



Title	Ostracoda from the Navidad Formation (Miocene), Chile
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Citation	北海道大学理学部紀要, 18(1-2), 57-84
Issue Date	1978-02
Doc URL	http://hdl.handle.net/2115/34824
Type	bulletin (article)
File Information	18_1-2_p57-84.pdf



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OSTRACODA FROM THE NAVIDAD FORMATION (MIOCENE), CHILE

by

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(with 1 table, 1 text-figure and 4 plates)

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Abstract

Altogether 28 species of fossil ostracods, of which seven species are new, are described from the Miocene Navidad Formation of Chile. The formation is considered as Upper Miocene in age, might be deposited under a rather deep water (300 m.), based on these ostracods.

Introduction

This paper gives the first detailed study on fossil ostracods in Chile. To date there have been only two studies of ostracods from Chile; Ohmert (1971), studied systematics of some ostracods from the Pliocene of Caldera, north of Chile, and Hartman (1962) who presented a comprehensive review of the recent ostracods from the Chilean Pacific Coast.

The extensive exposure of Tertiary sediments throughout the country offers attractive possibilities of using this kind of microfossil to solve the many questions of chronostratigraphic and palaeo-environmental interpretation.

In this paper, a description of 28 species distributed among 21 genera are presented. Seven of these species are described as new.

Stratigraphy

The ostracod materials presented in this paper were taken from the lower member of the Navidad Formation, cropping out at the Punta Perros locality, south side of the mouth of Rapel River, Valparaiso Province, V region, Chile (34°S latitude, 72°W longitude).

The Navidad Formation was first defined by Charles Darwin (1846) based on the sediments developing in the central section of Chilean Coast (34°S.

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Lat.). He assigned this formation to the early Tertiary from his studies of fossils, largely mollusks, contained in sandstone of the Navidad.

Most later workers have followed Darwin's designation, supposing the type

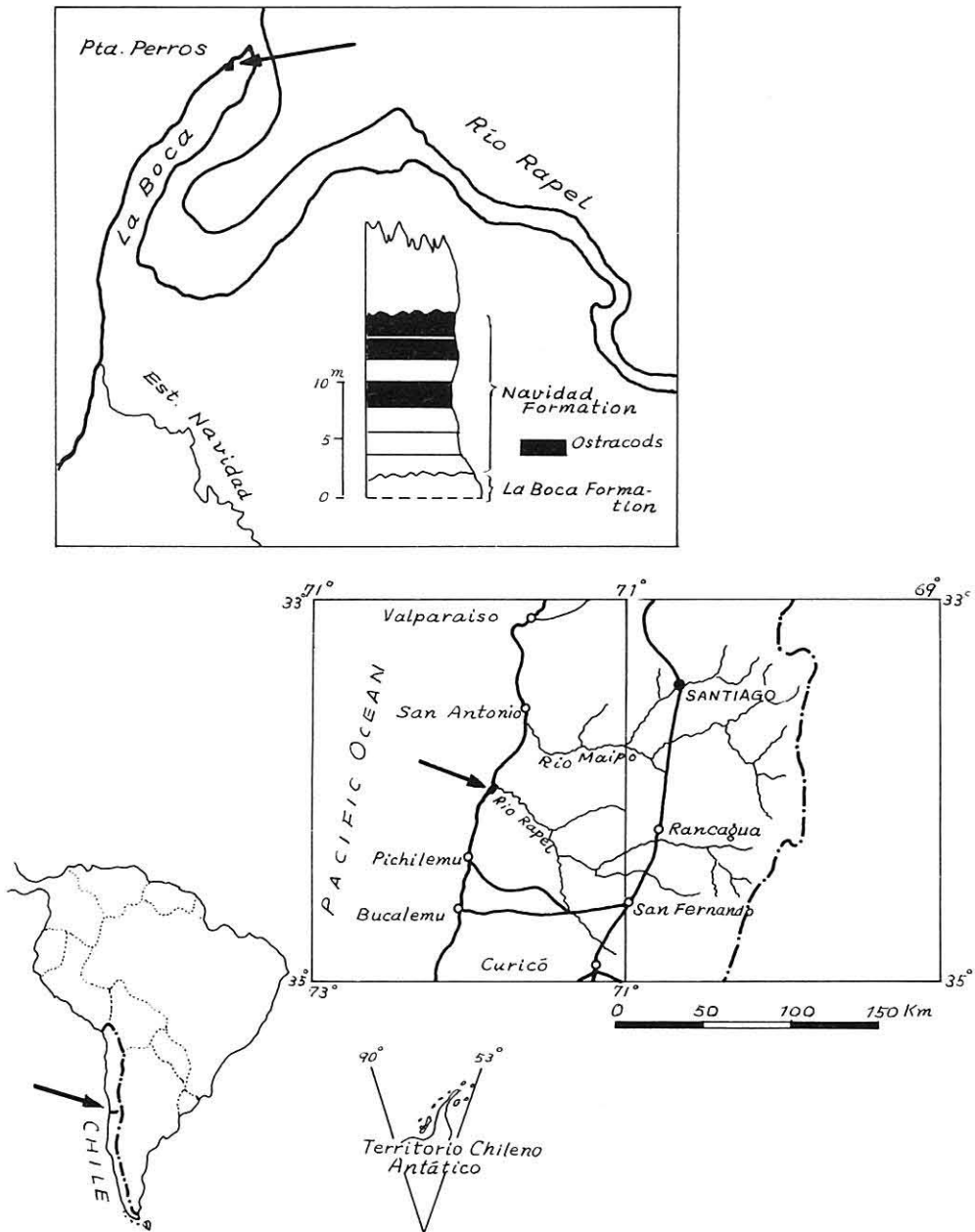


Fig. 1 Maps showing the position of the studied locality and the levels where the Ostracods were found.

locality being between Navidad Rivulet and the mouth of Rapel River. In the studies of microfossils of the so-called Navidad Formation, Martinez and Osorio (1964) have discovered the fact that the locality, which is traditionally accepted as the type locality of this formation, does differ in physiography from the description given by Darwin. The Darwin's Navidad Formation has been interpreted erroneously by many workers, especially those who have been engaged in the Chilean Tertiary, although it has been in common usage and regarded as the sort of generalized "stage" and "formation".

An outstanding work to be cited here may be Etchart (1973), who has redefined the Navidad Formation by dividing it into two different lithologic units that are well defined and easy to be identified, he called the lower unit the La Boca Formation and the upper the Navidad formation. This Navidad Formation consists of three members; the lower one is defined by the sequence cropping out on the cliff by Punta Perros. His definition does not show any clear implication in respect to its age, but is of very usefulness to future workers in this region.

The upper part of the Navidad Formation (s.l.) is assigned by Martinez and Osorio (1964) to the Tortonian from the studies of foraminifera and discoasters from this section. Tavera (1968) sustained Burdigalian (lower Miocene) for the Navidad Formation from the study of mollusks and compared the formation with the reference sequence of Patagonian. Dremel (in Herm, 1969) studied some planktonic foraminifera from the samples supplied by Herm and also assigned it to the Burdigalian or lower Miocene. There is, however, a lack of consistency of genera and species discriminated in Martinez and Osorio and in Dremel. This discrepancy may possibly be a result from the studies made at different stratigraphic position: Martinez and Osorio may have worked on the upper part of the Navidad Formation in Darwin's sense, or the base of Navidad formation in Etchart's sense; on the other hand, the materials collected by Herm may represent the base of the Navidad Formation in Darwin's sense or the La Boca Formation in Etchart's sense.

Field Work and Laboratory Studies

Field work was done in January, 1965, with intention toward the study of foraminifera from the Navidad Formation. Subsequently, some complementary works have been done in field in order to extend and advance their study to the comprehensive works of sedimentology and micropaleontology. During the course of a research program of foraminifera, it was noted that some analyzed samples are rich in a varied fossil ostracod. They generally occur in sediments at exposures crop out between the mouth of Rapel River to the north and

Navidad Rivulet to the south. Profile section was disposed of the locality 200 m south of Punta Perros; lower seven meters, base of the section, consists of lutite (and argilllutite) and overlain conformably by a sequence of medium- to coarse-grained sandstone, which attains to about 17 m in thickness. In this situation, the present author has decided to deal with them toward a preliminary report of ostracod contained. The materials for the micro-paleontological studies were taken at an interval of one meter from the basal argilllutites, which abound with foraminifera and ostracoda, and are especially prolific in varied ostracod forms at 4,6 and 7 meters levels.

For extraction of ostracod materials, the author followed a method ordinary for the studies of foraminifera as:

- 1) Cracking sediment samples into fragments of 0.5 – 1.0 cm size
- 2) Dehydration of sample of 100 cc
- 3) Saturation with kerosene
- 4) Boiling samples in a Na_2CO_3 solution
- 5) Washing sample through a 230 mesh screen
- 6) Drying residues, and
- 7) Picking specimens under a binocular microscope

Unlike the foraminifera, which are much more resistant to the mechanical agents mainly due to their architectures characterized by their round shape and possession of partings of septa, ostracod materials, especially valves disjointed, are much more fragile. It is, therefore, necessary to be very careful not to break off the specimens throughout the process of preparation that often results in a moderate washing. Such handling is not always a grand way for gaining specimens clean enough to make a detailed studies under a binocular microscope. It is often, then, necessary to clean them up by getting them wet with a diluted hydrogen peroxide solution of about 10 per cent. This method is however, not recommendable when carapaces are imbued with a ferric chloride, because the reaction of oxygenation could destroy a delicate ornamentation or internal features of the specimens.

Chrono-stratigraphy and Paleocology

Comparing with planktonic foraminifera, as it is recognized by a number of authors, ostracods are generally not used in regional chrono-stratigraphical correlations. Notwithstanding, they have been used sucessfully in local correlations in the Caribbean region.

With the available information on the stratigraphic distribution of some of the species studied in the Navidad Formation, it may be suggested an Upper

	Pleistocene	Pliocene	Miocene			Oligocene	Eocene	
			Upper	Middle	Lower			
<i>Cytherella harmoniensis</i>			—	—	—			van den Bold, (1960)
<i>Bythocypris bosquetiana</i>			—	—	—			van den Bold, (1971)
<i>Bythocypris (?) gibsonensis</i>			—	—	—			Marianos & Valentine, (1958); Butler, (1963)
<i>Krithe bartonensis</i>	—	—						Breman, (1975)
<i>Parakrithe vermunti</i>			—	—	—			van den Bold, (1958)
<i>Munseyella bermudezi</i>			—	—	—			van den Bold, (1963; 1966)
<i>Bradleya normani</i>	—	—						Benson, (1972)
<i>Actinocythereis bermudezi</i>			—	—	—			van den Bold, (1960)
<i>Hermanites reticulata</i>			—	—	—			Puri, (1955)
<i>Basslerites miocenicus</i>			—	—	—			Howe, (1935); Puri, (1953); van den Bold, (1958)
<i>Cytheropteron stictum</i>			—	—	—			van den Bold, (1972)

Table 1 Stratigraphical distribution of some ostracodes from the Navidad Formation.

Miocene as the probably age for that formation (See table 1).

The abundance of *Bradleya normani*, a typical psychrospheric form (Benson, 1972) restricted to great depth and low temperature conditions, is indicating a deep sea environment for the deposition of the Navidad Formation sediments during the Upper Miocene.

The presence of the genera *Argilloecia*, *Loxoconcha*, *Palmoconcha*, *Actinocythereis*, *Hermanites*, *Costa*, *Parakrithella* and *Wichmanella*, which together represent a depth tolerance beyond 200 meters, allows the present author to suggest 300 meters, at least, as the depth of deposition of the sediments of the Navidad Formation.

The occasional occurrence of some shallower species may be interpreted as a probably redeposition of the carapaces of those species in a deeper media.

Systematic Description

Subclass Ostracoda Latreille, 1806
 Order Podocopida Müller, 1894
 Suborder Platycopina Sars, 1866
 Family Cytherellidae Sars, 1866
 Genus *Cytherella* Jones, 1849

Cytherella steinforthi van den Bold, 1960

pl.1, figs.1-3

Cytherella steinforthi van den Bold, 1960 (p.150, pl.1, fig.3)

Summary of shell characters: Ovate in lateral outline. Anterior and posterior ends broadly round. Dorsal and ventral margins convex. Highest at mid-length. Cuneiform in dorsal view. The ventral margin on the left valve may be slightly concave. Right valve overlaps all over the periphery of the left one. Muscle scars pattern characteristic for the genus. *Size:* L.0.85 mm; H.0.55 mm; W.0.41 mm.

Cytherella grossmani Benson and Coleman, 1963

pl.1, figs.5, 6

Cytherella grossmani Benson and Coleman, 1963 (p.14, pl.1, figs.1-7); Swain and Gilby, 1967 (p.321, pl.31, figs.1-2, text-fig.10a); Swain and Gilby, 1974 (p.269, pl.1, figs.2-3).

Summary of shell characters: Outline almost elliptical. Dorsal and ventral margins convex. Anterior and posterior ends round; the posterior end narrower than anterior one. Highest at posterior one third of the length. Longest at mid-height. Longate ovoid in dorsal view. Widest at posterior one third. *Size:* L.0.75 mm; H.0.46 mm; W.0.36 mm.

Remarks: The studied specimens from the Navidad Formation are very much close to the specimens figured by Benson and Coleman (1963, figs. 1, 2 and 3). But they do not show such a relation with figures 4, 5, 6 and 7 by them, nor with those given by Swain and Gilby (1967–1974). The observation of the morphological variation due to the sexual dimorphism and ontogeny, thickness of the carapace and the development of the marginal groove, shows that the Navidad forms studied are of enough mature. In addition to these studied forms, there are some apparent immature forms in the collection.

Cytherella harmoniensis van den Bold, 1960

pl.1, fig.2

Cytherella harmoniensis van den Bold, 1960 (p.150, pl.1, figs.4a-b).

Summary of the carapace characters: Carapace elongate oval in a lateral view. Anterior and posterior ends widely round. Dorsal and ventral margins nearly in parallel, but the right valve slightly convex on the dorsal margin, meanwhile the left valve somewhat concave on the ventral margin. Highest behind the mid-length. Longest at mid-height. Fusiform in dorsal view. Widest at mid-length.

Size: L.0.82 mm; H.0.46 mm; W.0.31 mm

Family Cyprididae Baird, 1845
Subfamily Cypridinae Baird, 1845

Genus *Cyprinotus* Brady, 1886
Cyprinotus sp. aff. *Cyprinotus salinus* (Brady)
 pl.1, figs.4, 7

Compared with: *Cyprinotus salinus* (Brady) Wagner, 1957 (p.30, pl.IX, figs.1-5).

Description: A very thin shelled. Subtriangular shape in lateral view. Highest at mid-length. Anterior and posterior ends round; the posterior end narrower than the anterior end. Dorsal margin strongly convex in central part; its anterior half broadly arching, meanwhile posterior half consists of two shorter straight line conjugating with rather prominent convexity at posterior one third of it. Ventral margin slightly sinuate, slightly concave in the central part. Muscle scars pattern typical for the genus. Normal pores numerous and scattered all over the surface.

Size: L.1.05 mm; H.0.69 mm

Superfamily Bairdiacea Sars, 1880
 Family Bairdiidae Sars, 1888
 Genus *Bythocypris* Brady, 1880
Bythocypris bosquetiana (Brady), 1869
 pl.1, fig.12

Bythocypris sp. van den Bold, 1968 (p.49, pl.2, fig.11); *Bythocypris* sp. aff. *B. bosquetiana* (Brady) van den Bold, 1971 (p.336, pl.1, figs.5a-b).

Argilloecia sp. van den Bold, 1972 (p.422, pl.2, fig.11).

Description: Carapace bean-shaped. Dorsal margin convex just behind mid-length; ventral margin sinuous, concave at middle. Anterior end widely rounded; posterior margin narrowly rounded below midheight. Inner lamella wide anteriorly. Marginal zone narrow. Vestibulum wide along anterior margin. Right valve overlaps smaller left valve. Adductor muscle scars in vertical row of three, with two frontal scars in front of them. Hingement is adont; groove in right valve, rather deep, protruding near the posterior third.

Size: L.0.6 mm; H.0.31 mm; W.0.25 mm.

Bythocypris (?) *gibsonensis* Howe and Chambers, 1935
 pl.1, fig.11

Bythocypris (?) *gibsonensis* Howe and Chambers, 1935 (p.9, pl.III, fig.10, pl.IV, fig.3); Marianos and Valentine, 1958 (p.365, text-fig.2, pl.1, figs.3a-b-c); Huff, 1970 (p.76, pl.2, figs.1, 2, 3).

Bythocypris (?) cf. *gibsonensis* Butler, 1963 (p.39, pl.1, fig.1, pl.6, fig.g).

Description: Carapace elongate subreniform in lateral view. Dorsal margin symmetrically arching; highest at middle. Anterior and posterior margins

round, anterior is somewhat wider. Ventral margin almost straight in the left valve, barely concave in the right. Fusiform in dorsal view. Left valve overlaps the right dorsally and ventrally.

Size: L.0.91 mm; H.0.42 mm; W.0.25 mm

Remarks: Specimens from the Navidad Formation resembles clearly the species listed in synonymy, but are quite different from *Bythocypris* cf. *B. gibsonensis* described by van den Bold (1946, p.68, pl.1, fig.13) in having a linear upper half of the posterior margin.

Family Pontocyprididae G.W. Müller, 1894

Genus *Argilloecia* Sars, 1899

Argilloecia acuminata Müller, 1894

pl.1, fig.10

Argilloecia acuminata Bonaduce, Ciampo, and Masoli, 1975 (p.26, pl.8, figs.1-5).

Description: Carapace elongate subreniform in lateral view. Dorsal margin broadly arched, with a small depression near the anterodorsal margin and a protrusion at the last quarter of the length. Behind it a slight concavity develops and ends sharply in a truncated posterior margin. Ventral margin almost straight, except for a slight depression just before mid-length; its posterior half forms a sharp angle with the posterior end. Highest in the median area. Longest well below mid-height. Inner lamella wide, typical for the genus. *Size:* L.0.51 mm; H.0.22 mm; W.0.19 mm.

Argilloecia pacifica n. sp.

pl.1, figs.8, 9

Argilloecia sp. c. van den Bold, 1971 (p.337, pl.1, figs.2a-b).

Diagnosis: *Argilloecia* with dorsal and posterior margins blended as a continuous convex arch.

Description: Carapace elongate subreniform in lateral view. Dorsal margin boldly arched, blending into a narrowly convex posterior margin. Anterior margin, widely round, meets the dorsal margin in brow shape. Ventral margin sinuous; slightly concave before mid-length; it meets posterior end at right angle. Highest near mid-length; longest at lower one third. Inner lamella very well developed. Vestibula at the ends; wider along anterior margin. Muscle scars closely arranged in vertical rows of three and two behind them, constituting a round low rise. *Size:* L.0.56 mm; H.0.26 mm.

Remarks: Type species *Argilloecia* sp. c. figured by van den Bold (1971, p.337, pl.1, figs.2a-b) is supposed to be conspecific with the present species.

Genus *Hemicytherura* Elofson, 1941*Hemicytherura* sp.

pl.1, fig.22

Description: Sub-rhomboidal, to sub-oval in lateral view. Dorsal margin strongly convex; anterior margin protruded, obliquely rounded with coarse crenulations; posterior margin rather sharp pointed; ventral margin obscured by ventral swelling, low sinuous in internal view. Longest below the middle; highest just behind the middle.

Ornamentation reticulate, with some thick longitudinal ridges at the central and antero-central area; concentric and peripheric some other ridges. Very wide anterior inner lamella; line of concrecence near the outer margin. Wide anterior vestibulum.

Size: L.0.31 mm; H.0.20 mm.

Genus *Cytheropteron* Sars, 1866*Sytheropteron stictum* van den Bold, 1972

pl.1, figs.13, 14

Cytheropteron stictum van den Bold, 1972 (p.431, pl.1, figs.9-10; pl.4, fig.7; pi.5, fig.7; text-fig.8).

Description: Sub-triangular in lateral view. Dorsal margin strongly convex before mid-length, slopes to the caudal process. Anterior margin wide round. Ventral outline convex because the alar projection; in internal view, the ventral margin is undulate, somewhat concave at one third length from anterior margin. Posterior margin very low, acute, with caudal process outstanding. Sub-elliptic in dorsal view; anterior end somewhat truncate; posterior end depressed and protruded. Right valve overlaps the left at least on dorsal margin.

The external surface is covered by numerous round pits; alar expansion rimmed by three imbricate low ridges. Highest in the anterior third-length; longest near the ventral margin; widest around the mid-length. No ocular structure are present.

Size: L.0.49 mm; H.0.27 mm; W.0.27 mm.

Cytheropteron caboensis Swain, 1967

pl.1, figs.15, 16, 17

Cytheropteron caboensis Swain, 1967 (p.65, pl.9, fig.9)

Description: Sub-elliptical to sub-triangular in lateral view. Dorsal margin rather convex; a depression is observed where anterior and dorsal margins meet each other. Ventral margin externally obscured by alar projection, undulate

internally. Posterior margin round below, truncate above the mid-height. Longest below the mid-height; highest at mid-length.

Sub-ovoidal in dorsal view; both sides round, compress near the anterior border; alar projections truncate one fifth-length before acuminate posterior end. The widest at mid-length. Wide inner lamella at anterior and posterior margins; somewhat narrower ventrally. Wide anterior vestibulum.

Ornamentation rather coarse on the posterior half of the valve; it gradually becomes smoother, disappearing at the anterior half.

Size: L.0.43 mm; H.0.30 mm; W.0.28 mm.

Cytheropteron dissimilis n. sp.

pl.1, fig.18

Diagnosis: The species characterized by having coarse pitted ornamentation; alar expansion node-like shape; short longitudinal ridge near the postero-dorsal angle.

Description: Sub-triangular in lateral view. Dorsal margin wide round; anterior margin narrow, obliquely round; posterior margin acuminate, caudal process below the mid-height; ventral margin undulate, convex at the posterior third-length. Inner lamella wide; anterior vestibulum rather narrow. Typical hingement for the genus.

Coarse pitted ornamentation. Two ridges arise behind anterior margin, they extend along the anterior border of the alar expansion, and meet at nodose apex of alae. A high and short ridge stands like bullae near the postero-dorsal margin, a small cavity is in between.

Size: L.0.40 mm; H.0.23 mm.

Genus *Lobosocytheropteron* Ishizaki and Gunther, 1974

Lobosocytheropteron sp. A.

pl.2, fig.2

Description: Carapace sub-oval to sub-triangular in lateral view. Anterior end obliquely rounded; dorsal margin rather undulate; ventral margin slightly sinuate; posterior end pointing up, with a median caudal process, convex below, somewhat concave above. Highest before the middle; longest at mid-height.

Sagittate in dorsal view. Alae are laterally wide expanded, excavate above near the middle border; they end in sharp point. The widest is at one fifth length from the posterior end.

Size: L.0.53 mm; H.0.33 mm; W.0.40 mm.

Lobosocytheropteron sp. *B.*

pl.1, figs.19, 20, 21; pl.2, fig.1

Description: Carapace sub-triangular in lateral view. Dorsal margin convex, undulate, anterior margin obliquely rounded; ventral margin externally obscured by alar projection, internally convex, somewhat depressed before the middle; posterior margin protruded with a median caudal process convex above and below. The highest at one third from the anterior margin; longest below the mid-height.

Lanceolate in dorsal view; strongly depressed at the anterior end; protruded and sharpened the posterior. Alae long arched anteriorly; truncate posteriorly. The widest behind the middle.

External surface smooth, except a wide hole or depression above and near the central part of the alae border.

Size: L.0.66 mm; H.0.45 mm; W.0.45 mm.

Family Brachicytheridae Puri, 1954

Genus *Brachicythere* Alexander, 1933*Brachicythere minatoi* n. sp.

pl.2, figs.10, 11, 17

Diagnosis: The species characterized by having a round posterior margin; ventro-lateral carina conspicuously strong; lateral surface of the valves rather coarse pitted.

Description: Right valve subtriangular to hemicircular in lateral view. Dorsal margin very wide round; anterior and posterior halves almost symmetric. Anterior and posterior margins convex, seem to be prolongations of dorsal margin. The posterior margin a little narrower than the anterior. Ventral margin low convex, shows a small depression at a quarter length from the anterior end. The margins are well differentiated on the left valve. Dorsal margin rather straight, slopes backward, meeting posterior margin in a clear defined postero-dorsal angle. Posterior margin slight concave on the upper half, rather convex below the middle. The highest just at the anterodorsal angle. The longest, very low, under the mid-height. Fusiform in dorsal view; widest at mid-length.

Inner lamella well developed. Line of concrescence coincides with inner margin, except on the lower anterior margin, where a very narrow vestibulum is present; marginal pores canals straight, simple and numerous specially in the antero-ventral region. Selvage rather strong, separate from the outer margin. Two or three lists may be observed.

Left valve larger than right. Carapace ventrally flattened. The valves are

externally covered with numerous coarse pits; prominent ventral keel on each valve.

Size: L.0.60 mm; H.0.40 mm; W.0.35 mm.

Derivation of name: In honour to Professor Masao Minato of Hokkaido University.

Family Cytherideidae Sars, 1925
Subfamily *Krithinae* Mandelstam, 1958
Genus *Kritha* Brady, 1874
Kritha bartonensis (Jones)
pl.2, figs.5, 7, 8

Kritha bartonensis Breman, 1975 (pl.3, fig.27)

Kritha aff. *Kritha bartonensis* Hanai, 1959 (Pl.XVIII, figs.1a-b, 2a-b)

Kritha monosteracensis (Seguenza) Sissing, 1972 (p.84, pl.4, fig.7).

Description: Carapace sub-oval to sub-rectangular in lateral view. Anterior margin wide round; dorsal margin faint convex; ventral margin slowly sinuous with soft depression before mid-length; posterior margin obliquely rounded, almost truncate. Highest at mid-length; longest below the middle. Ovoidal in dorsal view. Left valve overlaps the right.

Inner lamella wide anteriorly, posteriorly narrower. Line of conrescence coincides with inner margin, but it separates in anterior border doing a narrow vestibulum.

Size: Male: L.0.69 mm; H.0.36 mm. Female: L.0.66 mm; H.0.37 mm.

Genus *Parakritha* van den Bold, 1958
Parakritha vermunti (van den Bold)
pl.2, fig.4

Cytheridea (Volocytheridea) vermunti van den Bold, 1946 (p.83; pl.7, figs.12a-c)

Parakritha vermunti van den Bold, 1958 (p.339, pl.4, figs.7a-f)

Description: Carapace elongate, subrectangular in lateral view. Dorsal margin straight. Ventral margin sinuous, slightly concave at the middle. Anterior margin wide round. Posterior margin obliquely round, protruded on the lower part. Longest near the base of the valve. Highest at mid-length. Fusiform in dorsal view. Left valve larger than right valve. Widest at mid-length.

Size: L.0.47 mm; H.0.23 mm; W.0.24 mm.

Family Hemicytheridae Puri, 1953
Genus *Aurila* Pokorný, 1955

Aurila sp.

pl.2, fig.19

Description: Carapace almost sub-triangular in lateral view. Dorsal margin quite convex; ventral margin faint sinuous. Highest at the middle; longest just below the middle.

Wide inner lamella. Line of concrecence coincides with the inner margin except on the anterior end, where a narrow vestibulum is developed. Hingement amphidonta-heterodonta; the antero-terminal element on the left valve is a deep socket; the antero-median is a prominent tooth followed by a faint crenulate bar; the postero-terminal element is an elongate socket; also there is an accommodation groove. Ornamentation composed by concentric reticulation, somewhat smooth on the central area; two peripheral ridges, better developed near dorsal and ventral margins.

Size: L.0.69 mm; H.0.47 mm.

Family Leguminocythereididae Howe, 1961

Genus *Basslerites* Howe, 1937

Basslerites aff. *Basslerites miocenicus* (Howe)

pl.2, figs.12, 13

Basslerella miocenica Howe, 1935 (p.31, pl.1, figs.19, 24, 26)

Basslerites miocenicus (Howe) Puri, 1953 (p.280, pl.8, figs.10-11; text-fig.11k); van den Bold, 1958 (pl.5, figs.5-6).

Description: Carapace subrectangular elongate in lateral view. Dorsal and ventral margins faint arched, sub-parallel. Anterior end wide round. The lower part posterior margin round, sub-truncate at the upper part. Highest at mid-length; longest at mid-height. Left valve, quite bigger, overlaps all over the periphery of the right valve, specially on ventral and posterior margins. In dorsal view, the widest is at one third length from the posterior end.

Inner lamella wide and thick. Line of concrecence coincides with inner margin, except at the middle of anterior end where it approximates to the outer margin. Therefore, a wide vestibulum U-shaped is present. Marginal pore canals straight and numerous. Four adductor muscle scars in vertical row; one frontal scar. Hingement amphidont-heterodonta type, rather strong compare with the size of the species. On the right valve, the anterior element is a blunt strong tooth, at one third length from the anterior margin; a wide and deep socket is just behind the anterior tooth there is a wide and deep socket followed by a thin, somewhat crenulate groove. Posterior tooth, rather blunt and stepped, stands at the postero-dorsal angle.

Size: L.0.48 mm; H.0.25 mm; W.0.21 mm.

Family Loxoconchidae Sars, 1925

Genus *Loxoconcha* Sars, 1866*Loxoconcha intrastellata* n. sp.

pl.4, figs.6, 7, 8, 12, 13

Diagnosis: The species characterized by having a very coarse reticulation; wide fossae with internal radial structures.

Description: Carapace elongate, sub-rectangular in lateral view. Dorsal and ventral margins straight and rather parallel; anterior margin slight obliquely rounded; posterior margin, with caudal process, obliquely round, protruded at the upper third-height. Highest at 1/3 length from the anterior margin; longest at the middle.

Sub-elliptical in dorsal view. Both laterals are rather parallel; anterior and posterior ends are basically rounded, but having thin and sharp keels. Ornamentation composed by a rather coarse and irregular reticulation with sharp muri and wide fossae. Every fossa shows inside a radial, stelliform structure as a kind of second order ornamentation.

Size: L.0.50 mm; H.0.27 mm; W.0.23 mm.

Derivation of name: *intra* (L)-inside; *stella* (L)-star

Genus *Palmoconcha* Swain and Gilby, 1974*Palmoconcha* (?) *kyokoeae* n. sp.

pl.4, figs.1, 2, 3, 4, 5

Diagnosis: The species characterized by having a prominent dorsal keel, sharp ventro-lateral keel like alar expansion and coarse pitted ornamentation.

Description: Carapace, heavy calcified, sub-elliptical in lateral view. Anterior margin round; posterior margin wide round in continuous curvature with ventral margin, truncate at the upper quarter-height; ventral margin rather sinuous, convex before the mid-length; dorsal margin obscured by dorsal ridge in external view, quite straight in internal view. The longest at mid-height; highest at mid-length. Nearly sub-hexagonal in dorsal view. Rather compress at both anterior and posterior ends, resembling sharp keels.

Inner lamella wide anterior and posteriorly. Strong selvage, almost a ridge, separate from the outer margin. Four adductor muscle scars in vertical row; a single frontal scar before them.

Hingement quite uncommon for the genus. On the right valve, the anterior element is a knob-like shaped tooth surrounded by hemicircular socket; socket continues in crenulate groove; the posterior element is an elongate pentalobate tooth.

The external surface of the valve is covered by coarse pits in nearly

concentric arrangement; ornamentation becomes feeble on the antero-central area. A characteristic irregularly sinuous ridge is topping the dorsal border. A very strong ventral ridge, better develops in female valves, looks like alar expansion. Low ridges rim anterior, ventral and dorsal margins. Those ridges produce reticulation with wide fossae in anterior and posterior margins.

Size: Male: L.0.51 mm; H.0.31 mm; W.0.30 mm Female: L.0.47 mm; H.0.30 mm; W.0.30 mm.

Remarks: Some of the features of the actual specimens are typical for the genus *Palmoconcha*. In the present author's opinion, these forms should be a new genus. The formal proposition of a new name has been temporarily delayed in order to do more accurate observation on internal structures.

Derivation of name: In honor to Miss Kyoko Otsuki to whom, with her parents, the actual author is indebted for their friendship and help during his stay in Japan.

Genus *Nipponocythere* Ishizaki, 1971

Nipponocythere ishizakii n. sp.

pl.2, figs.3, 6, 9

Nipponocythere sp. Ishizaki & Gunter, 1976 (p.25, pl.3, fig.15; pl.4, figs.15-17)

Diagnosis: *Nipponocythere* with gently sinuous hingement; weak ornamentation on the posterior half of the valve; anterior half is smooth.

Description: Carapace cuneiform, elongate in lateral view. Highest before mid-length. Longest below mid-height. Dorsal margin sinuous overreached by blunt marginal ridge at one third length from the posterior end. Ventral margin undulate. Anterior margin broadly round, with wider curvature ratio on the upper half. Posterior margin protruded at the lower mid-height. Ornamentation absent on the anterior half of the valve. Posterior half shows somewhat reticulate ornamentation composed by low longitudinal ridges crossed by very narrow others. Some few openings and rimmed funnel are spread all over the surface. Dorsal marginal ridge undulate, a little higher near the posterior end. Ventral marginal ridge convex, overreaching the ventral margin at one third length from the anterior end. Fusiform in dorsal view. The widest at mid-length.

Inner lamella rather wide. The anterior part of the line of concrescences is nearly close to the inner margin on the upper half, becoming more far on the lower third, where a wide vestibulum is developed.

Size: L.0.40 mm; H.0.21 mm; W.0.16 mm.

Derivation of name: In honor to Dr. Kunihiro Ishizaki of Tohoku University.

Family Pectocytheridae Hanai, 1957
 Genus *Munseyella* van den Bold, 1957
Munseyella bermudezi van den Bold, 1966
 pl.2, figs.14, 15, 16

Munseyella sp. B. van den Bold, 1963 (p.379, pl.5, figs.1a-b)

Munseyella bermudezi van den Bold, 1966 (p.22, pl.2, figs.1a-b); van den Bold, 1967 (p.309, pl.1, fig.2)

Description: Carapace elongate subtrapezoidal in lateral view. Highest at the anterior terminal of dorsal margin. Longest somewhat below mid-height. Dorsal margin, gently arched, limited posteriorly by a distinct posterodorsal angle. Anterior margin, widely round, meets dorsal margin at a obtuse antero-dorsal angle, where a tubercle (or hinge ear ?) better developed in the left valve. Posterior end, truncated vertically, is bordered by two spines, posterodorsally and posteroventrally. Ventral margin almost straight, scarcely sinuous.

In dorsal view, carapace nearly elliptical, truncated at the ends. Widest at mid-length. Left valve overlaps the right one, especially along the anterior margin and at the cardinal angle.

Very coarse ornamentation consists mainly of bold ridges and tubercles. A semi-peripheral ridge borders the entire anterior margin, and much of the ventral and dorsal margins. The ridge ends in the postero-central area after bending down at the posterior third of the carapace length. Four strong tubercles in nearly horizontal row at mid-height. Two narrower ridges, starting from the anteroventral area, converge posteriorly to form a prominent tubercle at posterior third. Finer reticulation and second order tubercles complement main ornamentation.

Size: L.0.40 mm; H.0.25 mm; W.0.19 mm.

Family Thaerocytheridae Hazel, 1967
 Subfamily Radleyinae Benson, 1972
 Genus *Bradleya* Hornibrook, 1952
Bradleya normani (Brady) Benson, 1972
 pl.3, figs.4, 5, 6

Bradleya normani Benson, 1972 (p.38, fig.13c, pl.1, fig.7, pl.7, fig.8)

? *Cythere normani* Brady, 1866 (p.379, pl.61, figs.5a-d); 1880 (p.101, 102, pl.XVII, figs.3a-d)

Description: Subrectangular in lateral view. Height about a half length. Dorsal and ventral margins in nearly parallel; ventral margin gently depressed. Anterior end widely round; posterior margin somewhat truncated.

Marginal zone thick; vestibulum absent, line of conrescence coincides with outer margin. Selvage strong, being almost a narrow ridge. Marginal pore canals straight, simple and numerous, 14 in the anterior margin. Four muscle scars in vertical row, two frontal scars. Hingement amphidont; in right valve, anterior element is an stepped tooth consists of a low distal lobe and a strong and higher proximal lobe. Median element consists of a deep socket followed by a groove. Posterior tooth is blunt and notched.

Surface ornamented with coarse reticulation. A semi-peripheral ridge, starting just below anterodorsal angle, runs in parallel to anterior margin to near the posterior end of ventral margin, where it is strong and higher and ends in a prominent spine posteriorly. A narrow carina arises near the scar tubercle area and continues to the posterodorsal area, forming a arch pointing anterodorsally. In the reticulation behind subcentral tubercle, a short and faint ridge is insinuated. Some fossae form a very low second order reticulation; it is especially distinct in the antero-central area. Fossae are polygonal, variable in size and shape, and their muri and sola are foveolate. One sieve-type, celate pore appears in very fossa.

Specimens from Navidad show an small prominence below the antero-dorsal angle that could be interpreted as a degenerate eye tubercle. Such structure does not occur in right valve.

Size: L.0.80 mm; H.0.69 mm; W.0.69 mm.

Family Trachyleberididae Sylvester-Bradley, 1948
Subfamily Trachyleberidinae Sylvester-Bradley, 1948
Genus *Actinocythereis* Puri, 1953
Actinocythereis bermudezi (van den Bold)

pl.2, fig.18

Trachyleberis bermudezi van den Bold, 1960 (p.164, pl.4, fig.1).

Description: Carapace rectangular in lateral view. Dorsal margin straight; ventral margin lightly concave before the middle. Anterior margin wide round. Posterior margin faint concave at the upper third, round below. The longest at mid-height; the highest at mid-length.

Ornamentation: Numerous spines are spread all over the external surface of the valve, basically smooth. It may observe some arrangement of those spines; a longitudinal row of eight spines stands near ventral margin; an irregular row is close to dorsal border; sub-central tubercle is covered by four spines; there are four more spines in square-shape disposure before sub-central tubercle. Anterior and posterior ends rimmed by spiny rows.

Size: L.1.10 mm; H.0.60 mm.

Genus *Costa* Neviani, 1928*Costa chilensis* n. sp.

pl.3, figs.1, 2, 3

Diagnosis: The species characterized by having three longitudinal ridges; median one is weaker and shorter than the others. A rather round depression on slope behind subcentral swelling.

Description: Carapace pyriform in lateral view. Dorsal margin straight; ventral margin almost straight, gently merges upward into posterior end. Highest at anterior cardinal angle. Anterior end widely round, rimmed by three spiny ridges, the outer one is a sort of flange crenulation. Posterior margin asymmetrical; upper half slightly concave, lower half convex. Longest near mid-height.

In dorsal view, nearly ovate, compressed near both ends; a considerable depression at mid-length. Widest just behind the depression. Inner lamella wide. Inner margin and line of conrescence coincide. Marginal pore canals numerous, sinuous, bundled in anterior margin. Selvage subperipheral. Muscle scars in vertical row of four, with a heart-shaped frontal scar.

Ornamentation consists of irregular reticulation. Two longitudinal ridges well developed. A third ridge, less conspicuous than the others, runs from behind the subcentral swelling to below the posterodorsal angle. Two more ridges, starting from the anterior cardinal angle, descend in nearly parallel to the anterior margin; outer one disappears in anteroventral area. Other one continues as a ventral ridge. This ridge, generally ends in a spine pointing backward. 8 to 9 fossae are present in a row between both the anterior ridges. A rather prominent ridge, starting from the subcentral swelling upward, bends backward gradually and then continues as a dorsal ridge postward.

Size: L.0.77 mm; H.0.47 mm; W.0.45 mm.

Genus *Hermanites* Puri, 1955*Hermanites reticulata* (Puri)

pl.3, figs.7, 8, 9, 10

Hermania reticulata Puri, 1955 (p.267, pl.11, figs.8-9, text-figs.9g-h)

Description: Carapace subrectangular, more or less elongate in lateral view. Dorsal margin straight; ventral margin almost parallel, gently convex. Highest at the anterior cardinal angle. Posterior margin convex on the lower half, concave on the upper one. Anterior margin wide round. Longest at mid-height. Sub-oval, truncate, in dorsal view.

Inner lamella well developed; vestibula absent. Strong selvage. Hingement

holamphidonta. Reticular type of ornamentation. A sharp keel near to the ventral margin, stands between the antero-ventral marginal rim and somewhat before posterior end. Two rims are bordering the anterior margin; one of them, next to the valvar enclosure, is low and crenulate; the other is higher and keel-like shape. A dorsal bullar serie is complements the peripheral ornamentation. Subcentral tubercle pitted. Glassy ocular tubercles in both valves. A basic reticulum, with very well developed muri and fossae, covers the surface. Pore-conuli attached to the muri.

Size: L.0.78 mm; H.0.46 mm; W.0.40 mm.

Subfamily Rocaleberidinae Bertels, 1969

Genus *Wichmannella* Bertels, 1969

Wichmannella meridionalis Bertels, 1969

pl.4, figs.9, 10, 11

Wichmannella meridionalis Bertels, 1969 (p.166, pl.2, figs.1a-c, pl.5, figs.2a-c); 1973 (p.325, pl.5, fig.2a); 1975 (p.3, figs.10-11).

Description: Carapace subrectangular in lateral view. Anterior end obliquely round, compressed anteroventrally. Posterior end round. Longest below mid-height. Dorsal margin straight, arising somewhat near the anterodorsal angle. Ventral margin, arching for its anterior half.

Ovoidal in dorsal view. Widest at posterior one quarter. Hingement amphidont-heterodont; in right valve, anterior element is a strong trilobate tooth with a semicircular socket behind it. Median element is a long crenulate groove which becomes wider near the posterior crescent shaped tooth.

Selvae well developed; list three to four. Four adductor muscle scars in a vertical row; not well separated scars in front of them.

Primary ornamentation consists of reticulation, rather parallel to the periphery; coarse spines grow up at intersections of muri. Normal pore canals seem to place in spines. Eye tubercle strong.

Size: L.1.10 mm; H.0.58 mm; W.0.50 mm.

Remarks: Frontal muscle scar seems to be simple, but it shows a faint fissure. This feature suggests that the Navidad specimens are in a possible transition between *Echinocythereis* and *Wichmannella* as was described by Bertels (1969). The development of the spiny second order ornamentation is variable, possibly due to the ontogeny.

Acknowledgements

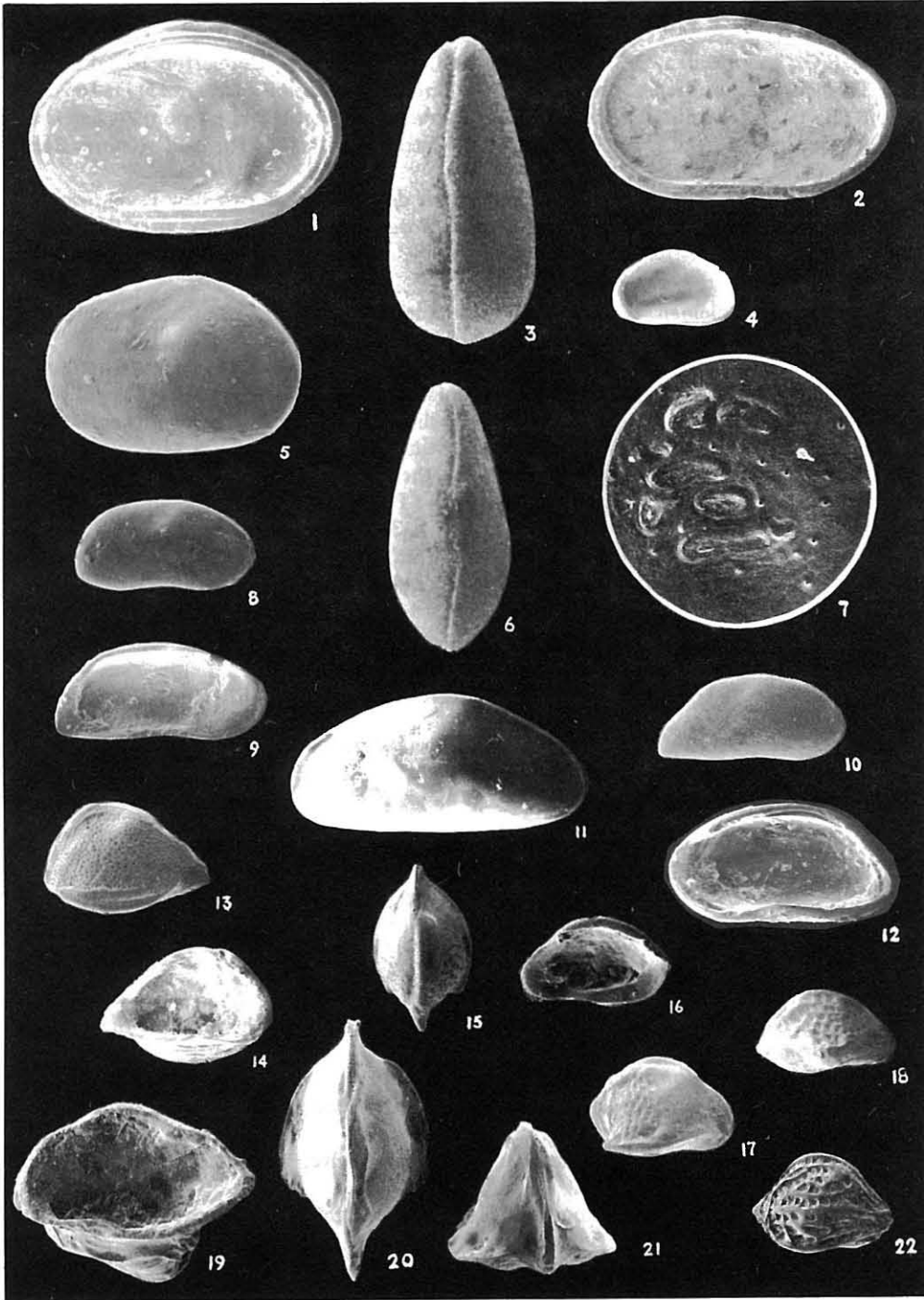
The author takes this opportunity to express his sincere appreciation to Prof. Masao Minato of Hokkaido University, Japan, who has invited him to the university and helped in many arrangements. Without his help, this work would not have been completed. Assoc. Prof. Kunihiro Ishizaki of Tohoku University, Japan, has encouraged the author with helpful suggestions and guidance, and kindly allowed him to use his library, collections and laboratory equipments. His thanks extends to Dr. Nachio Minoura of Hokkaido University, who kindly assisted him with the operation of the SEM. Mr. Sumio Kumano developed and printed all the photographs used in this work, and has given him warm and friendly entertainment. Miss Etsuko Mima has skillfully typed the manuscript.

Finally, the author wishes to express his acknowledgement to all the staff members of the Department of Geology and Mineralogy, Faculty of Sciences, Hokkaido University, who have helped him in many ways.

This research was supported by the Japan International Cooperation Agency (JICA) and Universidad de Chile.

Explanation of Plate 1

- Figs. 1, 3 *Cytherella steinforthi* van den Bold, 1960. 1. Right valve internal view; 2. Dorsal view. 60 X
- Fig. 2 *Cytherella harmoniensis* van den Bold, 1960. Left valve internal view. 60 X
- Figs. 4, 7 *Cyprinotus* sp. aff. *C. salinus* (Brady). 4. Right valve, 20 X. 7. Muscle scars, 700 X.
- Figs. 5, 6 *Cytherella grossmani* Benson & Coleman, 1963. 5. Left valve; 6. Dorsal view. 60 X.
- Figs. 8, 9 *Argilloecia pacifica* n. sp. 8. Right valve view; 9. Left valve internal view. 60 X.
- Fig. 10 *Argilloecia acuminata* Müller, 1894. Right valve view, 60 X.
- Fig. 11 *Bythocypris* (?) *gibsonensis* Howe & Chambers, 1935. Right valve view, 60 X.
- Fig. 12 *Bythocypris bosquetiana* (Brady). Right valve internal view, 60 X.
- Figs. 13, 14 *Cytheropteron sticutum* van den Bold, 1972. 13. Left valve; 14. Left valve internal view. 60 X.
- Figs. 15, 16, 17 *Cytheropteron caboënsis* Swain, 1967. 15. Dorsal view; 16. Right valve internal view; 17. Right valve. 60 X.
- Fig. 18 *Cytheropteron dissimilis* n. sp. Right valve, 60 X.
- Figs. 19, 20, 21 *Lobosocytheropteron* sp. *B.* 19. Right valve internal view; 20. Dorsal view; 21. Frontal view. 60 X.
- Fig. 22 *Hemicytherura* sp. Right valve, 60 X.

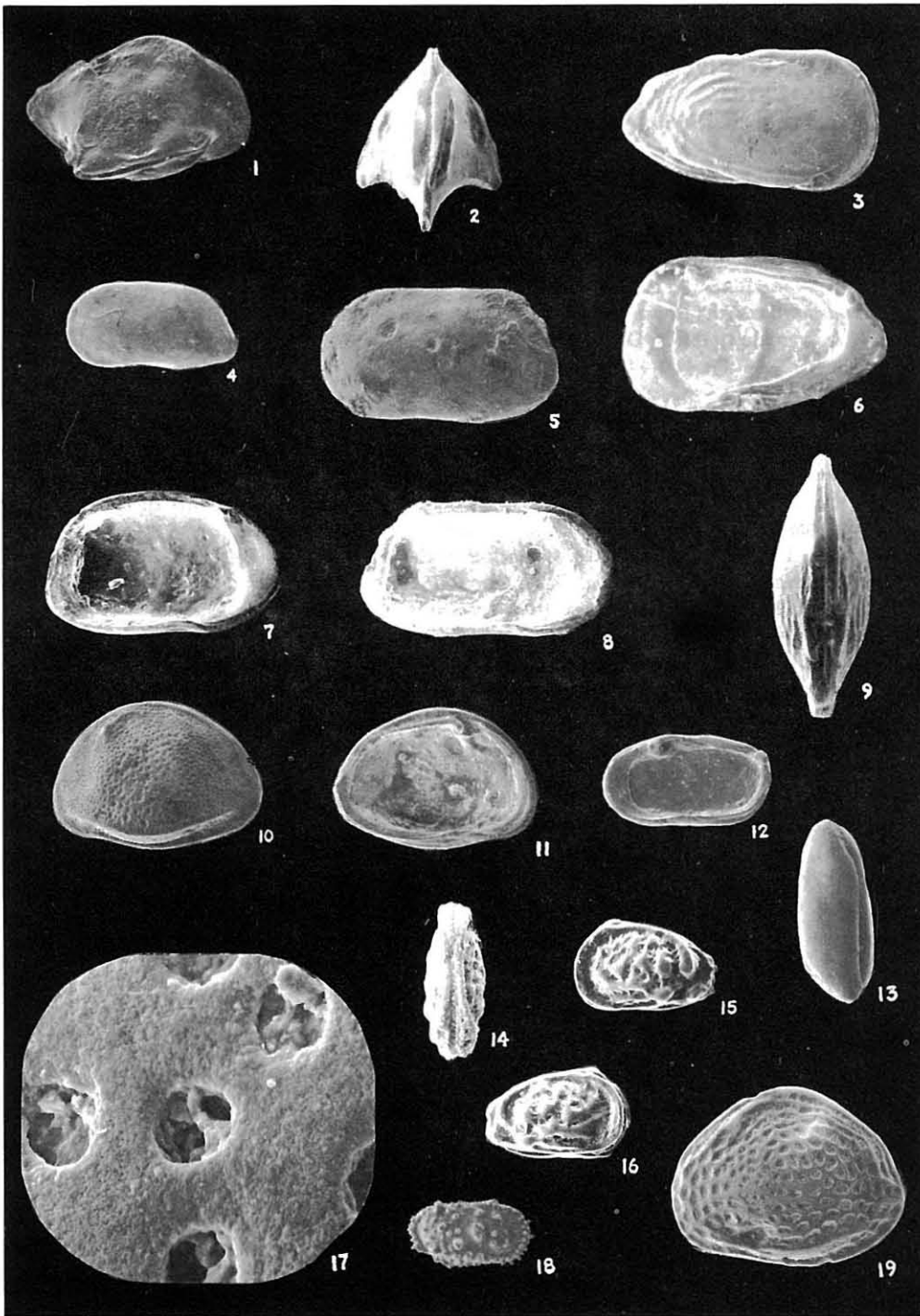


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Explanation of Plate 2

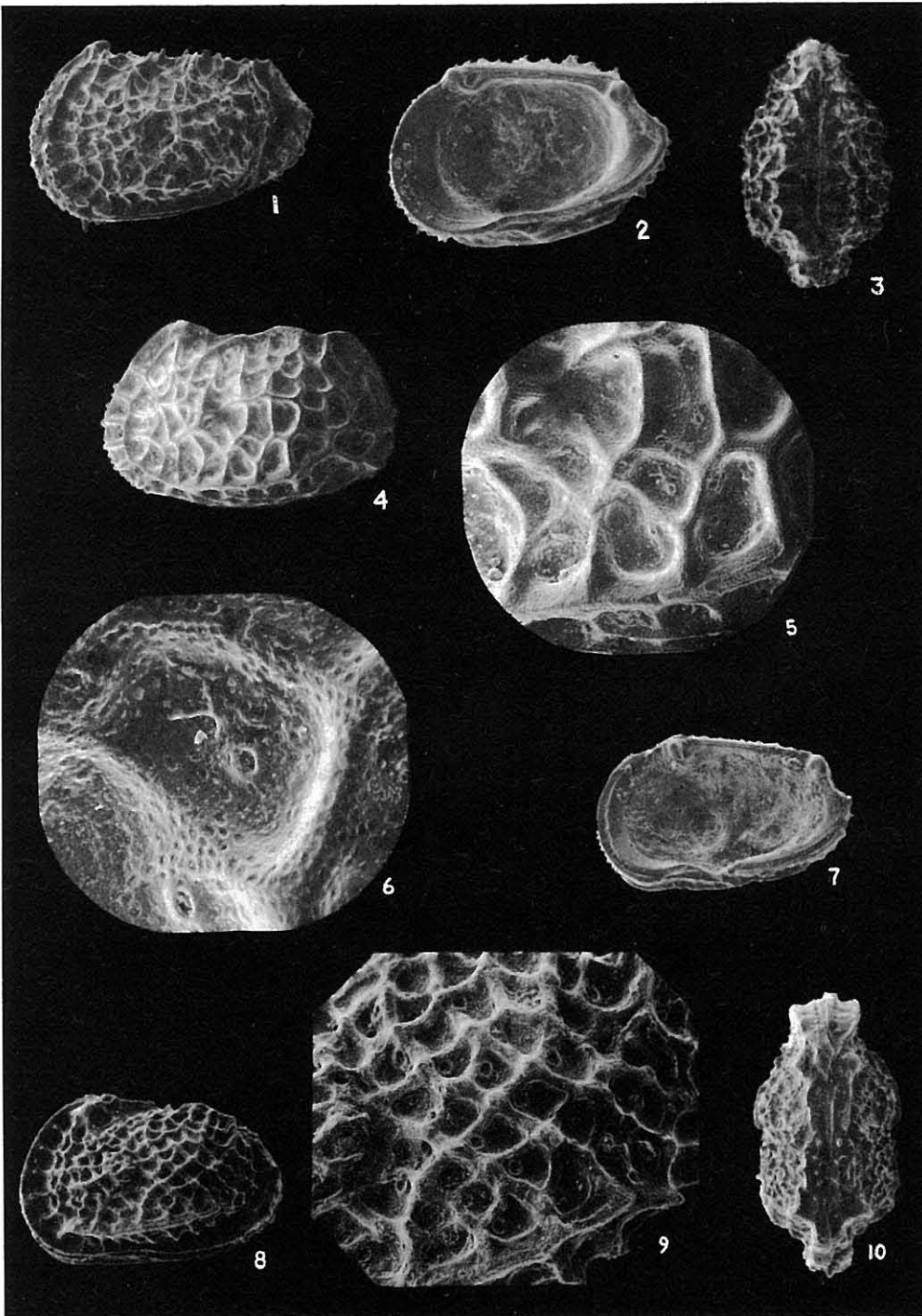
- Fig. 1 *Lobosocytheropteron* sp. B. Right valve, 60 X.
- Fig. 2 *Lobosocytheropteron* sp. A. Dorsal view, 60 X.
- Figs. 3, 6, 9 *Nipponocythere ishizakii* n. sp. 3. Right valve; 6. Right valve internal view; 9. Dorsal view. 120 X.
- Fig. 4 *Parakrithe vermunti* (van den Bold) Left valve lateral view, 60 X.
- Figs. 5, 7, 8 *Krithe bartonensis* (Jones). 5. Left valve (male); 7. Left valve internal view (female); 8. Left valve internal view (male). 60 X.
- Figs. 10, 11, 17 *Brachycythere minatoi* n. sp. 10. Left valve; 11. Internal view. 60 X. 17. Normal pores detail, 700 X.
- Figs. 12, 13 *Basslerites* aff. *B. miocenicus* (Howe). 12. Right valve internal view; 13. Dorsal view. 60 X.
- Figs. 14, 15, 16 *Munseyella bermudezi* (van den Bold). 14. Dorsal view; 15. Left valve; 16. Right valve. 60 X.
- Fig. 18 *Actinocythereis bermudezi* (van den Bold). Right valve, 15 X.
- Fig. 19 *Aurila* sp. Right valve, 60 X.



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Explanation of Plate 3

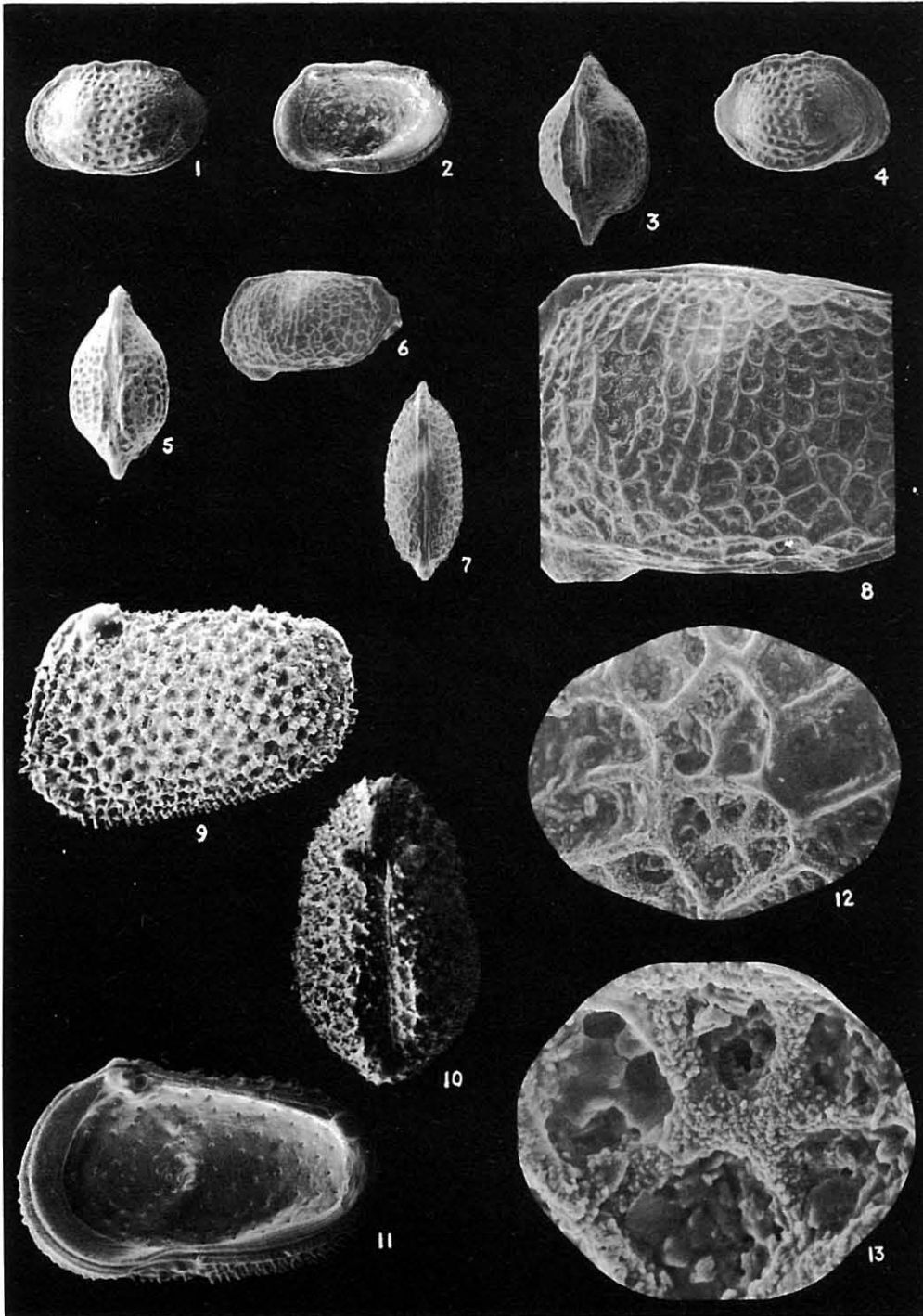
- Figs. 1, 2, 3 *Costa chilensis* n. sp. 1. Left valve; 2. Right valve internal view; 3. Dorsal view, 60 X.
- Figs. 4, 5, 6 *Bradleya normani* (Brady). 4. Left valve lateral view, 60 X. 5. Ornamentation detail, 200 X. 6. Fossae detail, 700 X.
- Figs. 7, 8, 9, 10 *Hermanites reticulata* (Puri). 7. Right valve internal view, 60 X. 8. Left valve, 60 X. 9. Ornamentation detail, 200 X. 10. Dorsal view, 60 X.



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Explanation of Plate 4

- Figs. 1, 2, 3, 4, 5** *Palmoconcha(?) Kyokoae* n. sp. 1. Left valve lateral view (male); 2. Right valve internal view (male); 3. Dorsal view (female); 4. Right valve lateral view (female); 5. Dorsal view (male). 60 X.
- Figs. 6, 7, 8, 12, 13** *Loxoconcha intrastellata* n. sp. 6. Left valve view, 60 X; 7. Dorsal view, 60 X; 8. Ornamentation detail, 200 X; 12. Reticulum detail, 700 X; 13. Intrareticular structure, 2000 X.
- Figs. 9, 10, 11** *Wichmanella meridionalis* Bertels, 1969. 9. Left valve lateral view; 10. Dorsal view; 11. Right valve internal view. 60 X.



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(Received on Oct. 12, 1977)