COMMONWEALTH OF AUSTRALIA.

DEPARTMENT OF NATIONAL DEVELOPMENT.

BUREAU OF MINERAL RESOURCES, GEOLOGY AND GEOPHYSICS.

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PERMIAN PRODUCTACEA OF WESTERN AUSTRALIA

BY

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COMMONWEALTH OF AUSTRALIA.

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SUMMARY.

The brachiopod super-family Productacea is represented in the Permian faunas of Western Australia by at least 34 species, many of which occur in at least two of the three major areas of marine Permian sediments. These areas, from north to south, are the Canning Basin, the Carnarvon Basin, and the Irwin Basin, together an area of approximately 150,000 square miles. The Permian succession in each of these basins begins with glacial sediments and is followed by a variety of sediments, marine and non-marine, with a total thickness of over 12,000 feet in the Carnarvon Basin. The marine formations are often richly fossiliferous, containing abundant remains of the Productacea.

Study of the Western Australian material has enabled discussion of certain features, the function and taxonomic value of which are imperfectly understood. Important amongst these are the shell structure, attachment scar, musculature, trail, and the living position of the shell.

The species are treated as belonging to the Productidae, one of the families making up the Productacea, distributed over the subfamilies Productinae and Strophalosiinae. Most productid genera have been erected on the basis of one or very few diagnostic features, most important of these being the ornamentation. The use of this feature as one of primary diagnostic importance is partly justified because of its important functional value. The cardinal process and other internal structures are regarded as important diagnostic features at a generic level. Ornamentation has not played as important a part in the generic subdivision of the Strophalosiinae as it has done for the Productinae. Specific discrimination in the Productidae is based on persistent variation in external features, ornamentation again playing a major role.

The collection studied consisted of well over three thousand specimens, most of them well preserved. There are seven species of *Aulosteges;* the genus *Dictyoclostus* is represented by three species; the genus *Krotovia* (emended) by four species; the genus *Linoproductus* by three species; the genus *Marginifera* by one species; the genus *Waagenoconcha* by one species. *Taeniothaerus,* an Indo-Pacific genus, is represented by seven species, one of doubtful affinities. In the subfamily Strophalosiinae, *Etheridgina* is represented by one species; *Strophalosia* by three species, one of them very doubtfully represented, and its subgenus *Heteralosia* by five species, one of these being doubtfully represented.

Most of the species lived as close-knit communities in the neritic, possibly the epineritic, zone, preferring a substratum of fine-grained silty sediment. Species of both subfamilies cohabited, but similar species of either subfamily apparently did not. The normal association is with bryozoa and other large-shelled brachiopods, especially spiriferids.

The majority of species range over several formations. At least eleven species are likely to have stratigraphical value. Only six species are common to all three basins, but seventeen are common to any two of them, indicating the provincial nature of the fauna.

The species in the lower part of the general succession, above the glacial sediments, are indicative of Artinskian age, but post-Artinskian species become more prominent towards the top of the succession, especially in the Canning Basin. The distribution of the species in general confirms existing correlations within the province. The fauna as a whole is distinct from those of other regions, particularly in the large number of species belonging to the genera *Aulosteges*, *Strophalosia*, and *Taeniothaerus*. It has its closest affinities with the Permian productid fauna of Timor, followed by that of the Indian Salt Range and Lower and Middle Productus Limestones. It is essentially dissimilar to that of Eastern Australia. The even distribution, lateral and vertical, of the species is thought to be governed more by ecology than by evolution.

No marked evolutionary phenomena were shown by the fauna as a whole, nor by its constituent species.

INTRODUCTION.

The sequence of Permian marine strata in Western Australia is, in area and thickness, one of the largest in the world, and contains a rich and diversified fauna. This fauna is unusual in some ways, particularly in the apparent absence of fusulinids and in the presence of numerous species of that valuable index fossil, the bizarre crinoid genus *Calceolispongia*. Nevertheless, the fauna has an element in common with Permian faunas elsewhere—the prevalence of those brachiopods familiarly known as productids.

The fauna is represented by probably as many as five hundred species, of which brachiopoda and bryozoa are most numerous. It has lacked systematic treatment in the past, probably less than one-third of the species having been adequately described. As a contribution to this greatly needed systematic study thirty-four species are described in this paper, many of them new, belonging to the subfamilies *Productinae* and *Strophalosiinae*. All species already described have been thoroughly re-studied, using both the material available to the original authors and that collected since the time of first description. The additional material has made it possible to revise, or enlarge, most of these earlier descriptions.

Over the last fifteen years intensive collecting from large areas of the marine Permian has resulted in the large collections drawn on for this study. It is conceivable, therefore, that the Western Australian Permian Productidae are reasonably well represented here, although more species probably await discovery and description.* Their existence is hinted at in the present collections by odd fragments so poorly preserved as not to warrant recording.

Although the description of species makes up the bulk of the work, other aspects of the productid fauna are included—morphological, taxonomic, ecological, stratigraphical and evolutionary. The last three of these other aspects have not been treated in as great detail as might be wished. All three of them depend absolutely on other interdependent studies not yet begun or not yet completed. Such studies include further detailed stratigraphical subdivision, comprehensive stratigraphical collecting of specimens, field studies of the faunas, and the petrological study of the sediments enclosing them.

HISTORICAL REVIEW.

Study of the Western Australian Productidae began with a description of a small assorted fauna, which included two productid species, by Hudleston in 1883. These species were referred to as *Productus* cf. *brachythaerus* and *Strophalosia* sp. Between 1880 and 1943 there were numerous sporadic references to productid species, over forty in all, but only fourteen of these were descriptive. The others were merely entries, many of them incorrectly determined, in faunal lists of Western Australian fossils. The best of these lists were those of Glauert (1910, 1926), and Raggatt and Fletcher (1937). These authors listed 34 species of productids, but some of these were synonymous one to another. Their references also included valuable bibliographies which

* Collections made since this study was concluded include some new species that await description.

contain nearly all works in which reference to Western Australia productid species had been made.

The descriptive papers concerned less than a dozen species, each paper briefly describing two or three species which were part of a larger and varied fauna. Most of the species in the very early papers were either undetermined or referred to familiar European species, an effect of the European training and background of these early authors. The most important of these references are: Hudleston, 1883; Foord, 1890; Etheridge, 1903, 1907a, 1907b, 1914, 1919; Hosking, 1931, 1933a, 1933b; and Prendergast, 1935.

In 1943 Prendergast made the first attempt at a systematic treatment of the family. She described 24 species including all except two of the already described species (one named by Etheridge, the other by Hosking) and revised most of the earlier identifications. On the material available at the time this total of 26 species would be representative. This material was part of the earlier collections, much of it indifferently preserved, preventing full and adequate description, and the figures illustrating many species were unsatisfactory. Since 1938 the Permian collections have been more than doubled, productid material being particularly well represented. This additional material, for the most part, is very well preserved.

At the beginning of this study barely twelve species could be said to have been established on a firm footing. It is a tribute to the high standard of Prendergast's work, dealing as it did with refractory material, that nearly all her species names still stand, although many of the species required additions to their descriptions, and some of them thorough revision.

SUMMARY OF STRATIGRAPHY.

Outcropping marine Permian sediments in Western Australia cover an area of at least 40,000 square miles, possibly 150,000 square miles, and in places are up to 12,000 feet thick. They occur in four areas (Fig. 1):

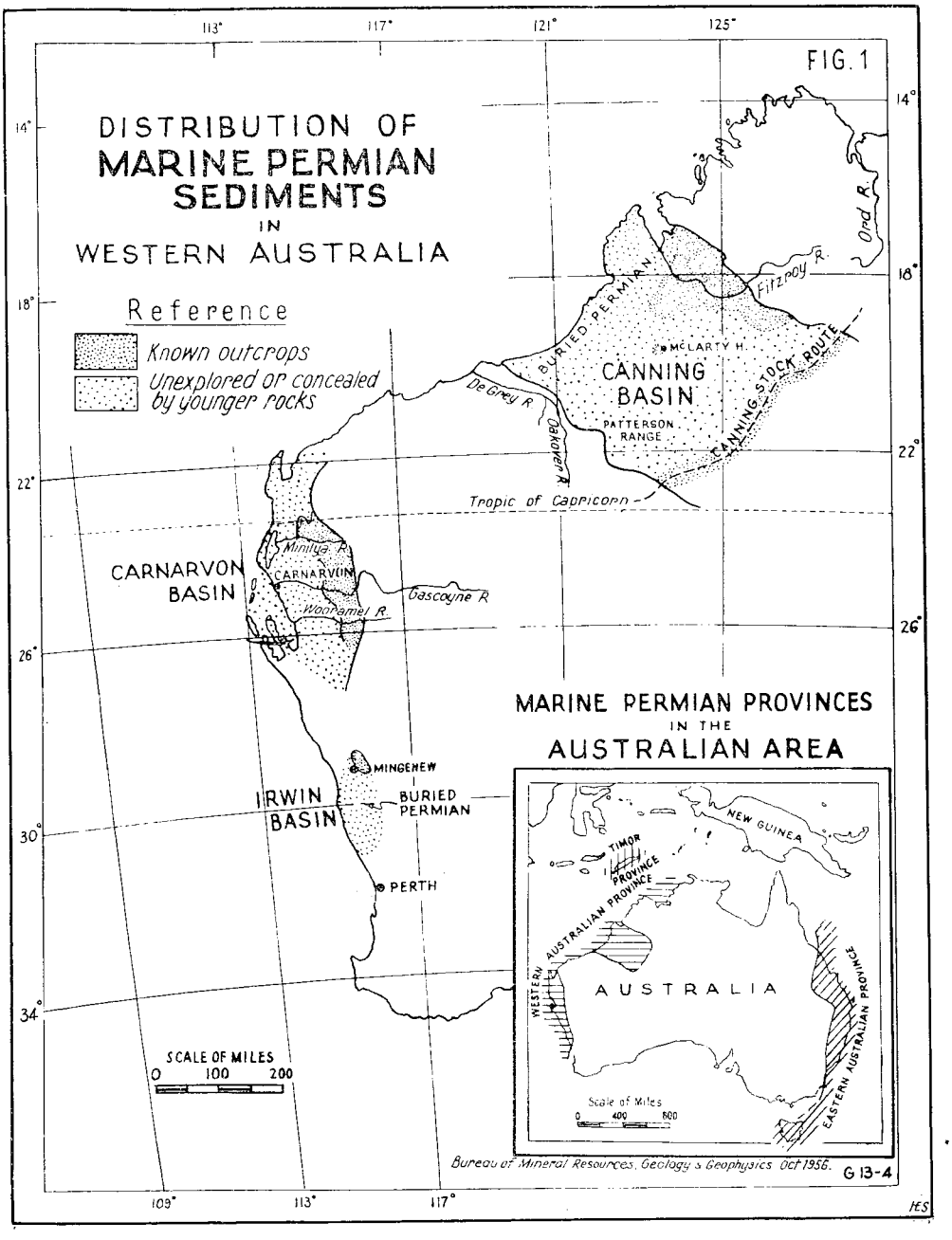
The Irwin River District: The smallest of the four, about 250 square miles in area, located near Mingenew, the sediments occurring in east-dipping fault blocks.

The Carnarvon (North-West Artesian) Basin: In which Permian rocks cover a belt about 40 miles wide, extending from latitudes 23 to 27 degrees south, an area of at least 15,000 square miles. They are disposed in a series of west-dipping fault blocks.

The Canning (Desert) Basin: This Basin has an area of approximately 140,000 square miles, and Permian rocks are estimated to occupy most of it. However, large parts in the south are obscured by Quaternary material and only in the Fitzroy Valley (West Kimberley District) is the Permian well exposed in a series of gently-dipping anticlines. The Permian of the West Kimberley is a roughly rectangular area, extending south-east from about 30 miles inland, just east of the port of Derby, as a belt up to 100 miles wide and at least 300 miles long.

The East Kimberley Basins: These are a series of small fault-bounded structures which extend at their north-easterly end into the Northern

Territory in the region of Bonaparte Gulf. Their stratigraphy has been described by Traves (1955), but not in great detail. Although some of these areas, including the Burt Range Basin, are situated in the Northern Territory just east of the Western Australian border, they are obviously part of the Western Australian Permian and so specimens from them are included in this study.



In the Irwin River District the succession for the northern part, in descending order, is as follows (from Clarke, Prendergast, Teichert and Fairbridge, 1951) :—

7. *Wagina Sandstone* .. .. 300 feet plus
   The topmost formation with rare plant remains.
6. *Carynginia Shale* .. .. 800 feet
   Jarositic shale and sandy silt, with few marine fossils.
5. *Irwin River Coal Measures* .. .. .. 160 feet
   Sandstone with coal seams and abundant plant remains.
4. *High Cliff Sandstone* .. .. 110 feet
   Few marine fossils.
3. *Fossil Cliff Formation* .. .. 180 feet
   Sandy silt, shale and mudstone, with lenticles of limestone at the base. Rich in marine fossils..
2. *Holmwood Shale* .. .. 1,650 feet
   Shale with fossiliferous limestone and calcareous mudstone near the top.
1. *Nangetty Glacial Formation* .. .. .. 800 feet (estimated)
   Glacial sediments, unfossiliferous so far as is known. Total thickness is at least 4,000 feet.

All specimens from the Irwin River District used in this study were collected from the Fossil Cliff Formation.

In the Carnarvon Basin the succession on the Minilya River, from near which many of the specimens from this area were collected, is as follows (after Condon, 1954; Teichert, 1947, 1950) :

14. *Mungadan Sandstone* .. .. 145 feet
    Coarse-grained, cross-bedded sandstone with few fossils.
13. *Coolkilya Greywacke* .. .. 625 feet
    Strongly ferruginous in places, with numerous fossil horizons.

The above sedimentary divisions, together with the Binthalya Subgroup (found only to the south, in the Kennedy Range) constitute the Kennedy Group of Condon (1954).

12. *Baker Formation* .. .. 150 feet
    Sandstone with sparse fauna.
11. *Norton Greywacke* .. .. 180 feet
    Quartz-greywacke with fossil horizons with restricted fauna.

The above two formations, according to Condon (1954), are approximate stratigraphical equivalents of the Nalbia and part of the overlying Coolkilya Sandstone, respectively, of Teichert (1950).

10. *Wandagee Formation* .. .. 425 feet
Essentially fine to medium-grained sandstone or greywacke, grey in colour, with siltstones; very highly fossiliferous, particularly in the lower part.

9. *Quinnanie Shale* .. .. 515 feet
Gypsiferous shale prominent, with minor development of sandstone and limestone, in parts fossiliferous.

8. *Cundlego Formation* .. .. 1,090 feet
Fine-grained shaly to coarse-grained sandstone, commonly cross-bedded with siltstone intercalations, and with fossils in some layers only.

7. *Bulgadoo Shale* .. .. 1,000 feet
Grey to black carbonaceous shale and siltstone, in places gypseous, and with few sandstone bands. Fossils sparse.

6. *Mallens Greywacke* .. .. 400 feet approx.
Largely quartzgreywacke, fossils very sparse.

5. *Coyrie Formation* .. .. 850 feet
Siltstone and quartzgreywacke with sparse, occasionally dwarfed, but varied fauna in some beds.

The above divisions, Coyrie Formation to Baker Formation inclusive, constitute the Byro Group of Condon (1954).

4. *Wooramel Sandstone* .. .. 250 feet
Medium-grained white sandstone with few fossils.

3. *Cordalia Greywacke* .. .. 170? feet
Fossils very sparse.

2. *Callytharra Formation* .. .. .. 540 feet
Quartzgreywacke, siltstone and limestone bands. Richly fossiliferous.

1. *Lyons Group* .. .. 4,600 feet
Glacial conglomerates and finer-grained glacial sediments; upper part shaly with fossiliferous calcareous bands.

The maximum thickness in the basin is over 12,000 feet. The formations vary in thickness from place to place; the Cordalia Greywacke, for example, lenses out completely to the south. The formation names (as also the rock-term "greywacke") are used according to the terminology of Condon (1954). The Callytharra Formation, Wandagee Formation, and Coolkilya Greywacke are the three most fossiliferous formations, and yielded most of the specimens from this basin.

In the West Kimberley District the succession is (after Guppy *et al.*, 1957; Teichert, 1947):

4. *Liveringa Formation* .. .. 1,850-3,000 feet
   Sandstone and greywacke with clays and grits, mostly ferruginized, with rich marine faunas in the lowest and highest members.
3. *Noonkanbah Formation* .. .. .. 1,400-2,200 feet
   Shale, siltstone, occasional limestone, some sandstone and greywacke, with rich marine fauna.
2. *Poole Sandstone* .. .. up to 1,300 feet
   Sandstone with grit and conglomerate, mostly ferruginized, with rich flora, and including at the base the *Nura Nura* Member, approximately 20 feet thick, with marine fauna.
1. *Grant Sandstone* .. .. up to 3,500 feet (exposed)
   Sandstone, grit, conglomerate, tillite, with fossil wood.

Most of the specimens collected from this area came from the three most fossiliferous divisions, the Nura Nura Member, the Noonkanbah Formation, and the Liveringa Formation.

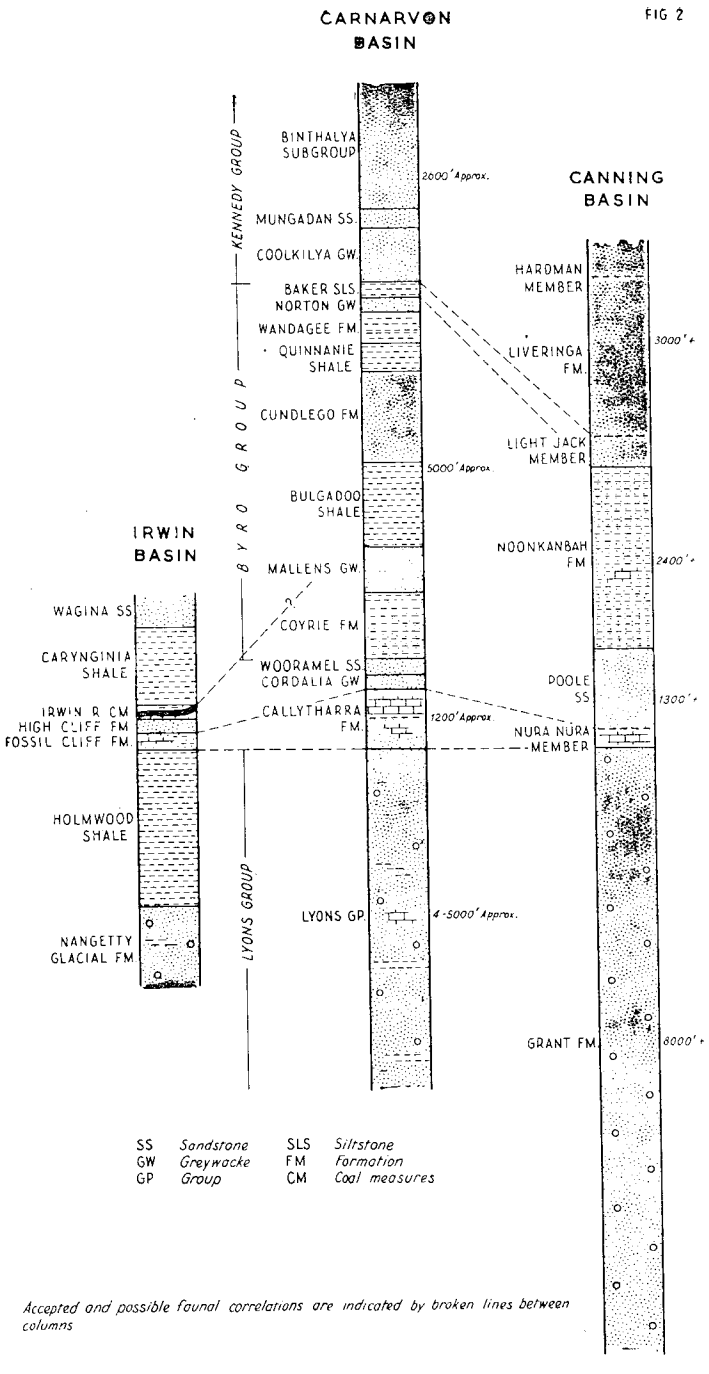
The Permian rocks of the East Kimberleys (Ord-Victoria Region) have been mapped by Traves (1955) in the following divisions:—

2. *Port Keats Group.*
   Fresh-water and marine shales and sandstone with thin limestone beds and narrow bands of coal. More than 1,500 feet thick at Port Keats.
1. *Weaber Group.*
   (Now thought to be mainly Carboniferous.) Marine sandstone and limestone.

Teichert (1947) discusses the regional and inter-regional correlation of the Western Australian Permian and concludes that the main glacial sediments are of Sakmarian age, and that the bulk of the sediments above the glacials are Artinskian, sedimentation ceasing shortly after the Artinskian. He further concludes that to accumulate the great thickness of sediments (6,000 to 7,000 feet for some areas in the Artinskian alone) sedimentation must have been rapid in some areas. These conclusions apply more truly to the Carnarvon Basin. Thomas and Dickins (1954) correlate the base of the Liveringa Formation with the basal Kungurian and suggest that this sequence (which may contain a disconformity) ranges up into the Kazanian, possibly into the Tartarian. (See also Guppy et al., 1957).

The original sedimentary environments of the Permian basins are fairly well established. Teichert (1947, pp. 133-134) describes the important sedimentary characteristics of the basin sequences and notes their resemblance to the "paralic basins" of Tercier (1939); these correspond to the "paraliageosynclines" of Kay (1951). The details of these environments, however, are still mostly unknown.

FIG 2



Accepted and possible faunal correlations are indicated by broken lines between columns

CORRELATION OF PERMIAN SUCCESSION IN W.A.

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The major faunal correlation of the various sequences in the three major areas is between the Fossil Cliff Formation, the Callytharra Formation, and the Nura Nura Member. The Wandagee Formation can almost certainly be correlated with at least part of the Noonkanbah Formation, and the Coolkilya Greywacke with the lower part of the Liveringa Formation. Evidence for such correlations is described by Teichert (1941), and Thomas and Dickins (1954). The succession in each area with the generally accepted correlation between sequences is shown in Fig. 2.

MORPHOLOGY.

A special morphological terminology of the Productacea has been developed, as it has in other groups. It may easily happen that the non-specialist will find it difficult to comprehend a detailed specific description. For this reason a brief account is given of the morphology and the terminology used here. For those totally unacquainted with these brachiopods detailed discussion of their morphology is available in Kozlowski (1914), Muir-Wood (1928), Licharew (1936), and to a lesser extent, in Dunbar and Condra (1932), and Sarycheva (1949, in Russian). The very specialized morphology of such aberrant groups as the Oldhaminidae Schuchert and Richthofenidae Waagen is not discussed here.

Outline of Morphology.

The following account of the basic morphology of productid shells should be studied together with Figure 4. The number and letter in parentheses which follow mention of each feature refer to the numbered illustration of that feature in the figure.

Shape and size: The pedicle (ventral) valve is convex and the brachial (dorsal) valve plane or concave (see Fig. 3). In some shells the brachial valve may have an initial slight convexity and then become plane or concave. Transversely the pedicle valve may be evenly convex; if not, it has steep flanks and a centre either flattened or indented by a *median sinus* (1 B) which runs from near the umbo, through the middle part, sometimes to the front or *anterior margin* (2 A). The *lateral margins* (3 A) are the side edges of the shell. The margins are often *upturned* (4 A).

Geniculation (5 F) is an abrupt increase in curvature of either valve. As a result of geniculation of one or both valves the anterior and lateral margins may lie close together and parallel, forming a *trail* (see Fig. 3). A reversal of curvature at the margin results in a *flange* (6 F).

The posterior part of the pedicle valve consists of the *umbonal region* (7 B) which leads to the *umbo* (8 A). This may be incurved over the *hinge-line* (9 A), erect, or reclined below the plane of the brachial valve. The *umbonal ridges* (10 A) run from the umbo to the hinge and the angle between them is the *umbonal angle*. A scar at the tip of the umbo, known as the *cicatrix of attachment* (11 A), indicates that the shell was for some part of its life attached to another object. The hinge-line is straight or V-shaped, with the

apex of the V pointing to the rear and its limbs straight or slightly curved. The ends of the hinge-line are the *cardinal* or *alar extremities* (12 A); in some shells they extend beyond the body as *ears* (13 B).

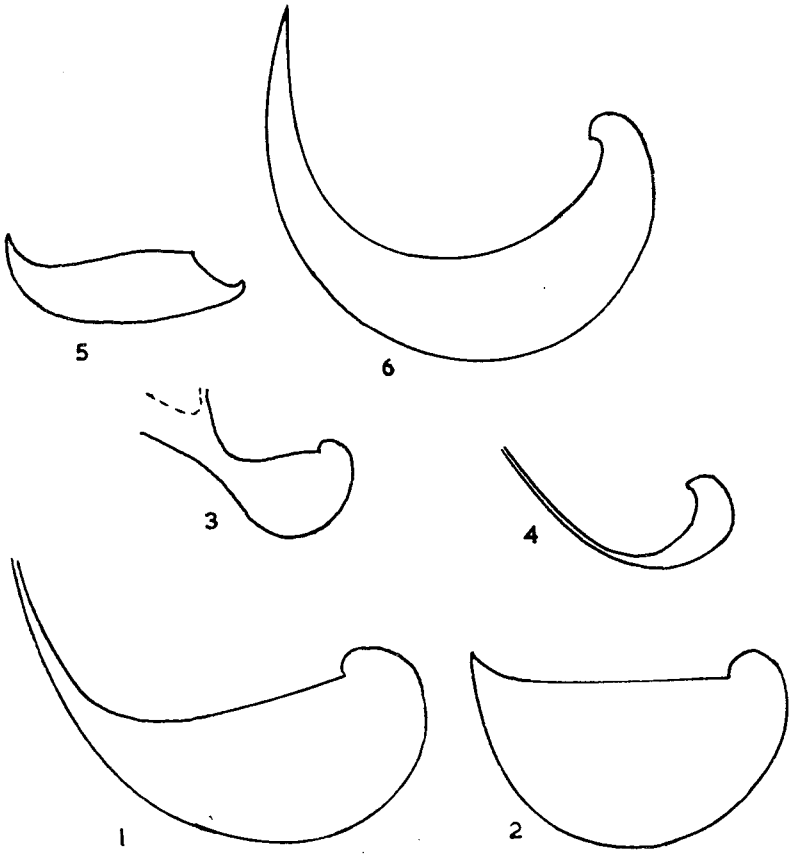


Fig. 3.—Variation in median longitudinal profile exhibited by shells of Productidae (figs. 2–4, 6 from Chao 1927, after Fredericks, 1915). Figs. 3, 4—visceral cavity of Fredericks' type *Producti proboscidii*; 2, 5—type *P. typici A.*; 6—type *P. typici B.*; 1—*P. typici A.* with trail, gradational to *P. proboscidii*. Figs. 1—*Taeniothaerus*, 2—*Pustula*, 3—*Proboscidella*, 4—*Linoproductus*, 5—*Aulosteges*, 6—*Krotovia*.

A *cardinal area* (14 A, E) may be present on the pedicle valve, between the hinge-line and the umbonal ridges; it is therefore triangular, though it may be distorted, and is split medially by a delthyrium closed by a deltidial plate, usually termed a *pseudodeltidium* (15 A) in productid morphology. The area is planar or slightly concave, and may show vertical and horizontal striations which are the marks of successive growth stages. In some shells there may be a corresponding area on the brachial valve, also with a closing plate or *pseudochilidium*.

The *visceral disc* (16 A) is the portion of each valve that covers the visceral chamber or cavity. The size of shells seen ranges from 10 to 180 mm. in

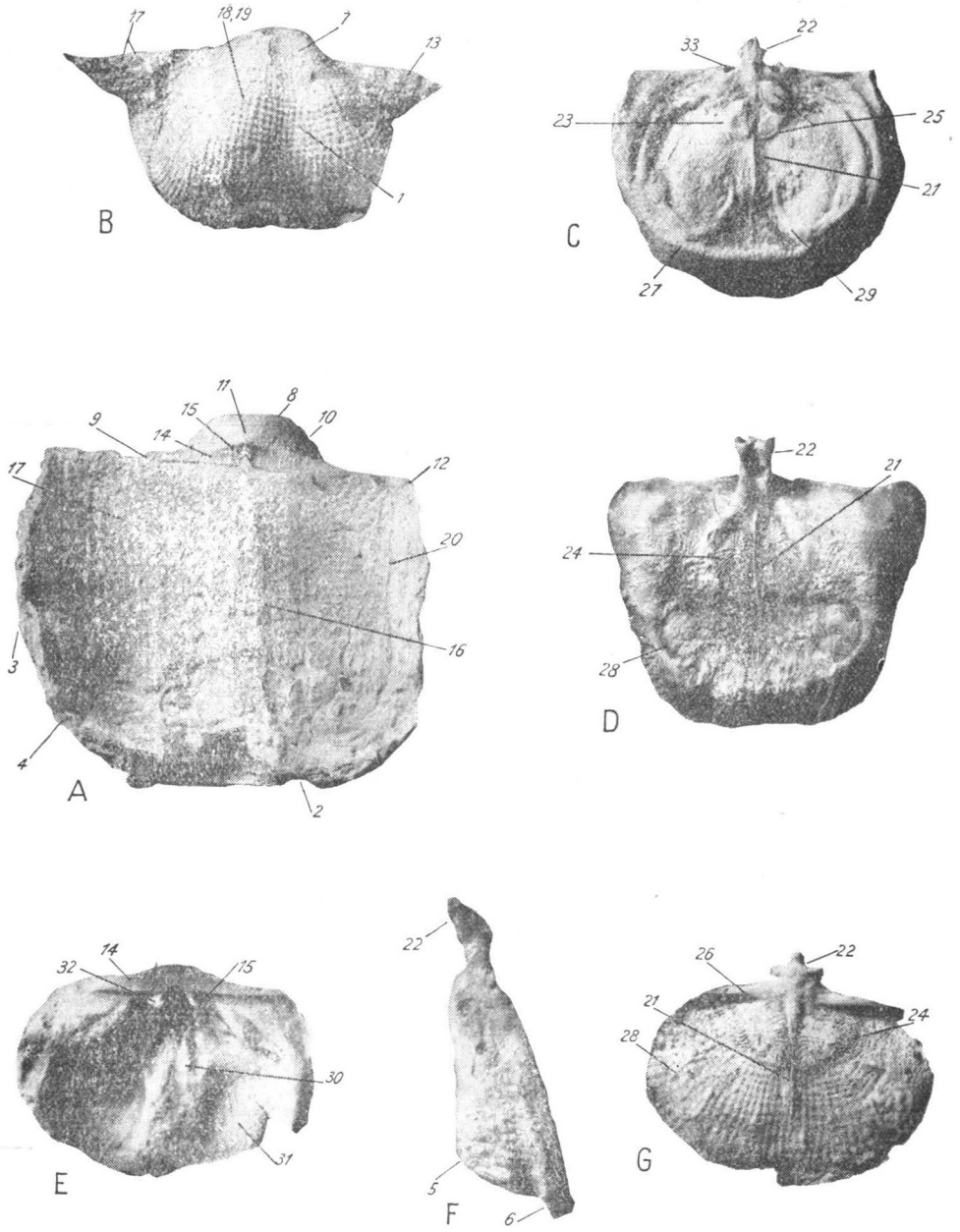
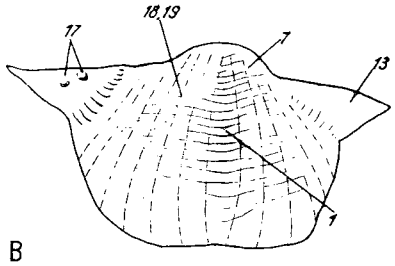


Fig. 4.—Important morphological features of productid shell. The features are numbered corresponding to the order in which they are described in the text. A—dorsal aspect of *Taeniothaerus* sp.; B—ventral aspect of *Dictyoclostus* sp.; C—internal view of brachial valve of *Strophalosia* sp.; D—internal view of brachial valve of *Taeniothaerus* sp.; E—internal view of pedicle valve of *Strophalosia* sp.; F—side view of brachial valve of *Taeniothaerus* sp.; G—internal view of brachial valve of *Dictyoclostus* sp.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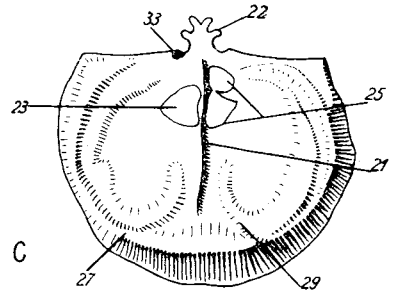
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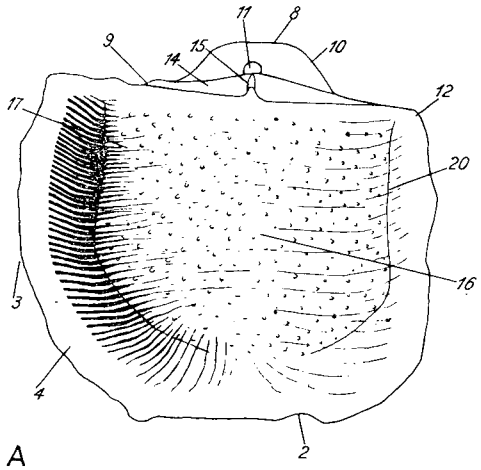
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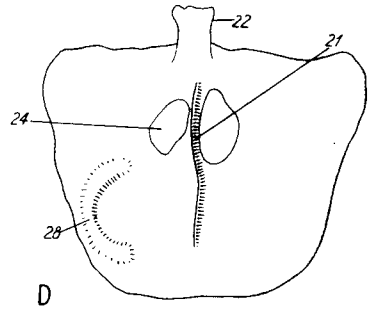
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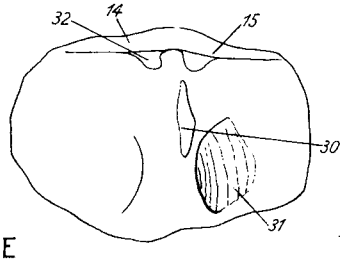
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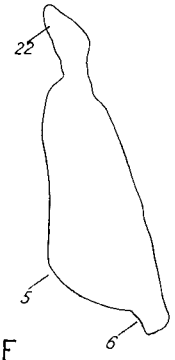
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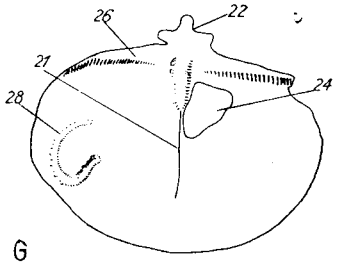
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G

greatest dimension of either length or width; a shell is small if the dimensions are less than 30 mm., medium if between 30 and 50 mm., and large if more than 50 mm.

Ornamentation: Ornamentation consists mainly of *spines* (see Plate 10, fig. 1), usually represented by *spine bases* (17 A, B). There may also be ridges radiating from the umbo named *costae* (18 B); ridges concentric around the umbo named *rugae* (19 B); and *concentric bands* (see Plate 10, fig. 14). Less obvious features are *growth lamellae* or *growth wrinkles* (20 A), which are fine concentric lines, the result of still-stages in growth, and are distinct from rugae which are actual folds in the shell substance; and *radial striae* which are fine grooves much less prominent than costae.

Internal features: Inside the brachial valve, the visceral disc is usually flat or undulating; it is divided by a *median septum* (21 C, D, G) arising at or near the base of the *cardinal process* (22 C, D, F, G). The cardinal process projects posteriorly from the centre of the hinge. It is smooth but grooved on the ventral side, and striated on the dorsal side; according to the number of grooves it may be bilobed, trilobed, or (rarely) quadrilobed.

The *adductor muscle impressions* lie one on each side of the median septum. They are generally oval, and their surface is smooth (23 C) or incised with a dendritic or tasselated pattern (24 D, G). They may be raised above, or, more rarely, depressed below, the visceral disc. In some genera, mostly those with smooth impressions, each impression is divided transversely into two parts (25 C).

Cardinal ridges (26 G) may border the hinge-line, or run at a small angle to it. They generally only reach the edge of the visceral disc, but in some shells continue around the disc until they meet, forming a *marginal ridge* (27 C).

The *brachial impressions* or *brachial ridges* are of two types. The *productinid type* (28 D, G) are hook-shaped and arise at the front or anterior end of the adductor muscle impressions; the *strophalosiinid* type (29 C) are longer, semi-circular in shape, and arise at the lateral or posterior edges of the muscle impressions. Inside the brachial impressions the surface is smooth or faintly pitted. Parts of the remainder of the surface may be deeply pitted—the internal expression of the spines—or reflect the external ornamentation (G). The anterior edge of the disc may be lined with rows of papillae or with a marginal ridge (C, D) bearing forward-pointing spiny pustules (particularly in geniculate valves), or with a shelly diaphragm that closes off the space between the two valves.

Inside the pedicle valve, the *adductor impressions* (30 E) lie at the rear of the valve. They are similar in appearance to those of the brachial valve, but are comparatively longer. The *diductor muscle impressions* (31 E) are larger than the adductor impressions, and are striated; they lie outside the area occupied by the adductors. In life, the diductors were attached to the striated part of the cardinal process, and, by contraction, opened the shell. Some genera possess *teeth* (32 E) which fit into *sockets* (33 C) in the hinge of the brachial valve. The rest of the valve is smooth, or pitted, or papillate.

ORIENTATION AND DIMENSIONAL TERMINOLOGY.

The orientation of the productid shell generally used for morphological discussion and description is similar to that suggested for the brachiopod shell by Thomson (1927, p. 5). The productid is considered as resting on the pedicle valve with the brachial valve uppermost, the plane of the brachial valve approximately horizontal and the posterior part of the shell (the umbo) away from the observer. This orientation is not applicable to shells with concave brachial valves. In this study such shells are placed so that a tangent to the curve of the brachial valve, at a point where the visceral cavity is deepest, is horizontal, again with the umbo furthest away.

Productid shells vary so much in shape that it is necessary to describe the way in which measurements of length, width, depth and other dimensions are obtained. In this Bulletin, these dimensions refer, except where otherwise stated, to the main body of the shell including the shell thickness but not including the trail. With the shell oriented as given above, the length is the measurement of the line joining the extreme posterior and anterior points. The *width,* or *breadth,* is measured at right angles to this line, between the extreme lateral edges. This may correspond with the hinge-line, but if it does not, the measurement of the hinge-line, or *length of hinge,* is also given. The *depth* or *height* is the greatest distance between the valves. The *curvilinear length* is the measurement of the median line around the external surface of the pedicle valve from the tip of the umbo to the anterior edge of the visceral cavity. The dimensions of the trail are given separately. These terms agree fairly well with those used generally.

SPECIAL MORPHOLOGICAL CONSIDERATIONS AND SOME BIONOMIC INTERPRETATIONS.

Under this heading certain morphological features are discussed, not so much for the sake of presenting complete descriptions of these features, as to emphasize certain points about which there still seems some confusion. They are particularly well shown in some of the local material which is very well preserved. Most of these features also have considerable biological and ecological significance.

The Trail: This term is used to describe the anterior portion of some shells, when both valves lie close together and parallel with only the mantle between them. A trail may result from the geniculation of either the brachial valve or the pedicle valve, or both. It may be closely simulated when the brachial valve is very concave, the visceral cavity thin, and both valves gradually become closer over the anterior portion of the shell (see fig. 3).

In *Productus,* as re-defined by Muir-Wood (1930), the trail is cut off from the visceral chamber by a thin shelly partition or diaphragm, developed about the margins, antero-lateral and anterior, of the visceral disc. In *Marginifera,* many species have a similar structure, a raised, callus-like ridge usually strongly developed. Again, in *Taeniothaerus, Marginirugus, Strophalosia,* and other genera the geniculated region of the brachial valve is thickened, which may result in a raised ridge, the edge transversely incised and usually less

pronounced than in *Marginifera*. These marginal structures are fairly widespread in the Productacea, as Licharew (1936, p. 91) and Huang (1932, p. 9) have pointed out.

In conjunction with the trail, the marginal ridge, whether highly developed or not, probably served as a filter. Thus, in *Taeniothaerus* the marginal ridge and, in front of it, that part of the brachial valve that forms the trail, are covered with anterior-pointing spiny pustules. These pustules have an approximately quincuncial pattern, that is, they are arranged in lines so that the gap between any two pustules is covered by a pustule in front and one behind. Each pustule fits into a corresponding depression in the opposing surface. When the valves were only slightly ajar the arrangement would be very efficient as a filter for large sedimentary particles, or as a protective device against predators. As well as the genera mentioned above, *Juresania, Dictyoclostus,* and others are similarly protected.

Ornamentation on the trail does not differ markedly as a rule from that over the main body of the shell. Growth lines are usually more crowded together, spines smaller and more closely packed, costae less pronounced; such effects are the normal reflection of maturity and old age. But in some genera whose patterns of ornamentation changes progressively with age, the trail may be ornamented quite differently from the rest of the shell.

It is commonly said that the trail is a development of old age, forming only when the visceral cavity has reached its maximum size. This is probably true for some species but not for all. By the addition of internal layers of shell material along the geniculated region and the trail, the visceral cavity

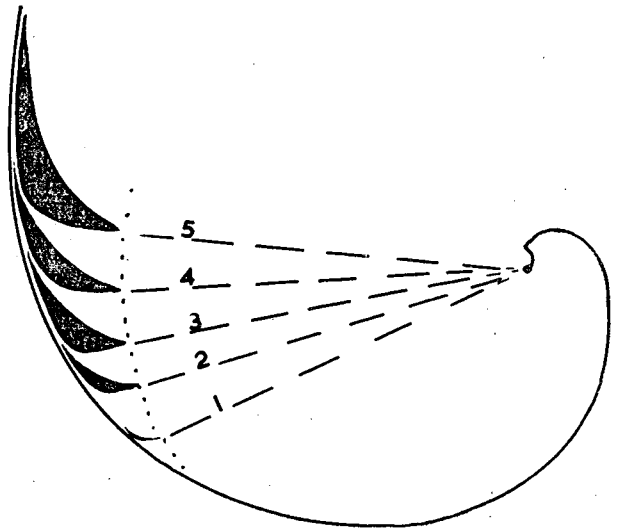

Fig. 5.—Enlargement of visceral cavity with formation of trail. Median longitudinal profile of a trailed shell, showing successive growth stages following on, or near upon, early maturity (1-5). By internal thickening of the geniculated region both trail and visceral cavity can be enlarged. Dotted line circumferential to hinge indicates maximum length of visceral disc of brachial valve once margins begin to upturn.

can become larger as the trail grows (Fig. 5). This can be seen in most of the Western Australian forms with trails, as for example, *Taeniothaerus teicherti,* and *Strophalosia kimberleyensis.* The trail may be still further developed, of course, after the visceral cavity has ceased to become larger.

Although the size of the trail does not seem to be of great taxonomic value, its presence and individual characteristics, species to species, are valuable in the discrimination of genera, and even of species.

Shell Structure: Dunbar and Condra (1932, pp. 177-183) have described productid shell-structure in detail. They emphasize the lamellose structure of the shell, the anterior-pointing roots of the spines, which do not communicate with the interior, and the fibrous structure of the spines and internal spiny pustules which give a pseudo-costate appearance to partially decorticated shells. The fibrous internal pustules (or pseudopunctae), like the spine roots, point anteriorly (Fig. 6).

Polished surfaces and thin sections of the Western Australian material confirm the main points of Dunbar and Condra's description (see Plate 21). In addition, however, the thin sections do not show the outer prismatic layer which is usual for brachiopods, although Muir-Wood (1928, p. 29) records it for British productid specimens.

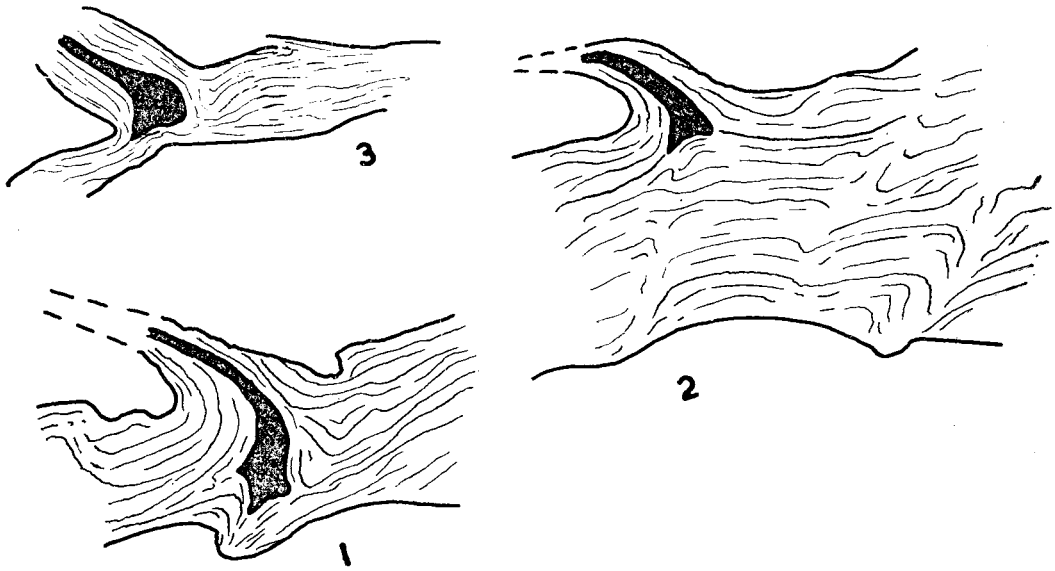

Fig. 6.—Camera-lucida drawings of thin sections of shell of (1) *Linoproductus cancriniformis* (Tschernyschew), (2) *Taeniothaerus teicherti* n. sp., (3) *Strophalosia prideri* n. sp. Magnified ten times. Roots of spines (black) incline anteriorly. Internal spikey pustules are reflected within the shell wall by successive dimplings of the principal lines of laminae (1 and 2); prolongations of pustules also incline anteriorly.

Cicatrix of attachment: A cicatrix of attachment is present on nearly all well-preserved specimens of the Strophalosiinae. Some productinids also, notably *Aulosteges, Taeniothaerus,* and *Juresania,* commonly have this feature. Usually the cicatrix is small in comparison with the size of the shell, and as the specimens as preserved are found free, this indicates that the shell was attached

only during early life, unless, as Prendergast mentions (1934, p. 39), the mantle assisted in attachment during life, the shell falling after death; but this does not seem at all likely.

The position of the cicatrix varies even within a single species. Usually it lies immediately behind the apex of the umbo. It may be deeply impressed, as in most *Strophalosia*-species, or be present only as a faint scar, as in the productinid genera *Taeniothaerus, Aulosteges* and *Juresania*. Its presence is nearly always accompanied by some distortion of the shell. This distortion is most commonly pronounced over the initial, or initial and middle, growth stages, the shell later becoming symmetrical. The distortion is not regular, even in the one species. An indication of the period of attachment is given by the size of the scar in comparison with the size of the shell, and also by the amount of distortion. In one of the local species, *Strophalosia prendergastae* sp. nov., the cicatrix is almost the same size in every specimen, but this is the only evidence suggesting that the period of attachment was constant for any one species. It probably varied from individual to individual.

The range of objects which served as the place of attachment has never been completely determined. Crinoid stems certainly acted as hosts; occasional specimens of *Strophalosia* (*Heteralosia*) *etheridgei* Prendergast, a local species, show the indentations of the stem segments on the cicatrix of attachment. Trechmann (1921) described the attachment of *Strophalosia lamellosa* Geinitz to *Horridonia horridus* (Sowerby). The local faunas have shown no evidence of the nature of the host for the young individuals of *Aulosteges*- and *Taeniothaerus*-species. Living in communities as they did, another adult shell probably served as the place of attachment.

Adductor musculature: There are two main types of adductor muscle impressions in the Productidae. Most Productinae show dendritic muscle scars; only *Marginifera, Avonia,* and *Krotovia,* the species of which are mostly small, have non-dendritic scars.

Prendergast (1943, p. 5) in discussing the dendritic impressions in *Productus* s.l. and *Aulosteges*, says they are "a reflection of the poorly developed articular apparatus in these two genera. Since the brachial valve is pivoted loosely on the cardinal process it is capable of movement not only in a plane perpendicular to the surface of the valve but also from side to side. This lateral skewing movement would cause a differential movement within the muscle itself, the fibres nearer the centre being less extended than the excentric fibres. A divided muscle would, therefore, be mechanically superior. In examining a dendritic muscle it will be noted that the bunches of fibres have an approximately radial arrangement with the radii on the inside much shorter than those towards the lateral margin. As the central muscles have a shorter pull this arrangement is what would be expected."

If one accepts this explanation one would expect to find the greatest development of the dendritic muscle impression in those species in which the margins are very little upturned, since the upturned margin is itself an aid to articulation and prevention of the skewing movement mentioned. But in the Western Australian forms it is those with sharply upturned margins that have large and deeply incised muscle patterns. Again, those genera of the

Productinae with non-dendritic impressions also have the same poorly developed articular apparatus. Perhaps the division into anterior and posterior parts in many species of these genera (and in the Strophalosiinae) may have served the same function as did the divided muscle described by Prendergast. These points, however, do not greatly affect the plausibility of Prendergast's explanation.

If the adductor muscles in the genera with dendritic impressions had, as part of their function, the prevention of swivelling of the brachial valve, the diductor muscles may also have assisted in this function. Each diductor muscle in specimens of these genera extends far up the flanks of the pedicle valve, so far that it is difficult to imagine any direct downward pull being exerted on the cardinal process by the extreme lateral portions of these muscles. Contraction of this part of each muscle would, however, ensure that the valves did not swivel during opening and closing.

The impressions of the Strophalosiinae are non-dendritic; in most genera they are divided into anterior and posterior pairs, are mostly raised, but may be depressed. In some specimens of *Strophalosia kimberleyensis* Prendergast the muscle impressions were button-like and were easily displaced from the valve, leaving behind a depression. Specimens of this species show, therefore, both raised and "depressed" impressions; and depressed impressions in other species may be due to the same phenomenon. In one species the impressions may be close to the hinge just below the base of the cardinal process; in another they may be nearer the centre of the visceral disc. Such variation seems linked with variation in the shape of the brachial impressions (see Maxwell, 1954).

In the Western Australian productinid specimens the muscle impressions of individuals within a species, and of species within genera, vary considerably in detail. No significant trends in this variation could be detected, so that as a taxonomic feature at the specific level the muscle impressions were of no value in the treatment of the Productinae. In the Strophalosiinae, on the other hand, the variation in position of the adductor muscle impressions has been used by some authors as a diagnostic specific feature (see Maxwell, 1954).

Cardinal process: The cardinal process is one of the characteristic and variable features of the Productidae. In common with other internal features it had been too much neglected as a taxonomic feature, until Sutton and Summerson (1943) described and figured the processes of many genera. This work showed clearly that the cardinal process was of great value as a generic discriminant.

In its simplest form the cardinal process may be no more than a button-like structure with only a suggestion of lobation. At its most complex, it may be the most conspicuous of the internal features, of large size, and so grooved as to result in three or four distinct lobes of distinctive shape. The processes of the genera in the series *Marginifera-Krotovia-Linoproductus-Dictyoclostus-Taeniothaerus* illustrate this increase in complexity of structure (see Sutton and Summerson, 1943; and illustrations in this Bulletin—pl. 9, figs. 4, 21; pl. 8, fig. 6; pl. 6, figs. 3, 12; pl. 12, fig. 1; pl. 16, fig. 5).

The Western Australian specimens do not add very much to morphological knowledge of this structure, but they do confirm its taxonomic importance. Although I have not been able to use it in separating species within any one genus (many species vary in detail from specimen to specimen, as is shown in the illustrations of *Taeniothaerus treicherti* sp. nov.), nevertheless, the overall plan of the structure is remarkably constant for the species of the one genus. Many genera can be recognized by the cardinal process alone.

Living Position: The accepted notion is that the productid shell rested on the pedicle valve, the spines acting as supports. A few authors, notably Muir-Wood (1928, p. 28), discuss the likelihood of the shell's being oriented with the pedicle valve uppermost, the margins or trail projecting into the substratum. Muir-Wood mentioned that many specimens of *Dictyoclostus,* apparently preserved in the living position, had the pedicle valve uppermost, although the angle of orientation varied. It is always difficult to judge with certainty whether or not a specimen is preserved in its original living position. Apart from that it is hard to reconcile the peculiar morphology of the productid shell with the idea that the animal lived with the margin buried in sediment. Most productid shells were completely unattached, in contrast to other brachiopods, such as terebratulids, attached throughout life, in which the living position was with pedicle valve up.

I think it likely that the more prevalent idea is essentially correct, and that in life the shell was oriented with the pedicle valve down, the spines acting less as supports than as sinuous roots to bind the shell to the surrounding sediment. The shell was probably almost completely buried, with even much of the concave brachial valve filled with mud and only the margins and umbo projecting. The overall appearance would be reminiscent of the lair of a trapdoor spider. In this living position large spines would have an anchoring or grapnel-like function, preventing tilting or overturning, and would also, with their number and sinuousness, tend to accumulate drifting sediment and bind it in the manner of shrub roots in sand. This binding action is well shown by the way in which many specimens are found with "horns", projecting backward, made up of the spines and sediment tightly bound up with them. The mass of fine spines which also occur on many productids would have a similar action, complementing that of the larger spines. The brachial valve, usually concave in mature specimens, would become at least partly filled in with sediment, the spines again assisting in retaining it. The umbo is imagined as projecting above the sediment.

In such a position, sediment would tend to accumulate around the animal; the margins would have to be raised; and this would result in the familiar upturning of the margins and the formation of a trail, because the animal could then maintain an intake of water free from contaminating sediment. With the brachial valve at least partly filled, and the sediment falling away from the raised margins, the only obvious sign of the animal would be the slight gape between the valves. The most suitable sort of sediment for such

a living habit would be a silt or fine sand—of the sort in which, as will be shown later, the great majority of Western Australian specimens are found preserved.

The extra effort imposed on the adductor apparatus by the sediment resting in the brachial valve would also help to explain the very large diductor muscle scars and cardinal process characteristic of species with greatly upturned margins. The diductor apparatus of such species is of a size seemingly out of proportion to the actual gain in shell weight resulting from the formation of upturned margins and trail. Again, the frequent presence of marks of injury on the pedicle valve, distortion of sinus, and the like, would be explained by the continual contact of the pedicle valve with the substratum. Pebbles or similar obstructions would be met with by the growing valve. The usual absence of such marks on the brachial valve would also follow.

Shells in the young stages of growth could not be so well camouflaged as mature individuals, since the margins would then be covered in sediment. The brachial valve in immature specimens is most often slightly convex, as indicated by the initial swelling of this valve in mature specimens. The valve would gather less sediment. The large anchoring spines at the rear of a shell exist from the first and might have held it in a semi-erect position, ensuring a pure water supply. As the animal grew the shell would tend to droop forward and downward into the sediment; the margins would begin to curve upward and sediment would accumulate in the brachial valve.

This concept of the living position results from the study of the Western Australian material, and is proposed essentially for the forms with ornamentation almost exclusively spinose and with upturned margins, which lived in a free, unattached condition after the earliest growth stages. The spinose ornamentation of these species was of the particular pattern which lent itself to firm purchase in the kind of sediment in which the animals thrived best. Cooper (1937) mentions this as a possibility.

Not all the productids lived in this position—Cooper (1942) described silicified specimens from Permian Texan limestone, beautifully preserved, belonging to the genus *Avonia*, in which the spines are so arranged as to keep the brachial valve lifted up from the substratum should the shell be overturned. Such a cage-like arrangement would only work properly on a firm substratum, but would not be at all well adapted to the fine sediment in which nearly all the Western Australian forms are found.

The above discussion suggests that the ornamentation fulfilled an essential function, dependent on the living position and the kind of substratum. The different patterns of ornamentation characteristic of productid genera may be explained, therefore, as being direct reflections of different living positions and different sedimentary environments, respectively, on the part of each of the genera concerned.

Examples taken from productid ornamentation may be extended to other brachiopods. Thus the dictyoclostid-type, with costae, is reminiscent of the

ornamentation of *Spirifer*. Some species of *Dictyoclostus*, like spirifers, have a comparatively small number of large heavy costae, and others have more numerous fine costae. The reticulate arrangement of rugae and costae has its counterpart in costate spirifers with prominent growth wrinkles which almost form fine concentric frills. Similar parallels between various groups can be made over a wide range of brachiopods.

TAXONOMY OF THE PRODUCTACEA.

Major Classification.

The history up to 1940 of the supra-generic classification of *Productus* and similar genera, including *Chonetes*, was described by Prendergast (1943, pp. 9-12). She concluded by assigning these genera to the well-known family Productidae, including within it the subfamilies Productinae, Strophalosiinae and Chonetinae. In 1941, however, Maillieux proposed that *Productus*-like shells (and others such as *Leptodus* and *Richthofenia*) should be regarded as a superfamily, the Productacea. The ready acceptance of this superfamily seems due, at least indirectly, to Cooper (1944). He advocated the abolition of the old brachiopod orders, Protremata and Telotremata, and their replacement by groups the diagnoses of which were largely based on the microstructure of the shell, whether punctate, pseudo-punctate or impunctate. This new sort of emphasis was rapidly adopted with a corresponding increase in the erection of new orders and superfamilies. As examples pertinent here, in the text-book of Moore, Lalicker, and Fischer (1952) strophemenoid brachiopods are given the status of an order, the Strophemenida, which includes the superfamilies Strophomenacea and Productacea. Another text, by Shrock and Twenhofel (1953), also accepts the Productacea, but chonetoid shells are discussed as the superfamily Chonetacea. In the past *Chonetes* and similar genera were regarded as a subfamily of the Productidae by some authors (e.g. Schuchert, 1913; Chao, 1928; Paeckelmann, 1931; and Huang, 1933) but as a separate family by others (e.g. Hall and Clarke, 1894; R. E. King, 1930; Dunbar and Condra, 1932; Grabau, 1934; Licharew, 1936; R. H. King, 1938).

Maxwell (1954) considered that the Productacea were made up of the families Productidae, Chonetidae, and Strophalosiidae. The last is given as "Family Strophalosiidae Stainbrook, 1947, emend." But Stainbrook had not altered the major classification at all; he was concerned mainly with altering the generic content of the already well-known major groupings, including the Strophalosiinae which he accepted as Schuchert's subfamily. Actually the author of the family Strophalosiidae is unknown (see Bryant, 1955). Maxwell then went on to divide the family Strophalosiidae into the subfamilies Productellinae and Strophalosiinae and emended the latter. This arrangement is not convincing. It is based on external features and, in the emendation of the Strophalosiinae, brings together *Strophalosia* and *Taeniothaerus*, which are two genera radically different internally and with no apparent phylogenetic connexion.

Stehli (1954) was the first since Maillieux to introduce entirely new categories into the major classification. He proposed two new families within the Productacea, the Dictyoclostidae and the Echinoconchidae. For the Dictyoclostidae he proposed three new subfamilies, the Dictyoclostinae, the Linoproductinae, and the Marginiferinae. Stehli does not give any evolutionary or phylogenetic evidence in support of his new categories.

Apart from the above, there does not seem to have been any other important attempt to classify within the Productacea, especially concerning shells similar to *Productus* and *Strophalosia*. At the present time, however, H.M. Muir-Wood and G. A. Cooper are reviewing the Productacea for the Treatise on Invertebrate Palaeontology. Because of this, and because the present work and my limited examination of extra-Australian material have not yielded evidence of sufficiently wide application, the classifications mentioned above are not examined in detail; for the same reasons no attempt is made either to introduce new divisions within the Productacea or to further the adoption of recently erected ones. The groups containing such exotic forms as *Leptodus, Richthofenia,* and other genera, are not discussed. Neither they nor the *Productella*-group have been found in the Western Australian Permian sediments.

Purely for convenience, therefore, the species of Productacea described herein are treated as belonging to two subfamilies, Productinae and Strophalosiinae, of the family Productidae. The diagnoses of these subfamilies are much the same as those given by Prendergast (1943, p. 12).

The Productinae include spinose Productacea with brachial impressions which usually arise at the anterior edge of the adductor muscle impressions, with adductor muscle impressions which are usually dendritic, with occasional cardinal area on the pedicle valve but without teeth.

The Strophalosiinae include spinose Productacea with teeth, with cardinal areas on both valves, with non-dendritic adductor muscle impressions, and brachial impressions which arise at the lateral edges of the adductor impressions.

Minor Classification.

Generic classification of the Productinae: The history of attempts at generic classification of the Productinae has been fully discussed by Thomas (1914), Dunbar and Condra (1932, pp. 184-187), and Licharew (1936, pp. 95-101). Of these, Licharew's discussion is the most critical; he draws attention to most of the weaknesses in the conception of many genera; in particular he attacks the erection of genera based on insufficiently described diagnostic characters, or on too small a number of them.

Because there has been no major contribution to the subject since 1936, and because of the almost complete coverage by the authors quoted, a further detailed history is not needed here. For the sake of continuity, however, a brief summary in general terms is given, including further developments since 1936. Before Thomas, species now included in the subfamily Productinae were contained in just a few genera, the most embracing being *Productus*. Within

this very embracing genus groups of like species were distinguished by referring them to a particular species considered typical, e.g., "group of *Productus longispinus*", "group of *P. semireticulatus*".

The productid shell is characterized by an enormous range of ornamentary modifications; and it is the ornamentation that has served as the principal feature in the discrimination of taxonomic units within both subfamilies Productinae and Strophalosiinae. Thomas (1914) did not depart from the emphasis on ornamentation, but he was the first to use ornamentation in a systematic way, thus giving the major impetus to a trend which has continued to the present day. Thomas emphasised both the basic type of ornamentation (whether wholly spinose, spinose and rugose, spinose and costate, or spinose, rugose and costate), and also the ontogenetic changes in basic ornamentation which are found in many productinid species. Thus his genus *Buxtonia* he defined as including those forms costate and spinose in youth and maturity, but spinose alone in old age.

His work paved the way for that of Chao (1927, 1928) and Muir-Wood (1928, 1930). Both these authors continued along the lines instituted by Thomas, but also drew attention to other features, Muir-Wood in particular placing more emphasis than had been usual on internal features. Her outstanding contribution was to re-study the types of old species, which resulted, most importantly, in her restriction of the name *Productus* to a small section of that all-embracing genus, and the erection of the new genus *Dictyoclostus* to cover the majority of the remaining species (Muir-Wood, 1930). Chao emphasised the importance of the shape of the visceral cavity as a diagnostic feature, and also the ontogenetic changes in ornamentation; nevertheless the five genera he erected are defined principally in terms of ornamentation. As a result of this special emphasis on ornamentation many genera and subgenera were erected between 1914 and 1932.

In the meantime Fredericks (1928, 1931) had advocated subdivision by features other than ornamentation. In particular he stressed the value of the shape of the visceral cavity as a diagnostic feature, and gave the well-known terms *Producti typici* A and B, and *Producti proboscidii* to the three most common types of visceral cavity (fig. 3). Later, however, he also came to use ornamentation as a primary diagnostic feature. Other workers accepted the diagnostic importance of the visceral cavity shape, but in less extreme fashion than Fredericks. Licharew (1936) pointed out that this neat classification of the visceral cavity shape was more apparent than real. Prendergast (1943) considered that in combination with other features the shape of the visceral cavity could be an important diagnostic feature.

Licharew (1936) emphasised the use of many features in combination, and the value of internal features. Most of his work, however, was devoted to criticism of already established genera and their phylogenetic arrangement, with the result that he refused to accept many of the genera erected by Chao, Muir-Wood, and Fredericks. His most radical point of departure lay in his

refusal to follow Muir-Wood in the restriction of the genus *Productus*. Forced by the weight of his own criticism he then proposed an alternative grouping of productid species into 25 groups, giving as representative of each a few species, many of them little known or confined to Russia. Most of the groups approximate to one or other of the established genera, some of them very closely indeed. It is unfortunate that he did not go further and make the groups more of a reality by including more well-known species within each. As it is, the grouping is incompletely expounded and difficult to comprehend. It cannot be regarded as much more than an expression of protest against the acceptance of some established genera and a suggestion upon which further work may be based.

Apart from ornamentation and the shape of the visceral cavity, variations in external form (possession of ears, median sinus, cardinal area, and variation in shape and size of these and other external features, exclusive of ornamentation) have been most used as diagnostic features. Outstanding examples of the use of such features are the genera *Proboscidella* Oehlert (pedicle valve produced anteriorly in a subcylindrical tube) and the rare *Kansuella* Chao, with narrow areas in both valves.

Internal features were little used for the most part in generic discrimination, because it was falsely supposed that the internal features of the productinid shell were so alike as hardly to merit attention (see Chao, 1927, p. 22). In 1943 Sutton and Summerson demonstrated the value of the cardinal process as a diagnostic feature. This work, together with that of Licharew (1936) and Prendergast (1943), has shown conclusively that internal features are just as suitable as ornamentation for generic discrimination and probably more reliable.

Generic classification in the Strophalosiinae: There are far fewer genera in the Strophalosiinae than in the Productinae. *Strophalosia* King, *Heteralosia* R. H. King (here regarded as a sub-genus), and *Etheridgina* Oehlert (= *Leptalosia* Dunbar and Condra) are widely recognised as genera within the subfamily. In addition, other genera or subgenera, considered to be related to *Strophalosia,* have been proposed—*Bilotina* Reed, *Wyndhamia* Booker, *Strophalosiina* Licharew, *Strophalosiella* Licharew and *Wyatkina* Fredericks. Of these *Wyndhamia* (Booker, 1929) is probably inseparable from *Strophalosia.* Its definition is obscure. *Strophalosiina* has as its genotype *Aulosteges tibeticus* Diener, and is therefore not a strophalosiinid at all (this confusion of *Aulosteges* and *Strophalosia* in many early Russian works is discussed in the systematic description of *Aulosteges*). *Wyatkina* Fredericks (1931, p. 210 footnote), with *Aulosteges gigas* Netschajew as holotype, is yet another group more properly referred to *Aulosteges,* as commonly understood, than to *Strophalosia. Strophalosiella* is incompletely defined and is of undecided affinities. Licharew described it as a *Strophalosia* with an ornamentation similar to that of *Linoproductus* Chao, but did not describe the internal features. *Branxtonia* Booker (1929) may also be a strophalosiinid, but its affinities

cannot be determined from the original description and illustrations. The material upon which it was founded was very poor. *Bilotina* Reed (1944) is a taxonomic puzzle. Some of these genera are discussed in greater detail in the description of the genus *Strophalosia* in the systematic descriptions.

Of the better known forms, *Heteralosia* was separated from *Strophalosia* because of the absence of spines on the brachial valve. Several Western Australian species show this character and they have been referred to *Heteralosia*. *Etheridgina* is distinguished from *Strophalosia* by its adnate condition. Strophalosiinids do not seem to have the patterns of ornamentation or the wide variation in ornamentary detail so characteristic of the Productinae. Up till now differences in degree of ornamentation have been little used as diagnostic features on a generic level.

Specific discrimination in the Productidae: For the most part the criteria used to separate and delineate species of productids are purely morphological, based on external features. If the hinge-line in a set of specimens is constantly longer than that of an otherwise similar described species then a new name might be given. If the ornamentation is consistently finer, or coarser, than that of a described species a new name might be given. The same applies to differences in depth of the median sinus, size and attitude of the umbo, or degree of curvature—longitudinal or transverse—of either valve. These are the sort of criteria which would be considered to be diagnostic at the species level. The species so delineated may be valid, but it must be admitted that many productid species are suspect. Apart from the limited criteria used many species are difficult to recognize because of poor illustrations; the founding of species on too few specimens, often badly preserved; neglect of the factor of variation; extreme national viewpoint; or neglect of the geographical and stratigraphical position of specimens.

MATERIAL AND METHODS.

The collection upon which this study was based consisted of more than 3,000 specimens, mainly drawn from three repositories: the Commonwealth Palaeontological Collection at the Bureau of Mineral Resources at Canberra, the Geology Department of the University of Western Australia, and the Australian Museum, Sydney. Those from the University of Western Australia form part of the Permian collections of the Geology Department, consisting of well over 10,000 specimens; most of them were brought together over the last seventeen years by various workers associated with the Department, in particular Dr. Curt Teichert, now of the United States Geological Survey, one of the foremost authorities on the Permian of Western Australia. The bulk of the collection was made up of specimens from the Bureau of Mineral Resources, which were collected over the last few years by various field parties of this organization, operating in the Carnarvon Basin and in the Kimberley area. Specimens from the Australian Museum were collected by various workers, in particular Dr. H. G. Raggatt, formerly Director of the Bureau of Mineral Resources, and Mr. H. O. Fletcher, Palaeontologist with the Australian Museum. Many of the

specimens from the Irwin River District were collected by myself or by accompanying students. A few specimens come from the collections of the Geological Survey of Western Australia.

The collection is therefore the result of many years' work by many people, some of them trained palaeontologists, operating over vast sparsely settled areas, in which the exigencies of field work, particularly the time-factor, often prevent thorough sampling and system in collecting. Nevertheless it is probably fairly representative of the Western Australian Permian Productacea, though there are certainly still some gaps to be filled, and better material to be found to replace present poor material. Thus recent expeditions of the Bureau of Mineral Resources and the Australian Museum have returned with new specimens which have made possible better definitions of several already described species, and confirmed the presence of a previously suspected new species. Nearly one-half of the total number of specimens studied come from the Carnarvon Basin, about one-quarter from the Irwin River district, and most of the remainder from the West Kimberley District.

Owing to the lamellose structure of the shell, fine ornamentary features of productid specimens are often not well preserved. In this collection, however, specimens have been generally so well preserved that in nearly every species it has been possible to describe precisely both internal and external features.

In the North-West and Kimberley divisions the climate is arid to semi-arid, in parts monsoonal, with brief wet and long dry periods. The enclosing sediments are mostly fine sandstones, in places rich in iron. Under these climatic conditions certain of the sedimentary beds have been locally enriched in iron; the calcite of the shells has been leached; and subsequently both internal and external casts have been formed, many of them with a case-hardened surface of desert varnish. This process is particularly well shown in the preservation of plates of the species of *Calceolispongia,* one of the most valuable index fossils in the Permian of Western Australia (see Teichert, 1949, pp. 31-34).

Where casts have not been formed weathering has freed the enclosing shells from the matrix, partially or wholly, very often with a minimum of surface wear.

From the aspect of gross preservation the specimens may, then, be divided into two groups. In the first the original shell material has been preserved; in the second the shell material has been removed or replaced, the shell being represented by casts which, if studied carefully, show details of both internal and external features. These casts have to be treated with caution, for some are neither truly external nor truly internal. Instead, leaching away of the shell material and its replacement by limonite seem to have gone on simultaneously with the filling in of the interior at such a rate that the resultant cast represents the shell as it would be with half the shell thickness stripped away. Gross features, both internal and external, are then shown—

coarse spine-bases, median septum, and cardinal ridges. Such specimens may be difficult to place in the proper species and may even give the false impression of a new species.

Comparatively few specimens were enclosed in matrix so dense and hard as to defy efficient preparation. These were found in dense or massive limestone, a comparatively rare sedimentary type in the local Permian, and in silicified or intensely ferruginized sandstone. Most specimens have a fine sandstone matrix which is fairly friable and can be treated mechanically.

The productid shell, particularly that of *Strophalosia,* is difficult to section because of the ease with which the shell lamellae flake away. Best results are obtained by embedding the piece of shell, after impregnation with canada balsam, in transparent embedding compound so that exact sections can be obtained without undue trouble. The Croft grinding machine (Croft, 1950) proved useful when controlled grinding was necessary. For mechanical treatment, small and delicate shells are embedded in paraffin wax before preparation. The wax can be dissolved away afterwards with xylol.

Although the bulk of the sepecimens studied were part of the Commonwealth Palaeontological Collection, Canberra, the choice of type specimens, where possible, was made from specimens of the University of Western Australia, the nearest major repository to the areas concerned.

SYSTEMATIC DESCRIPTIONS.

Before beginning on the descriptions proper a few prefatory notes are necessary.

(i) In the text of the species descriptions certain Australian vernacular expressions are used in the definition of many localities. To avoid possible confusion they are defined here.

Station: A large pastoral holding, sometimes several thousand square miles in area.

Paddock: A subdivision of a station, varying in size from a very large field to an area of a hundred or more square miles.

Homestead: A collection of buildings constituting the station-owner's or station-manager's home.

Hole: A soakage or natural dam for watering stock.

Fence: The wired fence dividing one paddock from another or the boundary of a station. In country largely devoid of prominent natural physiographical features, and mostly unsurveyed, such fences play a large part in the fixing of localities.

Some of the localities mentioned in the descriptions are those of specimens collected in the early days of investigation of the Western Australian marine Permian. Every effort has been made to pin-point these localities, many of

which are very vague, but some of them are beyond tracing. For nearly all the species concerned, however, other specimens are mentioned, the localities of which are sufficiently precise to guide future collectors.

(ii) The term "variety" has not been used in this paper, because it has no official standing in universal zoological nomenclature; the category "subspecies" is used, in the sense of Newell (1949). It is not used to suggest a morphologically variant population co-existing and cohabitating with the main population. Since there is the emphasis on the species as a population it should also be stressed that all specimens studied have been used to define the population they are considered to represent. For all new species, therefore, the holotype has been regarded simply as a representative name-bearer. The paratypes have been selected to cover as wide as possible a range of featural variation.

(iii) In 1951, application was made to the International Commission on Zoological Nomenclature for suspension of the Rules in connexion with seven species from the Lower Carboniferous of England described by Martin in 1793 and 1809 (*see* Muir-Wood, 1951; and *Bull. Zool. Nomen.*, 6 (1), 7-17, 1951). Two of the species, *Conchyliolithus Anomites productus* and *C.A. semireticulatus*, are the genotypes of *Productus* and *Dictyoclostus* respectively. At the time of writing no definite ruling on this application is known. The name *Dictyoclostus* has therefore been used pending the verdict of the Commission.

(iv) All dimensions quoted are in millimetres; the sign ± after a dimension indicates measurement along a broken edge; the term "approx." indicates a measurement also along a broken edge, but calculable to within a few millimetres.

(v) Selected synonymies only are given for the well-known species described in this Bulletin. Complete lists of references on these species can be obtained from Branson (1948).

(vi) Some of the genera described herein have never been given true diagnoses. For each of these genera I have tried to give an abbreviated description, or definition, which sums up the features considered typical by most authors.

(vii) The following abbreviations indicate the repository of specimens:—

B.M.: British Museum (Natural History), London.

Aust.Mus.: Australian Museum, Sydney.

U.W.A.: Geology Department, University of Western Australia.

G.S.W.A.: Geological Survey of Western Australia.

C.P.C.: Commonwealth Palaeontological Collection, Bureau of Mineral Resources, Canberra.

M.U.: School of Geology, University of Melbourne.

Phylum BRACHIOPODA.
Class ARTICULATA Huxley.
Order STROPHOMENIDA Moore, 1952.
Superfamily PRODUCTACEA Maillieux, 1941.
Family PRODUCTIDAE Gray, 1840.
Subfamily PRODUCTINAE Waagen, 1884.

Genus AULOSTEGES Helmersen.

1847—Helmersen, *Leonhard and Bronn's Jb. Miner.*, p. 331, text figure.

Type Species: Aulosteges variabilis Helmersen = *Orthis wangenheimi* Verneuil. Helmersen 1847, *Leonhard* and *Bronn's Jb. Miner.*, p. 331, with text figure.

Definition: Medium to large shells, rarely small, ovoid to quadrangular or triangular outline, concavo-convex or plano-convex dorso-ventrally, occasionally geniculate or subgeniculate. Ornamentation essentially spinose, mostly over both valves, with concentric wrinkles and, rarely, radial striae.

Pedicle valve convex to varying degrees with a well developed area and pseudodeltidium. Pseudodeltidium frequently ornamented with spines. Umbo sharp, pointed or rounded, often deformed and with cicatrix of attachment. Without teeth, or with very rudimentary teeth only. Median sinus often present. Without distinct ears.

Brachial valve flattish or concave, nearly always without area or, if present, area very narrow and linear. Cardinal margin with median triangular extension. Margins often upturned or rarely geniculate.

In brachial valve median septum present, separating dendritic adductor muscle impressions. Brachial impressions productiform. Cardinal process usually trilobed, complex, large, inclined to the plane of the brachial valve at angles from about 30 to 90 degrees. Marginal ridges often present along the cardinal margin.

In pedicle valve adductor impressions dendritic, most often more elongated than in brachial valve, bordered on either side by striated diductor muscle impressions.

Remarks: Representatives of this genus are usually medium-sized or large, although the size varies greatly. The pedicle valve may be unevenly or evenly convex or geniculate. It is nearly always deformed, often strongly so, the whole body of the valve being affected or the umbo alone. The area is isosceles in shape or inequilateral if the umbo is markedly deformed. Usually well developed, it may be flat or concave, the concavity sometimes being irregular, and is often marked by striations either parallel to the hinge-line or vertical to it, or both, resulting in a cross-hatched pattern. The narrow pseudodeltidium, ridge-like, triangular or parallel sided, divides the area; it rarely meets the hinge-line, leaving a triangular gap filled by a corresponding extension of the

cardinal margin of the brachial valve. It is probable that the pseudodeltidium bears minute spines, their absence in many forms being due to the secondary effects of preservation.

The surface of the pedicle valve is ornamented by spines, erect or adherent or both, varying greatly in size and arrangement even on the same specimen; but mostly the arrangement is a variant of that termed quincuncial. Concentric wrinkles are present and may be pronounced. On the brachial valve the ornamentation is as for the pedicle, pits representing the spine bases on the pedicle valve, with interspersed spines often finer than those on the pedicle valve.

The internal features are rather distinctive. For the brachial valve the description following is that of *A. wangenheimi* (B.M. BB3279) and may be considered characteristic. (Pl. 6, fig. 2; pl. 21, figs. 3-6, 8). For the size of the shell the cardinal process is large. It extends into the body cavity perpendicularly to the plane of the valve. From the posterior aspect, that is, facing the umbo, it appears as trilobed, the lines of growth very evident. From the antero-ventral aspect it appears as almost quadrilobed. The roots of the process lie a little posterior to the hinge-line, being buttressed by the triangular extension of the cardinal margin already referred to. Anteriorly the process continues as two thick ridges gradually separated by a sulcus which grows wider towards the base. It is this sulcus which, extending as a line almost to the termination, creates the apparent quadrilobed appearance from the ventral aspect. The ridges continue along the hinge as thick marginal ridges. These marginal ridges vary in development from individual to individual. From the base of the process two ridges arise and converge to meet in the middle line within a few millimetres, continuing anteriorly as the median septum almost to the edge of the visceral disc. Thus a diamond-shaped depression separates the process from the median septum. Just anterior to this depression, on either side of the median septum, are the adductor muscle impressions, markedly dendritic and sunken in subtriangular depressions. From the base of the muscle impressions the brachial impressions run almost to the lateral margins, subparallel to the hinge, and then curve anteriorly to give an open hook-like loop. The alar extremities carry swollen protuberances owing to the terminal enlargement of the marginal ridges. Much of the posterior surface is covered with fine pits, elsewhere being smooth, except the geniculated portion which may be pustulose.

This description, although containing reference to minor features individual to the species, is characteristic in a general way of all species of the genus. The main points to be noticed are: the strongly inclined cardinal process; its complexity of lobation; the conjoining of two ridges to form the base of the process; the markedly dendritic adductor muscle impressions; the productiform brachial impressions.

Species of the genus *Aulosteges* as described above form a distinct and easily recognizable group. They may be distinguished from the similar species of the Strophalosiinae by these features: a high area confined to the pedicle

valve; the absence, except in a very poorly developed form, of an area on the brachial valve; the absence of teeth, or their presence in a very rudimentary form; a fairly complex cardinal process which is either perpendicular or strongly inclined to the plane of the brachial valve; dendritic adductor muscle impressions; and the triangular extension of the cardinal margin of the brachial valve.

From species of the "*Productus spinosi*" group, species of this genus are distinguished by the high area, the strong inclination of the cardinal process to the brachial valve and, very frequently, by a degree of deformity. It is probable, however, that these differences are not as truly fundamental as those between *Aulosteges* and *Strophalosia*. By mixoperipheral growth of the pedicle valve, with consequent development of an area (e.g., *Juresania*), many productinids could very easily be confused with *Aulosteges*. It may very well be that *Aulosteges* is polyphyletic, and in this regard it is significant, although not a criterion, that the genus has been largely subdivided into several subgenera.

If *Aulosteges* is to be interpreted as above, *Wyatkina* Fredericks (1931) and *Strophalosiina* Licharew (1935) are to be regarded as subgenera of *Aulosteges*. As Hill (1950) suggests, *Wyatkina* may not be separable from *Aulosteges sensu strictu*. If it is found to be separate the following species, here described, might conceivably belong to *Wyatkina: A. fairbridgei, A. ingens, A. spinosus,* and *Taeniothaerus*(?) *fletcheri*. In the same paper Hill also suggests two other possible subgenera, one represented by *A. wolfcampensis* King (1930), a costate and spinose species with a ventral cardinal area; the other by *A. horrescens* (de Verneuil, 1845), *A. fragilis* (Netschajew, 1894), and *A. longa* (Netschajew, 1900), from the Russian Kazanian. This second group is made up of shells with thin to medium-sized visceral cavities, prevailing low, wide ventral areas, and with the area in some cases divided by a pair of oblique lines from the umbo, one each side. Most of the Western Australian species here assigned to *Taeniothaerus* Whitehouse (1928) are very similar to this Russian group, so much so that if the assignation of the Western Australian species to *Taeniothaerus* is correct (of which more will be said later) then probably the Russian group is also not separable from *Taeniothaerus*.

AULOSTEGES BARACOODENSIS Etheridge fil.

Pl. 1, figs. 1, 3, 4, 6.

1903—*A. baracoodensis,* Etheridge fil., *Bull. geol. Surv. W. Aust.,* p. 22, pl. 2, figs. 1-2a.

1933—*A. baracoodensis,* Etheridge fil.; revised Hosking, *J. Roy. Soc. W. Aust.,* 19, 33, pl. 1, figs. 1a-c, pl. 2.

Lectotype: (chosen Hosking, 1933) Aust.Mus. F.36218 (previously F.1569, Mining Museum, Sydney), Wooramel River, southern part of Carnarvon Basin. Probably Callytharra Formation.

Other Material: U.W.A. 10496, Fossil Cliff, Irwin River. Fossil Cliff Formation. 23437 a, b, same locality and horizon.

Diagnosis: Large-sized *Aulosteges*-species, subquadrate outline, with low, wide, ventral area. Ornamentation of elongated, mostly fine, spine-bases, reclined or erect. Cardinal process massive. Resembles most closely *A. lyndonensis* sp. nov., but distinguished from it by overall finer degree of ornamentation and smaller area.

Description: Dimensions of typical specimens are—

—	F36218.	U.W.A. 10496.	U.W.A. 23437b.
Length of hinge	50	44	39
Width	80	70	56
Length	81	67	41+
Curvilinear length	115±	90±	60+
Depth	20±	17±	12±

Shell large, often somewhat deformed, subquadrate, longer than wide, pedicle valve convex, the convexity of low degree. Its greatest width is anterior to middle of shell, the hinge-line being half to two-thirds of greatest width, and straight. Ears not highly developed, hardly offset from rest of valve; alar angles obtuse, more or less rounded. Median sinus mostly broad and weak, commencing just anterior to the umbonal region. Umbonal region often swollen with strong blunt umbo which may be deformed; generally straight or slightly incurved, and not overhanging the hinge-line. The area is high, triangular, the apical sides slightly curved, convex to the base (the hinge), approximately a half to two-thirds the width of the hinge-line, and transversely lined with growth ridges. It is generally undistorted, and in height one-half to two-thirds its width. The pseudodeltidium is narrow, erect, seemingly devoid of spines but composed of transverse laminae. It is not twisted. It fails to reach the cardinal margin, the triangular gap being filled by an extension of the brachial valve which buttresses the dorsal side of the cardinal process.

The brachial valve is concave to varying degrees with smoothly upturned margins hardly to be described as geniculate. The median septum is well developed and extends for about two-thirds the length of the valve.

The ornamentation of the pedicle valve consists in the main of elongated spine bases of fine to medium size, arranged over the visceral region in approximate quincunces. Towards the margins and ears they are more haphazardly placed. From them rise spines flat-lying or erect, both types occurring together. On the brachial valve the spines, inset between pits or dimples corresponding to the spine bases on the other valve, are finer and generally flat-lying. Concentric growth wrinkles are prominent on both valves, particularly towards the margins of mature specimens.

The cardinal process is trilobed, and spike-like at its extremity, as Etheridge originally described it. As a whole it is massive and extends well into the

umbonal cavity. Ventrally it appears to spring from the junction of two ridges, much as in *A. lyndonensis,* which, over the process proper, are separated by a depression. It is the faint continuation of this sulcus to the extremity, so splitting the median lobe, which gives an apparent quadrilobation from the ventral aspect. The main three lobes are small and parallel-disposed. A median septum is present in the brachial valve. The remaining internal features are unknown.

Variation within the Species: The number of specimens is limited and little can be judged as to the limits of variation in the species. The size of the area certainly varies, particularly in height, so that in some instances it is only one-sixth of the width, more rarely in others it may be as much as two-thirds. Distortion of the specimens does not allow of any estimate of the variation in shape. The ornamentation is the same in all specimens.

Comparison with other Species: A. baracoodensis approaches most closely another local species, *A. lyndonensis* sp. nov. The spines and spine bases of *A. baracoodensis* are more numerous than those of *A. lyndonensis* and are consistently finer in size. The constantly larger size of *A. baracoodensis,* in conjunction with its shallow visceral cavity and hinge-like features, render it quite distinct from other species of the same genus in Western Australia. Among foreign species it can be compared with *A. medlicottianus* Waagen (1884, p. 663, pl. 62). This species, from the Salt Range, has a wider area than that of *A. baracoodensis,* and has much more sparse and coarse ornamentation.

Remarks: A. baracoodensis was first described by Etheridge on the basis of two rather different specimens, one of which was later lost. Hosking revised the species in 1933, using the remaining co-type, and another local specimen considered conspecific.

Aulosteges reclinis sp. nov.

Pl. 1, figs. 2, 5, 7, 8-10; pl. 2, figs. 1-4.

Holotype: U.W.A. 31190, 4 miles north of Mount James on boundary fence between Nerrima and Kalyeeda Stations, Fitzroy area, West Kimberley District. Liveringa Formation, Hardman Member.

Paratypes: U.W.A. 29106, 29106a, 29109; Windmill at Selection Homestead, Fitzroy area, West Kimberley District. Liveringa Formation, probably Hardman Member. U.W.A. 31191, 1 mile south of Terrigan Hole, Nerrima Creek. Same general locality and formation. C.P.C. F21043, near base of Mount Hardman, West Kimberley District. Liveringa Formation, Hardman Member.

Diagnosis: Aulosteges-species with subtriangular outline, pedicle valve not strongly geniculated, the area being large, triangular and reclined. Is less convex than *A. dalhousii* Davidson with shorter hinge-line, and less pronounced geniculation of the pedicle valve.

Description: Dimensions of typical specimens are—

—	U.W.A. 31190.	29109.	31191.
Length of hinge-line	38	28	30
Width	50	50	58
Length	57	56	64
Curvilinear length	75	70	80
Height	18 (approx.)	..	..

The pedicle valve is of medium size, of low convexity, usually most convex anterior to the middle, and deformed. It is subtriangular in outline, with the transverse curve a low arch with steep, sometimes wall-like sides, flattened medially and indented by a broad strong sinus, which becomes more narrow towards the strongly indented anterior margin. The hinge-line is straight, less than two-thirds the greatest width. Longitudinally the valve is of a very low degree of convexity, almost flat for about two-thirds of its length, then becoming more convex, somewhat geniculated, then flattening out. Alar angles are obtuse, and hence there are no ears.

The umbonal region is poorly developed, not swollen. The umbo is triangular shaped, pointed, the umbonal angle being about 90°, extending far posterior to the hinge-line, the tip lying well below the hinge-line, and separated from it by a very large triangular undistorted area, vertically striated, extending for two-thirds the width of the hinge-line, very reclined, obtuse-angled, and slightly concave. It is bisected by a sharp, apparently annulated, pseudodeltidium, running from the tip of the umbo at least half way to the hinge. The remaining triangular gap, not filled by the pseudodeltidium, was probably filled by an extension of the brachial valve.

Ornamentation over the visceral disc consists of very elongated radially disposed spine-bases of medium size, giving a pseudo-costate appearance to the shell, and bearing erect spines. On the anterior and lateral margins, after subgeniculation, the spine-bases are much finer. Numerous growth wrinkles sometimes coincide with deformed parts of the pedicle valve.

The dendritic adductor muscle impressions in the pedicle valve are very elongated, raised, separated by a narrow sulcus. They occupy an area about one-third of the curvilinear length from the tip of the umbo. The striate divaricator impressions occupy large quadrangular areas, one either side of the adductors.

Only a few casts of brachial valves, indifferently preserved, were available for study. The hinge is the widest part. For the most part the valve is slightly convex over the visceral disc, with upturned margins, hardly to be described as geniculate, and with slight median swelling anteriorly. The anterior margin is sharply indented, corresponding to the median sinus of the pedicle valve. Ornamentation of pits corresponds to the spine bases on the

other valve. Whether or not it bears spines could not be determined. Internal characters of this valve are not well known. A narrow median septum extends across the visceral disc, not continuing into the cardinal process. The process is spike-like, inclined at a large angle to the plane of the brachial valve.

Variation within the Species: The small number of specimens gives only an approximate idea of the limits of variation in this species. The size of the area varies a little but it is always large in comparison to the size of the shell. The height varies from one-half to one-quarter of the width. The amount of reclination of the area varies within small limits, but the tip of the umbo always lies well below the hinge-line. The obtuse angle of reclination ranges from 100° to 130°. Some specimens are more misshapen than others. The amount of geniculation of the pedicle valve varies; in some specimens it is hardly apparent.

Comparison with other Species: In shape and size the form described as *Strophalosia tholus* Keyserling by Netschajew (1911, p. 146, German Résumé, pl. 8, fig. 1) comes close to this species. The ornamentation is, however, radically different; the area is more concave and shows some distortion.

A. wangenheimi de Verneuil var. *punjabica* Reed (1944, pl. 7, fig. 2) bears a close resemblance to *A. reclinis* in that both species have a similar high reclined triangular area, but the Indian variety differs in not possessing as convex a longitudinal profile and in the spine bases becoming coarser towards the margins. The shape of the Reed's variety is also more quadrangular. *A. wangenheimi* (de Verneuil) is distinguished by its distorted area, geniculated brachial valve, and slight median sinus.

A. randsi Hill (1950, p. 6, pl. 6, fig. 1) is a somewhat similar species, but seems to have a narrower area, which is distorted and unevenly developed, and the hinge-line appears to be shorter than that of the present species.

A. dalhousii Davidson (1862, pl. 2, figs. 7a-c), of all species of the genus, approaches most closely to the local form. It is, however, rather more convex in the pedicle valve, the geniculation of the pedicle valve is more pronounced and the hinge-line is relatively shorter. Nor does it seem to show the finer spine bases over the marginal post-geniculated portion of the pedicle valve which occurs in the Western Australian species.

Material: Twenty specimens showing internal and external features variously preserved in each specimen.

AULOSTEGES FAIRBRIDGEI sp. nov.

Pl. 2, figs. 5-12.

Holotype: U.W.A. 29348f, near Tutu windmill, Nerrima Creek, Luluigui-Myrooda area, West Kimberley District. Liveringa Formation, Hardman Member.

Paratypes: U.W.A. 29438a, b, e, same locality and horizon as holotype. 29201, west side of Mount Cedric, West Kimberley District. Liveringa Formation, Hardman Member. Aust. Mus. F.44722, F.44778, F.44781, F.44827; Ironstone ridge, Port Keats Native Mission, 154 air miles south-west of Darwin. Port Keats Group, probably equivalent, at least in part, of Liveringa Formation.

Diagnosis: *Aulosteges* with large shallow visceral cavity, large reclined area, attenuated umbo, and very regular ornamentation of elongate spine bases on both valves. Distinguished from *A. wynnei* Reed (1944, p. 114, pl. 7, figs. 5-7) by more elongate and regularly arranged spine bases and by usual presence of coarse, erect spine bases towards lateral and anterior margins.

Description: Dimensions of some typical specimens—

—	29438f.	29438a.	29438e.
Length of hinge-line	34	33	28
Width	58	52	44
Length	67	65	52
Curvilinear length	94	85	75
Depth	24	25	24

The visceral cavity is large in proportion to the overall size of the shell, owing to the combined absence of geniculation and pronounced median sinus, but quite shallow. The pedicle valve is convex, the convexity being of low or moderate degree and evenly so, but curving fairly abruptly from the flattened median portion to the lateral margins. The hinge is straight, about two-thirds the width, resulting in a subtrigonal outline. The median sinus commences anterior to the umbo, and remains broad and weak over the main visceral cavity, increasing in depth only in the later growth stages of mature specimens. The umbonal region is not strongly developed; the umbo is not bulbous, but still prominent and projecting well behind the hinge-line. The umbonal angle is about 60°. The tip of the umbo is erect or slightly incurved, swollen, knob-like, deformed, and lying a little below the plane of the brachial valve. The area is large and high, increasing in size with older specimens, slightly concave, triangular, extending over the whole hinge, and reclined below the plane of the brachial valve. Better preserved specimens show vertical striations. It is pierced by a narrow deep delthyrium, one-third filled by an erect, /\-shaped pseudodeltidium. The resultant gap is at least part, probably wholly, filled by a narrow triangular extension of the brachial valve.

The brachial valve is usually slightly convex initially but flattens out and becomes slightly concave at the margins, which may show slight upturning. This initial convexity is separated from the hinge-line by a narrow, flat belt which extends along the entire length of the hinge-line. No ears.

The pedicle valve is covered for the most part with very elongated, close set, fine spine bases in regular quincuncial arrangement, giving the appearance of numerous interrupted costae. On the anterior marginal surfaces of mature

and old specimens the pseudo-costation is less evident, replaced by a quincuncial arrangement of spines which become coarser, sparser and erect, particularly over the alar extremities. Whether the actual spines are flat-lying or erect is not known. The tip of the umbo is smooth. Growth wrinkles are rare. The surface of the brachial valve is ornamented with irregular low elongated pustules and, in later growth stages, with numerous fine pits.

Linear-striate diductor muscle scars are present on the pedicle valve of a few specimens. The adductor muscle impressions in this valve are elongated and somewhat raised areas in the centre of the posterior third of the valve. In the brachial valve a pronounced median septum extends from the anterior edge of the flat belt previously mentioned to about two-thirds of the distance to the anterior margin. It is narrow and high posteriorly but dies out gradually anteriorly. Two narrow erect ridges arise a short distance before the posterior termination of the septum, separated by a narrow deep sulcus, becoming more erect and convergent and projecting at an angle of about 45° to the plane of the valve to form the cardinal process. At about 8 millimetres from the base, the ridges join and form an apophyse which recurves to lie parallel with the plane of the valve. This apophyse is trilobed, the lobes being small, spike-like, and pointing posteriorly, not diverging. The posterior extremity of the cardinal process thus lies well within the umbonal cavity.

The adductor muscle impressions are dendritic, occupying small oval areas about one-third of the length of the median septum from the hinge-line.

Study of a growth series of specimens reveals certain changes during growth. Thus the area increases in size from younger to older individuals. The pseudo-costation gives way to stronger erect spine bases only in mature and old specimens. Young specimens may show slight deformation affecting the whole shell, which is not apparent in mature ones. The incurvature of the umbo seems to increase slightly with age. The general outline and shape are fairly constant although there is a trend towards greater elongation with increasing age.

Variation within the Species: Variation of features due to age differences in individuals have already been outlined. One the whole this species is quite stable in its characteristics. The inclination of the cardinal process to the plane of the brachial valve may vary between about 30 and 45 degrees, and the development of the median sinus is somewhat variable. It may be only a little more than a flattening of the median portion of the pedicle valve, but is mostly broad and weak, resulting in a shallow indentation of the anterior margin.

Comparison with other Species: In general shape this species is very similar to *Aulosteges wynnei* Reed (1944, p. 114, pl. 7, figs. 5, 6, 7), less so to *Aulosteges* cf. *gigas* Netschajew of Diener (1903, p. 182, pl. 8, figs. 13a-c, 14) and *Aulosteges guadalupensis* Shumard as described by Girty (1908, p. 277, pl. 20, figs. 22, 22a). The latter two forms, however, do not show the same elongation of the spine bases nor their regular arrangement with the resulting pseudo-costation characteristic of the local species, and although *Aulosteges wynnei* is closer

to *A. fairbridgei* in this respect, it does not possess the coarse, sparse and erect spine bases on the lateral and anterior margins, always found on mature specimens of *A. fairbridgei.*

There should be little room for confusing this with other local species of *Aulosteges.* None of them possesses either area or ornamentation of a comparable nature.

Material: Seventy specimens, all moulds, showing internal and external features.

Remarks: The specific name is given to honour Dr. Rhodes W. Fairbridge, Columbia University, who has done valuable work on the Permian of the Irwin Basin.

AULOSTEGES INGENS Hosking, revised.

Pl. 3, figs. 1-10.

1931—*Aulosteges ingens* Hosking, *J. Roy. Soc. W. Aust.,* 17, 15, pl. 5, figs. 1a-c, pl. 6, figs. 2a-c.

1943—*Aulosteges ingens* Hosking; Prendergast, *J. Roy. Soc. W. Aust.,* 28, 37.

Lectotype: (chosen here) G.S.W.A. 1/5000. Bed in bank of Wooramel River, 3 miles above R.20, Carnarvon Basin. Lower part of Byro Group.

Paratype: G.S.W.A. 1/4955. Same locality and horizon.

Diagnosis: Aulosteges-species, subquadrate, with pointed, twisted umbo. Ventral area large, wide as hinge, with prominent ridged pseudodeltidium. Distinguished from *A. gigas* Netschajew (1894, p. 155, pl. 3, figs. 1-3, pl. 4, figs. 3-5, 12) and *A.* cf. *gigas* Netschajew, figured Diener (1903, pl. 8, fig. 13), by absence of marked growth wrinkles, and by pseudodeltidium ridge-shaped, not rounded in section.

Description: Dimensions of some typical specimens are—

—	1/5000.	1/4955.	32045.
Length of hinge-line	42	43	31
Width	54	46	46
Length	59	..	50
Curvilinear length	95	..	75
Height	32	30	26

The following is taken from Hosking's original description:—

"Shell slightly longer than broad; ventral valve inflated, dorsal valve flat in the visceral region, but becoming concave towards the edges which are abruptly bent upwards, more or less at right angles to the plane of the valve. In the longitudinal direction the ventral valve is strongly arched anteriorly and posteriorly, but slightly flattened in the visceral region. Transversely the lateral slopes ascend steeply almost at right angles to the plane of the central portion which is flattened and depressed in the central line by a well developed sinus. The hinge is slightly shorter than the greatest width of the

shell. The lateral margins meet the hinge in a blunted right angle; they are almost straight posteriorly then curve rapidly to the anterior margin which is only very gently curved and slightly indented medially by the sinus; thus the shell has a pronounced quadrangular outline particularly from the dorsal aspect. The umbo of the ventral valve is high, slightly overturned and slightly twisted. One specimen bears a flattened mark of attachment to some foreign body. The area is high and unequally developed on the two sides of the pseudodeltidium. The distortion of the umbo and area varies in the two specimens. On both specimens the margin on one side of the area slopes at a constant angle from the umbo to the end of the hinge-line, but on the other side descends steeply nearly to the hinge-line with only a very narrow prolongation of the area running to the end of the hinge-line. One specimen has the abruptly narrowed side on the right, the other has it on the left of the pseudodeltidium.

"The less weathered specimen shows the area ornamented with vertical striations. The pseudodeltidium is strongly vaulted with a median ridge, which in the less weathered specimen is rounded, but in the more weathered specimen is sharp, making the pseudodeltidium Λ-shaped in cross section. It is about 3 mm. broad at the base and tapers to a point under the umbo. It is marked with horizontal annulations. Where the area is much distorted the pseudodeltidium is twisted to one side. The cardinal process of the dorsal valve is broadly triangular, coming to a sharp point under the pseudodeltidium.

"Both valves are ornamented with spine bases which are finer and more closely set on the dorsal than on the ventral valve. On the visceral portion of the ventral valve they are large and regularly arranged in more or less alternating rows. The spines evidently ran for some distance in the test before emerging at the surface, particularly towards the anterior where this produces a faintly ribbed appearance on the exfoliated shell. Faint longitudinal furrows on the cast are also probably caused by this. Stout tubular spines are thickly set around the margin and on the ears of the ventral valve. A few concentric growth lines are faintly seen on the visceral portion of the ventral valve and towards the margin of the dorsal valve."

This description was based on the two original specimens. Since the time of the original description only five or six additional specimens had been found. Material collected recently, however, from the Point Keats Native Mission, in the Northern Territory, just east of the Western Australian border, by an expedition of the Australian Museum, Sydney, included well over 100 specimens, some of which are mirror images of the type specimens. Bureau of Mineral Resources parties have also collected many more specimens from the West Kimberley District.

The new material has shown details of the internal features and has also provided a wider conception of the external features, best illustrated in the discussion on the range of variation.

The cardinal process begins as two pronounced ridges arising one each side of the median septum. These ridges become more prominent posteriorly, gradually converge, a sulcus between them, and meet just posterior to the hinge. The lobation begins posterior to this, each ridge more or less dividing, the inner divisions continuing to give a prominent median lobe, the outer diverging to give two strongly developed lateral lobes. The sulcus may continue to the extremity as a faint narrow incision tending to indent the median

lobe. As a whole the process is trilobed, tending to be quadrilobed, very strong and massive for the size of the shell, projecting well into the umbonal cavity, and is inclined ventrally to the plane of the brachial valve at angles up to 30 degrees.

The median septum is independent of the cardinal process; it is high and narrow just posterior to the adductor muscle impressions, and persists, gradually becoming less prominent, to the beginning of the upturning of the margins. The adductor muscle impressions are oval-shaped, dendritic, situated just anterior to the ridges which go to make up the base of the cardinal process. The brachial impressions are not shown by any specimen.

In the pedicle valve the adductor muscle impressions are dendritic, slightly raised, and seem to be more elongated than those of the brachial valve. The diductor impressions are linearly striate.

The additional material also contained many immature specimens. These usually have a very large area in comparison with their size, which may be more reclined than that of the adult shell, resulting in an appearance similar to that of *A. reclinis* sp. nov. but much smaller, and without the subgeniculation of the pedicle valve of that species.

Variation in the Species: The outline may range from subquadrate to elongate-oval, and the convexity of the pedicle valve from being greatest over the middle of the valve (most usual), to being greatest over the posterior third, in which instances the umbonal region is more swollen and the shell but little distorted. This variation in convexity may be correlated with that of the distortion of the umbo and hence of the valve. Where the umbo and pedicle valve are distorted, as they usually are, the umbo is more attenuated, the umbonal region less swollen, the area larger, and the convexity greatest over the middle. Where the umbo and valve are less distorted, the area is smaller, the umbonal slopes more swollen, and the convexity greatest posteriorly. This correlation in variation is very probably connected with the relative time of attachment of the young shell.

The area may extend from two-thirds to the entire length of the hinge. When the umbo is very attenuated and projects well above the plane of the brachial valve the area is slightly concave, often with a recurved margin reminiscent of that of *A. spinosus*; when the umbo is less distorted and the tip level with or a little below the plane of the brachial valve, the area is more pronouncedly concave. The height of the area, and hence its size, varies between three-quarters and one-quarter of the width. It is greatest in the more distorted shells.

The margins may be just upturned or there may be a trail up to 1 cm. long. The trail is covered with spines finer than those on the body of the shell.

Comparison with other Species: In the original description Hosking compared *A. ingens* closely with *A.* cf. *gigas* Netschajew as described by Diener (1903, p. 182, pl. 8, figs. 13a-c), an Indian species. *A. gigas* Netschajew (1894, p. 155, pl. 3, figs. 1-3, pl. 4, figs. 3-5, 12) was not compared. The additional

material has widened the content of the species so that the differences Hosking mentions as distinguishing *A. ingens* from *A.* cf. *gigas* (and also from *A. gigas*) comprise the following: The local species is less characterized by concentric growth wrinkles, the pseudodeltidium is more ridge-shaped than rounded in section, and, as far as can be seen, the area is not divided by a pair of oblique lines from the umbo. The comparison of this species with *A. gigas* Netschajew raises the question of its possible assignation to *Wyatkina* Fredericks (1931, p. 210 footnote) with type species *A. gigas*. The distinction between *Wyatkina* and *Aulosteges* has not yet been properly defined so that it has been thought best, at the time of writing, to leave the species *ingens* with *Aulosteges*.

A. ingens is distinguished from *A. fairbridgei* by its greater convexity, more usual distortion, and less regular ornamentation. The Timor form described by Broili (1916, p. 28, pl. 118, fig. 8) as *Strophalosia (Aulosteges) dalhousii,* probably belongs to this species.

Material: Over 150 specimens, mostly limonitic casts (the types show the actual shell material), showing both external and internal features.

AULOSTEGES LYNDONENSIS sp. nov.

Pl. 4, figs. 1-10.

Holotype: C.P.C. 1001, north bank of Lyndon River, north of Round Hill, $8\frac{3}{4}$ miles east of Mia Mia Homestead, Carnarvon Basin. Base of Bulgadoo Shale.

Paratypes: C.P.C. 1002, 1003, 1004, 1005, 1006, 1007; U.W.A. 34431, 34432. All same locality and horizon as holotype.

Diagnosis: Large, shallow *Aulosteges*-species, quadrangular, with large area co-planar with brachial valve and ornamentation of coarse spines. Similar to *A. baracoodensis* Etheridge fil. (revised Hosking, 1933), but with coarser ornamentation and larger area.

Description: The following are the dimensions of some of the type specimens, measurement in depth not being possible owing to flattening of the specimens. A rather close estimate of the depth is possible and is given here.

—	C.P.C. 1001.	1002.	1003.	1004.
Width of hinge	48	49	48	58
Width	72.4	72	64	80.2
Length	68.4	68	55	70
Curvilinear length	100 (approx.)	100 (approx.)	95 (approx.)	..
Height	32 (approx.)	28 (approx.)	27 (approx.)	..

Although all the specimens available show some preservational crushing and distortion, it is possible, nevertheless, by drawing on the whole range of specimens, to gain a fair indication of the shape and outline characteristic of the species. As can be seen from the table of dimensions this is one of the

larger *Aulosteges*-species found in Western Australia. The outline is subquadrangular, the width being greater than the length, the hinge about two-thirds of the width. The pedicle valve is of only moderate convexity and probably fairly evenly so over the visceral region; it is subgeniculate. Transversely the flanks are steep but not wall-like, tending to be flattened over the middle and interrupted by a narrow median sinus, which is most accentuated at the anterior. The margins are slightly splayed out. The alar extremities (there are no true ears) tend to be reflexed and are not differentiated from the body of the valve. The hinge-line is straight. The umbo is large, wide and shallow, the tip pointed, often showing a small cicatrix of attachment, and level with the plane of the brachial valve. It is distorted and twisted to a varying degree, the turning being either to left or right. The tip of the umbo is separated from the hinge by an area, always large, but varying in size, extending over the whole width of the hinge, roughly triangular in shape, but distorted. It is very slightly concave, level with the plane of the brachial valve or slightly reclined from it. It shows both vertical and horizontal striations, presenting a cross-hatched appearance. It is divided by a prominent annulated pseudodeltidium, which is up to 3 mm. wide and inverted-V-shaped in cross-section. In one specimen, the top of the ridge bears traces of what are almost certainly fine spine-bases. In keeping with the distortion of the umbo, the pseudodeltidium is mostly bent, reaching the hinge-line, but terminating anteriorly against the apex of a triangular-shaped notch up to 3 mm. wide, as high as wide, which is filled by a corresponding extension of the cardinal margin of the brachial valve.

The brachial valve is flat over the visceral region, with upturned margins. Over the initial growth stages it may be slightly convex. A median fold corresponds to the pedicle sinus, so that the anterior margin is indented. The margins are upturned evenly laterally and anteriorly, and although the pedicle valve is geniculate, the trail is not a prominent feature, extending over about 13 mm. in the best specimen. The upturning is abrupt only at the lateral margins, anteriorly being smooth and gradual.

On the pedicle valve there are spines and growth wrinkles. The spines near the umbo are fine, much less than a millimetre in diameter at the base, but over the visceral region they are coarse, becoming more numerous and finer again on the extreme margins. The attitude varies. Over the visceral region the spine-bases are mostly elongate, bearing semi-erect spines, but interspersed haphazardly are non-elongate bases bearing erect spines. The elongation tends to be more pronounced towards the anterior, so much so as to give a pseudo-costate appearance in some specimens. The arrangement is quite irregular. This spinose ornamentation extends over the whole valve, along the hinge and on the alar extremities, but is lacking at the tip of the umbo. Over the visceral region the growth wrinkles are widely and irregularly spaced, but become closer spaced and numerous on the trail.

On the brachial valve the ornamentation is similar to that of the opposing valve. The initial part is covered with very fine spine-bases, the outer parts

of the visceral disc with more coarse spines, the margins with more numerous and finer ones. The spines are not nearly so coarse as on the pedicle valve, are suberect or erect, and interspersed among them are occasional pits corresponding to the spines on the other valve. These pits are not nearly so numerous or so regularly arranged as they are, for example, on *Taeniothaerus miniliensis* sp. nov. Growth wrinkles are present as on the pedicle valve.

In the brachial valve a narrow, prominent median septum extends over the visceral disc from the base of the cardinal process, but does not contribute to the formation of this structure. Either side of it, about one centimetre from the hinge, are the oval-shaped finely dendritic adductor muscle impressions. They are slightly raised, but each occupies a depressed area, the depression passing smoothly into the general surface anteriorly; but posteriorly the border is more abrupt and ridge-like. This is low and rounded, and is removed from the hinge by a few millimetres, leaving a narrow ledge along the hinge-line. Towards the middle, each of these bordering ridges becomes very pronounced and posteriorly directed, the two ridges so formed being the base of the cardinal process. At first the ridges are separated by a deep sulcus, 2-3 mm. wide, which becomes less accentuated posteriorly. The process is large, projecting well behind the hinge (up to one centimetre in some specimens), and inclined at a low angle, averaging 15 degrees, to the plane of the brachial valve. In plan it becomes narrower posteriorly, an average width at the hinge being 8-10 mm., and at lobation, 4-6 mm. The lobation is not marked; from both aspects it is trilobed, most clearly so from the dorsal aspect, since the lobes tend to be directed dorsally. The lateral lobes lie parallel to the median lobe, or at a small angle to it, and are not markedly differentiated, so that the termination is blunt and abrupt. Lobes vary in size and disposition; in some instances the lateral lobes are larger than the median one, in others they are smaller. On the average all three lobes are much the same size. The rest of the posterior surface is smooth. No specimen shows the nature of the brachial impressions or the interior of the anterior surface.

The interior of the pedicle valve is unknown.

Variation in the Species: There are insufficient complete specimens to show significant variation in shape and size. Numerous fragmentary specimens, however, show wide variation in features of the cardinal region and in the cardinal process. As stated above, the area varies in size. In the specimen showing the smallest area the height is approximately one-eighth the width. In all others it is at least one-sixth the width, the maximum being one-quarter the width. The shape and size of the umbonal region vary correspondingly with the increased size of the area. There is also fortuitous variation of the amount of distortion of the area. In every specimen the distortion is marked, the area being unequally developed on the two sides of the pseudodeltidium. In the most outstanding example, in this respect, the part of the area on one side of the pseudodeltidium is at least four times as large as that on the other.

The cardinal process in all specimens is essentially similar in structure. It varies chiefly in size, although always large. The largest example is one

centimetre across at the base, and 7 mm. at the tip, the smallest 7 mm. at the base and 5 mm. at the tip. Variation in the size and disposition of the lobes has been described previously.

There is only minor haphazard variation in ornamentation, and this consists chiefly in the relative number and disposition of extremely elongate, and sub-erect, spine bases.

Comparison with other Species: The species most comparable with *A. lyndonensis* is a local one—*A. baracoodensis* Etheridge fil. Shape, size and internal features seem to be much the same in the two species, the principal difference being one of ornamentation, although, in addition, the area of *baracoodensis* seems to be smaller. In *A. baracoodensis* the spine-bases are much smaller, rather more numerous, and nowhere show the same degree of elongation.

A species with very similar ornamentation, shape, and size to the present one is *A. acanthophorus* Fletcher, 1945 (considered by Hill, 1950, to be but a variety of *A. (Taeniothaerus) subquadratus* (Morris, 1845)) from the lower Permian of Queensland. In Fletcher's species the area is much smaller, much more erect in attitude, and the umbo is more globose, is overturned, and overhangs the hinge.

The Moscow Basin form, *A. fragilis* (Netschajew) as figured by Sarycheva and Sokolskya (1952, p. 105, pl. 18, fig. 124) resembles *A. lyndonensis,* but the spines of the Russian species are more coarse, less numerous and more widely separated.

The Indian Salt Range species *A. medlicottianus* Waagen is similar to *A. lyndonensis,* especially in general shape, but is at once distinguished by the absence of spines on the brachial valve of Waagen's species.

Remarks: The specific name comes from the name of the prominent physiographic feature, the Lyndon River, on which the type locality is situated.

AULOSTEGES SPINOSUS Hosking, revised.

Pl. 5, figs. 1-9, 11, 12.

1931—*Aulosteges spinosus* Hosking, *J. Roy. Soc. W. Aust.,* 17, 17, pl. 3, figs. 7a-d.

1933—*A. spinosus* Hosking, *J. Roy. Soc. W. Aust.,* 19, 37.

1943—*A. spinosus* Hosking; Prendergast, *J. Roy. Soc. W. Aust.,* 28, 36, pl. 4, figs. 7-10.

Holotype: G.S.W.A. 1/4687 South bank of Wooramel River, below Callytharra Springs, Carnarvon Basin. Callytharra Formation.

Other material: Aus. Mus. F38444, 37710, Wandagee Station, Minilya River, Carnarvon Basin. Wandagee Formation. U.W.A. 32046, 34433, Glendevon Homestead, Woolaga Creek area, near Mingenew. Fossil Cliff Formation.

Diagnosis: Small to medium-sized *Aulosteges,* not inflated, characterized in particular by the sharp recurvature of the area along the cardinal margin. Ornamentation of fine to medium-sized spines on both valves.

Description: Dimensions of some typical specimens are:—

—	G.S.W.A. 1/4687.	F37710.	F38444.	34433.
Length of hinge-line	15	21	15	33
Width	22	43	20	55
Length	20	46	19	52
Curvilinear length	23	61	24	70
Height	..	..	8	20

In specimens with the margins entire the width is a little greater than the length; the hinge-line is shorter than the greatest width, resulting in a subquadrangular outline. Alar extremities are not differentiated as true ears, and are often broken off so that the shell appears subtriangular. The pedicle valve is gently convex, greatest convexity posterior or anterior about the middle; often distorted, particularly in the umbonal region; sometimes tending to subgeniculation depending on the position of greatest convexity. A broad ill-defined median sinus commences a short distance from the umbo. In young specimens it may not be present at all. The umbo is large, pointed, often twisted and straight or reclined so that the tip is most often below the plane of the brachial valve. The tips of some specimens show what is probably a cicatrix of attachment.

The triangular-shaped area is broad, extending one-half to the full length of the hinge, its height one-fifth to one-half its width. It is slightly concave, shows numerous growth lines and perpendicular striations resulting in a faint cross-hatching, and may be distorted. A distinctive feature is that the cardinal margin is recurved and erect so that a groove lies between it and the area proper. This may not be very evident in casts. A narrow, highly arched pseudodeltidium extends about half the distance to the cardinal margin, leaving a triangular-shaped delthyrium filled by an extension of the hinge of the brachial valve. The pseudodeltidium is lamellose, rarely slightly twisted, and if the preservation is good, it may show fine spine-bases. The valve is ornamented with elongated spine-bases of medium size and occasional fine growth wrinkles. The spines where preserved are rather erect. Spine-bases are present on all parts of the shell except the tip of the umbo. The arrangement might be termed subquincuncial, although the elongation of the spine-bases is radial. There are 20 to 25 spine-bases over a square centimetre on the median part of the valve.

The brachial valve is flat or slightly concave, the ornamentation being the same as that of the opposite valve except that the spines seem to be finer.

The thin median septum crosses the valve almost to the anterior margin, arising just anterior to the hinge-line. It does not contribute directly to the

cardinal process. Two thin ridges arise on either side of it, a few millimetres from the hinge-line. These increase sharply in height with a deep sulcus between, and at the hinge-line curve through almost a right angle in a ventral direction, for about 4 mm. in fully mature specimens. Just before the ventral extremity these two thin apophyses unite to give a spike-like bilobed cardinal process tending to tri-lobation. This orientation of the cardinal process, at a large angle to the brachial valve in a ventral direction, is characteristic of *Aulosteges*. For the size of the shell this cardinal process is rather delicate.

The true nature of the muscle scars and the brachial ridges has not been observed.

Variation within the Species: Certain characters of this species vary. Thus the height, and hence the size of the area, ranges from one-third to half the width. The umbo may be incurved to varying degrees so that the tip may project just above the plane of the brachial valve or be several millimetres below it. The amount of distortion of the shell varies, although all specimens show some deformation. Most specimens show growth wrinkles, but they may be almost entirely absent. The recurvature of the cardinal margin is less obvious in some specimens than others; this is particularly so with casts.

Comparison with other Species: Although some specimens of other local species show the recurvature of the area to a slight degree, in none of them is it so prominent and so sharply recurved as in *A. spinosus*. In other respects, however, specimens of *A. spinosus* may resemble the immature forms of *Taeniothaerus miniliensis* sp. nov. and *T. irwinensis* sp. nov.

There does not seem to be any foreign species with which close comparison might be made.

Remarks: The species was first described by Hosking (1931) on the existence of a single specimen, but the advent of new material has necessitated additions to the original description. These additions, mainly of the internals, have been based on specimens other than the holotype, an immature specimen, which does not show very much of the internal features. It is considered fairly certain, however, that these specimens are of the same species, as they have the same characteristics and, moreover, come from the same stratigraphical level as the holotype—the Fossil Cliff Formation.

Material: About twelve specimens, including limonitic casts revealing internal features.

AULOSTEGES sp. ind. A.

Pl. 5, figs. 19-21.

Material: U.W.A. 28114A, nine chains west of red sandstone *Calceolispongia* horizon, south-west of Wandagee Hill, Minilya River area, Carnarvon Basin. Coolkilya Greywacke, above Nalbia member, or possibly Baker Formation.

Description: General shape and size similar to immature *A. spinosus* Hosking, but the longitudinal curvature is more even, the greatest convexity lying over the middle half. Umbo wide but not deep, sharply terminated, not incurved, distorted, the tip lying about one millimetre below the plane of the brachial valve. The area is large, roughly triangular, distorted, persisting over the width of the hinge. It is a little undulating and is marked with lines of growth and vertical striations giving a cross-hatched appearance. Because of distortion, the area is developed to only one-half the extent on the left-hand side of the pseudodeltidium that it is on the right. The height is one-quarter the width. The pseudodeltidium is a rounded ridge, straight, annulated, persisting from the tip of the umbo almost to the hinge, the resultant small gap filled by a triangular extension of the brachial valve. The hinge-line is bent at this extension, being straight on either side of it, the angle formed by the two sections being very obtuse. The median sinus, as with *A. spinosus*, is hardly noticeable behind the anterior third of the valve. Ears are not developed.

The ornamentation on the pedicle valve is similar to that of *A. spinosus*, the spines being, if anything, coarser over the anterior and antero-lateral margins.

The brachial valve has an irregular subquadrangular outline. It is flat, except over the mid-posterior region, where it is very slightly convex. The anterior margin is a little upturned, where it is indented by the median sinus of the pedicle valve. The ornamentation consists of pits corresponding to the spine-bases of the pedicle valve, with interspersed very fine reclined spines. Faint growth wrinkles are present on both valves.

Internal features are unknown.

Remarks: This form closely resembles *A. spinosus*, but differs from it in being without any trace of the recurved cardinal margin. The area is also much distorted and the hinge-line is not straight, features not usually characteristic of *A. spinosus*. Without a greater range of material is it impossible to put aside the possibility that this form may be a young individual of, for example, *A. reclinis*, or *A. ingens*. Again, more material may extend the range of variation of *A. spinosus* to include the differing degree of development of those features mentioned above. For these reasons it is preferable to withhold a new name for the present.

Genus Dictyoclostus Muir-Wood.

1930—Muir-Wood, *Ann. Mag. nat. Hist.* (10), 5, p. 10.

Type species (Original designation) : *Anomites semireticulatus* Martin (pars.). Petrifacta Derbiensa, 1809, p. 7, pl. 32, figs. 1, 2; pl. 33, fig. 4.

Definition: Productids with elongate or quadrate outline, with the hinge the widest part of the shell. Pedicle valve usually strongly convex or geniculate; flanks often steep and wall-like; median sinus present more often than not.

Ears well developed, frequently demarcated from rest of valve. Much of visceral disc with semireticulate ornamentation often with spines. Trail costate; costae may bear spines; rows of spines on ears and along the cardinal margin. Diaphragm not developed. Ginglymus may be present.

Brachial valve concave or geniculate, with marginal ridges extending along the hinge. Hinge teeth and sockets absent. Ornamentation corresponding to that of pedicle valve, pits replacing spines.

Cardinal process trilobed, the lateral lobes usually well separated from the median lobe; lobation commencing immediately posterior to the hinge; extending more or less in the plane of the brachial valve. Adductor muscle impressions dendritic, separated by median septum. In the pedicle valve adductor impressions often more elongated than in brachial valve, and raised. Linearly striate diductor muscle impressions.

Remarks: The above definition includes in essentials the diagnosis of Muir-Wood, the emendment by Prendergast (1943) to include the possible presence of a ginglymus, and some further emendments by Miloradovitch (1945) and Sarycheva (1949). The essential internal features, noted above, are rather characteristic. This is true particularly of the cardinal process, which, in nearly every species of which this feature has been described, is essentially similar. The base of the process is formed by the conjunction of the median septum and the marginal ridges, and from the platform so resulting the process projects posteriorly as three distinct lobes, most often the laterals being almost at right angles to the central one. The dorsal surface is buttressed at the base by a slight projection of the cardinal margin (see Sutton and Summerson, 1943, pl. 54, figs. 2-8).

The ginglymus which Prendergast would include in the diagnosis is "a groove along the cardinal margin of the pedicle valve into which fits the narrow margin of the brachial valve, hence greatly increasing the efficiency of the articulation of the valves" (Prendergast, 1943, p. 4). The ginglymus is notched to give a "delthyrium" into which the cardinal process fits. As Prendergast further remarks, the ginglymus can only be seen if the two valves are displaced.

Since Muir-Wood's work on the constitution of the genus *Productus* (Muir-Wood, 1930) and her divorcing from the genus of the bulk of the semireticulate forms, the use of the name *Dictyoclostus* for these forms has become well-nigh universal. The correctness of the procedure she adopted seems quite apparent from her own article and has been further validated by Sutton (1938).

Antiquatonia Miloradovitch 1945 (with type-species *Productus antiquatus* Sowerby) is very similar to *Dictyoclostus*. It is distinguished primarily by especially demarcated ears—separated from the flanks by a ridge which bears a single row of large spines—and although recorded over widely separated regions does not seem to me to warrant more than subgeneric status. Two West Australian species can be tentatively assigned to *Antiquatonia*.

DICTYOCLOSTUS (?ANTIQUATONIA) CALLYTHARRENSIS Prendergast.

Pl. 6, figs. 3-14.

1903—*Productus semireticulatus* Martin; Etheridge fil., *Bull. geol. Surv. W. Aust.*, 10, 18, pl. 2, figs. 3-5.

1907—*Productus semireticulatus* Martin; Etheridge fil., *Ibid.*, 27, 29.

1910—*Productus semireticulatus* Martin; Glauert, *Bull. geol. Surv. W. Aust.*, 36, 87.

1924—*Productus semireticulatus* Martin; Chapman, *Ann. Rep. geol. Surv. W. Aust.*, 36.

1931—*Productus semireticulatus* Martin; Hosking, *J. Roy. Soc. W. Aust.*, 27, 8, 22.

1943—*Dictyoclostus callytharrensis* Prendergast, *J. Roy. Soc. W. Aust.*, 28, 13-16, pl. 1, figs. 1-7, pl. 2, fig. 1.

Lectotype (chosen here from author's syntypes G.S.W.A. 1/4967 (b)): specimen figured Prendergast (1943), pl. 1, fig. 3; ½ mile west of Callytharra Springs, Wooramel River District, Carnarvon Basin. Callytharra Formation. Figured herein pl. 6, figs. 9, 10.

Paratypes: G.S.W.A. 1/4967 (a); same locality and formation as syntypes.

Homeotypes: U.W.A. 2945a, b, c; 1.4 miles south of gate in fourth fence on road from Merlinleigh to Moogoorie Stations, Callytharra area, Minilya River District. Callytharra Formation. U.W.A. 12410a, b, c; Fossil Cliff, Irwin River area, near Mingenew. Fossil Cliff Formation.

Diagnosis: Dictyoclostus-species with large reflected ears offset from flanks. Semireticulation extending over two-thirds of visceral disc with fine spines. Less numerous coarse spines irregularly distributed over rest of surface. Closely resembles species of the Indian *D. spiralis-costatus* group of Waagen, but is distinguished from these by its finer ornamentation and lesser tendency for convergence of costae on trial.

Description: The size of the type specimens is as follows:—

—	Lectotype.	Paratypes.		
Length of hinge	59	59	44	66
Width	59	59	48	66
Length	40	42	41	..
Curvilinear length	70	71	71	..
Height	..	..	18	..

The outline is semicircular with the hinge-line the greatest width of the shell. Longitudinally, the pedicle valve is curved through 270 degrees, fairly evenly so, but flattened over the median portion and the trail. The transverse curve is a high arch, steep-sided, but not vertical, with a median depression. The median sinus arises over the unbonal region; is broad and shallow over the visceral disc; but thence becomes shallow, almost disappearing on the trail,

leaving the margin entire or only slightly indented. The ears are often not preserved but if present they are large and reflexed, separated from the body of the shell by a fold bearing a row of spines (3-4) of large size. A second row of large spines runs along the hinge-line.

The semireticulation is regular, costae and rugae equally prominent, covering at least two-thirds of the visceral disc. Over the semireticulate area the costae increase by division and intercalation; no increase takes place on the trail, and the costae become less and less prominent. The rugae become wider spaced anteriorly.

The spines over the semireticulate area, except the large ones mentioned above, are small, suberect, widely separated, arranged subquincuncially, each spine arising from a node at the intersection of a ruga and costa. Every fourth to sixth ruga bears spines, these being separated by eight or more costae; some irregularity is caused by the increase in costae. The larger spines on the trail seem to be quite irregular. Below each is a fold varying in intensity, which replaces two or three costae above each spine, this folding being independent of the costae, although two or more can just be discerned on each fold.

The unbonal region is broad and swollen, but the umbo is rather small, pointed, barely overhanging the hinge-line. The umbonal angle is approximately 90 degrees, and the umbonal ridges are low and rounded.

The brachial valve is flattened, slightly concave over the visceral cavity with a slight median swelling, and rather strongly geniculated. The ornamentation is similar to that of the pedicle valve, but the spines are replaced by pits which are not placed opposite the spines but slightly anterior to them. This is particularly noticeable in the row of pits corresponding to the spines demarcating the ears.

In the pedicle valve the dendritic adductor muscle impressions are barely separated, raised, narrower than in the brachial valve, and elongated postero-anteriorly. The linear-striated diductor impressions form a broad band, running cross-wise across the valve almost to the margins either side of the adductors. The muscle impressions occupy areas in the posterior third of the valve. The anterior half of the valve is covered with minute pits.

In the brachial valve the adductor impressions are dendritic, set on a slightly raised platform oval in shape, bisected by the median septum and set close to the hinge-line. Brachial impressions arise from the anterior edge of this platform, a short distance from the septum. They run subparallel to the hinge-line, almost to the edge of the visceral disc, then curve smoothly forward parallel to the margin for about 10-15 mm., and then curve sharply and terminate. forming a pronounced hook.

The median septum persists over two-thirds of the length of the valve. Posteriorly it is broad and flattish, becoming thinner and less elevated anteriorly. A pair of strong marginal ridges run parallel but anterior to the hinge-line. At

the junction of these and the septum there is a massive truncated-triangular platform, the apex bearing the lobate cardinal process, and projecting a short distance behind the hinge in the plane of the valve. The lobation is not marked; the ventral aspect is massively trilobed, the lobes being large, the laterals each separated from the central lobe by a broad, shallow sulcus. The dorsal surface is more distinctly trilobed and shows the growth lamellae. The areas either side of the muscle impressions are covered with fine pits. The anterior half of the valve reflects the surface semireticulation.

Variation within the Species: Specimens of this species vary in the depth of the sulcus between the visceral disc and the ears. If the sulcus is shallow the semireticulation extends over the ears and the auricular spines are smaller than when the sulcus is deep.

The extent of the semireticulation along the curvilinear length of the shell also varies, rugae being developed only before there is a change in the direction of growth, even if this does not amount to a geniculation.

The steepness of the flanks is not constant. In most of the specimens the flanks, as seen in the transverse curve, arise at about 60 degrees to the plane of the brachial valve, but in others the flanks are more wall-like though never vertical. The median sinus in some specimens persists so that the anterior margin is quite indented. The costae may converge slightly into the median septum; in the extreme case, two costae are lost by such convergence.

Comparison with other Species: Although specimens of this species have previously been assigned to *Productus* (i.e. *Dictyoclostus*) *semireticulatus* Martin, the only really diagnostic feature they have in common with it is the presence of semireticulate ornamentation.

This species is probably identical with the Timor species *Productus semireticulatus* Martin as figured by Broili (1916, pl. 116, figs. 14-16), differing only in the lesser development of the ears. It has much in common with forms from India and China. Of the Chinese specimens it is probably closest to *P. taiyuanfuensis* Grabau as figured by Chao (1927, p. 30, pl. 1, fig. 10, pl. 2, figs. 1-12, pl. 8, fig. 16). The costation of the Chinese form is, however, coarser, the larger spines more numerous, particularly along the inner edge of the ears, where they are almost touching. It is also more enrolled and swollen.

D. callytharrensis has many features in common with forms of the *D. spiralis-D. subcostatus* group of Waagen, 1884. As Reed (1931) has suggested, it seems likely that this whole group, *D. spiralis, indicus, vishnu, aratus,* and *subcostatus,* may actually be one species. In general the Western Australian specimens may be distinguished from the Indian group by the more prevailing tendency in the Indian species for the costae to converge and disappear in the sinus, and by the coarser ornamentation.

Material: About thirty specimens showing external and internal features, variously preserved.

DICTYOCLOSTUS (?ANTIQUATONIA) MAGNUS sp. nov.

Pl. 7, figs. 1-6.

1943—*Dictyoclostus spiralis* (Waagen); Prendergast, *J. Roy. Soc. W. Aust.*, 28, 18-19, pl. 2, figs. 8, 9.

Holotype: Aust. Mus. F.36514; Wyndham Gap, Carnarvon Basin, Callytharra Formation.

Paratypes: U.W.A. 32022, 32023; just south of Trig. Station K52 halfway along road between Middalya and Williambury Stations, Carnarvon Basin. Callytharra Formation. U.W.A. 32021; 4 miles south-south-east of junction of south branch and main Minilya River, Williambury Station, Carnarvon Basin. Callytharra Formation.

Diagnosis: Dictyoclostus-species of large size, in which reticulation extends over less than one-third of curvilinear length. Characterized particularly by the spiral ornamentation on the ears, and by grouping of costae in fasciculi on folds of trail. Differs from *D. spiralis* (Waagen) by the greater fineness of these costae, and by larger number of large spines on trail.

Description: The following dimensions give an approximation of the size of specimens of this species. Only one individual provided all dimensions.

—	Holotype.	Paratypes.		
	F36514.	32023.	32022.	32021.
Length of hinge-line	88	84	70	60
Length	49	49	51	45
Curvilinear length	130	125	120	123
Height	..	..	28	..

Members of this species are the largest of any in the *Dictyoclostus* group yet found in Western Australia. The pedicle valve is very convex, narrow, with a large, highly arched umbonal region. The umbo is small, barely overhanging the hinge-line. The transverse curve of the valve is a high narrow arch, with almost vertical sides and a fairly pronounced median depression. The umbonal angle is about 90 degrees, sometimes less. The valve is most convex in the posterior third, thence gradually flattening out. A pronounced sinus arises at about the middle of the visceral disc and continues uninterrupted to the anterior margin.

The ears are of moderate size, reflexed, almost enrolled, each separated from the steep lateral sides by a faint sinus and a weakly developed fold bearing two or three large spines. Four or five large spines are present along the hinge. Ears are ornamented by rugae and costae, the latter spirally arranged.

The semireticulation is strong and neat, covering less than a third of the curvilinear length, the costae being somewhat more prominent than the rugae. The costae continue almost to the tip of the beak. They increase in number both by bifurcation and intercalation, but rarely so on the visceral disc; no increase takes place on the trail. Anterior to the visceral disc they are grouped

into fasciculi on elevated folds which arise in front of large spines. The folds are not greatly elevated. Over the median part of the valve the costae converge towards, and sometimes disappear in, the median sinus. Some few small erect spines are scattered irregularly over the reticulated portion, each arising at a node, the intersection of a ruga and costa. Large spines are present over the anterior two-thirds of the valve, particularly on the trail. They range in number from ten to twenty, and have no regular arrangement.

The brachial valve is strongly but evenly geniculate. It possesses a pronounced median fold which becomes stronger anteriorly.

The ornamentation is that of the pedicle valve, except for the absence of spines and a rather greater area of reticulation. Pits occur more or less opposite to the spines on the pedicle valve.

Only one specimen showed the cardinal process. This was essentially the same as that described for *D. callytharrensis* but was a little more blunt and massive, in keeping with the greater size of *D. magnus*. Other internal features were not seen.

Variation within the Species: The number of specimens available is insufficient to give the probable limits of variation, but the following features show some variability. The depth of the median sinus of the ventral valve is mostly very pronounced, but in a few specimens it is broad and shallow. This may be due to distortion. The number of large spines on the trail varies—generally they number between 10 and 20. Finally, the development of folds following the large spines on the trail, which bear two or three closely spaced costae, is rather irregular, the folds being more apparent on some individuals than on others.

Comparison with other Species: This species has features in common with *D. callytharrensis* Prendergast, *D. wadei* Prendergast (revised), and the *spiralis-subcostatus* group of Waagen (1894) belonging to the same genus. It may be distinguished from the first of these by its larger size, and much more highly arched umbonal region. There is also more marked convergence of the costae towards the median sinus. It differs from *D. wadei* in the nature and arrangement of the costae and in the consistently larger size. The extent of reticulation on the pedicle valve is also less. The spiral ornamentation of the ears also distinguishes it from both these species.

The nearest of the Indian species are "*Productus*" *indicus* and "*Productus*" *spiralis*, both Waagen's species. The local species differs mainly from the former in its smaller ears, the fineness of the costation and the possession of a prominent median fold in the brachial valve. From the latter it differs in those points mentioned in the diagnosis.

In addition, "*Productus*" *inflatus* Tschernyschew, as figured by Chao (1927, pp. 36-40, pl. 2, fig. 13; pl. 3, figs. 1-5), bears superficial resemblance to *D. magnus*. The Chinese form, however, is very much smaller and shows coarser ornamentation; the hinge-line is shorter and the spiral ornamentation of the ears less marked.

DICTYOCLOSTUS WADEI Prendergast revised.

Pl. 7, figs. 7-10.

1943—*Dictyoclostus callytharrensis* var. *wadei* Prendergast, *J. Roy. Soc. W. Aust.*, 28, 16-17, pl. 2, figs. 2-4.

Holotype: U.W.A. 20453, ferruginous limestone, two miles east, 10 degrees south of Mount Nicholson, West Kimberley District. Noonkanbah Formation, lower half.

Other Specimens: U.W.A. 28696a, b, c, just south of Trig. Station 243, West Kimberley District. Noonkanbah Formation, or base of Liveringa Formation. U.W.A. 2746, Christmas Creek, West Kimberley District. Probably Noonkanbah Formation.

Diagnosis: Medium-sized *Dictyoclostus*-species, with reticulate ornamentation on posterior third of shell, the rugae being more prominent than the costae, but latter very large on trail, bearing large spines. Large spines on ears and on flanks bordering ears. Costae absent from ears.

Description: The largest complete specimen available (the holotype) is 64 mm. wide across the hinge, with a length of 54 mm. and a curvilinear length of 115 mm. The semireticulate ornamentation occupies about one-third of the posterior part of the pedicle valve, almost corresponding with the visceral disc. It is extremely strong, the rugae being very upstanding in comparison with the costae. This ornamentation does not extend to the ears, which are ornamented with rugae only. The ears are reflexed but continuous with the anterior margin of the shell. Two large spines and at least two smaller ones are on the ears, and three large spines, widely spaced, on the flanks just above the angle separating the ears, but not placed on either a pronounced ridge or sinus. These spines are difficult to find on decorticated specimens. The trail is ornamented by large regular costae, varying somewhat in width, bearing large spine-bases which show no regular distribution. The costae are often broader and less pronounced on the antero-lateral flanks. The umbo is swollen and highly arched. The beak just overhangs the hinge-line. No ginglymus was observed.

The brachial valve is strongly, but not abruptly, geniculated. The visceral disc is almost flat but with a fairly strong median fold in the anterior half. Its surface is ornamented similarly to the pedicle valve except that scattered pits correspond to the spines. The semireticulation is also very marked.

Internal features of the pedicle valve were not seen. Those of the brachial valve are similar to those of *D. callytharrensis* Prendergast except that the dendritic adductor muscle impressions are set closer to the hinge-line. The cardinal process shows a lesser tendency to lobation and instead is rounded, cap-like, the posterior extremity more or less rounded and set off by a slight depression.

Variation within the Species: Although only a few specimens are available, the following features show some variation. The costae on the trail vary somewhat in size. They are, however, always much larger than those of *D. callytharrensis*. In younger specimens they are generally smaller than in mature

specimens but are more pronounced. The degree to which they converge towards the sinus is also variable but is slight, less than in *D. callytharrensis,* no costae being lost in this way.

Comparison with other Species: This species differs from *D. callytharrensis* firstly in the much greater convexity of the ventral valve, the highly arched umbonal area, and the much greater steepness of the flanks; secondly in the constant presence of a well-marked sinus in the ventral valve resulting in an indented anterior margin; thirdly in the coarser nature of the costae, which are not formed, as they occasionally are in *D. callytharrensis,* by the coalescence of two or more costae; finally in the more pronounced semireticulation, and the shape of the ears—in *D. wadei* they are continuous with the lateral margin, but in *D. callytharrensis* they are distinct and join the lateral margin about half way down the flanks.

Of species from other countries *D. indicus* (Waagen) and *D. subcostatus* (Waagen) from the Salt Range approach the local species most closely. It is distinguished from the former species by the greater steepness of the flanks, more accentuated rugae, the ornamentation of the ears (ornamented with rugae only) and the absence of the more prominent costae dividing the ears from the rest of the shell, which is characteristic of *D. indicus.*

Similarly most of these distinguishing points serve to discriminate between the Western Australian species and *D. subcostatus.* In addition, the Indian species is much more transverse in shape.

Remarks: Prendergast described this species as a new variety, *wadei,* of *D. callytharrensis,* but considered that it possibly constituted a new species. With additional material to hand, it seems certain that it is a new and distinct species—indeed it resembles the Indian species *Dictyoclostus indicus* (Waagen) and *D. subcostatus* (Waagen) more closely than it does *D. callytharrensis* Prendergast. The specific name was proposed as a variety name of *D. callytharrensis* by Prendergast in 1943. It honours Dr. A. Wade, one of the pioneers of Western Australian geology in the West Kimberley District.

Material: Twelve specimens, six of which are poorly preserved.

Genus KROTOVIA Fredericks, emend.

1928—Fredericks, *Trans. geol.-prosp. Serv. U.S.S.R.,* 46, 790.

Type Species: Productus spinulosus J. Sowerby, 1814, MINERAL CONCHOLOGY OF GREAT BRITAIN, 1, pl. 68, fig. 3.

Diagnosis: Thin-shelled productid, usually small, sometimes geniculate, with thin visceral cavity. Median sinus absent or but slightly developed. Ornamentation of fine to medium-sized spines, numerous, covering whole shell surface, in irregularly quincuncial arrangement, sometimes regularly quincuncial. Weak growth wrinkles may occur. Some spine-bases weakly elongated anteriorly.

In brachial valve, adductor muscle impressions non-dendritic, platform-like, close to hinge, separated anteriorly by sulcus and short median septum. Cardinal process short, peg-like, bilobate, lobes barely separated; reminiscent of process of *Marginifera*. Much of internal surface finely papillate.

Internal features of pedicle valve unknown.

Remarks: The diagnosis has been emended to embrace important internal features shown by local representatives of the type species. The specific identity with the type species of these local specimens is considered certain. Two other local species of this genus also show essentially the same internal features.

Species of *Krotovia* may show weak incipient costae over the anterior parts of the shell in some specimens, owing usually to the elongation of the spine bases. Mainly because of this, it has been suggested that *Krotovia* overlaps with *Avonia* (Paeckelmann, 1931, p. 77; Prendergast, 1943, p. 30). If the presence or absence of radiating costae is taken as the criterion of distinction between the two genera, very few species are involved in this overlap. By and large, the absence of costae is a sure indication of *Krotovia*, their presence an indication of *Avonia*. This distinction is sufficiently constant and can be applied to so many species which, collectively, range over a wide stratigraphic interval, that it does not seem necessary to regard *Krotovia* as a subgenus of *Avonia* as has been done by Paecklemann (1931).

KROTOVIA MICRACANTHA (Hosking).

Pl. 7, figs. 16-18; pl. 9, figs. 20, 21.

1933—*Pustula micracantha* Hosking, *J. Roy. Soc. W. Aust.*, 19, 49-50, pl. 4, figs. 4a, b.

1943—*Krotovia micracantha* (Hosking); Prendergast, *J. Roy. Soc. W. Aust.*, 28, 30.

Lectotype (chosen here from author's syntypes, G.S.W.A. 1/4970(b)): Hosking (1933) pl. 4, figs. 4a, b; creek ½ mile west of Callytharra Springs, Wooramel River, Carnarvon Basin. Callytharra Formation.

Diagnosis: Small *Krotovia*-species with pedicle valve of low convexity, wider than long. Ornamentation includes faint concentric folds over ears and posterior portion. From dorsal aspect ears set off as distinct platforms. Distinguished from *K. spinulosa* (Sowerby) and species similar to this by lesser convexity of pedicle valve, wider outline and more numerous spines.

Description: Dimensions of the syntypes are as follows. No accurate estimate of the height can be given.

—	1.	2.
Length of hinge	12.5	14
Width	17	17
Length	14	13.5
Curvilinear length	25	23

The shell is small, thin-shelled, broader than long, with an outline oval to subquadrangular, the hinge being almost equal to the greatest width, which occurs across the middle. The pedicle valve is only moderately convex, fairly evenly so except at the anterior margin, which is subgeniculate. Transversely the convexity is also even over the median portion, tending to be steeper on the lateral slopes. No median sinus. The umbo is small, pointed, and only a little incurved, not overhanging the hinge. The alar extremities are not marked off on the pedicle valve, but on the brachial valve are more obvious, forming a distinct platform. The alar angles are just a little more than right angles.

Over the visceral part the brachial valve is concave, but less than appears to be so in the specimens, owing to flattening during preservation. The visceral cavity is thin, of the *Producti typici B* type. The valve is flattened over the alar extremities, the lateral edge of the platform being slightly upturned. Externally this valve is not geniculate. There is no area on either valve.

The ornamentation consists of spines, faint growth wrinkles, and concentric folds over the ears and extreme posterior part of the shell. On the pedicle valve the spines are numerous, fine, arranged in fairly regular quincunces. For the most part they are suberect, but along the cardinal margin and on the ears they are more reclined. In a space five by five millimetres over the middle of the visceral disc there are about 20 spines. On the ears and over the umbo there are about eight rows of concentric folds. They are not at all prominent and do not persist over the middle and anterior parts of the valve. The ornamentation on the brachial valve is the same as that on the pedicle valve.

Internally, the brachial valve has a short prominent median septum extending less than half-way to the anterior margin, ending as a high projecting ridge. Posteriorly it merges into a platform on which rests the short boss-like simply bilobed cardinal process. Lobes are short and markedly diverging at 90 degrees. A strong marginal ridge arises immediately anterior to the lobation, about one millimetre behind the edge of the hinge. Each ridge goes off laterally at 20 degrees, demarcating the ears, swings parallel to the lateral margin and very close to it, finally becoming less prominent and linking with its companion at the anterior. Its lesser prominence is due to its partial replacement by anteriorly directed spikey pustules. This marginal structure gives an appearance of internal geniculation. Adductor muscle impressions are smooth, non-dendritic, situated immediately either side of the median septum just in front of the platform of the cardinal process and level with it. Each impression is divided into a smaller posterior portion, oval-shaped antero-laterally, and a larger more elongated anterior portion. The anterior edge of each, at the median septum, is very raised, laterally becoming part of the flattened general surface of the valve (the visceral disc). Brachial impressions are hook-shaped, not very large, arising at the antero-lateral edge of the anterior portion of each muscle impression, that is, tending to be strophalosiinid. Internal features of pedicle valve are unknown.

Variation in the Species: The small number of specimens gives no idea of the variation in the species.

Comparison with other Species: This species appears to resemble most closely another local species, *K. senticosa.* On the available specimens *K. micracantha* may be distinguished from *K. senticosa* by the presence of ears forming a prominent platform on the brachial valve, and by the less prominent umbo not marked off from the lateral slopes.

It differs from the type species *K. spinulosa* (Sowerby) in its outline, less crowded spines and less swollen umbonal region.

Remarks: This species was originally described on the basis of three specimens. Only a few other specimens have since been found. The above description includes details of internal features not part of Hosking's original description. It also differs in minor detail. Thus the pedicle valve is described as subgeniculate rather than as having a "well-marked geniculation"—Hosking's phrase. The geniculation is actually slight but has been unduly emphasized by preservation. Again, Hosking did not note the absence of any cardinal area, important in this species, as the shape and ornamentation is very similar to some of the local *Strophalosia*-species. I follow Prendergast in referring the species to *Krotovia* rather than *Pustula.*

KROTOVIA SENTICOSA (Hosking).

Pl. 7, figs. 11-15.

1933—*Pustula senticosa* Hosking, *J. Roy. Soc. W. Aust.*, 19, 47-49, pl. 3, figs. 2-3.

1943—*Krotovia senticosa* (Hosking); Prendergast, *J. Roy. Soc. W. Aust.*, 28, 30.

Lectotype (chosen here from original author's syntypes G.S.W.A. 1/4970 (a)): Hosking (1933b), pl. 3, figs. 2a, b; creek ½ mile west of Callytharra Springs, Wooramel river, Carnarvon Basin. Callytharra Formation.

Diagnosis: Krotovia-species of broad oval outline, characterised in particular by its attenuated, pointed and incurved umbo, its breadth and comparatively shallow pedicle valve. Differs from *K. spinulosa* (Sowerby) and *K. micracantha* (Hosking) as outlined in the diagnosis of the latter species.

Description: The dimensions of the three types are—

—	1.	2.	3.
Length of hinge-line	24	18.5	17
Width	31	27	23
Length	23.5	21.5	17
Curvilinear length (approx.)	31	30	25
Height	..	..	..

The shell is of medium size, thin-shelled, oval to subquadrate in outline, broader than long, the hinge-line four-fifths the greatest width, which occurs across the middle. The pedicle valve is of shallow to moderate convexity, the exact degree difficult to judge owing to flattening of all specimens available.

It is most convex in the umbonal region, tending to flatten out anteriorly. Transversely it is of the same order of convexity but evenly so. There is no median sinus. The umbo is pointed and incurved, not swollen and, near the tip, is sharply delimited from the umbonal slopes. The umbonal angle is less than a right angle. There are no true ears, the alar extremities being somewhat flattened but not markedly differentiated from the rest of the valve. The alar angles are obtuse.

The concavity of the brachial valve is difficult to determine because of flattening, but almost certainly is less than appears in the specimens. It is at least of moderate concavity, tending to follow the pedicle valve, giving a visceral cavity of the *Producti typici B* type. There is no area on either valve.

The ornamentation consists of spines and faint growth lines. On the pedicle valve the spines are fine, erect or suberect, arranged in approximate quincunces. Over the middle portion there are about forty-five to the square centimetre. The alar extremities are free of spines. The growth lines are best observed on the alar extremities but even here are quite faint. There is no other concentric ornamentation. The ornamentation on the brachial valve corresponds to that of the pedicle valve, the spines being perhaps less numerous, up to forty in a square centimetre.

The internal features in the pedicle valve are unknown. In the brachial valve they are but poorly exposed, and then in only one specimen. From this specimen Hosking, in her original description, described the following internals:—"The cardinal process is short and very broad considering the small size of the pedicle umbo. On the ventral surface it is divided by a broad furrow into two rounded prominences, each of which bears a cup-like depression at the posterior end. Below the cardinal process is a fine thread-like median septum which extends a little over a third of the length of the shell. A brachial ridge, faintly seen, extends downwards and outwards from the base of the cardinal process in a gently sloping curve to the level of the anterior end of the median septum where it curves upwards again and ends at about two millimetres from the septum at about the middle of its length." Re-examination does not reveal anything which could be truly said to be a brachial 'ridge' or impression. The nature of the cardinal process is essentially as described by Hosking.

Variation within the Species: The small number of specimens prohibits any real estimate of variations in feature.

Comparison with other Species: This species may be distinguished from *K. spinulosa* (Sowerby), which it resembles, by the less prominent umbonal region, by its much larger size and broader outline. A comparison between *K. senticosa* and *K. micracantha* has been made in the description of the latter species.

Remarks: Members of this species, like *K. micracantha,* appear to be rare in local Permian sediments. Since the collection of the three types, only a few additional specimens have been found. This may, however, be due to the lack of intensive collecting.

KROTOVIA SPINULOSA (J. Sowerby).

Pl. 7, figs. 19-24.

1814—*Productus spinulosus* J. Sowerby, MINERAL CONCHOLOGY OF GREAT BRITAIN, 1, 155, pl. 68, fig. 3.

1860—*Productus spinulosus* J. Sowerby; Davidson, *Palaeontogr. Soc. Monogr.*, British Fossil Brachiopoda, 2 (5) 4, 175, pl. 34, figs. 18-21.

1914—*Pustula spinulosa* (J. Sowerby); Thomas, *Mem. geol. Surv. U.K., Palaeont.* 1, 314, pl. 18, figs. 7-9, pl. 19, figs. 7-8.

1930—*Krotovia spinulosa* (Martin) *sic;* Muir-Wood, *Ann. Mag. nat. Hist.*, (10), 5, 106 (mistake in author of species).

1943—*Krotovia spinulosa* (J. Sowerby); Prendergast, *J. Roy. Soc. W. Aust.*, 28, 30, pl. 4, figs. 11-13.

Holotype: Location unknown, listed as Royal Scottish Museum, Edinburgh, Fleming Collection. Carboniferous Limestone, West Lothian, Linlithgowshire (*fide* Prendergast, 1943).

Material: Includes Aust. Mus. F.37579, ¼ mile west of shale outcrop, northern bank of Minilya River—probably west of Coolkilya Pool. Probably Wandagee Formation. F.38442, F.38443, F.38446, Wandagee Station. Probably Wandagee Formation. U.W.A. 27224, 27335, north-west side of syncline, west of Coolkilya Pool, north bank of Minilya River. Topmost part of Wandagee Formation. U.W.A. 27413, north-east side of same syncline, same locality as 27224. Base of Wandagee Formation. U.W.A. 28145, 29415, probably few hundred yards south-east of Wandagee Hill, Mungadan Paddock, Wandagee Station. Coolkilya Greywacke. U.W.A. 28444, 350 yards west of a place on fence between Barrabiddy and Weer Paddocks, 2,200 yards south of gate in fence near Barrabiddy Creek, Wandagee Station. Upper Cundlego Formation. All the above localities are in the Carnarvon Basin.

Diagnosis: Krotovia-species with pedicle valve non-sinuate. Umbo small, pointed, slightly overhanging hinge. Ornamentation of fine suberect spines arranged subquincuncially. Cardinal process short, bilobate. Adductor muscle impressions platform-like, non-dendritic. Distinguished from *K. opuntia* (Waagen) by its shorter hinge-line, fewer spines.

Description: The following table of dimensions is typical for specimens of this species.

—	F.38443.	F.38446.	U.W.A. 27413.
Length of hinge	12	12.5	14
Width	17	17	17
Length	17	15.5	14.5
Curvilinear length	27	27	23
Depth	5	5	4

The shell is small, oval, thin, usually wider than long, the hinge less than the greatest width, which occurs across the middle. The pedicle valve is moderately convex, most strongly so over the initial half, non-geniculate and non-sinuate. The transverse curve is highest over the middle, flattening towards the margins. The visceral cavity is thin, the brachial valve moderately concave, falling rapidly away immediately below the umbo. There are no true ears, although on the brachial valve the alar extremities tend to be flattened. Alar angles are rounded, a little more than a right angle. The umbo is pointed, overhanging the hinge-line, and is not globose. The umbonal angle is a little less than a right angle. There are no cardinal areas. The hinge-line forms a very shallow V, the apex of the V pointing posteriorly; each limb is straight, forming with the other an obtuse angle of about 170 degrees.

The ornamentation on the pedicle valve consists essentially of numerous spine-bases, 20-25 in 5 mm. square, over the middle part of the valve. They are pustular and bear fine spines (coarse in comparison with size of the shell), one-half millimetre in diameter at the base. They are suberect for the most part, but are erect on the alar extremities. Spines preserved on one specimen are up to one centimetre long and taper gradually. The arrangement is subquincuncial.

On the brachial valve are spines similar to those of the pedicle valve but tending to be finer in size. Growth rings are few and not prominent, seen more readily on the brachial valve than on the pedicle valve. Preparation of specimen F.37579 showed important internal features of the brachial valve. The valve is thickened just in front of the middle of the hinge. The cardinal process is peg-like, continuous with the plane of this thickened part, and projects only 2 mm. behind the hinge. The extremity is set off by a cincture, bilobate, the small squat lobes barely separated. The dorsal surface could not be seen. The non-dendritic adductor muscle impressions are deltoid in shape, each impression set off over the anterior part by a sulcus in which the median septum arises. The anterior edge of each impression ends as a slight ledge, but laterally merges into the general surface. The median septum is slight, highest posteriorly, dying out about half-way over the visceral disc. The remaining surface is finely papillated. Brachial impressions could not be traced.

Variation in the Species: This species is very stable in its features. The only noteworthy variation seems to be in the number of spines. Even this is within narrow limits, as can be seen from the estimate given above.

Comparison with other Species: K. opuntia (Waagen) from the Salt Range is the only other species to which this one might be closely compared. Waagen's species is, however, rather more inflated than *K. spinulosa,* its hinge-line much wider and its spines more nodular and less numerous.

Remarks: The above description is based on the local material and is given in detail to show how closely the description fits that of the typical European *K. spinulosa.* The variation, particularly of ornamentation, is not as great as in the European forms. Thus there are no counterparts showing the coarser,

more nodular spine bases typified by "*Producta granulosa*" Phillips (see Davidson, 1861, pl. 34, figs. 20, 21) which is considered conspecific with *K. spinulosa.*

I have no doubt on the identity of this species, the type species of *Krotovia.* For this reason the description of certain important internal features, hitherto unknown, is inserted in the diagnosis of the genus.

Material: Twenty specimens, for the most part well preserved, one prepared to show the internal features of the brachial valve.

KROTOVIA sp. ind. A.

Pl. 9, figs. 22, 23.

Material: One specimen, C.P.C. 1952, Pell's Range, 14½ miles north-east of Towrana Homestead, army map co-ordinates 336,500 east-1,853,200 north, Carnarvon Basin. 118 feet above base of Callytharra Formation.

Description: The single specimen available shows the presence of a fourth species of *Krotovia* in the West Australian Permian. It is quite distinct from the other three described. In shape and size the specimen resembles local representatives of *K. spinulosa* (Sowerby), but is distinguished, as it is from the other two species, by the possession of more numerous and finer spines. Moreover, these spines, particularly in the brachial valve and the anterior parts of the pedicle valve, tend to be concentrically arranged. The brachial valve shows many fine concentric lines of growth. Dimensions are: width of hinge, 12.5 mm.; width, 17 mm.; length, 14.5 mm.; curvilinear length, 22 mm. Internal features unknown.

More and better preserved specimens will certainly show this to be a quite distinct species and permit more accurate comparison or identification with species from other areas.

Genus LINOPRODUCTUS *Chao.*

1927—Chao, *Palaeont. sinica,* ser.B, 5 (2), 128.

1928—Chao, *Ibid.,* 5 (3), 63.

1931—Paeckelmann, *Abh.preuss.geol.Landesanst.,* N.F., 136, 75, 206.

Type Species: Productus cora d'Orbigny, 1842, *Voy. Amer. Merid., Paleont.,* 3, 55, pl. 5, figs. 8-10.

Definition: Thin-shelled productinids with pedicle valve convex to varying degrees, often strongly so; brachial valve flat or slightly concave in visceral portion, sometimes geniculated. Visceral cavity large and deep. Hinge-line equal to or less than greatest width. Ears generally small and demarcated from rest of shell. No cardinal areas. Pedicle valve may be sinuate. Umbo usually pointed, not greatly incurved.

Surface ornamentation of fine radiating striae, sometimes with concentric wrinkles which are stronger on the brachial valve. Double row of spines along the hinge, but spines may or may not be present over the body of the shell.

Pedicle valve with marginal ridges weak and muscles weakly impressed. Adductor muscle scars dendritic. Median septum present in dorsal valve. Cardinal process prominent, possibly trilobed. Lateral ridges may be present.

Remarks: At first given subgeneric rank, Chao later raised *Linoproductus* to a full genus and most subsequent authors have followed suit—with the notable exception of Licharew (1936). He would retain it within the genus *Productus* in the strict sense (not that of Muir-Wood, 1930) embracing, in his comprehension, not only representatives of the groups of *Productus semireticulatus* and *P. productus,* but also *Linoproductus, Thomasina, Plicatifera* and *Horridonia.*

Although *Linoproductus* has been so generally accepted, it is still not at all clear just what species constitute it, or what combination of features define it. This uncertain status was largely occasioned by the erection in 1928 of the genus *Cancrinella* by Fredericks, with genotype *Productus cancrini* de Koninck (*Productus cancrini* de Verneuil by original designation—de Koninck is to be regarded as the author of this species; see Hill, 1950). Both explicitly and by direct inference *Cancrinella* overlaps *Linoproductus.* If it were clear that those species referred to *Cancrinella* constituted a natural group unwisely included by Chao within his *Linoproductus,* this would not be so very important, but it is not clear that this is so. It should be noted, however, that Chao (1928, p. 63) considered that the genus was made up of three 'sub-sections', the second of which, the *cancrini-series,* would seem to approximate to *Cancrinella*; but although Chao obviously was aware of Fredericks' *Cancrinella* this was the most he would concede towards recognizing it.

Since 1928 the rejection or not of *Cancrinella* has largely been a matter of personal choice on the part of authors. Most prominently, Dunbar and Condra (1932) consider it distinct from *Linoproductus,* whereas Paeckelmann (1931) and Licharew (1936) reject it (with other genera) as synonymous with the latter genus. The first two authors claim as the distinguishing features the small size, rugosity, thin shells and very thin visceral cavity of species they assign to *Cancrinella.* One of these, the species *cancriniformis,* to cite only one aberrant from their stipulation, is not particularly small; the degree to which the shell is wrinkled (rugosity) varies greatly; and the visceral cavity is not 'very thin'. In general all these distinguishing features are features of great variation, both in individual members of species and from species to species of those making up *Linoproductus* in general. On the other hand, Paeckelmann regards *Linoproductus* " (plus *Striatifera* Chao emend. 1928) and *Cora* (plus *Cancrinella*) " as synonymous, his argument being that the differences of sculpture (the primary feature) are of degree only and not sufficient to justify their separation.

It seems that, in the absence of more objective evidence, this question must remain open. This being allowed, it is best to adopt a conservative approach and hence—and not because it is thought that the name should be rejected—the name *Cancrinella* is not used.

LINOPRODUCTUS CANCRINIFORMIS (Tschernyschew).

Pl. 8, figs. 1-9.

1889—*Productus cancriniformis* Tschernyschew, *Mém. Comm. géol. St. Petersb.*, 3 (4), 373, pl. 7, figs. 32, 33.

1890—*P. undatus* Defrance; Foord, *Geol. Mag.*, (7), 152, pl. 7, fig. 6.

1897—*P. cancriniformis* Tschernyschew; Diener, *Palaeont. indica, Himalayan Fossils,* 1 (3), 25, pl. 6, figs. 6a-b, 7a-d.

1897—*P. cancriniformis* Tschern.; Diener, *Palaeont. indica, Himalayan Fossils,* 1 (4), 31, pl. 1, figs. 7-10.

1907—*P. undatus* Defrance; Etheridge fil., *Bull. geol. Surv. W. Aust.*, 27, 30.

1916—*P. cancriniformis* Tschern.; Broili, in Wanner, J., *Paläont. Timor,* 7 (12), 13, pl. 116, fig. 6.

1918—*P. bellus* Eth. fil., *Proc. S. Aust. Br. R. geogr. Soc. Aust.*, 18, 254, pl. 39, fig. 4-5; pl. 40, fig. 6.

1927—*Linoproductus cancriniformis* (Tschern.); Chao, *Palaeont. sinica,* Ser.B., 5 (2), 139, pl. 14, fig. 13.

1928—*Cancrinella cancriniformis* (Tschern.); Fredericks, *Trans. geol.-prosp. Serv. U.S.S.R.*, 46 (7), 791 (English Summary).

1943—*Linoproductus cancriniformis* (Tschern.); Prendergast, *J. Roy. Soc. W. Aust.*, 28, 23.

Specimens (in part): Aus. Mus. F.38453-38457, Minilya River, Carnarvon Basin. Wandagee Formation. U.W.A. 28516 (7 specimens), south of Wandagee Station, Carnarvon Basin. Wandagee Formation. U.W.A. 27568, west side of syncline south of Minilya River, Wandagee area, same general locality and formation. U.W.A. 27127, 27128, 27165, same locality and horizon. U.W.A. 29248, 1 mile south of north-west corner of Calwynyardah Station, Mount Wynne area, West Kimberley District. Liveringa Formation. In addition there are several hundred of C.P.C. specimens.

Diagnosis: Linoproductus-species of variable shape and convexity, with geniculate brachial valve, and with double row of spines along the hinge-line.

Distinguished from *L. undatus* (Defrance) by its geniculate brachial valve.

Description: Dimensions of some typical specimens are—

—	F.38457.	F.38455.	U.W.A. 27127.
Length of hinge-line	19	24	14
Width	23	27.5	20.5
Length	20.5	30	20
Curvilinear length	35	57	30
Height	9.5	..	7.5

The Western Australian representatives of this species are extremely variable in their characteristics. The visceral cavity is large, the convexity of the pedicle valve varying from low to moderate, particularly in the initial

stages. The umbo is generally pointed, overhanging the hinge-line, but not greatly incurved. The umbonal flanks vary from relatively steep and narrow to broad and flat. The ears are flat, distinct, but continuous with the lateral margin. The lateral flanks may be steep. Thus the shape varies from narrow, highly convex, to broad triangular and only moderately convex. The hinge-line may be equal to the greatest width, more so in swollen specimens.

Ornamentation on this valve consists of fine striae, 8-9 in 5 mm. at a distance of 10 mm. from the umbo. These striae are sometimes flexuous; at intervals they give rise to swollen, elongated, raised and erect spine-bases.

It is rarely that a single stria gives off more than one spine in its length. The total number of spines varies, larger specimens showing up to 50-60. The arrangement can be described as sub-regular or sub-quincuncial.

The concentric wrinkles are strongly developed on the ears and persist over the visceral disc. They vary in size and strength, but this is probably an effect of preservation.

Two rows of spines along the hinge-line can be seen only on the best preserved specimens.

The brachial valve is as described in the diagnosis. It is never deeply concave so that in comparison with the overall size the visceral cavity is large.

The internal features of this species have never been described. The Western Australian representatives show a median septum, thin and not greatly elevated, extending for about one-half to two-thirds of the distance to the point of geniculation. It widens posteriorly, becoming almost platform-like, to give a small button-like blunt cardinal process which projects hardly at all behind the hinge. From the ventral aspect it is bilobed, the lobation not marked, the lobes separated by a narrow incision which does not continue over the posterior surface. Each lobe is spooned-out by a shallow depression on the dorsal side, leaving a raised portion between, so that from the posterior aspect the process rather appears trilobed. The process does not appear to be demarcated from the rest of the surface by a sulcus. Moderately developed marginal ridges run from the base of the cardinal process at a small angle to the hinge-line. The ears are flat, and quite distinct from the rest of the visceral disc, which, from the intervior view, is arched, slightly convex. The wrinkles on the outside of the valve are well-marked, also in the anterior. In particular the lateral boundary of the ears is sharply defined by a wrinkle which continues around the margin, less emphasized at the point of geniculation. On the antero-lateral and anterior borders it bears numerous fine prickly pustules, which are also found on the wrinkles over the trail. None of the specimens show the nature of the brachial impressions, if any. The interior of the pedicle valve is unknown.

Variation within the Species: The Western Australian material shows a wide range of variation in most characteristics. The main variable features are—

(i) The degree and nature of the convexity of the pedicle valve. In this feature the specimens fall into two extremes, and intergrading forms. In one the valve exhibits a high degree of convexity from the first and is thence evenly

curved. In the other the degree of convexity is much less, the convexity increasing after the visceral disc. The variability in this respect then results in two main groups, one swollen, the other moderately convex.

(ii) The size and proportions of the umbo. Variation in this feature follows naturally upon that of the first. Specimens of higher convexity have swollen umbonal regions, so that up to one-third of the visceral cavity lies behind the hinge; those of the second group have more narrow, flatter umbonal regions. There are intergrading forms.

(iii) The steepness of the flanks. Variation in this feature also may be similarly correlated. Swollen, evenly convex, forms have steep flanks, more or less parallel-disposed and wall-like; the less bulbous forms show more gently sloping flanks.

(iv) The outline of the shell varies from elongate oval (swollen forms with steep flanks) to more quadrate (moderately convex with fairly low even transverse curvature).

Characteristics exhibiting more or less haphazard variation are the striae (flexuous to varying degrees); the number of spines and their arrangement; the angle at which they rise from the surface (in better preserved specimens the spines rise at angles up to about 45 degrees; casts and poorer specimens show only the flat-lying spine bases); and the relative abruptness of geniculation.

Young forms of this species are somewhat more globose than mature forms, the wrinkling is very marked, and the hinge-line occupies the greatest width of the shell.

Comparison with other Species: Although the original description by Tschernyschew was sketchy, examination of the relevant literature shows that this species is extremely variable and our material seems to come within the range of variability inferred by the original and later authors.

In 1918 Etheridge gave the name *Productus bellus* to a species from near Mount Marmion, in the West Kimberley District. As Prendergast points out (1935, p. 14) this form is actually *L. cancriniformis*, identical with the specimens here described.

Remarks: As was inferred in the discussion upon the variation of this species, it is possible that there may be two varieties (subspecies) here. The intergrading specimens are few in number, nor is their comparative rarity readily attributable to the exigencies of collecting. Both extremes of variation, however, can be found in the same rock slab. Bearing such apparent cohabitation in mind, and in the absence of any known isolating mechanism, it has been thought preferable to designate the whole as *L. cancriniformis*. The description has been a detailed one because of the uncertain status of the species and because of the possibility that the Western Australian forms may prove to be distinct if a revision of the species is undertaken.

Material: Several hundred specimens, many well preserved and including casts showing external and internal features.

LINOPRODUCTUS CORA (d'Orbigny).

1842—*Productus cora* d'Orbigny, *Voy. Amer. Merid., Paléont.*, 3, 55, pl. 5, figs. 8-10.

1914—*Productus cora* d'Orbigny; Kozlowski, *Ann. Paléont.*, 9, 48, pl. 4, fig. 19; pl. 5, fig. 5; pl. 6, figs. 1-10; text-fig. 8.

1916—*Productus cora* d'Orbigny; Broili, in Wanner, J., *Paläont. Timor*, 7, (12), 19, pl. 115 (1), fig. 14-15; pl. 116 (2), figs. 1-3.

1927—*Linoproductus cora* (d'Orbigny); Chao, *Palaeont. sinica*, Ser. B, 5 (2), 132, pl. 13, figs. 17-18; pl. 14, figs. 1-4.

1927—*Productus cora* d'Orbigny; Diener, *Leitfossilien*, Lief. 5, 24; Berlin.

1936—*Productus cora* d'Orbigny; Licharew, *Monogr. Palaeont.*, U.S.S.R., 39, 29.

1943—*Linoproductus cora* (d'Orbigny); Prendergast, *J. Roy. Soc. W. Aust.* 28, 20.

For complete synonymy *see* Broili (1916), Diener (1911), Licharew (1936), Branson (1948, p. 385).

Diagnosis: Linoproductus-species extremely variable in most features characterized especially by concentric folds on ears only. Adductor muscle impressions dendritic. Cardinal process trilobed. Distinguished from *L. tenuistriatus* (de Verneuil) by coarser ornamentation and greater convexity of pedicle valve.

Description: The confusion resulting from d'Orbigny's incomplete original description of specimens of *Productus cora* from Bolivia was not overcome even by the detailed re-description of topotypic material by Kozlowski in 1914.

This is probably due to the reluctance of many palaeontologists to accept a species distinguished by a great range of variation and persistence over such great areas and periods of time—features to which Kozlowski drew particular attention in his re-description. The description to follow will only elaborate on those features of the preceding diagnosis which need it (for a full description *see* Kozlowski, 1914).

The size of the shell varies—it may often attain relatively large dimensions. The degree of convexity in the median region of the pedicle valve varies but is mostly strong so that the visceral cavity is large. The beak is nearly always small, generally strongly incurved and overhanging the hinge-line. The transverse curve of the pedicle valve is usually entire and rarely impressed by a broad and shallow median sinus. There is never a median fold in the brachial valve. The umbonal angle is rarely greater than 90 degrees. The flanks are most often steep, forming a large angle with the flat plane of the ears. They flatten anteriorly and antero-laterally so that the frontal margin tends to be splayed-out, but this part of the shell is rarely preserved.

Ornamentation consists of fine rounded striae variable in intensity, sub-parallel, flexuous or irregular, sometimes showing all three arrangements in the one specimen.

A row of moderately thick spines is usually present along the hinge-line. On the body of the valve the number of spines is variable but never great. The confluence of one or more striae may give rise to a spine. The concentric folds or wrinkles on the ears rarely cross the visceral disc and if so are very faint.

The surface of the brachial valve may show faint growth lines.

The median septum runs the length of the visceral disc, the oval dendritic adductor impressions lying either side of it. The diductor impressions form large but narrow bands on the lateral sides of the adductor impressions. The rest of the interior reproduces the exterior ornamentation, although the striae are larger, flatter, and the interspaces narrower.

The median lobe of the cardinal process is larger than the lateral lobes and is concave from the internal aspect. The median septum may be separated from the base of the cardinal process by a shallow depression. The cardinal process lies either parallel to the general surface of the visceral disc or points inwards, forming a small angle with it.

Kozlowski sums up the principal variable features as—

(i) the shape of the shell;
(ii) the degree of convexity of the pedicle valve;
(iii) the incurvature of the beak;
(iv) the steepness of the flanks;
(v) the presence or absence of a median sinus;
(vi) the regularity and size of the striae;
(vii) the number of spines;
(viii) the concavity of the brachial valve.

These are the principal variable features only. It is no wonder, then, that confusion arises in endeavouring to decide whether or not a similar form under study comes within the limits of variability of *Linoproductus cora.*

Remarks: Faced with such a problem some workers seem to have decided on narrow limits of their own choosing; some have accepted the extremely wide limits of variation as laid down by Kozlowski and Diener (1911); but few have accepted this species without question. There are at least two attitudes to adopt in the endeavour to find a solution to such a problem as this. Firstly, the palaeontologist must accept the possible fact that there have been such species, of great variability, widespread in area and stratigraphical range. Most palaeontologists are reluctant to accept this notion. There is, however, little evidence, from genetics or other neozoological study, to prohibit such *rare* occurrences. The main objection seems to be that other such seemingly variable and widespread species have eventually been "split" with apparent success and validity—the argument from past usage and experience.

The second attitude, less common nowadays, is to plead that the occurrences of what seems to be the same species in far distant places and over great stratigraphical intervals are due to parallelism in development. Even when such a suggestion is coupled with the proviso that this can be decided only after

a study of the relative ontogeny of the species (see Chao, 1927, p. 130), it hardly agrees with the latest findings of geneticists and zoologists. Indeed, the parallel development of particular species of the same genus seems most improbable.

The most satisfactory solution to this ever-recurring problem, and one most advocated by palaeontologists disturbed at the snowballing increase of new names, is that if a reasonable doubt exists in the mind of the inquirer as to the mutual identity of two forms then either infra-specific categories or, preferably, a comparative abbreviation, can express the doubt.

Both Kozlowski (1914) and Diener (1911) included in *Linoproductus cora* such forms as "*Productus*" *lineatus* Waagen, "*P.*" *neffedievi* de Verneuil, and "*P.*" *ovatus* Hall. No opinion as to the correctness of their judgment can be expressed here, but others have questioned such a grouping (Chao, 1927, p. 129; Dunbar and Condra 1932, p. 243).

In Western Australia *L. cora* occurs only as the variety *foordi* (Etheridge fil.) and is described below.

LINOPRODUCTUS CORA FOORDI (Etheridge fil.).

Pl. 8, figs. 10-15.

1890—*Productus tenuistriatus* de Verneuil; Foord, *Geol. Mag.* dec. iii, 7, 151, pl. 7, figs. 4, 4a.

1903.—*P. tenuistriatus* de Verneuil, var. *foordi* Etheridge fil., *Bull. geol. Surv. W. Aust.*, 10, 19, pl. 1, figs. 3, 4; pl. 3, fig. 22.

1910—*P. tenuistriatus* var. *foordi* Eth. fil., Glauert, *Bull. geol. Surv. W. Aust.*, 36, 37.

1931—*P. tenuistriatus* var. *foordi* Eth. fil., Hosking, *J. Roy. Soc. W. Aust.*, 17, 8, 22.

1943—*Linoproductus cora* var. *foordi* (Eth. fil.) Prendergast, *J. Roy. Soc. W. Aust.*, 28, 22, pl. 3, figs. 3-5.

Specimens (in part): G.S.W.A. 1/4683; south bank of Wooramel River below Callytharra Springs, Carnarvon Basin. Callytharra Formation. Aus. Mus. F.36247, 36251-36255 incl., Gascoyne River, near Winnemia, Carnarvon Basin. Stratigraphic position uncertain. U.W.A. 10822; Fossil Cliff, Irwin River, near Mingenew. Fossil Cliff Formation. U.W.A. 23438a, b, c; same locality and horizon.

Diagnosis: Similar to *Linoproductus cora* (d'Orbigny) but smaller, without spines on main part of pedicle valve.

Description: The revised description of this form given by Prendergast requires no additional remarks, and is as follows:—

"The pedicle valve has an elongated oval outline in the larger specimens. It is gibbous in the visceral region falling rapidly at the sides to small, flat ears, and truncated posteriorly by a small umbo overhanging the hinge-line. Anteriorly there is a decrease in the curvature so that the shell is elongated rather than globular. A row of spines along the hinge, at about 10 degrees to the cardinal margin terminates in a group of from 4-6 spines on each ear. No

spines occur on the rest of the shell. The longitudinal striae are fine (20-40 measured over a breadth of 20 mm. at a distance of 10 mm. from the umbo) and vary in irregularity. On some specimens they may run almost parallel for the length of the shell but more usually two or more unite and re-divide later, having an irregular course. The striae increase by intercalation and this takes place in most specimens at about the same stage of growth. The amount of increase, too, varies, one or two striae being intercalated between a pair of primaries. Folds on the ears are not seen on the majority of specimens and where they are present never cross the visceral part of the shell.

"The brachial valve is concave, the ornamentation as in the pedicle valve, but crossed by concentric wrinkles. The valve is devoid of spines.

"The sizes of the specimens (pedicle valves) are shown by the following table:—

—	1.	2.	3.	4.	5.	6.
Height	29.1	22.8	31.0	23.7	23.0	14.1
Maximum width	29.4	25.1	27.0	27.0	24.0	13.3
Length of hinge-line	22.9	20.2	19.8	25.0	18.6	13.3
Curvilinear length	50.0	39.3	56.0	41.1	35.5	21.8

No specimens examined have both valves in position; it is thus impossible to estimate the thickness of the shell.

"The width of the hinge-line as shown by these figures is less than the maximum width of the shell. The ears in these specimens are very fragile and readily break off; the only complete specimen is a small one (No. 6).

"The internal structures are as described for the species *P. cora,* the muscles being inserted in definite fossae.

"*Comparison with other Forms:* These specimens have been referred for many years to *Productus tenuistriatus* Verneuil, although distinguished as a variety. Etheridge (1903) separated them as a variety, giving as his reasons the much coarser and more irregular ornamentation (in *P. tenuistriatus* there are 50-60 striae in 20 mm. at a distance of 20 mm. from the umbo). They differ from that species, too, in the width of the hinge-line, the arching of the pedicle valve and the regular anterior elongation, *P. tenuistriatus* being irregularly produced anteriorly. Etheridge has already said that this form belonged to the "*cora*" group (1907b, p. 30). Specimens from Timor (Broili, 1916, pl. cxv, figs. 15-16; pl. cxvi, figs. 1-3) probably belong to this variety of *P. cora.*

"This variety is not distinct from *P. cora* d'Orbigny. It is a variety within that species as can be seen by a comparison of Kozlowski's figures (pl. vi, figs. 7a, b) and figures accompanying this paper but a variety which has become stabilized in this area. The limits of variation are narrower than in those from South America. The shell shape is constant, as is the convexity of the pedicle valve; it is not sinuated and does not carry spines on the main part of the shell. The varietal name is retained for these specimens until the complete range of *Productus cora* d'Orbigny is seen in this country."

Remarks: Although a great many additional specimens have come to hand since this description, it needs no alteration beyond mentioning that the specimens do not show the variation in size as described by Koslowski, on the whole being a good deal smaller, as can be seen from the table of dimensions.

It does not therefore seem justifiable to regard this form as specifically distinct from *Linoproductus cora*. As Prendergast intimates it is best regarded as a geographic sub-species of d'Orbigny's species. The term "Height" in the table of dimensions, included in the quotation from Prendergast, is synonymous with "Length" as used herein.

Material: Several hundred specimens variously preserved, many excellently so; brachial valves very rare. The largest store of specimens is in the C.P.C. collection.

LINOPRODUCTUS LYONI Prendergast revised.

Pl. 8, figs. 16-22.

1943—*Linoproductus cancriniformis* var. *lyoni* Prendergast, *J. Roy. Soc. W. Aust.*, 28, 24, pl. 3, figs. 1-2.

Holotype: Aust. Mus. F.36530; 10 chains north-west of Gnarrea Pool near Winning Station, Carnarvon Basin. Lyons Group (upper part?).

Important Specimens: U.W.A. 32025, 32028, Glendevon Homestead, Woolaga Creek area, near Mingenew, Irwin River District. Fossil Cliff Formation. U.W.A. 32026, Trig. Station K.52, half way on road between Middalya and Williambury Stations, Carnarvon Basin. Callytharra Formation. U.W.A. 32027a, b, same locality and horizon.

Topotypes: Aust. Mus. F.36533, 36535, 36537, 36538, 36540.

Diagnosis: Medium-sized *Linoproductus*-species, with pedicle valve of comparatively shallow convexity, thin visceral cavity, and semicircular outline widest at hinge. Ornamentation resembles *L. cancriniformis* (Tschernyschew). Distinguished from *L. cora* var. *farleyensis* (Etheridge fil.) by its more coarsely striate ornamentation and narrower, more elongate spine bases.

Description: Dimensions of typical specimens—

—	U.W.A. 32025.	32026.	32028.
Length of hinge-line	46	38	52
Width	45	38	53
Length	35	31	58
Curvilinear length	53	40	55
Depth	9	..	..

The pedicle valve is semicircular in outline, the hinge-line straight, equal to greatest width; the valve is evenly convex, not at all globose. The ears are large, not set off from the rest of the shell, the alar angles being right angles. An outstanding feature is that the longitudinal profile is practically identical with the transverse. No median sinus or flattening. The whole surface is covered with fine radial striae (18-20 in 10 mm. at a distance of 20 mm. from the umbo) bearing swollen extremely elongated spine-bases arranged in approximate quincunx. Each stria gives rise to one spine-base. The striae are rarely flexuous, and increase by bifurcation and, more rarely, intercalation. Concentric wrinkles are particularly pronounced on the ears and lateral flanks but

often are also quite marked on the body of the shell. A row of coarse spines diminishing in size towards the umbo is sometimes found on the hinge-line, depending on the preservation. They are long and flexuous and point posteriorly.

The brachial valve is slightly concave and geniculated to form a trail. The largest trail measured was 15 mm. long. The brachial valve is sometimes distinguished by a narrow zone of reverse curvature around the edge of the visceral disc just before geniculation. It is not pronounced and does not form a definite ridge. The ornamentation mirrors that of the pedicle valve, the spine-bases being represented by similarly shaped depressions. It is not certain whether or not there were fine spines as well on this valve.

Immature specimens resemble closely the larger mature form, but the convexity is possibly less marked.

One specimen, U.W.A. 32025, shows something of the internal features, unfortunately not clearly enough for good photographic reproduction. The median septum is high and narrow, arising just anterior to the base of the cardinal process but not contributing to it, and persisting half-way across the visceral disc. The cardinal process is short, wide, barely projecting behind the hinge. It is trilobed, the median lobe the largest, the lateral lobes knob-like, projecting out from the median lobe. A pair of short but well defined marginal ridges run off along the hinge, from the base of the process, one each side. They persist only half way to the alar extremities. Nature of muscle impressions and brachial impressions (if present) is unknown.

Variation within the Species: Members of this species are rather stable in their characteristics. As shown in the estimate above the number of striae and, therefore, the number of spine bases vary within narrow limits. This seems to be the only worthy variation.

Comparison with other Species: Representatives of this species do not come within the apparent limits of variation of *L. cancriniformis*. The only important feature the two possess in common is the type of ornamentation. Even in this respect, *L. lyoni* differs from *L. cancriniformis* in that the spines of the former are finer and less erect.

Productus koninckianus de Vern. (Chao, 1928, p. 63, pl. 5, figs. 4-7) has some features in common with this species. It is, however, much smaller, more inflated and the striae are finer. The shape is different and the umbo more inflated and incurved. *Productus tumidus* Waagen (1884, p. 708, pl. 80, figs. 1-3) is also more inflated and bears more erect and swollen pustular spines.

Productus (*Linoproductus*) *janischewskianus* Stepanov (1934, p. 39, pl. 3, fig. 23) is also similar to our species but is much more inflated and less spinose.

Linoproductus cora var. *farleyensis* Etheridge fil. (Etheridge and Dun, 1909) from the Lower Marine of the Permian of New South Wales, is a very similar species. It is rather more globose than *L. lyoni* and, in particular, the radiating striae are finer, more flexuous, two or more coalescing to give larger, more nodular spine-bases.

Remarks: The form was first described by Prendergast on pedicle valves alone as "temporarily" a variety of *L. cancriniformis,* but the collection of much more material shows that it is specifically distinct. In contrast to *L. cancriniformis* it shows little variation, and even immature forms need never be confused with any variants of *L. cancriniformis.*

The specific name was originally given as a variety name of the species *L. cancriniformis* (Tschernyschew) by Prendergast (1943).

Material: About 20 specimens, immature and mature; preservation fair to good.

Genus MARGINIFERA Waagen emend. Licharew.

1884—Waagen, *Palaeont. indica,* Ser. 13, Salt Range Fossils, 1 (4), 713.
1936—Licharew, *Monogr. Palaeont. U.S.S.R.,* 39, 100 (English translation).

Type Species: Marginifera typica Waagen, *Palaeont. indica,* Ser. 13, Salt Range Fossils, 1 (4), 717, pl. 76, figs. 4-7; pl. 78, fig. 1.

Definition: Small thin-shelled productids externally resembling *Dictyoclostus* but much smaller, with reticulate umbonal area. Characterized by an internal flange-like ridge around the visceral disc of the pedicle valve, arising from the posterior margin and generally persisting across the anterior margin. A similar ridge tends also to develop on the interior of the brachial valve, particularly on the postero-lateral borders. The adductor muscle scars in the brachial valve are non-dendritic, possibly represented by two pairs, the inner pair most prominent. The cardinal process is generally blunt and thick. Ornamentation is of costae and rugae, the latter present over the initial portion of the shell. The pedicle valve bears erect spines over the reticulated and the anterior costate portions. The ears are sharply demarcated from both dorsal and ventral aspects.

Remarks: In degree of development, the marginal ridge, the principal diagnostic feature in the original diagnosis, varies considerably among the species of this genus, and for this reason many palaeontologists were disinclined to recognize it. Licharew, however, drew attention to the fact that members of many species conceivably belonging to *Marginifera* on the basis of possessing marginal ridges also possessed a more reliable and consistent feature in common, namely, non-dendritic adductor muscle scars possibly in twin pairs (Licharew, 1936, p. 100, English translation). Review of the descriptions of such species supports Licharew's proposition, in particular as regards the non-dendritic nature of the scars, and probably also with the occurrence of each muscle impression as a pair, the inner portion raised and prominent, the outer less obvious and tending to merge into the general surface of the valve.

In the same reference and following immediately his observation on the nature of the muscle impressions in *Marginifera,* Licharew also comments on the similarity in this feature and in ornamentation between certain so-called *Marginifera* species and those of *Avonia.* He concludes that *Marginifera* "remains a very wide, probably polyphyletic genus . . .", which again is

possibly correct; but nevertheless it is not considered that there is any room for reasonable confusion between species of *Avonia* and those of *Marginifera* characterized by the type-species.

Kozlowskia Fredericks 1933, with type-species *Productus capaci* d'Orbigny, has been adopted by Stehli (1954) and discussed fully by him. The only *Marginifera*-like species here described has features, all somewhat variable in degree of development, in common with both *Marginifera* as usually understood, and *Kozlowskia* is understood by Stehli. It has been retained as *Marginifera*.

MARGINIFERA GRATIODENTALIS (Grabau).

Pl. 9, figs. 1-14.

1892—*Productus gratiosus* var. *occidentalis* Schellwien, *Palaeontographica*, Bd. 32, 24, pl. 3, figs. 6-9; pl. 8, fig. 25.

1927—*Productus gratiosus* var. *occidentalis* Schellwien; Chao, *Palaeont. sinica*, Ser. B., 2, (2), 47-50, pl. 4, figs. 11-16.

1930—*Productus gratiosus* var. *occidentalis* Schellwien; King, *Univ. Texas Bull.* 3042, 71, pl. 14, fig. 1.

1934—*Productus gratiodentalis* Grabau, *Palaeont. sinica*, Ser. B., 8 (3), 36, pl. 10, figs. 7-8.

1943—*Dictyoclostus gratiosus* (Waagen); Prendergast, *J. Roy. Soc. W. Aust.*, 28, 17-18, pl. 2, figs. 5-7.

1944—*Marginifera gratiodentalis* (Grabau); Reed, *Palaeont. indica*, N.S., 23, *Mem.* 2, 98.

Material (in part): Aust. Mus. F.37567; quarter mile east of shale outcrop, Minilya River. Wandagee Formation? F.37569-37571; bank of Minilya River, same locality and horizon. U.W.A. 27185b, c, d, e, 28183a; north-east side of syncline, north bank of Minilya River, west of Coolkilya Pool, Wandagee area. Cundlego Formation. 28453a, b; 350 yards west of a place on fence between Barabiddy and Weer Paddocks, 2,220 yards south of gate in that fence near Barabiddy Creek, south of Wandagee Station. Cundlego Formation. 27227a, b; Wandagee area. Possibly Wandagee Formation. 34443; just east of Wandagee Hill. Coolkilya Greywacke or Baker Formation. All above localities in Carnarvon Basin.

Diagnosis: Small *Marginifera*-species externally like *Dictyoclostus*. Ears distinct, demarcated from body of shell, with cardinal spines present; in these features differing from *M. gratiosus* (Waagen). Adductor muscle impressions oval, elevated, non-dendritic.

Description: The following dimensions are typical of the species:—

—	27185b.	F.37569.	27227b.	34443.
Length of hinge-line	23	26	29	22
Length	15	16	19	16
Curvilinear length	28	32	38	28
Depth	6	5	6	5

The description of the external features of this species, given by Prendergast, is as follows:—

"The shells are small to moderate in size as may be seen from the table of dimensions. They have an irregularly hexagonal outline when viewed from the pedicle side, with the hinge-line the greatest width of the shell.

"The pedicle valve has a flattish visceral disc, which, following the geniculation of the shell, passes into a regularly curved trail. Transversely the shell arch is high, indented medially by a strong median sinus and falling gradually to the lateral margins in a slightly convex slope. The umbo is small, pointed and slightly overhanging the hinge-line. The ears are small and pointed, they have a convex profile in longitudinal section. The ornamentation is reticulate on the visceral disc, the reticulation sometimes irregular due to the enlarged rugae on some specimens. The rugae do not develop anterior to the geniculation, the trail carrying costae and scattered spine-bases. The latter are rarely numerous, not more than four or five being present. The costae converge slightly towards the sinus giving a very distinct and characteristic appearance to the shell.

"The brachial valve is trapezoidal in outline, the long straight hinge-line and the anterior margin being the parallel sides. It is regularly concave with a median fold which expands towards the anterior margin. The ears are excavated to fit tightly with those of the pedicle valve. The ornamentation is reticulate over the posterior third of the shell, the rugae then develop irregularly and the ornamentation of the rest of the shell may be described as costate. The costae radiate from the umbo, those in the central part of the shell converging towards and finally coalescing on the median fold."

With a great many more specimens to hand the following external features have also been noted: the ears are rather large considering the size of the shell, and are each demarcated from the body of the pedicle valve by a ridge, along the visceral side of which are coarse spines, rarely more than two in number; this ridge is reflected on the brachial valve and sets off the platform-like nature of each ear, which often bears a single spine. If the preservation is good, the pedicle valve shows a few spines along the cardinal margin. The rugae extend for about 12 mm. over the curve of the pedicle valve, the costae at this point numbering 10-12 over 10 mm.

The internal features are as follows. In the pedicle valve the ears are smooth and reflexed, and separated from the visceral cavity by a sharp change in curvature. Just below this abrupt line of division between the ears and the rest of the shell there is a further demarcatory line of sharp, small incisions. This line, in diminished intensity, runs all round the lateral and anterior margins, and immediately posterior to it there is a pronounced groove. The shell is much reduced in thickness thereafter, so that many specimens break off around this groove, the trail appearing shorter than it really is. The incisions continue as faint lines into the body of the valve for a distance of about 3 or 4 mm. There does not seem to be any definite marginal ridge on the interior of the brachial valve which would fit into this groove. The adductor muscle impressions are situated close under the umbo. They are elevated, non-dendritic, and for the most part lie immediately either side of the ventral sinus, or fold, as it appears internally. There appears to be only one pair.

The diductor muscle impressions do not encroach on the median sinus but are restricted to the deepest parts of the visceral cavity. The rest of the surface is covered with minute pits, resulting in a densely stippled appearance.

In the brachial valve the cardinal process is blunt and thick, showing no lobation, projecting only a short distance behind the hinge. The median septum appears as only a line initially; half way it becomes more pronounced and ends as a blunt apophyse jutting out under the ventral fold, at about two-thirds of the distance from the hinge-line to the anterior edge of the visceral disc. The adductor muscle impressions are small, smooth, elevated, non-dendritic, situated just anterior to the cardinal process, one either side of the line of the median septum. Brachial impressions are distinct, arising just anterior to the adductor impressions, diverging away from the hinge at about 40 degrees to the edge of the visceral disc, recurving in hook-like fashion, returning sub-parallel to the initial limb, almost to the starting point. The marginal ridge is not distinct except at the boundary of the ears and the visceral disc. Around the anterior margin of the visceral disc it takes the form of short, ridge-like pustules, elongated antero-posteriorly. The rest of the surface is smooth.

Variation within the Species: M. gratiodentalis is remarkably stable and specimens from different localities vary only slightly. The only features showing some variation are the ventral sinus (and correspondingly the dorsal median fold) which varies in depth, and the amount of geniculation of the brachial valve; but variation in the latter may be due to varying degree of deformation during preservation.

Comparison with other Species: M. gratiodentalis is distinct externally from other Western Australian semireticulate productinids by its small size. Internally it is, of course, radically different.

The more transverse outline, larger ears, smaller number of spines over the trail, and spines along the cardinal margin are features distinguishing this species from *Marginifera gratiosus* (Waagen). The chief distinguishing feature according to Schellwien (1892)—the lateral ridge demarcating the ears from the body of the shell—is not as well developed in the local specimens as it is in the original species first described by Schellwien and redefined by Grabau, being more a "step" than a ridge. The difference however appears to be insignificant and more of degree than of kind.

The form described as "*Productus gratiosus*" Waagen by Broili (1916, p. 12, pl. 116, figs. 4, 5, 7-B) is very similar to *M. gratiodentalis* and may be identical with it.

Remarks: In her description of the Western Australian forms of this species Prendergast mentioned that the generic placement was insecure since the internal structures were unknown. Preparation of species yielded the internal characters just described, which place this species in the genus *Marginifera* Waagen, of the group of *Marginifera splendens* (Norwood & Pratten) (Waagen, 1884, p. 715).

Material: About 50 specimens, half of them in fair to excellent preservation, six showing internal features.

Genus WAAGENOCONCHA Chao.

1927—Chao, Y. T. *Palaeont., sinica*, ser. B., 5 (2), 85.

Type Species: Productus humboldti d'Orbigny, 1842, *Voy. Amer. Merid., Paleont.*, 3 (4), 54, figs. 4-7.

Diagnosis: Features essentially those of *Pustula* Thomas, with sinuate pedicle valve, and surface marked by quincuncially arranged tubercular spines in the young and adult stages, becoming smaller and more closely packed together in old age. No pronounced concentric ornamentation.

Remarks: Although Chao himself did not regard *Waagenoconcha* as being any more than a subgenus of *Pustula* Thomas, most subsequent authors have treated it as a full genus—usually without comment. Speaking of the genera *Echinoconchus* Weller, *Waagenoconcha* Chao, and *Juresania* Fredericks, Chao stated: "Whether each of the latter three series is to be regarded only as a particular group within the genus *Pustula* or is to be separated under a subgeneric designation seems to depend mainly upon the value placed on these characters by different authors". In the case of *Waagenoconcha* the "characters", in essence, may be narrowed down to the definite quincuncial arrangement of the tubercular spines, the lack of any definite concentric ornamentation and, finally, the fact that in old age the spines become finer and more numerous, the transition usually being fairly abrupt. Placing the emphasis on this last feature, Chao admitted that he adopted a narrow limitation in conferring subgeneric rank upon his form. If all three features are taken in combination, however, it is probable that *Waagenoconcha* is worthy of generic rank.

WAAGENOCONCHA IMPERFECTA Prendergast.

Pl. 10, figs. 8-14; pl. 11, figs. 1-6.

1916—*Productus waageni* Rothpletz; Broili in Wanner J., *Paläont Timor*, 7 (12), 14, pl. 118, figs. 1-5.

1924—*Productus subquadratus* Morris, Chapman, *Ann. Rep. geol. Surv. W. Aust.*, 1923, 36.

1935—*Waagenoconcha imperfecta* Prendergast, *J. Roy. Soc. W. Aust.*, 21, 15, pl. 4, figs. 1-3.

1943—*Waagenoconcha imperfecta* Prendergast, *J. Roy. Soc. W. Aust.*, 28, 25, pl. 3, figs. 7-9.

1943—*Waagenoconcha vagans* Reed; Prendergast, *Ibid.*, 28, 26, pl. 3, fig. 6.

Holotype: U.W.A. 3044, Luluigui Station, West Kimberley District. Liveringa Formation, Hardman Member.

Allotypes (*fide* Prendergast, 1943): U.W.A. 2768, 2775, same locality and horizon.

Homeotypes: U.W.A. 27457, limestone at base of Mount Hardman, West Kimberley District. Liveringa Formation, Hardman Member. 20454, north flank of Mount Cedric, West Kimberley District. Liveringa Formation, Hardman Member.

Diagnosis: *Waagenoconcha*-species distinguished principally by the overall fineness of the spinose ornamentation, and by the frequent presence of strongly developed lines of growth.

Description: Dimensions of some typical specimens are—

—	3044.	20454.	29016a.	29016c.
Length of hinge-line	37	42	30	28
Width	44	54	45	42
Length	42	49	52	47
Curvilinear length	68	78	95	86
Height	14.5	20	26	20

The pedicle valve is moderately convex with the point of greatest convexity just behind the middle, the umbonal region being swollen, thereafter flattening out slightly. Transversely the valve is highly arched, the lateral slopes rather steep, the median portion flattened and indented by a broad, shallow sinus which begins a short distance from the umbo and becomes broader and shallower anteriorly; but always the margin is indented to varying degrees. Ears are absent or very small. The umbo is strongly developed, protruding well behind the hinge, the tip just overhanging the hinge and incurved. Umbonal angle approximately 70 degrees. The brachial valve is flat but may be slightly concave anteriorly with a slight median fold and with upturned margins. The hinge-line is straight, less than the greatest width.

The ornamentation is distinctive. Anteriorly the pedicle valve may be marked by accentuated concentric wrinkles or "bands", generally absent in the umbonal region, sloped sharply anteriorly, but gently to the preceding band. More widely spaced in the middle portion, they become more numerous and closely spaced, the transition often being abrupt, over the anterior third. The bands are not as numerous nor as prominent as is usual with species of *Echinoconchus* Weller. The unbanded posterior half of the valve is covered with very numerous fine spine-bases arranged in regular radiating quincunces. With the coming in of the bands the spine-bases become much finer and more numerous, the arrangement lapses to subquincuncial, and the spine-bases are in irregular rows. There does not seem to be any differential arrangement in size. The spines on the alar extremities are of no special size or arrangement. The brachial valve is ornamented similarly to the other valve, but the bands are less prominent.

The internal characters are also distinctive. The brachial valve shows a prominent median septum, half the length of the valve, becoming higher posteriorly and joining a pair of strongly developed marginal ridges which run along the hinge-line. The junction gives rise to the cardinal process. This is arched and swollen immediately over the junction and has a slight antero-posterior sulcus. It then becomes less bulbous, tilting dorsally, and protruding above the hinge-line, thus fitting snugly into the umbo. At a point

in the same plane as the brachial valve it divides into three lobes, the laterals slightly larger than the central one. The sulci between them are deeply impressed. All lobes point dorsally.

Adductor muscle scars are situated midway along, and apart from, the median septum. They are very finely dendritic, and are not raised. No brachial impressions could be seen. The anterior and lateral surfaces are covered with fine papillae corresponding to the external spine-bases. At the anterior and antero-lateral margins there may be several concentric rows of spikey pustules.

The pedicle valve shows a pair of very elongated adductor impressions close together. In many specimens they reach a length of 2 cm., but are only a few millimetres wide. The striate diductor muscle scars occupy a large area on either side of the adductors.

Variation in the Species: Specimens of this species vary most in outline. The figures for width given in the table of dimensions are typical, but some specimens may be proportionately wider. Such variation is shown in the figures illustrating this species. With greater width the flanks become correspondingly less steep. The transition from relatively coarse to finer spine-bases may be abrupt (the usual condition) or take place over the space between several wrinkles or bands. It may take place at any point from one-third to two-thirds of the curvilinear length of the pedicle valve.

Comparison with other Species: W. imperfecta is similar in general shape to the following species, but differs from them in the fineness of ornamentation and the presence of accentuated concentric wrinkles:—*Productus* (*Waagenoconcha*) *cylindricus* Waagen var. *discreta* Reed (1944), *Waagenoconcha silveana* (Stuckenburg, 1898) *W. abichi* (Waagen, 1884), *W. humboldti* (d'Orb.) as described by Waagen, 1884. It is almost certainly identical with the species described as *P. waageni* Rothpletz, by Broili (1916, p. 118, figs. 1-5). It is doubtful, however, if Broili's specimens are actually *P. waageni.* Prendergast's argument on this point seems fairly conclusive (Prendergast, 1943, p. 26).

Remarks: The banding, the cardinal process (see Sutton and Summerson, 1943, p. 327), and the highly inflated pedicle valve are features strongly reminiscent of the genus *Echinoconchus* Weller. The banding, however, is not as prominent as is usual in species of this group, perhaps because the Western Australian specimens are abraded. Also the single row of strong spines together with rows of finer ones, which is also considered typical of *Echinoconchus,* is absent.

Dunbar and Condra (1932, p. 204) stipulate that the row of large spine-bases lies on the posterior edge of each band, but Weller describes *E. alternatus* (Norwood and Pratten) in which they are on the anterior edge. The question is whether or not this differential arrangement is a necessary characteristic of the genus. The original describer of *Productus punctatus* Martin (see Davidson, 1862, p. 173) referred to the " thousands of small spines " covering the surface, and Weller (1915) in his generic diagnosis of *Echinoconchus*

did not stipulate any definite arrangement of the spine-bases. His specific descriptions immediately following, however, indicate that some differential arrangement of spines of different sizes is usual.

The species also has important features in common with *Waagenoconcha*-species, in particular the regular quincuncial arrangement of spine-bases and the transition from coarser to finer spine-bases (not, however, a feature of old age in this species). It contains, therefore, features characteristic of both *Waagenoconcha* and *Echinoconchus*. Were the diagnosis of *Waagenoconcha* emended to include forms with definite concentric ornamentation (not so prominent as in *Echinoconchus*) this species could be referred to that genus with less hesitation. Chao himself included "*Productus*" *purdoni* Davidson within *Waagenoconcha*, although this species has quite definite growth-lines. Balancing points for and against, it seems that this species has rather more essential features in common with *Waagenoconcha* than with *Echinoconchus*.

The specimen recorded by Prendergast (1943, p. 26) as *W. vagans* Reed really belongs to *W. imperfecta*. It is an impression of a brachial valve relatively wider than is typical for *W. vagans* and with finer ornamentation. Its margins, however, are upturned, although not strongly so, a fact which led Prendergast to place it with *W. vagans*. At the time this was the only real point of difference between it and specimens of *W. imperfecta*. This difference cannot be maintained, for additional specimens, typically *W. imperfecta*, also show occasional upturning of the margins of the brachial valve, to the same moderate degree as the specimen which Prendergast assigned to *W. vagans*.

Material: Over 50 specimens, variously preserved, many of them in the Commonwealth Palaeontological Collection, Canberra.

Genus Taeniothaerus Whitehouse.

1928—Whitehouse, *Rep. Aust. Ass. Adv. Sci.*, 18, 281-283.

Type Species: Productus subquadratus Morris. Morris (1845) in Strzelecki, "Physical Descriptions of New South Wales and Van Diemen's Land", p. 284; London.

Diagnosis: Morris's original description of the type species from Tasmania was as follows:—

"Somewhat quadrate, gibbose, surface marked with irregular, coarse longitudinal ribs, bearing bluntish spines; sides flattened; front produced; mesial furrow broad and distinct; hinge-line as wide as the shell.

"Width three inches, height two and one half inches. This shell somewhat resembles *P. antiquatus* but the mesial furrow is very defined and there are no traces of the concentric undulations which cover the rostral portion of that species.

"Location: Mount Dromedary and Mount Wellington."

Morris did not figure his species.

After a study of additional material Prendergast (1943) gave the following diagnosis:—

"Adult shell large, general outline subquadrate to elongate oval; pedicle valve evenly convex with median sinus; brachial valve slightly convex to flat with upturned margins. Pedicle valve sometimes with triangular concave area; delthyrium, where present, partially filled by triangular extension of cardinal margin of brachial valve.

"Ornamentation of coarse elongated spine bases possibly giving rise to long spines; spine bases not continuous into costae. Irregular concentric wrinkles or lamellae widely spaced over the whole shell.

"Muscle impressions as in *Aulosteges* and *Productus*. Brachial valve with median septum. Cardinal process large, varying angle of inclination to cardinal margin."

Remarks: In 1928 Whitehouse proposed a new genus, *Taeniothaerus,* with *Productus subquadratus* Morris as type species. Although no description or definition of the new genus accompanied this proposal, the genus was validly erected, since under Article 25 of the Rules of Nomenclature, citation of a type species is sufficient for the erection of a genus. The type species was originally described on the basis of a specimen, or specimens, of which only one remains, that selected by Prendergast in 1943. This specimen is very poorly preserved. Morris' description, though it may have been based on more than this specimen, does not give any real conception of the species. Naturally enough, since the type species was of uncertain status so also was the genus.

In 1943 Prendergast attempted the re-study of the type species. The complications involved in such a study are, first, the existence of only the one original specimen, this so poorly preserved that comparison between it and supposedly conspecific additional specimens is quite uncertain; second, the vagueness of the original locality, which makes it uncertain whether or not additional material is topotypic; and third, the fact that a traditional conception of the species has been created on the basis of descriptions, by later authors, of material from Queensland and New South Wales supposed by them to be the species *subquadratus.*

Prendergast was able to procure additional material from the general locality given for the original specimens. On the basis of this she completed her study and gave the diagnosis given above. Most unfortunately the manuscript containing the results of this work was lost at sea during the last world war, while in transit to the Royal Society of Tasmania. She had, however, incorporated the diagnosis of *Taeniothaerus* in another paper (Prendergast, 1943). Through the courtesy of the Director of the Tasmanian Museum I have been able to study a rough draft of the lost paper, which confirms the diagnosis given. Because this draft may not have been the final expression of opinion, I do not feel at liberty to pass on any other results of her work, except to say that it does confirm the difficulty involved in the re-study of the type species, caused by the above complications.

Despite her very thorough study, Prendergast's new diagnosis was so generalized that any real difference between *Aulosteges* (*sensu lato*) and

Taeniothaerus, as diagnosed, is hard to see. It narrows down to this, that whereas the pedicle valve of *Taeniothaerus* very often has an area, *Aulosteges* always has one. Hill (1950) gave expression to this subtlety of difference by making *Taeniothaerus* a sub-genus of *Aulosteges.*

During the last few years the original locality has been narrowed down to a locality situated in a quarry near the Upper Glenorchy reservoir, near Hobart (Hill, 1950, p. 7; personal communication dated 4th November, 1949, from Professor S. Warren Carey, Professor of Geology, University of Tasmania). I have been fortunate in obtaining a specimen from this locality and also a few other specimens from the same formation (Pl. 15, figs. 1-7). These specimens appear to be conspecific with the lectotype and show that the arrangement of spines approaches the quincuncial and that the umbonal region varies in degree of globosity.

Certain Western Australian species come well within the traditional conception of the genus. They show most resemblance to the Indian and Queensland species (these species are compared under the descriptions of the Western Australian species). Hill (1950), after study of Tasmanian material, has described the Queensland species as *T. subquadratus* or as varieties of it.

There seems little doubt that the Western Australian forms belong to *Taeniothaerus* as now understood. This being so, they add something to the conception of the genus. In the first place they vary greatly, particularly in the umbonal and hinge-line features, as does the Queensland material and also, it seems, the Tasmanian material. The ornamentation of the local forms is also distinctive. It is finer than that of *T. subquadratus,* although it can still be described as "coarse". The arrangement of spine-bases is quincuncial or subquincuncial and there is a transition in size of spine-bases from coarse to fine towards the margins. Details of such features are contained in the specific descriptions following.

Taeniothaerus is then a genus which shares features, external and internal, diagnostic to *Aulosteges* (*s.l.*) and *Waagenoconcha* Chao. In the local specimens there are some with a negligible area which closely approach *Waagenoconcha,* although the arrangement of spines is not so precisely quincuncial as in that genus. On the other hand the inclination of the cardinal process to the plane of the brachial valve and the size of the area are never so great as in the typical *Aulosteges* (*sensu strictu*). The combination of features exhibited by species of *Taeniothaerus* inclines one towards the suspicion that *Aulosteges,* as considered at present, is polyphyletic. Especially significant in this regard is the fact that the area even within the range of any one species of *Taeniothaerus* often varies considerably in size. By and large, however, it seems to have closest affinities with *Aulosteges,* although it is certainly far removed from the sort of *Aulosteges* typified by the *A. wangenheimi* group.

The Western Australian species definitely link *Taeniothaerus* with certain Russian species, mostly from the Kazanian, which belong to *Aulosteges* in its widest sense. These species, and their varieties, are: *A. horrescens* (de

Verneuil) (see Netschajew, 1911, p. 145, pl. 4, figs. 4-8, 10, 11; pl. 5, figs. 1-4); *A. fragilis* (Netschajew, 1894, p. 152, pl. 3, fig. 4; and 1911, p. 145, pl. 4, fig. 9, pl. 5, figs. 5, 8, and pl. 6, figs. 1, 2, 3, 5); the species described as *Strophalosia* sp. ind. No. 1 and figured by Netschajew (1911, p. 145, pl. 6, fig. 7); and *S.* spp. ind. Nos. 3, 4, 5 in Netschajew (1911, pl. 7, figs. 4, 3 and 1 respectively); and possibly *A. longa* (Netschajew, 1900, p. 34, pl. 2, fig. 6).

These species would be included in a possible sub-genus of *Aulosteges* anticipated by Hill (1950, p. 5). Were this sub-genus to be erected it would be extremely difficult to decide into what group certain specimens of one of the local species should be placed—the new sub-genus or *Taeniothaerus*. It could be argued then that these Russian species properly belong to *Taeniothaerus*. The effect of such inclusion would be to widen the comprehension of *Taeniothaerus* so that the diagnosis included shells smaller than is now the case, and a wider range of ornamentary detail.

As things stand the status of this genus remains somewhat unsatisfactory. An adequate conception of the genus can only be gained by study of the species at present assigned to it, the present diagnosis being insufficient. Most needed is that the precise characteristics of the type species be established, including the range of variation. As at present understood, it may be distinguished from *Aulosteges* (*sensu strictu*) by the average larger size of its species, by its smaller area, not persistently present, by the usual lack of much deformation of the pedicle valve, the lesser inclination of the cardinal process to the plane of the brachial valve, and the strong tendency of the spine-bases to be quincuncially arranged, often verging on *Waagenoconcha*-type ornamentation.

The case for and against the inclusion of *Taeniothaerus* as a sub-genus of *Aulosteges* is almost impossible to resolve. It could be said that the retention of *Taeniothaerus* as a sub-genus confirms a tendency to place any productid with an area into *Aulosteges*. Already this tendency has greatly increased the scope of that genus and the suspicion of its polyphyly has grown almost to the point of certainty. In this work I have treated *Taeniothaerus* as a genus.

In terms of individuals and species, *Taeniothaerus* in the West Australian Permian was a most successful genus. Its study leads one to the suspicion that some of the species here described are stratigraphically defined stages in a great *Taeniothaerus* "plexus", somewhat similar perhaps to the successional speciation in an oyster stock described by Stenzel (1949), or, in a lesser way, to the local *Calceolispongia* stock described by Teichert (1949). These species of *Taeniothaerus* are certainly the minimum record. Stratigraphical refinement in the West Australian Permian quite possibly will enable more detailed description of this plexus and the erection of further species. In view of the nature of the variation displayed by *Taeniothaerus*-species, these probably will be "community" species (see Leach, 1947), with considerable overlap, individual specimens of which will be difficult to identify. This is indicated by the species already described.

TAENIOTHAERUS COOLKILIENSIS sp. nov.

Pl. 11, figs. 7-12.

Holotype: U.W.A. 27444, north-east side of syncline north of Minilya River, west of Coolkilya Pool, Carnarvon Basin. Wandagee Formation.

Paratypes: U.W.A. 32042, 32043, 34429; Glendevon Homestead, Woolaga Creek area, Mingenew. Fossil Cliff Formation. U.W.A. 34430, same locality and horizon as holotype.

Diagnosis: Species of medium size, characterized particularly by pointed, attenuated umbo, projecting above plane of brachial valve, not incurved, usually twisted, with high triangular suberect area. Distinguished from *T. miniliensis* sp. nov. by a smaller less convex but more frequently distorted pedicle valve, and by its pointed projecting umbo.

Description: The size of the type specimens is shown by the following dimensions:—

—	27444.	32042.	32043.
Length of hinge-line	54	46	28
Width	56	61	48
Length	70	74	55
Curvilinear length	110	112	75
Depth	25	30	20.5
Trail	..	5	..

The shell is subquadrangular to roughly oval in outline, with the greatest width over the median portion. The hinge is nearly as long as the greatest width. The alar angles are squarish, with the ears only slightly developed.

The pedicle valve, often misshapen, is of moderate convexity, most highly so medially. The transverse curve of the valve is a low arch, steep-sided, flattened over the middle portion and indented by a shallow sinus which starts just in front of the umbo and becomes gradually more accentuated, resulting in an indented frontal margin. The umbonal region is not swollen, the umbo being rather attenuated, pointed, and extending well behind the hinge, and projecting a small but variable distance above the plane of the brachial valve, but only within narrow limits. It is most often distorted and twisted. The tip is not incurved and is separated from the hinge by a high triangular area, distorted, slightly concave, suberect and extending over half the width of the hinge. The area is penetrated to about half its height by a triangular gap filled by a corresponding extension of the brachial valve. A short, narrow, inconspicuous pseudodeltidium extends from the gap to the apex of the umbo.

The visceral disc, except the posterior part of the beak, is covered with pustular spine-bases, somewhat elongated, bearing erect spines of medium size. The marginal portions bear finer, more numerous spine-bases. Growth wrinkles are fairly pronounced, particularly over the later growth-stages of mature specimens. The alar extensions bear spines rather more coarse than on the rest of the valve.

The brachial valve is flat or slightly concave except immediately anterior to the hinge, where it is slightly convex, with margins gently but definitely upturned. It bears pits corresponding to the spine-bases on the other valve. It may or may not have spines as well.

The adductor muscle impressions in the pedicle valve are dendritic, elongated, raised, separated by a sulcus, and occupy areas in the posterior third of the shell. On either side lie the striated diductor muscle impressions, occupying large areas reaching almost to the lateral margins.

In the brachial valve the dendritic adductor impressions are enclosed in oval areas each separated by the median septum, and they are slightly raised. The median septum begins within 1 cm. of the hinge-line and extends across two-thirds of the length of the valve. At its posterior end two heavy ridges arise, one either side. They project well into the umbonal cavity behind the hinge, at about 30-40 degrees to the plane of the brachial valve. At first separated by a deep lozenge-shaped sulcus, they then join to form the spike-like posterior termination of the cardinal process which is tilted in a ventral direction.

The latex moulds of internal casts, from which this description of the cardinal process was drawn, do not show the exact nature of the lobation. The process seems, however, to have been trilobed, each lobe being very small and hardly separated.

The brachial ridges are not shown on any of the specimens.

Immature specimens differ from mature ones mainly in the greater reclination of the umbo and hence of the area, and also in the absence of upturned margins.

Variation within the Species: The area varies in size and in the amount of reclination. The width is usually about half the width of the hinge (mature forms), but it may extend almost the full width of the hinge (younger specimens). The height is fairly constant. The amount of reclination varies according to the projection of the tip of the umbo. This varies from almost level with the plane of the brachial valve to nearly a centimetre above it, but is never incurved.

The distortion of the beak and hence of the area varies a little. It is never severely twisted, but neither is it completely undeformed.

The brachial valve may be flat or slightly concave over the outer part of the visceral disc. The margins are smoothly upturned, but not geniculate.

Comparison with other Species: Specimens of *Taeniothaerus miniliensis* sp. nov. are distinguished from those of *T. coolkiliensis* by possessing a smaller area, less projecting umbo, more clearly defined median sinus, more swollen umbonal region and a more regular, less distorted pedicle valve.

Aulosteges ingens Hosking differs in being proportionately wider, more globose, the ornamentation less regular, and the area persisting over the whole of the hinge in contrast to that of the present species.

Of foreign species *A.* cf. *gigas* Netschajew as described by Diener (1903, p. 182, pl. 8, figs. 13a-c) is rather similar to *T. coolkiliensis,* but is made distinct by its broader, undistorted area, more swollen umbonal region and less attenuated, less projecting umbo.

Remarks: The specific name is derived from the name of a prominent locality in the Minilya River—Coolkilya Pool—which is near the holotype locality.

Material: Eight specimens, six as limonitic casts, showing both internal and external features, and two with the shell and ornamentation preserved.

TAENIOTHAERUS(?) FLETCHERI sp. nov.

Pl. 9, figs. 15-19; pl. 10, figs. 1-7.

Holotype: C.P.C. 1950, south side of Mt. Hardman, 120 feet stratigraphically below top; uppermost beds of Liveringa Formation.

Paratypes: U.W.A. 29427 b, 34444, Bell's Homestead, Ellendale area; Liveringa Formation. 29438, 29440, Tutu Windmill, Nerrima Creek, Noonkanbah area; Liveringa Formation, Hardman Member. C.P.C. 1951, same locality as holotype above. All above specimens are from same general locality, the West Kimberley District.

Diagnosis: Species similar to those of *Taeniothaerus,* with low wide area, swollen incurved umbo and ornamentation of numerous coarse reclined spines from elongated spine-bases, often with a row, or rows, of interspersed fine spines toward anterior margin of mature pedicle valves. Distinguished from *Taeniothaerus* sp. aff. *miniliensis* by more swollen umbonal region and fine spines in isolated rows only.

Description: Dimensions of some of the specimens are:

—	1950.	29427b.	29438.	29440.
Length of hinge-line	25	27	34	34
Width	52	50	48	42
Length	45	60	44	38
Curvilinear length	65	92	80	60
Depth	15	25	..	..

The shell is ovate in outline, tending to be wider than long, with hinge straight and less than the greatest width. Alar angles are obtuse with no ears.

The pedicle valve is undistorted, most strongly convex over the initial two-thirds. Transversely it is of low convexity, flattened medially but indented over the anterior by a broad swollen sinus. The umbonal region is wide, umbonal angle 110 degrees, with a broad swollen umbo, which is incurved, tending to overhang the cardinal area. This is triangular, low, extending over nearly all the hinge, more or less co-planar with the brachial valve. It is split medially by a triangular gap filled by an extension of the brachial cardinal margin. The pseudodeltidium is short, low, ridge-like, inconspicuous.

On the alar extremities spines are fine and very numerous; elsewhere the pedicle valve is ornamented with coarse (1 to 1.5 mm. in diameter) elongate spine-bases bearing suberect spines, 8-10 over a square centimetre of the median portion. The arrangement is subquincuncial. Anteriorly a concentrically arranged row of finer spines is usually inserted, sometimes two spines over the width of the row. This may be repeated again anteriorly. A row of coarse spines borders the visceral side of the cardinal area. On the alar extremities the fine spines have a tuft-like appearance. Growth wrinkles are rare.

The brachial valve is flat, with upturned margins in most mature specimens. It bears fine spines with interspersed shallow elongated depressions corresponding to spines on the pedicle valve.

In the pedicle valve the adductor muscle impressions are semi-dendritic, slightly raised, elongated antero-posteriorly, and are situated at the front edge of the posterior third of the valve. Diductor muscle impressions are striated, occupying broad swathes outside the adductor impressions.

In the brachial valve the dendritic adductor impressions are oval, one immediately each side of the median septum, separated from it by a narrow sulcus. They lie just in front of the beginnings of the cardinal process. The median septum is somewhat flexuous, raised, narrow, extending over two-thirds of the visceral disc, not contributing to the cardinal process. This begins as two narrow ridges at the posterior termination of the septum (6-10 mm. from hinge) at first separated by a depression, then joining over the hinge, and terminating as a trilobed narrow process. In younger specimens trilobation is not marked. In older specimens the lobes are small and sub-parallel. The angle of inclination to the plane of the visceral disc ranges from 10 to 30 degrees. Brachial ridges were not seen.

Immature specimens differ from mature ones in lacking upturned margins and in the lesser amount of development of internal features.

Variation in the Species: The plan outline, as with many *Taeniothaerus*- and *Aulosteges*-species, ranges from transverse to slightly elongate-oval. The umbo always rises a little above the hinge, the degree of incurvature varying. The development of fine spines over the anterior portion of the pedicle valve varies. There is usually at least one row, but there may be two or three. The concentric arrangement may be marked or hardly apparent. The varying angle of inclination of the cardinal process has been mentioned.

Comparison with other Species: Taeniothaerus sp. aff. *miniliensis* sp. nov. and *Aulosteges ingens* are closest to this species. The first species is compared in the diagnosis above. *A. ingens* differs in its more quadrate outline, its larger, usually distorted area, more reclined umbo, and absence of concentrically arranged fine spines.

The species described as *Productus abichi* new variety *aukitokazo* by Astre (1934, pp. 68-70) from the Permian of Madagascar resembles this species, but not closely enough for detailed comparison. Astre's species is certainly not *Productus* (i.e. *Waagenoconcha*) *abichi*, but an *Aulosteges* (s.l.) or *Taeniothaerus*.

Remarks: This species is provisionally assigned to *Taeniothaerus*. It might well be an aulostegid—one of the as yet unfounded or obscurely constituted subgenera of *Aulosteges*, e.g. *Wyatkina* Fredericks, 1931. The name honours H. O. Fletcher, Palaeontologist to the Australian Museum.

Material: Twenty specimens, most of them casts, but two very well preserved.

TAENIOTHAERUS IRWINENSIS sp. nov.

Pl. 11, figs. 13, 14; pl. 12, figs. 1-6.

1943—*Taeniothaerus subquadratus* (Morris); Prendergast, *J. Roy. Soc. W. Aust.*, 28, 27, pl. 4, figs. 1-6.

Holotype: U.W.A. 32044, Fossil Cliff, Irwin River area, near Mingenew. Fossil Cliff Formation.

Paratypes: U.W.A. 10932, 23437, 4786, 12396 (2 specs.); same locality and formation as for holotype. U.W.A. 32375, few yards west of Glendevon Homestead, Woolaga Creek, near Mingenew. Fossil Cliff Formation.

Diagnosis: *Taeniothaerus*-species of medium size and moderate convexity, with very small ventral cardinal area, and with ornamentation of fine subquincuncially arranged suberect and erect spines, no coarse spines on alar extremities. In these last two features it differs from *T. miniliensis* sp. nov.

Description: Specimens of this species are mostly broken or distorted. Only two are sufficiently well preserved to yield accurate measurement of dimensions. These are—

—	32044.	32375.
Length of hinge-line	37	36
Width	66	62
Length	64	62
Curvilinear length	105	98

The shell is medium to large, subquadrate, widest anterior to the middle, with the straight hinge-line a little more than half the width, and length approximately equal to width. Specimens are usually very thin-shelled, but this is probably an ecophenotypic feature. The pedicle valve is of moderate convexity, the greatest convexity over the posterior third, flattening gradually to the margins. The flanks are steep-sided. A broad median sinus of moderate depth arises at the umbonal region, is most pronounced over the central part of the shell, then gradually dies out leaving the margin almost entire. Ears are poorly developed, represented only by a recurvature of the alar flanks and not flattened or separated from the rest of the shell. The umbonal region is well developed, but the umbo is comparatively small, pointed, incurved, and just overhanging the hinge-line. In the holotype the tip is a little distorted and bears what seems to be a small cicatrix of attachment. It does not project more than 4 or 5 millimetres above the plane of the brachial valve. The holotype also shows a very small area, about a centimetre wide and a millimetre high.

Except for the tip of the umbo, the valve is covered with spine-bases, somewhat elongated, of moderate size, arranged subquincuncially, and bearing rather fine erect spines. Interspersed irregularly among them are nodular spine-bases, not elongated, bearing coarser, very erect spines. These are more numerous on the marginal areas. The size of the spine-bases and spines slightly decreases anteriorly. Numerous faint growth-wrinkles are also discernible.

The brachial valve is subquadrate, transversely oval. The visceral disc is flat with a slight median fold. The margins are upturned, smoothly geniculated to the front; but the trail would be small. Over the visceral disc, the valve is covered with faint elongate pits, in a radiating quincuncial fashion corresponding to the spine-bases on the other valve, with fine erect spines interspersed between them. The margins bear crowded fine erect spines, irregularly arranged. There are a great many faint growth-wrinkles. The straight hinge-line bears a central triangular extension which fits into a corresponding notch in the other valve.

The holotype, an extremely well preserved pedicle valve, shows no internal features. These, now described, are based on other specimens which, so far as pedicle valves are concerned, are considered of the same species beyond reasonable doubt. This statement would apply with less certainty to brachial valves since none was found conjoined to the pedicle valve. The brachial valves from which the following description of the internal features has been drawn were, however, found in intimate conjunction with the pedicle valves and could not belong to the pedicle valve of any other species found in the same formation. For this reason it is felt that the description is a true one for this species.

In the brachial valve the adductor muscle impressions are coarsely dendritic, elevated, and occupy large lozenge-shaped areas in the posterior third of the valve. Each area is separated by the narrow, erect, median septum which arises a short distance from the hinge-line and gradually becomes less accentuated, terminating at the point of upturning of the anterior margin.

The brachial impressions arise at the anterior end of the adductor impressions, and run parallel to the hinge-line almost to the edge of the visceral disc, then curve smoothly towards the front, following the edge of the visceral disc for about 7 or 8 millimetres, then recurving to form, in all, two-thirds of a circle, terminating abruptly.

The anterior and antero-lateral upturned margins are covered with numerous forward-projecting pustular spines closely crowded. The areas either side of the adductor muscle impressions bear numerous fine pits.

The hinge-line is thickened and shows a narrow area, completely internal. The cardinal process is extremely variable in shape. At one extreme of variation it is somewhat reminiscent of the process of *Dictyoclostus* (see Sutton and Summerson, 1943, pl. 54, figs. 2-8). At the other, it is closer to the *Taeniothaerus*-type. In the first examples, of the *Dictyoclostus*-type, its base is essentially a thickened truncated triangular plate, the sides of which go off parallel to the hinge-line as marginal ridges which soon become broad and ill-defined. Its base merges into the general surface of the valve, the median septum not contributing to the formation of the process. The termination is

trilobed; from dorsal and ventral aspects the central lobe is slightly larger than the laterals, which are at right angles to it. On the ventral side the lateral lobes continue anteriorly as short nodes or ridges a few millimetres in length, running parallel to the median septum and separated by a deep sulcus. The lobes are smooth in ventral aspect, but their dorsal sides show strongly marked growth lamellae. The whole process projects in the same plane as the brachial valve.

In examples of the *Taeniothaerus*-type the process projects further posteriorly (but still in the plane of the brachial valve) than does that of the *Dictyoclostus*-type; the ridges giving rise to the lateral lobes are more accentuated with a deeper sulcus between, but hardly extend on to the main body of the brachial valve; and the lateral lobes are smaller and parallel to the median lobe rather than diverging from it. There are gradations in shape between these two extremes.

In the pedicle valve adductor impressions are situated in the middle of the shell. They are extremely elongated, widening towards the front, oval, dendritic, converging slowly anteriorly, raised, and separated by a short depression. The diductor impressions are linear, striate, occupying a broad band either side of the adductors, and do not extend laterally to the margins. The rest of the interior is smooth.

Variation within the Species: The general shape and ornamentation seem fairly constant features in this species. The variation in the cardinal process has already been described. The area, though always small, ranges from practically indiscernible to about 2 millimetres in height, extending across half the width of the hinge. The cicatrix of attachment is only rarely seen.

Comparison with other Species: Aulosteges baracoodensis Etheridge fil. has a close superficial similarity to this species, chiefly in outline and ornamentation. It is, however, much less convex in profile, the visceral cavity much thinner, and the spines more crowded and elongated. More obvious points of difference are the much larger area and the very differently shaped cardinal process of *A. baracoodensis.*

T. irwinensis differs from *T. miniliensis* sp. nov. in being proportionately wider, with a shorter hinge-line, more regular median sinus, an area smaller in the average, and finer ornamentation of suberect to erect spines. The cardinal process of *T. miniliensis,* although variable, never approaches a shape reminiscent of the *Dictyoclostus*-type, as it does in *T. irwinensis.*

T. sp. cf. *subquadratus* (Morris) is larger and more convex than this species, has steeper lateral flanks, and has the swollen umbonal shoulders absent in this species. The ornamentation of *T.* sp. cf. *subquadratus* also seems to be coarser. *T. subquadratus* (Morris) differs in the same features.

No species from other areas appear to merit close comparison with *T. irwinensis. Krotovia meeki* Dunbar and Condra (1932, pl. 21, figs. 7-8) has a rather similar type of ornamentation of numerous, fine irregularly distributed spines, but differs in most other characters, as does also the form described as *Productus tenuituberculatus* Barbot by Netschajew (1911, pl. 3, fig. 6).

The muscle scars in the pedicle valve are reminiscent of *Strophalosia horrescens* var *lata* Netsch. (1911, pl. 5, fig. 42).

Remarks: Because the cardinal process approaches closely that of *Taeniothaerus,* because of the presence of a small area, and because the ornamentation differs only in degree from that typical of *Taeniothaerus,* this species has been assigned to *Taeniothaerus.* Nevertheless, it has close morphological affinities with *Pustula.* The specific name derives from the Irwin River, on which the holotype locality is situated.

Material: Twelve specimens, including two casts, most of them distorted but well preserved.

TAENIOTHAERUS MINILIENSIS sp. nov.

Pl. 12, figs. 7-11; pl. 13, figs. 1-9; pl. 14, figs. 1-8.

Holotype: U.W.A. 34445, west side of syncline, south bank of Minilya River, west of Coolkilya Pool, Carnarvon Basin. Lower part of Wandagee Formation.

Paratypes: U.W.A. specimens Nos. 27116, 27134, 27384, 27406, 27406a, 27408, 27454; north-east side of syncline, north bank of Minilya River, west of Coolkilya Pool. 27254a, 27328, 27358, 27545, 33,023; west side of syncline, south bank of Minilya River, west of Coolkilya Pool. Lower part of Wandagee Formation. 27600, east side of syncline, south bank of Minilya River, west of Coolkilya Pool. 22712, 33001; from same syncline as above specimens, but exact locality doubtful. All the above paratypes occur in the lower part of the Wandagee Formation and their general locality is the Carnarvon Basin.

Diagnosis: Taeniothaerus-species of large size, variable in size of area. Ornamentation of medium to fine spines, essentially quincuncial in arrangement, tending to become finer towards the margins. Large spines on alar extremities. Cardinal process very large, trilobed, inclined to plane of brachial valve. A species exhibiting great variation in its features. Distinguished from *T. subquadratus* (Morris) by finer ornamentation, larger area, less swollen umbonal shoulders.

Description: Dimensions of some of the type specimens are—

—	34445.	27116.	27384.	27358.	27406.	27254a.
Length of hinge-line	66	63	54	58	27	51
Width	74	91	78	76	64	70
Length	74	91	83	83	68	73
Curvilinear length	132	139	138	137	108	110
Depth	35	37	38	41	27	34
Trail	13	21	17	..	6	20

This species is exceedingly variable in its characteristics, so much so that it is difficult to make positive, clear-cut definition of many features. The discussion on the variation in the species is therefore an important part of this description.

Specimens are mostly very large, massive, subquadrangular to a little elongated in outline, with thick shell wall. The pedicle valve varies from moderately convex to globose, usually most convex over the posterior portion, anteriorly tending to flatten out. Transversely, the valve is highly arched, flattened medially, the flanks usually steep, the margins tending to be splayed out. A median sinus is usually present in most specimens. It is usually broad and weak, most accentuated over the middle, leaving the anterior margin slightly indented. The lateral and antero-lateral margins are irregular owing to the presence of radial corrugations, which are reflected internally. The straight hinge averages about three-quarters of the greatest width, which occurs across the middle. The ears are sometimes prominent but not sharply delimited from the rest of the shell. The alar angles are approximately right-angles.

The umbo is prominent but varies considerably in shape. It may be slightly incurved, but not deformed, barely projecting above the plane of the brachial valve; or it may be very large, distorted, projecting high above the hinge. Most specimens have an area generally slightly concave and extending three-quarters to the whole width of the hinge. Its height and size vary with the nature of the umbo. If the umbo is not distorted the area is low, undeformed and triangular in shape. If the umbo is high and deformed, the area over the central part of the hinge is also high and deformed along with the umbo, but the lateral extremities remain low and narrow. When well preserved it is marked with cross-hatched striations and has a ridge-like pseudodeltidium extending from the tip of the umbo to the apex of a triangular-shaped notch, into which fits a corresponding extension of the brachial valve. The shape and size of the pseudodeltidium and notch vary with the nature of the umbo.

The brachial valve is flat over the main portion of the visceral region with a slight median fold commencing midway over the visceral disc and increasing slightly towards the anterior margin. It is never very prominent. The valve is geniculate, lateral margins also being upturned. The abruptness of geniculation varies; in most specimens the geniculation is pronounced but gradual, though in a few it may be almost a right-angle. The trail is well developed, sometimes measuring over 3 centimetres long. The outline of the brachial valve varies with that of the pedicle valve, being more elongated in some specimens than in others.

The pedicle valve is ornamented by spines, growth-wrinkles, and the radial corrugations already mentioned. The spine-bases over the posterior third of the valve are of medium size, a little less than a millimetre in diameter, slightly elongated, between 20 and 30 occupying an area of a centimetre square. Towards the anterior, and particularly over the extreme marginal areas, the spine-bases become finer and more numerous. This transition may be sharp or gradual, usually taking place just before the edge of the visceral disc. The spines given off are suberect to reclined. The arrangement is fairly regularly quincuncial. The alar extremities bear numerous coarse undulating spines, which in some specimens are over 3 cm. long. In life they would have been longer. They curve backwards in a postero-lateral direction and are occasionally ventrally

inclined. The area immediately around the tip of the umbo is free of spines. Growth wrinkles are usually only faintly defined, becoming closer packed in old age. The radial corrugations are present on the lateral flanks, rarely more than four to each flank.

The brachial valve bears numerous pits corresponding to the spines on the pedicle valve, resulting in a "machined" appearance, the result of the quincuncial arrangement of the pits. From the middle of the visceral disc outwards, spine-bases are interspersed between the pits, rather smaller than those of the pedicle valve. Growth wrinkles and the reflection of the radial corrugations correspond to those of the pedicle valve.

In the brachial valve a prominent median septum extends from the base of the cardinal process almost to the point of geniculation. It is high and narrow. The adductor muscle impressions lie one on each side of the median septum, the posterior border being about 1 cm. from the base of the cardinal process. They are oval to triangular in shape and tend to be depressed anteriorly. In some specimens they are more deeply incised than in others. From the anterior margins of the impressions the brachial impressions arise. They are hook-shaped and at first run parallel or at a slight angle to the hinge, almost to the edge of the visceral disc, then curve parallel to the edge in an anterior direction, and finally swing back towards their starting point, terminating about 1 cm. away, to give the hook-shaped termination.

The shell is thickened a few millimetres in from the hinge-line, leaving a narrow ledge along the hinge. The thickening is accentuated over the posterior borders of the adductor muscle impressions, resulting in the depressed appearance of the posterior margins of the adductor impressions already referred to. On either side of the median septum the thickening gives rise to two pronounced ridges, separated by a deep sulcus, to form the base of the cardinal process. This lies about 5 mm. in front of the hinge. The ridges continue parallel in a posterior direction, inclined to the plane of the brachial valve at a varying angle of more than 20 degrees, but less than 40 degrees. The sulcus gradually becomes less pronounced towards the point of lobation, which is well behind the hinge. The lobation is complex, trilobed, tending to be quadrilobed if the median sulcus persists as a faint indentation. From the dorsal aspect it is trilobed, the striations of growth being very plain, and is buttressed by the triangular extension of the hinge of the brachial valve. Lateral lobes are well separated from the median lobe, but the amount of this separation varies. In some specimens the lobes are somewhat crenellated. The process may be up to 18 mm. long overall, up to 5 mm. wide across the middle, and more than 7 mm. wide across the lateral lobes. The details of lobation vary considerably but the structural plan is always the same.

The anterior and antero-lateral portions of the valve, from just before the point of upturning of the margins and over the trail, are covered with numerous forward-projecting spiky pustules, which are coarsest over the geniculated area and finer towards the extreme margins. The rest of the interior is smooth.

In the pedicle valve the adductor muscle impressions are situated in the posterior third of the valve. They tend to be elevated and are rather more elongated than those of the opposite valve. The radially striate diductor impressions occupy broad swathes, one on each side of the adductors, but extending farther towards the anterior margin by several centimetres and laterally almost to the margins. The edges of the visceral disc and the trail have elongated spiky pustules similar to those of the brachial valve.

Variation in the Species: The umbonal and hinge-line features show most variation in this species, other features varying in harmony. The variation in these features is described in terms of two groupings, largely to overcome the difficulty of describing what is essentially a continuum. The two groups represent two maxima (in number of specimens), but it must be emphasized that there are many specimens which establish a gradation between them.

In the first of these groupings the umbo is high, nearly always distorted and twisted, attenuated, blunt or pointed, projecting well above and behind the hinge-line, rarely inclined over it. With this distortion of the umbo the pedicle valve is also distorted, the median sinus rather narrow and often interrupted, the umbonal region not swollen. The valve is most convex over the middle portion. The middle portion of the area is high, often deformed and unequally developed each side of the pseudodeltidium. It is slightly concave, often with a tendency to recurvature of the cardinal margin. The pseudodeltidium is narrow, rarely more than a millimetre wide, parallel-sided, and often twisted. The triangular notch is usually high and narrow, 2-3 mm. wide and 2-5 mm. high. Young specimens have the same features less developed.

In the second group, the umbo, while still prominent, is much less outstanding than in the first group. It is generally slightly incurved, not overhanging the hinge-line, blunt, not twisted or distorted, projecting only a little above the plane of the brachial valve. The umbonal region is swollen so that the region of maximum convexity of the pedicle valve is more posterior than in the first group. The pedicle valve is not distorted, but tends to be more elongated, as does the outline of the brachial valve. The area is small, concave, triangular, extending from three-quarters to the full length of the hinge, and is rarely more than one-eighth high as wide. The ridge-like pseudodeltidium is short and narrow, the triangular notch wider in comparison with that of the other group.

Very many specimens have a cicatrix of attachment still preserved. This is always strongest on those specimens of the first group which have high distorted umbos and distorted shells. The wide range of variation in umbonal and allied features can probably be explained in terms of the nature and length of time of attachment of the young shell.

Other features, common to the whole range of specimens, show fairly wide variation. The size at maturity varies markedly, the largest having dimensions one-third as great again as the smallest. This variation is not exceptional, but, in this species, strikes the eye. The ornamentation is essentially the same. Some specimens have a more regular quincuncial arrangement of spine-bases

than others. The most outstanding variation in ornamental features, however, is that of the transition between relatively coarse spine-bases over the major portion of the visceral disc and the finer spines on the margins. In some specimens the transition is abrupt and the difference in size marked. In others the transition is very gradual. Others are intermediate in this respect.

Internally the two features showing most variation are the cardinal process and the adductor muscle impressions. The cardinal process is always essentially trilobed, tending more in some specimens than in others to become quadrilobed. It varies in size, some examples being rather squat and massive, others long and attenuated, and also in the complexity of folding of the lobes. In the more massive type the lobes tend to be more divergent from the median lobe and more crenellated than in the longer type. Variation in the adductor muscle impressions seems to be quite haphazard. As already mentioned, the shape may vary from oval to triangular, and in some specimens the impressions may be more deeply incised than in others.

Comparison with other Species: This species differs from the type species, *Taeniothaerus subquadratus* (Morris), and from its varieties (Hill, 1950), which occur commonly in the Permian of Eastern Australia, insofar as the ornamentation is finer, the spines more numerous, and the area larger and more persistently present.

Odd specimens of *A. ingens* Hosking may resemble *T. miniliensis,* but can be distinguished by their smaller size, relatively larger area, more frequent distortion, and coarser ornamentation, the spine-bases also being less regularly arranged than in *T. miniliensis.*

From both *T. permixtus* Reed and *T. brenensis* Reed (1932, p. 12, pl. 1, figs. 1-4; pl. 2, figs. 1-3; pl. 4, fig. 1; and p. 14, pl. 3, figs. 1-3 respectively) it is distinguished by its much finer ornamentation. The same criterion distinguishes *T. notabilis* Reed and *T. cotteri* Reed (1944, p. 75, pl. 16, fig. 1; and p. 75, pl. 15, figs. 3, 4, 7) from *T. miniliensis.* None of the above Indian species shows the prominent transition in size of spine-base so characteristic of the local species.

It can also be compared with the form described by Netschajew (1911, German summary, p. 147, pl. 7, fig. 1) as *Strophalosia* sp. ind. No. 5. This is a brachial valve which shows the same essential features, except that the cardinal process (which has apparently suffered in preservation) is of a rather different shape. Without the pedicle valve it is impossible to make an adequate comparison, but the brachial valve is very similar to that of *T. miniliensis.*

Some of the figures used by Netschajew to illustrate the species *Strophalosia fragilis* (actually an *Aulosteges* s.l.) under the variety names "*longa*" and "*lata*", and also the species *S. longa* are very similar in shape and outline to *T. miniliensis,* differing mainly in details of ornamentation (see Netschajew, 1911, pl. 4, fig. 9; pl. 5, figs. 7, 10; pl. 6, figs. 1-3). The range of variation shown by the figures of *S. fragilis* is strikingly similar to that of *T. miniliensis.*

Remarks: The great range of variation exhibited by this species cannot be over-emphasized. Without the full range of specimens (over 500) it would be quite excusable to consider that there were two or three distinct species present, each represented by a number of odd variant specimens.

It has already been mentioned that the collection can be divided roughly into two groups, each representing a more or less distinct variational trend. It was also mentioned that intergrading specimens linked these apparent trends in variation. Detailed stratigraphical collecting may show that the groups are a real expression of a split in variation—of the formation of an incipient subspecies from the old population. The only objective evidence in support of this hypothesis is that formations higher in the sequence than the Wandagee Formation (from which the bulk of the collection came) yield mostly specimens of the first group—that with large distorted umbo, large high area, and of a larger size than those specimens of the other group.

Pending the detailed stratigraphical analysis of this population the hypothesis cannot be seriously discussed. Against it are the facts that variant specimens representing all extremes of variation can be collected together in many localities of the Wandagee Formation; that there are intergrading specimens between the two obvious extremes of variation; and finally that the nature of the isolating mechanism, necessary to confirm such a trend in variation as a subspecies, cannot be ascertained. The collection has been described, then, as representing the one species.

The specific name is derived from the name of the prominent physiographic feature, the Minilya River, near which the type-locality is situated.

Material: Over 500 specimens, many excellently preserved, showing full details of internal and external features.

TAENIOTHAERUS sp. aff. MINILIENSIS sp. nov.

Pl. 14, figs. 9-11.

Material: One specimen, U.W.A. 34446, from top of Zone of *Calceolispongia abundans,* east limb of Minilya syncline, Minilya River, Carnarvon Basin. Wandagee Formation. Possibly U.W.A. 27406c, north-east side of same syncline, north of Minilya River, west of Coolkilya Pool. Same general area and formation.

Description: Dimensions of the two specimens are—

—	34446.	27406c.
Length of hinge-line	49	47
Width	57	59
Length	58	60
Curvilinear length	93	92
Depth	28	..
Trail	..	..

The specimens are similar in shape and form to *Taeniothaerus miniliensis,* but differ from it in several rather important details. Thus, the median sinus is much more pronounced than in that species, increasing in depth towards the margin so that the shell takes on a bilobed appearance. Correspondingly the median swelling on the brachial valve is more pronounced. The umbo is more attenuated, erect, with the tip a little overturned and showing traces of a cicatrix of attachment. The area is only a little concave, less than that in *T. miniliensis,* and does not extend the width of the hinge-line. Its height is one-quarter the width. The pseudodeltidium is narrow, and an inverted V in cross section.

On the pedicle valve the ornamentation of spine-bases and growth wrinkles follows essentially the same plan as does that of *T. miniliensis,* but the spine-bases are more sparse and much more elongated, bearing semi-erect spines. The spine-bases are rather coarse, about fifteen to the square centimetre over the middle part of the pedicle valve. The arrangement is radiating quincuncial, coarser spine-bases giving way to fine spine-bases over the latest growth stages. The growth wrinkles are more accentuated than is usual in specimens of *T. miniliensis.* The ears are not so well developed as in that species, but this is probably due to a difference in relative maturity. They bear coarse crowded spines which persist farther along the hinge towards the umbonal flanks than is the case with *T. miniliensis.* The brachial valve is ornamented with elongated pits, corresponding to the spine-bases on the pedicle valve, and with fine elongated spines interspersed between. There are growth wrinkles as on the pedicle valve.

Remarks: Although the differences between this species and *T. miniliensis* are pronounced, they are not so pronounced as to exclude the remote possibility that further specimens of the latter species may extend its range of variation to embrace the present form. For this reason, and also because there are only the two specimens, no new name has been proposed.

TAENIOTHAERUS sp. cf. SUBQUADRATUS (Morris).

Pl. 15, figs. 8-12.

Material: Includes U.W.A. 32316a, 34450, 34451, 34452, 34453; about 100 feet west of Glendevon Homestead, near Woolaga Creek, east of Mingenew township. Fossil Cliff Formation.

Description: The shell is large and massive, the pedicle valve being highly convex, the brachial valve flat, or slightly convex initially over the visceral region, with geniculated margins, forming a large trail. Dimensions of typical specimens, including the trail, are—

—	34450.	32316a.	34451.
Length of hinge-line	50	48	48
Width	63	72	65
Length	71	78	71
Curvilinear length	135 (approx.)	140	130
Height	36	..	..

The pedicle valve is most convex over the posterior third, particularly over the umbonal shoulders, thereafter flattening out. Transversely it is a high arch, flattened medially, with very steep wall-like flanks. The flattened median portion persists over the anterior two-thirds of the valve and is indented by a prominent median sinus which begins just after the umbo, is most pronounced over the middle (up to 4 mm. deep), then becomes more shallow but still indents the anterior margin slightly. The umbo is pointed, flattened, may be deformed, and projects only slightly above the hinge. Although the umbo proper is comparatively small, the umbonal region is very much swollen, forming prominent umbonal shoulders, resulting in the wall-like steepness of the flanks. The flanks remain sub-parallel over the visceral portion, then splay out gradually over the trail, particularly on the lateral margins.

The hinge is two-thirds to three-quarters the greatest width, which lies just anterior to the middle, and is separated from the umbo by a small concave triangular area which extends across half to two-thirds of the hinge. It is pierced at the centre by a triangular notch into which projects a corresponding extension of the brachial valve. One specimen showed this notch as equilateral in shape with the lateral edges curved. The pseudodeltidium was not preserved.

The brachial valve is slightly convex but only over the initial portion. This convexity passes into a median fold, not at all pronounced, which corresponds to the median sinus in the pedicle valve. Margins are slightly upturned.

Very little of the ornamentation is shown by any specimen. From what can be seen it seems to be very like that of *T. miniliensis*, perhaps a little coarser.

The internal features shown are also similar to those of *T. miniliensis* except that the cardinal process, revealed in two specimens, seems to be less massive and therefore more like that of *Aulosteges baracoodensis*.

Comparison with other species: Of all *Taeniothaerus*-species in Western Australia this is the one which comes closest to the type species *T. subquadratus* (see pl. 15, figs. 1-7). The shape, particularly in the swollen highly convex umbonal shoulder, flattened median portion as seen transversely, and the gradually splayed out margins, is very much the same as that shown by the lectotype. Correspondingly it is also very similar to the Queensland *subquadratus* (see Hill, 1950), particularly to Hill's variety *cracowensis*. If further specimens show the ornamentation to be the same, then the specific identity of this species with *subquadratus* would appear to be certain.

This species is distinguished from *T. miniliensis*, the closest of the Western Australian species, by the heavy, more globose umbonal shoulders and the distinctive median flattening of the pedicle valve.

Material: Six specimens, all limonitic casts, showing some internal features, but with little of the ornamentation preserved.

TAENIOTHAERUS TEICHERTI sp. nov.

Pl. 16, figs. 1-8; pl. 17, figs. 1-5.

Holotype: C.P.C. 1008, ½ mile east of Calvary Spring (or Calvary Gap Well), 7 miles south-east of Mooka Station Homestead, Wandagee area, Carnarvon Basin. Lower part of Wandagee Formation.

Paratypes: C.P.C. 1009, 1010, 1011, 1012, 1013, 1014, 1015, 1016, 1017; U.W.A. 34447, 34448, 34449; same locality and horizon as holotype.

Diagnosis: Taeniothaerus-species distinguished by very large massive shell, widest at hinge, and ventral cardinal area very small or—more usually—absent. Brachial valve with large lateral swellings internally. A very variable species. Distinguished from *T. miniliensis* sp. nov. by wider hinge, smaller area, if present at all, and more prominent internal swellings in brachial valve.

Description: Dimensions of typical specimens are—

—	1008.	1009.	1010.	1011.	1012.
Length of hinge-line	100	104	91	101	87
Width	88	97	84	80	76
Length	90	84	80	53	74
Curvilinear length	145	140	110	95	..
Height	45	30	..	..	..
Trail	37	30	..	..	..

Members of this species are large, massive, the visceral cavity being plano-convex. The outline is subquadrangular to quadrangular, widest at the hinge, which is straight. The pedicle valve is strongly convex, most strongly so just posterior to the middle, thereafter flattening out and curving abruptly to the lateral margins so that the flanks are steep, although not wall-like. Ears are present and well developed, but not sharply defined from the rest of the shell. The umbonal region is globose, so that a significant part of the visceral cavity lies posterior to the hinge, assuming the plane of the brachial valve to be horizontal. The umbo itself is rather large, pointed, incurved, slightly overhanging the hinge-line, with the umbonal ridges rounded. A very small area is rarely present, being obscured generally by the umbo. When present it is low, triangular, concave, about 10 mm. wide and 4 mm. high. The hinge is pierced by a large equilateral triangular notch, about 4 mm. wide at the base, and partially filled by a corresponding extension of the brachial valve. A median sinus commences just anterior to the umbo, is most accentuated over the visceral disc, where it is about 14 mm. wide, 4 mm. deep, and tends to die out towards the anterior margin, leaving it only slightly indented.

The brachial valve is flat over the visceral region, often with a slight median swelling or ridge; this arises about one-third of the distance across the visceral disc, increasing in prominence by slight degrees to the anterior margin, where it produces a shallow fold, corresponding to the median sinus in the

pedicle valve. The valve is usually geniculated, the abruptness of geniculation varying from specimen to specimen. Some are smoothly curved and some so abrupt as to form a right angle. The upturning of the margins begins just in front of the ears, so that from above these are hollowed out and concave, and correspondingly convex from below. In most specimens, even those where the upturning of the margins is slight (younger specimens), the anterior and antero-lateral margins are enormously thickened and lamellose, a thickness of 5-8 mm. being common. In some mature, perhaps gerontic, specimens, the margin is recurved to give a narrow flange most pronounced at the anterior. The appearance of one specimen suggests that the pedicle valve corresponded with this recurvature of the margin.

The ornamentation is of spines and many growth wrinkles. On the pedicle valve the surface is covered, except for a small area around the tip of the beak, with medium-coarse spine-bases, about 1 mm. in diameter, very elongated and flat-lying, and fairly closely packed, between fifteen and eighteen in a square centimetre over the middle portion of the valve. The distribution seems to be fairly even over the main body of the valve, with finer and closer packed spine-bases over the anterior portion, and more coarse and erect ones on the ears. The arrangement is radiating quincuncial. The elongation of the spine-bases continues below the surface of the shell, the roots pointing anteriorly, so that partially decorticated specimens are striated. Growth wrinkles are prominent and follow the usual arrangement—widely spaced initially, becoming closer spaced at the point of geniculation, and closely packed, lamellose, on the extreme margins.

On the brachial valve the ornamentation is of pits, corresponding to the spines on the pedicle valve, with a similar arrangement, giving a "machined" appearance to the surface, and also spines and growth wrinkles. The spines are smaller, on the whole, than those on the pedicle valve. They range from fine, about $\frac{1}{2}$ mm. in diameter, to minute, all variant sizes occurring indiscriminately together. Growth wrinkles are close-packed on the margins, as with the pedicle valve, resulting in an extremely thick margin.

The internal features of the brachial valve are shown extremely clearly by about 30 specimens. The adductor muscle scars are dendritic and enclosed in a roughly rhombic-shaped depression, which is deepest posteriorly and bisected by the median septum. This is well developed, arising at the base of the cardinal process, though not part of it, and continuing almost to the point of upturning of the valve. From the base of the adductor impressions, near the median septum, the brachial impressions begin, running parallel to the hinge almost to the edge of the visceral disc, then curving parallel to the antero-lateral margin for a short distance (between 9-12 mm.) and finally curving once more to form, overall, a smoothly curved hook or ladle shape. The termination points posteriorly, failing to reach the starting point by about 5-7 mm. The area nearly enclosed by the impressions is a little depressed, roughly circular, the diameter being of the order of 12 mm.

The cardinal process is nearly always massive, even for the size of the shell. It begins as two ridges about 8 mm. from the hinge. These run parallel or slightly converging, separated by a deep sulcus which, just before lobation, becomes a deep pit, then continues as before but less defined. The lobation is most pronounced but rather variable. The dorsal aspect is always trilobed, the growth striations visible. The lateral lobes from this aspect are generally large and well separated from the median lobe. The angle of separation ranges from a right-angle to about 45 degrees, the larger the lobes the greater being the separation. From the ventral aspect the process presents a more varied appearance. Most specimens are trilobed, tending towards quadrilobation owing to the continuation of the median sulcus almost to the tip of the median lobe. In a few specimens the median lobe is definitely divided in this way to give a four-lobed process. The shape of the lobes varies: some are sharp and pointed, others rounded and blunt. The process extends behind the hinge for 8 to 14 mm.; the angle of inclination to the plane of the brachial valve ranges between 20 and 40 degrees. The dorsal surface is buttressed by the triangular extension of the cardinal margin.

The median septum may continue into the base of the process but is very often separated from it by a slight depression.

The ridges from which the process arises continue anteriorly each at an angle of 30 to 50 degrees to the hinge, for a distance of about one centimetre. Each ridge then widens out to form triangular-shaped platforms; the posterior edge of each triangle is parallel to the hinge but separated from it, leaving a marginal ledge along the hinge 3 to 8 mm. wide. The lateral side of the triangular platform goes smoothly into the lateral margin, but the anterior apex sometimes continues as a marginal ridge, which in a few old specimens may even continue as indistinct and indented ridge all round the margin of geniculation. In most specimens it persists for only a few millimetres. The remaining diagonal side of the platform forms the raised borders of the posterior edges of the rhomb-shaped area containing both adductor impressions. In some specimens this raised border may persist part way around the anterior sides of the muscle areas. In describing this feature the word 'platform' has been used, and in this sense it applies to all specimens. In most specimens, however, it is more than a platform, being rather a rounded swelling which may reach a very great size, really the most outstanding characteristic of the species. Usually the stronger the geniculation the more prominent are these swellings and, in turn, the more massive is the cardinal process. The most pronounced swelling stands 8 mm. above the plane of the valve. It is made up of solid shell material, not being reflected as a depression on the external surface.

From a point a few millimetres before upturning, the rest of the surface, except the extreme margin, is covered with coarse pustular spines, projecting anteriorly. They are most prominent along the line of sudden upturning of the valve.

In the pedicle valve the muscle impressions are situated in the posterior quarter of the valve. The adductor impressions are not shown, but from the position of the diductor impressions they are probably more narrow and elongated

than in the brachial valve. The diductors are radially striate, occupying very large areas; they extend laterally almost to the alar regions, anteriorly over half the visceral region cavity, and are separated by a narrow corridor about one centimetre wide, in which lie the adductor impressions. The very large size of the diductor scars is in keeping with the massive brachial valve and its cardinal process.

Variation within the Species: The difference in development of the cardinal process has already been outlined. The internal lateral swellings vary in size from specimen to specimen. In a few specimens they are high and rounded, of solid shell material up to 8 mm. thick, but in a few others they are only one or two millimetres thick, flattened and platform-like. Most are gently rounded and 4 to 5 mm. in thickness.

As mentioned in the description proper, the margins, particularly at the anterior, are very often thickened. This is most noticeable in the brachial valve. Measured at the anterior the thinnest valve was 3 mm. and the thickest 9 mm. Where the valve is thicker at the margin there is a tendency for it to be very thin over the area covered by the brachial impressions and that between them.

These three features vary in harmony, as might be expected. Where there is a very massive cardinal process the swellings are large and the margin thickened, and the converse is largely true. Variation in these features may possibly be influenced by some local ecological factor, in which the amount of easily obtainable calcium carbonate would play a part. However, the ability to use and position this calcium carbonate cannot be regarded as altogether a localized ecophenotypic phenomenon.

The hinge-line of the specimens, and hence the plan outline, vary in length. Only one or two specimens show a hinge-line a few millimetres less than the median width. In the rest it is wider, and in some specimens, notably C.P.C. 1011, it is one-quarter again as wide as the median width. The average is one-eighth as wide again. Variation in this feature seems to be independent.

Comparison with other Species: T. teicherti is a highly individual species not likely to be confused with any other of the local species. *T. miniliensis* sp. nov. probably comes closest, but differs in its consistently shorter hinge-line, larger cardinal area, and usual absence of the internal lateral swellings. On the average, *T. miniliensis* has a less massive cardinal process and is smaller in size. With respect to the internal swellings the brachial valve described as *Strophalosia* sp. ind. No. 4, by Netschajew (1911, p. 147, pl. 7, fig. 3) may be compared with *T. teicherti.*

Remarks: Specimens of this species are very thick-shelled and conjoined valves are rare. The matrix inside and adhering to the specimens is generally gritty, unsorted, and often contains quantities of macerated shell material. The combination of these features indicates that this species might very well have lived under turbulent near-shore conditions. The very wide hinge-line, ensuring greater stability, and the variation in features easily affected by the supply of

available calcium carbonate, one of the many ecological factors which often show pronounced local change in the near-shore environment, further contribute to this opinion.

The name is given to honour Dr. C. Teichert, of the United States Geological Survey, an authority on the Western Australian Permian, who was responsible for making available the material upon which the above description was based.

Subfamily STROPHALOSIINAE Schuchert, 1913.

Genus ETHERIDGINA Oehlert emend. Prendergast, 1943.

1887—Oehlert, in Fischer's *Manuel de Conchyliologie,* p. 1728.

Type Species: Productus complectens Etheridge fil., 1876, *Quart. J. geol. Soc. Lond.,* 32, 454, pls. 24, 25.

Diagnosis (after Prendergast, 1943): Small strophalosiinids characterised by an adnate attachment to other shells by cementation of a large portion of the pedicle valve together with adherent or embracing spines. Shape concavo-convex to plano-convex dorso-ventrally, outline oval, often broader than long, with hinge less than greatest width. A small triangular area is present on the pedicle valve, with a narrow pseudodeltidium. A smaller area may also be present on the brachial valve. There are small teeth and dental sockets. The muscle scars are non-dendritic. On the brachial valve the ornamentation consists solely of concentric undulatory wrinkles. On the pedicle valve the spines are coarse and tenuous, present only on the upturned margins.

Remarks: Species of this genus occur in the Carboniferous of Scotland and North America, and possibly in the Permian of Western Australia, being first recorded there by Prendergast in 1943. The shell is always small, and although varying in its mode of attachment, has a distinctive and characteristic appearance. In Scotland crinoid stems are usually the host, the spines very elongated and embracing the stem. More usually, they are cemented by most of the pedicle valve to the flat surface of other shells (in Western Australia on the brachial valves of *Taeniothaerus miniliensis* most commonly), the spines on the margins being adherent to the host shell.

The presence of teeth and cardinal areas as characters of the type species was not fully realized until Prendergast made a close study of the type specimens (Prendergast, 1943, pp. 52-54). Earlier Dunbar and Condra (1932, pp. 260-262) proposed a new genus, *Leptalosia,* which might be regarded as synonymous with *Etheridgina,* since it possesses the same essential characteristics as given by Prendergast in her emended diagnosis of *Etheridgina.*

Prendergast felt no doubt that the two genera were identical. Although she had not examined the type species of *Leptalosia* her argument is convincing, so that *Leptalosia* is regarded herein as tentatively synonymous with *Etheridgina.*

Etheridgina is considered to be related to the *Strophalosia*-group. Oehlert, the founder of *Etheridgina,* referred it to *Productus,* under the mistaken impression that it had no area or teeth, and that it was not attached by cementation,

with accompanying distortion. In 1920 Gregor (p. 535) referred several North American species of *Strophalosia,* all small and adnate, to this genus, but by inference regarded it as a productinid. The presence of areas on both valves, cardinal teeth, and non-dendritic muscle impressions are, however, features which clearly show its relationship to *Strophalosia* (s. l.) As its species are distinct and form a morphologically similar group, it is treated here as a full genus, despite the remote possibility that the main taxonomic feature, the adnate condition, might be an ecophenotypic one. This possibility is usually framed as the proposition that *Etheridgina* (or *Leptalosia*) is really the spats of *Strophalosia* or *Aulosteges* or such forms with attached early growth stages. Only detailed examination and comparison of *Etheridgina* and *Leptalosia* species can resolve this proposition.

So far as the West Australian adnate specimens are concerned, some (but not all) definitely do not represent the early growth stages of known species of other genera. These, here described as *E.* (?) *muirwoodae* Prendergast, are attached by so large a part of the shell that detachment must certainly have resulted in mortal injury. Also, the curvature of the upturned margins is often very marked and cannot be compared with the initial curvature of any known local species. Again, the internal features are well developed and characteristic. Finally, in no specimen of local species does the cicatrix of attachment lead one to associate this feature with any of the specimens described here as *E.* (?) *muirwoodae.*

ETHERIDGINA(?) MUIRWOODAE Prendergast.

Pl. 17, figs. 6-11.

1914—*Strophalosia* sp., Etheridge fil., *Bull. geol. Surv. W. Aust.,* 58, 34, pl. 5, figs. 16-18.

1918—"*Strophalosia complecteus*", Eth. fil., *Proc. S. Aust. Br. geogr. Soc. Aust.,* 18, 253, pl. 40, figs. 11, 12.

1943—*Etheridgina muirwoodae* Prendergast, *J. Roy. Soc. W. Aust.,* 28, 54, pl. 6, figs. 14, 15.

Syntypes: Aust. Mus. F.16699, three specimens; figured by Etheridge (1918) as *Strophalosia complectens* (pl. 40, fig. 12). Balmaningarra, Mt. Marmion, West Kimberley District. Noonkanbah Formation.

Lectotype (here chosen): Entire specimen on Aust. Mus. F.16699, with conjoined valves.

Topotype: Aust. Mus. F.16812, one pedicle valve, figured by Etheridge (1918) as *Strophalosia complectens* (pl. 40, fig. 11). Same locality and formation as syntypes.

Other material includes: On U.W.A. 27469, 27115a; north-east side of syncline north of Minilya River, just west of Coolkilya Pool, Wandagee Station, Carnarvon Basin. Lower part of Wandagee Formation. On 27454; west side of same syncline, same locality and horizon. On U.W.A. 34446; east

side of same syncline, same locality and horizon. On C.P.C. 1028; ½ mile east of Calvary Gap Well, 7 miles south-east of Mooka Station Homestead, Carnarvon Basin. Lower part of Wandagee Formation.

Diagnosis: Small adnate species adherent by most of pedicle valve and by many coarse marginal spines, with area on both valves, cardinal teeth and non-dendritic muscle impressions. Closely resembles *E. complectens* (Etheridge fil.), but with thicker shell, more developed areas and teeth.

Description: Dimensions of some of the specimens are:

—	F. 16812.	F. 16699.	U.W.A. 27469.	U.W.A. 27454.
Length of hinge-line	7	8.5	4.5	5
Width	7.5	12	7.5	6.5
Length	6	9	6	6
Depth	..	..	..	2

Additional specimens obtained since the original description—substantially that given here—clearly belong to this species, but, as might be expected from a wider range of material, necessitate a few minor additions and alterations to the original description. The specimens are all small, the greatest dimension rarely exceeding one centimetre, the shape sub-quadrangular to transversely oval, wider than long. They are most often thick-shelled. The hinge-line varies in length from one-half to seven-eighths of the greatest width. The alar angles may be squarish, but are usually rounded. The pedicle valve is fixed to the underlying host shell. In all specimens obtained, this is another brachiopod, usually a specimen of *Taeniothaerus, Neospirifer*, or in the one instance, the brachial valve of *Chonetes* cf. *pratti* Davidson. The whole of the visceral disc is attached; in some instances the area affected may be over a centimetre square. The lateral and anterior margins, however, are usually sharply upturned and free of attachment. The attached portion follows closely the underlying irregularities of ornamentation of the host shell. Thus it may be corrugated, as seen on *Neospirifer marcoui* (Waagen), or nodular if on a spinose part of a productinid. The cardinal area is large, considering the size of the specimens, flat, extending the full width of the hinge, the height about one-fifth to one-eighth of the width; and, if well preserved, it may show longitudinal striations of growth. It has a large triangular pseudodeltidium hardly, if at all, raised above the surface of the area. The umbo is rarely noticeable. If the attached portion includes the umbonal region the area is perpendicular to the plane of attachment. If not included, the cardinal margin is upturned, the area almost parallel to the plane of attachment.

The ornamentation on the pedicle valve is, so far as is known, restricted to spines. These occur sparsely along the cardinal margin, nearly all the spines being distributed around the lateral and anterior margins. The number seems to vary: in one specimen there are more than twenty, fairly evenly distributed from one alar extremity anteriorly to the other; in another specimen

there are less than a dozen. This may not represent anything like the true variation in this feature, because of varying preservation. In other specimens there is a greater concentration of spines on the alar extremities, up to six spines on each. The spines are coarse, adherent to the host shell, and may be more than a centimetre in length.

The cardinal teeth are strong, diverging, separated by a semi-ovoid space, and slightly concave dorso-laterally. Prendergast describes the muscle impressions as taking "a tetrahedral form, one apex of the tetrahedron towards the umbo, and beneath the area. The muscular apophyses are slightly concave, they appear smooth and divided into a greater and lesser part by a narrow ridge parallel to and near their anterior margins. The edge separating them is a thickened ridge simulating a medium septum. The anterior face of the tetrahedron is narrow, and has curved side edges, due to the concavity of the apophyses. Any other markings on the inside of the shell have been obliterated".

Additional material shows that this description is essentially correct, although in some specimens the muscle impressions are not so strikingly developed as in the specimens upon which Prendergast's description was based. In one of the new specimens the area in front of the impressions is covered with numerous minute spikey pustules. Also, the teeth vary in size from minute to nearly one millimetre long.

The structure of the brachial valve is lamellose. It may be flat to concave. In some specimens the initial portion is convex, then recurves to become flat or slightly concave over the visceral disc, and upturns marginally. The area on this valve is smaller than that of the pedicle valve, the height about one-half. The pseudochilidium is also triangular. Both areas lie in the one plane, the line of division between them often being faint.

The surface of the brachial valve shows concentric wrinkles, very numerous and close-set, over the entire surface, which is undulatory, the wrinkles varying in intensity. No spines are present on the visceral disc of the brachial valve. Prendergast states that marginal spines were present because of numerous marginal pustules. This may or may not be so. In one other specimen the pustules are there, but they are merely the external reflection of irregularities in the pedicle valve, which closely follows the spine-bases present on the host shell.

The cardinal process is relatively large, inclined almost at right angles to the area. It is trifid, blunt, the lobation not marked, the lateral lobes adhering closely to the central lobe. The teeth sockets lie each side of the base of the process, and are each bounded to the anterior by a curved plate arising from the side of the cardinal process, making an angle with it of about 45 degrees. The plate quickly dies out on the surface of the valve. A very short median septum is present, separating the muscle impressions, which lie close to the base of the process. They are non-dendritic and are not divided into anterior and posterior elements. The brachial impressions have not been seen. Pitting is present over some of the internal surface. Description of these internal features is after Prendergast (1943).

Variation in the Species: Variation in the more important features is described above. This variation is what might be expected from an adherent form, and is due to the precise manner of attachment. Thus the degree of upturning of the margins is controlled directly by the size of the area of attachment. Where this is large the margins may be only a little upturned, if at all; where smaller, the margins will be steeply upturned so that the pedicle valve is very highly convex.

Comparison with other Species: As Prendergast stated, it was with some trepidation that she distinguished this form as a new species, mainly because her principal specimens had already been referred to *E. complectens* (the type of the genus) by the author of that species, Etheridge. It is agreed, however, that the differences between the two species are sufficiently pronounced to regard the local form as a new species. The specimens are larger and thicker-shelled than those of *E. complectens;* they possess relatively large and well-developed cardinal areas, strong teeth and characteristic muscle impressions, in these features being distinct in degree from *E. complectens.*

Prendergast also considered it possible that this species is really the adherent form of *Strophalosia etheridgei* Prendergast, the differences between them being probable modifications due to the fixed habit of *E. muirwoodae.* The main point of similarity (and really the only one) in support of this possibility is the similarity externally of the brachial valve in the two species. This is true, except that the concentric lines in the brachial valve of *E. muirwoodae* seem more evident than in the other species, but it does not seem sufficient evidence for supposing them to be habitat forms of the one species. The procedure of reconciling the radical differences between them by reference to difference in habitat might just as well be applied to other small species, e.g. *S. prendergastae,* and in any case is hypothetical. It seems best to regard this form as a species distinct from other local species superficially similar.

Remarks: As Prendergast noted, and as contained in the above synonymy, her specimens were headed *S. complecteus* in Etheridge's description (1918, p. 253), but in the text and description of figures he gave *S. complectens.* Almost certainly Prendergast was correct in assuming that the title name was due to a typographical error.

Material: About twenty specimens, conjoined and separate valves. Brachial valves very rare. In addition there are a great many examples showing trace and fragmentary specimens.

Genus Strophalosia King 1844.

1844—King, *Ann. Mag. nat. Hist.,* 14, 313.

Type species: At present the valid type species cannot be designated; see Maxwell (1954), and Bryant (1955).

Definition: Shell productoid, small to medium-sized, with shell structure essentially lamellose. Concavo-convex dorso-ventrally, the pedicle valve usually

rather evenly convex, the brachial valve with upturned margins. Well developed areas are present on both valves, that of the pedicle valve being larger, pseudodeltidium and pseudochilidium being present. Umbo often deformed, with a cicatrix of attachment, large or small.

Ornamentation of concentric lines of lamellae, with spines. On the pedicle valve spines usually cover the whole valve. They may be recumbent or erect, coarse or fine, but fairly uniform for any one species, the number varying from species to species. The arrangement varies from irregular to subquincuncial, to a disposition in approximate concentric lines. Brachial valve often bears spines similar in size, number and arrangement to those of pedicle valve.

In the pedicle valve teeth are present, fitting into sockets in the brachial valve. Adductor muscle impressions are paired, elongate, often raised. Diductor impressions are linearly striate.

In the brachial valve there is a median septum, nondendritic adductor muscle impressions, usually raised, paired, each pair most often further subdivided into posterior and anterior parts. Brachial impressions strophalosiinid not returning to muscle impressions. Cardinal process essentially trifid, well developed, compact.

Remarks: Not all *Strophalosia*-species bear spines on the brachial valve. The subgenus *Heteralosia* King 1938 has been erected to accommodate those forms without spines on the brachial valve. The internal features described are characteristic of the genus.

Several features show noteworthy variation from species to species within the genus. Amongst these are the nature and position of the adductor muscle impressions, the nature of the brachial impressions and the size of the cicatrix of attachment. Variation in all three of these features is probably interknit and traceable to shell-shape and to the duration and mode of attachment of members of the genus (see Prendergast, 1943, p. 38; and Maxwell, 1954).

Subgenera: There have been at least six attempts at subdivision of the genus. These subdivisions have been given the names *Bilotina* Reed 1944, *Etheridgina* Oehlert 1887, *Heteralosia* King, R.H. 1938, *Leptalosia* Dunbar and Condra 1932, *Strophalosiella* Licharew 1935, *Wyndhamia* Booker 1929. *Heteralosia* is treated here as a subgenus of *Strophalosia*, *Etheridgina* as a genus. *Wyndhamia* was proposed as a subgenus of *Strophalosia* to contain forms with the adductor muscle impressions undifferentiated into posterior and anterior elements, and without a cicatrix of attachment. Both *Wyndhamia* and *Branxtonia* Booker (1929), proposed as subgenera of *"Productus"*, are regarded by Maxwell (1954) as synonyms of *Strophalosia*.

Strophalosiella, a subgenus, is described as a *Strophalosia* with *Linoproductus* ornamentation. It has areas on both valves and would be regarded as well-founded were the internal features shown to be strophalosiinid. *Bilotina*, erected as a subgenus, was not separately defined. Its definition depends on the description of the type species. It is difficult to decide just what are considered to be the distinguishing characters. The only direct mention is that

the "cicatrix' of attachment of this valve suggests the genus *Strophalosia*" (Reed, 1944, p. 110). It is not certain whether or not there are cardinal areas and the internal features are unknown. The status of this subgenus is, then, very doubtful. *Strophalosiina,* also proposed as a subgenus, has as its type species *Aulosteges tibeticus* and is therefore a subgenus of *Aulosteges. Leptalosia* is regarded here as probably synonymous with *Etheridgina* (see also Prendergast, 1943).

STROPHALOSIA MULTISPINIFERA Prendergast revised.

Pl. 18, figs. 3-14.

1943—*Strophalosia multispinifera* Prendergast, *J. Roy. Soc. W. Aust.* 28, 50, pl. 5, figs. 6-8.

Holotype: U.W.A. 20458. Scarp 2 miles east of Christmas Creek Homestead, West Kimberley District. Noonkanbah Formation.

Other material: U.W.A. 20456; Hill C, south of road, Grant Range, West Kimberley District. Noonkanbah Formation. 27454 a, b; north-east side of syncline, north bank of Minilya River, just west of Coolkilya Pool, Wandagee Station, Carnarvon Basin. Lower part of Wandagee Formation. 34454, 34455, 34456, 34457; 8 miles south-west of Lyons River Homestead, 5 miles west of shearing shed on east-west fence parallelling main tributary into Binthabooka Creek, at intersection of that fence and minor tributary. Cundlego Formation.

Diagnosis: Strophalosia-species of large size, characterized by initial quincuncial arrangement of fine spines, followed by coarse spines tending to lie in concentric lines, and by grouping of spines on alar extremities. Probably closest to *S. indica* Waagen but larger than this species, and not of elongate outline.

Description: This is a large *Strophalosia*-species, as can be seen from the following table of dimensions. Depth could not be measured.

—	20458.	20456.	27454a.	34454.	34455.
Width of hinge	28	28	30	22	26
Width	42	43	46.2	35	44
Length	37	39	43	34	34
Curvilinear length	53	58	68	50	65

The pedicle valve is moderately convex, almost hemispherical, evenly convex, except the lateral and anterior margins, which tend to be steep. A median depression is present, not sufficiently marked to be termed a sinus. The alar extremities are flattened, not forming true ears, the alar angles a little more than right-angles. The hinge-line is straight, two-thirds to three-quarters the greatest width, which lies across the middle. The outline varies from subcircular to transversely oval, wider than long. The area extends along the whole hinge, the height about one-eighth the width; it is horizontally striated

and shows a triangular pseudodeltidium, half as wide as high, hardly raised above the surface of the area. The umbo is not prominent, blunt, the tip absorbed by a small cicatrix of attachment.

The ornamentation consists of spines and occasional faint concentric lines of growth lamellae. The spines are numerous (up to 25 on the middle portion over an area of a centimetre square), at first rather fine, elongated, suberect and arranged quincuncially. On the alar extremities they are more numerous, elongated. Over the anterior third of the valve the spines become much more coarse, up to a millimetre in diameter at the base, sparser, the bases often very elongated to give almost a pseudocostate appearance. They tend also to be arranged in concentric lines, each line separated by several millimetres. The spines on the brachial valve are finer than those on the pedicle valve. The arrangement seems to be similar.

The ornamentation as given here complements and differs from that given by Prendergast in the original description. Prendergast's description was incomplete because the only specimen showing anything of the ornamentation (the holotype) was rather badly weathered. Over much of this specimen the spine-bases were so worn that only the punctations of the spines were left, the true size of the spine-bases not being apparent, nor their elongation. The new material is well preserved.

In the pedicle valve the teeth are strong, separated by less than two millimetres at their beginning, diverging, rounded, concave dorso-laterally. On either side of the teeth a marginal ridge arises which is contiguous to, but stepped-down from, the hinge. This ridge persists only a few millimetres past the alar extremities, but sufficient to make a platform of them, so that the alar platforms of both valves fit tightly together. Internal casts tend then to show a more rounded outline than is really the case. The adductor muscle impressions are elongate, non-dendritic, situated at about one-third the curvilinear length of the valve from the umbo. The longitudinally striated diductor impressions lie either side of the adductor impressions, but extend further anteriorly.

The brachial valve is geniculate, the geniculated angle almost a right-angle. The visceral disc is flattish or slightly concave. The alar extremities are flat, the alar angle a little more than a right-angle. The area corresponds to that of the pedicle valve, with a pseudochilidium, but is a little smaller.

The adductor muscle impressions are non-dendritic, together forming a transverse rhombohedron, split by the median septum so that each is triangular-shaped. The anterior margin of each impression is raised, the posterior margin level with the general surface. Each impression consists of an anterior and posterior element, the anterior oval-shaped, the posterior tending to envelop the anterior one. The brachial impressions arise at the lateral edges of the posterior elements, run antero-laterally almost to the upturned edge, parallelling this to the anterior margin, where they curve in a posterior direction, each forming a hook, and terminate level with the anterior end of the median

septum, each termination having a minor hook, directed towards the middle. The cardinal process is blunt, extending up to five millimetres behind the hinge, co-planar with the cardinal area, but inclined at only a small angle to the plane of the visceral disc. It is essentially trilobed, the middle lobe split by a sulcus on the ventral side, the lateral lobes not nearly so prominent, nor markedly separated from the middle one. It arises from the junction of the median septum and a pair of marginal ridges. The latter run laterally at a small angle to the hinge (about 25 degrees) leaving a platform each side of the process immediately anterior to the hinge, and including also the alar extremities. The ridges are flattened just anterior to the alar extremities, but then become prominent once more and meet anteriorly, so encircling the visceral disc. The surface of the valve embraced by the marginal ridges and the brachial impressions is sometimes raised, leaving a perimetric ledge. The median septum is thin, not much raised, extending over two-thirds of the visceral disc. The rest of the surface is smooth.

Variation in the Species: The number of spines ranges between 20 and 25 in a centimetre square over the middle portion of the pedicle valve. The outline varies in keeping with the variation of the hinge-line width. This is most obvious for the brachial valve, in which the alar extremities may be obtusely rounded, as is usual, or tend to be squarish to give true ears. In the brachial valve the marginal ridge around the visceral disc, lateral and anterior, may be less prominent in some specimens than others, but is always discernible. The lateral lobes of the cardinal process may sometimes be as strongly developed as the central one. The indications are that the relative coarseness of the spines towards the margins also varies, although the difference in size between these and the other spines covering the visceral portion is always marked.

Comparison with other Species: Other species of the genus have similar ornamentation to this one, particularly *S. indica* and *S. tenuispina,* both Waagen's species (Waagen, 1884, p. 648, pl. 65, figs. 1-4; and p. 654, pl. 64, figs. 2-7). It differs from both these in its much larger size, from *S. indica* in its oval outline and geniculated brachial valve, and from *S. tenuispina* in the greater convexity of its pedicle valve, presence of spines on the brachial valve and differences in the internal features.

Material: Twenty-three specimens, mostly decorticated, showing some internal features, nine showing both external and internal features.

Strophalosia prideri sp. nov.

Pl. 18, figs. 15, 16; pl. 19, figs. 1-19.

1943—*Strophalosia jukesi* Etheridge fil.; Prendergast, *J. Roy. Soc. W. Aust.,* 28, 47, pl. 5, figs. 18-20.

Holotype: C.P.C. 1018; from right bank of Lyndon River, 9 miles east of Mia Mia Homestead, Carnarvon Basin. Bulgadoo Shale, near bottom.

Paratypes: C.P.C. 1019, 1020, 1021, 1022, 1023, 1024, 1025, 1026, 1027; U.W.A. 34458, 34459, 34460, 34461, 34462. All from same locality and horizon as holotype.

Diagnosis: Large *Strophalosia*-species, outline subtrigonal to oval, convexity accentuated towards margins, with pointed umbo and with numerous medium to coarse spines on both valves. Similar to *S. jukesi* Etheridge fil., but with outline more trigonal, coarser ornamentation, and umbo more pointed and projecting further posteriorly.

Description: Dimensions of certain of the type specimens are as follows (measurement of depth approximate):—

—	1018.	1019.	1020.	1021.	1022.	1023.
Length of hinge	24	23	25	15	18	26
Width	49	46	47	30	39.5	44
Length	41.5	44	41.5	27	36	42
Curvilinear length	60	60	57	34	50	65
Depth	7	7	7	3	5	7

This is one of the largest of the Western Australian species of *Strophalosia*. The outline is variable, mostly subtrigonal, sometimes oval, the greatest width lying anterior to the middle. The hinge-line is straight, one-half the greatest width. Despite the fact that nearly every specimen, although otherwise excellently preserved, has suffered some flattening, it is possible to give a fairly precise estimate of the convexity of the longitudinal outline. The pedicle valve is low to moderately convex, evenly so over the body of the valve, but with accentuated convexity at both posterior and anterior margins. The transverse curve is essentially similar, the lateral margins sloping steeply, almost vertically, with a median flattening which occasionally results in a broad shallow sinus over the anterior portion. The alar angles are often right-angles, the alar extremities being recurved, convex from a ventral aspect, resulting in small ears, which are not, however, sharply delimited from the rest of the valve. In other specimens, of oval outline, the alar angles are obtuse and there are no ears. The umbo is rather variable in shape. Mostly it is wedge-shaped, pointed, with a small cicatrix of attachment, suberect, although in some specimens the tip is bent over to become erect and even incurved. It never overhangs the hinge. The area is triangular, extending the whole width of the hinge, undistorted except for those few specimens where the umbo is distorted and horizontally striated. The height varies. In young specimens it may be as much as one-third the width. In mature specimens it is less, varying between one-quarter and one-eighth the width, the average being about one-sixth. For the most part the area is flat, but in specimens with some incurvature of the umbo it may be slightly concave, particularly at the apex. The pseudodeltidium is narrow, ridge-like, raised, subtriangular in shape. It is rarely more than a millimetre wide at the base.

The brachial valve is moderately concave, curving in sharply just under the hinge, with smoothly upturned margins. The area is smaller than that of the other valve, only half as high, with a pseudochilidium corresponding to the pseudodeltidium. Where present the ears are excavated concave, corresponding with the convex ventral aspect. In outline this valve follows that of the pedicle valve, the margins a little crimped and uneven.

The ornamentation consists of spines and concentric lines of lamellae, reflecting the lamellose structure of the shell wall. On the pedicle valve the spines are not very numerous, between twelve and fifteen over a square centimetre on the middle of the valve. They are suberect to erect, the latter more common towards the anterior margins. On the alar extremities they are more numerous and reclined. Over the initial parts of the valve they are of medium size, about half a millimetre at the base, but becoming coarser towards the margins, sometimes measuring up to a millimetre at the base. Initially they are arranged irregularly or subquincuncially, with growth tending to become arranged in lines following successive growth lamellae.

The ornamentation of the brachial valve follows that of the pedicle valve, the spines on the whole tending to be finer.

In the pedicle valve the teeth are moderately large, diverging, and concave from the dorsal aspect. The adductor muscle scars are situated on a raised platform, but themselves are a little depressed. They lie a little anterior to the hinge, and are elongate-oval in shape, separated by a narrow ridge. Whether or not each impression is in turn divided is unknown. The diductor impressions lie in depressions, one either side of the adductors and extending farther forward than these.

In the brachial valve the cardinal process is inclined at a large angle, about 70 degrees to the plane of the visceral disc, the posterior surface continuing in the same plane as the area. It is large and squat, as wide as high, the measurement being 4 mm. in the largest instance, and projecting well into the umbonal cavity. It is essentially trilobed, the large centre lobe being split at the apex to give two small, closely adjacent lobes, making in all a four-lobed process. The two lateral lobes are well separated from the central mass, inclined almost at right angles to it. The posterior surface shows the growth striations. The base of the process results from the junction of the median septum and two marginal ridges, each of which partially encloses a large tooth socket, then swings laterally at a slight angle to the hinge, almost to the lateral margin, then curves anteriorly, soon dying out in the body of the valve. The median septum extends over half to two-thirds of the length of the valve. The adductor muscles are situated immediately in front of the base of the cardinal process. Each is separated by the median septum, and consists of an anterior and posterior portion. The anterior part is raised, deltoid in shape, while the posterior is depressed, crescent-shaped, and partly envelops the anterior part. The muscle impressions are non-dendritic. Each brachial impression arises at

the lateral extremity of the posterior element of the adductors, curves antero-laterally to the edge of the visceral disc, but a few millimetres in from it, then curves in a semi-circle so that it parallels the median septum, and finally terminates in a hook a few millimetres anteriorly removed from the base of the septum. Most of the anterior half of the valve is covered with minute papillae which, over the upturned region of the valve, become elongated and spinose.

In young specimens the internals of the brachial valve are essentially similar to those described, but less developed. This applies particularly to the marginal ridge along the hinge and to the cardinal process, which is only a stub hardly extending behind the hinge, and barely lobed.

Variation in the Species: The outline and the degree of incurvature of the umbo are the two features which show most variation. Most specimens are subtrigonal, the greatest width lying anterior to the middle and the hinge being one-half the greatest width. In very few specimens is the hinge less than this. Less than one-fifth of the total number of specimens (150) tend to be transversely oval in outline. In these the hinge is proportionately wider, between one-half and three-fifths of the greatest width.

One-fifth of the specimens have the umbo erect, and in all of these the outline is nearly trigonal. Two-fifths of the total have the umbo suberect, and in the remainder, many of which tend to be oval, it is straight, or the tip may be just inclined dorsally. Variation in the size of the area has already been mentioned. It does not seem to vary in harmony with the features just described.

Not many specimens show the internals, which seem to be fairly stable. The cardinal process does, however, vary in attitude to the plane of the brachial valve. In most of the specimens available, it is inclined to about 60 degrees, but in some it is at a very much smaller angle. In every case the dorsal surface of the process is co-planar with the dorsal cardinal area.

Comparison with other Species: S. prideri may be rather closely compared with the Eastern Australian form, *S. jukesi* Etheridge fil., 1880, p. 45, pl. 13, figs. 39-43, the definition of which is still somewhat obscure. It may be distinguished from *S. jukesi,* as generally conceived, by the following features: the outline consistently tends to be more trigonal than that of *S. jukesi;* the umbo is more pointed, the ornamentation of spines more coarse and sparse. The cardinal process in *S. jukesi* is much more blunt and the lobation is not as obvious as that of the process of *S. prideri.*

Remarks: The material upon which this species has been described was unknown to Prendergast, who, in 1943, referred several incomplete ferruginous casts to *S. jukesi* Etheridge fil. These casts, although incomplete, show features identifying them with *S. prideri* rather than with *S. jukesi.*

The specific name is given to honour Professor R. T. Prider, head of the Department of Geology, University of Western Australia.

Material: Over 150 specimens, many distorted, but all well preserved.

Subgenus HETERALOSIA R. H. King.

1938—R. H. King, *J. Paleont.*, 12, 278.

Type Species—Heteralosia slocomi R. H. King, *J. Paleont.*, 12, 278, pl. 39, figs. 15-18.

Diagnosis: Features essentially those of *Strophalosia,* but with smooth, non-spinose brachial valve.

Remarks: The diagnostic feature distinguishing *Heteralosia* from *Strophalosia* is the absence of spines on the brachial valve. It is difficult to assess the significance of this as a taxonomic feature. From the practical point of view it is easily recognizable and serves to reduce the large number of species otherwise assigned to *Strophalosia.* This number of species has become cumbersome to handle as a single unit. The recognition of *Heteralosia* therefore serves a useful purpose, since it reduces this number considerably.

It is difficult to decide whether or not there is any phylogenetic basis for this recognition. The association of species with spinose brachial valves and those without spines on this valve is a common one, both in a particular formation and over wide regions. It cannot be said with certainty (since the overall stratigraphical ranges of most species are not known definitely) whether the *Heteralosia*-type came before or after the *Strophalosia*-type. The bionomic significance of the non-spinose valve is also unknown. It would appear, however, that this absence of spines is a superficial feature, since the changeover from spinose to non-spinose brachial valve is unaccompanied by any other fundamental changes in external or internal features. This opinion is based on study of the local species, and of species in the literature.

With this in mind, then, it is possible that the species constituting *Heteralosia* would represent a polyphyletic group. This being so, it seems best to regard *Heteralosia* as a subgenus of *Strophalosia.* As a subgenus it can still serve practical needs.

STROPHALOSIA (HETERALOSIA) ETHERIDGEI Prendergast.

Pl. 19, figs. 20-32.

1943—*Strophalosia etheridgei* Prendergast, *J. Roy. Soc. W. Aust.*, 28, 43-45, pl. 5, figs. 5-11 (not fig. 12).

1943.—*Strophalosia* sp. ind. A. Prendergast, *Ibid.*, 28, 51-52, pl. 6, figs. 10-12.

Lectotype (chosen here from original author's syntypes, G.S.W.A. 1/5242 a): Prendergast (1943), pl. 5, figs. 6, 7; creek ½ mile west of Callytharra Springs, Wooramel River, Carnarvon Basin. Callytharra Formation.

Diagnosis: S. (*Heteralosia*)-species, very small, not distorted, oval to circular outline, with ornamentation of sparse coarse spines and pronounced concentric laminae. Cardinal process bilobed, spike-like. Differs from *S.* (*H.*) *prendergastae* sp. nov. by fewer spines, lack of deformation, and more silky lustre and lamellose shell structure.

Description: This is after the orginal description by Prendergast, the new material necessitating only minor alterations. Dimensions of typical specimens are—

—	U.W.A. 27157a.	27157b.	27157d.	27157e.
Width of hinge	9	6	7	7.2
Width	11.5	9.5	10.5	10.5
Length	11	9	11	11
Curvilinear length	16.5	13	16	15
Height	approx. 2.5	..	..	..

Members of this species are all rather tiny. The near-geniculated margin of the brachial valves of many specimens indicates their maturity, despite the small size. The pedicle valve is moderately inflated, almost hemispherical, the convexity being much the same over most of the valve, except towards the cardinal margin where the slope is steep, and at the anterior margin where it tends to flatten out. The hinge is less than the greatest width, which occurs across the middle. The umbo is flattened, bearing a prominent cicatrix of attachment, and is separated from the hinge by a narrow triangular area, about one-tenth as high as wide, extending the whole width of the hinge. The pseudodeltidium is triangular, narrow, and slightly raised; in most specimens it has fallen away, leaving a gap. The ears are flattened and tiny, and hardly differentiated from the rest of the shell. The ornamentation consists of spines and concentric lines of lamellae. The shell structure is lamellose and silky. The spines are coarse for the size of the shell, not very numerous (about 25 on the holotype), and adhere to the surface of the shell, except towards the alar portions, where there are a few erect spines. In general the size of the spines increases towards the anterior margin.

The brachial valve is flat or slightly concave over the visceral portion, rather sharply upturned at the extreme margins. The surface is silky with concentric lines of lamellae. When crushed, these lamellae move one against the other, riffling out to follow the pedicle valve closely, so that the valve may appear to be deeply concave. There are no spines. The area is smaller than that of the pedicle valve, but with a pseudochilidium a little larger than the pseudodeltidium.

In the pedicle valve the adductor muscle impressions are set high up under the umbo on a raised eminence. The diductor impressions are set one each side, are depressed in fossae which die out anteriorly, and are longitudinally striate. The teeth are small, excavated, and a little diverging. From their bases a ridge runs out laterally either side, is most prominent at the alar angles, leaving a platform of the ears, and dies out midway along the lateral margin. In some specimens it continues all round the anterior margin as a cincture.

In the brachial valve the cardinal process begins at the junction of the median septum and a pair of slight ridges, a little removed from the hinge. Overall the cardinal process is spike-like, extending posteriorly at a slight angle to

the plane of the valve. At the hinge it is narrow but thence becomes slightly bulbous, the ventral surface appearing button-like, with a raised rim, divided by a median indentation which reaches the tip, so giving it a bilobed appearance. The termination inclines dorsally. From the dorsal aspect the process is bilobed with strong growth striations and with a median indentation running along its length to the hinge. The teeth sockets lie at the base of the process. The semi-marginal ridges which border the sockets anteriorly die out just either side of them. The adductor muscle impressions are slightly raised, set in the angle of the semi-marginal ridges and the median septum. No pairing of the adductors could be seen. They are non-dendritic. The median septum is narrow, raised, extending a little less than half-way across the visceral disc, the termination being raised higher than the rest, and bulbous. Around the lateral and anterior margins, at the point of upturning, the valve is thickened almost into a marginal ridge. This fits into the cincture described for the pedicle valve. The rest of the surface is covered with sparse papillae which, at the margins, are elongated anteriorly to form blunt spikes. They are most numerous along the upturned margin.

Variation within the Species: Members of this species are most stable in their characteristics. Apart from minor variation in outline, sometimes longer than wide by a millimetre, sometimes less wide than long, almost any individual might be taken as representative. Even immature individuals closely resemble adult specimens, except that the cicatrix of attachment is proportionately larger and the brachial valve shows a slight concave indentation, corresponding to the cicatrix on the other valve, which tends to disappear in the adult.

Comparison with other Species: Only one other local species can be at all closely compared with this one—*S.* (*H.*) *prendergastae* sp. nov. It is distinguished from the present one by possession of many more spines, by its deformed appearance, by its lack of silky lustre and lamellose structure on the pedicle valve, and by its larger size and consistently larger cicatrix of attachment.

A foreign shell meriting close comparison is that described as *Strophalosia* sp. ind. No. 7, by Netschajew (1911, p. 148, pl. 7, fig. 5). This is a broken pedicle valve which, from the illustrations, is identical with *S.* (*H.*) *etheridgei.*

Remarks: As with *S.* (*H.*) *prendergastae,* the study of many growth series of specimens shows that this species is not the immature form of some other species.

Material: Over 30 specimens, mostly single pedicle valves, with a few brachial valves and conjoined valves, all in excellent preservation.

STROPHALOSIA (HETERALOSIA) IRWINENSIS sp. nov.

Pl. 20, figs. 1-6.

1943—*Strophalosia* sp. cf. *gerardi* King; Prendergast, *J. Roy. Soc. W. Aust.,* 28, 46, pl. 5, figs. 14, 15.

Holotype: U.W.A. 23441a, Fossil Cliff, Irwin River, near Mingenew. Fossil Cliff Formation.

Paratypes: U.W.A. 12399, 23441b, 34463, 34464, 34465, 34466, 34466a. Same locality and horizon as holotype. U.W.A. 34467, Fossil Ridge, Holmwood Station, same general locality and horizon as holotype.

Diagnosis: Similar to *S. gerardi* King (1846), but more truly oval, evenly convex, with less prominent umbo, with brachial valve less concave and definitely without spines.

Description: The shape, size and outline of the shell are much the same as in *S.* (*H.*) *gerardi* King. The convexity of the pedicle valve is rather even, the greatest convexity occurring over the visceral region; a slight median sinus may be present, which dies out before the anterior margin; the outline, particularly of the pedicle valve, is transversely oval; the umbo is not prominent, the area very slightly concave, the height about one-eighth the width. In the local specimens with conjoined valves, the brachial valve follows the curve of the pedicle valve closely, but this is due to preservational flattening. Undistorted brachial valves are not deeply concave, the visceral disc being flat to slightly concave, the margins being upturned rather sharply. The alar extremities are rounded.

The ornamentation on the pedicle valve consists of subquincuncially arranged spines, tending to a concentric arrangement, and prominent growth lamellae. The size and number of spines varies on the local specimens. The spines are rather fine (one-third of a millimetre at the base) over the initial growth stages, but along the cardinal margin and over the later growth stages are more coarse. In one specimen the spines are up to one millimetre at the base. They may be reclined or suberect. The average number of spines over a square centimetre of the median portion is about fifteen, the extremes being ten and twenty-three over the same area. The cicatrix of attachment may measure up to 4 mm. in greatest dimension.

The brachial valve has no spines, the ornamentation consisting of concentric lines from the growth lamellae, and also faint radial striae interspersed between successive lamellae.

In the pedicle valve the cardinal teeth are prominent, well separated, a little diverging, and concave on the dorso-lateral sides. The non-dendritic adductor muscle impressions are situated on the floor of the valve immediately below the teeth, well up in the umbonal cavity. The nature of the diductor muscle impressions is unknown. In the brachial valve the adductor muscle impressions are non-dendritic, in two pairs. The anterior pair is most prominent, slightly raised, together making a rhomb-shape divided by the median septum. The posterior pair is hard to distinguish, but appears to be laterally oval-shaped, a little depressed. In one specimen, the anterior pair of adductors are linearly striated beneath the true exterior surface, which is partly worn away. The median septum extends from the base of the cardinal process over about two-thirds of the length of the valve. It is thin and raised. The cardinal process is spike-like, co-planar with the cardinal area, thus being inclined at an angle of about 60 degrees to the plane of the visceral disc. From the dorsal aspect it is trilobed; the central lobe is by far the largest and extends farther posteriorly than the laterals. From the ventral aspect it may appear

bilobed owing to the presence of a strong sulcus which tends to split the median lobe, and to the very minor development of the lateral lobes. The teeth sockets are deep, one immediately each side of the base of the process. The brachial impressions are not preserved. Minute papillae cover much of the rest of the surface, tending to become spinose and forward-projecting over the upturned portion, particularly at the anterior margin.

Variation in the Species: Variation in the nature of the spines and in the cardinal process has already been mentioned. The exact nature of the variation in these and other features cannot be determined, however, owing to the limited number of specimens.

Comparison with other Species: As indicated earlier this species has its closest affinities with *Strophalosia* (*Heteralosia*) *gerardi* King. Although Prendergast had only one specimen, she observed differences which led her to refrain from identifying it with *gerardi*. Additional material has confirmed and added to these differences, so that they justify considering the local form as a new species.

The specific name is derived from the name of the river, the Irwin, upon which the holotype locality is situated.

Material: Fifteen specimens, isolated and conjoined valves, many distorted, but with detail well preserved.

STROPHALOSIA (HETERALOSIA) KIMBERLEYENSIS Prendergast.

Pl. 20, figs. 7-19.

1890—*Strophalosia clarkei* Etheridge; Foord, *Geol. Mag.* dec. III. 7, 103, pl. 5, figs. 7-8, text-fig. 6.

1903—*Strophalosia* sp. ind., Etheridge fil., *Bull. geol. Surv. W. Aust,* 10, 20, pl. 1, figs. 10-12.

1943—*Strophalosia kimberleyensis* Prendergast, *J. Roy. Soc. W. Aust.,* 28, 47-50, pl. 6, figs. 1-5.

Holotype: U.W.A. 20452, north of Hill C, south side of Grant Range, West Kimberley District. Noonkanbah Formation, upper part.

Paratype: U.W.A. 20460, same locality and horizon as holotype. U.W.A. 20455, Noonkanbah Homestead, West Kimberley District. Noonkanbah Formation.

Other Material: A hundred or more specimens including U.W.A. 27797. 27582, 27616, from syncline just west of Coolkilya Pool, Minilya River. Wandagee Station, Carnarvon Basin. Wandagee Formation.

Diagnosis: Strophalosia (*Heteralosia*)-species, characterized by concentric lamellose shell structure without spines on brachial valve or main part of pedicle valve, but with row of spines along hinge of pedicle valve.

Description: This is substantially as written by Prendergast, new material necessitating some revision and additions.

Dimensions of typical specimens:

—	U.W.A. 20452.	20460.	20455.	27797.
Length of hinge	22	23.7	24.5	23
Width	27.8	30	29.3	27
Length	28.2	19.2	24.3	27
Curvilinear length	52	31	..	43
Height	10.8	..	..	11
Trail	4	..	..	5

The pedicle valve varies in outline from subquadrangular to ovate and semi-circular, longitudinally moderately to strongly convex, almost hemispherical, the umbonal region being depressed. Older specimens are usually more strongly convex. The hinge-line averages three-quarters of the greatest width, which occurs across the middle. There are no true ears, the alar angles being slightly obtuse and rounded. The area extends the full length of the straight hinge, its height is one-fifth its length, and it is bisected by a narrow closed delthyrium. The umbo is not prominent, not pointed, the apex set well back from the hinge, sometimes showing a small cicatrix of attachment.

In this species the shell structure is so loosely lamellose that the outer surface is particularly susceptible to damage, and the true ornamentation has been difficult to ascertain. Of a large number of specimens only a few brachial valves are considered to show the exact external surface. Some, however, which are only slightly weathered, show more of the ornamentation than do those upon which the original description was based.

The absence of spines was considered by Prendergast to be an important characteristic of this species. It can now be said that the species is spinose: there is a row of spines of medium size along the cardinal margin of the pedicle valve, six or seven each side of the umbo. Under the microscope the traces of the bases may be seen even on many imperfectly preserved specimens. The rest of the shell seems to be non-spinose; there are certainly no spines on the brachial valve. Over the remainder of the pedicle valve there are concentric lines of lamellae, fairly widely spaced. A few specimens show fine, close-set striae between successive lines of lamellae.

Whether or not these striae are continuous over many inter-lamellar spaces cannot be determined. On some specimens the surface of inner lamellae shows numerous very tiny pits. These do not show on the surface of the outer lamellae constituting the true outer surface. Sectioning has shown that they persist through many of the lamellae making up the shell wall. It is almost certain that this punctate appearance in section is due to the successive dimpling of each lamella, the reflection of papillae on the internal surface.

The brachial valve is flattish or slightly concave over the visceral disc, with evenly upturned margins, sometimes subgeniculate, internally usually geniculate owing to thickening at the lateral and anterior margins. The area corresponds to that of the pedicle valve, but the height is usually less. The ornamentation consists of concentric lines from the lamellae, and of very

minute close-set dimples, very much elongated radially, and commonly terminating anteriorly in a pit, corresponding to those on the pedicle valve. The interspaces might be termed striae, corresponding to those on part at least of the pedicle valve. There are no spines on this valve.

In the pedicle valve the teeth are strong, triangular and diverging from one another. Laterally they arise from a ridge which lies at a small angle to the hinge and separates it and the alar extremities from the visceral cavity. On either side, this ridge continues in front of the alar extremities, leaving them platform-like, and so to the lateral margins. In front of each of the alar platforms, behind the ridge, is a narrow groove, into which fits a ridge on the inside of the brachial valve. The adductors are elongated and situated almost under the teeth. The diductors are large, longitudinally striate, extending further anteriorly than the adductors, and separated by a median prominence, hardly to be called a septum. The anterior surface is dimpled.

In the brachial valve, owing to thickening of the shell, the interior surface is geniculate, a raised ridge separating the visceral disc from the trail. This ridge extends laterally and posteriorly, almost to the hinge, leaving the alar extremities thickened and platform-like. On the visceral disc the median septum extends for two-thirds of the length, and continues posteriorly as a prominent cardinal process, which extends well beyond the hinge, in the plane of the visceral disc. It is basically trilobed, but in some specimens there is a median depression on the main body of the process, which continues to the posterior extremity to give four lobes, the inner lobes almost conjoined, the extreme lateral ones well separated from these. At the base of the process, one either side of it, are the two tooth sockets. The adductor muscles are set in a depression anterior to the sockets, which decreases anteriorly and which is bounded posteriorly by a slight ridge. The anterior adductors are shield-shaped, elongated antero-posteriorly. The posterior pair are ovally elongated laterally, and the brachial impressions arise from their lateral extremities. The brachial impressions are very outstanding. They swing outwards almost to the lateral border, follow the lateral and antero-lateral borders of the visceral disc, and turn posteriorly parallel to the median septum. They may terminate at a point level with the end of the septum, or they may continue for a slight distance of 1 or 2 mm. beyond it. The anterior part of the inside surface is covered with numerous minute papillae, commonly elongated longitudinally. They are especially prominent over the cincture and geniculated region.

The most outstanding feature of the internals of both valves is that the actual visceral cavity is much smaller than would be thought from an inspection of the external appearance. This is due to the thickening of the posterior and alar margins on the inside of both valves, and also to the thickening of the lateral and anterior margins of the brachial valve.

Variation within the Species: Variation in outline and shape has already been mentioned, the important point being that with age the specimen becomes more highly convex. Other variable features, however, do not seem to vary in harmony. The median septum may extend from one-half to two-thirds

the length of the visceral disc. The cardinal process varies a little in shape and prominence. In some specimens it is more spike-like than blunt, and if so is usually trilobed. Where blunt and wide, it is usually quadrilobed.

Comparison with other Species: *S. (H.) kimberleyensis* is distinguishable from other species of the genus by the absence of spines over any other part of the surface except for a single row along the cardinal margin of the pedicle valve. Prendergast (1943) compares it with *Strophalosia clarkei* (Etheridge) and mentions that the external appearance of the two species is similar. The original author of *S. clarkei,* however, described it as having numerous slender spines. Externally, the two species could only be compared if the ornamentation of specimens of *S. clarkei* had been removed in the course of preservation. Even then, as Prendergast remarks, *S. (H.) kimberleyensis* is distinguished by the flattened umbonal region, longer hinge-line and more concave brachial valve.

Material: Several hundred specimens, well preserved, although most are abraded and many are distorted.

STROPHALOSIA (HETERALOSIA) PRENDERGASTAE sp. nov.

Pl. 20, figs. 20-35.

1943—*Strophalosia* cf. *Strophalosia beecheri* Rowley; Prendergast, *J. Roy. Soc. W. Aust.,* 28, 41-42, pl. 5, figs. 1-3.

Holotype: U.W.A. 28444a; 350 yards west of the fence between Barabiddy and Weer Paddocks, 2,220 yards south of gate in that fence, near Barabiddy Creek, south of Wandagee Homestead, Carnarvon Basin. Cundlego Formation.

Paratypes: 28444b; same locality and horizon as holotype. U.W.A. 20449; Waltharrie Pools, Wooramel River. Callytharra Formation. U.W.A. 34468, 34469, 34470, 34471, 34472, 34473; limestone at base of Mount Hardman, West Kimberley District. Liveringa Formation, Hardman Member. U.W.A. 34474; Fossil Ridge, Holmwood Station, near Mingenew, Irwin River District. Fossil Cliff Formation.

Diagnosis: *Heteralosia*-species with thin visceral cavity, distinguished in particular by very numerous fine spines and by unusually large cicatrix of attachment; these features distinguish it from *S. (H.) etheridgei* Prendergast.

Description: Representatives of this species are all small in size, with an irregular outline due to attached mode of life in the early growth stages.

Dimensions of some of the type specimens are—

—	28444a.	28444b.	34468.	34469.
Length of hinge	7.5	7.5	7.5	6.8
Width	12.5	13.5	13	9.5
Length	11.5	15.7	12.5	9
Curvilinear length	20	23	18	12
Height	4	5	..	2.5

The cicatrix of attachment is large, usually to one side of the umbo, so that the umbonal region is most distorted, resulting in the hinge being at an angle to the direction of growth. The resultant irregular outline is most obvious from the dorsal aspect. In front of the cicatrix the pedicle valve is more or less regularly, and rather strongly, convex. It may, however, show some flattening over the visceral region. Transversely the flanks are steep, the middle somewhat flattened but without a median sinus. There are no true ears; the alar extremities sometimes show a slight recurvature but are not differentiated from the body of the valve. The alar angles are obtuse. The hinge-line is straight, one-half to two-thirds the greatest width, which lies across or slightly in front of the middle. The umbonal region is not prominent, being flattened by the cicatrix of attachment, and is separated from the hinge by a narrow area, about one-eighth as high as wide, persisting over the entire width of the hinge. In most specimens the area is equally developed either side of the low narrow triangular pseudodeltidium and is not distorted. Except for the area of attachment the surface of the valve is covered by numerous fine spine-bases, rather elongated, giving off reclined, semi-erect and erect spines. The spines vary in size from fine to very fine, none exceeding half a millimetre at the base. The reclined spines are finest. Even allowing for the effects of decortication, the number of spines seems to vary somewhat. On the pedicle valve of the holotype there are about 80; on that of a partially decorticated paratype there are 40. The limits of variation of this feature probably lie within these figures. The arrangement of the spine-bases is irregular or subquincuncial, spines of varying attitude and size occurring indiscriminately together. The lamellose character of the shell, common to species of the genus, is not very noticeable on this valve. On one partially decorticated specimen, a paratype 28444b, the spines are nearly all removed and the exposed elongated roots of the bases give an almost pseudocostate appearance to the surface. Growth wrinkles are not prominent.

The brachial valve is moderately concave. Most specimens have this valve crushed in, so that the concavity appears to be greater than it actually is. Over the initial part the valve is flat, mirroring the cicatrix on the pedicle valve; then it becomes smoothly concave, gradually flattening towards the anterior margin. The lamellose structure of the shell is more apparent on this valve, resulting in concentric lines of laminae. So far as can be judged, no spines are present. The area is similar to that of the pedicle valve, with a well developed pseudochilidium. The angle between the two areas is very obtuse.

In the pedicle valve the cardinal teeth are small, bluntly triangular, scarcely diverging. At their lateral sides they are excavated, concave from a brachial aspect.

In the brachial valve the cardinal process is large, and from the dorsal aspect bulbous, bilobed, the lobation hardly discernible. It extends well into the umbonal cavity, in the same plane as the area of the valve, and arises from the junction of the median septum and a pair of slight marginal ridges, one either side of the septum, which partially enclose the prominent tooth sockets.

The above internal characters were described from specimens the identity of which was undoubted. Other internal features can be drawn from a limonitic internal cast, which is most probably a specimen of this species. This is not absolutely certain, however, and so the description of this specimen is made separately. The median septum extends over half the visceral disc. It is thin and barely raised. Joining it to form the beginning of the cardinal process are two marginal or semi-marginal ridges, separated from the hinge by about a millimetre, and forming the anterior edge of the tooth sockets: in front of these, on the flattened portion corresponding to the cicatrix on the other valve, are the adductors. They seem to be in two pairs. The posterior are oval laterally, the smaller anterior pair are on the curve at which the valve begins its concavity. The rest of the surface is covered with minute papillae, finer on the anterior portion.

In the pedicle valve only the position of the raised adductors can be seen. They are placed on the anterior edge of the flattened area of attachment.

Variation within the Species: The size of the cicatrix of attachment and resultant distortion of the shell are variable features in this species. In some specimens the cicatrix is small, less than 10 sq. mm.; the largest is 15 sq. mm. The size is always such as to indicate that the specimen must have lived attached for much of the early stages of growth.

In ornamentation the variation present is difficult to assess owing to the particular degree of decortication and weathering suffered by many specimens. As mentioned above, the spines vary in number, attitude, and size, differences in these particulars apparently being haphazard. The average number is 50-60 on the pedicle valve, erect spines being larger than those reclined, and more numerous towards the anterior. The arrangement is irregularly subquincuncial over the visceral disc, but tends to be quite irregular towards the margins.

Comparison with other Species: This species was compared to *S. beecheri* Rowley (Weller, 1914, p. 146, pl. 19, figs. 37-38) by Prendergast (1943). It is similar to Rowley's species, but it differs from it in that the local species is more densely spinose, does not show concentric lines of lamellae to the same extent as *S. beecheri,* and possesses a larger cicatrix of attachment. Actually, comparison between the two species is difficult, as the identity of the American species rests solely on one pedicle valve from the Carboniferous Louisiana limestone of Illinois. Besides the morphological differences there is also a great difference in the age of occurrence of the two species, *S. (H.) prendergastae* being Middle Permian, and *S. beecheri* Carboniferous (Mississippian).

This species should not be confused with any other of the Western Australian species.

It differs from the local species, *S. (H.) etheridgei* Prendergast, in its much larger, more numerous spines, larger size, larger cicatrix of attachment, more quadrate outline and consistent distortion; for the same reasons it also differs from the shell described as *Strophalosia sp.* ind. No. 7, by Netschajew (1911, p. 148, pl. 7, fig. 5).

Remarks: The specific name is given to honour K. L. Prendergast, who was the first to make a systematic study of Western Australian Productacea.

Material: Twelve specimens showing both external and internal features, variously preserved, most of them well preserved.

Uncertain Species.

The following two species have been recorded but are doubtfully present. They are *Strophalosia clarkei* Etheridge (Pl. 18, figs. 1, 2 herein) from the Carnarvon Basin, and *S.* (*Heteralosia*) *tenuispina* Waagen, from the Irwin River District.

The first species has recently been revised by Maxwell (1954, pp. 546-547). Hitherto its definition was most obscure. Prendergast (1943) referred two of her specimens, both brachial valves (Aust. Mus. F36234, F36235), to *S. clarkei.* These almost certainly belong to *S. multispinifera* Prendergast, herein revised. The fact that this is Prendergast's own species has no bearing on this opinion, for the original description of *multispinifera* was limited to pedicle valves.

S. (*H.*) *tenuispina* may conceivably be present in the West Australian Permian.

Strophalosia (Heteralosia) tenuispina Waagen.

Pl. 20, figs. 36, 37.

1884—*Strophalosia tenuispina* Waagen, *Palaeont. indica,* Salt Range Fossils, p. 654, pl. 64, figs. 2-7.

1943—*Strophalosia tenuispina* Waagen; Prendergast, *J. Roy. Soc. W. Aust.,* 28, 52, pl. 6, fig. 9.

1944—*Strophalosia* (*Heteralosia*) *tenuispina* Waagen; Reed, *Palaeont. indica,* N.S., 23 (2), 106.

Material: U.W.A. 20451. One indifferently preserved pedicle valve. Fossil Cliff, Irwin River, near Mingenew. Fossil Cliff Formation.

The diagnosis and description are taken directly from Prendergast (1943, p. 52). The dimension of height given is synonymous with length as used in this paper.

"*Diagnosis*: Shell circular to oval in outline, hinge-line equal to maximum width, pedicle valve but slightly inflated, dorsal valve concave. Surface ornamentation finely lamellose with sparsely distributed oblique spines. Pedicle valve non-sinuate, area high, with flat, narrow, linear pseudodeltidium. Small scar of attachment.

"Brachial valve with small linear area, surface ornamentation not known.

"*Description*: This species is known by a single specimen of a pedicle valve from the Irwin River.

"*Dimensions of valve*:

Height	17.8 mm.
Maximum width	21.3 mm.

"The specimen is rather weathered, but shows the fine spines; these are represented now only as rather worn bases; the spines are tangential to the shell surface and some of them adpressed. They are arranged more or less in

concentric rows, each row separated from the previous one and that following by lamellae. On the lateral margins larger spines are developed, and these show a curious marking, almost a facet developed on the ventral surface of each spine. Whether this is the effect of weathering it is impossible to say. The spines, apart from their concentric arrangement, also show a roughly quincuncial arrangement.

"The area of this species is very distinctive among *Strophalosias,* being flat and in the plane of the commissure of the valves. It is interrupted by a very narrow, parallel-sided pseudodeltidium."

For comparison with other species Prendergast refers to the account of *Strophalosia* (i.e., *Heteralosia*) *etheridgei* in the same work. No mention of *S. tenuispina* is made there. If anything this species most closely resembles *S.* (*H.*) *irwinensis* of all other local *Heteralosia*-species. The only apparent difference is that the hinge-line is wider than in any of the specimens described as *S.* (*H.*) *irwinensis.*

Remarks: The record of this species was based solely on one pedicle valve rather indifferently preserved. The state of the specimen is such that it could be *S.* (*H.*) *tenuispina,* but equally as well belong to other species, in particular the local species *S.* (*H.*) *irwinensis.* It seems presumptuous to decide one way or the other. Having noted the possibility of misidentification in view of the nature of the specimen, and since it is possible that the form is *S.* (*H.*) *tenuispina,* it has been decided to record the species as described by Prendergast.

ECOLOGICAL OBSERVATIONS.

A palaeoecological study of the Western Australia productids, distributed over wide areas and occurring throughout much of the Permian succession, would require, first, investigation of the individual species, followed by a synthesis of the resultant information to give the synecology of genera, and groups of genera, over different areas at different times. For such a task both material and data are grossly insufficient at the present time, particularly with regard to the necessary field studies. The discussion which follows is, then, confined to general observations more or less connected together to give an over-all picture.

Evidence for this discussion has been gathered from a study of the enclosing sediments; from studies of the associated faunas, of the morphological features of the species and the bionomic interpretations thereof, of their associations, species to species, as preserved in the rocks, and of their mode of preservation; and from field studies in the Irwin River area.

The Enclosing Sediments.

The matrix in which the vast majority of specimens are found has been either little altered beyond normal consolidation, or to some extent enriched in iron.

Where the enclosing sediment has not been much altered most specimens are contained in an essentially similar matrix. This is a very fine sandstone, friable, micaceous, often with a high primary iron-content present as a coating

on the grains, and ranging in colour from grey-green to brown and reddish-brown. It is generally calcareous; most of the calcite is composed of organic fragments. With an increasing amount of iron, usually limonite, the sandstone becomes harder and less friable; the granular calcareous matter is gradually leached away, and the sediment finally becomes a hard uniform limonitic mass, the original characters of the sediment being largely lost. In the less extreme instances, however, the sediment appears to have been, before alteration, the same very fine sandstone as that preserved unchanged. Moulds of specimens found in the intensely ferruginized material, of which, for example, the Liveringa Formation is largely composed, are often hollow, and on being broken occasionally yield a fine loose sand, preserved from further alteration by the hard casing of the mould. For many specimens this sand is probably almost unchanged from the sediment originally enclosing the shell and the substratum in which the animal lived.

Such an occurrence is unusual. Sedimentary analysis of the sand showed it to be a very fine sand (Wentworth terminology), 70 per cent. by weight falling into the size category 1/8th to 1/16th millimetres, and over 10 per cent. into the clay fraction. It was composed of subangular grains showing medium sorting, predominantly of quartz with occasional authigenic rims. The subsidiary minerals were altered potash felspar, biotite and muscovite. Heavy minerals, including calcite, were rare. The brownish colour of the sand was due to iron-coating. There was no unaltered sediment outside the moulds, so whether or not the quartz authigenesis preceded the limonitization of the sediment could not be determined.

It is probably significant that so many specimens should be consistently found in a sediment of the same general lithological type, at different stratigraphical levels and at different places. This applies particularly to the succession above the Callytharra Formation in the Carnarvon Basin. (It also seems to apply in the sediments of another area with which I am familiar—the Carboniferous and Permian of the Hunter Valley in New South Wales. More productids, both species and individuals, are found in the finer than coarser sediments; the coarser is relatively richer in pelecypoda and gastropoda.)

The emphasis so far has been on the most prevalent enclosing sediment. Species of the Productacea, however, are not confined entirely to the one type of matrix. In the Nura Nura member and Callytharra and Fossil Cliff Formations, they are also found in impure limestone bands. For the most part this limestone is not massive, but appears to be made up very largely of the same very fine micaceous sand as mentioned, together with fragmentary organic remains, the whole cemented by calcium carbonate.

An occasional matrix is a fine red silt, in colour and consistency like jewellers' rouge. In most instances this silt occurs as blebs in the usual fine sandy matrix of the Carnarvon Basin, sometimes infilling enclosed shells, more or less as a secondary matrix. In several examples, however, specimens of *Linoproductus cancriniformis* occur in slabs of the silt, packed haphazardly together, and morphologically exactly the same as specimens of the same species

which occur most frequently in the other sediment. Occurrences such as these may be due to post-mortem transport or to slumping. At least one species occurs in numbers in coarse sandstones and grits. This is *Taeniothaerus teicherti,* an extremely large and robust form, well equipped for near-strandline conditions. The matrix is persistently gritty, with well rounded pebbles and broken-up shell fragments.

The Associated Fauna.

It is not possible just now to give a detailed and comprehensive account of the faunal associations of the West Australian Productacea. Instead, only those associations are discussed which are the most obvious and, more important, which persistently occur.

Although productid specimens occur isolated amongst specimens of other invertebrate groups, the specimens of any one species are usually found packed together in "fossil" communities, so reflecting the gregariousness typical of brachiopods. These communities commonly are associated with communities of other productids (nearly always of different genera), other brachiopods, and other invertebrate groups, although occasionally the community may be so densely packed that other animals are not found within an area of a few square yards on the same bed. This sharing of the same general environment with a rich and varied fauna indicates a lack of marked ecological preferences on the part of most productid species.

The most intimate association is with bryozoa of both branching and encrusted types. This is well exemplified in the Fossil Cliff Formation, the fauna of which might be described, in terms of individuals present, as a brachiopod-bryozoan assemblage. In this instance there may have been some re-working; nevertheless this close association of brachiopoda (including the productids) and bryozoa is common in other formations of the general succession.

Other brachiopoda are also frequently found with productid species. Most commonly these are large forms, *Neospirifer fasciger* (Keyserling), *N. byroensis* (Glauert), *N. rostalinus* (Hosking), *N. hardmanni* (Eth. fil.), *Streptorhynchus luluigui* Hosking and *Cleiothyridina royssii penta* Prendergast being representative, particularly in the Wandagee Formation and Nalbia member in the Carnarvon Basin. Species of *Chonetes* and *Dielasma* are also commonly associated.

Plates of the bizarre crinoid genus *Calceolispongia* are very often found with productid species, large and small. *Calceolispongia* was an animal of gregarious habit, living in communities of countless individuals (Teichert, 1949), so large and compact that other shelled animals could not inhabit the same area. However, the persistent presence of the heavy basal plates, not so easily transported as the other plates, suggests that the communities of both groups lived close together. Small productids, such as the small *Strophalosia*-species, may have used the stems of *Calceolospongia,* or of the other rarely found crinoids, as points of attachment during their early life (see also Stehli,

1954, p. 287). The cicatrix of attachment of a few of these *Strophalosia* specimens shows traces of crinoid stem markings. Certainly, *Calceolispongia* and small *Strophalosia*-species are commonly associated in the sediments.

Simple corals are comparatively rare in the Western Australian Permian. They are occasionally found attached to large productid shells. *Pterophyllum australe* Hinde is very common in the Fossil Cliff Formation together with one or two species of productids. *Thamnopora immensa,* the only coral to occur in great numbers above the Callytharra Formation and its equivalents, occurs associated with species of *Linoproductus* in the Nalbia Member. Specimens of *Taeniothaerus miniliensis,* and the large *Dictyoclostus*-species, also acted as host to the so-called parasitic worm *Conchotrema* (Teichert, 1945), to an orbiculoid brachiopod, to adherent spats of *Strophalosia*-species and, possibly, *Aulosteges*-species, and to *Etheridgina.* Though some of these occurrences can be determined as having taken place after the death of the host animal, others cannot. *Strophalosia, Etheridgina,* and the orbiculoid probably fastened on to the shell both during and after the life of the host. Specimens of these forms can be found attached near the anterior margin of the brachial valve of the host shell, with the spine-bases of the host, beneath the area of attachment, being only partially developed. These occurrences indicate an attachment probably commensal during the life of the host animal. On the other hand, a host shell may have attached specimens over all parts of both valves, so that some of these forms must have taken up their position after the death of the host.

A close association with abundant pelecypoda and gastropoda seems to have been comparatively rare. The pectinids are the most commonly associated of the pelecypoda, and the bellerophontids of the gastropoda, wherever such association is found. *Conularia warthi* Waagen (scyphopod?) is commonly associated with productids, particularly in the Callytharra Formation and Fossil Cliff Formation.

The faunal associations so far described are similar to those in the Permian sediments of the Hunter Valley of New South Wales. In this area productids are most closely associated with bryozoa, other brachiopods (particularly spiriferids), simple corals and occasional crinoids. Abundant association with pelecypod and gastropod individuals is rare. The same mutual exclusion is discussed by Stehli (1954).

Inter-relationships of Productid Species.

A species of a genus is rarely found in isolation; usually it will be associated with species of other genera, although, as far as can be seen, there was little commingling of closely similar species. The relative abundance of individuals of the associated species, however, varies at different localities and over different parts of the sequence. Thus *Taeniothaerus miniliensis* and *Linoproductus cancriniformis* are species often found together over much of the general succession above the Callytharra and its equivalents, but the former is especially abundant in the Wandagee Formation and the latter in the Coolkilya Greywacke.

The commensal relationship between species of *Etheridgina, Strophalosia* (and possibly *Aulosteges*-species), and large-shelled species has been mentioned. Common host species are *Taeniothaerus miniliensis, T.* sp. cf. *miniliensis, Dictyoclostus callytharrensis, D. magnus,* and large *Neospirifer* species, and, particularly, *Waagenoconcha imperfecta.* The attachment of *Strophalosia* to productinid shells has also taken place in other areas; Trechmann (1921) described the attachment of specimens of *S. lamellosa* Geinitz to the long cardinal spines of *Horridonia horridus* (Sowerby).

The bionomics of the group are treated in the discussion on morphology (pp. 19-26). The most important ecological features mentioned there are the functional value attributed to the ornamentation, and the living position adopted by the living animal.

Conclusions.

The habitat of the group can only be described in general terms, for the information on particular species is sparse. The productids were gregarious, living in large communities. It is suggested that in the populations characterized by upturned margins (the majority) each individual rested almost covered by the surrounding sediment, well camouflaged, so that there would not be much evidence of the presence of the animal except for part of the margins and umbo of the shell and the slight slurry caused by the current of water set up by the water-circulatory system.

If the population density was high, the areas occupied by such communities, productinid or strophalosiinid, were largely free of other shelly benthos, except perhaps bryozoa and smaller strophalosiinids; if the population density was not high, a community cohabited to varying degrees with other forms. Such forms, for the most part also gregarious, comprised in particular bryozoa, large spiriferids, *Calceolispongia*-species, other brachiopoda such as *Streptorynchus*- and *Chonetes*-species, and possibly small communities of simple corals or of the tabulate genus *Thamnopora.*

The nature of the sediment, the associated fauna, and the particular morphology of the productid shell indicate a near-shore environment in the neritic, possibly the infra-neritic, zone. Disturbance of the substratum by currents or wave action is suggested by the evidence of slumping, the presence of fragmental broken-down remains, and the frequent separation of the two valves of productid specimens, as well as the constituent parts of other organisms (e.g. *Calceolispongia*). This action, with the fine-grained sediment, must have made the surrounding water turbid at times. Productid species must have been fairly tolerant of such conditions. The rich fauna associated with productid species indicates environments favorable to benthonic life, although, as can be judged from the distribution of productid species and of the other faunal elements, such environments were not static but shifted laterally and in time. Close comparisons and analogies can be made between the above picture and that of Stehli (1954).

	IRWIN BASIN.	CARNARVON BASIN.															CANNING BASIN.				
	FOSSIL CLIFF.	U. LYONS GP.	CALLYTHARRA.	CORDALIA.	WOORAMEL.	COYRIE.	MALLENS.	BULGADOO.	CUNDLEGO.	QUINNANIE.	WANDAGEE.	NORTON.	BAKER.	NALBIA MEMBER.	COOLKILYA.	MUNGADAN.	BINTHALYA S. GP.	NURA NURA MEMBER.	POOLE.	NOONKANBAH.	L. LIVERINGA.	U. LIVERINGA.
PRODUCTINAE.																					
Aulosteges baracoodensis	X	..	X	..	..	..	..	..	..	..	x	..	..	..	..	..	..	..	..	..	..	..
A. reclinis	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	X
A. fairbridgei	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	X
A. ingens	..	..	..	..	..	X	x	..	..	..	X	..	..	..	..	..	..	..	..	X	x	X
A. lyndonensis	..	..	x	..	..	..	..	X	..	..	..	..	..	..	..	..	..	..	..	..	..	..
A. spinosus	X	..	X	..	..	..	..	..	..	..	..	..	..	..	X	..	..	..	..	..	..	..
A. sp. ind. *A.*	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	x	..	x	..	..
Dictyoclostus callytharrensis	X	X	X	..	..	..	..	..	..	..	x	..	..	..	..	..	..	X	..	..	..	..
D. magnus	X	..	X	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	X	..	..
D. wadei	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
Krotovia micracantha	..	..	X	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
K. senticosa	..	..	X	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
K. spinulosa	..	..	x	..	..	..	..	..	X	..	X	..	..	..	X	..	..	..	..	..	..	..
K. sp. ind. A	..	..	X	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
Linoproductus cancriniformis	X	X	X	..	..	X	..	..	..	..	X	..	..	..	X	..	..	X	..	X	X	..
L. cora foordi	X	X	X	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
L. lyoni	X	X	X	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	x	..	..
Marginifera gratiodentalis	..	..	..	..	..	..	..	..	X	x	X	x	x	X	X	..	..	..	..	X	..	..
Taeniothaerus coolkiliensis	X	..	..	..	..	..	..	..	..	..	X	..	..	..	..	..	..	..	..	..	..	..
T. *irwinensis*	X	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	x	..	..	..	..
T. (?) *fletcheri*	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	X
T. miniliensis	..	..	..	..	..	..	..	..	..	..	X	..	..	..	..	..	..	..	..	..	..	..
T. sp. aff. *miniliensis*	X	..	..	..	..	..	..	..	..	x	..	..	..	..	..	..	..	..	..	..	..	..
T. cf. *subquadratus*	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
T. teicherti	..	..	..	..	..	..	..	..	..	..	X	x	..	..	..	..	..	..	..	..	..	..
STROPHALOSIINAE.																						
Etheridgina muirwoodae	..	..	..	..	..	..	..	..	..	..	X	..	..	..	..	..	..	..	..	X	X	..
Strophalosia multispinifera	..	..	..	..	..	x	..	..	X	..	X	..	..	..	..	..	..	..	..	X	..	..
S. prideri	..	..	X	..	..	..	..	X	x	..	..	..	..	..	..	..	..	..	..	..	..	..
S. (*Heteralosia*) *etheridgei*	X	..	X	..	..	..	..	..	..	..	X	..	..	..	..	..	..	..	..	..	..	..
S. (*H.*) *irwinensis*	X	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	X	..	..
S. (*H.*) *kimberleyensis*	..	..	..	..	..	..	..	..	..	..	X	X	X	x	..	..	..	..	..	X	X	X
S. (*H.*) *prendergastae*	X	..	X	..	..	..	..	..	X	..	..	..	..	..	..	..	..	..	..	..	..	..
S. (*H.*) *tenuispina*	X	..	..	..	..	..	..	..	..	..	X	..	..	..	..	..	..	..	..	..	..	..

TABLE 1.

Stratigraphical distribution in the three areas of marine Permian sediments in Western Australia. The Irwin Basin is represented by the only formation in which productinid and strophalosiinid species occur. Positive occurrence is denoted by X, doubtful occurrance is denoted by x.

	CARNARVON BASIN.																CANNING BASIN.				
	U. LYONS GP.	CALLYTHARRA.	CORDALIA.	WOORAMEL.	COYRIE.	MALLENS.	BULGADOO.	CUNDLEGO.	QUINNANIE.	WANDAGEE.	NORTON.	BAKER.	NALBIA MEMBER.	COOLKILYA.	MUNGADAN.	BINTHALYA S. GP.	NURA NURA MEMBER.	POOLE.	NOONKANBAH.	L. LIVERINGA.	U. LIVERINGA.
PRODUCTINAE.																					
Dictyoclostus callytharrensis	X	X	..	..	..	..	..	..	..	x	..	..	..	..	..	..	x	..	x	..	..
Linoproductus cancriniformis	X	X	..	..	X	..	..	..	..	X	..	..	..	X	..	..	X	..	X	X	..
L. cora foordi	X	X	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
L. lyoni	X	X	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	x	..	..
Aulosteges baracoodensis	..	X	..	..	..	..	..	..	..	x	..	..	..	..	..	..	..	..	..	..	..
A. spinosus	..	X	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
D. magnus	..	X	..	..	..	..	..	..	..	..	..	..	..	..	..	..	X	..	..	..	..
Krotovia micracantha	..	X	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
K. senticosa	..	X	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
K. spinulosa	..	x	..	..	..	..	..	X	..	X	..	..	..	X	..	..	..	..	..	..	..
K. sp. ind. *A.*	..	X	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
Taeniothaerus irwinensis	..	X	..	..	..	..	..	..	..	..	..	..	..	..	..	..	x	..	..	..	..
T. miniliensis	..	X	..	x	x	..	..	..	x	X	x	..	x	X	..	..	..	..	X	x	..
Aulosteges lyndonensis	..	x	..	..	..	..	X	..	..	..	..	..	..	..	..	..	..	..	..	..	..
A. ingens	..	..	..	..	X	x	..	..	..	X	..	..	..	..	..	..	..	..	X	x	X
Marginifera gratiodentalis	..	..	..	..	..	..	..	X	x	X	x	x	X	X	..	..	..	..	X	..	..
Taeniothaerus coolkiliensis	..	..	..	..	..	..	..	..	..	X	..	..	..	..	..	..	..	..	..	..	..
T. sp. aff. *miniliensis*	..	..	..	..	..	..	..	..	..	X	..	..	..	..	..	..	..	..	..	..	..
T. teicherti	..	..	..	..	..	..	..	..	..	X	x	..	..	..	..	..	..	..	..	..	..
Aulosteges sp. ind. *A.*	..	..	..	..	..	..	..	..	..	..	..	..	..	X	..	..	..	..	..	..	..
D. wadei	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	X	..	..
Waagenoconcha imperfecta	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	x	X
Aulosteges reclinis	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	X
A. fairbridgei	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	X
T. (?) *fletcheri*	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	X
STROPHALOSIINAE.																					
S. (*Heteralosia*) *etheridgei*	..	X	..	..	..	..	..	..	..	X	..	..	..	..	..	..	..	..	..	..	..
S. (*H.*) *irwinensis*	..	X	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
S. (*H.*) *prendergastae*	..	X	..	..	..	..	..	x	..	X	..	..	..	..	..	..	..	..	X	X	X
Strophalosia multispinifera	..	..	..	..	x	..	..	X	..	X	..	..	..	..	..	..	..	..	..	..	..
S. prideri	..	..	..	..	..	..	X	..	..	..	..	..	..	..	..	..	..	..	..	..	..
S. (*H.*) *kimberleyensis*	..	..	..	..	..	..	..	..	..	X	X	..	X	x	..	..	..	..	X	..	..
Etheridgina muirwoodae	..	..	..	..	..	..	..	..	..	..	X	..	..	..	..	..	..	..	X	X	..

TABLE 2.

Same as for Table 1, but Irwin Basin omitted. Species arranged in order of first appearance in the Carnarvon Basin. Positive occurrence denoted by X, doubtful by x.

	IRWIN BASIN.	CARNARVON BASIN.																CANNING BASIN.				
	FOSSIL CLIFF.	U. LYONS GP.	CALLYTHARRA.	CORDALIA.	WOORAMEL.	COYRIE.	MALLENS.	BULGADOO.	CUNDLEGO.	QUINNANIE.	WANDAGEE.	NORTON.	BAKER.	NALBIA MEMBER.	COOLKILYA.	MUNGADAN.	BINTHALYA S. GP.	NURA NURA MEMBER.	POOLE.	NOONKANBAH.	LIGHTJACK	LIVERINGA. HARDMAN
PRODUCTINAE.																						
*A. reclinis**	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	X
*A. fairbridgei**	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	X
A. ingens	..	..	..	..	..	X	x	..	..	..	X	..	..	..	..	..	..	..	..	..	..	..
A. lyndonensis	..	..	x	..	..	..	..	X	..	..	..	..	..	..	..	..	..	..	..	..	..	..
A. spinosus	..	X	..	X	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
A. sp. ind. *A.*	..	..	..	..	..	..	..	..	..	..	..	..	..	..	X	..	..	..	..	..	..	..
Dictyoclostus callytharrensis‡	..	X	X	X	..	..	..	..	..	..	x	..	..	..	..	..	..	x	..	x	..	..
D. magnus‡	..	X	..	X	..	..	..	..	..	..	..	..	..	..	..	..	..	X	..	..	..	..
*D. wadei**	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	X	..	..
Krotovia micracantha	..	..	..	X	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
K. senticosa	..	..	..	X	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
Linoproductus cora foordi†	..	X	X	X	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
L. lyoni†	..	X	X	X	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	x	..	..
Waagenoconcha imperfecta	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	x	X
Taeniothaerus coolkiliensis	..	X	..	..	..	..	..	..	..	..	X	..	..	..	..	..	..	..	..	..	..	..
T. (?) *fletcheri*	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	X
T. irwinensis‡	..	X	..	X	..	..	..	..	..	..	..	..	..	..	..	..	..	x	..	..	..	..
T. sp. aff. *miniliensis*	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
T. cf. *subquadratus*	..	..	..	..	..	..	..	..	..	..	X	..	..	..	..	..	..	..	..	..	..	..
*T. teicherti**	..	X	..	..	..	..	..	..	..	..	X	x	..	..	..	..	..	..	..	..	..	..
STROPHALOSIINAE.																						
Etheridgina muirwoodae†	..	..	..	..	..	..	..	..	..	..	X	..	..	..	..	..	..	..	..	X	X	..
S. (*Heteralosia*) *irwinensis**	..	X	..	X	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
S. (*H.*) *kimberleyensis*†	..	..	..	..	..	..	..	..	..	..	X	X	..	X	x	..	..	..	..	X	..	..
Strophalosia multispinifera†	..	..	..	..	..	x	..	..	X	..	X	..	..	..	..	..	..	..	..	X	..	..
S prideri	..	..	..	..	..	..	..	X	x	..	..	..	..	..	..	..	..	..	..	..	..	..

* Species of particular stratigraphical value. † Stratigraphically valuable species common to two basins. ‡ Stratigraphically valuable species common to all three basins.

TABLE 3.

Stratigraphical distribution of species with restricted ranges. X, positive occurrences. x, doubtful occurrences.

DISTRIBUTION AND FAUNAL RELATIONSHIPS.

Distribution and Regional Correlation.

The stratigraphical distribution of the species is shown in Tables 1 and 2. Further collecting is likely to extend the range of some species.

The general distribution charts show some species with short ranges: these have been selected to make up Table 3. Not all the species can be considered as of equal value for stratigraphical work. Those species which, by reason of their widespread distribution, abundant preservation, and ease of recognition, are considered to be of particular value, are distinguished by asterisks. Of these, some are common to both Canning and Carnarvon Basins; and one species is common to all three major areas, *Dictyoclostus magnus*. The species without asterisks have short ranges so far as is known at present, but some of them have been only recently recognized, or are doubtfully distinct, as is indicated by open nomenclature. Others have less limited overall range, but vary in frequency of individuals from one formation to another. Thus *Taeniothaerus miniliensis* is particularly prominent in the Wandagee and Noonkanbah Formations; *Linoproductus cancriniformis* in the Coolkilya Greywacke; *Marginifera gratiodentalis* in the Cundlego and Wandagee Formations (not found below the Cundlego); *Dictyoclostus callytharrensis* and *S.* (*Heteralosia*) *etheridgei* are very abundant in the Callytharra Formation.

Only five species are common to all three areas—*Dictyoclostus callytharrensis; D. magnus; Linoproductus cancriniformis; S.* (*Heteralosia*) *prendergastae;* and possibly, *Linoproductus lyoni.* Those common to the Carnarvon Basin and the Canning Basin are: *A. ingens; D. callytharrensis; D. magnus; Linoproductus cancriniformis;* possibly *L. lyoni; Taeniothaerus miniliensis; S.* (*Heteralosia*) *kimberleyensis; S.* (*H.*) *prendergastae;* and *Strophalosia multispinifera.* Twelve species are common to the Irwin District and the Carnarvon Basin: *Aulosteges baracoodensis; A. spinosus; Dictyoclostus callytharrensis; D. magnus; Linoproductus cancriniformis; L. cora foordi; L. lyoni; Taeniothaerus coolkiliensis; T. irwinensis; S.* (*Heteralosia*) *etheridgei; S.* (*H.*) *irwinensis;* and *S.* (*H.*) *prendergastae.*

Of the species common to the Carnarvon Basin and Irwin River District five are common in, and restricted to, the Fossil Cliff and Callytharra Formations, thus confirming the generally accepted correlation between these formations. The inclusion of the Nura Nura member of the Poole Sandstone in the Canning Basin in this correlation is supported by the presence of *Dictyoclostus magnus,* restricted to the Callytharra and Fossil Cliff Formations and to the Nura Nura member.

Above the Callytharra Formation and its equivalents, the detailed correlation between formations of the Carnarvon and Desert Basins is not much affected by the productid species. They certainly suggest the general corelation of the Byro Group (Coyrie Formation to Baker Sandstone) with the Noonkanbah Formation and possibly the Lightjack member of the Liveringa

Formation. The Wandagee Formation can be considered to have its closest equivalent in the Noonkanbah Formation. The only evidence to suggest a correlation of the Coolkilya Greywacke with the Lightjack member (apart from the species with longer ranges common to both) is that many species, hitherto commonly represented, are no longer present above these two formations.

By and large, then, the productid fauna confirms the already accepted correlations for the marine Permian in Western Australia put forward by Teichert (1941) and Thomas and Dickins (1954).

Apart from the aspect of correlation, the distribution of the species shows other features. In the Irwin Basin, with a total sedimentary thickness of nearly 4,000 feet, productid species are found only in the one richly fossiliferous formation, the Fossil Cliff Formation, which contains fourteen species. In the Carnarvon Basin productid species are found most abundantly in the Callytharra Formation (as least fifteen species), the Wandagee Formation (at least thirteen species), and the Coolkilya Greywacke (six species). Between and above these are formations either very poor in productid species, or chiefly characterized by a molluscan fauna of pelecypoda, or generally poor in marine fossils of any kind. In the Canning Basin the Nura Nura member contains less than four productid species, the Poole Sandstone above this apparently none at all, the Noonkanbah Formation at least ten species, the Lightjack member of the Liveringa Formation not more than six, and the Hardman member (removed from the Lightjack by approximately 2,000 feet of sediment) six species. The productid fauna of the Hardman member is conspicuously different from the earlier fauna.

Finally, the formations most abundant in productid species and individuals are also those with a rich invertebrate fauna; that is, the overall distribution of the productids follows that of the remaining fauna, with the exception of some molluscan species. Such distributional parallels are certain to be bound up with the tectonic and sedimentary history of the Permian basins.

Inter-regional Affinities and Correlation.

Special Characteristics of the Local Fauna: Very many species in the fauna—those belonging to the genera *Aulosteges, Taeniothaerus* and *Strophalosia* (*s.l.*)—possess a ventral cardinal area; the individuals of these species were attached during at least part of their life. A second general characteristic of the fauna is that many of the productinid species, and some of the strophalosiinid species, have sharply upturned or geniculate margins. A third is the preponderance of species with predominantly spinose ornamentation. A fourth is the absence of the more bizarre productid genera, as for example those of the families *Lyttonidae* and *Richthofenidae,* common in the Permian of other regions. Collectively these features give a highly individual character to the Western Australian Permian Productacea.

Comparison with Other Faunas: So far the fauna has been referred to as though it were a unit, and could be considered as such for the purpose of comparison with other faunas. This is not strictly true. The species found in the

sequences below the Mungadan Sandstone in the Carnarvon Basin and the middle part of the Liveringa Formation in the Canning Basin, and including those of the Fossil Cliff Formation of the Irwin District, can be considered as a single fauna for purposes of comparison. In the Canning Basin, however, the species found in the upper part of the Liveringa constitute quite a new fauna, containing only species of *Aulosteges, Waagenoconcha,* and possibly *Taeniothaerus.* The earlier fauna has affinities with the Permian Productidae of Timor, India (particularly the Salt Range), Russia (Zechstein and the Urals), and eastern Australia, in that order of closest affinity. The evidence for this lies in the close comparison that can be made between the local species and species from these other regions. Included among the compared species are a few identical with local species, some separated only by minor differences, and some differentiated by open nomenclature. Estimates of affinity based on such comparisons must be treated with care. But as the species compared are many for any one region, are part of a definite fauna, and have similar distributional histories, they can be safely compared.

Of the Timor species four are identical with Western Australian species; *Aulosteges ingens, Dictyoclostus callytharrensis, Linoproductus cora foordi,* and *Waagenoconcha imperfecta. Aulosteges spinosus* and *Marginifera gratiodentalis* have near counterparts in the Timor species. This is a considerable total in view of the comparatively small productid fauna so far described from that island, and is relatively higher than for any other region. The local fauna is thus considered to have its closest affinities with that of Timor.

Local species identical with, or closely comparable to, Indian species (Salt Range and Himalayan) are *Aulosteges ingens, Dictyoclostus magnus, Linoproductus cancriniformis, Marginifera gratiodentalis, Taeniothaerus* cf. *subquadratus, Waagenoconcha imperfecta,* and *Strophalosia (Heteralosia) irwinensis.*

L. cancriniformis is also a Russian species. *Aulosteges ingens* and *A. fairbridgei* are closely compared with Russian species. The smaller number of species comparable with those of Russia is somewhat misleading. It is certainly small, but nevertheless the broad outlines of a fauna such as is described by Netschajew (1911) and, to a lesser extent, by Sarycheva and Sokolskaya (1952) from Western Russia have much in common with those of the Western Australian fauna.

The similarity of the Permian faunas of western and eastern Australia has been long argued, the more prevalent opinion being that the two are essentially dissimilar. Among the Productacea only one species is presumably identical—*Taeniothaerus subquadratus.* Three other species are very closely comparable. The important single similarity is, of course, that species of *Taeniothaerus* occur in both areas. The eastern Australian productid faunas have not yet been completely revised; but I have been able to study much of the eastern Australian material, and am satisfied that the productid faunas of the two regions are essentially dissimilar.

The fauna of the upper part of the Liveringa Formation also has its closest affinities with Timor, India and Russia. The significance of the species *Waagenoconcha imperfecta, Aulosteges ingens,* and *A. reclinis* has already been mentioned. Another species, *Aulosteges fairbridgei,* is equally comparable with Russian and Indian species. The number of species involved is not large enough to decide just where the affinities of the fauna lie. There is certainly no equivalent in eastern Australia.

Inter-continental Correlations: The fauna, except for that of the upper part of the Liveringa Formation, is essentially Artinskian in age. The earliest-appearing species include *Dictyoclostus callytharrensis, D. magnus, Linoproductus cancriniformis, L. cora foordi, Aulosteges spinosus, Taeniothaerus* cf. *subquadratus,* and *S. (Heteralosia) irwinensis.* The species *cora foordi* and *callytharrensis* are identical with forms typical of the Bitaoeni Beds (Artinskian) of Timor; the remainder are identical with or little removed from species typical of the Indian Lower Productus Limestone or its equivalents. The Callytharra Formation and its equivalents and the uppermost part of the Lyons Group in the Carnarvon Basin may be correlated therefore with the Lower Productus Limestone. Some species even in the earliest fauna have, however, affinities with those of the Middle Productus Limestone; and the number of these increases higher in the succession. They include such species as *Aulosteges ingens, Krotovia spinulosa, Marginifera gratiodentalis* (closely similar to *gratiosa* Waagen), and *Waagenoconcha imperfecta.* These species have their closest equivalents in species typical of the Middle Productus Limestone or of the Basleo Beds of Timor. Both these divisions are usually considered as Artinskian with some post-Artinskian elements.

The later fauna, of the Hardman member of the Liveringa Formation, includes the species *Aulosteges fairbridgei, A. reclinis, A. ingens, Taeniothaerus fletcheri,* and *Waagenoconcha imperfecta,* at least two of which are represented in the Basleo Beds of Timor, and which also have close affinities with species in the Russian Kazanian. The post-Artinskian element has become altogether preponderant in this fauna, and it may well be that it is indeed post-Artinskian. The productids, however, do not furnish conclusive evidence that this is so.

The Productacea, both in their affinities and the correlations they suggest, largely complement conclusions on the general affinities of the Western Australian Permian faunas and their inter-regional correlation, established by Teichert (1941; 1951) and Thomas and Dickins (1954).

EVOLUTIONARY ASPECTS.

Deficiencies in knowledge of the sedimentary record and of the detailed stratigraphical distribution of the species have prevented the effective study of the evolutionary changes that may have taken place at the species level. Nevertheless it was expected that the long-ranging species would show overall evolutionary changes, and also that the faunas as a whole might have exhibited features affecting currently held ideas on the phylogeny of the Productacea.

Although not realized, such expectations were in keeping with the size of the collection and the great thickness of sediments from which it came, representing a significant part of Permian time and distributed over a large province.

A few examples of the apparent lack of evolutionary change exhibited by the species will illustrate what is roughly characteristic of the whole fauna. *Taeniothaerus miniliensis,* an exceedingly variable species, first appears in the Callytharra Formation of the Carnarvon Basin and is found in many of the formations up to, and including, the Coolkilya Greywacke. It is particularly prominent in the Wandagee Formation and, to a lesser extent, in the Coolkilya Greywacke. It is therefore one of the longer-ranging species, persisting through a considerable part of the sediment laid down during Artinskian times. Its range is at least equal to the overall range of *Calceolispongia*-species in the same region, which, according to Teichert (1949, p. 46) extends over a period of 6,000,000 years. During this time at least thirteen species of *Calceolispongia* developed in ten different horizons (Teichert, 1949).

Taeniothaerus miniliensis during this period shows a trend towards an increase in size, and predominance of individuals with larger umbones and large ventral cardinal areas. These individuals represent one of the two principal modes of variation described for this species. The increase in overall size and dimensions of the umbo and area might be described as representing a time-trend in variation; it could conceivably be the result of a bias in collecting. Nevertheless such trends towards increase in size are common enough in marine benthos which live in close-knit communities (see Newell, 1949; Stenzel, 1949). *Calceolispongia* is, of course, an outstanding example of this kind.

Linoproductus cancriniformis is another species, present in great numbers of individuals, which persists from the upper part of the Lyons Group of the Carnarvon Basin, through the Callytharra Formation, the Wooramel Sandstone, and the Wandagee Formation, and finally is present in great numbers in the Coolkilya Greywacke. Variation in the oldest and youngest representatives of this species does not seem to show any significant change. The same conclusions apply to *Krotovia spinulosa* (a species very stable in its characteristics) which has an intermittent local range, probably from the Callytharra to the Coolkilya Greywacke, certainly from the Cundlego Formation to the Coolkilya Greywacke. It also applies to *Marginifera gratiodentalis,* another stable species, ranging from the Cundlego Formation to the Coolkilya Greywacke and absent only from the intervening Baker Formation. It applies probably to *Aulosteges ingens,* which is very sparsely represented early in the succession.

Little can be said concerning more general trends in the Western Australian Productacea. Prendergast (1943) suggested that a general trend could be observed in species of *Aulosteges* and *Taeniothaerus* comparable to that shown by species of *Aulosteges* of the Permian of the Texas Glass Mountains (King, 1930), in which there is a trend from species with low areas, spinose, with both

radiate and concentric ornamentation, to species of which a high proportion had high areas but with little or no radiate or costate ornamentation. This transition takes place from the Wolfcamp to the Word.

The two species selected by Prendergast as illustrating this comparable trend, *Aulosteges baracoodensis* and *Taeniothaerus "subquadratus"* (here described as *T. irwinensis* sp. nov.), are both essentially spinose and show no such ornamentary changes as the Glass Mountain species. Although the area of *A. baracoodensis* is higher than that of *T. irwinensis* both species are most prolific at the same stratigraphical level.

With a far greater number of species now described, belonging to the similar genera, *Aulosteges* and *Taeniothaerus,* it is possible to re-examine this suggestion of a trend similar to the Texan one—embracing only the increase in height of the area, as the ornamentation of all the local species is essentially spinose. The evidence is rather conflicting. A selected series such as *A. baracoodensis—A. lyndonensis—A. ingens—A. fairbridgei—A. reclinis* gives support to the suggestion that such a trend is present. But the size of the area varies within any one species of this series. Specimens of *A. ingens,* for example, may show an area proportionately no higher than selected specimens of *A. lyndonensis,* another species in which the height of the area varies. Nor is the series, as given, arranged in strict order of first appearance. *A. ingens* probably appears as early as *A. baracoodensis,* although it is most prolific high in the sequence. Finally, some of the species making up the series are found only in particular areas. All that can be said is that, in a very general way, an increase in height of the area is shown by species as they occur higher in the succession.

The species of *Taeniothaerus* offer no more convincing evidence, even though they can be studied as found in the one basin, the Carnarvon Basin. The first-appearing species all have low areas. They occur in the Callytharra Formation. Of the three species persisting higher in the sequence, only one, *T. miniliensis,* is represented in several successive formations. As mentioned before, it does show an apparent increase in height of area. One of the remaining two species, *T. coolkiliensis,* has been found in the Wandagee Formation of the Carnarvon Basin (that is, fairly high in the sequence) and it possesses a comparatively high area; but the other, *T. teicherti,* occurring in the Wandagee Formation and overlying Norton Greywacke, has little or no area.

There is then no worthwhile evidence to suggest that a general trend towards increase in height of area, from lower to higher in the sequence, took place in species of these genera. Even if such a trend were more strongly suggested, the evidence supporting it is of such a kind that it is difficult to gauge its true significance. On present data it could be described only as a morphological series, the details of which would have to be established on more detailed stratigraphical knowledge and more comprehensive and systematic collections than are now available. Except, perhaps, in *T. miniliensis,* it certainly could not be considered as the expression of a plexus of descent, or of continuous genetic relationship.

None of the other genera exhibits featural changes which might be interpreted as a trend of any kind. Questions on the phylogeny of the group are not affected by the Western Australian material. The outstanding faunal characteristics of the group may be explained more readily by distributional than by evolutionary factors, as may the faunal break which distinguishes the species highest in the West Kimberley sequence from the species found in lower beds in the general succession.

REFERENCES.

ASTRE, G., 1934.—La faune permienne des Grès à Productus d'Ankitokazo dans le Nord de Madagascar. *Ann. géol. Serv. Min. Madagascar*, 4, 63-93

BATHER, F. A., 1927.—Biological Classification: Past and Future. *Quart. J. geol. Soc. Lond.*, 83 (2), Presidential address, pp. lxii-civ.

BOOKER, F., 1929.—Preliminary Note on new sub-genera of *Productus* and *Strophalosia* from the Branxton District. *J. Roy. Soc. N.S.W.*, 43, 24-32.

BOOKER, F., 1930.—A Review of some of the Permo-Carboniferous Productidae of New South Wales with a tentative reclassification. *Ibid.*, 44, 65-76.

BRANSON, C. C., 1948.—Bibliographic Index of Permian Invertebrates. *Mem. geol. Soc. Amer.*, 26.

BROILI, F., 1916.—Die permischen Brachiopoden von Timor. 104 pp., 13 pls in Wanner, J., *Paläont. Timor*, 7 (12).

BRYANT, D. L., 1955.—Index, type species, and bibliography of productid genera. *J. Paleont.*, 29, 283-294.

CHAPMAN, F., 1924.—List of Fossils from West Kimberley. *Ann. Rep. geol. Surv. W. Aust.*, 1923, 35-36.

CHAO, Y. T., 1927.—Productidae of China, pt. 1: Producti. *Palaeont. sinica*, Ser. B, 5 (2).

CHAO, Y. T., 1928.—Productidae of China, pt. 2: Chonetinae, Productinae and Richthofeninae. *Ibid.*

CLARKE, E. de C., PRENDERGAST, K. L., TEICHERT, C., and FAIRBRIDGE, R. W., 1951.—Permian Succession and Structure in the northern part of the Irwin Basin, Western Australia. *J. Roy. Soc. W. Aust.*, 35, 31-84.

COOPER, G. A., 1937.—Brachiopod Ecology and Paleoecology. *Rep. Comm. Paleoecol.*, 1936-1937, 26-53.

COOPER, G. A., 1942.—Ecology of some Permian brachiopods. *Ibid.*, 1941-1942, 36-37.

COOPER, G. A., 1944.—Phylum Brachiopoda: in Shimer, H. W., and Shrock, R. R., *Index Fossils of North America*, N.Y., Wiley.

CONDON, M. A., 1954.—Progress Report on the Geology of the Carnarvon Basin. *Bur. Min. Resour. Aust. Rep.* 15.

CROFT, W. N., 1950.—A parallel-grinding instrument for the investigation of fossils by serial sections. *J. Paleont.*, 24, 693-698.

DAPPLES, E. C., KRUMBEIN, W. C., and SLOSS, L. L., 1948.—Tectonic Control of Lithologic Associations. *Bull. Amer. Ass. Petrol. Geol.*, 32 (10), 1924-1927.

DAVIDSON, T., 1858-1863.—Monograph of the British fossil Brachiopoda: 1858, 2 (4), The Permian Brachiopoda; 1858-1863, 2 (5) The Carboniferous Brachiopoda. *Palaeontogr. Soc. Monogr.*

DAVIDSON, T., 1862.—On some Carboniferous Brachiopoda collected in India by A. Fleming, M.D., and W. Purdon, Esq., F.G.S. *Quart. J. geol. Soc. Lond.*, 18, 25-35.

DEFRANCE, T., 1826.—*Dict. des Sci. nat.*, 63, 354.

DIENER, C., 1897a.—The Permo-Carboniferous Fauna of Chitichun, No. 1. *Palaeont. indica*, Ser. 15, 1 (3).

DIENER, C., 1897b.—The Permian Fossils of the Productus Shales of Kumaon and Curhwal. *Ibid.*, Ser. 15, 1 (4).

DIENER, C., 1899.—Anthracolithic Fossils of Kashmir and Spiti. *Ibid.*, Ser. 15, 1 (2).

DIENER, C., 1903.—Permian Fossils of the Central Himalayas. *Ibid.*, Ser. 15, 1 (4).

DIENER, C., 1911.—Anthrocolithic Fossils of the Shan States. *Ibid.*, N.S.3 (4).

DIENER, C., 1927.—Leitfossilien des marinen Perm. *Leitfossilien.* Lieferung 5, Berlin.

DOUGLAS, J. A., 1936.—A Permo-Carboniferous Fauna from South-West Persia (Iran). *Palaeont. indica*, N.S.22, (6).

DUNBAR, C. O., and CONDRA, G. E., 1932.—Brachiopoda of the Pennsylvanian System in Nebraska. *Geol. Surv. Nebr.*, Ser. 2, Bull. 5.

ETHERIDGE, R., 1872.—Description of the Palaeozoic and Mesozoic Fossils of Queensland. *Quart. J. geol. Soc. Lond.*, 28, 317-150.

ETHERIDGE, R., jun., 1876.—On an adherent form of *Productus* and a small *Spiriferina* from the Lower Carboniferous Limestone Group of the East of Scotland. *Quart. J. geol. Soc. Lond.*, 32, 454-465.

ETHERIDGE, R., jun., 1878.—A Catalogue of Australian Fossils, stratigraphically and zoologically arranged. Cambridge.

ETHERIDGE, R., jun., 1880.—On a Collection of Fossils from the Bowen River Coalfield and the Limestone of Fanning River, North Queensland. *Proc. Roy. phys. Soc. Edinb.*, 5, 263-328.

ETHERIDGE, R., jun., 1903.—Description of Carboniferous Fossils from the Gascoyne District, Western Australia. *Geol. Surv. W. Aust. Bull.* 10.

ETHERIDGE, R., jun., 1907a.—Fossils from Mingenew, Irwin River Coalfield. *Geol. Surv. W. Aust. Bull.* 27, 19-25.

ETHERIDGE, R., jun., 1907b.—Descriptions of Carboniferous Fossils from the Irwin River. *Ibid.*, pp. 26-37.
ETHERIDGE, R., jun., 1914.—Western Australian Carboniferous Fossils chiefly from Mt. Marmion, Lennard River, West Kimberley. *Geol. Surv. W. Aust. Bull.* 58.
ETHERIDGE, R., jun., 1918.—Observations on Carboniferous and other Fossils. *Narrative of an expedition of Exploration in North-Western Australia. Proc. S.Aust. Br. R. geogr. Soc. Aust.*, 18, 250-262.
ETHERIDGE, R., and Dunn, W. S., 1909.—Notes on the Permo-Carboniferous Producti of Eastern Australia, with Synonymy. *Rec. geol. Surv. N.S.W.*, 8 (4), 293-304.
FLETCHER, H. O., 1945.—A new *Aulosteges* from the Lower Permian of Queensland. *Rec. Aust. Mus.*, 21, 313-316.
FOORD, A. H., 1890.—Notes on the Palaeontology of Western Australia. *Geol. Mag.*, 7, 97-106, 146-155.
FRECH, F., 1901.—Die Dyas. *Lethea Geognostica*, 3 (2) 435-578.
FRECH, F., and NOETLING, F., 1902.—Die Dyas (Schluss). *Ibid.*, 4 (2), 579-788.
FREDERICKS, G., 1915.—Sur les *Productus* du Carbonifère Superieur et de L'Artinskien. *Mém. Comm. géol. St. Petersb.*, N.S. 103, 1-63.
FREDERICKS, G., 1928.—Communication for the Classification of the Genus *Productus*. *Bull. geol.-prosp. Serv. U.S.S.R.*, 46 (7), 789-792. (English Summary.)
FREDERICKS, G., 1931.—The Upper Palaeozoic Fauna of the Kharaulakh Mountains, *Bull. Acad. Sci. U.S.S.R., Cl. Math. Sci. Nat., Ser.* 6, 2, 222-226 (English Summary).
GEINITZ, H. B., 1842.—Uber Einige Petrefakte des Zechsteins und Muschelkalks. *Neues Jb. Min. Geol. Paläont.*, 576-579.
GEINITZ, H. B., 1861.—Dyas oder die Zechsteinformation und das Rothliegende. Leipzig.
GIRTY, G., 1903.—Carboniferous Formations and Faunas of Colorado. *Prof. Pap. U.S. geol. Surv.*, 16.
GIRTY, G., 1908.—The Guadalupian Fauna. *Prof. Pap. U.S. geol. Surv.*, 58.
GLAUERT, L., 1910.—A list of Western Australian Fossils. *Geol. Surv. W. Aust. Bull.* 36, 71-106.
GLAUERT, L., 1926.—A list of Western Australian Fossils. Supplement No. 1. *Geol. Surv. W. Aust. Bull.* 88, pp. 36-71.
GRABAU, A., 1931.—The Permian of Mongolia. *Amer. Mus. nat. Hist.: nat. Hist. Central Asia*, 4.
GRABAU, A., 1934.—Early Permian Fossils of China. I. *Palaeont. sinica*, Ser. B. 8 (3).
GRAY, J. E., 1840.—*Synopsis of the Contents of the British Museum*, 42nd Edition. London.
GRAY, J. E., 1848.—On the arrangement of the Brachiopoda. *Ann. Mag. nat. Hist., Ser.* 2, 2, 435-440.
GREGOR, D. K., 1920.—North American species of the Brachiopod *Etheridgina*. *Geol. Mag.*, 57, 535-538.
GUPPY, D. J., LINDNER, A. W., RATTIGAN, J. H., and CASEY, J. N., 1950.—The Geology of the Fitzroy Basin, Western Australia. *Bur. Min. Resour. Aust. Bull.* 36 (in press).
HALL, J., and CLARKE, J. M., 1894.—NATURAL HISTORY OF NEW YORK. Palaeontology, Vol. 8, An Introduction to the Study of the Genera of Palaeozoic Brachiopoda, Pt. 2, New York.
HAMLET, B., 1928.—Permische Brachiopoden, Lamellibranchiaten und Gastropoden von Timor. *Jaarb Mijnw. Dienst Mijnb. Ned.-O-Ind.*, 2, 1-115.
HELMERSEN, G., 1847.—Letter to the Editor. *Leonhard and Bronn's Jb. Miner.*, 330-331.
HILL, D., 1950.—The Productinae of the Artinskian Cracow Fauna of Queensland. *Pap. Dep. Geol. Univ. Qld*, 3 (2).
HOSKING, L. V. F., 1931.—Fossils from the Wooramel District, Western Australia. *J. Roy. Soc. W. Aust.*, 17, 7-52.
HOSKING, L. V. F., 1932.—Western Australian Orthotetinae. *Ibid.*, 18, 43-53.
HOSKING, L. V. F., 1933a.—Specific Naming of *Aulosteges* from Western Australia. *Ibid.*, 19, 33-41.
HOSKING, L. V. F., 1933b.—Fossils from the Wooramel District, Series Two. *Ibid.*, 19, 43-66.
HUANG, T. K., 1932.—Late Permian Brachiopoda of South-Western China. *Palaeont. sinica*, Ser. B, 9 (1).
HUANG, T. K., 1933.—Late Permian Brachiopoda of South-Western China. Pt. II. *Ibid.*, Ser. B, 9 (2).
HUDLESTON, W. H., 1883.—Notes on a Collection of Fossils and of Rock Specimens from Western Australia, North of the Gascoyne River. *Quart. J. geol. Soc. Lond.*, 39, 582-595.
JACK, R. L., and ETHERIDGE, R., 1892.—*The Geology and Palaeontology of Queensland and New Guinea*. Brisbane and London.
JOHNSTON, R. M., 1888.—*Systematic Account of the Geology of Tasmania*. Hobart.
KAY, MARSHALL, 1951.—North American Geosynclines. *Mem. geol. Soc. Amer.*, 48.
KING, R. E., 1930.—The Geology of the Glass Mountains, Texas, Pt. II., Faunal Summary and Correlation of the Permian Formations with Descriptions of Brachiopoda. *Univ. Texas Bull.*, 3042.

KING, R. H., 1938.—New Chonetidae and Productidae from Pennsylvanian and Permian Strata of north-central Texas. *J. Paleont.*, 12, 257-279.
KING, W., 1844.—On a new Genus of Palaeozoic Shell. *Ann. Mag. nat. Hist.*, 14, 313-317.
KING, W., 1846.—Remarks on certain Genera belonging to the Class Palliobranchiata. *Ibid.*, 18, 26-42, 83-94.
KING, W., 1850.—A Monograph of the Permian Fossils of England. *Palaeontogr. Soc. Monogr.*, 3.
KONINCK, L. G. DE, 1847a.—Monographie du genre *Productus*. *Mém. Soc. Sci. Liège*, 4 (1), 73-278.
KONINCK, L. G. DE, 1847b.—Recherches sur les animaux Fossiles. Première Partie: Monographie des genres *Productus et Chonetes*. Liège.
KONINCK, L. G. DE, 1876-77.—Recherches sur les Fossiles Paléozoique de la Nouvelle-Galles du Sud (Australie). *Mém. Soc. sci. Liège, Ser.* 2, 6, 7; and 1898, *Palaeont. Mem. geol. Surv. N.S.W.*, 6.
KOZLOWSKI, R., 1914.—Les Brachiopodes du Carbonifère superieur de Bolivie. *Ann. Paléont.*, 9, 1-100.
LEACH, D., 1940.—A statistical investigation of the *Anthracomyas* of the basal *similis-pulchris* zone in Scotland. *Quart. J. geol. Soc. Lond.*, 96, 13-37.
LICHAREW, B., 1934a.—Die Fauna der Permischen Ablagerungen des Kolyma-Gebietes. *Geologische Expedition ins Kolyma-Gebiet* 1929-30, Bd. 1 (2), (German summary).
LICHAREW, B., 1934b.—Brachiopoda. In Zittel, K., *Textbook of Palaeontology*, Russian ed., 1,458-552. Leningrad.
LICHAREW, B., 1935.—Bemerkungen über einige oberpaläozoische Brachiopoden. *Neues Jb. Min. Geol. Paläont.*, B.9, 369-373.
LICHAREW, B., 1936.—Brachiopoda of the Permian System of the U.S.S.R. *Monogr. Palaeont. U.S.S.R.*, 39 (English Summary).
MAILLIEUX, E., 1941.—Repartition des brachiopodes dans le Devonien de l'Ardenne. *Bull. Mus. Hist. nat. Belg.*, 17, 1-14.
MANSUY, H., 1913.—Faunes des Calcaires à *Productus*, Ser. 1. *Mém. Serv. géol. Indoch.*, 2 (4).
MARTIN, W., 1809.—*Petrificata Derbiensia*, or *Figures and Descriptions of Petrifactions collected in Derbyshire*. Wigan.
MAXWELL, W. G. H., 1954.—*Strophalosia* in the Permian of Queensland. *J. Paleont.*, 28, 533-559.
MILORADOVITCH, B. V., 1935.—Upper Palaeozoic Brachiopoda from the Northern Island of Novaya Zemlya. *Trans. Arctic Inst., Leningr.*, 19.
MILORADOVITCH, B. V., 1945.—Some data on the morphology of productid shells. *Bull. Acad. Sci. U.S.S.R., Ser. Biol.*, 4 (English Summary).
MOORE, R. C., 1952.—Brachiopods, *In* Moore, R. C., Lalicker, C. G., and Fischer, A. G., *Invertebrate Fossils*, N.Y., McGraw-Hill.
MORRIS, J., 1845.—Section of Mollusca, pp. 270-291, in Strzelecki, 1854, *Physical Description of New South Wales and Van Diemen's Land*. London.
MUIR-WOOD, H. M., 1928.—The British Carboniferous Producti, 11. *Productus* (*Sensu strictu*); *semireticulatus* and *longispinus groups*. *Mem. geol. Surv. U.K., Palaeont.* 3 (1).
MUIR-WOOD, H. M., 1930.—The Classification of the British Carboniferous Brachiopod sub-family Productinae. *Ann. Mag. nat. Hist.* (ser. 10), 5, 100-108.
MUIR-WOOD, H. M., 1951.—The Brachiopoda of Martin's "Petrificata Derbiensia". *Ibid.*, Ser. 12, 4, 97-118.
MURCHISON, R. I., VERNEUIL, E. de., and KEYSERLING, A., 1845.—*Géologie de la Russie d'Europe et des Montagnes de l'Oural*, 2 (3). London and Paris.
NETSCHAJEW, A., 1894.—Die Fauna der permischen Ablagerungen des östlichen Teiles des europaischen Russlands. *Trud. obstch. Est. Kazan*, 28 (4).
NETSCHAJEW, A., 1900.—Erster Beitrag zur "Fauna der permischen Ablagerungen des östlichen Theils des europaischen Russlands". *Ibid.*, 39 (6).
NETSCHAJEW, A., 1911.—Die Fauna der permischen Ablagerungen des europaischen Russlands, I. Brachiopoda. *Mém. Comm. géol. St. Petersb.*, N.S., 61.
NEWELL, N. D., 1949.—Phyletic Size-increase—An important trend illustrated by fossil invertebrates. *Evolution*, 3, 103-124.
NORWOOD, J., and PRATTEN, H., 1854.—Notice of Producti in the Western States and Territories, with descriptions of twelve New Species. *J. Acad. nat. Sci. Philad.*, 2nd Ser., 3.
OEHLERT, D. P., 1887.—Brachiopodes. Appendix in Fischer, P., *Manuel de Conchyliologie*, Paris, 1189-1334.
D'ORBIGNY, A., 1842.—Paléontologie: in *Voyages dans l'Amerique meridionale*, 3. Paris.
PAECKELMANN, W., 1931.—Die Brachiopoden des deutschen Unterkarbons. 2 Teil: Die Productinae und Productus-Ähnlichen Chonetinae. *Abh. preuss. geol. Landesanst.*, N.F. 136.

PHILLIPS, J., 1836.—Illustrations of the Geology of Yorkshire; Pt. 2, The Mountain Limestone District. London.
PRENDERGAST, K. L., 1935.—Some Western Australian Upper Palaeozoic Fossils. *J. Roy. Soc. W. Aust.*, 21, 9-35.
PRENDERGAST, K. L., 1943.—Permian Productinae and Strophalosiinae of Western Australia. *Ibid.*, 28, 1-73.
RAGGATT, H. G., and FLETCHER, H. O., 1937.—A Contribution to the Permian-Upper Carboniferous problem and an analysis of the Upper Palaeozoic (Permian) of the North-West Basin, Western Australia. *Rec. Aust. Mus.*, 20 (2), 150-184.
REED, F. R. COWPER, 1931.—New Fossils from the Productus Limestone of the Salt Range, with notes on other Species. *Palaeont. indica*, N.S., 17.
REED, F. R. COWPER, 1932.—New Fossils from the Agglomeratic Slate of Kashmir. *Ibid.*, 20 (1).
REED, F. R. COWPER, 1944.—Brachiopoda and Mollusca from the Productus Limestones of the Salt Range. *Ibid.*, 23 (2).
SARYCHEVA, R. G., 1949.—Morphology, ecology and evolution of Carboniferous productids near Moscow (genera *Dictyoclostus, Pugilis* and *Antiquatonia*). *Trav. Inst. Paléont. Acad. Sci. U.R.S.S.*, 18.
SARYCHEVA, R. G., and SOKOLSKAYA, A. N., 1952.—Index of Palaeozoic brachiopods from the sub-Moscovian Basin. *Ibid.*, 38.
SCHELLWIEN, E., 1892.—Die Fauna des karnischen Fusulinenkalks. *Palaeontographica*, Bd. 39, 91-136. Stuttgart.
SCHUCHERT, C., 1913.—Brachiopoda. In Zittel, K., *Textbook of Palaeontology*, ed. Eastman, C. R., 2nd Ed. London, Macmillan.
SHROCK, R. R., *and* TWENHOFEL, W. H., 1953.—*Principles of Invertebrate Palaeontology.* N.Y., McGraw-Hill.
SOWERBY, J., 1812-1815.—*The Mineral Conchology of Great Britain*, Vol. 1. London.
STAINBROOK, M. A., 1947.—Brachiopoda of the Percha Shale of New Mexico and Arizona. *J. Paleont.*, 21, 197-328.
STEHLI, F. G., 1954.—Lower Leonardian Brachiopoda of the Sierra Diablo. *Amer. Mus. nat. Sci.*, 105 (3), 259-358.
STENZEL, H. B., 1949.—Successional Speciation in Paleontology—The case of the Oysters of the *sellaeformis* stock. *Evolution*, 3, 34-50.
STEPANOV, D. L., 1934.—The Brachiopoda of the Bryozoan Limestones of the Kolwa River Region (Northern Urals), pt. 1, Strophomenacea. *Trans. Oil-Geol. Inst. U.S.S.R.*, Ser. A, 37, 1-63.
STUCKENBURG, G., 1898.—Allgemeine Geologische Karte von Russland, Blatt 127. *Mém. Comm. géol. St. Petersb.*, 16 (1).
SUTTON, A. H., 1938. Taxonomy of Mississippian Productidae. *J. Paleont.*, 12, 537-539.
SUTTON, A. H., and SUMMERSON, C. H., 1943.—Cardinal Process of Productidae. *Ibid.*, 17, 323-330.
TEICHERT, C., 1941.—Upper Paleozoic of Western Australia: Correlation and Paleogeography. *Bull. Amer. Ass. Petrol. Geol.*, 25, 371-415.
TEICHERT, C., 1945.—Parasitic Worms in Permian Brachiopod and Pelecypod Shells in Western Australia. *Amer. J. Sci.*, 243, 197-209.
TEICHERT, C., 1947.—Stratigraphy of Western Australia. *Bull. Amer. Ass. Petrol. Geol.*, 31, 1-70; and *J. Roy. Soc. N.S.W.*, 80, 81-142.
TEICHERT, C., 1949.—Permian Crinoid *Calceolispongia*. *Mem. geol. Soc. Amer.*, 34.
TEICHERT, C., 1950.—Some Recent Additions to the Stratigraphy of Western Australia. *Bull. Amer. Ass. Petrol. Geol.*, 34, 1787-1794.
TEICHERT, C., 1951.—The marine Permian faunas of Western Australia (an interim review). *Paläont. Zbl.*, 24, 76-90.
TERCIER, J., 1939.—Dépôts marins actuels et series géologiques. *Eclog. geol. Helv.*, 32, 47-100.
THOMAS, G. A., and DICKINS, J. M., 1954.—Correlation and Age of the Marine Permian Formations of Western Australia. *Aust. J. Sci.*, 16, 219-223.
THOMAS, I., 1914.—The British Carboniferous Producti, I: Genera *Pustula* and *Overtonia*. *Mem. geol. Surv. U.K., Palaeont.*, 1 (4), 197-366.
THOMSON, J. A., 1927.—Brachiopod Morphology and Genera (Recent and Tertiary). *N.Z. Board Sci. Art* (Wellington, N.Z.), *Manual* 7.
TRAVES, D. M., 1955.—The Geology of the Ord-Victoria Region, Northern Australia. *Bur. Min. Resour. Aust. Bull.* 27.
TRECHMANN, C. T., 1921.—Some Remarkably Preserved Brachiopods from the Lower Magnesian Limestone of Durham. *Geol. Mag.*, 58, 538-543.
TSCHERNYSCHEW, T. H., 1889.—Beschreibung des Central-Urals und des West-Abhanges. *Allgem. geol. Karte Russld, Bl.* 139: *Mém. Comm. géol. St. Petersb.*, 3 (4) (German Summary).
TSCHERNYSCHEW, T. H., 1902.—Die Obercarbonischen Brachiopoden des Urals und des Timan. *Mém. Comm. géol. St. Petersb.*, 16 (2).

VERNEUIL, P. E. P. DE, 1845.—Paléontologie, in Murchison, R. I., Verneuil, P. E. P. de, and Keyserling, A. de, *Géologie de la Russie d'Europe et des Montagnes de l'Oural*, **2** (3). London and Paris.

WAAGEN, W., 1884.—Salt Range Fossils: Brachiopoda. *Palaeont. indica*, Ser. 13, 1 (4), 545-770.

WELLER, S., 1914.—The Mississippian Brachiopoda of the Mississippi Valley Basin. *Geol. Surv. Ill., Monogr.*, 1.

WHITEHOUSE, F. W., 1928.—Notes on Upper Palaeozoic Marine Horizons in Eastern and Western Australia. *Rep. Aust. Ass. Adv. Sci.*, 18 (for 1926), 281-283.

PLATE 1.

FIGS. 1, 3, 4, 6—*Aulosteges baracoodensis* Etheridge fil. .. .. .. Page 36

Figs. 1, 3—Ventral and dorsal views (x $\frac{2}{3}$) of U.W.A. 10496; Fossil Cliff, Irwin River District. Fossil Cliff Formation.

Figs. 4, 6—Ventral and dorsal views (x $\frac{2}{3}$) of lectotype, Aust. Mus. F.36218; Wooramel River, Carnarvon Basin. Callytharra Formation.

FIGS. 2, 5, 7, 8-10—*A. reclinis* sp. nov. .. .. Page 38

Fig. 2—Upright longitudinal view of paratype U.W.A. 29109; Windmill at Selection Homestead, West Kimberley District. Liveringa Formation.

Figs. 5, 7, 8, 10—Longitudinal, posterior, dorsal and ventral views (x $\frac{2}{3}$) of holotype U.W.A. 31190; 4 mi. north Mt. James on boundary fence between Nerrima and Kallaida Stations, West Kimberley District. Hardman Member of Liveringa Formation.

Fig. 9—Upright longitudinal view of C.P.C. F.21043; near base of Mt. Hardman, West Kimberley District. Probably Hardman Member.

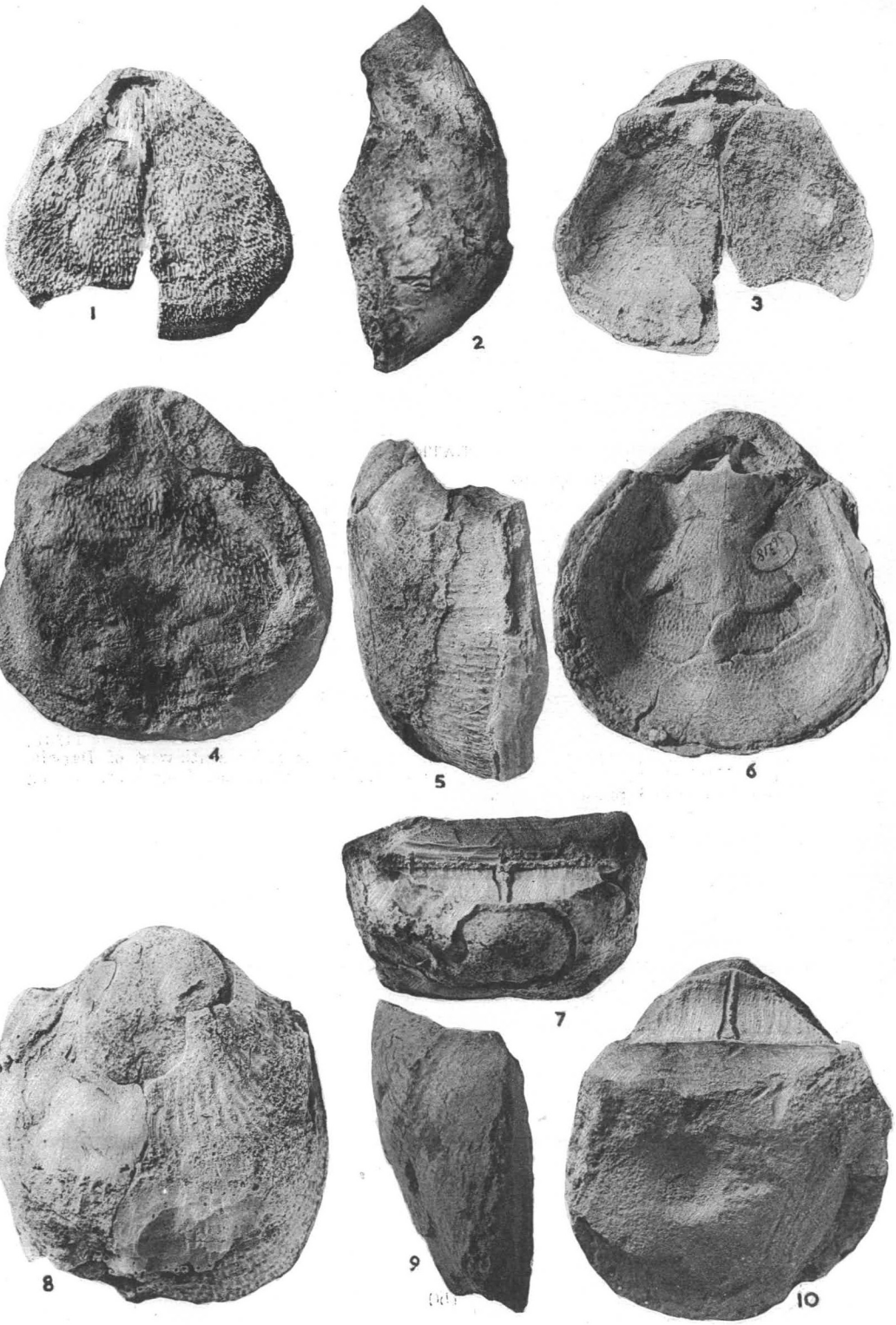
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PLATE 2.

FIGS. 1-4—*Aulosteges reclinis* sp. nov. .. .. Page 38

Figs. 1, 2—Ventral and posterior views of same specimen as Fig. 9, Plate 1.

Fig. 3—Impression of external surface from an internal aspect of brachial valve. U.W.A. 29106a; same locality and horizon as for specimen Fig. 2, Plate 1.

Fig. 4—Ventral view of same specimen shown in Fig. 2, Plate 1.

FIGS. 5-12—*A. fairbridgei* sp. nov. .. .. Page 40

Figs. 5, 6—Dorsal and ventral views of paratype U.W.A. 29438b showing deformed umbo; locality, horizon as for holotype, next figures.

Figs. 7-10—Posterior, cardinal area, upright longitudinal and ventral views of holotype, U.W.A. 29438f; Tutu Windmill, Nerrima Creek, Luluigui-Myrooda area, West Kimberley. Hardman Member.

Figs. 11, 12—Dorsal interior and upright longitudinal views of Aus. Mus. F.44781; Ironstone ridge, Port Keats Native Mission, 154 air miles south-west of Darwin. Port Keats Group. Shows impressions of median septum and long ridges giving rise to cardinal process.

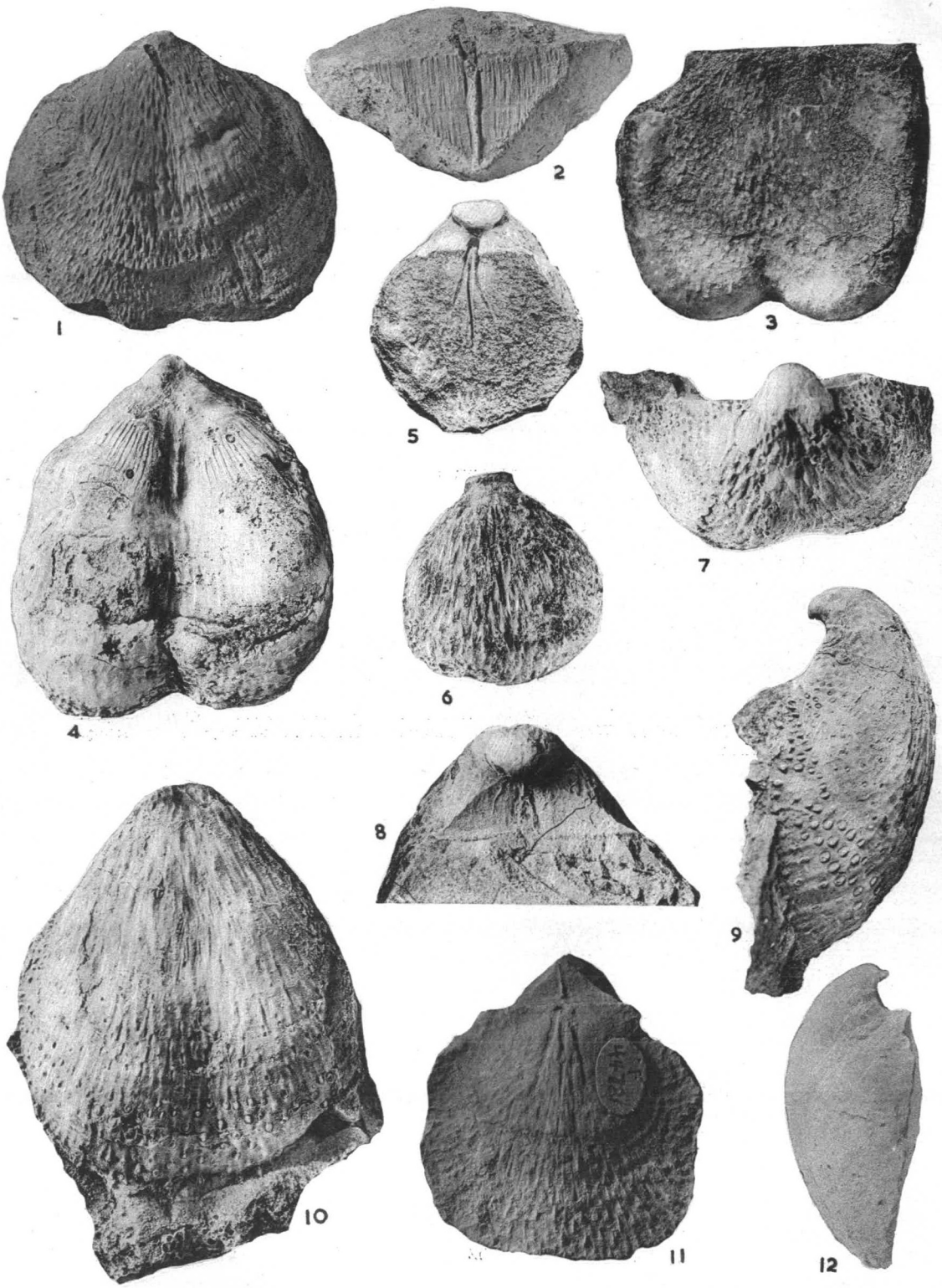
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PLATE 3.

FIGS. 1-10—*Aulosteges ingens* Hosking revised .. .. Page 43

Figs. 1-4—Dorsal, ventral, posterior and upright longitudinal views (x $\frac{2}{3}$) of lectotype G.S.W.A. 1/5000; bed in bank of Wooramel River, 3 miles above (Trig.?) R.20. Carnarvon Basin. Above Callytharra Formation.

Figs. 6, 8—Dorsal and ventral views of paratype G.S.W.A. 1/4955, same locality as above.

Figs. 5, 10—Dorsal view of internal mould, natural size, and external ventral surface, much reduced, of Aus. Mus. 44817, Pt. Keats Mission, 154 air miles south-west of Darwin, Northern Territory. Port Keats Group.

Fig. 7—Dorsal internal impression of Aus. Mus. F.44805, same locality as above.

Fig. 9—Brachial valve, U.W.A. 32027, latex cast (x $\frac{2}{3}$) south flank of the ridge just east of Mt. Cedric, West Kimberley District. Hardman Member of Liveringa Formation.

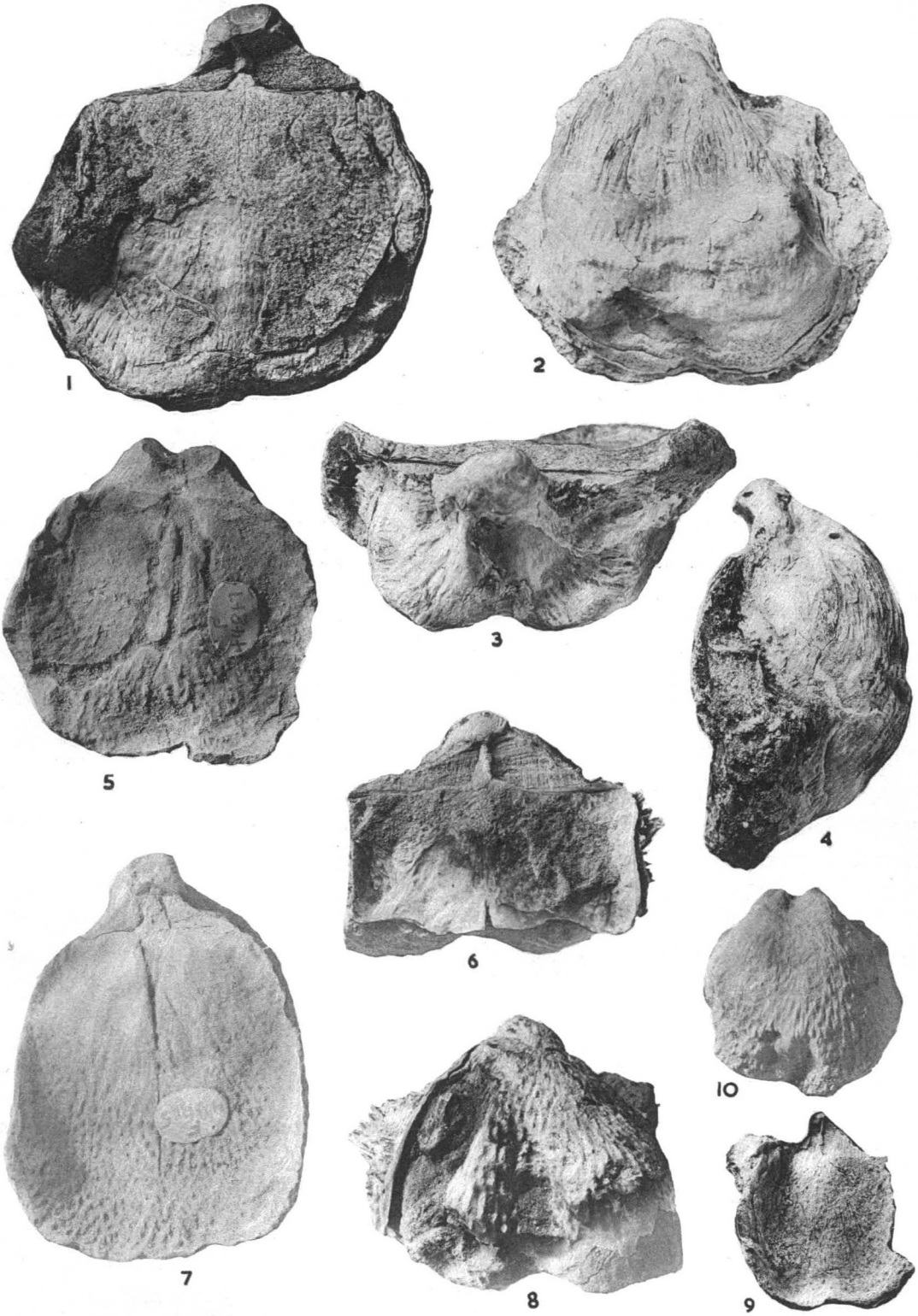
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PLATE 4.

FIGS. 1-10—*Avlosteges lyndonensis* sp. nov. .. .. Page 46

Figs. 1, 2, 3—Dorsal, ventral and upright longitudinal views of holotype, C.P.C. 1001 (Fig. 3 x $\frac{2}{3}$); north bank of Lyndon River, north of Round Hill. $8\frac{3}{4}$ miles east of Mia Mia Homestead, Carnarvon Basin. Base of Bulgadoo Shale.

Figs. 4, 6, 7—Cardinal process and adductor muscle impressions C.P.C. 1005, 1006, 1007 respectively. Same locality as above.

Fig. 5—Extremely large cardinal area of a paratype (broken specimen). Same locality as above.

Fig. 8—Dorsal view of paratype, C.P.C. 1002, showing distorted area. Same locality as above.

Figs. 9, 10—Dorsal and ventral views of C.P.C. 1956 (x $\frac{2}{3}$), 2,000 feet west of Callytharra Spring, Wooramel River, Carnarvon Basin. 120 feet above base of Callytharra Formation.

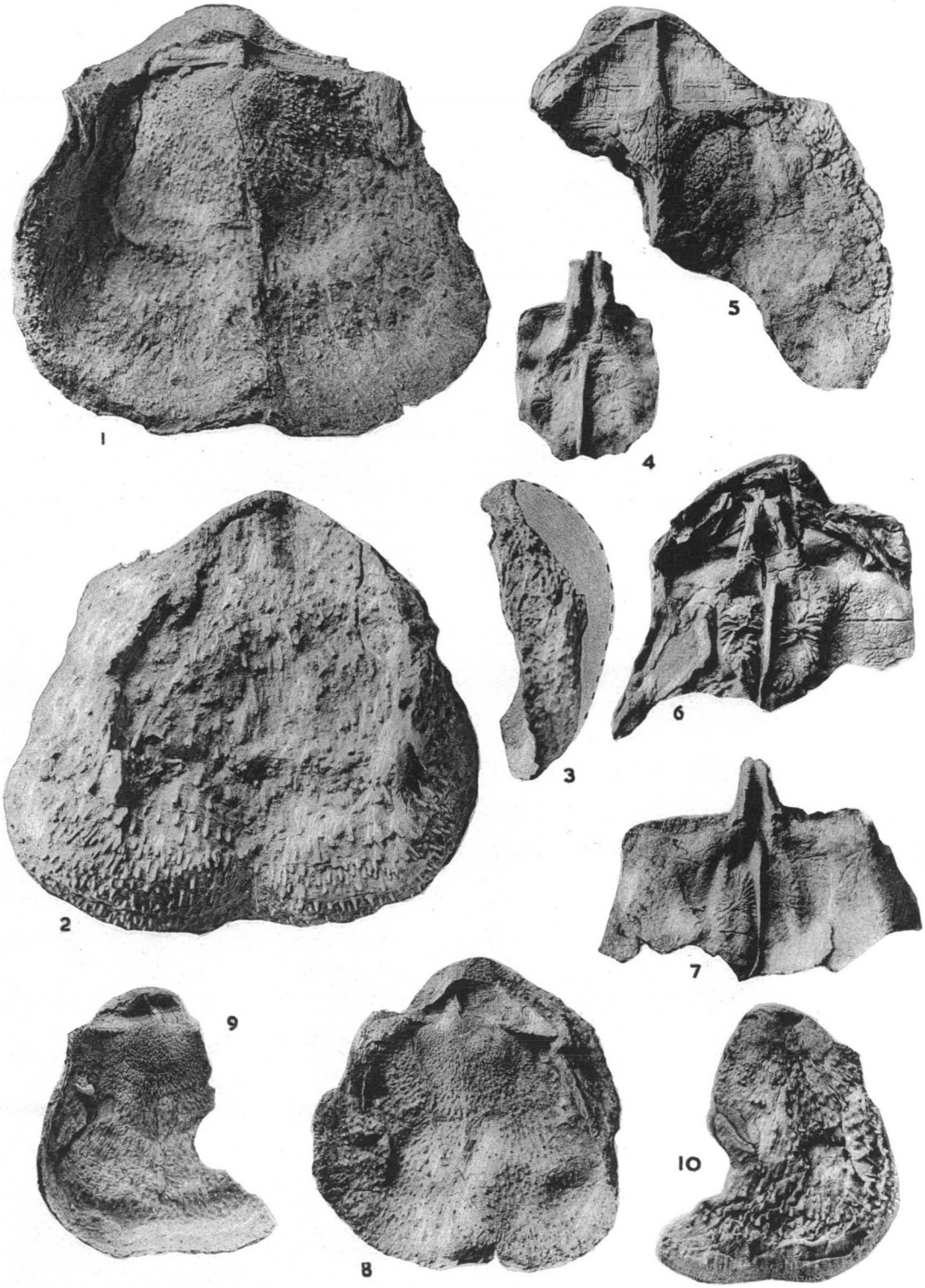
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PLATE 5.

FIGS. 1-9, 11, 12—*Aulosteges spinosus* Hosking .. .. Page 49

Figs. 1-3—Dorsal impression, upright longitudinal and ventral views of U.W.A. 34433; Glendevon Homestead, Woolaga Creek, Irwin River District. Fossil Cliff Formation.

Figs. 4-6—Ventral, dorsal and upright longitudinal views of sediment-filled pedicle valve, Aus. Mus. F.37710, Wandagee Station.

Figs. 7-9—Ventral, dorsal and upright longitudinal views of holotype G.S.W.A. 1/4687, a pedicle valve. Fig. 9 shows reflexed cardinal margin. South bank of Wooramel River, below Callytharra Springs, Carnarvon Basin. Probably Callytharra Formation.

Figs. 11, 12—Ventral and upright longitudinal views of broken specimen showing cardinal process, U.W.A. 27288, west side of syncline south of Minilya River, west of Coolkilya Pool, Carnarvon Basin. Lower part Wandagee Formation.

FIGS. 10, 13-18—*Taeniothaerus miniliensis* sp. nov.—immature specimens .. Page 96

Figs. 10, 16, 17—Upright longitudinal, dorsal and ventral views of U.W.A. 34438, given particularly to show cardinal process and spinose brachial valve; same locality and horizon as for specimen figured 11, 12 above.

Figs. 13-15—Upright longitudinal, dorsal, and ventral views of worn specimen U.W.A. 34440; same locality and horizon as figs. 11, 12.

Fig. 18—Dorsal view of U.W.A. 34437, with projecting umbo. Same locality and horizon as for 27288, figs. 11, 12.

FIGS. 19-21—*Aulosteges* sp. ind. A. .. .. Page 51

Dorsal, upright longitudinal and ventral views of U.W.A. 281142; nine chains west of red sandstone *Calceolispongia* horizon, south-west of Wandagee Hill, Carnarvon Basin. Coolkilya Greywacke, above Nalbia member.

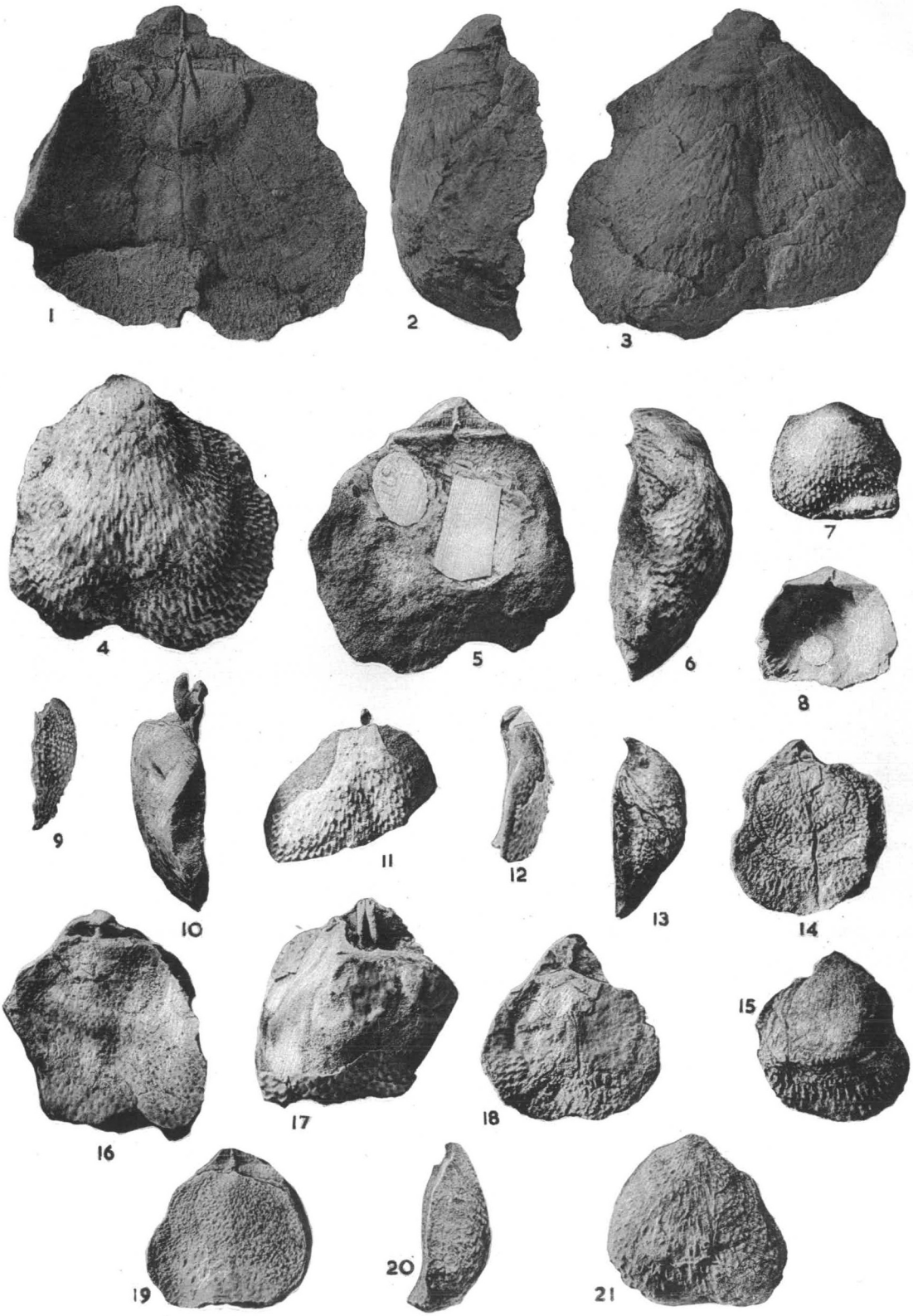
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PLATE 6.

FIG. 1—*Aulosteges reclinis* sp. nov. .. .. Page 38
Dorsal view of limonitic cast, U.W.A. 32025a, showing impression of median septum and large reclined cardinal process; outcrop on south flank of ridge just east of Mt. Cedric, West Kimberley District. Hardman Member of Liveringa Formation.

FIG. 2—*A. wangenheimi* (Verneuil) (see also Plate 21) .. .. .. Page 35
Internal features of brachial valve of plaster cast of B.M. BB 3279 (T. Davidson Collection) from Mt. Grebeni, near Orenburg, Russia.

FIGS. 3-14—*Dictyoclostus callytharrensis* Prendergast .. .. .. Page 54

Figs. 4-7—Ventral, posterior transverse, dorsal and upright longitudinal views of paratype, G.S.W.A. 1/4967a; ½ mile west of Callytharra Springs, Wooramel River, Carnarvon Basin. Callytharra Formation.

Fig. 8—Reticulate sculpturing on another paratype G.S.W.A. 1/4967a; same locality and horizon as paratype, figs. 4-7.

Figs. 9, 10—Ventral and upright longitudinal views of syntype G.S.W.A. 1/4967b, showing highly reflexed ears; same locality and horizon as paratype, figs. 4-7.

Figs. 11, 13—Ventral and dorsal views of paratype G.S.W.A. 1/4767a; dorsal view showing ginglymus; same locality as preceding.

Figs. 3, 12—Internal features of brachial valves, Aust. Mus. F. 36508, x ⅔ Barragooda Pool, Arthur River; and U.W.A. 29452a (latex cast), 1.4 miles south of gate in fourth fence on road from Merlinleigh to Moogoorie Stations. Both specimens from Callytharra Formation, Carnarvon Basin.

Fig. 14—Internal features of broken pedicle valve, a paratype G.S.W.A. 1/4967a, same locality and horizon as holotype, figs. 4-7.

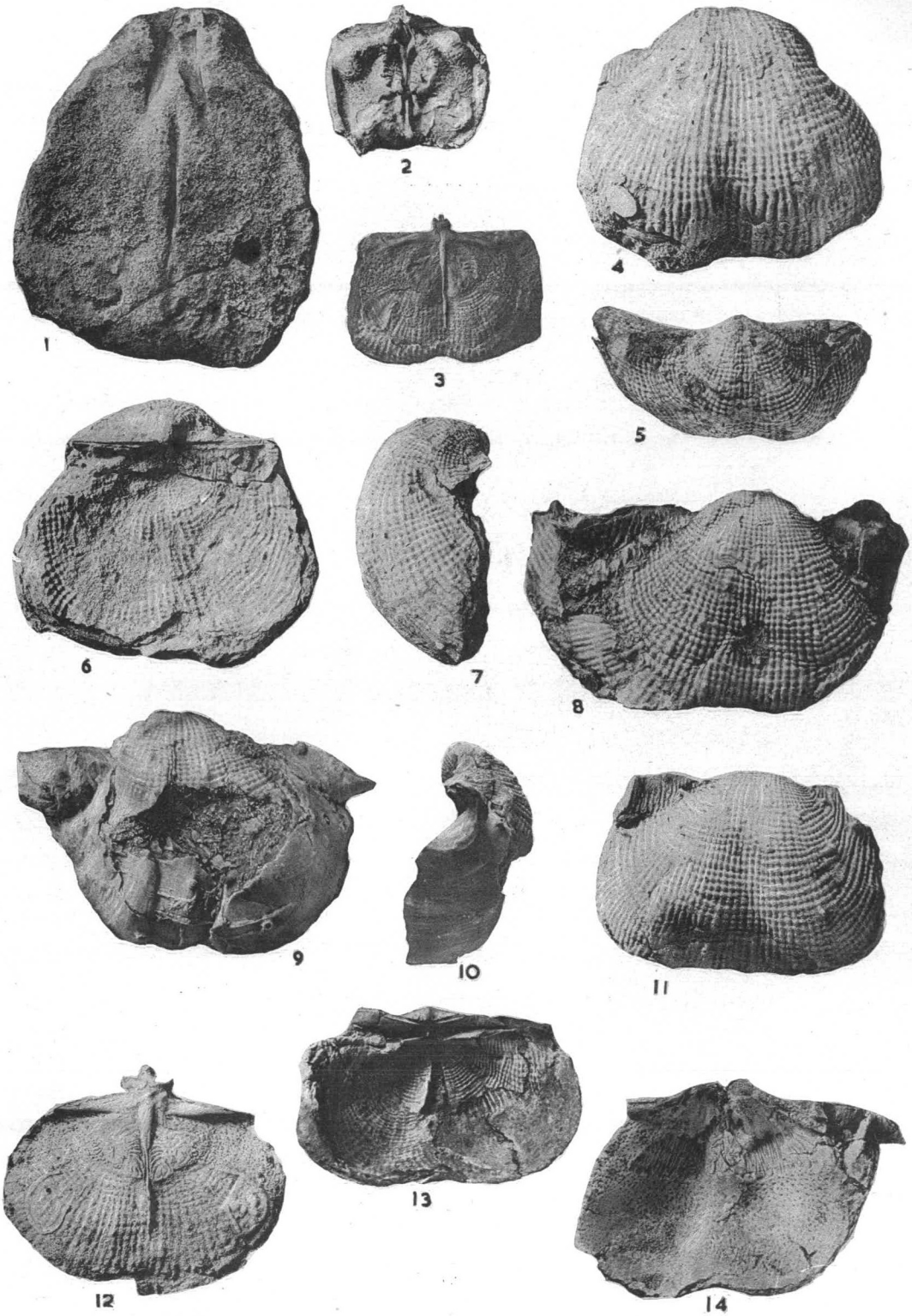
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PLATE 7.

FIGS. 1-6—*Dictyoclostus magnus* sp. nov. .. .. Page 57

Fig. 1—Postero-ventral view of paratype U.W.A. 32021 (x ½); 4 miles south-south-east of junction of south branch and main Minilya River, Williambury Station. Carnarvon Basin. Callytharra Formation.

Figs. 2, 3—Ventral and upright longitudinal views (x ½) of holotype pedicle valve, Aus. Mus. F.36514, Wyndham Gap, Carnarvon Basin. Callytharra Formation.

Figs. 4, 5, 6—Posterior upright longitudinal views and posterior view more from ventral aspect than fig. 4 to show extent of trail (x ½); paratype U.W.A. 32022, just south of Trig. K52, half-way along road between Middalya and Williambury Stations, Carnarvon Basin. Callytharra Formation.

FIGS. 7-10—*D. wadei* Prendergast revised .. .. Page 59

Figs. 7, 10—Ventral and upright longitudinal views (x ⅔) of holotype pedicle valve U.W.A. 20453; ferruginous limestone, 2 miles 10 degrees south of Mt. Nicholson, West Kimberley District, Canning Basin. Noonkanbah Formation.

Fig. 8—Anterior view of inverted broken pedicle valve (x ⅔), U.W.A. 28696a; just south of Trig. 243, West Kimberley District. Noonkanbah Formation.

Fig. 9—Impression of external of brachial valve (x ⅔), U.W.A. 28696b; same locality and horizon as fig. 8, 28696a.

FIGS. 11-15—*Krotovia senticosa* (Hosking) .. .. Page 63

Figs. 11, 12—Dorsal and ventral views (x ⅔) of lectotype G.S.W.A. 1/4970a; creek ½ mile west of Callytharra Springs. Wooramel River, Carnarvon Basin. Callytharra Formation.

Fig. 13—Dorsal view of another type, G.S.W.A. 1/4970a.

Figs. 14, 15—Pedicle valve, broken and showing internal features of brachial valve, and upright longitudinal view of same specimen, right-hand side encrusted with sediment, G.S.W.A. 1/4970a; same locality as other types.

FIGS. 16-18—*K. micracantha* (Hosking) .. .. Page 61

Figs. 16, 17—Dorsal and ventral views of lectotype, G.S.W.A. 1/4970b, same locality and formation as for *K. senticosa* above.

Fig. 18—Dorsal view of other type, G.S.W.A. 1/4970b; same locality, horizon.

FIGS. 19-24—*K. spinulosa* (J. Sowerby). .. .. Page 65

Figs. 19-22—Dorsal, posterior, upright longitudinal and ventral views of Aus. Mus. 38446, Wandagee Station, Minilya River, Carnarvon Basin.

Fig. 23—Pedicle valve cut away to show internal structures in brachial valve (x 2) of Aus. Mus. F.37579, ¼ mile west of shale outcrop, north bank of Minilya River (west of Coolkilya Pool?), Carnarvon Basin. Wandagee Formation.

Fig. 24.—Ventral view of Aus. Mus. F.18443, same locality and formation as for figs. 19-22.

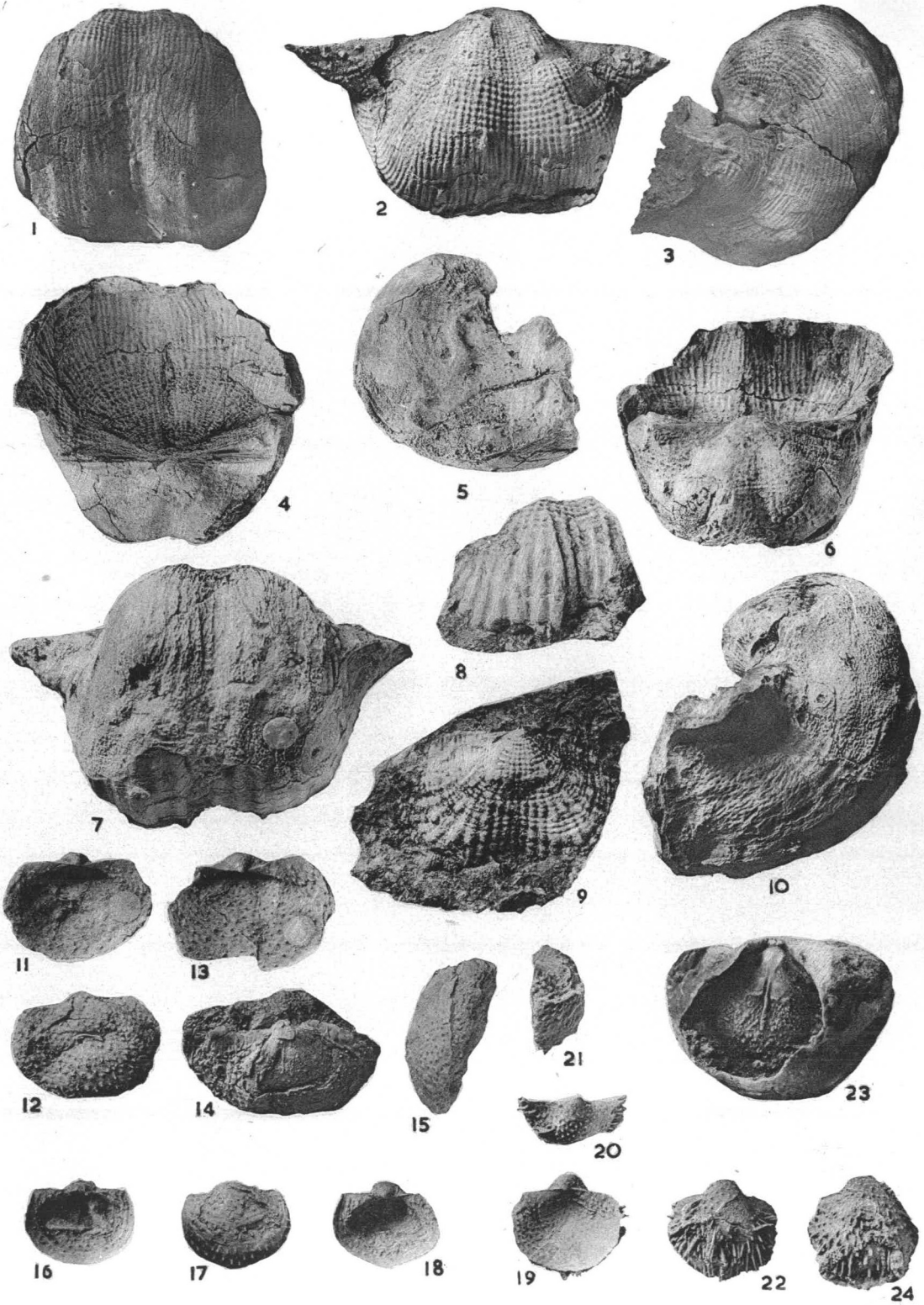
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PLATE 8.

FIGS. 1-9—*Linoproductus cancriniformis* (Tchernyschew) .. .. .. Page 69

Fig. 1—Ventral view of limonitic cast, U.W.A. 27165a, east of Wandagee Hill, Nalbia Paddock, Wandagee area, Carnarvon Basin. Coolkilya Greywacke.

Figs. 2-4—Dorsal, ventral and upright longitudinal views of U.W.A. 27127, west side of syncline south of Minilya River, Carnarvon Basin. Wandagee Formation.

Figs. 5, 6—Longitudinal view of brachial valve showing large trail and plan view of internal features including stubby cardinal process, specimen U.W.A. 29364, same locality and formation as above specimen 27127.

Fig. 7—Antero-ventral view of Aus. Mus. F.38455, Minilya River, probably near locality of 27127 above.

Figs. 8, 9—Ventral and dorsal views of Aus. Mus. F.38456, same locality as F.38455 above.

FIGS. 10-15—*L. cora foordi* (Etheridge fil.) .. .. Page 74

Figs. 10, 11—Dorsal view showing depressed brachial valve, and ventral view of U.W.A. 32391, Fossil Cliff, Irwin River, near Mingenew township. Fossil Cliff Formation.

Figs. 12, 13—Ventral and longitudinal views of U.W.A. 32392, same locality and formation as 32391 above.

Fig. 14—View of internal of pedicle valve, U.W.A. 23438, same locality and formation as 32391 above.

Fig. 15—Central view of 32392a, same locality and horizon as 32391 above.

FIGS. 16-22—*L. lyoni* Prendergast revised. .. .. Page 76

Figs. 16-18—Dorsal, upright longitudinal and ventral views of the cast U.W.A. 32025, Glendevon Homestead, Woolaga Creek area, near Mingenew township. Fossil Cliff Formation.

Fig. 19—Ventral view of cast U.W.A. 32028, showing cardinal spines; same locality and formation as 32025 above.

Figs. 20, 21—Holotype spec., Aus. Mus. F.36530, 10 chains north-west of Gnarrea Pool near Winning Station, Carnarvon Basin. Lyons Group (?upper part). Fig. 21, upright longitudinal view of lower left specimen, sediment opaqued out.

Fig. 22—Impression side of brachial valve of cast U.W.A. 32025 above.

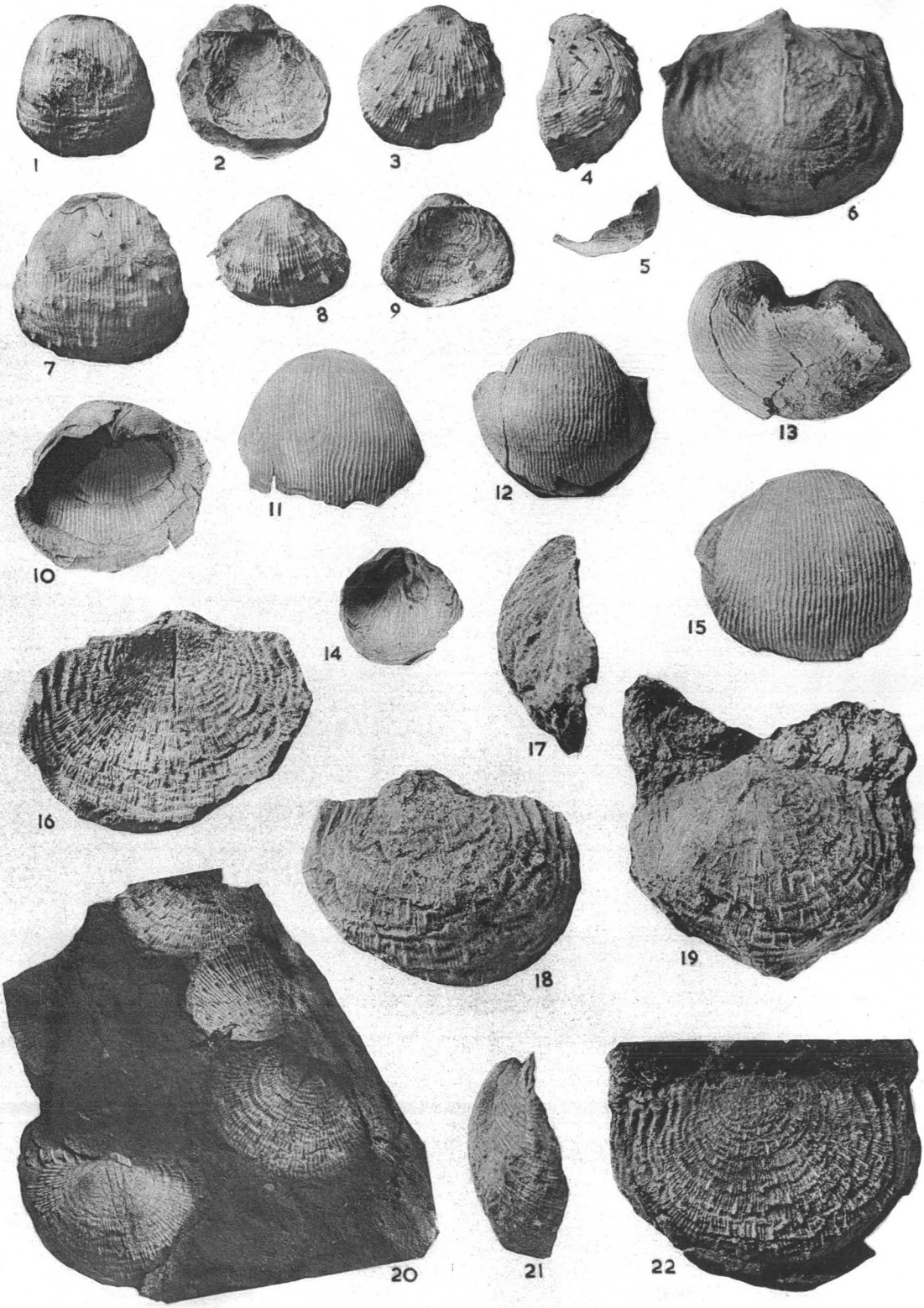
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PLATE 9.

FIGS. 1-14—*Marginifera gratiodentalis* (Grabau) .. .. Page 79

Figs. 1-3—Dorsal, ventral, upright longitudinal views of Aus. Mus. F.37569; ¼ mile east of shale outcrop, north(?) Minilya River (west of Coolkilya Pool?), Carnarvon Basin. Probably Wandagee Formation.

Fig. 4—View of internal features of brachial valve, U.W.A. 28453b, 350 yards west of place on fence between Barabiddy and Weer Paddocks, 2,200 yards south of gate in that fence near Barabiddy Creek, south of Wandagee Station, Carnarvon Basin. Cundlego Formation.

Figs, 5, 6—Upright longitudinal and plan view showing internal features of brachial valve, U.W.A. 28453a; same locality, formation as 28453b above.

Figs. 7, 8, 9—Dorsal views of pedicle valves showing cincture setting off platform of ears, U.W.A. 27185e, and platform of adductor muscle impressions against striate linear diductor impressions, U.W.A. 27185c, 27185d; north-east side of syncline, north bank Minilya River, west of Coolkilya Pool, Carnarvon Basin. Cundlego Formation.

Figs. 10, 11—Posterior and ventro-posterior views of U.W.A. 27185e, locality and formation given above.

Fig. 12—Dorsal view of U.W.A. 27185b; same locality and formation as above for 27185c, d, e.

Figs. 13, 14—Posterior and ventro-posterior views of brachial valve U.W.A. 27185, to show demarcation of ears; same locality, formation as 27185c, d, e.

FIGS. 15-19—*Taeniothaerus* (?) *fletcheri* sp. nov. .. .. Page 91

Figs. 15, 17—Dorsal and ventral views (x ⅔) of paratype U.W.A. 29427b, Bell's Homestead, Ellendale area, West Kimberley District. Liveringa Formation.

Fig. 16—Dorsal view of U.W.A. 29427 showing long alar spines of pedicle valve curving out postero-laterally (latex cast).

Fig. 18—Ventral view of paratype U.W.A. 34444, showing large elongated spine-bases with small less elongated ones.

Fig. 19—Brachial valve C.P.C. 1955, 120 feet stratigraphically below Mt. Hardman, on south side; West Kimberley District. Liveringa Formation.

FIGS. 20, 21—*Krotovia micracantha* (Hosking) .. .. Page 61

Internal and external views (x 1⅓) of brachial valve C.P.C. 1954, 2,000 feet west of Callytharra Spring, Wooramel River, Carnarvon Basin. 120 feet above base of Callytharra Formation.

FIGS. 22, 23—*Krotovia* sp. ind. A. .. .. Page 67

Dorsal and ventral views (x 1⅓) of C.P.C. 1952, Pell's Range, Carnarvon Basin, 14½ miles north-east of Towrana Homestead, army map grid co-ordinates 336,500 east-1.853,200 north. 118 feet above base of Callytharra Formation.

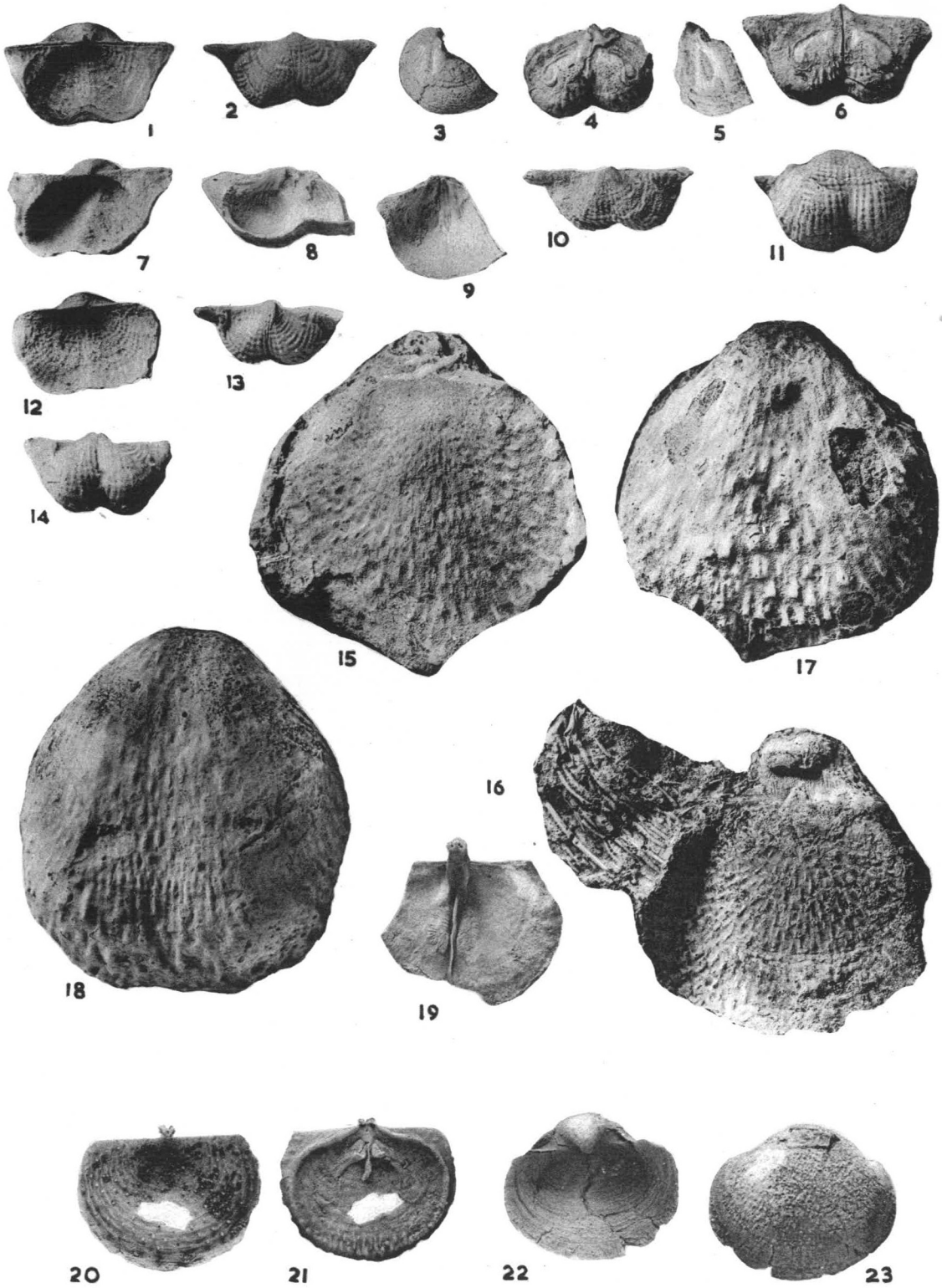
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PLATE 10.

FIGS. 1-7—*Taeniothaerus* (?) *fletcheri* sp. nov. (cont.) .. .. Page 91

Figs. 1, 2—Dorsal and ventral views (x $\frac{3}{8}$) of holotype C.P.C. 1950, 120 feet stratigraphically below top of Mt. Hardman, on south side, West Kimberley District. Hardman Member, Liveringa Formation.

Fig. 3—Cardinal process (latex cast) of U.W.A. 32024, probably *T.* (?) *fletcheri*; Tutu Windmill, Nerrima Creek, Noonkanbah area, West Kimberly District. Hardman Member of Liveringa Formation.

Figs. 4-6—Ventral, posterior and upright longitudinal views of paratype U.W.A. 29438; same locality, formation as 32024 above.

Fig. 7—Pedicle valve (paratype) U.W.A. 29440, showing ornamentation of elongated spines tending to form rows particularly over anterior part.

FIGS. 8-14—*Waagenoconcha imperfecta* Prendergast .. .. Page 82

Figs. 8, 9, 10—Upright longitudinal, ventral and dorsal views of U.W.A. 3044 (holotype), showing quincuncially arranged spines giving place to fine spines, incurved umbo, absence of area; Luluigui Station, West Kimberley District. Hardman Member.

Fig. 11—Posterior view of specimen U.W.A. 32029; base of Mt. Hardman, West Kimberley District. Hardman Member.

Fig. 12—Dorsal view of limonitic cast, U.W.A. 2045a, showing impression of internal features (x $\frac{3}{8}$); north flank of Mt. Cedric, West Kimberley District. Hardman Member.

Fig. 13—Impression of external of brachial valve, one of original type specimens, U.W.A. 2775, Luluigui Station, West Kimberley District. Hardman Member.

Fig. 14—Anterior view of inverted pedicle valve, specimen U.W.A. 29016b, showing banding and fine pits, remnants of spine-bases; outcrop $\frac{3}{4}$ mile west of Luluigui Homestead, West Kimberley District. Hardman Member.

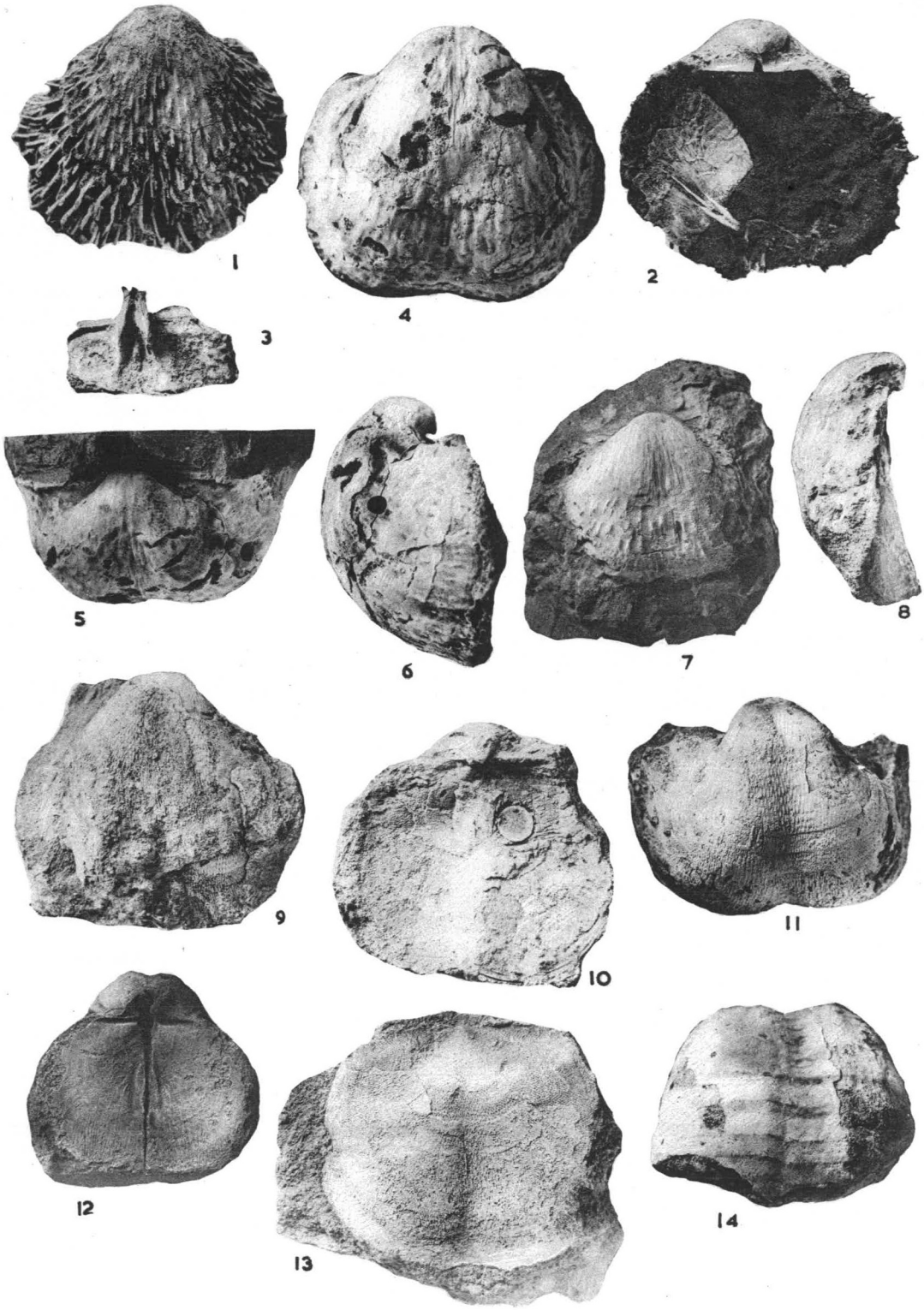
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PLATE 11.

FIGS. 1-6—*Waagenoconcha imperfecta* Prendergast (con.) .. .. .. Page 82

Fig. 1—Dorsal view of same specimen as figure 14, of preceding plate.

Figs. 2-4—Upright longitudinal view of U.W.A. 29016a and plan and oblique views of brachial valve (3, 4) of same specimen showing internal features, particularly cardinal process curving into umbonal cavity (Fig. 4 x $\frac{2}{3}$); same locality, formation as 29016b above.

Figs. 5, 6——Dorsal and upright longitudinal views of specimen U.W.A. 29016c; same locality, formation as paratype 29016b above.

FIGS. 7-12—*Taeniothaerus coolkiliensis* sp. nov. .. .. Page 89

Fig. 7-10—Upright longitudinal, ventral, posterior and dorsal views of holotype U.W.A. 27444 (x $\frac{2}{3}$); north-east side of syncline north of Minilya River, west of Coolkilya Pool, Carnarvon Basin. Wandagee Formation.

Figs. 11, 12—Dorsal views of internal casts showing impressions of internal features, U.W.A. 32042 (x $\frac{2}{3}$), and 32043; Glendevon Homestead, Woolaga Creek area, east of Mingenew township. Fossil Cliff Formation.

FIGS. 13, 14—*T. irwinensis* sp. nov. .. .. **Page 93**

Cardinal processes of U.W.A. 12398 and paratype 12396; Fossil Cliff, Irwin River, near Mingenew township. Fossil Cliff Formation.

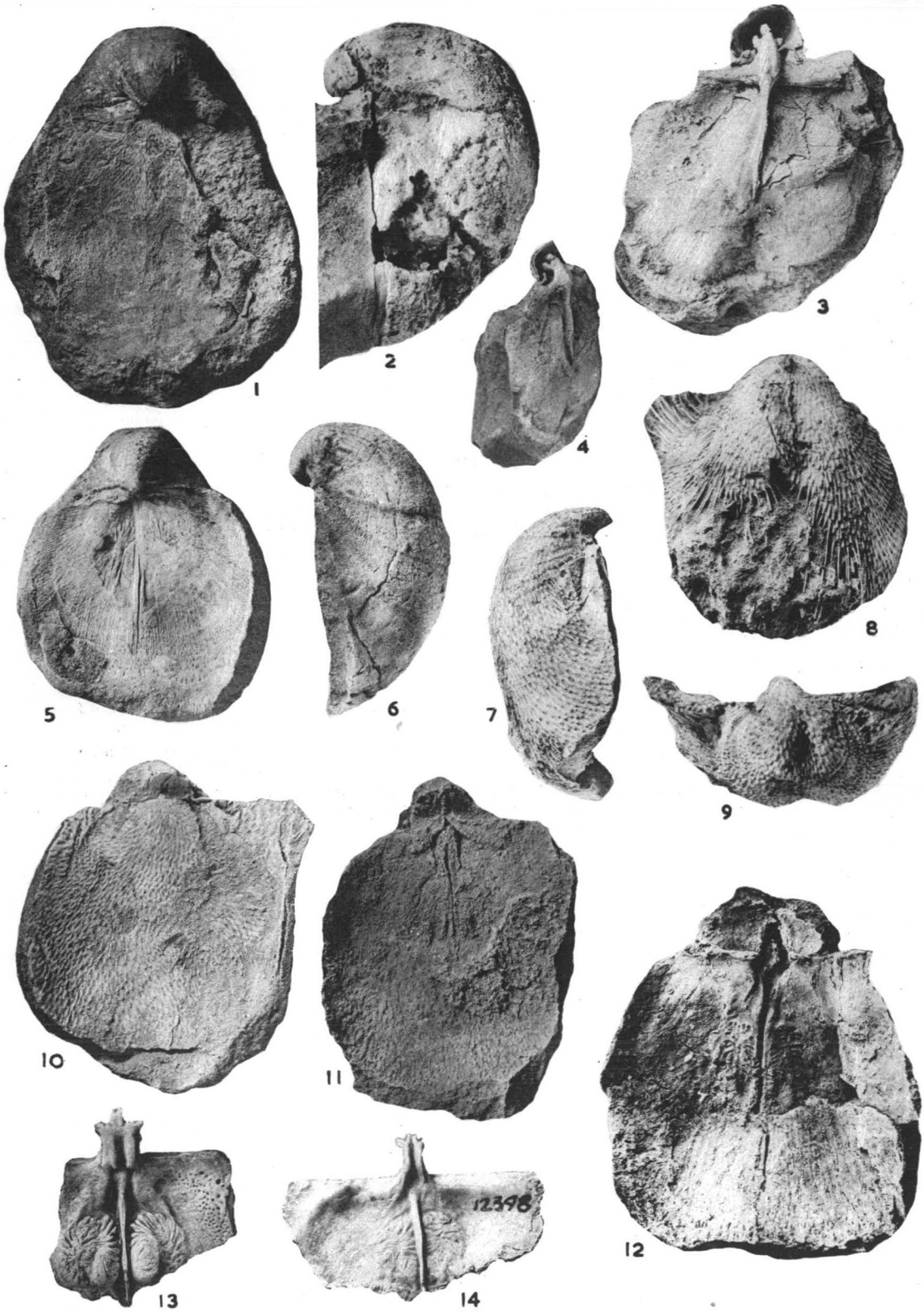
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PLATE 12.

FIGS. 1-6—*Taeniothaerus irwinensis* sp. nov. (cont.) .. .. Page 93

Figs. 1-3—Internal, upright longitudinal, external views of paratype brachial valve U.W.A. 10932 (Figs 2, 3 x $\frac{2}{3}$); Fossil Cliff, Irwin River, near Mingenew Township. Fossil Cliff Formation.

Figs. 4, 5—Ventral and upright longitudinal views of holotype pedicle valve, U.W.A. 32044 (x $\frac{2}{3}$), same locality, formation, as 10932 above.

Fig. 6—Transverse view of U.W.A. 23437 showing small area and incurved umbo; same locality and formation as 10932 above.

FIGS. 7-11—*T. miniliensis* sp. nov. .. .. Page 96

Fig. 7—Ventral view showing cardinal process projecting through broken valve and alar spines x $\frac{2}{3}$; paratype U.W.A. 27545, west side of syncline, south bank of Minilya River, west of Coolkilya Pool, Carnarvon Basin. Wandagee Formation.

Fig. 8—Dorsal view of paratype U.W.A. 27406, x $\frac{2}{3}$; north-east side of same syncline as 27545 above, but north bank of Minilya River. Wandagee Formation.

Figs. 9-11—Dorsal, posterior and upright longitudinal views of holotype U.W.A. 34445 (Fig. 9 x $\frac{2}{3}$); same locality, formation, as 27545 above.

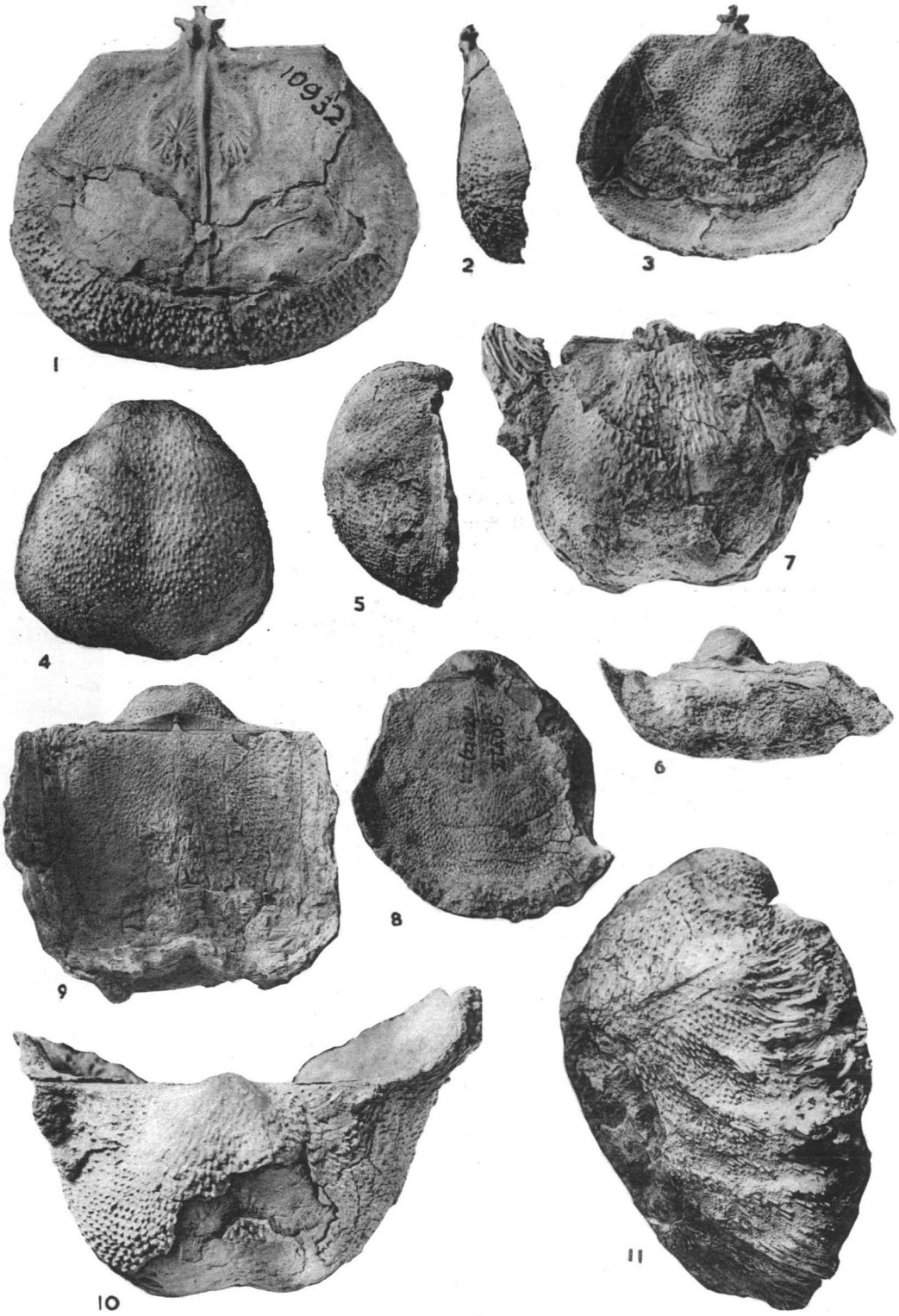
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PLATE 13.

All figures x $\frac{2}{3}$.

FIGS. 1-9—*Tacniothaerus miniliensis* sp. nov. (cont.) .. .. Page 96

Figs 1-3—Ventral, upright longitudinal and dorsal views of paratype U.W.A. 27254a; same locality as 27545, preceding plate, fig. 7.

Fig. 4—Dorsa view of paratype U.W.A. 27454; with attached *Etheridgina muirwoodae* Prendergast; same locality, formation as 27406, preceding plate, fig. 8.

Figs. 5, 6—Upright longitudinal and dorsal views of decorticated spec. U.W.A. 27600a; east side of syncline north bank of Minilya River, west of Coolkilya Pool. Wandagee Formation.

Fig. 7—Brachial valve showing internal features of paratype U.W.A. 27134; same locality, formation as 27406 figured preceding plate.

Figs. 8, 9—Upright longitudinal and internal features of 27254 (portion of pedicle valve adhering to cardinal margin); same locality, formation, as 27545 figured preceding plate.

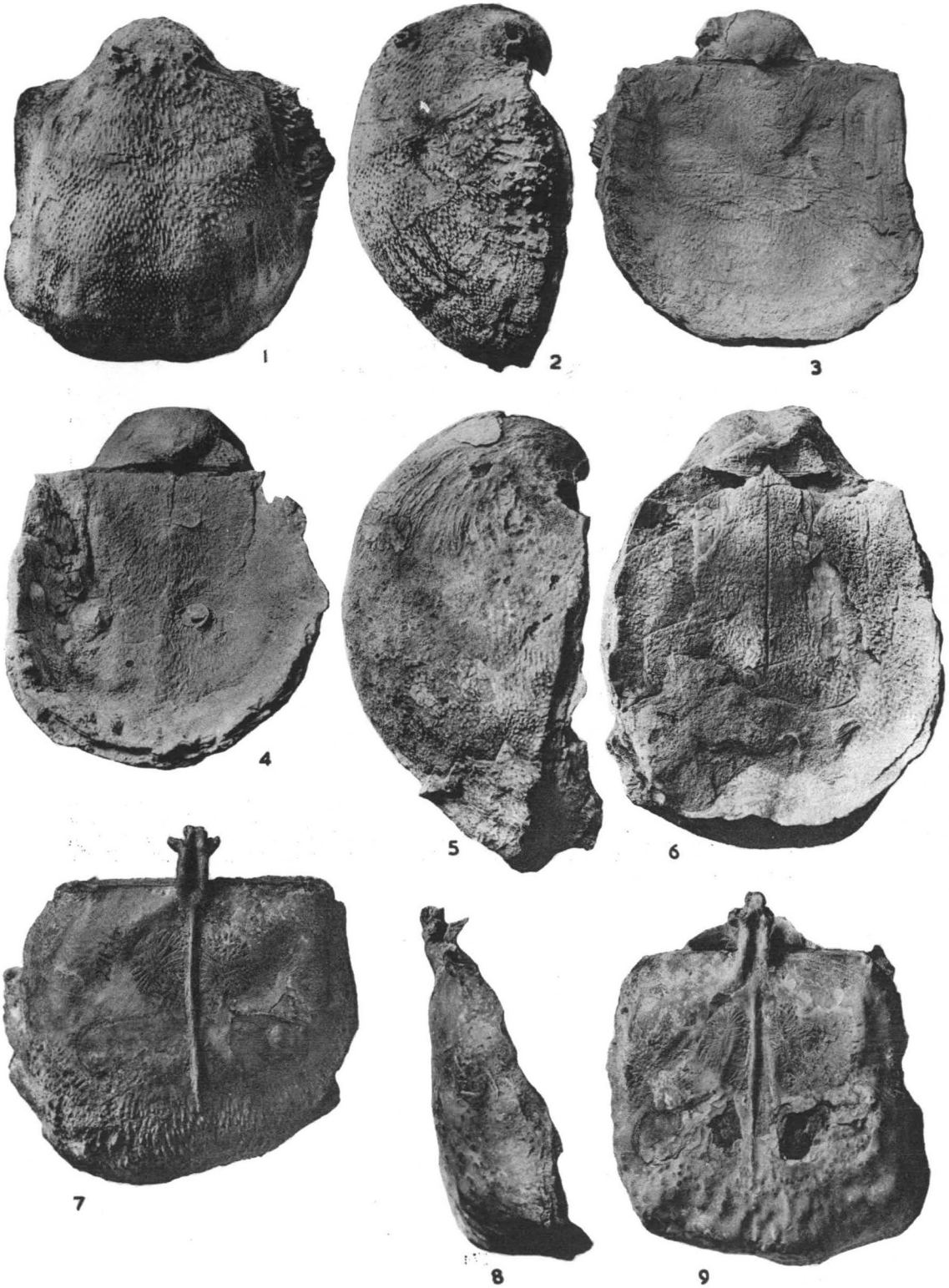
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PLATE 14.

All figures except Fig. 8, x $\frac{2}{3}$.

FIGS. 1-8—*Taeniothaerus miniliensis* sp. nov. (cont.) .. .. Page 96

Fig. 1—Dorsal view of paratype U.W.A. 27358; same locality, formation as 27545 figured plate 12.

Fig. 2—Upright longitudinal view of paratype brachial valve U.W.A. 27134 figured preceding plate.

Fig. 3—Upright longitudinal view of paratype U.W.A. 27116, with attached *Etheridgina muirwoodae* Prendergast; same locality, formation, as 27406 figured plate 12.

Fig. 4—Posterior view of decorticated paratype U.W.A. 22712, showing distorted umbo and diductor muscle impressions; from same syncline as above specimens but exact locality doubtful.

Fig. 5—Dorsal view of immature paratype U.W.A. 27600; same locality, formation, as 27545 figured plate 12, but east side of syncline.

Fig. 6—Internal features, minus cardinal process, of brachial valve of paratype 27454 figured plate 13.

Fig. 7—Dorsal view of U.W.A. 27254c, with higher area and more distorted umbo than is usual; same locality, formation, as 27545 figured plate 12.

Fig. 8—Posterior view of paratype U.W.A. 27406, figured plate 12, showing cicatrix of attachment. Nat. size.

FIGS. 9-11—*T.* sp. aff. *miniliensis* sp. nov. .. .. Page 101

Ventral and dorsal views of U.W.A. 34446, from top of zone of *Calceolispongia abundans* Teichert, east limb of Minilya syncline, Minilya River; and ventral view of U.W.A. 27406c showing transition from coarse to fine spine-bases; same locality, formation as 27406 figured plate 12. Both above specimens from Carnarvon Basis. Wandagee Formation.

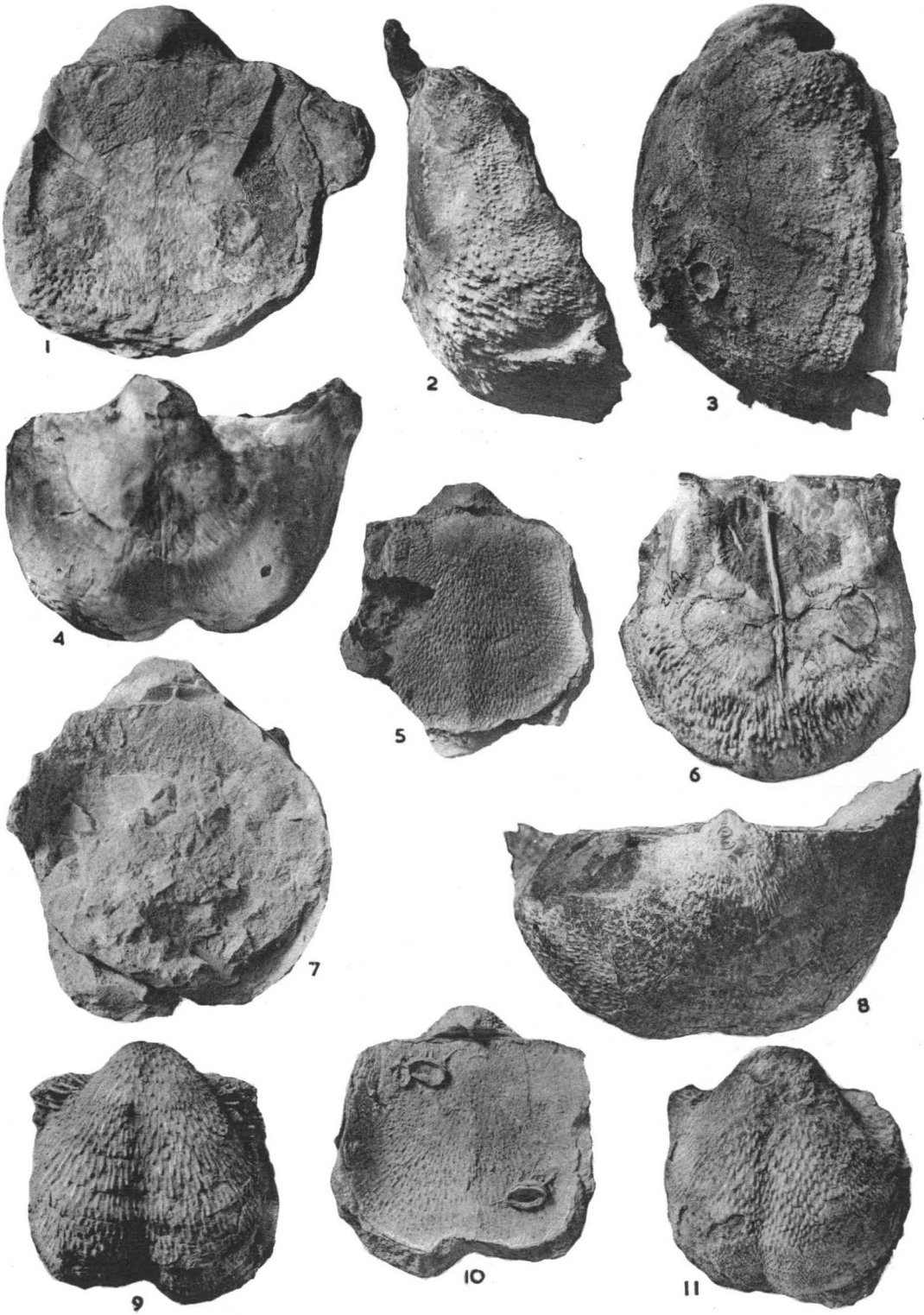
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PLATE 15.

All figures x $\frac{2}{3}$.

FIGS. 1-7—*Taeniothaerus subquadratus* (Morris) .. .. Page 87

Figs. 1-2—Ventral and upright longitudinal views of B.M.91171, Mt. Wellington and Mt. Dromedary, Tasmania. Permian, possibly Cascades stage.

Fig. 3—Crushed, partially decorticated specimen, Univ. of Queensland F.11050, Granton Quarry, near Mt. Dromedary, Tasmania. Granton substage of Cascades stage, Lower Marine series of Tasmania. Shows trace of cardinal process and long spines.

Figs. 4-6—Ventral, upright longitudinal and dorsal views of Melbourne University specimen, 1994, rather decorticated but showing remnants of spine-bases. From limestone about Upper Glenorchy reservoir, Glenorchy, Tasmania. Granton substage, Cascades stage, Lower Marine series of Tasmania.

Fig. 7—Ventral view of partly crushed specimen, University of Sydney, 11571, Collinsvale Quarry, near Hobart, Tasmania. Stratigraphical position probably as for two preceding specimens.

FIGS. 8-12—*T.* cf. *subquadratus* (Morris) .. .. Page 102

Figs. 8, 11—Upright longitudinal and posterior views of U.W.A. 34451; Glendevon Homestead, near Woolaga Creek, east of Mingenew township. Fossil Cliff Formation. Internal cast.

Figs. 9, 10, 12—Ventral, upright longitudinal and posterior views of U.W.A. 32316a; same locality, formation as 34451 above. Internal cast.

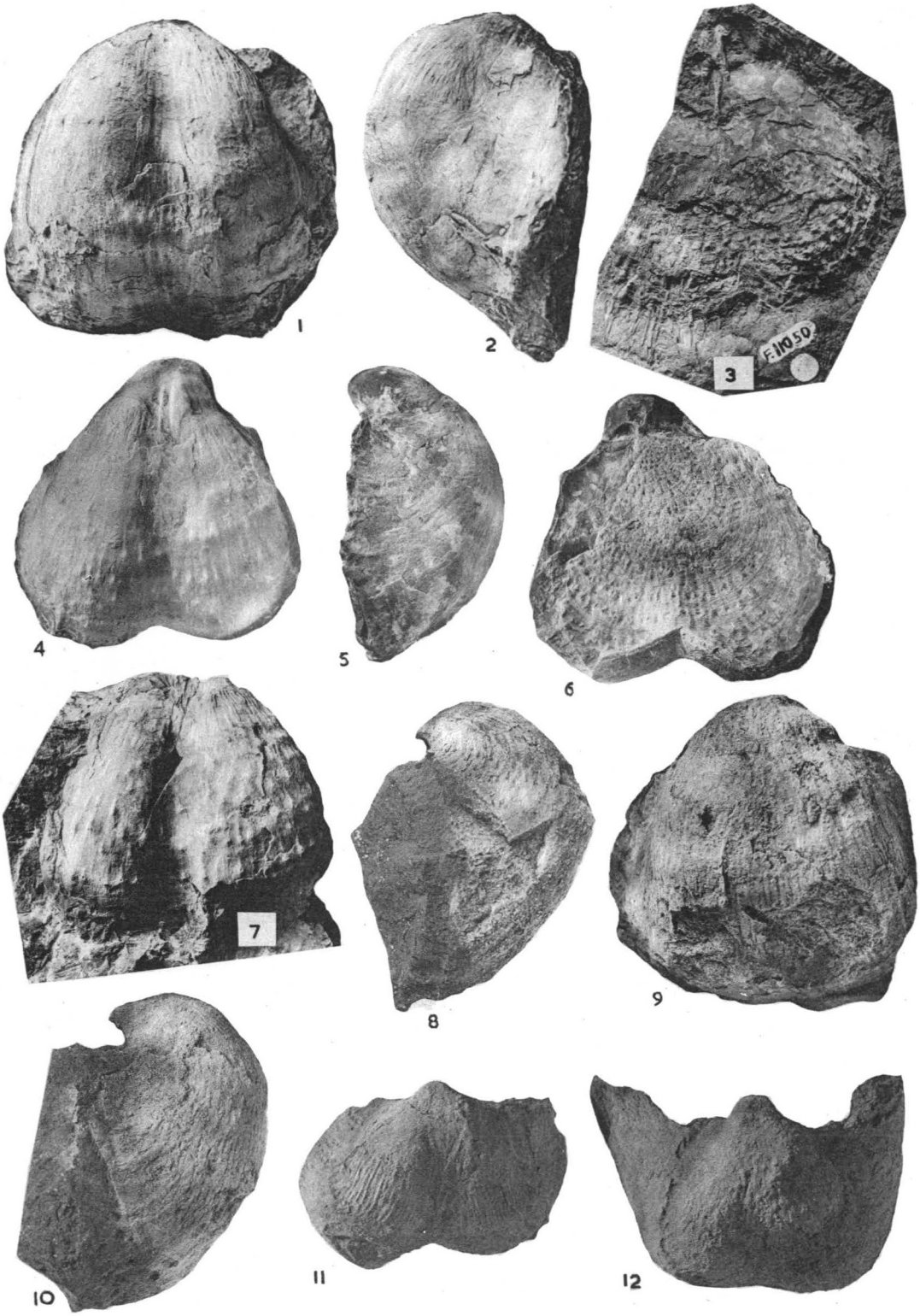
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PLATE 16.

All figures x $\frac{2}{3}$.

FIGS. 1-8—*Taeniothaerus teicherti* sp. nov. .. .. Page 104

Figs.1-3—Dorsal, posterior and upright longitudinal views of holotype C.P.C. 1008; $\frac{1}{2}$ mile east of Calvary Spring, 7 miles south-east of Mooka Station Homestead, Carnarvon Basin. Lower part Wandagee Formation.

Figs. 4, 5, 8—Upright longitudinal, internal and external views of paratype C.P.C. 1012; same locality, formation as holotype above.

Fig. 6—Internal view of paratype C.P.C. 1014; same locality, formation as holotype above.

Fig. 7—Upright longitudinal view of paratype, C.P.C. 1015, showing marginal flange; same locality, formation as holotype above.

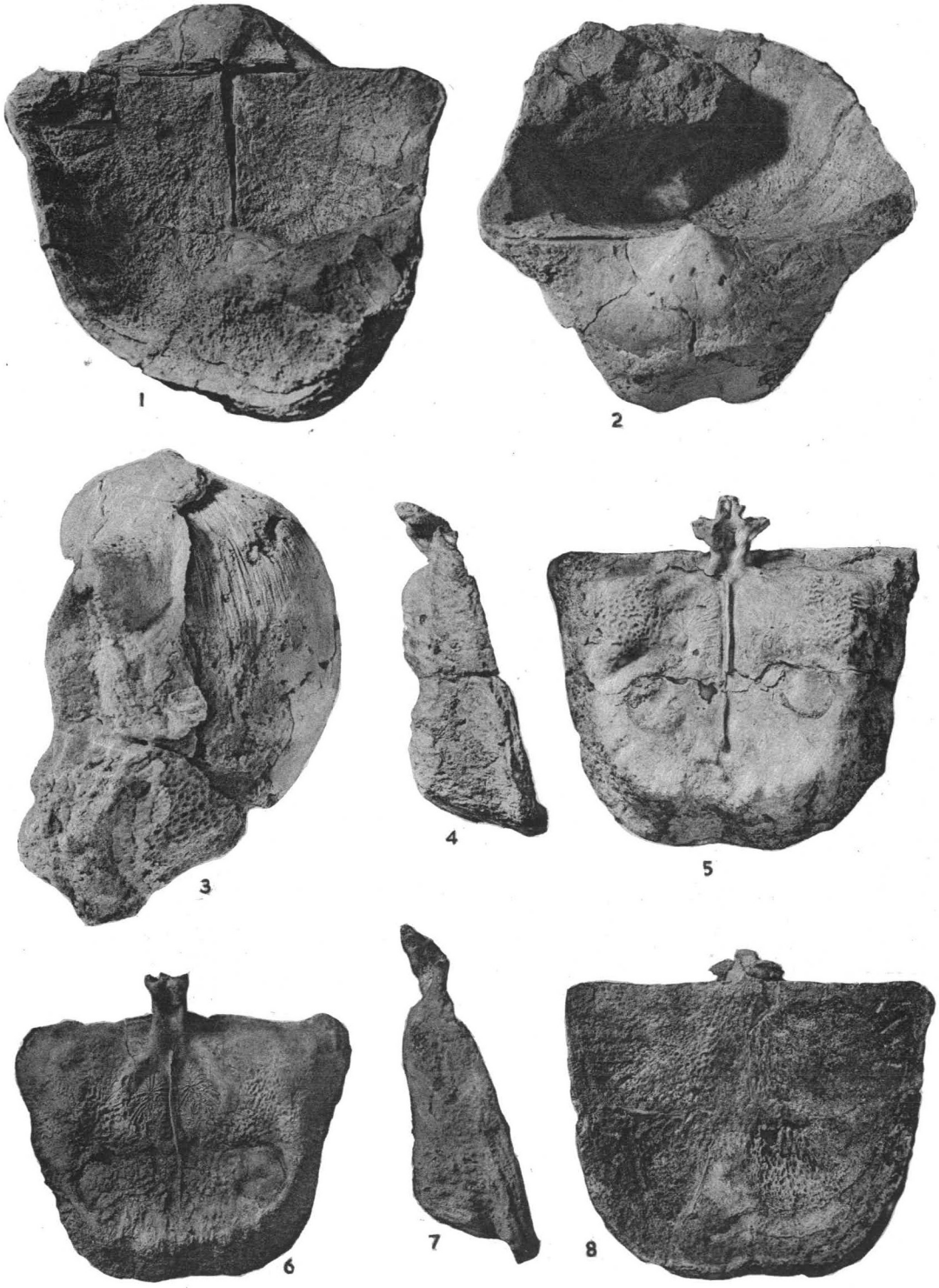
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PLATE 17.

FIGS. 1-5—*Taeniothaerus teicherti* sp. nov. x $\frac{2}{3}$ (cont.) .. .. .. Page 104

Fig. 1—Dorsal view of paratype C.P.C. 1011; same locality, formation, as holotype 1008, figured preceding plate.

Fig. 2—Dorsal view of paratype C.P.C. 1010; locality, formation as for holotype, figured preceding plate.

Fig. 3—Same of paratype C.P.C. 1013.

Figs. 4, 5—Upright longitudinal and internal views of brachial valve paratype C.P.C. 1016; locality, formation as above.

FIGS. 6-11—*Etheridgina muirwoodae* Prendergast .. .. Page 109

Fig. 6—Pedicle valve on *Taeniothaerus miniliensis* sp. nov. showing cardinal teeth; U.W.A. 27469, north-east side of syncline north of Minilya River, west of Coolkilya Pool, Carnarvon Basin. Lower part Wandagee Formation.

Fig. 7—View to show cardinal areas on both valves (top left) of lectotype, one of three types all attached to valve of *Neospirifer* sp. Aus. Mus. F.16699, Balmaningarra, Mt. Marmion, West Kimberley District.

Fig. 9—Plan aspect of same types showing teeth and raised adductor muscle platforms.

Fig. 8—Two specimens attached to distorted *Linoproductus* cf. *cancriniformis* Tschern.; Aus. Mus. F.16812 (topotype), same locality as lectotype above.

Fig. 10—Specimen on C.P.C. 1028 showing adherent spines and reflection of spine-bases from underlying host shell x 2; same locality, formation, as for holotype of *T. teicherti* figured plate 16.

Fig. 11—Posterior view of specimen, together with bryozoan, on trail of pedicle valve of U.W.A. 27116, figured plate 14, fig. 3. x 3.

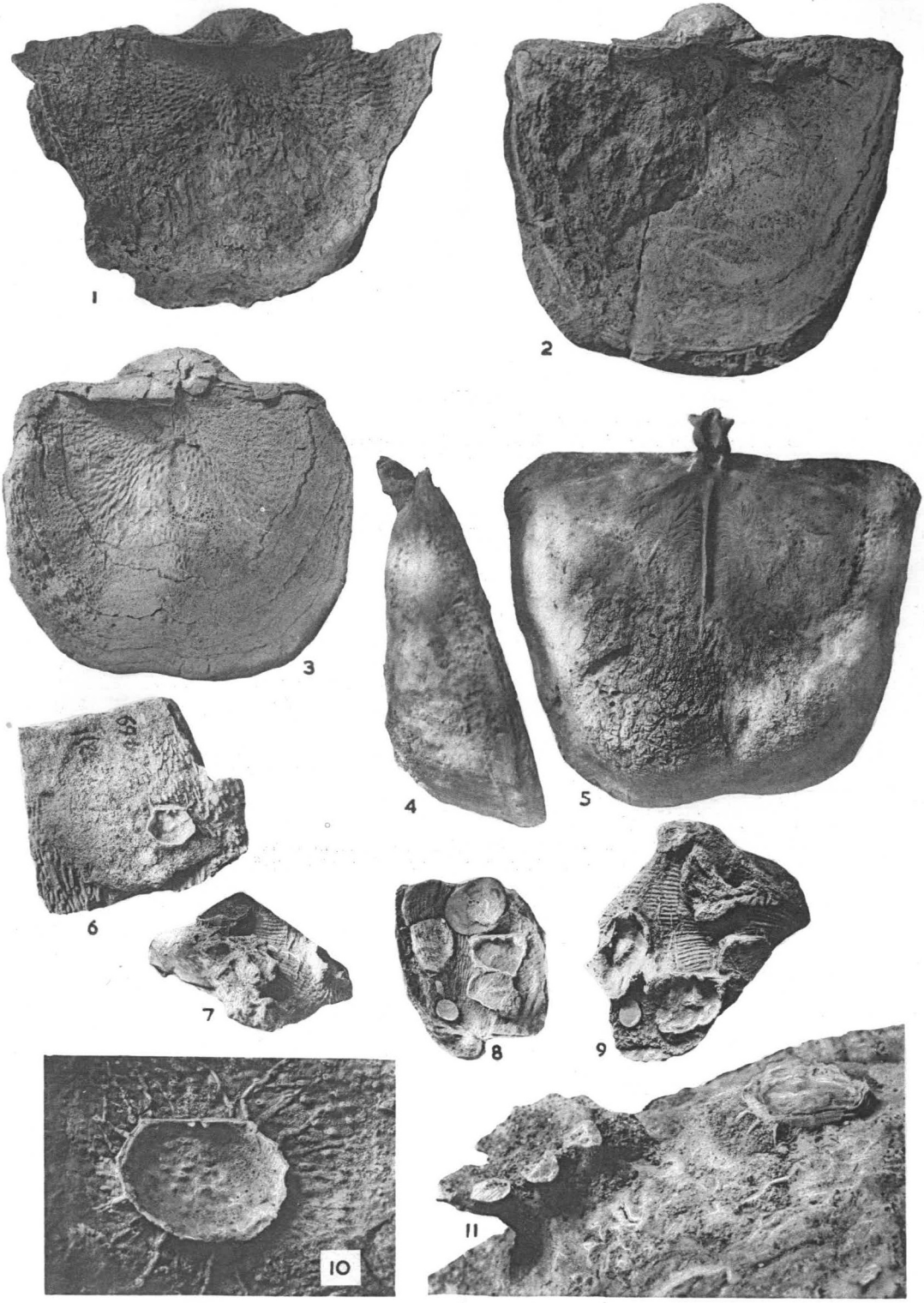
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PLATE 18.

FIGS. 1, 2—*Strophalosia clarkei* (Etheridge).
Internal views of two specimens, B.M.B. 5885, Capertee, N.S.W. (figured Etheridge fil., 1880). Shows depressions either side of median septum. Plaster casts. x $\frac{2}{3}$.

FIGS. 3-14—*S. multispinifera* Prendergast (revised) .. .. Page 114

Figs. 3, 4—Ventral and upright longitudinal views of sediment-filled worn pedicle valve, holotype U.W.A. 20458; scarp 2 miles east of Christmas Creek Homestead, West Kimberley District. Noonkanbah Formation.

Fig. 5—Internal view of U.W.A. 27454b; locality, formation as for 27454, figured plate 13, fig. 4.

Figs. 6, 7—Upright longitudinal and internal view of U.W.A. 34456; 8 miles south-west of Lyons River Homestead—detailed locality in text. Wandagee Formation.

Figs. 8, 9, 10—Upright longitudinal, ventral and dorsal views of pedicle valve, U.W.A. 27454a x 9/10; locality, formation as for 27454, figured plate 13, fig. 4.

Figs. 11, 12, 14—Ventral view of pedicle valve U.W.A. 34454, and ventral and dorsal views of U.W.A. 34455. Locality as for 34456 above.

Fig. 13—Internal features of pedicle valve (limonitic cast) U.W.A. 29057; Ellendale Station, 1½ miles north-west of Boal Bore, West Kimberley District. Possibly Liveringa Group.

FIGS. 15, 16—*S. prideri* sp. nov. .. .. Page 116

Dorsal and ventral views of holotype, C.P.C. 1018; right bank Lyndon River, 9 miles east of Mia Mia Homestead, Carnarvon Basin. Base of Bulgadoo Shale.

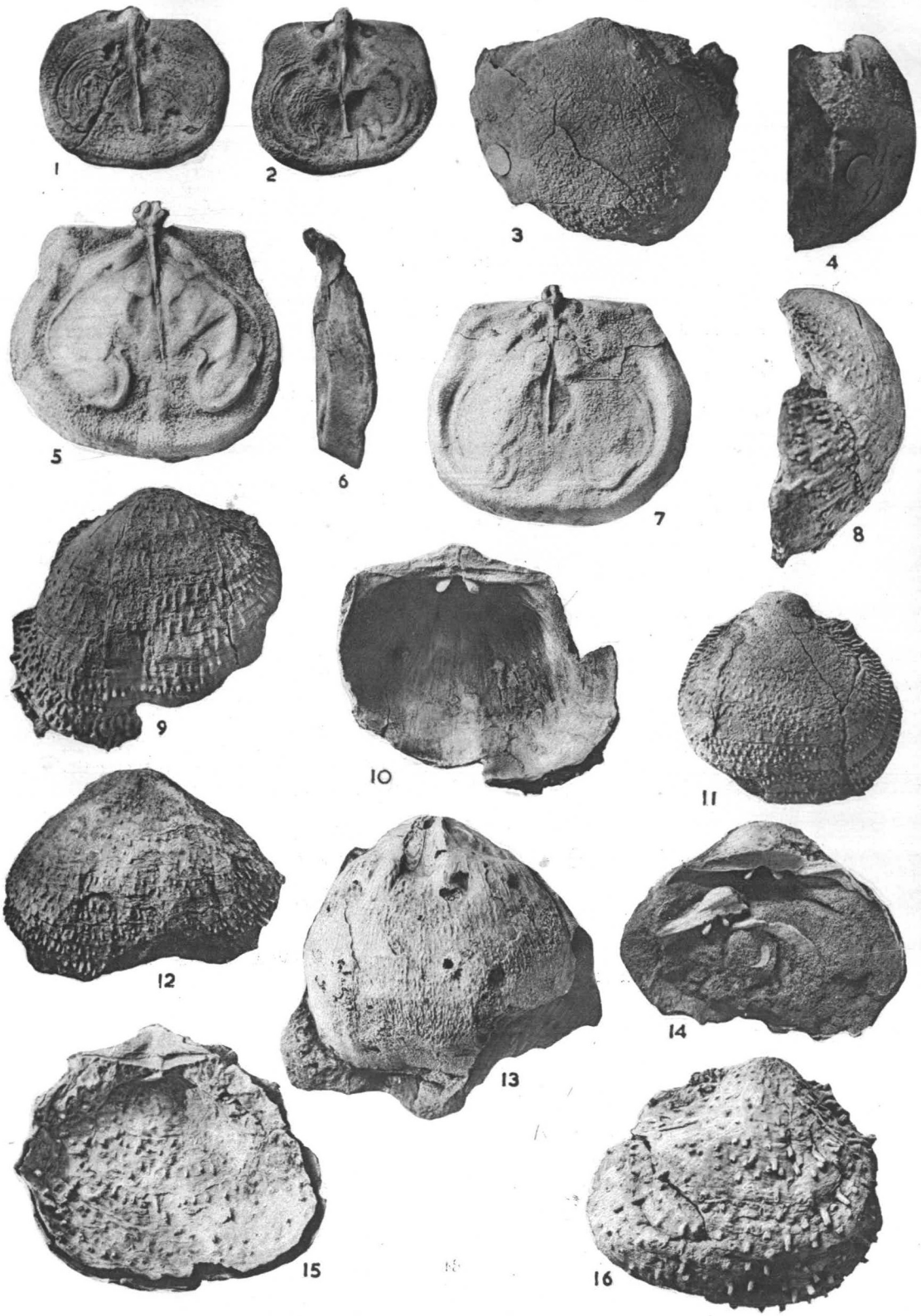
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PLATE 19.

FIGS. 1-19—*Strophalosia prideri* sp. nov. (cont.) .. .. Page 116

Fig. 1—Upright longitudinal view of holotype (preceding plate, figs. 15, 16) pedicle valve crushed.

Figs. 2, 3—Dorsal and ventral views of paratype C.P.C. 1019; locality, formation as holotype.

Figs. 4, 9—Upright longitudinal and internal view of brachial valve C.P.C. 1024; holotype locality.

Fig. 5—Internal view of brachial valve paratype U.W.A. 34458; holotype locality.

Fig. 6—Dorsal view of paratype C.P.C. 1020; holotype locality.

Figs. 7, 8—Ventral and upright longitudinal views of paratype C.P.C. 1023; holotype locality.

Figs. 10-13—Growth series, dorsal views of paratypes C.P.C. 1025, 1026, 1021, 1022; holotype locality.

Figs. 14, 15—Upright longitudinal and internal views of paratype C.P.C. 1027; holotype locality.

Fig. 16—Pedicle valve showing adductor muscle impressions, paratype U.W.A. 34459; holotype locality.

Figs. 18, 19, 17—Growth series, internal views of brachial valves (fig. 17 broken spec.) paratypes U.W.A. 34460, 34461, 34462; holotype locality.

FIGS. 20-32—*S.* (*Heteralosia*) *etheridgei* Prendergast.. .. .. .. Page 120

Fig. 20—Internal view of pedicle valve U.W.A. 27157e with umbo broken away, showing raised adductor muscle impression, x 2; type locality, creek ½ mile west of Callytharra Springs, Wooramel River, Carnarvon Basin. Callytharra Formation.

Figs. 21, 22, 29—Upright longitudinal and ventral views of same specimen, figs. 21, 22 natural size, fig. 29 x 1½.

Figs. 23, 32—Ventral and dorsal (x 2) views of U.W.A. 27157e above.

Figs. 24, 25, 26—Growth series, internal views of brachial valves (x 2) U.W.A. 27157f, g, h; locality, formation as above, 27157e.

Figs. 27, 28—Internal (x 1½) showing one of the cardinal teeth, and ventral views of U.W.A. 20448; Fossil Cliff, Irwin River, near Mingenew township. Fossil Cliff Formation.

Figs. 30, 31—Ventral views of immature specimens, U.W.A. 27157k and 27157b; locality, formation as above, 27157e.

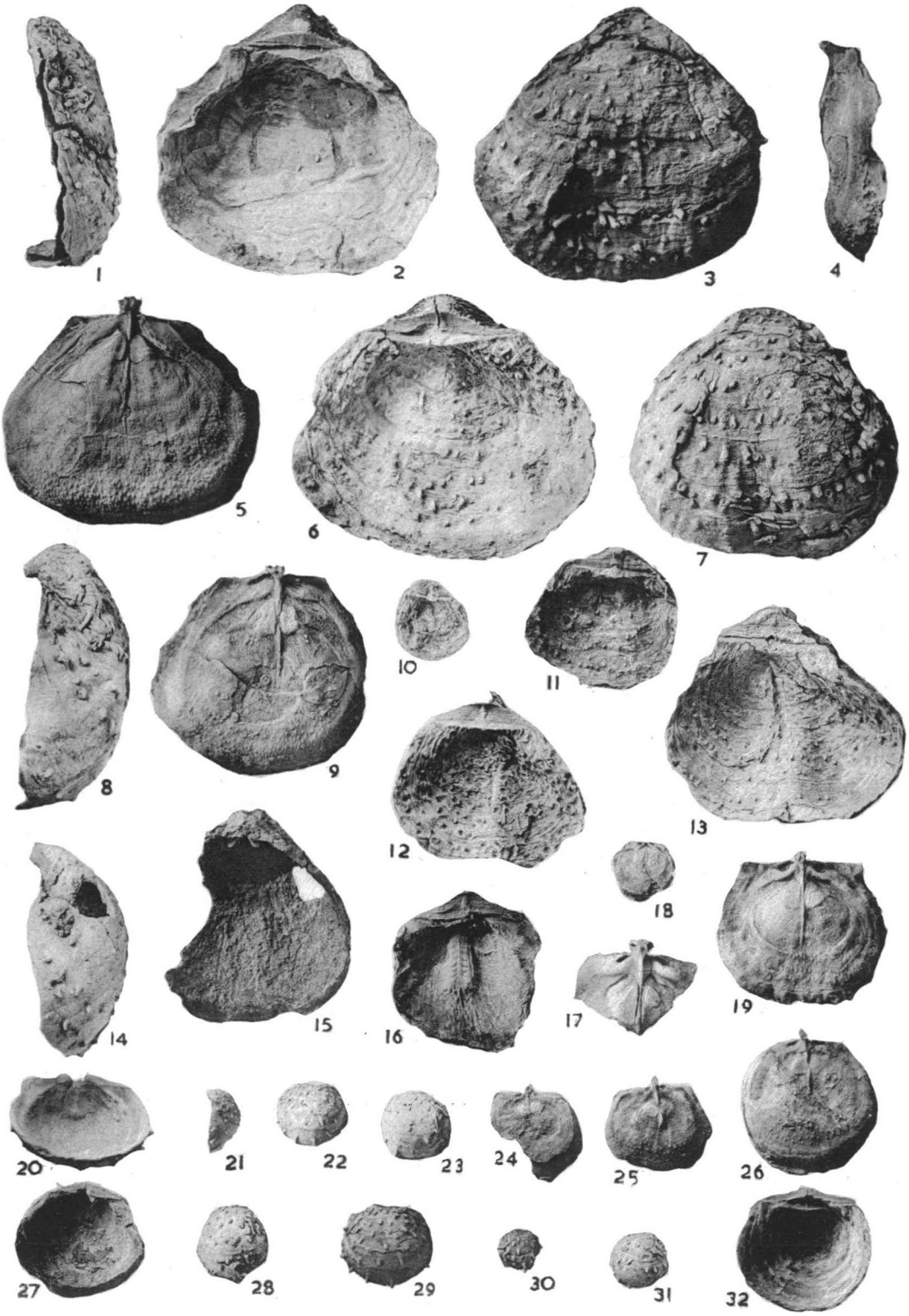
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PLATE 20.

FIGS. 1-6—*S.* (*Heteralosia*) *irwinensis* sp. nov. .. .. Page 122

Figs. 1, 2—Internal and ventral views of holotype U.W.A. 23341a; Fossil Cliff, Irwin River, near Mingenew township. Fossil Cliff Formation.

Figs. 3, 4—Internal and ventral views of paratype U.W.A. 12399; same locality, formation as 23341a above.

Fig. 5—Dorsal view of complete specimen, paratype U.W.A. 23341b; locality, formation as 23341a above.

Fig. 6—Internal view of paratype brachial valve, U.W.A. 34463 (x 2); same locality, formation as 23341 above.

FIGS. 7-19—*S.* (*Het.*) *kimberleyensis* Prendergast .. .. Page 124

Figs. 7, 8—Dorsal and posterior views of crushed specimen, U.W.A. 27582a, showing bases of cardinal spines; east side of syncline, south of Minilya River, west of Coolkilya Pool, Carnarvon Basin. Wandagee Formation, lower part.

Figs. 9, 10, 11—Internal, upright longitudinal and dorsal views of U.W.A. 27797; Nalbia Paddock, Wandagee area, general locality, formation as 27582a above.

Figs. 12, 13, 17—Same views of paratype U.W.A. 20455; Noonkanbah Homestead, West Kimberley District. Noonkanbah Formation.

Fig. 14—Dorsal view of U.W.A. 27797b; locality, formation as for 27797 above.

Fig. 16—Internal view of paratype U.W.A. 20460, showing cardinal teeth, raised adductor impressions, depressed diductor impressions; north of Hill C, south side of Grant Range, West Kimberley Division. Liveringa Formation.

Figs. 15, 18, 19—Ventral, posterior and dorsal views of holotype U.W.A. 20452; same locality, formation as 20460 above.

FIGS. 20-35—*S.* (*Het.*) *prendergastae* sp. nov. .. .. Page 127

Figs. 20-24—Dorsal (x 2), dorsal (natural size), upright longitudinal, ventral (x 1½) and ventral (natural size) views of holotype U.W.A. 28444a; flattening of the umbo due to cicatrix of attachment. 350 yards west of place on fence between Barabiddy and Weer Paddocks, 2,200 yards south of gate in that fence, near Barabiddy Creek, south of Wandagee Homestead, Carnarvon Basin. Cundlego Formation.

Figs. 25-28—Dorsal, upright longitudinal, dorsal (x 2), and ventral (x 1½) views of paratype U.W.A. 20449; Waltharrie Pools, Wooramel River, Carnarvon Basin. Callytharra Formation.

Figs. 29-31—Ventral (x 1½), ventral and upright longitudinal views of paratype U.W.A. 34468; limestone at base of Mt. Hardman, West Kimberley District. Liveringa Formation.

Fig. 32—Internal view of brachial valve, right side of cardinal process broken off, paratype U.W.A. 34470; same locality, formation as 34468 above.

Figs. 33-35—Dorsal (x 2), ventral, and ventral (x 1½) views of immature paratype U.W.A. 34469, showing large cicatrix of attachment (figs. 34, 35) and pseudodeltidium (fig. 33). Same locality, formation as for 34468 above.

FIGS. 36, 37—*S.* (*Het.*) *tenuispina* Waagen .. .. Page 130

Upright longitudinal and ventral views of U.W.A. 20451, pedicle valve; Fossil Cliff, Irwin River, near Mingenew township. Fossil Cliff Formation.

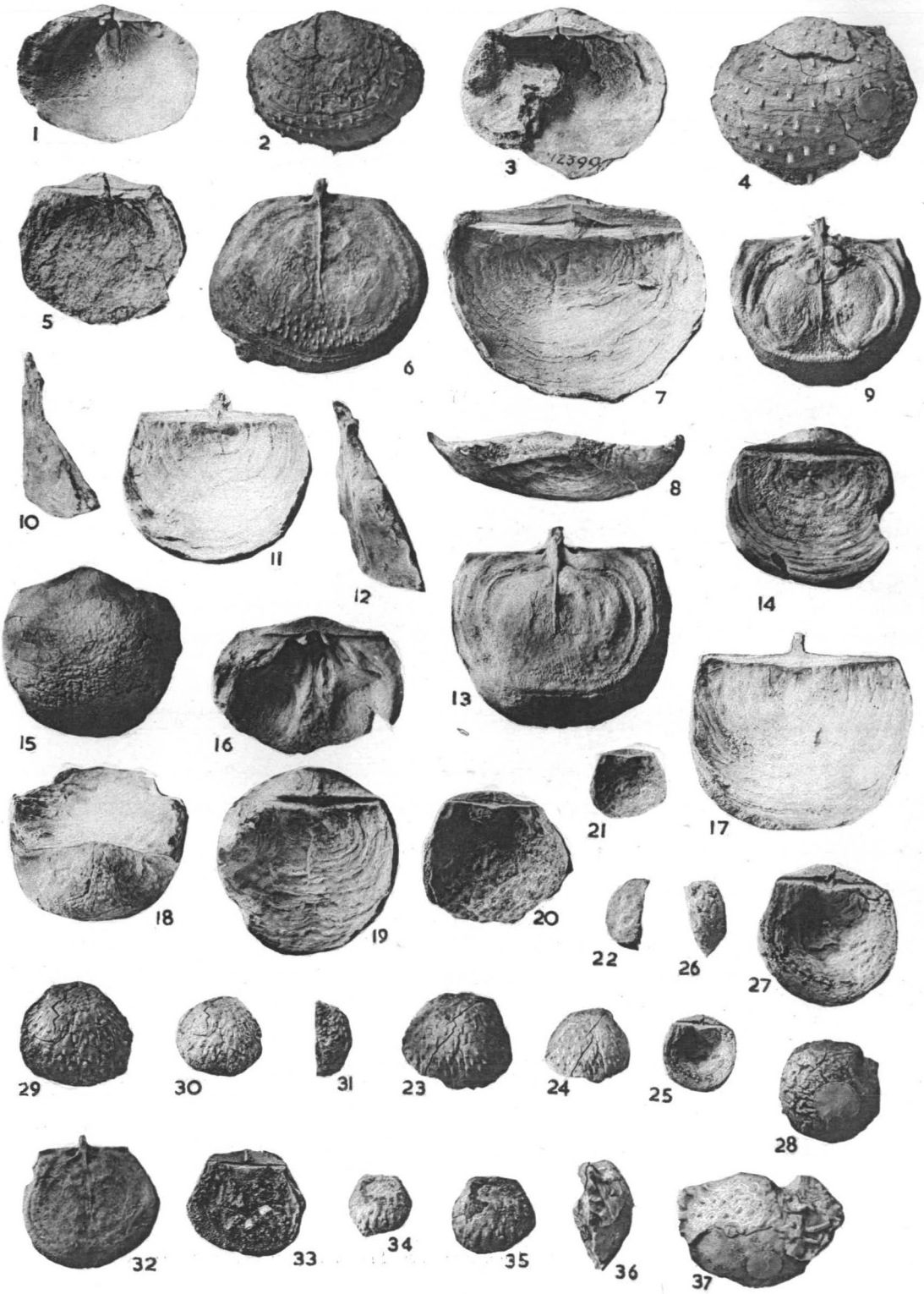
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PLATE 21.

FIGS. 1, 2, 9-11—*Taeniothaerus miniliensis* sp. nov.

Fig. 1—Dorsal view of largest specimen found (x $\frac{3}{4}$), cardinal area small, U.W.A. 27116; figured with locality, formation, plate 14, fig. 3.

Fig. 2—Dorsal view of U.W.A. 27380 (x $\frac{3}{4}$), showing rhynchonellid and coral, *Amplexus* sp., attached to alar extremities; same locality, formation as 27406, figured plate 12, fig. 8.

Figs. 9-11—Polished sections of shell of *Taeniothaerus miniliensis* specimens, showing roots of spine bases, shell laminae, and anterior inclination of internal spikey pustules. Fig. 9 portion of brachial valve anterior to trail; Figs. 10, 11 include geniculated region and part of trail, and show the shell thickening over the geniculated region. In all figures the spines point anteriorly, the external surface is uppermost. x 5.

FIG. 7—*Taeniothaerus irwinensis* sp. nov. C.P.C. 1953, 2,000 feet west of Callytharra Spring, Wooramel River, Carnarvon Basin; Callytharra Formation. Internal view of brachial valve showing cardinal process and perfectly preserved dendritic muscle impressions.

FIG. 12—A commonly preserved association shown by a brachial valve of a *Taeniothaerus* with fragmentary remains of bryozoa.

FIGS. 3-6, 8—*Aulosteges variabilis* Helmersen 1847.

Reproduction of some of Helmersen's original figures of *A. variabilis* = *Orthis wangenheimi* Verneuil.

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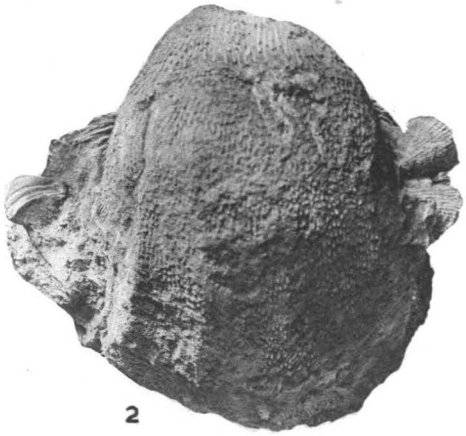

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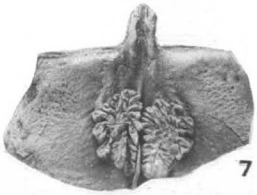

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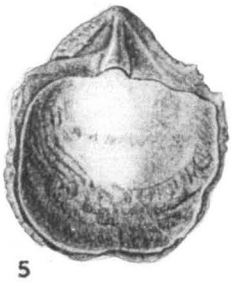

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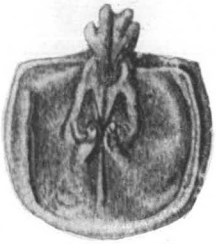

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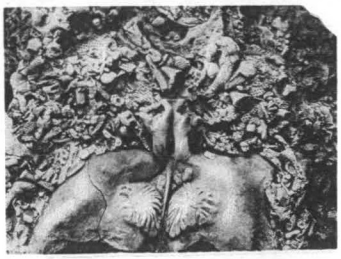

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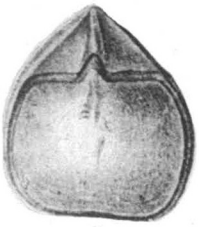

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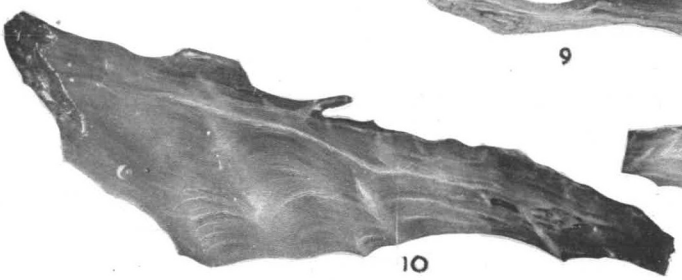

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