# 11.—Permian Brachiopod Retimarginifera n. gen. n. sp. from the Byro Group of Carnarvon Basin, Western Australia

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**Abstract**

A Productid species from the Permian Byro Group of the Carnarvon Basin, which was previously referred to *Dictyoclostus gratiosus* (not Waagen) by Prendergast (1943) and to *Marginifera gratiodentalis* (not Grabau) by Coleman (1957) is described as *Retimarginifera perforata* n. gen. n. sp. The genus is classed in the Paucispiniferinae Muir-Wood and Cooper 1960, which is transferred from the Linoproductidae to the Marginiferidae. Muir-Wood and Cooper's definitions of other Marginiferid subfamilies are emended.

## Introduction

In 1966 Dr. P. J. Coleman, Department of Geology, University of Western Australia, kindly loaned me a collection of Marginiferid shells from the Permian Byro Group of the Carnarvon Basin, Western Australia. These had previously been referred to *Marginifera gratiodentalis* Grabau but Grabau's species is not conspecific, belonging to the Dictyoclostidae, whereas the West Australian specimens belong to the Marginiferidae.

## Stratigraphy

The specimens described herein come from the Cundlego Formation in the middle part of the Byro Group in the Carnarvon Basin (Fig. 1). Further occurrences have been reported by Coleman (1957) from the slightly younger Wandagee Formation, and also from the Baker Formation at the top of the Byro Group, or from the Coolkilya Greywacke at the base of the overlying Kennedy Group. Condon (1967, p. 169) listed *M. gratiodentalis* from the Wandagee Formation, Norton Greywacke, and the Coolkilya Greywacke (p. 184), with no mention of it in the Baker Formation. Elsewhere he emphasised that it, with other species, is "found no higher than the Baker Formation" (p. 156) and this is correct, according to a letter from Mr. Condon (in litt, November, 1968). There has been confusion over the limits of the top of the Byro Group and the Coolkilya Formation, because Condon (1954, p. 85) put the base of the Coolkilya much higher than proposed by Teichert (1950, 1957), as outlined by Dickins (1963). The outline presented by Dickins (1963) as amended by Condon (1967) is followed herein because this was the order in which the collections were arranged when assessed by the writer at the Bureau of Mineral Resources.

### *Correlation of the Lower Byro Group (Stage D 1)*

*New Zealand, eastern Australia*—Dickins (1963) recognised two faunas in the Byro Group, both referred to Stage D. D 1 is found in the lower formations of the Byro Group up to and including the Wandagee Formation (Fig. 1). To judge from fossil lists presented by Dickins (1963, p. 14) and Coleman (1957), and examination of collections at the Bureau of Mineral Resources, Geology and Geophysics, Canberra, during April 1963, the D 1 fauna is distinguished by the diversity of genera, such as *Kiangsella*, *Waagenoconcha*, *Lialosia*, *Fusispirifer* and other transverse spiriferids, *Yochelsonia*, *Hoskingia*, *Glyptoleda*, *Heteropecten*, *Palaeocosmomya*, *Girtypecten?*, *Acanthopecten?*, *Stachella?*, *Bellerophon*, *Macrochilina*, *Euphemites* and *Straparollus*. Cold water genera especially typical of eastern Australia such as *Deltopecten*, *Eurydesma* and *Keeneia* are not known at this horizon.

A few brachiopods, notably *Echinalosia prideri* (Coleman) and *Aulosteges ingens* Hosking which are especially characteristic of the lower Byro Group and equivalent horizons of Western Australia are found in the upper Takitimu Group of New Zealand (Waterhouse 1967). This correlation is reinforced by the approach of the underlying Telfordian faunas of New Zealand to the Callytharra-Wooramel faunas below the Byro Group in the Carnarvon Basin, and of the overlying Braxtonian faunas of New Zealand to the D 2 faunas in the Carnarvon Basin, as shown in Table 1.

*Urals. (World Standard)*—Various formations within the lower Byro Group, up to and including the Wandagee Formation, have yielded Baigendzinian (=upper Artinskian, ?Kungurian) ammonoids (Glenister and Furnish, 1961). Thomas and Dickins (1954) correlated the faunas with those of the Lower Productus Limestone of the Salt Range, which accords well with the ammonoid evidence.

### *Correlation of the Upper Byro and Lower Kennedy (Stage D 2)*

Dickins (1963) separated the upper Byro faunas of the Norton Greywacke and Baker Formation from the D 1 faunas of older horizons, and referred the faunas of the overlying Coolkilya Greywacke at the base of the Kennedy Group to the same D 2 substage. The writer examined the collections at the Bureau of Mineral Resources, Canberra, and fully agrees with this distinction, though preferring to see the difference upgraded to stage rank. At the D 1-D 2 boundary *Taeniothaerus* and many Strophalosiids disappeared, together with molluscs such as *Platyceras**, *Nuculanella**,

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* Asterisked species reappeared in the Coolkilya Greywacke.

**TABLE 1**

*Correlation of Permian sequences. The lower Texan stages should be subdivided, and the Skinner Ranch included with the Lenox Hills*

| Russian Standard | Ammonoid Subdivisions in Russia | Western Australia | | United States, Texas | | New Zealand Stages |
|---|---|---|---|---|---|---|
| | | Carnarvon Basin Formations | Stages Dickins (1963) | Glass Mts. Formations | Stages | |
| Tatarian | | | | Ochoan | | Makarewan |
| | | | | | | Waiitian |
| | | Kennedy Group | F | Capitan | Capitan | Puruhauan |
| Kazanian | | | E | Word | Wordian | Braxtonian (Flettian) |
| Ufimian | (no ammonoids) | | $D_2$ | Road Canyon | Roadian | (Barrettian) |
| Kungurian | (few ammonoids) | Byro Group | $D_1$ | Cathedral Mountain | Leonard | Mangapirian |
| | Baigendzinian | | | | | |
| Artinskian | Aktastinian | ? Wooramel Group | C | Skinner Ranch | | Telfordian |
| Sakmarian | Sakmarian | Callytharra Form | B | Lenox Hills | Wolfcamp | |
| | Asselian | Lyons Group | A | Neal Ranch | | Horizon B |
| | | | | | | Horizon A |

*Quadratonucula, Peruvispira, Chaenomya, Leptomphalus**, *Macrochilina**, *Nuculopsis**, *Paleosolen**, *Pseudobaylea**, *Naticopsis, Plagiostroma**, *Acanthopecten, Astartella, Allorisma, Heteropecten**. *Megadesmus* also dropped out according to the lists in Dickins (1963), but is probably represented as so-called *Cardiomorpha blatchfordi*. Genera such as *Warthia, Schizodus* and *Cancrinella* also persisted.

Glenister and Furnish (1961) have suggested on the basis of ammonoids that the Coolkilya Formation, including upper Byro as defined by Teichert, ranged from Baigendzinian into the lower Guadalupian (including basal Word). Dickins (1956, 1963) referred the upper Byro to the upper Artinskian, and Coolkilya (restricted) to the Kungurian. Changes are now necessary to these ages, because of redefinitions and subdivisions within the standard sections of North America and Russia. In the Glass Mountains, Texas, the standard sequence for North American Permian, the lower Guadalupian of Glenister and Furnish has been replaced in the new Road Canyon Formation by Cooper and Grant (1964), and recognised as a possibly distinct brachiopod stage by Nassichuk et al (1965), called Roadian by Furnish (1966 Table 1, p. 269). The Russian world standard has also been reinterpreted. When Dickins (1963) proposed a Kungurian age for the Coolkilya Formation he accepted the views of Licharev (1959) and others that the Kungurian Stage was followed by the Kazanian Stage, and that an intervening so-called Ufimian Stage should not be recognised. However the Soviet Commission on Permian Stratigraphy has set aside this view, and officially recognised the Ufimian Stage (Licharev 1966). They have also lowered the Kungurian boundary. Thus the Kungurian correlation needs to be readjusted to the new Soviet interpretation. Waterhouse (1969 b) showed that the Ufimian as now understood rather than Kungurian was probably equivalent to the Road Canyon, upper Byro and other faunas. Certainly there is a very distinct pre-Kazanian fauna, with characteristic fusulinids, brachiopods and ammonoids, developed widely above Baigendzinian faunas in Siberia, Arctic Canada, China, Japan, Australia and New Zealand. This fauna is present in the upper Byro Group. It possibly includes the Coolkilya fauna as well, though Dickins (1956) did compare several bivalves with species from the Basleo beds of Timor. The Basleo beds are of Wordian (Kazanian) age, but Dickins considered that the affinities indicated a post-Artinskian age, and that absence of certain key genera ruled out a Kazanian correlation (Dickins, 1956, p. 39).

## Systematic description

### Order **Productida**

### Family Marginiferidae Stehli 1954

*Diagnosis*

Marginal ridge well defined in both valves or dorsal valve, cardinal process sessile to erect, broad median shaft, narrow backleaning median lobe and broad lateral lobes, costellae of variable strength, spines in row along hinge and/or umbonal slopes, specialised into very sturdy regularly arranged halteroid spines in some genera, comparatively few over visceral disc and trail, present or absent on dorsal valve. Muscle scars usually not dendritic or lobate.

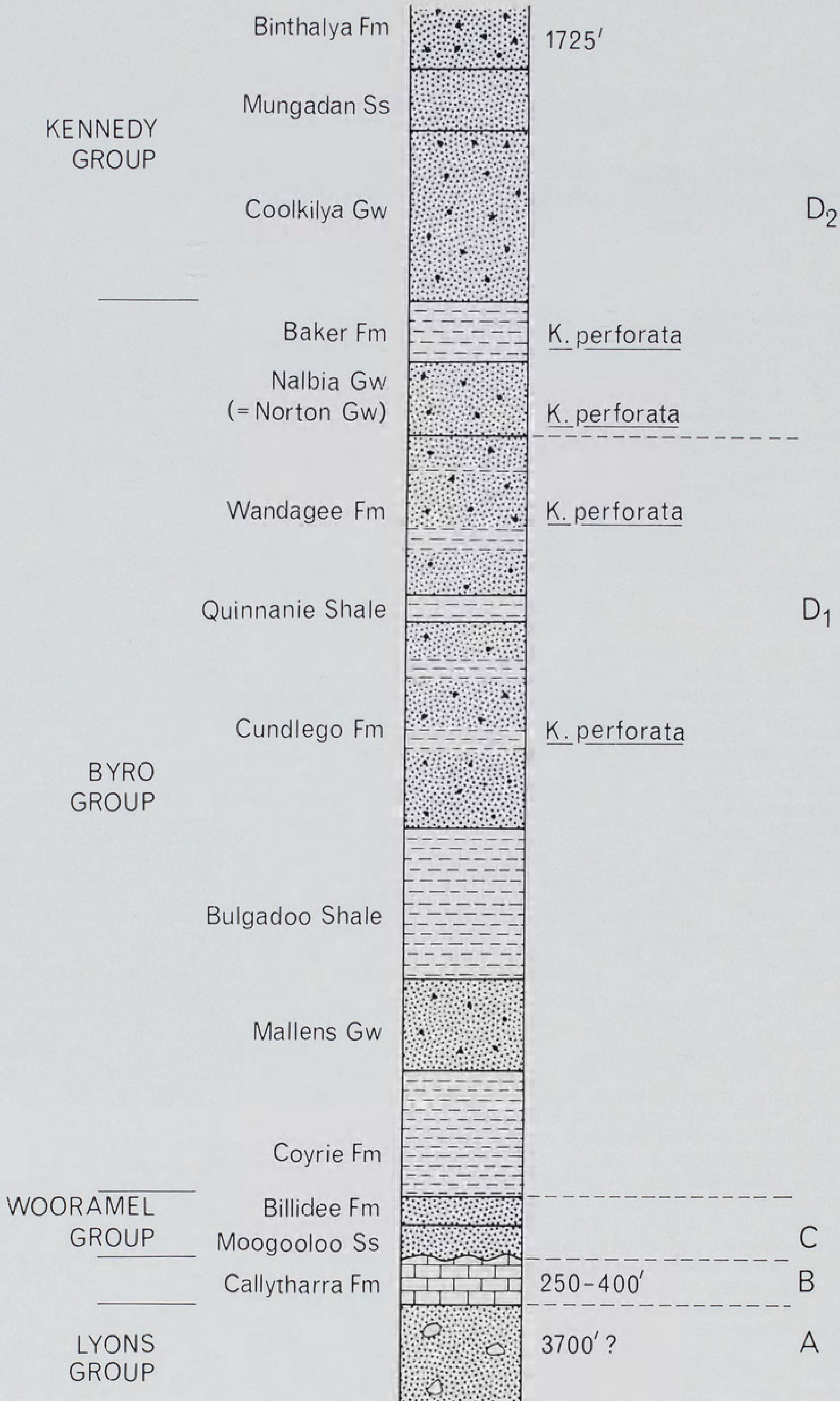



Fig. 1.—Sequence of formations in Carnarvon Basin, showing occurrences of *Retimarginifera perforata* n. sp., and subdivision of faunal stages by Dickins (1963), based on Dickins (1963, fig. 2).

*Subfamily classification*

Muir-Wood and Cooper (1960), followed by Muir-Wood (1965), recognised four subfamilies in the Marginiferidae partly on shape, partly on the presence or absence and strength of the marginal ridges. Their classification is not always consistently applied. For instance the Marginiferinae was defined as having a continuous externally crenulated marginal ridge around the dorsal valve, and smooth adductors, in contrast to the Costispiniferinae, with crenulated ridges across the ears of both valves, and prominent endospines and smooth or rarely dendritic adductors. However *Marginifera* and *Hystriculina* do have marginal ridges across the ears of both valves, so that the definition of Marginiferinae erred. Endospines occur in the genus *Kozlowskia*, yet this is classed in the Marginiferinae. *Elliotella* was described as having no marginal ridge in the ventral valve (Muir-Wood and Cooper, 1960, p. 224), and *Liosotella* as having no marginal ridge in the dorsal valve (Muir-Wood and Cooper, 1960, p. 228), yet both were classed in the Costispiniferinae. In fact, examination of the type species at the Smithsonian Institution shows that marginal ridges are present in both valves of both *Elliottella* and *Liosotella*.

The subfamily Paucispiniferinae was classed in the Linoproductidae by Muir-Wood and Cooper (1960) and Muir-Wood (1965). *Paucispinifera*, as clearly shown in illustrations by Muir-Wood and Cooper (1960, pl. 122, figs. 1-16) and confirmed from examination of types at the Smithsonian Institution, Washington, has a marginal ridge in both valves, a characteristic cardinal process with narrow median lobe, a peculiar structure called a zygidium, found also in the Marginiferid genus *Kozlowskia*, smooth adductor scars, and transversely arranged large halteroid spines. These features are typical of the Marginiferidae, not of the Linoproductidae, and the subfamily should be classed with the Marginiferidae (Waterhouse, 1969a, p. 232). The genus is distinguished in part by its cardinal process, which at least in the type species *P. auriculata* Muir-Wood and Cooper examined at the Smithsonian Institution has an anteriorly extended median lobe. Otherwise, its most characteristic feature lies in the symmetrically disposed large halteroid spines across the ventral valve. The same spine pattern is seen in *Kozlowskia*, and some other genera referred to the Marginiferinae and Costipiniferinae by Muir-Wood and Cooper, but is not present in either *Marginifera*, or *Costispinifera*. In view of this, and because of the fact that the development of marginal ridges in these forms does not accord well with the arrangement of genera in Muir-Wood and Cooper, the three subfamilies are redefined as follows, using spines as the chief guide for classification.

A. Marginiferinae: Marginiferidae with spines restricted to ventral valve, not differentiated into transverse row of about six large halteroid spines, halteroid spines arranged in radial rows over umbonal slopes.

*Marginifera, Anemonaria, Hystriculina, Liosotella, ?Elliotella Anemonaria.*

B. Paucispiniferinae: Marginiferidae with spines restricted to ventral valve, characterised by three to six large halteroid bracing spines developed in one of three concentric rows across shell.

*Paucispinifera, Kozlowskia, ?Alifera, Eomarginifera, Paramarginifera, Retimarginifera, Probolionia* closely allied, *Sajakella.*

*Yakovlevia* and *Muirwoodia*, referred to the Paucispiniferinae by Muir-Wood and Cooper (1960), and *Duartia*, referred to the Marginiferinae by Muir-Wood (1965) are not Marginiferid.

C. Costispiniferinae: Marginiferidae characterised by spines on both valves, not differentiated into few large regularly arranged halteroid ones on ventral valve.

*Costispinifera, Desmoinesia, Echinauris, Promarginifera, Spinomarginifera.*

*Inflata* and *Nudauris* are not Marginiferid, as claimed by Muir-Wood and Cooper (1965) but are Dictyoclostid.

## Subfamily Paucispiniferinae Muir-Wood and Cooper

### Genus *Retimarginifera* n. gen.

*Type species.*—*Retimarginifera perforata* n. sp.

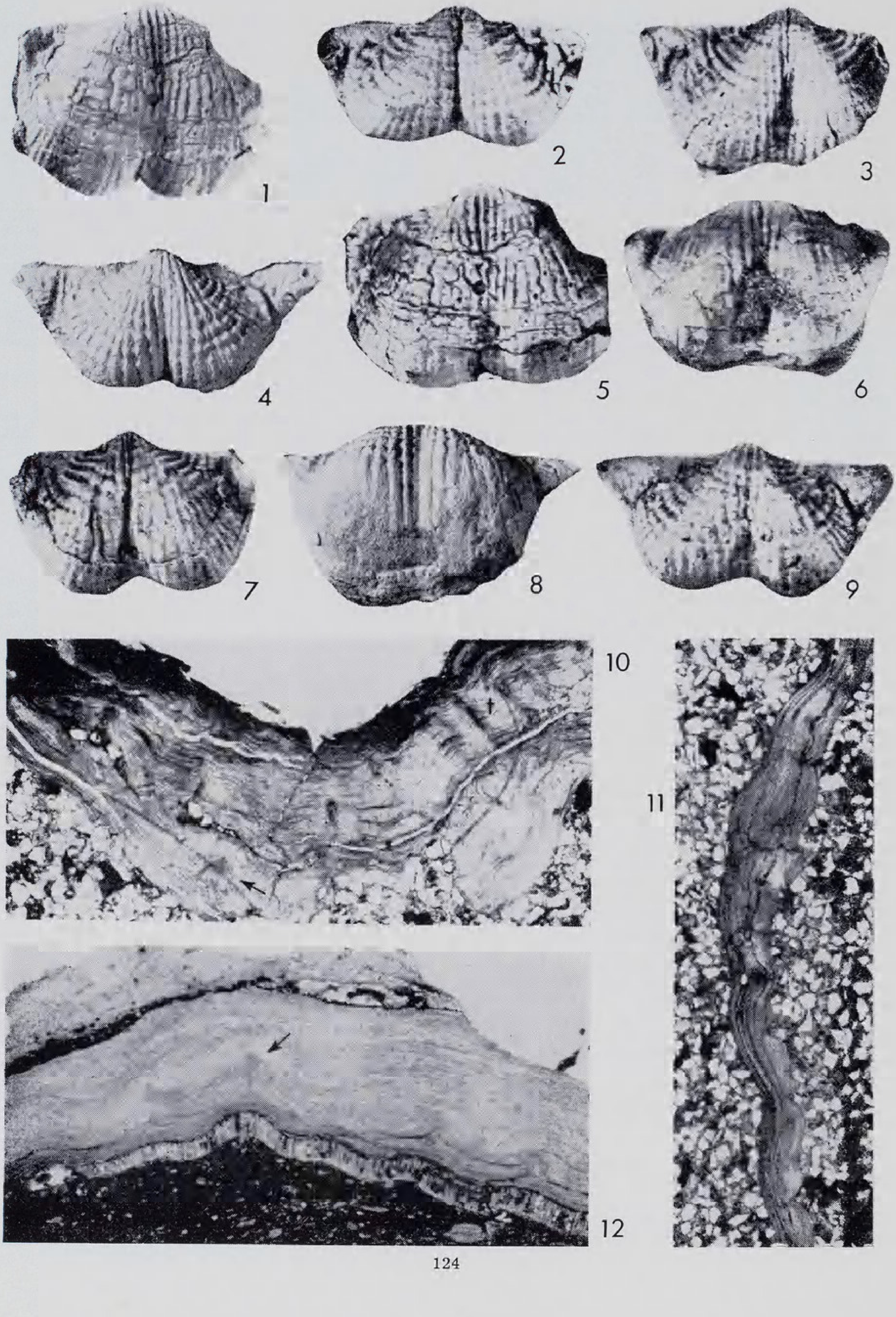
*Diagnosis.*—Transverse shells with large ears, deep ventral sulcus, well defined dorsal fold. Halteroid body spines, usually in one to three transverse rows of 4 to 8, as well as row of hinge spines, limited to pedicle valve. Posterior disc reticulate, costae and concentric rugae strong, sturdy marginal ridge in both valves, marginiferid cardinal process, smooth adductors, large endospines.

### Discussion

*Kozlowskia* Frederiks, with type species *Productus capacii* D'Orbigny is more globular than the new genus, and has a shallower sulcus and less prominent concentric and radial ornament. The sulcus and fold are less defined, or absent.

Fig. 2.—1-11, *Retimarginifera perforata* n. gen. n. sp. 1-9 external aspects of ventral valves, x 2. 1, 5 specimen 59281 from locality UWA 29401 under different lighting. 2, holotype specimen 59282 from locality 27185, showing spines. 3, specimens 59283 from locality UWA 27185. 4, 8, posterior and anterior aspects of specimen 63828 from WC 20.1, showing extensive ears, with single large spine base. 6, specimen 56384 from locality UWA 27185c. 7, specimen 56385 from locality UWA 27185. 9, specimen 56356 from UWA 27185h, with halteroid spine base on each ear. 10, transverse thin section of pedicle valve 63829 from locality UWA 29401, across sulcus, with external surfaces on top, showing slightly wavy lamellae of secondary layer, penetrated by taleolae (†). Note suggestion of inner pustule (arrowed), x 3 approx. 11, transverse thin section of dorsal valve of same specimen, exterior to right, x 35.

12, "*Productus*" *himalayense* Diener, transverse thin section of ventral valve showing lamellar secondary shell with scattered pustules (arrowed), and an inner prismatic layer. Specimen collected by Dr. Gerhard Fuchs, Geologische Bundesanstalt, Vienna, from Kashmir. x 25.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*Paucispinifera* Muir-Wood and Cooper 1960, based on *P. auriculata* Muir-Wood and Cooper, is closer in general shape, and has moderately well defined costae, but concentric ornament and sulcus are inconspicuous.

The genus is possibly represented by *Productus altimontanus* Merla, *P. rimuensis* Merla, *Marginifera hoofti* Renz in the Karakorum and *Marginifera pusilla* Schellwien in south-east Europe, all of Lower Permian age.

*Retimarginifera perforata* n. sp.

Figs. 2, 1-11, 3

*Dictyoclostus gratiosus* Prendergast (not Waagen) 1943: p. 17, pl. 2, figs. 5-7.

*Marginifera gratiodentalis* (not Grabau) Coleman 1957: p. 79, pl. 9, figs. 1-14.

*Kozlowskia* n. sp. Waterhouse 1969 a: p. 232, Fig 41.

*Material.*—Material examined by the writer comprises two specimens with valves conjoined and three ventral valves from UWA 29401, a figured dorsal valve UWA 28453a; seven ventral valves, and one specimen with valves conjoined (the dorsal one masked), from UWA 27185, and a block WC 20.1 with four ventral valves, all kept at University of Western Australia. The shell material is preserved, slightly worn and decorticated sufficiently to obscure external growth lamellae and interior pustulation. Many have lost the anterior trail, and cardinal extremities. Coleman's description was based on these and a further 35 or so specimens, kept at the University of Western Australia. Prendergast based her description on five specimens, kept at the Australian Museum, Sydney.

*Localities.*—UWA 27185—Cundlego Formation, *Calceolispongia* stage horizon north-east side of syncline on north bank of Minilya River, west of Coolkilya Pool, WC 20.1, *Dictyoclostus* zone, same description. UWA 28453—Cundlego Formation, 350 yards west of fence between Barrabiddy and Weer Paddocks, 2220 yards south of gate in the fence near Barrabiddy Creek south of Wandagee Station. UWA 29401, Cundlego Formation—locality 1, horizon 1, of C. Teichert, Wandagee area. Other localities for specimens not examined by the writer are recorded by Coleman (1957, p. 79), including occurrences in both the Wandagee Formation and Baker Formation, Western Australia.

*Holotype.*—Specimen 59282 from locality UWA 27185, fig. 2, 2.

*Figured topotypes.*—Specimens 59283-29286 from locality UWA 27185.

*Diagnosis.*—Transverse alate shells with sulcus deep anteriorly, costellae and wrinkles well developed, endospines elongated. Inner shell penetrated by large taleolae.

*External features.*—The species has been carefully described by Prendergast (1943) and Coleman (1957). Salient features are the transverse outline and prominent ears, set off in the dorsal valve of the holotype by a low ridge. A deep ventral sulcus commences 3-5 mm in front of the umbonal tip, widens rapidly to the start of the trail, and then becomes parallel-sided with a reduced sinal angle. The fold is anteriorly placed, the trail high and geniculate. Five to seven costae occur in 5 mm, increasing by branching and implantation, with low well rounded crests. One or two pairs may converge within the sulcus. Ears are smooth. About 15 growth rugae lie over the visceral disc, better defined in the specimens from locality UWA 27185, dividing radial ornament into tubercles, as in Dictyoclostidae. The rugae are less pronounced over the anterior disc, and missing or faint over the trail. Growth laminae are also present, about 5 mm per millimeter. Spines arise abruptly from costal crests, reach 1 mm in diameter though this varies, and are restricted to ventral valve. They form three rows, one along the hinge, and one row of usually three or so spines each side of the umbo just inside the ear, and 2-5 spines in a more erratic row each side of the sulcus. A pair of large halteroid spines lies on the ears, a pair on the posterior umbonal flanks, and an anterior pair on the sulcal flanks (Fig. 3). Other spines are few, with some anteriorly as in a specimen from UWA 29401 (Fig. 2, 1).

*Internal features.*—Coleman described the ventral adductor muscle scars as an undifferentiated non-dendritic pair. A low marginal ridge crosses the inner ears and is visible anteriorly in the holotype.

The dorsal valve has a sessile cardinal process with elevated median shaft, broad lateral sulci, and very low lateral lobes. A broad platform lies in front of the process, passing into a short median septum which is highest at its anterior end. The posterior adductor scars are obscure, the anterior adductors small, rounded, anteriorly placed, not dendritic. Brachial ridges are well rounded, and not clearly connected with the septum. The marginal ridge lies just within the hinge, strongly pocked across the inner ears, and faintly defined in front. About 8 elongated, narrow crested endospines lie each side of the midline between the septum and brachial ridges, immediately behind the marginal ridge.

*Shell structure.*—The decorticated shell of several specimens from localities UWA 27185 and 29401 is flecked with white taleolae, 0.3 mm or more apart, and matrix-filled pores of similar spacing, rare posteriorly, and more common anteriorly, presumably later plugged by the taleolae. Pores and taleolae are only 0.1 to 0.2 mm apart in a large worn shell from UWA 29401. A polished transverse surface of a pedicle valve 1 mm thick from UWA 29401 has about 20 thick laminae, with large taleolae normally about 0.3 mm apart, extending from the inner surface half-way into the shell. Thin sections

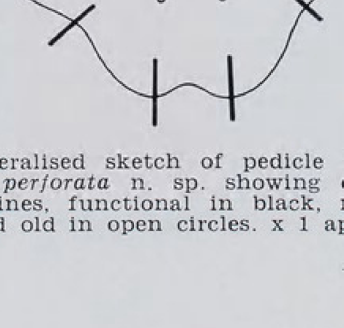

Fig. 3.—Generalised sketch of pedicle valve of *Retimarginifera perforata* n. sp. showing distribution of halteroid spines, functional in black, non functional and old in open circles. x 1 approx.

of another more complete specimen (Fig. 2, 10) show numerous fine lamellae parallel to outer surface, interrupted by the large calcareous rods (taleolae), usually 0.10 mm across, and larger pores with matrix-filled cores, and the lamellae bulging inwards to each side. An innermost zone of smooth tissue is present, with large pustules doming outwards, only 0.7 to 1 mm apart, seemingly too numerous for spine bases. There are no visible taleolae.

A transverse thin section of the dorsal valve (Fig. 2, 11) 0.5 mm thick, is made up of numerous parallel lamellae with a thin outer yellowish band 0.05 mm thick of 2 to 5 lamellae. The inner edge is embayed by large pustules, and rare taleolae are visible in the inner layer, with a couple extending into the outer layer, but not disturbing the laminate structure.

Other Productida have an outer layer with dense taleolae, but no tubes and pores, examples including other Paucispiniferinae (Fig. 2, 12) *Anidanthus* (Waterhouse, 1968a) and *Kuvelousia* (Waterhouse, 1968b). (-See Waterhouse 1970, p. 47.)

*Prendergast's specimens.*—These specimens, examined at the Australian Museum, Sydney, appear to be closely related and perhaps conspecific, but the types were not to hand for comparison. The figured specimen **F** 37569 (Prendergast, 1943, pl. 2, figs. 5-7) has spines, whereas the unfigured **F** 37570 has more body spines, and no obvious hinge row, perhaps due to preservation. Three costae pass forward from a spine base over parts of the shell. F 37571 has a few spines along the hinge, umbonal slopes and outer sulcus.

### *Resemblances*

These shells were identified with *Marginifera gratiodentalis* (Grabau, 1934) by Coleman (1957). *Productus gratiodentalis* was proposed by Grabau for shells described by Schwellwien (1892, p. 24, pl. 3, figs. 6-9; pl. 8, fig. 25) as *Productus gratiosus occidentalis* from the Fusuline beds of the Carnic Alps. Pointing out that the Carnic specimens belonged to a full species distinct from *gratiosus* Waagen, Grabau (1934, p. 36) assigned a new name to Schellwien's species, because *occidentalis* was preoccupied. No type specimen has been designated, but the selection of a lectotype should be deferred until the preservation of Schellwien's figured specimens can be ascertained. Compared with the specimens from Western Australia, they have a more posterior sulcus and finer concentric wrinkles seemingly more restricted to the posterior part of the shell. The radial ornament is much stronger over the anterior inner ears. Schellwien implied through his comparison with *P. gratiosus* Waagen that the Carnic shells are Dictyoclostid, as in Branson (1948, p. 334). It appears unlikely that the Australian shells are in any way related to specimens assigned to *occidentalis* Schellwien or *gratiodentalis* Grabau by Chao (1925, pl. 2, fig. 6; 1927, p. 47, pl. 4, figs. 11-16); Grabau (1934, p. 36, pl. 10, figs. 7-8; 1936, p. 118, pl. 12, figs. 2a-d, 3a, b, 4a, b, 5) and King (1931, p. 71, pl. 14, figs. 1-3). All of these shells are more or less easily distinguished, apparently lacking halteroid spines, and having finer concentric ornament and a shallow sulcus except in the specimens described by Chao (1925). None of them was compared to *Marginifera*, though the genus was recognised and species described elsewhere by the various authors. Sestini (1965, p. 178, pl. 22, figs. 6, 7) assigned the species to *Marginifera*, but her Karakorum specimen resembles neither the Australian nor European shells.

**TABLE 2**

*Dimensions in mm of* Retimarginifera perforata *n. sp.*
Ventral valves

| Width | Length | Height | Umbonal angle | Cardinal angle | Sinal angle | Sinal angle at start of trail |
|---|---|---|---|---|---|---|
| Locality UWA 29401 | | | | | | |
| 26·7 | 21·6 | 10 | | 60° | 23° | 33° |
| 24·3 | 16·5 | 11·2 | 90° | 75° | 20° | 28° |
| +23 | 18·4 | 9·4 | 95° | | 25° | 35° |
| 29·6 | 18·7 | 11 | 115° | 55° | 22° | 40° |
| +27·5 | 17·5 | 8·1 | 102° | 70° | 24° | 35° |
| Locality UWA 27185 | | | | | | |
| +20·3 | 13·9 | 7·6 | 110° | | 25° | 40° |
| 22·0 | 11·6 | 7·8 | ?80° | 55° | 25° | 38° |
| +21·5 | 13·8 | 7·4 | ?65° | | 20° | 35° |
| +20·6 | 12·5 | 6·6 | 95° | | 30° | 35° |
| +24 | 12·6 | 6·4 | 112° | | 30° | 40° |
| 22·2 | 13·3 | 8·3 | | | | |
| 24·5 | 13·8 | 7·8 | 112° | 65° | 19° | 30° |
| 24·4 | 13·3 | 7·7 | 95° | 55° | 28° | 38° |
| Locality WC 20·1 | | | | | | |
| 25·0 | 16·6 | 10·6 | 115° | 45° | 15° | 33° |

Dorsal valve UWA 28433a

| Width | Length | Height | Cardinal angle | Fold angle at Anterior | Fold angle at Trail | Septum length |
|---|---|---|---|---|---|---|
| 28·4 | 14·7 | 8·7 | 53° | 25° | 40° | 8·7 |

Fold angle measured at start of trail and at anterior margin.

Most specimens have lost a little of the cardinal extremities and something of the trail. Septum length shows the distance between the cardinal process and anterior end of the septum.

None of the American species of *Kozlowskia* is particularly close. The type species *Productus capacii* as figured by D'Orbigny (1842, pl. 3, figs. 24-26), Kozlowski (1914, pl. 2, figs. 1-15; pl. 5, fig. 13; text-fig. 1, 2) and Muir-Wood and Cooper (1960, pl. 63, figs. 13-19) is less consistently transverse and more oval in outline, with feeble concentric ornament and less pronounced

**TABLE 3**

*Statistical Summary for* R. perforata, *ventral valves*

| | Width | Length | Height | Umbonal angle | Sinal angle |
|---|---|---|---|---|---|
| n .... | 14 | 14 | 14 | 12 | 12 |
| $\bar{x}$ .... | 23·9642 | 15·2928 | 8·5642 | 98·83° | 23·83° |
| s .... | 2·5577 | 2·8298 | 1·5309 | 14·7920 | 3·9545 |
| V .... | 10·6730 | 18·5041 | 17·8756 | 14·9671 | 16·5946 |
| $\sigma \bar{x}$ .... | 0·6836 | 0·7563 | 0·4092 | 4·2701 | 1·1416 |
| $\tau$ width : | | (W) 0·6866 | (W) 0·5868 | $\tau$ Umb.° | 0·0066 |

complete specimens only

| | Width | Length | Height |
|---|---|---|---|
| n .... | 8 | 8 | 8 |
| $\bar{x}$ .... | 24·8250 | 15·6750 | 9·3000 |
| s .... | 2·2752 | 3·1063 | 1·4465 |
| V .... | 9·1649 | 19·8169 | 15·5538 |
| $\sigma \bar{x}$ .... | 0·8044 | 1·0982 | 0·5114 |
| $\tau$ width : | | 0·7791 | 0·6312 |

n = number of specimens
$\bar{x}$ = mean
s = standard deviation
V = coefficient of variation
$\sigma \bar{x}$ = standard error of the mean
$\tau$ width = correlation coefficient (width —)
$\tau$ Umb.° = correlation coefficient with umbonal angle.

sulcus and fold. A specimen figured as *P. longispinus* (not Sowerby) by Salter (1861, p. 64, pl. 4, fig. 2) is more elongated, with a moderately well formed sulcus, and emphasized costellae. The scattered tubercles shown over the ventral valve, if they represent spine-bases, would rule out any close alliance, and such also seem to be represented by Kozlowski (1914, pl. 2, fig. 9b) but Kozlowski (1914, p. 22) stated in his text that spines are rare. Specimens examined at the Smithsonian Institution from Apillipampa south of Capinote, Brazil, (USNM 124030a, b; Muir-Wood and Cooper, 1960, pl. 63, figs. 13-19) have 6 halteroid spines, and a few others only. There is no hinge row, perhaps because they have been rubbed off, for the specimens are not well preserved. The ears have been lost from USNM 124030b, but growth lines show that they were large. A small ventral valve kindly made available by Dr. Richard E. Grant from the U.S. Geological Survey, Washington, D.C. has been sectioned. Unfortunately the shell is partly silicified and no taleolae or spine bases can be discerned. Laminations are less pronounced than in the Australian species.

*Marginifera himalayensis* Diener (1899) is also close in shape, but has larger ears and more numerous spines. The types have been examined at the Geological Survey of India, Calcutta. Specimen F 6285 (Diener, 1899, pl. 6, fig. 2) is selected as lectotype. The species seems to have symmetrically disposed halteroid spines, and a row of hinge spines is preserved on some (e.g. F 6236—pl. 2, fig. 2, and F 6238—pl. 2, fig. 4), so that the specimens are not *Marginifera*, but possibly belong to the Paucispiniferinae. It is possibly a new genus, distinguished by the strong concentric ornament of the dorsal valve, and cluster of tubercles or spine bases on the outer ears (as in F 6238), and shell structure. The shell structure has been examined in specimens collected from the type locality in Kashmir by D. G. Fuchs, Geologische Bundesanstalt, Vienna. The outer shell structure in the ventral valve (Fig. 2, 12) differs considerably from that of *perforata*, coming much closer to that of *Anidanthus* described by Waterhouse (1968a). The innermost band, 0.125 mm thick, consists of parallel prisms perpendicular to the surface, each about 0.13 mm thick. This layer is not preserved in *K. perforata*. The inner secondary layer has cloudy calcite lamellae less conspicuous than in *K. perforata*, but essentially the same in possessing large whorls due to ?pustules, spaced about 0.4 to 0.6 mm apart in a single row and thus too numerous to have been spine bases. The outer layer, just as thick, has small calcite and matrix filled pores, about 0.1 to 0.05 mm in diameter, possibly due to taleolae, but very obscure. The pores resemble those of *Anidanthus* and *Kuvelousia*, and are much smaller than in *K. perforata*.

*Productus altimontanus* Merla (1934, pl. 20, figs. 27-32, 36-41) and *P. rimuensis* Merla (1934, pl. 24, figs. 7-16, 20) from the Lower Permian of the Karakorum Range are close in outline and ornament, but their spine pattern is not certain. Another externally similar species was described as *Marginifera hoofti* Renz (1940, p. 27, pl. 4, figs. 12a-c) from Upper Uralian beds of locality 5, Shukpa Kuchang Glacier, of the Karakorum. Unfortunately its spinose ornament has not been described, but the illustrated specimen resembles the new form in outline and ornament. *"Marginifera" pusilla* Schellwien (1892, pl. 4, figs. 11-21) has a few large halteroid spines in a concentric row, and strong radial ornament and large ears, and so probably belongs to the same plexus as the new form. It came from the Auernigg beds of east Europe. Concentric ornament is less defined.

*Marginifera reticulata* King (1931, pl. 22, figs. 3, 10) might also prove to be allied. It comes from the Leonard of the Glass Mountains, and has similar ornament and deep sulcus, but is slightly more rectangular in outline, with smaller ears and longer visceral disc.

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