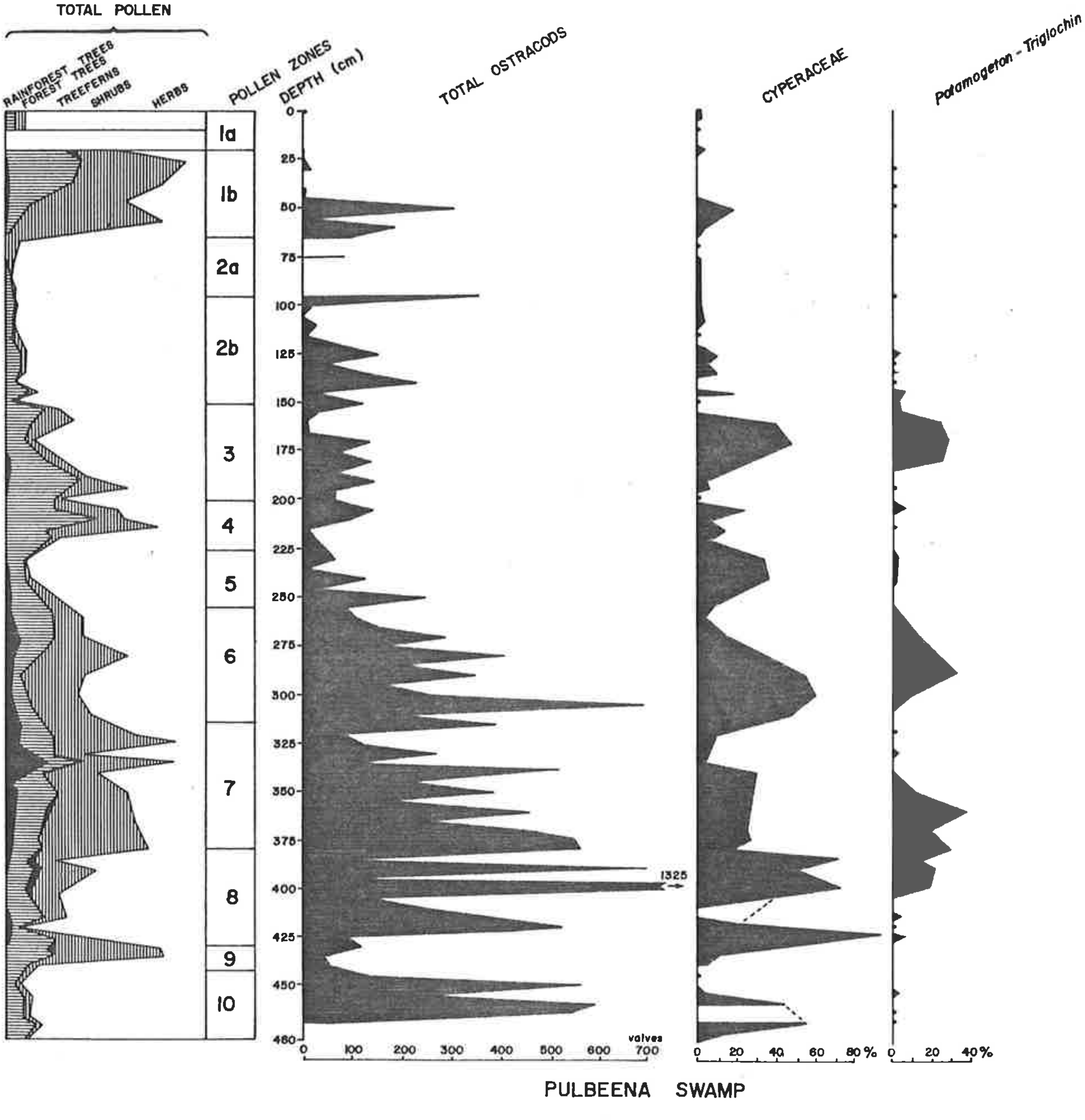


FIG. 6.3 Distribution of all ostracod valves in 10 g samples matched against the total pollen, Cyperaceae, *Potamogeton-Triglochin* curves obtained from Colhoun *et al.* (in press) for the Pulbeena Swamp profile.

level was probably low but water was still permanent at most times. Only once, during deposition of level PS 165, did water cover the entire area at Pulbeena. At approximately the same time (∿43,000 yBP) fire burnt across the area (Colhoun *et al.*, in press). Additionally, there was very little water at the top 10 cm of this sequence, a period when marl was being formed.

Similarly, for the whole of zone 5, marl is thought to have formed under low spring activity as ostracod numbers are low, but still indicate permanent water, and percentages of Graminae are high. No dates are postulated for this zone and the others below. This is explained in Colhoun *et al.* (in press).

Zone 6 to 8 represent a sequence being deposited under much higher water levels at most times with intermittent and extensive water level fluctuations. This is demonstrated by great variations in ostracod numbers and by a much diversified fauna. Numbers of aquatic pollen were also very high during most times. Flooding of the entire Pulbeena area, which probably became a shallow lake, as seen between deposition of levels PS 355-370 at least, did not re-occur since then except perhaps for a short time at level PS 165. Conditions for ostracods were at their optimum at level PS 400 and to a lesser extent at level PS 420 and eutrophic waters are postulated for levels PS 405-410.

Little spring activity is postulated for samples PS 385 and PS 395 and the short lived zone 9.

Zone 10 which was deposited above the alluvial sands records extensive water level fluctuations although water remained permanent at most times. Low water levels which relate to low spring activity correspond to peaks of Graminae. At level PS 460 eutrophic conditions are postulated as for levels PS 405-410.

6.4.3 Ostracods from Mowbray Swamp

The ostracod fauna recovered at this site is less diverse than at Pulbeena Swamp. 40 samples out of the 82 examined did not yield any ostracods - these correspond mainly to peaty layers in which Mg-Fe sulfate crystals [Leonhardite ($MgSO_4$ $4H_2O$) and Melanterite ($FeSO_4$ $7H_2O$) (van de Geer, pers. comm.)] are common. In the marl layers on the other hand, ostracods are generally present and usually more so in the layers where the above mentioned sulfate crystals are absent.

It appears that the site chosen by van de Geer *et al.* (in prep.) in an inter-mound depression was not the deepest depression at Mowbray, since a few samples taken at the base of the swamp at the bottom side of one of the drains near Mella yielded richer ostracod faunas than at the section measured by van de Geer *et al.* (in prep.). This explains the absence of *L. mowbrayensis* in the samples from the section studied here (Fig. 6.4), although the species was originally collected from Mowbray Swamp. This ostracod is present, however, in the dark peaty marl rich in pyrite crystals which was collected in one of the depressed areas, at the bottom side of one of the man made drains. This layer was not investigated further as there is no pollen and ^{14}C dates available for it and it is likely to be facies equivalent to one of the bottom layers in the section studied below. Further, the absence of ostracods such as *C. viridis* and *S. proxila* in that section indicates that water level was probably never very high at the studied site.

The pollen zonation defined by van de Geer *et al.* (in prep.) will be retained here as the boundaries of the various zones in general correspond to lithological changes which, in turn, relate to changes in ostracod faunas. Samples from that section are preceded by MS and followed by the height in cm from the top of the section.

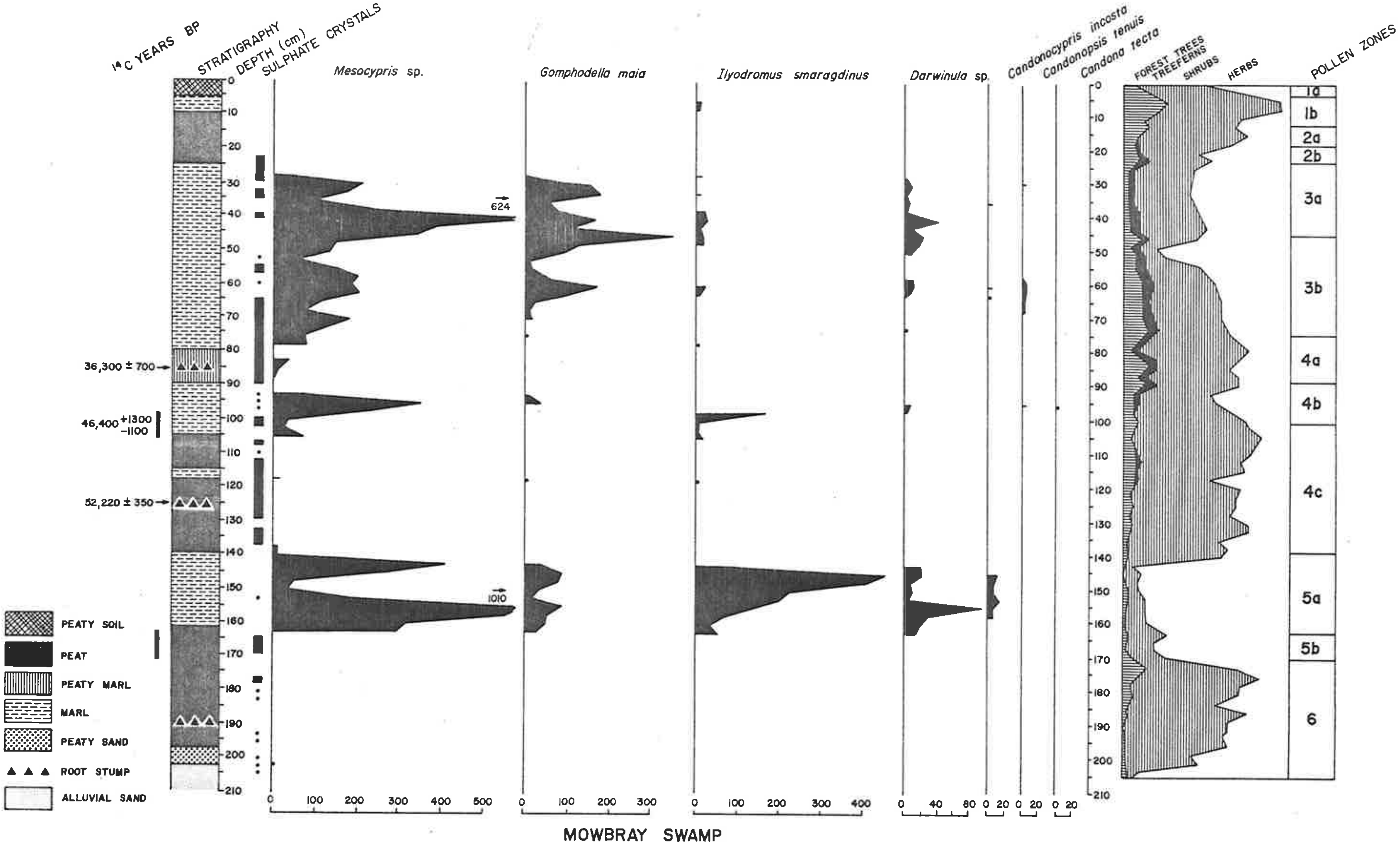


FIG. 6.4 ^{14}C dates, stratigraphy, distribution, Mg-Fe sulphate crystals and ostracods plus total pollen zonation of the Mowbray Swamp profile. Same remarks on ostracod numbers as for Fig. 6.2. Data on ^{14}C dates, stratigraphy and pollen zonation from van de Geer *et al.* (in prep.).

Zone 1 (0-11.2 cm) + Zone 2 (11.2-23.7 cm)

These two zones are combined here as ostracods are absent in nearly all samples except for a few valves of *I. smaragdinus* at level MS 8.5 and MS 10. Little water was probably flowing from the spring as shown further by the poor representation of Cyperaceae and the absence of *Potamogeton*.

Zone 2 (11.2-76.2 cm)

van de Geer *et al.* (in prep.) subdivided this zone into two parts mainly on the basis of the abundance of *Potamogeton*, Cyperaceae and Graminae pollen. This subdivision can be recognized also on the ostracod diagram (Fig. 6.4) as ostracod numbers fluctuate proportionately with fluctuating values of *Potamogeton* and Cyperaceae. At level MS 40, ostracod numbers are at their highest for this zone and this corresponds to the highest peak for *Potamogeton* and high values of Cyperaceae.

In zone 3a (23.7-45 cm), ostracod numbers fluctuate in accordance with the values of aquatic pollen (Cyperaceae and *Potamogeton*). At level MS 40, as mentioned above, water level must have been fairly high to allow abundant *Potamogeton* to grow and to provide optimum conditions for *Mesocypris* sp. and perhaps also *Darwinula* sp. Water was permanent during this entire period. The presence of Mg-Fe sulfate crystals in samples MS 32.5 and MS 35 corresponds to a general decrease in numbers of some ostracod species and the absence of others. An exception occurs at level MS 35 where *C. incosta* and *C. tenuis* are found, although in small numbers. This phenomenon cannot be adequately interpreted as sulphate crystals are also found in another sample MS 40 which is very rich in ostracods.

In zone 3b (45-76.2 cm), ostracod numbers are lower than at zone 3a but these are still substantial. Water was permanent at least for the period covering samples MS 50-70 except perhaps at level MS 52.5 where *G. maia* is poorly represented. It is surprising to note that the highest diversity and numbers of ostracods recorded in zone 3b do not correspond to an increase in aquatic pollen. This phenomenon remains unexplained as it appears contradictory to the conclusion drawn for most other levels at Mowbray and Pulbeena Swamps. Perhaps the water level was too low and therefore prevented the growth of macrophytes. The lower boundary of zone 3b ought to be lowered down to level 78.7 cm to include sample MS 77.5 which yields ostracods.

Zone 4a (76.2-88.7 cm)

At times there was no water and at others water was ephemeral as indicated respectively by the absence of ostracods in some samples and the low numbers of *Mesocypris* sp. in others (MS 82.5-87.5). This corresponds to low percentages of Cyperaceae and traces of *Potamogeton*. It is of interest to note that Mg-Fe sulfate crystals are found in all samples from this zone as in the bottom of zone 3b where ostracod numbers are low.

Zone 4b (88.7-101.2 cm)

Mesocypris sp. is found in nearly all samples except at both ends of the zone where Mg-Fe sulfate crystals occur. Similarly this species is poorly represented in levels MS 100-102.5 where the same crystals are found. Perhaps, based on ostracod data alone, the limits of this zone ought to be shifted to levels 92-105 cm to include all samples which yield ostracods. Six of the seven ostracod species found at Mowbray Swamp are represented at some stage of this zone. Water was permanent at level MS 95 at least, and perhaps also at the two adjacent levels as shown by the presence of *G. maia* and *Darwinula* sp. The high numbers of *Mesocypris* sp. at level MS 95 coincide with the highest values for Cyperaceae in this zone.

Zone 4c (101.2-138.7)

This zone is almost completely devoid of ostracods if one considers that the boundary between zones 4b and 4c is to be lowered down to level 105 cm as explained before. Note that this newly proposed boundary corresponds to a change of lithology as well. A few valves of *Mesocypris* sp., and rare ones of *G. maia* and *I. smaragdinus* are found together. This corresponds to a small percentage of *Potamogeton* and a slight increase of Cyperaceae numbers which are generally low or nil in this zone. Thus spring activity, with fresh water flowing, was renewed for a short period of time for this level. A few *Mesocypris* sp. valves are also found at level MS 137.5 where Cyperaceae are also present. The other levels were probably formed under little spring activity or without water, or under conditions where sulfate rich waters were flowing at times. It is impossible to be more precise as the Mg-Fe sulfate crystals found at these levels do not necessarily indicate that they were being precipitated at the time. This phenomenon could have occurred at a much later time with the crystals forming preferentially in the porous peaty layers characteristic of zones 4a, 4c and the bottom of zone 5 (called here zone 5b - see below). But this might not have always been the case either, as levels rich in Mg-Fe sulfate crystals have also reduced numbers of ostracods compared to adjacent, Mg-Fe sulfate crystal free, levels (e.g. MS 100-102.5).

Zone 5 (138.7-171.2 cm)

Ostracods are present only down to level MS 162 where a change of lithology is evident (marl above, peat below). Also, as Mg-Fe sulfate crystals are absent in the ostracod layers but are common above and below them, it is suggested here that zone 5 should be divided into two parts: zone 5a (138.7-162 cm) and zone 5b (162-175 cm).

The ecological significance of the unusually high numbers of *I. smaragdinus* in most samples of zone 5a is not understood. Water was, however, permanent for the period covering MS 152.5-162. The high numbers of *Mesocypris* sp. at level MS 155 surprisingly do not correspond to an increase in Cyperaceae pollen.

Zone 6 (171.2-205 cm)

Ostracods are absent in this zone despite the fact that Cyperaceae percentages are high for some levels and that other aquatics are found as well. Ostracods could have been present at the time and leached out or washed away at a later stage.

The results are summarized below:

The occurrence of ostracods in the samples at the site studied usually corresponds to levels with high percentages of carbonates. When inorganic and carbon rich sediments peak together (see Fig.6.5), the samples are devoid of carbonates. For zones 3a, 3b, 4b and 5a, the distribution of ostracods is usually paralleled by the curve for aquatic plants (Fig. 6.5). Water was therefore present between levels MS 27.5 and MS 77.5 and it was permanent between levels MS 27.5 and MS 70. Sulfate rich waters were flowing intermittently during this period of time. A ^{14}C date of 36,000 yBP obtained for level MS 80-87.5 from

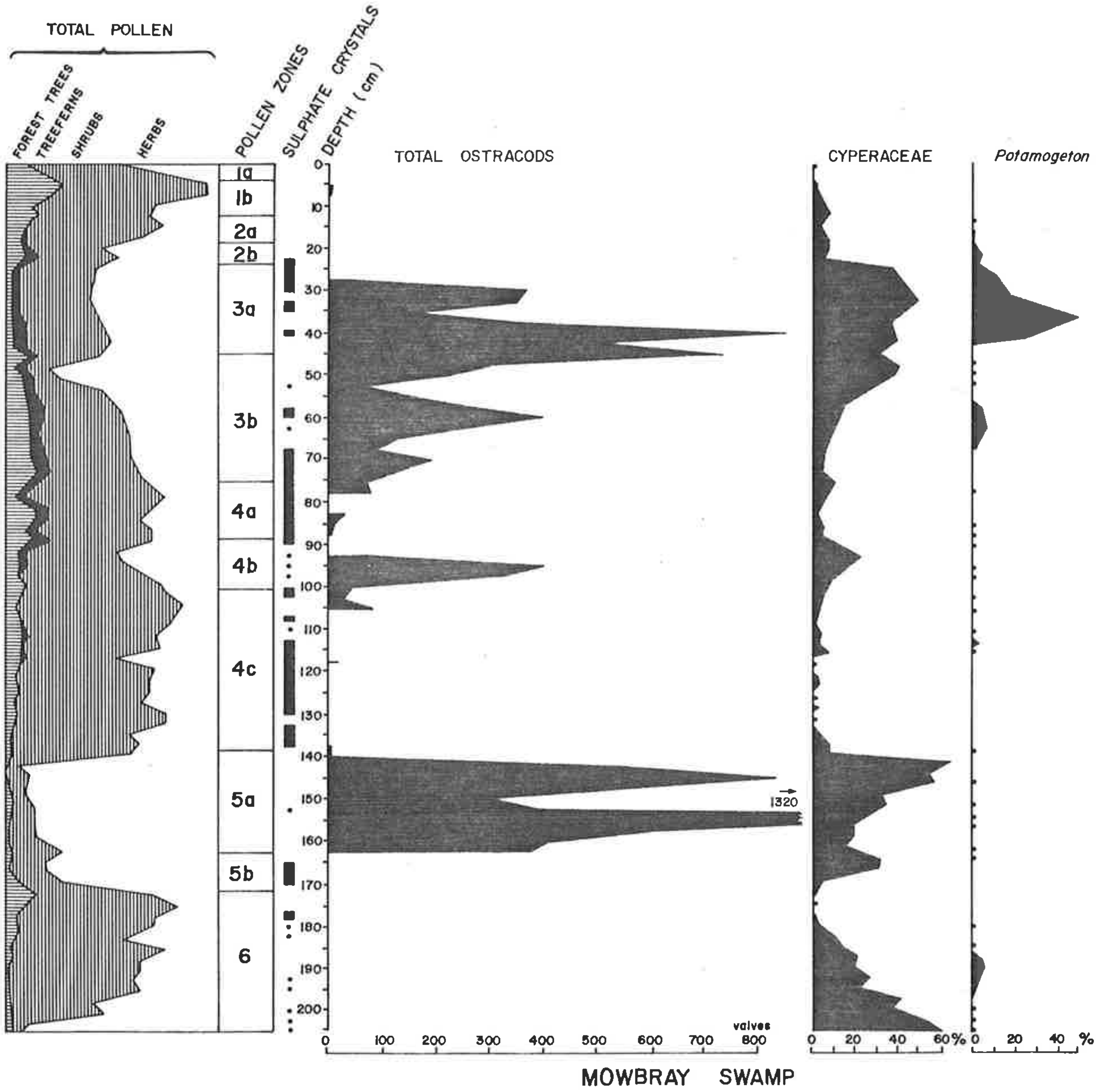


FIG. 6.5 Distribution of all ostracod valves in 10 g samples matched against the total pollen, Cyperaceae, *Potamogeton* curves obtained from van de Geer *et al.* (in prep.).

van de Geer *et al.* (in prep.) indicates that zone 3a and 3b presumably predate the Holocene and started approximately 35,000 years ago. During zone 4a, spring activity with fresh water flowing was reduced between levels MS 82.5-87.5 and there was probably no fresh water at others. This occurred around 36,000 yBP - sulfate rich waters probably flowed quite often during this period. During zone 4b, water was most often free of Mg-Fe sulfate and it flowed intermittently from the spring as there is no evidence of permanent water conditions except for level MS 95 and perhaps adjacent ones.

Zone 4c, which predates the date of 46,000 yBP and which probably lasted 10,000 years, represents either a dry period or one with sulfate rich waters flowing and with a short period of fresh water flowing at levels MS 117.5 and MS 137.5.

Zone 5a was deposited under permanent aqueous conditions and is thought to end at about 56,000 yBP since there is an enriched ^{14}C date 52,200 ± 350 yBP for level MS 125. Below that zone, ostracods are not found but it is suggested that they could have been present at the time and later leached out or washed away in parts of zone 7.

6.5 INTERPRETATION OF THE DATA FOR BOTH SITES

6.5.1 Comparison between Pulbeena and Mowbray Swamps

The two sites studied here, which are characterized by an alternation of marl, peaty marl and peat deposited in a lowland under the influence of intermittent spring activity, differ in a number of ways. The chosen sites at Pulbeena and Mowbray Swamps lie in a depression between a number of springs. Fluctuations in water levels are best recorded at such sites. At Pulbeena Swamp, even during poor water flow from the springs, water is still likely to accumulate in the depressions. There also, rainwater is likely to be kept for a short period of time and to have an additional effect on the fauna and flora. At Mowbray Swamp, on the other hand, since the chosen site is not located in the lowest depression, only substantial wet phases would have been recorded. Additionally, at Mowbray Swamp, waters rich in Mg-Fe sulfate were often present and for long periods of time. The hydrological (and climatological) significance of this phenomenon remains unexplained at this stage. It appears, however, that crystals formed during the driest periods when peat accumulated. In general, ostracod figures fluctuate with those of aquatic pollens (Figs. 6.3, 6.5) at both sites. Ostracods are therefore indicators of water regimes and this is more evident at Pulbeena Swamp because the location of this site is a more appropriate environment for ostracods to live.

More ecological information has yet to be obtained on the fresh water ostracods recovered at both sites in order to provide a better understanding of the past water regimes.

A short period of water flow is recorded at both sites during the Holocene, but it is not known whether this is a synchronous event. Between the beginning of the Holocene period and approximately 35,000 yBP, the driest period recorded at Pulbeena occurs between 12,000 and 18,000 yBP. Until more ^{14}C dates are available, it cannot be determined whether this period is represented by the peat layer between levels MS 10 and MS 27 where ostracods are absent at Mowbray Swamp. At about 35,000 yBP, and for younger levels, water was present at both sites. Also due to the lack of ^{14}C dates, it is not known whether the very wet phase represented by rich and diversified ostracod faunas recorded at Pulbeena Swamp below level PS 255 coincides with one of the wet phases at Mowbray Swamp recorded by moderately high ostracod numbers and by diversified faunas. Colhoun *et al.* (in press) point out, however, that the site at Mowbray Swamp covers a much longer time span (up to 110,000 yBP) than at Pulbeena which is thought to cover only the last 80,000 years.

6.5.2 Comparison with other similar sites where ostracods are found

Boneo Swamp, Victoria

Chapman (1919) described a few ostracods and molluscs from Boneo Swamp, west of Cape Schanck in Victoria. The ostracods were collected from a marl layer. There is no mention of peat by Chapman (1919). This deposit, of supposed Pleistocene age, has the following fauna in common with the Tasmanian sites studied here: [names in brackets refer to Chapman's names] *L. mowbrayensis* (= *L. sicula*, see Hornibrook, 1955), *C. novaezelandiae* (= *C. assimilis*), *L. lacustris* (= *Cythere lubbockiana*). Additionally, Chapman (1919) recorded *Mytilocypris* aff. *mytiloides* and *M. praenuncia* (= both *Cypris mytiloides* of Chapman), *Strandesia? tenuisculpta* (= *Cypris tenuisculpta*), *Alboa worooa* n.gen., n.sp. and (*Cypris sydneia*). The latter was not found in Chapman's collection. These ostracods are not found in either of the two Tasmanian sites. It is likely that the ostracods at Boneo Swamp belong to two mixed faunas: a freshwater one with at least the species similar to the Tasmanian ones, and a slightly saline one as indicated by the presence of *M.* aff. *mytiloides*. *L. lacustris*, which can tolerate saline conditions, could fit in either faunal assemblage. The presence of the halobiont gastropod *Coxiella* recognized by Chapman (1919) further indicates that Boneo Swamp must have been saline at some stage.

Pyramid Valley Swamp, New Zealand

The ostracod fauna of Pyramid Valley Swamp which represents part of a Holocene sequence, has been investigated by Hornibrook (1955) and to a lesser extent by Deevey (1955). This deposit is characterized by an alternation of peat, marl and clay. The ostracod species recovered from it are similar in many ways to those from the two Tasmanian sites. The following species are present at Pulbeena and Pyramid Valley: *C. viridis*, *L. mowbrayensis*, *C. novaezelandiae* (= *C. assimilis* of Hornibrook, 1955) and perhaps *Darwinula* sp. At Pyramid Valley, the following genera are related to the Tasmanian species: *Ilyodromus stanleyanus* (King, 1855). *Gomphocythere duffi* (Hornibrook, 1955) [closely related to *Gomphodella*] and *Candona* sp.

The planktonic ostracod *Newnhamia fenestrata* King, 1855 is recorded at two levels by Hornibrook (1955) at Pyramid Valley. This ostracod, which is a typically freshwater species and which definitely requires open water conditions, is usually found in lakes and large water bodies today in Australia and New Zealand (Timms, 1970, De Deckker, 1979). These conditions probably never prevailed at the two Tasmanian sites and perhaps also, waters there were too rich in mineral contents for *N. fenestrata* to live.

It is interesting to note that the composition of the fauna is similar in two locations so distant from one another. Even though some species are different, similar trophic levels probably prevailed as many species are shared and as most of the others belong to either similar genera or related ones. The only exception lies with *Mesocypris* sp. which is not recorded from Pyramid Valley.

For none of the sites mentioned in this chapter, can the ostracods provide an age for the deposits.

Relevance of all the data mentioned above to palaeoclimates will be discussed in Chapter 9.

PLATE VI.1

Gomphodella maia n.gen., n.sp.

1 C dorsal, female, PS315
2 C dorsal, female, PS315
3 C ventral, female, PS370
4 C ventral, female, PS315
5 RV internal, female, PS405
6 LV internal, male, PS370
7 LV external, female, PS315
8 RV internal, male, PS370
9 LV internal, male, PS405
10 RV external, female, PS315
11 RV internal, male, PS405
12 LV internal, male, PS370
13 LV external, juvenile, PS315
14 LV internal, juvenile, PS315
15 RV external, juvenile, PS315
16 C dorsal, juvenile, PS405
17 C dorsal, male, PS405
18 C ventral, male, PS405

Gomphodella australica (Hussainy, 1969)

19 RV external, female, PS150
20 LV external, female, PS150
21 LV dorsal, female, PS120

Scale: 1 - 200 μ for 1 - 18
2 - 200 μ for 19 - 21

PS = Pulbeena Swamp
MS = Mowbray Swamp
followed by depth in
cm from top of section.

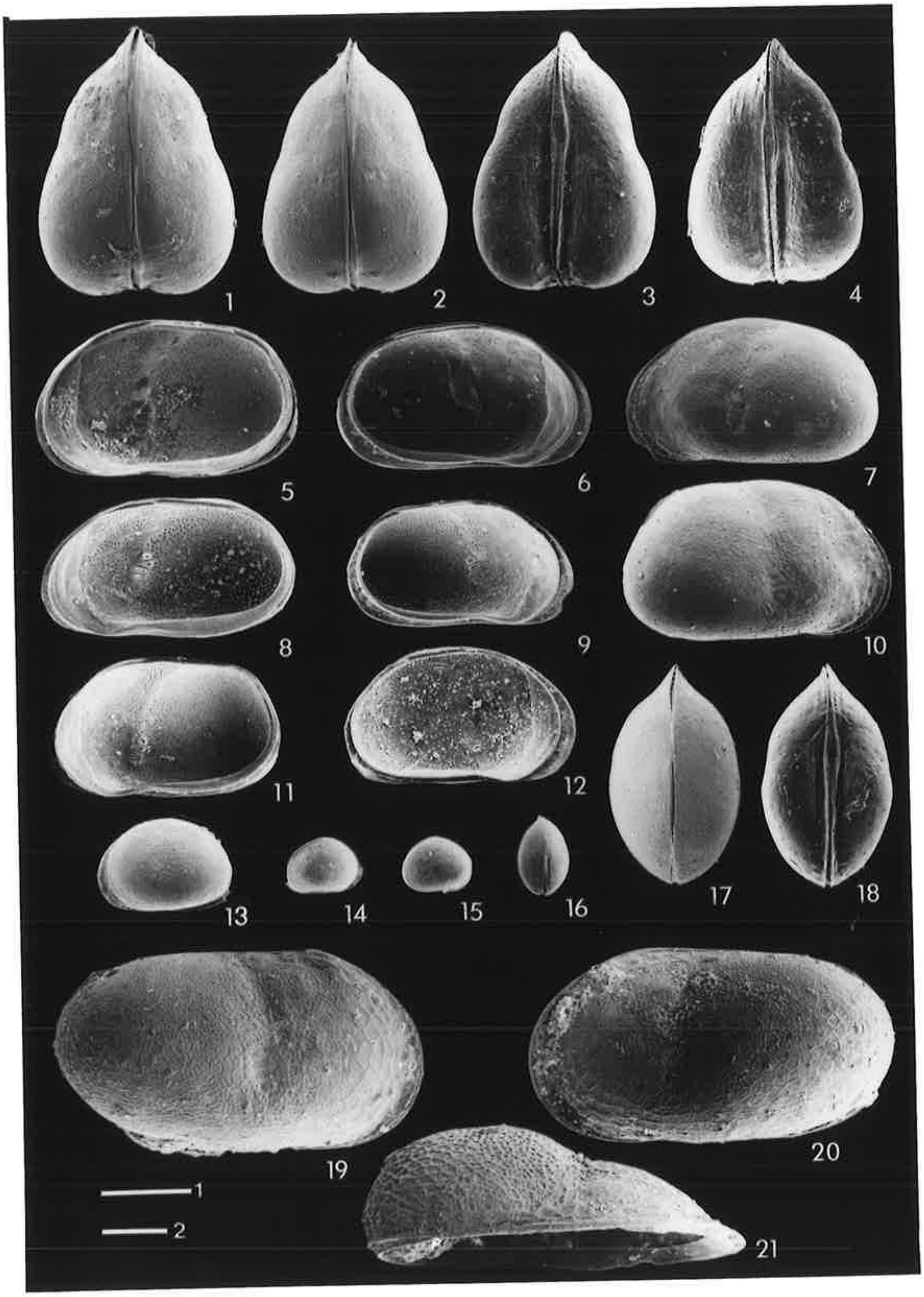

1
2
3
4
5
6
7
8
9
10
11
12
17
18
13
14
15
16
19
20
1
2
21

PLATE VI.2

Mesocypris sp.

1 LV external, MS265
2 RV external, MS355
3 LV internal, MS355
4 LV internal, MS265
5 C dorsal, MS305
6 LV external, MS265
7 C showing RV, MS355
8 C dorsal, MS355
9 C dorsal, MS355
10 RV internal, MS265
11 LV internal, MS355
12 LV external, juvenile, MS355
13 RV external, juvenile, MS280
14 RV internal, juvenile?, MS280
15 LV internal, juvenile, MS355
16 C ventral, MS305
17 RV external, MS 280
18 C dorsal, MS280
19 C ventral, detail of 16

Scale: 1 - 200 μ for 1 - 18
2 - 20 μ for 19

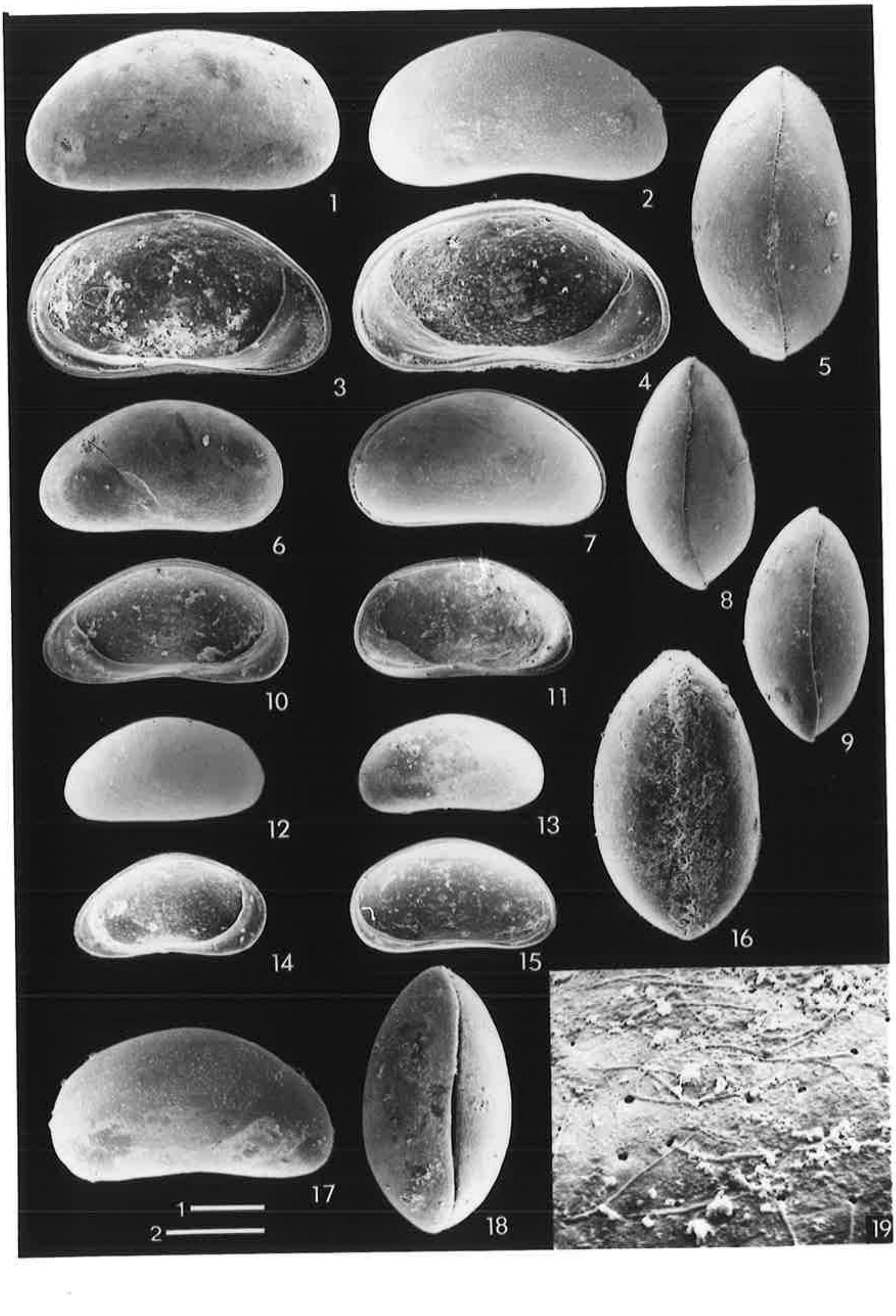

1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
1
2

PLATE VI.3

Limnocythere mowbrayensis Chapman, 1914

1 RV external, female, PS390
2 LV external, female, PS390
3 C dorsal, female, PS390
4 RV external, female, PS460
5 LV external, male, PS390
6 LV external, male, PS460
7 RV external, female, PS460
8 LV dorsal, male, PS95
9 LV dorsal, male, PS390
10 LV external, female, PS460
11 LV internal, male, PS95
12 RV dorsal, female, PS390

Limnocythere sp.

13 RV external, female, PS250
14 RV external, male, PS250
15 RV internal, female, PS250
16 LV dorsal, female, PS250

Scale: 200 μ

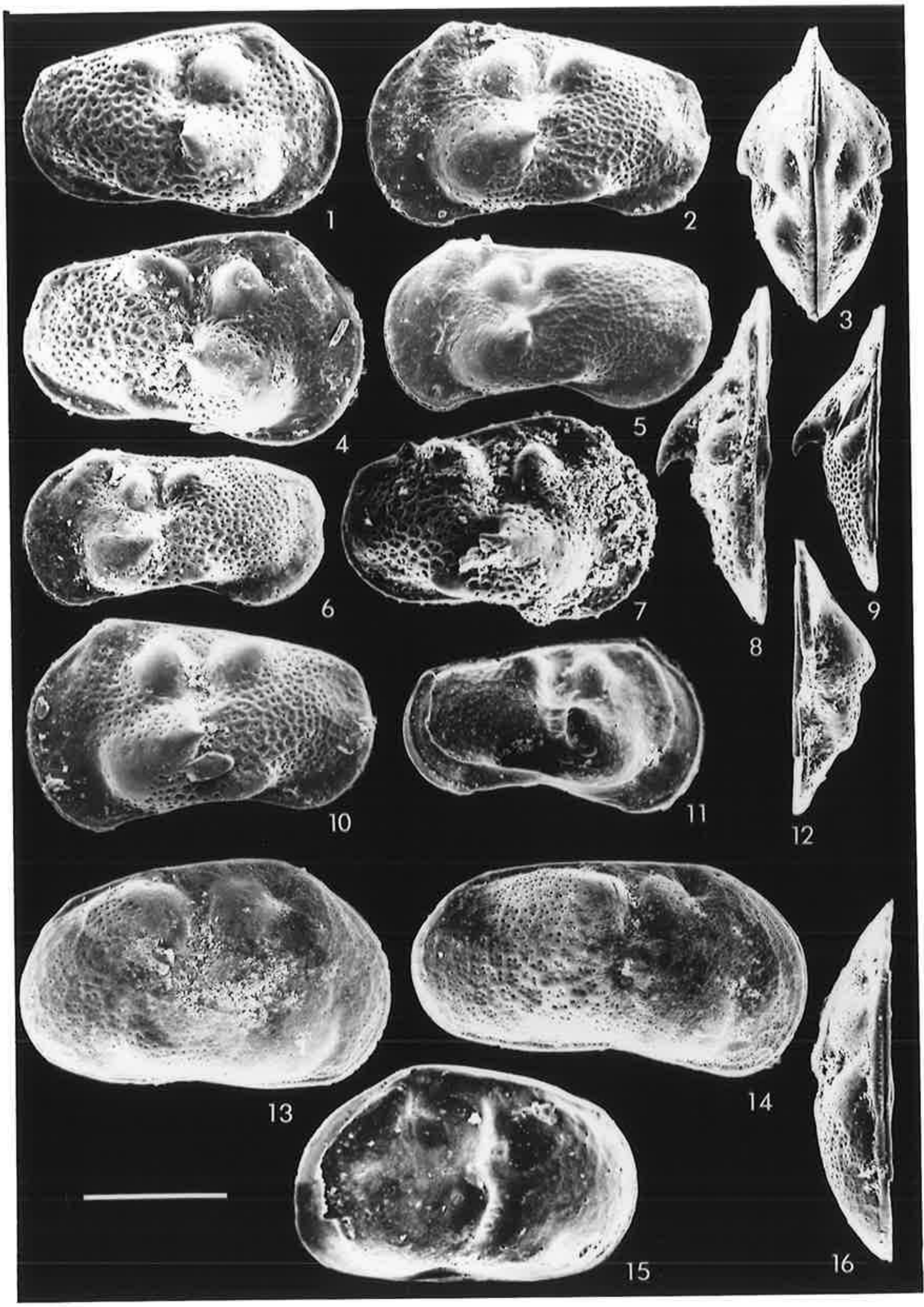

1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16

PLATE VI.4

Leptocythere lacustris n.sp.

1	LV external, PS50
2	RV external, PS270
3	RV external, PS240
4	LV internal, PS50
5	RV internal, PS240
6	LV external, PS240
7	LV external, PS265
8	C dorsal, PS310

Darwinula sp.

9	LV external, PS370
10	RV external, PS370
11	RV internal, PS370
12	LV internal, PS370
13	C dorsal, PS405
14	LV external, PS390
15	C dorsal, PS390
16	RV dorsal, PS370
17	LV internal, central muscle field, detail of 12

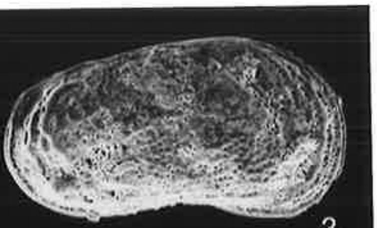
Scale: 1 - 200 µ for 1 - 8

2 - 200 µ for 9 - 16

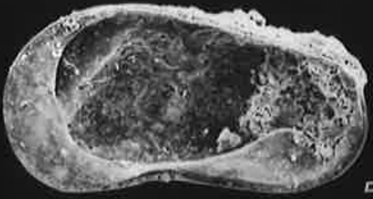
3 - 20 µ for 17


1

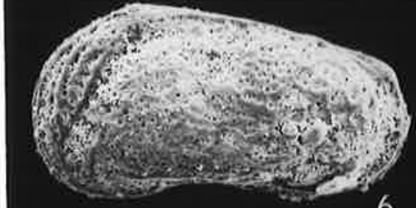

2


3


4


5


8


6


7


9


10


13


11


12


14


15


16

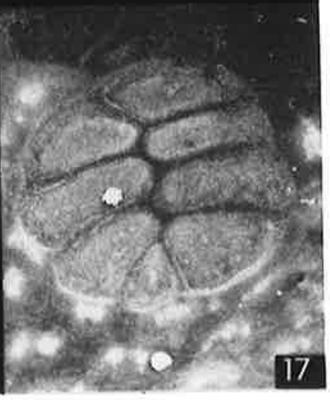

17

PLATE VI.5

Ilyodromus smaragdinus Sars, 1894

1 LV internal, PS350
2 RV external, PS350
3 RV internal, PS350
4 LV external, PS350
5 C dorsal, juvenile, PS 350
6 C dorsal, PS405
7 LV internal, PS355
8 RV internal, juvenile, PS405
9 RV external, juvenile, PS405
10 RV external, detail of 9

Candonocypris incosta n.sp.

11 LV internal, MS35
12 RV external, PS240
13 LV internal, PS240
14 RV internal, MS35
15 LV external, PS240
16 RV internal, PS240

Candonocypris novaezelandiae (Baird, 1843)

17 LV internal, PS405
18 RV external, PS405
19 RV internal, PS405
20 LV external, PS405
21 C dorsal, PS405
22 RV dorsal, PS405

Scale: 300 μ for 1 - 9; 400 μ for 11 - 22; 30 μ for 10

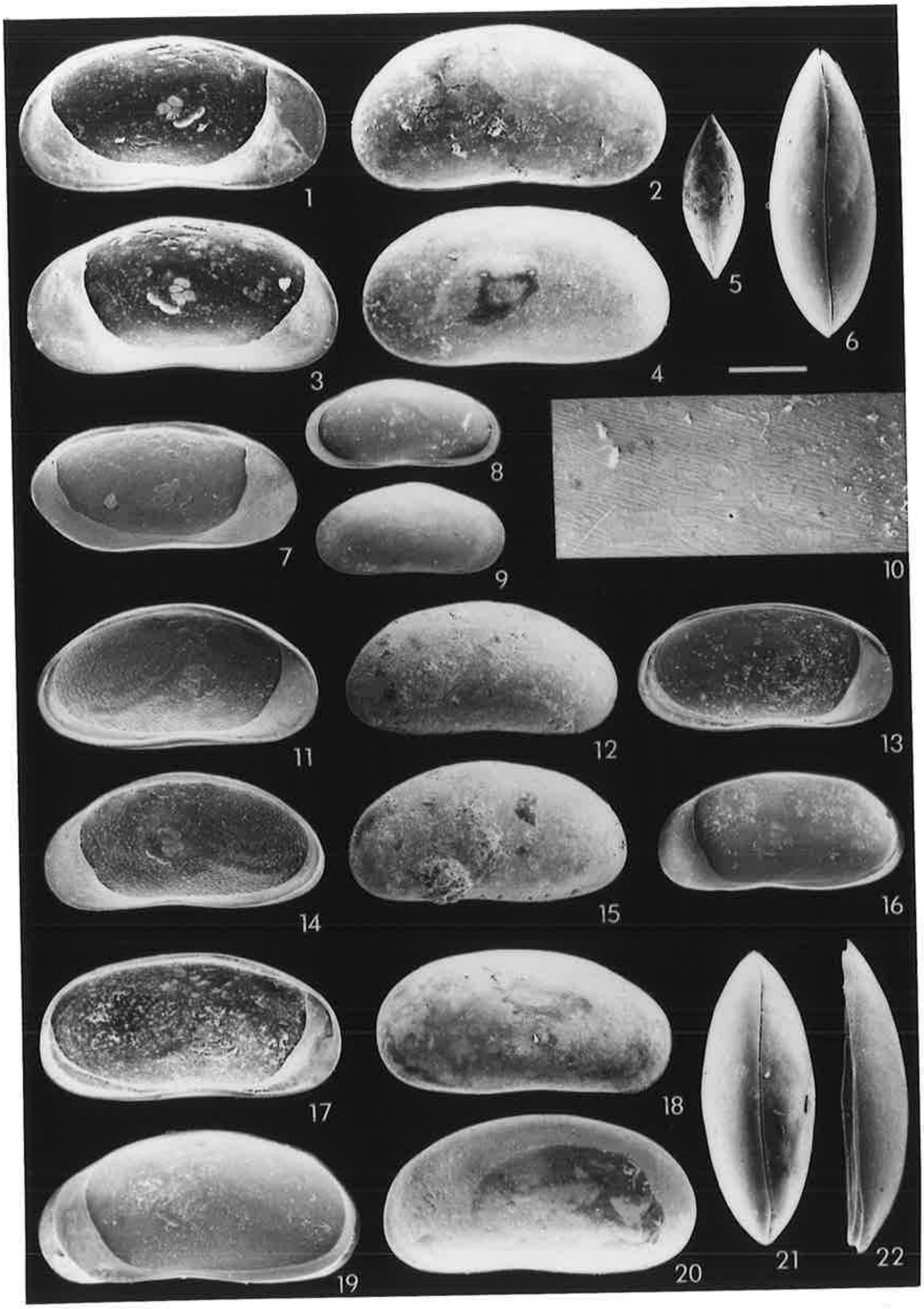

1
2
5
6
3
4
8
10
7
9
11
12
13
14
15
16
17
18
21
22
19
20

PLATE VI.6

Sarscypridopsis proxila n.sp.

1 LV external, paratype, PS390
2 RV external, paratype, PS390
3 C dorsal, PS270
4 RV internal, holotype, PS390
5 LV internal, paratype, PS390
6 LV external, juvenile, PS280
7 LV external, juvenile, PS280
8 C dorsal, PS280
9 RV dorsal, paratype, PS390

Cypretta viridis (Thomson, 1878)

10 RV external, PS360
11 LV external, PS360
12 RV internal, juvenile, PS390
13 LV internal, PS390
14 RV internal, PS390
15 LV dorsal, PS360
16 RV ventral, PS360

Scale: 1 - 250 μ for 1 - 9
2 - 200 μ for 10 - 16

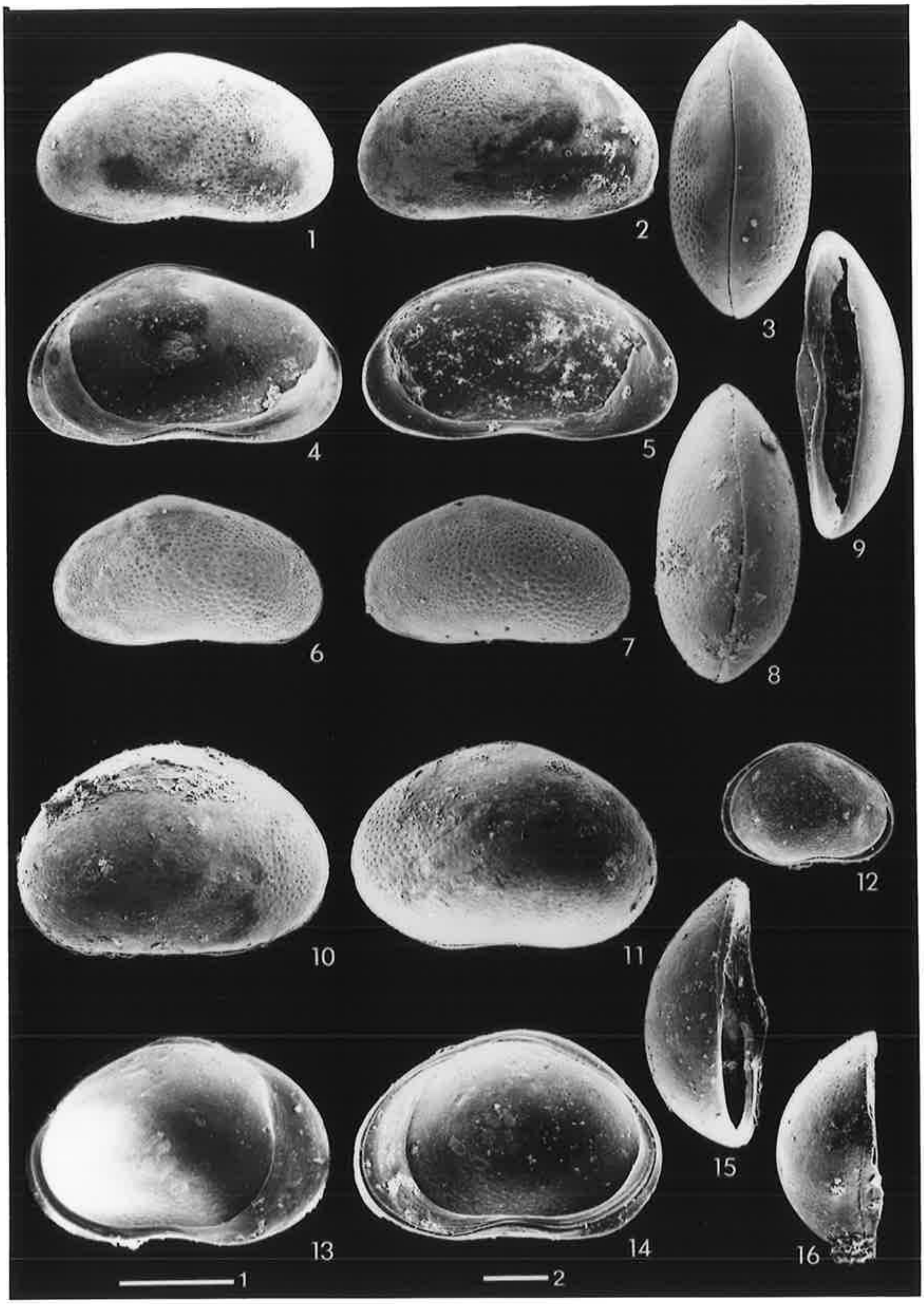

1
2
3
4
5
9
6
7
8
12
10
11
15
13
14
16
1
2

PLATE VI.7

Ilyodromus multifarius n.sp.

1	LV internal, holotype, PS455
2	RV internal, paratype, PS455
3	LV internal, dorso-lateral view of 4, PS180
4	LV internal, PS180
5	RV external, paratype, PS455
6	LV internal, central muscle field, detail of 4

Candonopsis tenuis (Brady, 1886)

7	RV internal, female, PS365
8	LV internal, female, PS365, partly broken
9	RV internal, male, PS180
10	LV internal, female, PS400
11	RV internal, male, PS180
12	LV internal, male, PS180
16	LV internal, central muscle field, detail of 12
17	LV internal, central muscle field, detail of 8

Candona tecta n.sp.

13	RV internal, paratype, PS400
14	LV internal, holotype, PS400
15	C dorsal, PS430

Scale: 1 - 200 μ for 1 - 5, 11

2 - 200 μ for 7 - 10, 12 - 15

3 - 25 μ for 6, 16 - 17


1


2


3


4


5


6


7


8


9


10


11


12


13


14


15


16


17

CHAPTER 7

ANALYSIS OF THE OSTRACODS FROM A 3 METRE CORE FROM LAKE GEORGE, NEW SOUTH WALES

7.1 INTRODUCTION

The study of the ostracods recovered from a core at Lake George was undertaken for a number of reasons: firstly, the sedimentary record represents a long period of time: 70,000 years; secondly, to check whether ostracods can be preserved in the sediments of a large drainage basin which is known to have dried up at times and, presumably, underwent deflation and pedogenesis processes; finally, as the pollen and spores sequence from an adjacent core is known, to compare the information on the aquatic vegetation against the ostracod data.

Lake George lies in a large internal drainage basin (∿930 km^2) in the Southern Tablelands of New South Wales (Fig. 7.1). This graben-type basin is bound on its western side by the Lake George Fault running north/south, which forms a sharp escarpment of about 250 m above the lake floor, which in turn is 673 m in altitude (see Fig. 7.1: section A-B). The present level of the lake varies extensively. During major droughts, it falls rapidly, and on several occasions has been completely dry (Burton and Wilson, 1973). Ancient shore lines up to 37 m above the lake floor have been extensively studied by Coventry (1976). Above this height, the lake would overflow westwards through the 500 m wide Geary's Gap (Fig. 7.1). Fluctuation in water levels over the last 160 years have been reviewed by Burton and Wilson (1973), and Coventry and Walker (1977) have described the geomorphology, surficial

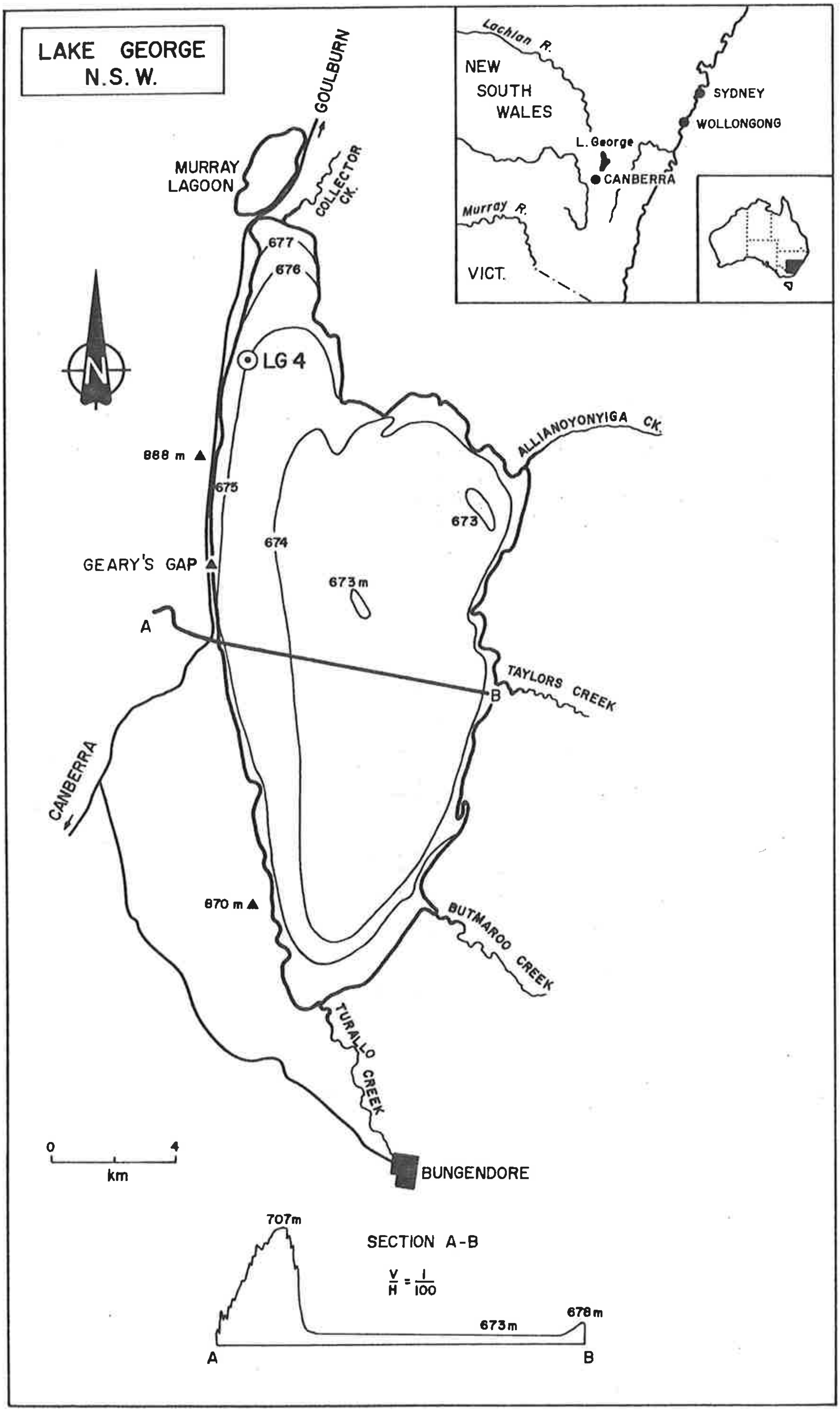


FIG. 7.1 Map showing the location of core LG4 in Lake George.

sediments and soils of the Lake George Basin with particular attention to abandoned shorelines. Recently, Singh *et al.* (in press a) studied the fire and vegetation histories recorded in a core 8.6 m long (labelled LG2) and covering the last 350,000 years. Additionally, Singh *et al.* (in press b) described the Cainozoic history from a core 36 m long (labelled LG4) taken in the north western corner of the lake (Fig. 7.1). The upper 2.94 m of the core LG4 taken by Singh *et al.* (in press b) have been studied here for the recovery of ostracods to determine past lake level fluctuations for approximately the last 70,000 years and to test these results against the palynological data and facies analyses of Singh *et al.* (in press a; in press b), and the abandoned shorelines study of Coventry (1976) and Coventry and Walker (1977).

7.2 METHODS

Core LG4, taken adjacent to the site of core LG2 of Singh *et al.* (in press, a) was obtained from Dr. G. Singh. The lithological changes in both cores occur at the same depths (Singh, pers. comm.) and therefore, all depths referred to in the present study correspond to the same levels in core LG2. Similarly, ^{14}C dates obtained for samples from various levels of core LG2 will be correlated with similar levels in core LG4. Palaeomagnetic studies of Singh *et al.* (in press b) had previously been carried out on this core. 132 samples, most of them weighing 10 g, were taken from the upper 3 m of the 36 m long core LG4 at 2 cm intervals.

As the upper 2.94 m of the core, which consists of grey, plastic to sandy clay, were originally cut into approximately 50 cm long sections, and as sediment compaction occurred in some of these sections, fewer samples were taken. Depth intervals for the samples were later adjusted so that all samples would cover identical proportions of each 50 cm section of the core. This was done to allow more adequate correlation with the core LG2 for which ^{14}C dates were available. All depths mentioned in Fig. 7.2 and in the text have been adjusted. Table 7.1 records the percentage of recovery in each core section and the adjustments required for each sample normally covering 2 cm.

TABLE 7.1

Section of core	Length of core	Core recovery	Number of samples	Adjusted interval
top 0- 50 cm	50 cm	48 cm	24	Kept to 2 cm
50-100	50	48	24	Kept to 2 cm
100-149	49	49	25	Kept to 2 cm except bottom one is 1 cm
149-196	47	37	19	2.47 cm
196-244	48	30	15	3.2 cm
244-294	50	50	25	2 cm

Numbering of the samples in the text refers to the upper limit of the sample in cm from the top of the core, preceded by the letters LG (e.g. sample interval 148-150.65 cm is labelled as LG148). All samples were treated with diluted H_2O_2 for approximately two months to dissociate clay particles, as the core was dry when sampled for ostracods and all samples had become indurated. Further procedures are identical to those mentioned for the samples from the Victorian lakes (Chapter 5).

7.3 RESULTS

Only ostracods and vertebrate fragments were recovered from the samples. These will be discussed separately before an attempt is made to reconstruct the lake history. As many of the ostracod valves recovered in the samples, after treatment with H_2O_2, were broken, counting of valves could not be done accurately. Therefore presence of species with only estimates of their abundance can be presented in Fig. 7.2. It seems that compaction of the sediment in parts of the core and the drying out of the sediment are the main causes for the damage of the ostracod valves. It appears that valves were not transported as there is no apparent sorting of valves of different sizes (e.g. valves of adults and juveniles were most often found together in the samples).

7.3.1 Systematics and ecological information

7.3.1.1 Ostracods

The ostracod species recovered from the samples studied here are introduced below. Only the species not dealt with in detail in Chapter 4 are described here.

The highly ornamented and rectangular shaped *Ilyocypris australiensis* Sars, 1889 (Plate VII.2: Figs. 1-10) differs from the smaller, less reticulated *Limnocythere dorsosicula* n.sp. (Plate VII.1) which is characterized by a row of three to six spines along the edge of the right valve posterodorsally. The rare *Diacypris* aff. *dictyote* De Deckker, 1980 (Plate VII.4: Figs. 11-18) is oval to circular in shape and has a smooth to reticulate shell with a few small spines posteroventrally along the edge of the shell. The other ostracods have a smooth shell: *Mytilocypris praenuncia* (Chapman, 1936) (Plate VII.3: Figs. 11-17) is the largest ostracod (2-3 mm) and is triangular in shape. Many specimens of these large ostracods, which are broken, are referred to as *Mytilocypris* sp. because they lack the diagnostic features necessary for specific identification (e.g. the posterior end of the valve). *Platycypris baueri* Herbst, 1957 (Plate VII.3: Figs. 1-10) is ellipsoidal in shape with the greatest height of the shell at ⅔ from the anterior. *Ilyodromus viridulus* (Brady, 1886) (Plate VII.4: Figs. 1-10) is ellipsoidal to rectangular in shape with a flattened dorsum and broad inner lamellae anteriorly.

Diacypris aff. *dictyote* De Deckker, 1980
Plate VII.4: Figs. 11-18

1980 *Diacypris dictyote* n.sp. De Deckker, p.

Description: Oval to circular shape with concave ventrum. External surface of shell smooth to coarsely but regularly reticulate. Greatest height at about ⅔ from the anterior. In dorsal view, broad with both ends pointed. Left valve slightly larger than right one except dorsally where the overlap over the right valve is more prominent. Fine denticulation present on the posteroventral edge of both valves. Internally, selvage prominent in both valves: in left one, it is placed at ⅓ of the inner lamella width from the edge of the valve anteriorly and it is close to the inner margin posteriorly; in the right valve, it is near the edge of the valve anteriorly and near the inner margin posteriorly. The width of the inner lamellae is variable but it is slightly larger anteriorly.

Size range: L: 640-840 μ.

Ecology: All *Diacypris* species inhabit saline waters and therefore it is likely that the species examined here indicates such water conditions although salinities were probably low (<10°/oo). This is substantiated by the presence of similar specimens of *D.* aff. *dictyote* found with *I. australiensis*, *I. viridulus* and *C. novaezelandiae* in a number of samples from a trench dug at 2 km west of the Walls on the lake floor of Lake Mungo, N.S.W. given to me by Dr. J.M. Bowler. These ostracods are indicative of freshwater conditions except for *I. australiensis* which can tolerate salinities up to 7°/oo (for more details see discussion on this species below). Similarly, *D* aff. *dictyote* is found with *I. australiensis* and *I. viridulus* in two samples from Lake George and in one with *L. dorsosicula* (see Fig. 7.2). Care, however, must still be taken as the presence of these ostracods together does not necessarily mean that they co-occurred in the lake.

Remarks: This species is rare in the Lake George samples. It differs morphologically from *D. dictyote* because of the absence of a dorsal keel so typical of the species in the left valve, and the fine reticulation all along the valves. It is not certain whether this forms a new species as the shell morphology of *Diacypris* species is known to vary. This is particularly the case for the height of the keel in *D. dictyote* (see De Deckker, 1980a), although it is always visible, whereas in *D.* aff. *dictyote* it is not seen on specimens from either Lake George or the trench dug at Lake Mungo. Additionally, the salinity range of *D. dictyote* of 12-142°/oo (De Deckker and Geddes, 1980) is exclusive of the range for the species studied here.

Ilyodromus viridulus (Brady, 1886)
Plate VII.4: Figs. 1-10

1886 *Cypris viridula* n.sp., Brady, p. 88.

1889 *Herpetocypris viridula* (Brady), Sars, p. 41.

1894 *Ilyodromus viridulus* (Brady), Sars, p. 39.

Description: Smooth ellipsoidal to rectangular shell with both ends broadly rounded and dorsum almost horizontal in the hinge area. Ventrum slightly concave in the mouth region. Greatest height at about ⅓ from the anterior. Surface of the shell occasionally shows fine hexagonal grooves anteriorly and posteriorly. The left valve is slightly longer all along. Shell narrow in dorsal view. Internally, the inner lamellae are at least twice as broad anteriorly. In the left valve, the selvage is near the edge of the valve anteriorly and it is often broad and follows the inner margin posteriorly and ventrally where it is the broadest. In the right valve, the selvage is faint and peripheral all along except posteriorly where it is placed at ⅓ of the inner lamella width from the edge of the valve. Anterior inner lamella often faintly reticulated. Juveniles are more elongated than adults.

Size range: Adults: L: 1,050-1,200 μ.

Ecology: *I. viridulus* is known from few localities in Australia. Sars (1889) raised it from dried mud from two freshwater localities near Rockhampton in Queensland. It is considered to be a freshwater species. So far it has never been found in slightly saline waters. As a fossil, it is also common in samples from a trench dug 2 km west of the Walls on the floor of Lake Mungo, N.S.W.

Remarks: The diagnostic feature of this species is its overall shape with the almost flat dorsum and the broader inner lamellae. A faint reticulation of the shell is occasionally visible on some specimens whereas others are smooth or faintly striated longitudinally. These striations, so typical of most *Ilyodromus* species are thought to act as a strengthening feature (compared to other ostracods). In *I. viridulus*, such striations are unnecessary as the shell is rather thick. On some living specimens, however, striations have been found and they are usually restricted to the anterior and posterior areas of the shells, although they can also be seen all over the shell. It is likely that *I. substriatus* Sars, 1894, which is recorded from New Zealand and has a similar shell outline and similar inner lamellae, needs to be synonymized to *I. viridulus*. Further study of the soft parts is necessary to confirm this suggestion.

7.3.1.2 Vertebrate fragments

Vertebrate fragments were recovered in a number of samples. They are considered to be fish bones, mostly vertebrae. Rarely, jaw fragments were recovered (Plate VII.2: Figs. 11-13) but were not further identified. Although the presence of fish fragments indicates conditions of permanent water, they can only be extrapolated for the immediate vicinity of the interval where they were found as, in places, there is evidence of reworking of these fossils. In sample LG114, fish bones, nearly all broken, are abundant. Such abundance of bones usually occurs at the shore of lakes and therefore, such a location is postulated for the coring site at the times of deposition of level LG114.

7.3.2 Detailed study of the core

The pollen zonation of Singh *et al.* (in press, b) for the upper 3 m of their core will not be retained here as the boundaries did not coincide with those of the respective phases extrapolated from the ostracod data. Comparison between the two zonations, which are, however, still fairly similar, will be discussed in section 7.4.2.

Zone 1 (0-20 cm = LG1-18)

No ostracods were recovered. The presence of seeds and rootlets in most samples and of angular quartz grains in all samples indicates that the lake was either dry or ephemeral. Lake level probably rarely reached the coring site.

Zone 2 (20-92 cm = LG20-90)

Ostracods are few in numbers and even absent in some samples. *I. viridulus* and *D.* aff. *dictyote*, which are poorly represented, are rarely found together. They probably indicate ephemeral

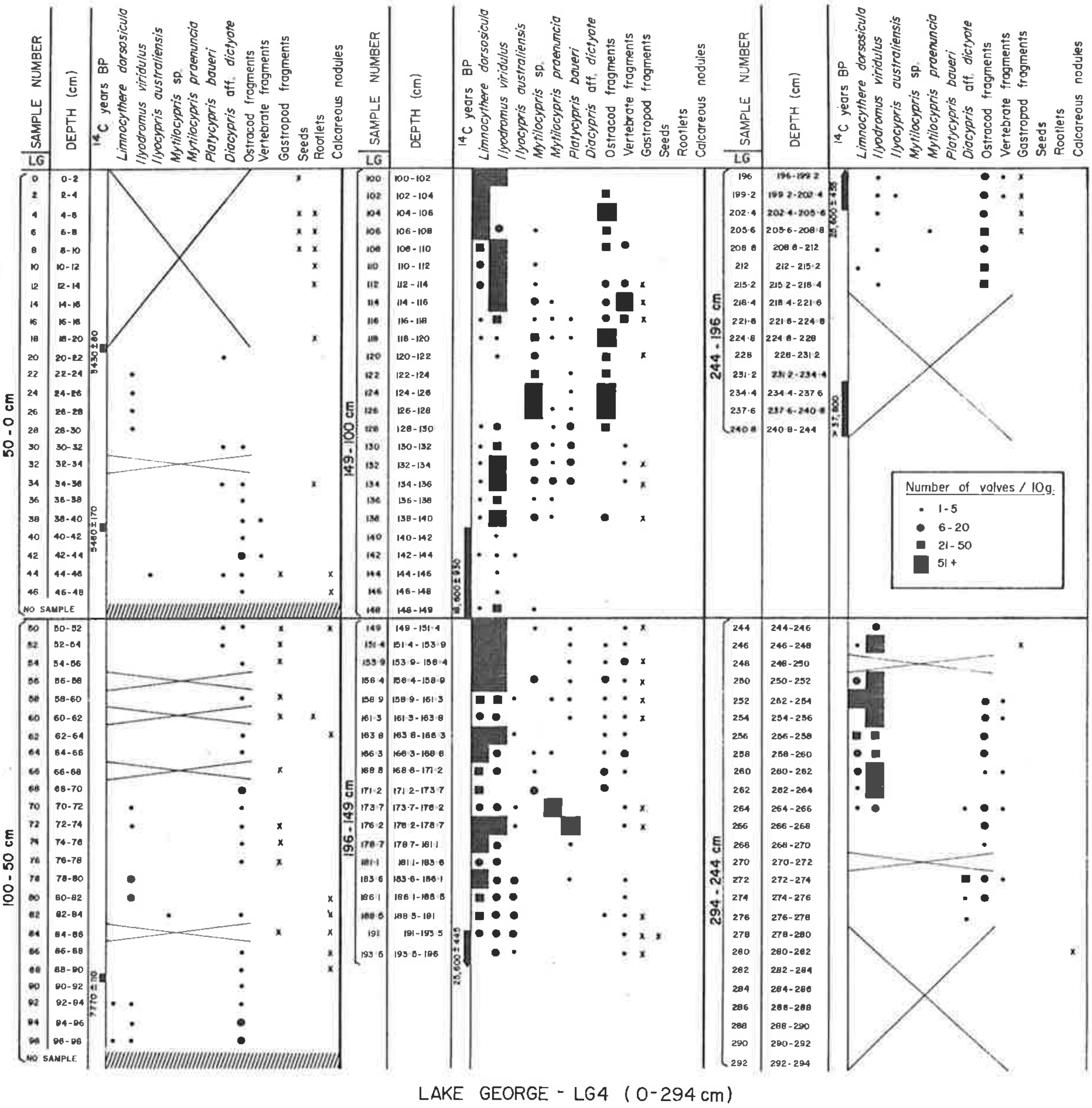


FIG. 7.2 Distribution of fossil ostracods and other remains obtained from core LG4 from Lake George. For sample distribution in the core, refer to Table 7.1. ^{14}C dates from Singh *et al.* (in press a, b). Crosses indicate only the presence of remains in the samples.

water for the lake. This would explain the absence of vertebrate fragments in all samples except LG38 and 42. Water could have been slightly saline when *D.* aff. *dictyote* was present in samples LG20, 30, 34, 44, 50 and 52. The presence of *Mytilocypris* sp. in sample LG82 also indicates slightly saline water for that level. *I. australiensis* found with *D.* aff. *dictyote* in sample LG44 could still point to slightly saline conditions as the former species occurs today in such waters in a number of localities up to a salinity of 7°/oo with one additional record at 10.37°/oo.

Additionally, many fragments of large ostracods were recovered from a number of samples (see Fig. 7.2), but unfortunately it is not possible to determine whether they belong to the halobiont mytilocypridinid ostracods or the large freshwater ostracods such as *Eucypris virens* (Jurine, 1820) or *Heterocypris leana* (Sars, 1896).

Samples LG78 and 80, which yield substantial numbers of *I. viridulus* indicate a short, but definite, freshwater phase. This appears to also be the case for samples LG22-28 and LG70-72 where *I. viridulus* is found but in smaller quantities.

Secondary carbonate nodules in a few samples (LG44, 46, 52 and 62) and in the lower part of the zone at levels LG80-88, point to soil formation at some stage. The precise time of soil formation is not known as pedogenesis can affect older layers and destroy evidence of a lacustrine phase by leaching ostracod shells. Fragments of calcareous precipitates around stems (samples LG60, 66-74) cannot be fully explained but this phenomenon could indicate carbonate rich waters.

Zone 3 (92-112 cm = LG92-110)

The lake was full for the bottom part of this zone (LG100-110) where ostracod numbers are high. There are enough ostracod valves in these samples to be sure that reworking of the samples did not occur as valves of adults and juveniles are found together. Water salinity fluctuated between fresh and slightly saline as *I. viridulus* co-occurs in samples with juveniles of the halobiont *Mytilocypris* (samples LG104, 110). At other times, especially for samples LG100-104, 108, water was probably fresh. There is no evidence that water was permanent except for sample LG108 where vertebrate fragments are found. It is likely that for samples in which *L. dorsosicula* abounds, water was permanent as *Limnocythere* species, in Australia, are rarely found in temporary pools.

Zone 4 (112-118 cm = LG112-116)

This is a transitional zone between the freshwater one above and the saline one below. Faunal components typical of both zones are present in samples LG112-116 with a decrease of faunal elements of zone 5 towards the top of zone 4, being replaced progressively by higher numbers of faunal elements typical of zone 3. Water was permanent but it is likely that sample LG114 was located near the shore of the lake as vertebrate fragments abound in this sample. Similarly, only adult valves of *I. viridulus* are found - sorting must have occurred and a likely place for this to have happened would be near the shore of the lake. A similar phenomenon is postulated for sample LG116 although ostracod valves and vertebrate fragments are fewer.

Zone 5 (118-130 cm = LG118-128)

Water was ephemeral and saline as indicated by the presence of *M. praenuncia* and (rare) *P. baueri*. Water salinity could have reached 43°/oo. The absence of *I. australiensis* which can inhabit saline waters up to 7°/oo probably indicates that water salinity must have been above that value. The rare *I. viridulus* valves belong to juveniles, therefore they do not indicate a freshwater phase with certainty. The absence of vertebrate fragments in these samples does not necessarily indicate the ephemerality of the lake water. Fishes which can live in saline waters (see further information in Chapter 5) probably did not reach the lake as there is no connection from Lake George to other major saline waters to allow such fishes to be introduced in the lake during a saline water phase. The presence of freshwater fishes at other periods when freshwater occurred, is easily understood as a number of rivers are connected to Lake George.

Zone 6 (130-140 cm = LG130-138)

Water was permanent at times (in samples LG130-134) and it fluctuated between fresh and slightly saline. This would explain the co-occurrence in samples of the freshwater ostracod *I. viridulus* and the halobiont ostracods *M. praenuncia* and *P. baueri*. Surprisingly, *L. dorsosicula*, which is known to live in waters up to 2°/oo salinity is rare in the samples. It is most likely that the bottom two samples of this zone (LG136, 138) represent a fresher phase as the halobiont ostracods are rare.

Zone 7 (140-148 cm = LG140-146)

Water was probably absent at most times and very likely ephemeral when present as ostracods are rare. They also indicate freshwater conditions (∿2°/oo).

Zone 8 (148-196 cm = LG148-193.5)

This zone is characterized by high percentages of freshwater ostracods. In some samples, halobiont species co-occur with some freshwater ones but they are usually in very low numbers. Therefore water was likely to be fresh at most times. Exceptions occur, however, for samples LG173.7 and 176.2 in which are found respectively, many *M. praenuncia* and *P. baueri*. A saline phase, up to 42°/oo is postulated for sample LG173.7 whereas fluctuation between fresh and saline water is inferred for LG176.2 as in the latter *P. baueri* co-occurs with freshwater species. Water was permanent at most times, except in LG171.2, 178.7-181.1, as indicated by the presence of vertebrate fragments.

Below sample LG176.2, water remained fresh, even though *I. australiensis*, which can tolerate salinities up to 7°/oo, is present in most samples as halobiont ostracods are absent or rare in all samples. It is likely that the water level dropped when *I. australiensis* was present in the lower portion of the zone (LG183.6-193.5) as this species has never been found in deep lakes. This would explain the low numbers of *L. dorsosicula* in most samples.

Zone 9 (196-218.4 cm = LG196-215.2)

Complete ostracods which are rare in this zone are found with a number of broken valves of ostracods. These fragments belong to large and small ostracods but they are unidentifiable. It is likely that the lake level rarely reached the coring site but when it did, ostracod valves were reworked. This is also indicated by the absence of vertebrate fragments below sample LG199.2. Water could have been saline for sample LG205.6 as indicated by the rare valves of *M. praenuncia*.

Zone 10 (218.4-244 cm = LG218.4-240.8)

Ostracods are absent in this zone. The lake was either dry for the entire zone or pedogenesis at the top of the zone destroyed evidence of a wet phase.

Zone 11 (244-264 cm - LG244-262)

The lake level reached the coring site and water was fresh. There is little indication that water was permanent except for samples LG250, 252 and 258. This is further substantiated by the low numbers of *L. dorsosicula* in most samples.

Sample LG248, on the other hand, is devoid of ostracods: the lake level probably receded then past the coring site or the lake could have even been completely dry.

Zone 12 (264-278 cm = LG264-276)

Ostracods are rare or absent in most samples. The presence of *D.* aff. *dictyote* in four samples is noted but unfortunately little palaeoecological data can be obtained from this species. As suggested previously, it could indicate slightly saline waters. Water was certainly ephemeral at most times except perhaps at level LG264 and LG272 where vertebrate fragments are found with many ostracods (compared to other samples in the zone only).

Level LG270 represents a dry phase as ostracods are absent.

Zone 13 (278-294 cm = LG278-292)

No ostracods are found - the lake was either dry for the entire zone or pedogenesis occurred at the top of this zone and leached out evidence of a wet lacustrine phase.

7.4 HISTORY OF LAKE GEORGE

7.4.1 Interpretation of the ostracod data

^{14}C dates for six levels of core LG2 taken from Singh *et al.* (in press, a) are transferred to corresponding levels in core LG4 as both cores are adjacent to one another and changes in lithologies occurred at the same depth in each core (see Fig. 7.2). Similarly, the date of 128,000 years deduced from the palaeomagnetic record by Singh *et al.* (in press, b) at level 420 cm in core LG2 will be used here to date approximately the younger layers which are too old to be dated by the conventional ^{14}C dating method. For this purpose, sedimentation rate is assumed to have been constant. The bottom part of the 3 m section studied here for ostracods is therefore estimated to be about 70,000 years old, but date estimates for levels below the 2 m depth are to be treated with caution. The lake history is summarized below.

0-20 cm (= 0-∿2,600 yBP). The lake was probably dry at most times or lake level rarely reached the coring site as no ostracods are found.

20-92 cm (= ∿2,600-∿7,500 yBP). The lake was characterized by ephemeral waters which were slightly saline at various intervals (for samples LG20, 30, 34, 44, 50, 52 and 82). Short freshwater phases are definitely noticeable at level LG78-80 (= ∿7,200 yBP) and for short intervals for levels LG22-28 (∿2,600-∿4,000 yBP) and LG70-72 (∿6,800 yBP). There is evidence of soil formation on a number of occasions (levels LG44, 46, 52, 62 and 80-88).

92-112 cm (= ∿7,500-∿12,000 yBP). Water was present during the interval LG92-100 (= ∿7,500-∿9,500 yBP), but the lake was definitely full and water fresh at most times for the other interval LG100-110 (= ∿9,500-∿12,000 yBP) except for short periods of time when it was slightly saline as seen in samples LG104, 110.

112-118 cm (= ∿12,000-∿13,400 yBP). This is a transitional zone between the fresh one at nearly all times above this zone and the saline one below. At levels LG114 and 116, the shore line of the lake was near the core site at some stage.

118-130 cm (= ∿13,400-∿16,000 yBP). Water was ephemeral and saline (it could have reached 43°/oo).

130-140 cm (= ∿16,000-∿18,000 yBP). Water was permanent at all times and it fluctuated between fresh and slightly saline. The bottom part of this zone (samples LG136-138) represents a freshwater phase.

140-149 cm (= ∿18,000-∿19,500 yBP). Water was probably absent at most times near the core site and it was ephemeral when present.

149-196 cm (= ∿19,500-∿25,500 yBP). Water was likely to be fresh and permanent at most times. For the interval LG149-158.9 the lake yielded the most diversified fauna recorded in this core. Water level was probably at its highest between ∿19,500 and ∿20,800 yBP. A similar phenomenon applies for a short period of time around 21,500 yBP for level LG163.8. Saline water conditions prevailed for levels LG173.7 and 176.2 (= ∿22,800-∿23,500 yBP).

Dates for the events described below are to be treated with caution since rate of sedimentation is assumed to have been constant.

196-218.4 cm (= ?∿25,500-∿36,000 yBP). It is likely that the lake level rarely reached the core site. Water could have been saline for sample LG205.6 (= ∿30,000 yBP).

218.4-244 cm (= ?∿36,000-47,000 yBP). The lake was dry.

244-264 cm (= ?∿47,000-57,000 yBP). The lake had permanent fresh water at most times except for samples LG250, 252 and 258. The lake could even have been dry at level LG248 (= ∿50,000 yBP).

264-278 cm (= ?∿57,000-∿64,000 yBP). Water was ephemeral at most times and perhaps slightly saline. For level LG264 and 272, there is an indication that water was permanent.

278-294 cm (= ?∿64,000-∿70,000 yBP). The lake was either dry during this entire period, or at about 64,000 yBP, pedogenesis destroyed the record of a lacustrine phase.

7.4.2 Comparison with previous work carried out at Lake George

Coventry (1976) and Coventry and Walker (1977) have identified abandoned beaches from Lake George and were able to plot a water level curve for the lake for the last 27,000 years. Four major strandlines are recognized by these authors: The maximum lake level was registered between 27,000 and 21,000 yBP. During the last 21,000 years, the lake level never again reached this maximum. Other high levels occurred at about 15,000 yBP, about 7,000-8,000 yBP and between 3,000 and 4,000 yBP. These latter three levels are also recognized from the recovery of ostracods. The maximum lake level recognized by Coventry (1976) and Coventry and Walker (1977) for the period 27,000 to 21,000 yBP does not coincide very well with the one postulated here between 19,500 and 25,500 yBP. The wet phase recorded here between 19,500 and 21,000 yBP apparently did not leave major strandlines although it is assumed on the ostracod data that the lake level was at its highest between ∿19,500 and ∿20,800 yBP. Additionally, these authors mentioned above, who identified a strandline established between 7,000 and 8,000 yBP, did not extend a high lake level phase further back in time. The ostracod data on the other hand indicate that this phase extended as far back as 11,000 yBP.

Singh *et al.* (in press b), on the basis of facies analyses and records of plant microfossils examined on the cores LG2 and LG4, identified a number of short phases of "fresh water spells" and other longer fresh water ones which all correspond fairly well to those identified here. Those identified by Singh *et al.* (in press b) are as follows, as calculated from their diagrams:

- short spells ephemeral to fresh water around 4,000, 5,000, 10,000, 15,000 yBP and one older than 25,000 yBP (perhaps at around 30,000 yBP);

- long fresh water phases at 6,500 to 5,000 yBP
  12,000 to 8,000 yBP
  17,000 to 16,000 yBP
  22,000 to 19,000 yBP
  ∿30,000 to 25,000 yBP.

The freshwater phase between 6,500 and 5,000 yBP with the short spell of ephemeral water is not recognized in the present study. The other phases recognized by Singh *et al.* (in press b) coincide very well with those recognized here. One discrepancy occurs for the duration of the freshwater phase between 17,000 and 16,000 yBP of Singh *et al.* (in press b) and which is extended to approximately 18,000 yBP here. Further ^{14}C dates are necessary to obtain a better definition of the timing of this important phase as it is adjacent to the "glacial maximum" recorded in other parts of the world.

It is obvious from the present study that the data obtained from the ostracods are fairly similar to that obtained by Coventry (1976) and Coventry and Walker (1977) based on dated stranded beach lines of the lake and by Singh *et al.* (in press, b) who examined facies changes and plant microfossils.

The discrepancies in the timing of some fresh water phases obtained from the different studies will have to be checked by supplementary ^{14}C dates.

Discussion on palaeoclimatic interpretation of the results presented here, and comparison with those from Pulbeena and Mowbray Swamps, will be discussed in Chapter 9.

PLATE VII.1

Limnocythere dorsosicula n.sp.

1	LV external, female, LG183.6
2	RV external, female, LG183.6
3	RV internal, juvenile, LG183.6
4	LV external, male, LG183.6
5	RV external, female, LG183.6
6	RV external, juvenile, LG183.6
7	LV external, male, LG183.6
8	RV external, female, LG183.6
9	RV external, male, LG183.6
10	LV dorsal, female, LG183.6
11	C dorsal, female, LG173.7
12	RV external, male, LG183.6
13	RV internal, male, LG183.6
14	LV internal, male, LG183.6
15	LV internal, female, LG183.6

Scale: 200 µ

LG = Lake George, followed by
depth in cm from top of core

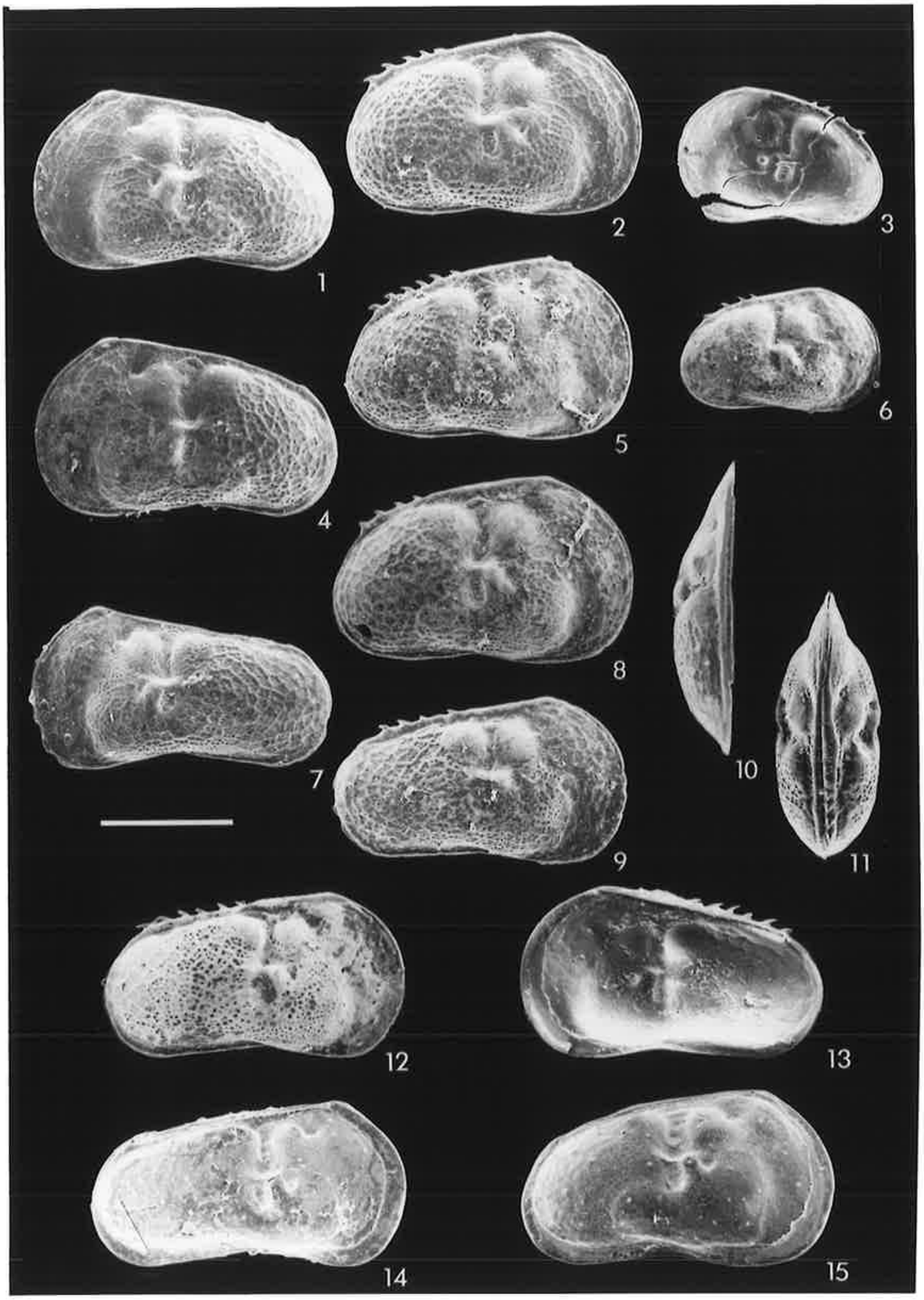

1
2
3
4
5
6
7
8
9
10
11
12
13
14
15

PLATE VII.2

Ilyocypris australiensis Sars, 1889

1	LV external, LG173.7
2	RV external, LG173.7
3	RV internal, juvenile, LG183.6
4	LV external, LG 188.5
5	RV external, LG 188.5
6	LV external, juvenile, LG 188.5
7	RV internal, LG 183.6
8	LV external, LG 188.5
9	RV internal, LG 186.1
10	LV internal, LG 188.5

Fish

11	jaw fragment, LG114
12	jaw fragment, LG114
13	jaw fragment, LG114

Scale: 1 - 200 μ for 1 - 10
2 - 500 μ for 11 - 13

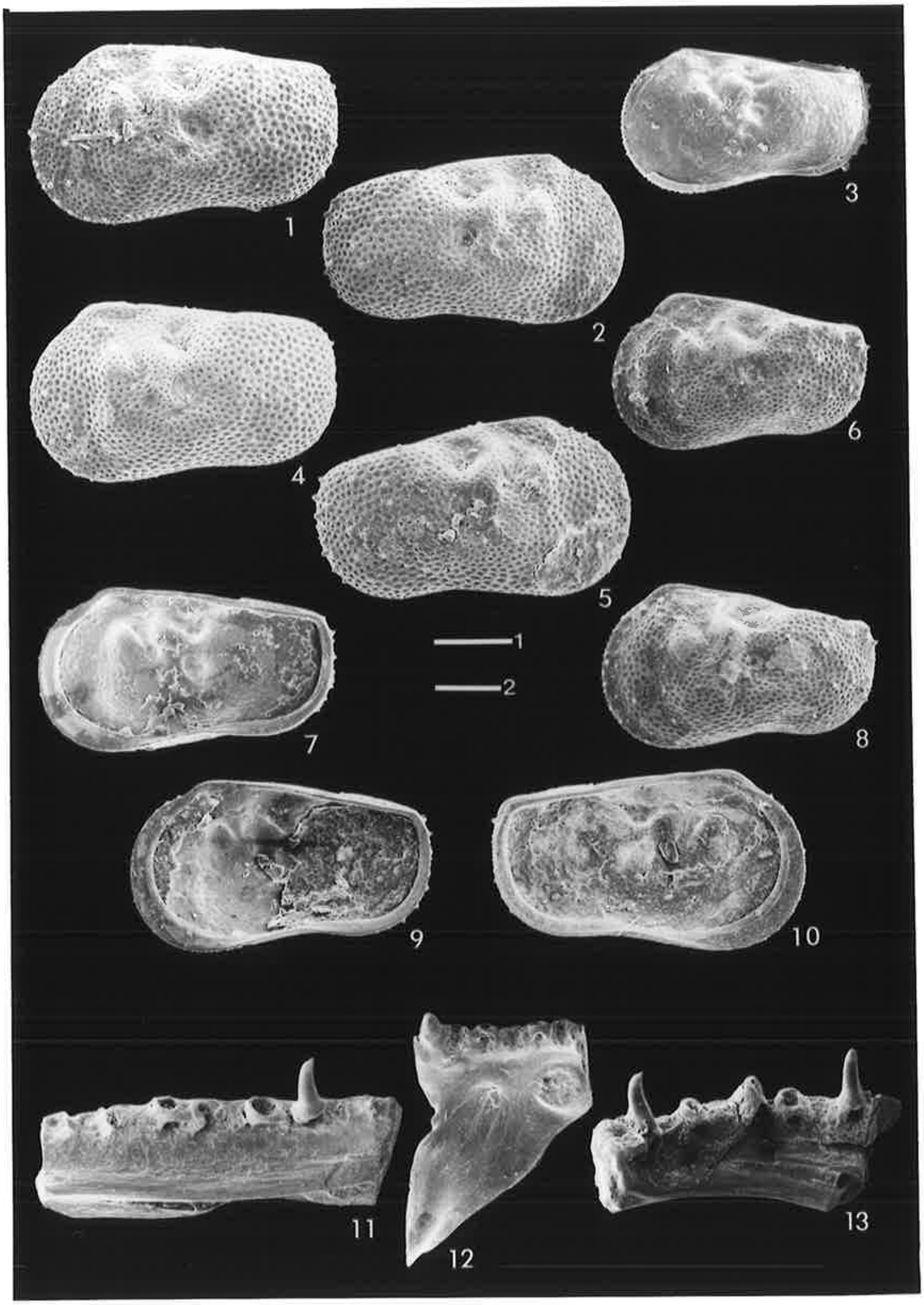

1
2
3
4
5
6
7
8
9
10
11
12
13
1
2

PLATE VII.3

Platycypris baueri Herbst, 1957

1 LV internal, LG134

2 LV internal, fragment, LG128

3 RV internal, fragment, LG128

4 LV internal, fragment, LG128

5 LV external, LG134

6 LV external, fragment, LG128

7 internal mold of C showing right side and fragment of RV, LG134

8 internal LV, partly broken, LG134

9 internal LV, fragment, LG128

10 same specimen as 7 but tilted to show latero-ventral view

Mytilocypris praenuncia (Chapman, 1936)

11 LV internal, partly broken, LG173.7

12 LV internal, LG134

13 LV internal, anterior broken off, LG173.7

14 RV internal, juvenile, LG173.7

15 RV internal, juvenile, LG134

16 LV internal, anterior and dorsum broken off, LG173.7

Mytilocypris praenuncia? (Chapman, 1936)

17 LV internal, anterior broken off, LG173.7

Scale: 1 - 250 μ for 1 - 10

2 - 500 μ for 11 - 17

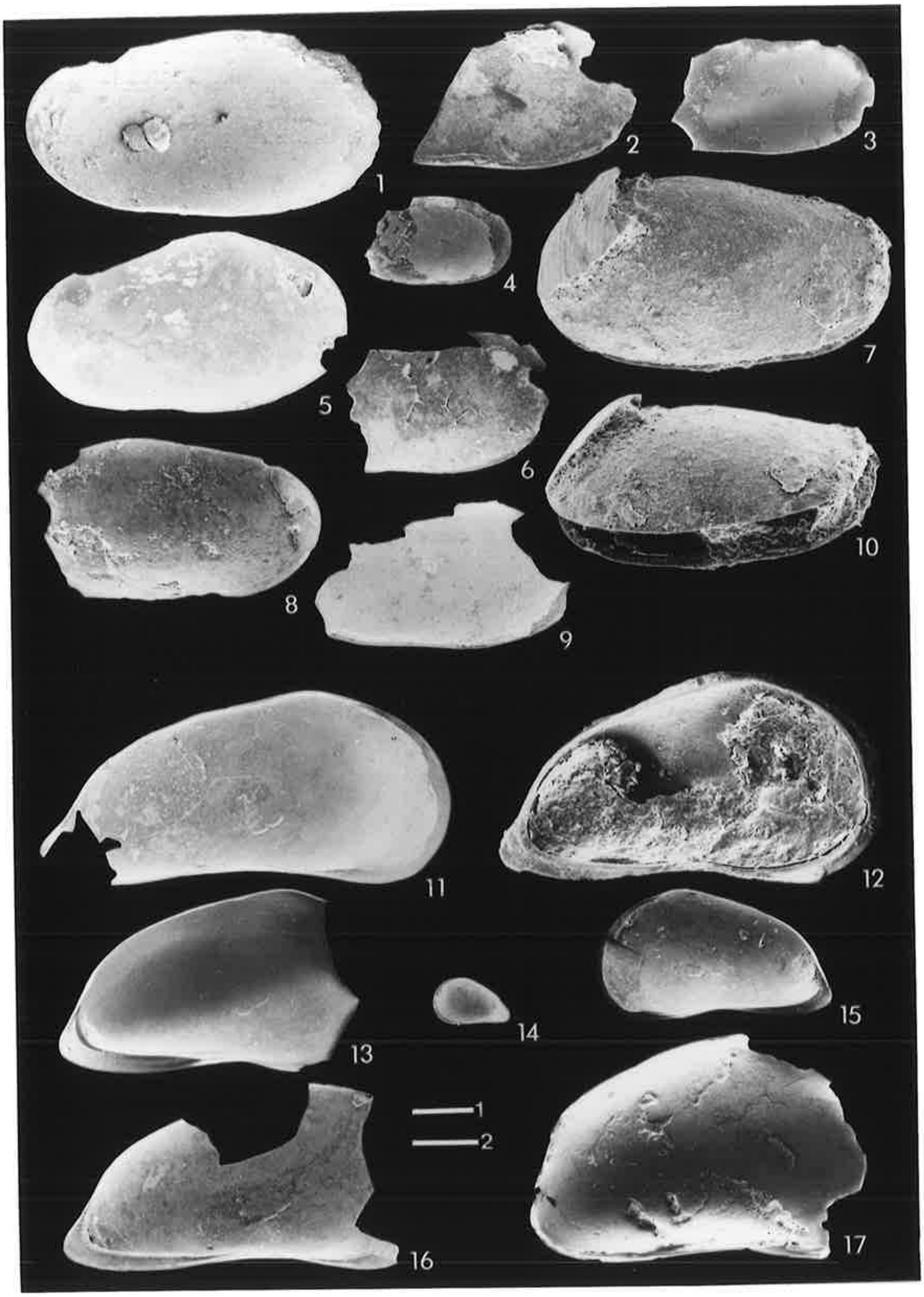

1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
1
2

PLATE VII.4

Ilyodromus viridulus (Brady, 1886)

1	LV external, LG149
2	RV external, LG149
3	RV internal, juvenile, LG149
4	LV internal, LG149
5	RV internal, LG149
6	RV external, LG149
7	LV external, juvenile, LG149
8	LV internal, juvenile, LG149
9	LV external, juvenile, LG149
10	RV internal, juvenile, LG149

Diacypris aff. *dictyote* De Deckker, 1980

11	RV internal, LG272
12	RV external, LG30
13	RV external, posterior detail of 12
14	LV internal, LG30
15	RV external, LG272
16	RV internal, anterior and dorsum broken off, LG272
17	RV external, detail of 12
18	RV internal, posterior detail of 11

Scale: 1 - 250 μ for 1 - 10

2 - 200 μ for 11 - 12, 14 - 16; 100 μ for 13, 18; 20 μ for 17

1

2

3

4

5

6

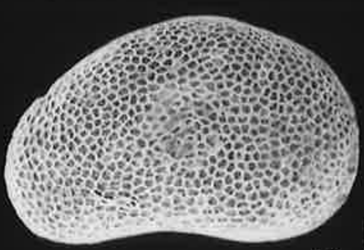
7

8

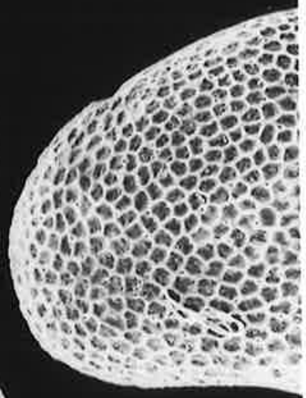
9

10

11



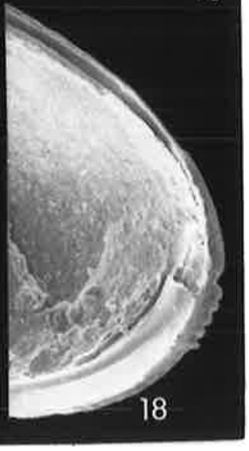
12



13

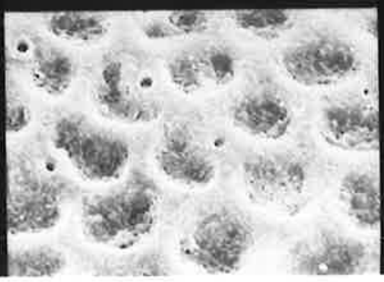
14

15



18

16



17

CHAPTER 8

OSTRACODS FROM A SHORT CORE FROM PILLIE LAKE, SOUTH AUSTRALIA

8.1 INTRODUCTION

This study is undertaken to trace, from the data obtained from fossil ostracods, the past history of a solution lake located near the coast. This is of particular interest since the Holocene history of coastal lakes near the Coorong Lagoon in South Australia is already known (von der Borch, 1976), allowing comparison with Pillie Lake. Additionally, since geochemical analyses of the core are provided by Dr. R.V. Burne, an examination is made to check whether past salinities of the lake, obtained from the fossil ostracod data, can be related to the different types of sediment.

Pillie Lake is situated 10 km south of Port Lincoln at the southern end of Eyre Peninsula (Fig. 8.1). The lake is approximately 1 km long, 0.5 km wide and is about 1 km from the bay at Port Lincoln Proper (Fig. 8.1). The lake forms part of a depression in the Quaternary calcarenites which cover most of the Eyre Peninsula. The lake floor consists of white carbonate clay (mainly aragonite), and when visited in November 1979, water was present only in small fissures in parts of the lake floor. There the ostracods *Mytilocypris praenuncia* (Chapman, 1936) and *Diacypris spinosa* De Deckker, 1980 were found swimming among very small mats consisting of the charophyte *Lamprothamnium papulosum* in water of 26.2°/oo salinity. Dead shoots of the halophytes *Ruppia* and/or *Lepilaena* sp. were also noticed on the dried lake floor.

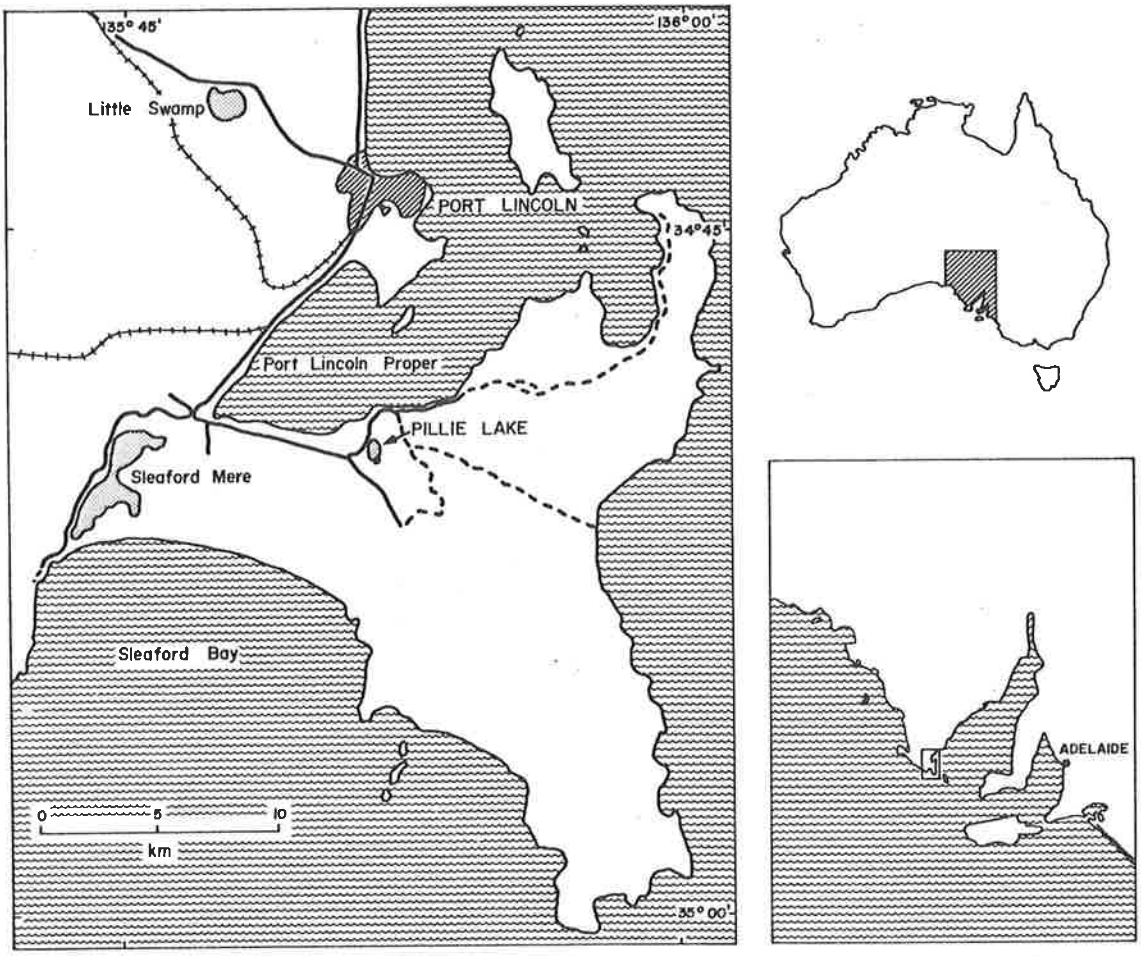


FIG. 8.1 Map showing the location of Pillie Lake on the Eyre Peninsula.

The fissures mentioned above are thought to be the location of major discharges of ground water during wet periods, usually during winter months when the water table rises.

8.2 METHODS

A 62 cm long core was taken in the centre of the lake which was dry at the time. Sixteen samples were taken at predetermined intervals from the core, and treated with diluted H_2O_2, and then sieved and dried in the same way as were samples from the Victorian lakes (see Chapter 5). Ostracods were picked but not counted. Only the presence and relative abundance of species in each sample was noted as the samples had dried prior to treatment. Disaggregation of the samples with diluted H_2O_2 was not complete and therefore not all valves were recovered after treatment.

8.3 RESULTS

The lithology of the 62 cm long core is described in Fig. 8.2. Sixteen samples, to be preceded by the letters LP, were taken from that core and their position is indicated in Fig. 8.2. Ostracods, isopod fragments, foraminifers, gastropods and charophyte oogonia were recovered. Taxonomic features and ecological significance of these fossils will be assessed before discussion of their presence in the samples tracing past changes in the lake history.

8.3.1 Systematics and ecological information

8.3.1.1 Ostracods

The ostracods found in the Pillie Lake core are easily distinguished from one another on the following shell features. The two *Mytilocypris* species have a large (∿3 mm) and triangular adult shell; *M. mytiloides* (Brady, 1886) (Plate VIII.3: Figs. 11-14) has a very pointed and most often narrow posterior in comparison with *M. praenuncia* (Chapman, 1936) which has a rounded posterior (Plate VIII.1: Figs. 1-3, 5, 6, 8, 9). The rectangular *Limnocythere mowbrayensis* Chapman, 1914 (Plate VIII.3: Figs. 1-6) has a broad lateral ala on each valve which is best visible in dorsal view.

Leptocythere lacustris n.sp. (Plate VIII.3: Figs. 8-10) has a much more reticulated shell than all the species discussed in this chapter and is characterized by a deep longitudinal groove anteriorly almost parallel to the curvature of the shell. *Reticypris* sp. (Plate VIII.1: Figs. 11-13) has a thin rectangular shell which is regularly reticulated. *Platycypris baueri* Herbst, 1957 (Plate VIII.1: Figs. 4, 7, 10) has a smooth rectangular to ellipsoidal shell with the convex area of the ventrum at ⅓ from the anterior. There are two *Diacypris* species with a smooth to pseudopunctate shell. *D. spinosa* De Deckker, 1980 (Plate VIII.4: Figs. 1-9) is characterized by posterodorsal spines along the valves margin, whereas *D. compacta* (Herbst, 1958) (Plate VIII.1: Figs. 14-21) has no spines and in the samples studied it has a more rectangular shape (elsewhere it is usually more circular). The thick shelled *Cyprideis australiensis* Hartmann, 1978 (Plate VIII.2) is diagnosed by the small posteroventral spine on the right valve and the numerous broad sieve pores on the outside of the shell.

Information on taxonomy and ecology for the species not fully described in Chapter 4 is provided below.

Cyprideis australiensis Hartmann, 1978

Plate VIII.2

1978 *Cyprideis australiensis* n.sp., Hartmann, p. 85.

1978 *Cyprideis westraliensis* n.sp., McKenzie, p. 176.

1979 *Cyprideis australiensis* Hartmann, Hartmann, p. 229.

Description: Ellipsoidal to rectangular shell with dorsum slightly more arched than ventrum which is faintly concave in the mouth region. Greatest height at about ⅓ from the anterior in male and about ½ in female. In dorsal view, the shell is much narrower in male with both extremities more or less bifid as the area where both valves meet does not extend as far as the longest parts of the valves. In female, the shell is broadest at about ⅔ from the anterior. The left valve is slightly longer all along its periphery. The right valve has a very distinctive but small posteroventral spine. The shell is thick (compared to other ostracods described below) with the external surface ranging from smooth to coarsely pitted. Many large normal sieve pores are common all over the shell. Internally, the inner lamellae are generally narrow but broadest anteriorly. The selvage is prominent, near the periphery in the left valve and met by a peripheral groove in front of the broad selvage in the right valve anteriorly. Posteriorly, in the right valve, the selvage is broad and near the edge of the shell. The hinge is amphidont with, at both extremities, elongated rows of teeth in the right valve and corresponding sockets in the left valve. The central muscle field consists of a vertical row of four adductor scars with a V-shaped scar above and in front, and between them there is a small but prominent fulcral point. There is also a much larger mandibular scar in front of the vertical row of four and below the V-shaped scar, and a smaller one just below the vertical row. Both valves are perforated especially in the dorsal area. Juveniles have a more arched dorsum with the greatest height usually at about 2/5 from the anterior. The diagnostic spine is also present on the right valve.

Size range: Adults: L: 1,100-1,300 μ.

Ecology: *C. australiensis* has been collected by Hartmann (1978, 1979) from a number of saline localities in Western Australia but these are not athalassic as they all form part of estuaries. The salinity range for his collections is 2.2-35°/oo. The synonymous species, *C. westraliensis*, was described by McKenzie (1978) from two Western Australian athalassic saline lakes: Lake Preston at 64.5°/oo and Lake Coolongup at 10.3°/oo salinity (data from Williams and Buckney, 1976). This species has also been collected at 12.9°/oo salinity (16.11.1978) in South Australia from the Coorong Lagoon which is indirectly connected to the sea. It has been found in Little Dip Lake near Robe at a salinity of 28°/oo and on the Eyre Peninsula in South Lake Newland at 29.2°/oo salinity. This ostracod, like other species in the genus, typically inhabits estuaries. It has never been found in any ephemeral salt lake and this confirms the fact that it requires permanent water to reproduce as, like marine ostracods, it does not have eggs which can withstand desiccation and additionally, as it broods its first instar in the shell (McKenzie, 1978). The transport of this ostracod into permanent salt lakes is likely to have been caused by birds, a phenomenon recently reviewed by De Deckker (1977).

Remarks: *C. australiensis* and *C. westraliensis* are synonymous and descriptions of each species were both published in November 1978. The former nomen is recognized here as the valid one as Hartmann (1978, 1979) provided more illustrations (especially a more complete one for the diagnostic hemipenis) and a more complete description of the species. This species is easily recognized by its thick shell and the posteroventral spine in the right valve.

Reticypris sp.

Plate VIII.1: Figs. 11-13

Description: Shell rectangular in shape and regularly reticulated all over except along the periphery of each valve. The dorsum is inclined behind the greatest height which varies between ⅓ and ½ from the anterior. The ventrum is slightly concave behind mid-length. The shell is narrow in dorsal view with both ends tapering. The left valve is larger and often overlaps the right one dorsally where it is taller. Internally, the anterior inner lamellae are larger. The selvage is very faint anteriorly and placed half-way between the inner margin and the edge of the valve whereas posteriorly it is near the inner lamella and prominent but narrow.

Size range: L: 650-820 μ.

Remarks: Two *Reticypris* species, *R. herbsti* McKenzie, 1978 and *R. clava* n.sp. (= *R.* n.sp.1 in De Deckker and Geddes, 1980) cannot be distinguished on the features of the shell alone. The only way to distinguish both species at the fossil stage is to compare the "ostracod assemblages" in which they are found as both species have different salinity tolerances. *R. clava* was found in South Australia near the Coorong Lagoon by De Deckker and Geddes (1980) at salinities between 5-131°/oo and in Victorian lakes between 4-42°/oo. *R. herbsti* is found in the same surveys between 12-141°/oo with rare records up to 218°/oo and 99-172°/oo respectively. It is likely that the rare specimens found in the core from Pillie Lake belong to *R. clava* as it co-occurs in the samples with *L. mowbrayensis* which inhabits waters below 6°/oo salinity.

8.3.1.2 Isopoda

Haloniscus searlei Chilton, 1920
Plate VIII.3: Figs. 21, 22

1920 *Haloniscus searlei* n.sp., Chilton, p. 724.

Remarks: Only exoskeletal fragments of this isopod have been recovered in the samples studied here. These consist mainly of elongated cones which are slightly arched and hollow. They are brittle and their external surface consists of parallel rows of disconnected and alternating faint and arched grooves. Occasionally rimmed pores with two smaller pores inside and one below are present. These fragments with pores (Plate VIII.3: Fig. 22) belong to the distal segments of the posterior appendages of the animal whereas those which are more conical (Plate VIII.3: Fig. 21) and without pores correspond to spines attached to the telson. Such exoskeletal fragments have also been found in Holocene lacustrine sediments from the maar Lakes Keilambete and Gnotuk in Victoria (see Chapter 5). They indicate that water was saline and either permanent or at least present every year. This oniscoid isopod inhabits a variety of saline water bodies from 3.6 to 191.7°/oo salinity (Williams, in press) and most of these are permanent, but *H. searlei* can survive periods of desiccation (De Deckker and Geddes, 1980; Williams, in press) provided that the lake is filled with water every year. It appears that this isopod can survive short periods of lake desiccation by seeking cover and moisture under mats of dead halophytes often seen on the lake floors. Long periods of drought would prevent *H. searlei* from colonizing saline water bodies and this appears to explain its absence in salt lakes in central Australia as periodicity of rainfall becomes less constant further away from the coast. Consequently, the presence of *H. searlei* indicates either permanent water conditions or a periodicity of rainfall such as seen for areas where lakes would be filled every year.

8.3.1.3 Foraminifera

Elphidium sp. *sensu*, Cann and De Deckker, in press
Plate VIII.3: Fig. 15

19.. *Elphidium* sp. group A, Cann and De Deckker, p. *

Description: Test planispiral, involute and finely perforate. The number of chambers in the final whorl varies between 9 and 13. The chambers increase in size gradually. There is no keel and no umbilical boss. The aperture is a thin interiomarginal arch-like slit surrounded by many small pointed tubercles. Sutures are broad, depressed, straight to gently curving and filled with many tubercles especially in the umbilical region. Retral processes are often covered.

Size range: Average diameter 650 μ and width through the umbilical region about 220 μ.

Ecology: This species, recently studied by Cann and De Deckker (in press) and De Deckker and Geddes (1980), is common in many ephemeral athalassic salt lakes in the region of the Coorong Lagoon in South Australia. Cann and De Deckker (in press) demonstrated that it can withstand phases of lake desiccation and that therefore there is no need for a connection to marine water for *Elphidium* sp. to occur in a salt lake and that the lake does not necessarily need to have permanent water. This is further demonstrated by the presence of this species in Holocene sediments in the maar Lakes Gnotuk and Keilambete in Victoria which are some 30 km from the sea (see Chapter 5). These lakes had permanent water at the time as indicated by the presence of another foraminifer *Ammonia beccarii* (Linné, 1758) in the same samples (see

---

* Manuscript due for publication in May 1981.

Chapter 5). As for the isopod *H. searlei*, it is suggested that rainfall periodicity has to be constant for the lakes in which these organisms live, to fill them with water every year, as they seem not to survive long periods of lake desiccation. This would explain the absence of foraminifers in ephemeral lakes a long way from the coast where rainfall periodicity becomes more variable. The salinity range of this species is not known as it was not possible to assess whether they were alive at the time of collecting in the ephemeral salt lakes: protoplasm remains coloured for long periods of time after death (De Deckker and Geddes, 1980 and Cann and De Deckker, in press). The latter authors demonstrated that *Elphidium* sp. can survive, in a "dormant" stage, salinities up to 80°/oo or more for some time and pseudopodia would protrude from the test after placing the specimens in sea water.

Remarks: Cann and De Deckker (in press) did not provide a specific name for their specimens which are similar to those mentioned here as they felt that the morphology of *Elphidium* sp. in the salt lakes near the Coorong Lagoon was so variable that, until ecological factors affecting such morphological changes are known, there is uncertainty on the species identity.

8.3.1.4 Gastropoda

Coxiella sp.
Plate VIII.8: Figs. 16-29

Remarks: Shells of the halobiont gastropod *Coxiella* sp. were found in the upper two samples from the Pillie Lake core. The taxonomy of *Coxiella* is in a confused state at present (De Deckker and Geddes, 1980 and Mellor, 1979). Apart from the fact that these gastropods are not found in fresh water, no ecological information can be obtained from the fossil material, until they can be identified at the specific level. In the Victorian deep maar lakes study (see Chapter 5), the presence of *Coxiella* sp. was of significance for reconstructing water depths for the lakes but this does not apply for the shallow Pillie Lake.

8.3.1.5 Characeae

Until recently, the presence of fossil charophyte oogonia in sediments was used to indicate the presence of fresh water. Burne *et al.* (1980) demonstrated that at least *Lamprothamnium papulosum* grows in saline waters and that it can photosynthesize efficiently at salinities up to one or two times that of sea water.

The oogonia recovered from the Pillie Lake core are thought to belong to *L. papulosum* as they are very elongated compared to other charophyte oogonia found in the south east of Australia. This identification, however, cannot be used with certainty as overall shapes of *L. papulosum* oogonia can vary extensively even though they most often remain elongated (for variations see Plate VIII.4: Figs. 10-16). This phenomenon can be explained as the habit of this alga varies in different salt lakes, probably due to changes in water salinity, oxygen content of the water and temperature. Such changes are characteristic of salt lakes.

The presence of charophyte oogonia in the core, tentatively identified as *L. papulosum*, indicates saline water conditions.

8.3.2 History of Pillie Lake

The following events in the history of Pillie Lake can be recognized from the fossil data.

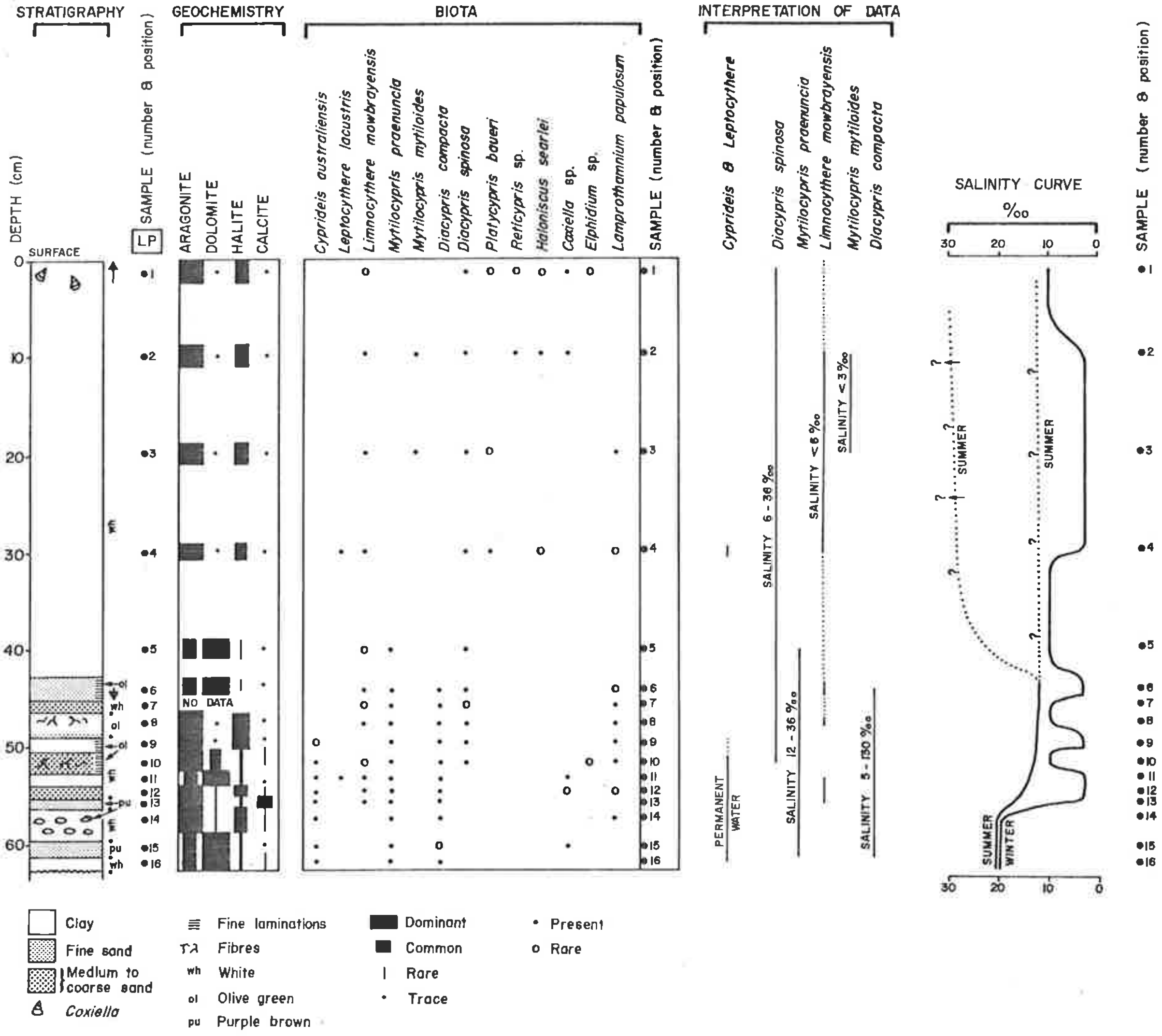


FIG. 8.2 Stratigraphy, geochemistry, fossil ostracods and other remains recorded from the Pillie Lake core, and the interpretation of the data from fossil ostracods for past salinity levels of the lake.

- The presence of *Cyprideis australiensis* in samples LP10 to LP16, with rare valves of the species in LP9, indicates that water was permanent in the lake for the time of deposition of levels LP16 to 10 and perhaps LP9.

- At some stage during the years when *Limnocythere mowbrayensis* was present, water salinity for the lake must have been below 6°/oo (samples LP2-4, 6, 8 and 11-12). This phenomenon is less certain for other samples where the species is rare: LP1, 5, 7, 10 and in LP13 where only juveniles have been recovered. Water was probably permanent at some stage for samples LP2-4, 6, 8 and 11-12.

- The elongated specimens of *Mytilocypris mytiloides* in samples LP2, 3 indicate water salinity below 3°/oo and the shorter specimens in sample LP3 indicate that salinity could have reached 25°/oo.

- The record of *Diacypris spinosa* in samples LP1-10 indicates that during winter months, water salinity was likely to be below 20°/oo salinity. It is interesting to note that when water was permanent (as indicated by the presence of *C. australiensis*), *D. spinosa* was absent (except in LP9 where one valve of *C. australiensis* was found and LP10 where the species is poorly represented).

- As *Leptocythere lacustris* and *Elphidium* sp. are few in number in the samples in which they occur, they are of little palaeoecological significance here.

- The presence of *Haloniscus searlei* shows that, in addition to the other fossils which indicate that the lake was subject to drying up in the upper part of the core, the drying up phases were probably similar to that of today.

Past changes in the lake history are summarized in Fig. 8.2 and described below.

Water was permanent between LP16 and 10 and the average winter salinity* was of the order 20°/oo until LP13 and then salinity dropped to around, or less than 6°/oo until LP11. It is likely that salinity was higher at other times as *M. praenuncia* is also present in these samples since the lowest salinity tolerance for this species is 12°/oo.

For LP9 and younger layers, water was probably not permanent and salinity fluctuated although it remained generally low (<10°/oo) in winter. It was definitely below or around 6°/oo at some stage for LP8 and 4-2 as shown by the presence of *L. mowbrayensis*. For the other samples it was below 20°/oo in winter because *D. spinosa* found in them requires such salinities in winter. An exception probably occurs for samples LP7 and 5 where *D. spinosa* is rare.

8.3.3 Discussion on supplementary data obtained from the Pillie Lake core

Pillie Lake is likely to be filled with water from a combination of rainwater falling directly on the lake floor and from ground water discharge into the lake. The latter process should therefore be

---

* All the salinity values discussed here refer to winter values for a number of reasons:

- From the work of De Deckker and Geddes (1980) on the fauna of lakes near the Coorong Lagoon, it appears that water salinity, during the winter months, is the factor controlling the presence of ostracods - water salinity very likely controls the hatching of the ostracods.

- As the catchment area of Pillie Lake is small, the lake could never be very deep. It is therefore easier to predict winter salinities rather than the summer ones since the latter are likely to fluctuate extensively from year to year. Additionally, a sudden retreat of the water table in summer could cause the lake to dry up without the salinity of the water reaching high levels.

similar to that described for the lakes adjacent to the Coorong Lagoon in South Australia by von der Borch *et al.* (1975). There a "freshwater" lens overlies generally denser interstitial water of oceanic origin and, additionally, there is a zone of continental and marine water which is diffuse and highly complex when it is close to the sea (von der Borch, 1976). Assuming that this phenomenon occurs for Pillie Lake, the recognition of salinity changes in the lake history would indirectly provide information on movement of the zone of interface between marine and continental waters. Saline water would indicate discharge of water from the marine groundwater zone whereas, water of low salinity would indicate discharge of continental groundwater. Therefore the change from permanent to ephemeral water associated with a progressive decrease in water salinity from the bottom of the core to the top, would indicate a progressive decrease in marine groundwater influence. This would result from a progressive regression of the sea. Dating of the sediments from the core would provide a better definition of this postulated phase of sea regression. It is suggested here that it corresponds to the lowering of the sea level recorded since the last high sea level strand placed at around 6,000 yBP for the Coorong area in South Australia by von der Borch *et al.* (1975) and von der Borch (1976). ^{14}C dating of sediments from the core studied here should verify this hypothesis.

It is interesting to note that the distribution of ostracods in the samples when compared to the chemical analyses of the sediments of the corresponding samples (provided by Dr. R.V. Burne - see Fig. 8.2) has led to the discovery of an unusual phenomenon: dolomite was being precipitated in Pillie Lake under a variety of conditions. For samples LP10-11 and 15-16, dolomite was precipitating when permanent water conditions prevailed. This is the opposite case for dolomite formation in the Coorong area where von der Borch (1976) demonstrated that this occurs in ephemeral lakes which are fed solely by evaporitically modified continental groundwater. However, Folk and Land (1975) have postulated that the phenomenon noticed here in the bottom part of Pillie Lake (LP10-11 and 15-16) is feasible provided that reduction in salinity occurs, in what they called the schizohaline environment, that is where hypersaline and near fresh conditions alternate. Such conditions could have occurred in the phreatic mixing zone of Pillie Lake. The high Mg/Ca was therefore maintained, as it appears today in the water of the lake emerging from the fissures $(\frac{Mg}{Ca} = \frac{20}{1})$ in the lake floor. Under the conditions postulated by Folk and Land (1975) water can remain permanent in a lake and dolomite can still precipitate. On the other hand, at a younger stage in Pillie Lake, in samples LP5-6, dolomite was formed under ephemeral water conditions and there is indication that salinity of the lake water in winter was at least below 20°/oo. These latter conditions are more in line with those postulated by von der Borch (1976) for the lakes distal to the Coorong Lagoon.

The palaeoclimatological implication of the results obtained from the Pillie Lake core will not be dealt with in Chapter 9 since ^{14}C dates are not yet available for timing the events mentioned above.

PLATE VIII.1

Mytilocypris praenuncia (Chapman, 1936)

1 LV internal, posterior broken off, LP10
2 LV internal, juvenile, LP10
3 RV internal, juvenile, LP10
5 RV internal, LP10
6 LV internal, LP10
8 LV external, LP5
9 RV external, LP10

Platycypris baueri Herbst, 1957

4 LV internal, dorsum broken off, LP4
7 RV external, dorsum distorted and partly broken off, LP4
10 RV external, dorsum distorted, LP4

Reticypris sp.

11 RV external, LP2
12 LV external, LP2
13 RV internal, LP2

Diacypris compacta (Herbst, 1958)

14 RV external, LP14
15 LV external, LP14
16 LV external, LP14
17 LV internal, LP14
18 LV internal, LP14
19 RV internal, LP14
20 RV internal, LP14
21 LV dorsal, LP14

Scale: 1 - 500 μ for 1 - 3, 5 - 6, 8 - 9;
250 μ for 4, 7, 10
2 - 200 μ for 11 - 21

LP = Pillie Lake followed by sample number

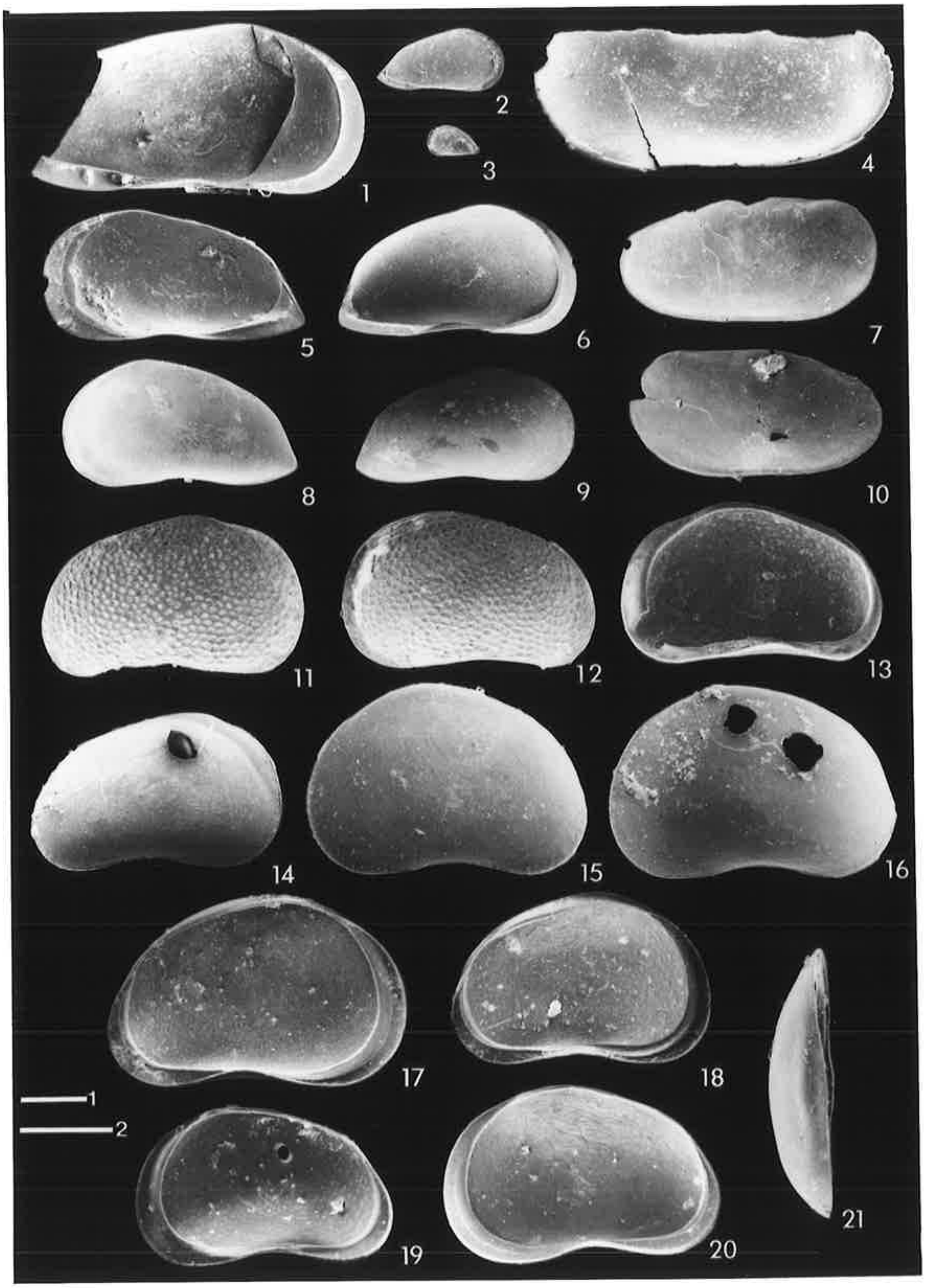

1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
1
2

PLATE VIII.2

Cyprideis australiensis Hartmann, 1978

1	LV external, female, LP12
2	RV internal, male, LP15
3	C dorsal, female, LP15
4	LV external, female, LP12
5	RV external, female, LP12
6	LV external, male, LP15
7	RV external, male, LP15
8	C dorsal, male, LP15
9	LV internal, male, LP15
10	RV internal, male, LP15
11	RV external, juvenile, LP15
12	LV external, detail of 6
13	LV external, juvenile, LP15
14	RV external, juvenile, LP15
15	LV external, juvenile, LP15

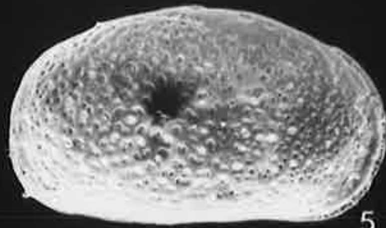
Scale: 500 μ for 1 - 11, 13 - 15; 50 μ for 12

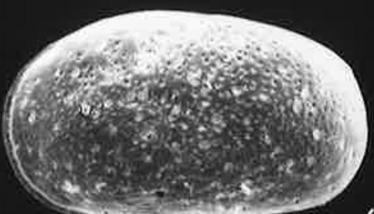

1


2


3

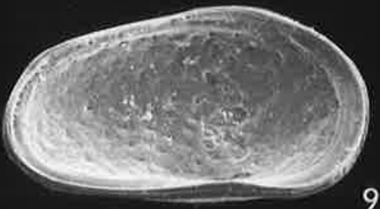

4

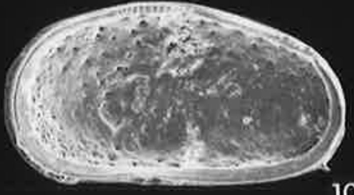

5


6

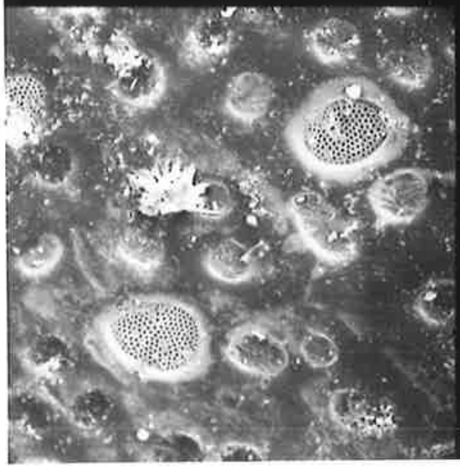

7


8


9


10


11


12


13


14

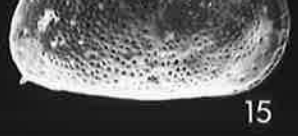

15

PLATE VIII.3

Limnocythere mowbrayensis Chapman, 1914

1 LV external, male, LP2
2 RV external, female, LP2
3 RV external, male, LP2
4 RV external, female, LP2
5 RV external, juvenile, LP2
6 C dorsal, male, LP5
7 RV internal, female, LP2

Leptocythere lacustris n.sp.

8 LV external, LP11
9 LV internal, LP11
10 LV external, LP11

Mytilocypris mytiloides (Brady, 1886)

11 RV internal, anterodorsal area broken off, LP2
12 LV internal, anterior and dorsum broken off, LP2
13 LV external, LP2
14 RV internal, LP2

Elphidium sp.

15 side view, LP16

Coxiella sp.

16 dorsal view, LP1
17 apical view, LP1
18 apertural view, LP1
19 umbilical view, LP1
20 apertural view (aperture area broken off), LP1

Haloniscus searlei Chilton, 1920

21 fragment of spine attached to telson, LP2
22 fragment of distal segment of posterior appendage, LP2

Scale: 1 - 200 μ for 1 - 10, 15
2 - 500 μ for 11 - 14, 16 - 22

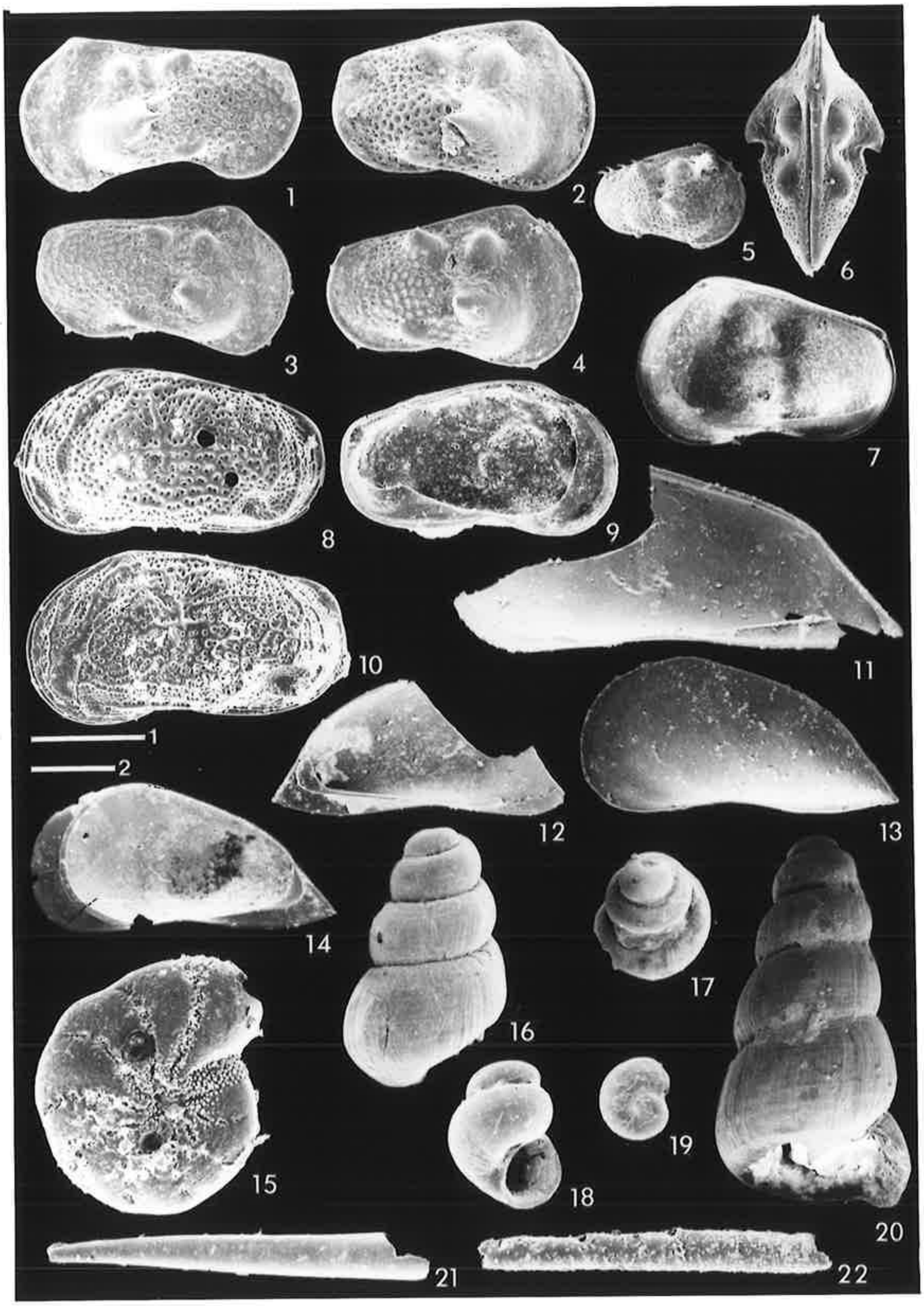

1
2
5
6
3
4
7
8
9
10
11
1
2
12
13
14
16
17
15
18
19
20
21
22

PLATE VIII.4

Diacypris spinosa De Deckker, 1980

1 LV external, LP10

2 LV internal, LP10

3 RV external, juvenile, LP10

4 LV internal, LP10

5 RV external, LP10

6 RV internal, LP10

7 RV internal, LP10

8 RV internal, juvenile, LP10

9 RV external, juvenile, LP10

Lamprothamnium papulosum - charophyte oogonium

10 side view, LP10

11 side view, LP10

12 side view, LP10

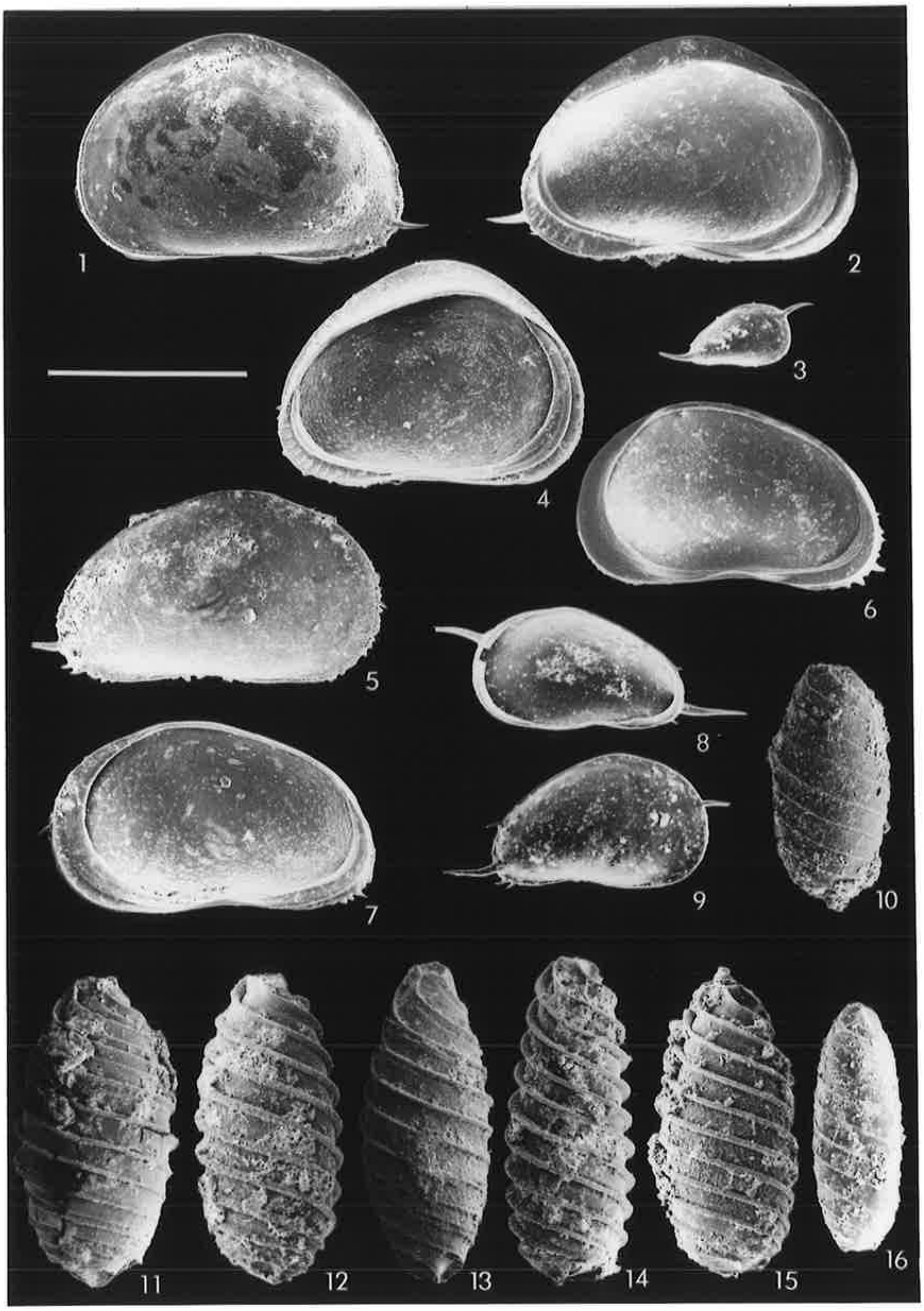
13 side view, LP10

14 side view, LP10

15 side view, LP10

16 side view, LP10

Scale: 500 μ


1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16

CHAPTER 9

CONCLUSIONS

9.1 INTRODUCTION

The previous four chapters have indicated that, through the study of fossil ostracods, it is usually possible to extrapolate data on past water quality and environmental conditions. In the present chapter, these data are considered *in toto*. It will deal, firstly, with palaeoclimates (section 9.2), then with ostracod palaeoecology (section 9.3).

It is important to recognize that palaeoclimatic information registered in a sedimentary sequence deposited in a waterbody can only apply directly to the climatic zone which includes the waterbody. Even though similar lakes with similar water budgets should have reacted in the same fashion to climatic changes, it is not an easy task to determine all the factors which affect lakes. For example, Lakes Gnotuk and Keilambete, which are similar in many ways, did not register similar changes in water salinities all the time. There are discrepancies which remain as yet unexplained (see discussion below).

9.2 PALAEOCLIMATES

9.2.1 Information available from ostracods and lakes

In the case of the four maar lakes in Victoria, the recovery of ostracods permitted a reconstruction of water level curves for each lake. For lakes Gnotuk and Keilambete, it was assumed that an increase in water salinity (as indicated by the ostracod fauna) corresponded to a decrease in lake level and *vice versa*. For the deeper Lake Bullenmerri, the presence of ostracods indicated a shallowing of the lake since no ostracods are present at great depths due to the formation of an anoxic layer. Little information could be obtained from Lake Purrumbete since ostracods were absent in the entire core. This suggests that water remained fresh and the lake level had not dropped dramatically during the last 7,000 years. Lakes Gnotuk and Keilambete proved to be more sensitive recorders since salinity changed more drastically and frequently. This is a direct result of their smaller volume of water and shallower water depth compared to Lake Bullenmerri. These two lakes (Gnotuk and Keilambete), dried up during the very arid phase prior to the last 10,000 years and this would explain the flat bottom topography of each lake as pedogenesis must have prevailed during that period. (This phase is already documented for Lake Keilambete in Bowler and Hamada (1971).) Lake Bullenmerri did not dry up during that period as demonstrated by Dodson (1979). A study of the ostracod fauna from a longer core (>5 m long) would be informative for the period predating 10,000 yBP.

It is interesting, however, to note that the similar lakes Gnotuk and Keilambete did not register identical and synchronous salinity changes for some periods during the last 10,000 years. The total dissolved solids content of the water of Lake Gnotuk must have changed fairly drastically after each flooding by some of Lake Bullenmerri's water. Lake Keilambete therefore should prove to be a more reliable and accurate recorder but one should be aware of all the additional difficulties in interpreting changes of salinities since precipitation of salts alters water salinity. At present, the extent of such change cannot be assessed. Additionally, the amount of salts lost during the high water levels of Lake Keilambete, causing the lake to overflow, cannot be estimated. Fluctuations of water levels recorded in Lakes Bullenmerri, Gnotuk and Keilambete will be referred to in the discussion on climatic changes below (section 9.2.3).

The sequence studied at Lake George obviously yields more information since it covers a much longer time span. However, as the coring site was chosen in one of the shallowest areas of the lake, only the significant wet phases of the lake were recorded. Large fluctuations of water salinity did not occur at Lake George, compared to the Victorian maar Lakes Gnotuk and Bullenmerri, since salts do not appear to have continuously accumulated in this large basin (salts were probably lost through deflation processes and through the water table). The ostracod data at Lake George, on the other hand, indicates whether water had been permanent, ephemeral or absent and whether it had been fresh or slightly saline. The difficulty in interpreting the Lake George core lies in the fact that ^{14}C dates are too few to date accurately the changes recorded in the core.

Like that of Lake George, the records of Pulbeena and Mowbray Swamps are important because they represent long periods of time. At both Tasmanian sites, the ostracod fauna testifies to the presence of water and whether it was permanent or ephemeral. Supplementary information was also provided by correlating water flow from the springs with diversity of the ostracod fauna. All these data can be used to interpret the spring's activity at both sites and, assuming that they are a direct reflection of precipitation, information on past climates could be presented.

Errors in timing events registered in Lake George, Pulbeena and Mowbray Swamps should be greater for these sequences which cover a long time span because each sample represents a much longer period of time.

Additionally, errors are likely to be made because, in all three sites, it has been impossible to assess sedimentation rates to extrapolate with confidence dates for the various events (e.g. dates for the events prior to 25,000 yBP at Lake George are to be considered with caution because the effects of pedogenesis and deflation during the dry phases are not known). The three maar lakes (Lake Purrumbete is ignored here) are therefore better recorders for the Holocene period since quite a number of ^{14}C dates are available for the assessment of sedimentation rates, and because samples represent a time shorter time interval.

The study of the ostracod fauna at Pillie Lake cannot, at this stage, yield much information on past climates since no ^{14}C dates are yet available. It illustrated, however, a progressive change in water salinity and change from permanent to ephemeral water conditions. The two factors are thought to be related to a regression of sea level affecting the marine-freshwater groundwater interface.

9.2.2 Previous data

Most palaeoclimatic information for Australia derives from palaeobotanical data. Rarely are water levels of lakes derived from these data which are mainly concerned with changes of vegetation and from which climatic changes are extrapolated. The most significnat studies in eastern Australia are those of Kershaw (1978) for north-eastern Queensland for the glacial-interglacial period, Dodson (1974a) for Lake Keilambete for the Holocene, Dodson (1974a, 1975) for Lake Leake in south-eastern South Australia for the last 50,000 years, Colhoun *et al.* (in press) and van de Geer *et al.* (in prep.) for Pulbeena and Mowbray Swamps respectively and Singh (in press) for the Holocene of Lake Frome in South Australia.

Water level curves for waterbodies in Australia are few. The work of Bowler (1970, in press) and Barton *et al.* (in press) which discussed changes of the water level of Lake Keilambete for the Holocene, and that of Bowler and Hamada (1971) which extended the water level curve for the last 30,000 years for the same lake, were based on analysis of sediments. Additionally, Bowler *et al.* (1976) presented a water level curve for the Willandra lakes in western New South Wales for the last 45,000 years based on studies of sediments and geomorphological features characteristic of arid and wet phases.

The water level curve based on studies of sediments and plant microfossils of Singh *et al.* (in press, b) for Lake George, and which includes the information of Coventry (1976) and Coventry and Walker (1977) based on stranded shore lines for the last 25,000 years for the same lake, covers the last 400,000 years by extrapolation from the palaeomagnetic record.

9.2.3 Interpretation

Although it has been the subject of many discussions (Galloway, 1970, 1971; Dury, 1973; Brackenbridge, 1978), it has not yet been possible to estimate which of the two factors, evaporation and precipitation, or which proportion of each, changed in the past and directly caused lake levels to change. However, provided it is possible to determine these factors and their effects, correlation of water levels with changes of climates should become a relatively simple task for the maar lakes' studies since these lakes are small closed basins with well-defined catchment areas.

Discussion here will be restricted to the changes in water levels, water quality or water regimes for the sites studied, assuming that such changes are direct reflections of climatic alterations. No reference, however, will be made to possible changes in evaporation and/or precipitation.

The following changes during the Holocene are obtained for the maar lakes principally, and from Lake George to a lesser extent.

During the last 2,000 years, lake levels in the maar lakes were generally higher than that of today. A drop in lake levels for the last 150 years has been reported by Bowler (1970) for Lake Keilambete and Currey (1970) for Lake Bullenmerri. It is not known whether this is due to an anthropogenic effect. Currey (1970) and Churchill *et al.* (1978) reported the suggestion of Sutcliffe (*in* Currey, 1970) that this drop in lake level was caused by an increase in annual temperature, but this has not been further substantiated. The water level of Lake George fluctuated frequently for the same period of time (Burton and Wilson, 1973) and since the lake was often dry, it is not possible to detect a general trend in the change of lake level.

In Lake Keilambete, two episodes of level drop were recorded at about 300 yBP and around 600-750 yBP. This was not detected in Lake Bullenmerri. The oldest of these two events was also detected by Barton *et al.* (in press) on their magnetic curve. There is no record available for that period for Lake Gnotuk. These two short events have not been detected elsewhere in Australia.

Lake levels were high in Lake Bullenmerri and Keilambete until approximately 1,800 years ago. In Lake Bullenmerri, tree stumps, dated at approximately 1,800 yBP and which emerged during the drop in lake level which started about 150 years ago, indicate that lake levels were low at around 1,800 yBP. Similar tree stumps, dated at 1,890 yBP by Bowler (1970), have emerged recently near the shore line of Lake

Keilambete which has a continuously dropping water level (Bowler, 1970; Barton, 1978). The presence of tree stumps on the shore of both lakes, and dated 1,800-1,900 yBP, indicate that after that period of time, lake levels rose to submerge the trees until recently and that no drop in lake level occurred during the last 1,800 years otherwise the tree stumps would have decayed and would not have been found in recent times.

Other tree stumps, which recently emerged on the shore of Lake Gnotuk (Yezdani, 1970), should be dated to establish whether the change in water level extrapolated here at around 1,300 yBP for that lake is accurately dated or whether it should be synchronous with the changes recorded in the other two maar lakes at around 1,800 yBP. The period of high lake level mentioned above is not recorded in Lake George.

Between 1,800 yBP and 3,800-4,000 yBP, lake levels were lower or closer to that of today for the three maar lakes and even fluctuated at times. At Lake George, however, during that period of time, there is evidence of short periods of the lake filling up with freshwater. No explanation can be offered for this difference in lake levels registered in the two different regions.

Between 3,800-4,000 yBP and 5,500-5,600 yBP, the water level rose in all three maar lakes. In both Lakes Gnotuk and Keilambete, levels were higher than today. At approximately 5,500-5,600 yBP and before, lake levels were even higher. The duration of this period is not well defined but, from the record in Lakes Bullenmerri and Gnotuk, it appears to have lasted about 400 years. From Yezdani's (1970) record for Lake Gnotuk, and from the record of Lake Keilambete, this period lasted perhaps 800 years. The record at Lake George for this period is not satisfactory since the timing of lake fluctuation is poorly defined. Although Singh *et al.* (in press b) postulate a freshwater phase between

5,000 and 6,500 yBP for Lake George, the ostracod data do not substantiate this.

During the 6,000-7,000 yBP period, lake levels fluctuated. Between 6,000-6,600-6,700 yBP, water levels were higher than those of today in Lakes Gnotuk and Keilambete. In Lake Bullenmerri, it was probably similar. At about 6,600-6,700 yBP, there was a transition in Lakes Bullenmerri and Gnotuk: before that time, lake levels were much lower. This transition is not recorded in Lake Keilambete. This particular low level phase had started at 7,800 yBP in Lake Bullenmerri and 8,300 in Lake Gnotuk. The record of Lake Keilambete indicates the opposite: the lake level was higher than that of today between 8,300 and 7,200 yBP (extrapolated from the absence of ostracods which is explained by the lake being deep and stratified). In Lake George, lake levels fluctuated but the timing of these fluctuations is not available (except for one short high water level phase dated at 6,800 yBP) and there is disagreement between Singh *et al.*'s (in press b) data and the ostracod data.

At 8,300 yBP a synchronous event is recorded in all three maar lakes: before that time lake levels were much lower than that of today. In Lakes Gnotuk and Keilambete, lake levels remained low between 8,300 and 10,700 yBP. In Lake Bullenmerri, it is only possible to say that it remained low between 8,300 and 8,700 yBP because the record (obtained from the core studied here) does not extend past that period of time although there is no evidence of the lake having dried up for the last 16,000 years (Dodson, 1979).

On one occasion, at 8,900 yBP in Lake Gnotuk and at 9,100 yBP in Lake Keilambete, there is evidence of the lakes having dried up for a short period of time [the timing of these events could be synchronous because the dates mentioned above result from correlation with other cores and are therefore approximated].

Between 10,000-10,200 yBP and 10,700-10,800 yBP the two maar lakes Gnotuk and Keilambete were subject to drying up and lake levels were the lowest ever recorded for the last 10,700-10,800 years.

At Lake George, on the other hand, during the 7,500-9,500 yBP period, water was present in the lake and prior to that period, between the 9,500-12,000 yBP period, the lake was definitely full and contained fresh water.

The timing of events prior to 25,000 yBP recorded at Lake George has been previously queried in Chapter 7 because of the lack of ^{14}C dates. Similar problems apply for the two Tasmanian sites studied here since sedimentation rates cannot be assessed adequately and ^{14}C dates, although some extend much further back in time than at Lake George, are too few.

At Pulbeena Swamps, the driest period ever recorded occurred between 12,000 and 18,000 yBP except for a short-lived wet phase around 15,000 yBP. There is no adequate ^{14}C date available at Mowbray Swamp to check whether the dry period recorded in the upper part of the profile is synchronous with that of Pulbeena Swamp, although it is expected to be so. The record is more precise at Lake George, where a permanent water phase is recorded between 16,000 and 18,000 yBP. There was no water around 18,000 yBP in Lake George and at Pulbeena Swamp. The short phases of ephemeral water seen at Lake George between 13,400-16,000 yBP and 18,000-19,500 yBP could coincide with the short periods of water flow at Pulbeena Swamp dated at 15,000 yBP and 19,000 yBP. It is not possible to be more precise.

The wettest phase recorded between 19,500 and 25,500 yBP preceded by a period of little water between 25,500 and 36,000 yBP in Lake George corresponds to a wet phase seen at Pulbeena and Mowbray Swamps after 35,000 yBP. The timing of the variation in water flow at the latter two sites during the 22,000-35,000 yBP period cannot be defined.

During the 35,000-50,000 yBP period at Pulbeena Swamp water was flowing but conditions were not favourable for ostracods whereas at Mowbray Swamp there is a definite wet phase between 36,000 and 46,000 yBP. Lake George was dry during that time (this statement needs to be verified by additional ^{14}C dates).

During the 46,000-52,000 yBP period, water did not flow at Mowbray Swamp but this was not the case at Pulbeena Swamp although no adequate dating can be given for this event since the enriched ^{14}C dates, although separated by 65 cm, only differ by 1,000 years.

There is evidence of two extensive wet phases prior to about 50,000 yBP at Pulbeena Swamp and prior to 52,000 yBP at Mowbray Swamp. Two phases, one of permanent and fresh water and the other of ephemeral and saline water, probably before 50,000 yBP, have also been recorded at Lake George. At the present stage, it is not possible to determine whether all these phases relate to similar climatic events.

Summarizing, at the present stage, it appears difficult to assess all the factors which are likely to affect lake levels and this is best demonstrated in the comparative study of Lake George with Lakes Gnotuk and Keilambete: during the early stages of the Holocene, when the two Victorian maar lakes were subject to drying up, Lake George was full. Therefore, since correlation of climatic events for adjacent areas in Australia, postulated from changes in lake level, appears to be a difficult task for some periods, correlation between Australia and other parts of the world should be even more difficult. However, such attempts at correlation of climatic events have already been made by Rognon and Williams (1977) between Australia and Africa for the last 40,000 years and by Bowler (1978) between Australia, Africa, China and south-eastern Europe for the last 50,000 years. Street and Grove (1979) presented a summary of lake level fluctuations for the world for the last 30,000 years. Additionally, Peterson *et al.* (1979) examined climatic conditions which operated on all continents during the glacial maximum at 18,000 yBP and Burrows (1979) concentrated on the cool periods registered in the Southern Hemisphere during the Holocene.

When examined in broad terms, correlations between continents appear possible and changes in lake levels appear to be synchronous. For example, most lakes were dry in parts of Australia and Africa around 18,000 yBP apart from a few exceptions: the Willandra lakes in eastern Australia where brief high water levels were registered (Bowler *et al.*, 1976) and the equatorial lakes in Africa, Lakes Mobutu Sese Seko and Manyara where levels were high (Street and Grove, 1976). These phenomena remain unexplained. Although Bowler (1978) pointed to the remarkable similarity of the changes in lake levels for Lake Keilambete and Lake Abhe in Ethiopia (see Gasse and Street, 1978; Gasse, 1980), it appears from the results obtained by Bowler (in press) and in the present thesis, that this statement is partly incorrect. The fluctuations registered in both lakes are similar but they are not synchronous. There is a shift of the order of 1,000 to 2,000 years between similar changes in the two lakes. This displacement is also noticed for lake level changes between Australia and Africa as most lake levels were very high in most parts of Africa around 8,000-9,000 yBP (Street and Grove, 1976) whereas the three Victorian maar lakes (Bullenmerri, Gnotuk and Keilambete) were much lower but rose during the 5,500-6,500 yBP period.

On a broader scale, on the other hand, if the 1,000-2,000 years gap is eliminated, lake level fluctuations in Australia and Africa are fairly similar (i.e. the long wet phase with high lake levels between 25,000 and 40,000-45,000 years), and these can be correlated even with other parts of the world as illustrated in Bowler (1978, Fig. 10). Further palaeolimnological investigations are necessary in other parts of Australia to check whether the timing of lake level fluctuations in Australia corresponds to those better known areas of the world (e.g. Africa where 67 lake basins have been studied compared to 28 in Australia - Street and Grove, 1979).

9.3 REMARKS ON OSTRACOD PALAEOECOLOGY

Since studies on Australian Quaternary ostracods, prior to the present investigation were rare and only of taxonomical nature, information on ostracod palaeoecology cannot be adequately compared. The discussion presented here is therefore restricted to the sites examined in this thesis.

The association of species of fossil ostracods recovered in the samples appears to be similar to those found in waterbodies today even though most samples yield more than one population, because yearly layers could not be sampled separately.

For the salt lake ostracods which are better known in Australia, there does not seem to be any extinct species among their fossil representatives except for *Diacypris* aff. *dictyote*. Moreover, there is no obvious evidence of migration of species since the fossil ostracods found in the maar lakes in Victoria and Pillie Lake in South Australia have living representatives in the same areas today. The only exception is for *Diacypris dictyote* found near the bottom of the Lake

Keilambete core and not yet recorded in Victoria although it is found in many lakes near the coast in South Australia.

The Tasmanian fossil species will not be discussed here since the living fauna of fresh waters is not yet adequately known on the Australian mainland, and is almost unknown in Tasmania.

It is of interest to note that ostracod faunas have changed fairly rapidly through time in the fossil sites studied. This is likely to have resulted from environmental changes and this demonstrates that ostracods are effectively exploiting the mechanisms of transport to invade new environments. Mechanisms of transport across oceans must have been effective as well, since a few ostracod species are common to New Zealand and Australia. This is well documented for *Limnocythere mowbrayensis* which is found in Pulbeena Swamp and Pillie Lake sediments in Australia, and in the deposit at Pyramid Valley Swamp in New Zealand (see discussion in Chapter 6). In the Tasmanian and New Zealand sites, associations of species are also very similar and even if species are not identical, some are phylogenetically related (e.g. *Gomphodella* and *Gomphocythere*). It is not known whether *L. mowbrayensis* is a fairly recent invader in one of the two countries or whether it has remained morphologically unchanged for a long period of time. Further, work is needed to check whether cosmopolitan species like *Eucypris virens* and *Sarscypridopsis aculeata* are recent invaders of the Australian temporary pool environment, probably introduced by man, or whether their distribution is a much older phenomenon since none have yet been found as fossil.

9.4 CONCLUSION

The present work has demonstrated the types of studies which can be undertaken using non-marine ostracods and their fossil remains.

Further work should prove rewarding in extending our knowledge of evolution and dispersal of ostracods and evolution of lakes in relation to climates. Since changes of climates and environments occurred rapidly during the Quaternary and correspondingly affected most species, ostracods, which inhabit most aquatic environments and which can easily be preserved as fossils, deserve more attention in the future.

BIBLIOGRAPHY

ABSOLON, A. 1973 - Ostracoden aus einigen Profilen spät-und postglazialer Karbonatablagenungen in Mitteleuropa. *Mitt. Mayer. Staatssamml. Paläont. Hist. Geol.* 13: 47-94.

ABSOLON, A. 1975 - Zur Migration der Süsswasserostracoden. *Vestn. Lesk. Spol. Zool.* 39: 161-166.

ALM, G. 1916 - Monographie der Schwedischen Süsswasser Ostracoden nebst systematischen Besprechungen der Tribus Podocopa. *Zool. Bidr. Uppsala* 4: 1-247.

BADA, J.L. & MANN, E.H. 1980 - Amino acid diagenesis in deep sea drilling project cores: Kinetics and mechanisms of some reactions and their applications in geochemistry and heat flow determinations. *Earth - Sci. Rev.* 16: 21-55.

BANKS, M.R., COLHOUN, E.A. & VAN DE GEER, G. 1976 - Late Quaternary *Palorchestes azael* (Mammalia, Diprotondontidae) from northwestern Tasmania. *Alcheringa* 1: 159-166.

BARCLAY, M.H. 1966 - An ecological study of a temporary pond near Auckland, New Zealand. *Aust. J. Mar. Freshwat. Res.* 17: 239-258.

BARCLAY, M.H. 1968 - Additions to the freshwater ostracod fauna of New Zealand. *N.Z. J. Mar. Freshwater Res.* 2: 67-80.

BARTON, C.E. 1978 - Magnetic studies of some Australian lake sediments. Ph.D. Thesis, Australian National University.

BARTON, C.E., BOWLER, J.M. & POLACH, H.A. (in press) - Magnetic stratigraphy and sedimentology, and ^{14}C ages of three Australian maars. *Quat. Res.*

BAYLY, I.A.E. 1967 - The general biological classification of aquatic environments with special reference to those of Australia. In: A.H. Weatherley (ed.). Australian Inland Waters and Their Fauna: Eleven Studies. A.N.U. Press, Canberra.

BAYLY, I.A.E. 1970 - Further studies on some saline lakes of south-east Australia. *Aust. J. Mar. Freshwat. Res.* 21: 117-129.

BAYLY, I.A.E. 1973 - The sand fauna of Lake Pedder: a unique example of colonization by the Phreatoicidae (Crustacea: Isopoda). *Aust. J. Mar. Freshwat. Res.* 24: 303-306.

BAYLY, I.A.E. 1976 - The plankton of Lake Eyre. *Aust. J. Mar. Freshwat. Res.* 27: 661-665.

BAYLY, I.A.E. & WILLIAMS, W.D. 1966 - Chemical and biological studies on some saline lakes of south-east Australia. *Aust. J. Mar. Freshwat. Res.* 17: 177-228.

BAYLY, I.A.E. & WILLIAMS, W.D. 1973 - Inland Waters and Their Ecology. Longman, Melbourne.

BENSON, R.H. & MAC DONALD, H.C. 1963 - Postglacial (Holocene) ostracodes from Lake Erie. *Uni. Kans. Paleontol. Contrib. Arthropoda Art.* 4: 1-26.

BOWLER, J.M. 1971 - Late Quaternary environments: a study of lakes and associated sediments in south-eastern Australia. Ph.D. Thesis, Australian National University.

BOWLER, J.M. 1976 - Aridity in Australia: Age, origins and expression in aeolian landforms and sediments. *Earth-Sci. Rev.* 12: 279-310.

BOWLER, J.M. 1978 - Glacial age aeolian events at high and low latitudes. In: E.M. van Zinderen Bakker (ed.). Antarctic Glacial History and World Palaeoenvironments. Balkema, Rotterdam.

BOWLER, J.M. (in press) - Australian salt lakes: a palaeohydrologic approach. In: Williams, W.D. (ed.). Salt Lakes: Proceedings of an International Symposium. Junk, The Hague.

BOWLER, J.M., HOPE, G.S., JENNINGS, J.N., SINGH, G. & WALKER, D. 1976 - Late Quaternary climates of Australia and New Guinea. *Quat. Res.* 6: 359-394.

BRACKENBRIDGE, G.R. 1978 - Evidence for a cold, dry full-glacial climate in the American southwest. *Quat. Res.* 9: 22-40.

BRADSHAW, J.S. 1957 - Laboratory studies on the rate of growth of the foraminifer "*Streblus beccarii* (Linné) var. *tepida* (Cushman)". *J. Pal.* 31: 1138-1147.

BRADSHAW, J.S. 1961 - Laboratory experiments on the ecology of foraminifera. *Contrib. Cushman Found. Foramin. Res.* 12: 87-106.

BRADY, G.S. 1886 - Notes on freshwater Entomostraca from South Australia. *Proc. Zool. Soc. London* 54: 82-93.

BREHM, V. 1939. Eine neue, subfossile *Limnocythere* von Neueseeland. *Zool. Anz.* 127: 191-193.

BURNE, R.V., BAULD, J. & DE DECKKER, P. 1980 - Saline lake charophytes and their geological significance. *J. Sed. Pet.* 50: 281-293.

BURROWS, C.J. 1979 - A chronology for cool-climate episodes in the southern hemisphere - 12,000-1,000 yrBP. *Palaeogeogr. Palaeoclimatol. Palaeoecol.* 27: 287-347.

BURTON, G.M. & WILSON, E.G. 1973 - Lake George, N.S.W.: its relevance to salinity problems in agriculture. *Bur. Min. Res. Rec. 1973/166.*

CANN, J.C. & DE DECKKER, P. (in press) - Fossil Quaternary, and living foraminifera from athalassic (non marine) saline lakes, southern Australia. *J. Pal.*

CARBONEL, P. & PEYPOUQUET, J.P. 1979 - Les ostracodes des séries du Bassin de l'Omo. *Bull. Inst. Géol. Bassin Aquitaine* 25: 167-199.

CHAPMAN, F. 1914 - Notes on Testacea from Pleistocene marl of Mowbray Swamp, North West Tasmania. *Mem. Natl. Mus. Victoria, Melbourne* 5: 55-61.

CHAPMAN, F. 1919 - On an ostracod and shell marl of Pleistocene age from Boneo Swamp, West of Cape Schanck, Victoria. *Proc. Roy. Soc. Victoria* 32: 24-32.

CHAPMAN, F. 1936 - Cypridiferous limestone from the Mallee. *Rec. Geol. Surv. Vic.* 5: 296-298.

CHAPMAN, M.A. 1963 - A review of the freshwater ostracods of New Zealand. *Hydrobiologia* 22: 1-40.

CHAPMAN, M.A. 1966 - On *Eucypris mytiloides* (Brady) and three new species of *Eucypris* Vavra (Cypridae, Ostracoda). *Hydrobiologia* 27: 368-378.

CHAPMAN, M.A. 1967 - Ostracoda. In: Bayly, I.A.E., Bishop, J.A. & Hiscock, I.D. (eds.). An Illustrated Key to the Genera of the Crustacea of Australian Inland Waters. Australian Society for Limnology. Special Issue.

CHAPMAN, M.A. & LEWIS, M.H. 1978 - An introduction to the freshwater Crustacea of New Zealand. Collins, Auckland.

CHESSMAN, B.C. & WILLIAMS, W.D. 1974 - Distribution of fish in inland saline waters in Victoria, Australia. *Aust. J. Mar. Freshwat. Res.* 25: 167-172.

CHURCHILL, D.M., GALLOWAY, R.W. & SINGH, G. 1978 - Closed lakes and the palaeoclimatic record. In: Pittock, A.B.P., Frakes, L.A. Jensen, D., Peterson, J.A. & Zilman, J.W. (eds.). Climatic change and variability. Cambridge University Press, Cambridge.

COBB, M.A. 1975 - Sampling and measurement of mound springs, Great Artesian Basin, South Australia. Progress Report 2 - Marree, Curdimurka and Billa Kalina Sheets. *Dept. Mines S.A. Rep. Book 75/90* (unpubl.).

COLHOUN, E.A., VAN DE GEER, G. & MOOK, W.G. (in press) - Pulbeena Swamp, North Western Tasmania: stratigraphy, pollen analysis and palaeoclimatic interpretation. *Quat. Res.*

COLHOUN, E.A. (ed.) 1979 - Quaternary Excursion to northwest and west Tasmania. Field Guide - Australian Quaternary Excursion. 13-16 April 1979. University of Tasmania, Hobart.

COLIN, J.P. & DANIELOPOL, D.L. 1978 - New data on the systematics of the Limnocytheridae (Ostracoda, Cytheracea). *Geobios*. 11: 563-567.

COOK, P.J., COLWELL, J.B., FIRMAN, J.B., LINDSAY, J.M., SCHWEBEL, D.A. & VON DER BORCH, C.C. 1977 - The late Cainozoic sequence of south east South Australia and Pleistocene sea level changes. *BMR J. Aust. Geol. Geophys.* 2: 81-88.

COOPE, G.R. 1977 - Quaternary Coleoptera as aids in the interpretation of environmental history. In: Shotton, F.W. (ed.). British Quaternary Studies. Oxford University Press, Oxford.

COVENTRY, R.J. 1976 - Abandoned shorelines and the late Quaternary history of Lake George, New South Wales. *J. Geol. Soc. Aust.* 23: 249-273.

COVENTRY, R.J. & WALKER, P.H. 1977 - Geomorphological significance of Late Quaternary deposits of the Lake George area, N.S.W. *Aust. Geogr.* 13: 369-376.

CRISMAN, T.L. 1978 - Reconstruction of past lacustrine environments based on the remains of aquatic invertebrates. In: Walker, D. & Guppy, J.C. (eds.). Biology and Quaternary Environments. Australian Academy of Science, Canberra.

CURREY, D.T. 1970 - Lake systems. Western Victoria. *Aust. Soc. Limn. Bull.* 3: 1-13.

DANIELOPOL, D.L. 1977 - On the origin and diversity of European freshwater interstitial ostracods. In: Löffler, H. & Danielopol, D.L. (eds.). Aspects of Ecology and Zoogeography of Recent Fossil Ostracods. Junk, The Hague.

DANIELOPOL, D.L. & McKENZIE, K.G. 1977 - *Psychrodromus* gen.n. (Crustacea, Ostracoda), with redescription of the cypridid genera *Prionocypris* and *Ilyodromus*. *Zool. Scr.* 6: 301-322.

DE DECKKER, P. 1975 - Determination of an Ostracod collection in relation to *Australocypris* (Cyprididae). *Aust. J. Mar. Freshwat. Res.* 26: 423-424.

DE DECKKER, P. 1976a - *Trigonocypris*, a new ostracod genus from Queensland. *Aust. J. Zool.* 24: 145-157.

DE DECKKER, P. 1976b - Comparative morphology of some Australian cypridacid ostracods - M.Sc.(Hons.) Thesis, Macquarie University.

DE DECKKER, P. 1977 - The distribution of the "giant" ostracods (family: Cyprididae Baird, 1845) endemic to Australia. In: Löffler, H. & Danielopol, D.L. (eds.). Aspects of Ecology and Zoogeography of Recent and Fossil Ostracoda. Junk, The Hague.

DE DECKKER, P. 1978 - Comparative morphology and review of mytilocypridinid ostracods (family Cyprididae). *Aust. J. Zool. Suppl. Ser.* 58: 1-62.

DE DECKKER, P. 1979a - Comparative morphology and review of Australian Notodromadinae Kaufmann, 1900 (Crustacea: Ostracoda). *Senckenbergiana biol.* 59: 417-463.

DE DECKKER, P. 1979b - Ostracods from the mound springs area between Strangways and Curdimurka, South Australia. *Trans. R. Soc. S. Aust.* 103: 155-168.

DE DECKKER, P. 1979c - The middle Pleistocene ostracod fauna of the West Runton freshwater bed, Norfolk. *Palaeontology* 22: 293-316.

DE DECKKER, P. 1979d - Evaluation of features distinctive in the taxonomy of the Cypridacea, above the generic level. In: Krstic, N. (ed.). Taxonomy, biostratigraphy and distribution of ostracods. Serbian Geological Society, Beograd.

DE DECKKER, P. 1980a - Taxonomic notes on some Australian ostracods with description of new species. *Zool. Scr.* 9:

DE DECKKER, P. 1980b - On *Scottia audax* (Chapman). *Stereo - Atlas of Ostracod Shells* 7: 37-44.

DE DECKKER, P. (in press a) - Ostracods of athalassic salt lakes: a review. In: Williams, W.D. (ed.). Salt Lakes: Proceedings of an International Symposium. Junk, The Hague.

DE DECKKER, P. (in press b) - Terrestrial ostracods in Australia. *Rec. Aust. Mus.*

DE DECKKER, P. & GEDDES, M.C. 1980 - Seasonal fauna of ephemeral saline lakes near the Coorong Lagoon, South Australia. *Aust. J. Mar. Freshwat. Res.* 31: 677-699.

DE DECKKER, P., GEURTS, M.A. & JULIA, R. 1979 - Seasonal Rhythmites from a Lower Pleistocene lake in northeastern Spain. *Palaeogeogr. Palaeoclimat. Palaeoecol.* 26: 43-71.

DE DECKKER, P. & JONES, P.J. 1978 - Checklist of ostracoda recorded from Australia and Papua New Guinea 1845-1973. *Bur. Min. Res. Rep.* 195: 1-184.

DEEVEY, E.S. 1955 - Paleolimnology of the upper swamp deposit, Pyramid Valley. *Rec. Cant. Mus.* 6: 291-344.

DELORME, L.D. 1971a - Paleoecology of Holocene sediments from Manitoba using freshwater ostracods. *Geol. Assoc. Can. Spec. Pap.* 9: 301-304.

DELORME, L.D. 1971b - Paleoecological determinations using Pleistocene freshwater ostracods. *Bull. Centre Rech. Pau - SNPA* 5 suppl.: 341-347.

DELORME, L.D., ZOLTAI, S.C. & KALAS, L.L. 1977 - Freshwater shelled invertebrate indicators of paleoclimate in northwestern Canada during late glacial times. *Can. J. Earth Sci.* 14: 2029-2046.

DEVOTO, G. 1965 - Lacustrine Pleistocene in the Lower Liri Valley. *Geol. Rom.* 4: 291-368.

DIEBEL, K. & PIETRZENIUK, E. 1969 - Ostracoden aus dem Mittle pleistozän von Süßenborn bei Weimar. *Paläont. Abb.* A. 3: 367-388.

DIEBEL, K. & PIETRZENIUK, E. 1975 - Ostracoden aus dem holozänen Travertin von Bad Langensalza. *Quartärpalaöntologie* 1: 27-55.

DIEBEL, K. & PIETRZENIUK, E. 1977 - Ostracoden aus dem Travertin von Taubach bei Weimar. *Quartärpalaöntologie* 2: 119-137.

DIEBEL, K. & PIETRZENIUK, E. 1978a - Die Ostracoden des eeminterglazialen Travertins von Burgtonna in Thüringen. *Quartärpalaöntologie* 3: 87-91.

DIEBEL, K. & PIETRZENIUK, E. 1978b - Die Ostracoden aus dem jungpleistozanen (weichselkalt-zietlichen) Decksichichiten von Burgtonna in Thüringen. *Quartärpalaöntologie* 3: 207-221.

DIEBEL, K. & WOLFSCHLÄGER, H. 1975 - Ostracoden aus dem jungpleistozänen Travertin von Ehringsdorf bei Weimar. *Abh. Zentr. Geol. Inst.* 23: 91-136.

DODSON, J.R. 1974a - Vegetation and climatic history near Lake Keilambete, western Victoria. *Aust. J. Bot.* 22: 709-717.

DODSON, J.R. 1974b - Vegetation history and water fluctuations at Lake Leake, south-eastern South Australia I. 10,000 BP to present. *Aust. J. Bot.* 22: 719-741.

DODSON, J.R. 1975 - Vegetation history and water fluctuations at Lake Leake, south-eastern South Australia II. 50,000 to 10,000 BP. *Aust. J. Bot.* 23: 185-831.

DODSON, J.R. 1979 - Late Pleistocene vegetation and environments near Lake Bullenmerri, western Victoria. *Aust. J. Ecol.* 4: 419-427.

DURY, G.H. 1973 - Paleohydrologic implications of some pluvial lakes in north western New South Wales, Australia. *Geol. Soc. Am. Bull.* 84: 3663-3676.

EAGAR, S.H. 1969 - A Pleistocene mummified ostracod from the Wairapa district. *N.Z. J. Mar. Freshwat. Res.* 3: 607-609.

EAGAR, S.H. 1970 - A new species of *Eucypris* (Ostracoda) from Wellington. *N.Z. J. Mar. Freshwat. Res.* 4: 195-202.

EAGAR, S.H. 1971 - A checklist of the Ostracoda of New Zealand. *J. R. Soc. N.Z.* 1: 53-64.

ELLIS, P. & WILLIAMS, W.D. 1970 - The biology of *Haloniscus searlei* Chilton, an isopod living in Australian salt lakes. *Aust. J. Mar. Freshwat. Res.* 21: 51-69.

EUGSTER, H.P. 1980 - Geochemistry of evaporitic lacustrine deposits. *Ann. Rev. Earth Planet. Sci.* 8: 35-63.

EUGSTER, H.P. & HARDIE, L.A. 1978 - Saline lakes. In: Lerman, A. (ed.). Chemistry, Geology and Physics of Lakes. Springer, New York.

FREY, D.G. 1964 - Remains of animals in Quaternary lake and bog sediments and their interpretations. *Arch. Hydrobiol. Eigebn. Limnol.* 2: 1-114.

FOLK, R.L. & LAND, L.S. 1975 - Mg/Ca ratio and salinity: two controls over the crystalization of dolomite. *Am. Assoc. Petrol Geol.* 59: 60-68.

GAUTHIER, H. 1928a - Ostracodes et cladocerès de l' Afrique du Nord (2e note). *Bull. Soc. Hist. Nat. Afr. Nord.* 19: 69-79.

GAUTHIER, H. 1928b - Recherche sur la faune des eaux continentales de l' Algérie et de la Tunisie. Minerva, Alger.

GAUTHIER, H. 1951 - Contribution à l' étude de la faune des eaux douces au Sénégal (Entomostracés). Minerva, Alger.

GALLOWAY, R.W. 1970 - The full-glacial climate in the south-western United States. *Ann. Ass. Am. Geogr.* 60: 245-256.

GALLOWAY, R.W. 1971 - Evidence of Late Quaternary climates. In: Mulvaney, D.J. & Golson, J. (eds.). Aboriginal Man and Environment in Australia. ANU Press, Canberra.

GASSE, F. 1974a - Les diatomées des sédiments holocènes du bassin du Lac Afrera (Giuletti) (Afar Septentrional, Ethiopie). Essai de reconstruction de l' évolution du milieu. *Int. Revue ges. Hydrobiol.* 59: 95-122.

GASSE, F. 1974b - Les diatomées holocènes du bassin inférieur de l' Aouache (Dépression de Danakil, Ethiopie). Leur signification paléoécologigue. *Int. Revue ges. Hydrobiol.* 59: 123-146.

GASSE, F. 1980 - Late Quaternary changes in lake levels and diatom assemblages in the south-eastern margin and surrounding seas. In: Sarnthein, M., Seibold, E. & Rognon, P. (eds.). Palaeoecology of Africa 12. Balkema, Rotterdam.

GEDDES, M.C. 1976 - Seasonal fauna of some ephemeral saline waters in western Victoria with particular reference to *Parartemia zietziena* Sayce (Crustacea: Anostraca). *Aust. J. Mar. Freshwat. Res.* 27: 1-22.

GEDDES, M.C., DE DECKKER, P., WILLIAMS, W.D., MORTON, D. & TOPPING, M. (in press) - On the chemistry and biota of some saline lakes in Western Australia. In: Williams, W.D. (ed.). Salt Lakes: Proceedings of an International Symposium. Junk, The Hague.

GILL, E.D. & BANKS, M.R. 1956 - Cainozoic history of Mowbray Swamp and other areas of north western Tasmania. *Rec. Queen Vic. Mus., Launceston* 6: 1-36.

GLOVER, C.J.M. & SIM, T.C. 1978 - Studies on Central Australian fishes: A progress report. *South Aust. Nat.* 52: 35-44.

HABERMEHL, M.A. 1980 - The Great Artesian Basin, Australia. *BMR J. Aust. Geol. Geophys.* 5: 9-38.

HARDIE, L.A. & EUGSTER, H.P. 1970 - The evolution of closed basin brines. *Spec. Pap. Miner. Soc. Am.* 3: 279-290.

HARDIE, L.A., SMOOT, J.P. & EUGSTER, H.P. 1978 - Saline lakes and their deposits: a sedimentological approach. *Spec. Pap. Miner. Soc. Am.* 3: 7-41.

HARTMANN, G. 1964 - Asiatische Ostracoden: systematische und Zoogeographische Untersuchungen. *Int. Revue ges. Hydrobiol., Syst. Beih.* 3: 1-155.

HARTMANN, G. 1978 Die ostracoden der Ordnung Podocopida G.W. Müller, 1894 der tropisch-subtropischen Westküste Australiens (Zwischen Derby im Norden und Perth im Süden). In: Hartmann-Schröder, G. & Hartman, G. Zur Kenntnis des Eulitorals des australischen Küsten unter besonderer Berucksichtigung der Polychaeten und Ostracoden. *Mitt. Hamb. Zool. Mus. Inst.* 75: 64-219.

HARTMANN, G. 1979 - Die ostracoden der Ordnung Podocopida G.W. Müller, 1894 der warm-temperierten (antiborealen) West -und Südwestküste Australiens (Zwischen Perth im Norden und Eucla im Süden). *Mitt. Hamb. Zool. Mus. Inst.* 76: 219-301.

HARTMANN, G. & KÜHL, C. 1978 - Zur Variabilität der Obeiflächen ornamente des Schalen lebender Ostracoden - Populationen. *Mitt. Hamb. Zool. Mus. Inst.* 75: 221-223.

HECKY, R.E. & KILHAM, P. 1973 - Diatoms in alkaline, saline lakes: ecology and geochemical implication. *Limnol. Ocean.* 18: 53-71.

HENRY, M. 1919 - On some Australian Freshwater Copepoda and Ostracoda. *J. Roy. Soc. N.S.W.* 53: 29-50.

HENRY, M. 1923 - A monograph of the freshwater Entomostraca of New South Wales, Part III. Ostracoda. *Proc. Linn. Soc. N.S.W.* 48: 267-286.

HERBST, H.V. 1957 - Neue Cypridae (Crustacea, Ostracoda) aus Australien. I. *Zool. Anz.* 158: 217-225.

HERBST, H.V. 1958 - Neue Cypridae (Crustacea, Ostracoda) aus Australien. II. *Zool. Anz.* 160: 177-192.

HERBST, H.V. 1961 - Nomenklatorische Bemerkungen über Cypridae (Crustacea, Ostracoda). *Zool. Anz.* 167: 142-145.

HORNIBROOK, N. de B. 1953 - A note on the Ostracoda *Limnocythere mowbrayensis* Chapman 1914, and *L. sicula* Chapman, 1919. *Mem. Nat. Mus. Victoria, Melbourne* 18: 155-156.

HORNIBROOK, N. de B. 1955 - Ostracoda in the deposits of Pyramid Valley Swamp. *Rec. Cant. Mus.* 6: 267-278.

HUSSAINY, S.U. 1969 - Ecological studies on some microbiota of lakes in western Victoria. Ph.D. Thesis, Monash University.

HUSSAINY, S.U. 1969a - Description of the male of *Candonocypris assimilis* G.O. Sars 1894 (Cyprididae, Ostracoda). *Proc. Roy. Soc. Vic.* n.s. 82: 305-307.

HUSSAINY, S.U. 1969b - A new species of *Gomphocythere* (Limnocytheridae, Ostracoda) from Australia. *Proc. Roy. Soc. Vic.* n.s. 82: 299-304.

HUSSAINY, S.U. 1971 - Reproduction and ontogeny of *Gomphocythere australica* Hussainy (Cytheridae, Ostracoda). *Proc. Roy. Soc. Vic.* n.s. 84: 129-135.

HUTCHINSON, G.E. 1957 - A Treatise on limnology. Vol. I. John Wiley & Sons, New York.

JACOBSON, G. & SCHUETT, A.W. 1980 - Water levels, balance and chemistry of Lake George, New South Wales. *BMR J. Aust. Geol. Geophys.* 4: 25-32.

JOYCE, E.B. 1975 - Quaternary volcanism and tectonism in southeastern Australia. In: Suggate, R.P. & Creswell, M.M. (eds.). Quaternary studies. *R. Soc. N.Z. Bull.* 13: 169-176.

KAESLER, R.L. 1975 - Morphology of *Cypridopsis vidua* (O.F. Müller): variation with environment. *Bull. Am. Paleont.* 65: 225-244.

KEMPF, E.K. 1967a - *Ilyocypris scharzbachi* n.sp. (Crustacea, Ostracoda) und ein vorlaüfiges Ostrakoden - Diagramm aus dem pleistozänen Löß von Kärlich (Neuwieder Becken). *Sonderveröff. Geol. Inst. Univ. Köln* 13: 65-79.

KEMPF, E.K. 1967b - Ostrakoden aus dem Holstein - Interglazial von Tönisberg (Niederrheingebiet). *Monatsber. Dtsch. Akad. Wiss. Berlin* 9: 119-139.

KEMPF, E.K. 1980 - Index and bibliography of non marine ostracoda 4. Bibliography A. *Sonderveröff. Geol. Inst. Univ. Köln* 38: 1-185.

KERSHAW, A.P. 1978 - Record of last interglacial-glacial cycle from north-eastern Queensland. *Nature (London)* 272: 159-161.

KLIE, W. 1932 - Die ostracoden der Deutschen limnologischen Sunda-Expedition. *Arch. Hydrobiol. Suppl.* 11: 447-502.

KLIE, W. 1938 - Krebstiere oder Crustacea III. Ostracoda, Muschelkrebse. In: Dahl, F. (ed.). *Die Tierwelt Deutschlands* 34: 1-230.

KING, R.L. 1855 - On Australian Entomostracans. *Proc. Roy. Soc. Tas.* 3: 56-75.

KORNICKER, L.S. & SOHN, I.G. 1971 - Viability of ostracode eggs egested by fish and effect of digestive fluids on ostracode shells - ecologic and paleoecologic implications. *Bull. Centre Rech. Pau - SNPA.* 5 Suppl.:125-135.

KRSTIC, N. 1976 - Variability of Candoninae adductor scars. *Abh. Verh. naturwiss. Ver. Hamburg* (N/F) 18/19 Suppl.: 309-314.

LANGBEIN, W.D. 1961 - Salinity and Hydrology of closed lakes. *U.S. Geol. Surv. Prof. Pap.* 412: 1-20.

LÖFFLER, H. 1969 - Recent and subfossil distribution of *Cytherissa lacustris* (Ostracoda) in Lake Constance. *Mitt. Internat. Verein. Limnol.* 17: 240-251.

LÖFFLER, H. 1975a - The evolution of ostracod faunas in alpine and prealpine lakes and their value as indicators. *Bull. Am. Paleont.* 65: 433-443.

LÖFFLER, H. 1975b - The onset of meromictic conditions in alpine lakes. In: Suggate, R.P. & Cresswell, M.M. (eds.). Quaternary studies. *R. Soc. N.Z. Bull.* 13: 211-214.

LÖFFLER, H. 1977 - "Fossil" meromixis in Kleinsee (Carinthia) indicated by ostracodes. In: Löffler, H. & Danielopol, L.D. (eds.). Aspects of Ecology and Zoogeography of Recent and Fossil Ostracoda. Junk, The Hague.

LÖFFLER, H. 1978a - Limnological and paleolimnological data on the Bale Mountain lakes (Ethiopia). *Verh. Internat. Verein. Limnol.* 20: 1131-1138.

LÖFFLER, H. 1978b - The paleolimnology of some Carithian lakes with reference to Wörthersee. *Pol. Arch. Hydrobiol.* 25: 227-232.

LÜTTIG, G. 1955 - Die Ostracoden des Interglazials von Elze. *Paläont. Z.* 29: 146-169.

McDOWALL, R.M. (ed.) 1980 - Freshwater fishes of south-eastern Australia. Reed, Sydney.

McKENZIE, K.G. 1966a - Freshwater ostracoda from North-Western Australia. *Aust. J. Mar. Freshwat. Res.* 17: 259-279.

McKENZIE, K.G. 1966b - *Mytilocypris*, a new ostracode genus from Tasmania. *Proc. Roy. Soc. Tas.* 100: 27-30.

McKENZIE, K.G. 1968 - A new species of *Paracypria* (Ostracoda, Cyprididae) from Victoria, Australia. *Zool. Anz.* 185: 384-389.

McKENZIE, K.G. 1971a - Distribution of freshwater Ostracoda. *Bull. Centre Rech. Pau-SNPA* 5 suppl.: 179-190.

McKENZIE, K.G. 1971b - Ostracoda from Lake Peunde, near Mt. Wilhelm, New Guinea. *Zool. Anz.* 186: 391-403.

McKENZIE, K.G. 1977 - Illustrated generic key to South African continental Ostracoda. *Ann. S. Afr. Mus.* 74: 45-103.

McKENZIE, K.G. 1978 - Ostracoda (Crustacea: Podocopida) from southern Australian salt lakes, with the description of *Reticypris* new genus. *Trans. R. Soc. S. Aust.* 102: 175-190.

McKENZIE, K.G. 1980 - Ostracoda and water resources: diagnosis and prognosis. In: Williams, W.D. (ed.). An ecological basis for water resource management. ANU Press, Canberra.

McKENZIE, K.G. & GILL, E.D. 1968 - Ostracoda from the Murray River Valley West of Wentworth, N.S.W. *Aust. J. Sci.* 30: 463-464.

McKENZIE, K.G. & HUSSAINY, S.U. 1968 - Relevance of a freshwater cytherid (Crustacea, Ostracoda) to the continental drift hypothesis. *Nature (London)* 220: 806-808.

MACKERETH, F.J.H. 1958 - A portable core sampler for lake deposits. *Limnol Ocean.* 3: 181-191.

MADDOCKS, G.E. 1957 - The geochemistry of surface waters of the Western District of Victoria. *Aust. J. Mar. Freshwat. Res.* 15: 35-52.

MEHES, G. 1939 - Ostracodes de la Nouvelle Calédonie. *Rev. Suisse Zool.* 46: 549-565.

MELLOR, M. 1979 - A study of the salt lake snail *Coxiella* Smith 1894, *sensu lato*. B.Sc.(Hons.) Thesis, University of Adelaide.

MITCHELL, B.D. (in press) - Limnology of mound springs and temporary pools South and West of Lake Eyre. *Nature Conservation Soc. S. Aust., Adelaide.*

MÜLLER, G.W. 1900 - Deutschlands Süsswasser-ostracoden. *Zoologica* 12: 1-112.

NEAL, J.T. (ed.) 1975 - Playas and dried lakes - occurrence and development. Dowden, Hutchinson and Ross, In.c., Stroudsberg.

NEGADAEV-NIKONOV, K.N. 1971 - Crustacea - Rakoobraznye. In: Plejtocen Tiraspolia: 55-71. Kishinev. [In Russian]

NEUSTRUEVA, I.Y. 1977 - Ostracod biofacies in Paleozoic and Mesozoic lake sediments of the USSR. In: Löffler, H. & Danielopol, D.L. (eds.). Aspects of Ecology and Zoogeography of Recent and Fossil Ostracoda. Junk, The Hague.

OKUBO, I. 1975 - Studies on Ostracoda in fish ponds - I - Two species in fish ponds on the Chiba Prefectural Freshwater Fisheries Experimental Station. *Bull. Jap. Soc. Scientific Fisheries* 41: 155-165.

OLLIER, C.D. 1968 - Maars. Their characteristics, varieties and definition. *Bull. Volcanol.* 31: 45-73.

OLLIER, C.D. & JOYCE, E.B. 1964 - Volcanic physiography of the western plains of Victoria. *Proc. Roy. Soc. Vic.* n.s. 77: 357-376.

PATERSON, C.G. & WALKER, K.F. 1974 - Recent history of *Tanytarsus barbitarsis* Freeman (Diptera: Chironomidae) in the sediments of a shallow, saline lake. *Aust. J. Mar. Freshwat. Res.* 25: 315-325.

PENNY, J.T. & RACEK, A.A. 1968 - Comprehensive revision of a worldwide collection of freshwater sponges (Porifera - Spongillidae). *Bull. U.S. Nat. Mus.* 272: 1-184.

PETERSEN, G.M., WEBB, T. III, KUTZBACH, J.E., VAN DER HAMMEN, T., WIJMSTRA, T.A. & STREET, F.A. 1979 - The continental record of environmental conditions at 18,000 yrBP: An initial evaluation. *Quat. Res.* 12: 47-82.

PETKOVSKI, T.K. 1958 - Süsswasser-ostracoden aus Jugoslavien II. Subfam. Ilyocyprinae. *Mus. Mac. Scient. Natur.* 2(8): 53-57.

PEYPOUQUET, J.P., CARBONEL, P. & DE HEINZELIN, J. 1979. Les ostracodes indicateurs de l' évolution des environnements lacustres de la fin du Cénozoique dans la branche orientale du Rift africain. *Bull. Inst. Géol. Bassin Aquitaine* 25: 201-219.

RACEK, A.A. 1966 - Spicular remains of freshwater sponges. *Mem. Conn. Acad. Arts Sci.* 17: 78-83.

RACEK, A.A. 1969 - The freshwater sponges of Australia (Porifera: Spongillidae). *Aust. J. Mar. Freshwat. Res.* 20: 267-310.

RAUP, D.M. & STANLEY, S.M. 1971 - Principles of Paleontology. Freeman & Co., San Francisco.

REEVES, C.C. 1968 - Introduction to paleolimnology. Developments in sedimentology 11. Elsevier, Amsterdam.

REINECK, H.-E. & SINGH, I.B. 1975 - Depositional Sedimentary Environments. Springer-Verlag, Heydelberg.

RICHARDSON, J.L. 1968 - Diatoms and lake typology in East and Central Africa. *Int. Revue ges. Hydrobiol.* 53: 299-338.

RICHARDSON, J.L., HARVEY, T.J. & HOLDSHIP, S.A. 1978 - Diatom in the history of shallow East African lakes. *Pol. Arch. Hydrobiol.* 25: 341-353.

ROBINSON, E.J. 1980 - The ostracod fauna of the interglacial deposits at Sugworth, Oxfordshire. *Phil. Trans. Roy. Soc. Lond. B.* 289: 99-106.

ROGNON, P. & WILLIAMS, M.A.J. 1977 - Late Quaternary climatic changes in Australia and North AFrica: a preliminary interpretation. *Paleogeogr. Paleoclimat. Paleoecol.* 21: 285-327.

ROME, D.R. 1969 - Morphologie de l' attache de la furca chez les Cyprididae et son utilisation en systématique. In: Neale, J.W. (ed.). The Taxonomy, Morphology and Ecology of Recent Ostracoda. Oliver and Boyd, Edinburg.

ROSENFELD, A. & VESPER, B. 1977 - The variability of sieve-pores in recent and fossil species of *Cyprideis torosa* (Jones, 1850) as an indication for salinity and palaeosalinity. In: Löffler, H. & Danielopol, L.D. (eds.). Aspects of Ecology and Zoogeography of Recent and Fossil Ostracoda. Junk, The Hague.

SARS, G.O. 1885 - On some Australian Cladocera, raised from dried mud. *Forch. Vidensk. Selsk. Krist.1885* 8: 1-46.

SARS, G.O. 1889a - On some Freshwater Ostracoda and Copepoda raised from dried Australian mud. *Forch. Vidensk. Selsk. Krist. 1889* 8: 3-79.

SARS, G.O. 1889b - On a small collection of Freshwater Entomostraca from Sydney. *Forch. Vidensk. Selsk. Krist.1889* 9: 1-9.

SARS, G.O. 1894 - Contributions to the knowledge of the freshwater Entomostraca of New Zealand as shown by artificial hatching from dried mud. *Forch. Vidensk. Selsk. Krist. 1894* 5: 1-62.

SARS, G.O. 1896a - On some Freshwater Entomostraca from the Neighbourhood of Sydney, partly raised from dried mud. *Arch. Math. Naturv.* 18: 1-81.

SARS, G.O. 1896b - On some West Australian Entomostraca raised from dried sand. *Arch. Math. Naturv.* 19: 1-35.

SARS, G.O. 1924 - The freshwater Entomostraca of the Cape Province (Union of South Africa) Part II. Ostracoda. *Ann. South Afr. Mus.* 20: 105-193.

SCOTT, T.D., GLOVER, C.J.M. & SOUTHCOTT, R.V. 1974 - The marine and freshwater fishes of South Australia. Government Printer, Adelaide.

SHIEL, R.J. 1976 - Associations of Entomostraca with weedbed habitats in a billabong of the Goulbourn River. *Aust. J. Mar. Freshwat. Res.* 27: 533-549.

SHIEL, R.J. 1980 - Billabongs of the Murray-Darling system. In: Williams, W.D. (ed.). An ecological basic for water resource management. ANU Press, Canberra.

SHORNIKOV, E.I. 1966 - Sexual dimorphism and shell variation in *Leptocythere*. In: Vyalov, O.S. (ed.). Fossil Ostracoda - papers from the First All-Union Symposium on Fossil Ostracoda (Lvov, 1963). Translated by Israel Program for Scientific Translation, Jerusalem (1971).

SINGH, G. (in press) - Late Quaternary pollen records and seasonal palaeoclimates of Lake Frome, South Australia. In: Williams, W.D. (ed.). Salt Lakes: Proceedings of an International Symposium. Junk, The Hague.

SINGH, G., KERSHAW, A.P. & CLARK, R. (in press a) - Quaternary vegetation and fire history in Australia. In: Gill, A.M., Groves, R.A. & Noble, I.R. (eds.). Fire and Australian Biota. Australian Academy of Science, Canberra.

SINGH, G., OPDYKE, N.D. & BOWLER, J.M. (in press b) - Late Quaternary stratigraphy, paleomagnetic chronology and vegetational history from Lake George, Australia. *Quat. Res.*

SKOKSBERG, T. 1917 - Results of Dr. E. Mjobergs Swedish scientific expeditions to Australia 1910-1913. XVI. A new freshwater ostracod. *K. Sven. Vetenskapakad. Handl.* 52: 9-22.

SOHN, I.G. 1976 - Antiquity of the adductor muscle attachment scar in *Darwinula* Brady & Robertson, 1855. *Abh. Verh. naturwiss. ver. Hamburg (N/F)* 18/19 suppl.: 305-308.

SOHN, I.G. & KORNICKER, L.S. 1973 - Morphology of *Cypretta kawatai* Sohn & Kornicker, 1972 (Crustacea, Ostracoda), with a discussion of the genus. *Smith. Contrib. Zool.* 141: 1-28.

SPRIGG, R. 1979 - Stranted and submerged sea-beach systems of southeast South Australia and the aeolian desert cycle. *Sedim. Geol.* 22: 53-96.

STARK, D.M. 1976 - Paleolimnology of Elk Lake, Itasca State Park, Northwestern Minnesota. *Arch. Hydrobiol. suppl.* 50: 208-274.

STREET, A.F. & GROVE, A.T. 1976 - Environmental and climatic implications of late Quaternary lake-level fluctuations in Africa. *Nature (London)* 261: 385-390.

STREET, A.F. & GROVE, A.T. 1979 - Global maps of lake-level fluctuations since 30,000 yrBP. *Quat. Res.* 12: 83-118.

SWAIN, F.M. 1977 - Paleoecological implications of Holocene and late Pleistocene ostracods, Lake Lahonton Basin, Nevada. In: Löffler, H. & Danielopol, D.L. (eds.). Aspects of Ecology and Zoogeography of Recent and Living Ostracoda. Junk, The Hague.

SYWULA, T. 1966 - Faunistic studies: Ostracoda and Copepoda. In: Latour & Garczynski, R. (eds.). Investigations into inland saline areas of Poland. Hydrochemical studies. *Badania Fizjograficzne nad Polska Zackodnia* 28: 7-65.

TETART, J. 1974 - Les entomostracés des milieux peu profonds de la vallée du Rhône. Essai d' étude écologique: composition des associations et répartition des espèces. *Trav. Lab. Hydrobiol.* 64/65: 109-245.

THOM, B.G. & CHAPPELL, J. 1965 - Holocene sea levels relative to Australia. *Search* 6: 90-93.

TIMMS, B.V. 1970a - Aspects of the limnology of five small reservoirs in New South Wales. *Proc. Linn. Soc. NSW* 95: 46-59.

TIMMS, B.V. 1970b - Chemical and zooplankton studies on lentic habitats of north-eastern New South Wales. *Aust. J. Mar. Freshwat. Res.* 21: 11-33.

TIMMS, B.V. 1973 - A comparative study of the limnology of three maar lakes in western Victoria. Ph.D. Thesis, Monash University.

TIMMS, B.V. 1975 - On the origin of salts in Lakes Bullenmerri and Gnotuk, western Victoria. *Aust. Soc. Limn. Bull.* 6: 5-8.

TIMMS, B.V. 1976 - A comparative study of the limnology of three maar lakes in western Victoria. I. Physiography and physiochemical features. *Aust. J. Mar. Freshwat. Res.* 27: 35-60.

TIMMS, B.V. 1977 - A study of some coastal dune lakes in western Victoria. *Proc. R. Soc. Vic.* n.s. 89: 167-172.

TIMMS, B.V. 1979 - The benthos of some lakes in north eastern Queensland. *Proc. R. Soc. Qld.* 90: 57-64.

TIMMS, B.V. 1980a - Farm dams. In: Williams, W.D. (ed.). An ecological basis for water resource management. ANU Press, Canberra.

TIMMS, B.V. 1980b - The benthos of Australian lakes. In: Williams, W.D. (ed.). An ecological basis for water resource management. ANU Press, Canberra.

TIMMS, B.V. (in press) - Animal communities in three Victorian lakes of differing salinity. In: Williams, W.D. (ed.). Salt Lakes: Proceedings of an International Symposium. Junk, The Hague.

TIMMS, B.V. & BRAND, G.W. 1973 - A limnological survey of the Basin Lakes, Nalangil, Western Victoria, Australia. *Aust. Soc. Limn. Bull.* 5: 32-40.

TUDOR, E.R. 1973. Hydrological interpretations of diatom-assemblages in 2 Victorian western district crater lakes. M.Sc. Thesis, Melbourne University.

VAN DE GRAAF, W.J.E., CROWE, R.W.A., BUNTING, J.A. & JACKSON, M.J. 1978 - Relict Early Cainozoic drainages in arid Western Australia. *Z. geomorph. NF* 21: 379-400.

VAN HARTEN, D. 1979 - Some new shell characters to diagnose the species of the *Ilyocypris gibba - biplicata - bradyi* group and their ecological significance. In: Krstic, N. (ed.). Taxonomy, biostratigraphy and distribution of ostracodes. Serbian Geological Society, Beograd.

VESPER, B. 1975 - The problems of noding on *Cyprideis torosa* (Jones, 1850). *Bull. Am. Paleont.* 65: 205-216.

VICTOR, R. & FERNANDO, C.H. 1980 - On *Heterocypris makua* (Tressler) 1937, a freshwater ostracod (Crustacea: Ostracoda) from the Hawaiian Islands, with notes on the other species of the genus. *Can. J. Zool.* 58: 1288-1297.

VON DER BORCH, C.C. 1976 - Stratigraphy and formation of Holocene dolomitic carbonate deposits of the Coorong area, South Australia. *J. Sed. Pet.* 46: 952-966.

VON DER BORCH, C.C., LOCK, D. & SCHWEBEL, D. 1975 - Groundwater formation of dolomite in the Coorong region of South Australia. *Geology* 15: 283-285.

WILLIAMS, W.D. 1964 - A contribution to the lake typology in Victoria, Australia. *Verh. Internat. Verein. Limnol.* 15: 158-168.

WILLIAMS, W.D. 1978 - Limnology of Victorian salt lakes, Australia. *Verh. Internat. Verein. Limnol.* 20: 1165-1174.

WILLIAMS, W.D. 1979 - Notes on the freshwater fauna of north-western Australia, especially the Kimberleys. *Rec. West Aust. Mus.* 7: 213-227.

WILLIAMS, W.D. (in press) - On the ecology of *Haloniscus searlei* (Isopoda, Oniscoidea) an inhabitant of Australian salt lakes. *Rec. Aust. Mus.*

WILLIAMS, W.D. & BUCKNEY, R.T. 1976 - Chemical composition of some inland waters in south, western and northern Australia. *Aust. J. Mar. Freshwat. Res.* 27: 379-397.

WOILLARD, G. 1978 - Grande Pile Peat Bog: a continuous record for the last 140,000 years. *Quat. Res.* 9: 1-24.

YEZDANI, G.H. 1970. A study of the Quaternary vegetation history in the volcanic lakes region of western Victoria. Ph.D. Thesis, Monash University.