



BIOGEOGRAPHIC PATTERNS IN AUSTRALIAN CAINOZOIC OSTRACODA, WITH THE DESCRIPTION OF *ORLOVIBAIRDIA* NEW GENUS.

K. G. McKENZIE

RIVERINA COLLEGE OF ADVANCED EDUCATION, WAGGA WAGGA, AUSTRALIA. 2650

ABSTRACT

After some general remarks on the concept of dynamism in geology, illustrative examples taken from vertebrate and invertebrate groups are cited. Following this, the distributions in time and space of several Cainozoic marine ostracode genera, including *Orlovibairdia* new genus with the type species *Orlovibairdia angulata* (Brady) 1870, are analysed in terms of the schedule of rifting and suturing which has been established on physical and other grounds for Australasia and its neighbouring plates.

INTRODUCTION

Dynamism is inherent in geology because geology is inherently time-oriented. Developments in plate tectonics, therefore, which have sparked a renewed interest in the concept of a dynamic Earth, have served merely to accentuate an underlying theme. Time's river flows continually and irreversibly; continually, the rocks of our planet accept the records of new, different epochs. Earth's lithosphere is the lithographic master upon which the history of its atmosphere, hydrosphere, tectonosphere and biosphere is engraved. If, locally, the record may have been partially erased by subsequent events it is reassuring to remember that palimpsests remain for our interpretation. That we use an uniformitarian approach in making such interpretations is no contradiction of the concept of dynamism unless our uniformitarianism is static and fails to appreciate that all things evolve. Palaeontology, which studies the records of an evolving biosphere, and biogeography, the study of the distribution (dispersal) of an evolving biosphere, are static only when they are purely descriptive. Both sciences have accumulated enormous amounts of data which are now being utilised in papers more or less influenced by the dynamic approach (Hughes (ed.) 1973, Hallam (ed.) 1973, Tarling and Runcorn (eds.) 1973).

Some tendency to think statically is still evident. For example, to state merely that lungfish, which arose in the Devonian, may equally have evolved in Laurasia as in Gondwanaland is to fossilise our thinking at the Palaeozoic Ursprung of the group and to miss an opportunity for dynamic interpretation. Dynamically, it is

not only significant that lungfish faunas could have been continuous throughout Pangaea up to the Triassic but also that, following the separation of Laurasia from Gondwanaland (about 180 m. y. B.P.) there was no subsequent opportunity for north-south faunal mixing in the Mesozoic. The group's survival depended upon Gondwanan taxa. The breach of Pangaea by Tethys, the subsequent developments of the Atlantic, Indian and Southern Oceans, the origin of the Sahara and Arabian Deserts all give us times (which are becoming more precisely defined) when geographic separation determined major branchings in the dipnoan evolutionary tree. (A corollary to this rationalisation is that prior to the Triassic factors other than geographic separation should be considered as influencing their gross evolutionary changes). Thus the present distribution of lungfish species in Australia, Africa and South America depends for its elucidation upon dynamic thinking which spans the interval Devonian-Recent.

RATIONALE

Australasia lies at a terminus of three dispersal routes in the southern hemisphere. The habitus of Australasian Cainozoic marine faunas, as a result, is comprised of elements derived from these three routes together with the endemic taxa. As has been indicated in earlier papers (Fleming 1962, McKenzie 1973) the routes are Tethyan, Austral and peri-Pacific. It must be recognised that a further category exists even though until recently it has rarely been emphasised. This category comprises the deepwater taxa which disperse through the psychrosphere. The present psychrosphere (cold,

bottom Water Mass system) appears to have originated in the late Eocene or early Oligocene as a development from a former warmer (thermospheric) deep sea (Benson 1975).

It is now recognised that the constituent elements of former Gondwanaland have continued to drift throughout the Cainozoic and the positions of individual elements at particular times are becoming more precisely defined in the relevant space. I have published elsewhere a rationale for studying Cainozoic freshwater faunas in detail from the viewpoint of defining times of continental rifting and suturing (McKenzie 1971) but in this paper wish to emphasise the point that shallow water marine faunas equally may be used to yield such information by studying the appearances and extinctions of taxa in dispersing lineages and clades. Ideal for this kind of work are distinctive species which are wide ranging geographically and also have a significant and relatively well known fossil record.

Austral, Tethyan and endemic taxa can be recognised throughout the organic world. Among vertebrates, consider the examples listed below:

1. Caecilians are predominantly tropical Amphibia, highly endemic at the generic and specific level which occur in Central and South America to 35°S. Lat.; Africa between about 13°N. and 13°S. Lat., the Seychelles, India (to Sikkim, about 28°N. Lat.), Sri Lanka, southeastern Asia—including the Philippines and Indonesia—up to Weber's Line. With the exception of the Seychelles, all the island records—Trinidad, Sri Lanka, Java, Sumatra, Palawan, Mindanao—are from places which would have been connected to the mainland at times of sea level regression due to glaciation during the Pleistocene. Caecilians are absent from North America, Asia north of 30°N Lat., Europe, Madagascar, Australia and Antarctica. (A. G. C. Grandison personal communication June 1975). Most species are aquatic for at least some stage in their life cycle but this does not imply that they can cross marine barriers.

Presumably, the initial dispersal of the group occurred prior to the rifting apart of West Africa/Brasil and East Africa/Madagascar/India. The fossil record from an European Riss-Würm interglacial deposit can probably be disregarded but the Bolivian fossil of Carboniferous age needs rechecking since it suggests an origin in South America for this Gondwanan group. The next dispersive phase would have initiated with the suturing of India against Asia in the Neogene which led to the southeastern Asian radiation.

2. The tropical, eel-like synbranchid teleosts comprise freshwater, brackish and some marine species and have a disjunct distribution. In the Americas, they

range from Mexico to northern Argentina; other species occur on or near the coasts of tropical Africa; and the remaining species come from India, New Guinea and Australia. (R. A. Ringuelet personal communication February 1971). The group's marine ancestors probably established this pattern in an initial radiation along the southern shores of late Mesozoic Tethys.

3. In spite of their well documented territorial behaviour, the number of endemic taxa among flying birds must remain a constant source of surprise for anyone who has observed stragglers or storm-blown individuals making haven on islands hundreds of miles off the established migration routes for their species; even in non-migratory birds the capacity for flight favours a wide dispersal. Nevertheless, in Australasia endemic bird groups include the New Zealand wrens; the Australian bowerbirds and the New Guinea birds of paradise.

Considering invertebrates, the predominantly aquatic crustaceans include many groups which exhibit similar biogeographic patterns. Thus the austral distribution of freshwater calanoid copepods is well known; as is the endemicity to Australia of anaspidaceans. A third group, the fairy shrimps, include the Recent genus *Streptocephalus* whose distribution is illustrated in Figure 1. The distribution pattern can only be interpreted properly by thinking dynamically because the data are recorded on a Cretaceous map. As there are no *Streptocephalus* records from South America and Australia (Sars' tentative referral of an Australian species to *Streptocephalus* is not valid), the dispersal of the genus must postdate the breakup of Gondwanaland. The origin may well have been in Laurasia, because of the records from North America and Europe, with the genus dispersing to Africa and India in the Neogene when these plates collided with Eurasia. This seems preferable to postulating an origin in Africa because that alternative strikes difficulty in explaining the dispersal of populations to North America. Either way it is a circum-Tethyan pattern.

METHOD

An exemplar method is used in this paper to discuss the significance of some marine biogeographic patterns. This method has often been criticised on the ground that the distribution patterns of single taxa may be used in support of virtually any hypothesis. Such critics need to be reminded that the term exemplar means that other instances which confirm the published conclusions, occur in the group considered—that the exemplar is, indeed, an example from a larger correlated sample.

In defence of the use of an exemplar technique here, it should be noted that the interpretation of *dynamic* biogeographic patterns proceeds within some powerful

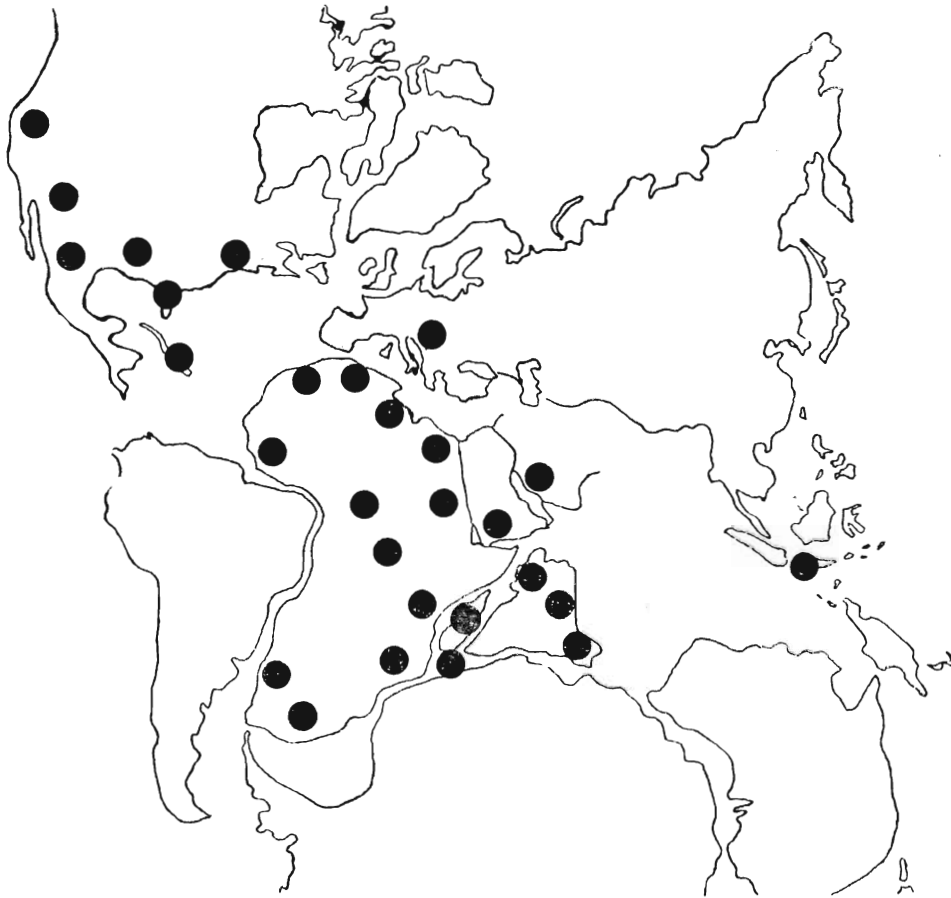


Fig. 1. Distribution of *Streptocephalus*. All records are from the Recent.

constraints. These include : the physical evidence ; the fossil record ; and the biology of the taxa concerned. The geographic dynamics of plate tectonics are far from completely known but there is no doubt that some continental plates have drifted relative to each other while others have collided; and dates for these events are becoming more precise. An organism which by virtue of its biology cannot cross a deep oceanic barrier today could not have crossed Mesozoic Tethys (assuming biologic continuity in the lineage) and hence its occurrence on the shelves of now adjacent plates can only postdate the time at which these collided during the Cainozoic disruption of Tethys. The fossil record assists to confirm this and since Ostracoda are abundant in Cainozoic marine sediments the fossils of ostracode exemplars can be used to test hypothesised times for drift or collision which are based on other evidence. The results of such dynamic studies provide more rigorous confirmations for plate tectonics than do either the patterns of modern taxa which have very poor or non-existent fossil records or the patterns of those fossil taxa which are likewise static because they are temporally restricted. An instance of the latter kind of pattern is the distribution of *Mesosaurus*,

restricted to the early Permian of South America and South Africa which is commonly quoted as, for example, evidence for, ".....at the least, close connections between these two areas." (Romer 1973).

The deduction that marsupial dispersal to Australia occurred via a southern connection in the late Cretaceous to early Cainozoic, which is championed by some workers (Cox 1973, Jardine and McKenzie 1972), labours under a difficulty which often characterises vertebrate faunas but less often microfaunas, namely, a lack of material. Fortunately, rich, although as yet incompletely described, vertebrate faunas await study in other areas which are significant in terms of Cainozoic global tectonics, e.g., northern India.

Jardine (in Sneath and McKenzie 1973) states the obvious, that biogeographers, ".....should seek the hardest available evidence." Geographically, the best evidence is the rapidly accumulating information on the plate tectonics of continental masses relative to each other, in time and space ; and biologically, the hardest available evidence is an abundance of specimens in taxa whose biology is relatively well understood. The exemplars employed in this paper meet these biological criteria

and have the added advantage of being dynamic to the extent that their fossil records are more or less precisely known.

The points made above can be driven home by reference to the known distribution in space and time of the foraminiferan *Austrotrillina*, a large benthic miliolid (Adams 1973). The dispersal potential of *Austrotrillina* would be similar to that of most benthic marine Ostracoda. *Austrotrillina* first appeared in the middle East in the Lower Oligocene and by the Middle Oligocene had arrived in the Far East. Evidently, it was dispersed along the northern margin of Tethys. By the late Oligocene and early Miocene it occurred in Mediterranean Europe, East Africa and widely through Indonesia and the Pacific. The African records put a time on the closure of the eastern Mediterranean by the impingement of the African plate against Eurasia. It was not until the Middle Miocene that *Austrotrillina* got to India and Australia, which suggests that the collision between these masses and Eurasia and the Pacific plate did not much antedate the Middle Miocene.

The ostracode patterns to be discussed will be evaluated in terms of whether they confirm or conflict with such a schedule.

SYSTEMATIC DESCRIPTION

- Family* : Bairdiidae Sars 1888
Subfamily : Bythocypridinae Maddocks 1969
Genus : *Orlovibairdia* new genus
 (Plate I)

Bairdia (partim)—Brady 1870, 1890

Nesidea (partim)—Muller 1912

Anchistrocheles (?) (partim) : Triebel 1960, Maddocks 1969

Etymology : For Professor Academician Yu. A. Orlov, to whom this volume is dedicated, general editor for the *Osnovy Palaeontologii*.

Type Species : *Orlovibairdia angulata* (Brady) 1870

Diagnosis : A bythocypridine bairdiid genus characterised by a subreniform, thin, ventromarginally compressed carapace; ornamented by pitting; and denticulate both anteriorly and posteroventrally. Inner lamellae broad; with narrow elongate anterior and posterior vestibules; radial pore canals numerous, short and straight; normal pore canals scattered, simple, rimmed; muscle scars typically bythocypridine, comprising four large central adductors plus less prominent frontal, mandibular and dorsal scars; hinge simple, of ridge and groove type.

Discussion : Although most bairdiines have a more complex adductor muscle scar pattern, in some species (e.g. *Bairdia* sp. from the Lias of Germany illustrated

in Triebel (1960)) the muscle scar pattern is similar to that of the bythocypridines so it is necessary to employ other criteria in distinguishing *Orlovibairdia* from the bairdiine genera.

Orlovibairdia differs from *Bairdia* and *Bairdoppilata* by reason of its thin marginally compressed carapace since in both these genera the carapace is robust and inflated. It differs from *Triebelina*, *Glyptobairdia* and *Havanardia* because they are ornamented typically by prominent ridges on the valves and because species in which such ridges do not occur are inflated and robust. The same features—a relatively thin and marginally compressed carapace—suffice to distinguish the new genus from all the other taxa which either have been lumped into *Bairdia* or have been given form generic names in recognition of some striking feature of shape or ornamentation. (*Bairdia*, as understood here, includes *Neonesidea* and *Paranesidea*.)

When compared with bythocypridine taxa, *Orlovibairdia* is distinguished from *Bythocypris* and *Zabythocypris* because their carapaces are smooth not pitted and lack the marginal denticulations of *Orlovibairdia*.

The new genus seems closest to *Anchistrocheles* and *Pussella* from which it differs in that they are smooth and lack the series of marginal denticles which characterise *Orlovibairdia*. Also, these two genera tend to have inner lamellae which are invaginated posterodorsally a feature which does not occur in the new genus.

Geological Age : Palaeogene-Recent.

Orlovibairdia angulata (Brady), 1870

Description : "Testa compressa a latere visa, elongata, subreniformis, altitudine maxima dimidiam longitudinis aequante prope medium sita, extremitate antica oblique subrotundata dentibus IV—X circiter fimbriata, postica valde declivi, curvata; margine superiore arcuato, obsolete angulato, inferiore ante medium sinuato, pone medium in laminam convexam dentatam producto, versus extremitatem anticam in processo fere rectangulare excurrente; supra visa compressa, ovato, latitudine maxima longitudinis partem tertiam vix superantem medio sita, extremitatibus aequis mucronatis. Superficies testae foveolis parvis rotundatis dense ornata."

To this, the original description by Brady, can be added the details regarding internal features which form part of the generic diagnosis.

Discussion : Brady's measurements of species were often in error and such is the case here. The length given by Brady was 0.7 mm but when I measured the types (an entire carapace plus the disarticulated right and left valves of a second syntype) their average length was near 1.00 mm.

The difference between published and actual length is significant in this instance because the Recent Austra-

lasian taxon, *Orlovibairdia arcaforma* (Swanson) 1977 varies in length from 0.6—0.75 mm over a latitudinal range from Sahul Shelf to Banks Strait in Australian waters. It seems then that, as with other ostracode genera, the *Orlovibairdia* species from lower latitudes are shorter than those from higher latitudes, a confirmation of Bergmann's Rule.

PATTERNS

SAIPANETTIDAE

The genus *Saipanetta* as the type for a new family was first described in 1967, in a paper which recognised a considerable history for the family extending at least as far back as the Jurassic. In modern seas, there appear to be two common types: a brown form restricted to warm shallow (0-50 m) waters near a reef front and a white form which occurs in cold deep water (about 500 m to over 2000 m). These types are represented by the species *Saipanetta claudi* (McKenzie) 1967 (brown) and *Cardobairdia glabra* van den Bold 1968 (white). Figure 2' gives the distribution of Saipanettidae in time and space on a map which has the continental configurations plotted as for the Cretaceous (Smith, Briden and Drewry

1973). The map indicates that the Tethyan Province s.s. of Tethys was the region of origin for the group which did not much expand its distribution before the Palaeogene. During the Palaeogene, Tethys was still open throughout its length and saipanettids ranged from the Gulf of Mexico to southeastern Australia. Saipanettids remained in the Mediterranean at least until the Langhian (Oertli 1961) but presumably were a casualty of the later Miocene salinity crisis since there are no more recent Mediterranean records. This salinity crisis correlates with the final disruption of Tethys which had earlier become attenuated by the opening of the Atlantic and Indian Oceans during the late Cretaceous and Palaeogene. The earliest southeastern Australian records are Middle Eocene and confirm the physical evidence that Australia had separated from Antarctica by this time. The earliest known New Zealand records are Neogene but on the rifting evidence (New Zealand broke away from Australia about 80 m.y. B.P.), future records from the Palaeogene and even late Cretaceous are a possibility.

Following the disruption of Tethys, two post-Miocene dispersal areas for saipanettids remained: the Indo-

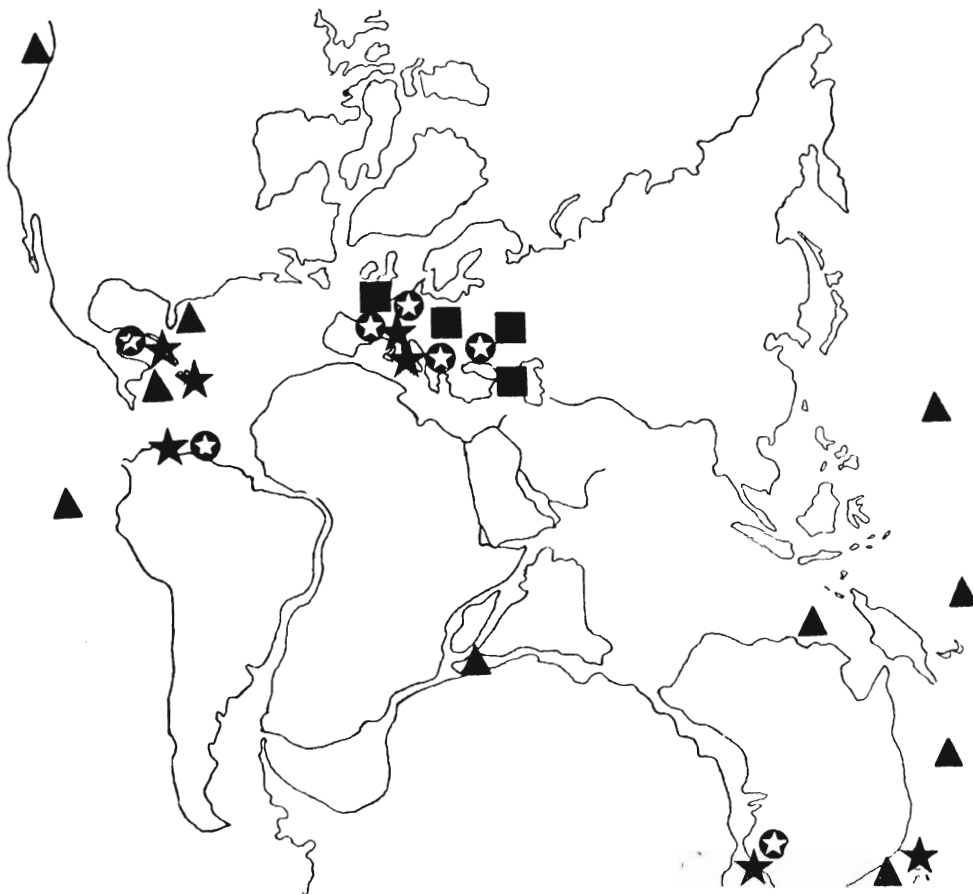


Fig. 2. Distribution of Saipanettidae. Squares = Mesozoic; stars in circles = Palaeogene; Stars = Neogene; triangles = Recent.

West Pacific and the Caribbean. In the former region, they range today from Sri Lanka to Samoa and from Saipan to New Zealand. Indonesian and northern Australian shelf species have been recognised in the Miocene of the Bombay offshore well (D. K. Guha personal communication January 1975) indicating that by this time India had become sutured to the rest of Asia, so that Neogene saipanettid records from southern India are a possibility. In the Caribbean (van den Bold 1974) saipanettids could have migrated through the Panamanian passage at any time between the Palaeocene and Pliocene. This could have happened at about Oligocene time since they now occur off the Galapagos which originated in the Oligocene. The Galapagos species ranges northwards to Alaska Bay.

In conclusion, the absence of any Southern South American and South African records suggests strongly that the primary dispersal route was Tethyan.

Uroleberis

The xestoleberidid genus *Uroleberis* is another example of a taxon with Tethyan affinities. Again, there are two common modern types: a strongly punctate tropical form exemplified by *Uroleberis foveolata* (Brady) 1880

and a weakly punctate more temperate form exemplified by such taxa as *Uroleberis minutissima* (Chapman) 1926, and by the type species *Uroleberis parnensis* (Apostolescu) 1955. Figure 3 gives the known distribution of *Uroleberis* in time and space on a Cretaceous map. Like Saipanettidae, *Uroleberis* originated in the Tethyan Province of Tethys, the earliest records being from the Upper Cretaceous of Poland and Belgium. By the lower Palaeocene, *Uroleberis* reached the Crimea (Sheremeta 1969) and by the lower Eocene it appeared on the opposite shore of Tethys in the Rakhi Nala District of Pakistan (Siddiqui 1971). The first recorded occurrence in southeastern Australia is Upper Eocene (McKenzie 1974). Westwards, *Uroleberis* first appears in the Caribbean in the Lower Miocene (van den Bold 1972) on the known data. But earlier records can be anticipated, since by this time the Atlantic was relatively wide and a sweepstakes dispersal mode would be mandatory for taxa migrating westwards whereas in the upper Cretaceous Caribbean immigrants could disperse there along the almost continuous Atlantic shelf of North America—Europe. Like the Saipanettidae, this genus was a casualty of the Mediterranean salinity crisis and now occurs in two widely separated regions: the Caribbean and Indo-



Fig. 3. Distribution of *Uroleberis*. Symbols as in Figures 2.

West Pacific. It is comparatively rare in the Caribbean and in the temperate to subtropical Indo-West Pacific but is a typical member of shallow and intermediate depth shelf assemblages in tropical Australian and Indonesian waters.

In view of the earlier comment on the correlation between tropical environments and strongly punctate *Uroleberis* species, it is interesting to note that in the Palaeogene of the Ukraine, strongly punctate taxa do not appear until the Upper Eocene, Bartonian (Sheremata 1969) when seas were warm everywhere, whereas in the cool late Cretaceous of nearby Poland *Uroleberis* was represented by a smooth form. The strongly punctate *Uroleberis foveolata* appears in the Miocene of the Bombay offshore well (Guha pers. comm. cit.).

The absence of South American records (Middle Eocene—Miocene of the Magellanes Basin, Chile; Lower Miocene of the Pirabas Formation, Brazil; Tertiary of Argentina) and of South African records even to the present day (Hartmann 1974) confirms the Tethyan relationships of this genus.

Orlovibairdia (Figure 4)

Fossil records of *Orlovibairdia* are few compared to

those for saipanettids (which number about 60 in the Caribbean alone (van den Bold 1974)) and *Uroleberis* but are interesting in that they indicate dispersal for the taxon via the Southern Ocean from an Australasian origin in the Upper Eocene. There appears to be a more or less continuous series of forms from punctate to highly punctate; and a similar relationship exists between these and temperature (latitude) in modern seas as occurs in *Uroleberis*, i.e. the more punctate forms appear in warmer (lower) latitudes. Punctate forms occur between 70°S Lat. to about 55°S Lat. and strongly punctate types range from 45°S. Lat. to about 10°S. Lat.

Orlovibairdia is absent from the Recent of South Africa and Madagascar (Hartmann 1974, Maddocks 1966) nor is it known fossil from the Ethiopian Region as a whole. It does not occur in the Tertiary of Brazil, Chile or Argentina as far as I am aware but lives in the Straits of Magellan today and is also known from Antarctic waters (Brady 1870, Muller 1908). The record by Brady from cold deepwater off the Azores (Brady 1880) is anomalous and needs to be checked against the original material although the taxon could conceivably have travelled into high northern Atlantic latitudes via Antarctic Bottom Water. There are no fossil Tethyan records



Fig. 4. Distribution of *Orlovibairdia*. Symbols as in Figure 2. Note that the record from off the Azores is considered doubtful.

as far as I am aware but the genus occurs today in the Sahul Shelf fauna, off northwestern Australia (McKenzie 1974) and along the eastern coast of Queensland in the latitude of Gladstone (V. Labutis personal communication April 1975) as well as in Bass Strait (Triebel 1960). It ranges throughout New Zealand waters (Hornibrook 1952, Maddocks 1969).

In fact, all the fossil records are from southeastern Australia where *Orlovibairdia* is known to range from the top of the Eocene to the lower Miocene (punctate forms). It would appear then to have evolved in Australasia and subsequently to have carried out a circum-Antarctic peregrination. The first forms which were strongly punctate probably did not develop until the later Miocene warming but since this time have reached not only northwestern Australia but also New Zealand where *Orlovibairdia arcaforma* (Swanson) 1977 is a typical species. On this evidence, any fossil records from southeast Asia will be restricted to the Neogene

following suture of the Australasian plate against the Indonesian Archipelago.

Hanaiceratina and *Loxoconchella* (Figure 5)

Hanaiceratina was recently described, with the type species *Hanaiceratina arenacea* (Brady) 1880, for several Australasian and Indo-Pacific species and ranges from Neogene to Recent (McKenzie 1974). It has been selected as an exemplar for two reasons. Firstly, *Hanaiceratina* belongs in the family Bythocytheridae which is a characteristic group for the Cainozoic of Australasia where it has radiated more widely than elsewhere both as regards diversity of genera and numbers of species. Secondly, *Hanaiceratina* ranges today from Australasia probably to Japan and the fossil record indicates that this periPacific dispersal pattern initiated in Australia. On the physical evidence, northward dispersal of *Hanaiceratina* must date from the time of impact of the Australasian Plate against the Pacific and Eurasian Plates which took place with

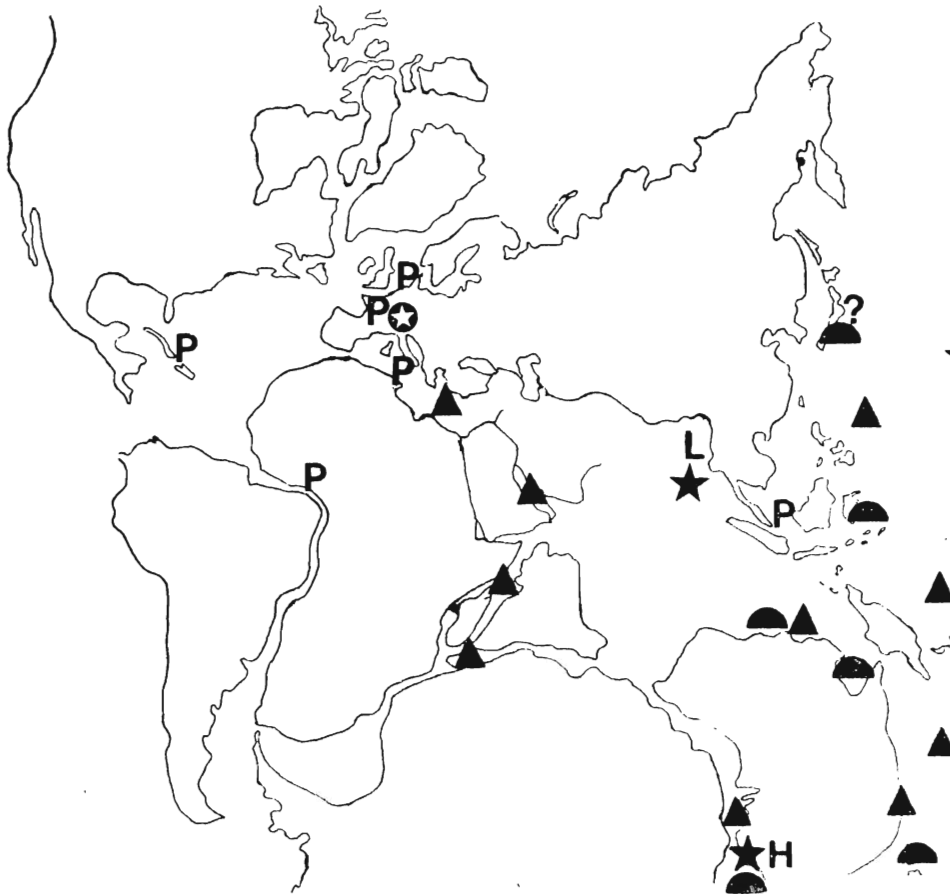
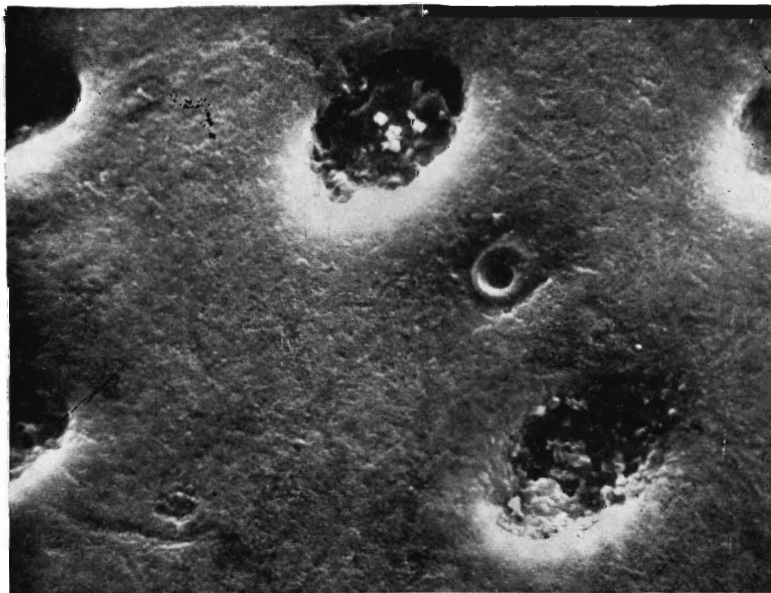
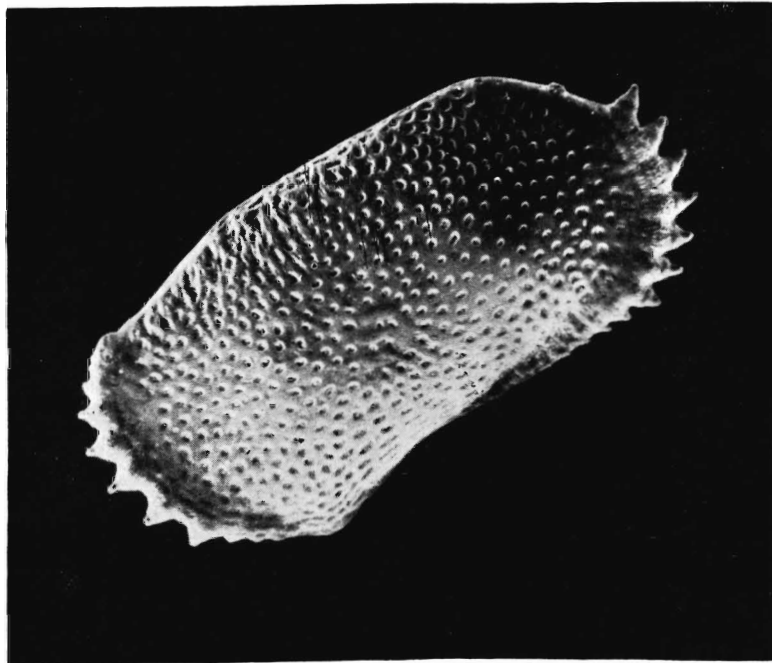


Fig. 5. Distribution of *Phlyctocythere*, *Loxoconchella* and *Hanaiceratina*. P with star in circle = Palaeogene record of *Phlyctocythere*; other Ps are the Recent distribution of *Phlyctocythere* species, according to van Morkhoven (1963). L with stars = Neogene records of *Loxoconchella*; triangles = Recent records of *Loxoconchella*. H with star = Neogene records of *Hanaiceratina*; hemicircles = Recent records of *Hanaiceratina*. Note that the record from Japan is considered questionable



resulting local structural complexity in the region once known to structural geologists as the Halmahera Knot and now more precisely located in Sulawesi (King 1973).

Hanaiceratina first appears in southeastern Australia, according to Crespin (1943) in the warm Lower Miocene and carries through to the Pliocene; further, it still lives in the area, in Bass Strait (McKenzie 1974). The New Zealand form is considered to be restricted to North Island waters (Hornibrook 1952). All the Indo-Pacific records are of living species (Brady 1880, Keij 1953, Hanai 1961) which reinforces the argument of the previous paragraph.

The loxocochnid genus *Loxoconchella* is far more widely dispersed than *Hanaiceratina* and is used here to exemplify movement in the opposite direction, i.e. southwards from the ancient Indo-Pacific to India and Australasia. As noted by van Morkhoven (1963), *Loxoconchella* probably evolved from the Palaeogene genus *Phlyctocythere* which was first described from the Lutetian of France and subsequently from the French Eocene and Lower Oligocene (Ducasse 1969) and the Lower Oligocene (Latdorfian) of Germany (Moos 1973). *Loxoconcha pellucida* Müller 1894, a species living in the Mediterranean today is thought to be a modern *Phlyctocythere*. The earliest records of *Loxoconchella* are Neogene, from the Hawaiian Islands (Holden 1967) and the Andaman Islands (Guha 1968). There are no Neogene fossil records from either India or Australasia. The present distribution of *Loxoconchella* ranges from the Mediterranean (Puri, Bonaduce and Molloy 1964) the Red Sea (Hartmann 1964), East Africa and the Persian Gulf (van Morkhoven 1963), Sri Lanka (Brady 1886), Australia (Triebel 1954, McKenzie 1967, McKenzie and Swain unpublished data) and the Pacific islands of Hawaii, Fiji, Samoa, New Caledonia, Easter Island (records listed in Holden 1967), Saipan, Onotoa (McKenzie unpublished data). The most parsimonious hypothesis from this record is that *Loxoconchella* moved into Indian, Australasian and African waters subsequent to the suturing of India and Australasia against Eurasia and the Pacific and the Neogene closure of Tethys caused by the impingement of Africa against Asia Minor.

Of the two common forms of *Loxoconchella* one is smooth and the other is ornamented by a subcentral boss on each valve. It is the smooth form which has moved onto Australasian shelves. Smooth species which have been described include *L. honoluluensis* (Brady) 1880, *L. papillosa* (Brady) 1886, *L. pulchra* McKenzie 1967; and bullate species include *L. anomala* (Brady) 1880 and *L. dorsobullata* (Hartmann) 1964.

CONCLUSION

It appears from the above analyses that the dynamic biogeography of the exemplars is consistent with the

schedule for drift and suturing, which has been worked out on physical and other grounds, relative to Australasia and its neighbouring plates. In particular, the analyses confirm that Tethyan taxa with a sufficiently long Cainozoic record may well have reached Australasia via Tethys in the late Cretaceous-early Cainozoic while the Tethyan corridor was open; austral elements did not reach southern Australia before the Palaeocene-Eocene; peri-Pacific taxa did not arrive in Australasian waters before the Neogene, nor did Australian taxa take up a peri-Pacific journey prior to the Neogene.

It is also apparent that what is true for Australasia is equally true for other plates (e.g. India) although the evidence presented here is more limited. In particular, the closure of the eastern Mediterranean in the Neogene is further established by the ostracode evidence.

ACKNOWLEDGEMENTS

I thank Prof. M. R. Sahni for the opportunity to contribute to this volume; and Dr. D. K. Guha, Miss A. G. C. Grandison, Prof. R. A. Ringuelet and Mr. V. Labutis for data which are acknowledged in the text.

The Stereoscan Electron Microscope pictures in Plate I were taken on the Cambridge SEM at the British Museum (Natural History).

Mrs. L. Vennell typed the manuscript.

REFERENCES

- ADAMS, C. G. 1973. Some Tertiary Foraminifera. In: A. Hallam (ed.), "Atlas of Palaeobiogeography" Elsevier, Amsterdam. pp. 453-468.
- BENSON, R. H. 1975. The origin of the psychrosphere as recorded in changes of deep-sea ostracode assemblages. *Lethaia*. **8**: 69-83.
- VAN DEN BOLD, W. A. 1972. Ostracoda of the La Boca Formation, Panama Canal Zone. *Micropaleontology*. **18**: 410-442.
- VAN DEN BOLD, W. A. 1974. Taxonomic status of *Carbobairdia* (van den Bold, 1960) and *Abyssocypris* n. gen.: two deepwater ostracode genera of the Caribbean Tertiary. In: W. A. van den Bold (ed.), "Ostracoda: the Henry V. Howe Memorial Volume" pp. 65-79. *Geoscience and Man*, 6. Louisiana State University, Baton Rouge.
- VAN DEN BOLD, W. A. 1975. Neogene biostratigraphy (Ostracoda) of Southern Hispanola. *Bull. Amer. Paleont.* **66**(286): 549-639.
- BRADY, G. S. 1870. Halt-Bay (detroit de Mangellan). In: M. de Folin (ed.) "Fonds de la Mer" Folin and Perrier, Paris. 195-202.
- BRADY, G. S. 1880. Ostracoda. In J. Murray (ed.) "Challenger" Reports. **1**: 1-184.
- BRADY, G. S. 1886. Notes on Entomostraca collect by Mr. A. Haly in Ceylon. *J. Linn. Soc., Lond.* **19**: 293-317.
- BRADY, G. S. 1890. On Ostracoda collected by H. B. Brady, Esq., L.L.D., FRS., in the South Sea Islands. *Trans. Roy. Soc. Edinburgh*. **35**: 489-525.
- COX, C. B. 1973. Systematics and Plate Tectonics in the spread of marsupials. In: N. F. Hughes (ed.) "Organisms and

- Continents through Time" pp. 113-119. *Spec. Paps Palaeont.* 12.
- CRESPIN, I. 1943. The stratigraphy of the Tertiary marine rocks in Gippsland, Victoria. *Palaeont. Bull. Canberra.* 4 : 1-101.
- DUCASSE, O. 1969. Biozonation de l'Eocene nord-aquitain. *Bull. Soc. geol. de France.* 11 : 491-501.
- FLEMING, C. 1962. New Zealand biogeography, a palaeontologist's approach. *Tuatara.* 10 : 53-108.
- GUHA, D. K. 1968. On the Ostracoda from Neogene of Andaman Islands. *J. geol. Soc. India.* 9 : 58-66.
- HALLAM, A. (ed.) 1973. Atlas of Palaeobiogeography. Elsevier, Amsterdam. 531 pp.
- HANAI, T. 1961. Studies on the Ostracoda from Japan : hingement. *J. Fac. Sci., Univ. Tokyo.* 13 : 345-377.
- HARTMANN, G. 1964. zur Kenntnis der Ostracoden des Roten Meers. *Kiel. meersforsch.* 20 : 35-127.
- HARTMANN, G. 1974. Die Ostracoden des Untersuchungsgebiets. *Mitt. Hamburg Zool. Mus. Inst.* 69 : 229-520.
- HOLDEN, J. 1967. Late Cenozoic Ostracodes from the drowned terraces in the Hawaiian Islands. *Pacific Sci.* 21 : 1-50.
- HORNIBROOK, N. DE B. 1952. Tertiary and Recent marine Ostracoda of New Zealand. *N. Z. Geol. Surv. Palaeont. Bull.* 18 : 1-82.
- HUGHES, N. F. (ed.) 1973. Organisms and Continents through Time. Palaeontological Association, London. 334 pp.
- JARDINE N, AND McKENZIE, D. P. 1972. Continental drift and the evolution and dispersal of marsupials *Nature, Lond.* 235 : 20-24.
- KEIJ, J. 1953. Preliminary note on the Recent Ostracoda of the Snellius Expedition. *Proc. Kon. Nederl. Akad. Wetensch Amsterdam.* Ser. B. 56 : 155-168.
- KING, L. 1973. An improved reconstruction of Gondwanaland. In : D. H. Tarling and S. K. Runcorn (eds.) "Implications of Continental Drift to the Earth Sciences", Academic Press London. pp. 851-863.
- MADDOCKS, R. F. 1966. Distribution patterns of living and subfossil podocopid ostracodes in the Nosy Be area, northern Madagascar. *Univ. Kansas paleontol. Contribs.* 12 : 1-72.
- MADDOCKS, R. F. 1969. Revision of Recent Bairdiidae (Ostracoda). *Bull. Smithsonian Inst.* 295 : 1-126.
- McKENZIE, K. G. 1967a. Saipanellidae, a new family of Podocopid Ostracoda, *Crustaceana.* 13 : 103-113.
- McKENZIE, K. G. 1967b. Recent Ostracoda from Port Phillip Bay, Victoria. *Proc. Roy. Soc. Vict. n.s.* 80 : 61-106.
- McKENZIE, K. G. 1971. Palaeozoogeography of freshwater Ostracoda, In : H. J. Oertli (ed.) "The Palaeoecology of Ostracoda" SNPA, Pau. 207-237.
- McKENZIE, K. G. 1974. Cenozoic Ostracoda of Southeastern Australia with the description of *Hanaiceratina* new genus In : W. A. van den Bold (ed.), "Ostracoda : the Henry V Howe Memorial Volume" *Geoscience and Man*, 6. Louisiana State University, Baton Rouge. 153-182.
- VAN MORKHOVEN, F.P.C.M. 1963. Post-Palaeozoic Ostracoda. Elsevier, Amsterdam. 2 : 478 pp.
- MOOS, B. 1973. Ein weiteres Vorkommen der Gattung *Phlyctocythere* Keij (Ostr.). *Geol. Jb.* A6 : 97-99.
- MÜLLER, G. W. 1908. Die Ostracoden. *Deutsche Sudpol. Exped.* 10 : 53-181.
- MÜLLER, G. W. 1912. Die Ostracoden. *Das Tierreich.* 31 : 1-434.
- OERTLI, H. J. 1961. Ostracodes du Langhien-type. *Riv. Ital. Paleont.* 67 : 17-44.
- PURI, J. S., BONADUCE, G. AND MALLOY, J. 1964. Ecology of the Gulf of Naples. *Pubbl. staz. zool. Napoli*, 33 suppli : 87-199.
- ROMER, A. S. 1973. Permian reptiles. In : A. Hallam (ed.) "Atlas of Palaeobiogeography" Elsevier Amsterdam. pp. 159-167.
- SHEREMATA, V. 1969. Palaeogene Ostracoda of the Ukraine. Lvov Univ. Press. Lvov (in Russian). 274 pp.
- SIDDIQUI, Q. 1971. Early Tertiary Ostracoda of the family Trachyleberididae from West Pakistan. *Bull. Br. Mus. Nat. Hist. (Geol.) Suppl.* 9 : 1-98
- SMITH, A. G., BRIDEN J. C. AND DREWRY, G. E. 1973. Phanerozoic world maps. In : N. F. Hughes (ed.) "Organisms and Continents through Time" *Spec. Paps Palaeont.*, 12. Palaeontological Association, London. 1-42
- SNEATH, P.H.A. AND McKENZIE, K. G. 1973. Statistical methods for the study of biogeography. In : N. F. Hughes (ed.) "Organisms and Continents through Time" *Spec. Paps Palaeont.*, 12. Palaeontological Association, London. 45-60.
- TARLING, D. H. AND RUNCORN, S. K. 1973. Implications of Continental Drift to the Earth Sciences. Academic Press, London. 1 and 2. 1184 pp.
- TRIEBEL, E. 1954. *Loxoconchella* n. g. (Crust., Ostr.) *Senck. Leth.* 35 : 17-21.
- TRIEBEL, E. 1960. Die taxonomische Stellung und die Gattungen der Unterfamilie Macrocypridinae (Ostracoda). *Senck. Biol.* 41 : 109-124.

EXPLANATION OF PLATE

PLATE I

- Orlovibairdia* cf. *arcaforma* (Swanson) 1977 from Banks Strait, between Flinders Island and Tasmania. Recent.
 Upper picture : left valve of carapace, $\times 125$.
 Lower picture : detail of left valve, including a rimmed simple normal pore canal, $\times 2350$.